# TETAP

# Town of Tiburon
## Tiburon Boulevard (SR 131)
## Traffic Operations Study

*Final Report*

Prepared for:

Town of Tiburon,
Marin County,
California Department of Transportation (Caltrans), and
Metropolitan Transportation Commission (MTC)

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# Glossary of Terms

| Term | Description |
|---|---|
| Average Delay | Additional travel time resulting from signal timing or congestion |
| Cycle / Cycle length | A complete sequence, measured in seconds, of all signal phases |
| Natural Cycle Length | Optimum cycle length of an intersection if it were to operate independently (free operation). |
| Offset | The time relationship (expressed in seconds) determined by the difference between the defined interval portion of the coordinated phase green and a system reference point |
| Phase | The portion of a signal cycle allocated to any signal combination of one or more traffic movements simultaneously receiving the right of way during one or more intervals |
| Progression Speed | The vehicular travel speed at which the signal lights are set under signal coordination. |
| Saturation Flow Rate | The number of vehicles per lane that can travel through an intersection during one hour of continuous green time |
| Signal Group | A group of signals with the same cycle length (or half-cycle) in a coordination plan |
| SimTraffic | A macroscopic simulation model that can animate traffic flow on a roadway network based on given signal timing parameters |
| Split | A percentage of a cycle length allocated to each of the various phases in a cycle |
| Stops | The total number of stops at all intersections in the signal group in a one-hour period |
| Synchro | A signal timing software developed specifically for actuated traffic signal timing optimization |
| Total Delay | Total delay, in hours, for all vehicles in a signal group during a one-hour period |
| Total Travel Time | The total amount of time, in hours, for all vehicles to traverse through the corridor |
| WWV Clock | A radio-synchronized clock that can be installed in a signal controller cabinet to automatically update the controller's time settings via transmitted radio. |

## 1.1 Project Summary

The Town of Tiburon received a TETAP grant to study the traffic operations along Tiburon Boulevard (SR 131) from Blackfield Drive to Beach Road. Increasing traffic and congestion along the corridor have resulted in complaints from residents regarding corridor operations and safety. The project goal is to develop recommendations to improve traffic flow and vehicular, pedestrian, and bicycle safety along the corridor.

The study area includes seven (7) traffic signals from Blackfield Drive to Beach Road located within the Town of Tiburon. In addition, there are four (4) traffic signals west of the study area from the Southbound U.S. Highway 101 freeway ramps to Blackfield Drive that were considered in the analysis. These four signals are within County of Marin jurisdiction.

The project tasks included collection, reduction, and review of traffic data; field review; input of traffic data into the signal timing software; evaluation of corridor operations and signal timing; development of corridor improvement recommendations; and development of improvement cost estimates.

## 1.2 Project Area

**Figure 1** illustrates the project area. Tiburon Boulevard is an east-west arterial that extends from U.S. Highway 101 to Downtown Tiburon and is the main roadway within and into the Town of Tiburon. The corridor provides access to and from the residential, school, recreational, and commercial areas in Tiburon and Belvedere and connects both municipalities to U.S. Highway 101 and the region. In addition, four Golden Gate Transit bus routes operate along the corridor.

## 1.3 Existing Signal System and Timing

All of the corridor signals, from the SB 101 ramps to Beach Road, are operated and maintained by the California Department of Transportation (Caltrans), have Type 170 traffic controllers, and utilize the Caltrans local software.

Four (4) of the project intersections currently operate under signal coordination during the AM peak and PM peak periods. These intersections include:

- SB 101 ramps
- NB 101 ramps
- Redwood Highway Frontage Road
- Strawberry Drive/Bay Vista Drive

The SB 101 ramps intersection is currently coordinated with the traffic signals to the west of that intersection (Tower/Kipling) and operates with a cycle length of 66 seconds during the AM period (7:45 – 9:15 AM) and a cycle length of 71 seconds during the PM period (2:30 – 7:30 PM). Cycle length, typically measured in seconds, represents the time for the traffic signal to completely sequence (or cycle) through all the signal phases.

The intersections at the NB 101 ramps, Redwood Highway Frontage Road, and Strawberry Drive/Bay Vista Drive are coordinated together and operate with a 110 second cycle length during both the AM period (7:45 – 9:15 AM) and the PM period (2:30 – 7:30 PM).

The remaining seven (7) signals, from Blackfield Drive to Beach Road, operate independently under free, or actuated, operation. In addition, there is no existing signal interconnect or communication between the signals. These signals include:

- Blackfield Drive/Greenwood Cove Drive
- Trestle Glen Boulevard
- Avenida Miraflores/Pine Terrace
- Rock Hill Drive
- San Rafael Avenue
- Lyford Drive
- Beach Road

**Figure 1: Project Area**

## 2.1 Introduction

Data collection and reduction was the initial stage of the study and consisted of the following tasks:

- Kick-off Meeting and Data Gathering
- Field Review
- Collect Traffic Volumes

## 2.2 Kick-off Meeting and Data Gathering

An initial meeting was conducted with the Town of Tiburon staff to review and finalize project objectives and to gather available data for the project. In addition, Kimley-Horn contacted Caltrans and Marin County to review any special operation considerations they may have and to gather any additional traffic data. Lastly, KHA contacted several consulting firms currently conducting studies along the corridor to collect any further traffic data collected with those studies. Data that was collected includes the following:

- Electronic aerial photographs of the corridor
- Hard copies of the existing timing cards for the intersections
- Existing turning movement count information
- Study results

## 2.3 Field Review

A field review was conducted to observe the traffic conditions in the corridor and to collect traffic data for the analysis. Field review served to confirm a number of elements for the study such as intersection geometrics and lane configuration, distances between intersections, pedestrian and bicycle activity, existing signal operation, traffic patterns, and speed limits in the corridor.

