Traffic Analysis Review:

Four Corners Intersection Study
Marin County, CA
DRAFT Report

August 11, 2017

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Introduction

This report summarizes the findings of PRISM Engineering regarding the subject "Four Corners" intersection within Marin County, the intersection of the Panoramic Highway at Muir Woods Road / Sequoia Valley Road. This report focuses on a review of the previously prepared ***TETAP Marin County Panoramic Highway at Four Corners Intersection Improvement Feasibility Study, June 30, 2003***, and specifically reviews Alternatives 2 and 3 from that report for relevance and completeness with data and analysis methodologies in place from this year (2017), as well as review of design. The roundabout Alternative 1 was eliminated from review due to lack of sufficient right-of-way to implement safely and efficiently (slopes and topography constraints).

A site visit was made during the last week in July to observe traffic control, as well as vehicle movements observed from an aerial position using drone camera. Traffic conditions were measured and observed in tallied counts and video (turning movements at the subject intersection). Also, 24 hour counts in 15 minute intervals were taken at several locations including 1) Panoramic Highway south of Muir Woods Road, 2) Muir Woods Road at both ends (near Panoramic Highway and another near Highway 1), and on the 3) Shoreline Highway 1 just southwest of Muir Woods Road. This data helped to establish existing traffic patterns, directionality, and magnitude, as well as provide insight as to how drivers may be navigating the Four Corners intersection during the peak time periods. During the site visit, measurements of lane widths were taken and later correlated with newly taken aerial photography so that conceptual plan sketches for Alternative 4 could be drawn very close to scale. Observation of signs, striping, and pavement markings were also noted in the field.

PRISM Engineering hired Traffic Counts Plus, a data collection firm to collect turning movement traffic data for both the am and pm peak hours at the intersection of Highway 1 and Panoramic Highway at Muir Woods Road, as well as 24-hour hose counts at several locations. Data was collected on July 18 (TUE) and July 27 (THU) at the following locations:

- Panoramic Highway at Muir Woods Road (AM peak hour turn move count)
- Panoramic Highway at Muir Woods Road (PM peak hour turn move count)
- Muir Woods Road just west of Panoramic Highway (24-hour count)
- Muir Woods Road just north of Shoreline Highway 1 (24-hour count)
- Panoramic Highway 300 feet south of Muir Woods Road (24-hour count)
- Highway 1 just south of Muir Woods Road (24-hour count)

These sets of traffic volumes helped give us an idea of the traffic patterns in the area, and the magnitude of traffic volumes at various locations in the Muir Woods National Monument vicinity.

Existing Conditions

Traffic conditions in the study area are unique in that they are primarily recreational related, being adjacent to the Muir Woods National Park. Because of the presence of recreational traffic, many of the drivers and cyclists in this location are not familiar with the subject study intersection, the Four Corners intersection. PRISM Engineering was able to observe during peak conditions, situations where driver confusion is taking place primarily pertaining to who has the right-of-way. The intersection is nonstandard because of challenging mountainous topography of the immediate landscape. **Figure 1** shows the July 2017 traffic count summary information. The peak hour information shown in the turning movement diagrams does not represent the maximum volume for turning limits, rather represents the volume of traffic taking place during typical peak hours in the morning and in the evening related to commuter traffic. The highest level of turning movement traffic is taking place in the middle of the day near the noon hour. These are not the typical commuter peak travel trips (those are actually lower), but a high percentage of midday traffic would be related to recreational purpose. The 24-hour traffic counts taken in July 2017 along Panoramic Highway just south of the study intersection, and on Muir Woods Road just west of the study intersection indicate that the volumes for the noon hour are as much as two times higher than volumes sample during the commuter peak hours (ie 8-9am or 4-5 pm).

Figures 2 and 3 show the 15-minute interval bar graph profile chart for the July 2017 24-hour count data. The Panoramic Highway's highest *hourly* volume (sum of highest four bars) south of the intersection was 532 vehicles per hour from 12:15-1:15 pm. This compares to the PM peak hour volume of 419 vehicles per hour (4:15 to 5:15 pm).

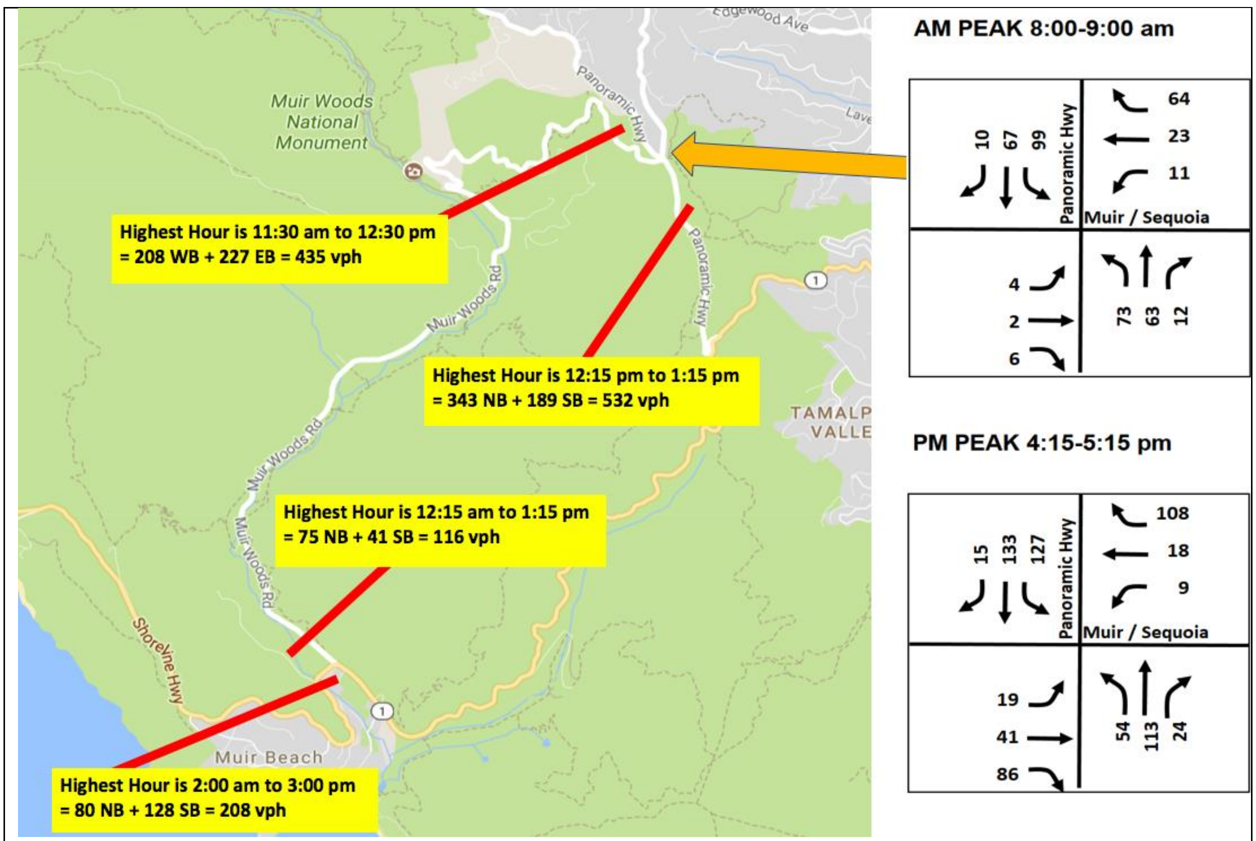
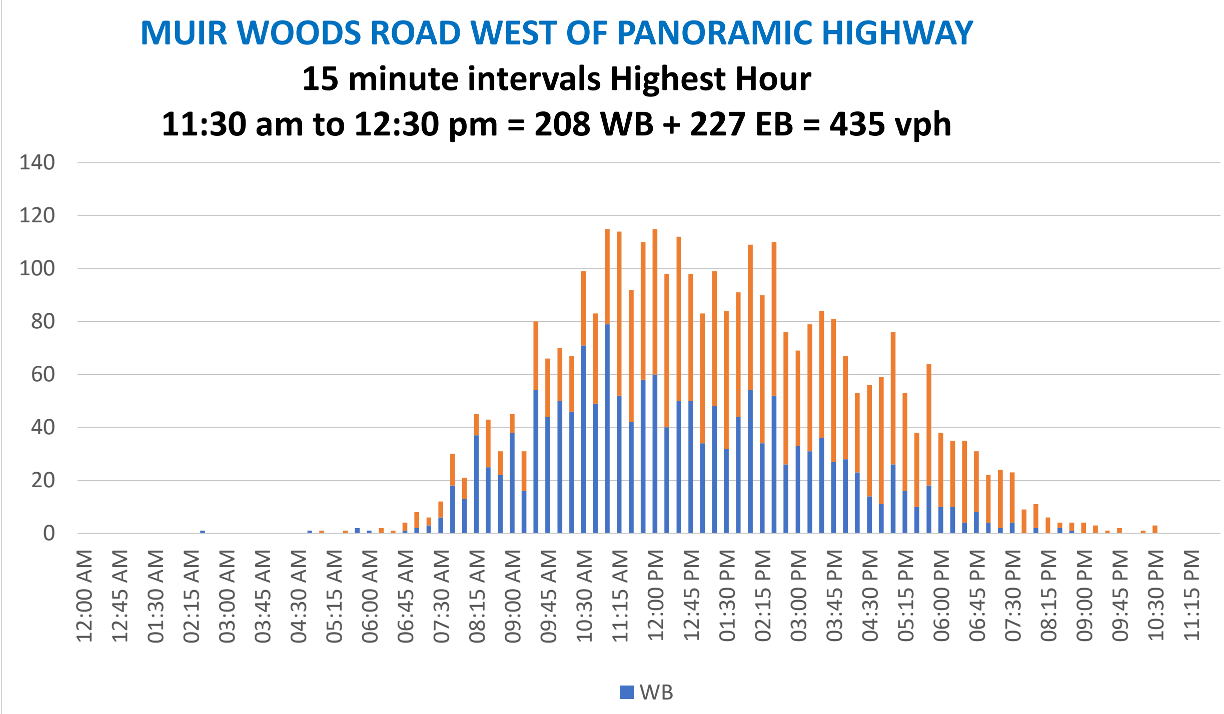


