FINAL

SONOMA US 101 RAMP METERING IMPLEMENTATION PLAN

March 2014

Prepared by:

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March 3, 2014 Project #: 13496

Ms. Linda Lee and Ms. Winnie Chung
Metropolitan Transportation Commission
101 Eighth Street
Oakland, CA 94607

Mr. Alan Chow and Mr. Adrian Levy
Caltrans District 4
Office of Traffic Systems, Mail Station 5F
111 Grand Ave
Oakland, CA 94612

RE: Sonoma US 101 Ramp Metering Implementation Plan (Final)

Dear Ms. Lee, Ms. Chung, Mr. Chow, and Mr. Levy:

Kittelson & Associates, Inc. (KAI) is pleased to submit this Ramp Metering Implementation Plan for US 101 in Sonoma County. This report is Deliverable 4.2B of the project.

We would like to give credit to Jorge Barrios, who developed much of the information described in this report.

Please call me at (510) 433-8082 if you have any questions.

Sincerely,
KITTELSON & ASSOCIATES, INC.

Kevin Chen, PE
Associate Engineer

Mark Bowman, PE
Senior Principal Engineer

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LIST OF EXHIBITS

EXECUTIVE SUMMARY

The Metropolitan Transportation Commission (MTC) is working with the California Department of Transportation (Caltrans) and the Sonoma County Transportation Authority (SCTA) to implement a ramp metering strategy for US 101 in Sonoma County. A technical committee comprised of representatives from local agencies was organized to provide insight and feedback to the study team as the ramp metering plan is developed. The local agencies include:

- SCTA
- City of Cotati
- City of Petaluma
- City of Rohnert Park
- City of Santa Rosa
- Town of Windsor
- Sonoma County
- Sonoma-Marin Area Rail Transit (SMART)

A ramp metering study was initiated in April 2013 to support the development of a ramp metering implementation plan for US 101 by:

1. Coordinating with the local agencies to develop a plan for evaluating the effects of ramp metering on arterial streets.
2. Collecting and compiling data for use in the development of a ramp metering plan for US 101 in both the northbound and southbound directions.
3. Preparing a report to document the comparison of before and after ramp metering conditions on freeway mainline, ramps, and arterial streets.

The recommended metering plan is summarized as follows:

- All on-ramps within the study corridor, including freeway connectors from SR 12, will be metered. The study corridor includes freeway sections between the Gravenstein Highway interchange and Shiloh Road interchange in the northbound direction, and between the Arata Lane interchange and the Pepper Road interchange in the southbound direction.
- During the AM peak period, ramp meters will be operational between 6:00 and 10:00 AM for both the northbound and southbound directions.
- During the PM peak period, ramp meters will be operational between 3:00 and 7:00 PM for both the northbound and southbound directions.

The recommended metering rates were developed through an iterative process, optimally balancing ramp delays and queues, as well as mainline travel time savings.

All on-ramp queues would be contained within available storage except for the SR 12 eastbound to US 101 northbound connector during the PM peak period between 5:15 and 6:00 PM. Queues may exceed storage by about 26 vehicles. These 26 vehicles would be queued between the diverge point from eastbound SR 12 and the northbound/southbound US 101 split, where there is additional storage for about 29 vehicles. Therefore, the end of queue would not extend far enough to block eastbound SR 12 mainline operations

It is recommended that Caltrans closely monitor queues at this location during the initial two weeks of ramp meter activation. If excessive queues continue to occur after that, an alternative ramp metering strategy is recommended to avoid queuing beyond available storage.

With the implementation of the recommended ramp metering plan, freeway travel times would be reduced during the peak period, by approximately 1–4 minutes, depending on the direction of travel and the time period. Congested speeds, caused by freeway bottlenecks, would be improved, and freeway queue lengths would generally be reduced. This is primarily attributed to increased freeway bottleneck throughputs due to ramp metering.

In terms of system performance measures, overall vehicle-hours of travel would be reduced 1 to 10 percent, while average travel speeds on the mainline are expected to improve 5 to 17 percent.

INTRODUCTION

The Metropolitan Transportation Commission (MTC) is working with the California Department of Transportation (Caltrans) and the Sonoma County Transportation Authority (SCTA) to implement a ramp metering strategy for US 101 in Sonoma County. A technical committee comprised of representatives from local agencies was organized to provide insight and feedback to the study team as the ramp metering plan is developed. The local agencies include:

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3. Preparing a report to document the comparison of before and after ramp metering conditions on freeway mainline, ramps, and arterial streets.

STUDY PROGRESS

A series of deliverables have been completed for this ramp metering implementation plan. Below is a summary of deliverables to date:

- Deliverable 2.5 - Existing Conditions Memo (Final was submitted on 11/21/2013)
- Deliverable 3.1 - FREQ Calibration (Final was submitted on 1/8/2014; also incorporated in this report)
- Deliverable 4.1 - Metering Rates (Final was submitted on 2/18/2014; also incorporated in this report)
- Deliverable 4.2 - Ramp Metering Implementation Report (current report)

The next phase of this study will be to finalize the metering plan, monitor traffic conditions following ramp meter activation, and conduct an “after” study of the effects of ramp metering.

STUDY AREA

US 101 is a freeway facility that serves the local and regional travel needs to and through Sonoma County. The US 101 corridor supports several travel markets including daily commuter trips, local freight and goods movements, recreational trips, regional trips, and intercity/local travel. It is a major north-south freeway that serves various cities located along the corridor such as Petaluma, Cotati, Rohnert Park, Santa Rosa, and the Town of Windsor. US 101 is the major interregional connector linking the San Francisco Bay Area to the northern California coast.

The study area includes the following freeway sections (shown in Exhibit 1):

- US 101 Northbound: south of the Gravenstein Highway (SR 116) interchange to north of the Shiloh Road interchange, PM 12.868 to PM 27.649 (approximately 15 miles)
- US 101 Southbound: north of the Arata Lane interchange to south of the Pepper Road interchange, PM 30.5 to PM 8.871 (approximately 22 miles)

Exhibit 2 lists the interchange on-ramps and connectors that are included in this ramp metering implementation plan.

Exhibit 1: Study Limits

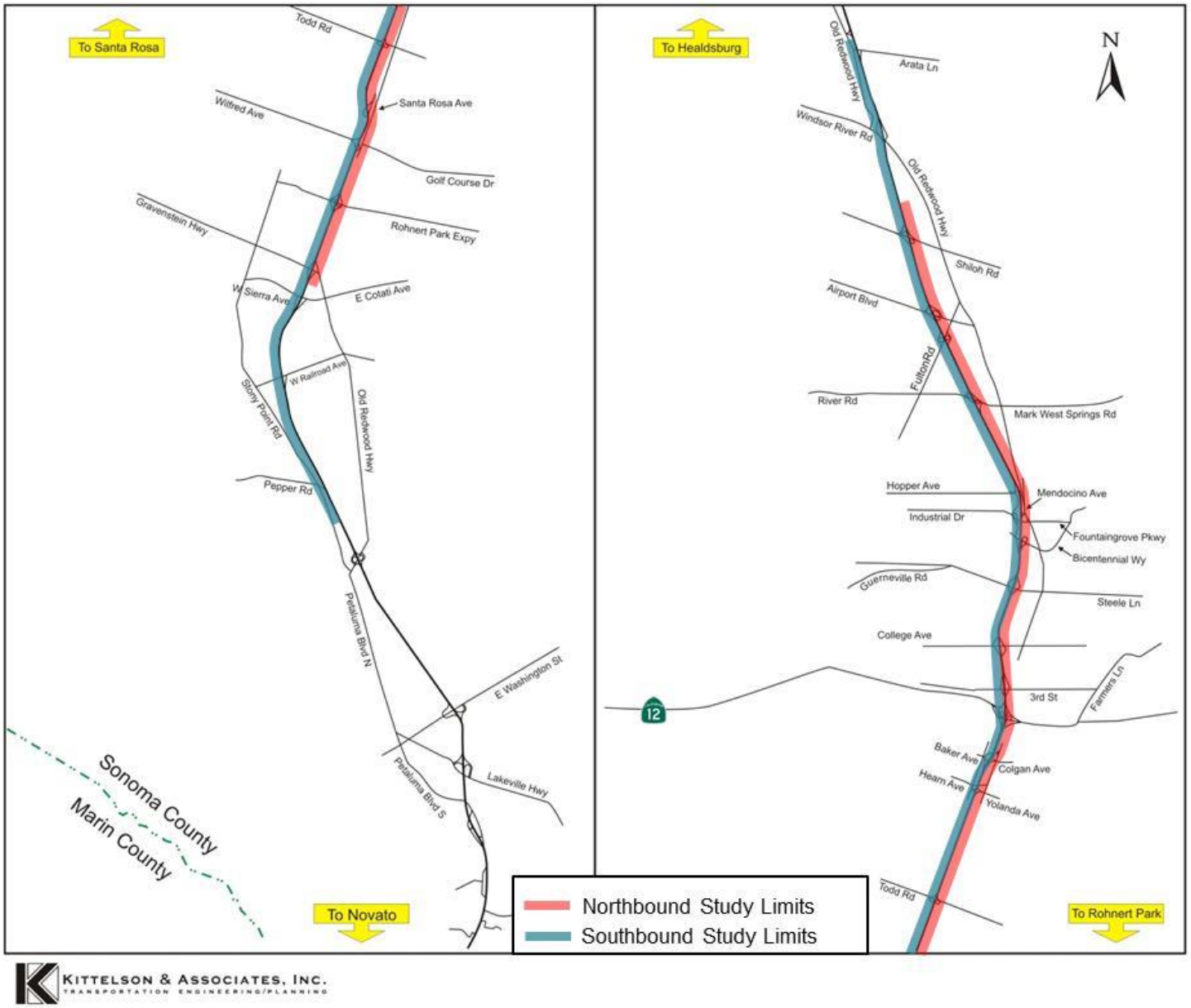

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Exhibit 2: List of On-ramps and Connectors Along US 101

US 101 Southbound	US 101 Northbound
Arata Lane/ Old Redwood Highway on-ramp	Gravenstein Highway (SR 116) on-ramp
Old Redwood Highway/ Windsor River Road on-ramp	Rohnert Park Expressway EB on-ramp
Shiloh Road WB on-ramp	Rohnert Park Expressway WB on-ramp
Shiloh Road EB on-ramp	Golf Course Drive/Wilfred Avenue on-ramp
Airport Boulevard on-ramp (under construction)	Todd Road on-ramp
Fulton Road on-ramp (under construction)	Yolanda Avenue/Hearn Avenue on-ramp
River Road WB on-ramp	Baker Avenue on-ramp
River Road EB on-ramp	SR 12 EB connector
Hopper Avenue on-ramp	SR 12 WB connector
Mendocino Avenue on-ramp	Downtown/6th Street on-ramp
Bicentennial Way on-ramp	College Avenue on-ramp
Steele Lane/Guerneville Road on-ramp	Steele Lane/Guerneville Road on-ramp
College Avenue on-ramp	Mendocino Avenue on-ramp
Downtown/3rd Street on-ramp	River Road EB on-ramp
SR 12 WB connector	River Road WB on-ramp
SR 12 EB connector	Fulton Road on-ramp (under construction)
Baker Avenue/Colgan Avenue on-ramp	Airport Boulevard on-ramp (under construction)
Hearn Avenue/Yolanda Avenue on-ramp	Shiloh Road EB on-ramp
Todd Road on-ramp	Shiloh Road WB on-ramp
Golf Course Drive/Wilfred Avenue on-ramp	
Rohnert Park Expressway WB on-ramp	
Rohnert Park Expressway EB on-ramp	
Gravenstein Highway (SR 116) on-ramp	
Sierra Avenue on-ramp	
Pepper Road on-ramp	

STUDY APPROACH

This chapter provides a summary of the traffic operations analysis methodologies that were applied to develop the ramp metering plans presented in this report.

Existing freeway data were collected by Caltrans and the consulting team during the period from Tuesday, April 30 to Sunday, May 19, 2013, during good weather conditions. The following data were collected:

- Mainline and ramp traffic volumes (from Caltrans in-pavement vehicle detectors and machine tube counters)
- Consultant's GPS floating car travel time surveys
- Incident logs from 511.org and California Highway Patrol (CHP) websites
- Consultant's field observations (on-ramp queues and mainline conditions)

A decision was initially made by the Ramp Metering Technical Committee (RMTC) that ramp metering should be considered on US 101 for the weekday AM and PM peak commute periods in both directions of travel and for southbound travel on Sunday afternoons, when weekend traffic returns to the Bay Area. After evaluation of the traffic data and field observations, it was determined that ramp metering would not result in significant operational benefits in the southbound direction during Sunday afternoons, as there was no recurring congestion observed. Therefore, no metering plan was developed for the Sunday afternoon peak period.

A determination was made that the set of data collected at the times shown in Exhibit 3 best reflected typical conditions along the corridor, excluding incident effects.

The FREQ macroscopic simulation software was used to develop ramp metering rates for the corridor. Performance measures for the freeway corridor are reported based on simulated constraints and throughput results, such as travel times, congested speeds, vehicle hours of travel, vehicle miles of travel, etc., which are further discussed in the Freeway Traffic Operations with Ramp Metering section.

Exhibit 3: Traffic Data Used to Develop Ramp Metering Plan

Date	Northbound		Southbound	
	AM Peak Period	PM Peak Period	AM Peak Period	PM Peak Period
Tuesday, April 30, 2013	Yes	Yes	Yes	No
Wednesday, May 1, 2013	Yes	Yes	Yes	Yes
Thursday, May 2, 2013	Yes	No	Yes (before 7:30 AM)	No
Friday, May 3, 2013	n/a	Yes	n/a	n/a
Friday, May 10, 2013	n/a	Yes	n/a	n/a
Sunday, May 5, 2013	n/a	n/a	n/a	Yes
Sunday, May 19, 2013	n/a	n/a	n/a	Yes

n/a = not applicable; time period not studied.

Inputs to the FREQ model included traffic volumes, geometries, capacities, percent trucks and profile grades. Freeway capacities for the FREQ calibration were set based on traffic counts through freeway subsections operating at capacity (bottleneck subsections). Peak 15-minute capacities were developed throughout the corridor, and average peak hour capacities were applied where appropriate to better calibrate the model to reflect actual lengths and duration of queues. Auxiliary lane capacities were generally set based on the lower of the maximum traffic volumes from the upstream on-ramp and downstream off-ramp for each subsection.

An iterative process of evaluation was conducted to optimally balance ramp delays and queues, as well as mainline travel time savings. The goal of developing a ramp metering plan was to improve traffic operations on the freeway with containment of vehicle queues on the freeway on-ramps. Consideration was also given to keeping the on-ramp metering delays within the limits the general public is accustomed to in San Francisco Bay Area (generally 2.5 minutes or less).

The number of meter rates produced by FREQ exceeded the number that can be accommodated by the ramp meter field equipment. To address that limitation, the number of meter rates was constrained to a maximum of six (6) meter rates for each on-ramp. The effects of the constrained ramp meter rate plan were modeled in FREQ to evaluate the effects of the final recommended metering rates and the performance of the transportation system under that plan was evaluated.

EXISTING CONDITIONS

This section describes existing traffic operations along US 101. High Occupancy Vehicle (HOV) lanes have been constructed on US 101 from Old Redwood Highway in Petaluma to Windsor River Road in Windsor. Additional freeway improvements are planned or in construction at several interchanges along the study corridor (including Old Redwood Highway, Hearn Avenue, Airport Boulevard/Fulton Road). The HOV lanes are restricted to HOV use from 7:00 to 9:00 AM and from 3:00 to 6:30 PM, Monday through Friday.

FREEWAY MAINLINE TRAFFIC VOLUMES

Caltrans provided mainline traffic volumes collected by permanent vehicle detectors in 15-minute time intervals. Traffic volumes on US 101 were highest in downtown Santa Rosa where northbound traffic volumes peak at approximately 4,600 to 4,700 vehicles during the typical weekday AM and PM peak hours. Friday traffic volumes peak slightly higher at approximately 5,100 vehicles per hour. This northbound section includes two mixed flow lanes and one HOV lane.

Southbound traffic volumes in downtown Santa Rosa peak at approximately 4,800 vehicles during the AM peak hour and at approximately 5,300 vehicles during the PM peak hour. Southbound Sunday traffic peaks at approximately 4,900 vehicles per hour. In this southbound section, the freeway mainline has two mixed flow lanes, one HOV lane and one auxiliary lane, which adequately serve existing traffic demand.

HOV LANE UTILIZATION

The HOV percentage for the corridor was based on several sources, including the Caltrans District 4 Year 2011 Annual HOV Lane Report, recently collected detector counts, and the PeMS database. HOV lanes carried approximately 16 percent of the total traffic volume on US 101 during the AM peak period in both directions of travel and northbound during the PM peak period. The southbound HOV lane carried approximately 21 percent of the total freeway traffic volume during the PM peak period.

FREEWAY TRAFFIC OPERATIONS

A summary of traffic bottleneck locations and queues is provided in Exhibit 4 and is illustrated in Exhibit 5. The following bottlenecks and queues were observed on US 101 northbound:

A. **Between the SR 12 on-ramp and the College Avenue off-ramp:** During the AM peak period, queues from this bottleneck often extend through the upstream bottleneck location, described below, to beyond the Golf Course Drive off-ramp. During the PM peak period, queues sporadically extend to the upstream bottleneck, described below. Note that there are two consecutive on-ramps within this section (on-ramps from SR 12 and from Sixth Street), while the bottleneck typically occurs at the SR 12 on-ramp, it occasionally shifts to the Sixth Street on-ramp.

B. **Between the Yolanda Avenue on-ramp and the Baker Avenue off-ramp:** During the AM peak period, this bottleneck often becomes embedded in queues from the downstream bottleneck, discussed above, and sporadic congestion occurs from the bottleneck to Golf Course Drive. During the PM peak period, queues from this bottleneck extend past Todd Road.

On US 101 southbound, the following bottlenecks were observed:

C. **Between the Hearn Avenue on-ramp and the Todd Road off-ramp:** During the AM peak period, queues from this bottleneck sporadically extend as far as Hearn Avenue. No bottleneck was identified at this location during the PM peak period.

D. **Between the SR 12 on-ramp and the Baker Avenue off-ramp:** During the AM peak period, queues from this bottleneck extend north, beyond the Downtown off-ramp. During the PM peak period, queues from this bottleneck extend through the upstream bottleneck, described below, to beyond Hopper Avenue.

E. **Between the College Avenue on-ramp and the Downtown off-ramp:** No bottleneck was identified at this location during the AM peak period. During the PM peak period, this bottleneck becomes embedded in queues from the downstream bottleneck, discussed above.

F. **Between the Guerneville Road off-ramp and the Guerneville Road on-ramp:** During the AM peak period, queues from this bottleneck sporadically extend through the upstream bottleneck, described below, to beyond River Road. Further evaluations of the actual floating car data shows congestion in this area is intermittent, and would be more appropriate to be described as sporadic slow-down, rather than solid queues. No bottleneck was identified at this location during the PM peak period.

G. **Between the River Road on-ramp and the Hopper Avenue off-ramp:** During the AM peak period, this bottleneck is sporadic and sometimes becomes embedded in queues from the downstream bottleneck, discussed above. Further evaluations of the actual floating car data shows congestion in this area is intermittent, and is limited to between the two on-ramps from River Road and occasionally between the River Road off-ramp and on-ramp. No bottleneck was identified at this location during the PM peak period.

