FINAL

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

May 26, 2009

System Metrics Group, Inc.

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Executive Summary

This final Comprehensive Performance Assessment Report represents the fifth and sixth milestones of the Corridor System Management Plan (CSMP) development process. It expands upon the preliminary performance assessment milestone by providing updated corridor performance data; finalizing a list of bottleneck locations through additional field visits; and identifying the causes of each bottleneck location.

Background

In November 2006, California voters approved Proposition 1B, a measure which allocated $4.5 billion of bond funds to the Corridor Mobility Improvement Account (CMIA). The CMIA will fund improvements to the state highway system that relieves congestion by expanding capacity, enhancing operations, or otherwise improves travel times within high-congestion travel corridors. The projects that have been proposed for the Riverside SR-91 Corridor include the construction of High Occupancy Vehicle (HOV) lanes from Adams Street to the SR-60/I-215 interchange, and improvements to the interchange and connectors at SR-71. As a requirement to obtain CMIA funding for these projects, Caltrans District 8 is developing the Riverside SR-91 CSMP to be submitted to the California Transportation Commission (CTC). When finalized, the CSMP will provide an assessment of existing and future conditions of the corridor; an evaluation of proposed projects using micro-simulation modeling; and an analysis of project benefits and costs.

Caltrans and the CTC defined the Riverside SR-91 study corridor as the 22 mile stretch from the Orange/Riverside County line (CA PM 0.0) to the I-215/SR-60 interchange (CA PM 21.7) in Riverside. The corridor passes through the cities of Corona, Norco, and Riverside. The corridor is a six to ten-lane freeway with a continuous High Occupancy Vehicle (HOV) lane in each direction. In the eastbound direction, the HOV lane terminates west of the Madison Interchange.

Corridor-wide Performance and Trends

In order to identify how well or poorly a corridor is performing, the existing conditions of the SR-91 study corridor were analyzed using the performance measures of mobility, reliability, safety, productivity, and pavement condition. These performance measures were based on data from 2005 to 2008 with a focus on the 2007 model year. The following briefly summarizes the results of each performance measure:

- Mobility – a directional pattern of delay appeared in both the mainline and HOV facilities. The westbound direction experienced greater congestion during the AM peak, and the eastbound direction experienced more congestion during the PM peak. In 2007, eastbound delay on the mainline (1,200,000 vehicle-hours) exceeded westbound delay (890,000 vehicle-hours) by 30 percent. Similarly, eastbound delay on the HOV facility (250,000 vehicle-hours) was 40 percent greater than westbound delay (145,000 vehicle-hours). Travel times for both mainline and HOV facilities experienced a gradual decline between 2005 and 2008.

- Reliability – the variability of travel time during peak periods declined overall from 2005 to 2008. On the eastbound direction of the mainline facility, travel time variability during the peak hour decreased from 10 minutes in 2005 and 2006 to eight 8 minutes in 2007 and 2008. In the westbound direction of the mainline facility, travel time variability during the peak hour also declined from 19 minutes in 2005 to 10 minutes in 2008. In the eastbound direction of the HOV facility, travel time variability during the peak hour initially increased from 6 minutes in 2005 to 10 minutes in 2006, declined to 7 minutes in 2007, and remained about the same at 8 minutes in 2008. In the westbound direction of the HOV facility, travel time variability increased from 10 minutes in 2005 to 18 minutes in 2006, and decreased to 11 minutes and 7 minutes in 2007 and 2008, respectively.

- Safety – the latest safety data available is based on the three-year period from January 2004 to December 2006. This data does not separate accidents by mainline and HOV facilities. Both directions experienced fewer collisions in 2005 and 2006 than in 2004. An average of 100 collisions occurred each month in the eastbound direction, as opposed to an average of 77 collisions that occurred each month in the westbound direction.

- Productivity – the trends in productivity losses are comparable to the delay trends. In 2007, the largest productivity losses occurred during the PM peak hours in the eastbound direction of the mainline (5.4 lost lane-miles) and HOV facilities (1.0 lost lane-mile), which relatively correspond to the time period and direction which experienced the most delay. Productivity during the PM peak in the eastbound direction improved from 2007 to 2008 on the mainline (by 0.8 lost lane-miles), and by 0.3 lost lane-miles on the HOV facility. Productivity improved overall on the corridor from 2007 to 2008 on both the mainline (by 3.0 lost lane-miles) and HOV (0.3 lost-lane mile) facilities.

- Pavement Condition – the pavement condition on SR-91 is considered average relative to the rest of the freeways in the Inland Empire. Major pavement distress if found primarily in the central portion of the corridor near La Sierra, and also at the western end of the corridor near the I-215/SR-60 interchange. The total number of distressed lane-miles has increased since 2003 (with the exception of a decline in 2004). In 2003, the corridor comprised about 20 distressed lane-miles, which more than tripled to over 70 lane-miles in 2006-2007. However, most of the increase was considered minor pavement distress while major pavement distress decreased throughout this period.

Bottleneck Locations and Areas

Bottleneck locations were identified along the SR-91 study corridor. The causes for each of the bottleneck locations were further identified and detailed in this report. Data analyses from 2007 PeMS and probe vehicle runs, combined with extensive field visits, confirmed the bottleneck locations listed in Exhibits ES-1 and ES-2. The tables also show the corresponding "bottleneck areas" for each bottleneck location. Bottleneck areas refer to segments of the corridor that extend from one bottleneck location to the next.

Exhibit ES-1: Eastbound SR-91 Identified Bottleneck Locations and Areas

Bottleneck Location	Bottleneck Area	Active Period		From		To		Distance (miles)
		AM	PM	Abs	CA	Abs	CA	
Serfas Club Dr On	ORA/RIV Co Line to Serfas Club Dr On		✓	37.2	0.0	41.1	R3.8	3.8
Maple St On	Serfas Club Dr On to Maple St On		✓	41.1	R3.8	41.6	4.2	0.5
Lincoln Ave On	Maple St On to Lincoln Ave On		✓	41.6	4.2	42.9	5.5	1.3
I-15 Off	Lincoln Ave On to I-15 Off		✓	42.9	5.5	44.4	7.0	1.5
I-15 On	I-15 Off to I-15 On*		✓	44.4	7.0	45.1	7.7	0.7
McKinley St On	I-15 On to McKinley St On		✓	45.1	7.7	46.5	9.2	1.4
Magnolia Ave On	McKinley St On to Magnolia Ave On	✓	✓	46.5	9.2	48.0	10.6	1.5
Madison Off	Magnolia St On to Madison Off	✓		48.0	10.6	53.9	16.5	5.9
Arlington Ave On	Madison Off to Arlington Ave On	✓		53.9	16.5	55.4	18.0	1.5
Central Ave On	Arlington Ave On to Central Ave On	✓		55.4	18.0	55.9	18.6	0.5
Not a bottleneck location	Central Ave On to SR-60/I-215	N/A		55.9	18.6	59.0	21.7	3.1

* segment is not included in the bottleneck area analysis due to insufficient detection

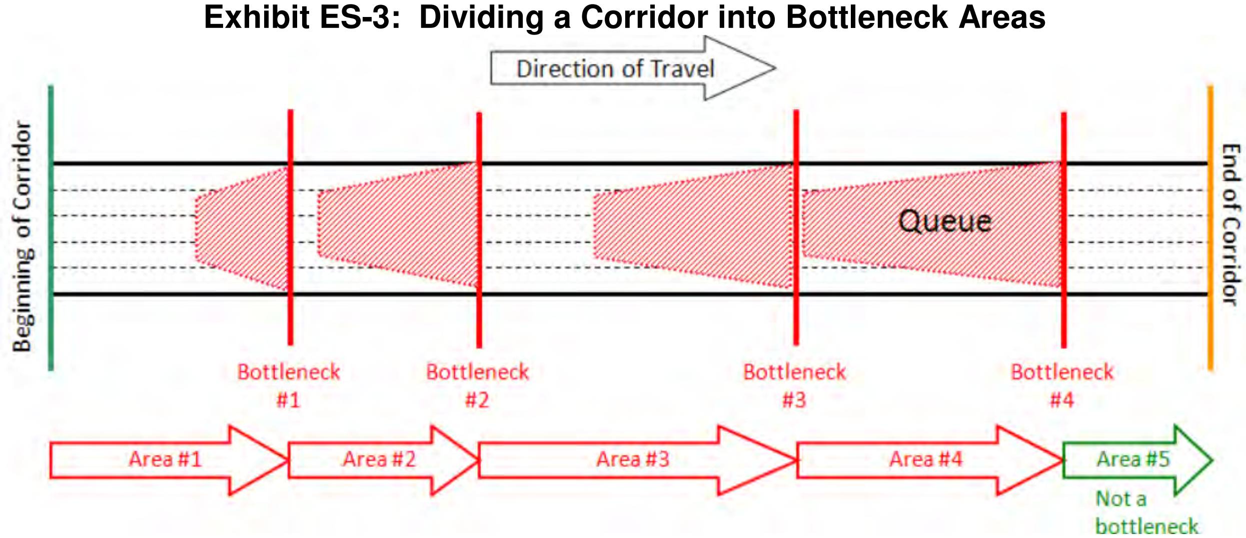
Exhibit ES-2: Westbound SR-91 Identified Bottleneck Locations and Areas

Bottleneck Location	Bottleneck Area	Active Period		From		To		Distance (miles)
		AM	PM	Abs	CA	Abs	CA	
SR-60/I-215 On	SR-60/I-215 to SR-60/I-215 On*		✓	59.0	21.7	58.8	21.5	0.2
14th St On	SR-60/I-215 On to 14th St On		✓	58.8	21.5	57.3	19.8	1.5
Arlington Ave On	14th St On to Arlington Ave On		✓	57.3	19.8	55.1	17.6	2.2
Tyler St On	Arlington Ave On to Tyler St On		✓	55.1	17.6	50.3	12.9	4.7
Pierce St On	Tyler St On to Pierce St On	✓	✓	50.3	12.9	48.0	10.6	2.3
I-15 On	Pierce St On to I-15 On	✓		48.0	10.6	45.2	7.8	2.8
School St/Grand Blvd On	I-15 On to School St/Grand Blvd On	✓		45.2	7.8	43.3	5.9	1.9
Lincoln Ave On	School St/Grand Blvd On to Lincoln Ave On	✓		43.3	5.9	42.7	5.3	0.6
Serfas Club Dr On	Lincoln Ave On to Serfas Club Dr On	✓		42.7	5.3	40.9	R3.5	1.8
Green River Road On	Serfas Club Dr On to Green River Road On	✓		40.9	R3.5	38.3	R0.9	2.6
Not a bottleneck location	Green River Road On to RIV/ORA Co Line*	N/A		38.3	R0.9	37.3	0.0	1.0

* segment is not included in the bottleneck area analysis due to the short distance in length or insufficient detection

Exhibit ES-3 illustrates the general concept of bottleneck areas in one direction. The red lines in the exhibit represent the bottleneck locations and the arrows represent the bottleneck areas. Dividing the corridor into bottleneck areas makes it easier to compare the various segments of the freeway with each other.

Exhibit ES-3: Dividing a Corridor into Bottleneck Areas



The performance statistics of mobility, safety, and productivity were used to analyze each bottleneck area as was done for the entire corridor. This allows for the relative contribution of each bottleneck area to the degradation of the corridor to be gauged. The analysis of bottleneck areas is based on 2007 data.

- *Mobility by Bottleneck Area* – In the eastbound direction, the bottleneck area between the County Line and Serfas Club Drive experienced the greatest delay with roughly 240,000 annual vehicle-hours of delay during the PM peak. In the westbound direction, the bottleneck area between I-15 and School Street/Grand Boulevard experienced the greatest delay with almost 136,000 annual vehicle-hours of delay during the AM peak.

- *Safety by Bottleneck Area* – From 2004-2006, the bottleneck areas from Central Avenue to SR-60/I-215 in the eastbound direction, and Arlington Avenue to Tyler Street in the westbound direction experienced the highest average annual accidents at around 250 and 160, respectively. On average, the eastbound direction also experienced more annual accidents (1,220) than the westbound direction (920).

- *Productivity by Bottleneck Area* - In the eastbound direction, the bottleneck area between the County Line and Serfas Club Drive experienced the worst productivity of all the segments on the corridor with almost 1.7 lost lane-miles in the PM peak. In the westbound direction, the bottleneck area between I-15 and School/Grand experienced the greatest productivity loss during the AM peak with almost 2.0 lost lane-miles. The segments which experienced the highest lost-lane miles (or lowest productivity) correspond to the same segments that experienced the highest levels of annual vehicle-hours of delay.

Bottleneck Causality Analysis

By definition, a bottleneck is a condition where traffic demand exceeds the capacity of the roadway facility. In many cases, the cause of the bottlenecks is attributed to such conditions such as a sudden reduction in capacity, roadway geometry, heavy merging and weaving, driver distractions, or a surge in demand that the facility cannot accommodate. Through numerous field visits conducted in December 2008 and January 2009, the cause of each bottleneck location was identified on SR-91. Some of the contributing causes of the bottleneck locations are related to:

- Cross weaving traffic at interchanges
- Heavy ramp volumes merging on to the mainline facility when mainline traffic is already heavy
- Platoon merging from the on-ramp
- Uphill vertical grade or roadway curvature that affects sight-distance.

A detailed description of the causality of each bottleneck location is provided in Section 5 of this report. It should be noted that many of the bottlenecks that were visible in 2006 and early part of 2007 have now disappeared with the reduction in demand likely associated with higher gas prices and the depressed economy; however, should mainline traffic growth reach 2006 levels, these bottlenecks are likely to reoccur.

The bottleneck locations identified in Exhibits ES-1 and ES-2, along with the results from the causality analysis will be used for the SR-91 micro-simulation model calibration process.

Next Steps

Subsequent to this Comprehensive Performance Assessment, alternative investment strategies will be modeled and evaluated to understand their relative benefits to the corridor as compared to their costs. The results from this evaluation will form a recommended implementation plan that identifies existing and potential future funding opportunities that will improve the corridor's future performance.

1. INTRODUCTION

This document represents the draft for the fifth and sixth milestones of Riverside 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 voters in 2006. The CMIA will partially fund the construction of High Occupancy Vehicle (HOV) lanes from Adams Street to the SR-60/I-215 Interchange, and the interchange and connectors at SR-71/SR-91.

The two milestones are called the Comprehensive Performance Assessment and the Causality of Performance Degradation. They build on the third milestone, the "Preliminary Performance Assessment" (already developed), and the fourth 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 decision can build on its findings and conclusions, and investment alternatives are tested to ensure reasonable returns on investment for public funds.

This report is 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 is 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 (eighth milestone in the CSMP guidelines) 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 and updated sections without re-writing the entire document.

The remainder of this report is organized into four sections (Section 1 is this introduction):

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 to include a subsection on corridor demand profiles.

3. *Corridor-Wide Performance and Trends*
   The section presents multiple years of performance data for the defined CSMP freeway facility of the corridor, including mobility, reliability, safety, and productivity performance measures. The section has also been augmented to include the performance of the HOV facility and the pavement condition of the freeway. When available, the performance data has been updated to reflect conditions up to December 2008.

4. *Bottleneck Identification*
   The 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 regards to their contribution to corridor performance degradation.

5. *Bottleneck 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 conclusions. Sections 4 and 5 provide valuable input in selecting projects to address the critical bottlenecks. Moreover, they provide the baseline against which the micro-simulation models will be validated. Finally, this section represents the sixth milestone of the CSMP development process.

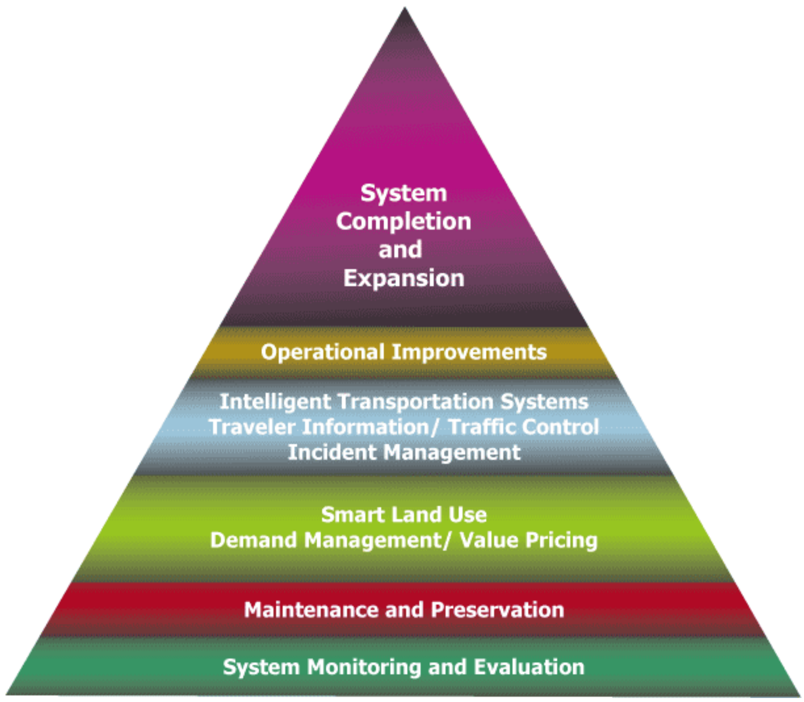
The remainder of this introduction provides some background on system management, a framework that eventually led to the CSMP requirement. It also includes a discussion on data sources and the state of detection on the SR-91 freeway facility.

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 current California Administration as part of its Strategic Growth Plan and by the Southern California Association of Governments (SCAG), the Metropolitan Planning Organization for Riverside 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.

Exhibit 1-1: System Management Pyramid



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.

Existing Data Sources

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

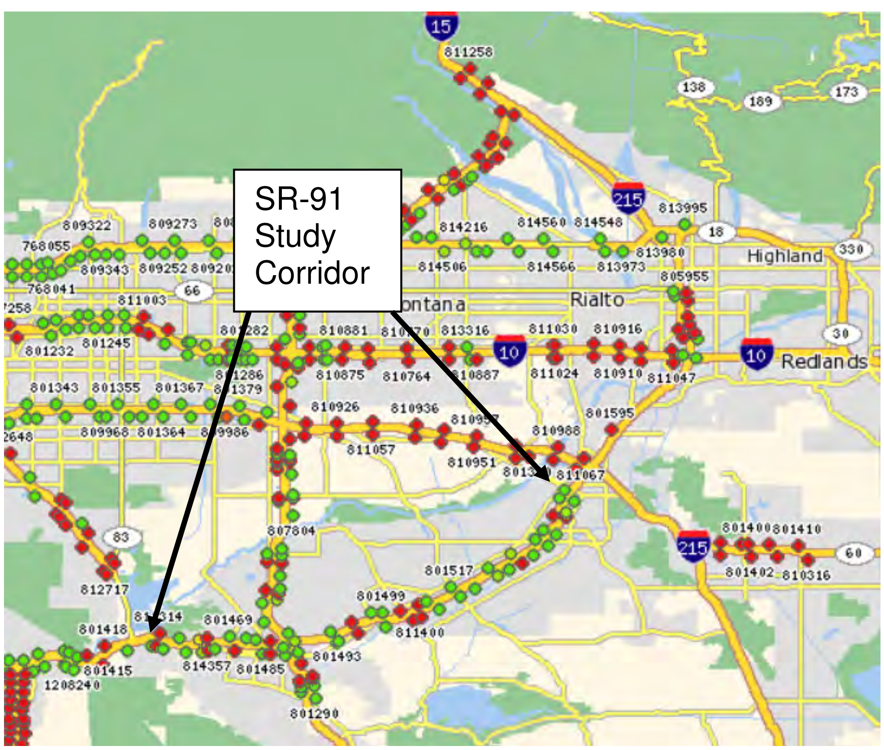
- Caltrans Highway Congestion Monitoring Program (HICOMP) report and data files (2004 to 2007)
- Caltrans Freeway Performance Measurement System (PeMS)
- Caltrans District 8 probe vehicle runs (electronic tachometer runs)
- Caltrans Traffic Accident Surveillance and Analysis System (TASAS) from PeMS
- Various traffic study reports
- Aerial photographs (Google Earth) and Caltrans photologs
- Internet (e.g., RTA, Omnitrans, and Metrolink transit websites).

Details for each data source are provided in their applicable sections of this report. However, given the need for comprehensive and continuous monitoring and evaluation, detection coverage and quality are discussed in more detail below.

Freeway Detection Status

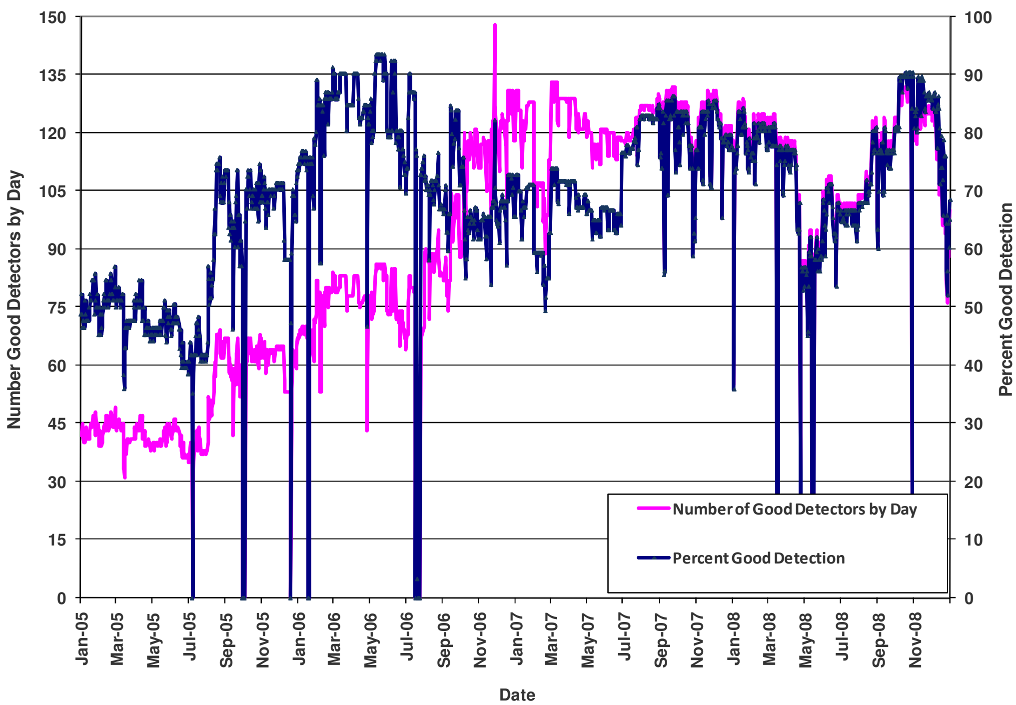
Exhibit 1-2 depicts the corridor freeway facility with the detectors in place as of December 30, 2008. This data was chosen randomly to provide a snapshot of the detection status. The exhibit shows that there are many detectors on the mainline, the majority functioning well (based on the green color). Furthermore, it illustrates some seemingly small gaps between detectors at some locations.

Exhibit 1-2: PeMS Sensor Data Quality (December 30, 2008)



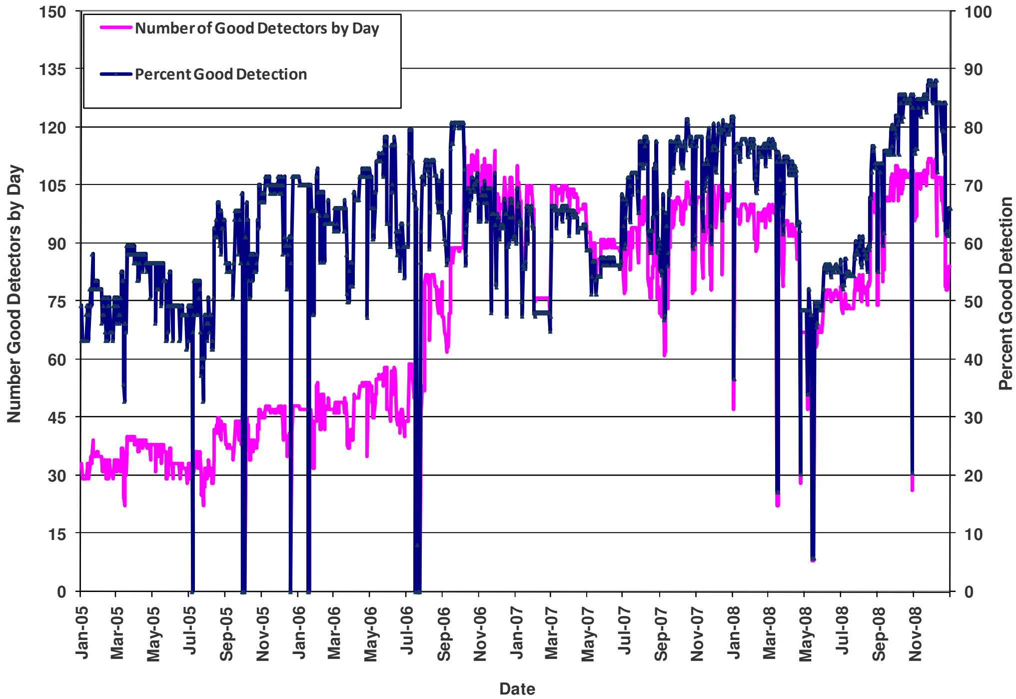
The following exhibits provide a better picture of how the detectors on the corridor performed over a longer period of time. Exhibits 1-3 and 1-4 report the number and percentage of daily “good” detectors on the mainline (ML) facility (including ramps) of the Riverside SR-91 Corridor from 2005 to 2008. Exhibits 1-5 and 1-6 report the same information for the HOV facility. The left y-axis shows the scale used for the number of detectors, while the right y-axis shows the scale used for the percent good detectors. These exhibits suggest that detection in the eastbound direction (Exhibit 1-3) was better than the westbound direction (Exhibit 1-4) since the eastbound direction reported a larger number of good detectors (120) than the westbound direction (105), most notably in the last half of 2007. In the first half of 2008, the quality of detection on the mainline declined in both directions, but recovered in the last half of the year to almost 90 percent of reported good data.

Exhibit 1-3: ML Eastbound SR-91 Number & Percentage of Daily Good Detectors (2005-2008)



Source: SMG Analysis of PeMS Data

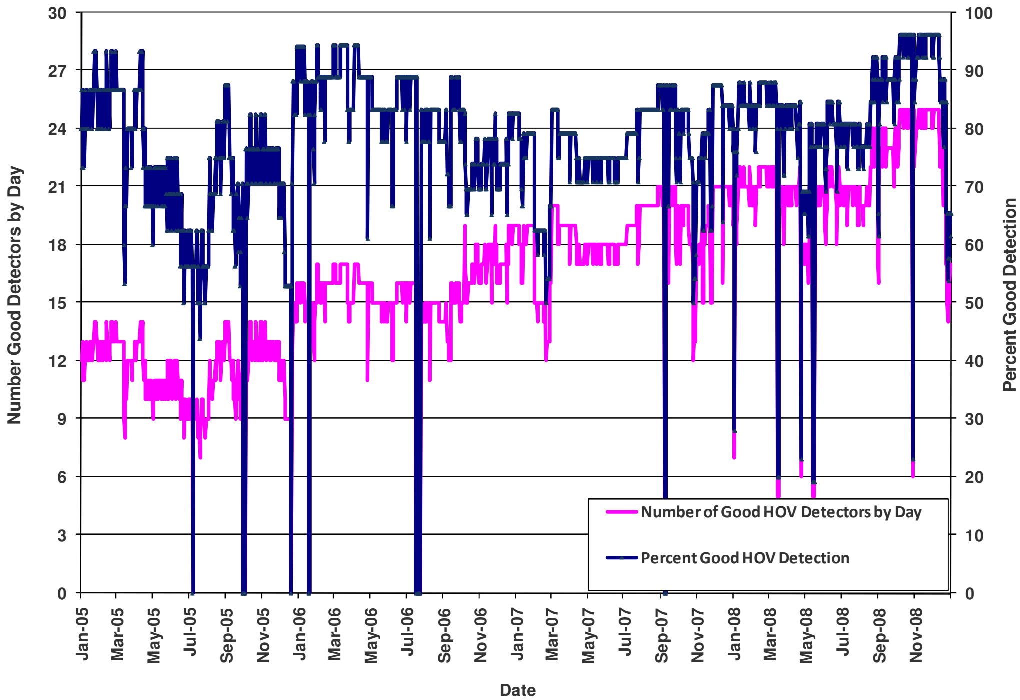
Exhibit 1-4: ML Westbound SR-91 Number & Percentage of Daily Good Detectors (2005-2008)



Source: SMG Analysis of PeMS Data

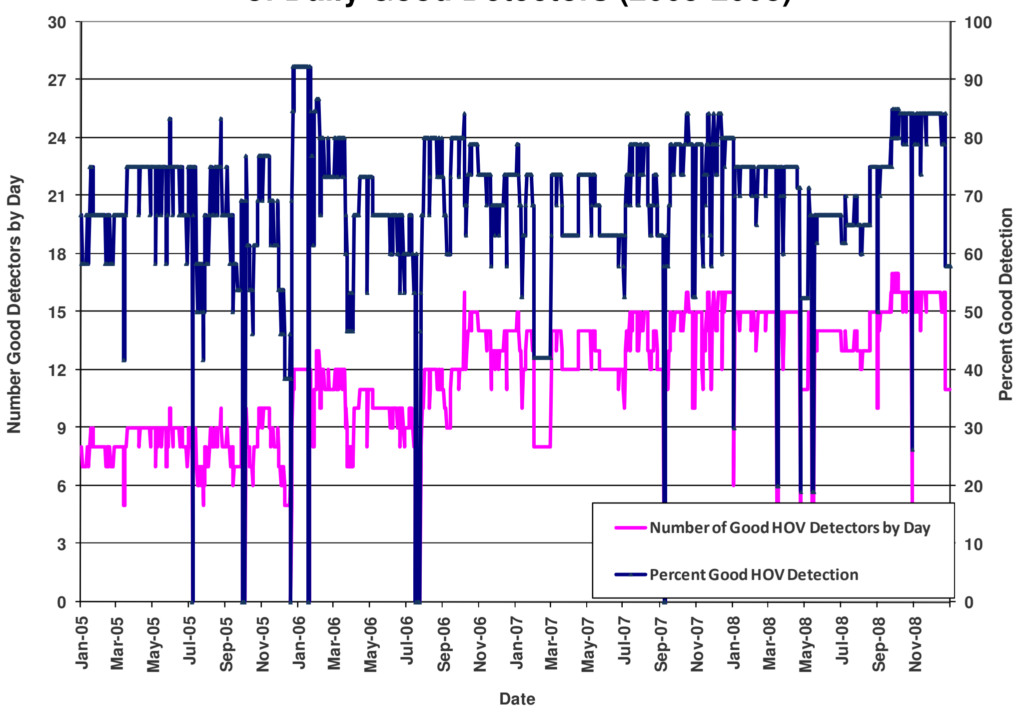
The quality of detection on the HOV facility was more consistent than the mainline facility, as shown in Exhibits 1-5 and 1-6. Throughout the 2005-2008 period, the HOV facility experienced a gradual increase of good detectors. Overall, the eastbound HOV lane (Exhibit 1-5) had better detection than the westbound HOV lane (Exhibit 1-6). Detectors in the eastbound direction consistently reported around 70-90 percent of good data, which is higher than the reported 60-80 percent of good data in the westbound direction. Additionally, the eastbound HOV lane exhibited a greater number of good detectors (roughly 25) than the westbound HOV lane (roughly 15) in the latter half of 2008.

Exhibit 1-5: HOVL Eastbound SR-91 Number & Percentage of Daily Good Detectors (2005-2008)



Source: SMG Analysis of PeMS Data

Exhibit 1-6: HOVL Westbound SR-91 Number & Percentage of Daily Good Detectors (2005-2008)



Source: SMG Analysis of PeMS Data

Part of the increased detection quality in 2008 on the mainline and HOV facilities may be attributed to improved maintenance of the existing detection. Regardless of the reason, this trend is very encouraging and should allow for detailed analysis capabilities now and in the future. By comparing detectors in detail for the SR-91 study corridor, we identified a number of detectors that were added to the corridor in 2007 and 2008. These are listed in Exhibit 1-7.

Exhibit 1-7: SR-91 Detection Added (2007-2008)

VDS	Location	Type	CA PM	Abs PM	Date Online
EASTBOUND					
811316	M 1.7 E/O GREEN RIV.	HOV	R2.8	40.03	1/11/2007
810849	M .75 E/O LINCOLN	HOV	4.50	41.84	6/27/2007
814357	M .75 E/O LINCOLN	Mainline	4.50	41.84	10/7/2008
807285	VAN BUREN	HOV	14.10	51.44	10/7/2008
807325	ADAMS	HOV	15.71	53.05	12/13/2007
814770	MCKINLEY LOOP ON	On Ramp	9.15	46.49	10/7/2008
814815	ARLINGTON	Off Ramp	17.93	55.27	10/7/2008
WESTBOUND					
813443	GREEN RIVER	HOV	R.995	38.31	12/13/2007
810854	M .75 E/O LINCOLN	Mainline	4.50	41.93	6/27/2007
814351	M .75 E/O LINCOLN	Mainline	4.50	41.93	10/7/2008
813795	M 1.3 M W/O ADAMS	HOV	14.30	51.73	4/19/2008

Source: System Metrics Group (using PeMS data)

Finally, an analysis of mainline gaps without detection is shown in Exhibit 1-8. There are several segments extending over 0.75 miles without detection in each direction. These should be considered for deployment of additional detection when funding becomes available.

Exhibit 1-8: SR-91 Gaps In Detection (December 2008)

Location		Abs PM		Length (Miles)
From	To	From	To	
EASTBOUND				
.41 E/O CO LINE	.45 W/O RTE 71	37.65	38.85	**1.20**
.45 W/O RTE 71	RTE 71	38.85	39.80	**0.96**
.66 W/O SERFAS CL	SERFAS CLUB	40.29	41.05	**0.76**
LINCOLN	MAIN	42.85	43.84	**0.99**
.1 E/O E GRAND BL	.11 W/O PROMENADE	44.14	45.87	**1.73**
.2 W/O BUCHANAN ST	MAGNOLIA	47.34	48.56	**1.22**
TYLER	VAN BUREN	50.54	51.44	**0.90**
.11 E/O JACKSON	ADAMS	52.06	53.06	**1.00**
WESTBOUND				
0.95 E/O CANYON RD	GREEN RIVER	37.37	38.23	**0.86**
GREEN RIVER	1.7 E/O GREEN RIV.	38.23	40.12	**1.89**
1.7 E/O GREEN RIV.	SERFAS CLUB	40.12	40.87	**0.75**
SERFAS CLUB	MAPLE	40.87	41.65	**0.78**
.75 E/O LINCOLN	LINCOLN	41.93	42.71	**0.78**
.1 E/O E GRAND BL	MCKINLEY	44.23	46.52	**2.29**
MCKINLEY	.2 W/O BUCHANAN ST	46.52	47.43	**0.91**
MAGNOLA	LA SIERRA	48.48	49.31	**0.83**
TYLER	VAN BUREN	50.34	51.41	**1.07**
VAN BUREN	ADAMS	51.41	52.99	**1.58**
ADAMS	MADISON	52.99	54.02	**1.03**
MADISON	ARLINGTON WB ON	54.02	55.15	**1.13**
CENTRAL	.2 W/O IVY ST	55.78	56.63	**0.85**

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 1-8) and discuss the ramifications of its findings (e.g., have the gaps been filled, is detector reliability improving or diminishing, etc.). Similar place holder pages have been inserted throughout the document for future updates.

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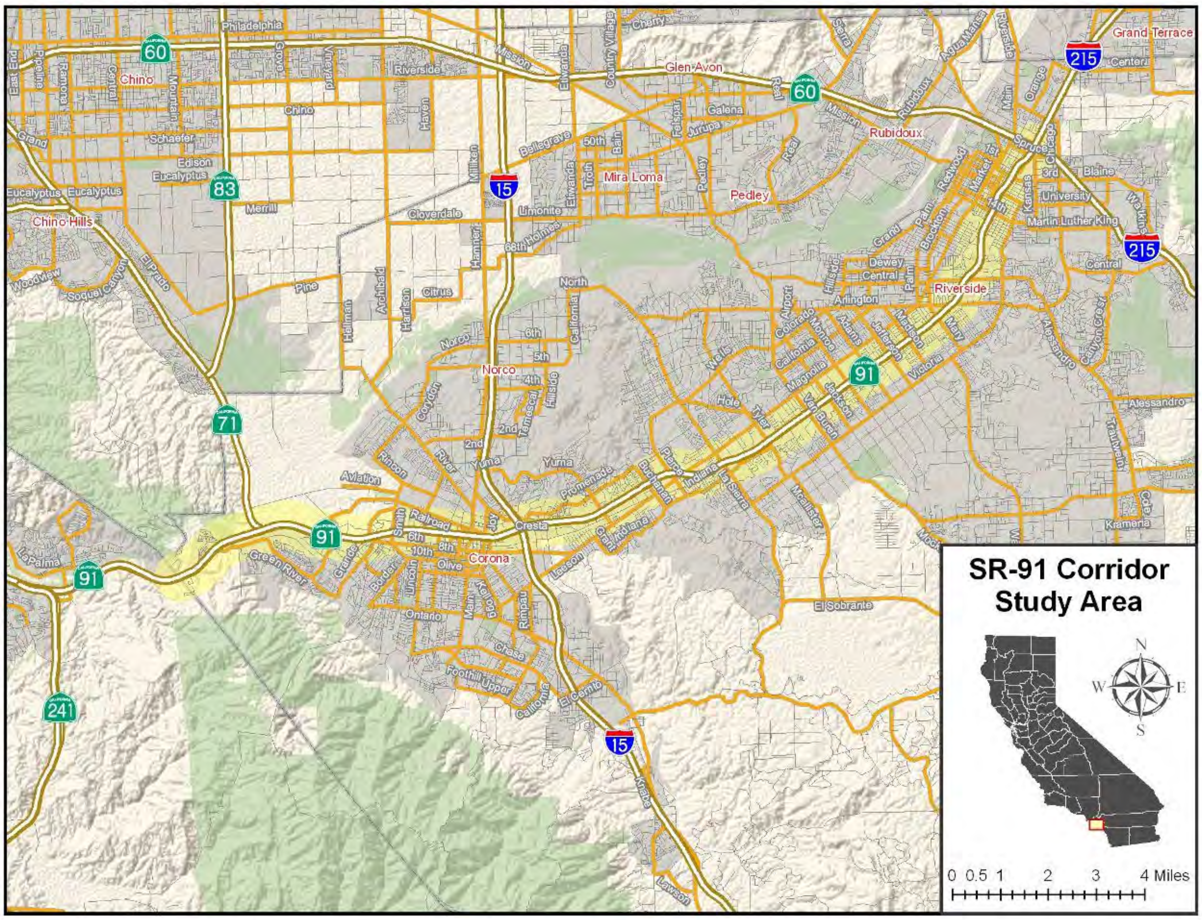
2. CORRIDOR DESCRIPTION

The Riverside County SR-91 corridor begins at the Orange County/Riverside County line (CA post mile 0.0) to the I-215/SR-60 junction (post mile 21.659), and extends approximately 22 miles. Riverside SR-91 traverses through the cities of Corona, Norco, and Riverside.

Exhibit 2-1: Map of SR-91 Study Area



Corridor Roadway Facility

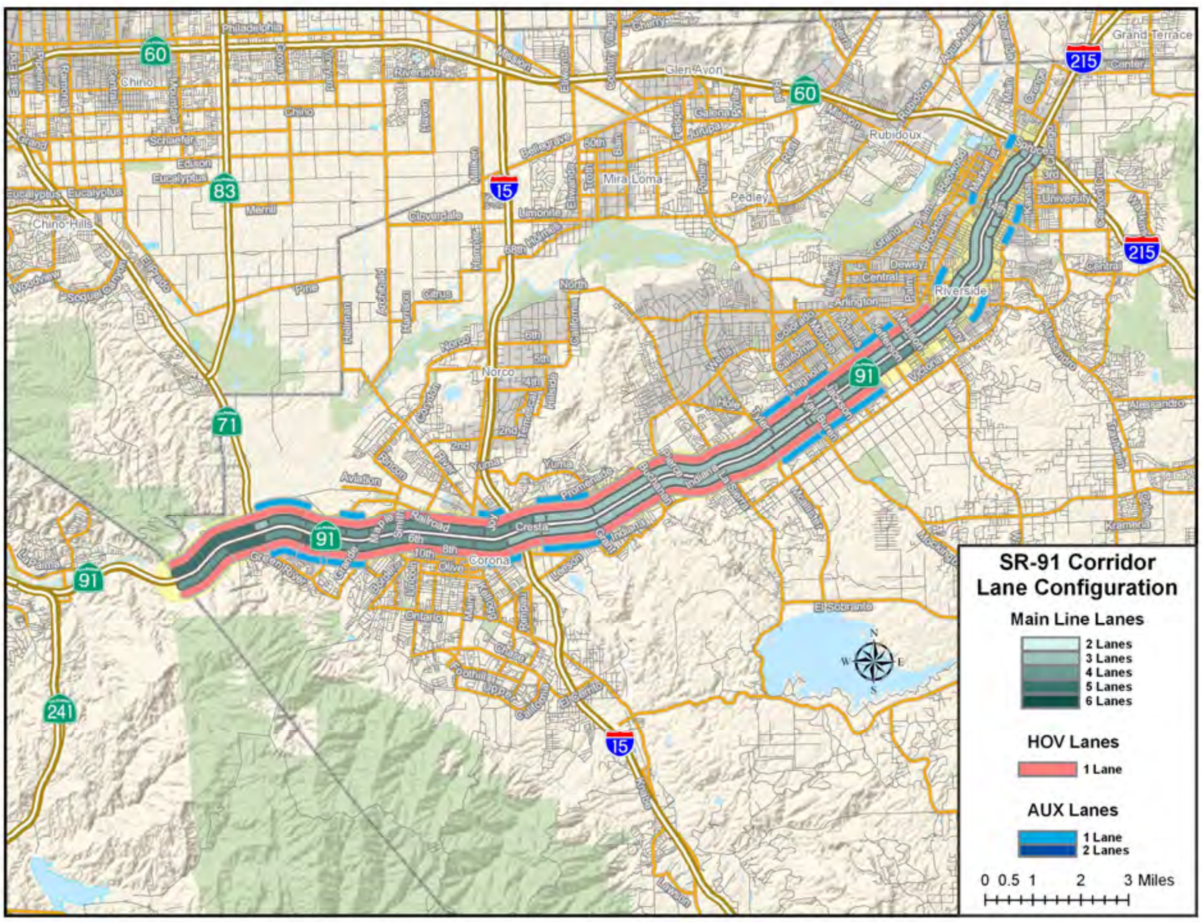
The SR-91 study corridor traverses in an easterly to northerly direction as shown in Exhibit 2-1. About every seven miles, the corridor has a major freeway-to-freeway interchange with another state highway. These include:

- SR-71 (Chino Valley Freeway), which provides north-south access from Corona to Chino Hills and Pomona.

- I-15 (Corona Freeway), which provides north-south access from Riverside County to San Bernardino County.
- I-215/SR-60 Interchange, which provides east-west access from Los Angeles County to Riverside County.

As depicted in Exhibit 2-2, SR-91 is a six to ten-lane freeway with a concrete median barrier that separates eastbound and westbound traffic for most of the corridor. Note that Exhibit 2-2 lists the lanes in each direction, so five lanes is equivalent to a ten-lane freeway. There are auxiliary (aux) lanes along many sections of the corridor, but they are not continuous nor are they always available for both sides of the freeway. There are also continuous High Occupancy Vehicle (HOV) lanes on the corridor except for both directions east of the Mary Street interchange. Metered ramps Single Occupancy Vehicle (SOV) and HOV bypass lanes are also present along the study corridor.

Exhibit 2-2: SR-91 Corridor Lane Configuration



According to the 2007 Caltrans Annual Traffic Volumes Report, the SR-91 Corridor carries between 153,000 and 275,000 annual average daily traffic (AADT)[1] as shown in Exhibit 2-3. The highest AADT was reported near the Orange County/Riverside County line area.

SR-91 is also part of the Surface Transportation Assistance Act (STAA) route, which means that trucks may operate on the corridor as shown in Exhibit 2-4. Exhibit 2-5 identifies trucks as a percentage of AADT (listed as total truck percentage). According to the 2007 Annual Average Daily Truck Traffic on the California State Highway System published by Caltrans in September 2008, this corridor's daily truck traffic ranges from 5 percent to 7.7 percent of the total daily traffic.

Exhibit 2-3: Major Interchanges and AADT along the SR-91 Corridor

Source: AADT and truck percentages are from the Caltrans Traffic and Vehicle Data Systems Unit

[1] AADT is the total annual volume of vehicles counted divided by 365 days.