Figure 1. Existing Traffic Count Summary



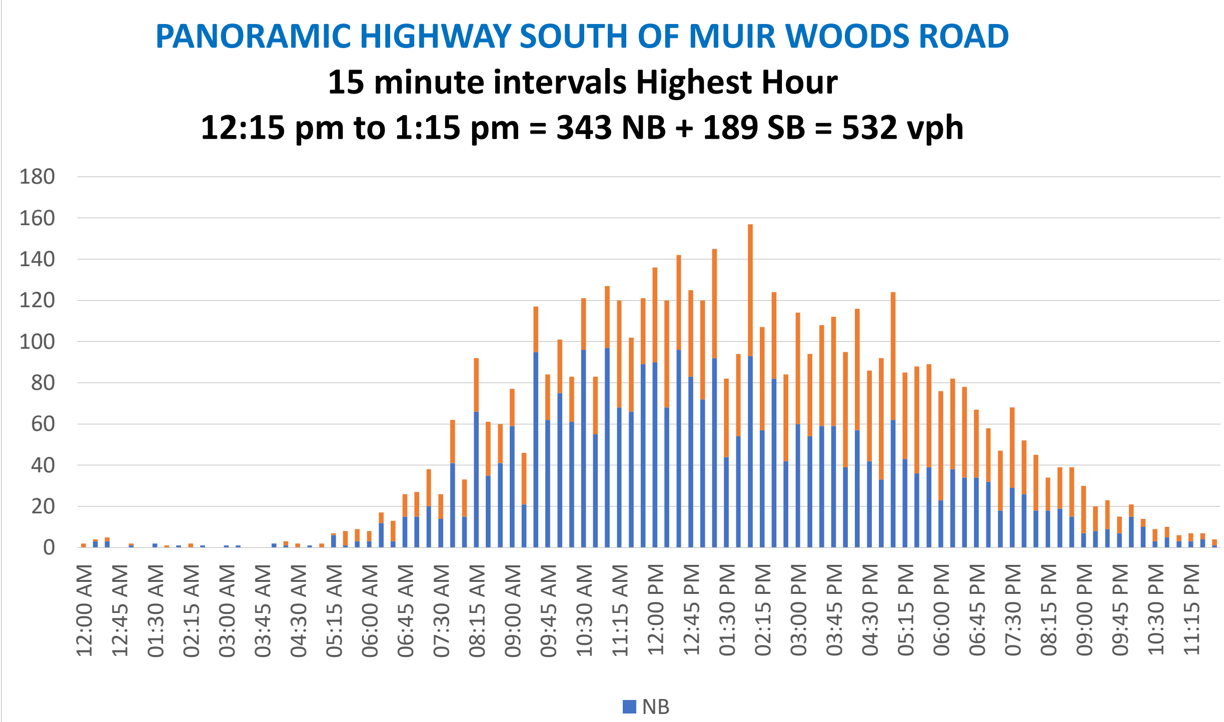
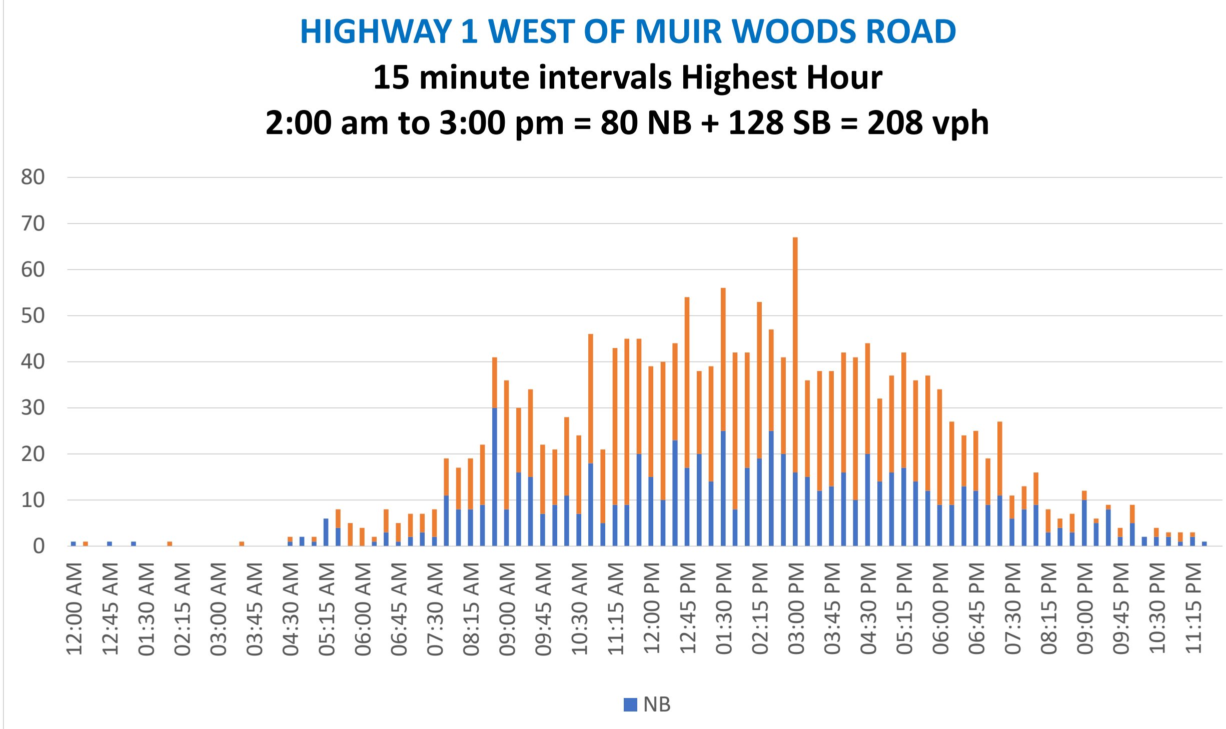