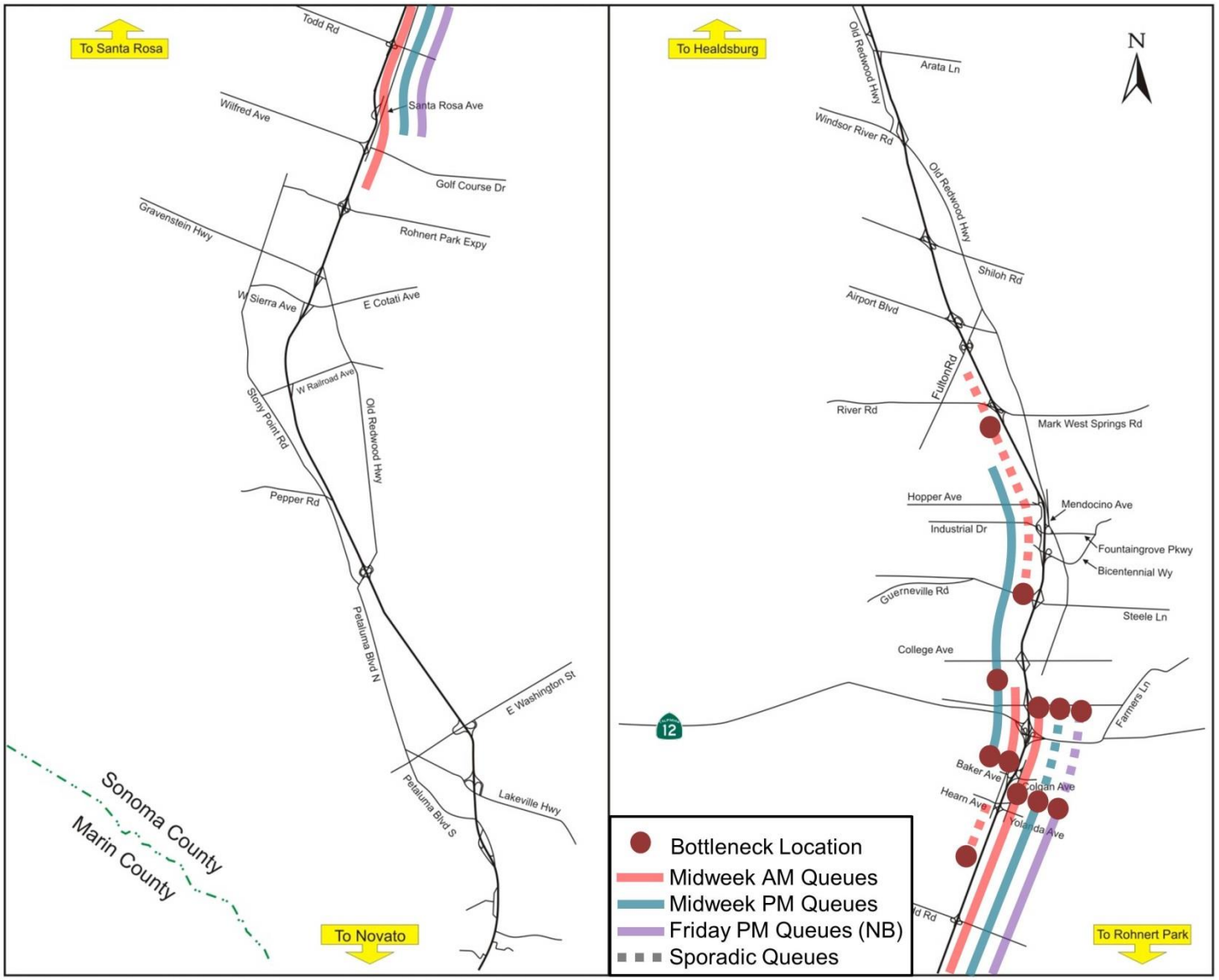
In November 2013, Phase I of the Graton Casino was opened in Rohnert Park. The casino project consists of a 314,368 square foot facility comprising casino, entertainment, restaurants, back of house, and other ancillary functions[1]. The casino is located on the west side of US 101 between the Golf Course Drive and Rohnert Park Expressway interchanges. While existing conditions data were collected and documented prior to the opening of the casino, it is suggested that Caltrans continue to monitor potential changes to traffic conditions on US 101 in the vicinity of the casino, for both weekday and weekend conditions.

[1] Kimley-Horn and Associates, Inc., January, 2013.

Exhibit 4: Summary of Weekday Freeway Bottleneck Locations and Queues

Direction and Location	AM Peak Period		PM Peak Period	
	Bottleneck	Queue	Bottleneck	Queue
Northbound				
Between SR 12 on-ramp and College Avenue off-ramp	✓	South beyond the Golf Course Drive off-ramp	✓	Sporadic to upstream bottleneck
Between Yolanda Avenue on-ramp and Baker Avenue off-ramp	✓	Embedded in downstream queue	✓	South past Todd Road
Southbound				
Between Hearn Avenue on-ramp and Todd Road off-ramp	✓	Sporadic to Hearn Avenue off-ramp		
Between SR 12 on-ramp and Corby Avenue off-ramp	✓	North beyond the Downtown off-ramp	✓	North beyond Hopper Avenue
Between College Avenue on-ramp and Downtown off-ramp			✓	Embedded in downstream queue
Between Guerneville Road off-ramp and Guerneville Road on-ramp	✓	Sporadic beyond River Road		
Between River Road on-ramp and Hopper Avenue off-ramp	✓	Embedded in downstream queue		

Exhibit 5: Existing Freeway Bottleneck Locations and Queues



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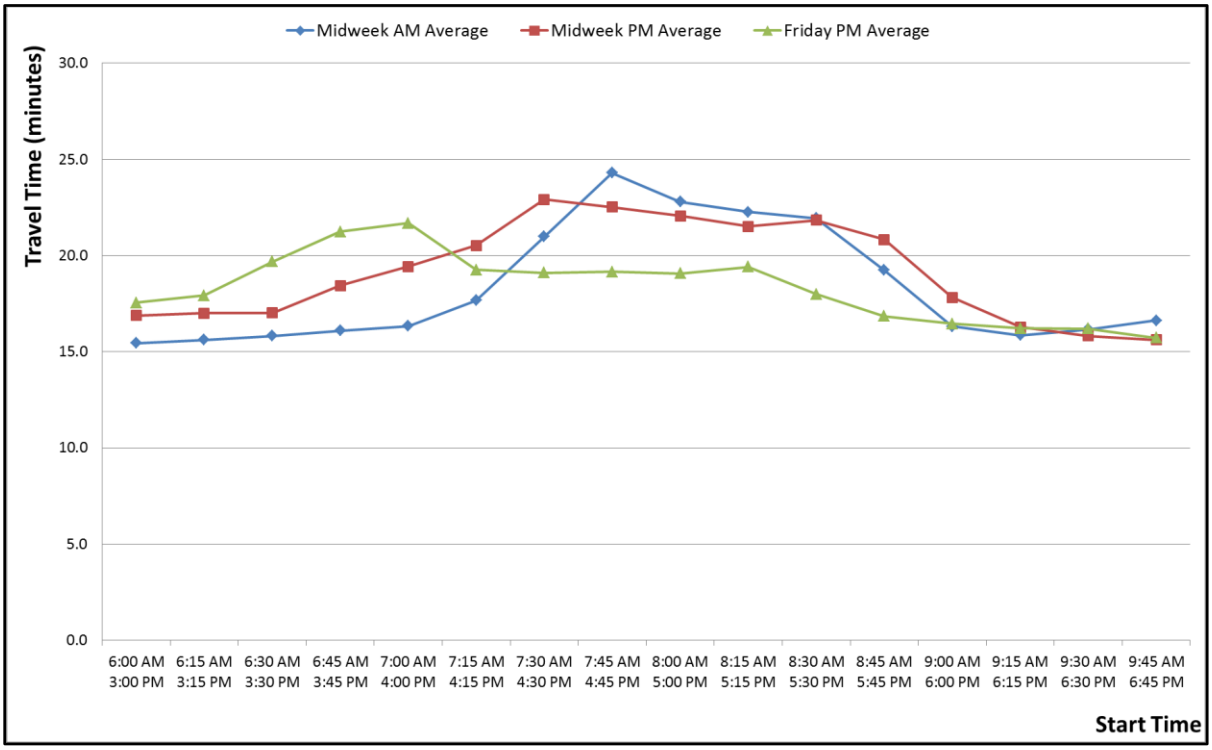
EXISTING FREEWAY TRAVEL TIMES

Floating car surveys were conducted using GPS-equipped vehicles at approximately 15-minute headways. Free flow travel times on US 101 are approximately 16 minutes in the northbound direction, and approximately 21 minutes in the southbound direction. With recurring congestion, the approximate maximum travel times are:

- Northbound:
  - Midweek AM Peak - 21 to 24 minutes at approximately 7:30 to 8:30 AM
  - Midweek PM Peak - 21 to 23 minutes at approximately 4:15 to 6:00 PM
  - Friday PM Peak - 20 to 22 minutes at approximately 3:30 to 4:15 PM
- Southbound:
  - Midweek AM Peak - 25 to 27 minutes at approximately 7:45 to 8:45 AM
  - Midweek PM Peak - 26 to 29 minutes at approximately 3:30 to 5:30 PM
  - Sunday PM Peak - 21 to 22 minutes throughout the survey period

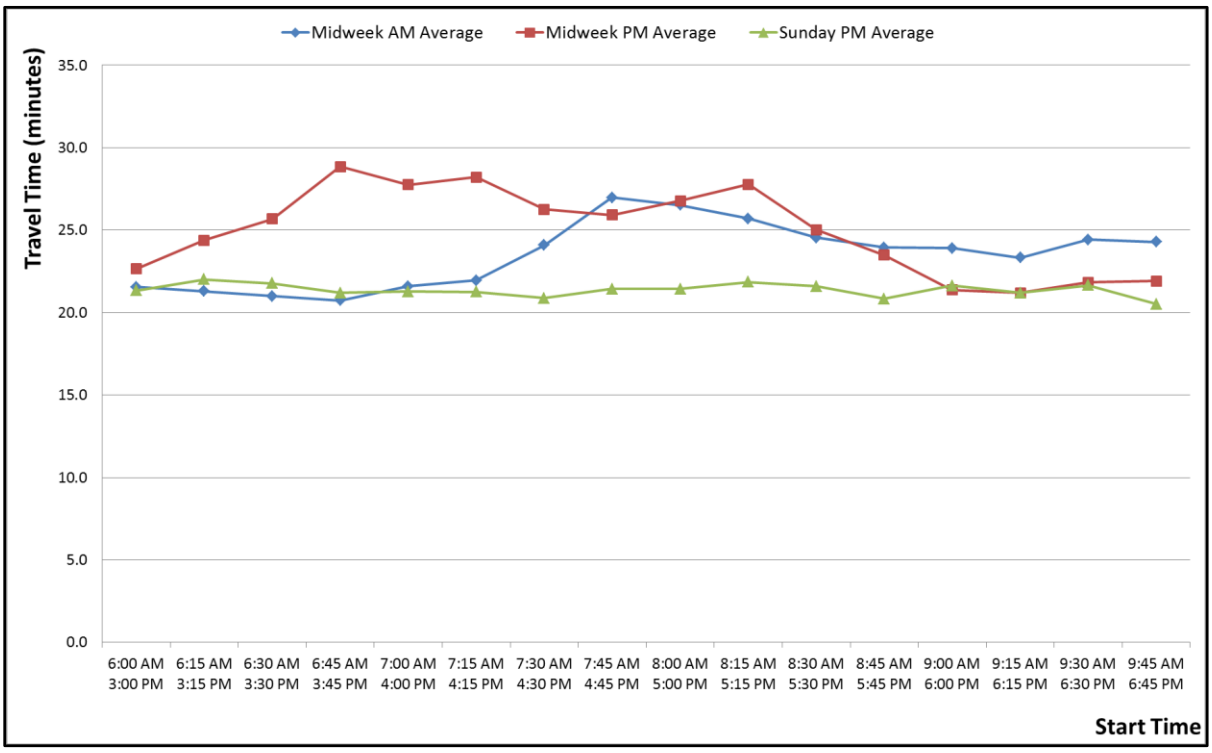
Travel times are shown graphically in Exhibit 6 and Exhibit 7.

Exhibit 6: US 101 Northbound Travel Times



Note: travel times are between Sierra Avenue off-ramp to Old Redwood Highway off-ramp, approximately 17 miles.

Exhibit 7: US 101 Southbound Travel Times

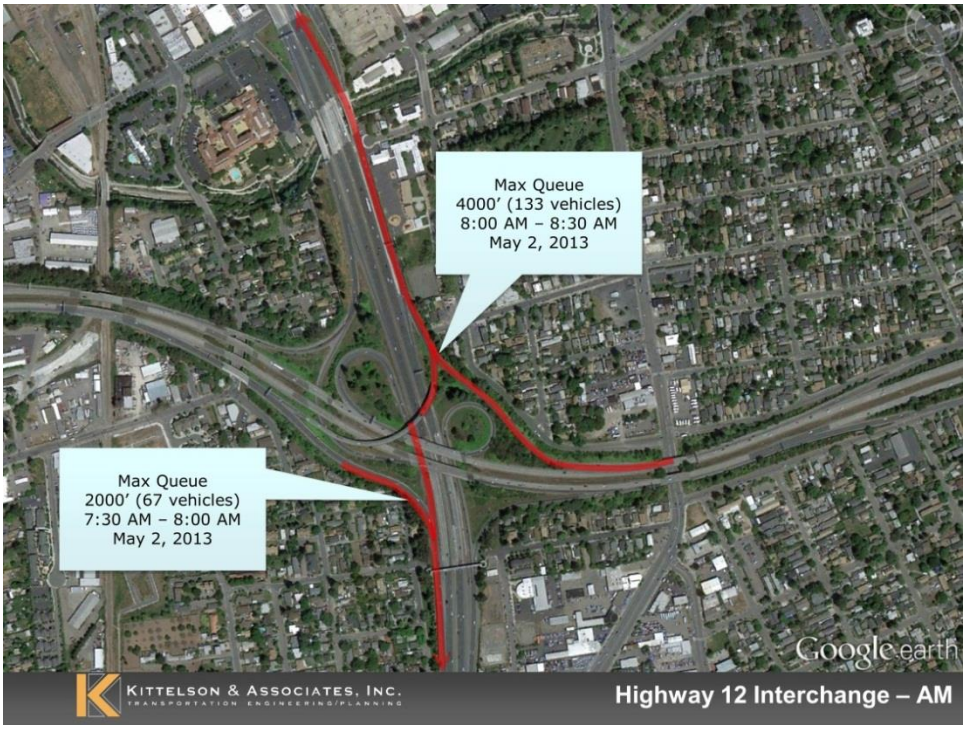


Note: travel times are between Arata Lane on-ramp to Old Redwood Highway off-ramp, approximately 23 miles.

EXISTING FREEWAY ON-RAMP VEHICLE QUEUES

The most significant on-ramp vehicle queues occurred at the SR 12 interchange, where queues develop regularly during both the midweek AM and PM peak hours. Typical midweek peak hour queues at the SR 12 on-ramps are shown in Exhibit 8. Slightly longer queues were observed in the southbound direction during the Friday afternoon peak hour.

Exhibit 8: SR 12 and US 101 Interchange Ramp Queues – Midweek AM



A queue was also observed at the northbound Baker Avenue on-ramp during the midweek PM peak hour, as shown in Exhibit 9. Other on-ramp queues that were observed were likely attributable to incidents that were observed. No vehicle queues were observed on Sunday.

Exhibit 9: Baker Avenue and US 101 Northbound Ramp Queues – Midweek PM

FREQ MODEL CALIBRATION AND VALIDATION

This section provides a summary of the FREQ model calibration results for existing conditions.

Four FREQ models are developed and calibrated for the purpose of developing ramp metering rates for the corridor:

- **Northbound AM Peak Period: 6 AM–10 AM**
- **Northbound PM Peak Period: 3 PM–7 PM**
- **Southbound AM Peak Period: 6 AM–10 AM**
- **Southbound PM Peak Period: 3 PM–7 PM**

These time periods include time before congestion occurs, during congested periods, and when queues dissipate. The FREQ model was set up to analyze at 15-minute time intervals.

FREQ MODEL DEVELOPMENT AND INPUT DATA

The FREQ model was developed based on a set of comprehensive data including traffic volumes, geometries, and capacities. The freeway capacities reflect the presence of heavy vehicles and profile grades that exist in the corridor.

Selection of Data for FREQ Model Evaluation

Existing midweek peak-period traffic operations were observed for three consecutive days between April 30, 2013 and May 2, 2013, during following time periods:

- Midweek AM northbound and southbound: 6 AM–10 AM
- Midweek PM northbound and southbound: 3 PM–7 PM

As discussed during the September 26, 2013 Ramp Metering Technical Committee (RMTC) meeting, no special metering plans will be developed for Friday PM peak period, as observed conditions were similar to midweek PM peak period. In general, Monday traffic conditions are similar or lighter compared to midweek conditions; therefore, metering plans developed for midweek AM and PM peak periods are intended to work during Monday through Friday. In addition, as discussed in the meeting, since no existing freeway bottlenecks were observed during Sunday afternoons, no metering plans are proposed for Sundays and Saturdays as part of this implementation plan.

Based on field observations and evaluation of traffic counts, floating car surveys, and CHP incident logs, the following incidents were determined to have affected survey results:

- On Tuesday, April 30, 2013, from approximately 1:30 PM to 4:30 PM, the Route 12 westbound to US 101 southbound connector was closed due to an overturned truck. The ramp closure

appeared to have a significant effect on southbound freeway operations, but did not appear to affect northbound traffic flow.

- On Thursday, May 2, 2013, collisions at Pepper Road during the AM peak period and at Yolanda Avenue (Hearn Avenue) during the PM peak period were observed to significantly impact travel speeds on the corridor in the southbound direction.

Existing freeway bottleneck locations and queues were determined using the remaining valid traffic data from all three survey days, which represent typical conditions along the corridor.

Since the traffic counts collected on Wednesday, May 1, 2013 were not affected by incidents, they were selected as a set of input data for the purpose of FREQ modeling. In addition, freeway travel times and speed contour maps collected on this date were used to compare against the FREQ calibration results.

FREQ Model Free Flow Speeds

Model free flow speeds are set to 65 miles per hour (mph) in both directions on US 101, based on observations during uncongested times. This is also consistent with the posted speed limit along the corridor.

Existing Traffic Volumes

The freeway mainline entry counts represent actual demand volumes as they were collected upstream of the freeway queues. All on-ramp counts, as well as off-ramp counts upstream of congestion, represent demand volumes as tube counters were set upstream of queues. Off-ramp counts, downstream of freeway queues, represent constrained traffic counts. Therefore, additional adjustments were made to these constrained off-ramp counts to account for congestion, as necessary.

FREQ Model Capacities

Freeway capacities for the FREQ calibration were set based on traffic counts through freeway subsections (SS) operating at capacity (bottleneck section). 2,100 vehicles-per-hour-per-lane (vphpl) was determined as a basic mainline subsection capacity for the FREQ models. This is based on northbound mainline bottleneck throughput counts north of the SR 12 on-ramp during the AM peak period (average between 7:15 AM to 8:30 AM). This capacity already accounts for factors such as heavy vehicles, grades, typical merging, diverging, and weaving effects. Specific adjustments were made at certain locations to account for additional factors, described in the next section.

All on-ramp and off-ramp capacities were set using the default value of 1,500 vphpl, except for the freeway connector ramps at the SR 12 interchange. All freeway-to-freeway connectors at the SR

12/US 101 interchange were set at 1,800 vphpl, except for the US 101 southbound to SR 12 connector, which was set at 2,000 vphpl based on existing throughput counts.

Based on Exhibit 13-10 of HCM 2010, the general capacity of ramp roadways is between 1,800 passenger cars per hour per lane (pcphpl) and 2,200 pcphpl depending on the free-flow speed of the ramp. 1,500 vphpl is conservatively on the low side, which accounts for heavy vehicle adjustments.

Auxiliary lane capacities were generally set based on the lower of the two 15-minute maximum traffic volumes from the upstream on-ramp and the downstream off-ramp of the subsection with an auxiliary lane. Auxiliary lanes generally operate at lower capacities than mainline through lanes because of the need for traffic to exit the lane at the off ramp and enter the lane at the on-ramp. In the final few hundred feet the only vehicles that can realistically use the auxiliary lane (without making an aggressive merge) are vehicles destined for the off ramp. In the first few hundred feet, the only vehicles that can realistically use the auxiliary lane are those entering at the on-ramp.

Mainline Capacities at Specific Locations

While a majority of freeway subsection capacities were set using an average capacity of 2,100 vphpl, as described above, the capacity for US 101 mainline between the Hearn Avenue/Yolanda Avenue and Highway 12 interchanges was set at 1,940 vphpl. This reduced capacity was set based on constrained throughput counts on US 101 northbound south of the Baker Avenue on-ramp. This section operates at capacity (immediately downstream of the bottleneck section between Yolanda on-ramp and Baker off-ramp) during the PM peak period between 3:30 PM and 5:00 PM. This reflects lower capacity due to closely-spaced interchanges in this area, including a system interchange and corresponding weaving activities.

High Occupancy Vehicle Lane and Mainline Occupancy

Both directions of US 101 feature HOV lanes for nearly their entire length, as described under the Existing Conditions section on page 9. The hours of operation are identical in the two directions: 7:00–9:00 AM and 3:00–6:30 PM, Monday–Friday. Due to the limitation of the FREQ software, HOV lane operation was assumed to be in place throughout the entire peak period. Since there is no traffic congestion on the mainline outside of the actual enforced HOV lane hours, and FREQ did not simulate unnecessary traffic congestion during those times, these models are sufficient for the purpose of developing ramp metering rates for the corridor.

The HOV percentage for the corridor was based on several sources, including the Caltrans District 4 Year 2011 Annual HOV Lane Report, recently collected detector counts, and the PeMS database.

1. Northbound AM Peak Period: The HOV percentage was set at approximately 16 percent.
2. Northbound PM Peak Period: The HOV percentage was set at approximately 16 percent.
3. Southbound AM Peak Period: The HOV percentage was set at approximately 16 percent.

4. Southbound PM Peak Period: The HOV percentage was set at approximately 21 percent.

HOV percentage varies throughout the corridor and over time. Since the FREQ software does not allow HOV percentage input to vary over time, a representative average value was chosen, and adjusted as needed, to calibrate each of the four peak period models.

FREQ MODEL CALIBRATION RESULTS

Exhibit 10 and Exhibit 11 provide a summary comparison of simulated bottleneck and queue lengths compared to field observed data. In general, simulated queues match up reasonably well with observed queue lengths. Exhibit 12 provides a comparison of the congestion duration associated with each bottleneck, between observed and FREQ simulated conditions. In general, the FREQ simulation results match well with the observed conditions, with some cases that the model conservatively simulated longer congestion duration by about 15 minutes.