Exhibit 2-4: San Bernardino/Riverside County Truck Networks

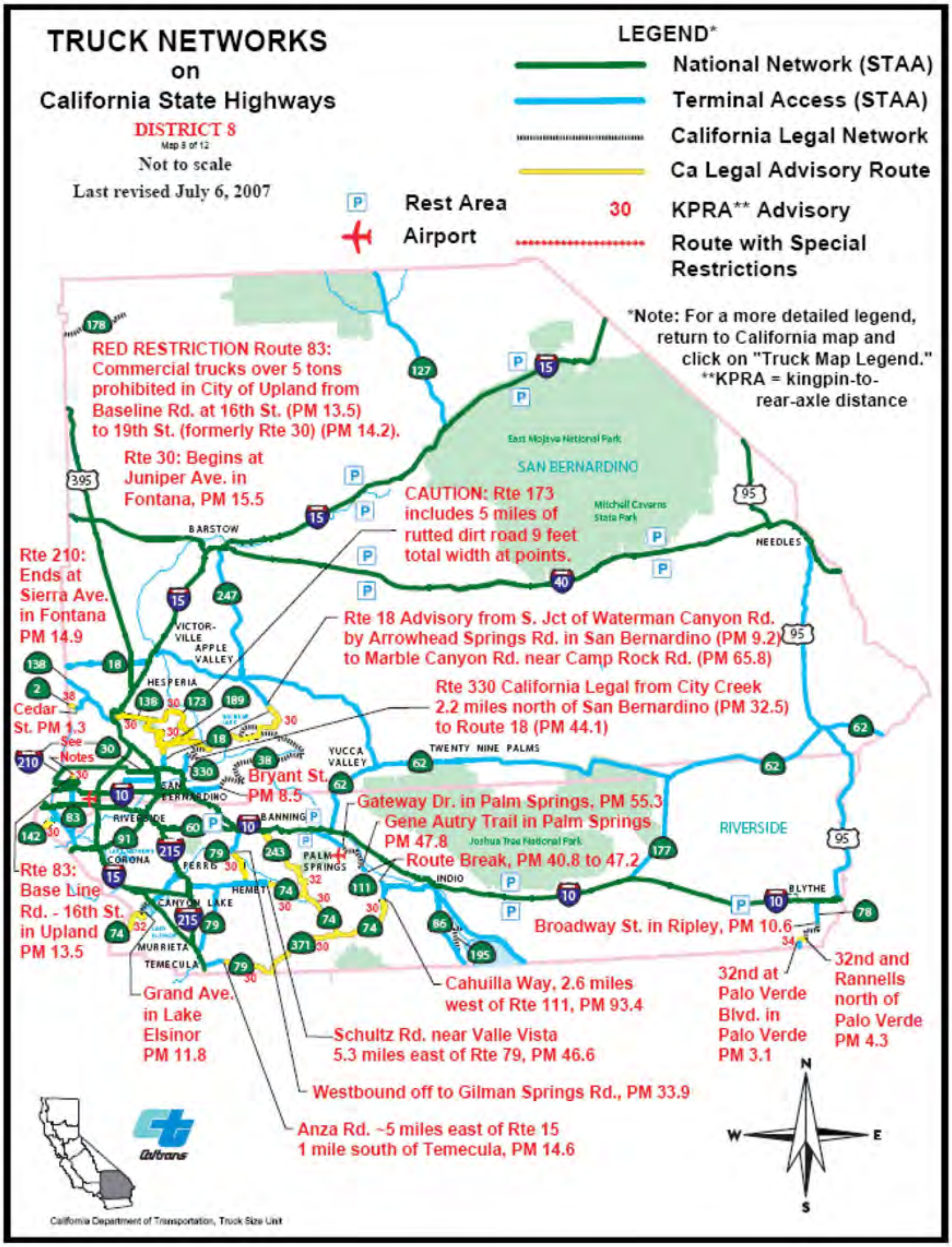
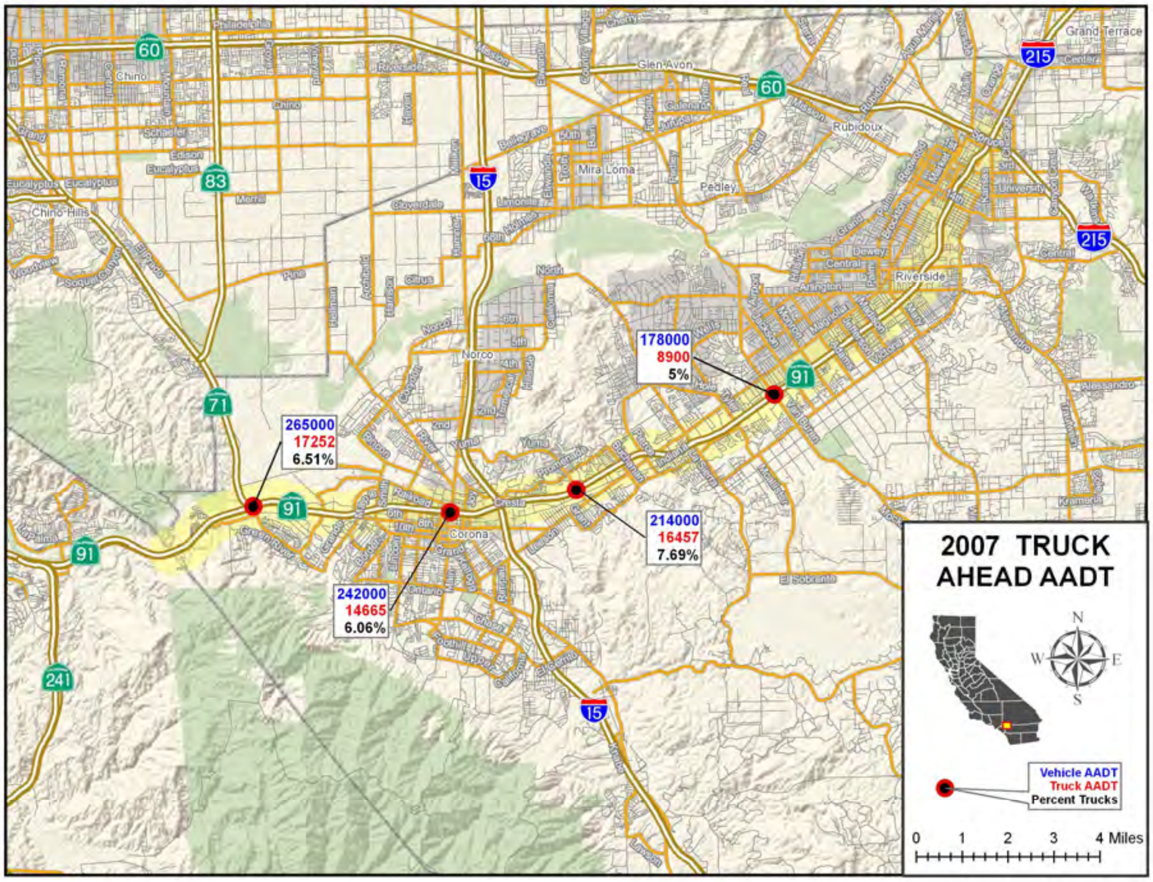


Exhibit 2-5: Truck Percentages



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Recent Roadway Improvements

Several roadway improvements have recently been completed and others are currently under construction along the corridor. These include:

- The SR-91 auxiliary lane project began construction in late October 2007 and opened to traffic in March 2008. This project added an auxiliary lane on eastbound SR-91 from SR-71 to the Serfas Club Drive Interchange.
- The I-15/SR-91 connector pavement rehabilitation project began construction in late November 2007. This project involved the repair and resurfacing of bridge decks of the northbound I-15 to the westbound SR-91 connector and the bridges over Temescal Wash.
- The La Sierra Interchange project involves local street closures as well as some rolling freeway closures on SR-91.
- The Green River Road Interchange project, which replaced the existing bridge, began construction in September 2007 and is nearing completion.
- A landscaping and paving project at the Lincoln Avenue Interchange in the City of Corona involved local closures at Lincoln Avenue.
- The SR-60/SR-91/I-215 improvement project was completed in December 2008. Among the major improvements are: four miles of HOV lanes and widened freeways on I-215, SR-60, and SR-91; major structural improvements at eight local interchanges; two sweeping 'flyover' connector ramps between the I-215/SR-60 and the SR-9 to create a new elevation for the SR-91 freeway in both the eastbound and westbound directions; and a new truck bypass connector leading from the southbound I-215 to the eastbound SR-60.
- A bi-county project with Caltrans District 8, Orange County, and Riverside County is anticipated to begin construction in late 2009. This will involve the construction of a continuous lane on eastbound SR-91 from the SR-241 Toll Road Interchange in Orange County to SR-71 in Riverside County.

When these projects are completed, the performance of the corridor will have to be revisited to account for likely shifting traffic patterns.

Transit

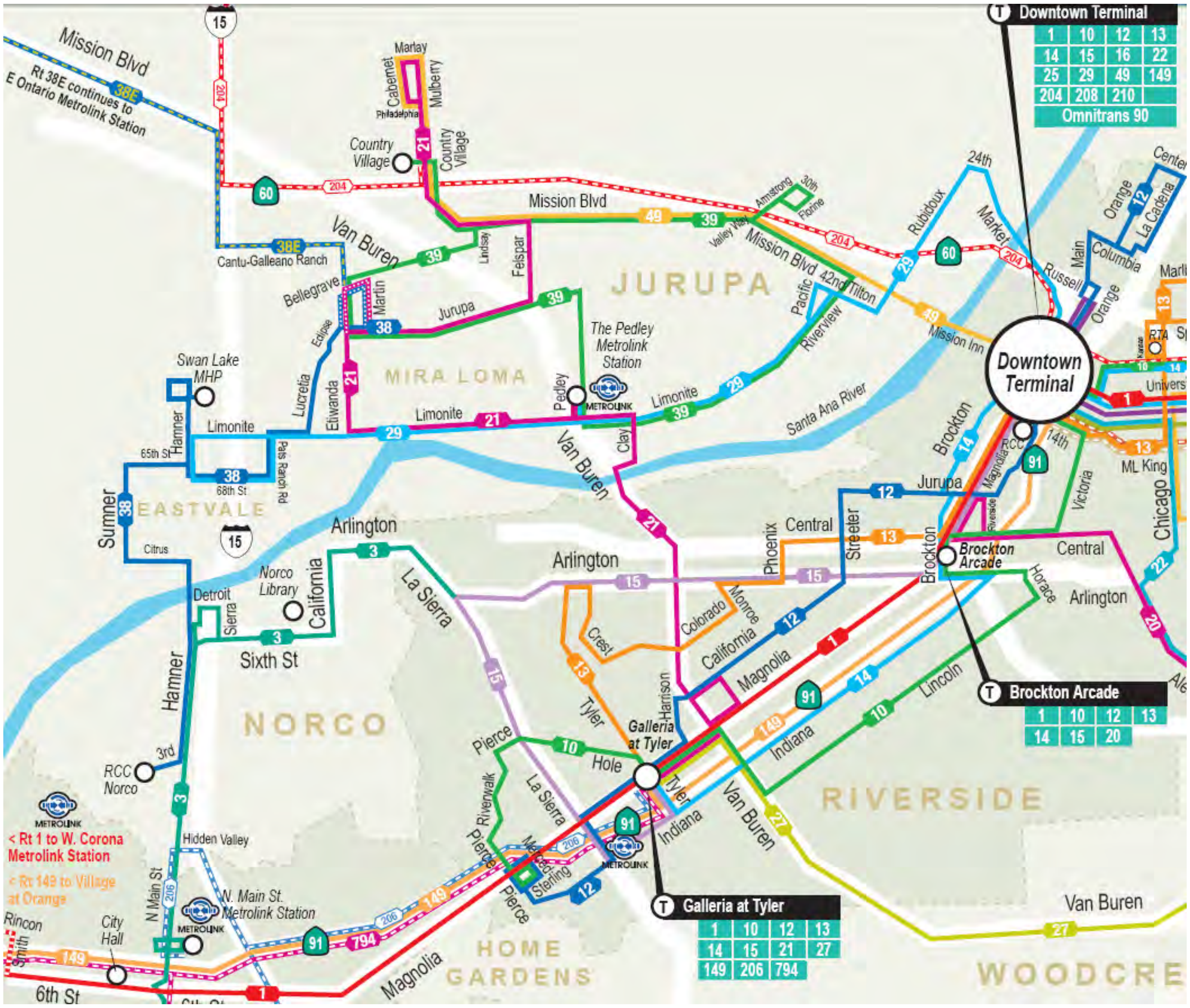
Major transit operators within the SR-91 study corridor include the Riverside Transit Agency, Omnitrans, and Metrolink commuter rail service

Established in 1975, Riverside Transit Agency (RTA) provides 38 fixed routes, five commuter routes, and Dial-A-Ride services in western Riverside County. RTA bus service links communities in Riverside County and Orange County along SR-91. Exhibit 2-6 graphically illustrates the transit lines which service the SR-91 study corridor area:

- Route 149 travels along SR-91 between the Downtown Terminal in Riverside to the Village at Orange in Anaheim. It provides both weekday and weekend service.
- Route 794 is a limited-stop express service that also travels along the SR-91, and connects the Galleria at Tyler Mall in the City of Riverside to the City of Corona and the South Coast Metro area in Orange County.
- Route 1 is a local service line that operates along 6th Street and Magnolia Avenue and connects The University of California, Riverside to the Corona Metrolink station.
- Other local routes that operate within close proximity to the study corridor include routes: 3, 10, 12, 13, 14, and 15.

Omnitrans is a joint powers authority which represents the County of San Bernardino and the 15 cities served by Omnitrans. It also offers bus service within the vicinity of the SR-91 Corridor. Route 215 connects San Bernardino to Riverside via the I-215 and SR-91. It provides service from the 4th Street Transit Mall in San Bernardino to the RTA Downtown Terminal in Riverside.

Exhibit 2-6: RTA Map Servicing the SR-91 Corridor



The Southern California Regional Rail Authority (SCRRA) is a joint powers authority that operates the Metrolink regional rail service throughout Southern California. Three lines service the areas along the study corridor:

- The Riverside Line provides service from the Los Angeles Union Station to downtown Riverside with stops in Montebello/Commerce, Industry, Pomona, Pedley, and Ontario. This line operates 12 trains on the weekdays and averages nearly 5,200 riders per day, which is roughly a 9 percent increase from 2006.

- The 91 Line provides service from the Los Angeles Union Station to downtown Riverside with stops in Commerce, Norwalk/Santa Fe Springs, Fullerton, Corona, and Riverside at La Sierra. This line operates 9 trains on the weekdays and averages over 2,250 riders per day, which reflects an increase of approximately 9 percent from 2006.

- The Inland Empire-Orange County Line connects the city of San Bernardino in San Bernardino County to the City of San Juan Capistrano in San Diego County. There are a total of 14 stations for this line with various stops in the cities of Riverside, Corona, and Orange County. This line operates 16 trains on the weekdays, six trains on Saturdays, and four trains on Sundays. Average weekday ridership in 2007 was slightly above 4,800, which reflects a growth of 7 percent since 2006.

Exhibit 2-7 Metrolink System Map

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Intermodal Facilities

Two small airports operate within the vicinity of the SR-91 study corridor, the Corona and Riverside Municipal Airports. The Corona Municipal Airport is located less than one-mile north of the study corridor between Serfas Club Drive and Lincoln Avenue. It has one runway and no control tower. In 2004, the Airport experienced roughly 68,000 aircraft operations, all of which were general aviation.

Exhibit 2-8 Corona Municipal Airport

The Riverside Municipal Airport is located approximately two-miles north of the study corridor between Van Buren Boulevard and Central Avenue. It serves the Inland Empire area with over 110,000 annual flight operations. It is tower-controlled with full-service runways.

Exhibit 2-9 Riverside Municipal Airport

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Trip Generators

Major special event facilities can generate significant trips on the SR-91 Corridor. A number of these facilities are shown in Exhibit 2-10.

One category of trip generators is educational institutions. These include:

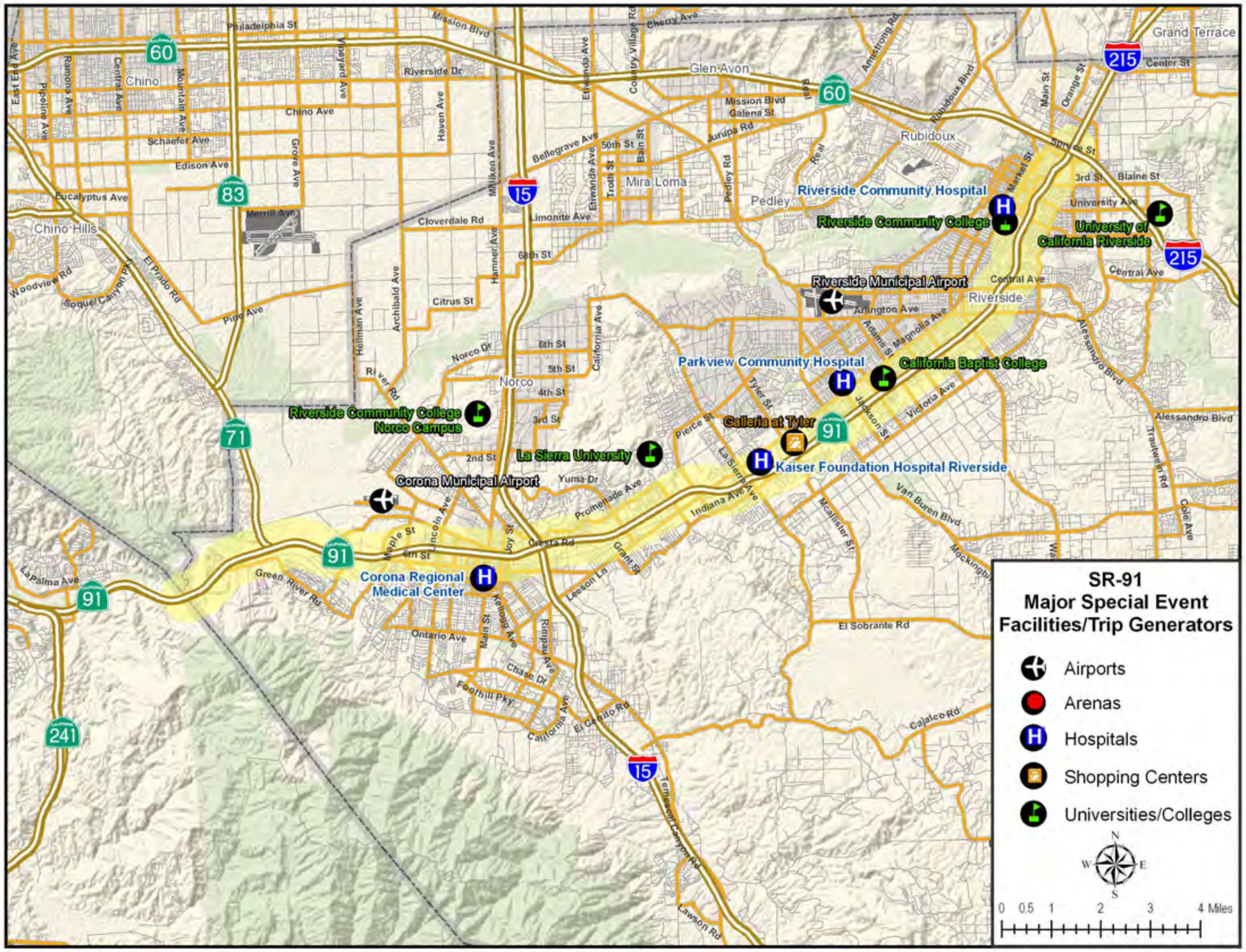
- The University of California, Riverside is the largest four-year university in Riverside County. It is located approximately 1.75 miles southeast of the SR-60/I-215 Interchange. In 2006, it had a student enrollment of almost 17,000 and it offers both graduate and undergraduate degrees.
- Riverside Community College District has campuses in close proximity to the SR-91 Corridor in the cities of Riverside and Norco.
- Riverside City College is located in downtown Riverside at 4800 Magnolia Avenue, adjacent to the SR-91 freeway west of 14th Street. It serves over 19,000 students.
- Riverside Community College Norco Campus is located at 2001 Third Street in Norco within two-miles northwest of the SR-91/I-215 interchange. It serves over 8,500 students.
- La Sierra University is located approximately one-mile north of the SR-91, just west of La Sierra Avenue. It is a private Christian university offering graduate and undergraduate programs. According to the *La Sierra University's Fast Facts 2004-2005*, student enrollment was approximately 2,000.
- California Baptist College is located right off the SR-91 at Adams Street. It is a private Christian university serving over 3,100 students offering both graduate and undergraduate programs.

In addition to educational institutions, hospital facilities can also be a major trip generator.

- The Parkview Community Hospital is situated north of SR-91 between Van Buren Boulevard and Adams Street. It is a 193-bed acute care hospital that has served the community since 1958.
- The Kaiser Foundation Hospital Riverside is located north of SR-91 between Tyler and La Sierra. It is a short term hospital with 215 total beds.
- The Riverside Community Hospital is located in downtown Riverside and west of SR-91 at 14th Street. It has over 400 physicians on staff and over 1,400 employees.
- Corona Regional Medical Center is located south of SR-91 on Main Street. It is a 240-bed community hospital network comprising a 160-bed acute care hospital and an 80-bed rehabilitiation campus.

Another major trip generator is the Galleria at Tyler. It is a shopping mall and movie complex located immediately off the SR-91 Tyler Street Interchange. It offers nearly 175 dining, entertainment, and shopping options.

Exhibit 2-10: Major Trip Generators



Source: SMG Analysis of PeMS Data

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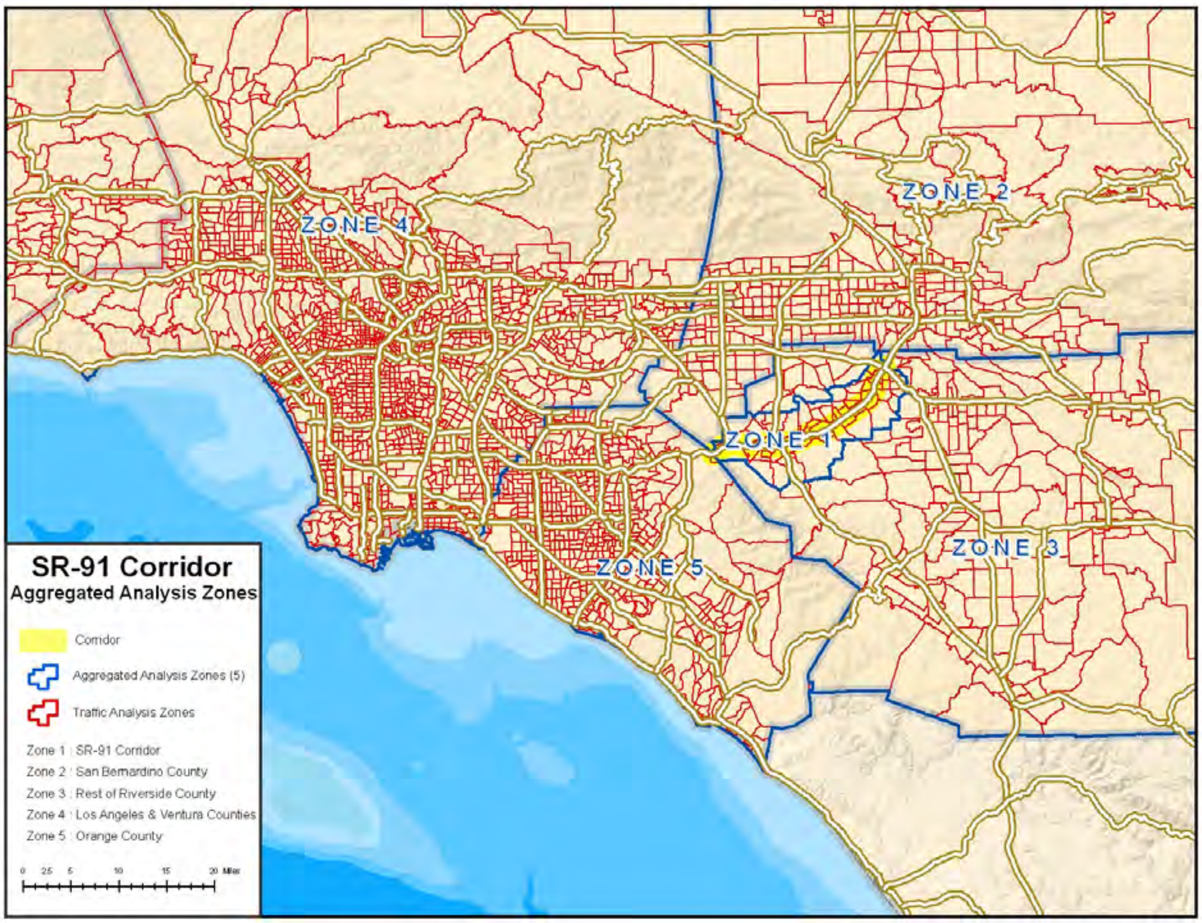
Demand Profiles

An analysis of origins and destinations was conducted to determine the travel pattern of trips made on the SR-91 study corridor. Based on SCAG's travel demand model, this "select link analysis" isolated the SR-91 study corridor and identified the origins and destinations of trips made on the corridor. The origins and destinations were identified by Traffic Analysis Zone (TAZ), which were grouped into five aggregate analysis zones shown in Exhibit 2-11.

Exhibit 2-11: Aggregate Analysis Zones for Demand Profile Analysis



Based on this aggregation, demand on the corridor was summarized by aggregated origin-destination zone as depicted in Exhibits 2-12 and 2-13 for the AM and PM peak periods. This analysis shows that a large number of trips using the SR-91 study corridor represent travel within Riverside and San Bernardino Counties, but also to and from Orange County.

During the AM peak period, 66 percent of all trips originate in Riverside/San Bernardino Counties and terminate outside those counties. The majority of these trips are destined for Orange County. The remaining trips depicted in Exhibit 2-12 originate and terminate in Riverside/San Bernardino Counties (19 percent); originate outside Riverside/San Bernardino Counties and terminate outside those counties (11 percent); or originate outside Riverside/San Bernardino Counties and terminate in Riverside/San Bernardino Counties (3 percent). This data suggests that AM congestion is concentrated in the westbound direction with a significant number of trips destined for counties outside of Riverside and San Bernardino, mainly Orange County.

Exhibit 2-12: AM Peak Origin Destination by Aggregated Analysis Zone

		To Zone					
	AM Trips	SR-91 Corridor	San Bernardino County	Rest of Riverside Co	LA and Ventura Counties	Orange County	Outside Zones
From Zone	SR-91 Corridor	1,613	840	11,268	18,710	29,649	412
	San Bernardino County	45	64	5,737	3,140	13,087	114
	Rest of Riverside County	399	417	3,824	6,897	11,879	154
	LA and Ventura Counties	21	0	698	281	1,987	569
	Orange County	353	23	2,675	2,994	6,564	946
	Outside Zones	10	67	183	404	472	117

19.1%	Trips starting and ending in Riverside/San Bernardino Counties
66.4%	Trips starting in Riverside/San Bernardino and ending outside Riverside/San Bernardino
3.2%	Trips starting outside Riverside/San Bernardino and ending in Riverside/San Bernardino
11.3%	Trips starting outside Riverside/San Bernardino and ending outside Riverside/San Bernardino

During the PM peak period (which experiences roughly 30 percent more demand than the AM for travel on SR-91), the picture is slightly different. Roughly 45 percent of trips originate and terminate in Riverside/San Bernardino Counties. The remaining trips originate outside Riverside/San Bernardino Counties and terminate in Riverside/San Bernardino (35 percent); originate in Riverside/San Bernardino Counties and terminate outside those counties (18 percent); or originate and terminate outside Riverside/San Bernardino Counties (3 percent). Of the 35 percent of trips that originate outside Riverside and San Bernardino Counties, 82 percent of those originate in Orange County.

Exhibit 2-13: PM Peak Origin Destination by Aggregated Analysis Zone

	PM Trips	To Zone: SR-91 Corridor	San Bernardino County	Rest of Riverside Co	LA and Ventura Counties	Orange County	Outside Zones
From Zone	SR-91 Corridor	24,846	17,871	9,063	4,301	13,076	439
	San Bernardino County	17,476	0	1,171	274	6,754	151
	Rest of Riverside County	7,916	778	541	1,312	5,676	215
	LA and Ventura Counties	6,947	323	2,531	0	362	568
	Orange County	25,764	10,601	14,234	237	0	916
	Outside Zones	841	171	225	906	2,153	205

44.5%	Trips starting and ending in Riverside/San Bernardino Counties
18.0%	Trips starting in Riverside/San Bernardino and ending outside Riverside/San Bernardino
34.5%	Trips starting outside Riverside/San Bernardino and ending in Riverside/San Bernardino
3.0%	Trips starting outside Riverside/San Bernardino and ending outside Riverside/San Bernardino

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3. CORRIDOR-WIDE 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 objective of the measures is to provide a sound technical basis for describing traffic performance on the corridor. Data from the mainline (ML) and high-occupancy vehicle (HOV) facilities are analyzed separately under each performance measure. The base year for the analysis and modeling is 2007 for the SR-91 study corridor.

The performance measures focus on four key areas:

- **Mobility** describes how well people and freight move along the corridor
- **Reliability** captures the relative predictability of travel along the corridor
- **Safety** provides an overview of collisions along the corridor
- **Productivity** describes the productivity loss due to traffic inefficiencies
- **Pavement Condition** describes the structural adequacy and ride quality of the pavement.

MOBILITY

The mobility performance measures are both measurable and straightforward for documenting current conditions. They can also be forecasted, which makes them useful for future comparisons. Two primary measures are typically used to quantify mobility: delay and travel time.

Delay

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

$$\left(\text{Vehicles Affected per Hour}\right)\times\left(\text{SegmentLength}\right)\times\left(\text{Duration}\right)\times\left[\frac{1}{\left(\text{Congested Speed}\right)}-\frac{1}{\left(\text{Threshold Speed}\right)}\right]$$

In the formula above, the *Vehicles Affected per Hour* value depends on the methodology used. Some methods assume a fixed flow rate (e.g., 2000 vehicles per hour per lane), while others use a measured or estimated flow rate. The segment length is the distance under which the congested speed prevails. The duration is how long the congested period lasts (measured in hours), with the congested period being the amount of time spent below the threshold speed. The threshold speed is the speed under which congestion is considered to occur. Any speed can be used, but two commonly used threshold speeds are 35 mph and 60 mph.

Caltrans defines the threshold speed as 35 mph and assumes a fixed 2,000 vehicles per hour per lane are experiencing the delay to estimate severe delay for reporting congestion for the statewide Highway Congestion Monitoring Report (HICOMP).

In calculating total delay, PeMS uses the 60 mph threshold speed and the observed number of vehicles reported by detection systems. The congestion results of HICOMP and PeMS are difficult to compare due to these methodological differences, so they are discussed separately in this assessment.

Caltrans HICOMP

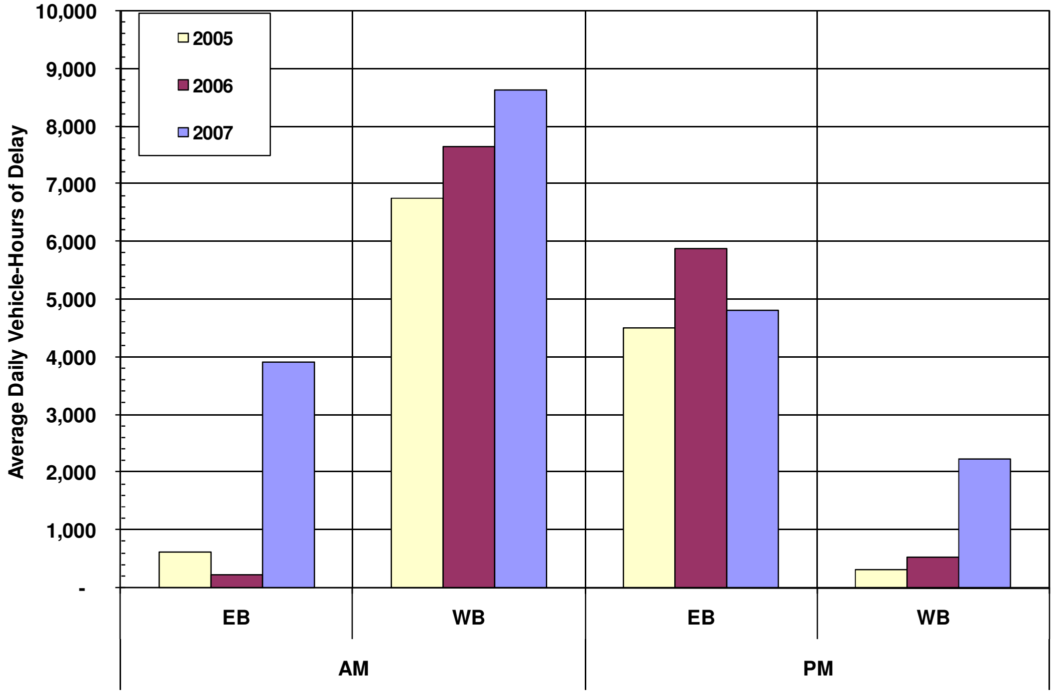
The HICOMP report has been published by Caltrans annually since 1987.[2] Delay is presented as average daily vehicle-hours of delay (DVHD). In HICOMP, Caltrans attempts to capture recurrent congestion during “typical” incident-free weekday peak periods. Recurrent delay is defined in HICOMP as a condition where speeds drop below 35 mph for a period of 15-minutes or longer during weekday AM or PM commute periods.

For the analysis of the SR-91 study corridor, a mix of automatic detection data and probe vehicle (tachometer or “tach” run) data have historically been used. Where “good” PeMS data is available, detector data is used; where District 8 staff believes that better results are obtained by manual data collection and field observation, probe vehicle data is used. The most current HICOMP report is available for 2007. HICOMP data is available for the mainline facility only.

Exhibit 3-1 summarizes HICOMP data for the yearly delay trends in 2005, 2006, and 2007 during the AM and PM peak period in both directions of the study corridor. As indicated in the exhibit, congestion is directional – morning congestion occurs in the westbound direction and afternoon congestion occurs in the eastbound direction.

[2] Located at <www.dot.ca.gov/hq/traffops/sysmgtpl/HICOMP/index.htm>

Exhibit 3-1: Average Daily Vehicle-Hours of Delay by Peak Period (HICOMP)



Source: SMG Analysis of PeMS Data

Exhibit 3-2 shows a complete list of congested segments reported by the HICOMP report for the SR-91 Corridor. A congested segment may vary in distance or size from one year to the next as well as from day-to-day.

Exhibits 3-1 and 3-2 reveal that total congestion in the AM peak is greater than the PM peak and that the AM peak worsened by 60 percent from 2006 (7,849 hours of delay) to 2007 (12,514 hours of delay). In 2007, westbound delay during the AM peak was highly concentrated between McKinley Boulevard in Corona and Serfas Club Drive/SR-71. This segment alone experienced 8,254 hours of delay during the AM peak, the highest delay of any other segment on the corridor in either direction.

In the eastbound direction, congestion is concentrated in the PM peak. During the 2005-2007 period, congestion steadily increased to 7,044 hours of delay in 2007. Similar to the westbound direction, the segment that experienced the most delay in the eastbound direction is between Serfas Club Drive and McKinley with 2,955 hours of delay.

The maps in Exhibits 3-3 and 3-4 show the 2007 AM and PM peak period delay listed in Exhibit 3-2. The approximate locations of the congested segments, the duration of congestion, and the reported recurrent daily delay are shown on the maps.

Exhibit 3-2: HICOMP Hours of Delay for Congested Segments (2005-2007)

Period	Dir	Generalized Congested Area	Generalized Area Congested Hours of Delay 2005	2006	2007
AM	EB	East of Van Buren Blvd to e/o Ivy Street			
		Van Buren Blvd to w/o Madison St	611		
		West of Jackson St to w/o Ivy St OC		215	
		e/o McKinley to B/n La Sierra & Van Buren			214
		B/n La Sierra & Van Buren to 2 mi w/o 91/215/60 IC			3,679
	WB	La Sierra Ave to Pierce St			
		McKinley St to e/o SR-71			
		East of SR-71 to Orange/Riverside County Line			
		La Sierra Ave to Buchanan St	336		
		Buchanan St to McKinley St	141		
		McKinley St to I-15	1,848		
		I-15 to w/o Prado OH	4,281		
		West of Prado OH to Orange/Riverside County Line	144		
		La Sierra Ave to e/o McKinley St		164	
		East of McKinley St to I-15		2,227	
		I-15 to w/o Serfas Club Dr		5,055	
		West of Serfas Club Dr to Orange/Riverside County Line		189	
		b/n Serfas Clube Drive & SR-71 to County Line			225
		McKinley to b/n Serfas Clube Drive & SR-71			8,254
		Magnolia to McKinley			142
AM PEAK PERIOD SUMMARY			7,361	7,850	12,514
PM	EB	Orange/Riverside County Line to McKinley St			
		McKinley St to Corona/Riverside City Line			
		Indiana Ave to e/o Pachappa UP			
		Tenth St to Junction I-215/SR-60			
		Serfas Club Dr to I-15	2,803		
		I-15 to e/o McKinley St	510		
		West of Van Buren Blvd to Madison St	331		
		Central Ave to I-215	861		
		Orange/Riverside County Line to I-15		3,016	
		I-15 to Magnolia Ave		527	
		Van Buren Blvd to Junction I-215/SR-60		2,325	
		County Line to Serfas Club Drive			1,419
		Serfas Club Drive to McKinley.			2,955
		McKinley to Magnolia			301
		1 mi w/o 060/215 to 060/215			133
	WB	West of Spruce St to Ivy St			
		La Sierra Ave to Pierce St			
		McKinley St to Main St			
		East of La Sierra Ave to w/o Pierce St	312		
		Third St UC to Arlington Ave		217	
		East of La Sierra Ave to e/o Buchanan St		307	
		Van Buren to McKinley			313
		060/215 to 1.5 e/o Adams			1,923
PM PEAK PERIOD SUMMARY			4,816	6,392	7,044
TOTAL CORRIDOR CONGESTION			**12,177**	**14,242**	**19,558**

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

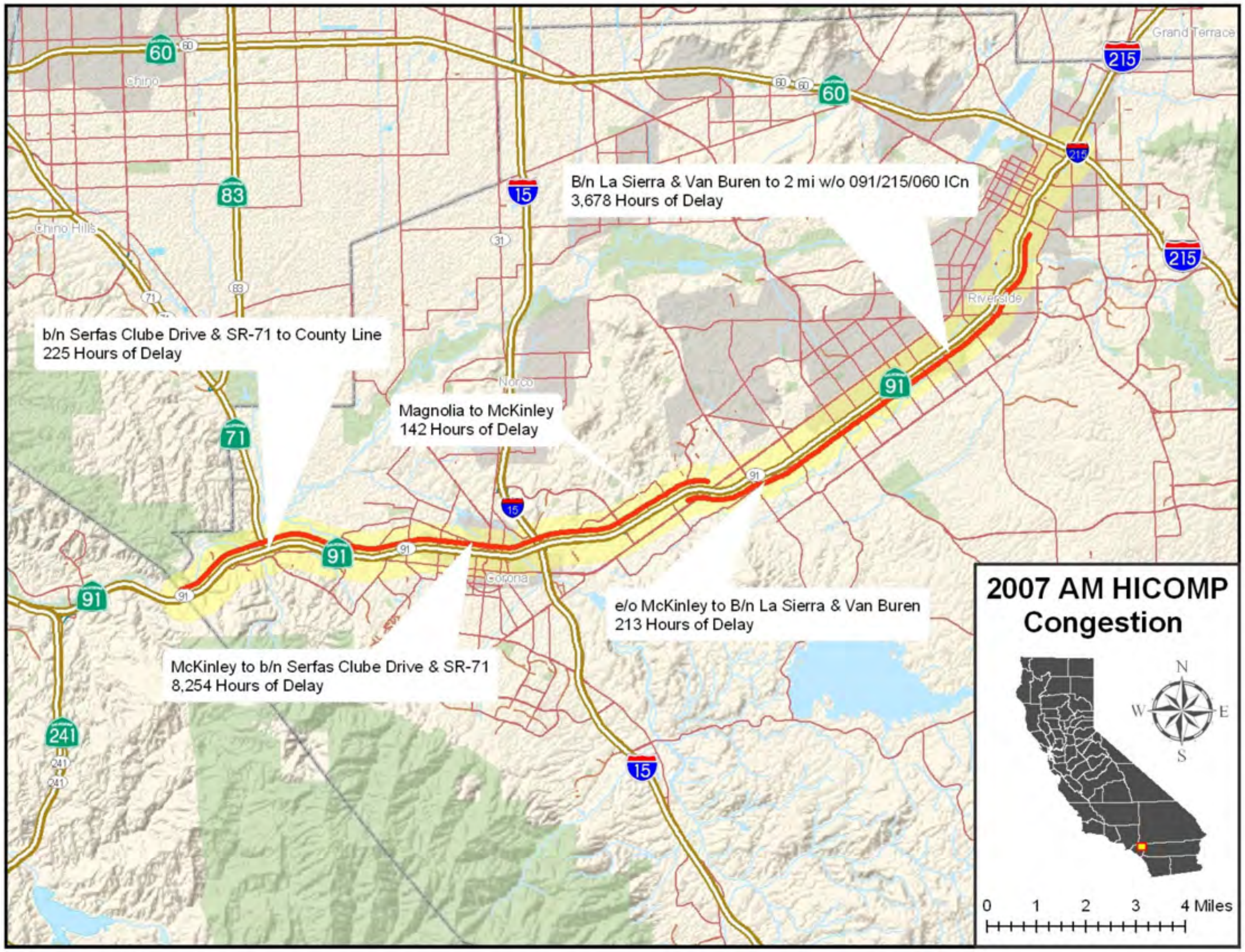
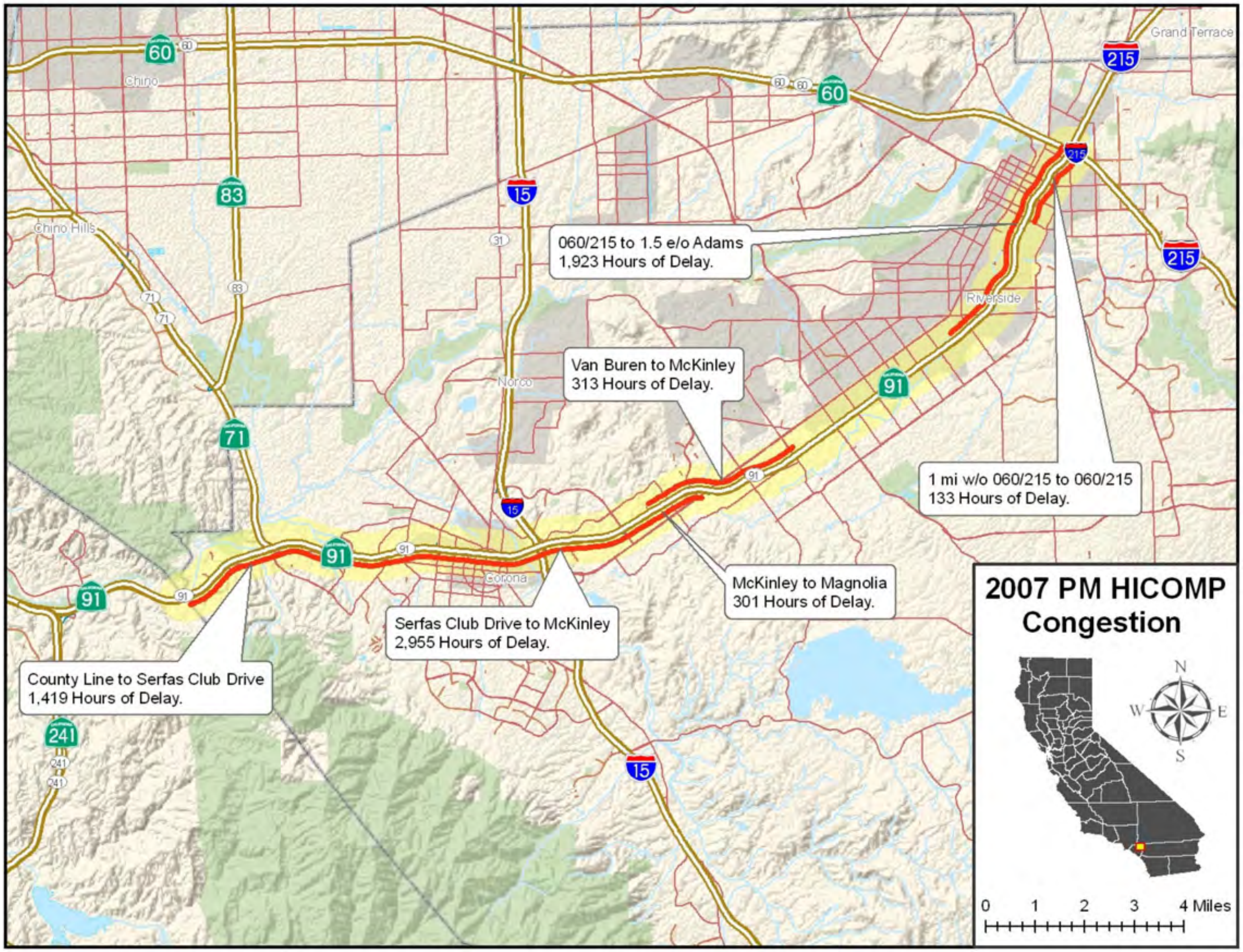


Exhibit 3-4: 2007 PM Peak Period HICOMP Congested Segments Map (2007)



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Freeway Performance Measurement System (PeMS)

Using freeways 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.

Performance assessments were conducted initially for the three-year period between 2005 and 2007. These assessments were recently updated through December 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 in this section 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 and 3-6.

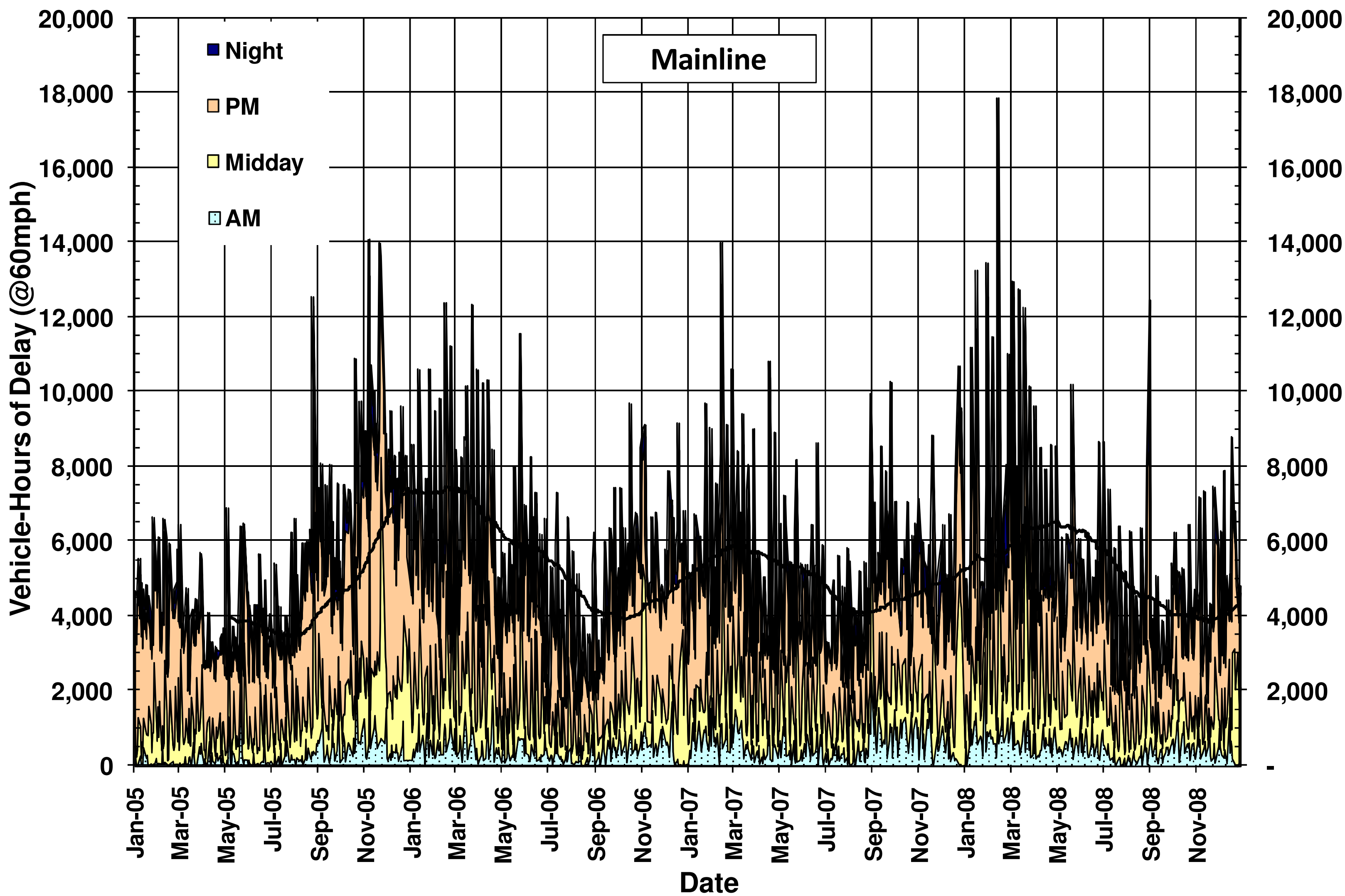
The performance assessment includes four years of PeMS data filtered to exclude data considered to be of poor quality. The study team used estimated or imputed data for sensors with sufficient observed data to provide for reasonable estimates.

