KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING / PLANNING
155 Grand Avenue, Suite 900, Oakland, CA 94612 P 510.839.1742 F 510.839.0871

REVISED DRAFT MEMORANDUM

Date: July 2, 2015 Project #: 13683.302
To: Winnie Chung
Metropolitan Transportation Commission (MTC)
Adrian Levy, Alan Chow
Caltrans
From: Jorge Andres Barrios
Project: Solano I-80 Ramp Metering - Stage II Implementation Before Study
Subject: Deliverable 3.2A – Draft Optimal Metering Rates

This memorandum presents the optimal metering rates for the I-80 Stage II Ramp Metering Implementation Plan in Solano County. Kittelson & Associates, Inc. (KAI) developed these optimal metering rates based on our understanding of the project through its Feasibility and Stage I stages, the available storage capacity on the on-ramps, the calibrated FREQ models documented in Deliverable 3.1 of this project, and our experience performing field work on the corridor.

EXECUTIVE SUMMARY

The optimal metering rates are expected to result in up to 3.2 minutes (or nine percent) of travel time savings on the eastbound mainline on a typical Friday afternoon and up to 6.5 minutes (or 22 percent) on the westbound mainline on a typical Sunday afternoon. Delays and queues at the on-ramps are not expected to hinder traffic operations on local streets. Exhibit 1 below provides a high-level summary of the potential ramp metering strategies.

Exhibit 1: Summary of Ramp Metering Considerations

PM Peak Period Metering Plan												
Corridor	Day of Week	From	11 AM	12 PM	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM	7 PM	8 PM
		To:	12 PM	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM	7 PM	8 PM	9 PM
I-80 EB	Monday through Thursday											
I-80 EB	Typical Friday											
I-80 EB	Long-Weekend Friday											
I-80 WB	Typical Sunday											
AM Peak Period Metering Plan												
Corridor	Day of Week	From	4 AM	5 AM	6 AM	7 AM	8 AM	9 AM	10 AM	11 AM	12 PM	1 PM
		To:	5 AM	6 AM	7 AM	8 AM	9 AM	10 AM	11 AM	12 PM	1 PM	2 PM
I-80 WB	Monday through Friday											

Ramp meters on standby, resting in green unless freeway conditions deteriorate
Ramp meters actively metering under typical conditions

EXISTING ON-RAMP QUEUES

Appendix A contains the list of on-ramps within Stage II limits, including those metered as part of Stage I. As part of the "before" data collection, visual observations of these on-ramps were performed by KAI staff to establish baseline conditions, including the presence of any on-ramp queues (usually due to delays at the merge point). Any queues of this nature are likely to interact with ramp metering queues and contribute to the total number of vehicles that must be accommodated on each on-ramp.

Existing on-ramp queues, described in more detail in Appendix B, were taken into account in the development of optimal metering rates, as described in later sections.

TIME PERIODS

Two FREQ models were developed and calibrated for the purpose of developing optimized ramp metering rates for the corridor. The FREQ models are based on 15-minute counts, meaning that the optimal metering rates will be responsive to 15-minute fluctuations in ramp volumes.

Exhibit 2: FREQ Model Summary

Corridor	Day of Week	FREQ Time Coverage	Proposed Metering Hours
I-80 Eastbound	Typical Friday	2 PM – 7PM	Noon – 8 PM
I-80 Westbound	Typical Sunday	3 PM – 7 PM	3 PM – 8 PM

These corridors were selected based on the implementation plan included in the *Solano I-80 Final Staging and Metering Plan* produced by KAI in July 2013[1] (the "Feasibility" study). In the Feasibility study, I-80 eastbound on Friday afternoons and I-80 westbound on Sunday afternoons were identified as the corridors benefiting the most from timely implementation of below-demand ramp metering.

Potential ramp metering strategies for other days of week and associated peak periods are included in the *Considerations for Alternative Metering Periods* section.

[1] *Solano County I-80 Ramp Metering Deliverable 3.4B –Final Ramp Metering Feasibility and Implementation Plan,* Kittelson & Associates, Inc. (submitted on July 1, 2013)

ASSUMPTIONS

The following assumptions, which are in accordance with those in the Feasibility study, were used in the development of optimal metering rates:

- Generally, ramps downstream of a bottleneck were recommended for metering at the hourly demand rate or higher for each ramp. On free-flow sections, the ramp meters may rest on solid green.
- Ramp meters would operate with a policy of one car per green for all locations, except when the additional throughput of two cars per green is necessary to maintain on-ramp queues within the available storage.
- Ramp meter rates were developed based on practical metering operation of 240 vehicles per hour per lane (vphpl) as a minimum limit and 900 vphpl as a maximum limit. Ramps with two cars per green operation were assumed to serve up to 1,000 vphpl
- The ramp metering implementation plan would increase freeway capacity by approximately 2.5 percent[2].
    - The 2.5 percent increase in capacity was applied only in sections to be metered under Stage II. In other words, capacity was held constant in the Stage I section of I-80 eastbound in Fairfield and in the FREQ model sections that will not be metered.
- The travel time savings quantified for the I-80 mainline are based on the optimal metering rates. These optimal rates will be subject to fine-tuning prior to and following activation to prevent on-ramp queuing from spilling beyond the available storage. The adjustments will not significantly impact mainline travel times.

[2] This is a conservative assumption based on capacity increases observed from other Bay Area freeway corridors where ramp meters were implemented.

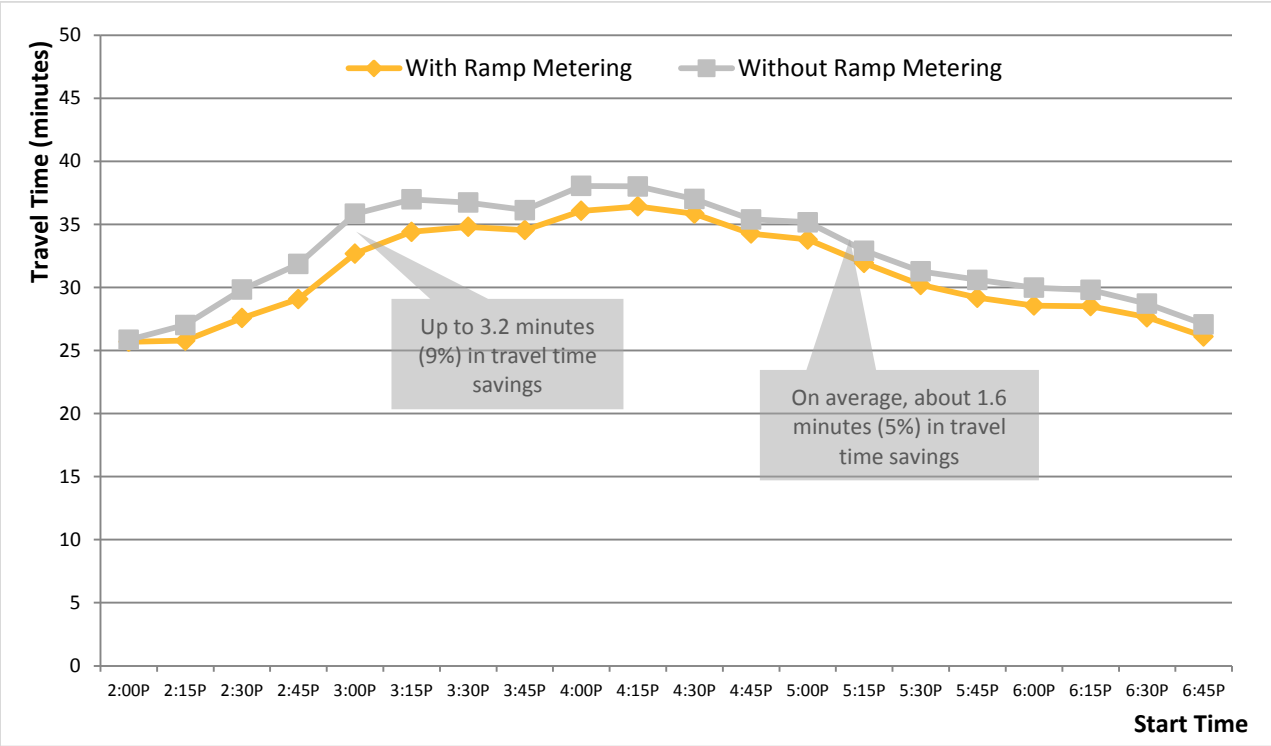
FINDINGS

Ramp metering rates are based on the FREQ corridor optimization module, with the objective to maximize passenger input to the freeway under the constraint that ramp queues do not exceed available storage. On-ramp storage lengths, calculated from a 30 feet per vehicle assumed length, are shown graphically on aerial photos attached in Appendix C. The following findings apply to the FREQ-optimized corridors: I-80 eastbound on typical Friday PM peak periods and I-80 westbound on typical Sunday PM peak periods.

- Exhibit 3 and Exhibit 4 present the travel time savings that are expected following the implementation of ramp metering on eastbound and westbound I-80, respectively. Appendix D contains the optimal ramp metering rates used in the analysis.
    - Optimal ramp metering rates on Stage I on-ramps were re-calculated based on the updated traffic data collected as part of Stage II.
    - Average delays at the on-ramps due to ramp metering were compared with previous estimates from the Feasibility study. The range of the average delays in this study is in line with the range in the Feasibility study (i.e., one to four minutes). Local on-ramps are on the lower end of this delay range, while freeway-to-freeway connectors are on the higher end.
- All on-ramp queues[3] would be contained within available storage without affecting traffic on local streets. Two on-ramps required special adjustments to the optimal metering rates:
    - On westbound I-80, SR 37 on-ramp queues due to ramp metering are likely to interact with existing queues at the merge point downstream. Optimal metering rates were adjusted upward to limit additional queuing at this location. The complex interaction between queues at this location will be a focus of the activation field observations.
    - On eastbound I-80, hourly flow rates on the Alamo Drive on-ramp occasionally exceed 1,000 vehicles per hour. Optimal ramp metering rates were adjusted to 1,000 vehicles per hour under the assumption that Alamo Drive would operate with two cars per green. With two cars per green, on-ramp queues on Alamo Drive are expected to be contained within the available storage. The activation field observations will verify that throughput at this on-ramp meets or exceeds the 1,000 vehicles per hour assumption.