Figure 2. Existing 24-hour Count Summary Near Four Corners Intersection



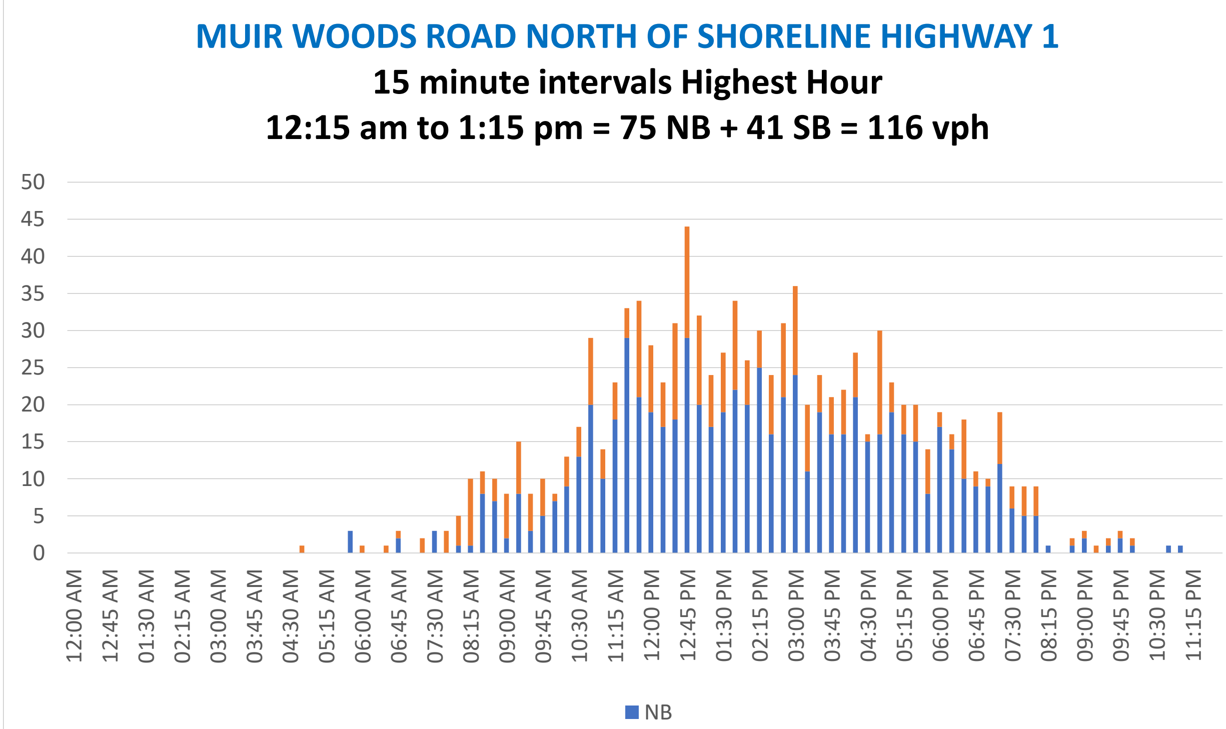


Figure 3. Existing 24-hour Count Summary Near Four Corners Intersection

Existing Level of Service at Four Corners Intersection: LOS B overall, Midday

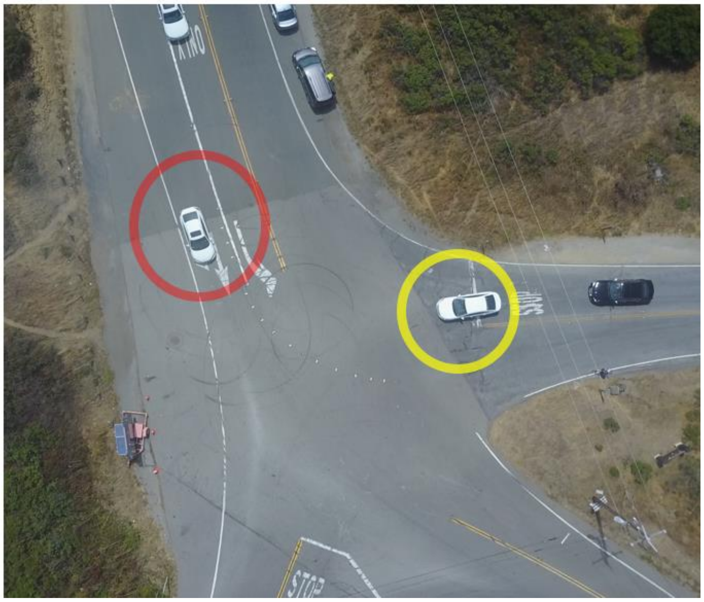
New traffic counts were taken at the Four Corners intersection for am and pm peak hours. The resulting peak hour level of service was LOS A overall for both peak hour time periods, but the side street level of service for stop sign approaches was LOS B for the Muir Woods EB approach during the am peak hour (8:00-9:00 am), and LOS C for the same approach in the pm peak hour (4:15-5:15 pm). Calculations were made in Synchro 9 using the highway capacity manual 2000 and 2010 methods. Detailed capacity calculation sheets are contained in the appendix. These calculations were for the commuter peak time periods, which are lower than the midday peak.

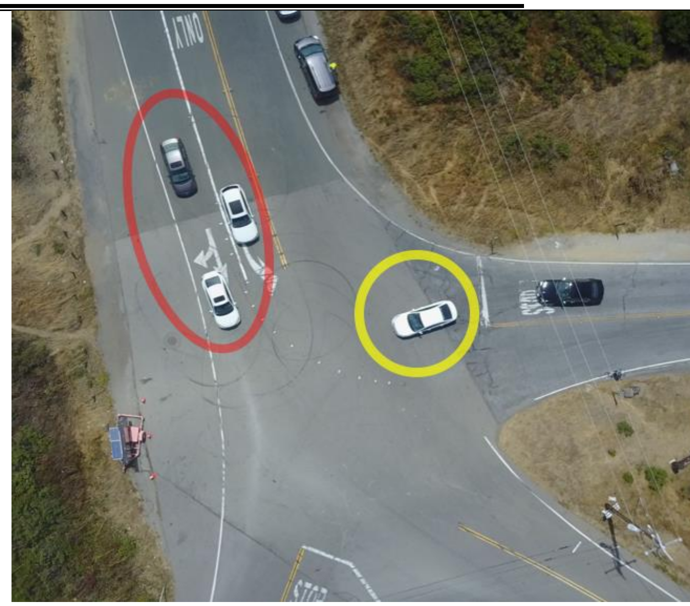
As can be seen from **Figures 2 and 3**, the 24-hour bell curves shown indicate that the highest volumes are actually taking place during the middle of the day, especially near the Four Corners intersection. It has been noted previously that the highest hourly volume along the Panoramic Highway just south of the study intersection was 532 cars per hour between 12:15 and 1:15 PM. This compares to the PM peak hour volume of 419 vehicles per hour. Using the ratio of 532/419, the PM peak hour turning movements were factored up to account for this increase in traffic profile level during the midday time period. The calculated level of service for this midday time was calculated to be LOS B conditions with only 10.4 seconds of delay, a slight increase over commuter peak calculations. The side street Muir Woods Road EB approach calculated at LOS D with 27.3 seconds of average delay per vehicle.

Midday peak hour Traffic Patterns, an Aerial Observation

In order to understand the detailed real-time dynamics of traffic interaction at the Four Corners intersection, PRISM Engineering utilized drone video aerial photography in order to observe and document some of these movements during the critical midday time period. Twenty (20) minutes of traffic flow was observed overhead the Four Corners intersection during the midday peak hour. This is the time when the traffic volumes are at the highest levels. There were several vehicle cluster interactions observed where a “right-of-way” confusion issue had manifested. Due to topography, extreme angles of sight distance, and the presence of tourist traffic unfamiliar with the area or the intersection, there are many instances where traffic flow and right-of-way is not optimized. From our observations, many drivers are behaving as if there is uncertainty in who has the right of way to pass through the intersection.

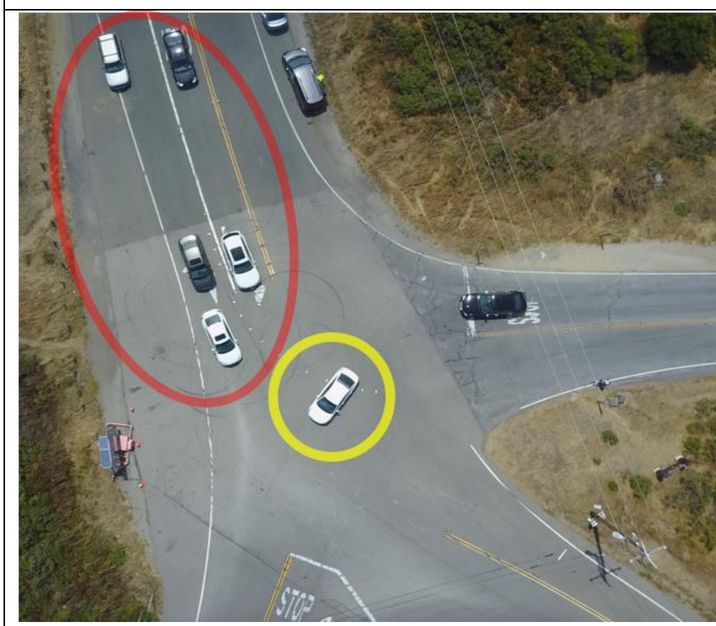
Figure 4 has been prepared to illustrate a real-world example of the situation with pictures from an overhead aerial drone video. The situation in this figure describes a particular circumstance where a driver with the full right-of-way to pass through the intersection actually slowed down to a stop, not sure of how to safely proceed. In the meantime, a car from the stop sign controlled side street, Muir Woods Road eastbound approach, came through the intersection slowly at about 5 mph. In total, five northbound cars on Panoramic Highway had to come to a stop when they had the full right-of-way to proceed. Each picture is captioned with an explanation of what is taking place, as we observed from the full motion video.





1. The white car on the left in the red circle is the problem car. It stops when it doesn't have to. There is indecisiveness, some confusion about right of way.

2. The white car in the yellow circle is nudging out from Muir Woods Road EB approach even when cars are approaching. This would indicate they don't really know who has the right-of-way, or that they can't see well enough at the stop bar.



3. The vehicle in the yellow circle is causing 5 cars to stop who have the right-of-way. The 5 cars with the right-of-way are not progressing forward into through lane north on Panoramic Highway.

4. As the side street car in the yellow circle continues to slowly (5 mph or less) cross the intersection to Sequoia Valley Road, all other cars are still waiting, then proceed slowly.

Figure 4. Overhead View of Traffic Patterns, Confusion over ROW during Midday Peak Hour

There are several reasons as to why these situations are taking place.