Weekday delay for the mainline facility is presented in Exhibits 3-5 and 3-6 during the four-year period of 2005-2008. Within the exhibit, there is a 90-day moving average to “smooth” out the day-to-day variations and illustrate the seasonal and annual changes in congestion over time. Similar to HICOMP data, the PeMS data shows a directional congestion pattern of delay with the westbound direction experiencing greater congestion during the AM peak and the eastbound direction experiencing more congestion during the PM peak. However, unlike HICOMP data, PeMS data shows that PM delay is significantly and greater than AM delay during all four years analyzed.

The average total eastbound delay consistently fluctuated between 4,000 and 6,000 hours (Exhibit 3-5), with a noticeable decline of delay during the summer months. Delay in the westbound direction was noticeably less than the eastbound direction with the average total westbound delay lingering below 4,000 hours (Exhibit 3-6). A gradual decline in delay occurred in the westbound direction starting in March 2007 and continuing through 2008. Out of the four years analyzed, 2005 was year which experienced the greatest delay in both directions of travel. However, overall delay in the eastbound direction remained consistent while the westbound direction experienced a pattern of decline starting in 2007.

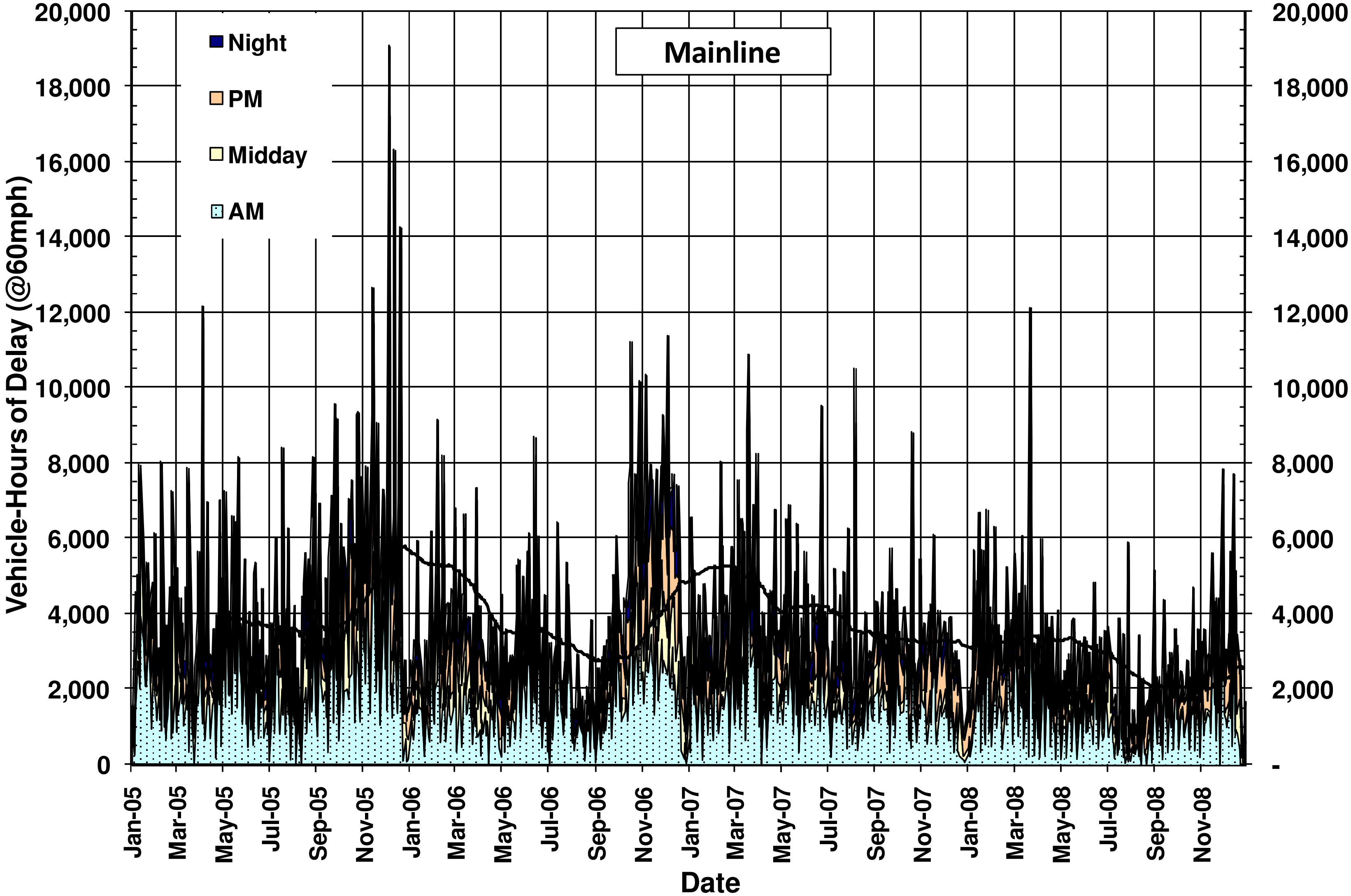
Exhibits 3-7 and 3-8 show that delay on the HOV facility followed the same pattern as the mainline facility with more congestion having occurred in the PM for the eastbound direction and in the AM for the westbound direction. During the 2005-2008 period, the average HOV eastbound delay hovered around 1,000 hours with the highest delay having occurred around February 2008. Similar to the mainline trend, the westbound HOV facility experienced less delay than the eastbound direction with an average delay around 600 hours during the same four-year period. However, the gradual decline of delay experienced on the westbound mainline facility was not as apparent on the HOV westbound facility in 2007 and 2008.

Exhibit 3-5: SR-91 Eastbound Mainline Average Daily Delay by Time Period (2005-2008)



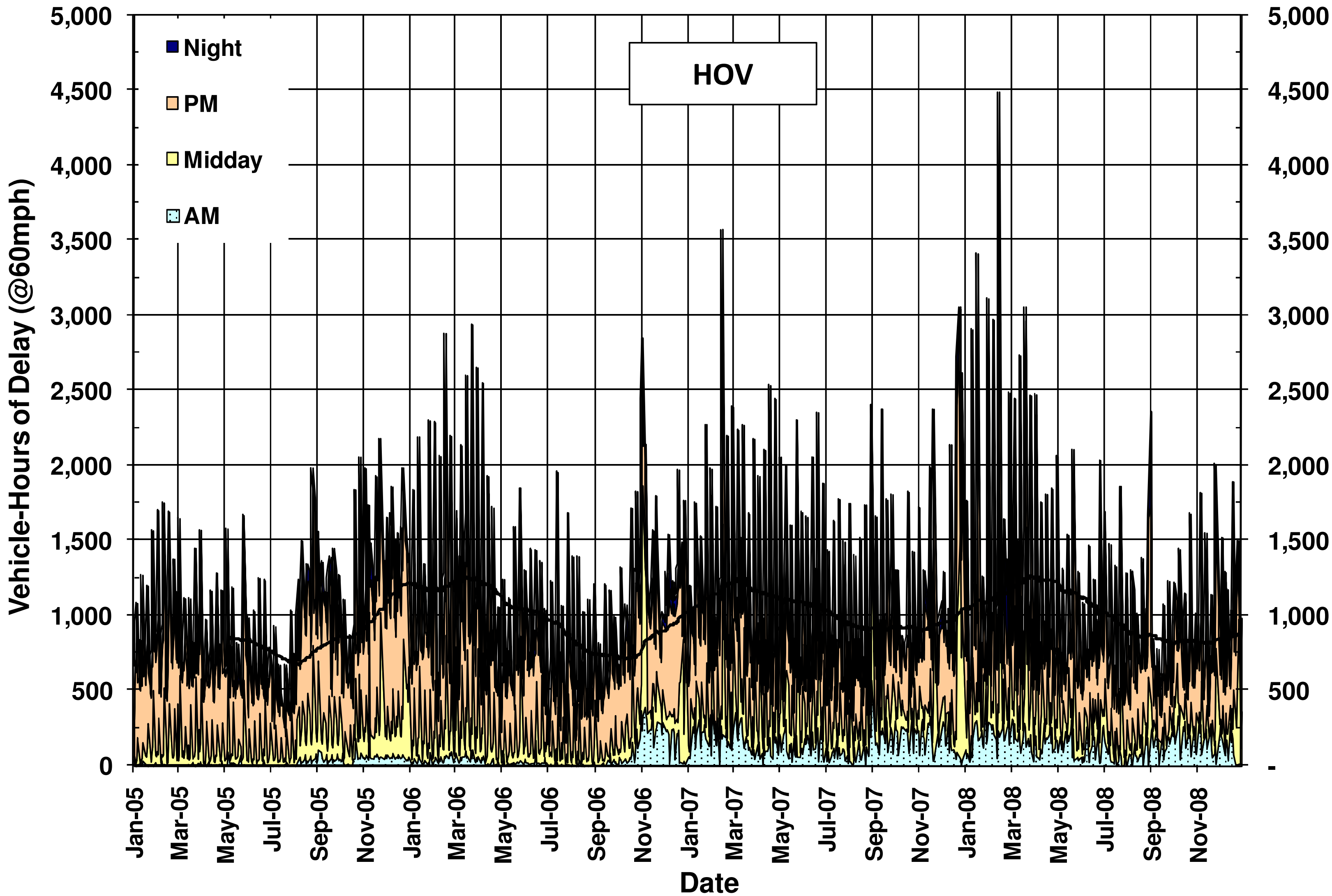
Source: SMG Analysis of PeMS Data

Exhibit 3-6: SR-91 Westbound Mainline Average Daily Delay by Time Period (2005-2008)



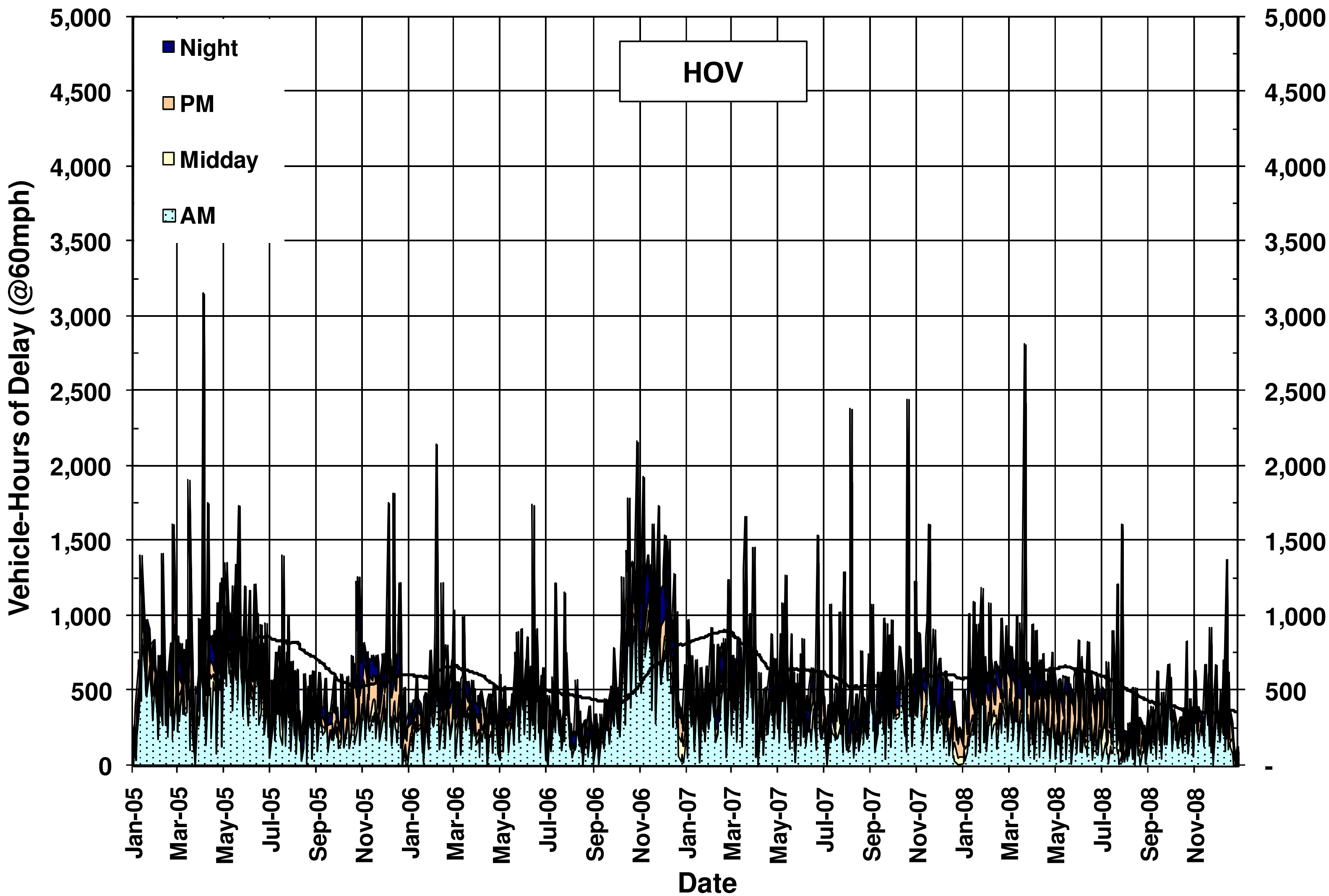
Source: SMG Analysis of PeMS Data

Exhibit 3-7: SR-91 Eastbound HOVL Average Daily Delay by Time Period (2005-2008)



Source: SMG Analysis of PeMS Data

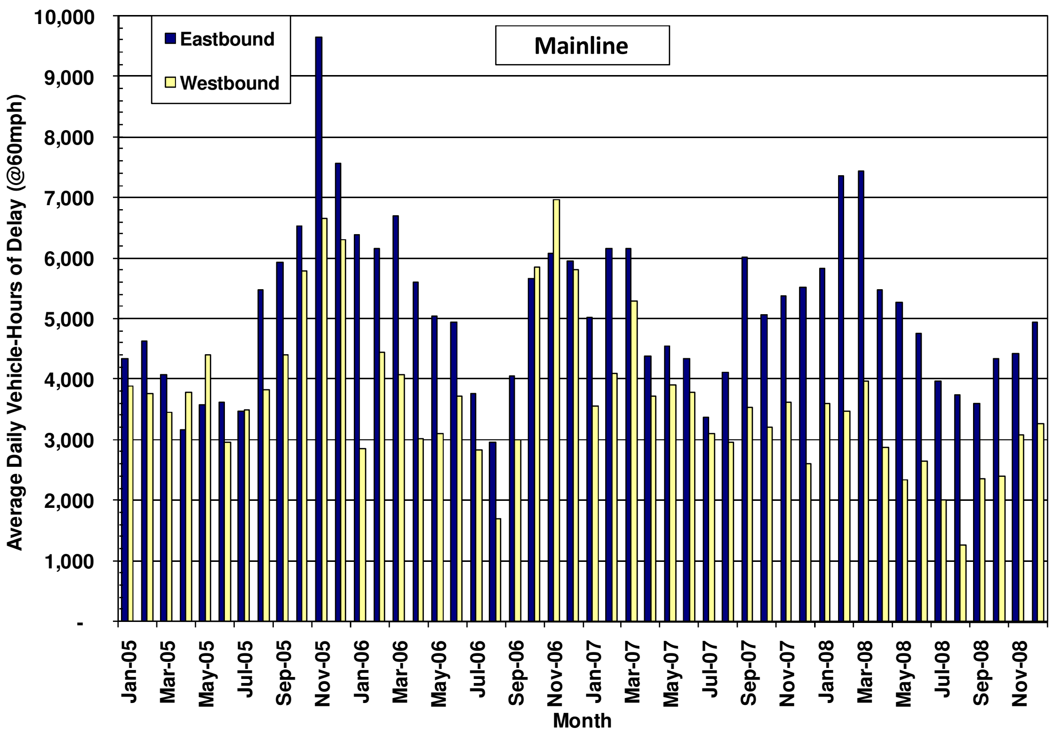
Exhibit 3-8: SR-91 Westbound HOVL Average Daily Delay by Time Period (2005-2008)



Source: SMG Analysis of PeMS Data

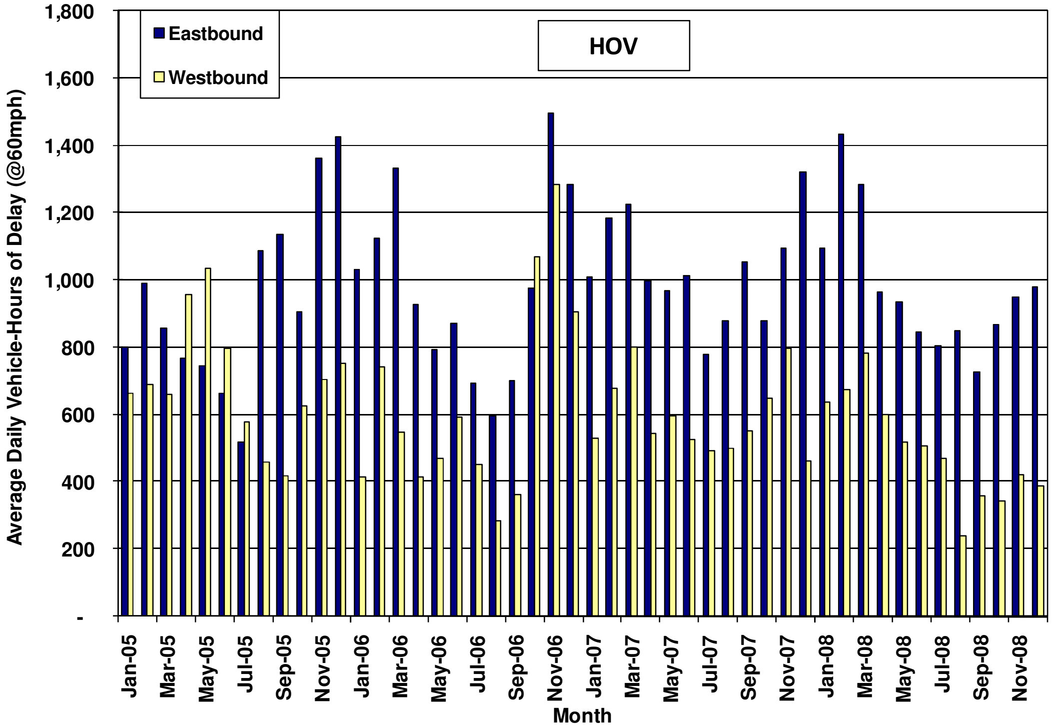
The average daily weekday delay by month for the mainline and HOV facilities are depicted in Exhibits 3-9 and 3-10. These exhibits again illustrate that delay in the eastbound direction is greater than the westbound and that seasonal dips in delay occur in the summer months in both the mainline and HOV facilities.

Exhibit 3-9: SR-91 Mainline Average Weekday Delay by Month (2005-2008)



Source: SMG Analysis of PeMS Data

Exhibit 3-10: SR-91 HOVL Average Weekday Delay by Month (2005-2008)



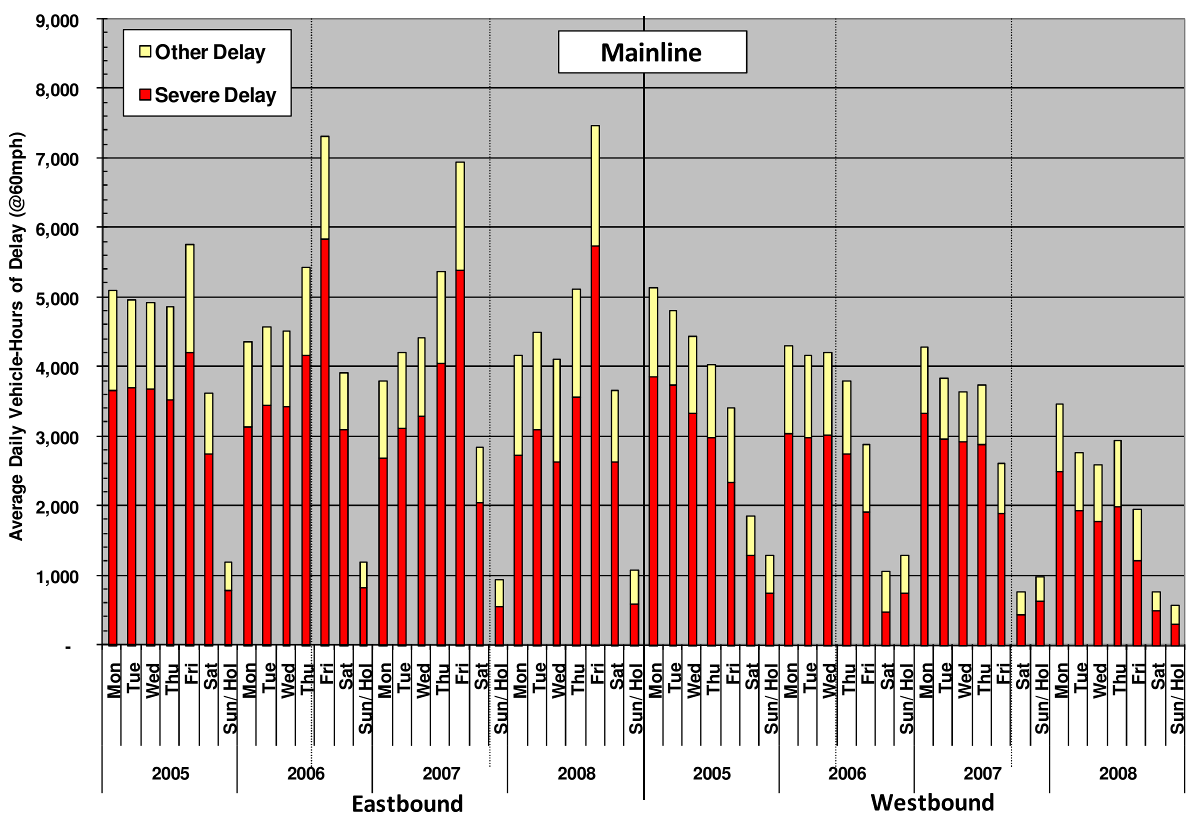
Source: SMG Analysis of PeMS Data

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 occurring when speeds are below 35 miles per hour
- Other delay – delay occurring when speeds are between 35 and 60 miles per hour.

Severe delay, as depicted in Exhibits 3-11 and 3-12 represent 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 cause temporary slowdowns rather than widespread breakdowns. Exhibit 3-11 shows that severe delay comprised 75 percent of all weekday delay on the mainline facility during the 2005-2008 period. In the eastbound direction of the mainline, the level of congestion grew during the workweek and peaked on Fridays. In contrast, the westbound direction of the mainline shows greater delay on Mondays with a gradual decrease as the workweek progressed. Delays were minimal on weekends in both directions of the mainline.

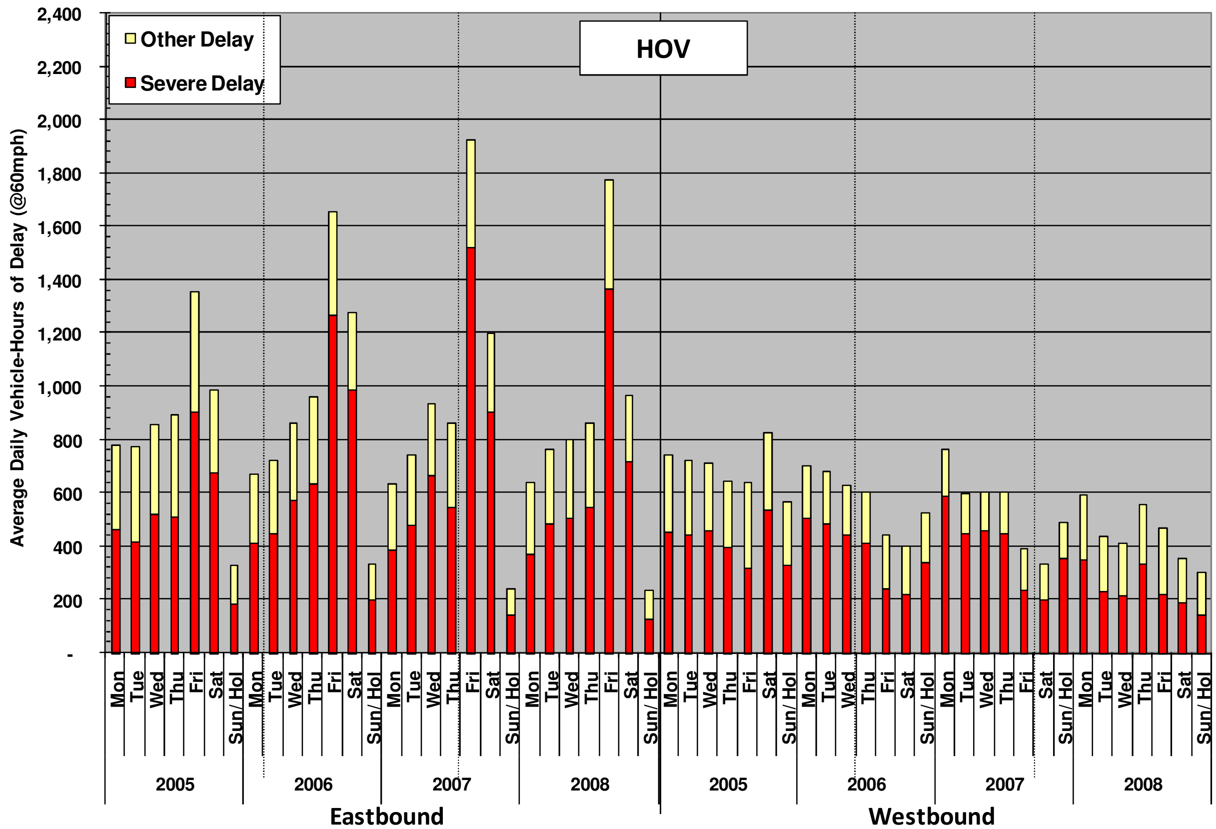
Exhibit 3-11: SR-91 Mainline Average Delay by Day of Week by Severity (2005-2008)



Source: SMG Analysis of PeMS Data

On the HOV facility, Exhibit 3-12 shows that severe delay comprised roughly 65 percent of all weekday delay, which is about 10 percent less than the mainline facility. Similar to the mainline facility, congestion on the eastbound HOV grew during the workweek and peaked on Fridays, whereas congestion on the westbound HOV was highest on Mondays and declined during the work week.

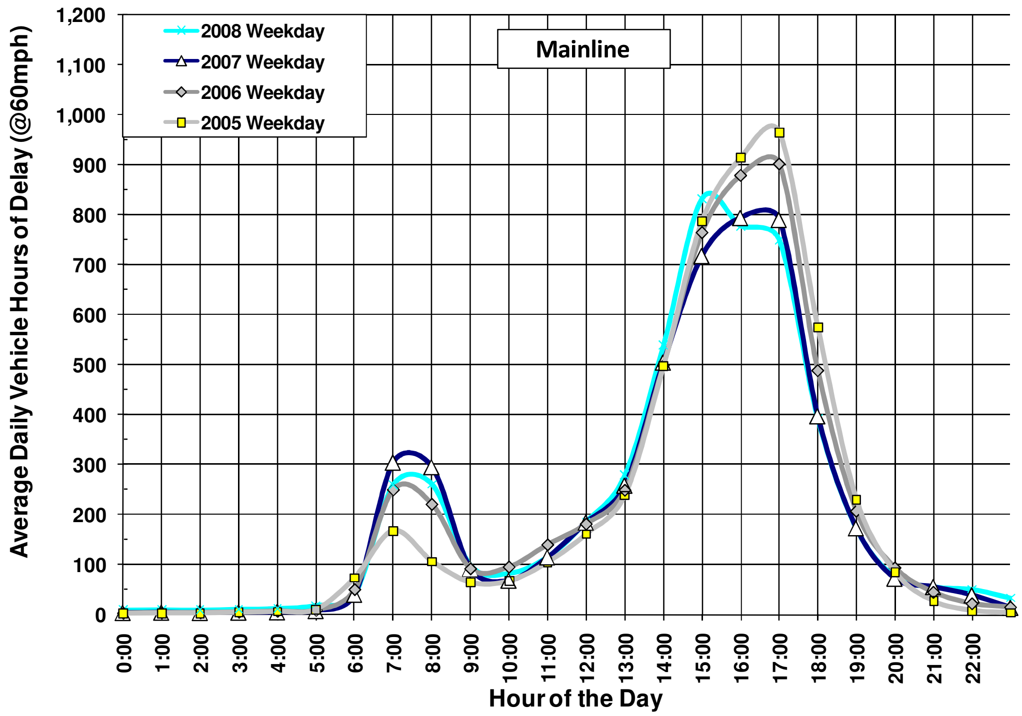
Exhibit 3-12: SR-91 HOVL Average Delay by Day of Week by Severity (2005-2008)



Source: SMG Analysis of PeMS Data

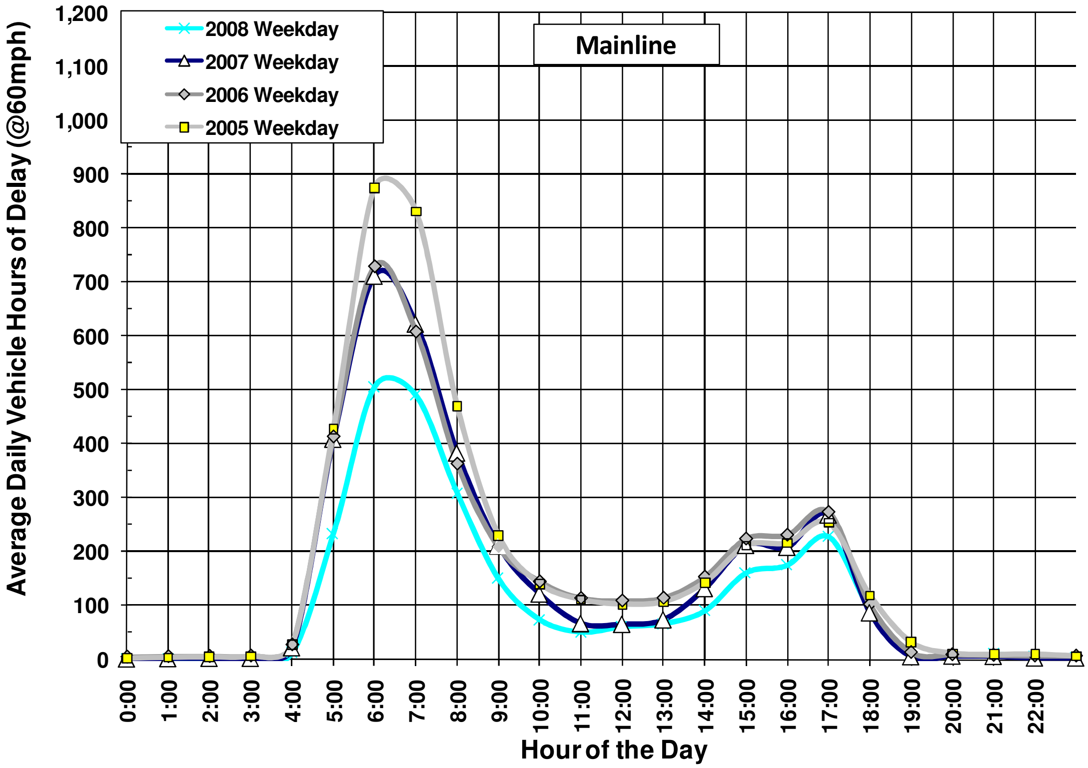
Another way to understand the characteristics of congestion and related delays is shown in Exhibits 3-13 through 3-16, which summarize weekday delays by time of day from 2005-2008. For the mainline facility in 2007, Exhibit 3-13 shows that the peak hourly delay in the eastbound direction is approximately 800 vehicle-hours at around 5:00 PM. Conversely, Exhibit 3-14 shows that the peak hourly delay in the westbound mainline is about 700 vehicle-hours at around 6:00 AM. For both directions of the mainline, 2005 experienced the greatest delay and 2008 experienced the least delay during their respective peak hours. However, the peak hour in the eastbound mainline appeared to have shifted from 5:00 PM in the previous years to 3:00 PM in 2008.

Exhibit 3-13: Eastbound Mainline Average Weekday Hourly Delay (2005-2008)



Source: SMG Analysis of PeMS Data

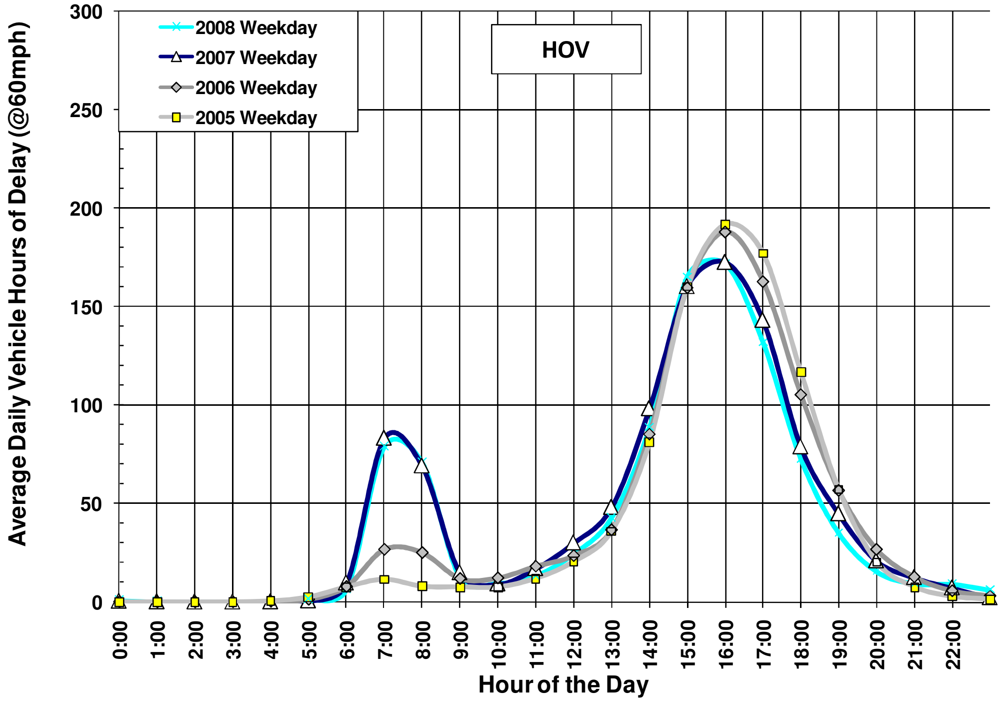
Exhibit 3-14: Westbound Mainline Average Weekday Hourly Delay (2005-2008)



Source: SMG Analysis of PeMS Data

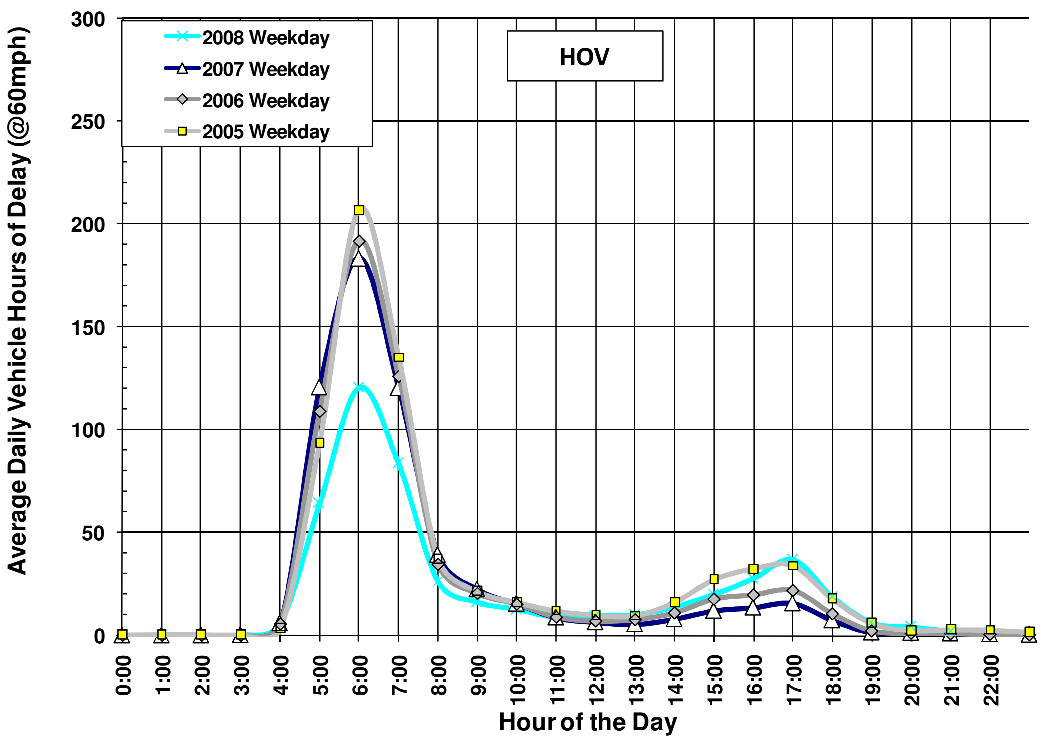
Delay on the HOV facility in Exhibits 3-15 and 3-16 reveal a slightly different pattern than the mainline facility. Exhibit 3-15 shows that the peak hourly delay in the eastbound HOV facility is approximately 170 vehicle-hours at around 4:00 PM, which is one hour earlier than the eastbound mainline facility. Exhibit 3-16 shows that the peak hourly delay in the westbound mainline is about 180 vehicle-hours at around 6:00 AM, which is the same peak hour as the mainline westbound facility. Unlike the mainline, the peak hour in the eastbound HOV facility did not shift in 2008 but remained the same as the previous years.

Exhibit 3-15: Eastbound HOVL Average Weekday Hourly Delay (2005-2008)



Source: SMG Analysis of PeMS Data

Exhibit 3-16: Westbound HOVL Average Weekday Hourly Delay (2005-2008)



Source: SMG Analysis of PeMS Data

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Travel Time

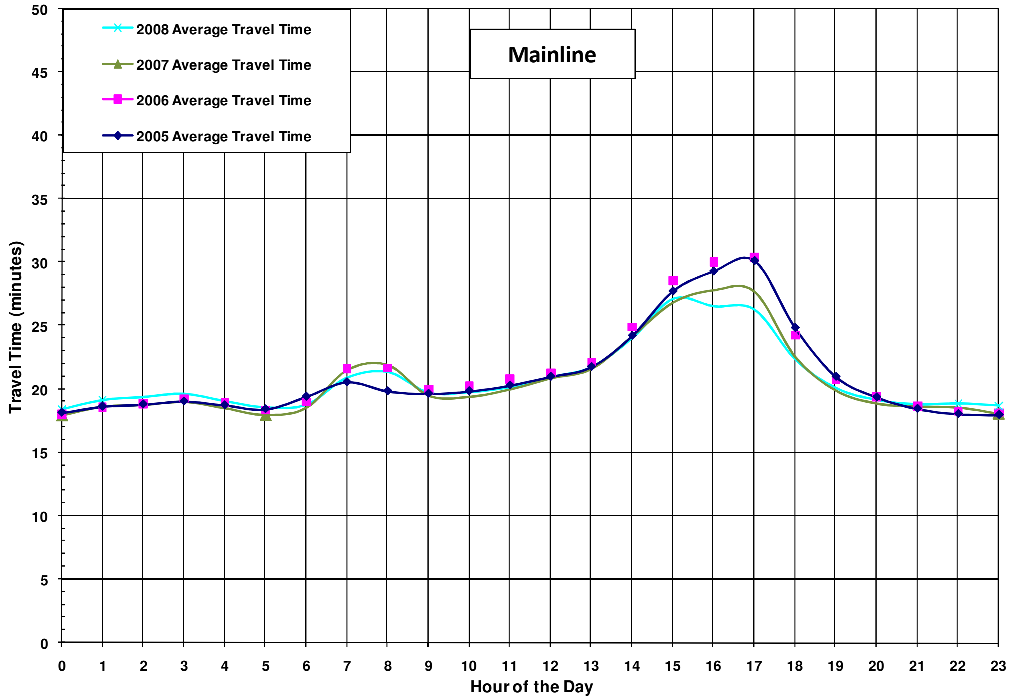
Travel time is reported as the amount of time it takes for a vehicle to travel between two points on a corridor as estimated using PeMS data. For the SR-91 corridor, this travel time is the time to traverse the 22 miles on the SR-91 corridor from the Orange County/Riverside County line to the I-215/SR-60 interchange. Travel time on parallel arterials was not included for this analysis.

Exhibits 3-17 through 3-20 summarize the travel times estimated for the mainline and HOV facilities using PeMS data. As shown in Exhibits 3-17 and 3-18, travel along the mainline takes about 18 minutes during the off-peak periods. This corresponds to a speed of just over 70 mph.

Exhibits 3-17 and 3-18 illustrate that travel times for both directions of the mainline have decreased between 2005 and 2008. During the 6:00 AM peak hour, travel time in the westbound mainline is estimated to have been roughly 24 minutes in 2008 (Exhibit 3-18). This is lower by 20 percent than the 30 minutes estimated for 2005. During the PM peak hour at 5:00 PM, travel time for the eastbound mainline is estimated to be 17 minutes in 2008, which is lower by 43 percent than the 30 minutes estimated in 2005. The 2007 base year experienced a travel time of 28 minutes in both directions during the respective peak hours.

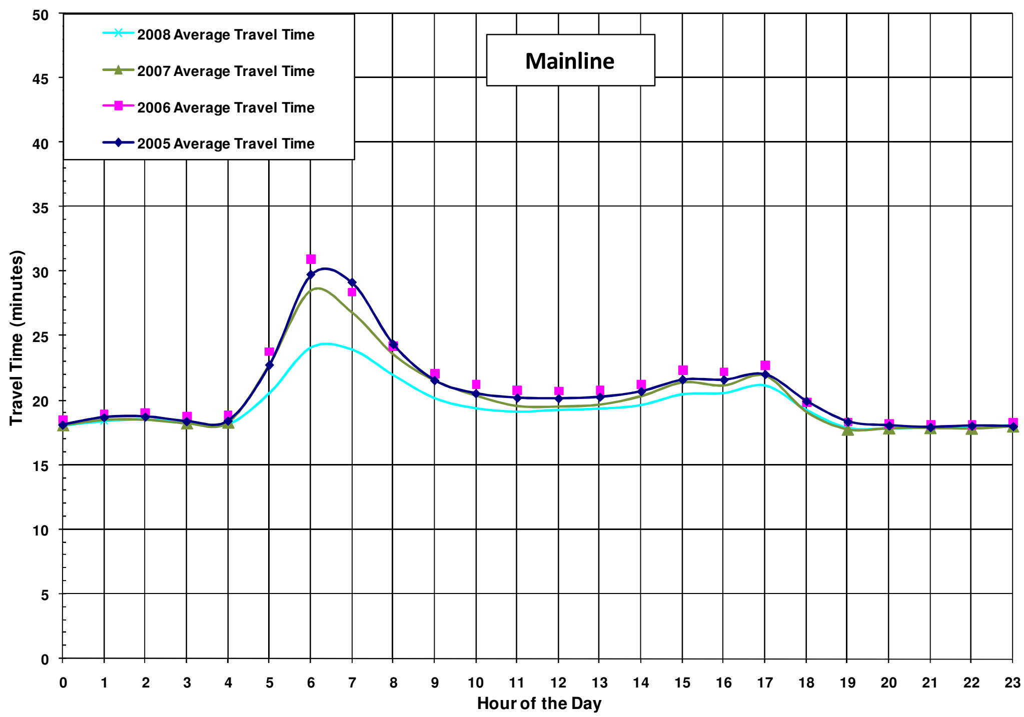
Travel times on the HOV facilities displayed the same characteristics as the mainline facility. Again, travel times on the HOV facility in both directions are lowest in 2008 compared to the earlier three years. This is particularly evident in the westbound direction (Exhibit 3-18), which shows a travel time of approximately 25 minutes during the 6:00 AM peak hour, which is at least a 5 minute improvement from the previous years. Exhibit 3-17 suggests that the peak hour on the eastbound HOV lane occurred one hour earlier (4:00 PM) than the eastbound mainline facility, which experienced a 5:00 PM peak hour.