**Figure 2** illustrates the lane configuration and signal phasing for the project intersections. In addition, a photo log containing pictures taken throughout the corridor is included in the Appendix.

**Figure 2: Lane Configuration and Phasing**

## 2.4 Collect Traffic Volumes

Peak hour turning movement volumes for the AM and PM periods, collected in early June of 2000 with the Easton Point EIR, were obtained from Crane Transportation Group. **Figures 3 and 4** illustrate the peak turning movement volumes for the AM and PM peak periods, respectively.

In addition, 24-hour directional tube counts were collected for seven days from Monday, March 5th to Sunday, March 11th, 2001 at three (3) locations on Tiburon Boulevard to gather daily and weekly traffic patterns along the corridors. **Table 1** summarizes the 24-hour average daily volumes. Detailed summaries of the 24-hour counts and figures showing the average weekday and weekend trends are included in the Appendix.

**Table 1: 24-Hour Average Daily Volumes**

| Location | Period | Westbound Average | Eastbound Average | Total |
|---|---|---|---|---|
| Tiburon Boulevard east of NB 101 ramps | Weekday (M-F) | 18847 | 23655 | 42502 |
| | Weekend (S-S) | 15340 | 17260 | 32599 |
| Tiburon Boulevard east of Trestle Glen Boulevard | Weekday (M-F) | 12419 | 12787 | 25206 |
| | Weekend (S-S) | 10660 | 10433 | 21092 |
| Tiburon Boulevard west of Lyford Drive | Weekday (M-F) | 8562 | 7938 | 16500 |
| | Weekend (S-S) | 7219 | 7306 | 14525 |

**Figure 3: AM Peak Turning Movement Volumes**

**Figure 4: PM Peak Turning Movement Volumes**

## 3.1 Introduction

A signal operations and timing analysis was conducted to review signal coordination along the corridor for the AM, PM, and off-peak conditions. The primary goal of the timing analysis was to determine the feasibility of coordination and to recommend timing operation to improve traffic operations and corridor safety.

As part of the analysis, two existing stop sign controlled intersections, Tiburon Boulevard at Stewart Drive and Tiburon Boulevard at Mar West Street, were assumed to be signalized. Both of these intersections have recently been studied for signal warrants and are potential future signal locations.

A study was recently completed by Korve Engineering to evaluate the signal warrants at Stewart Drive. Although the study showed that the Caltrans signal warrants were not satisfied, the study concluded that since there is limited sight distance and difficulty for left turn traffic to exit Stewart Drive, the Town should consider funding the installation of a signal.

Signal warrants were reviewed at Mar West Street with the recent Easton Point EIR study performed by Crane Transportation Group. The study concluded that under cumulative conditions (build-out of anticipated development on the Tiburon Peninsula), the Mar West Street intersection would meet Caltrans signal warrants.

This section summarizes the procedures and recommendations of the signal timing evaluation. This signal timing analysis included the following tasks:

- Model Development
- Signal Grouping
- Phasing Evaluation
- Signal Coordination Plan Development
- Signal Coordination Plan Evaluation
- Time-of-operation
- Simulation Model

## 3.2 Model Development

Once the data was collected, signal timing data was input into the Synchro 4 model for the existing AM and PM peak conditions. Where available, peak hour volumes from the raw turning movement counts were used for the analysis. At those locations where turning movement counts were not available, the rounded volumes provide by Crane Transportation Group were used. The model was calibrated by verifying the input data and adjusting the

model parameters so that the simulation output reasonably matched the observed conditions in the field. Data such as the degree of saturation, average delay, and travel speed were reviewed for model calibration. Adjustments, as required, were made to the volumes, saturation flow rates, and lost times to achieve a reasonable match.

## 3.3 Signal Grouping

The first step in the signal timing analysis was to establish signal groupings within the corridor. The goal of signal grouping is to group those intersections together that have similar cycle lengths, higher platooning traffic, and shorter travel time between intersections.

The signal grouping was evaluated by reviewing the intersection's *natural cycle lengths* and the *coordinability factors* as calculated by Synchro. The *natural cycle length* is calculated for each intersection and is the optimum cycle length of an intersection if it were to operate free. A *coordinability factor* is calculated in Synchro for each roadway section between adjacent intersections. The *coordinability factor* measures the desirability of coordinating two adjacent intersections and is based on travel time, storage space, platooning of vehicles, traffic volume, and natural cycle length differences between adjacent intersections.