[3] Ramp queues are in number of vehicles and reflect unserved demand at the end of each simulation time interval and would accumulate into the next time interval. Note that the queues shown are steady state at the end of each time interval, which compares the flow rate versus metering rate. Ramps with zero steady state queues at the end of the time interval would have transient short queues within that time, which would vary throughout the period when platoons of vehicles arrive from an upstream signal; however, the queues are expected to be of short duration (persisting for only a few signal cycles during the period) and length. Monitoring of 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.

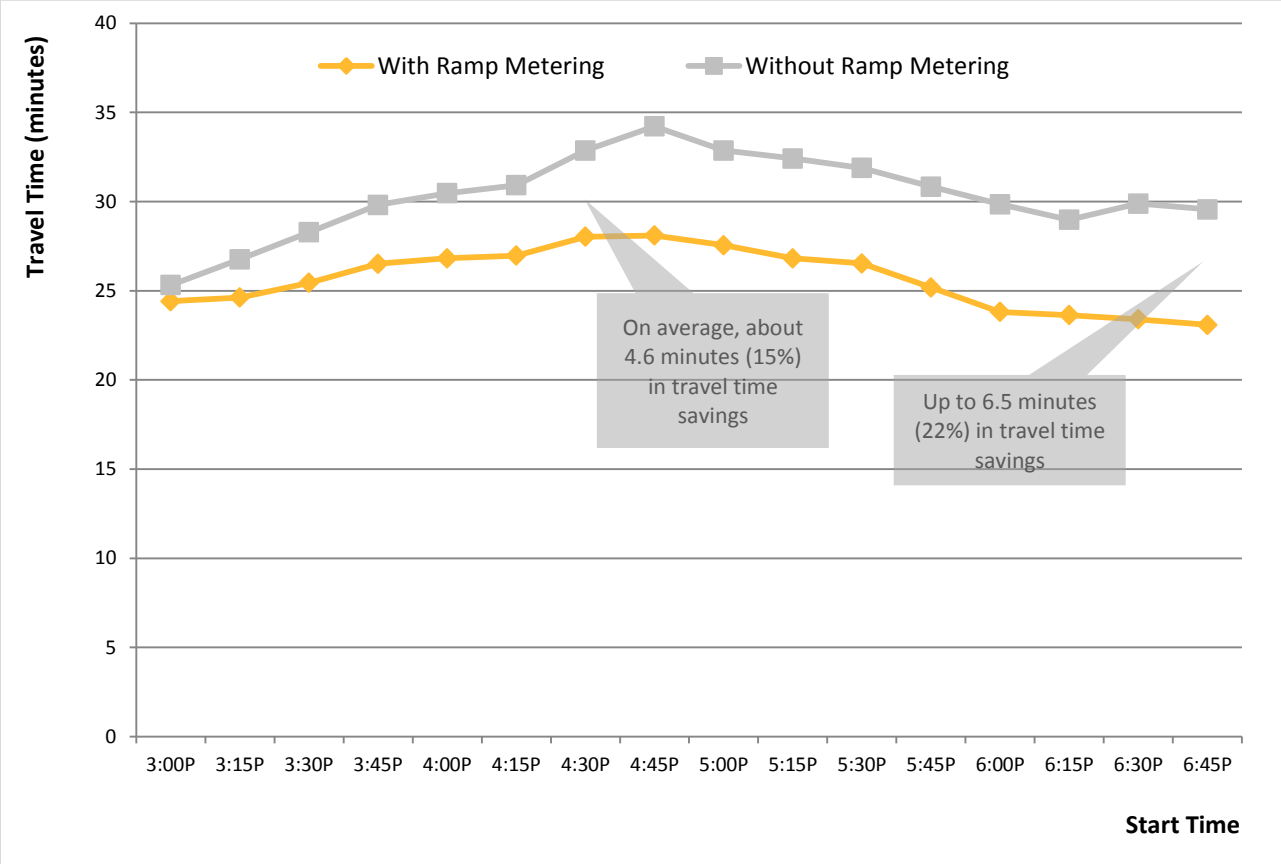
Exhibit 3: I-80 Eastbound Typical Friday PM– Travel Time Comparison



Start Time	Without Ramp Metering	With Ramp Metering	Savings	
			Minutes	Percent
2:00 PM	25.9	25.7	0.2	1%
2:15 PM	27.0	25.8	1.3	5%
2:30 PM	29.8	27.6	2.3	8%
2:45 PM	31.9	29.1	2.8	9%
3:00 PM	35.9	32.7	3.2	9%
3:15 PM	37.0	34.4	2.6	7%
3:30 PM	36.7	34.8	1.9	5%
3:45 PM	36.1	34.6	1.6	4%
4:00 PM	38.1	36.1	2.0	5%
4:15 PM	38.0	36.4	1.6	4%
4:30 PM	37.0	35.9	1.2	3%
4:45 PM	35.4	34.3	1.1	3%
5:00 PM	35.2	33.8	1.4	4%
5:15 PM	32.9	31.9	1.0	3%
5:30 PM	31.3	30.2	1.1	3%
5:45 PM	30.6	29.2	1.4	5%
6:00 PM	30.0	28.6	1.4	5%
6:15 PM	29.8	28.5	1.3	4%
6:30 PM	28.7	27.6	1.1	4%
6:45 PM	27.1	26.1	1.0	4%
Average	32.7	31.2	1.6	5%

Travel time is on GP lanes for a distance of 27.79 miles from Magazine Street to north of Leisure Town Road.

Exhibit 4: I-80 Westbound Sunday PM– Travel Time Comparison



Start Time	Without Ramp Metering	With Ramp Metering	Savings	
			Minutes	Percent
3:00 PM	25.3	24.4	0.9	4%
3:15 PM	26.8	24.6	2.2	8%
3:30 PM	28.3	25.5	2.8	10%
3:45 PM	29.8	26.5	3.3	11%
4:00 PM	30.5	26.8	3.7	12%
4:15 PM	30.9	27.0	4.0	13%
4:30 PM	32.9	28.0	4.8	15%
4:45 PM	34.2	28.1	6.1	18%
5:00 PM	32.9	27.6	5.3	16%
5:15 PM	32.4	26.8	5.6	17%
5:30 PM	31.9	26.5	5.4	17%
5:45 PM	30.8	25.2	5.7	18%
6:00 PM	29.9	23.8	6.0	20%
6:15 PM	29.0	23.6	5.4	18%
6:30 PM	29.9	23.4	6.5	22%
6:45 PM	29.6	23.1	6.5	22%
Average	30.3	25.7	4.6	15%

Travel time is on all lanes (no HOV enforcement on Sundays) for a distance of 26.46 miles from north of I-505 to south of Tennessee Street.

CONSIDERATIONS FOR OTHER DAYS AND PEAK PERIODS

Three other time periods have been analyzed as part of the Feasibility or Stage I studies:

- Monday through Thursday ("midweek") PM peak period on I-80 eastbound
- Long-weekend Friday PM peak period on I-80 eastbound
- Weekday AM peak period on I-80 westbound

FREQ models were not used to optimize ramp metering for these alternative peak periods. Instead, the considerations in this section were based on the May 2014 traffic volume data, floating car runs, and congestion reports documented in the Stage II Before memo. January 2015 INRIX data provided by MTC were also taken into consideration.

The proposed approach to be explored during *Task 3.3 – Time of Day Plans* is to first accommodate the optimal metering rates for the typical Friday PM peak period on I-80 eastbound and the typical Sunday PM peak period on I-80 westbound. The intent would be to deliver the most benefits to the I-80 corridor for those two periods. Opportunities to fit in near-optimal metering rates for the alternative peak periods would then be sought.

The remainder of this section provides specific considerations for each alternative peak period in light of this proposed approach.

Eastbound PM Peak Period, Monday through Thursday: 2 PM-7PM

Currently, Stage I ramp meters in Fairfield operate at solid green in the midweek PM peak period, except when the I-80 mainline becomes congested, at which point the meters switch to typical Friday metering rates. A review of January 2015 INRIX data and a comparison of Stage I and Stage II traffic volumes suggest that Monday through Thursday congestion on I-80 has increased over the last two years, especially in Fairfield. Because of this, additional ramp metering on Monday through Thursday is now more likely to result in significant travel time savings.

It is proposed that ramp metering be gradually extended to Monday through Thursday, eventually using metering rates similar to or higher than the typical Friday rates. At first, the current plan (i.e., cycling only when I-80 becomes congested) could be maintained in Fairfield and extended to Vallejo and Vacaville. In the future, the ramp meters could be programmed to cycle more regularly.

Eastbound Long-Weekend Friday 1 PM-8 PM

The Stage I time-of-day plans produced by KAI[4] recommended that ramp meters in Fairfield operate for an extended period—from 2 PM to 8 PM—on long-weekend Fridays. The ramp metering rates on long-weekend Fridays were identical to those identified for typical Fridays. A review of January 2015 INRIX congestion scans and comments received from stakeholders as part of this project suggest that congestion now starts before 2 PM on long-weekend Fridays.

Ramp metering is most effective when implemented before congestion starts. To gain additional travel time savings on long-weekend Fridays, ramp meters can be programmed to start operating at noon. In the first two hours of operation (noon – 2 PM), the ramp meters could display solid green unless the I-80 mainline becomes congested, at which point the meters would switch to the metering rates at the beginning of typical Friday operations (2 PM). The 7-8 PM cycling is also proposed to be expanded to all ramps in Stage II, using metering rates similar to those at the end of typical Friday operations.

Westbound AM Peak Period, Monday through Friday: 5 AM-10 AM

The AM peak period of weekdays on I-80 westbound is generally free-flow. Nevertheless, ramp metering may still provide safety benefits by smoothing the on-ramp merging process during non-recurring congestion. Therefore, it is proposed that ramp meters operate at solid green in the weekday AM peak period, except when the I-80 mainline becomes congested, at which point the meters would switch to 4-second cycle lengths, equivalent to 900 vehicles per hour per lane.

CONCLUSION

The KAI team derived optimal metering rates based on our understanding of the project through its Feasibility and Stage I stages, the available storage capacity on the on-ramps, the calibrated FREQ models documented in Deliverable 3.1 of this project, and our experience performing field work on the corridor.

The optimal metering rates are expected to result in up to 3.2 minutes of travel time savings on the eastbound mainline on typical Friday afternoons, equivalent to travel time reduction of nine percent. Similarly, travelers on westbound mainline on Sunday afternoons may experience up to 6.5 minutes of travel time savings due to ramp metering, or about 22 percent lower than the baseline. Delays and queues at the on-ramps due to ramp metering have been assessed and are not expected to hinder traffic operations on local streets.