Exhibit 3-17: Eastbound Mainline Travel Time by Time of Day (2005-2008)



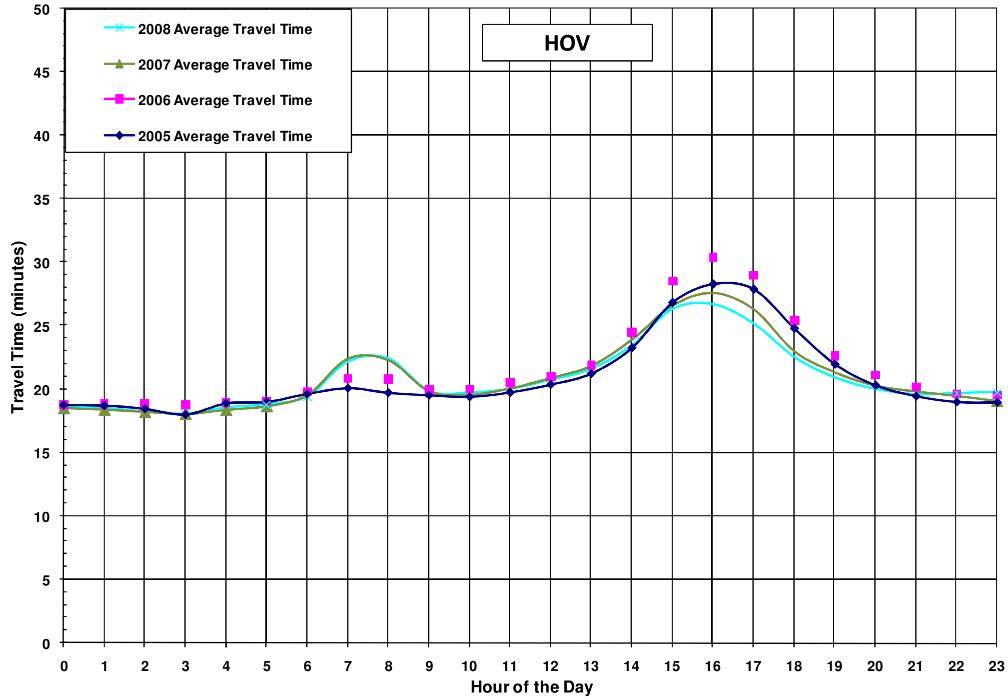
Source: SMG Analysis of PeMS Data

Exhibit 3-18: Westbound Mainline Travel Time by Time of Day (2005-2008)



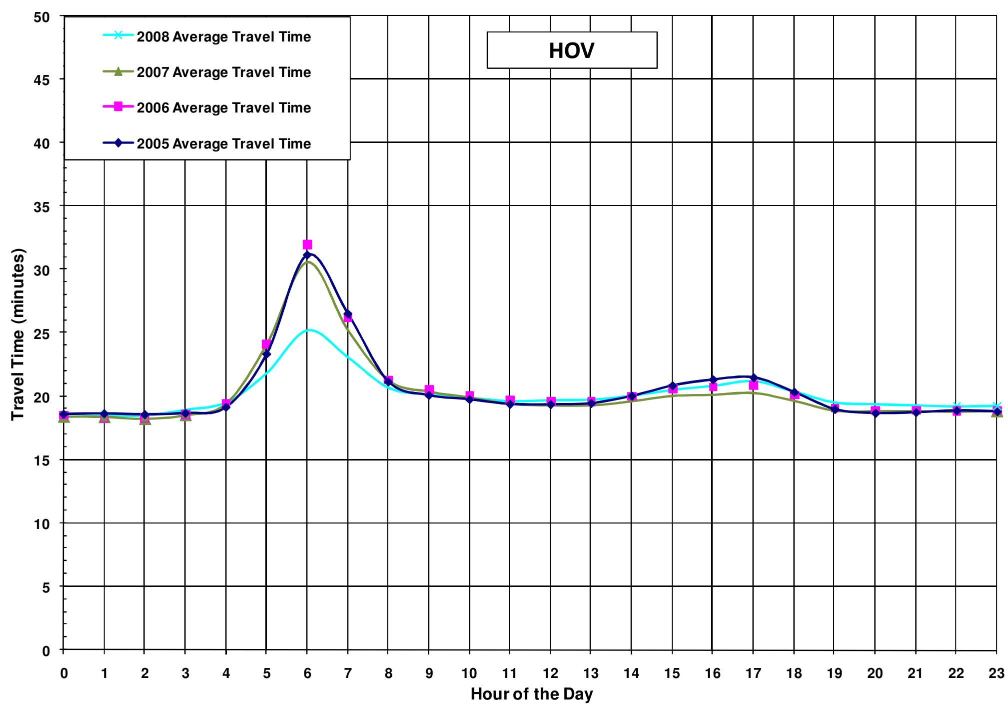
Source: SMG Analysis of PeMS Data

Exhibit 3-19: Eastbound HOVL Travel Time by Time of Day (2005-2008)



Source: SMG Analysis of PeMS Data

Exhibit 3-20: Westbound HOVL Travel Time by Time of Day (2005-2008)



Source: SMG Analysis of PeMS Data

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RELIABILITY

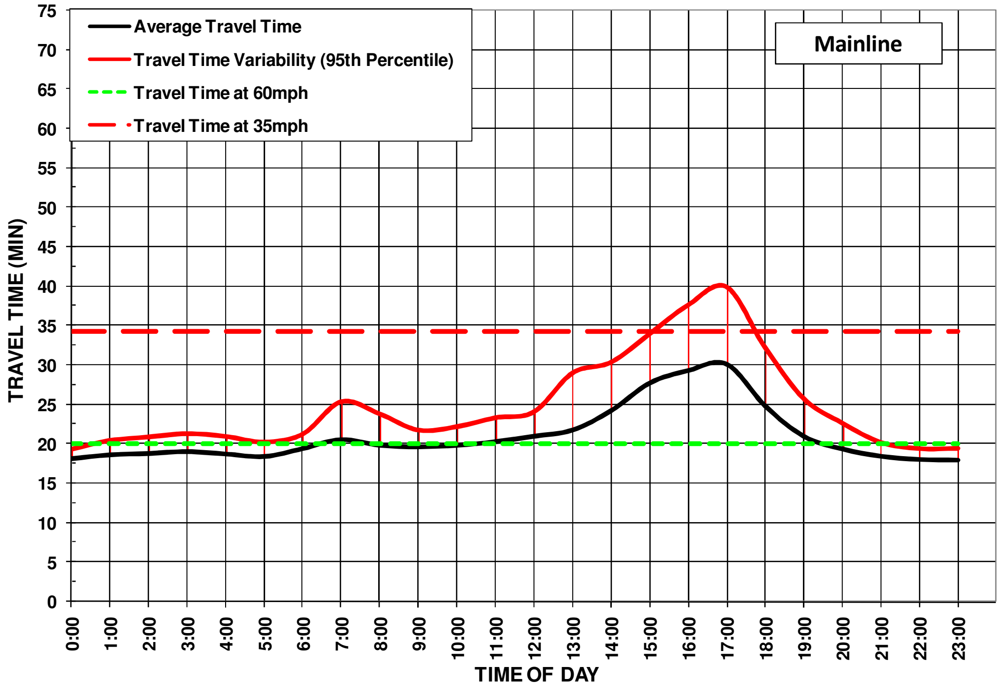
Reliability captures the degree of predictability in the public's travel time. Unlike mobility, which measures the rate of travel, the reliability measure focuses on how travel time varies from day to day. To measure reliability, the study team used statistical measures of variability on the travel times estimated from the PeMS data. The 95th percentile was chosen to represent the maximum travel time that most people would experienced on the corridor. Severe events, such as fatal collisions, could cause longer travel times, but the 95th percentile was chosen as a balance between extreme events and a "typical" travel day.

Exhibits 3-21 to 3-36 on the following pages illustrate the variability of travel time along the SR-91 Corridor on weekdays for the years 2005, 2006, 2007, and 2008. Exhibits 3-21 through 3-28 present travel time variability on the mainline in the eastbound direction followed by the westbound direction. Similarly, Exhibits 3-29 through 3-36 show travel time variability on the HOV facility beginning with the eastbound and followed by the westbound direction.

For the mainline facility, the 5:00 PM peak hour was the most unreliable in addition to being the slowest hour in the eastbound direction. In 2005 (shown in Exhibit 3-21), motorists driving the entire length of the corridor had to add 10 minutes to an average travel time of 30 minutes (for a total travel time of 40 minutes) to ensure that they arrived on time 95 percent of the time. This is 20 minutes longer than the 20-minute travel time at 60 mph. In 2006 (Exhibit 3-22), the time needed to arrive on time 95 percent of the time remained the same, but declined to 36 minutes in 2007 (Exhibits 3-23), and further declined to 34 minutes in 2008 (Exhibit 3-24). In the westbound direction of the mainline, the 7:00 AM peak hour was the most unreliable. In 2005 (Exhibit 3-25), the time required to arrive on time 95 percent of the time was 48 minutes, which decreased to 44 minutes in 2006 (Exhibit 3-26), decreased again to 40 minutes in 2007 (Exhibit 3-27), and further declined to 34 minutes in 2008 (Exhibit 3-28). Both directions of the mainline experienced a consistent improvement in travel times throughout this four-year period.

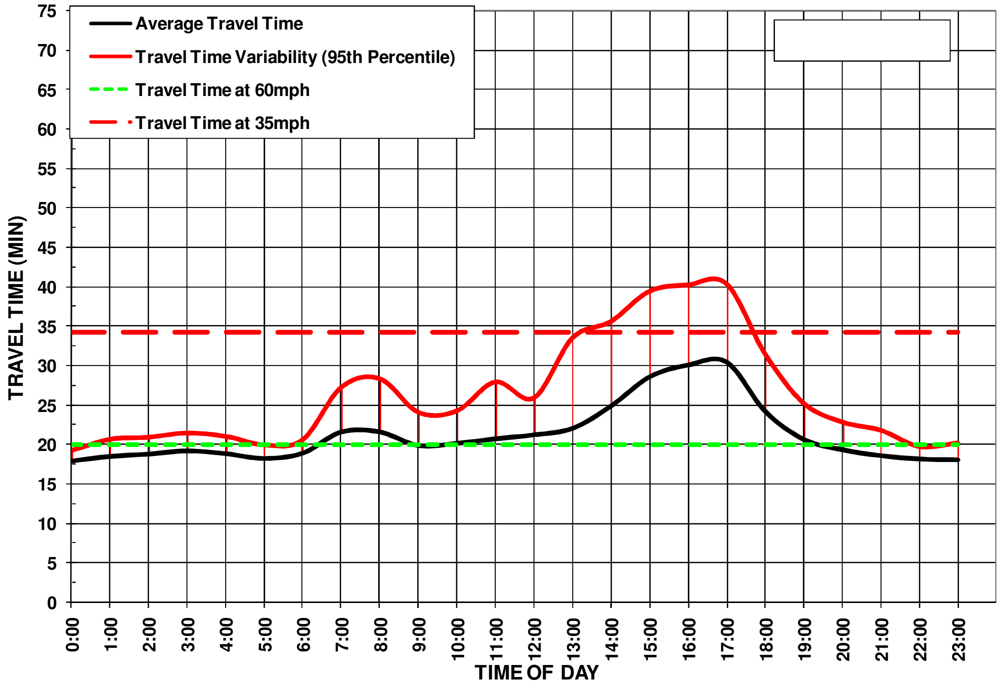
Unlike the mainline facility which experienced a clear improvement in travel times, the HOV facility witnessed mixed results. During the 4:00 PM peak hour (Exhibit 3-29) of the eastbound HOV facility, a driver needed to add 6 minutes to an average travel time of 28 minutes to ensure an on-time arrival 95 percent on the weekdays in 2005. This corresponds to a total travel time of 34 minutes. In 2006 (Exhibit 3-30), the time needed to arrive on time 95 percent of the time increased to 41 minutes, but decreased to 34 minutes in 2007 (Exhibit 3-31), and remained about the same at 35 minutes in 2008 (Exhibit 3-32). In the westbound direction of the HOV facility, the 6:00 AM peak hour was the most unreliable and the slowest hour. In 2005 (Exhibit 3-33), the time required to arrive on time 95 percent of the time was 41 minutes, which increased to 50 minutes in 2006 (Exhibit 3-34), decreased back to 41 minutes in 2007 (Exhibit 3-35), and decreased again to 32 minutes in 2008 (Exhibit 3-36).

Exhibit 3-21: Eastbound Mainline Travel Time Variability (2005)



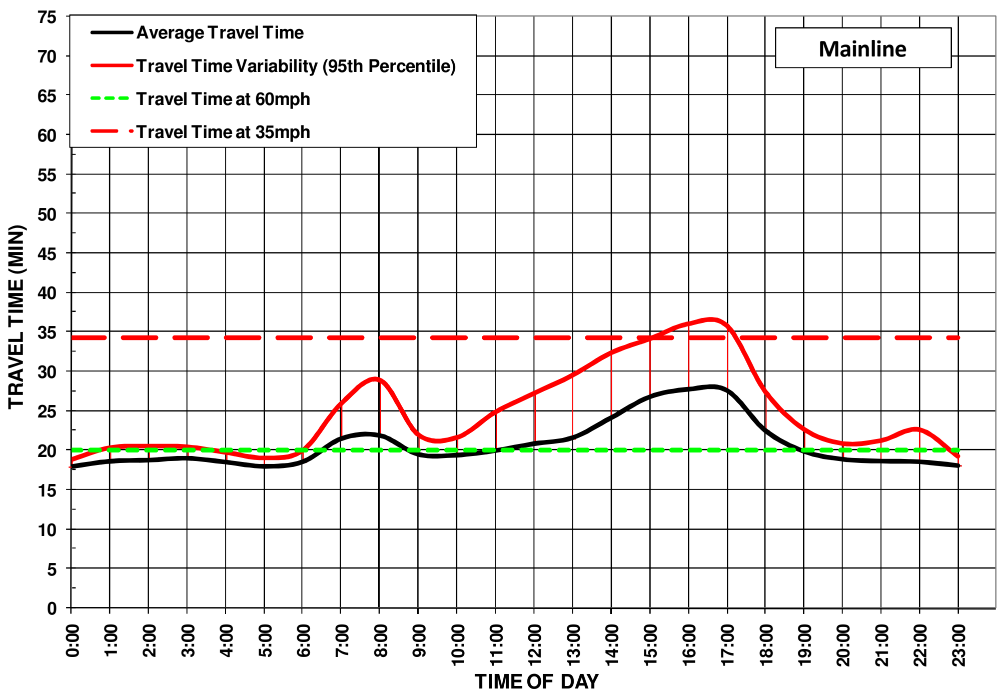
Source: SMG Analysis of PeMS Data

Exhibit 3-22: Eastbound Mainline Travel Time Variability (2006)



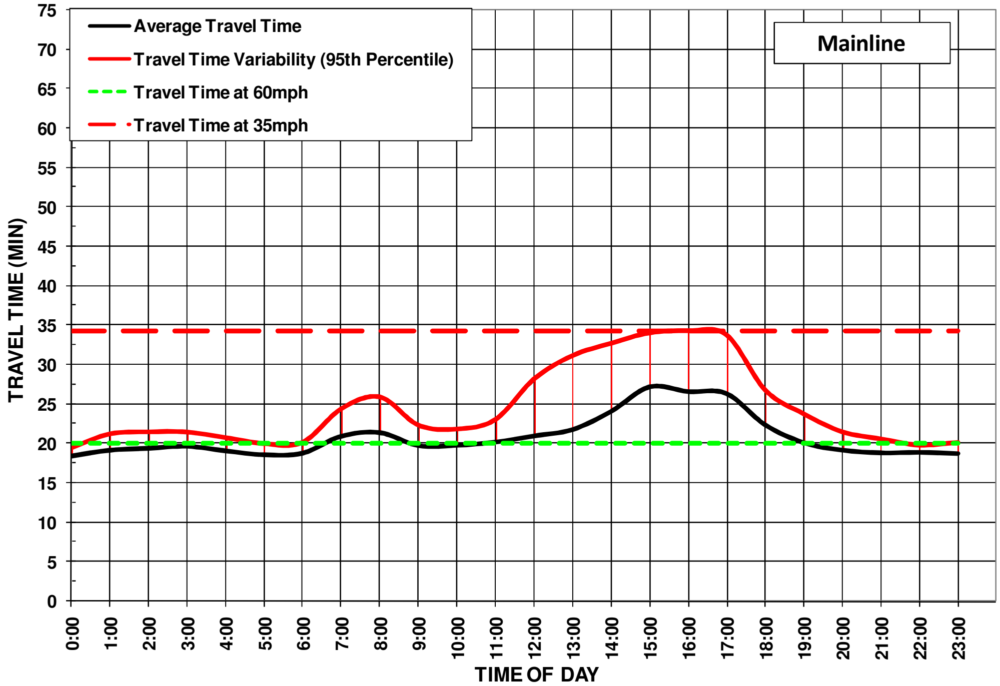
Source: SMG Analysis of PeMS Data

Exhibit 3-23: Eastbound Mainline Travel Time Variability (2007)



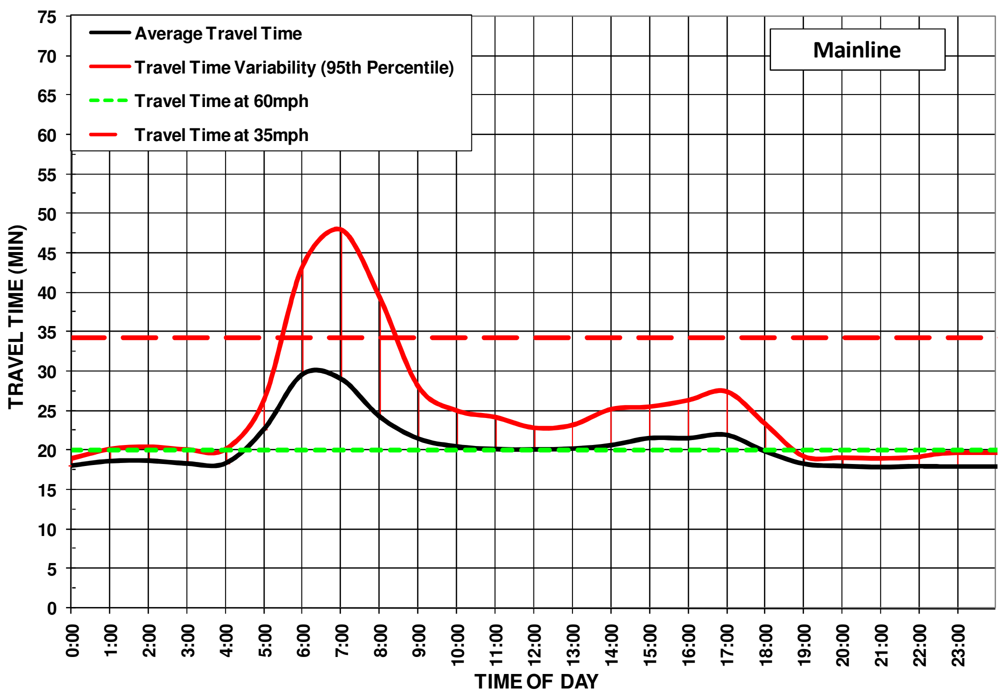
Source: SMG Analysis of PeMS Data

Exhibit 3-24: Eastbound Mainline Travel Time Variability (2008)



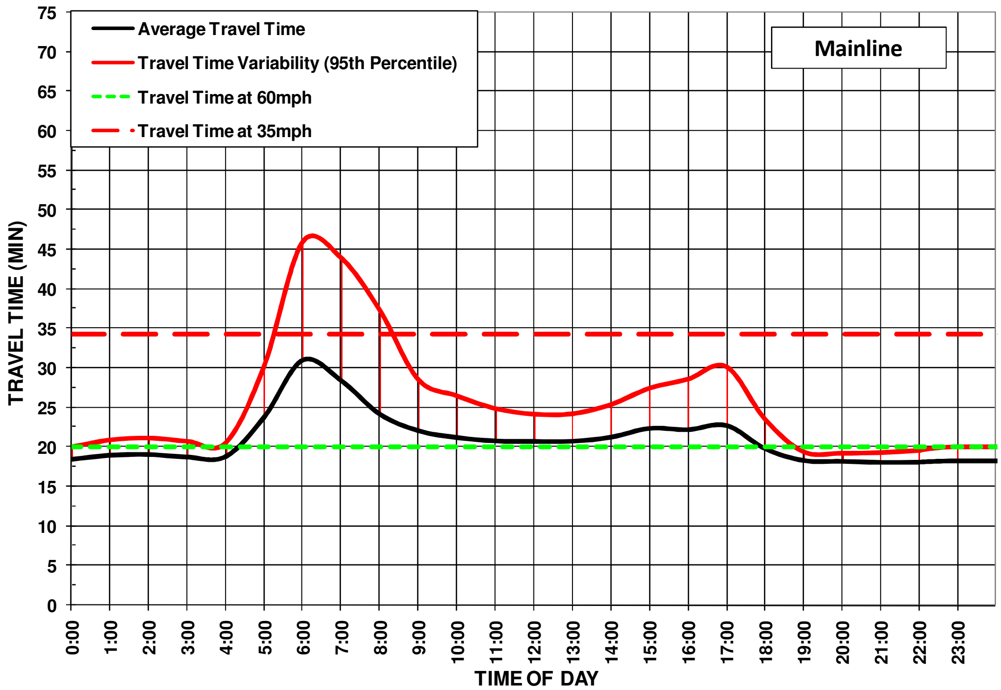
Source: SMG Analysis of PeMS Data

Exhibit 3-25: Westbound Mainline Travel Time Variability (2005)



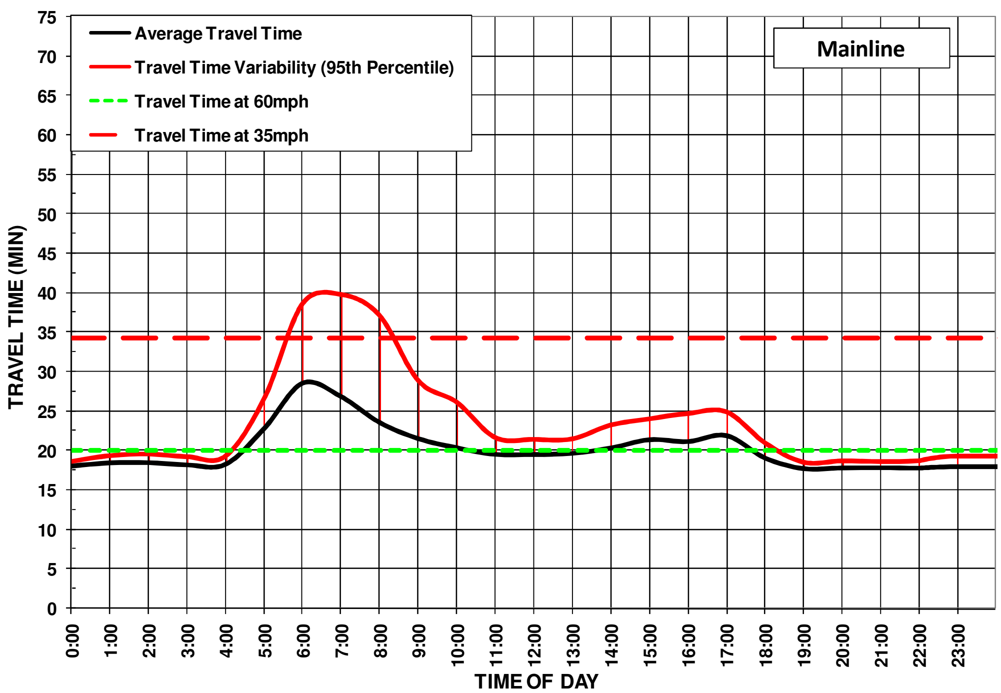
Source: SMG Analysis of PeMS Data

Exhibit 3-26: Westbound Mainline Travel Time Variability (2006)



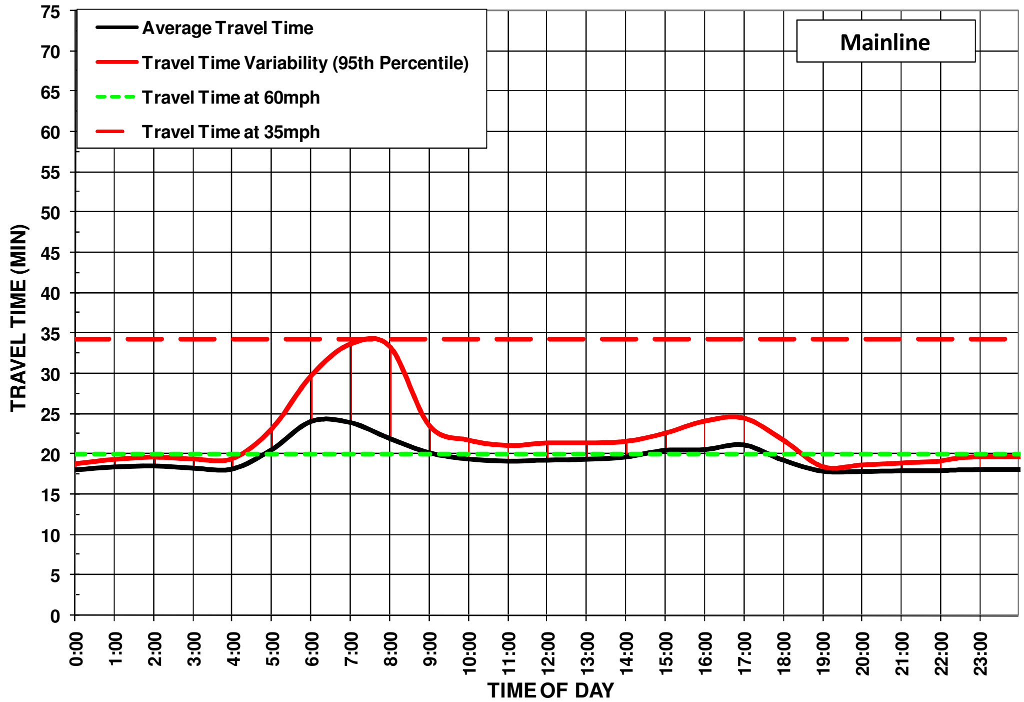
Source: SMG Analysis of PeMS Data

Exhibit 3-27: Westbound Mainline Travel Time Variability (2007)



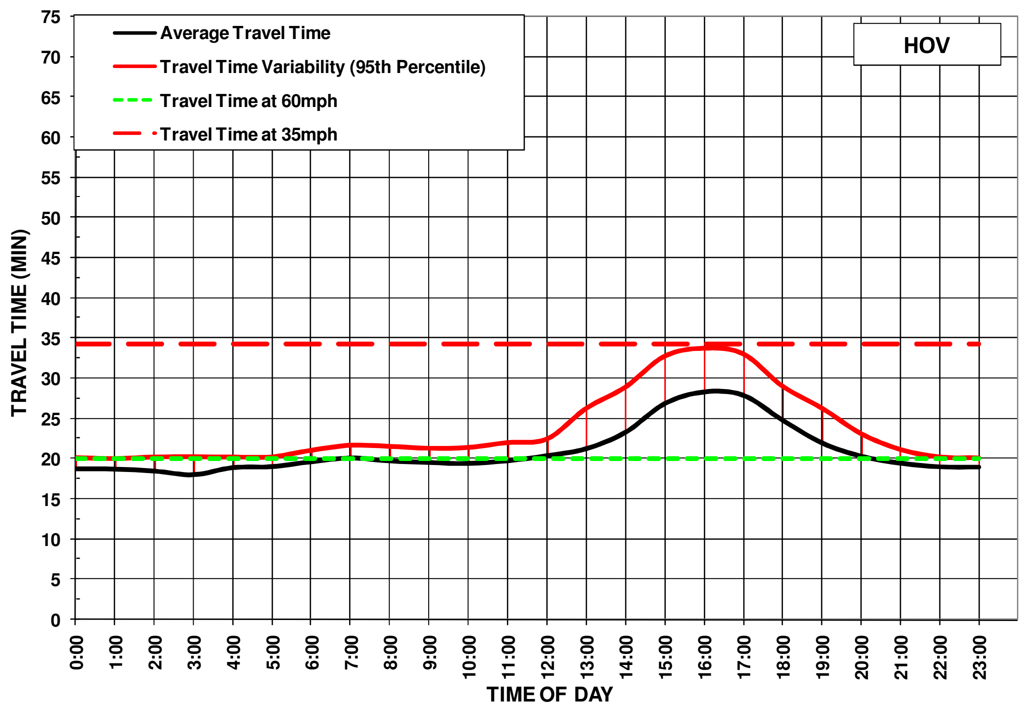
Source: SMG Analysis of PeMS Data

Exhibit 3-28: Westbound Mainline Travel Time Variability (2008)



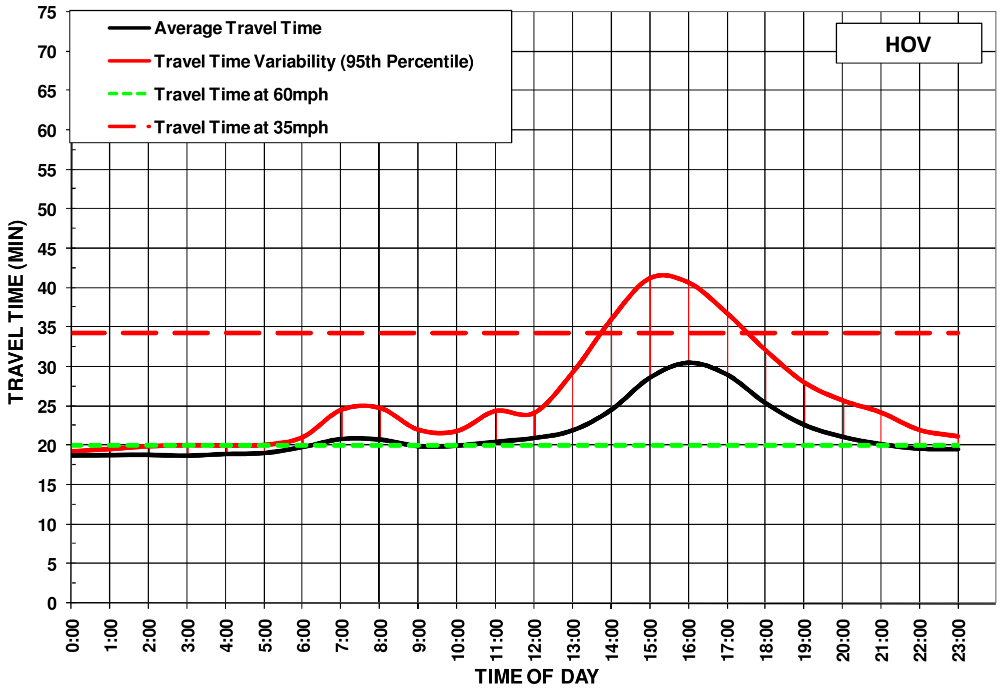
Source: SMG Analysis of PeMS Data

Exhibit 3-29: Eastbound HOVL Travel Time Variability (2005)



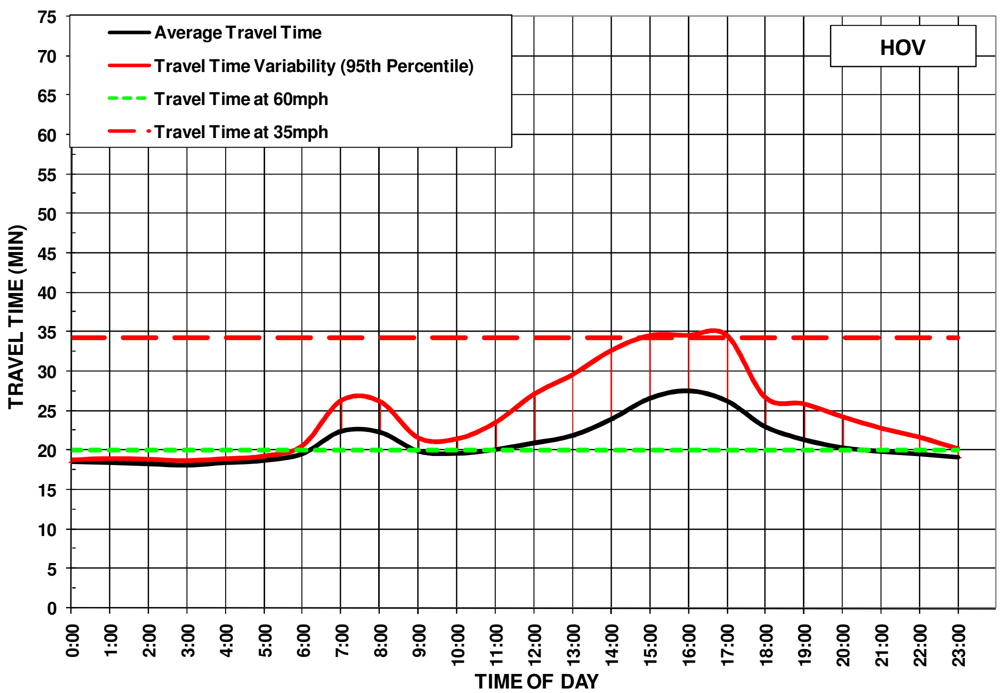
Source: SMG Analysis of PeMS Data

Exhibit 3-30: Eastbound HOVL Travel Time Variability (2006)



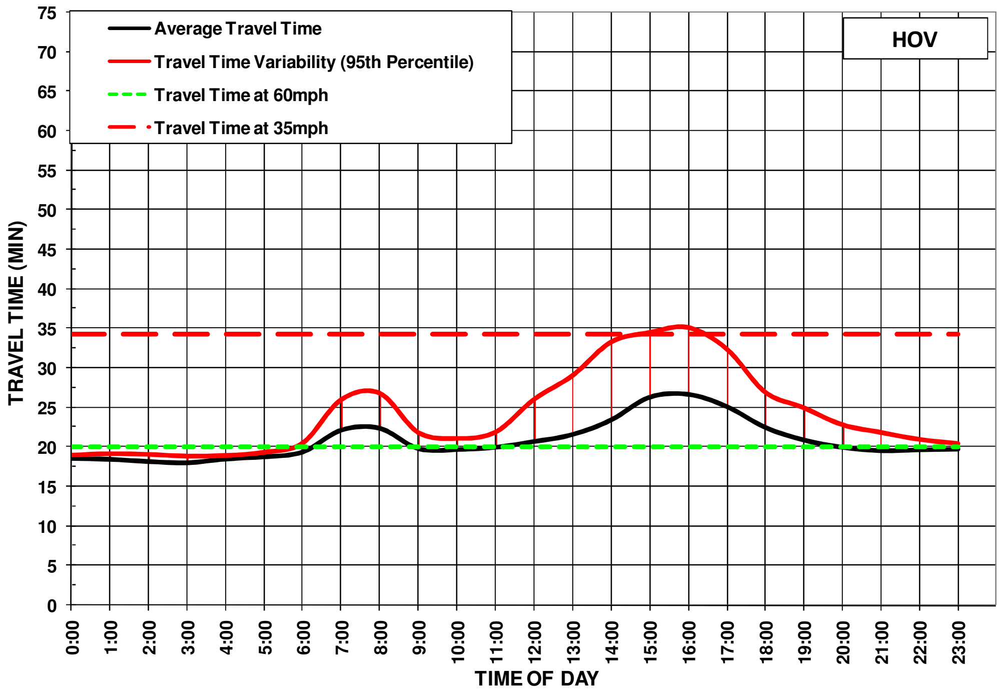
Source: SMG Analysis of PeMS Data

Exhibit 3-31: Eastbound HOVL Travel Time Variability (2007)



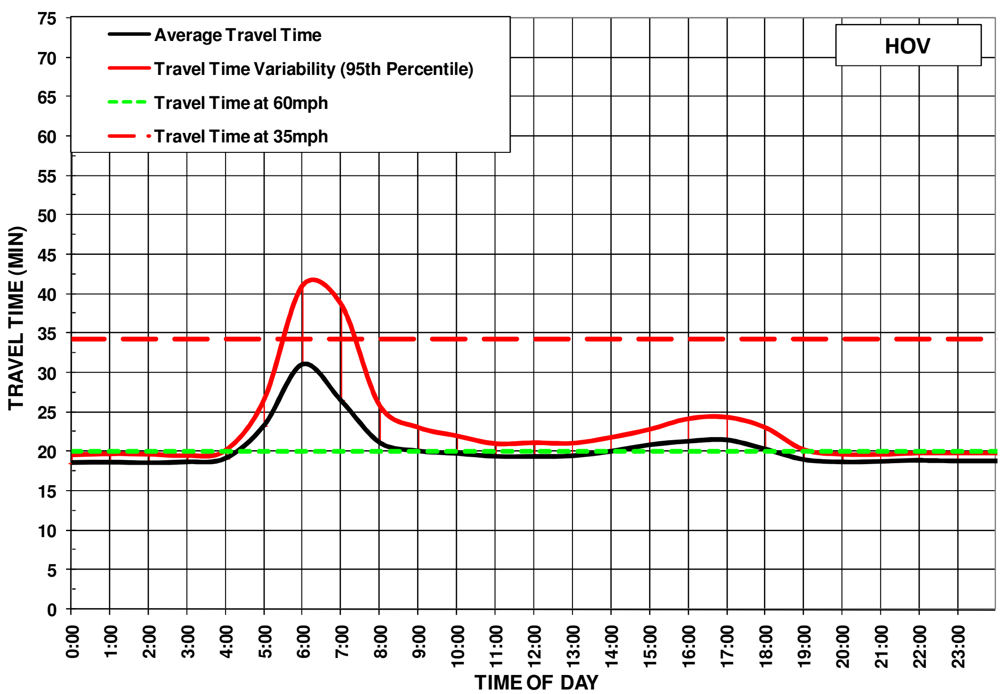
Source: SMG Analysis of PeMS Data

Exhibit 3-32: Eastbound HOVL Travel Time Variability (2008)



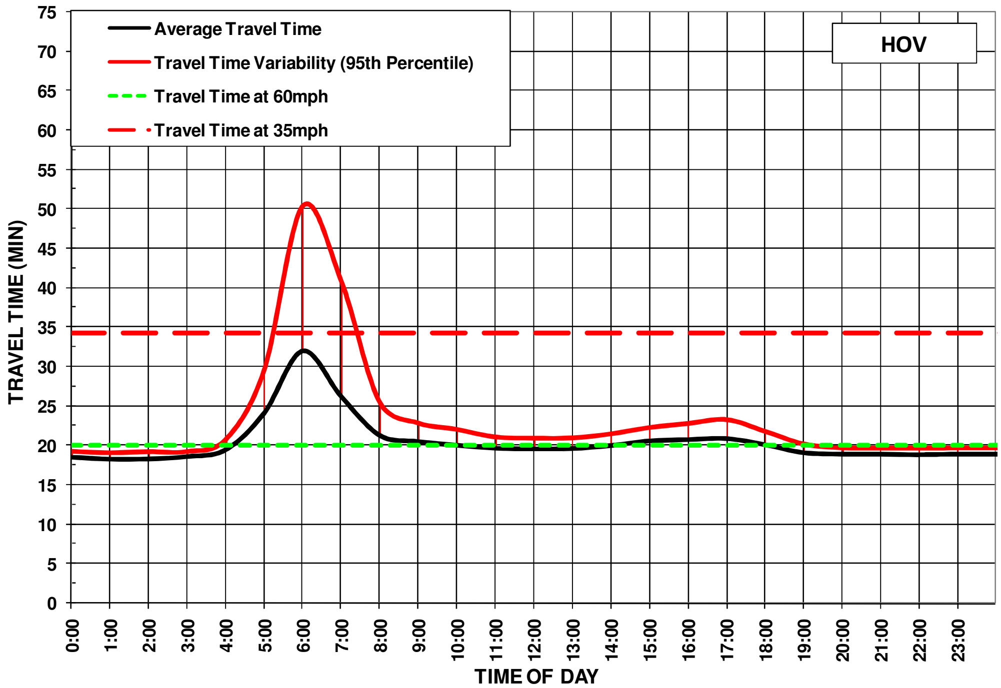
Source: SMG Analysis of PeMS Data

Exhibit 3-33: Westbound HOVL Travel Time Variability (2005)



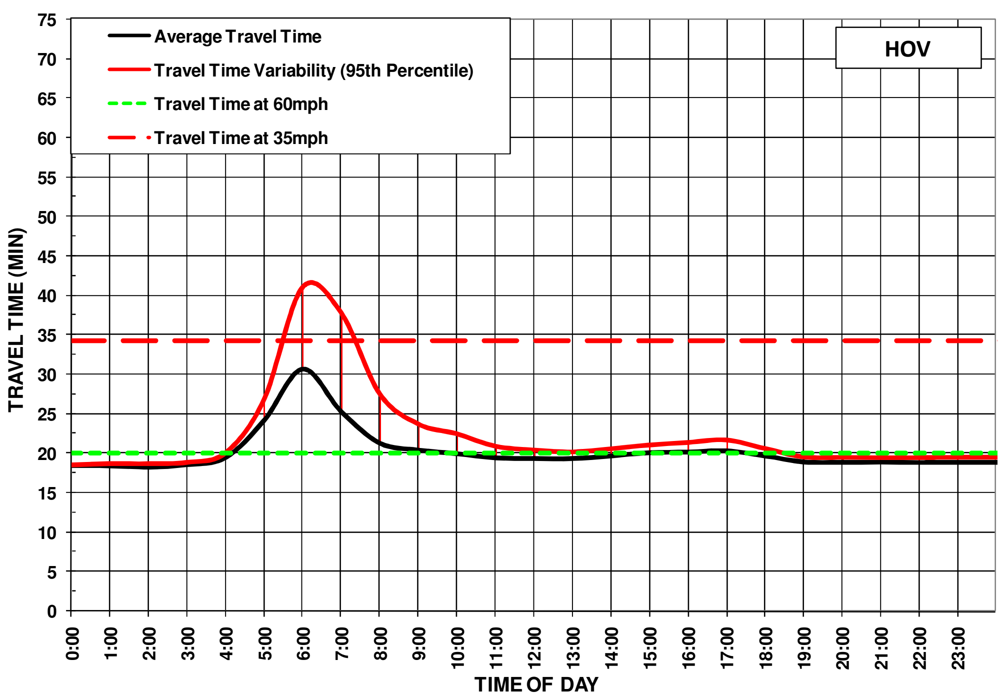
Source: SMG Analysis of PeMS Data

Exhibit 3-34: Westbound HOVL Travel Time Variability (2006)



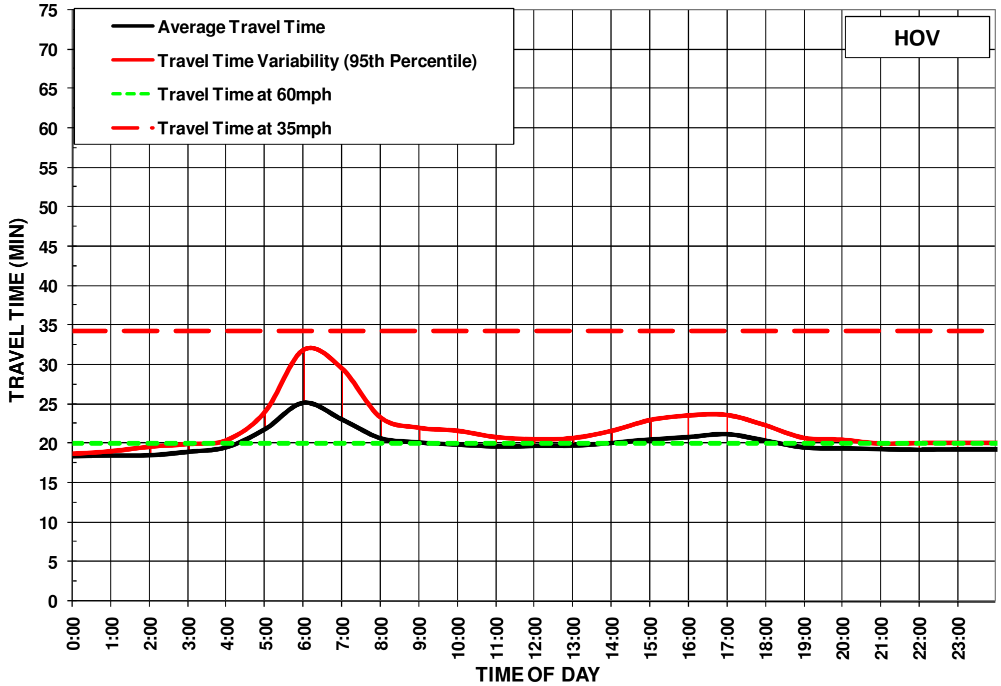
Source: SMG Analysis of PeMS Data

Exhibit 3-35: Westbound HOVL Travel Time Variability (2007)



Source: SMG Analysis of PeMS Data

Exhibit 3-36: Westbound HOVL Travel Time Variability (2008)



Source: SMG Analysis of PeMS Data

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SAFETY

The adopted performance measures to assess safety are: the number of accidents and 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 description 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).

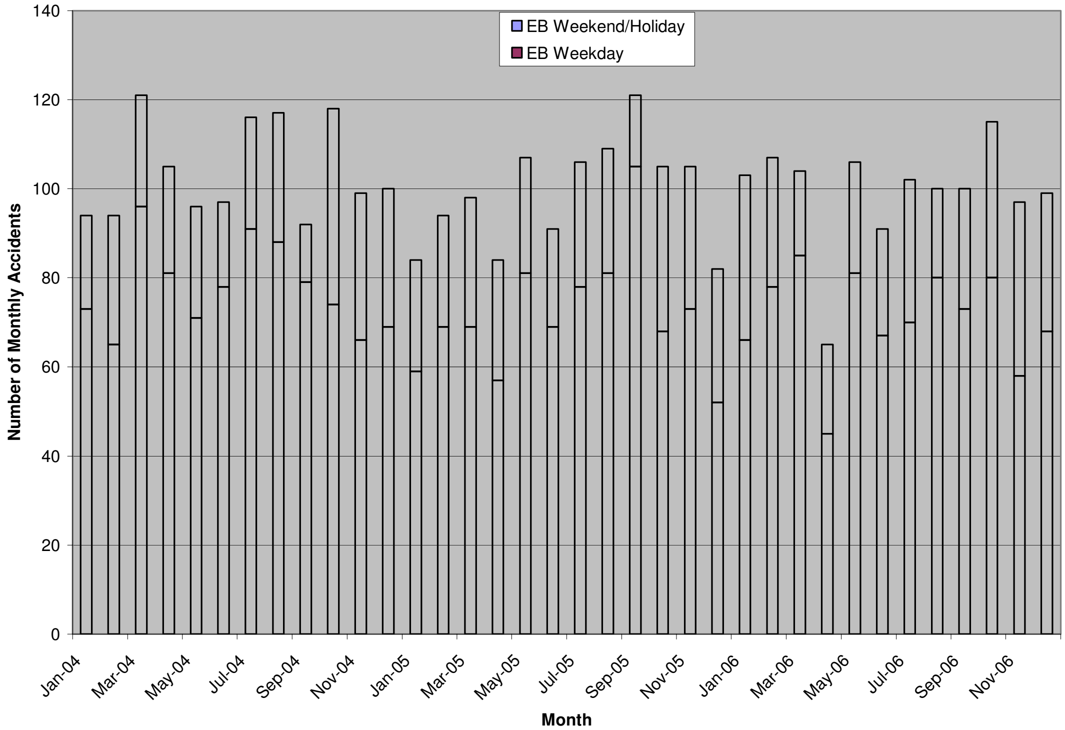
The safety assessment in this report is intended to characterize the overall accident history and trends in the corridor, and to highlight notable accident concentration locations or patterns that are readily apparent. This report is not intended to supplant more detailed safety investigations routinely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

Exhibits 3-37 and 3-38 illustrate the accidents that occurred on the eastbound westbound directions of the SR-91 Corridor. Caltrans typically analyzes the latest three-year safety data. The latest available data from January 1, 2004 through December 31, 2006 were analyzed and summarized. Note that these are comprehensive and do not rely on automatic detection systems.

As depicted in the exhibits, both the eastbound and westbound directions experienced fewer collisions in 2005 and 2006 than in 2004. An average of 100 collisions occurred each month in the eastbound direction, as opposed to an average of 77 collisions that occurred each month in the westbound direction. In each direction, there is a downward trend in total number of accidents starting in 2004.