Based on review of the signal spacing, traffic patterns, and natural cycle lengths, the following signal grouping was established for the timing evaluation:

- Group 1: SB 101 ramps with the signal west of the project area (at Tower/Kipling)
- Group 2: NB 101 ramps to Blackfield Drive
- Group 3: Trestle Glen Boulevard to San Rafael Avenue
- Group 4: Lyford Drive to Beach Road

The SB 101 ramps intersection is currently coordinated with the signals west of the project area and the intersections between the NB 101 ramps and Strawberry Drive are currently coordinated together. The existing coordination grouping and timing was assumed to remain for these intersections. Because Blackfield Drive is closely spaced to these intersections and has similar traffic conditions, it is recommended that Blackfield Drive be included in the existing signal group between the NB 101 ramps and Strawberry Drive.

Because of the long distance between Blackfield Drive and the intersection of Trestle Glen Boulevard, this is a good breakpoint for the signal coordination groups. In addition, the traffic in the downtown area is not as heavy as on the western section of the corridor and the intersections require lower cycle lengths. Therefore, the intersections between Lyford Drive and Beach Road were analyzed as a separate group.

## 3.4 Phasing Evaluation

The existing phasing, i.e. the use of protected left turns, split phasing, or permissive left turn phasing, was reviewed at the existing intersections in the corridor. The existing phasing is adequate and no phase changes are recommended.

In addition, the phasing was reviewed for the potential signalized intersections at Stewert Drive and Mar West Street. Stewart Drive is a tee-intersection with one exclusive left turn lane in the eastbound direction. The intersection phasing was reviewed with a permissive left turn, where the left turn vehicles must yield to the opposing through traffic before turning, and with a protected left turn phase, where the left turn has an exclusive, or "protected" phase. Based on a review of the existing traffic volumes and the existing line of sight in the eastbound direction, it is recommended that the intersection operate with a protected left turn phase. There is a high westbound through traffic during the peak period and a short line of sight, therefore making it difficult for the eastbound left traffic to safely turn left under a permissive phase.

Mar West Street is a 4-legged intersection with exclusive left turn lanes on Tiburon Boulevard in the eastbound and westbound directions. The signal phasing was reviewed for permissive left turn phasing and protected left turn phasing in the eastbound and westbound directions. The analysis showed that the intersection would operate more effectively with permissive left turn phasing, similar to the adjacent Beach Road intersection. There is low left turn traffic (<75 vph) and only moderate opposing through traffic, thus providing sufficient breaks in traffic for permissive left turn phase operation.

The recommended phasing at Stewart Drive and Mar West Street is shown in **Figure 2** and the signal timing output reports are included in the Appendix.

## 3.5 Signal Coordination Analysis

Signal coordination plans were developed for the AM and PM peak periods to determine the impact of coordination on corridor operation. The signal timing plan development process included the selection of the optimum cycle lengths and final split/offset optimization.

Selecting the optimum cycle length is a critical step in developing signal coordination plans. Providing a high cycle length may provide for better progression along the corridors, but would most likely increase side street delay and queuing. At the same time, decreasing the cycle length to reduce the side street delay may increase the overall delay and queuing. Selecting a cycle length that is significantly lower than an intersection's natural cycle length may result in over-saturated conditions because the movements don't meet their minimum

timing requirements. On the other hand, selecting a cycle length significantly above an intersection's natural cycle length may cause adverse queuing and increased delay on the side streets. In these locations, half-cycling of the minor intersections was reviewed.

A cycle length optimization run was completed for the AM and PM periods using the Synchro signal timing software. Several performance measures including delay, stops, and travel time were calculated and reviewed for several cycle length scenarios. In general the optimum timing plan would have the lowest delay, fewest stops, and lowest travel time. Optimum cycle lengths were selected based on the performance measures and verification of the following items:

- Minimum pedestrian time met
- Minimum vehicle time met for each movement
- Good progression along the corridor
- Minimized impact on side street delay
- No adverse queuing or delays due to the cycle length being much higher or lower than an intersection's natural cycle length

In discussions with Marin County and Caltrans, it was noted that there is presently a Project Study Report study being conducted by Caltrans to review the lane configuration and operation at the SB 101 ramps intersection. In addition, Caltrans noted that timings have been periodically adjusted at the NB 101 ramps, Redwood Highway Frontage Road, and Strawberry Drive intersections. Therefore, the existing coordination cycle length and phase split timing were maintained at the SB 101 ramps, NB 101 ramps, Redwood Highway Frontage Road, and Strawberry Drive intersections.

Based on the analysis, the following coordination cycle lengths, as summarized in **Table 2**, are recommended for each signal group and time of day.