[4] *Deliverable 3.3B – Revised TOD Plans*, Kittelson & Associates, Inc. (December 27, 2013)

Potential ramp metering strategies for other days of week and associated peak periods were also evaluated and are summarized in Exhibit 1.

APPENDIX A: STAGE II RAMP METER LOCATIONS

	Eastbound		Westbound
1	Redwood Pkwy On-ramp	1	I-505 Connector
2	Columbus Pkwy On-ramp	2	E Monte Vista Ave/ Nut Tree Village On-ramp
3	SR 37 EB Connector	3	E Monte Vista Ave/Browns Valley Parkway On-ramp
4	American Canyon Road On-ramp	4	Mason Street On-ramp
5	Red Top Road On-ramp	5	Davis Street On-ramp
6	SR 12 (west) EB Connector	6	Alamo Drive On-ramp
7	Green Valley Road/I-680 On-ramp *	7	Pena Adobe Road On-ramp
8	Suisun Valley/Pittman Road On-ramp	8	Lagoon Valley Road On-ramp
9	Abernathy Road On-ramp	9	North Texas Street On-ramp
10	Auto Mall Parkway On-ramp	10	Air Base Parkway On-ramp
11	W Texas Street/Beck Ave On-ramp	11	Travis Blvd Loop On-ramp
12	Travis Blvd On-ramp	12	Travis Boulevard Diagonal On-Ramp
13	Air Base Parkway On-ramp	13	W Texas Street/Rockville Road On-ramp
14	North Texas Street On-ramp	14	Abernathy Road On-ramp
15	Lagoon Valley Road On-ramp	15	SR 12 (east) WB Connector
16	Pena Adobe Road On-ramp	16	Green Valley Road On-ramp
17	Alamo Drive On-ramp	17	Red Top Road On-ramp
18	Davis Street On-ramp	18	American Canyon Road On-ramp
19	Mason Street On-ramp	19	Columbus Pkwy On-ramp
20	Allison Drive Loop On-ramp	20	SR 37 EB Connector
21	Allison Drive Diagonal On-ramp	21	Redwood Street On-ramp
22	I-505 Connector		
23	Orange Drive On-ramp		

Indicates on-ramps metered as part of Stage I
* The I-680 northbound to eastbound freeway connector will be evaluated for metering feasibility at a later stage.

APPENDIX B: EXISTING ON-RAMP QUEUES

Exhibits 47 and 48 of the *Deliverable 2.5: Final Before Ramp Metering Conditions* memorandum submitted by KAI on February 16, 2015 (the "Stage II Before memo") present the May 2014 on-ramp queues on eastbound and westbound I-80, respectively. These exhibits are included in the next page for ease of reference.

In the eastbound direction during the typical Friday PM peak period, on-ramp queues were observed only at the Stage I on-ramps with active meters, with the exception of the I-680 connector. In the westbound direction, on-ramp queues were observed at four locations during the Sunday PM observations:

- **I-505 Connector:** Small queues of up to six vehicles (180 feet) were occasionally observed.
- **E Monte Vista Avenue/Browns Valley Parkway:** A small queue of three vehicles or 90 feet was observed once.
- **SR 37 to I-80 WB Connector:** Long queues of about 26 vehicles or nearly 800 feet were commonly observed, with maximum queues of 48 vehicles extending for approximately 1,440 feet. Roadway improvements commenced after May 2014—including the widening to two general purpose plus one HOV lanes at the limit line[5]—provide additional queue storage.
- **Redwood Street:** Queues between six and nine vehicles—or about 180 to 270 feet—were regularly observed.

[5] *Project Plans for Construction on State Highway in Solano County,* Caltrans (revised March 2012)

Exhibit 47: Observed Eastbound On-Ramp Queues Summary [May 2014]

On-Ramp Location	I-680 NB	Pittman Rd/Suisun Valley Road	Chadbourne Rd	Auto Mall Pkwy	Beck Avenue	Travis Blvd	Air Base Pkwy	Manuel Campos/N Texas
Eastbound Midweek PM								
Average	0' (0)	150' (5)	120' (4)	60' (2)	180' (6)	165' (6)	165' (6)	45' (2)
50th Percentile	0' (0)	150' (5)	120' (4)	60' (2)	180' (6)	180' (6)	180' (6)	45' (2)
Maximum	0' (0)	150' (5)	180' (6)	60' (2)	210' (7)	240' (8)	210' (7)	60' (2)
Eastbound Typical Friday PM								
Average	**> 3,600' (>120) ***	90' (3)	240' (8)	75' (3)	390' (13)	390' (13)	120' (4)	150' (5)
50th Percentile	**> 3,600' (>120) ***	90' (3)	330' (11)	60' (2)	240' (8)	240' (8)	90' (3)	90' (3)
Maximum	**> 3,600' (>120) ***	240' (8)	450' (15)	240' (8)	**1620' (54)**	1200' (40)	570' (19)	690' (23)
Eastbound Memorial Day Weekend Friday PM								
Average	**> 3,600' (>120) ***	90' (3)	180' (6)	60' (2)	390' (13)	180' (6)	30' (1)	120' (4)
50th Percentile	**> 3,600' (>120) ***	60' (2)	150' (5)	60' (2)	360' (12)	150' (5)	30' (1)	120' (4)
Maximum	**> 3,600' (>120) ***	120' (4)	480' (16)	180' (6)	**870' (29)**	450' (15)	30' (1)	210' (7)

Note: on-ramps not included in the exhibit did not have existing queues based on field observation. Queues are measured in feet from ramp meter limit line. Values are shown in feet (number of vehicles). Approximately 30 feet per vehicle length was assumed. * Long queues were observed on I-680 northbound connector extending to I-680 northbound mainline. Bold text indicates queues exceeded available storage.

Exhibit 48: Observed Westbound On-Ramp Queues Summary [May 2014]

On-Ramp Location	I-505 Connector	E Monte Vista Ave/Browns Valley Pkwy	SR 37 Connector	Redwood Street
Westbound Sunday PM				
Average	165' (6)	90' (3)	792' (26)	180' (6)
50th Percentile	165' (6)	90' (3)	420' (14)	180' (6)
Maximum	180' (6)	90' (3)	1440' (48)	270' (9)

Note: on-ramps not included in the exhibit did not have existing queues based on field observation. Queues are measured in feet from freeway on-ramp merge location. Values are shown in feet (number of vehicles). Approximately 30 feet per vehicle length was assumed.

Appendix C: Queue Storage Aerials

I-80 Eastbound

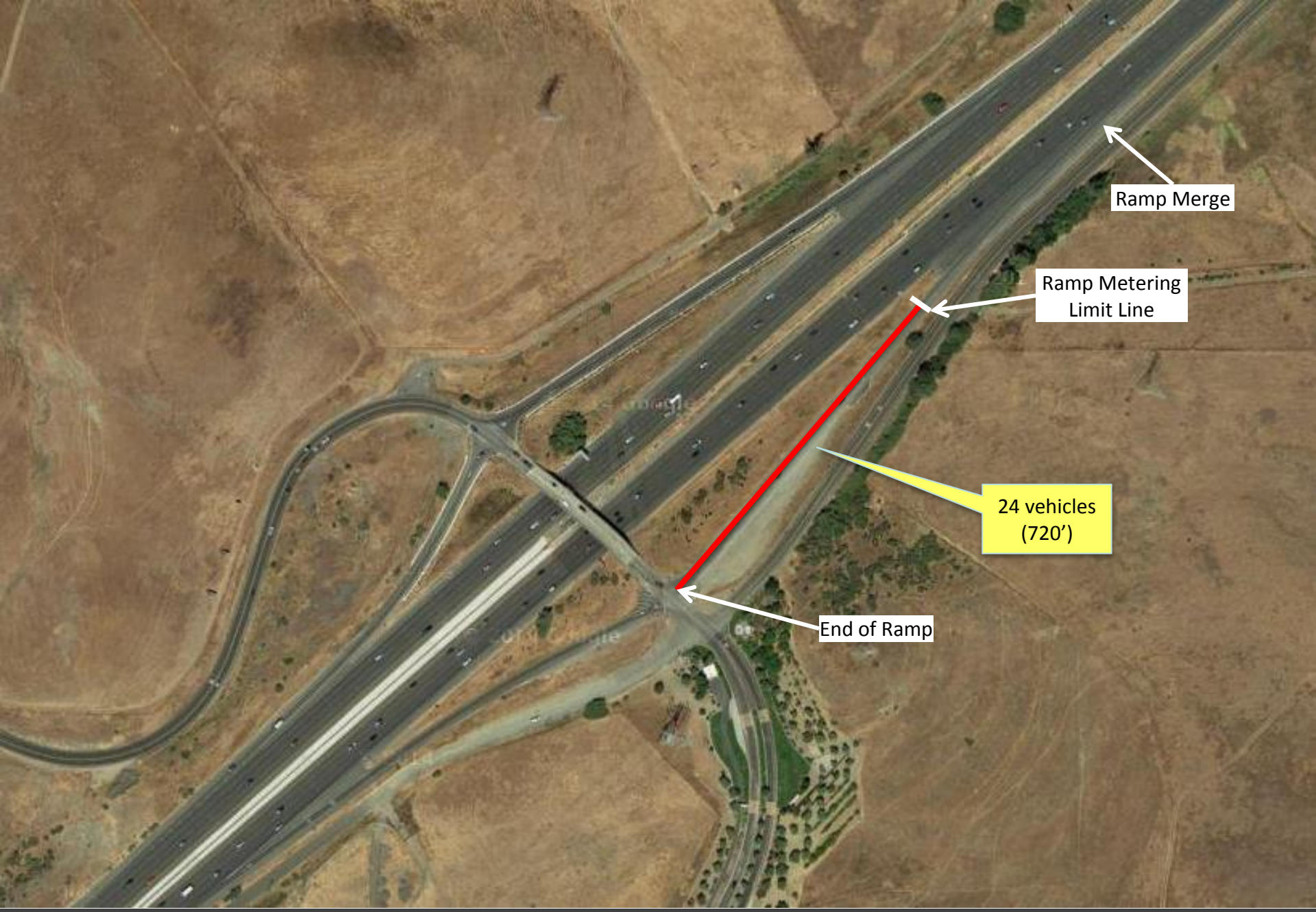
KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