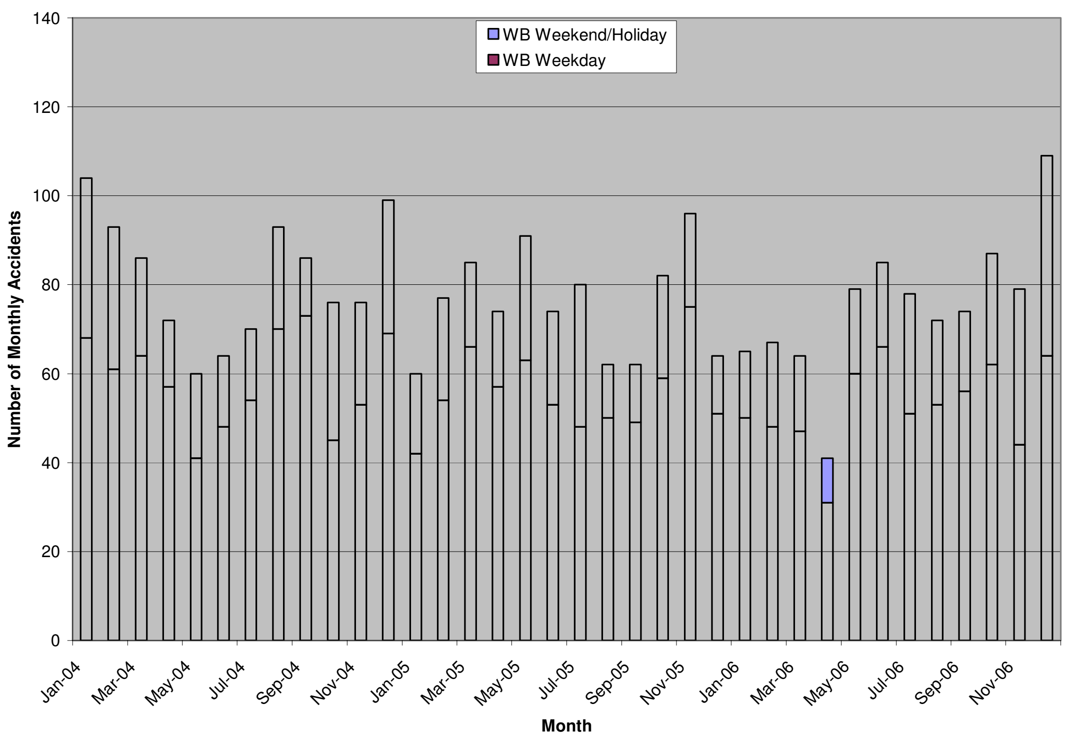
However, a significant point is that monthly eastbound accidents are higher on average than westbound accidents. This may be due to the higher congestion levels during the PM peak period (particularly in the eastbound direction).

Exhibit 3-37: Eastbound Monthly Accidents (2004-2006)



Source: SMG Analysis of PeMS Data

Exhibit 3-38: Westbound Monthly Accidents (2004-2006)



Source: SMG Analysis of PeMS Data

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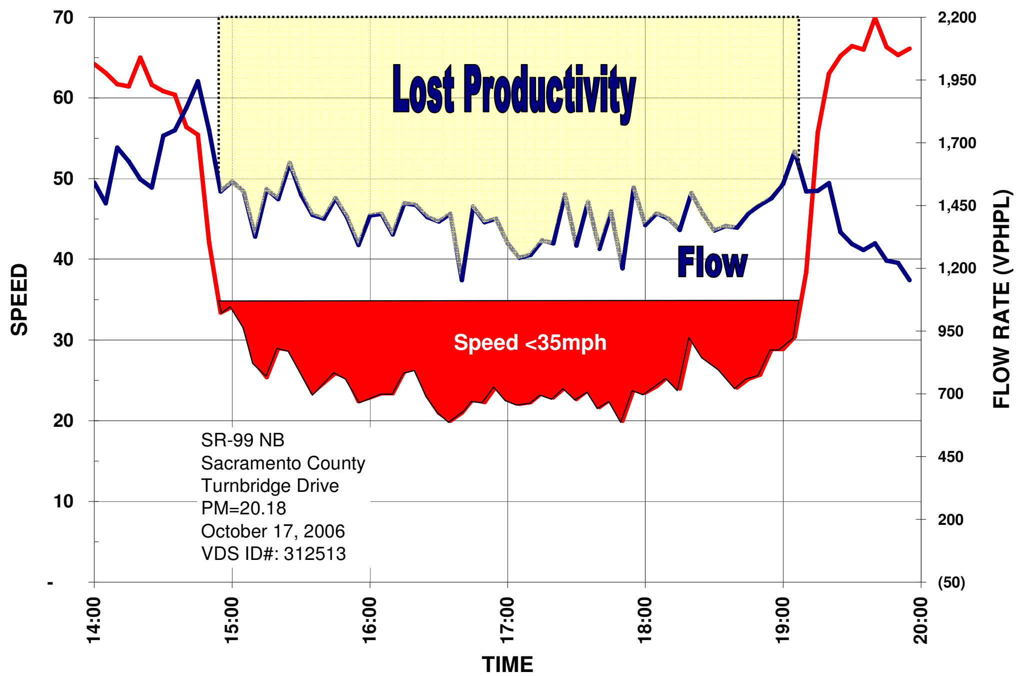
PRODUCTIVITY

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, productivity is the number of people served divided by the level of service provided. For highways, it is the number of vehicles compared to the capacity of the roadways.

For the corridor analysis, productivity is defined as the percent utilization of a facility or mode under peak conditions. The highway productivity performance measure is calculated as actual volume divided by the capacity of the highway. Travel demand models generally do not project capacity loss for highways, but detailed micro-simulation tools can forecast productivity. For highways, productivity is particularly important because the lowest "production" from the transportation system occurs often when capacity is needed the most.

This loss in productivity example is illustrated in Exhibit 3-39. As traffic flows increase 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 need to be added in order to achieve maximum productivity. For example, losing six lane-miles implies that congestion has caused a loss in capacity roughly equivalent to one lane along a six-mile section of freeway.

Exhibit 3-39: Lost Productivity Illustrated



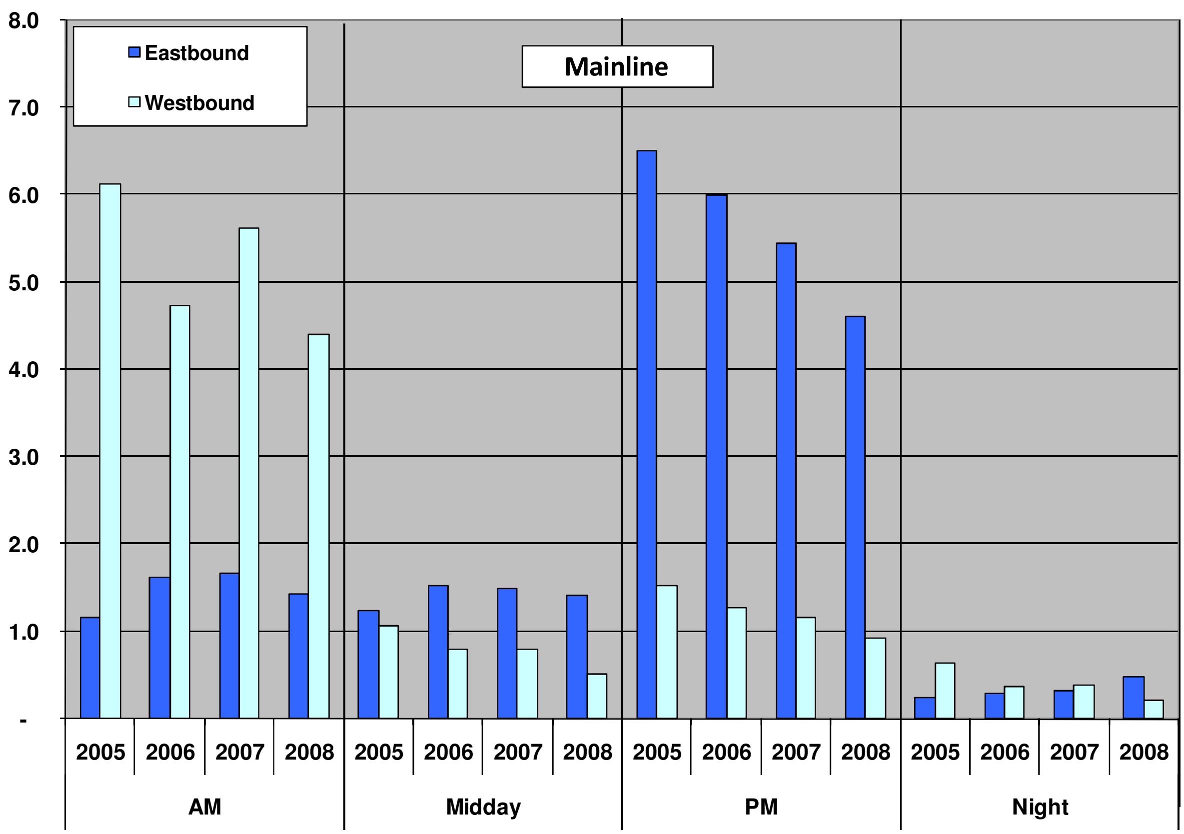
Equivalent lost lane-miles is computed as follows (for congested locations only):

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

Exhibits 3-40 and 3-41 summarize the productivity losses on the SR-91 Corridor mainline and HOV facilities during the 2005-2008 period. The trends in the productivity losses are comparable to the delay trends. The largest productivity losses occurred in the PM peak hours in the eastbound direction, which is the time period and direction that experienced the most congestion. Productivity during the PM peak in the eastbound direction improved continuously from 2005 to 2008 on the mainline, and from 2006 to 2008 on the HOV facility. Productivity during the AM peak in the westbound direction also improved, but only from 2007 to 2008 on both mainline and HOV facilities.

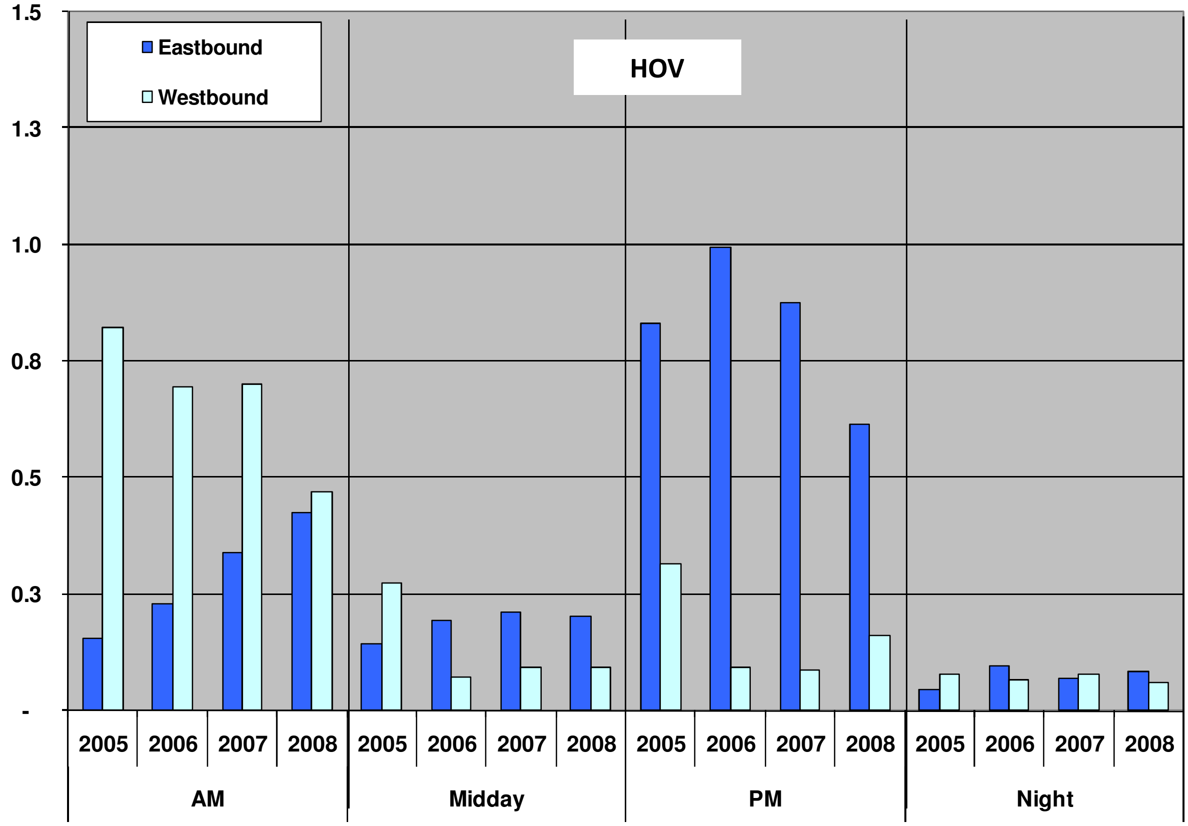
Strategies to combat such productivity losses are primarily related to operations. These strategies include: building new or extending auxiliary lanes, developing more aggressive ramp metering strategies without negatively influencing the arterial network, and improving incident clearance times.

Exhibit 3-40: Average Lost Lane-Miles by Direction, Time Period, and Year (ML)



Source: SMG Analysis of PeMS Data

Exhibit 3-41: Average Lost Lane-Miles by Direction, Time Period, and Year (HOVL)



Source: SMG Analysis of PeMS Data

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PAVEMENT CONDITION

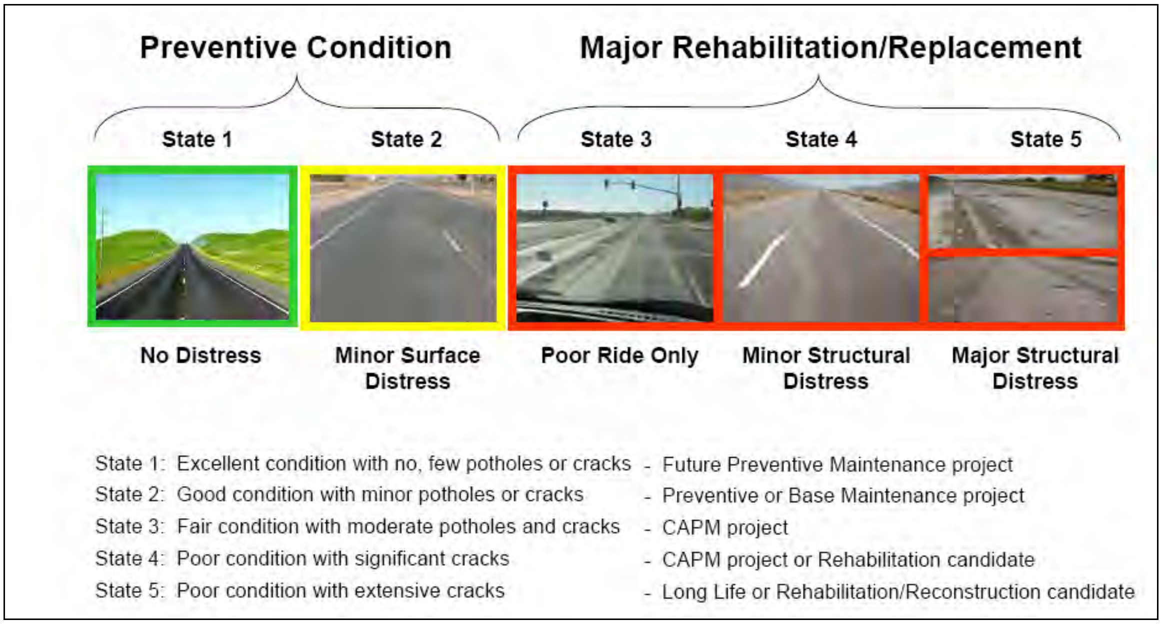
The condition of the roadway pavement (or ride quality) on the corridor can influence its traffic performance. Rough or poor pavement conditions can decrease the mobility, reliability, safety, and productivity of the corridor, whereas smooth pavement can have the opposite effect. Pavement preservation 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.

Performance Measures

Caltrans conducts an annual Pavement Condition Survey (PCS) that can be used to compute two performance measures commonly estimated by Caltrans: 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 3-42 provides an illustration of this distinction. The first two pavement conditions include roadway that provides adequate ride quality and is structurally adequate. The remaining three conditions are included in the calculation of distressed lane-miles.

Exhibit 3-42: Pavement Condition States Illustrated



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 at 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 Condition

The most recent pavement condition survey, completed in November 2007, recorded 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.

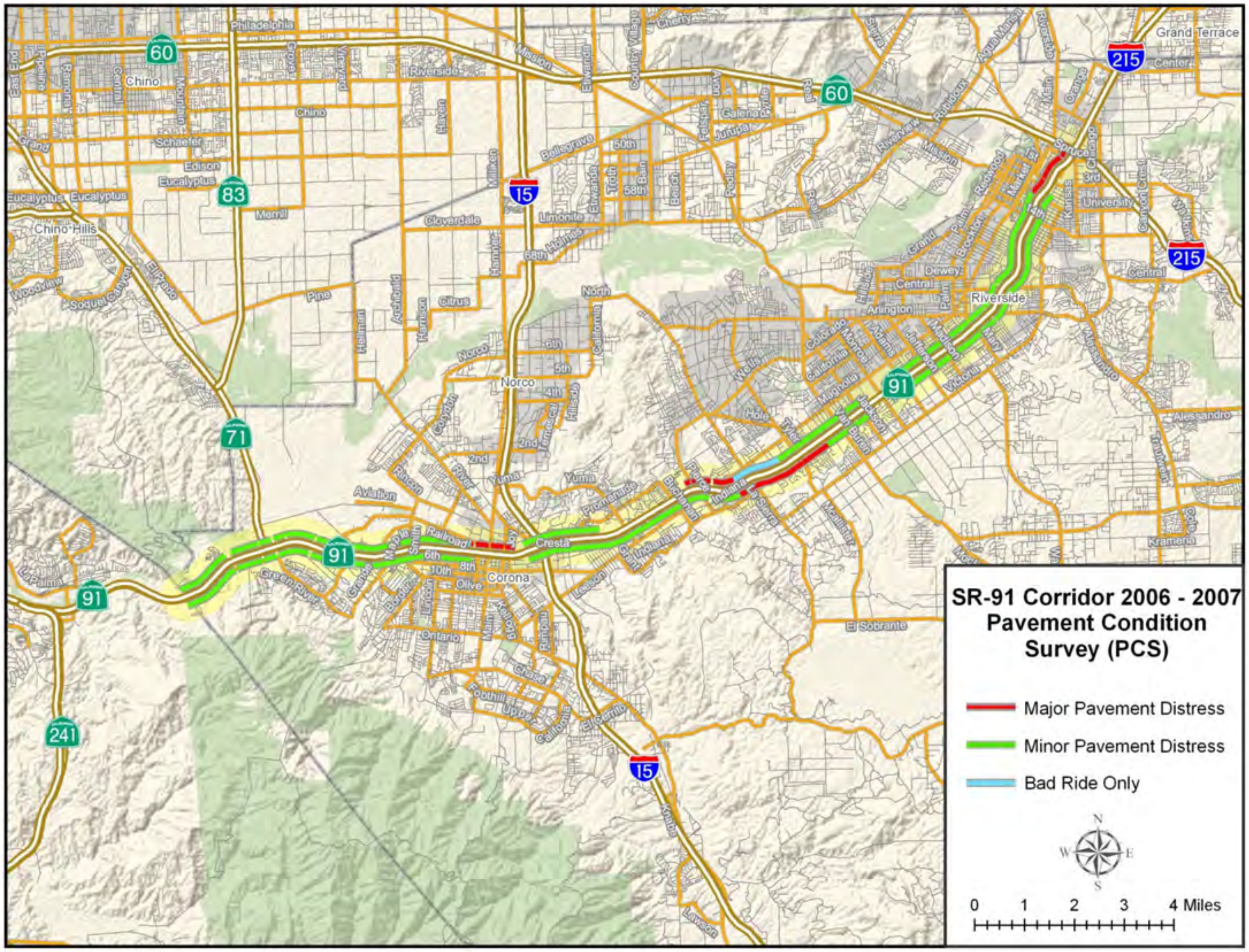
Exhibit 3-43 shows the pavement distress recorded along the SR-91 Corridor for the 2007 PCS data. The three categories shown in this exhibit represent the three distressed conditions that require major rehabilitation or replacement and were presented earlier in Exhibit 3-42.

The SR-91 Corridor exhibits average pavement condition for a freeway in the Inland Empire. The corridor has very little major pavement distress, which is common on highways outside the urban core area. However, the majority of the corridor does show signs of minor pavement distress.

Exhibit 3-44 compares results from prior pavement condition surveys along the SR-91 Corridor. The total number of distressed lane-miles remained steady from 2003 to 2004. Since 2004, the number of distressed lane-miles has more than tripled. Most of the increase has been in minor pavement distress.

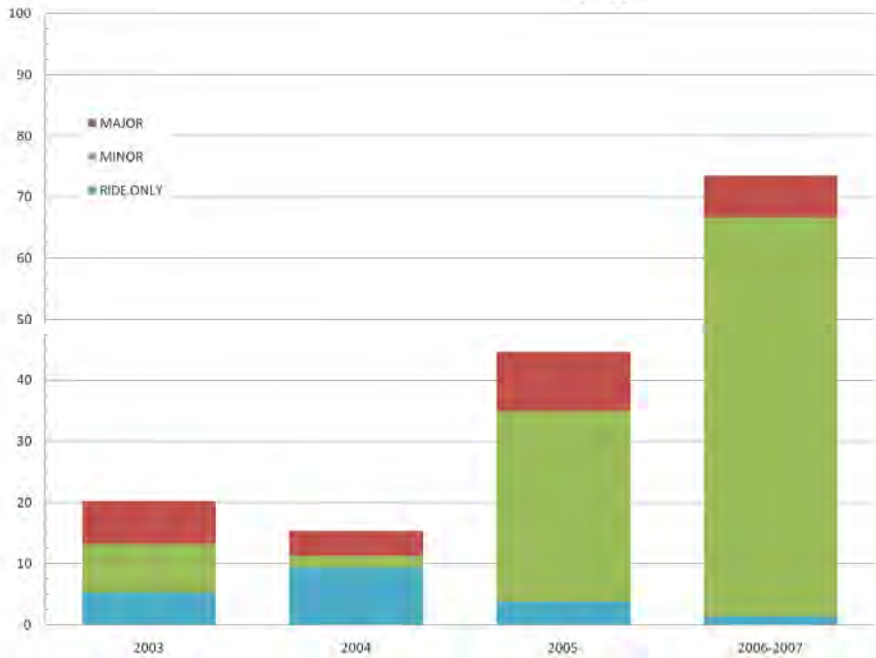
The change in the percent mix of distressed lane-miles is presented more clearly in Exhibit 3-45. As the exhibit shows, both ride quality issues and major pavement distress have declined and been replace by minor pavement distress since 2004. While the distress on highways split fairly evenly among the three categories in 2003, minor pavement distress dominated distressed lane-miles in the 2007 PCS data. As shown in Exhibit 3-46, nearly 90 percent of distressed lane-miles were due to minor pavement distress in the last survey.

Exhibit 3-43: Distressed Lane-Miles on SR-91 Corridor (2006-2007)



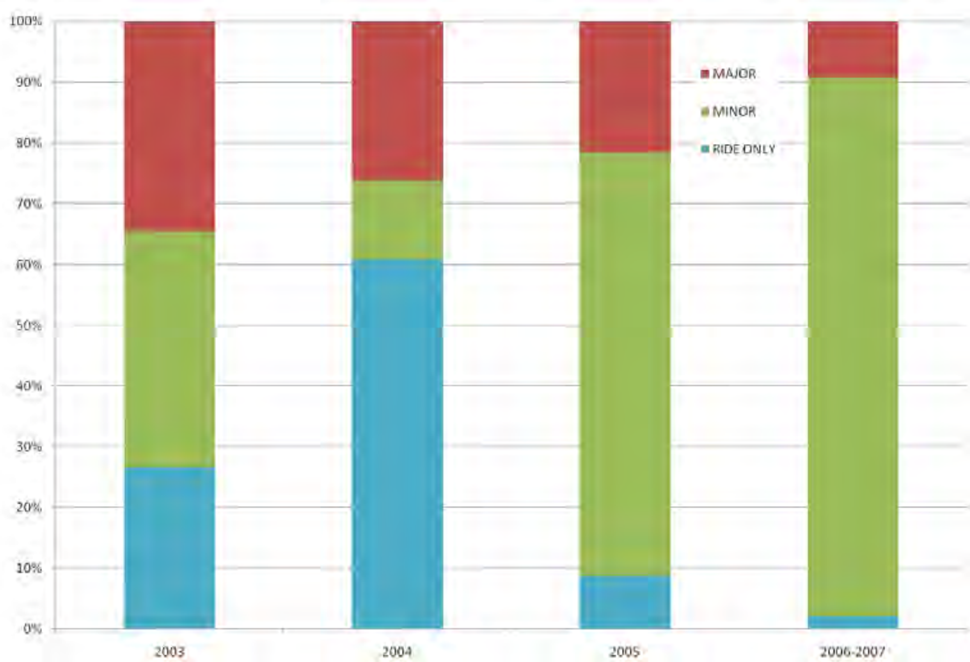
Source: SMG mapping of 2007 Pavement Condition Survey data

Exhibit 3-44: SR-91 Distressed Lane-Miles Trends



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

Exhibit 3-45: SR-91 Distressed Lane-Miles by Type



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

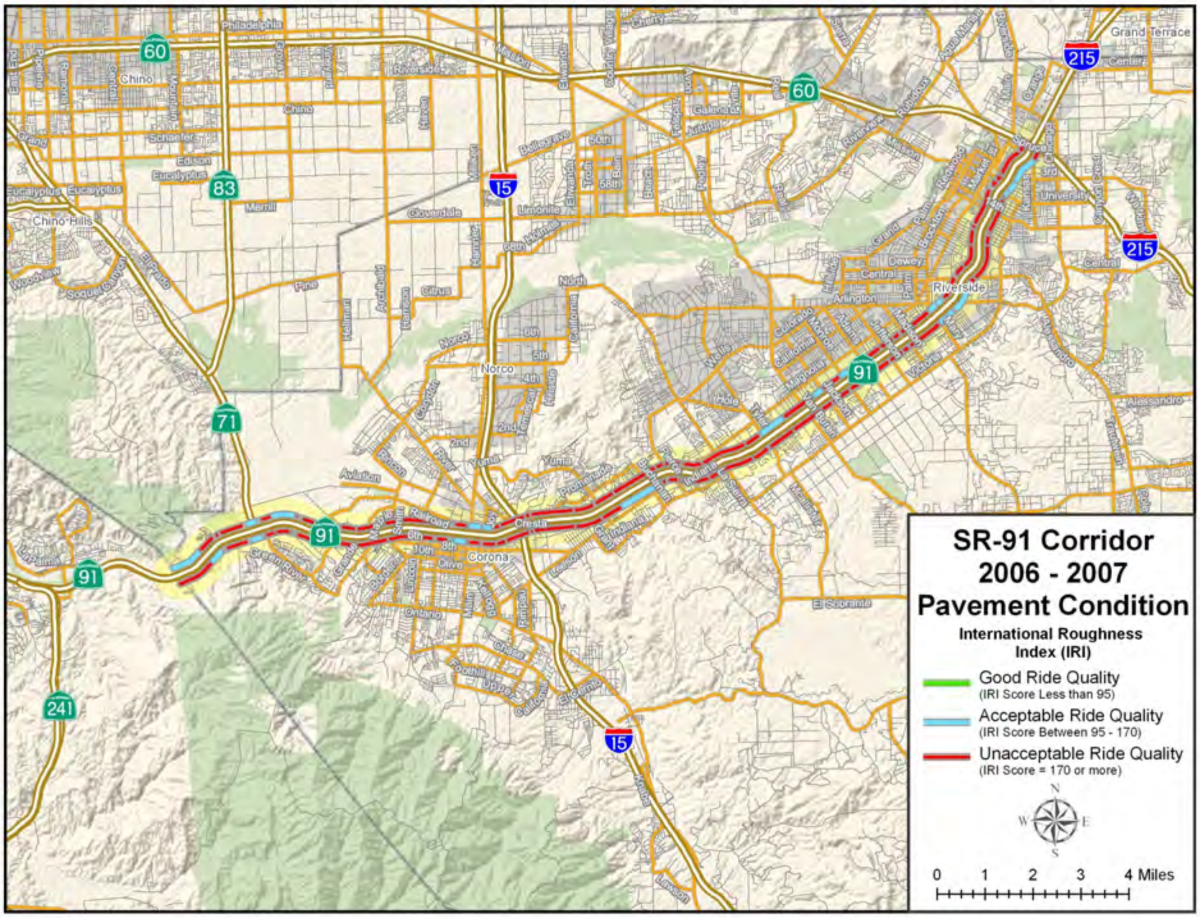
Exhibit 3-46 shows IRI along the study corridor for the lane with the poorest pavement condition in each freeway segment. The worst pavement quality is shown since pavement investment decisions are made on this basis. As seen in the exhibit, nearly the entire corridor has at least one lane with ride quality issues (IRI greater than 170), but it is important to keep in mind that some lanes have better quality than others within the same roadway section.

In fact, the corridor exhibits relatively good ride quality when the conditions on all lanes are considered. The study corridor is comprised of roughly 182 lane-miles, of which:

- 26 lane-miles, or 14 percent, are considered to have good ride quality (IRI ≤ 95)
- 91 lane-miles, or 50 percent, are considered to have acceptable ride quality (95 < IRI ≤ 170)
- 66 lane miles, or 36 percent, are considered to have unacceptable ride quality (IRI > 170)

Note: the lane-miles do not add due to rounding.

Exhibit 3-46: SR-91 Road Roughness (2006-2007)

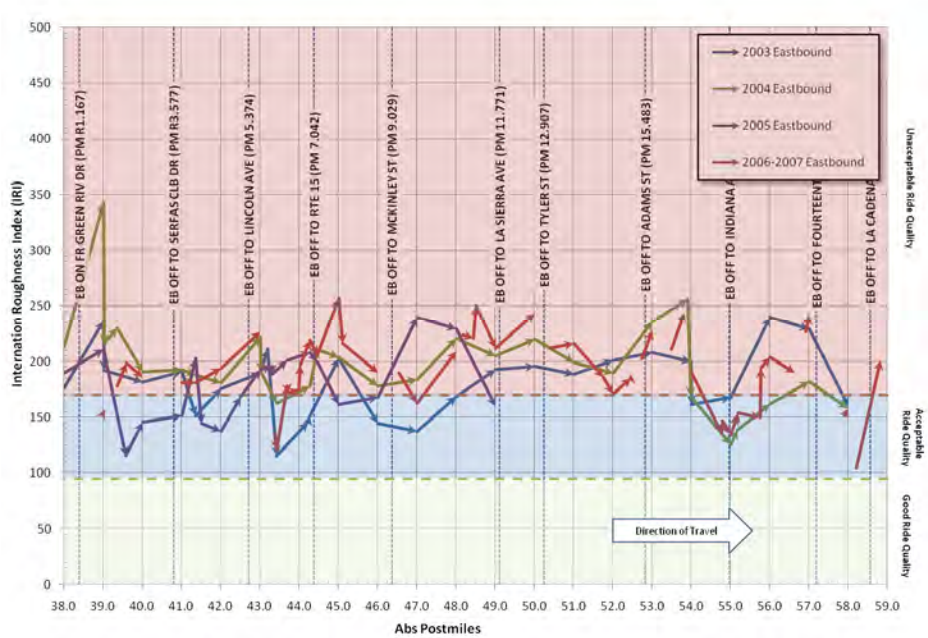


Source: SMG mapping of 2007 Pavement Condition Survey data

Exhibits 3-47 and 3-48 present ride conditions for the worst lane in each section on the SR-91 Corridor using IRI from 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). The exhibits exclude a number of sections that were not measured or had calibration issues (i.e., IRI = 0) during the 2007 PCS survey. This is shown as breaks in the 2006-2007 line.

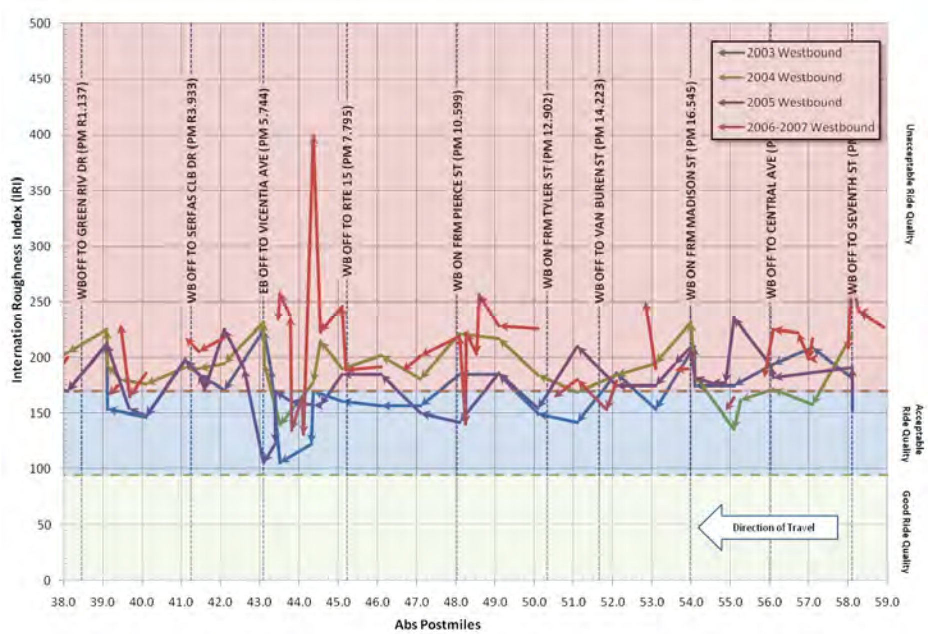
Over time, the surveys show fairly consistent patterns of good, acceptable, and unacceptable conditions. Ride quality has remained fairly constant over the last several surveys, despite the aging of the freeway.

Exhibit 3-47: Eastbound SR-91 Road Roughness (2003-2007)



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

Exhibit 3-48: Westbound SR-91 Road Roughness (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 dated June 2008. They were identified based on a variety of data sources, including HICOMP, probe vehicle runs, and PeMS. Significant field visits were also conducted in December 2008 and January 2009 to confirm these bottleneck locations. As a result of the field work and additional data analysis, the reoccurring bottlenecks were identified for both directions. The initial analysis from the Preliminary Performance Assessment is found in the Appendix.

Eastbound Bottlenecks

Starting from the Orange/Riverside County Line and moving eastbound, the following bottlenecks were identified:

- Serfas Club Drive On-ramp: queuing at this bottleneck location extends as far back as west of SR-71.
- Maple Street On-ramp: heavy volumes from the on-ramp contribute to this bottleneck location.
- Lincoln Avenue On-ramp: this on-ramp adds heavy volumes to the existing mainline traffic.
- I-15 Off-ramp: the off-ramp traffic at this location queues back onto the mainline traffic, causing a bottleneck location.
- I-15 On-ramp: heavy volumes from the on-ramp and the loss of an auxiliary lane contribute to this bottleneck location.
- McKinley Street On-ramp: this on-ramp adds heavy volumes to the existing mainline traffic.
- Magnolia Avenue On-ramp: this is a minor bottleneck that occurs as a result of heavy on-ramp volumes.
- Madison Street Interchange: a lane drop contributes to this bottleneck location.
- Arlington Avenue On-ramp: heavy volumes from this on-ramp combined with a curve to the left and a short auxiliary lane, contribute to this bottleneck location.
- Central Avenue On-ramp: heavy volumes from this on-ramp contribute to a bottleneck condition.

Westbound Bottlenecks

Starting from SR-60/I-215 and moving westbound, the following bottlenecks were identified:

- I-215 On-ramp: the reduction of lanes from five lanes to three at the Mission Inn interchange cannot accommodate the demand.
- 14th Street On-ramp: heavy volumes from this on-ramp contribute to a bottleneck condition.

- Arlington Avenue On-ramp: although not a significant bottleneck, congestion and queuing was observed at the on-ramp merge location.
- Tyler Street On-ramp: data analysis results indicate that this was a bottleneck location during the PM peak hours in 2007
- Pierce Street On-ramp: a geometric roadway curve to the left and a heavy ramp merge at the crest of the turn contributes this bottleneck location.
- I-15 On-ramp: heavy volumes on the northbound I-15 to westbound SR-91 connector ramp queues back onto the I-15 mainline during the AM peak hours.
- School Street/Grand Boulevard On-ramp: data analysis results indicated that this was a bottleneck location during the AM peak hours in 2007.
- Lincoln Avenue On-ramp: heavy ramp merging causes the mainline flow to break down at this location.
- Serfas Club Drive On-ramp: heavy ramp merging causes the mainline flow to break down at this location as well.
- Green River Road On-ramp: the downhill merge at the Green River Road on-ramp causes a bottleneck condition to occur.

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 these bottleneck areas, the performance statistics that were presented earlier for the entire corridor can be segmented 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

The analysis of bottleneck areas is based on 2007 data (when available) and limited to the mainline facility due to the limited detection available on the HOV facility. Based on this approach, the study corridor comprises several bottleneck areas, which differ by direction. Exhibit 4-1 illustrates the general concept of bottleneck areas in one direction. The red lines in the exhibit represent the bottleneck locations and the arrows represent the bottleneck areas.

Exhibit 4-1: Dividing a Corridor into Bottleneck Areas

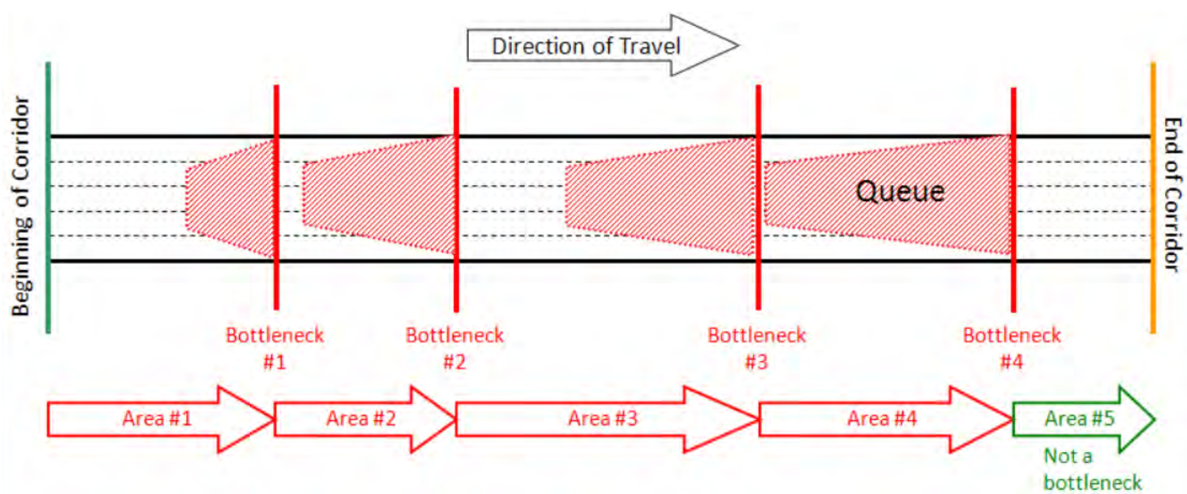
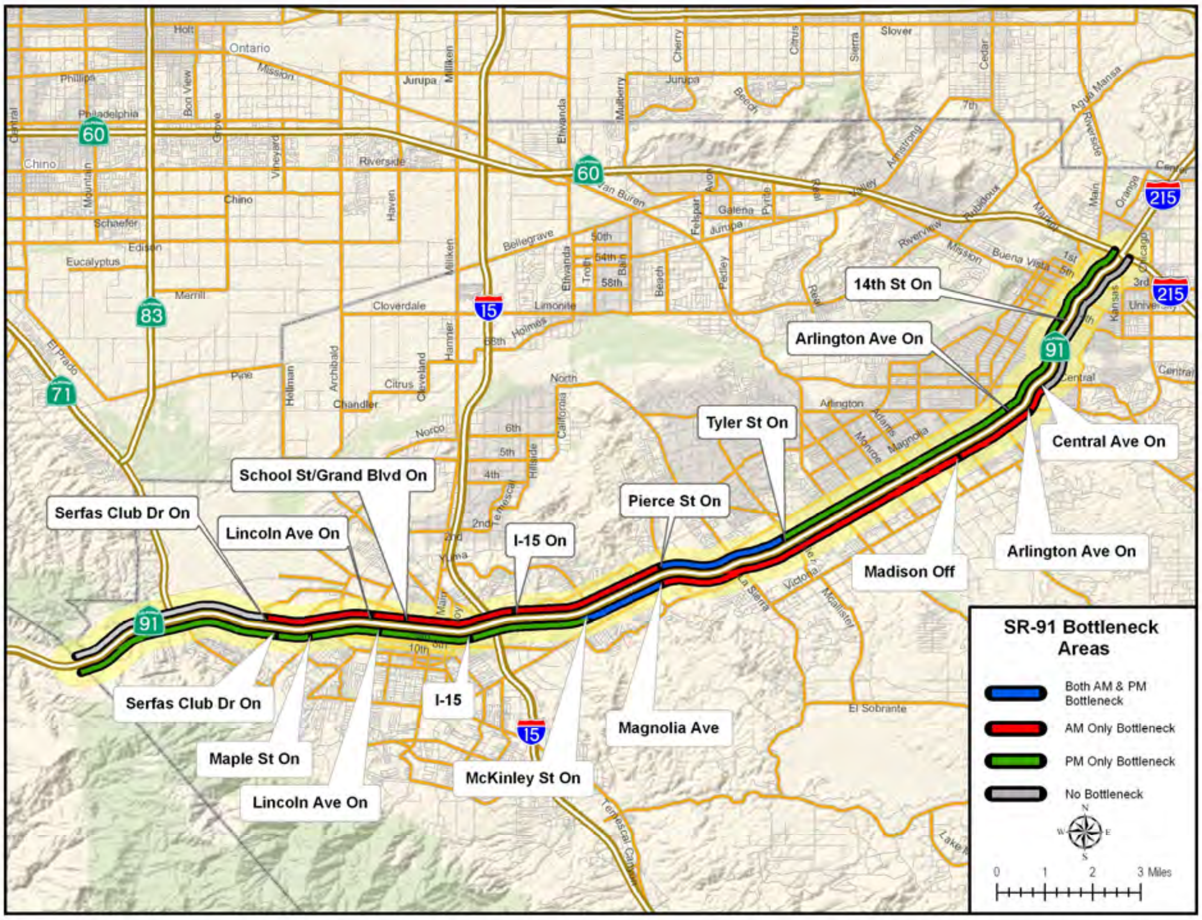


Exhibit 4-2 graphically illustrates the location of each of the bottleneck locations and areas for the SR-91 Corridor. Exhibits 4-3 and 4-4 further summarize each bottleneck location and associated bottleneck area.

Exhibit 4-2: SR-91 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, and productivity 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

Bottleneck Location	Bottleneck Area	Active Period		From		To		Distance (miles)
		AM	PM	Abs	CA	Abs	CA	
Serfas Club Dr On	ORA/RIV Co Line to Serfas Club Dr On		✓	37.2	0.0	41.1	R3.8	3.8
Maple St On	Serfas Club Dr On to Maple St On		✓	41.1	R3.8	41.6	4.2	0.5
Lincoln Ave On	Maple St On to Lincoln Ave On		✓	41.6	4.2	42.9	5.5	1.3
I-15 Off	Lincoln Ave On to I-15 Off		✓	42.9	5.5	44.4	7.0	1.5
I-15 On	I-15 Off to I-15 On*		✓	44.4	7.0	45.1	7.7	0.7
McKinley St On	I-15 On to McKinley St On		✓	45.1	7.7	46.5	9.2	1.4
Magnolia Ave On	McKinley St On to Magnolia Ave On	✓	✓	46.5	9.2	48.0	10.6	1.5
Madison Off	Magnolia St On to Madison Off	✓		48.0	10.6	53.9	16.5	5.9
Arlington Ave On	Madison Off to Arlington Ave On	✓		53.9	16.5	55.4	18.0	1.5
Central Ave On	Arlington Ave On to Central Ave On	✓		55.4	18.0	55.9	18.6	0.5
Not a bottleneck location	Central Ave On to SR-60/I-215	N/A		55.9	18.6	59.0	21.7	3.1

* segment is not included in the bottleneck area analysis due to insufficient detection

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

Bottleneck Location	Bottleneck Area	Active Period		From		To		Distance (miles)
		AM	PM	Abs	CA	Abs	CA	
SR-60/I-215 On	SR-60/I-215 to SR-60/I-215 On*		✓	59.0	21.7	58.8	21.5	0.2
14th St On	SR-60/I-215 On to 14th St On		✓	58.8	21.5	57.3	19.8	1.5
Arlington Ave On	14th St On to Arlington Ave On		✓	57.3	19.8	55.1	17.6	2.2
Tyler St On	Arlington Ave On to Tyler St On		✓	55.1	17.6	50.3	12.9	4.7
Pierce St On	Tyler St On to Pierce St On	✓	✓	50.3	12.9	48.0	10.6	2.3
I-15 On	Pierce St On to I-15 On	✓		48.0	10.6	45.2	7.8	2.8
School St/Grand Blvd On	I-15 On to School St/Grand Blvd On	✓		45.2	7.8	43.3	5.9	1.9
Lincoln Ave On	School St/Grand Blvd On to Lincoln Ave On	✓		43.3	5.9	42.7	5.3	0.6
Serfas Club Dr On	Lincoln Ave On to Serfas Club Dr On	✓		42.7	5.3	40.9	R3.5	1.8
Green River Road On	Serfas Club Dr On to Green River Road On	✓		40.9	R3.5	38.3	R0.9	2.6
Not a bottleneck location	Green River Road On to RIV/ORA Co Line*	N/A		38.3	R0.9	37.3	0.0	1.0

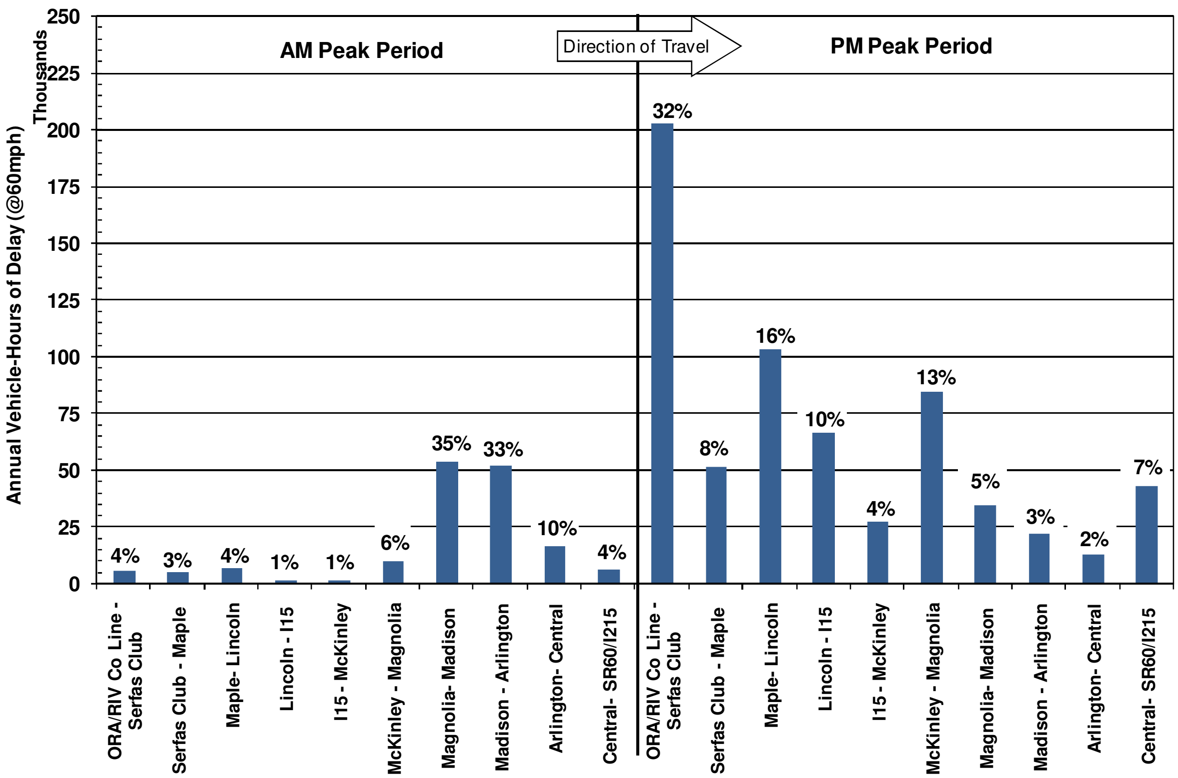
* segment is not included in the bottleneck area analysis due to the short distance in length or insufficient detection

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.