**Table 2: Recommended Coordination Cycle Lengths**

| Signal Group | Intersections | Time of Day | Cycle Length (sec) |
|---|---|---|---|
| Group 1 | SB 101 Ramps (coordinated with signals to west) | AM Peak | 67 |
| | | PM Peak | 71 |
| Group 2 | NB 101 Ramps to Blackfield Drive | AM Peak | 110 |
| | | PM Peak | 110 |
| Group 3 | Trestle Glen Boulevard to San Rafael Avenue | AM Peak | 110* |
| | | PM Peak | 100 |
| Group 4 | Lyford Drive to Beach Road | AM Peak | 70 |
| | | PM Peak | 70 |

Note: *Group 3 signals coordinated with the Group 2 signals

Once the cycle lengths were selected, optimum splits were developed in the Synchro model and adjusted, as needed, to provide sufficient split time for each movement. In addition, offsets were developed in Synchro and adjusted based to provide optimum corridor progression. The offsets were set with a progression speed at the existing speed limit. Even though vehicles in the corridor were observed to travel at or above the speed limit, coordinating the signals at the speed limit encourages drivers to comply at the limit.

## 3.6 Signal Coordination Plan Evaluation

The existing signal timings were modeled in Synchro to provide an evaluation of the proposed timing plans. An evaluation of the existing timing versus proposed timing plans was conducted by comparing several performance measures output from Synchro. The following performance measures were compared and are summarized in **Table 3***:*

- Total Delay (hr): The total delay for all vehicles traveling along the corridor in a one-hour period
- Total Stops (number): The total amount of stops along the corridor at all intersections in a one-hour period
- Total Travel Time (hr): The total amount of time for all vehicles to traverse through the corridor

**Table 3: Timing Evaluation Summary**

| Time Period | Timing Plan | Delay | | Stops | | Travel Time | |
|---|---|---|---|---|---|---|---|
| | | Total (hr) | % Change from Existing | Total (#) | % Change from Existing | Total (hr) | % Change from Existing |
| AM | Existing | 96 | - | 10269 | - | 266 | - |
| | Proposed | 69 | -28.1% | 8843 | -13.9% | 239 | -10.2% |
| PM | Existing | 40 | - | 7404 | - | 183 | - |
| | Proposed | 35 | -12.5% | 5449 | -26.4% | 177 | -3.3% |

Note: Evaluated based on intersections between Blackfield Drive and Beach Road

The evaluation showed that there will be a reduction in delay, stops, and travel time ranging from 10.2% to 28.1% during the AM time period and 3.3% to 26.4% during the PM time period with signal coordination plans. While few drivers would notice a change of 3% for any of the performance measures, many drivers would notice changes greater than 10%. When changing to coordinated signal operation, the number of stops are most recogniized by drivers on the main street, while the change in delay is most noticed by drivers on the side streets. On the other hand, changes in travel time are more difficult to notice on relatively short roadway segments such as Tiburon Boulevard.

In addition to the improved traffic flow through the corridor, signal coordination will cause vehicles to platoon together by synchronizing the interruptions in Tiburon Boulevard traffic. These platooned interruptions create larger gaps in the major street traffic, thus providing additional time for side street vehicles at nearby unsignalized intersections to enter the Tiburon Boulevard flow, and for pedestrians to cross the street.

Based on the analysis, it is recommended that the Town, and Caltrans, review implementation of signal coordination plans along the corridor.

Detailed signal timing summary sheets for proposed timing plans are included in the Appendix. In addition, time-space diagrams for the proposed timings showing the corridor progression are included in the Appendix.

## 3.7 Time of Operation

The beginning and ending periods for signal coordination were reviewed and selected based on the analysis of the 24-hour traffic distribution. The time of operation was reviewed for both the weekday and weekend and were selected based the peaks in traffic volumes during each time period. For the offpeak and weekend operation, the weekday volumes and traffic

patterns were compared to the off peak and weekend volumes and patterns to determine if a weekday plan would be suited for those time periods.

**Table 4** summarizes the recommended time of operation.

**Table 4: Recommended Time-of-Operation**

| Group | Plan Description | Time of Operation (Monday-Friday) | Time of Operation (Saturday-Sunday) |
|---|---|---|---|
| 1 | AM Plan | 7:45 AM – 9:45 AM (Existing) | None |
| | PM Plan | 2:30 PM – 7:00 PM (Existing) | None |
| 2 | AM Plan | 7:45 AM – 9:45 AM | None |
| | PM Plan | 2:30 PM – 7:00 PM | 10:00 AM – 5:00 PM |
| 3 | AM Plan | 7:45 AM – 9:45 AM | None |
| | PM Plan | 2:30 PM – 7:00 PM | 10:00 AM – 5:00 PM |
| 4 | AM Plan | 7:45 AM – 9:45 AM | None |
| | PM Plan | 9:45 AM – 6:00 PM | 10:00 AM – 5:00 PM |

Final ranges for time-of-operation should be determined during implementation of the signal timing plan and after careful observations during the fine tuning process. The time-of-operation of the coordination plans should be carefully weighted against the possible degradation of responsiveness of the traffic signals to side street traffic.

## 3.8 Simulation Model

A traffic simulation model will be developed for the existing and proposed timings using the Simtraffic software. A simulation model is animation software that gives a visual representation of the roadway network and vehicles throughout the corridors as if you were viewing them from an airplane. The simulation model is an effective tool in presenting the proposed timings and evaluating their operation, and can be used for presentation to the Town Council.