- The first is that the intersection is very wide and difficult for drivers to see clearly see approaching traffic from the other three approaches, especially as they try to proceed from a stop sign controlled side street (either Sequoia Valley Road westbound approach or the Muir Woods Road eastbound approach).
- The Muir Woods Road eastbound approach is stop sign controlled and is coming upward on a grade making it difficult to see deeper into the intersection until the car actually enters the intersection crossing the stop bar.
- Skewed angles of intersection approaches, the angle between Panoramic Highway to the north and Muir Woods Road being only 35°, and the angle between Panoramic Highway from the south to the north to either Sequoia Valley Road or Panoramic Highway are both at 145° angle's. Since intersections are usually oriented with approaches at 90° to each other, this is an unusually extremely skewed intersection.
- The side street is not obvious. Typically, a side street along a major street such as the panoramic highway would be at 90° angles perpendicular to the main street. Because sequoia Valley Road is at a 145° angle with the northbound approach a panoramic highway, it could appear to be the main street to a driver unfamiliar with the area. This condition also makes it difficult for drivers to know the right-of-way. Too many observations need to be made and there isn't enough reaction time.

Review of TETAP Study.

PRISM Engineering reviewed the ***TETAP Marin County Panoramic Highway at Four Corners Intersection Improvement Feasibility Study, June 30, 2003***, completed previously for Marin County and the MTC. Specifically, we reviewed only Alternatives 2 and 3 of that study pertaining to revised channelized striping or raised curbs for the intersection to better define edge lines of the traveled way. These TETAP alternatives kept existing traffic controls in place (free flows on Panoramic Highway approaches, and stop sign control of the side streets Muir Woods Road and Sequoia Valley Road). We did not review the roundabout alternative (Alternative 1) in that report as instructed by County staff, since it was deemed currently infeasible due to lack of sufficient funds to build, as well as lack of available right-of-way to properly and safely construct (since retaining walls, etc. would likely be necessary due to steep slopes and topography constraints immediately surrounding the intersection).

Review of Alternatives 2 and 3.

On past and current traffic analysis procedures and methods:

1) The traffic analysis procedures used were HCM 2000 methodologies. The manual worksheets contained in the appendix of the TETAP Report show very similar results to the output from Synchro 9 calculated in this report. **Figure 5** shows a comparison of the software generated turning movement volumes from the TETAP report in 2003 (they did not have actual traffic count data at the time and these were estimates based on a software balancing program), and the actual accounts taken by PRISM Engineering in July 2017.

a. The results of peak traffic in the TETAP report yielded LOS D results (30.5 secs delay avg) for the side street of Muir Woods Road, the worst approach.
b. In the PRISM Engineering calculation for midday peak volumes based on actual counts, the numbers differ slightly (see F**igure 5**) but the results are very similar with LOS D for the side street Muir Woods Road EB approach which is currently at LOS D with 27.3 seconds of average delay.

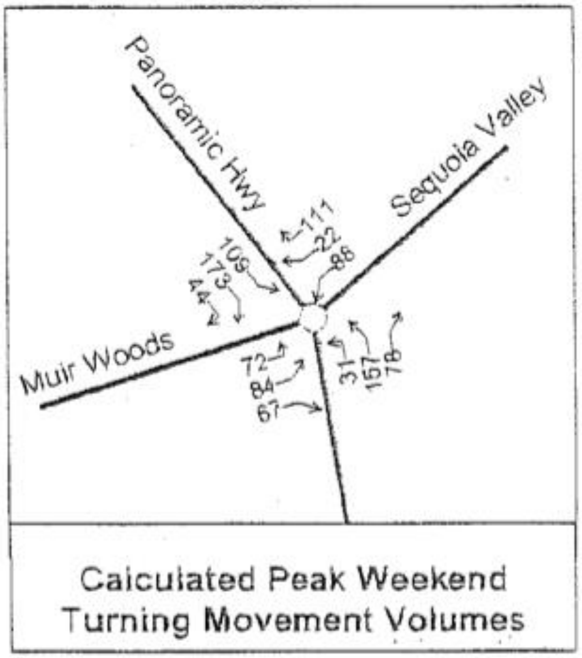
2) This is essentially the same result. This is based on both analyses using the same methodology, the Highway Capacity Manual 2000 methods. PRISM Engineering utilized the Synchro 9 software to make this calculation. The TETAP calculation is contained in the appendix of this report..

On relevance to current design standards in the CA MUTCD, the CA Highway Design Manual, the CA Vehicle Code, and the AASHTO Green Book:

3) The TETAP report relied on design standards in the California MUTCD and Highway Design Manual for a 40-foot bus design vehicle, which are still relevant today. The TETAP alternative tightened up the intersection (brought striping further forward within the intersection, about 15 feet) especially for the northbound approach on Panoramic Highway, however, the eastbound approach of Muir Woods Road was not aligned with Sequoia Valley Road. In fact, Sequoia Valley Road is skewed about 60° from the centerline of the Muir Woods Road approach, a sharp angle.
4) Because of this 60° skewed angle, the design layout situation will continue to contribute to driver confusion and would not solve one of the main problems of the intersection: skewed angles and sight distance constraints for side street traffic entering.
5) Turning templates were laid on to the TETAP Alternative 2 and 3 design concepts to determine the ability for a 40-foot vehicle to make a left turn out from Muir Woods Road to go northbound on Panoramic Highway. In our check of left turn lane alignments for each of the four intersection approaches on the TETAP design, we utilized the Highway Design Manual (HDM) 40-foot bus design vehicle turning template shown from Figure 404.5E. **Figure 6** shows this HDM template (lower left corner) as well as *how* it was applied to the Alternative 2 design layout. The template showed that this movement was not possible without encroaching upon lanes or approaches of opposing traffic. In **Figure 6** the dashed red and orange lines show that for the 40-foot design vehicle, the front wheels would need to cross into the Sequoia Valley WB approach (unacceptable), as well as leave the pavement on the north side of the intersection. Of course, this vehicle could make a tighter turn but not without encroaching nearly completely on the southbound Panoramic Highway lane of the SB approach. This is unacceptable, and a flaw in the design concept.

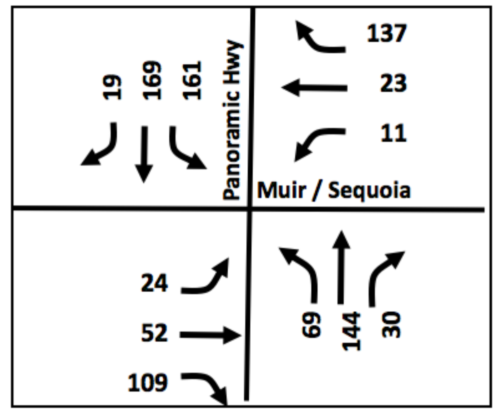
Comments / Recommendations RE: TETAP Alternatives 2 and 3

Disadvantages of Alternative 2 or 3 Design Concept. The proposed alignment of striping for the intersection approaches in both of these TETAP alternatives did not optimize sight distance and turning movement conditions, especially for large vehicles. This was especially true for the eastbound Muir Woods Road approach, where there was still a 60° angle remaining between the Muir Woods Road approach centerline and Sequoia Valley Road approach centerline.



From TETAP report, 2003, estimated by software

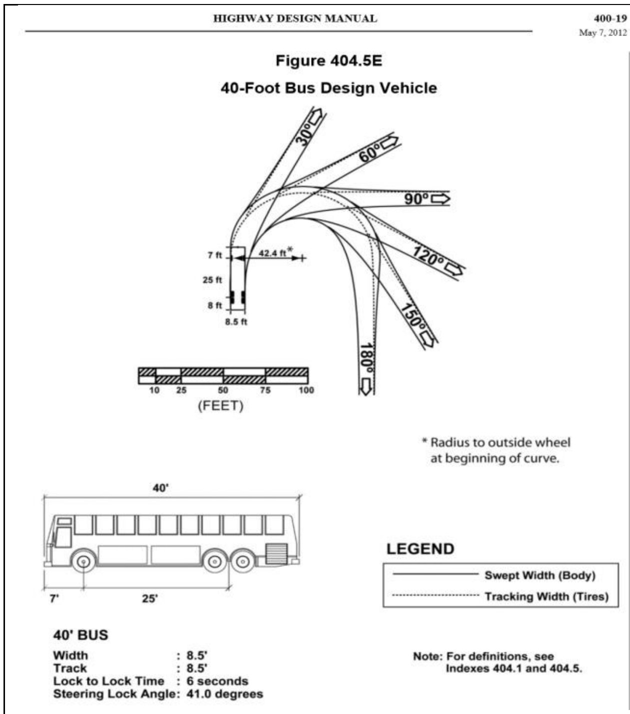
MIDDAY PEAK 12:15-1:15 pm



These volumes were calculated by taking the PM Peak Hour actual turning movement count from 2017 and factoring it up using the 24 hour hourly volumes data also from 2017.