Redwood Parkway EB On-Ramp

KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

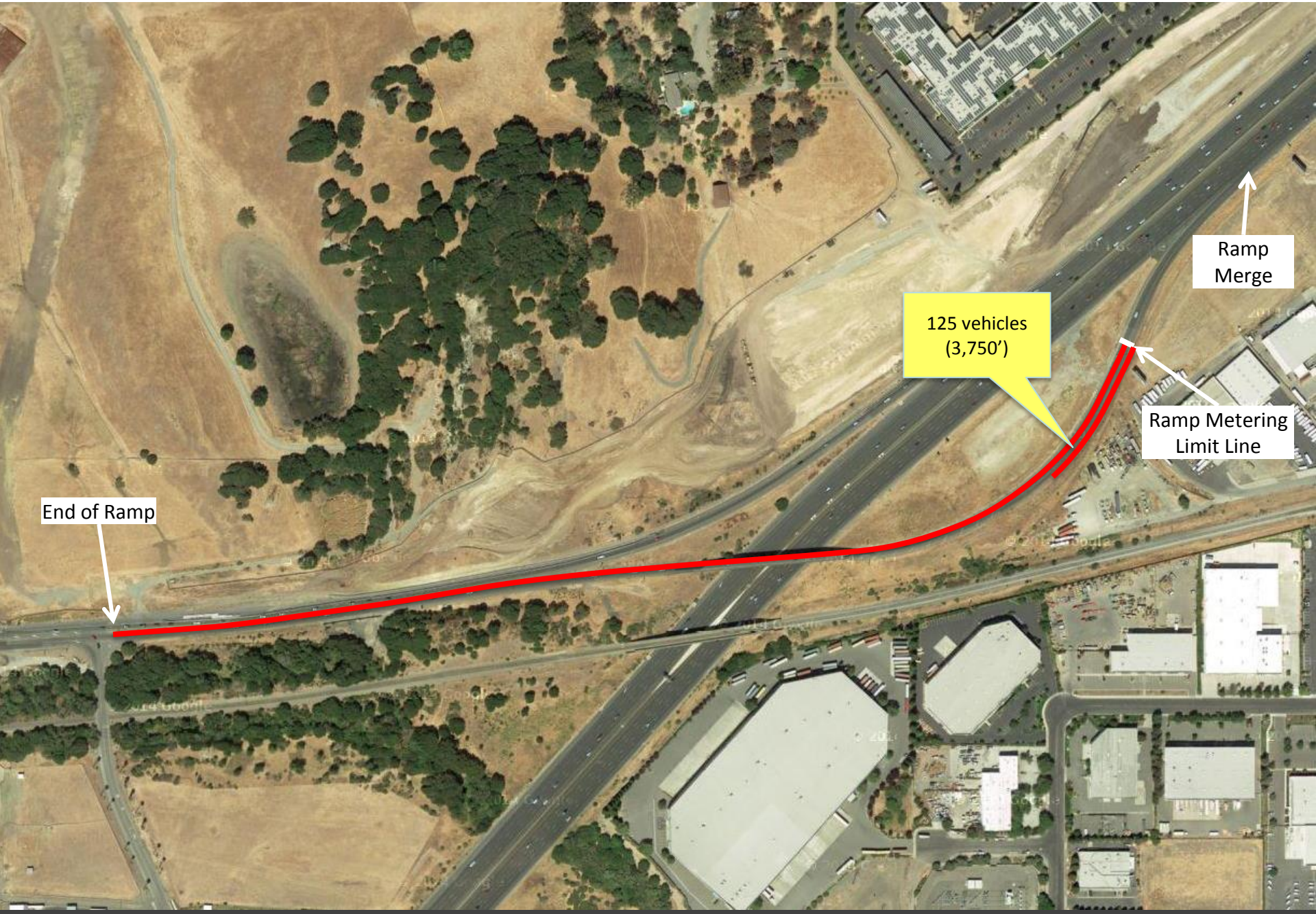
Columbus Parkway EB On-Ramp

SR 37 Connector to EB I-80



American Canyon Road EB On-Ramp

Red Top Road EB On-Ramp



KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

SR 12 (East) Connector to I-80 EB

Suisan Valley/Pittman Road EB On-Ramp

KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

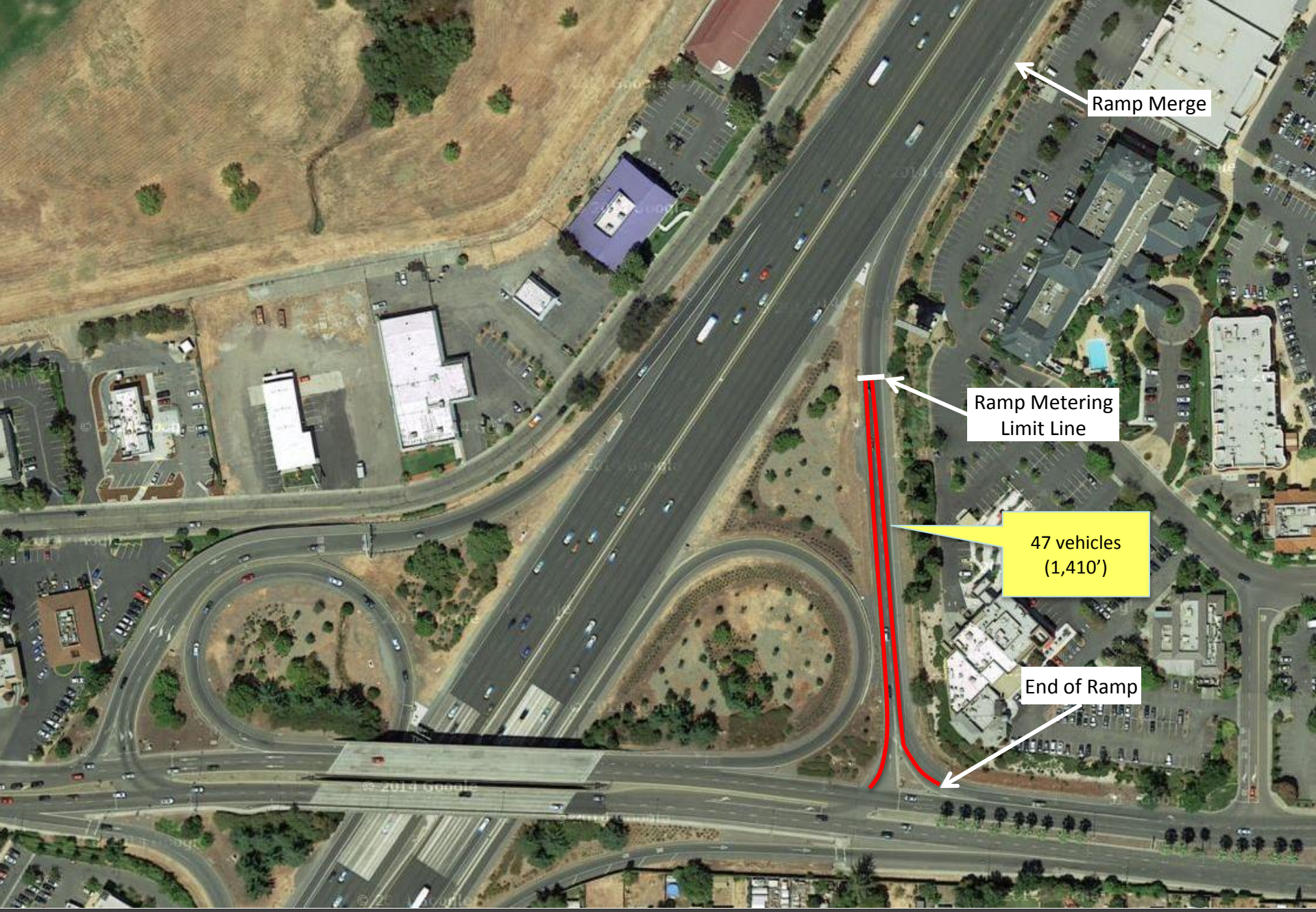
Chadbourne Road/Abernathy Road EB On-Ramp

KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

Auto Mall Parkway EB On-Ramp

KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

W Texas Street/Beck Avenue EB On-ramp



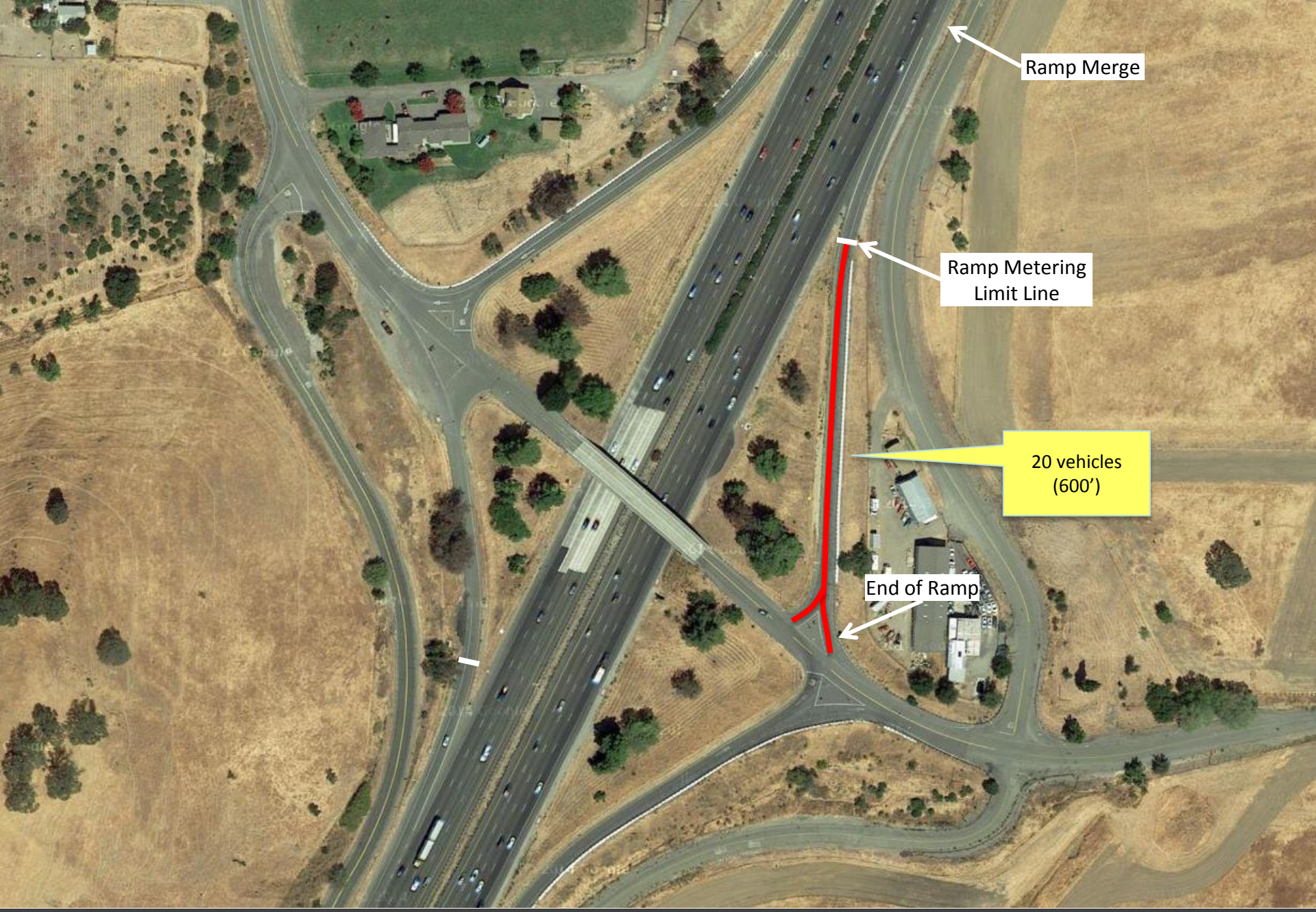
Travis Boulevard EB On-Ramp

KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

Air Base Parkway EB On-ramp

KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

North Texas Street / Manuel Campos Pkwy EB On-Ramp



Lagoon Valley Road EB On-Ramp

KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

Pena Adobe Road EB On-Ramp

KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

Alamo Drive EB On-Ramp

Davis Street EB On-Ramp

Mason Street On-Ramp

KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

Allison Drive Loop EB On-Ramp

Allison Drive Diagonal EB On-Ramp

I-505 Connector to EB I-80

Orange Drive EB On-Ramp

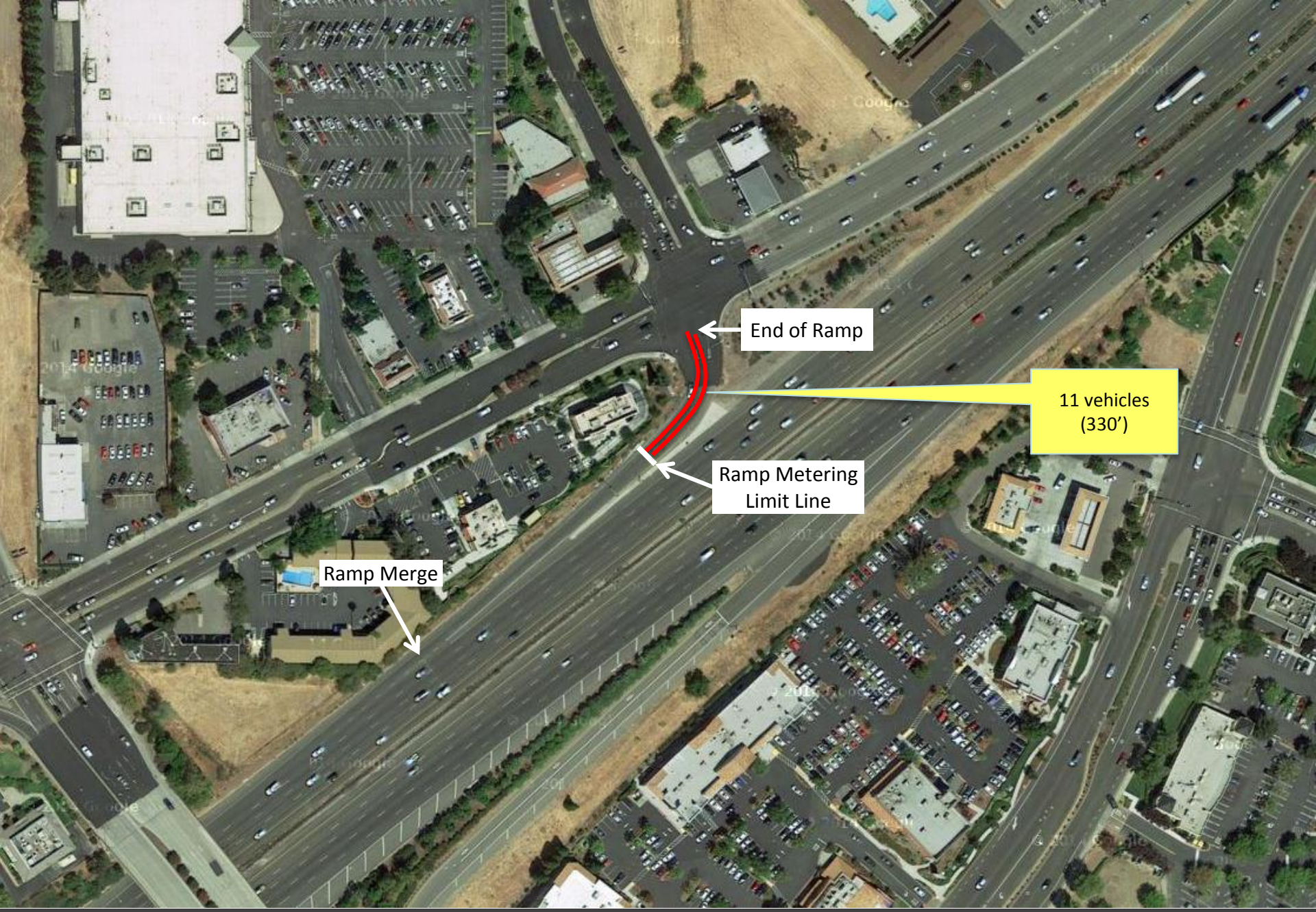
I-80 Westbound

KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

I-505 Connector to WB I-80

KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

E Monte Vista Avenue/ Nut Tree Village WB On-Ramp



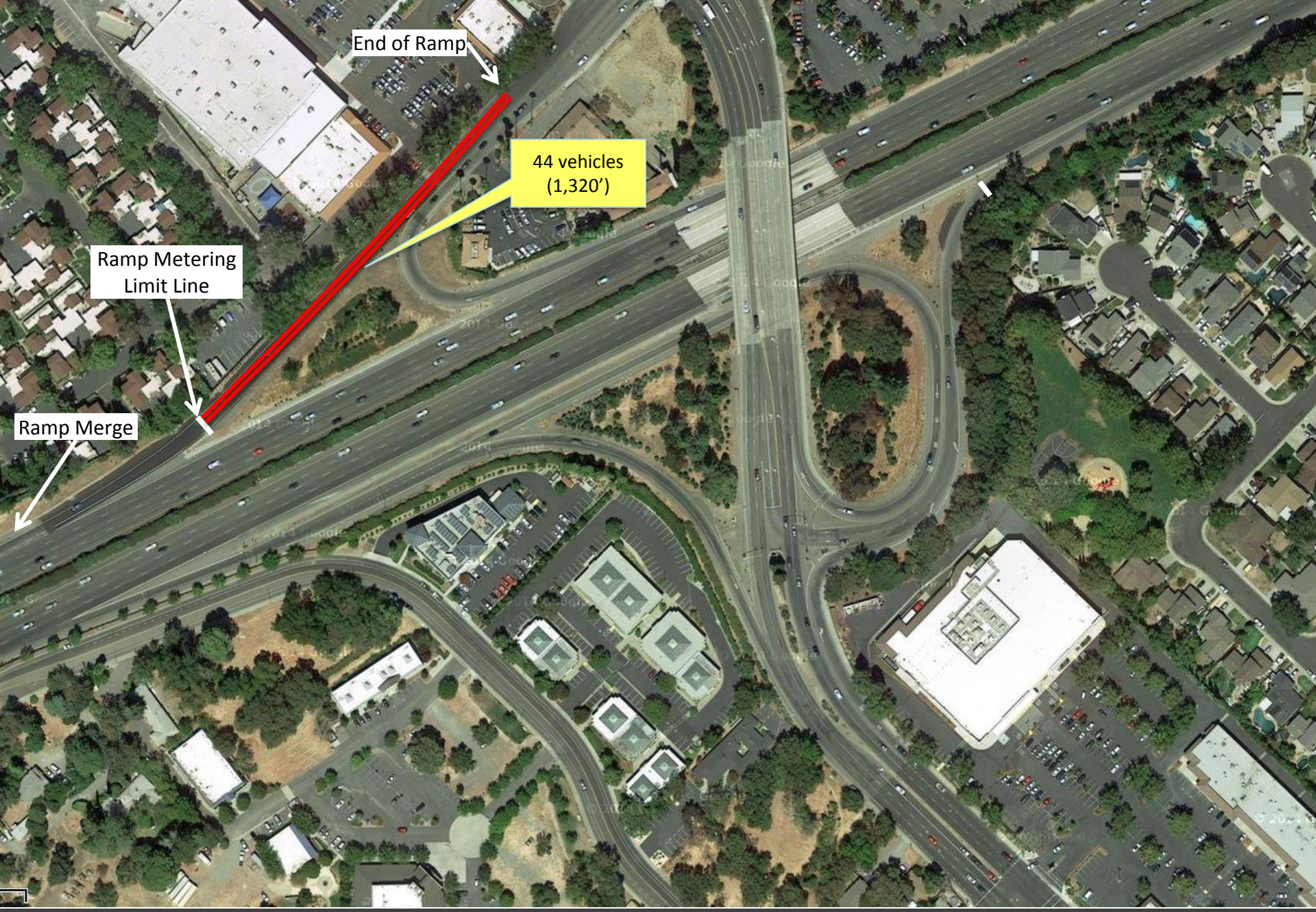
KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