## 4.1 Introduction

The overall project goal is to develop recommendations to improve traffic flow and vehicular, pedestrian, and bicycle safety along the project corridor. Kimley-Horn conducted a review of various intersection and corridor improvements to provide improved operation and safety in the corridor. This section summarizes the following corridor improvement options:

- Signal Interconnect
- Traffic Improvement Options
- Geometric Improvements

## 4.2 Signal Interconnect

As discussed in Section III, installation of coordination timing plans in the corridor will improve traffic operations during the peak periods. Coordination timing plans can be implemented through various methods including time-based operation or through some form of signal interconnect.

**Time-based Coordination**

With time-based coordination, the signal controllers are not physically connected together but rather have their time clocks set to the same time. Time-based coordination can be installed by manually verifying the clocks within the controllers to ensure that are on the same time. As an alternative, radio-synchronized clocks (WWV clocks) can be installed in each controller cabinet to automatically update the time settings via radio. Since the time-clocks within the controllers tend to float from "actual" time in a short period of time, the best method is through radio-synchronized clocks so that maintenance staff do not have to continually verify the controller clocks.

The estimate of probable cost to install a radio-synchronized clock at an intersection is $1500 each. Therefore, cost to install radio-synchronized clocks along the entire corridor from Blackfield Drive to Beach Road (excluding the potential signals at Stewart Drive and Mar West Street), is $10,500.

**Wireless and Wireline Communication Options**

There are several interconnect options including microwave radio, spread spectrum radio, CDPD, lease phone lines, twisted-pair cable, and fiber optic cable. Advantages and disadvantages for each signal interconnect option are summarized in **Table 5**.

**Table 5: Interconnect Options**

| Interconnect Medium | Advantages | Disadvantages |
|---|---|---|
| Twisted Pair | • Easy to maintain<br>• Less expensive than other hardwired options | • Low bandwidth capacity |
| Fiber Optics | • Highest bandwidth<br>• Can be used for both data and video transmission | • High maintenance requirement<br>• Expensive<br>• City not familiar with maintenance<br>• Requires new conduit system |
| Lease Phone Line | • Low initial cost | • Monthly service fee can be very high<br>• Subject to disruption due to phone company activities |
| Microwave | • Lower cost for long transmission | • Unlicensed version subject to interference<br>• Licensed version requires FCC approval<br>• Can be expensive<br>• Requires line of sight |
| Spread Spectrum | • Lower cost<br>• Versatile | • Requires line of sight<br>• Subject to interference |
| CDPD (Cellular) | • Lower initial cost<br>• Less interference | • Airtime charges |

***Wireline Options***

Twisted-pair is the most commonly used communication medium for traffic signal interconnection. A twisted-pair cable consists of two cooper wires twisted around each other to reduce interference from external sources, and is installed between controllers in underground conduit that is expensive to install.

Fiber Optic communication provides a high-volume means for transmitting data and video via several communications channels. Information is transmitted by coded light impulses that travel through the glass by the means of internal reflections. Once the information is reach at it destination, the signals would be convert to dielectric pulses and decoded. Similar to twisted-pair, fiber optic cable is installed between controllers in underground conduit that is expensive to install.

Leased phone lines are essentially the same medium as twisted copper pair, except the communication medium is leased from a telephone service provider. The typical cost for one lease line is $120 per month.

***Wireless Options***

Microwave systems transmit data point-to-point via large dish-type transmitters at each intersection. Spread spectrum is similar to microwave and transmits data point to point via small radio antennas mounted at each intersection. Both spread spectrum and microwave require direct line of sight for operation and are subject to interference from other sources. Because the Tiburon Boulevard corridor has large changes in vertical and horizontal alignment, this system is not practical for this corridor.

Cellular Digital Packet Data (CDPD) use the cellular network for data transmission. CDPD permits remote terminals to use the same frequency pair for transmitting and receiving data. CDPD does not require new frequencies or network, since it can use idle capacity on an existing network. Users of cellular network pay for the airtime and the cost vary depending on usage. CDPD requires a central computer to be maintained for the operation of the system.

**Recommendation**

The primary purpose for the signal interconnect between controllers on Tiburon Boulevard at this time is to implement signal coordination plans. Each of the wireless and wireline interconnect options are expensive to install for the specific purpose of implementing coordination timing plans. Coordination plans can be effectively implemented at a significantly lower cost through time-based coordination. Therefore, it is recommended, at this time, that radio-synchronized clock (WWV clock) installation be considered for the operation of signal coordination. In the future, if the Town or Caltrans has additional communication needs such as transmission of video or traffic data for traffic monitoring, other interconnect options could be evaluated.

## 4.3 Traffic Improvement Options

Several signal improvement options are available to assist in providing enhanced safety for pedestrian and bicycle traffic. These options include:

- Install Coordination Speed Signs
- Preliminary Exclusive Pedestrian Phase
- Countdown pedestrian heads
- Lighted crosswalks

- Zebra striped crosswalks

**Coordination Speed Signs**

Many drivers are currently accustomed to speeding from one signal to the next, in the hope to arrive while the downstream signal is green. However, operating the signals under coordination would require a change in driver behavior to minimize speeding between signals and encourage vehicles to optimally arrive at each signal for smooth traffic flow.