Exhibit 10 – Graphical Comparison of FREQ Simulated vs Observed Congestion – AM Peak Period

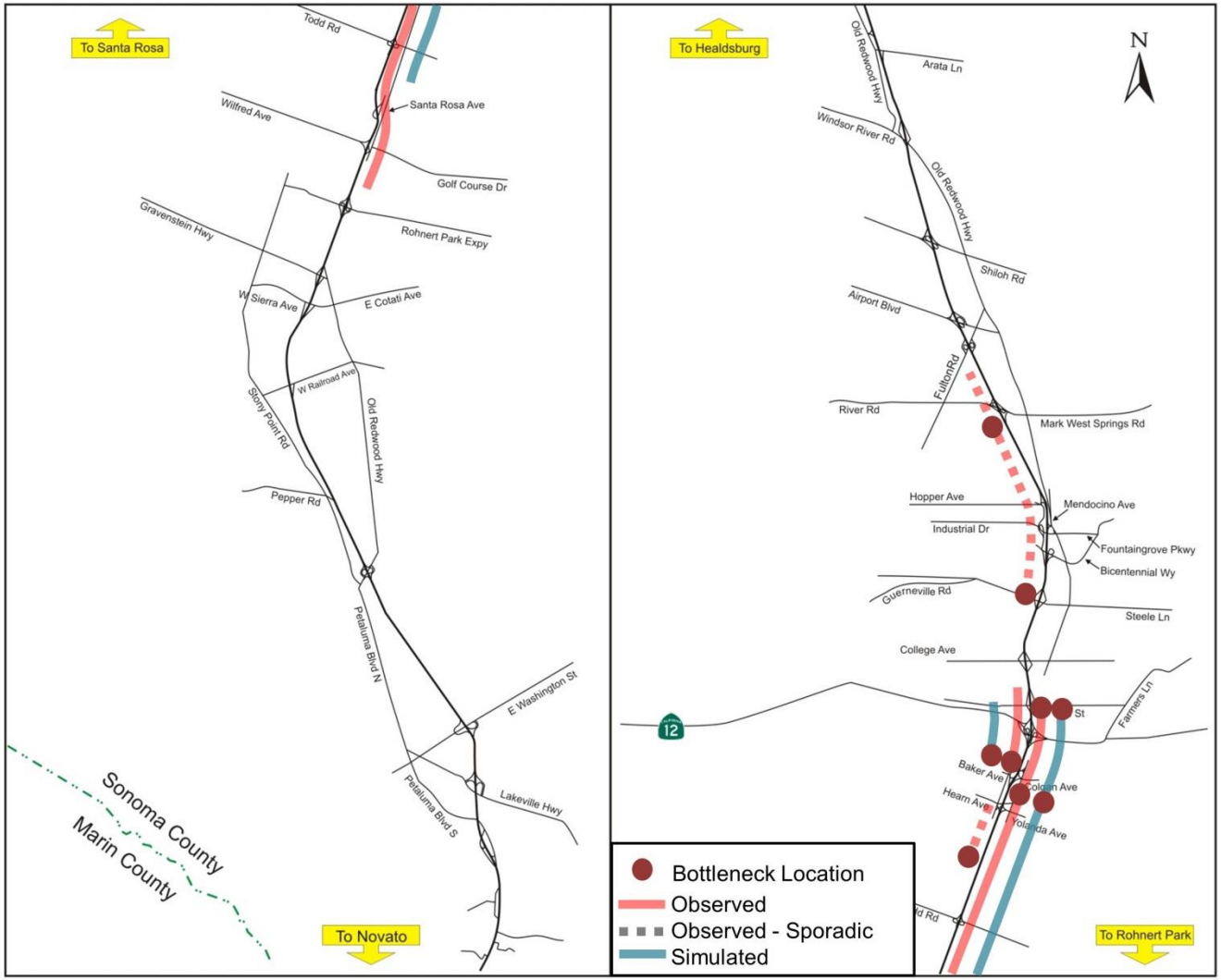


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Exhibit 11 – Graphical Comparison of FREQ Simulated vs Observed Congestion – PM Peak Period

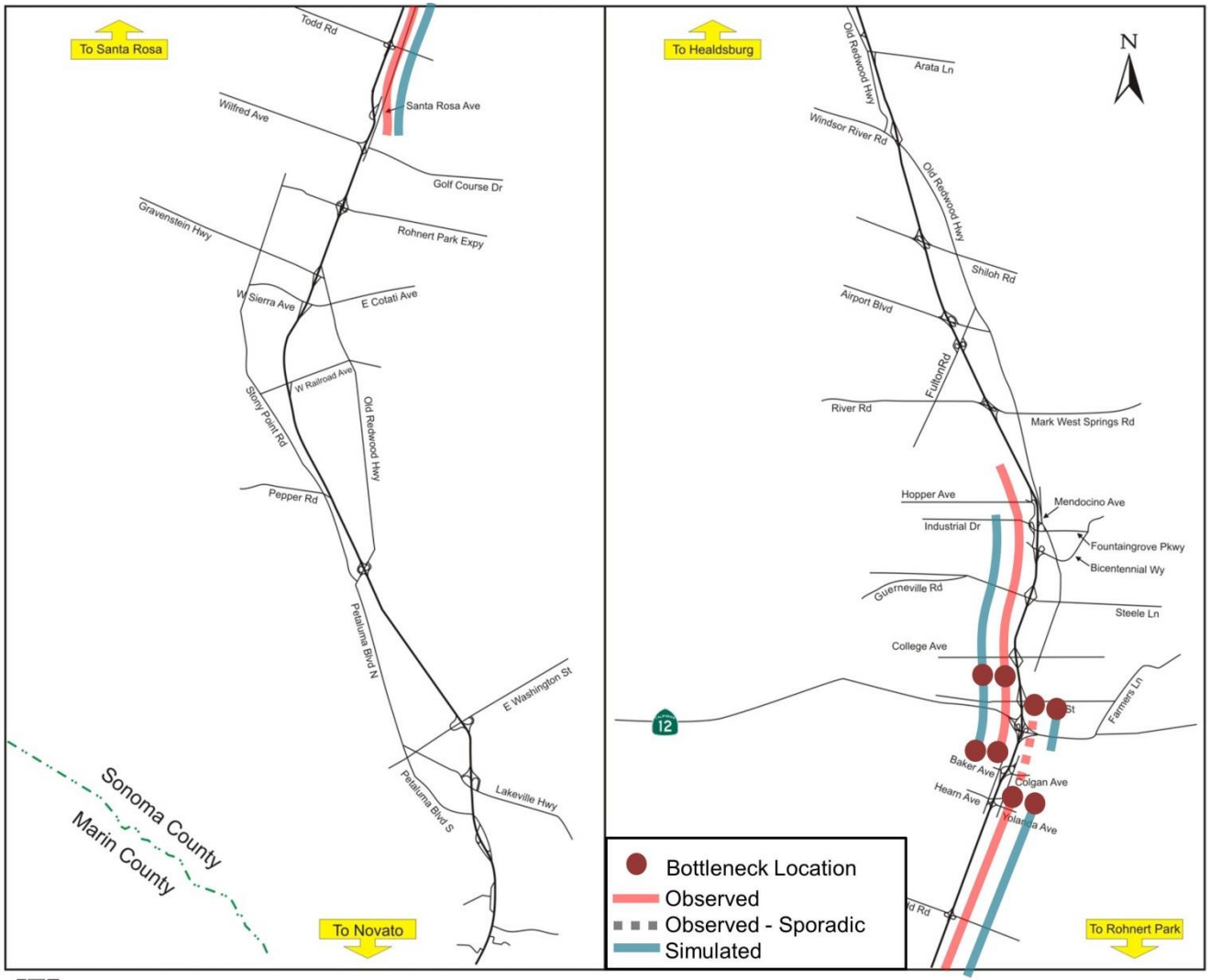

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Exhibit 12: Comparison of Congestion Duration – Observed vs FREQ Calibrated Models

Label	Bottleneck Location	Observed		Simulated	
		Start	End	Start	End
	Northbound AM				
A	Between SR 12 on-ramp and College Avenue off-ramp	7:15 – 7:30 AM	9:00 AM	7:30 AM	9:15 AM
B	Between Yolanda Avenue on-ramp and Baker Avenue off-ramp	7:15 – 7:30 AM	9:00 AM	7:30 - 7:45 AM	9:15 AM
	Northbound PM				
A	Between SR 12 on-ramp and College Avenue off-ramp	Sporadic 4:00 to 5:15 PM		Sporadic 3:30 to 5:45 PM	
B	Between Yolanda Avenue on-ramp and Baker Avenue off-ramp	3:15 PM	6:15 PM	3:15 PM	6:30 PM
	Southbound AM				
C	Between Hearn Avenue on-ramp and Todd Road off-ramp	Sporadic 7:45 to 8:15 AM		Did not show in simulation	
D	Between SR 12 on-ramp and Baker Avenue off-ramp	7:30 AM	9:00 AM	7:15 AM	9:15 AM
F	Between Guerneville Road off-ramp and Guerneville Road on-ramp	Sporadic 7:30 to 8:15 AM		Near capacity 7:30 to 8:00 AM	
G	Between River Road on-ramp and Hopper Avenue off-ramp	Sporadic 7:30 to 8:00 AM		Near capacity 7:30 to 8:00 AM	
	Southbound PM				
D	Between SR 12 on-ramp and Corby Avenue off-ramp	3:15 PM	6:00 PM	3:00 PM	6:00 PM
E	Between College Avenue on-ramp and Downtown off-ramp	3:15 PM	6:00 PM	3:00 PM	6:00 PM

Note: Observed conditions are primarily based on Wednesday, May 1, 2013 data. Valid data from Tuesday, April 30, and Thursday, May 2, 2013 were used as additional references to determine typical existing conditions.

Travel Times

Exhibit 13 shows comparisons of FREQ simulated versus observed travel times through the US 101 northbound corridor during AM peak period. As shown, differences are within ±15 percent in most cases except for one time interval, when compared to observed floating car data. Simulated travel times are generally higher and more conservative than observed data.

Exhibit 13: Graphical Comparison of Observed vs Simulated Travel Times – US 101 Northbound AM

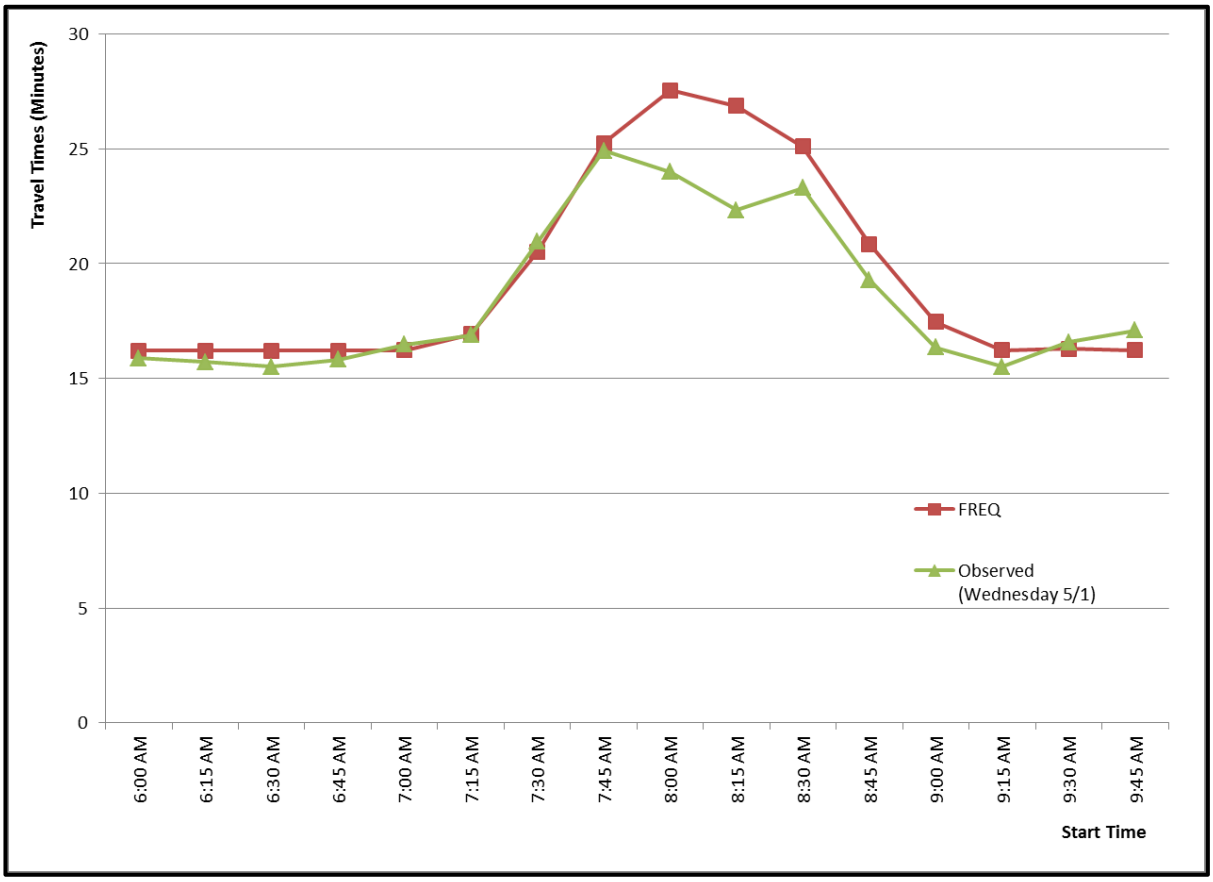


Exhibit 14 shows comparisons of FREQ simulated versus observed travel times through the US 101 northbound corridor during PM peak period. As shown, differences are within ±15 percent in all cases except for two time intervals, when compared to observed floating car data. Simulated travel times are generally higher and more conservative when compared to observed data.

Exhibit 14: Graphical Comparison of Observed vs Simulated Travel Times – US 101 Northbound PM

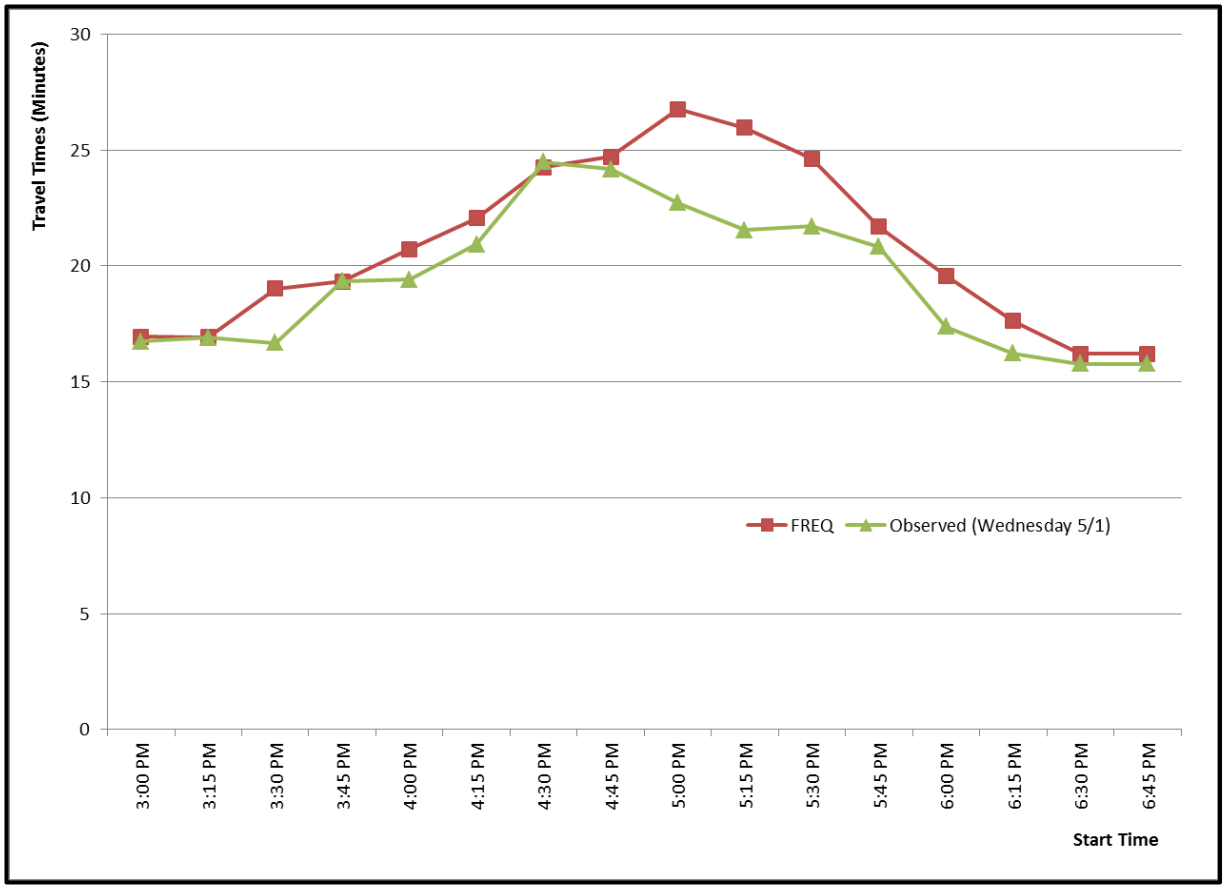


Exhibit 15 shows comparisons of FREQ simulated versus observed travel times through the US 101 southbound corridor during AM peak period. As shown, differences are within ±15 percent in all cases, when compared to observed floating car data.

Exhibit 15: Graphical Comparison of Observed vs Simulated Travel Times – US 101 Southbound AM

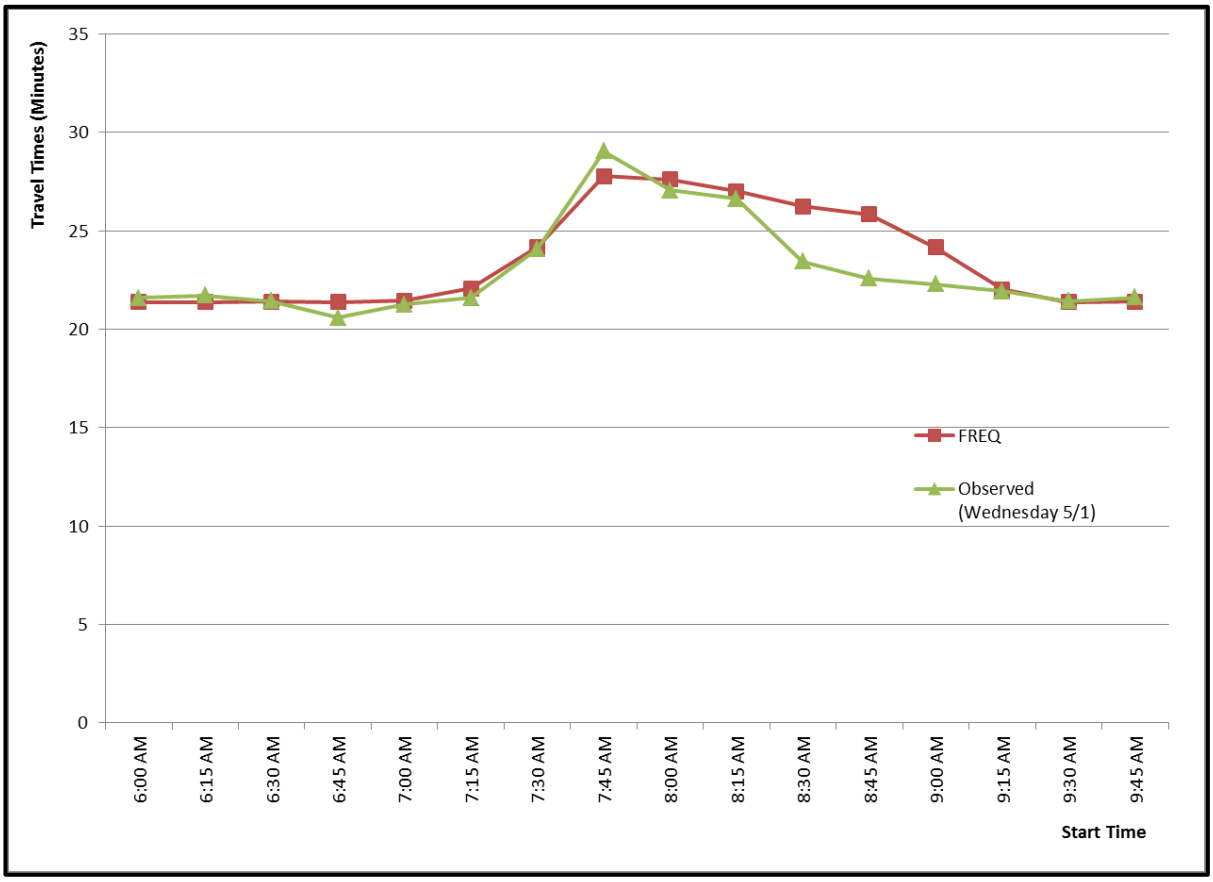
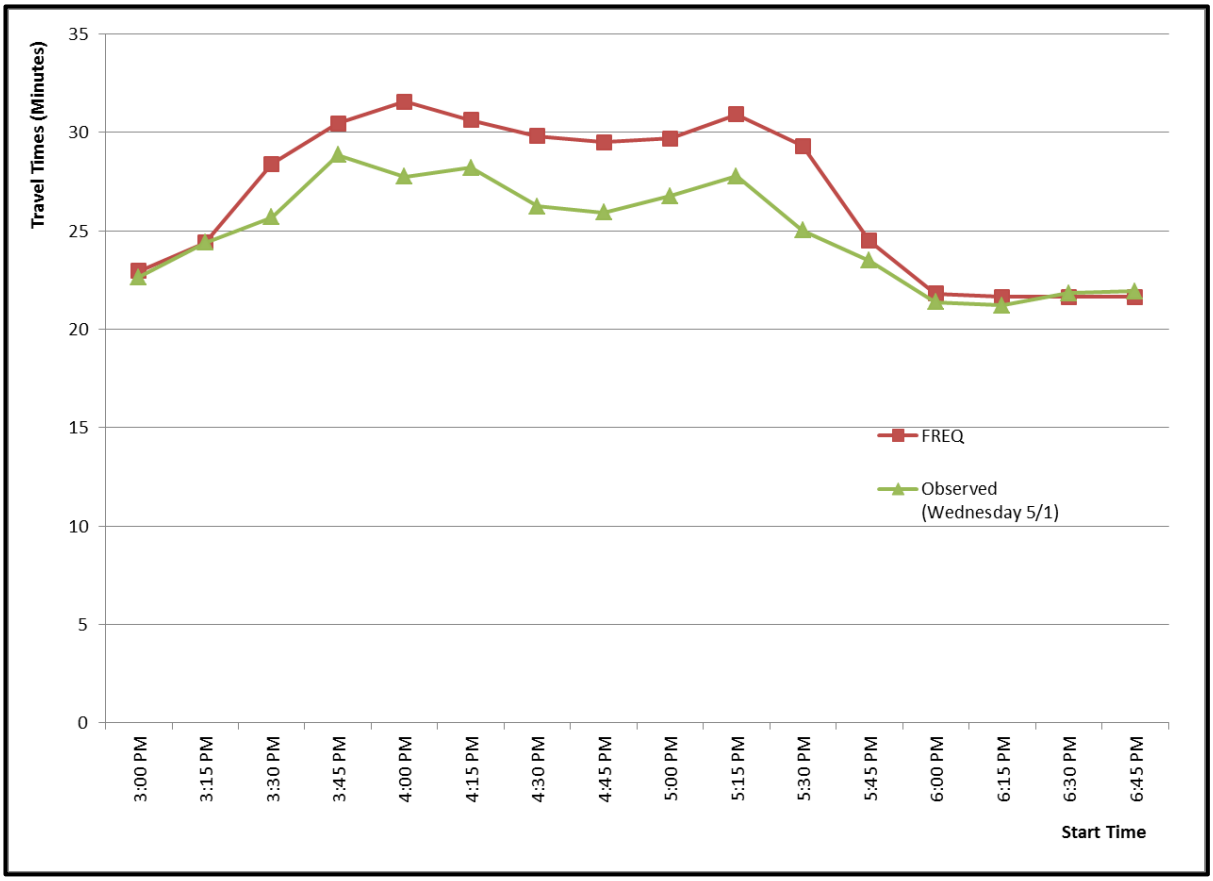