From PRISM Engineering report, 2017

Figure 5. Comparison of Peak Volumes: TETAP 2003 estimated vs 2017 actual



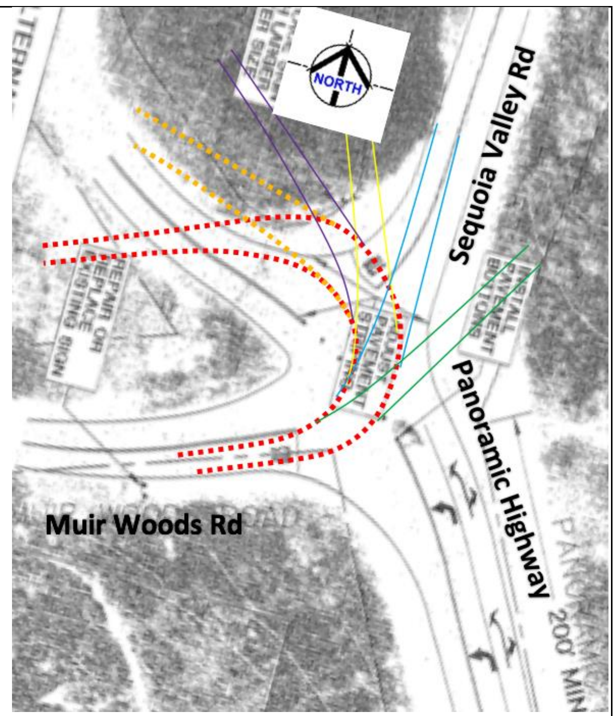


Figure 6. 40-foot Bus Design Vehicle turn template check of TETAP Alt. 2

These side street centerlines should be as parallel and collinear as possible. The intersection approaches could have been squared up more, but as it stands, Alternatives 2 and 3 do not pass the design vehicle turn test as defined in the Highway Design Manual, Figure 404.5E, and illustrated in **Figure 6**. In addition, these alternatives left in place the existing traffic control as stop sign control for side streets and no stop for the Panoramic Highway (TWSC). Because the intersection remains nonstandard in design layout (Sequoia Valley Road approach striping remains significantly skewed to the Panoramic Highway), the skewed approach would contribute to driver confusion, cause instances of indecision or hesitation for some drivers entering the intersection, even when they have the right-of-way (such as drivers on Panoramic Highway where there is no stop sign control). It was observed by aerial video during the midday peak hour, where drivers on Panoramic Highway would come to a full stop to examine their choices of where they need to turn or whether another car is entering the intersection or not.

Another disadvantage of the TETAP Alternative 2 or 3 design concept was traffic control to remain as two-way stop control (TWSC) for the side streets of Muir Woods Road and Sequoia Valley Road. These approaches would remain at an unacceptable LOS D condition with approximately 28-31 seconds of average delay for each side. This unacceptable delay encourages drivers to take more chances to enter the intersection after stopping, but before there is a gap in traffic, nosing their vehicle slowly out into the intersection to try and make a maneuver into traffic flows that already have the right-of-way (observed several times). This delay coupled with sight distance constraints would remain with this alternative.

Advantages of Alternative 2 or 3 Design Concept. One of the significant improvements proposed for the intersection in either Alternative 2 or 3 was to bring lane striping and center line striping further forward into the intersection for the Panoramic Highway, essentially narrowing the distance between approaches. The striping was proposed to come forward an additional 15 feet toward the north. We feel that this is a good idea to improve safety because it brings driver turning movement choices closer into focus, and it makes it easier for drivers to see each other from a sight distance standpoint. Turning movements and directional intent are more clearly defined.

Recommendations. It is recommended that the County of Marin does not implement Alternatives 2 or 3 as defined in the TETAP report because of the geometric and operational disadvantages which have been explained above. These conceptual designs do not significantly improve over the existing condition, and do not improve level of service or safety.

In a newly proposed Alternative 4 design concept, which follows, turning movements and directional lines are much more clearly defined, the intersection geometry is even smaller in size, and edge, lane, and center line striping saree adjusted significantly as needed to achieve nearly perpendicular intersections of traffic flows between Panoramic Highway and the side streets of Muir Woods Drive and Sequoia Valley Road. Traffic control has also been modified to AWSC.

Alternative 4. New Conceptual Design, All-way Stop

Determining how to improve on Alternatives 2 and 3 of the TEPAC report first required establishing more traffic and design details about the Four Corners intersection. Specifically, PRISM Engineering assessed the existing condition of striping and pavement marking locations, as well as measuring physical dimensions of lane widths and pavement width, etc. PRISM Engineering made a field visit to personally observe traffic control and road conditions, take pictures and video, measure lane widths, and observe signage and striping currently in place. We also took aerial photos and video of the intersection as shown in **Figure 7** which shows 1) a wide view, 2) a close-up view, as well as 3) some detail of pavement markings and raised markers extant at the intersection in July 2017 (see lower left photo).

In order to improve traffic operations at the intersection, the goal for this alternative is twofold:
1) improve alignment, and 2) improve traffic control.

Improve Alignment. This can be done by *first* aligning the side street and main street intersection approaches as close to 90 degrees as possible within the existing pavement right-of-way. This is to be done through striping since the asphalt concrete pavement is already in place.

Improve Traffic Control. Eliminate right-of-way confusion at the intersection by implementing the intersection a four-way stop (AWSC) within a "squared-up" design, install stop signs for each approach to achieve organized uniform traffic flow control for all drivers entering the intersection. PRISM Engineering analyzed the intersection as an All-Way Stop Control implementation for the midday peak hour traffic volumes collected in July (weekday midday peak). Our analysis indicated that LOS B conditions would exist with only 13.4 seconds of average delay for all approaches of an All-Way Stop Control (AWSC) traffic control installation, an improvement over the existing LOS D condition with TWSC on Muir Woods Road approach. We utilized the HCM 2010 methodology in Synchro 9 for the AWSC configuration at the intersection. The midday peak summer volumes used are similar in magnitude to the "software generated" TETAP report estimated volumes for summer peak weekend, however, the turning movements in the July 2017 peak hour traffic counts are far more accurate as they represent a real-world sample of driver patterns, factored up using the July 2017 "same day" 24-hour traffic count data to determine midday peak turning movements. The AWSC configuration improves significantly over the TETAP Alternative 2 and 3 TWSC configuration because the side streets of Muir Woods Road and Sequoia Valley Road improve from an LOS D condition under TWSC to an LOS B conditions under AWSC. Only the SB approach on Panoramic Highway would operate at LOS C with 17 seconds of average delay. All other stop sign approaches would operate at LOS B conditions with 11 seconds or less of average delay. Having verified that traffic operations would work from a level of service standpoint using the highest recreational peak volumes for the midday peak hour in summer, the next step was to investigate how to improve intersection geometry by "squaring up" the intersection approaches to minimize sight distance issues and constraints as well as right-of-way confusion. In addition, it was necessary to design an intersection that could handle turning movement needs for a 40-foot bus design vehicle at all approaches.

WIDE VIEW. Four Corners intersection, July 2017 Aerial Photo by PRISM Engineering, Existing Conditions.

CLOSE-UP. Existing Conditions at intersection. Muir Woods Road is nearly perpendicular to Sequoia Valley Road.

Pavement Marking details for northbound approach, Panoramic Highway. Raised Markers for left turn lane guidance to Muir Woods Road. Left Turn lane separate from Through/Right lane. No stop. LT lane is only 10 feet wide. Thru/RT lane is 11.5 feet wide, as measured in field.

Sequoia Valley Road approach is (unnecessarily) very wide with two STOP pavement markings. Panoramic Highway SB approach is not aligned with Panoramic Highway to the south, but points directly to east to road shoulder, rather than bending naturally towards the south.

Figure 7. New Aerial Photography of Intersection, July 2017

PRISM Engineering's approach to this problem was to establish 12-foot conceptual travel pathways that could travel through the intersection for both directions of Panoramic Highway, and provide a smooth curved pathway between the side streets of Muir Woods Road and Sequoia Valley Road as if their centerlines were the same line (collinear).

Figure 8 shows the new July 2017 aerial photograph of the intersection with existing lane striping. 12-foot color-coded pathways that intersect at right angles to each other in the center core of the intersection have been transparently overlaid onto the photo, revealing the proposed shift in lane alignments. It is possible for vehicles to travel along these new proposed smooth curve pathways using the additional pavement that is already available, especially on the east side of Panoramic Highway south of Muir Woods Road. The centerline of Panoramic Highway would need to shift to the east to accommodate the adjustments needed to square up the intersection. Lane widths can expand from 10 feet (existing) to 12 feet (proposed) to better accommodate large vehicles. The red 12' pathway shows that the new northbound through/right lane would need to shift about 7 feet east of its current position, but there is ample pavement available to make this possible. Also, the centerline double yellow striping on Panoramic Highway south of Muir Woods Road would need to shift about two feet to the east east (generally speaking, as the alignment of this pathway is not consistently parallel to the existing centerline striping). Muir Woods Road centerline striping would also need to change, bending more towards the north approaching Panoramic Highway. The red and orange pathways represent the northbound and southbound through-lane proposed travel pathways for Panoramic Highway, respectively.

Once these pathway guides shown in **Figure 8** were squared up to be as perpendicular as possible between side street and main street pathways and within existing pavement constraints, PRISM Engineering applied standard MUTCD lane striping and corner edge striping treatments compatible with pathway locations using 12-foot lane widths, as shown in **Figure 9**.

