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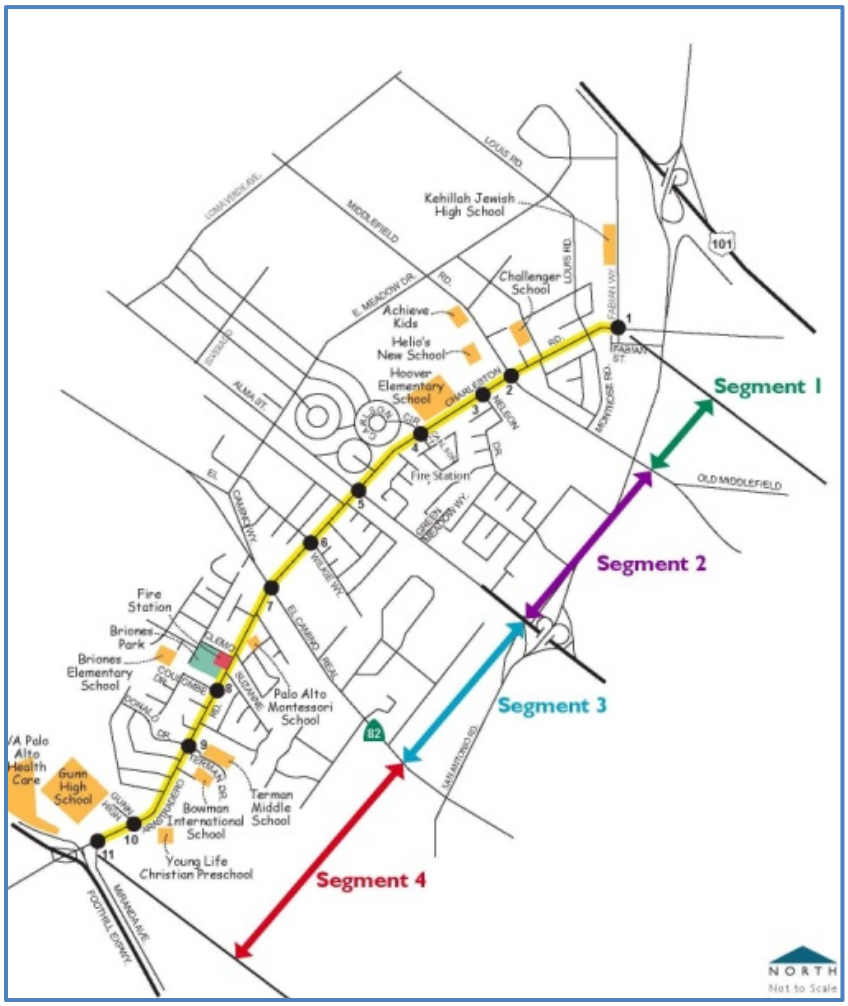

FINAL

Charleston - Arastradero Corridor Trial Improvements:

Arastradero Road Striping Alternatives

In the City of Palo Alto

June 3, 2009

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Introduction and Summary

Introduction

The City of Palo Alto is completing a multi-year effort to address transportation and urban design issues along the Charleston-Arastradero Corridor from San Antonio Road on the east to Foothill Expressway on the west, a distance of approximately 2.5 miles. Charleston Road extends east from El Camino Real (SR 82) to San Antonio Road and carries approximately 15,500 vehicles daily. Arastradero Road extends west from the Charleston/El Camino intersection to Foothill Expressway, and carries 18,300 vehicles daily, and east of Donald/Terman this volume has been as high as 20,800 vehicles daily, a volume 18 to 34 percent higher than Charleston Road. Monitoring of volumes from 2003 through late 2008 reveals there has been little change in the daily and peak hour totals. Land uses along the corridor are primarily single-family residential and schools, with commercial uses near Fabian, Middlefield and El Camino Real. The combination of high traffic volumes with high quality residential uses and major school activity for K-12 children is a setting that implies significant conflicts between mobility, safety, and the quality of life in the corridor.

At the outset of this effort in 2003, both roads were four lane undivided streets with signals at major intersections. The Palo Alto City Council authorized a study of potential improvements in this corridor with the following basic objectives:

- Improve the quality of bike and pedestrian experience
- Enhance school commute safety for K-12 students
- Enhance the streetscape environment and quality of life in the corridor
- Determine the effects of future traffic growth on the corridor up to 2015
- Minimize traffic shift to adjacent streets

Planning work in 2003-2004 resulted in a decision to initiate a trial of reducing the number of through lanes between signals from four to two on Charleston Road from Fabian to Alma, one through lane in each direction plus a center median with left turn lanes at selected locations. The Palo Alto City Council approved a one-year trial program to assess the performance of the alternative designs. The revision of Charleston Road, reducing the four through lanes to two with a striped median, was completed in 2006. It should be noted that two through lanes in each direction are maintained through three major signalized intersections (Alma, Middlefield, Fabian), and then the two lanes merge back to one once past the signal.

A specific improvement to the driveway at Gunn High School on the western end of the Arastradero Road segment was the construction of a westbound right turn lane into the Gunn High School driveway, the site of noticeable congestion in the morning and afternoon school peak periods. Additional improvements to the entrance drive into Gunn High School were made in summer 2008, and the driveway congestion has been corrected. However, the increased number of pedestrians and bicycles at the signalized driveway intersection slows westbound traffic making a right turn into the driveway. The increased pedestrian and bicycle traffic is apparently the result of a concerted effort on the part of the school district and PTA to encourage non-vehicle commuting to high school.