Exhibit 16 shows comparisons of FREQ simulated versus observed travel times through the US 101 southbound corridor during PM peak period. As shown, differences are within ±15 percent in all cases except for one time interval, when compared to observed floating car data. Simulated travel times are generally higher and more conservative when compared to observed data.

Exhibit 16: Graphical Comparison of Observed vs Simulated Travel Times – US 101 Southbound PM



Traffic Volumes

FREQ simulated (or processed) origin-destination traffic volumes were compared to actual traffic volume counts at on-ramps and off-ramps, as well as input traffic volumes at the beginning (entry) and ending (exit) subsections of the freeway mainline. In general, simulated traffic volumes matched actual counts reasonably well.

CONCLUSIONS REGARDING FREQ MODEL CALIBRATION

The FREQ models developed and calibrated for US 101 were satisfactorily validated. Major bottleneck locations, lengths of queues, and duration of congestion were shown to match reasonably well with observed conditions on the speed contour maps. Simulated travel times were within 15 percent of the floating car run travel times in a majority of cases. Finally, traffic volumes processed by FREQ matched reasonably well with traffic counts at origins (on-ramps) and destinations (off-ramps) along the freeway corridor.

Further details of the FREQ calibration results are included in Appendix B.

RECOMMENDED METERING PLAN

The calibrated FREQ model was used to develop ramp metering rates for the US 101 corridor. Caltrans is currently in the process of repairing or upgrading existing ramp metering equipment along the corridor, and will complete this effort prior to activation of ramp meters. It should be noted, however, that equipment theft or vandalism could happen at any time.

ASSUMPTIONS

The following assumptions were made during the development of the ramp metering rates:

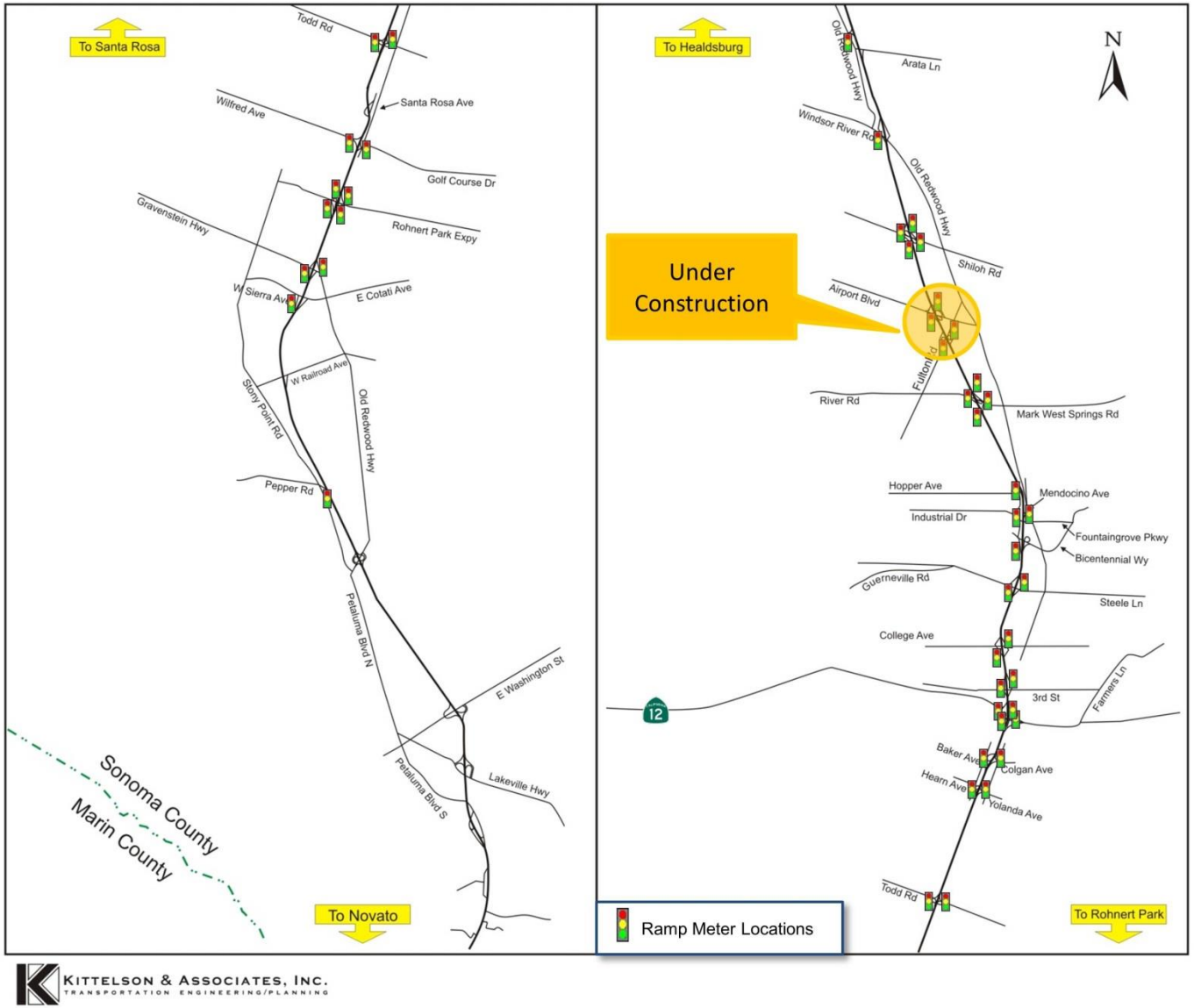
1. Ramp meters would be operational for all on-ramps within the corridor for both the northbound and southbound directions:
    a. AM Peak Period: 6:00 to 10:00 AM
    b. PM Peak Period: 3:00 to 7:00 PM
2. Ramp meters would operate with a policy of one car per green for all locations except for the Baker Avenue/Colgan Avenue northbound on-ramp, and the SR 12 eastbound to US 101 northbound connector, which would serve two cars per green.
3. Preliminary rates were developed based on a practical metering operation of 240 vehicles per hour per lane (vphpl) as a minimum limit, and 900 vphpl as a maximum limit. For two cars per green operations, a maximum rate of 1,000 vphpl is assumed based on a two car per green policy.
4. Ramp metering rates are based on the FREQ corridor optimization module maximizing vehicle-miles of freeway travel, with the constraint that queue lengths would be limited to available storage under typical conditions. On-ramp storage lengths are shown graphically on aerial photos, attached in Appendix A.
5. Due to FREQ software limitations, 2-lane on-ramps, or locations where two on-ramps merge together on a collector-distributor system prior to entering the freeway mainline (such as the SR 12 connector ramps), are modeled as a single-lane on-ramp. Metering rates were then proportionally divided based on demand volumes.
6. At the Airport Boulevard and Fulton Road interchanges, there are on-going construction activities, and permanent closures of certain ramps are already in effect. Based on the current schedule, the interchange construction will be complete sometime after the initial activation of ramp meters for the rest of the corridor. If electrical equipment is ready at the time of ramp metering activation, meters at this interchange will be set to operate with solid green throughout the peak periods. After the interchange construction is complete and a traffic pattern is settled, it is recommended that Caltrans collect new counts and set appropriate metering rates for the new Airport Boulevard on-ramps.
7. Although it is possible that when ramp metering is implemented, existing travel patterns (i.e., such as drivers diverting to different routes or choosing to travel at a different time) could

change, for the purposes of this analysis, it was assumed that no diversion would occur, and on-ramps would serve the same traffic volumes as they currently serve.

8. With the implementation of ramp metering, traffic flows are better controlled and platoons of traffic are spread out before merging onto the freeway. Therefore, a 2.5 percent increase in freeway capacity was assumed at freeway bottleneck locations. This is a conservative assumption based on capacity increases observed from other Bay Area freeway corridors where ramp meters were implemented.
9. Caltrans' existing ramp metering controllers allow a total of six metering plan settings per location, for both the AM and PM peak periods. Each metering plan consists of a preferred metering rate setting based on typical freeway conditions (i.e., mainline speed, or occupancy data).

Exhibit 17 illustrates ramp meter locations along the study corridor.

Exhibit 17: Ramp Meter Locations



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RAMP METERING RATES

Exhibit 18 through Exhibit 21 provide summaries of recommended metering rates for US 101 northbound AM, northbound PM, southbound AM, and southbound PM peak periods, respectively. Available storage, as well as the number of on-ramp lanes leading up to the meter limit line, is shown in the exhibits. Expected on-ramp queue lengths and average delays at the on-ramps are also included.

During the development of the recommended metering rates, an iterative process of evaluation was conducted, optimally balancing ramp delays and queues, as well as mainline travel time savings. Keeping the on-ramp metering delays within the limits the general public is accustomed to in the San Francisco Bay Area was also a consideration.

All on-ramp queues would be contained within available storage, except for the SR 12 eastbound to US 101 northbound connector during the PM peak period:

a. On-ramp queues would exceed the available storage of 34 vehicles between about 5:15 and 6:00 PM.
b. Estimated maximum queue length is 60 vehicles, which indicates that approximately 26 vehicles would be queued between the diverge point from eastbound SR 12 and the northbound/southbound US 101 split, where there is additional storage for about 29 vehicles. Therefore, the end of queue would not extend far enough to block eastbound SR 12 mainline operations.
c. Existing traffic counts showed that vehicles were using the SR 12 connector ramps to get from SR 12 eastbound to Downtown Santa Rosa/Third Street, although signage on the road directs drivers to the downstream off-ramp at South E Street to reach Downtown. With the implementation of ramp metering, these drivers may elect to use the off-ramp at South E Street, avoiding the connector metering and effectively reducing the expected queues at this location.
d. It is recommended that Caltrans closely monitor queues at this on-ramp during the initial two weeks of ramp meter activation. If excessive queues continue to occur after that, an alternative ramp metering strategy is recommended at this location to avoid queuing beyond available storage.

The ramp queues reported are based on the FREQ analysis, which reflects unserved demand at the end of each simulation time interval and would accumulate into the next. Ramps with zero steady state queues at the end of the simulation period would have transient short queues within the 15-minute time interval, which would vary throughout, when platoons of vehicles arrive from an upstream signal. However, these platoon queues are expected to be short in duration and length. Monitoring the metering operation after initial activation would verify that the transient queues do not exceed the available storage. If they do, the metering rate could be adjusted accordingly.

Note that at the Baker Avenue northbound on-ramp, the initial ramp metering recommendation was to meter it at one car per green which yields a maximum rate of 900 vph. With the initial plan, the expected on-ramp queue would spill over the available on-ramp storage by approximately 24 vehicles between 5 PM and 6 PM. However, based on feedback received with the stakeholders, the recommended metering plan has been modified to operate with a two cars per green at this location to reduce the potential for on-ramp queue spillback. With this modification, potential freeway travel time savings on the freeway mainline would be reduced compared to the initial recommended metering plan.

City of Santa Rosa staff provided field data that showed the northbound on-ramp from Baker Avenue receives unusually high platoon volumes of traffic from the Santa Rosa Avenue northbound left turn lane. It is recommended that Caltrans closely monitor queues at this on-ramp during the initial two weeks of ramp meter activation. If excessive queues are formed and affect arterial street operations on Santa Rosa Avenue, alternative ramp metering strategies are recommended at this location to avoid queuing beyond available storage. Such alternative strategies may include:

- Option 1: Operate ramp meter with solid green during the highest peak traffic periods;
- Option 2: Widen or restripe the existing on-ramp to provide two mixed-flow traffic lanes leading up to the ramp meter limit line.

Expected on-ramp queue charts with ramp metering are included in Appendix C.

Exhibit 18: Recommended Ramp Metering Rates – Northbound AM Peak Period

On-Ramp Location	From	To	Gravenstein Hwy	Rohnert Park Exp EB	Rohnert Park Exp WB	Golf Course Drive	Todd Road	Hearn/Yolano Ave	Baker /Colgan*	SR 12 EB Connecor *	SR 12 WB Connecor	6th Street/DT
MF Lanes at Limit Line			2	1	2	2	1	1	1	1	1	1
HOV by pass			1	1	1	0	0	1	0	0	0	0
Total Available Storage - Vehicles (lane feet)			18 (540)	18 (540)	57 (1710)	22 (660)	3 (90)	42 (1260)	24 (720)	34 (1020)	39 (1170)	18 (540)
Arterial Storage (included above) (vehicles)			0	0	7	0	0	2	3	0	0	0
Time Interval		Demands - Hourly Flow for the Entire On-ramp										
1	6:00 AM	6:15 AM	312	84	224	152	212	304	240	437	267	80
2	6:15 AM	6:30 AM	516	80	276	144	276	412	244	668	380	84
3	6:30 AM	6:45 AM	676	112	412	212	380	568	316	837	587	124
4	6:45 AM	7:00 AM	608	136	476	276	368	628	368	909	807	140
5	7:00 AM	7:15 AM	684	180	528	340	520	632	388	844	640	172
6	7:15 AM	7:30 AM	952	172	576	440	480	808	472	1,050	822	212
7	7:30 AM	7:45 AM	1,012	156	852	488	480	992	640	968	976	288
8	7:45 AM	8:00 AM	1,052	196	688	380	492	1,028	672	936	928	512
9	8:00 AM	8:15 AM	804	192	600	352	484	1,008	652	826	822	364
10	8:15 AM	8:30 AM	928	172	572	440	436	860	672	875	849	492
11	8:30 AM	8:45 AM	708	172	596	428	372	940	536	755	773	420
12	8:45 AM	9:00 AM	712	148	392	408	376	832	540	782	774	384
13	9:00 AM	9:15 AM	540	180	524	492	372	632	484	971	809	308
14	9:15 AM	9:30 AM	648	200	472	392	364	648	520	941	779	284
15	9:30 AM	9:45 AM	608	176	556	464	628	732	492	975	753	320
16	9:45 AM	10:00 AM	700	188	512	424	488	696	532	988	712	312
Time Interval		Ramp Metering Rate Per Lane Per Hour										
1	6:00 AM	6:15 AM	900	900	900	900	900	900	1000	1000	900	900
2	6:15 AM	6:30 AM	900	900	900	900	900	900	1000	1000	900	900
3	6:30 AM	6:45 AM	900	900	900	900	900	900	1000	1000	900	900
4	6:45 AM	7:00 AM	900	900	900	900	900	900	1000	1000	900	900
5	7:00 AM	7:15 AM	300	240	260	290	600	660	550	1000	900	330
6	7:15 AM	7:30 AM	420	240	260	290	600	720	550	1000	800	330
7	7:30 AM	7:45 AM	420	240	300	290	600	800	550	920	900	330
8	7:45 AM	8:00 AM	470	240	300	290	600	900	660	920	900	520
9	8:00 AM	8:15 AM	420	240	270	290	600	900	660	860	900	330
10	8:15 AM	8:30 AM	420	240	270	290	600	770	660	860	820	520
11	8:30 AM	8:45 AM	300	240	270	290	600	830	550	800	790	520
12	8:45 AM	9:00 AM	300	240	270	290	600	830	550	800	790	330
13	9:00 AM	9:15 AM	900	900	900	900	900	900	1000	1000	900	900
14	9:15 AM	9:30 AM	900	900	900	900	900	900	1000	1000	900	900
15	9:30 AM	9:45 AM	900	900	900	900	900	900	1000	1000	900	900
16	9:45 AM	10:00 AM	900	900	900	900	900	900	1000	1000	900	900
Time Interval		Cumulative Ramp Queue Length in Vehicles at End of Time Slice										
1	6:00 AM	6:15 AM	0	0	0	0	0	0	0	0	0	0
2	6:15 AM	6:30 AM	0	0	0	0	0	0	0	0	0	0
3	6:30 AM	6:45 AM	0	0	0	0	0	0	0	0	0	0
4	6:45 AM	7:00 AM	0	0	0	0	0	0	0	0	0	0
5	7:00 AM	7:15 AM	0	0	0	0	0	0	0	0	0	0
6	7:15 AM	7:30 AM	0	0	0	0	0	0	0	13	6	0
7	7:30 AM	7:45 AM	15	0	30	0	0	21	19	25	25	0
8	7:45 AM	8:00 AM	13	0	28	0	0	26	19	29	32	0
9	8:00 AM	8:15 AM	0	0	20	0	0	26	14	20	12	8
10	8:15 AM	8:30 AM	0	0	9	0	0	27	15	24	19	0
11	8:30 AM	8:45 AM	9	0	1	0	0	31	10	13	15	0
12	8:45 AM	9:00 AM	16	0	0	0	0	14	9	8	11	14
13	9:00 AM	9:15 AM	0	0	0	0	0	0	0	0	0	0
14	9:15 AM	9:30 AM	0	0	0	0	0	0	0	0	0	0
15	9:30 AM	9:45 AM	0	0	0	0	0	0	0	0	0	0
16	9:45 AM	10:00 AM	0	0	0	0	0	0	0	0	0	0
Time Interval		Average Metering Delays (Minutes)										
1	6:00 AM	6:15 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	6:15 AM	6:30 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	6:30 AM	6:45 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	6:45 AM	7:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	7:00 AM	7:15 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	7:15 AM	7:30 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	0.0
7	7:30 AM	7:45 AM	0.5	0.0	1.3	0.0	0.0	0.7	1.0	1.2	1.0	0.0
8	7:45 AM	8:00 AM	0.8	0.0	2.5	0.0	0.0	1.4	1.7	1.8	1.9	0.0
9	8:00 AM	8:15 AM	0.3	0.0	2.3	0.0	0.0	1.6	1.5	1.8	1.6	0.7
10	8:15 AM	8:30 AM	0.0	0.0	1.6	0.0	0.0	1.8	1.3	1.5	1.1	0.2
11	8:30 AM	8:45 AM	0.4	0.0	0.6	0.0	0.0	1.9	1.4	1.5	1.3	0.0
12	8:45 AM	9:00 AM	1.1	0.0	0.0	0.0	0.0	1.6	1.1	0.8	1.0	1.1
13	9:00 AM	9:15 AM	0.3	0.0	0.0	0.0	0.0	0.3	0.2	0.2	0.4	0.3
14	9:15 AM	9:30 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	9:30 AM	9:45 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	9:45 AM	10:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Notes:

Light-shaded cells indicate on-ramp queues that would be contained within available storage. Expected average delays are also shown in light-shaded cells.