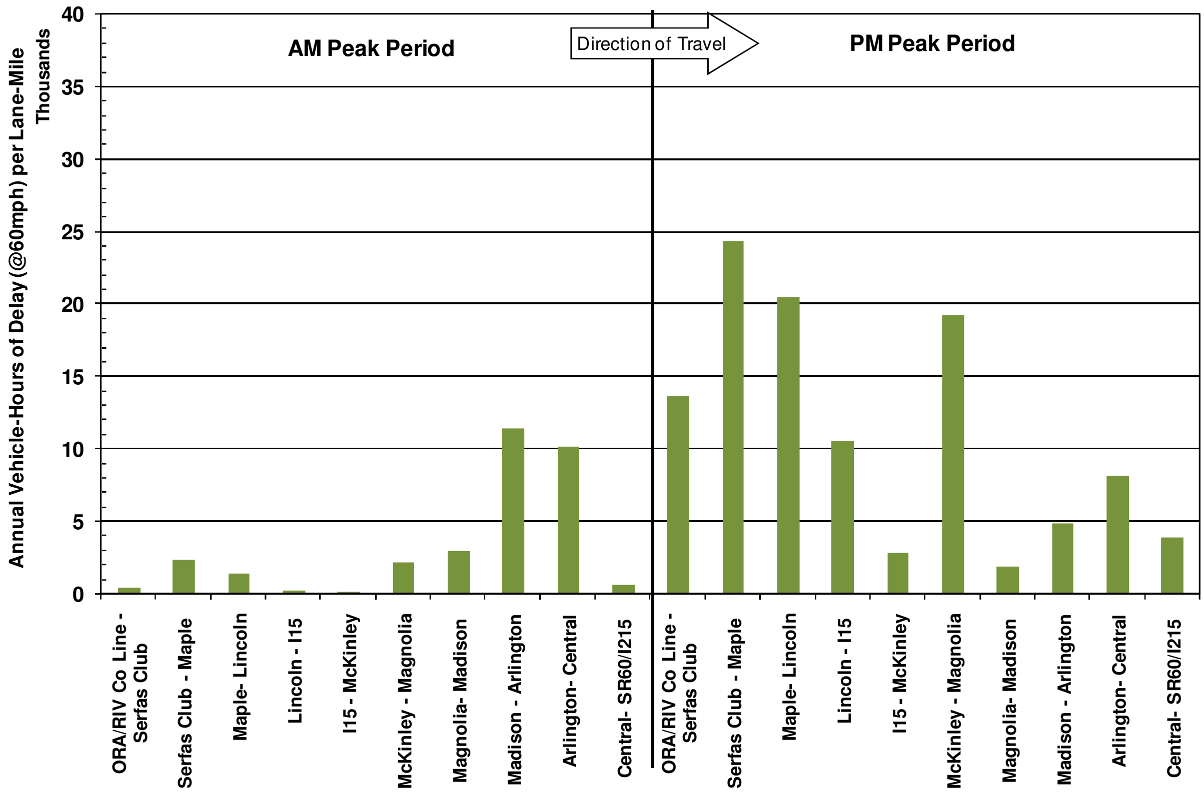
Exhibits 4-5 and 4-7 illustrate the vehicle-hours of delay experienced by each bottleneck area. These exhibits reiterate the directional pattern of travel on SR-91. As depicted in Exhibit 4-5, delay in the eastbound direction is concentrated in the PM peak with more than four times the delay than the AM peak. The bottleneck area between the County Line and Serfas Club Drive experienced the greatest delay in the eastbound direction with roughly 240,000 annual vehicle-hours of delay, or 32 percent of the corridor's delay during the PM peak. As expected, Exhibit 4-7 shows that delay in the westbound direction is concentrated in the AM peak. The westbound AM peak experienced more than twice the delay of the PM peak. During the AM peak, the bottleneck area between I-15 and School Street/Grand Boulevard suffered the greatest westbound delay with almost 136,000 annual vehicle-hours of delay (28 percent), followed by the bottleneck areas at Lincoln (19 percent), and at Serfas Club Drive (18 percent).

Exhibit 4-5: Eastbound SR-91 Annual Vehicle-Hours of Delay (2007)



Source: SMG Analysis of PeMS Data

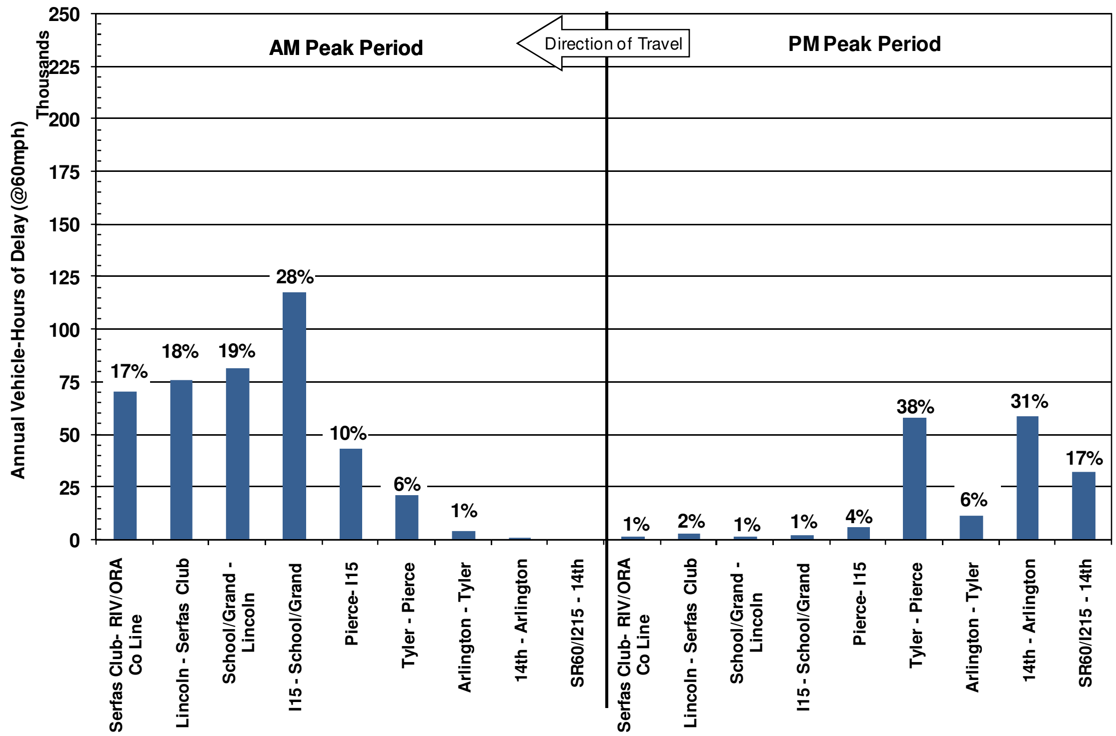
Exhibit 4-6: Eastbound SR-91 Delay per Lane-Mile (2007)



Source: SMG Analysis of PeMS Data

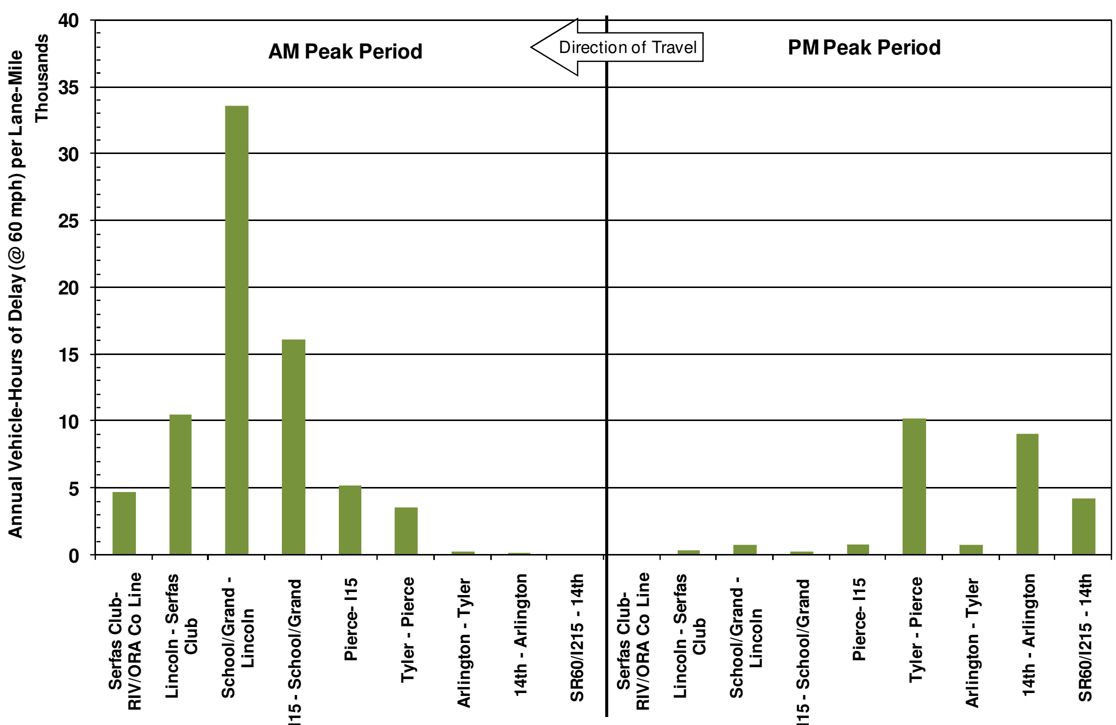
Exhibits 4-6 and 4-8 have been normalized to reflect delay per lane-mile. The delay calculated for each bottleneck area was divided by the total lane-miles for each bottleneck area to obtain delay per lane-mile. The results of these exhibits reveal different delay results than Exhibits 4-5 and 4-7. In the eastbound direction (Exhibit 4-6), the bottleneck areas from Serfas Club to Maple, and from Maple to Lincoln were the segments that experienced the highest delay per lane mile on the corridor during the PM peak. This is different from the delay illustrated in Exhibit 4-5, which shows that the highest delay occurred between the County Line and Serfas Club Drive. Similarly, during the AM peak in the westbound direction (Exhibit 4-8), the bottleneck area between School Street/Grand and Lincoln experienced the highest delay per lane-mile, which differs from the delay illustrated in Exhibit 4-7 that identified I-15 to School Street/Grand Boulevard as the segment with the highest delay.

Exhibit 4-7: Westbound SR-91 Annual Vehicle-Hours of Delay (2007)



Source: SMG Analysis of PeMS Data

Exhibit 4-8: Westbound SR-91 Delay per Lane-Mile (2007)



Source: SMG Analysis of PeMS Data

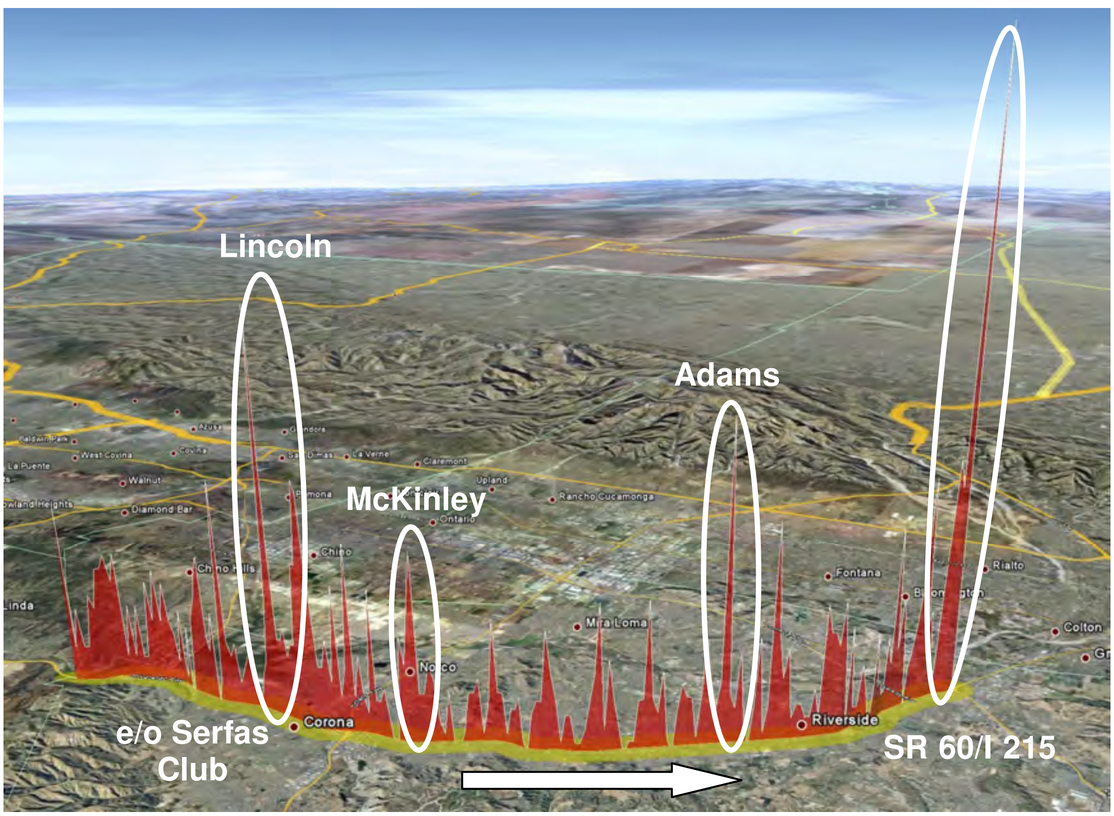
Safety by Bottleneck Area

As previously indicated in Section 3, 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. The following discussion examines the pattern of collisions by bottleneck areas.

Exhibit 4-9 shows the location of all collisions plotted along the SR-91 Corridor in the eastbound direction. The spikes show the total number of collisions (fatality, injury, and property damage only) that occurred within 0.1 mile segments in 2006. The highest spike corresponds to roughly 46 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.

As Exhibit 4-9 shows, a large group of collisions occurred at three notable locations in 2006. Moving eastbound, the first location is near Lincoln Avenue; followed by McKinley Street; around Adams Street, and at the SR-60/I-215 Interchange.

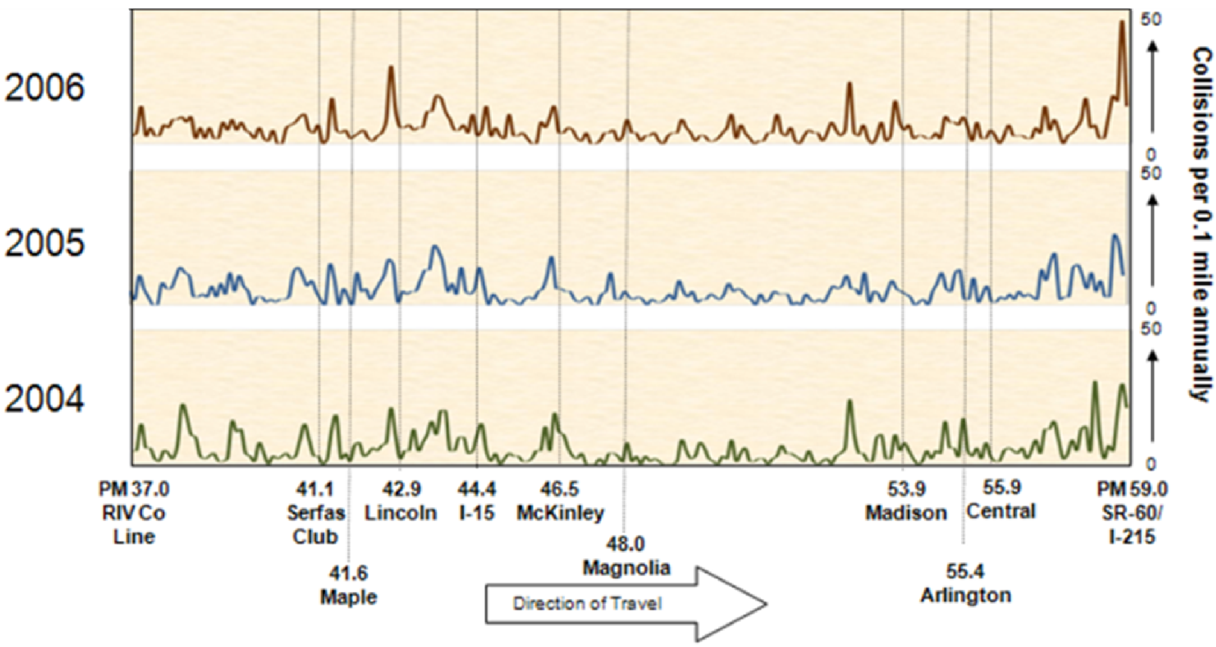
Exhibit 4-9: Eastbound SR-91 Collision Locations (2006)



Source: SMG analysis of TASAS data

Exhibit 4-10 illustrates the same data for the three-year period between 2004 and 2006. The vertical lines in the exhibit separate the corridor by bottleneck area. Exhibit 4-10 suggests that the high accident locations identified in 2006 (Exhibit 4-9) were the same in the preceding years. Again, spikes were noticeable around Lincoln Avenue (PM 42.9), at McKinley Street (46.5), around Adams Street (PM 52.8), and at the SR-60/I-215 Interchange (PM 58.8). In addition to being high-collision locations, Lincoln Avenue and MicKinley Street are bottleneck locations as well. The exhibit also shows that the pattern of collisions has stayed fairly consistent from one year to the next.

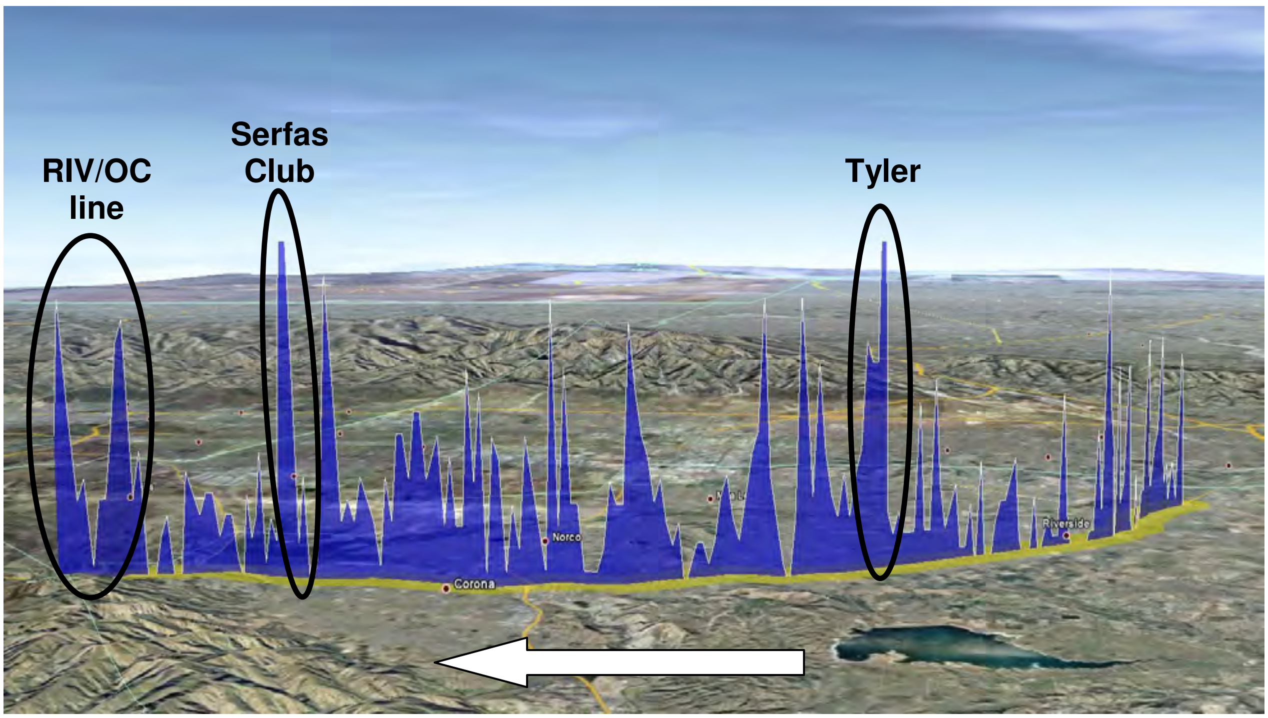
Exhibit 4-10: Eastbound SR-91 Location of Collisions (2004-2006)



Source: SMG analysis of TASAS data

Exhibit 4-11 shows the same 2006 collision data for the SR-91 in the westbound direction. The largest spike in this exhibit corresponds roughly to 24 collisions per 0.1 miles. The westbound direction did not experience as many accidents as the eastbound direction. Exhibit 4-11 groups the high accident locations into three clusters. Moving westbound, these clusters are near Tyler Street; at Serfas Club Drive; and at the Riverside/Orange County line.

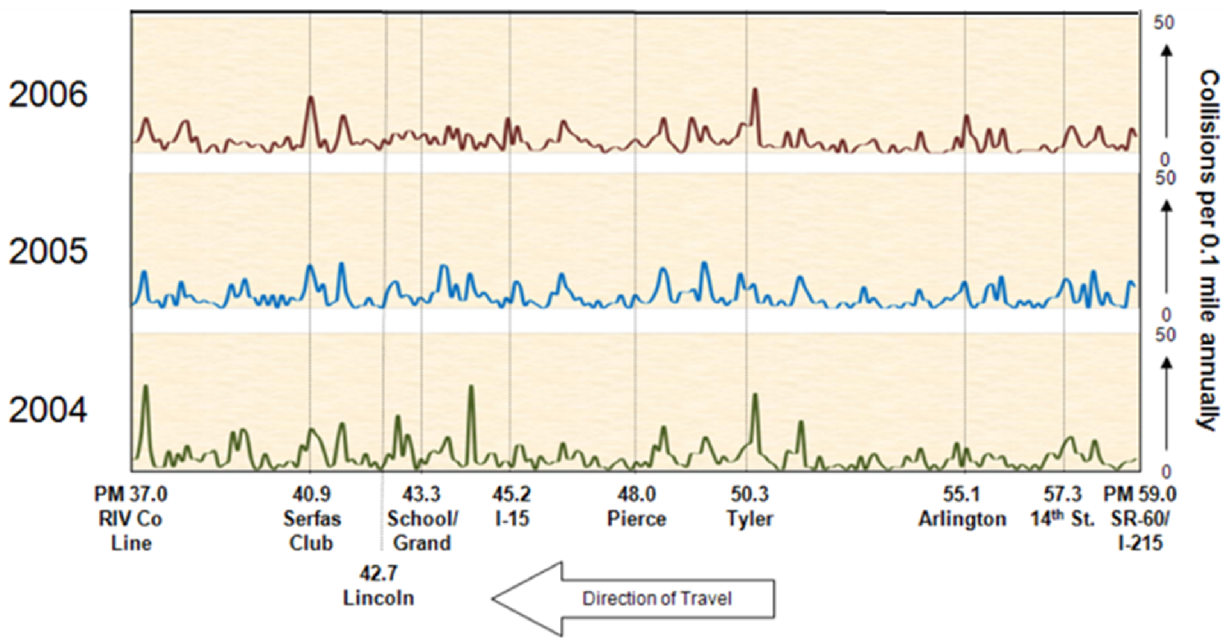
Exhibit 4-11: Westbound SR-91 Collision Locations (2006)



Source: SMG analysis of TASAS data

Exhibit 4-12 shows the trend of collisions for the westbound direction from 2004 to 2006 period. The pattern of collisions has been fairly steady from one year to the next with an overall decrease from 2004, particularly near the County line. The high accident locations depicted in Exhibit 4-11 existed in the preceding years. Moving westbound, these locations are near Tyler Street (PM 50.3); at Serfas Club Drive (PM 40.9); and at the Riverside/Orange County line (PM 37.0). These high-collision locations are also bottleneck locations.

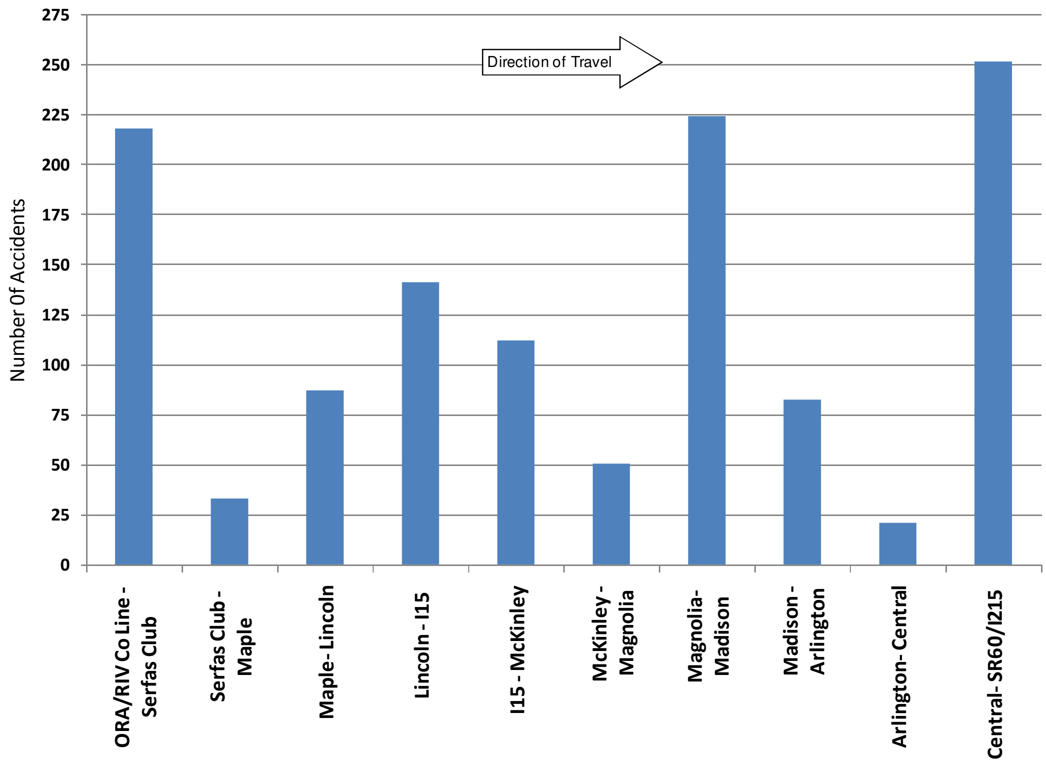
Exhibit 4-12: Westbound SR-91 Collision Locations (2004-2006)



Source: SMG analysis of TASAS data

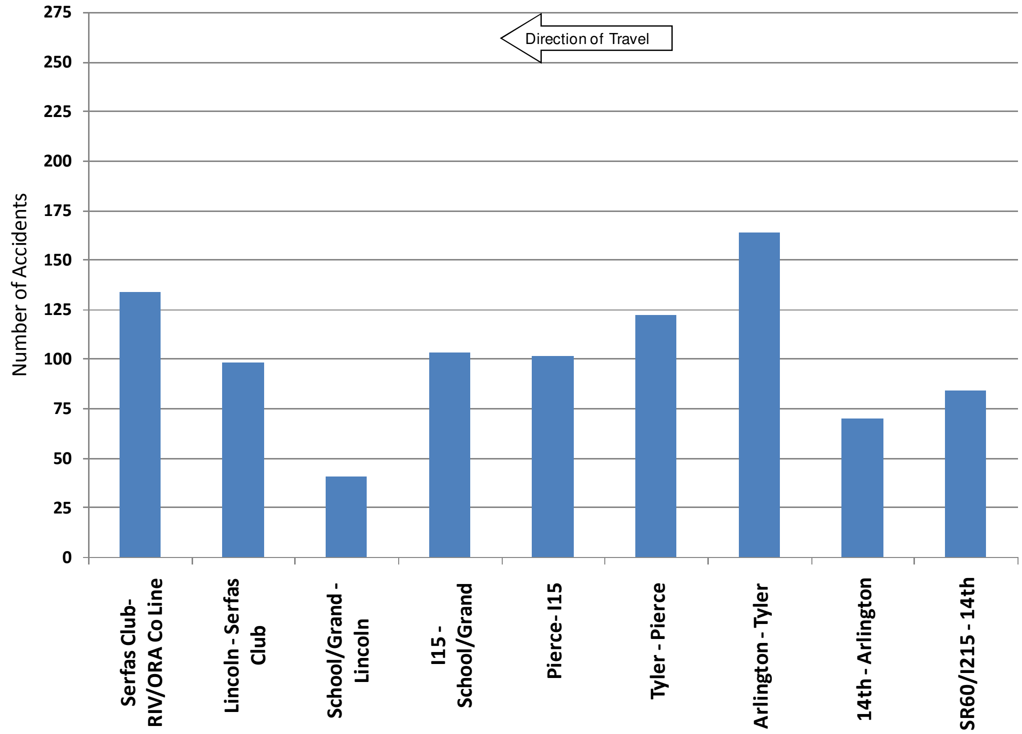
Exhibits 4-13 and 4-14 summarize the average number of annual accidents that occurred from 2004 to 2006 by bottleneck area as reported by TASAS. The bars show the average number of accidents that occurred in 2004, 2005, and 2006, the latest three years available in TASAS. The eastbound direction clearly experienced more accidents than the westbound. The bottleneck areas that exhibited the most accidents are Central Avenue to SR-60/I-215 in the eastbound direction, and Arlington Avenue to Tyler Street in the westbound direction.

Exhibit 4-13: Eastbound SR-91 Average Annual Accidents (2004-2006)



Source: SMG analysis of TASAS data

Exhibit 4-14: Westbound SR-91 Average Annual Accidents (2004-2006)



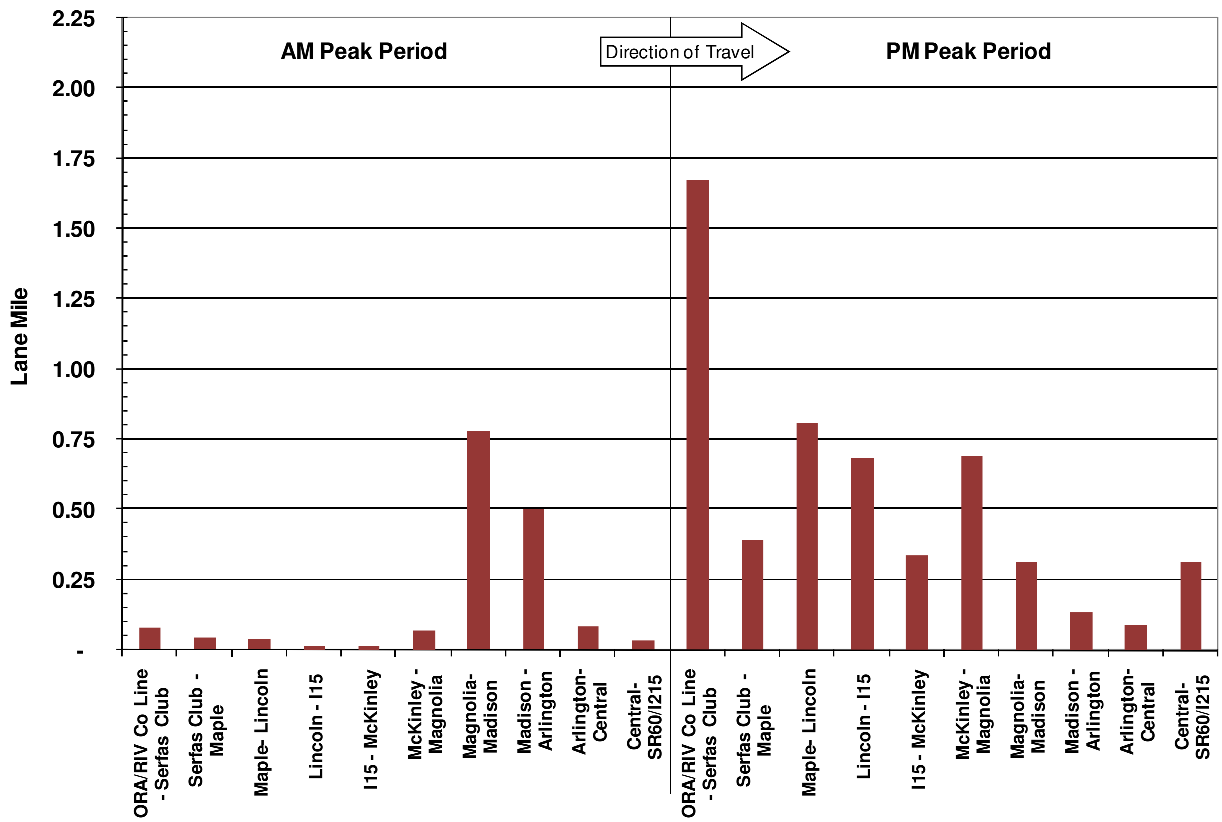
Source: SMG analysis of TASAS data

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 4-15 and 4-16 show the productivity losses for both directions of the corridor. In the eastbound direction, the bottleneck area between the County Line and Serfas Club Drive experienced the worst productivity of all the segments on the corridor with almost 1.75 lost lane-miles in the PM peak. During the AM peak period, the eastbound direction experienced relatively high levels of productivity with most segments experiencing less than 0.25 lost lane-miles.

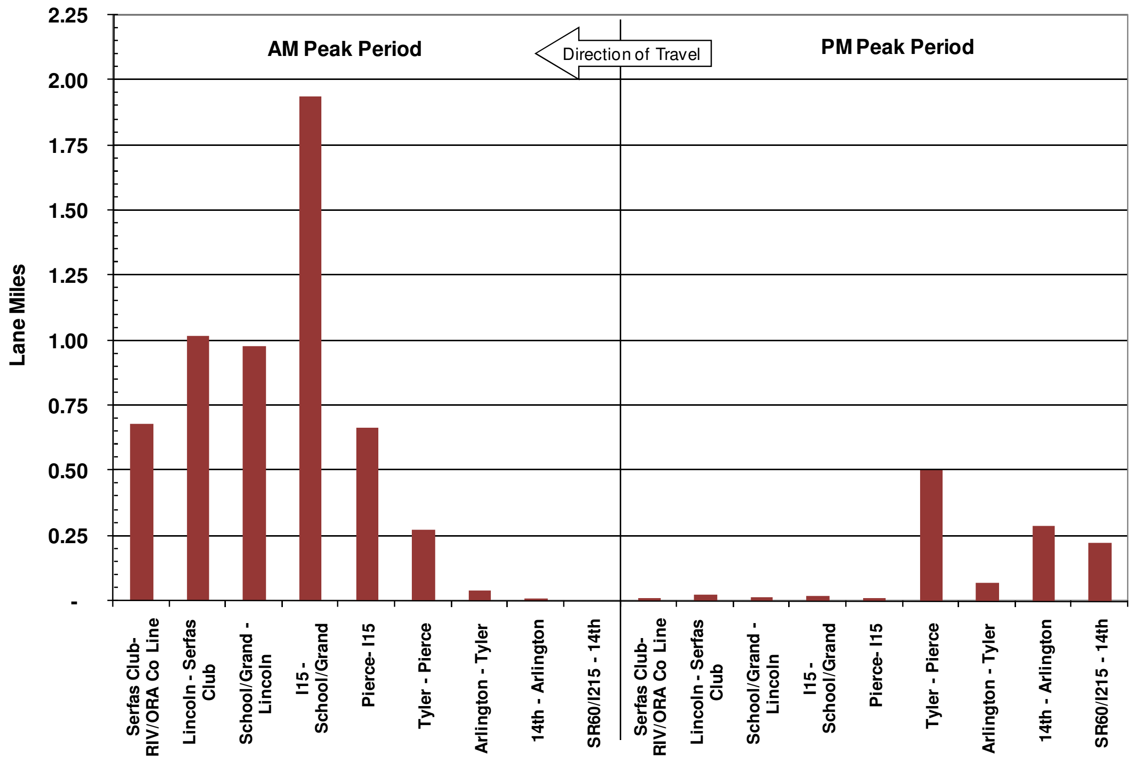
Exhibit 4-15: Eastbound SR-91 Lost Lane-Miles (2007)



Source: SMG analysis of TASAS data

In the westbound direction, the bottleneck area between I-15 and School/Grand experienced the greatest productivity loss during the AM peak with almost 2.0 lost lane-miles. Notably, the segments of the corridor with the highest productivity losses are the same segments that experienced the highest levels of annual vehicle-hours of delay (refer to Exhibit 4-5 and 4-7).

Exhibit 4-16: Westbound SR-91 Lost Lane-Miles (2007)



Source: SMG analysis of TASAS data

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

5. BOTTLENECK CAUSALITY ANALYSIS

Bottlenecks are the location of corridor performance degradation and resulting congestion and lost productivity. It is important to verify the specific location and cause of each major bottleneck to determine appropriate solutions to traffic operational problems.

The location of each major bottleneck should be verified by multiple field observations on separate days. The cause of each major bottleneck can also identified by field observations and additional traffic data analysis. For the SR-91 Corridor, field observations were conducted by the project consultant team on multiple days (midweek) in November and December 2008, and January 2009, 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. Due to the limited vehicle detector stations along this corridor, traffic volume data was not readily available for consideration. Nevertheless, major bottleneck conditions were verified and their causes identified. Below is a summary of the causes of the bottleneck locations.

Mainline Facility

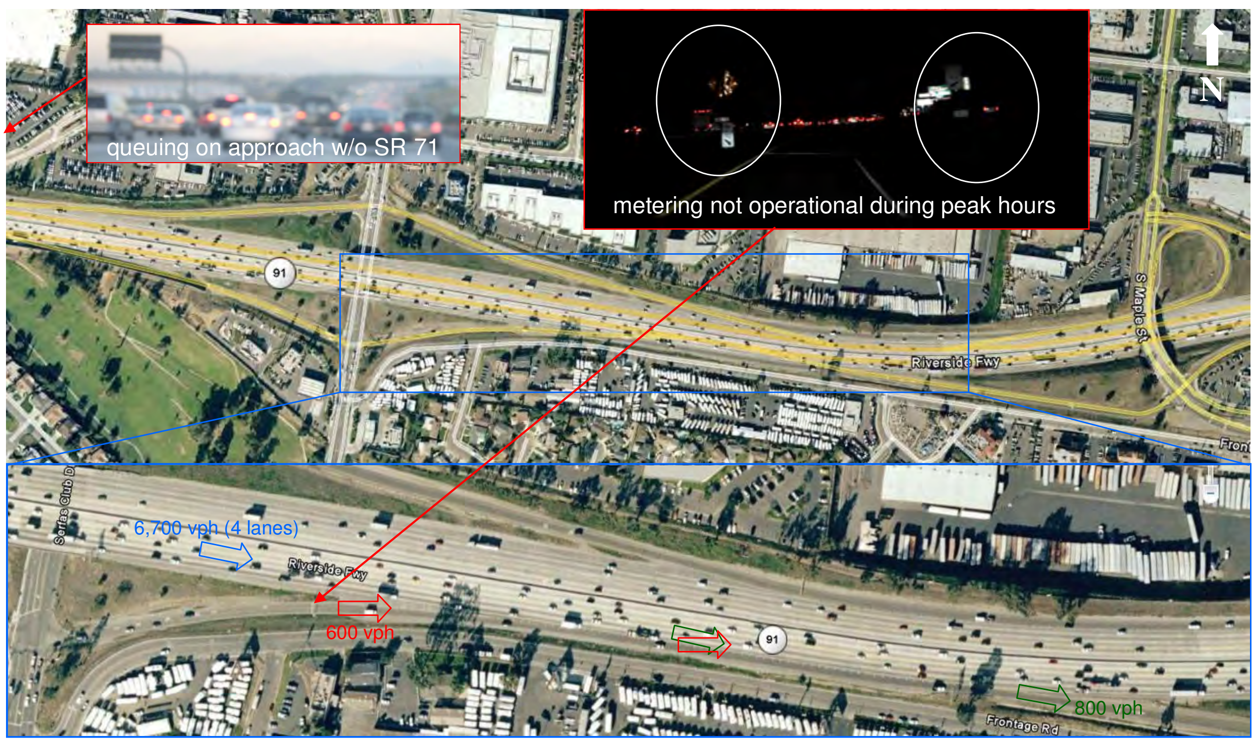
Eastbound Bottlenecks and Causes

Major eastbound bottlenecks and congestion occur mostly during the PM peak hours. The following is a summary of the eastbound bottlenecks and the identified causes.

Serfas Club Drive On

Exhibit 5-1 is an aerial photograph of the SR-91 mainline at the Serfas Club Drive Interchange. During the PM peak hours, the volume of traffic from SR-91 mainline reaches over 6,700 vehicles per hour (vph) in 4 lanes (mixed-flow lanes). The Serfas Club Drive on-ramp adds over 600 vph to the existing traffic on the mainline during the PM peak hours, resulting in fairly heavy mainline traffic demand. Additionally, downstream off-ramp traffic to Maple Street (carrying over 800 vph) creates cross weaving with the SR-91 on-ramp traffic. Significant bottleneck and traffic congestion was observed at this location during field reviews. Queuing extended as far back as west of SR-71. The merging and weaving are likely to be the cause of this bottleneck. As indicated from the inset photograph, ramp metering operation was not observed during the peak hours on any of the field site visits.

Exhibit 5-1: Eastbound SR-91 at Serfas Club Drive On



Maple Street On

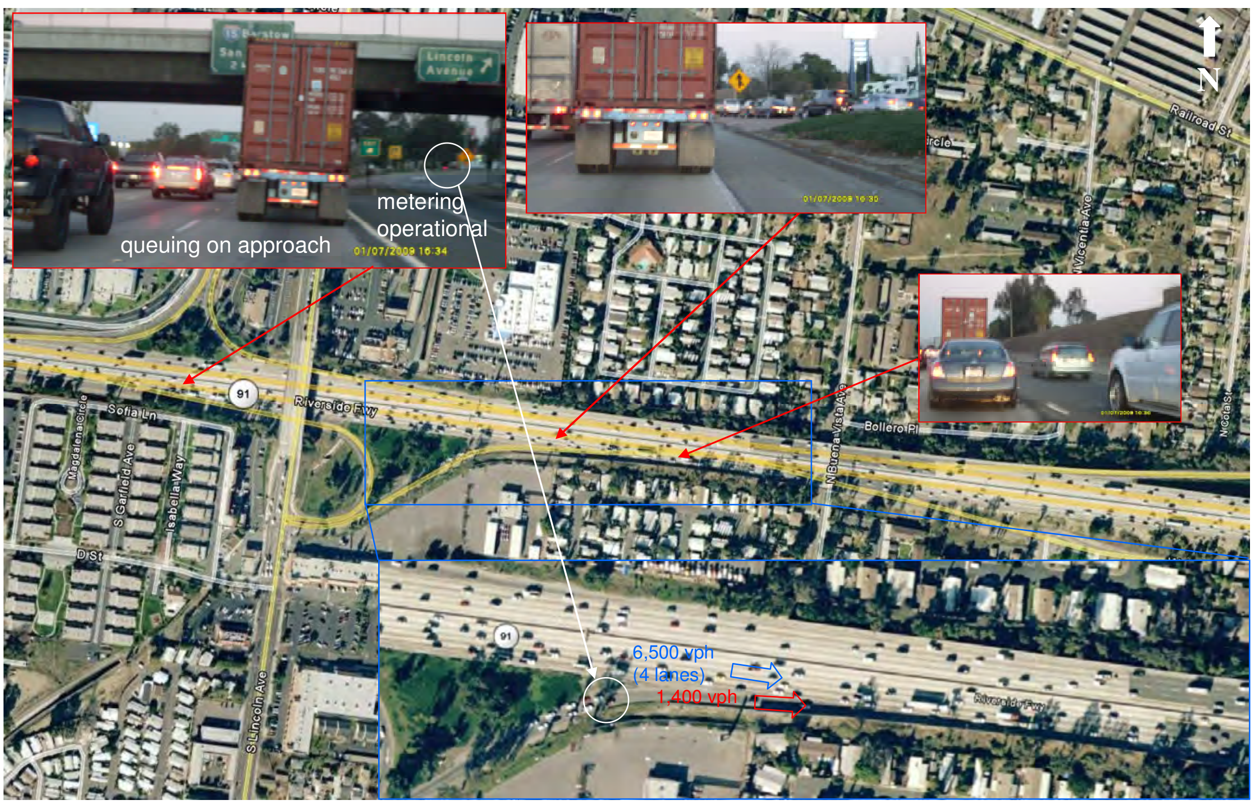
Exhibit 5-2 is an aerial photograph of the SR-91 mainline at the Maple Street on-ramp. During the PM peak hours, the volume of traffic from the SR-91 mainline reaches over 6,500 vehicles per hour (vph) in 4 lanes. The Maple Street on-ramp adds over 600 vph to the existing mainline traffic during the PM peak hours, resulting in fairly heavy mainline traffic demand. Bottleneck and traffic congestion was observed at this location during field visits. Ramp merging is likely to be the cause of this bottleneck. As indicated, ramp metering operation was not observed during the peak hours on any of the field site visits.