E Monte Vista Ave/Browns Valley Parkway WB On-Ramp

KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

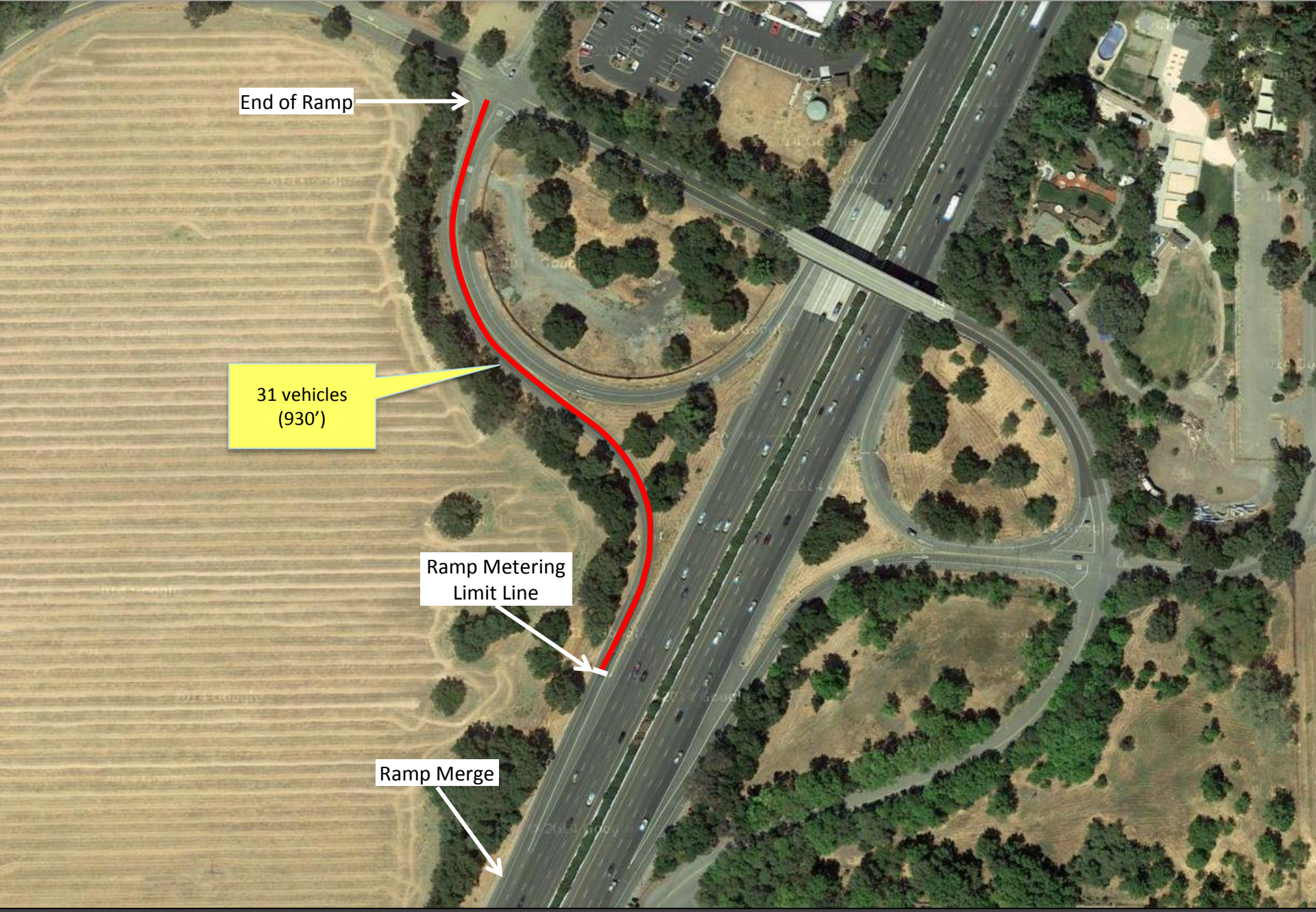
Mason Street WB On-Ramp

Davis Street WB On-Ramp

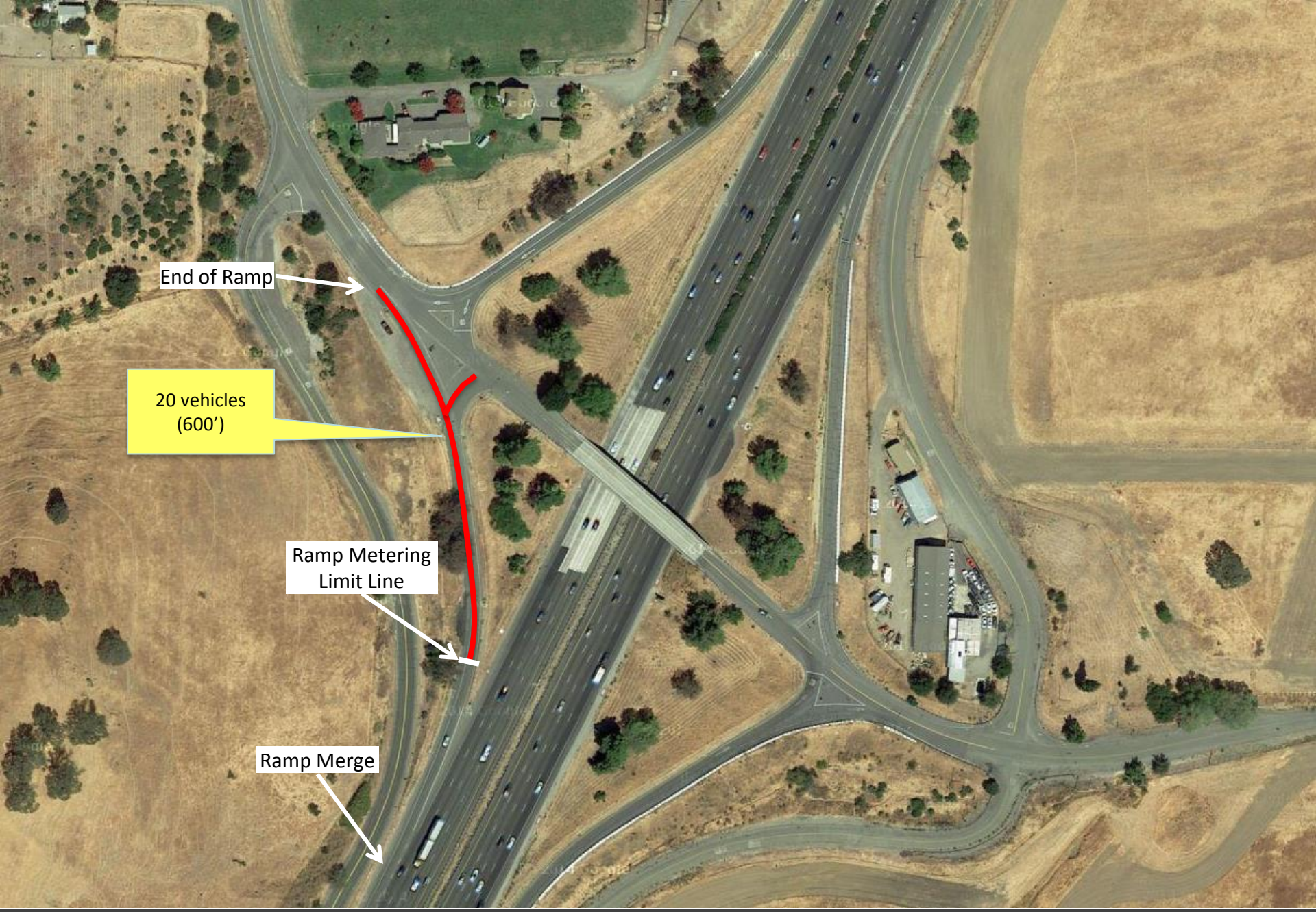


KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

Alamo Drive WB On-Ramp



Pena Adobe Road WB On-Ramp



KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

Lagoon Valley Road WB On-Ramp

KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

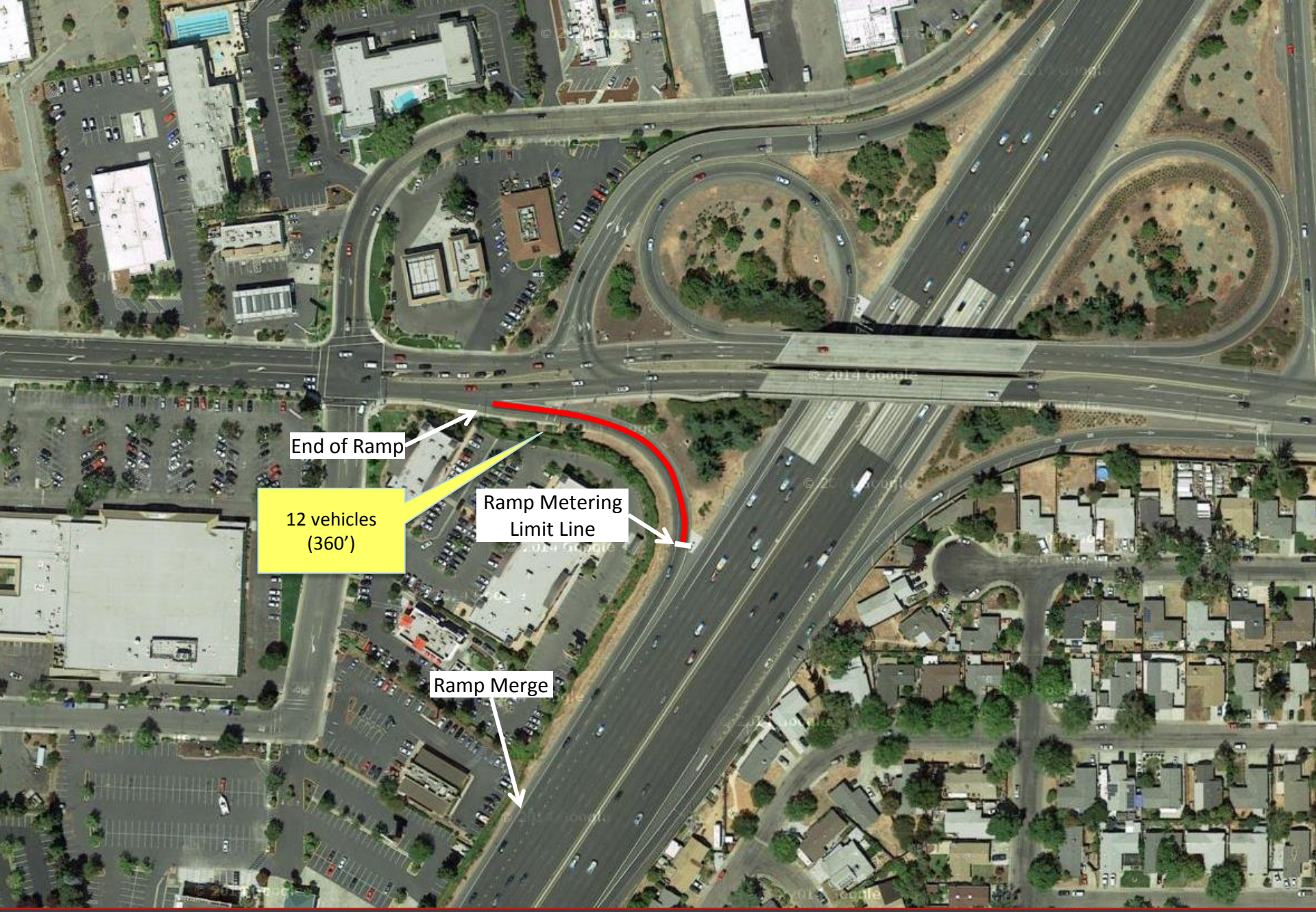
North Texas/Manuel Campos Pkwy/ Lincoln Hwy WB On-Ramp

KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

Air Base Parkway WB On-ramp

KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

Travis Boulevard Loop WB On-Ramp



KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

Travis Boulevard Diagonal WB On-Ramp

KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

W Texas Street/Rockville Road WB On-ramp

Abernathy Road WB On-Ramp

SR 12 (East) Connector to WB I-80

Green Valley Road WB On-Ramp

Red Top Road WB On-Ramp

American Canyon Road WB On-Ramp

Columbus Parkway WB On-Ramp

SR 37 Connector to WB I-80

KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

Redwood Street WB On-Ramp

Appendix D: Optimal Ramp Metering Rates

Solano I-80 Eastbound Friday PM - FREQ Ramp Metering Summary

	Redwood Pkwy On-ramp	Columbus Pkwy On-ramp	SR 37 EB Connector	American Canyon Road On-ramp	Red Top Road On-ramp	SR 12 (west) EB Connector	Suisun Valley/Pittman Road On-ramp	Abernathy Road On-ramp	Auto Mall Parkway On-ramp	W Texas Street/Beck Ave On-ramp	Travis Blvd On-ramp	Air Base Parkway On-ramp	North Texas Street On-ramp	Lagoon Valley Road On-ramp	Pena Adobe Road On-ramp	Alamo Drive On-ramp	Davis Street On-ramp	Mason Street On-ramp	Allison Drive Loop On-ramp	Allison Drive Diagonal On-ramp	I-505 Connector	Orange Drive On-ramp
General Purpose (GP) Lanes	1	1	2	1	1	2	2	2	1	2	2	1	1	1	1	1	1	2	1	1	1	1
HOV Bypass Lanes	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	1	1	0	1
GP Proportion	1.00	1.00	1.00	1.00	1.00	1.00	0.86	1.00	1.00	1.00	1.00	0.86	0.86	1.00	1.00	1.00	1.00	1.00	0.86	0.86	1.00	0.86
Avail. Storage - Veh	6	42	208	24	13	125	38	20	9	23	47	25	17	20	16	34	13	16	19	25	46	17
Avail. Storage - Ln-Ft	180	1,260	6,240	720	390	3,750	1,140	600	270	690	1,410	750	510	600	480	1,020	390	480	570	750	1,380	510
Avail. Storage - Veh (Ln-Ft)	6 (180)	42 (1,260)	208 (6,240)	24 (720)	13 (390)	125 (3,750)	38 (1,140)	20 (600)	9 (270)	23 (690)	47 (1,410)	25 (750)	17 (510)	20 (600)	16 (480)	34 (1,020)	13 (390)	16 (480)	19 (570)	25 (750)	46 (1,380)	17 (510)

DEMAND (HOURLY FLOW RATE)

1	2:00 PM	296	348	1,408	244	84	1,432	708	564	60	688	1,188	496	728	56	12	812	328	440	244	120	248	336
2	2:15 PM	228	368	1,440	236	128	1,412	800	512	80	580	1,168	488	692	56	28	712	312	488	208	112	160	364
3	2:30 PM	264	328	1,296	256	120	1,436	664	456	132	700	976	448	836	92	28	672	316	496	216	136	180	412
4	2:45 PM	304	288	1,512	296	80	1,508	632	464	160	608	884	408	848	112	40	784	396	420	244	156	228	320
5	3:00 PM	224	360	1,540	384	104	1,380	792	544	144	588	1,000	496	760	124	28	1,096	376	376	248	144	216	400
6	3:15 PM	368	268	1,572	312	152	1,396	776	472	196	608	836	456	900	104	16	872	372	520	244	140	124	392
7	3:30 PM	340	360	1,628	380	140	1,404	748	588	224	776	1,056	496	828	76	28	792	408	464	232	160	164	396
8	3:45 PM	296	316	1,584	264	148	1,476	584	488	200	696	848	612	916	112	32	712	448	472	236	132	140	248
9	4:00 PM	288	432	1,576	380	148	1,424	712	564	208	772	964	528	888	132	32	732	396	424	176	176	104	360
10	4:15 PM	284	348	1,448	304	136	1,484	560	472	232	796	788	496	956	180	20	692	388	432	212	120	144	308
11	4:30 PM	336	276	1,632	320	128	1,548	616	452	236	736	872	440	988	156	44	812	408	412	192	144	192	304
12	4:45 PM	304	332	1,716	324	116	1,428	560	492	184	728	904	532	1,008	156	28	848	448	420	252	128	168	320
13	5:00 PM	280	368	1,636	236	132	1,432	748	588	196	844	972	596	896	116	28	1,040	428	440	280	192	160	304
14	5:15 PM	324	384	1,524	244	80	1,556	600	464	160	740	852	564	1,052	132	24	648	504	484	284	164	124	380
15	5:30 PM	272	440	1,504	312	132	1,304	500	480	156	648	884	484	992	76	36	684	500	332	216	168	120	256
16	5:45 PM	364	344	1,524	384	124	1,444	552	364	140	572	864	476	928	76	28	732	500	392	208	100	128	328
17	6:00 PM	324	380	1,512	272	100	1,540	484	348	156	620	948	528	772	60	20	688	396	400	228	156	164	348
18	6:15 PM	296	372	1,536	340	140	1,328	512	296	96	600	1,072	572	732	48	24	660	320	424	164	96	156	276
19	6:30 PM	268	388	1,520	192	116	1,408	536	260	80	520	920	500	720	48	24	684	352	428	196	168	136	268
20	6:45 PM	240	388	1,272	292	104	1,164	504	196	128	524	964	500	664	44	28	512	288	404	176	164	108	396

RAMP METERING RATE PER GP LANE PER HOUR

1	2:00 PM	330	390	710	260	900	720	720	260	380	530	590	620	730	900	900	1,000	900	900	900	900	900	900
2	2:15 PM	270	280	590	260	900	720	720	260	380	340	590	460	730	900	900	1,000	900	900	900	900	900	900
3	2:30 PM	270	320	590	260	900	690	720	260	380	340	470	500	840	900	900	1,000	900	900	900	900	900	900
4	2:45 PM	350	320	760	260	350	720	720	260	290	340	470	600	730	900	900	1,000	900	900	900	900	900	900
5	3:00 PM	270	410	780	370	700	680	720	300	410	370	470	500	810	900	900	1,000	900	900	900	900	900	900
6	3:15 PM	400	300	790	330	390	680	720	250	330	370	440	500	730	900	900	1,000	900	900	900	900	900	900
7	3:30 PM	390	420	820	410	320	680	720	300	310	430	510	500	730	900	900	1,000	900	900	900	900	900	900
8	3:45 PM	330	360	800	280	900	720	720	240	310	430	460	460	840	900	900	1,000	900	900	900	900	900	900
9	4:00 PM	330	490	800	400	900	690	720	300	290	430	460	460	840	900	900	1,000	900	900	900	900	900	900
10	4:15 PM	320	400	730	330	900	740	720	240	290	430	440	460	840	900	900	1,000	900	900	900	900	900	900
11	4:30 PM	380	310	830	340	900	740	720	240	330	430	440	600	900	900	900	1,000	900	900	900	900	900	900
12	4:45 PM	350	390	860	350	900	740	720	240	380	430	440	600	900	900	900	1,000	900	900	900	900	900	900
13	5:00 PM	320	420	820	260	900	720	720	330	330	530	460	600	900	900	900	1,000	900	900	900	900	900	900
14	5:15 PM	370	440	770	260	900	720	720	240	290	430	460	600	900	900	900	1,000	900	900	900	900	900	900
15	5:30 PM	300	510	760	330	900	720	720	240	380	390	460	460	840	900	900	1,000	900	900	900	900	900	900
16	5:45 PM	410	390	770	410	900	720	720	240	380	370	460	460	840	900	900	1,000	900	900	900	900	900	900
17	6:00 PM	370	440	770	290	900	720	720	830	380	370	460	600	760	900	900	1,000	900	900	900	900	900	900
18	6:15 PM	330	430	780	370	900	690	720	830	380	340	510	600	760	900	900	1,000	900	900	900	900	900	900
19	6:30 PM	300	440	770	260	900	740	720	830	380	340	610	600	840	900	900	1,000	900	900	900	900	900	900
20	6:45 PM	280	450	650	260	900	740	720	830	380	530	610	600	840	900	900	1,000	900	900	900	900	900	900

RAMP QUEUE LENGTH (VEH)

1	2:00 PM	0	0	0	0	0	0	0	11	0	0	2	0	0	0	0	0	0	0	0	0	0	0
2	2:15 PM	0	22	65	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	2:30 PM	0	24	94	0	0	14	0	0	0	5	9	0	0	0	0	0	0	0	0	0	0	0
4	2:45 PM	0	16	92	9	0	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	3:00 PM	0	4	87	13	0	36	0	0	0	0	15	0	0	0	0	24	0	0	0	0	0	0
6	3:15 PM	0	0	85	8	0	45	0	0	0	0	4	0	11	0	0	0	0	0	0	0	0	0
7	3:30 PM	0	0	82	1	0	56	0	0	0	0	13	0	7	0	0	0	0	0	0	0	0	0
8	3:45 PM	0	0	78	0	0	65	0	2	0	0	0	17	0	0	0	0	0	0	0	0	0	0
9	4:00 PM	0	0	72	0	0	76	0	0	0	0	11	15	0	0	0	0	0	0	0	0	0	0
10	4:15 PM	0	0	69	0	0	77	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0
11	4:30 PM	0	0	62	0	0	94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	4:45 PM	0	0	61	0	0	81	0	3	0	0	6	0	0	0	0	0	0	0	0	0	0	0
13	5:00 PM	0	0	60	0	0	79	0	0	0	0	19	0	0	0	0	10	0	0	0	0	0	0
14	5:15 PM	0	0	56	0	0	108	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0
15	5:30 PM	0	0	52	0	0	74	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0
16	5:45 PM	0	0	48	0	0	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	6:00 PM	0	0	41	0	0	100	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
18	6:15 PM	0	0	35	0	0	87	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0
19	6:30 PM	0	0	30	0	0	69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	6:45 PM	0	0	23	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