* The Baker Avenue on-ramp and the SR 12 eastbound to US 101 northbound connector is assumed to meter with two cars per green operation.

Exhibit 18: Recommended Ramp Metering Rates – Northbound AM Peak Period (Continued)

On-Ramp Location	From	To	College Avenue	Steele Lane	Mendocino Avenue	River Road EB	River Road WB	Fulton Road	Airport Blvd	Shiloh Road EB	Shiloh Road WB
MF Lanes at Limit Line			2	2	1	1	1	1	2	1	1
HOV by pass			0	1	1	0	0	0	0	0	0
Total Available Storage - Vehicles (lane feet)			36 (1080)	30 (900)	37 (1110)	17 (510)	37 (1110)	22 (660)	50 (1500)	24 (720)	39 (1170)
Time Interval		Demands - Hourly Flow for the Entire On-ramp									
1	6:00 AM	6:15 AM	164	248	180	28	60	116	124	16	32
2	6:15 AM	6:30 AM	240	256	196	60	88	204	188	20	44
3	6:30 AM	6:45 AM	364	380	328	60	124	208	132	64	56
4	6:45 AM	7:00 AM	336	336	404	48	120	276	332	32	36
5	7:00 AM	7:15 AM	320	248	384	52	152	192	200	52	64
6	7:15 AM	7:30 AM	432	456	584	72	188	236	244	40	84
7	7:30 AM	7:45 AM	504	444	624	96	276	368	300	64	84
8	7:45 AM	8:00 AM	732	628	792	104	280	396	408	40	152
9	8:00 AM	8:15 AM	580	552	672	64	224	432	292	68	104
10	8:15 AM	8:30 AM	572	536	700	68	304	408	412	48	112
11	8:30 AM	8:45 AM	520	500	712	96	220	360	460	80	112
12	8:45 AM	9:00 AM	508	560	712	76	260	340	372	60	104
13	9:00 AM	9:15 AM	488	352	560	76	136	216	332	48	80
14	9:15 AM	9:30 AM	416	416	484	64	156	276	328	64	108
15	9:30 AM	9:45 AM	404	380	520	72	108	248	272	80	116
16	9:45 AM	10:00 AM	416	448	556	40	128	164	284	64	116
Time Interval		Ramp Metering Rate Per Lane Per Hour									
1	6:00 AM	6:15 AM	900	900	900	900	900			900	900
2	6:15 AM	6:30 AM	900	900	900	900	900			900	900
3	6:30 AM	6:45 AM	900	900	900	900	900			900	900
4	6:45 AM	7:00 AM	900	900	900	900	900			900	900
5	7:00 AM	7:15 AM	330	600	900	900	900			900	900
6	7:15 AM	7:30 AM	330	600	900	900	900			900	900
7	7:30 AM	7:45 AM	330	600	900	900	900			900	900
8	7:45 AM	8:00 AM	330	600	900	900	900	Interchange Under		900	900
9	8:00 AM	8:15 AM	330	600	900	900	900	Construction		900	900
10	8:15 AM	8:30 AM	330	600	900	900	900			900	900
11	8:30 AM	8:45 AM	330	600	900	900	900			900	900
12	8:45 AM	9:00 AM	330	600	900	900	900			900	900
13	9:00 AM	9:15 AM	900	900	900	900	900			900	900
14	9:15 AM	9:30 AM	900	900	900	900	900			900	900
15	9:30 AM	9:45 AM	900	900	900	900	900			900	900
16	9:45 AM	10:00 AM	900	900	900	900	900			900	900
Time Interval		Cumulative Ramp Queue Length in Vehicles at End of Time Slice									
1	6:00 AM	6:15 AM	0	0	0	0	0			0	0
2	6:15 AM	6:30 AM	0	0	0	0	0			0	0
3	6:30 AM	6:45 AM	0	0	0	0	0			0	0
4	6:45 AM	7:00 AM	0	0	0	0	0			0	0
5	7:00 AM	7:15 AM	0	0	0	0	0			0	0
6	7:15 AM	7:30 AM	0	0	0	0	0			0	0
7	7:30 AM	7:45 AM	0	0	0	0	0			0	0
8	7:45 AM	8:00 AM	17	0	0	0	0	Interchange Under		0	0
9	8:00 AM	8:15 AM	0	0	0	0	0	Construction		0	0
10	8:15 AM	8:30 AM	0	0	0	0	0			0	0
11	8:30 AM	8:45 AM	0	0	0	0	0			0	0
12	8:45 AM	9:00 AM	0	0	0	0	0			0	0
13	9:00 AM	9:15 AM	0	0	0	0	0			0	0
14	9:15 AM	9:30 AM	0	0	0	0	0			0	0
15	9:30 AM	9:45 AM	0	0	0	0	0			0	0
16	9:45 AM	10:00 AM	0	0	0	0	0			0	0
Time Interval		Average Metering Delays (Minutes)									
1	6:00 AM	6:15 AM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
2	6:15 AM	6:30 AM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
3	6:30 AM	6:45 AM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
4	6:45 AM	7:00 AM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
5	7:00 AM	7:15 AM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
6	7:15 AM	7:30 AM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
7	7:30 AM	7:45 AM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
8	7:45 AM	8:00 AM	0.8	0.0	0.0	0.0	0.0	Interchange Under		0.0	0.0
9	8:00 AM	8:15 AM	0.9	0.0	0.0	0.0	0.0	Construction		0.0	0.0
10	8:15 AM	8:30 AM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
11	8:30 AM	8:45 AM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
12	8:45 AM	9:00 AM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
13	9:00 AM	9:15 AM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
14	9:15 AM	9:30 AM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
15	9:30 AM	9:45 AM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
16	9:45 AM	10:00 AM	0.0	0.0	0.0	0.0	0.0			0.0	0.0

Notes:

Light-shaded cells indicate on-ramp queues that would be contained within available storage. Expected average delays are also shown in light-shaded cells.

Exhibit 19: Recommended Ramp Metering Rates – Northbound PM Peak Period

On-Ramp Location	From	To	Gravenstein Hwy	Rohnert Park Exp EB	Rohnert Park Exp WB	Golf Course Drive	Todd Road	Hearn/Yolano Ave	Baker/ Colgan*	SR 12 EB Connecor *	SR 12 WB Connecor	6th Street/DT
Lanes at Limit Line			2	1	2	2	1	1	1	1	1	1
HOV by pass			1	1	1	0	0	1	0	0	0	0
Total Available Storage - Vehicles (lane feet)			18 (540)	18 (540)	57 (1710)	22 (660)	3 (90)	42 (1260)	24 (720)	34 (1020)	39 (1170)	18 (540)
Time Slice		Demands - Hourly Flow for the Entire On-ramp										
1	3:00 PM	3:15 PM	692	328	564	732	624	720	792	1,006	930	596
2	3:15 PM	3:30 PM	764	240	680	604	584	800	836	1,011	893	596
3	3:30 PM	3:45 PM	668	380	660	1,004	608	916	864	1,020	916	624
4	3:45 PM	4:00 PM	580	348	604	792	616	960	760	1,055	913	528
5	4:00 PM	4:15 PM	676	364	744	792	636	892	832	914	810	632
6	4:15 PM	4:30 PM	628	324	540	764	564	908	912	994	794	588
7	4:30 PM	4:45 PM	676	276	584	744	664	968	960	829	767	684
8	4:45 PM	5:00 PM	544	296	572	728	632	888	900	922	930	736
9	5:00 PM	5:15 PM	624	332	568	920	624	960	1,008	1,035	881	696
10	5:15 PM	5:30 PM	600	300	472	652	500	976	820	1,128	876	768
11	5:30 PM	5:45 PM	616	256	528	636	424	964	992	1,074	802	560
12	5:45 PM	6:00 PM	624	188	580	716	376	832	812	941	727	688
13	6:00 PM	6:15 PM	692	232	700	612	360	808	832	884	760	564
14	6:15 PM	6:30 PM	556	192	540	612	352	848	800	918	686	480
15	6:30 PM	6:45 PM	664	272	640	624	360	624	716	862	646	536
16	6:45 PM	7:00 PM	524	228	604	548	332	692	688	897	703	516
Time Slice		Ramp Metering Rate Per Lane Per Hour										
1	3:00 PM	3:15 PM	300	300	250	370	670	660	1000	1000	900	610
2	3:15 PM	3:30 PM	300	270	280	370	670	660	1000	1000	900	610
3	3:30 PM	3:45 PM	300	270	280	470	670	830	1000	1000	900	610
4	3:45 PM	4:00 PM	270	300	280	390	670	830	1000	1000	900	520
5	4:00 PM	4:15 PM	300	300	260	390	670	830	1000	1000	790	610
6	4:15 PM	4:30 PM	270	300	260	390	670	830	1000	1000	790	520
7	4:30 PM	4:45 PM	300	240	260	370	670	900	1000	1000	790	720
8	4:45 PM	5:00 PM	240	270	250	370	670	800	1000	1000	900	720
9	5:00 PM	5:15 PM	270	270	250	460	670	900	1000	1000	900	720
10	5:15 PM	5:30 PM	270	270	250	320	670	900	1000	1000	900	720
11	5:30 PM	5:45 PM	270	240	250	320	670	900	1000	1000	790	650
12	5:45 PM	6:00 PM	270	240	250	370	670	770	1000	1000	790	650
13	6:00 PM	6:15 PM	300	240	300	370	670	770	1000	1000	790	520
14	6:15 PM	6:30 PM	240	240	300	370	670	770	1000	1000	790	520
15	6:30 PM	6:45 PM	900	900	900	900	900	900	1000	1000	900	900
16	6:45 PM	7:00 PM	900	900	900	900	900	900	1000	1000	900	900
Time Slice		Cumulative Ramp Queue Length in Vehicles at End of Time Slice										
1	3:00 PM	3:15 PM	0	0	0	0	0	0	0	2	8	0
2	3:15 PM	3:30 PM	15	0	7	0	0	17	0	5	6	0
3	3:30 PM	3:45 PM	13	15	11	16	0	15	0	10	10	1
4	3:45 PM	4:00 PM	6	14	1	19	0	25	0	24	13	1
5	4:00 PM	4:15 PM	3	15	30	22	0	19	0	2	18	4
6	4:15 PM	4:30 PM	4	8	18	18	0	17	0	0	19	17
7	4:30 PM	4:45 PM	3	8	14	19	0	12	0	0	13	5
8	4:45 PM	5:00 PM	1	7	14	16	0	14	0	0	21	6
9	5:00 PM	5:15 PM	3	11	12	16	0	5	2	9	16	0
10	5:15 PM	5:30 PM	0	10	0	19	0	3	0	41	10	9
11	5:30 PM	5:45 PM	1	7	0	18	0	0	0	60	13	0
12	5:45 PM	6:00 PM	2	0	2	12	0	0	0	45	0	7
13	6:00 PM	6:15 PM	4	0	6	0	0	0	0	16	0	17
14	6:15 PM	6:30 PM	6	0	0	0	0	3	0	0	0	9
15	6:30 PM	6:45 PM	0	0	0	0	0	0	0	0	0	0
16	6:45 PM	7:00 PM	0	0	0	0	0	0	0	0	0	0
Time Slice		Average Metering Delays (Minutes)										
1	3:00 PM	3:15 PM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.0
2	3:15 PM	3:30 PM	0.7	0.0	0.4	0.0	0.0	0.7	0.0	0.2	0.5	0.0
3	3:30 PM	3:45 PM	1.3	1.3	0.9	0.5	0.0	1.1	0.0	0.5	0.5	0.1
4	3:45 PM	4:00 PM	1.0	2.4	0.6	1.3	0.0	1.3	0.0	1.0	0.8	0.1
5	4:00 PM	4:15 PM	0.4	2.4	1.5	1.6	0.0	1.5	0.0	0.9	1.2	0.3
6	4:15 PM	4:30 PM	0.4	2.1	2.4	1.6	0.0	1.2	0.0	0.1	1.4	1.1
7	4:30 PM	4:45 PM	0.3	1.7	1.7	1.5	0.0	0.9	0.0	0.0	1.3	1.0
8	4:45 PM	5:00 PM	0.2	1.4	1.5	1.4	0.0	0.9	0.0	0.0	1.1	0.5
9	5:00 PM	5:15 PM	0.2	1.7	1.4	1.0	0.0	0.7	0.1	0.3	1.3	0.1
10	5:15 PM	5:30 PM	0.0	2.0	0.3	1.6	0.0	0.3	0.1	1.5	0.9	0.4
11	5:30 PM	5:45 PM	0.1	1.9	0.0	1.7	0.0	0.0	0.0	3.0	0.9	0.2
12	5:45 PM	6:00 PM	0.1	0.1	0.1	1.3	0.0	0.0	0.0	3.3	0.5	0.3
13	6:00 PM	6:15 PM	0.3	0.0	0.4	0.6	0.0	0.0	0.0	2.1	0.0	1.3
14	6:15 PM	6:30 PM	0.6	0.0	0.1	0.0	0.0	0.1	0.0	0.5	0.0	1.5
15	6:30 PM	6:45 PM	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
16	6:45 PM	7:00 PM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Notes:

Light-shaded cells indicate on-ramp queues that would be contained within available storage. Dark-shaded cells indicate on-ramp queues that would exceed available storage. Expected average delays are also shown in light-shaded cells.

* The Baker Avenue on-ramp and the SR 12 eastbound to US 101 northbound connector is assumed to meter with two cars per green operation.

Exhibit 19: Recommended Ramp Metering Rates – Northbound PM Peak Period (Continued)

On-Ramp Location	From	To	College Avenue	Steele Lane	Mendocino Avenue	River Road EB	River Road WB	Fulton Road	Airport Blvd	Shiloh Road EB	Shiloh Road WB
Lanes at Limit Line			2	2	1	1	1	1	2	1	1
HOV by pass			0	1	1	0	0	0	0	0	0
Total Available Storage - Vehicles (lane feet)			36 (1080)	30 (900)	37 (1110)	17 (510)	37 (1110)	22 (660)	50 (1500)	24 (720)	39 (1170)
Time Slice	Demands - Hourly Flow for the Entire On-ramp										
1	3:00 PM	3:15 PM	616	728	924	108	344	276	392	100	204
2	3:15 PM	3:30 PM	628	656	840	84	324	300	324	104	184
3	3:30 PM	3:45 PM	776	772	868	100	280	260	464	144	204
4	3:45 PM	4:00 PM	596	640	768	100	248	360	348	120	180
5	4:00 PM	4:15 PM	764	600	808	80	284	240	384	140	200
6	4:15 PM	4:30 PM	612	584	728	84	280	348	468	112	172
7	4:30 PM	4:45 PM	652	856	884	100	272	260	464	196	132
8	4:45 PM	5:00 PM	684	664	904	64	220	340	456	144	188
9	5:00 PM	5:15 PM	824	708	924	84	300	300	472	204	208
10	5:15 PM	5:30 PM	740	776	972	140	244	324	468	116	160
11	5:30 PM	5:45 PM	708	652	836	96	232	352	564	128	204
12	5:45 PM	6:00 PM	608	628	784	80	176	348	504	56	188
13	6:00 PM	6:15 PM	660	516	716	104	180	280	396	72	148
14	6:15 PM	6:30 PM	552	516	672	56	152	284	332	44	144
15	6:30 PM	6:45 PM	512	456	600	68	180	232	284	36	160
16	6:45 PM	7:00 PM	408	512	592	36	140	184	244	56	136
Time Slice	Ramp Metering Rate Per Lane Per Hour										
1	3:00 PM	3:15 PM	350	600	900	900	900			900	900
2	3:15 PM	3:30 PM	350	600	900	900	900			900	900
3	3:30 PM	3:45 PM	390	600	900	900	900			900	900
4	3:45 PM	4:00 PM	300	600	900	900	900			900	900
5	4:00 PM	4:15 PM	370	600	900	900	900			900	900
6	4:15 PM	4:30 PM	300	600	900	900	900			900	900
7	4:30 PM	4:45 PM	300	600	900	900	900			900	900
8	4:45 PM	5:00 PM	350	600	900	900	900	Interchange Under		900	900
9	5:00 PM	5:15 PM	390	600	900	900	900	Construction		900	900
10	5:15 PM	5:30 PM	390	600	900	900	900			900	900
11	5:30 PM	5:45 PM	350	600	900	900	900			900	900
12	5:45 PM	6:00 PM	350	600	900	900	900			900	900
13	6:00 PM	6:15 PM	350	600	900	900	900			900	900
14	6:15 PM	6:30 PM	300	600	900	900	900			900	900
15	6:30 PM	6:45 PM	900	900	900	900	900			900	900
16	6:45 PM	7:00 PM	900	900	900	900	900			900	900
Time Slice	Cumulative Ramp Queue Length in Vehicles at End of Time Slice										
1	3:00 PM	3:15 PM	0	0	0	0	0			0	0
2	3:15 PM	3:30 PM	0	0	0	0	0			0	0
3	3:30 PM	3:45 PM	0	0	0	0	0			0	0
4	3:45 PM	4:00 PM	0	0	0	0	0			0	0
5	4:00 PM	4:15 PM	2	0	0	0	0			0	0
6	4:15 PM	4:30 PM	0	0	0	0	0			0	0
7	4:30 PM	4:45 PM	8	0	0	0	0			0	0
8	4:45 PM	5:00 PM	3	0	0	0	0	Interchange Under		0	0
9	5:00 PM	5:15 PM	10	0	0	0	0	Construction		0	0
10	5:15 PM	5:30 PM	0	0	0	0	0			0	0
11	5:30 PM	5:45 PM	0	0	0	0	0			0	0
12	5:45 PM	6:00 PM	0	0	0	0	0			0	0
13	6:00 PM	6:15 PM	0	0	0	0	0			0	0
14	6:15 PM	6:30 PM	0	0	0	0	0			0	0
15	6:30 PM	6:45 PM	0	0	0	0	0			0	0
16	6:45 PM	7:00 PM	0	0	0	0	0			0	0
Time Slice	Average Metering Delays (Minutes)										
1	3:00 PM	3:15 PM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
2	3:15 PM	3:30 PM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
3	3:30 PM	3:45 PM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
4	3:45 PM	4:00 PM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
5	4:00 PM	4:15 PM	0.1	0.0	0.0	0.0	0.0			0.0	0.0
6	4:15 PM	4:30 PM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
7	4:30 PM	4:45 PM	0.4	0.0	0.0	0.0	0.0			0.0	0.0
8	4:45 PM	5:00 PM	0.5	0.0	0.0	0.0	0.0	Interchange Under		0.0	0.0
9	5:00 PM	5:15 PM	0.5	0.0	0.0	0.0	0.0	Construction		0.0	0.0
10	5:15 PM	5:30 PM	0.2	0.0	0.0	0.0	0.0			0.0	0.0
11	5:30 PM	5:45 PM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
12	5:45 PM	6:00 PM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
13	6:00 PM	6:15 PM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
14	6:15 PM	6:30 PM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
15	6:30 PM	6:45 PM	0.0	0.0	0.0	0.0	0.0			0.0	0.0
16	6:45 PM	7:00 PM	0.0	0.0	0.0	0.0	0.0			0.0	0.0

Notes:

Light-shaded cells indicate on-ramp queues that would be contained within available storage. Expected average delays are also shown in light-shaded cells.