Exhibit 5-2: Eastbound SR-91 at Maple Street On

<u>Lincoln Avenue On</u>

Exhibit 5-3 is an aerial photograph of the SR-91 mainline at the Lincoln Avenue Interchange. During the PM peak hours, the volume of traffic from the SR-91 mainline reaches over 6,500 vehicles per hour (vph) in 4 lanes. The Lincoln Avenue on-ramp adds heavy traffic volumes of over 1,400 vph to the existing traffic on the mainline during the PM peak hours despite ramp metering operation that was observed during the peak hours of site visits. This heavy demand results in a saturated condition of 7,900 vph, which reaches the threshold level (typically near 2,000 vph per lane). Significant bottleneck and traffic congestion was observed at this location during the field reviews, as evident in the inset photographs. It is likely that the ramp merging is the cause of this bottleneck. In addition there is some weaving from the I-15 bound traffic that compounds the bottleneck condition.

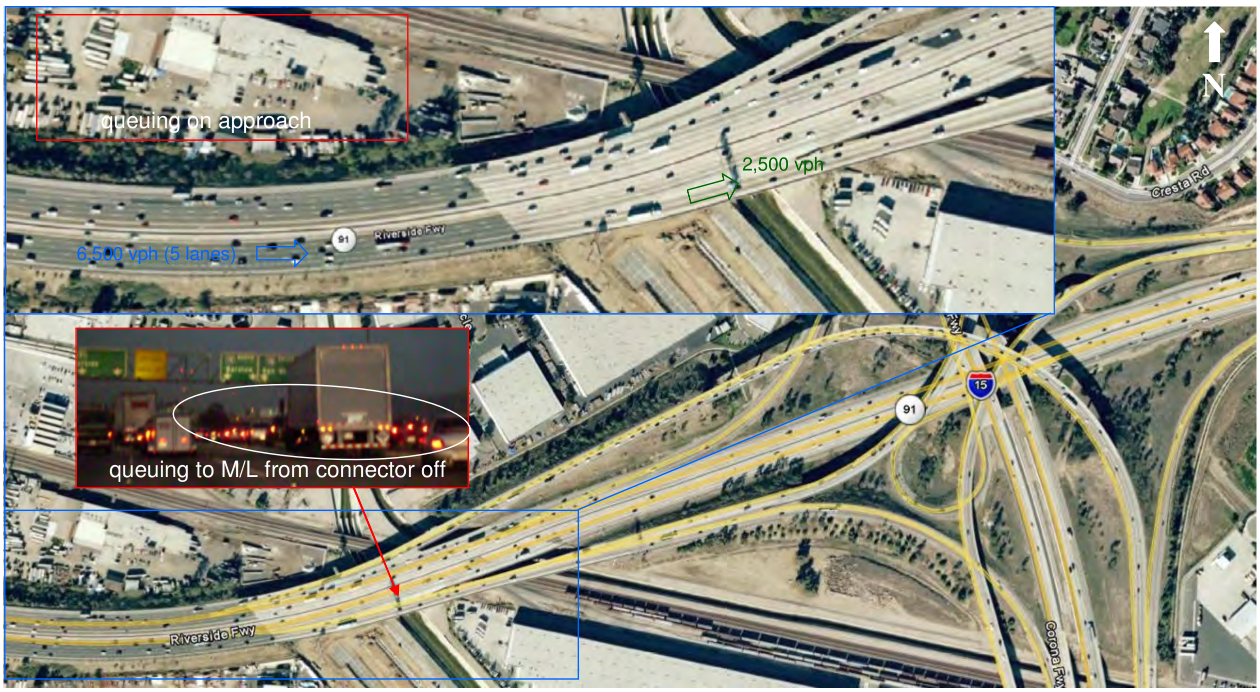
Exhibit 5-3: Eastbound SR-91 at Lincoln Avenue On



I-15 Off

Exhibit 5-4 is an aerial photograph of the SR-91 connector off-ramps to I-15. As evident in the inset photographs, the I-15 off-ramp traffic queues back onto the SR-91 mainline causing the congestion. This is due to the heavy demand for the southbound I-15. This causes the mainline flow to slow down.

Exhibit 5-4: Eastbound SR-91 at I-15 Off



I-15 On

Exhibit 5-5 is an aerial photograph of the eastbound SR-91 at the I-15 Interchange. During the PM peak hours, the volume of traffic from the SR-91 mainline reaches over 4,700 vph in 3 lanes. The I-15 connector on-ramps adds over 2,300 vph of demand to the existing mainline traffic during the PM peak hours, in one additional (auxiliary) lane, bringing the total demand to over 7,000 vph in 4 lanes, more than what the facility is able to handle. With the steep and long uphill grade and loss of the auxiliary lane to McKinley Street exit, the demand exceeds the threshold level and results in oversaturation and bottleneck conditions. With the termination of the auxiliary lane, mainline demand is squeezed into three lanes. Past the bottleneck location, increasing speeds are observed.

Exhibit 5-5: Eastbound SR-91 at I-15 On

McKinley Street On

Exhibit 5-6 is an aerial photograph of the eastbound SR-91 at the McKinley Street on-ramps. As indicated, approximately 1,100 vph enters the freeway during the PM peak hours on consecutive ramps. With the mainline traffic demand at 4,700 vph in 3 lanes, the addition of the on-ramps traffic demand totals over 5,800 vph in 3 lanes, reaching the threshold level. Add to this the long uphill grade likely affecting (reducing) the capacity values, the mainline traffic flow results in a saturated bottleneck condition. Significant bottleneck and congestion was observed during the field site visits.

Exhibit 5-6: Eastbound SR-91 at McKinley Street On

<u>Magnolia Avenue On</u>

Exhibit 5-7 is an aerial photograph of the eastbound SR-91 at the Magnolia Avenue on-ramp. During the PM peak hours, the volume of traffic from SR-91 mainline reaches over 4,500 vehicles per hour (vph) in 3 lanes. The Magnolia Avenue on-ramp adds over 800 vph to the existing mainline traffic during the PM peak hours. Minor bottleneck condition and traffic congestion were observed at this location during the field visits. On days when mainline demand is higher, the impact of this bottleneck to the mainline traffic condition is likely to be much more significant.

Exhibit 5-7: Eastbound SR-91 at Magnolia Avenue On

Madison Street Interchange

Exhibit 5-8 is an aerial photograph of the eastbound SR-91 at the Madison Street Interchange. As shown in the inset photograph, significant traffic congestion and queuing is evident while approaching the interchange. This is primarily due to the lane drop, as shown in the exhibit. About half mile west of this location, the High Occupancy Vehicle (HOV) lane ends and continues on as the new mixed-flow number one lane and the outermost lane is dropped at this location, as shown in the inset photograph.

The combined mainline and HOV lane traffic exceeds over 6,700 vph during the AM peak hours. Further west at 3 lanes plus the HOV lane can accommodate this traffic, but when the capacity is reduced to only 3 mixed-flow lanes, the demand exceeds the threshold level and breaks down, resulting in the bottleneck condition. East of the bottleneck location, volumes are normalized below the threshold level and speeds increase, as evident in the inset photograph.

Exhibit 5-8: Eastbound SR-91 at Madison Street Interchange

<u>Arlington Avenue On</u>

Exhibit 5-9 is an aerial photograph of the eastbound SR-91 at the Arlington Avenue on-ramp. During the AM peak hours, the volume of traffic from SR-91 mainline reaches over 4,900 vehicles per hour (vph) in 3 lanes. The Arlington Avenue on-ramp adds over 900 vph to the existing mainline traffic during the AM peak hours. This brings the mainline traffic to the threshold level, breaking down the mainline flow.

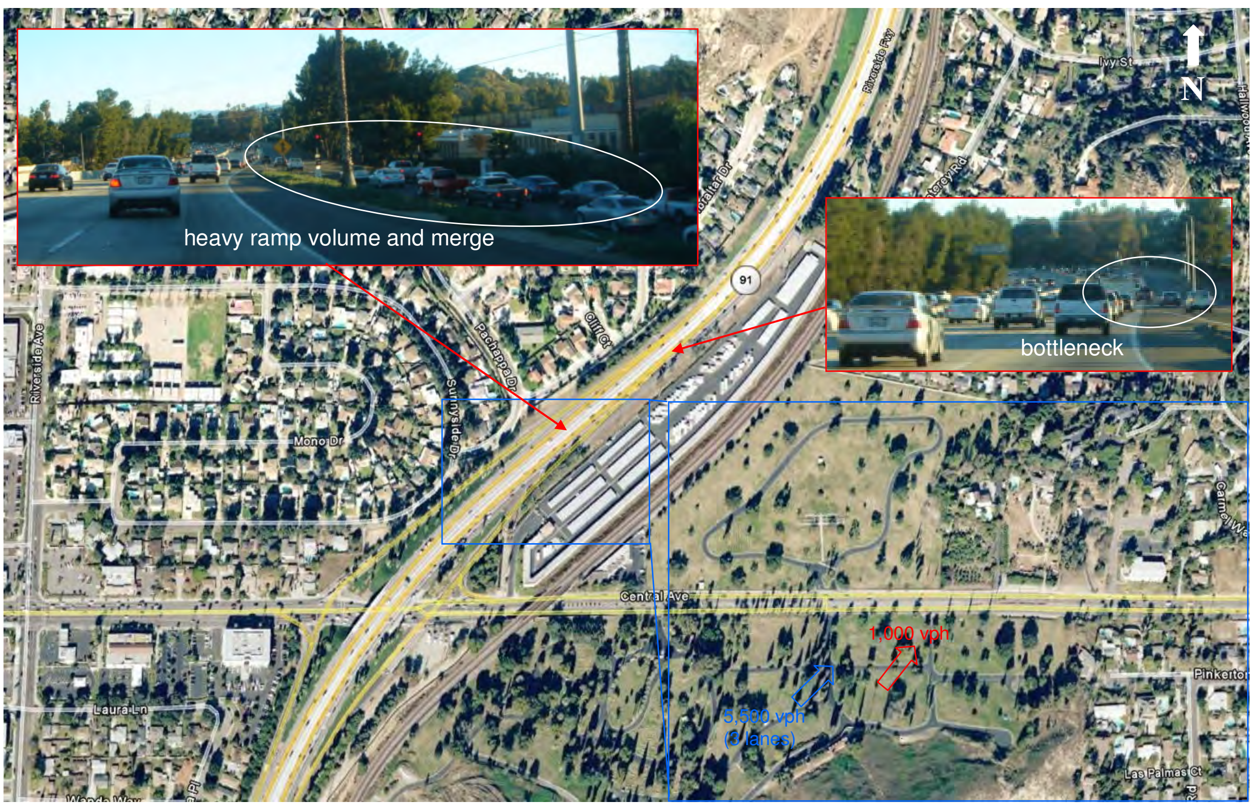
In addition, the roadway geometrics with the varying grade, curve to the left, and short auxiliary lane, are likely to impact the capacity values. Significant congestion and queuing was shown as evident in the inset photographs approaching the interchange and at the bottleneck location. East of the bottleneck location, increasing speeds are observed.

Exhibit 5-9: Eastbound SR-91 at Arlington Avenue On

<u>Central Avenue On</u>

Exhibit 5-10 is an aerial photograph of the eastbound SR-91 at the Central Avenue on-ramp. During the AM peak hours, the volume of traffic from SR-91 mainline reaches over 5,500 vehicles per hour (vph) in 3 lanes. The Central Avenue on-ramp adds over 1,000 vph to the existing mainline traffic during the AM peak hours, bringing the mainline traffic to over the threshold level, breaking down the mainline flow. In addition, the roadway geometrics with the varying grade and curve to the left are also likely to impact the capacity values. Significant congestion and queuing was observed as evident in the inset photographs approaching the interchange and at the bottleneck location.

Exhibit 5-10: Eastbound SR-91 at Central Avenue On



Westbound Bottlenecks and Causes

Major westbound bottlenecks and congestion occur mainly during the AM peak hours, with several during the PM peak. The causes of these bottleneck locations are summarized below.

<u>I-215 On</u>

The SR-91/SR-60/ I-215 interchange reconstruction was recently completed and open to traffic in December 2008. Recent aerial photographs are not yet available. With the new interchange, additional lanes from the northbound and southbound I-215 connector to the westbound SR-91 are added. These additional lanes terminate at the approach to the Mission Inn Avenue Interchange, going from as many as five lanes down to three. The total combined demand of over 7,000 vph cannot be accommodated by the reduced lanes. The lane drop causes the bottleneck condition to occur during the PM peak hours.

<u>14th Street On</u>

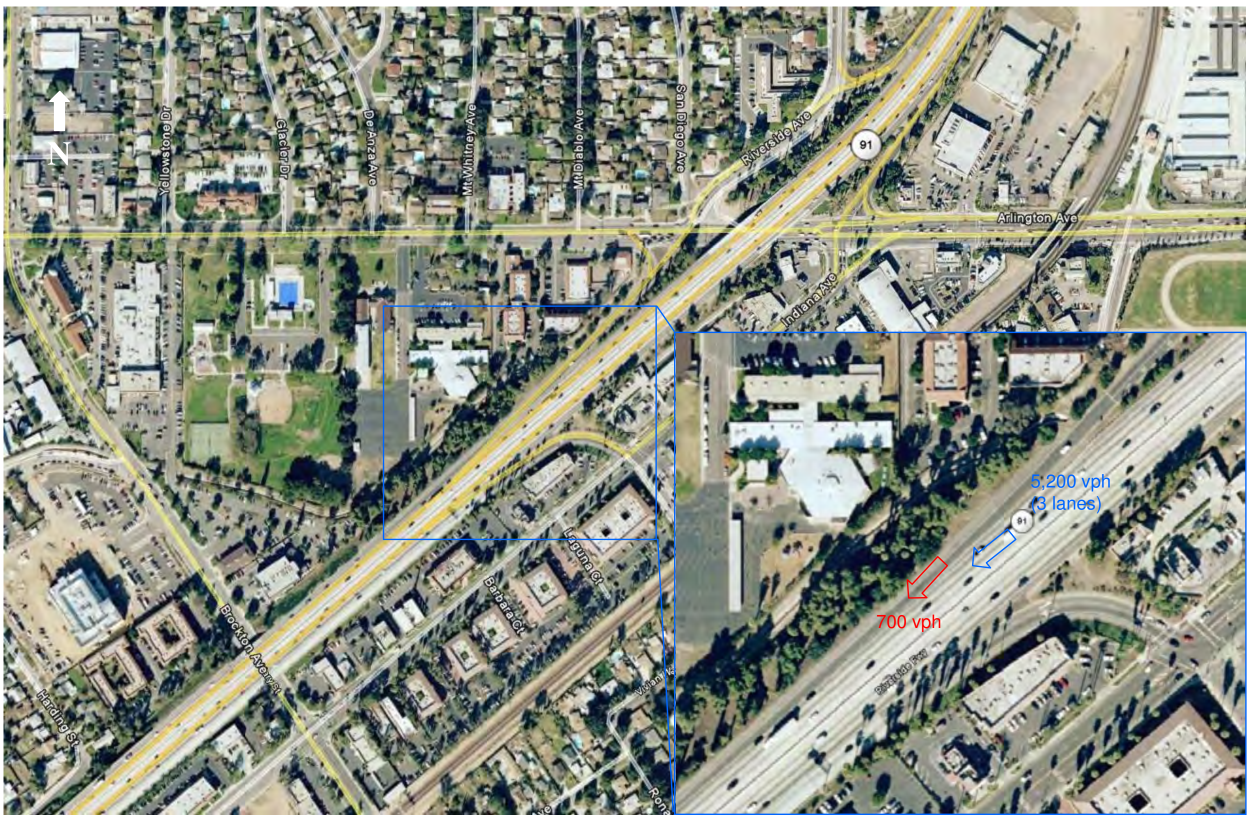
Exhibit 5-11 is an aerial photograph of the westbound SR-91 mainline at the 14th Street on-ramp. During the PM peak hours, the volume of traffic from the SR-91 mainline reaches over 5,000 vehicles per hour (vph) in 3 lanes. The 14th Street on-ramp adds over 800 vph to the existing mainline traffic during the PM peak hours, bringing the mainline traffic to the threshold level, resulting in a bottleneck condition. Significant congestion and queuing was observed, as evident in the inset photographs approaching the interchange and at the bottleneck location. Just past the bottleneck location, increasing speeds are observed.

Exhibit 5-11: Westbound SR-91 at 14th Street On

<u>Arlington Avenue On</u>

Exhibit 5-12 is an aerial photograph of the westbound SR-91 mainline at the Arlington Avenue on-ramp. As illustrated, the on-ramp at this location exceeds 700 vph during the PM peak hours, while the approaching mainline demand is over 5,200 vph. Combined, the total demand reaches over 5,900 vph in 3 lanes, reaching the threshold level, resulting in the bottleneck condition. Although not a significant bottleneck, in terms of the amount of congestion and delay it causes on a regular basis, congestion and queuing was observed at the on-ramp merge location.

Exhibit 5-12: Westbound SR-91 at Arlington Avenue On



<u>Tyler Street On</u>

Exhibit 5-13 is an aerial photograph of the westbound SR-91 at the Tyler Street on-ramp. Although a bottleneck condition and congestion was not observed during any of the field site visits at this location, data analysis results indicated that this was a bottleneck location during the PM peak hours in 2007. The current on-ramp volume is over 900 vph while the approaching mainline volume exceeded 4,700 vph in 3 lanes. Combined, they total over 5,600 vph in 3 lanes. While not quite at the threshold level, when the mainline demand is higher, it is likely to result in a bottleneck condition and traffic queues to form.

Exhibit 5-13: Westbound SR-91 at Tyler Street On

Pierce Street On

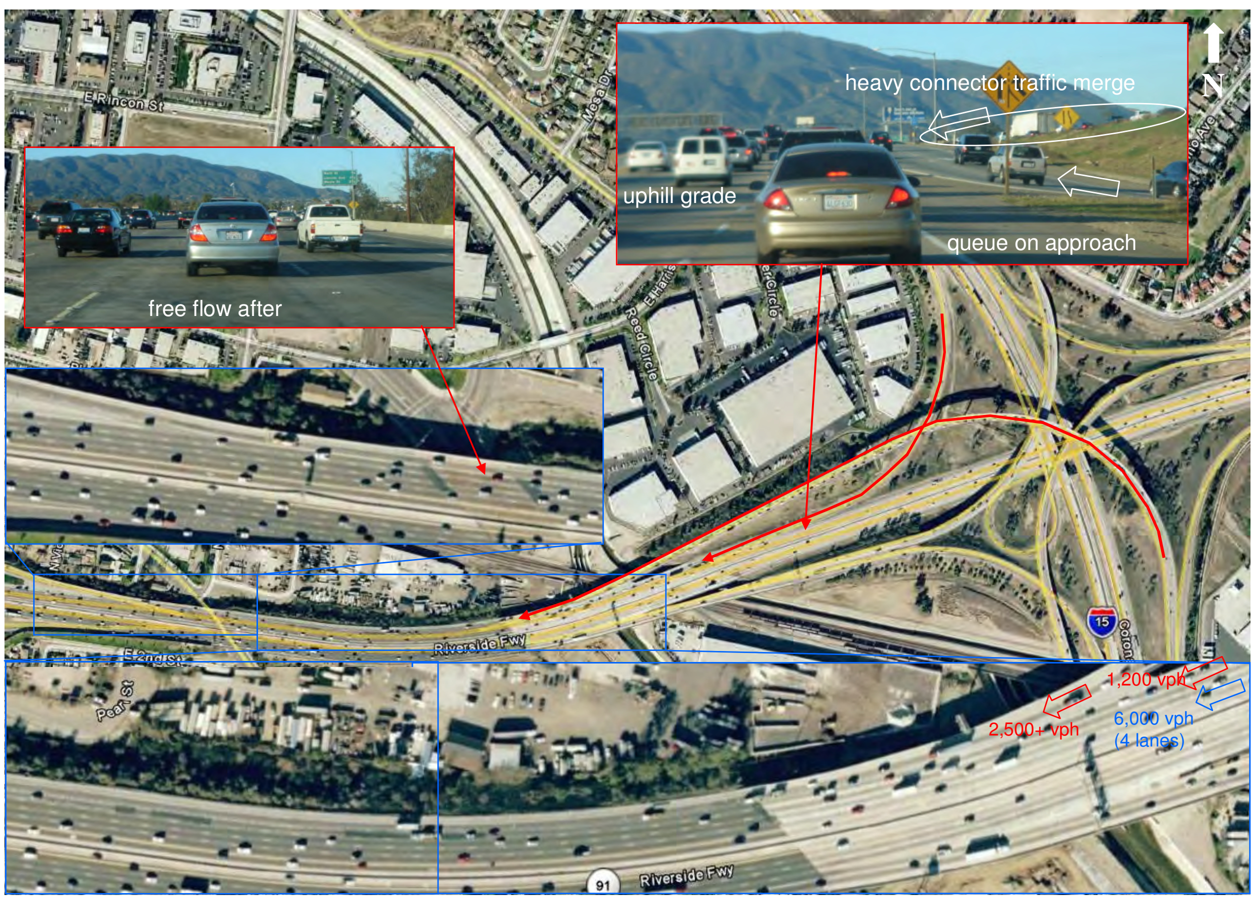
Exhibit 5-14 is an aerial photograph of the westbound SR-91 mainline at the Pierce Street on-ramp and Magnolia Avenue on-ramp. During the PM peak hours, the volume of traffic from the SR-91 mainline reaches over 4,700 vph in 3 lanes. The Pierce Street on-ramp adds over 900 vph to the existing mainline traffic during the PM peak hours, even with active ramp metering, bringing the mainline traffic near the threshold level. With the geometric roadway curve to the left, affecting sight distance, and heavy ramp merge at the crest of the turn, the mainline flow breaks down, resulting in the bottleneck condition and traffic congestion, as evident in the inset photograph. Past the bottleneck location, increasing speeds are observed.

Exhibit 5-14: Westbound SR-91 at Pierce Street On

I-15 On

Exhibit 5-15 is an aerial photograph of the westbound SR-91 mainline at the I-15 on-ramps. During the AM peak hours, the volume of traffic from the SR-91 mainline reaches over 6,000 vph in 4 lanes. The I-15 connector on-ramps adds over 3,000 vph to the existing mainline traffic during the AM peak hours, in one additional lane, bringing the total demand to over 9,000 vph in 5 lanes. As indicated in the inset photograph, heavy volumes on the northbound I-15 to westbound SR-91 connector ramp queues back onto the I-15 mainline during the AM peak hours. With the uphill grade and loss of a lane to the Main Street exit, the result is an oversaturated and bottleneck condition, as evident in the inset photograph. In addition to the merging of the I-15 connector ramp traffic, weaving from the Main Street off-ramp traffic is also likely to contribute to the bottleneck condition. With this condition, the demand cannot be accommodated and congestion and queuing results. Past the bottleneck location, increasing higher speeds are observed.

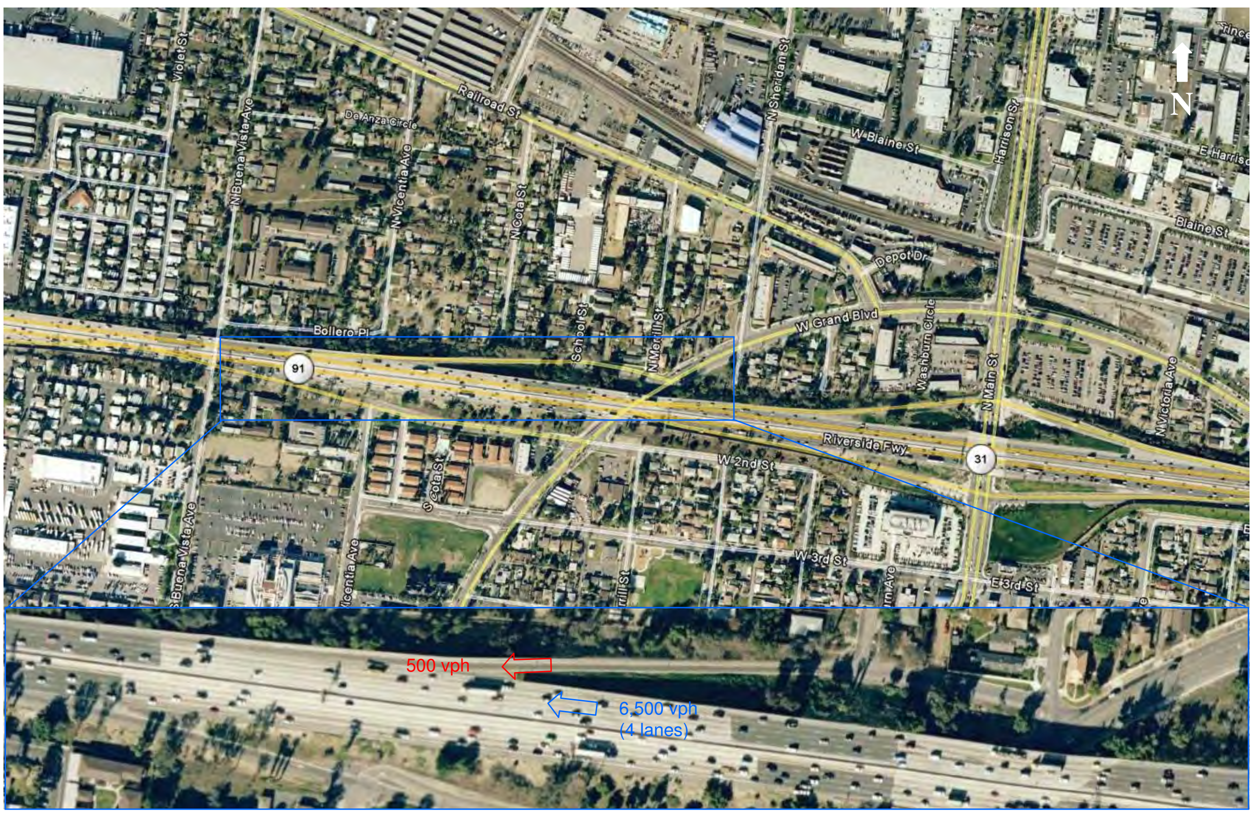
Exhibit 5-15: Westbound SR-91 at I-15 On



School Street/Grand Blvd On

Exhibit 5-16 is an aerial photograph of the westbound SR-91 at the School Street on-ramp. Although a bottleneck condition and congestion was not observed during any of the field site visits at this location, data analysis results indicated that this was a bottleneck location during the AM peak hours in 2007. The current on-ramp volume is at over 500 vph while the approaching mainline volume exceeds 6,500 vph in 4 lanes. Combined, they total over 7,000 vph in 4 lanes. While not quite at the threshold level, when the mainline demand is higher, it is likely to result in a bottleneck condition and traffic queues to form.

Exhibit 5-16: Westbound SR-91 at School Street On



<u>Lincoln Avenue On</u>

Exhibit 5-17 is an aerial photograph of the westbound SR-91 mainline at the Lincoln Avenue on-ramp. During the AM peak hours, the volume of traffic from the SR-91 mainline reaches over 6,200 vph in 4 lanes. The Lincoln Avenue on-ramp adds over 1,200 vph to the existing mainline traffic during the AM peak hours, increasing the mainline traffic to over 7,400 vph. At this location, ramp metering operation was not observed during the peak hours of any of the field site visits. Although not quite at the threshold level, without ramp control, the heavy ramp merging causes the mainline flow to break down, resulting in the bottleneck condition and traffic congestion, as evident in the inset photograph. Past the bottleneck location, free flow conditions are observed.

Exhibit 5-17: Westbound SR-91 at Lincoln Avenue On

<u>Serfas Club Drive On</u>

Exhibit 5-18 is an aerial photograph of the westbound SR-91 mainline at the Serfas Club Drive on-ramp. During the AM peak hours, the volume of traffic from the SR-91 mainline reaches over 7,000 vph in 4 lanes. The Serfas Club Drive on-ramp adds to over 1,200 vph to the existing mainline traffic during the AM peak hours, increasing the mainline traffic to over the threshold level, resulting in a bottleneck condition. Also, at this location, ramp metering operation was not observed during the peak hours of the field site visits. Past the bottleneck location, increasing speeds are observed.

Exhibit 5-18: Westbound SR-91 at Serfas Club Drive On

Green River Road On

Exhibit 5-19 is an aerial photograph of the westbound SR-91 mainline at the Green River Road on-ramp. During the AM peak hours, the downhill merge at the Green River Road on-ramp causes the bottleneck condition to occur. At the Green River Road interchange, is the crest of the grade where traffic flow is slow on the approach. The merge causes the flow to breakdown. Past the curve near the county line, the roadway widens and speeds increase.

Exhibit 5-19: Westbound SR-91 at Green River Road On

HOV Facility

A bottleneck and causality analyses were also conducted for the HOV facility of the SR-91 Corridor. PeMS was primarily used to conduct the HOV analysis. HOV lanes (HOVL) along the SR-91 Corridor operate on a full-time basis separated by a buffer with varying widths. It has a vehicle occupancy requirement of two plus (2+) in both directions.

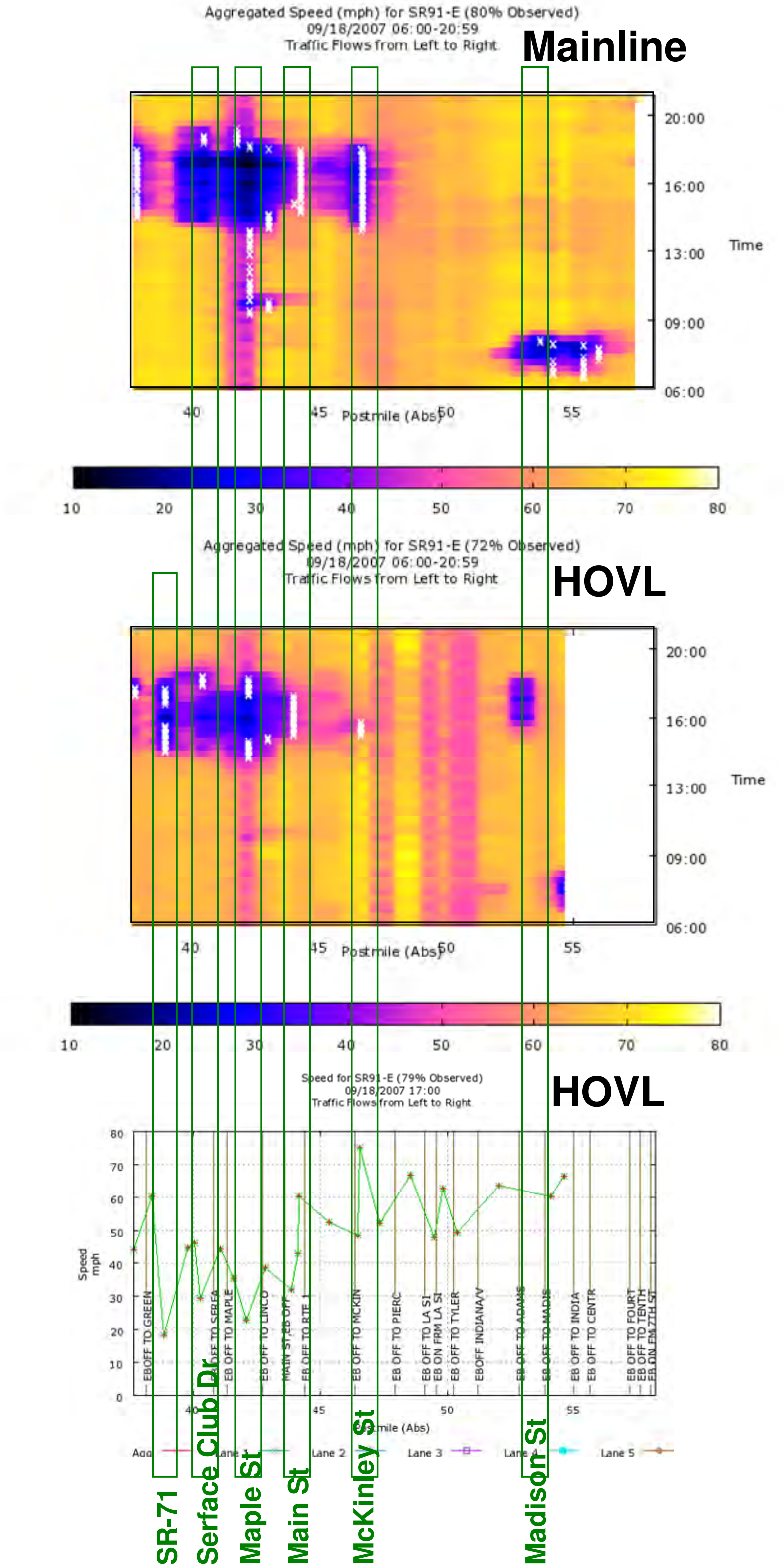
Eastbound HOV Bottlenecks and Causes

In the eastbound direction, six major HOVL bottlenecks were identified based on data analysis, at the following locations:

- West of SR-71 ingress/egress (Caltrans postmile R2.1)
    - This HOVL bottleneck location is at the beginning of the HOVL and just beyond the terminus of the HOT (Express) lane. The cause of this bottleneck is due to the single occupant vehicles (from the HOT lane) trying to exit out before the HOVL in the congested mainline traffic stream.
- Serfas Club (Caltrans postmile R3.5)
- Maple Street (Caltrans postmile 4.2)
    - These bottleneck locations are likely caused by the heavy demand on the HOVL where peak volumes exceed 1,500 vph during the PM peak hours that the facility at these two locations cannot accommodate efficiently. The heavy congestion on the mainline is also likely to impact the flow of the HOVL.
- Main Street ingress/egress (Caltrans postmile 6.5)
    - This bottleneck location is likely caused by the congestion and bottleneck on the mainline, which influences the flow on the HOVL. Also traffic bound for I-15 exiting out of the HOVL into the congested mainline traffic stream slows down impacting the flow of the HOVL.
- McKinley Street (Caltrans postmile 10.0)
    - This bottleneck location is due to the steep uphill grade affecting the flow at the peak where volume reaches 1,500 vph during the PM peak hours.
- Madison Street HOV lane terminus & outside lane drop (Caltrans postmile 16.5)
    - The bottleneck at Madison Street HOV lane terminus point is due to the lane drop on the mainline, where the total traffic demand exceeds the available capacity of the roadway facility with the loss of the outside lane.

Exhibit 5-20 presents the PeMS speed contour diagram of the eastbound SR-91 mainline and HOV lane for weekday in September 2007, indicating the locations of the congestion and bottlenecks. Multiple 2007 and 2008 sample days and monthly averages were reviewed, indicating the same bottleneck locations.

Exhibit 5-20: Eastbound SR-91 ML & HOVL PeMS Speed Contour (Sept 2007)



Westbound HOV Bottlenecks and Causes

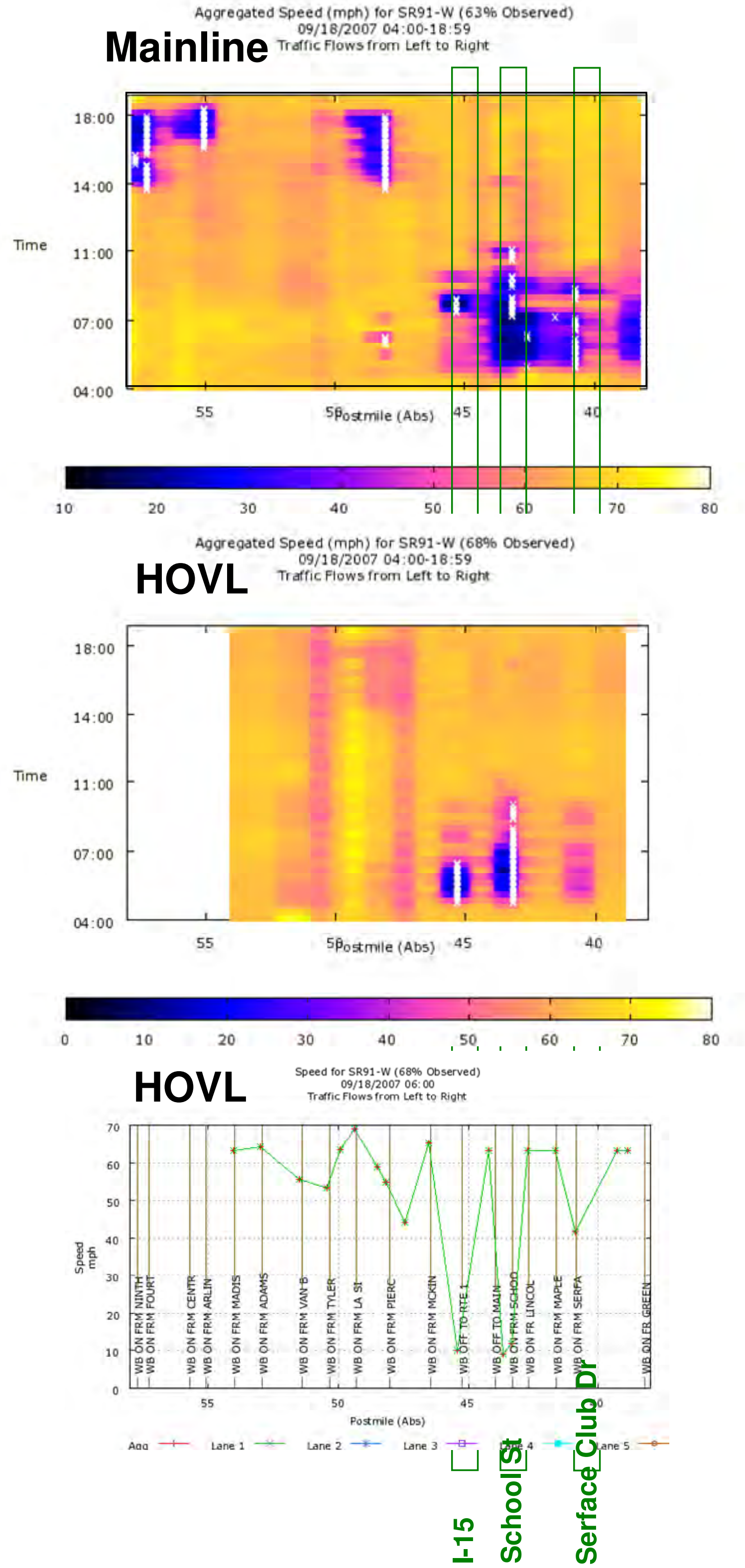
In the westbound direction, three bottlenecks were identified based on data analysis, at the following locations:

- I-15 On (Caltrans postmile 7.5)
- School Street (Caltrans postmile 5.8)
- Serfas Club Drive (Caltrans postmile R3.5)

These bottlenecks are caused by the heavy demand on the HOVL where volumes exceed 1,500 vph during the AM peak hours. The congestion and bottleneck condition on the mainline traffic flow is likely to influence the HOV facility where the slow speeds on the mainline results in slower speeds on the HOVL.

Exhibit 5-21 presents the PeMS speed contour diagram of the westbound SR-91 mainline and HOV lane for weekday in September 2007, indicating the locations of the congestion and bottlenecks. Multiple 2007 and 2008 sample days and monthly averages were reviewed, indicating the same bottleneck locations.

Exhibit 5-21: Westbound SR-91 ML & HOVL PeMS Speed Contour (Sept 2007)



Page Intentionally Left Blank for Future Updates on Bottleneck Causality

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.

4A. BOTTLENECK ANALYSIS

In this section, the results of the bottleneck analysis are presented. The bottleneck analysis was conducted to identify potential bottleneck locations. 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 the following:

- Caltrans District 8 Preliminary Performance Assessment SR-91 Corridor
- Caltrans Highway Congestion Monitoring Program (HICOMP) 2007 report;
- Probe vehicle runs (electronic tachometer runs)
- Freeway Performance Measurement System (PeMS)
- Aerial photos (Google Earth) and Caltrans photologs

District 8 Preliminary Performance Assessment SR-91 Corridor

District 8 staff developed a preliminary corridor assessment that focused on the SR-91 from I-15 in the City of Corona to the SR-91/SR-60/I-215 Interchange in the City of Riverside.

This report identified six potential bottleneck locations, which will more fully examined in the comprehensive analysis to be conducted by the study team. The potential bottleneck locations are summarized in Exhibit 4-1 below.

Exhibit A4-1: District 8 Identified Potential Bottleneck Locations

#	Dir	Period	Bottleneck Location	Bottleneck Area Postmile Range		Potential Causes
				PeMS "Absolute	Caltrans	
1	Westbound	AM	County Line to La Sierra Ave	37.3/49.6	0/12.3	Fwy/Fwy Merge
4		PM	Pierce St to La Sierra Ave	48/49.6	10.7/12.3	Merge Demand
3			Arlington Ave to 60/91/215 IC	55.1/58.9	17.8/21.6	Construction at the IC
2	Eastbound	AM	Central Ave to Van Buren Blvd	55.9/51.6	18.6/14.3	HOV Lane Drop, Nearby Colleges, Auto Mall
5		PM	Magnolia Ave to I-15 IC	48.4/44.4	11.1/7	Fwy/Fwy Merge
6			60/91/215 IC to Van Buren Blvd	58.9/51.6	21.6/14.3	Construction at the IC, HOV Lane Drop at Mary St

HICOMP

In review of the Caltrans 2007 Highway Congestion Monitoring Program (HICOMP) Report, potential problem areas are initially identified. As illustrated in Exhibits 4-2 and

4-3, the downstream end of congested segments could potentially be bottleneck areas in the westbound direction, as outlined in red circles, and in the eastbound direction, as outlined in blue circles.