This can be achieved by installing advisory signs that inform drivers about the progression speed of the signal coordination. The signs could static in format, similar to existing posted speed limit signs, or electronic, which can be activated only during periods of signal coordination.

**Preliminary Pedestrian Phase**

A preliminary pedestrian phase time is an initial period of time prior to the vehicle movement where the pedestrians have an exclusive phase to begin crossing the street. Typically, this time is between 5 and 10 seconds and gives pedestrians an opportunity to enter into the crosswalk safely prior to the vehicles receiving a green phase. Often times right turn traffic will enter the intersection at the start of the green phase and not see the pedestrians entering the intersection. A good candidate for this operation is at the Trestle Glen Boulevard intersection in the southbound direction. Because of the steep vertical alignment of Trestle Glen Boulevard with Tiburon Boulevard, the line of sight for vehicles to see pedestrians when exiting Trestle Glen Boulevard is limited.

**Countdown Pedestrian Heads**

An option to assist in providing additional pedestrian and bicycle safety at signalized intersections is to install countdown pedestrian signal heads. Countdown pedestrian heads show the amount of Flashing Don't Walk time, or pedestrian clearance phase that remains for a pedestrian or bicycle to complete crossing the street. Countdown pedestrian heads will give the pedestrian and bicycles crossing Tiburon Boulevard a better indication of how much time remains for them to safely cross.

**Lighted Crosswalks**

Lighted crosswalks are used to provide a visual indication to drivers that a pedestrian is crossing in the crosswalk. A series of lights outline each side of the crosswalk and pedestrians have a pedestrian pushbutton, similar to at signals, which activates the crosswalk lights. Lighted crosswalks are typically used in high pedestrian traffic locations at mid-block locations and in areas with lower travel speed. Lighted crosswalks would be useful in the Downtown area where travel speed is low and

pedestrian traffic is high.

**Zebra Striping**

Finally, another option to provide additional pedestrian and bicycle safety for people crossing Tiburon Boulevard is by using Zebra striped crosswalks rather than the standard crosswalk striping at the signalized intersections. Zebra striping are a series of diagonal or longitudinal lines to define the crosswalk. This type of crossing provides greater visibility to the driver, particularly in locations where a pedestrian crosswalk is difficult to see or is not expected.

## 4.4 Geometric Improvements

Kimley-Horn conducted a review of the existing geometry at intersections in the corridor to evaluate geometric improvement options that would provide better corridor operation and safety. Specifically, improvements were reviewed at the intersections of Cecilia Way, Reed Ranch Road, Stewart Drive, Gilmartin Drive, and Trestle Glen Boulevard.

Cecilia Way, Reed Ranch Road, Stewart Drive, and Gilmartin Drive are tee-intersections that are currently stop sign controlled. Traffic exiting each of these roadways must yield to the through traffic on Tiburon Boulevard when entering Tiburon Boulevard. During peak periods, it can be difficult for left turning traffic to exit these roadways due to heavy traffic on Tiburon Boulevard. Therefore, the installation of left turn acceleration lanes was reviewed for these intersections. A left turn acceleration lane is a small pocket or merge area in the center of the roadway that provides left turn traffic an area to accelerate within, prior to entering the main stream of traffic. In addition, the installation of a pedestrian crosswalk was reviewed at the Gilmartin Drive intersection.

A field review was conducted at each intersection to observe existing traffic operation and to determine if a merge lane could by installed within the existing roadway width. Based on the field review, there is currently a short, left turn acceleration lane at Stewart Drive that was installed recently by Caltrans. Although this lane is shorter than typical, the existing roadway width and alignment does not allow for a longer lane. A traffic signal at this location may be the only option to provide the left turn traffic an easier entrance to Tiburon Boulevard.

In review of the roadway geometry at Gilmartin Drive, it is not feasible to install a left turn acceleration lane within the existing roadway width. It would require roadway widening to the south to provide a dedicated lane. In addition, there is sufficient line of sight in each direction for traffic exiting the roadway and the traffic on Tiburon Boulevard is not as heavy during the peak periods at this intersection. Therefore, a left turn acceleration

lane is not recommended at Gilmartin Drive.

The installation of a pedestrian crosswalk at Gilmartin Drive was reviewed to determine if a pedestrian crosswalk would be beneficial at this intersection. Based on the field review, a crosswalk is not recommended. There are not a regular or frequent number of pedestrians crossing at the intersection and it is estimated that drivers would not be accustomed to seeing pedestrians crossing the roadway. Drivers are not as attentive to pedestrians when they are not accustomed to seeing pedestrians at a specific location. In addition, it is estimated that a crosswalk would give pedestrians a false sense of security, and would not be as cautious in crossing.

Field review confirmed that left turn acceleration lanes would be both feasible and useful at the intersections of Cecilia Way and Reed Ranch Road. Traffic on Tiburon Boulevard is heavy during peak periods and traffic travels at higher speeds at both of these locations. Therefore, concept plans to install a left turn acceleration lane were developed for both of these intersections and are illustrated in **Figures 5 and 6**.