Observations of traffic on Arastradero Road in the fall of 2008 revealed that westbound congestion still exists from 7:40 a.m. to just after 8:00 a.m., but to a lesser extent than before the change in the driveway configuration. Strategies for eliminating the conflicts between right turning vehicles with pedestrians and bicyclists involve routing bicyclists down the Hetch Hetchy right of

way just east of the school. However, this raises additional community issues that cannot be addressed at this time. In the future, relocation of bicycle access away from the signalized intersection of Gunn High and Arastradero will serve to reduce the remaining congestion at this intersection.

Summary

Initially, a number of striping alternatives were considered for Arastradero Road between El Camino Real and Foothill Expressway. During the planning leading to a recommended alternative, a large number of field observations by the consultant, city planning and engineering staff, school officials and the Stakeholders Committee were made along with two weeks of machine counts, manual turn counts of vehicles, pedestrians and bicyclists, and several school starting and ending time observations of the Gunn High School driveway congestion problem. Finally, three striping alternatives other than "Do Nothing" were developed in detail:

1. Four Lanes + Narrow Median (narrow bike lanes and complete parking prohibition)
2. Two Lanes + Wide Median (wide bike lanes and most parking retained)
3. Hybrid of Two and Four Lane (two westbound lanes retained west of Donald and Terman, two through lanes east and west at Donald and Terman, otherwise, the Two Lane + Median alternative
4. Do Nothing – Retain present Four Lane Undivided (with narrow bike lanes and parking)

Evaluation criteria for the entire Charleston-Arastradero Corridor were adopted by the Palo Alto City Council in 2003. Evaluation of the performance of striping alternatives in the corridor are:

1. No increase in peak, off-peak corridor travel time
2. No significant increase in delay or critical movement delay at all nine signalized intersections
3. Reduce off-peak 85th percentile speeds by at least 20 percent
4. Reduce crash rates by at least 25 percent
5. Increase pedestrian volumes by at least 20 percent by 2010
6. Increase bicycle volumes by at least 20 percent by 2010
7. Increase public transit boardings by at least 40 percent by 2010

The evaluation of the trial striping on Charleston Road found that the reduction in lanes had no significant effect on traffic performance (criteria 1 and 2) and that speeds had been reduced (criterion 3). The remaining four criteria are for longer term assessments.

The Arastradero Road portion of this corridor is far more problematic, because volumes are higher than on Charleston Road with an average weekday traffic volume of 18,300 to as high as 20,800. There are eleven schools and other traffic generators along this corridor. Pedestrian and bicycle volumes during the morning commute and when schools let out in the afternoon have increased significantly since 2006. The results of detailed traffic operations analysis concluded that peak hour directional volumes are unlikely to rise much above present levels, even if enrollment at Gunn High School increases as planned, and even with new commercial and other development planned in the corridor. The reason is that at the two ends of Arastradero Road, there are significant bottlenecks at the signalized intersections of Arastradero Road at El Camino Real (the east end), and at Foothill Expressway (the west end).

Any large increase in traffic demand during the peak hours simply cannot get through these two intersection bottlenecks onto Arastradero Road. The most likely outcome in future years will be that some current commute traffic to destinations beyond the corridor will relocate to alternate routes and some discretionary trips by corridor residents will be avoided during the peak hours where traffic congestion will continue to occur at both El Camino Real and Foothill Expressway. Drivers who have to use the corridor in the peak hours, especially the a.m. peak, will essentially crowd out commuters who have non-local destinations as well as corridor residents who can travel at other times of the day.

A detailed traffic operations analysis was completed for the four alternatives (includes the Do Nothing). Of all alternatives, the Hybrid Alternative performs best and is the recommended alternative. Specifically, the Hybrid Alternative has many advantages listed below.

- The Hybrid Alternative best realizes the overall goals and objectives for improvements in the Charleston-Arastradero Corridor:
  - Greatly improved pedestrian and bicycle safety;
  - Greatly improved pedestrian and bicycle access and mobility with frequent opportunities to cross Arastradero Road between signalized intersections;
  - A potential 3 to 5 mph reduction in vehicle travel speeds, even in off-peak hours because vehicles will not be able to pass one another along most blocks along Arastradero;
  - Improved vehicular safety through left turn lanes/two-way left turn lanes for vehicles to get out of the way of oncoming traffic;
  - Adequate room for parking on the north side, and at night on the south side;
  - Ultimately, the median will provide an opportunity for landscaping and esthetic improvements along the corridor;
  - Improved sight distance between pedestrians, bicyclists and vehicles on Donald at the signal; and
- The Hybrid Alternative best preserves needed vehicular capacity while buffering pedestrian and bicycle traffic from vehicular traffic, and it is likely that corridor traffic performance will be at least as good as the current four-lane, undivided cross section.

The Charleston-Arastradero Corridor Improvements Trial Improvements: Striping Alternatives for Arastradero Road

The Current Traffic Operations and Safety Problems of Arastradero Road

In the past six years planning for improvements in this corridor has been focused around the concept of "road diets." Four-lane, undivided urban arterial roads have been found to be particularly hazardous to pedestrians as average daily traffic volumes rise above 12,000 vehicles daily. With all segments of both Charleston Road and Arastradero Road having volumes significantly greater than 12,000 vehicles daily, it was obvious that a new approach was necessary. A survey of existing conditions revealed that accidents in the corridor had three primary collision factors. While all the segments had similar patterns, those for Arastradero Road between El Camino Real and Foothill Expressway show the need for improvements:

1. Unsafe speeds – 36%
2. Auto right of way – 25%
3. Improper turning – 11%

Accident data for a five year period, 1997 through 2002 reveals that the accident rate in the entire Charleston/Arastradero Corridor is 6.2 accidents per million vehicle miles of travel. A "vehicle mile" is one vehicle driving one mile, an indication of exposure to accidents. The statewide average accident rate for four-lane undivided urban arterials is 4.95 accidents per million vehicle miles of travel. Applying statistical analysis we find that the 6.2 rate in the corridor would not be exceeded due to chance variation over 99 percent of the time – in other words, the higher than average accident rate in the corridor is almost certainly not due to random variation, but more due to traffic conditions. Further, out of the 471 accidents over five years, 78 involved injuries. Out of the 24 pedestrian and bicycle accidents in these same five years, 23 involved an injury, or 96 percent of all pedestrian and bicycle accidents were injury accidents, each of which could easily have been fatal. It should also be noted that four lane urban arterials with medians have an average accident rate of only 2.4 accidents per million vehicle miles of travel, and for that of two-lane arterials with a median, the rate is only 2.05 accidents per million vehicle miles of travel. The simple step of adding a median appears to be directly related to a 50 to 60 reduction in all accidents on four lane urban arterials. Of the 471 accidents, 221 were rear end and sideswipe accidents, about 47 percent of all accidents.

Unsafe speeds usually indicate rear end accidents at both signalized and unsignalized intersections. On Arastradero, many of these accidents are rear end and sideswipe accidents at unsignalized intersections where a vehicle in the left lane will stop and wait for gaps in oncoming traffic to complete their turn. Because they are in a moving lane, however, these stopped motorists are subject to being hit by traffic following them. Auto right of way usually refers to an accident where a vehicle turning left onto a side street or turning left from a side street is hit by oncoming traffic. Because traffic is relatively heavy there are few safe gaps in traffic for making these maneuvers. Improper turning typically refers to drivers turning from the wrong lane. Perhaps more than half the accidents on Arastradero are related to a lack of left turn lanes coupled with high through volumes and high speeds. The 85th percentile speeds on Arastradero are close to 40 mph with maximum speeds that approach 50 mph by almost 170 vehicles daily, about 1 percent of all traffic. Detailed data on volumes and speeds are in the appendices. Given the volumes of bicycles and pedestrians, this is a very unsafe combination of traffic conditions. Because of these conditions, the concept of a road diet for both Charleston Road and Arastradero Road became the model for pursuing improvements for all.

The Concept of "Road Diets" as Related to Charleston and Arastradero Roads

The improvements under consideration for Arastradero Road are examples of "road diet" improvements that have been gaining acceptance throughout the world. Four-lane, undivided arterial roads are especially vulnerable to operations and safety problems when average daily traffic volumes are much above 12,000 vehicles daily. In many instances such roads traverse residential areas, or community business centers. As traffic volumes increase, congestion quickly rises, and traffic collisions increase faster than do the traffic volumes. Surveys in many cities with such roads also indicate that livability along the roads deteriorates rapidly.

One reason for the congestion is that the left-most through lane becomes a de facto left turn lane because a single left turning vehicle can often block the lane for up to a minute or more as the driver waits for a gap in oncoming traffic to complete the turn. Drivers behind the stopped vehicle trying to make a left turn then merge into the right lane with resulting sideswipe accidents. Likewise, because vehicles stop unexpectedly in the left lane to make a turn, they are more commonly involved in rear end accidents.

Of special concern when volumes on a four-lane road increase beyond 12,000 vehicles daily, is that it becomes very difficult to impossible for a pedestrian to find gaps in traffic long enough to safely cross the road. On a 60-foot wide roadway, the pedestrian needs about 15 seconds to make it all the way across. With high traffic volumes, pedestrians become impatient and enter the road regardless, and they try to force the traffic to stop by assuming they have legal right of way. The problem with this is that while one driver in a lane may stop, another may bypass the stopped vehicle and hit the pedestrian as they move across the adjacent lane. Pedestrians cannot always be seen by oncoming motorists when they are hidden by a stopped vehicle. Because of the ambiguity of whether the stopped motorist is waiting for a left turn or stopped for a pedestrian, many bypassing drivers decide that the reason is for a left turn resulting in greatly increased risks for the crossing pedestrian.

Because of these congestion and traffic safety problems, many cities have evaluated the feasibility of reducing the four through lanes to two, and adding left turn lanes, bike lanes, on-street parking and improving pedestrian crossings. Additionally, the space not needed for the through lanes can be landscaped, such as landscaped medians. The research to date shows that road diet treatments, if implemented carefully, can achieve many positive results including:

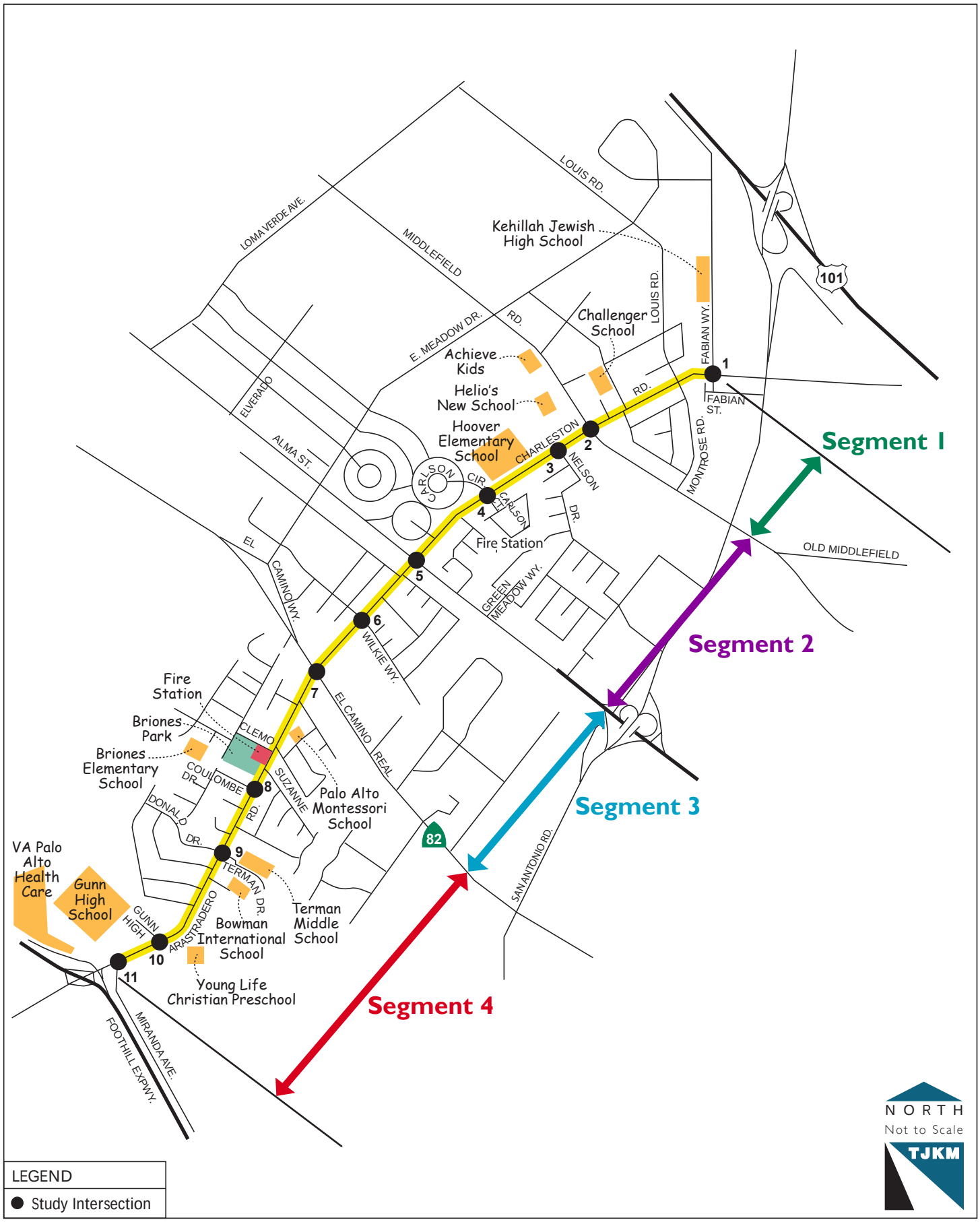
- Reductions of 30 to 70 percent of the drivers traveling in excess of the speed limit, and even outright reductions in average speeds;
- Reductions in all types of accidents from 10 to 60 percent;
- Improved bike mobility;
- Improvements in the appearance of the neighborhood through landscaping and amenities for pedestrians, bicyclists and transit;
- Better access and mobility into abutting neighborhoods as well as for crossing the arterial street; and
- Enthusiastic acceptance by 80 to 90 percent of the residents and businesses along the arterial placed on a road diet.

During the planning of the corridor evaluation and trial improvements, the above goals and objectives played a major part in planning for the ultimate design of both Charleston Road and Arastradero Road. Along the way detailed traffic operations issues have emerged since 2004. This report describes the most recent analysis for the Arastradero Road segment. Figure 1 shows the relationship of Arastradero Road to the entire corridor planned for improvements.

City of Palo Alto – Charleston-Arastradero Trial Traffic Improvements

Figure 1

Study Corridor and Segments



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Arastradero Road Striping Alternatives

The striping alternatives evaluation looked at several preliminary designs, and of those, three have been developed to the conceptual plan level. All alternatives maintain the current lane configuration from the Gunn High School driveway west to Foothill Expressway. East of the Gunn High School driveway, the alternatives are:

1. Two lanes each direction with narrow median + left turn lanes at intersections (parking mostly removed on both sides)
2. One lane each direction with median + left turn lanes at intersections (parking mostly retained on both sides)
3. A Hybrid of Alternatives 1 and 2 with two through lanes each direction at Terman and two through lanes westbound west of Terman and one lane eastbound. East of Terman there is one lane in each direction + left turn lanes at intersections (parking mostly retained on the north side, and at night on the south side)
4. Do Nothing

Alternatives 1 and 3 have been determined to be the more effective improvements. Alternative 1, the two through lanes in each direction with a narrow median and left turn lanes at signals will operate better than existing conditions in terms of congestion. With this alternative, parking must be prohibited at all times, however, and problems remain with pedestrians crossing Arastradero between signals. Either Alternative 1 or 3 is preferable to the Do Nothing Alternative. Alternative 3, the Hybrid Alternative, works better than Existing Conditions in terms of travel time (average speed), and of course is far better in terms of pedestrian and bicycle safety and circulation. Alternative 2 is compromised by the continuing westbound congestion at the Gunn High School driveway in the a.m. peak as well as eastbound congestion at Donald and Terman. This alternative performs the worst of all in terms of delays per vehicle. It was this finding that led to development of the Hybrid Alternative that retains the necessary westbound capacity at Gunn High School during the a.m. peak.

Among the earlier alternatives was starting Gunn High School arrival times 30 minutes earlier so that the peak arrival times at Gunn High School and at Terman Middle School had less overlap. This also was found to be ineffective, because by the time congestion eases for Gunn High, it starts again for Terman with congestion lasting for over 90 minutes overall. A second consideration was that the school district would find it very difficult to implement because of the related schedules for extracurricular activities, labor agreements and other considerations.