- As indicated, in the AM peak, there are potentially three major bottlenecks in the westbound direction and one major bottleneck in the eastbound direction, as identified in the 2007 HICOMP:
  - Green River (westbound)
  - Serfas Club Drive (westbound)
  - I-15 (westbound)
  - 14th Street (eastbound)

- As indicated, in the PM peak, there are potentially two major bottlenecks in the westbound direction and four major bottlenecks in the eastbound direction, as identified in the 2007 HICOMP:
  - McKinley Avenue (westbound)
  - Arlington Avenue (westbound)
  - I-15 Avenue (eastbound)
  - Pierce Avenue (eastbound)
  - 14th Street (eastbound)
  - SR-91/SR-60/I-215 Interchange (eastbound)

Further analysis would be needed, however, to determine their 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 A4-2: 2006 HICOMP AM Congestion Map with Potential Bottlenecks

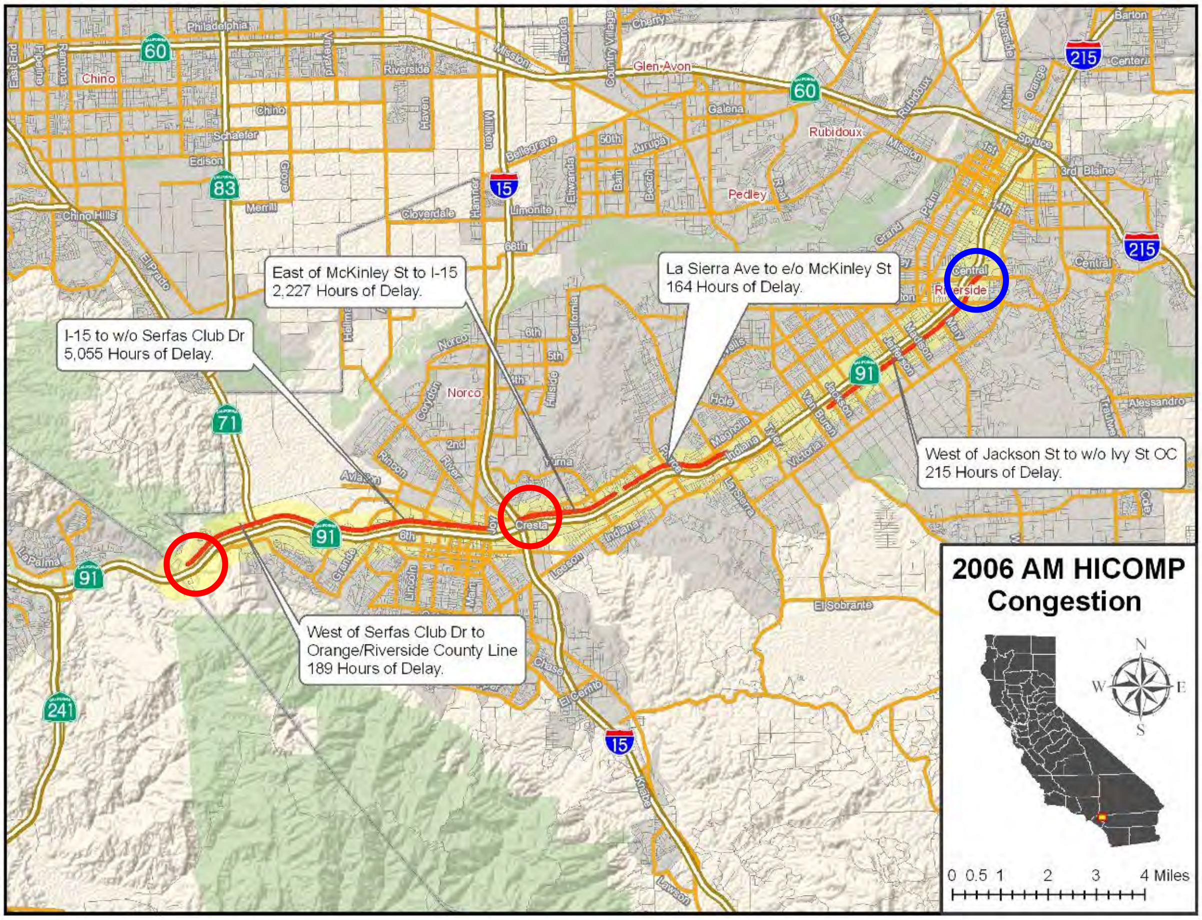
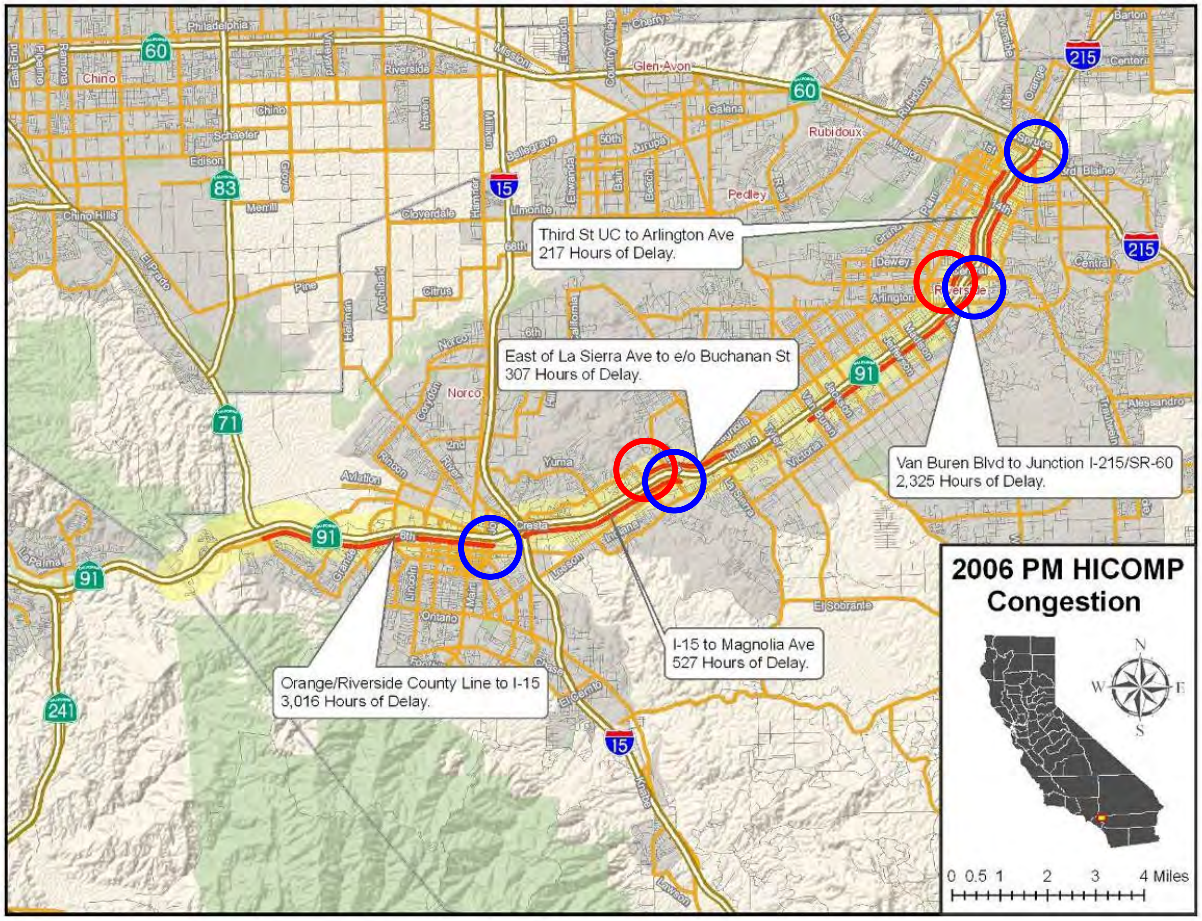


Exhibit A4-3: 2006 HICOMP PM Congestion Map with Potential Bottlenecks

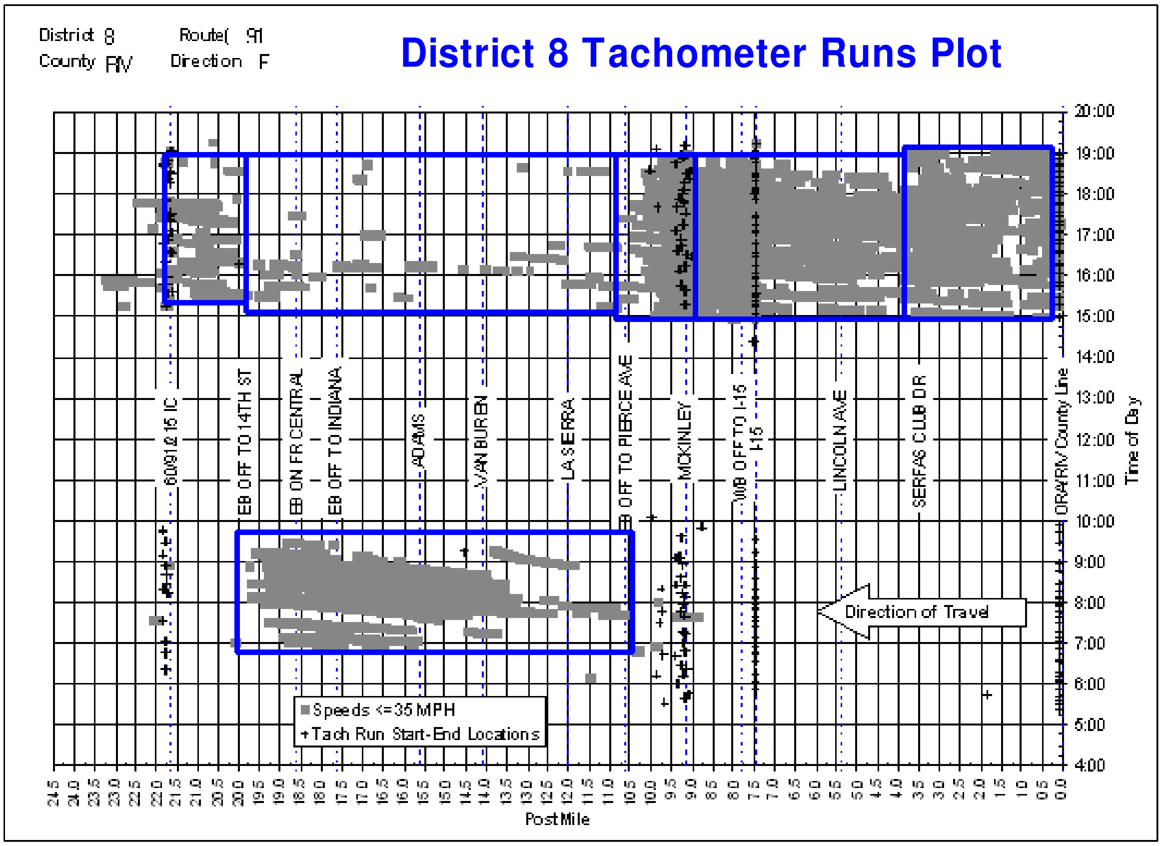


Probe Vehicle Runs

The probe vehicle runs (electronic tachometer runs) provide speed plots across the corridor at various departure times. A vehicle equipped with an electronic (GPS or tachometer) device is driven along the corridor at various departure times, typically in a middle lane, during the peak period, at regular, 15 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.

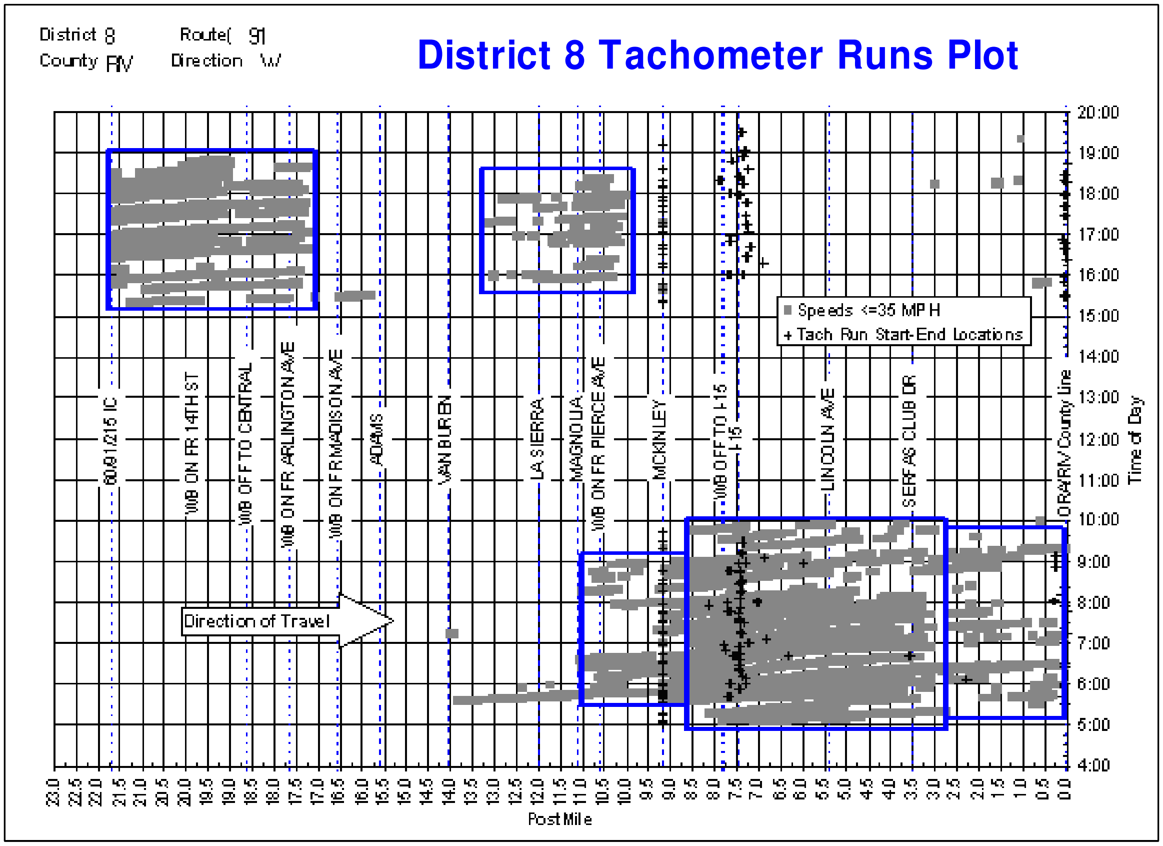
Caltrans District 8 collected probe vehicle run data on multiple mid-week days in both the spring (March and April) and fall (September and November) of 2006 for the SR-91 freeway from the Orange County Line to the 60/91/215 interchange in the City of Riverside. Exhibit 4-4 illustrates the eastbound and Exhibit 4-5 illustrates the westbound probe vehicle runs presented in speed contour diagram from 4AM to 8PM.

Exhibit A4-4: Eastbound SR-91 Probe Vehicle Runs (2006)



- As indicated, the major eastbound bottlenecks from the probe vehicle runs were identified at:
  - Serfas Club Drive (PM)
  - I-15 Off (PM)
  - McKinley (PM)
  - Pierce Avenue Off (PM)
  - 14th Street Off (AM & PM)
  - I-215/SR-60 Off (AM & PM)

Exhibit A4-5: Westbound SR-91 Probe Vehicle Runs (2006)



- As indicated, the major <u>westbound</u> bottlenecks from the probe vehicle runs were identified at:
  - Arlington Avenue On (PM)
  - Pierce Avenue On (PM)
  - I-15 Off (AM)
  - Serfas Club Drive On (AM)
  - Green River/County Line (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

Speed contour and profile plots for sample days in September and April 2007 and 2007 quarterly weekday average long contours were analyzed for the eastbound direction. Exhibits 4-6 to 4-9 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). Along the vertical axis is the time period from 4AM to 8PM. Along the horizontal axis is the corridor segment from the Orange County Line to the SR-91/SR-60/I-215 interchange in the City of Riverside. 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. The horizontal length of each plot is the congested segment, queue lengths. The vertical length is the congested time period. The PeMS eastbound speed contour analysis results indicated reoccurring bottleneck locations across multiple weekdays and quarterly averages.

- As indicated from Exhibits 4-6 to 4-9 the major eastbound bottlenecks identified from the PeMS data plots were identified at:
    - Serfas Club Off (PM)
    - Lincoln Off (AM & PM)
    - Lincoln On (PM)
    - I-15 Off (AM)
    - McKinley On (AM & PM)
    - Pierce Off (AM & PM)
    - Adams Off (AM)
    - Madison On (AM)
    - Arlington On (AM)
    - Central On (AM)
    - I-215/SR-60 Off (AM & PM)

Exhibit A4-6: PeMS Eastbound SR-91 Speed Contour Plots (September 2007)

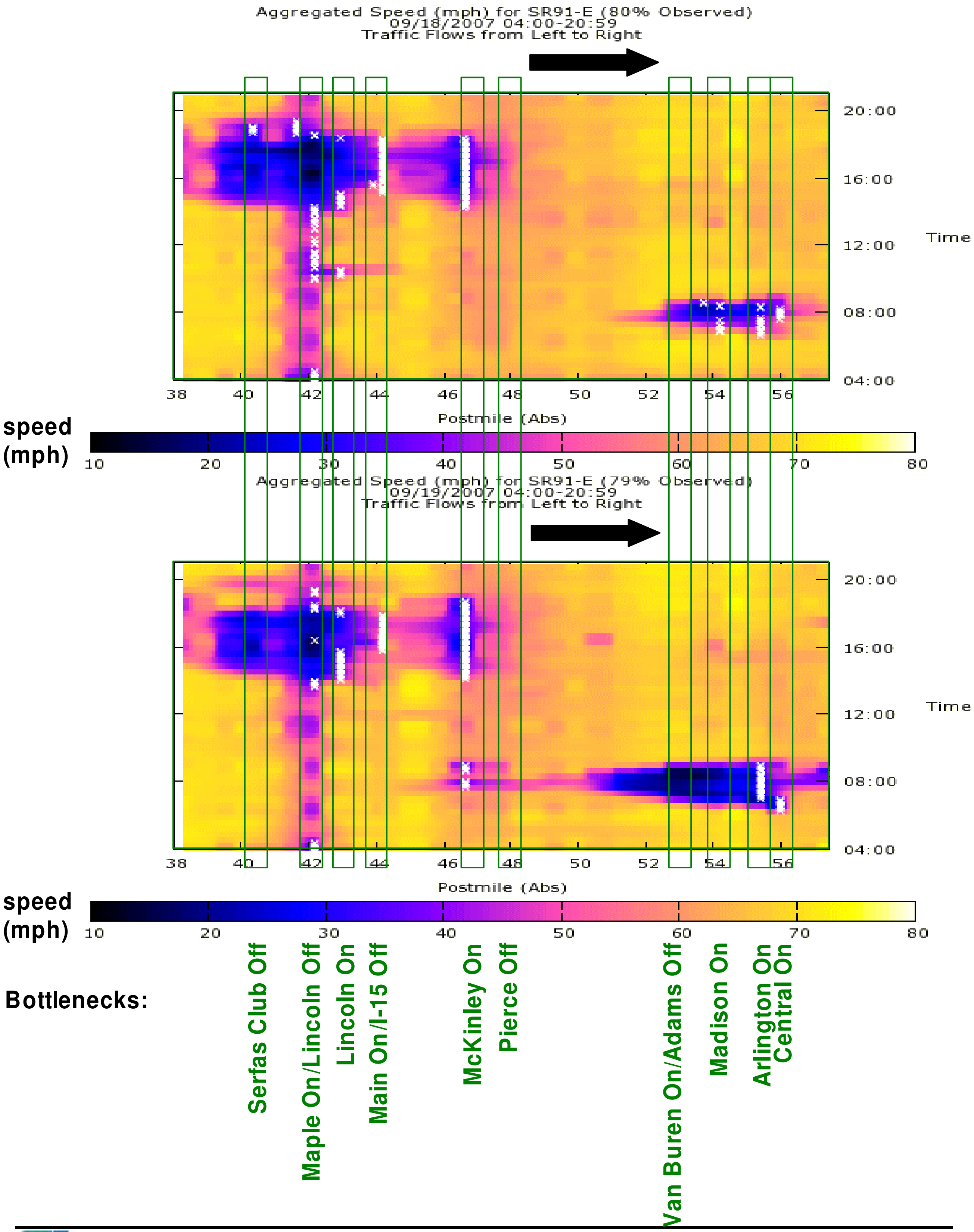


Exhibit A4-7: PeMS Eastbound SR-91 Speed Profile Plots (September 19, 2007)

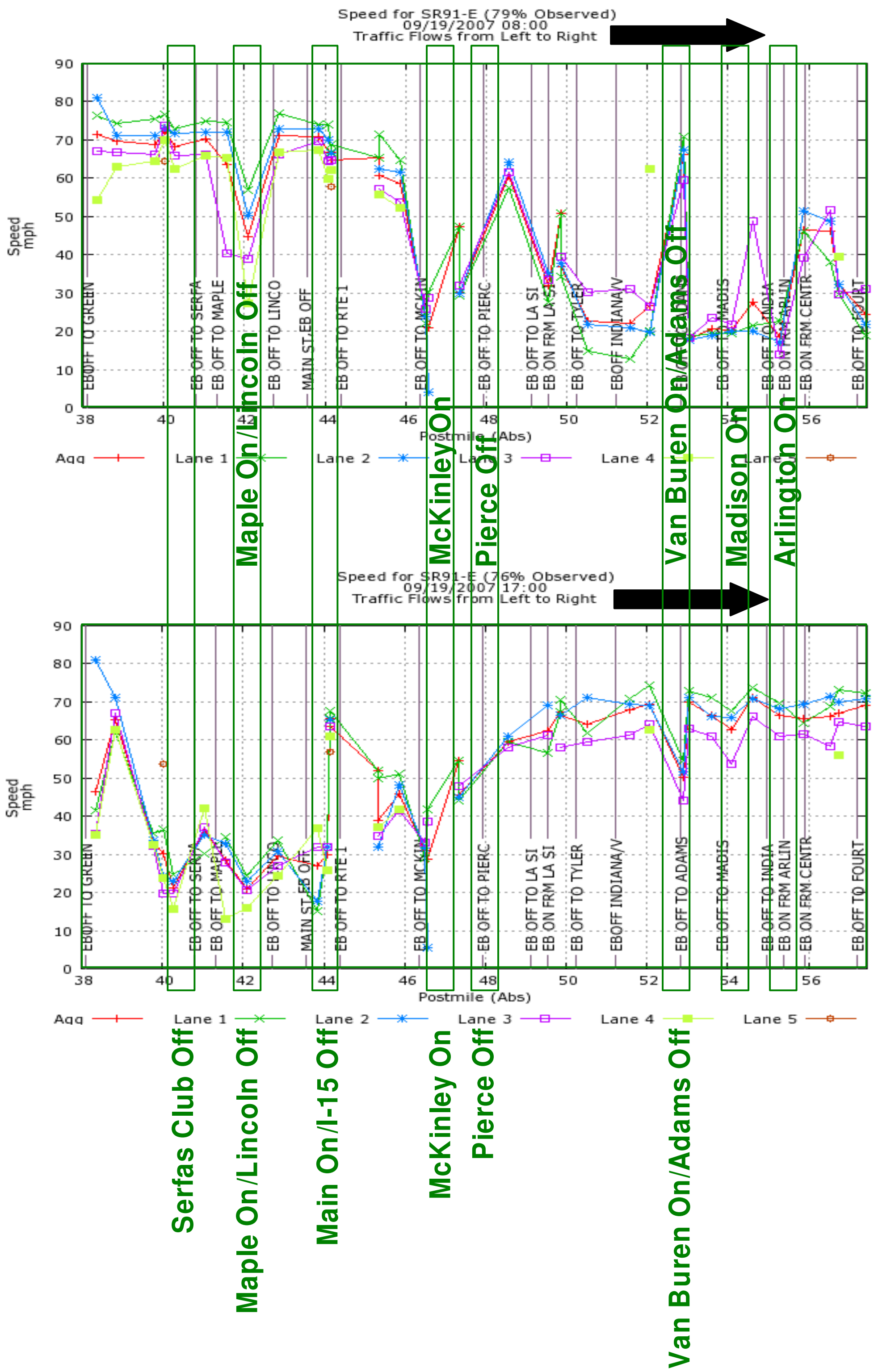


Exhibit A4-8: PeMS Eastbound SR-91 Speed Contour Plots (April 2007)

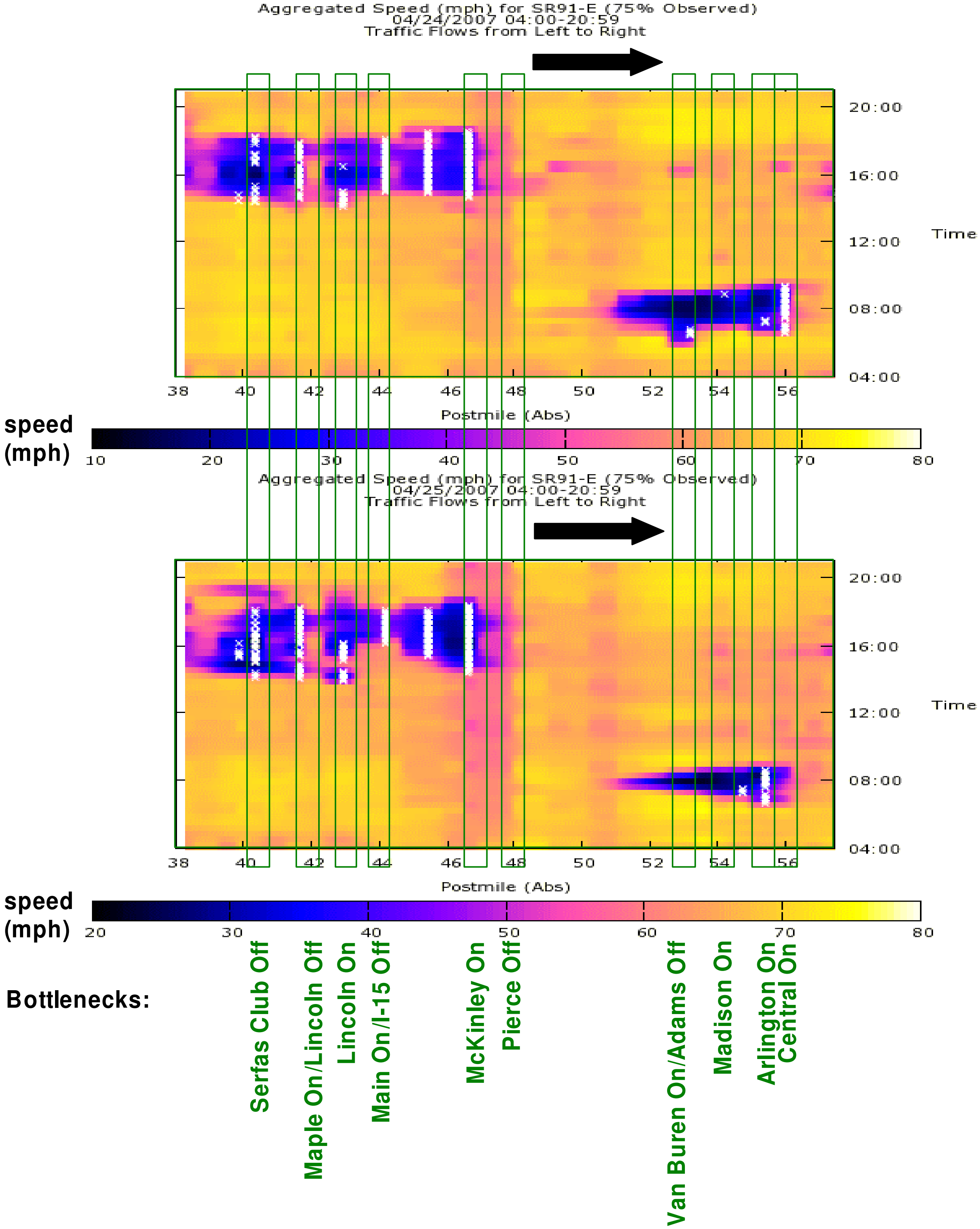
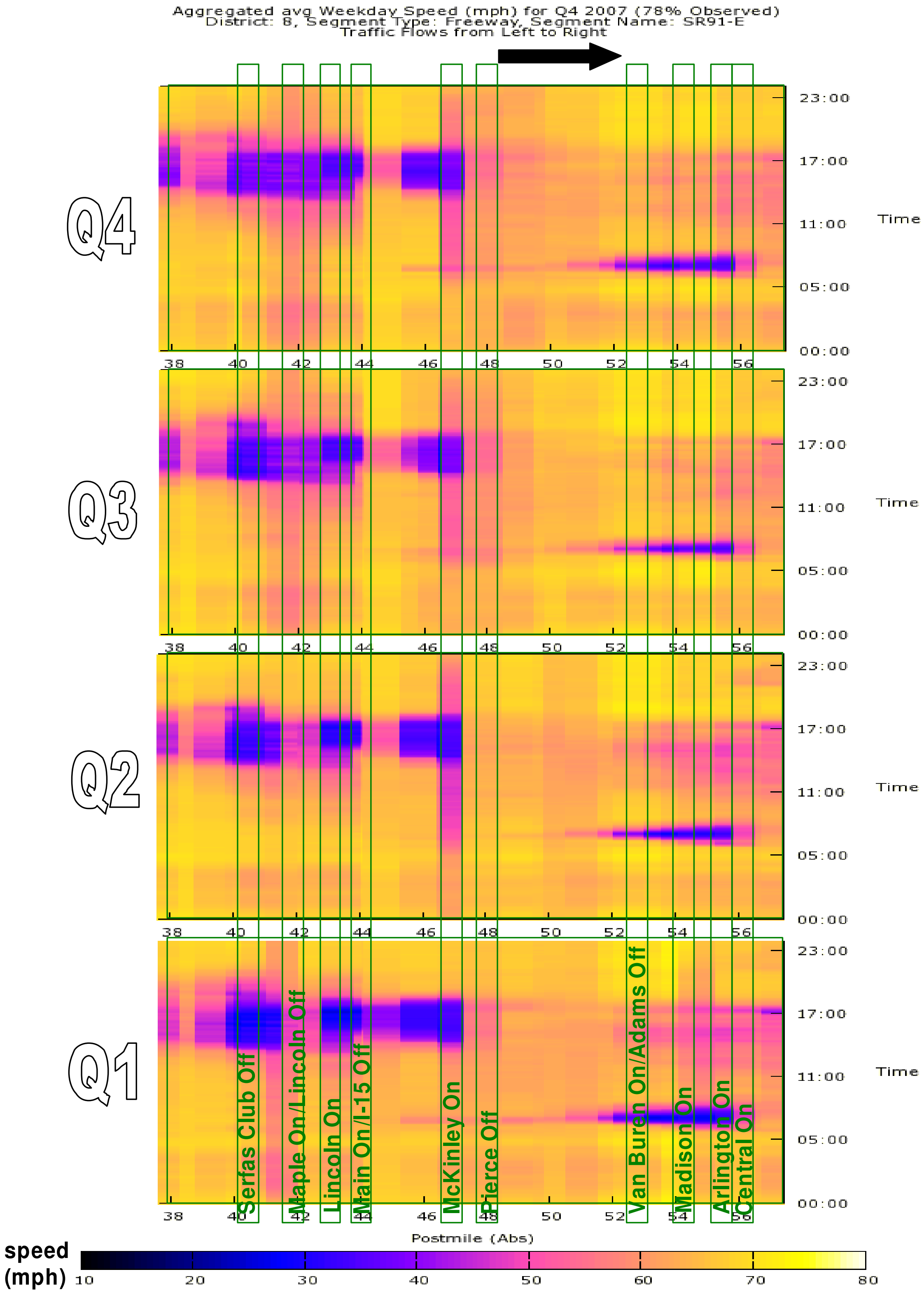


Exhibit A4-9: PeMS Eastbound SR-91 Long (Speed) Contours (2007 Avg by Qtr)



WESTBOUND

Exhibit 4-10 illustrates the speed contour plots on Tuesday, September 18, 2007 and Wednesday, September 19, 2007. The speed contour plots represent a typical weekday sample to illustrate the bottleneck locations and congestion formed from them. 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 the I-215 interchange to the Orange County Line.

Exhibit 4-11 illustrates the speed profile plots on Wednesday, September 19, 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 7AM 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).

In addition to sample days in September 2007, additional sample days were also analyzed. Exhibit 4-12 illustrates the speed contours of additional weekday samples in April 2007. The same bottleneck locations are identified on each of the two different sample days, indicating a reoccurring pattern of the bottleneck locations.

In addition to multiple days, larger averages were also analyzed. Exhibit 4-13 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 A4-10: PeMS Westbound SR-91 Speed Contour Plots (September 2007)

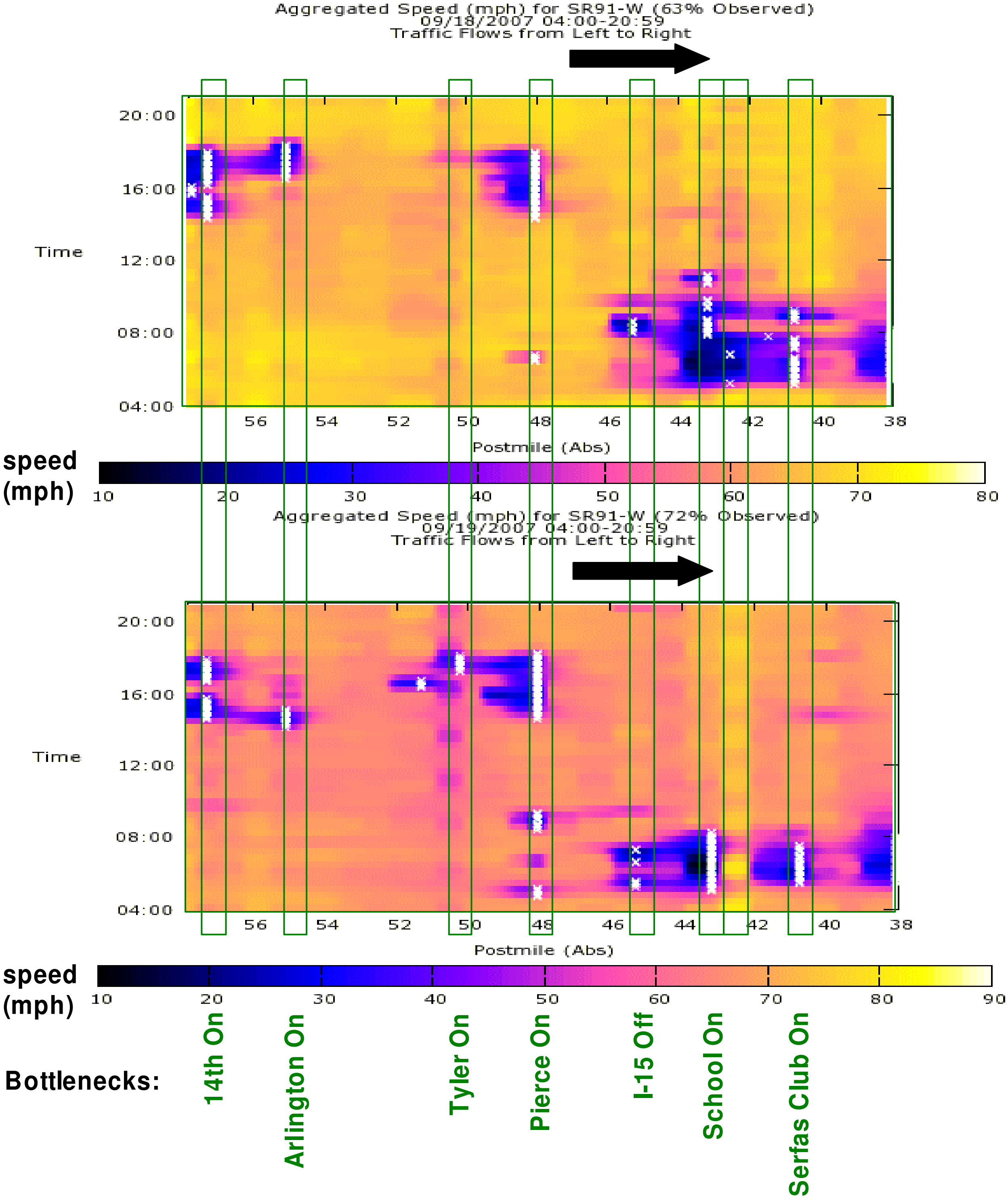


Exhibit A4-11: PeMS Westbound SR-91 Speed Profile Plots (September 19, 2007)

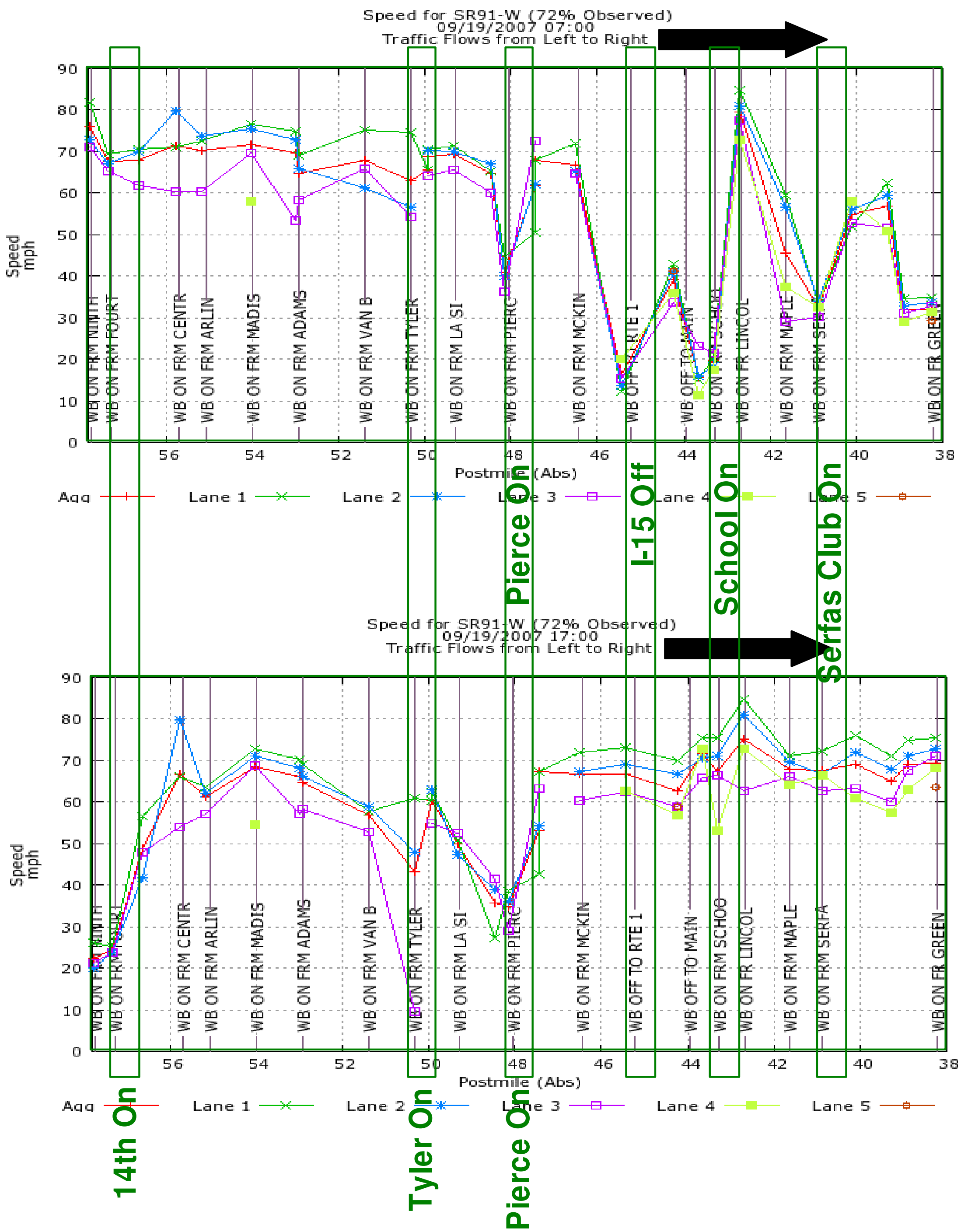


Exhibit A4-12: PeMS Westbound SR-91 Speed Contour Plots (April 2007)

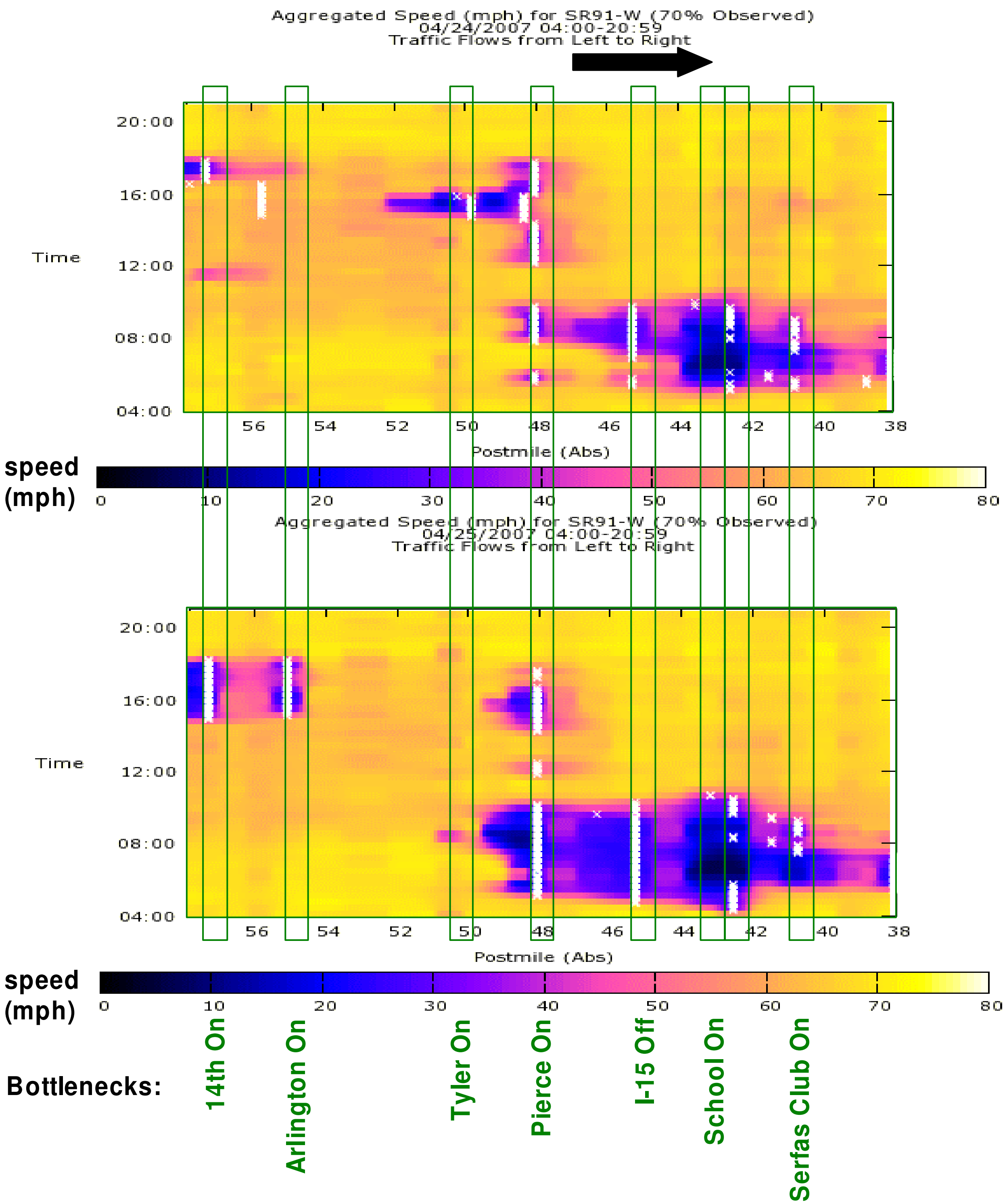
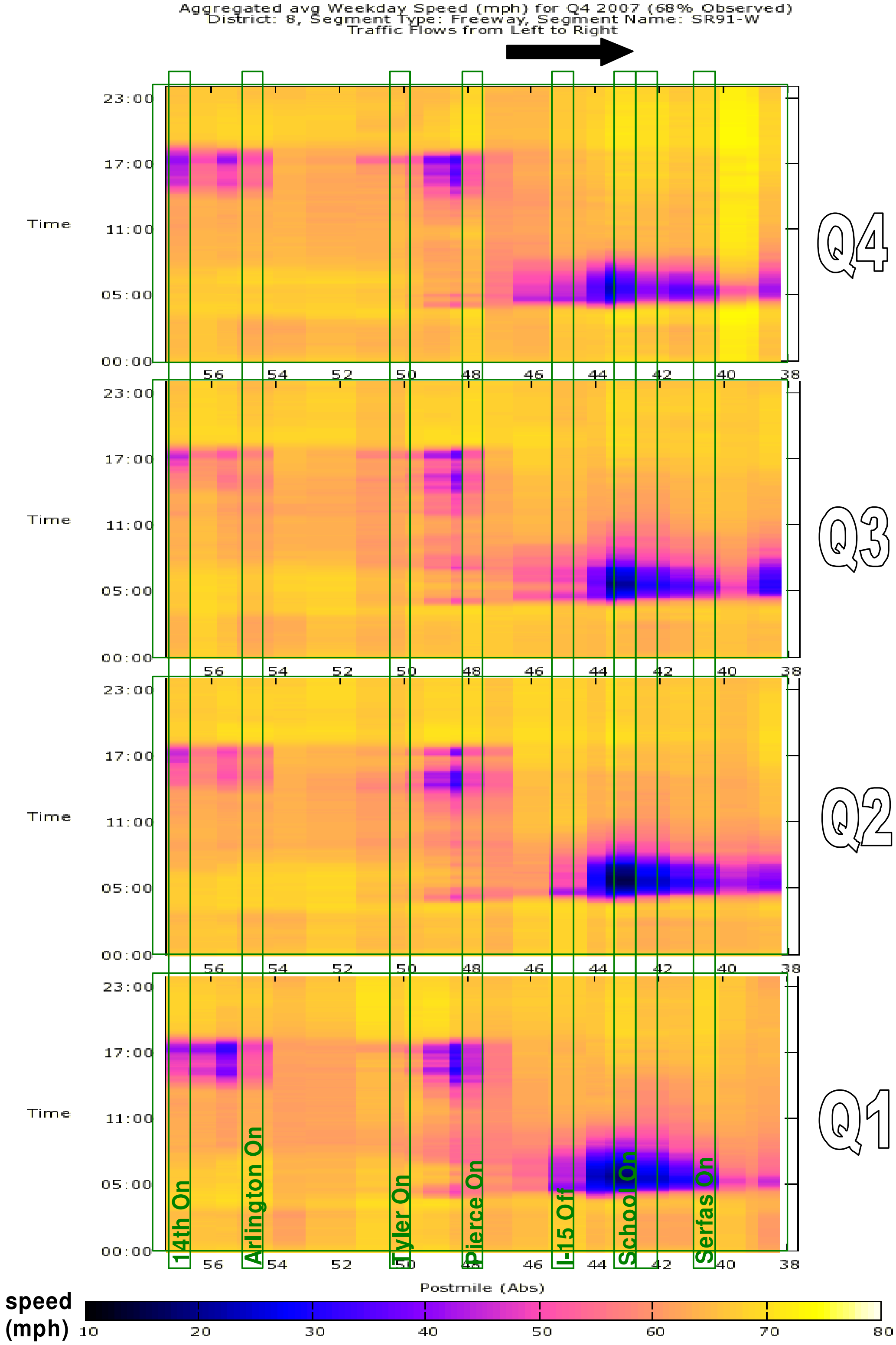


Exhibit A4-13: PeMS Westbound SR-91 Long (Speed) Contours (2007 Avg by Qtr)



- As indicated from Exhibits 4-6 to 4-9, the major westbound bottlenecks identified from the PeMS data plots were identified at:
  - 14th On (PM)
  - Arlington On (PM)
  - Tyler On (PM)
  - Pierce On (AM & PM)
  - I-15 Off (AM)
  - School On (AM)
  - Serfas Club On (AM)
  - Green River/County Line (AM)

Bottleneck Summary

Exhibit 4-14 provides a summary of the potential bottleneck locations based on the various sources: 2006 HICOMP report, the Caltrans District 8 SR-91 Internal Comprehensive Corridor Assessment, Caltrans District 8 probe vehicle runs, and PeMS speed profile and speed contour plots. The rows in bold represent bottlenecks that were identified from multiple sources and are most likely to be major reoccurring bottlenecks.

It should be noted that these locations have not been field-verified. Additional data and/or extensive field reviews will be necessary to confirm their actual locations and identify causes of the bottlenecks.

Exhibit A4-14: Riverside County SR-91 Identified Bottlenecks Summary Table

BOTTLENECK LOCATION	Bottleneck Area Post Mile Range		HICOMP [a] Report		Caltrans [b] Probe Veh. Runs		PeMS [c] Speed Contours	
	ABS	CT	AM	PM	AM	PM	AM	PM
WESTBOUND								
14th on to Central off	57.3/56.0	19.8/18.6	-	-	-	-	-	✓
Arlington on to Madison off	55.1/54.3	17.6/16.8	-	✓	-	✓	-	✓
Tyler on to La Sierra off	50.3/49.6	12.9/12.2	-	-	-	-	-	✓
Pierce on to McKinley off	48.0/47.5	10.6/9.5	-	-	-	✓	✓	✓
McKinley on to I-15 off	47.0/45.2	9.0/7.8	✓	✓	✓	-	✓	-
School on to Lincoln off	43.3/42.8	5.9/5.4	-	-	-	-	✓	-
Serfas Club on to Green River of	40.9/38.5	R3.5/1.1	✓	-	✓	-	✓	-
Green River/County Line	37.3	R0.0	✓	-	✓	✓	✓	-
EASTBOUND								
Green River on to Serfas Club of	38.4/40.8	R1.1/3.6	-	-	-	✓	-	✓
Maple on to Lincoln off	41.6/42.7	4.2/5.4	-	-	-	-	✓	✓
Lincoln on to Vicentia off	42.9/43.1	5.5/5.7	-	-	-	-	-	✓
Main on to I-15 off	43.9/44.4	6.5/7.0	-	✓	-	✓	✓	-
McKinley on to Pierce off	47.0/48.0	9.5/10.6	-	✓	-	✓	✓	✓
Van Buren on to Adams off	51.6/52.8	14.2/15.5	-	-	-	-	✓	-
Madison on to Indiana off	54.1/55.0	16.8/17.6	-	-	-	-	✓	-
Arlington on to Central off	55.4/55.6	18.0/18.3	-	-	-	-	✓	-
Central on to 14th off	55.9/57.2	18.6/19.8	✓	✓	✓	✓	✓	-
La Cadena on to I-215/SR-60 off	58.6/58.9	21.3/21.6	-	✓	✓	✓	✓	✓

Notes:
[a] Based on 2006 HICOMP report
[b] Based on Caltrans District 8 sample probe vehicle runs, taken in 2006
[c] Based on Performance Measurement System (PeMS) sample daily speed contours taken from April and September 2007, and 2007 quarterly
n/a – Data not available
- No indication of bottleneck from this source

This concludes the Appendix of the Comprehensive Performance Assessment. Again, this Appendix is a copy of the Preliminary Performance Assessment, the third milestone of the CSMP process, which used data analyses and initial field observations to preliminarily identify potential bottleneck locations. The Preliminary Performance Assessment is included in the Appendix of this Comprehensive Performance Assessment as a reference to enable readers to follow the entire process of how bottleneck locations were identified. This Comprehensive Performance Assessment builds on the findings of the Preliminary Assessment by providing updated corridor performance data; finalizing a list of bottleneck locations through additional field visits; and most importantly, identifying the causes of each bottleneck location. The final list of bottleneck locations identified for the SR-91 Corridor can be found on page 89.