Both intersections would require the removal of a portion of the median island on the east side of the intersection, installation of new striping, and minor modification to the existing striping. Also, an additional improvement is recommended to provide better delineation of the existing right turn merge lane used by vehicles turning right off Cecilia Way and Reed Ranch Road. This includes installation of additional striping parallel to the roadway on the northwest corner of the intersection, as illustrated on the figures, to give drivers on Tiburon Boulevard a better indication of the merge lane.

Estimates of probable cost were developed for the improvements at Cecilia Way and Reed Ranch Road and are summarized in **Tables 6 and 7**, respectively.

**Figure 5: Cecilia Way Geometric Improvements**

**Figure 6: Reed Ranch Road Geometric Improvements**

**Table 6: Cecilia Way Improvements: Estimate of Probable Cost**

| Item | Description | Quantity | Unit | Unit Price | Total |
|---|---|---|---|---|---|
| 1 | Install Thermoplastic Striping and Markers | 455 | LF | $3.00 | $1,365 |
| 2 | Install Thermoplastic Pavement Marking | 84 | SF | $5.00 | $420 |
| 3 | Install Sign and Post | 1 | EA | $300.00 | $300 |
| 4 | Relocate Sign | 1 | EA | $200.00 | $200 |
| 5 | Remove Striping and Marking | 1 | LS | $500.00 | $500 |
| 6 | Remove Curb | 345 | LF | $3.50 | $1,208 |
| 7 | Remove Median | 2260 | SF | $3.50 | $7,910 |
| 8 | Install Pavement | 2260 | SF | $5.00 | $11,300 |
| 9 | Install Median Curb | 290 | LF | $10.00 | $2,900 |
| 10 | Misc. Labor and Mobilization | 1 | LS | $5,000.00 | $5,000 |
| Sub-Total | | | | | $31,103 |
| Contingency @ 20% | | | | | $6,221 |
| Sub-Total Construction | | | | | $37,323 |
| Engineering @ 20% | | | | | $12,500 |
| Construction Admin @ 20% | | | | | $7,465 |
| TOTAL | | | | | $57,288 |

**Table 7: Reed Ranch Road Improvements: Estimate of Probable Cost**

| Item | Description | Quantity | Unit | Unit Price | Total |
|---|---|---|---|---|---|
| 1 | Install Thermoplastic Striping | 850 | LF | $3.00 | $2,550 |
| 2 | Install Thermoplastic Pavement Marking | 84 | SF | $5.00 | $420 |
| 3 | Install Sign and Post | 1 | EA | $300.00 | $300 |
| 4 | Relocate Sign | 1 | EA | $200.00 | $200 |
| 5 | Remove Striping and Marking | 1 | LS | $500.00 | $500 |
| 6 | Remove Curb | 300 | LF | $3.50 | $1,050 |
| 7 | Remove Median | 2245 | SF | $3.50 | $7,858 |
| 8 | Install Pavement | 2245 | SF | $5.00 | $11,225 |
| 9 | Install Median Curb | 160 | LF | $10.00 | $1,600 |
| 10 | Misc. Labor and Mobilization | 1 | LS | $5,000.00 | $5,000 |
| Sub-Total | | | | | $30,703 |
| Contingency @ 20% | | | | | $6,141 |
| Sub-Total Construction | | | | | $36,843 |
| Engineering and Surveying | | | | | $12,500 |
| Construction Admin @ 20% | | | | | $7,369 |
| TOTAL | | | | | $56,712 |

The intersection of Trestle Glen Boulevard is currently nearing capacity during the AM peak period for which there are instances of considerable queuing in the westbound direction. The east leg of the intersection is on a downgrade and there are several vertical curves just east of the intersection making it difficult for westbound traffic arriving at the intersection to see the back of the queue. Therefore, a review of the intersection lane configuration was conducted to determine potential improvements to the lane geometry that would provide additional intersection capacity.

The existing lane configuration of Trestle Glen Boulevard is illustrated in **Figure 2**. There is presently an exclusive right turn lane and exclusive through lane in the westbound direction, an exclusive left turn lane and exclusive through lane in the eastbound direction, and an exclusive left lane and exclusive right lane in the southbound direction. The critical movement at the intersection is the westbound through movement in the AM period. Therefore, additional capacity at the intersection would be best served with the installation of an additional westbound through lane.

The intersection delay and queuing was summarized for Trestle Glen Boulevard with the existing and proposed lane configurations to evaluate the impact of the improvements on intersection operation. The results are summarized in **Table 8.**

**Table 8: Trestle Glen Boulevard: Delay and Queue Comparison**

| Lane Configuration | Intersection Delay (sec/veh) | | WB Average Queue Length (feet) | |
|---|---|---|---|---|
| | AM Peak | PM Peak | AM Peak | PM Peak |
| Existing | 20.0 | 11.3 | 930 | 65 |
| Proposed | 10.5 | 8.9 | 250 | 65 |
| % Change | -47.5% | -21.2% | -73% | 0% |

Note: Based on 1997 HCM Methodology

Synchro timing sheets for each alternative are included in the Appendix.

An evaluation was conducted to determine if it was feasible to install an additional lane in the westbound direction within the roadway width or if roadway widening would be required. Based on the evaluation and using standard design guidelines, it is not feasible to add an additional through lane within the existing roadway width. There is existing guardrail on the north and south sides of Tiburon Boulevard just west of the intersection. Caltrans design standards require 4-foot shoulders adjacent to guardrail, thus not providing sufficient room to add an additional lane in this segment.