Comparing **Figure 8** to **Figure 9,** it can be seen that the edge line striping has been moved from its original location to accommodate the change in alignment of all approach lanes. The centerline and lane line striping has also been adjusted for the Muir Woods Road eastbound approach to direct traffic towards Sequoia Valley Road, curving left to help eliminate the 60 degree skewed angle. These centerline stripings have also been adjusted for the Panoramic Highway northbound approach, and the Sequoia Valley Road approach. The shifting of the centerlines and adjusting curvature as shown allows for adequate room and setting up lanes to better accommodate the turn moves of large vehicles.

Figure 10 is the proposed Alternative 4 intersection design check using the HDM Figure 404.5E 40-foot bus design vehicle template. Colored dashed lines are overlaid on top of the design concept to illustrate that the 40-foot design vehicle wheels can safely navigate the all left turns within the intersection without encroachment of opposing lanes.

Figure 8. Alt. 4 Proposed 12' Pathways for Each Lane Approach, Four Corners

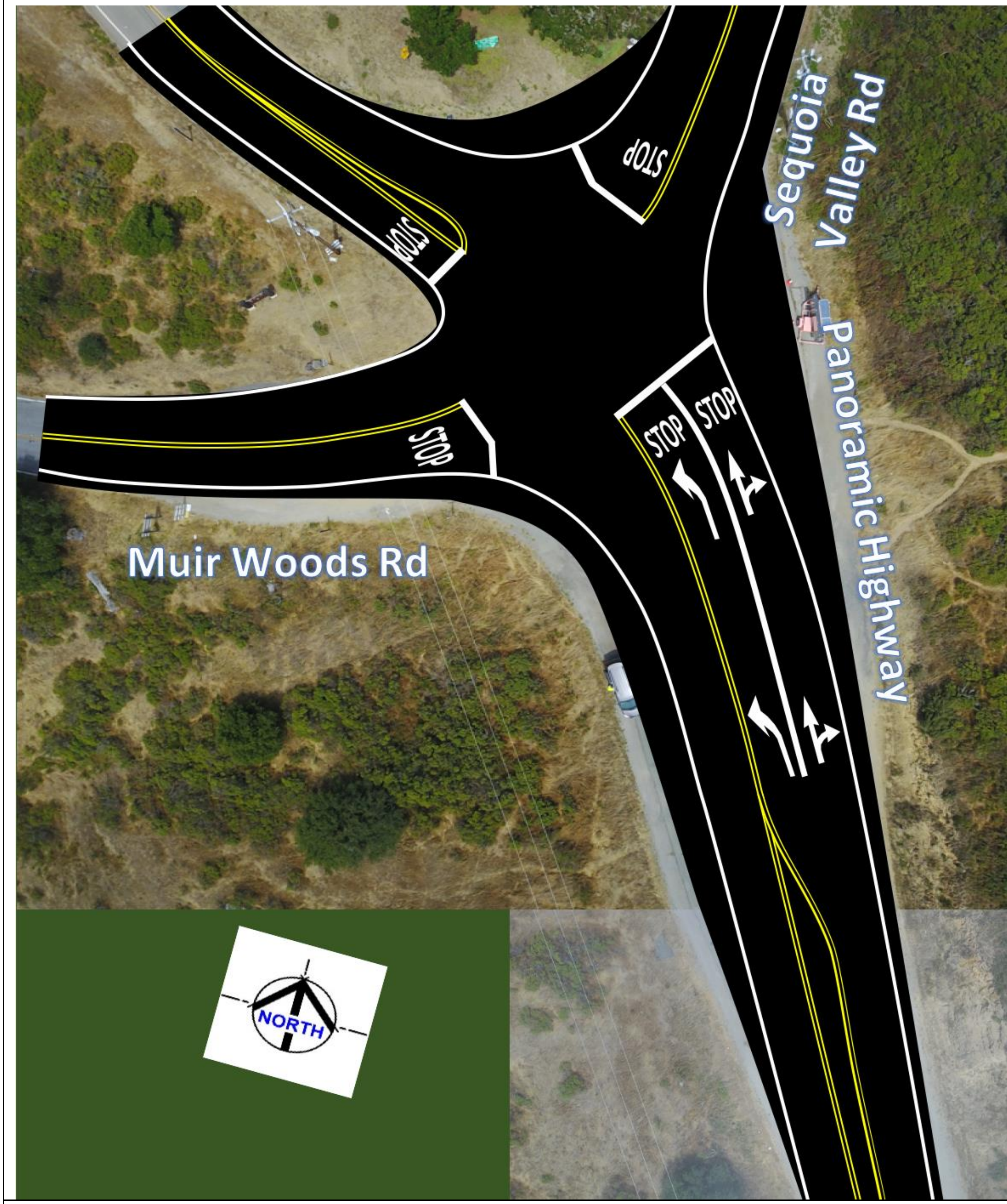


Figure 9. Alt. 4 Intersection Layout, Striping and Pavement Markings

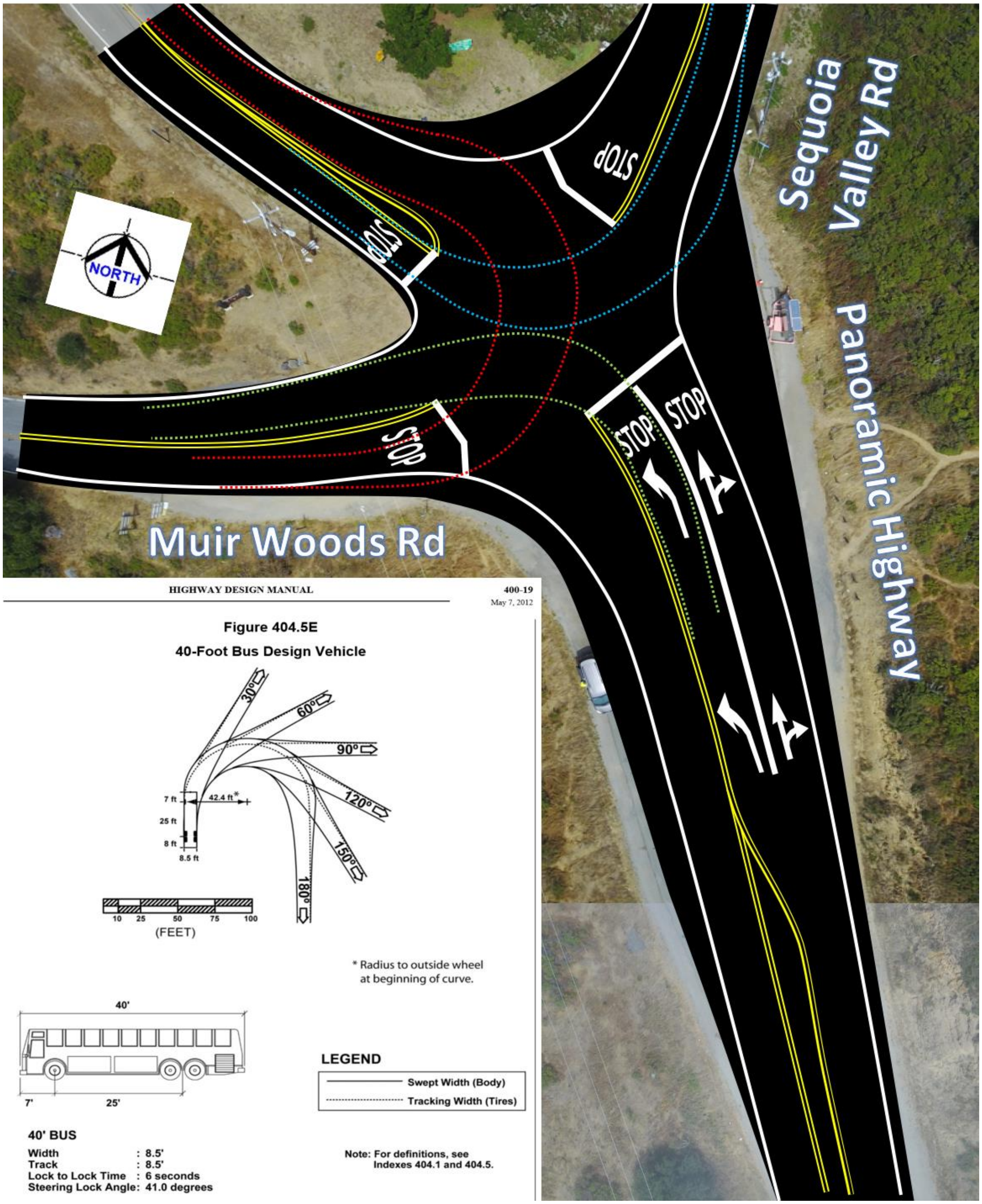


Figure 10. Alt. 4 Bus Design Vehicle Turn Check for Left Turns: *Ample Space*.