A more detailed description of each alternative follows. Figures 2a through 4b following this discussion provide a graphic presentation of the alternatives.

Alternative 1: Four Lanes Throughout with Narrow Median + Left Turn Lanes at Signals

In this alternative, some urban design and safety features are added to the present cross section. This is similar to the alternative that was implemented on the western end of Charleston. The improvements include:

1. Left turn lanes would be provided at the signalized intersections at Gunn High School, Donald/Terman, and Coulombe.
2. Median between side streets would be 6-feet wide, widening to 10 feet at intersections of side streets, with no or limited tapers. Left turns would be made from 10-foot wide area that is only as long as the width of the cross street.
3. Signals would be timed with adaptive control to reduce signal delays as much as possible, with shorter cycle lengths generally than the two-lane or hybrid alternatives.

4. Crosswalks would be provided at selected locations between signalized locations, with the median refuge island treatment shown in Figures 2a and 2b. For the trial installation, only one median refuge island would be constructed as shown in Figure 2b (east of Coulombe). The striped median would provide a pedestrian refuge of sorts at unsignalized intersections for unmarked crosswalks.
5. Capacity improvements would be made at Donald and Terman:
   a) lengthening the westbound left turn lane on Arastradero;
   b) restriping southbound Donald to provide one southbound through-right lane and one southbound left turn lane (parking would be prohibited on west side of Donald); and
   c) not allowing pedestrian movements other than during the exclusive pedestrian phase during the times of peak school bike and pedestrian traffic at Terman Middle School.

Alternative 2: One Lane Each Direction + Median/Left Turn Lanes All Intersections

In this alternative, the same improvements are proposed for Donald/Terman along with adaptive traffic signal control.

1. Left turn lanes would be provided at the signalized intersections at Gunn High School, Donald/Terman, and Coulombe.
2. A median would be provided between signalized intersections from east of Gunn High Driveway.
3. Crosswalks would be provided at selected locations between signalized locations, with the median refuge island treatment shown in Figures 3a and 3b. For the trial, only one median refuge island would be constructed as shown in Figure 3b. The striped median would provide a pedestrian refuge of sorts at unsignalized intersections for unmarked crosswalks.
4. Signals would be timed with adaptive control to reduce signal delays as much as possible, but cycle lengths will be longer than they are today, generally.
5. Capacity improvements would be made at Donald and Terman:
   a) Lengthening the westbound left turn lane on Arastradero;
   b) Restriping southbound Donald to provide one southbound through-right lane and one southbound left turn lane (parking would be prohibited on west side of Donald);
   c) not allowing pedestrian movements other than during the exclusive pedestrian phase during the times of peak traffic at Terman Middle School; and
   d) providing two through lanes eastbound on the approach at Terman, dropping the second lane at Pomona.

Alternative 3: Hybrid of Alts 1 & 2 (Two Through Lanes Donald/Terman → Gunn)

In this alternative, attributes of Alternatives 1 and 2 are combined. With one westbound through lane at Donald and Terman, a.m. peak traffic that would reach the Gunn High School driveway queues instead at Donald and Terman and meters traffic into the Gunn signal. However, westbound a.m. peak queues are exchanged for long queues at Donald and Terman that have the potential of reaching McKeller for about 15 to 20 minutes. If two lanes are provided for westbound traffic at this intersection, the queues again shift to the Gunn signal, but they also extend through Donald and Terman creating difficulties for side street motorists and for pedestrians at the signal. Therefore, Alternative 3 attempts to offset these negative impacts by providing the same vehicular capacity westbound as before. Westbound and eastbound vehicular capacity with just one through lane in either direction is sufficient at Coulombe. Tables 1through IV show the caparisons of traffic performance of each alternative compared with existing conditions

today for the a.m. and p.m. peaks. At other times of the day there is little difference in performance between the alternatives and existing conditions. Details regarding the Hybrid alternative include:

1. Left turn lanes would be provided at the signalized intersections at Gunn High School, Donald/Terman, and Coulombe.
2. A median would be provided between signalized intersections from east of Gunn High Driveway.
3. Crosswalks would be provided at selected locations between signalized locations, with the median refuge island treatment as shown in Figure 4b. For the trial, only one mid-block crosswalk would be installed. Additional such crosswalks would be installed in the permanent installation if the Hybrid Alternative is approved for permanent installation. The striped median would provide a pedestrian refuge of sorts at unsignalized intersections for unmarked crosswalks.
4. Signals would be timed with adaptive control to reduce signal delays as much as possible, but cycle lengths will be longer than they are today, generally.
5. Capacity improvements would be made at Donald and Terman:
   a) Lengthening the westbound left turn lane on Arastradero;
   b) Restriping southbound Donald to provide one southbound through-right lane and one southbound left turn lane (parking would be prohibited on west side of Donald);
   c) not allowing pedestrian movements other than during the exclusive pedestrian phase during the times of peak traffic at Terman Middle School; and
   d) providing two eastbound through lanes at Terman, dropping the second lane at Pomona.
6. Provision of two through westbound lanes from east of Donald and Terman through Gunn High School separated from the single eastbound through lane by a 12 foot median.

The crosswalk treatment with a median refuge was discussed extensively in an earlier report. It features a crosswalk from the curb (which could be extended out to the bike lane in Alternatives 2 and 3, but not with Alternative 1) out to a physical median 10 to 17 feet wide. Rather than have the crosswalk go straight across the entire street, instead crossing the second half of the street would be offset so that pedestrians manage their movements for each direction of traffic separately. In many instances it is possible to have the pedestrian walk facing oncoming traffic in the median, thus reinforcing the need for pedestrians to catch the eye of the drivers that will be stopping for them. For Alternative 1, because there are two lanes in each direction, this crosswalk strategy is less safe than the single through lane per direction alternatives 2 and 3. However, because the median island cuts the crossing distance by more than 50 percent, there will be increased safety even with the four-lane alternative over existing conditions. Note that it will be necessary to construct a raised median (and pedestrian fences on the median) rather than just implement modified striping for any of the alternatives excepting Do Nothing.