There is an existing bridge on the south side of Tiburon Boulevard just west of the intersection that would make widening of the roadway on the southwest side of the intersection very costly. Therefore, an alternative to add the westbound through lane was developed that would maintain the existing roadway alignment on the southwest side of the intersection but would require minor widening of the road on the northwest side of the intersection. **Figure 7** illustrates the recommended improvements.

The plan would include the following improvements:

- Remove existing guardrail on the northwest side of the intersection and install an 8" high curb, gutter, and a 5-foot sidewalk.
- Sliver widen the south side of Tiburon Boulevard east of the intersection.
- Provide a 200' long second westbound through lane east of the intersection.
- Restripe the roadway west of the intersection to accommodate the second westbound through lane provided.

An estimate of probable cost was developed for the improvement plan and is summarized in **Table 9**.

**Table 9: Trestle Glen Boulevard Improvements: Estimate of Probable Cost**

| Item | Description | Quantity | Unit | Unit Price | Total |
|---|---|---|---|---|---|
| 1 | Install Thermoplastic Striping and Markers | 5730 | LF | $3.00 | $17,190 |
| 2 | Install Thermoplastic Pavement Marking | 479 | SF | $4.00 | $1,916 |
| 3 | Install Sign and Post | 1 | EA | $300.00 | $300 |
| 4 | Install Curb and Gutter | 305 | LF | $15.00 | $4,575 |
| 5 | Install Sidewalk | 1525 | SF | $8.00 | $12,200 |
| 6 | Remove Striping and Marking | 1 | LS | $5,000.00 | $5,000 |
| 7 | Remove Guard Rail | 270 | LF | $5.00 | $1,350 |
| 8 | Remove Sidewalk | 965 | SF | $4.00 | $3,860 |
| 9 | Install Pavement | 1642 | SF | $5.00 | $8,210 |
| 10 | Misc. Labor and Mobilization | 1 | LS | $20,000.00 | $20,000 |
| Sub-Total | | | | | $74,601 |
| Contingency @ 20% | | | | | $14,920 |
| Sub-Total Construction | | | | | $89,521 |
| Engineering and Surveying | | | | | $30,000 |
| Construction Admin @ 20% | | | | | $17,904 |
| TOTAL | | | | | $137,425 |

**Figure 7: Trestle Glen Boulevard Geometric Improvements**

It is estimated that providing two westbound through lanes west of the Trestle Glen Boulevard, as shown in **Figure 7**, may result in a higher delay for traffic exiting Blackies Pasture Road and turning left onto Tiburon Boulevard. There is currently an exclusive westbound through lane for left turn traffic exiting Blackies Pasture Road to enter, but would be eliminated as shown in **Figure 7**. Therefore, a second Trestle Glen alternative was developed to retain a left turn merge lane for the Blackies Pasture traffic. **Figure 8** illustrates the plan.

The plan would include the following improvements:

- Remove existing guardrail on the northwest side of the intersection and install an 8" high curb, gutter, and a 5-foot sidewalk.
- Sliver widen the south side of Tiburon Boulevard east of the intersection.
- Provide a 200' long second westbound through lane east of the intersection.
- Re-stripe the roadway west of the intersection to accommodate the second westbound through lane provided.
- Reduce the eastbound lanes west of Reed Ranch Road from two lanes to one lane.
- Install left turn merge area for traffic exiting Blackies Pasture Road

An estimate of probable cost was developed for the improvement plan and is summarized in **Table 10**.

**Table 10: Trestle Glen Boulevard Improvements: Estimate of Probable Cost**

| Item | Description | Quantity | Unit | Unit Price | Total |
|---|---|---|---|---|---|
| 1 | Install Thermoplastic Striping and Markers | 8900 | LF | $3.00 | $26,700 |
| 2 | Install Thermoplastic Pavement Marking | 714 | SF | $4.00 | $2,856 |
| 3 | Install Sign and Post | 4 | EA | $300.00 | $1,200 |
| 4 | Install Curb and Gutter | 305 | LF | $15.00 | $4,575 |
| 5 | Install Sidewalk | 1525 | SF | $8.00 | $12,200 |
| 6 | Remove Striping and Marking | 1 | LS | $7,500.00 | $7,500 |
| 7 | Remove Guard Rail | 270 | LF | $5.00 | $1,350 |
| 8 | Remove Sidewalk | 965 | SF | $4.00 | $3,860 |
| 9 | Install Pavement | 1642 | SF | $5.00 | $8,210 |
| 10 | Misc. Labor and Mobilization | 1 | LS | $25,000.00 | $25,000 |
| Sub-Total | | | | | $93,451 |
| Contingency @ 20% | | | | | $18,690 |
| Sub-Total Construction | | | | | $112,141 |
| Engineering and Surveying | | | | | $35,000 |
| Construction Admin @ 20% | | | | | $22,428 |
| TOTAL | | | | | $169,569 |

**Figure 8: Trestle Glen Boulevard Geometric Improvements #2**