Conclusions

Intersection with TWSC current configuration. The Four Corners intersection summer peak hour turning movement numbers contained in the 2003 TETAP report are similar in magnitude to the newly collected Year 2017 midday summer peak hour turning movements. Both yielded LOS A conditions overall, with LOS A conditions for Panoramic Highway uncontrolled northbound and southbound approaches. The TETAP estimated numbers yielded LOS D conditions for the side street approaches of Muir Woods Road and Sequoia Road which are stop sign controlled. The PRISM Engineering midday summer peak analysis also resulted in LOS D for the Muir Woods approach and LOS C for Sequoia Valley Road. The TWSC side street stop sign control intersection operates at LOS A conditions overall average in both cases. Even with no stop sign controls in place for the northbound and southbound approaches of Panoramic Highway, there is still 7.5 seconds of average delay for the northbound left turn movement, and 4.5 seconds of delay for the southbound through movement (because of the conflict with NBL). Delays on the Muir Woods approach are unacceptable.

Intersection with AWSC stop sign control for each approach. If an all way stop control (AWSC) intersection is installed at this location (four stop signs), LOS B conditions overall would result with an average delay of 13.4 seconds per vehicle. The southbound approach of Panoramic Highway would operate at LOS C conditions with an average delay of 17 seconds. All other approaches including the side streets would operate at LOS B conditions with approximately 11 seconds of delay each for these three approaches. This means that an AWSC implementation will improve the side street level of service from LOS D and C, to LOS B. This will improve safety conditions as drivers will experience less delay in trying to enter the intersection. Gaps in traffic will be created by stop sign control. Bicycles can more safely enter and pass through the intersection. Lines of travel would be obvious and well defined.

Potential for Queues. Because the northbound approach of Panoramic Highway would only have an average delay of 11.4 seconds per vehicle during the peak summer midday time period (this is an LOS A/B condition with very little delay), it is not anticipated that an AWSC installation could cause traffic to back up on Panoramic Highway in any significant way. It is important to note that because of driver confusion over right of way at the intersection under its existing configuration, the intersection already tends to operate inefficiently as a TWSC, and capacity in much lower than would normally be expected for TWSC. Because of sight distance constraints related to skewed angles at the intersection, there remain safety concerns over

- who has the right-of-way
- directionality and intent of driver maneuvers through the intersection
- interaction between different modes of traffic such as bicycles and cars.

SUMMARY.

- There is ample asphalt concrete pavement at this intersection to allow some expansion or modifications to edge line and lane line and center line striping.
- This flexibility in design space available on the ground today has enabled the development of Alternative 4 which is shown in **Figure 9**.
- Stop bars are proposed for each of the four approaches as shown.
- 12 foot wide lanes are proposed for the northbound Panoramic Highway approach, as there is pavement available and this helps with increasing turning radius options for large vehicles.
- The edge line striping for panoramic highway south of the intersection has been modified to accommodate a smoother and sweeping curve, continuing northerly past the intersection. The new alignment better orients vehicles towards their intended path.
- In addition, the edge lines of Sequoia Valley Road and Muir Woods Road have also been modified to accommodate a smooth path way from side street to side street in both directions.
- Large trucks and a 40-foot bus design vehicle as defined in the HDM (see **Figure 10**) can be accommodated for safe turning movements with this configuration.

It is recommended that the Alternative 4 design concept configuration shown in **Figure 9** be implemented by Marin County at this intersection. Bicycles will still be obligated to share the road with vehicles (Class III) because of the lack of any road width greater than 24 feet on all streets into and out of this intersection. Pedestrians will also need to share the road as the terrain and topography has trails off street, but local roadways do not have sufficient pavement width or flat ground to install shoulders or sidewalks/pathways for parallel pedestrian traffic. There is some room for parking today, and most of that would remain even with Alternative 4 shifting edge lines to the east.

APPENDIX

Traffic counts were taken at the Four Corners intersection for am and pm peak hours. The resulting peak hour level of service was LOS A overall for both peak hours, but with LOS B for the Muir Woods EB approach in the am and LOS C for the same approach in the pm peak hour. This was for the commuter peak hour which is lower than the recreational midday peak hour traffic. The midday peak hour traffic has LOS B conditions for the side streets of Muir Woods Road and Sequoia Valley Road.

With AWSC LOS B conditions are possible for the midday summer peak condition, with LOS B for all approaches except the southbound Panoramic Highway approach which would be at LOS C. The average delay for the intersection would be 13.4 seconds per vehicle.

HCM Unsignalized Intersection Capacity Analysis
3: Panoramic Highway & Muir Woods Rd/Sequoia Valley Rd

08/10/2017

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	19	41	86	9	18	108	54	113	24	127	133	15
Future Volume (Veh/h)	19	41	86	9	18	108	54	113	24	127	133	15
Sign Control		Stop			Stop			Free			Free	
Grade		0%			0%			0%			0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	26	57	119	12	25	149	75	156	33	175	184	21
Pedestrians												
Lane Width (ft)												
Walking Speed (ft/s)												
Percent Blockage												
Right turn flare (veh)												
Median type								None			None	
Median storage veh)												
Upstream signal (ft)												
pX, platoon unblocked												
vC, conflicting volume	1012	884	194	1014	878	172	205			189		
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	1012	884	194	1014	878	172	205			189		
tC, single (s)	7.1	6.5	6.2	7.1	6.5	6.2	4.1			4.1		
tC, 2 stage (s)												
tF (s)	3.5	4.0	3.3	3.5	4.0	3.3	2.2			2.2		
p0 queue free %	82	76	86	91	89	83	95			87		
cM capacity (veh/h)	144	235	847	132	237	871	1366			1385		

Direction, Lane #	EB 1	WB 1	NB 1	NB 2	SB 1
Volume Total	202	186	75	189	380
Volume Left	26	12	75	0	175
Volume Right	119	149	0	33	21
cSH	358	506	1366	1700	1385
Volume to Capacity	0.56	0.37	0.05	0.11	0.13
Queue Length 95th (ft)	83	42	4	0	11
Control Delay (s)	27.3	16.2	7.8	0.0	4.3
Lane LOS	D	C	A		A
Approach Delay (s)	27.3	16.2	2.2		4.3
Approach LOS	D	C			

Intersection Summary			
Average Delay	10.4		
Intersection Capacity Utilization	55.8%	ICU Level of Service	B
Analysis Period (min)	15		

HCM 2010 AWSC
3: Panoramic Highway & Muir Woods Rd/Sequoia Valley Rd 08/10/2017

Intersection	
Intersection Delay, s/veh	13.4
Intersection LOS	B

Movement	EBU	EBL	EBT	EBR	WBU	WBL	WBT	WBR	NBU	NBL	NBT	NBR
Lane Configurations												
Traffic Vol, veh/h	0	19	41	86	0	9	18	108	0	54	113	24
Future Vol, veh/h	0	19	41	86	0	9	18	108	0	54	113	24
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	0	26	57	119	0	12	25	149	0	75	156	33
Number of Lanes	0	0	1	0	0	0	1	0	0	1	1	0

Approach	EB	WB	NB
Opposing Approach	WB	EB	SB
Opposing Lanes	1	1	1
Conflicting Approach Left	SB	NB	EB
Conflicting Lanes Left	1	2	1
Conflicting Approach Right	NB	SB	WB
Conflicting Lanes Right	2	1	1
HCM Control Delay	11.6	11.1	11.4
HCM LOS	B	B	B

Lane	NBLn1	NBLn2	EBLn1	WBLn1	SBLn1
Vol Left, %	100%	0%	13%	7%	46%
Vol Thru, %	0%	82%	28%	13%	48%
Vol Right, %	0%	18%	59%	80%	5%
Sign Control	Stop	Stop	Stop	Stop	Stop
Traffic Vol by Lane	54	137	146	135	275
LT Vol	54	0	19	9	127
Through Vol	0	113	41	18	133
RT Vol	0	24	86	108	15
Lane Flow Rate	75	189	202	186	380
Geometry Grp	7	7	2	2	5
Degree of Util (X)	0.139	0.32	0.323	0.293	0.599
Departure Headway (Hd)	6.722	6.089	5.767	5.669	5.676
Convergence, Y/N	Yes	Yes	Yes	Yes	Yes
Cap	531	586	619	628	634
Service Time	4.496	3.862	3.85	3.754	3.739
HCM Lane V/C Ratio	0.141	0.323	0.326	0.296	0.599
HCM Control Delay	10.6	11.7	11.6	11.1	16.9
HCM Lane LOS	B	B	B	B	C
HCM 95th-tile Q	0.5	1.4	1.4	1.2	4

HCM 2010 AWSC
3: Panoramic Highway & Muir Woods Rd/Sequoia Valley Rd 08/10/2017

Intersection	
Intersection Delay, s/veh	
Intersection LOS	

Movement	SBU	SBL	SBT	SBR
Lane Configurations				
Traffic Vol, veh/h	0	127	133	15
Future Vol, veh/h	0	127	133	15
Peak Hour Factor	0.92	0.92	0.92	0.92
Heavy Vehicles, %	2	2	2	2
Mvmt Flow	0	175	184	21
Number of Lanes	0	0	1	0

Approach	SB
Opposing Approach	NB
Opposing Lanes	2
Conflicting Approach Left	WB
Conflicting Lanes Left	1
Conflicting Approach Right	EB
Conflicting Lanes Right	1
HCM Control Delay	16.9
HCM LOS	C