Exhibit 20: Recommended Ramp Metering Rates – Southbound AM Peak Period

On-Ramp Location	From	To	Arata Lane	Old Redwood Hwy	Shiloh Road WB	Shiloh Road EB	Airport Blvd	Fulton Road	River Road WB	River Road EB	Hopper Avenue	Mendocino Avenue	Bicenten. Way	Steele Lane	College Avenue
Lanes at Limit Line			1	1	1	1	1	1	1	1	1	1	2	2	2
HOV by pass			1	1	0	1	0	0	1	1	1	0	1	0	0
Total Available Storage Vehicles (lane feet)			30 (900)	47 (1,410)	17 (510)	29 (870)	35 (1,05	24 (720)	16 (480)	40 (1,200)	9 (270)	5 (150)	26 (780)	62 (1,860)	42 (1,260)
Time Slice		Demands - Hourly Flow for the Entire On-ramp													
1	6:00 AM	6:15 AM	100	500	152	188	220	108	204	172	180	48	284	244	256
2	6:15 AM	6:30 AM	128	612	152	252	172	152	216	248	212	36	408	436	400
3	6:30 AM	6:45 AM	180	708	252	336	208	208	328	288	204	84	496	536	456
4	6:45 AM	7:00 AM	220	752	276	316	248	196	284	308	272	96	456	580	456
5	7:00 AM	7:15 AM	248	800	308	384	336	140	408	264	244	84	516	532	484
6	7:15 AM	7:30 AM	260	948	352	432	364	264	564	424	380	124	652	708	628
7	7:30 AM	7:45 AM	376	1,012	488	612	376	400	796	428	444	156	856	688	760
8	7:45 AM	8:00 AM	404	984	444	532	384	288	640	468	412	180	1,048	788	848
9	8:00 AM	8:15 AM	372	892	456	536	420	252	564	348	364	176	768	804	708
10	8:15 AM	8:30 AM	424	1,028	388	560	512	196	616	436	400	220	736	808	700
11	8:30 AM	8:45 AM	380	1,052	420	496	424	312	716	448	408	180	836	700	656
12	8:45 AM	9:00 AM	264	812	348	376	368	252	640	400	336	124	792	544	736
13	9:00 AM	9:15 AM	160	612	364	388	400	176	480	356	252	216	592	572	664
14	9:15 AM	9:30 AM	160	744	300	376	440	176	392	336	292	164	672	684	576
15	9:30 AM	9:45 AM	232	732	380	316	448	156	452	368	300	224	756	632	532
16	9:45 AM	10:00 AM	200	588	336	360	464	168	432	316	240	256	752	760	620
Time Slice		Ramp Metering Rate Per Lane Per Hour													
1	6:00 AM	6:15 AM	900	900	900	900			900	900	900	900	900	900	900
2	6:15 AM	6:30 AM	900	900	900	900			900	900	900	900	900	900	900
3	6:30 AM	6:45 AM	900	900	900	900			900	900	900	900	900	900	900
4	6:45 AM	7:00 AM	900	900	900	900			900	900	900	900	900	900	900
5	7:00 AM	7:15 AM	310	680	350	360			370	360	600	600	380	370	400
6	7:15 AM	7:30 AM	310	810	350	360			500	360	600	600	380	370	400
7	7:30 AM	7:45 AM	350	810	450	530			900	330	600	600	380	370	400
8	7:45 AM	8:00 AM	350	810	430	360	Interchange Under Construction		500	360	600	600	440	370	400
9	8:00 AM	8:15 AM	500	810	430	500			500	360	600	600	380	450	400
10	8:15 AM	8:30 AM	420	810	400	590			600	360	600	600	380	450	400
11	8:30 AM	8:45 AM	380	900	430	450			600	420	600	600	380	450	470
12	8:45 AM	9:00 AM	310	900	900	360			600	420	600	600	380	450	900
13	9:00 AM	9:15 AM	900	900	900	900			900	900	900	900	900	900	900
14	9:15 AM	9:30 AM	900	900	900	900			900	900	900	900	900	900	900
15	9:30 AM	9:45 AM	900	900	900	900			900	900	900	900	900	900	900
16	9:45 AM	10:00 AM	900	900	900	900			900	900	900	900	900	900	900
Time Slice		Cumulative Ramp Queue Length in Vehicles at End of Time Slice													
1	6:00 AM	6:15 AM	0	0	0	0			0	0	0	0	0	0	0
2	6:15 AM	6:30 AM	0	0	0	0			0	0	0	0	0	0	0
3	6:30 AM	6:45 AM	0	0	0	0			0	0	0	0	0	0	0
4	6:45 AM	7:00 AM	0	0	0	0			0	0	0	0	0	0	0
5	7:00 AM	7:15 AM	0	1	0	0			0	0	0	0	0	0	0
6	7:15 AM	7:30 AM	0	2	2	4			0	1	0	0	0	3	0
7	7:30 AM	7:45 AM	5	14	6	5			0	11	0	0	2	3	5
8	7:45 AM	8:00 AM	21	23	9	27	Interchange Under Construction		15	22	0	0	20	26	30
9	8:00 AM	8:15 AM	0	10	15	18			14	8	0	0	3	18	25
10	8:15 AM	8:30 AM	0	29	14	0			0	14	0	0	0	12	19
11	8:30 AM	8:45 AM	0	29	12	0			7	8	0	0	0	0	0
12	8:45 AM	9:00 AM	0	0	0	0			0	0	0	0	0	0	0
13	9:00 AM	9:15 AM	0	0	0	0			0	0	0	0	0	0	0
14	9:15 AM	9:30 AM	0	0	0	0			0	0	0	0	0	0	0
15	9:30 AM	9:45 AM	0	0	0	0			0	0	0	0	0	0	0
16	9:45 AM	10:00 AM	0	0	0	0			0	0	0	0	0	0	0
Time Slice		Average Metering Delays (Minutes)													
1	6:00 AM	6:15 AM	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	6:15 AM	6:30 AM	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	6:30 AM	6:45 AM	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	6:45 AM	7:00 AM	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	7:00 AM	7:15 AM	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	7:15 AM	7:30 AM	0.0	0.1	0.2	0.3			0.0	0.1	0.0	0.0	0.0	0.1	0.0
7	7:30 AM	7:45 AM	0.4	0.6	0.6	0.5			0.0	0.9	0.0	0.0	0.1	0.3	0.2
8	7:45 AM	8:00 AM	1.8	1.2	1.2	2.0	Interchange Under Construction		0.8	2.2	0.0	0.0	0.7	1.2	1.3
9	8:00 AM	8:15 AM	0.4	1.2	1.7	2.4			1.5	2.4	0.0	0.0	0.9	1.6	2.1
10	8:15 AM	8:30 AM	0.0	1.3	2.2	0.4			0.7	1.6	0.0	0.0	0.0	1.1	1.7
11	8:30 AM	8:45 AM	0.0	1.7	1.9	0.0			0.4	1.5	0.0	0.0	0.0	0.3	0.4
12	8:45 AM	9:00 AM	0.0	0.6	0.3	0.0			0.2	0.2	0.0	0.0	0.0	0.0	0.0
13	9:00 AM	9:15 AM	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	9:15 AM	9:30 AM	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	9:30 AM	9:45 AM	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	9:45 AM	10:00 AM	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0	0.0	0.0

Notes:

Light-shaded cells indicate on-ramp queues that would be contained within available storage. Expected average delays are also shown in light-shaded cells.

Exhibit 20: Recommended Ramp Metering Rates – Southbound AM Peak Period (Continued)

On-Ramp Location	From	To	3rd Street/DT	SR 12 WB Connecor	SR 12 EB Connecor	Baker/Cogla n Avenue	Hearn/Yolan da Avenue	Todd Road	Golf Course Drive	Rohnert Park Exp WB	Rohnert Park Exp EB	Gravenstein Hwy	Sierra Avenue	Pepper Road
Lanes at Limit Line			1	1	2	2	2	1	2	1	1	1	1	1
HOV by pass			0	1	0	0	0	0	1	1	1	1	1	0
Total Available Storage Vehicles (lane feet)			15 (450)	26 (780)	44 (1320)	28 (840)	15 (450)	19 (570)	30 (900)	15 (450)	30 (900)	36 (1,080)	17 (510)	13 (390)
Time Slice		Demands - Hourly Flow for the Entire On-ramp												
1	6:00 AM	6:15 AM	112	628	512	144	208	236	288	264	168	432	220	144
2	6:15 AM	6:30 AM	112	596	576	248	316	248	296	212	132	472	268	100
3	6:30 AM	6:45 AM	228	780	800	196	348	276	336	260	140	336	248	100
4	6:45 AM	7:00 AM	176	780	708	148	368	208	320	240	132	412	232	76
5	7:00 AM	7:15 AM	180	856	668	116	260	236	384	224	148	432	236	124
6	7:15 AM	7:30 AM	232	1,040	760	212	384	248	512	308	196	520	256	196
7	7:30 AM	7:45 AM	384	1,076	896	212	396	252	476	292	160	492	304	260
8	7:45 AM	8:00 AM	480	960	912	348	464	280	608	380	216	600	380	244
9	8:00 AM	8:15 AM	388	900	760	244	364	216	484	260	248	536	352	236
10	8:15 AM	8:30 AM	312	1,060	668	280	336	216	496	272	192	468	344	288
11	8:30 AM	8:45 AM	388	932	684	168	412	248	412	296	240	512	332	240
12	8:45 AM	9:00 AM	400	1,064	768	240	332	192	364	224	272	552	216	216
13	9:00 AM	9:15 AM	372	928	792	180	376	204	392	248	192	452	208	232
14	9:15 AM	9:30 AM	348	984	728	200	396	204	408	224	308	348	120	212
15	9:30 AM	9:45 AM	296	1,064	780	148	352	244	468	196	240	444	224	188
16	9:45 AM	10:00 AM	432	796	776	184	296	212	344	184	232	412	164	244
Time Slice		Ramp Metering Rate Per Lane Per Hour												
1	6:00 AM	6:15 AM	900	900	900	900	900	900	900	900	900	900	900	900
2	6:15 AM	6:30 AM	900	900	900	900	900	900	900	900	900	900	900	900
3	6:30 AM	6:45 AM	900	900	900	900	900	900	900	900	900	900	900	900
4	6:45 AM	7:00 AM	900	900	900	900	900	900	900	900	900	900	900	900
5	7:00 AM	7:15 AM	900	730	310	600	600	900	900	900	900	900	900	900
6	7:15 AM	7:30 AM	900	860	360	600	600	900	900	900	900	900	900	900
7	7:30 AM	7:45 AM	900	900	450	600	600	900	900	900	900	900	900	900
8	7:45 AM	8:00 AM	900	800	450	600	600	900	900	900	900	900	900	900
9	8:00 AM	8:15 AM	900	730	360	600	600	900	900	900	900	900	900	900
10	8:15 AM	8:30 AM	900	900	360	600	600	900	900	900	900	900	900	900
11	8:30 AM	8:45 AM	900	800	360	600	600	900	900	900	900	900	900	900
12	8:45 AM	9:00 AM	900	900	360	600	600	900	900	900	900	900	900	900
13	9:00 AM	9:15 AM	900	900	900	900	900	900	900	900	900	900	900	900
14	9:15 AM	9:30 AM	900	900	900	900	900	900	900	900	900	900	900	900
15	9:30 AM	9:45 AM	900	900	900	900	900	900	900	900	900	900	900	900
16	9:45 AM	10:00 AM	900	900	900	900	900	900	900	900	900	900	900	900
Time Slice		Cumulative Ramp Queue Length in Vehicles at End of Time Slice												
1	6:00 AM	6:15 AM	0	0	0	0	0	0	0	0	0	0	0	0
2	6:15 AM	6:30 AM	0	0	0	0	0	0	0	0	0	0	0	0
3	6:30 AM	6:45 AM	0	0	0	0	0	0	0	0	0	0	0	0
4	6:45 AM	7:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
5	7:00 AM	7:15 AM	0	0	12	0	0	0	0	0	0	0	0	0
6	7:15 AM	7:30 AM	0	6	22	0	0	0	0	0	0	0	0	0
7	7:30 AM	7:45 AM	0	10	21	0	0	0	0	0	0	0	0	0
8	7:45 AM	8:00 AM	0	14	24	0	0	0	0	0	0	0	0	0
9	8:00 AM	8:15 AM	0	23	34	0	0	0	0	0	0	0	0	0
10	8:15 AM	8:30 AM	0	23	21	0	0	0	0	0	0	0	0	0
11	8:30 AM	8:45 AM	0	21	12	0	0	0	0	0	0	0	0	0
12	8:45 AM	9:00 AM	0	22	24	0	0	0	0	0	0	0	0	0
13	9:00 AM	9:15 AM	0	0	0	0	0	0	0	0	0	0	0	0
14	9:15 AM	9:30 AM	0	0	0	0	0	0	0	0	0	0	0	0
15	9:30 AM	9:45 AM	0	0	0	0	0	0	0	0	0	0	0	0
16	9:45 AM	10:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
Time Slice		Average Metering Delays (Minutes)												
1	6:00 AM	6:15 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	6:15 AM	6:30 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	6:30 AM	6:45 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	6:45 AM	7:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	7:00 AM	7:15 AM	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	7:15 AM	7:30 AM	0.0	0.2	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	7:30 AM	7:45 AM	0.0	0.5	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	7:45 AM	8:00 AM	0.0	0.9	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	8:00 AM	8:15 AM	0.0	1.5	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	8:15 AM	8:30 AM	0.0	1.5	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	8:30 AM	8:45 AM	0.0	1.7	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	8:45 AM	9:00 AM	0.0	1.4	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	9:00 AM	9:15 AM	0.0	0.8	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	9:15 AM	9:30 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	9:30 AM	9:45 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	9:45 AM	10:00 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Notes:

Light-shaded cells indicate on-ramp queues that would be contained within available storage. Expected average delays are also shown in light-shaded cells.

Exhibit 21: Recommended Ramp Metering Rates – Southbound PM Peak Period

On-Ramp Location	From	To	Arata Lane	Old Redwood Hwy	Shiloh Road WB	Shiloh Road EB	Airport Blvd	Fulton Road	River Road WB	River Road EB	Hopper Avenue	Mendocino Avenue	Bicenten. Way	Steele Lane	College Avenue
Lanes at Limit Line			1	1	1	1	1	1	1	1	1	1	2	2	2
HOV by pass			1	1	0	1	0	0	1	1	1	0	1	0	0
Total Available Storage - Vehicles (lane feet)			30 (900)	47 (1,410)	17 (510)	29 (870)	35 (1,05	24 (720)	16 (480)	40 (1,200)	9 (270)	5 (150)	26 (780)	62 (1,860)	42 (1,260)
Time Slice		Demands - Hourly Flow for the Entire On-ramp													
1	3:00 PM	3:15 PM	184	556	424	412	828	120	564	304	308	340	1,092	1,148	824
2	3:15 PM	3:30 PM	316	680	460	384	752	152	548	308	296	264	920	1,104	816
3	3:30 PM	3:45 PM	320	644	424	700	1,036	160	624	388	284	304	1,064	1,164	840
4	3:45 PM	4:00 PM	228	652	404	512	872	172	532	448	244	300	1,052	1,028	804
5	4:00 PM	4:15 PM	272	784	440	512	1,004	136	504	348	192	308	1,044	1,052	896
6	4:15 PM	4:30 PM	276	700	376	540	852	164	424	340	180	192	908	968	920
7	4:30 PM	4:45 PM	204	700	408	752	1,080	172	468	364	240	240	1,008	880	884
8	4:45 PM	5:00 PM	280	632	452	560	1,000	124	440	412	232	220	912	1,000	888
9	5:00 PM	5:15 PM	268	720	360	668	1,092	180	452	304	284	320	1,084	844	1,052
10	5:15 PM	5:30 PM	244	740	352	460	996	260	400	360	228	236	960	924	1,004
11	5:30 PM	5:45 PM	252	696	336	408	960	204	440	280	220	284	1,016	796	884
12	5:45 PM	6:00 PM	220	500	324	324	788	152	348	312	212	352	836	660	856
13	6:00 PM	6:15 PM	132	692	416	380	684	92	472	288	248	244	872	772	752
14	6:15 PM	6:30 PM	200	592	392	312	496	104	388	264	288	208	776	740	652
15	6:30 PM	6:45 PM	216	724	300	328	452	152	384	236	268	216	728	672	632
16	6:45 PM	7:00 PM	164	488	264	152	448	100	308	228	228	172	712	676	592
Time Slice		Ramp Metering Rate Per Lane Per Hour													
1	3:00 PM	3:15 PM	310	560	430	360			460	330	600	600	440	630	430
2	3:15 PM	3:30 PM	310	560	370	360			460	330	600	600	440	590	430
3	3:30 PM	3:45 PM	310	400	430	590			500	330	600	600	450	590	400
4	3:45 PM	4:00 PM	310	560	430	450			460	330	600	600	450	520	400
5	4:00 PM	4:15 PM	310	600	430	450			460	290	600	600	450	520	470
6	4:15 PM	4:30 PM	310	560	370	450			370	290	600	600	380	520	490
7	4:30 PM	4:45 PM	310	560	430	590			370	290	600	600	440	520	470
8	4:45 PM	5:00 PM	310	560	450	500	Interchange Under Construction		370	330	600	600	380	520	470
9	5:00 PM	5:15 PM	310	560	350	590			370	290	600	600	470	450	550
10	5:15 PM	5:30 PM	310	600	350	360			370	290	600	600	440	450	550
11	5:30 PM	5:45 PM	310	560	350	360			370	250	600	600	440	900	470
12	5:45 PM	6:00 PM	310	400	350	360			290	250	600	600	360	900	470
13	6:00 PM	6:15 PM	310	900	350	360			900	250	600	900	360	900	400
14	6:15 PM	6:30 PM	900	900	900	900			900	900	900	900	900	900	900
15	6:30 PM	6:45 PM	900	900	900	900			900	900	900	900	900	900	900
16	6:45 PM	7:00 PM	900	900	900	900			900	900	900	900	900	900	900
Time Slice		Cumulative Ramp Queue Length in Vehicles at End of Time Slice													
1	3:00 PM	3:15 PM	0	0	0	0			4	0	0	0	14	0	0
2	3:15 PM	3:30 PM	1	0	17	0			3	0	0	0	0	0	0
3	3:30 PM	3:45 PM	3	29	16	3			8	0	0	0	2	3	16
4	3:45 PM	4:00 PM	0	20	11	0			7	11	0	0	5	11	29
5	4:00 PM	4:15 PM	0	27	12	0			0	11	0	0	4	22	29
6	4:15 PM	4:30 PM	0	26	11	2			0	9	0	0	11	17	29
7	4:30 PM	4:45 PM	0	27	8	18			4	11	0	0	12	0	27
8	4:45 PM	5:00 PM	0	13	9	11	Interchange Under Construction		4	15	0	0	19	5	28
9	5:00 PM	5:15 PM	0	17	12	9			8	5	0	0	20	2	32
10	5:15 PM	5:30 PM	0	17	10	17			0	6	0	0	7	13	23
11	5:30 PM	5:45 PM	0	16	8	15			0	3	0	0	9	0	25
12	5:45 PM	6:00 PM	0	16	3	0			0	5	0	0	11	0	24
13	6:00 PM	6:15 PM	0	0	17	0			0	2	0	0	18	0	23
14	6:15 PM	6:30 PM	0	0	0	0			0	0	0	0	0	0	0
15	6:30 PM	6:45 PM	0	0	0	0			0	0	0	0	0	0	0
16	6:45 PM	7:00 PM	0	0	0	0			0	0	0	0	0	0	0
Time Slice		Average Metering Delays (Minutes)													
1	3:00 PM	3:15 PM	0.0	0.0	0.0	0.0			0.2	0.0	0.0	0.0	0.4	0.0	0.0
2	3:15 PM	3:30 PM	0.1	0.0	1.3	0.0			0.4	0.0	0.0	0.0	0.3	0.0	0.0
3	3:30 PM	3:45 PM	0.4	1.7	2.3	0.2			0.6	0.0	0.0	0.0	0.1	0.1	0.7
4	3:45 PM	4:00 PM	0.0	2.3	1.9	0.0			0.9	0.9	0.0	0.0	0.2	0.4	1.7
5	4:00 PM	4:15 PM	0.0	2.0	1.7	0.0			0.1	1.9	0.0	0.0	0.3	1.0	1.9
6	4:15 PM	4:30 PM	0.0	2.4	2.0	0.2			0.0	1.8	0.0	0.0	0.6	1.2	1.8
7	4:30 PM	4:45 PM	0.0	2.4	1.5	0.9			0.3	1.7	0.0	0.0	0.8	0.3	1.8
8	4:45 PM	5:00 PM	0.0	2.0	1.2	1.6	Interchange Under Construction		0.6	2.0	0.0	0.0	1.1	0.2	1.8
9	5:00 PM	5:15 PM	0.0	1.4	1.8	1.0			0.8	2.0	0.0	0.0	1.2	0.3	1.7
10	5:15 PM	5:30 PM	0.0	1.5	2.0	1.8			0.2	1.1	0.0	0.0	0.9	0.6	1.6
11	5:30 PM	5:45 PM	0.0	1.6	1.7	2.3			0.0	1.1	0.0	0.0	0.5	0.3	1.6
12	5:45 PM	6:00 PM	0.0	2.1	1.1	0.3			0.0	0.9	0.0	0.0	0.8	0.0	1.6
13	6:00 PM	6:15 PM	0.0	0.3	1.6	0.0			0.0	0.8	0.0	0.0	1.1	0.0	1.8
14	6:15 PM	6:30 PM	0.0	0.0	0.3	0.0			0.0	0.0	0.0	0.0	0.4	0.0	0.5
15	6:30 PM	6:45 PM	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	6:45 PM	7:00 PM	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0	0.0	0.0

Notes:

Light-shaded cells indicate on-ramp queues that would be contained within available storage. Expected average delays are also shown in light-shaded cells.