Comparison of Striping Alternatives

As with Charleston Road, modifying the number of lanes affects traffic operations, but not to the extent that would be imagined. The assumption is that vehicle capacity is reduced by half, but it is not reduced by much, if at all, because the delays caused by vehicles stopped in the left lanes waiting to make left turns turn those lanes into de facto left turn lanes. On Arastradero this is apparent in comparing operations for existing striping versus the Hybrid Alternative. The Hybrid Alternative is slightly slower eastbound and significantly faster westbound than existing in the a.m. peak. Table II shows this same comparison for the p.m. peak. Generally, the objective is to have

the percent change greater than 1.00 for average speeds and less than 1.00 for the delay per vehicle in Tables I and II. More detailed traffic operations are shown in Tables III and IV.

Table I: Comparison of Existing and Striping Alternatives (a.m. Peak)

Direction and Alternative	*SimTraffic Results*		*% Change Alternative\Existing*	
	Average Speed (mph)	*Delay/Vehicle (seconds) (route)*	*Average Speed (mph)*	*Delay/Vehicle (seconds) (route)*
Existing EB Arastradero	17	115		
Existing WB Arastradero	10	267		
Alternative 1 Eastbound	18	96	106%	83%
Alternative 1 Westbound	14	164	140%	61%
Alternative 2 Eastbound	17	112	100%	97%
Alternative 2 Westbound	8	348	80%	130%
Alternative 3 Eastbound	16	126	94%	110%
Alternative 3 Westbound	12	203	120%	76%

The data in Tables I through IV are derived from a traffic operations model that was calibrated, or closely matched to existing traffic operations. By this we mean that the operations model estimates travel times and delays quite close to what actually occurs in the field. The model used is Synchro 6 and SimTraffic 6, an animated micro-simulation model that is widely used by traffic engineers throughout the nation for these types of analysis. The "Existing" data in these four tables are derived from the SimTraffic model output, but the model estimates almost duplicate field observations in terms of travel times and delays along the corridor.

Table II: Comparison of Existing and Striping Alternatives (p.m. Peak)

Direction and Alternative	*SimTraffic Results*		*% Change Alternative\Existing*	
	Average Speed (mph)	*Delay/Vehicle (seconds) (route)*	*Average Speed (mph)*	*Delay/Vehicle (seconds) (route)*
Existing EB Arastradero	19	187		
Existing WB Arastradero	26	139		
Alternative 1 Eastbound	21	64	111%	34%
Alternative 1 Westbound	25	44	96%	32%
Alternative 2 Eastbound	17	107	89%	57%
Alternative 2 Westbound	24	52	92%	37%
Alternative 3 Eastbound	21	69	111%	37%
Alternative 3 Westbound	24	52	92%	37%

The modeling output for existing conditions for the a.m., midday and p.m. peak closely coincides with the GPS floating car studies conducted in May 2007. In the a.m. peak, during the Gunn High School peak from 7:40 a.m. through 8:10 a.m., the modeled and observed average speeds agreed within 1 mph in each direction. During the midday, the observed speeds of 20 mph in either direction are in close agreement with the 19 mph eastbound and 20 mph westbound model estimates. Likewise, the 23 mph observed eastbound and 21 mph observed westbound p.m. peak speeds are reasonably close to the model estimates of 20 mph eastbound and 19 mph westbound. The model can confidently be used to assess alternative designs. Because the midday peak is non-problematic for all of the alternatives, modeling and simulation results are not detailed in this report.

In Tables III and IV, note that additional queuing is expected with the single lane at Coloumbe, and because of signal timing changes to make Arastradero flows more efficient, longer eastbound left turn queues are expected at the Gunn High School signal in the a.m. peak. In the p.m. peak the Alternative 3 queues are generally shorter at Gunn High as compared with existing, but again because of the single lane, queues at Coulombe are expected to increase over existing. However, one major change is that the current shared through plus left turns eastbound on Arastradero at Coulombe will be converted to an eastbound through lane plus an eastbound left turn lane with a protected arrow left turn. This has the effect of increasing the average delay for these left turns, but greatly reduces the delays experienced in the existing, eastbound through lane.

One major change is the length of the signal cycle for the a.m. peak. It increases to 170 seconds at Donald/Terman while Coulombe and Gunn are half-cycled at 85 seconds. This would occur only from 7:40 a.m. to 8:10 a.m., and otherwise, cycle lengths would average approximately 90 to 112 seconds for all other periods. Once adaptive signal timing is available in the corridor, these cycle lengths should average less than current cycle lengths, and delays will be further reduced. The results in Tables III and IV are based upon time of day coordination. Adaptive signal timing should reduce the delays by 10 to 30 percent as well as travel times.

Table III: Detailed Travel Time Comparisons of Striping Alternatives (7:00-9:00 a.m.)