AVG. METERING QUEUE DELAY (MIN/VEH)

1	2:00 PM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	2:15 PM	0.0	3.6	2.7	0.0	0.0	0.0	0.0	1.1	0.0	0.0	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	2:30 PM	0.0	4.4	4.4	0.0	0.0	0.6	0.0	0.0	0.0	0.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	2:45 PM	0.0	3.3	3.7	1.8	0.0	1.2	0.0	0.0	0.0	0.0	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	3:00 PM	0.0	0.6	3.4	2.0	0.0	1.6	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0
6	3:15 PM	0.0	0.0	3.2	1.5	0.0	1.9	0.0	0.0	0.0	0.0	0.3	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	3:30 PM	0.0	0.0	3.0	0.1	0.0	2.4	0.0	0.0	0.0	0.0	0.7	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	3:45 PM	0.0	0.0	3.0	0.0	0.0	2.6	0.0	0.2	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	4:00 PM	0.0	0.0	2.7	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.7	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	4:15 PM	0.0	0.0	2.9	0.0	0.0	3.1	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	4:30 PM	0.0	0.0	2.3	0.0	0.0	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	4:45 PM	0.0	0.0	2.1	0.0	0.0	3.4	0.0	0.4	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	5:00 PM	0.0	0.0	2.2	0.0	0.0	3.3	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
14	5:15 PM	0.0	0.0	2.2	0.0	0.0	4.2	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	5:30 PM	0.0	0.0	2.1	0.0	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	5:45 PM	0.0	0.0	1.9	0.0	0.0	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	6:00 PM	0.0	0.0	1.6	0.0	0.0	3.9	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	6:15 PM	0.0	0.0	1.4	0.0	0.0	3.9	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	6:30 PM	0.0	0.0	1.2	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	6:45 PM	0.0	0.0	1.1	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Stage I

Queue Beyond On-Ramp Storage

Lower Delay — Higher Delay

Solano I-80 Westbound Sunday PM - FREQ Ramp Metering Summary

	I-505 Connector	E Monte Vista Ave/ Nut Tree Village On-ramp	E Monte Vista Ave/Browns Valley Parkway On-ramp	Mason Street On-ramp	Davis Street On-ramp	Alamo Drive On-ramp	Pena Adobe Road On-ramp	Lagoon Valley Road On-ramp	North Texas Street On-ramp	Air Base Parkway On-ramp	Travis Blvd Loop On-ramp	Travis Boulevard Diagonal On-Ramp	W Texas Street/Rockville Road On-ramp	Abernathy Road On-ramp	SR 12 (east) WB Connector	Green Valley Road On-ramp	Red Top Road On-ramp	American Canyon Road On-ramp	Columbus Pkwy On-ramp	SR 37 EB Connector	Redwood Street On-ramp
General Purpose (GP) Lanes	2	2	2	1	1	2	1	1	1	2	1	1	1	1	3	1	1	1	1	2	1
HOV Bypass Lanes	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	1
GP Proportion	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.84	1.00	1.00	0.84	1.00	1.00	1.00	1.00	1.00	1.00	0.84	0.84
Avail. Storage - Veh	72	13	11	36	20	44	31	20	22	56	24	12	13	16	197	20	29	13	56	96	14
Avail. Storage - Ln-Ft	2,160	390	330	1,080	600	1,320	930	600	660	1,680	720	360	390	480	5,910	600	870	390	1,680	2,880	420
Avail. Storage - Veh (Ln-Ft)	72 (2,160)	13 (390)	11 (330)	36 (1,080)	20 (600)	44 (1,320)	31 (930)	20 (600)	22 (660)	56 (1,680)	24 (720)	12 (360)	13 (390)	16 (480)	197 (5,910)	20 (600)	29 (870)	13 (390)	56 (1,680)	96 (2,880)	14 (420)

DEMAND (HOURLY FLOW RATE)

1	3:00 PM	1,064	768	724	368	268	616	32	68	400	744	736	276	324	48	772	504	116	172	184	1,564	776
2	3:15 PM	1,056	708	796	384	312	636	16	44	380	716	648	256	288	44	948	468	188	192	180	1,588	940
3	3:30 PM	1,068	632	772	356	236	512	12	20	376	748	692	228	304	72	968	436	136	216	236	1,628	884
4	3:45 PM	1,112	720	744	388	252	484	32	56	260	916	640	240	292	36	892	460	168	232	192	1,680	860
5	4:00 PM	1,084	684	772	388	236	484	24	48	364	776	652	224	308	28	836	416	144	188	280	1,720	776
6	4:15 PM	1,032	720	796	296	212	444	24	76	340	812	680	232	324	32	816	472	188	196	188	1,616	748
7	4:30 PM	972	748	808	348	232	532	44	64	328	772	672	200	288	40	796	484	212	140	172	1,704	816
8	4:45 PM	856	584	660	400	204	504	20	52	352	668	548	256	252	36	772	376	164	240	192	1,396	908
9	5:00 PM	1,064	620	676	328	204	444	16	44	296	708	608	260	280	52	800	420	196	240	144	1,648	740
10	5:15 PM	876	716	620	272	196	444	4	32	348	772	572	176	288	36	748	396	188	176	208	1,432	816
11	5:30 PM	940	616	684	332	256	460	20	44	324	652	620	216	240	40	804	396	140	172	228	1,416	784
12	5:45 PM	856	680	632	372	216	368	16	52	272	596	612	188	228	36	708	420	160	236	160	1,308	796
13	6:00 PM	824	580	592	328	268	372	36	32	292	552	692	216	196	40	584	380	112	180	156	1,596	912
14	6:15 PM	884	636	604	308	276	500	20	40	344	652	760	264	272	40	656	300	164	188	220	1,520	808
15	6:30 PM	780	556	616	328	248	452	24	60	276	552	560	180	244	36	728	368	144	168	168	1,216	892
16	6:45 PM	744	552	540	260	288	400	44	68	300	564	552	216	296	36	656	312	224	188	160	1,300	856

RAMP METERING RATE PER GP LANE PER HOUR

1	3:00 PM	660	460	430	500	300	330	900	900	610	460	880	420	410	290	300	630	290	360	290	530	600
2	3:15 PM	650	420	480	520	360	340	900	900	570	450	700	380	300	290	290	390	290	360	290	650	800
3	3:30 PM	400	290	370	330	270	270	900	900	360	300	770	360	300	290	290	450	290	360	290	720	750
4	3:45 PM	580	360	380	330	280	260	900	900	360	430	770	370	300	290	290	480	290	360	290	740	730
5	4:00 PM	570	350	390	440	270	260	900	900	400	410	770	360	300	290	290	430	290	360	330	760	660
6	4:15 PM	540	360	410	340	270	260	900	900	430	430	820	360	330	290	290	490	290	360	290	700	630
7	4:30 PM	500	370	410	410	270	280	900	900	410	410	820	360	310	290	290	500	290	360	290	750	690
8	4:45 PM	440	290	330	460	270	270	900	900	440	350	650	380	300	290	290	390	290	360	290	590	770
9	5:00 PM	550	310	340	380	270	260	900	900	380	370	730	390	300	290	330	440	290	360	290	740	630
10	5:15 PM	460	360	310	330	270	260	900	900	440	410	690	360	300	290	300	420	290	360	290	610	690
11	5:30 PM	490	310	350	350	280	260	900	900	410	340	750	360	330	290	320	410	290	360	290	620	670
12	5:45 PM	710	440	410	700	270	260	900	900	540	400	730	360	300	290	290	430	290	360	290	570	680
13	6:00 PM	510	340	360	450	300	260	900	900	450	400	900	360	300	290	290	570	290	360	290	900	900
14	6:15 PM	550	380	360	430	320	270	900	900	520	410	900	400	340	290	290	370	290	360	290	720	630
15	6:30 PM	480	330	370	440	280	260	900	900	410	340	900	360	310	290	290	460	290	360	290	540	760
16	6:45 PM	460	330	320	360	320	260	900	900	450	350	900	360	380	290	290	390	290	360	290	700	900

RAMP QUEUE LENGTH (VEH)

1	3:00 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63	13
2	3:15 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	20	0	0	0	72	10
3	3:30 PM	67	13	8	7	0	0	0	0	4	7	0	0	0	0	44	16	0	0	0	54	9
4	3:45 PM	55	13	4	21	0	0	0	0	0	0	0	0	0	0	50	11	0	0	0	37	7
5	4:00 PM	41	9	2	8	0	0	0	0	0	0	0	0	0	0	41	8	0	0	0	18	5
6	4:15 PM	29	9	0	0	0	0	0	0	0	0	0	0	0	0	28	3	0	0	0	7	4
7	4:30 PM	22	11	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	3
8	4:45 PM	16	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
9	5:00 PM	7	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	5:15 PM	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	5:30 PM	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	5:45 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	6:00 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	6:15 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
15	6:30 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
16	6:45 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

AVG. ON-RAMP QUEUE DELAY (MIN/VEH)

1	3:00 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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	1.2
2	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	0.0	0.0	1.2	2.5	0.0	0.0	0.0	3.2	0.8
3	3:30 PM	3.8	1.2	0.6	1.1	0.0	0.0	0.0	0.0	0.6	0.7	0.0	0.0	0.0	0.0	2.7	2.2	0.0	0.0	0.0	2.4	0.7
4	3:45 PM	3.0	1.1	0.3	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	1.4	0.0	0.0	0.0	1.6	0.5
5	4:00 PM	2.3	0.8	0.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	1.1	0.0	0.0	0.0	0.7	0.4
6	4:15 PM	1.7	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.4	0.0	0.0	0.0	0.3	0.4
7	4:30 PM	1.4	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.3
8	4:45 PM	1.1	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
9	5:00 PM	0.4	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	5:15 PM	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	5:30 PM	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	5:45 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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	6:00 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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	6:15 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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1
15	6:30 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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
16	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Queue Beyond On-Ramp Storage

Lower Delay — Higher Delay