Exhibit 21: Recommended Ramp Metering Rates – Southbound PM Peak Period (Continued)

On-Ramp Location	From	To	3rd Street/DT	SR 12 WB Connecor	SR 12 EB Connecor	Baker/Cogla n Avenue	Hearn/Yolan da Avenue	Todd Road	Golf Course Drive	Rohnert Park Exp WB	Rohnert Park Exp EB	Gravenstein Hwy	Sierra Avenue	Pepper Road
Lanes at Limit Line			1	1	2	2	2	1	2	1	1	1	1	1
HOV by pass			0	1	0	0	0	0	1	1	1	1	1	0
Total Available Storage - Vehicles (lane feet)			15 (450)	26 (780)	44 (1320)	28 (840)	15 (450)	19 (570)	30 (900)	15 (450)	30 (900)	36 (1,080)	17 (510)	13 (390)
Time Slice		Demands - Hourly Flow for the Entire On-ramp												
1	3:00 PM	3:15 PM	696	648	596	200	380	308	416	240	324	424	116	180
2	3:15 PM	3:30 PM	740	856	612	148	356	232	428	156	440	340	136	148
3	3:30 PM	3:45 PM	736	848	736	260	428	256	400	188	508	580	140	188
4	3:45 PM	4:00 PM	752	896	704	268	320	264	404	256	424	480	144	156
5	4:00 PM	4:15 PM	796	876	716	276	340	360	408	196	368	344	132	180
6	4:15 PM	4:30 PM	704	916	712	276	420	348	368	160	344	368	220	160
7	4:30 PM	4:45 PM	820	844	832	300	396	308	400	260	396	440	192	164
8	4:45 PM	5:00 PM	708	752	748	176	372	268	468	272	324	416	156	176
9	5:00 PM	5:15 PM	836	880	704	352	428	256	424	300	400	440	144	184
10	5:15 PM	5:30 PM	936	836	676	340	388	268	412	156	384	376	136	148
11	5:30 PM	5:45 PM	816	752	720	308	368	248	508	216	332	492	92	128
12	5:45 PM	6:00 PM	636	676	580	236	352	256	460	172	272	312	128	200
13	6:00 PM	6:15 PM	736	744	624	224	336	208	488	168	412	420	112	136
14	6:15 PM	6:30 PM	708	756	604	172	324	212	424	184	324	324	156	168
15	6:30 PM	6:45 PM	644	644	644	88	280	164	340	188	280	236	124	120
16	6:45 PM	7:00 PM	532	540	552	232	312	140	344	184	240	324	104	92
Time Slice		Ramp Metering Rate Per Lane Per Hour												
1	3:00 PM	3:15 PM	900	900	900	600	600	900	900	900	900	900	900	900
2	3:15 PM	3:30 PM	900	730	310	600	600	900	900	900	900	900	900	900
3	3:30 PM	3:45 PM	900	730	350	600	600	900	900	900	900	900	900	900
4	3:45 PM	4:00 PM	900	730	350	600	600	900	900	900	900	900	900	900
5	4:00 PM	4:15 PM	900	730	350	600	600	900	900	900	900	900	900	900
6	4:15 PM	4:30 PM	900	730	350	600	600	900	900	900	900	900	900	900
7	4:30 PM	4:45 PM	900	730	410	600	600	900	900	900	900	900	900	900
8	4:45 PM	5:00 PM	900	650	360	600	600	900	900	900	900	900	900	900
9	5:00 PM	5:15 PM	900	730	360	600	600	900	900	900	900	900	900	900
10	5:15 PM	5:30 PM	900	730	360	600	600	900	900	900	900	900	900	900
11	5:30 PM	5:45 PM	900	630	350	600	600	900	900	900	900	900	900	900
12	5:45 PM	6:00 PM	900	630	310	600	600	900	900	900	900	900	900	900
13	6:00 PM	6:15 PM	900	650	310	600	600	900	900	900	900	900	900	900
14	6:15 PM	6:30 PM	900	650	310	900	900	900	900	900	900	900	900	900
15	6:30 PM	6:45 PM	900	900	900	900	900	900	900	900	900	900	900	900
16	6:45 PM	7:00 PM	900	900	900	900	900	900	900	900	900	900	900	900
Time Slice		Cumulative Ramp Queue Length in Vehicles at End of Time Slice												
1	3:00 PM	3:15 PM	0	0	0	0	0	0	0	0	0	0	0	0
2	3:15 PM	3:30 PM	0	0	0	0	0	0	0	0	0	0	0	0
3	3:30 PM	3:45 PM	0	0	9	0	0	0	0	0	0	0	0	0
4	3:45 PM	4:00 PM	0	8	10	0	0	0	0	0	0	0	0	0
5	4:00 PM	4:15 PM	0	12	14	0	0	0	0	0	0	0	0	0
6	4:15 PM	4:30 PM	0	24	17	0	0	0	0	0	0	0	0	0
7	4:30 PM	4:45 PM	0	21	20	0	0	0	0	0	0	0	0	0
8	4:45 PM	5:00 PM	0	18	27	0	0	0	0	0	0	0	0	0
9	5:00 PM	5:15 PM	0	23	23	0	0	0	0	0	0	0	0	0
10	5:15 PM	5:30 PM	0	18	12	0	0	0	0	0	0	0	0	0
11	5:30 PM	5:45 PM	0	20	17	0	0	0	0	0	0	0	0	0
12	5:45 PM	6:00 PM	0	6	7	0	0	0	0	0	0	0	0	0
13	6:00 PM	6:15 PM	0	1	8	0	0	0	0	0	0	0	0	0
14	6:15 PM	6:30 PM	0	0	4	0	0	0	0	0	0	0	0	0
15	6:30 PM	6:45 PM	0	0	0	0	0	0	0	0	0	0	0	0
16	6:45 PM	7:00 PM	0	0	0	0	0	0	0	0	0	0	0	0
Time Slice		Average Metering Delays (Minutes)												
1	3:00 PM	3:15 PM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	3:15 PM	3:30 PM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	3:30 PM	3:45 PM	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	3:45 PM	4:00 PM	0.0	0.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	4:00 PM	4:15 PM	0.0	0.8	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	4:15 PM	4:30 PM	0.0	1.5	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	4:30 PM	4:45 PM	0.0	1.9	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	4:45 PM	5:00 PM	0.0	1.8	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	5:00 PM	5:15 PM	0.0	1.7	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	5:15 PM	5:30 PM	0.0	1.7	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	5:30 PM	5:45 PM	0.0	1.8	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	5:45 PM	6:00 PM	0.0	1.4	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	6:00 PM	6:15 PM	0.0	0.3	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	6:15 PM	6:30 PM	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	6:30 PM	6:45 PM	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	6:45 PM	7:00 PM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Notes:

Light-shaded cells indicate on-ramp queues that would be contained within available storage. Expected average delays are also shown in light-shaded cells.

FREEWAY TRAFFIC OPERATIONS WITH RAMP METERING

This section presents simulated freeway mainline traffic operations and travel time comparisons on US 101 with implementation of the recommended metering plan presented in the previous section.

FREEWAY TRAVEL TIMES

Exhibit 22 through Exhibit 29 provide summaries of potential freeway mainline travel times savings with the implementation of the recommended ramp metering plan.

In the northbound direction, expected travel time savings would range between one to two minutes during the AM peak period, and would be between approximately two to three minutes during the PM peak period.

In the southbound direction, expected travel time savings would range between two and one-half to four minutes during the AM peak period, and would be between approximately one and one-half to three minutes during the PM peak period.

FREEWAY BOTTLENECK AND QUEUES

Exhibit 30 and Exhibit 31 provide a comparison of expected freeway mainline queues and congested travel speeds during the peak of each analysis period. In summary, congested travel speeds would be increased with the implementation of the recommended metering plan.

During the AM peak period, the speeds for the congested section between the Santa Rosa Avenue interchange and the Third Street interchange on US 101 northbound would increase from 19 mph to 23 mph during the peak. For the southbound direction, congested speeds approaching the SR 12 bottleneck location would increase from 14 mph to 31 mph.

During the PM peak period, the speeds for the congested section between the Santa Rosa Avenue interchange and the Third Street interchange on US 101 northbound would increase from 19 mph to 21 mph during the peak. For the southbound direction, congested speeds approaching the SR 12 bottleneck location would increase from 19 mph to 23 mph.

Expected freeway queue lengths associated with bottleneck locations would also be reduced as illustrated, on the order of approximately one-quarter to three-quarters of a mile.

Exhibit 22: Freeway Travel Time Comparison – Northbound AM Peak Period

Start Time	Without Metering	With Metering	Difference	
	Minutes	Minutes	Minutes	Percent
6:00 AM	16.2	16.2	0.0	0%
6:15 AM	16.2	16.2	0.0	0%
6:30 AM	16.2	16.2	0.0	0%
6:45 AM	16.2	16.2	0.0	0%
7:00 AM	16.2	16.2	0.0	0%
7:15 AM	16.9	16.8	-0.2	-1%
7:30 AM	20.5	19.3	-1.2	-6%
7:45 AM	25.3	23.8	-1.4	-6%
8:00 AM	27.6	25.9	-1.7	-6%
8:15 AM	26.9	25.7	-1.2	-4%
8:30 AM	25.1	23.6	-1.5	-6%
8:45 AM	20.9	19.3	-1.6	-8%
9:00 AM	17.5	17.1	-0.4	-2%
9:15 AM	16.2	16.2	0.0	0%
9:30 AM	16.3	16.3	0.0	0%
9:45 AM	16.2	16.2	0.0	0%
Average Difference			-1.0	
Maximum Difference			-1.7	

Exhibit 23: Freeway Travel Time Comparison (Graphical) – Northbound AM Peak Period

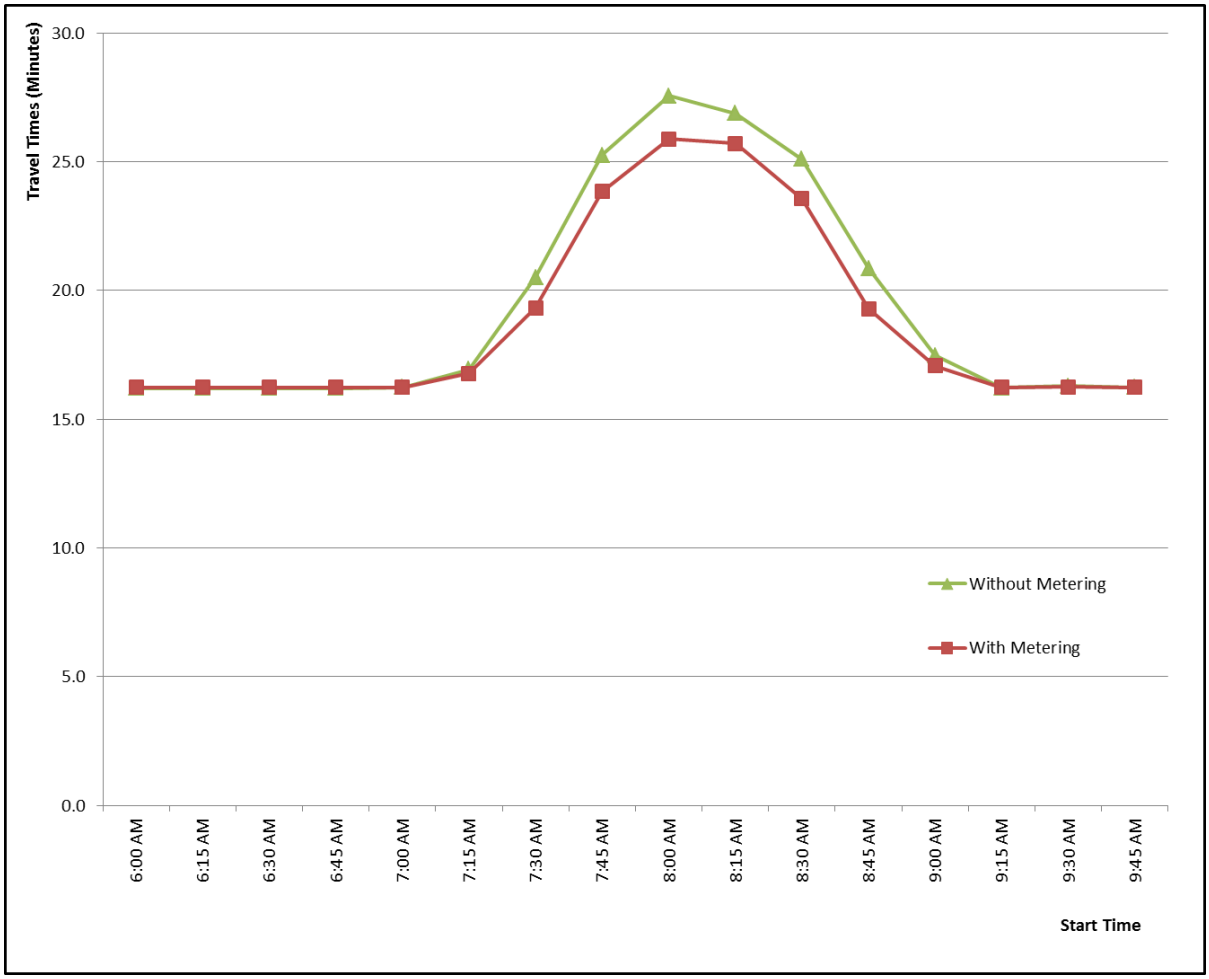

Exhibit 24: Freeway Travel Time Comparison – Northbound PM Peak Period

Start Time	Without Metering	With Metering	Difference	
	Minutes	Minutes	Minutes	Percent
3:00 PM	17.0	17.0	0.0	0%
3:15 PM	16.9	16.2	-0.7	-4%
3:30 PM	19.0	17.6	-1.4	-8%
3:45 PM	19.3	17.3	-2.1	-11%
4:00 PM	20.7	18.4	-2.3	-11%
4:15 PM	22.1	19.3	-2.8	-13%
4:30 PM	24.3	22.3	-1.9	-8%
4:45 PM	24.7	22.4	-2.3	-9%
5:00 PM	26.8	25.8	-1.0	-4%
5:15 PM	26.0	23.7	-2.2	-9%
5:30 PM	24.6	22.4	-2.3	-9%
5:45 PM	21.7	19.3	-2.4	-11%
6:00 PM	19.6	17.3	-2.3	-12%
6:15 PM	17.6	16.2	-1.4	-8%
6:30 PM	16.2	16.2	0.0	0%
6:45 PM	16.2	16.2	0.0	0%
Average Difference			-1.9	
Maximum Difference			-2.8	

Exhibit 25: Freeway Travel Time Comparison (Graphical) – Northbound PM Peak Period

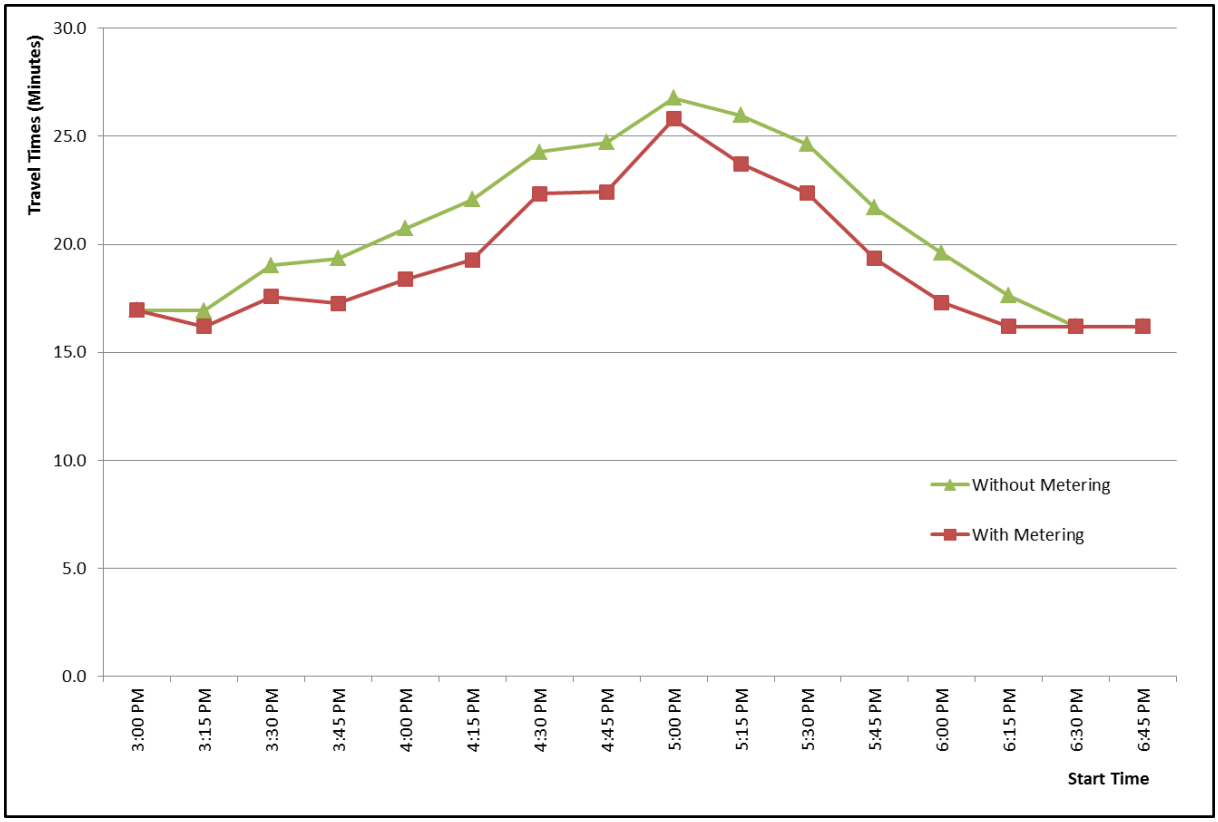

Exhibit 26: Freeway Travel Time Comparison – Southbound AM Peak Period

Start Time	Without Metering	With Metering	Difference	
	Minutes	Minutes	Minutes	Percent
6:00 AM	21.4	21.4	0.0	0%
6:15 AM	21.4	21.4	0.0	0%
6:30 AM	21.4	21.4	0.0	0%
6:45 AM	21.4	21.4	0.0	0%
7:00 AM	21.5	21.5	0.0	0%
7:15 AM	22.1	21.9	-0.2	-1%
7:30 AM	24.2	23.0	-1.2	-5%
7:45 AM	27.8	24.5	-3.3	-12%
8:00 AM	27.6	23.9	-3.7	-13%
8:15 AM	27.0	23.0	-4.0	-15%
8:30 AM	26.3	22.6	-3.6	-14%
8:45 AM	25.8	21.6	-4.2	-16%
9:00 AM	24.2	21.4	-2.8	-11%
9:15 AM	22.0	21.4	-0.6	-3%
9:30 AM	21.4	21.4	0.0	0%
9:45 AM	21.4	21.4	0.0	0%
Average Difference			-2.6	
Maximum Difference			-4.2	

Exhibit 27: Freeway Travel Time Comparison (Graphical) – Northbound AM Peak Period

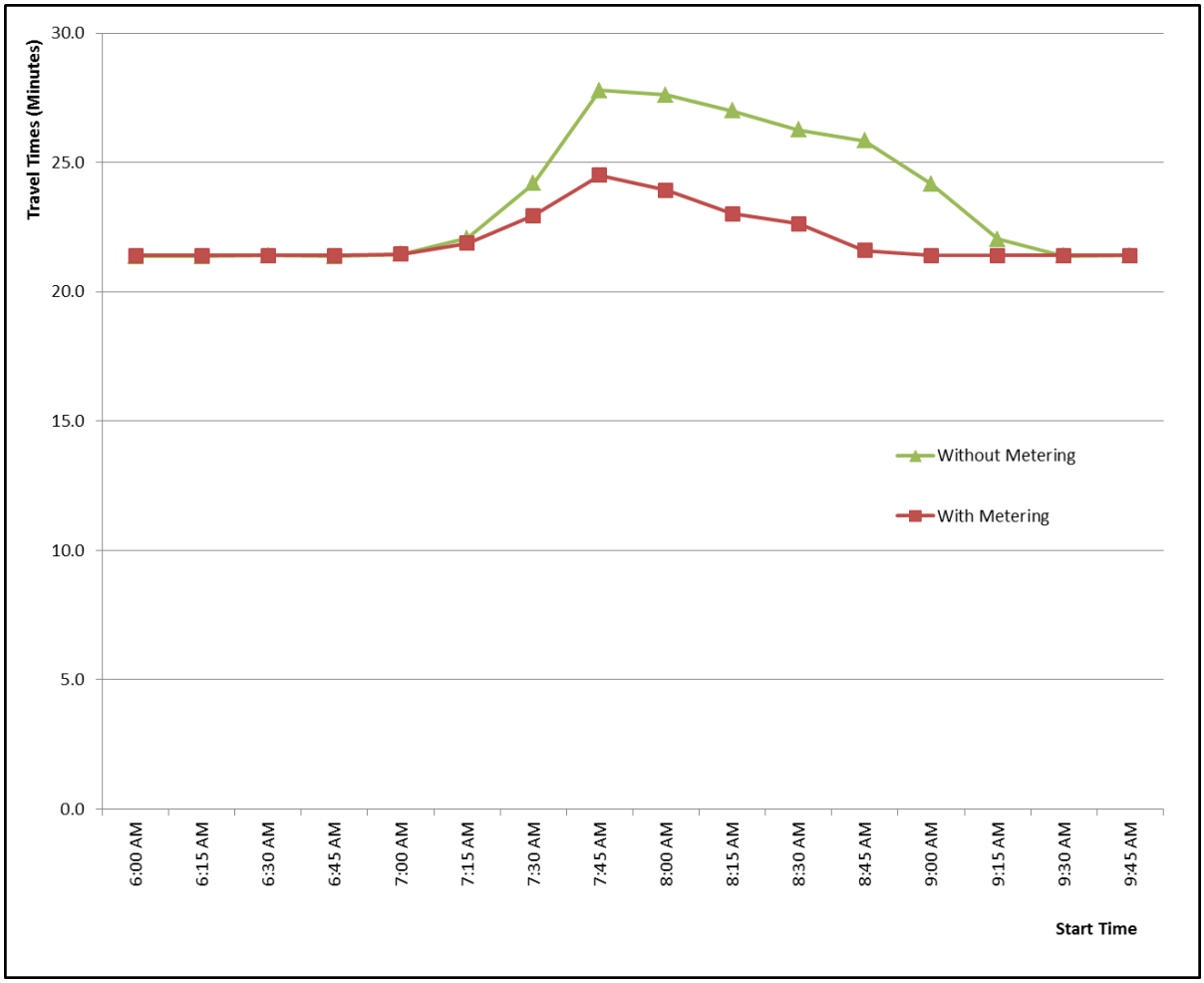

Exhibit 28: Freeway Travel Time Comparison – Southbound PM Peak Period

Start Time	Without Metering	With Metering	Difference	
	Minutes	Minutes	Minutes	Percent
3:00 PM	23.0	22.5	-0.4	-2%
3:15 PM	24.4	23.4	-1.0	-4%
3:30 PM	28.4	26.2	-2.2	-8%
3:45 PM	30.5	27.4	-3.0	-10%
4:00 PM	31.6	28.5	-3.1	-10%
4:15 PM	30.6	28.1	-2.5	-8%
4:30 PM	29.8	27.7	-2.1	-7%
4:45 PM	29.5	27.1	-2.4	-8%
5:00 PM	29.7	27.8	-1.9	-6%
5:15 PM	30.9	29.4	-1.5	-5%
5:30 PM	29.3	28.0	-1.3	-5%
5:45 PM	24.5	23.6	-0.9	-4%
6:00 PM	21.8	21.7	-0.2	-1%
6:15 PM	21.7	21.7	0.0	0%
6:30 PM	21.7	21.7	0.0	0%
6:45 PM	21.7	21.7	0.0	0%
Average Difference			-1.7	
Maximum Difference			-3.1	