ID	Intersection of Arastradero	Existing		Alternative 1		Alternative 2		Alternative 3	
		Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)	LOS
8	Coulombe	8.3	A	4.5	A	18.6	B	39.9	D
9	Terman/Donald	71.5	E	45.5	D	99.1	F	38	D
10	Gunn High School	107.6	F	112.1	F	112.1	F	103.3	F

Segment Travel Times	Existing Times		Alt. 1 Times		Alt. 2 Times		Alt. 3 Times	
	Total* (sec)	Delay** (sec)	Total (sec)	Delay (sec)	Total (sec)	Delay (sec)	Total (sec)	Delay (sec)
Westbound								
ECR --> Coulombe	47.6	11.7	44.7	8.9	116.2	86.0	123.1	87.4
Coulombe --> Donald/Terman	50.3	32.0	39.3	21.2	119.4	109.4	42.3	24.0
Donald/Terman --> Gunn	104.4	69.0	99.6	64.3	83.6	48.8	102.1	66.6
Total Time in Seconds	202.3	112.7	183.6	94.4	319.2	244.2	267.5	178.0
Speed (mph)	17.8		19.6		11.3		13.4	
Eastbound								
Gunn --> Donald/Terman	99.3	63.0	69.9	31.7	84.0	47.8	82.1	45.6
Donald/Terman --> Coulombe	34.8	16.3	24.5	5.5	38.5	19.5	44.3	25.3
Coulombe --> ECR	95.6	57.8	72.4	37.6	74.5	39.5	80.5	45.6
Total Time in Seconds	229.7	137.1	166.8	74.8	197.0	106.8	206.9	116.5
Speed (mph)	15.6		21.5		18.2		17.4	

Queuing Analysis: SimTraffic, 7:00-9:00 a.m.

ID	Intersection /Movement	Lengths of 95th Percentile Queues (in feet @ 25'/vehicle)			
		Existing	Alternative 1	Alternative 2	Alternative 3
7	Arastradero @ ECR LT	125	125	125	150
7	Arastradero @ ECR EBT	425	400	400	425
8	Arast/Coulombe EBLT	475 (Shared TL)	75	75	75
8	Arast/Coulombe EBT	400	175	325	550
8	Arast/Coulombe WBT	200	200	275	225
9	Arast/Donald EBLT	75	75	75	75
9	Arast/Donald EBT	300	275	325	275
9	Arast/Donald WBT	375	325	275	350
9	Arast/Terman WBLT	175	225	350	275
10	Arast/Gunn EBLT	175	300	300	300
10	Arast/Gunn EBT	275	475	475	425
10	Arast/Gunn WBT	575	550	375	550

* Total Travel Time, ** Delay is seconds/vehicle

Table IV: Detailed Travel Time Comparisons of Striping Alternatives (4:00-6:00 p.m.)

ID	Intersection of Arastradero	Existing		Alternative 1		Alternative 2		Alternative 3	
		Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)	LOS
8	Coulombe	3.5	A	4.2	A	6.2	A	11.5	B
9	Terman/Donald	10.5	B	8.4	A	11.8	B	4.8	A
10	Gunn High School	11.2	B	7.7	A	12.3	B	25.7	C

Segment Travel Times	Existing Times		Alt. 1 Times		Alt. 2 Times		Alt. 3 Times	
	Total* (sec)	Delay** (sec)	Total (sec)	Delay (sec)	Total (sec)	Delay (sec)	Total (sec)	Delay (sec)
Westbound								
ECR --> Coulombe	45.9	11.0	48.4	11.4	43.7	12.1	51.8	14.3
Coulombe --> Donald/Terman	25.1	6.7	29.6	11.3	27.9	9.6	23.0	4.9
Donald/Terman --> Gunn	54.5	17.4	52.8	16.6	52.6	17.5	61.2	25.4
Total Time in Seconds	125.5	35.1	130.8	39.3	124.2	39.2	136.0	44.6
Speed (mph)	28.6		27.5		28.9		26.4	
Eastbound								
Gunn --> Donald/Terman	49.2	12.2	55.2	18.1	79.2	31.9	54.3	17.1
Donald/Terman --> Coulombe	23.4	5.5	25.7	7.7	40.7	21.9	28.3	9.8
Coulombe --> ECR	93.7	61.1	62.7	27.8	67.3	32.5	66.7	31.2
Total Time in Seconds	166.3	78.8	143.6	53.6	187.2	86.3	149.3	58.1
Speed (mph)	21.6		25.0		19.2		24.1	

Queuing Analysis: SimTraffic, 4:00-6:00 p.m.

ID	Intersection /Movement	Lengths of 95th Percentile Queues (in feet @ 25'/vehicle)			
		Existing	Alternative 1	Alternative 2	Alternative 3
7	Arastradero @ ECR LT	125	125	125	125
7	Arastradero @ ECR EBT	650	325	300	250
8	Arast/Coulombe EBLT	225 (Shared TL)	75	75	75
8	Arast/Coulombe EBT	200	150	300	350
8	Arast/Coulombe WBT	300	250	325	200
9	Arast/Donald EBLT	75	75	125	75
9	Arast/Donald EBT	300	250	275	200
9	Arast/Donald WBT	250	225	350	100
9	Arast/Terman WBLT	125	125	275	75
10	Arast/Gunn EBLT	150	150	250	125
10	Arast/Gunn EBT	200	250	300	275
10	Arast/Gunn WBT	425	300	225	300

* Total Travel Time, ** Delay is seconds/vehicle

Additional Considerations Regarding Striping Alternatives

Beyond the normal measures of effectiveness in Tables I through IV, modifying the striping on Arastradero Road will also result in other operational effects that are discussed below in the form of benefits and problems with each.