HCM Unsignalized Intersection Capacity Analysis
3: Panoramic Highway & Muir Woods Rd/Sequoia Valley Rd 08/07/2017

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	4	2	6	11	23	64	73	63	12	99	67	10
Future Volume (Veh/h)	4	2	6	11	23	64	73	63	12	99	67	10
Sign Control		Stop			Stop			Free			Free	
Grade		0%			0%			0%			0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	4	2	7	12	25	70	79	68	13	108	73	11
Pedestrians												
Lane Width (ft)												
Walking Speed (ft/s)												
Percent Blockage												
Right turn flare (veh)												
Median type								None			None	
Median storage veh)												
Upstream signal (ft)												
pX, platoon unblocked												
vC, conflicting volume	603	534	78	535	532	74	84			81		
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	603	534	78	535	532	74	84			81		
tC, single (s)	7.1	6.5	6.2	7.1	6.5	6.2	4.1			4.1		
tC, 2 stage (s)												
tF (s)	3.5	4.0	3.3	3.5	4.0	3.3	2.2			2.2		
p0 queue free %	99	99	99	97	94	93	95			93		
cM capacity (veh/h)	330	398	982	410	399	987	1513			1517		

Direction, Lane #	EB 1	WB 1	NB 1	NB 2	SB 1
Volume Total	13	107	79	81	192
Volume Left	4	12	79	0	108
Volume Right	7	70	0	13	11
cSH	536	657	1513	1700	1517
Volume to Capacity	0.02	0.16	0.05	0.05	0.07
Queue Length 95th (ft)	2	14	4	0	6
Control Delay (s)	11.9	11.5	7.5	0.0	4.5
Lane LOS	B	B	A		A
Approach Delay (s)	11.9	11.5	3.7		4.5
Approach LOS	B	B			

Intersection Summary			
Average Delay	6.0		
Intersection Capacity Utilization	29.1%	ICU Level of Service	A
Analysis Period (min)	15		

HCM Unsignalized Intersection Capacity Analysis
3: Panoramic Highway & Muir Woods Rd/Sequoia Valley Rd

08/07/2017

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	19	41	86	9	18	108	54	113	24	127	133	15
Future Volume (Veh/h)	19	41	86	9	18	108	54	113	24	127	133	15
Sign Control		Stop			Stop			Free			Free	
Grade		0%			0%			0%			0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	21	45	93	10	20	117	59	123	26	138	145	16
Pedestrians												
Lane Width (ft)												
Walking Speed (ft/s)												
Percent Blockage												
Right turn flare (veh)												
Median type								None			None	
Median storage veh)												
Upstream signal (ft)												
pX, platoon unblocked												
vC, conflicting volume	797	696	153	798	691	136	161			149		
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	797	696	153	798	691	136	161			149		
tC, single (s)	7.1	6.5	6.2	7.1	6.5	6.2	4.1			4.1		
tC, 2 stage (s)												
tF (s)	3.5	4.0	3.3	3.5	4.0	3.3	2.2			2.2		
p0 queue free %	91	86	90	95	94	87	96			90		
cM capacity (veh/h)	227	316	893	218	318	913	1418			1432		

Direction, Lane #	EB 1	WB 1	NB 1	NB 2	SB 1
Volume Total	159	147	59	149	299
Volume Left	21	10	59	0	138
Volume Right	93	117	0	26	16
cSH	469	621	1418	1700	1432
Volume to Capacity	0.34	0.24	0.04	0.09	0.10
Queue Length 95th (ft)	37	23	3	0	8
Control Delay (s)	16.6	12.6	7.6	0.0	4.0
Lane LOS	C	B	A		A
Approach Delay (s)	16.6	12.6	2.2		4.0
Approach LOS	C	B			

Intersection Summary			
Average Delay	7.6		
Intersection Capacity Utilization	46.1%	ICU Level of Service	A
Analysis Period (min)	15		

HCM 2010 AWSC
3: Panoramic Highway & Muir Woods Rd/Sequoia Valley Rd 08/07/2017

Intersection	
Intersection Delay, s/veh	10.6
Intersection LOS	B

Movement	EBU	EBL	EBT	EBR	WBU	WBL	WBT	WBR	NBU	NBL	NBT	NBR
Lane Configurations												
Traffic Vol, veh/h	0	19	41	86	0	9	18	108	0	54	113	24
Future Vol, veh/h	0	19	41	86	0	9	18	108	0	54	113	24
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	0	21	45	93	0	10	20	117	0	59	123	26
Number of Lanes	0	0	1	0	0	0	1	0	0	1	1	0

Approach	EB	WB	NB
Opposing Approach	WB	EB	SB
Opposing Lanes	1	1	1
Conflicting Approach Left	SB	NB	EB
Conflicting Lanes Left	1	2	1
Conflicting Approach Right	NB	SB	WB
Conflicting Lanes Right	2	1	1
HCM Control Delay	9.8	9.4	9.9
HCM LOS	A	A	A

Lane	NBLn1	NBLn2	EBLn1	WBLn1	SBLn1
Vol Left, %	100%	0%	13%	7%	46%
Vol Thru, %	0%	82%	28%	13%	48%
Vol Right, %	0%	18%	59%	80%	5%
Sign Control	Stop	Stop	Stop	Stop	Stop
Traffic Vol by Lane	54	137	146	135	275
LT Vol	54	0	19	9	127
Through Vol	0	113	41	18	133
RT Vol	0	24	86	108	15
Lane Flow Rate	59	149	159	147	299
Geometry Grp	7	7	2	2	5
Degree of Util (X)	0.101	0.231	0.229	0.207	0.434
Departure Headway (Hd)	6.214	5.584	5.188	5.075	5.224
Convergence, Y/N	Yes	Yes	Yes	Yes	Yes
Cap	578	643	692	707	690
Service Time	3.943	3.313	3.222	3.109	3.251
HCM Lane V/C Ratio	0.102	0.232	0.23	0.208	0.433
HCM Control Delay	9.6	10	9.8	9.4	12.2
HCM Lane LOS	A	A	A	A	B
HCM 95th-tile Q	0.3	0.9	0.9	0.8	2.2

HCM 2010 AWSC
3: Panoramic Highway & Muir Woods Rd/Sequoia Valley Rd 08/07/2017

Intersection	
Intersection Delay, s/veh	
Intersection LOS	

Movement	SBU	SBL	SBT	SBR
Lane Configurations			✣	
Traffic Vol, veh/h	0	127	133	15
Future Vol, veh/h	0	127	133	15
Peak Hour Factor	0.92	0.92	0.92	0.92
Heavy Vehicles, %	2	2	2	2
Mvmt Flow	0	138	145	16
Number of Lanes	0	0	1	0

Approach	SB
Opposing Approach	NB
Opposing Lanes	2
Conflicting Approach Left	WB
Conflicting Lanes Left	1
Conflicting Approach Right	EB
Conflicting Lanes Right	1
HCM Control Delay	12.2
HCM LOS	B

TWO-WAY STOP CONTROL SUMMARY

General Information		Site Information	
Analyst	J West	Intersection	Panoramic Hwy/Muir/Sequoia
Agency/Co.	Kimley-Horn and Associates	Jurisdiction	Marin County, CA
Date Performed	2/18/2003	Analysis Year	2002
Analysis Time Period	Sunday Summer Peak	Project ID	Marin County-TETAP Project 097026022

East/West Street:	Muir Woods/Sequoia	North/South Street:	Panoramic Highway
Intersection Orientation:	North-South	Study Period (hrs):	0.25

Vehicle Volumes and Adjustments

Major Street	Northbound			Southbound		
Movement	1	2	3	4	5	6
	L	T	R	L	T	R
Volume	31	157	78	109	173	44
Peak-Hour Factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00
Hourly Flow Rate, HFR	31	157	78	109	173	44
Percent Heavy Vehicles	0	--	--	0	--	--
Median Type	Undivided					
RT Channelized			0			0
Lanes	1	1	0	0	1	0
Configuration	L		TR	LTR		
Upstream Signal		0			0	

Minor Street	Westbound			Eastbound		
Movement	7	8	9	10	11	12
	L	T	R	L	T	R
Volume	88	22	111	72	84	67
Peak-Hour Factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00
Hourly Flow Rate, HFR	88	22	111	72	84	67
Percent Heavy Vehicles	0	0	0	0	0	0
Percent Grade (%)		0			0	
Flared Approach		N			N	
Storage		0			0	
RT Channelized			0			0
Lanes	0	1	0	0	1	0
Configuration		LTR			LTR	

Delay, Queue Length, and Level of Service

Approach	NB	SB	Westbound			Eastbound		
Movement	1	4	7	8	9	10	11	12
Lane Configuration	L	LTR		LTR			LTR	
v (vph)	31	109		221			223	
C (m) (vph)	1365	1344		374			357	
v/c	0.02	0.08		0.59			0.62	
95% queue length	0.07	0.26		3.64			4.03	
Control Delay	7.7	7.9		27.6			30.5	
LOS	A	A		D			D	
Approach Delay	--	--	27.6			30.5		
Approach LOS	--	--	D			D		

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