Exhibit 29: Freeway Travel Time Comparison (Graphical) – Southbound PM Peak Period

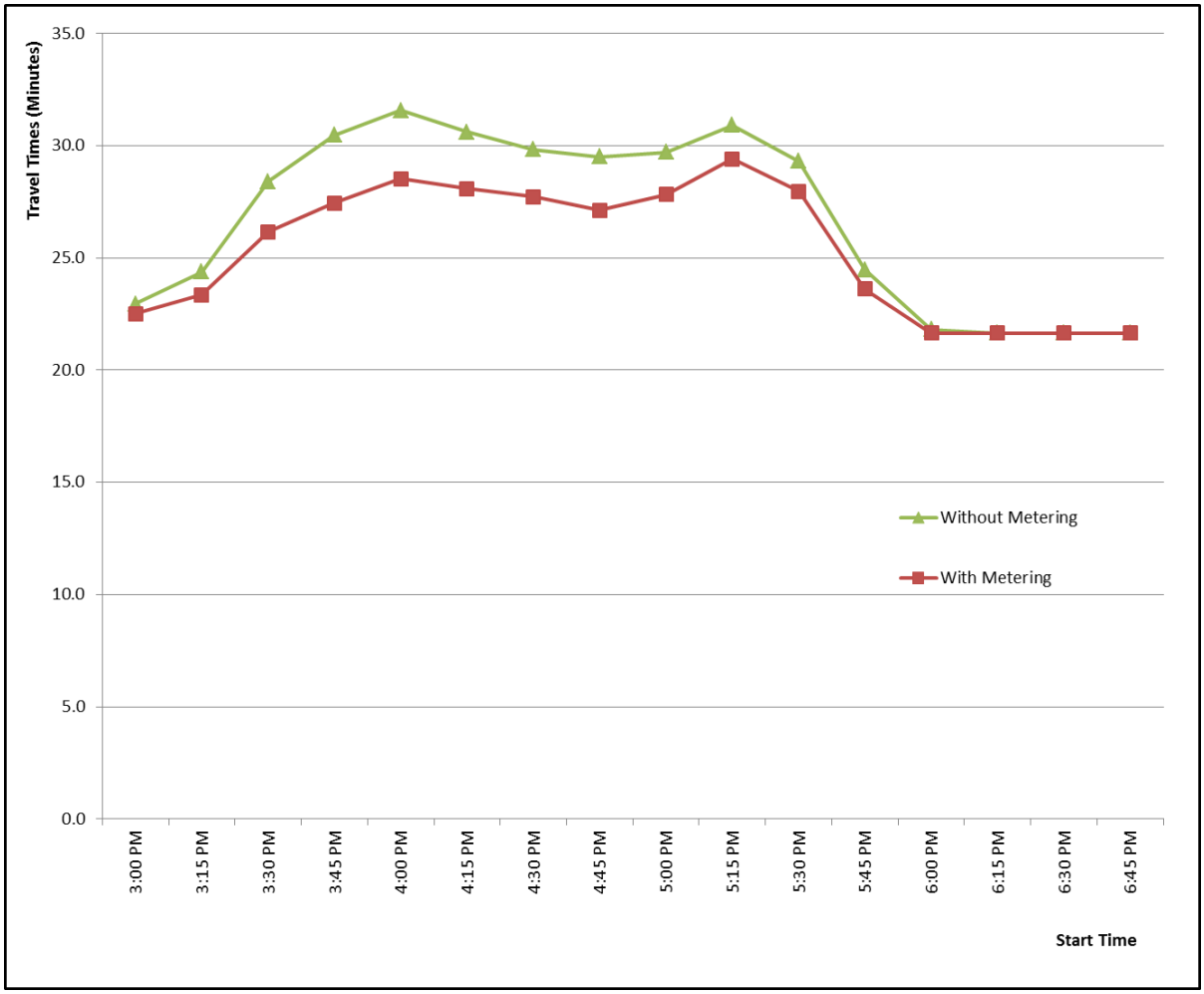

Exhibit 30: Freeway Queues and Congested Speeds Comparison – AM Peak Period

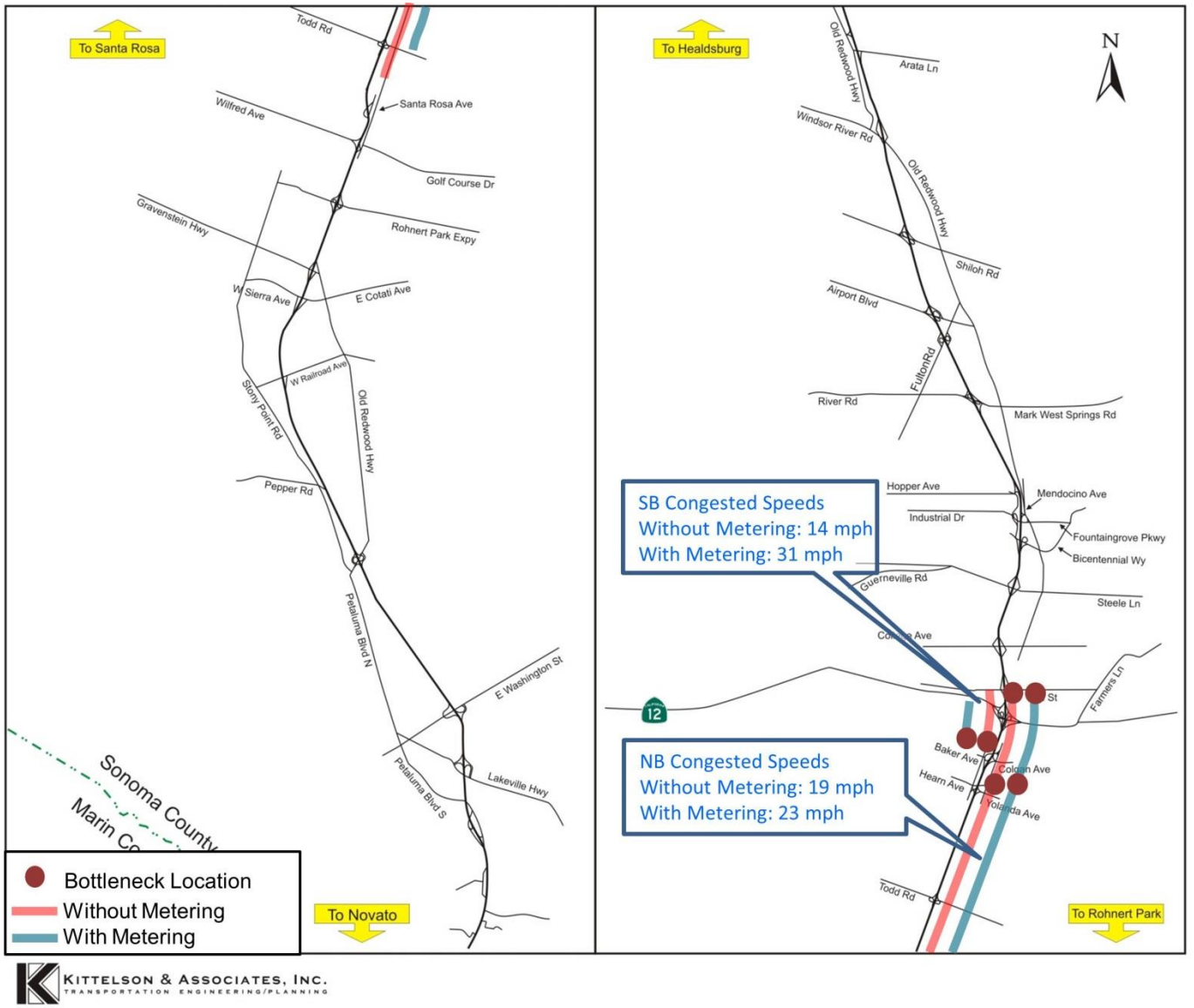

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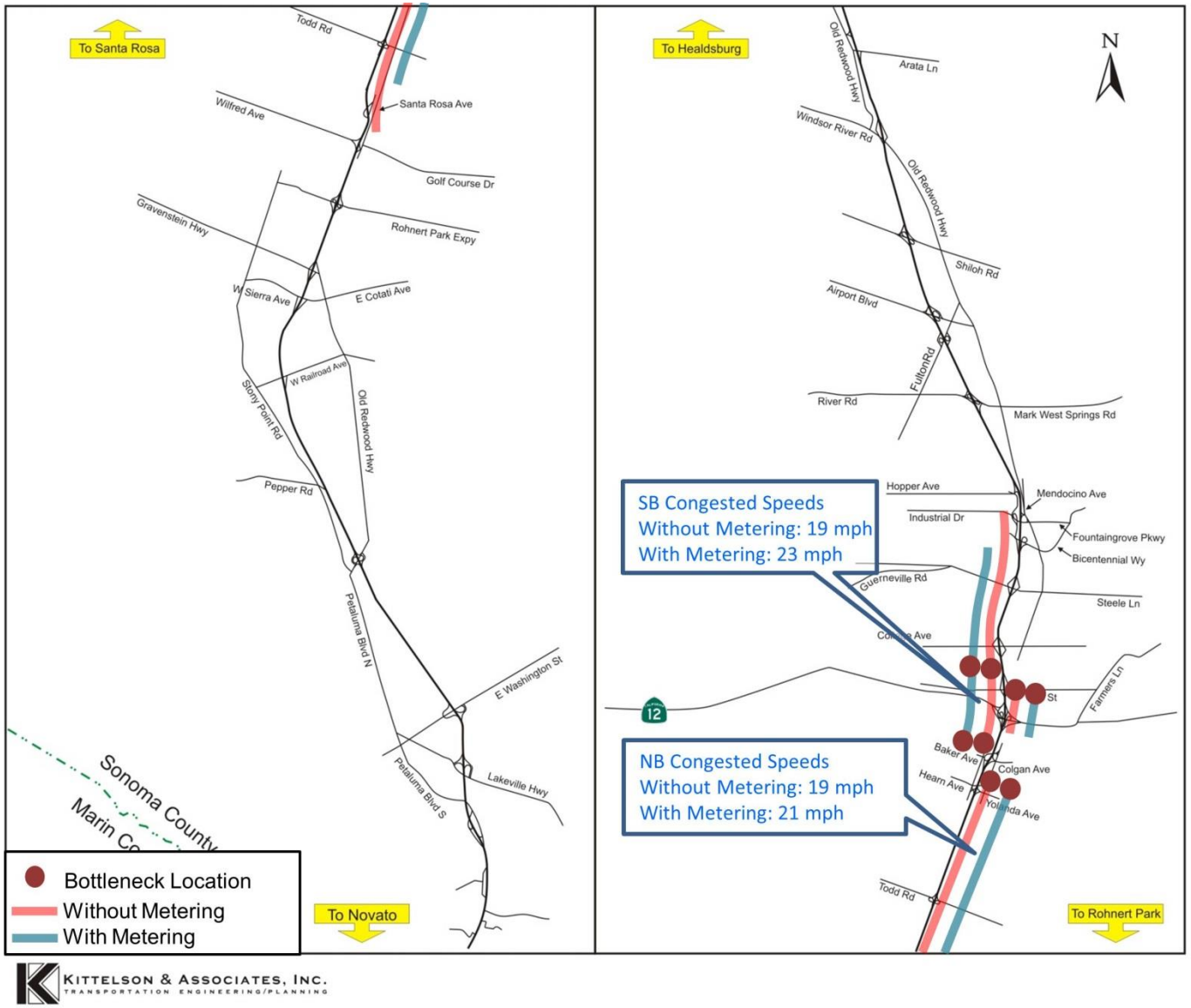
Exhibit 31: Freeway Queues and Congested Speeds Comparison – PM Peak Period



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SYSTEM PERFORMANCE MEASURES

Exhibit 32 provides a summary of freeway system-wide performance measures over the 4-hour AM and PM peak periods. Expected on-ramp delays were included as part of the total system vehicle-hours of travel (VHT). As shown in the exhibit, overall VHT are reduced under each analysis scenario as a result of the expected operational benefits from ramp metering. Vehicle-miles of travel (VMT) remain relatively unchanged, as all traffic would be served at the end of each analysis period. Average travel speeds on the mainline are expected to improve 5 to 17 percent.

Exhibit 32: System Performance Measures

	Scenario	VHT Vehicle Hours of Travel (Mainline & On-Ramps)	VMT Vehicle Miles of Travel (Mainline)	Average Speed (MPH - Mainline)
AM Peak Period				
Northbound	Without Metering	3,552	182,006	51.9
	With Metering	3,505	182,793	54.5
	Difference	-47	787	2.6
	% Difference	-1%	0%	5%
Southbound	Without Metering	4,431	257,075	58.1
	With Metering	4,306	256,914	62.5
	Difference	-125	-161	4.4
	% Difference	-3%	0%	8%
PM Peak Period				
Northbound	Without Metering	5,484	224,367	40.9
	With Metering	4,914	225,128	48.0
	Difference	-570	761	7.1
	% Difference	-10%	0%	17%
Southbound	Without Metering	6,072	271,083	44.8
	With Metering	6,030	271,299	48.4
	Difference	-42	216	3.6
	% Difference	-1%	0%	8%

THROUGHPUT COMPARISON

Exhibit 33 and Exhibit 34 provide comparisons of freeway throughput downstream of bottleneck and congested locations. While total peak period throughput remains relatively unchanged, this exhibit showed that the freeway would be able to serve more traffic during the height of the peak periods.

Exhibit 33: Freeway Throughput Comparison – AM Peak Period

Start Time		Northbound North of 3rd Street Interchange				Southbound South of Baker Interchange			
		Without RM	With RM	Difference	% Diff	Without RM	With RM	Difference	% Diff
1	6:00 AM	2,208	2,208	0	0%	2,116	2,116	0	0%
2	6:15 AM	2,588	2,588	0	0%	2,400	2,400	0	0%
3	6:30 AM	3,285	3,285	0	0%	3,057	3,057	0	0%
4	6:45 AM	3,306	3,306	0	0%	3,016	3,016	0	0%
5	7:00 AM	4,046	4,046	0	0%	3,173	3,172	-1	0%
6	7:15 AM	4,397	4,497	100	2%	3,918	3,999	81	2%
7	7:30 AM	4,462	4,562	100	2%	3,861	3,957	96	2%
8	7:45 AM	4,462	4,562	100	2%	3,924	3,986	62	2%
9	8:00 AM	4,486	4,586	100	2%	3,882	3,986	104	3%
10	8:15 AM	4,492	4,592	100	2%	3,843	3,931	88	2%
11	8:30 AM	4,482	4,582	100	2%	3,774	3,866	92	2%
12	8:45 AM	4,515	4,600	85	2%	3,807	3,841	34	1%
13	9:00 AM	4,429	4,231	-198	-4%	3,687	3,446	-241	-7%
14	9:15 AM	3,918	3,918	0	0%	3,645	3,180	-465	-13%
15	9:30 AM	4,320	4,320	0	0%	3,287	3,287	0	0%
16	9:45 AM	4,069	4,069	0	0%	3,267	3,267	0	0%
Total		**63,465**	**63,962**	**487**	**1%**	**54,657**	**54,507**	**-150**	**0%**

Note: Throughput is measured in flow rates (vehicles per hour).

Exhibit 34: Freeway Throughput Comparison – PM Peak Period

Start Time		Northbound North of 3rd Street Interchange				South of the Baker Interchange			
		Without RM	With RM	Difference	% Diff	Without RM	With RM	Difference	% Diff
1	3:00 PM	4,655	4,713	58	1%	3,591	3,676	85	2%
2	3:15 PM	4,398	4,452	54	1%	3,596	3,675	79	2%
3	3:30 PM	4,698	4,744	46	1%	3,681	3,774	93	3%
4	3:45 PM	4,590	4,646	56	1%	3,627	3,721	94	3%
5	4:00 PM	4,475	4,489	14	0%	3,757	3,841	84	2%
6	4:15 PM	4,603	4,514	-89	-2%	3,675	3,545	-130	-4%
7	4:30 PM	4,398	4,552	154	4%	3,692	3,777	85	2%
8	4:45 PM	4,634	4,683	49	1%	3,534	3,407	-127	-4%
9	5:00 PM	4,739	4,739	0	0%	3,755	3,663	-92	-2%
10	5:15 PM	4,741	4,741	0	0%	3,772	3,860	88	2%
11	5:30 PM	4,498	4,695	197	4%	3,669	3,455	-214	-6%
12	5:45 PM	4,342	4,358	16	0%	3,109	2,988	-121	-4%
13	6:00 PM	4,128	4,131	3	0%	3,677	3,700	23	1%
14	6:15 PM	3,930	4,027	97	2%	3,191	3,297	106	3%
15	6:30 PM	3,914	3,980	66	2%	3,122	3,122	0	0%
16	6:45 PM	4,003	3,540	-463	-12%	2,954	2,949	-5	0%
Total		**70,746**	**71,004**	**258**	**0%**	**56,402**	**56,450**	**48**	**0%**

Note: Throughput is measured in flow rates (vehicles per hour).

RAMP METERING EFFECTS ON HIGHWAY SAFETY

Ramp metering not only allows for consistent traffic flow on the mainline and more efficient use of freeway capacity, it also improves safety, both in the merge area and on the mainline, particularly when mainline congestion has not already occurred downstream of the ramp. In the merge area, ramp metering allows a single vehicle or a small platoon (usually two vehicles) to merge onto the mainline and into traffic gaps, resulting in minimal interference and the reduced potential for sideswipe crashes. The speed differential would be reduced between entering vehicles and mainline vehicles because multiple vehicles would not have to compete for the same gaps in mainline traffic. Queues would also be less likely to form at the merge point and the full length of the acceleration distance could be used. On the mainline, the smoother merging process makes it unnecessary for mainline vehicles to slow down considerably (and sometimes unexpectedly), to let vehicles enter the freeway. Consequently, ramp metering minimizes lane change maneuvers by impatient upstream drivers, reduces rear-end collisions, and is less likely to cause upstream backups.

These safety benefits are well documented in a range of studies dating back to 1975, as presented in Exhibit 35. The implementation of ramp metering achieved safety benefits in all the locations. While the measures of effectiveness are different in each of the studies, the reduced number of collisions is substantial in each case. For instance, the two studies along I-580 in the Tri-Valley region (Dublin, Pleasanton, Livermore) of the Bay Area indicated a reduction of 21 and 25 percent in total collisions, measured for the same 10- to 12-month period, before and after the implementation. Based on the other studies, the safety impact could be as high as 50 percent.

Exhibit 35: Ramp Metering Effects on Highway Safety

Location	Collision Reduction	Year of Evaluation
Pleasanton, CA	21% in total collisions	2004
Livermore, CA	25% in total collisions	2008
Sacramento, CA	50% (*)	1984
Los Angeles, CA	20% (*)	1975
Portland, OR	43% in peak period collisions	1982
Seattle, WA	38% in collision rate	1981–1987
Denver, CO	50% in rear-end & side-swipe collisions	1982
Minneapolis-St. Paul, MN	26% in peak hour collisions	2000
Detroit, MI	50% in total collisions	Not Known
Long Island, NY	15% in collision rate	1987–1991

* Source of data did not indicate whether the reduction was in total collision or collision rate.

APPENDICES

Appendix A: On-Ramp Storage Aerial Graphics

Appendix B: FREQ Calibration Memo

Appendix C: Expected On-ramp Queue Charts with Ramp Metering