Effects of Longer Cycle Lengths and Platoons/Queues

The conversion to one through lane in each direction results in a lengthening of the average cycle lengths at all times of the day. Longer cycle lengths are needed to enable comparable capacity with the reduction from two lanes to one lane in either direction. The action alternatives do take left turns out of the through traffic lanes, and the improvements at Donald/Terman significantly improve performance in the entire corridor, because this intersection is the main bottleneck outside of the Gunn High School a.m. inbound peak congestion in the corridor. The longer cycle lengths in each of the alternatives will also result in some higher delays for left turns out of, and even left turns into the side streets, because the resulting platoons and queues will be roughly twice as long and even longer than with the current striping on Arastradero Road. Delays for side street traffic are expected to increase from the current 20 to 35 seconds in the a.m. peak to between 60 and 100 seconds depending upon the location of the various side streets and signals along Arastradero Road. For nearby streets, the queues at the signals prevent reaching the left turn lanes on Arastradero as well as turning left from the side streets due to the much longer queues and platoons. However, adaptive signal coordination will minimize the increases in cycle lengths for most cycles during the day.

Benefits and Additional Problems by Alternative

Other than longer cycle lengths, the following benefits accrue to the Three-lane and Hybrid alternatives:

- These two wide-median alternatives best realize the overall goals and objectives for improvements in the Charleston-Arastradero Corridor:
  - Greatly improved pedestrian and bicycle safety;
  - Greatly improved pedestrian and bicycle access and mobility with frequent opportunities to cross Arastradero Road between signalized intersections;
  - A potential 3 to 5 mph reduction in vehicle travel speeds, even in off-peak hours because vehicles will not be able to pass one another along most blocks along Arastradero;
  - Improved vehicular safety through left turn lanes/two-way left turn lanes for vehicles to get out of the way of oncoming traffic;
  - Adequate room for parking on both sides for Alternative 1, and on the north side in Alternative 3 all hours of the day, and at night on the south side;
  - Ultimately, the median will provide an opportunity for landscaping and esthetic improvements along the corridor;
  - Improved sight distance between pedestrians, bicyclists and vehicles on Donald at the signal; and
- The Hybrid Alternative best preserves needed vehicular capacity while buffering pedestrian and bicycle traffic from vehicular traffic, and it is likely that corridor traffic performance will be at least as good as the current four-lane, undivided cross section. The Three-lane alternative does not perform as well as existing striping on Arastradero Road.

Some of the additional problems that may occur with a three-lane cross section:

- Rear-end accidents may rise due to longer queues that surprise motorists;
- Motorists have been observed to accept less than adequate gaps after about a 60 second or more delay in turning left into and out of side streets;
- Backing from residential driveways will be more difficult due to the long platoons and queues;
- Queues blocking side streets near signals will be common for some hours of the day;
- An accident or any blockage of the through lane in busy times will lead to extensive queuing and gridlock, and this can also materially affect emergency access times unless the design ensures there is 20 feet clear between the median and curb; and
- There is limited capacity for an increase in peak hour volumes. However, the capacity bottlenecks of El Camino Real and Foothill Expressway ensure that actual peak hour demand volumes probably cannot get to Arastradero, but will most likely queue on the approaches on El Camino Real and on Foothill Expressway.

Some of the benefits of the four-lane median alternative are:

- Shorter cycle lengths, and the potential for even better performance because fewer vehicles will block the through lanes waiting for a turn;
- Safer, but not ideal storage of vehicles waiting to make a left turn;
- Pedestrian refuge in the median island;
- Median can be landscaped;
- Queues will not be longer than they are today, and can be shorter due to adaptive signal control and left turn storage at minor intersections.

Some of the potential additional problems with the four-lane median alternative are:

- Speeds will not be reduced from today's relatively high 85th percentile speeds, especially outside the peak hours and most all hours on weekends;
- Bike lanes are extremely narrow and less safe – vehicles may more readily encroach on bike lanes because the vehicle lanes are only 10 feet wide, in fact bike lanes may be less safe than existing lanes;
- Many vehicles trying to turn left will not adequately be clear of through lane traffic, and there could actually be an increase in rear-end accidents over today; and
- Parking removal is mandatory.

Recommendations

TJKM concludes, on the basis of the extensive set of data collected in this corridor from 2004 through 2008 and with discussions with the Stakeholders Committee and city staff, that the road diet design is valid and should be implemented as a trial on Arastradero Road.

TJKM recommends that the Hybrid Alternative be selected for trial installation.

The non-signalized pedestrian crosswalk west of Clemo should have a physical median refuge island rather than merely striping. This is different than the trial striping on Charleston where only striping was implemented for the trial. If the trial is ultimately approved, there should be additional, similar crosswalks along the corridor for the permanent installation. At these locations there will need to be a raised, pedestrian refuge island coupled with a crosswalk that is split to two nearby crossing locations at the median rather than having the crosswalk go straight across Arastradero. This is called the "Danish Offset" style of crosswalk.

All other features of the Hybrid Alternative should be presented to the Palo Alto City Council for approval, and if approved, final design for signing and striping trial should then be started for the installation within the repaving program in the summer of 2010.

To minimize potential traffic delay due to the longer queues in the single travel lanes of the hybrid alternative, the city should implement adaptive traffic signal timing plans for appropriate subsystems of signals along Arastradero Road and Charleston Road. Appropriate signal timing plans will maintain efficient traffic flows. At present the city's signal system consists of McCain "BiTran" software. This software system has a proven record with signal coordination in the City of Palo Alto and with other agencies. Once the lane configuration is modified on Arastradero Road, new timing plans configured for adaptive operation should be implemented to obtain maximum benefits.

Figure 5 on the following page shows a typical cross section and plan view for the permanent installation of a landscaped median should the trial installation of Alternative 3 prove successful and desired.

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Appendix A – 2006 and 2007 Traffic Volume and Speed Data

Appendix B – Simulation Modeling

Appendix C – Existing Striping on Arastradero Road