DEVELOPMENT OF A BICYCLE LEVEL OF SERVICE METHODOLOGY FOR TWO-WAY STOP-CONTROLLED (TWSC) INTERSECTIONS

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by

Nathan Johnston

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COMMITTEE MEMBERSHIP

TITLE:	Development of a Bicycle Level of Service Methodology for Two-Way Stop-Controlled (TWSC) Intersections
AUTHOR:	Nathan Johnston
DATE SUBMITTED:	March 2014
COMMITTEE CHAIR:	Anurag Pande, PhD Associate Professor of Civil and Environmental Engineering
COMMITTEE MEMBER:	Cornelius Nuworsoo, PhD Professor of City and Regional Planning
COMMITTEE MEMBER:	Kimberley Mastako, PhD Associate Professor of Civil and Environmental Engineering

ABSTRACT

Development of a Bicycle Level of Service Methodology for Two-Way Stop-Controlled (TWSC) Intersections

Nathan Johnston

This thesis fills a missing piece in research on multimodal performance measures for traffic on streets and highways. The Highway Capacity Manual (HCM) published by the Transportation Research Board (TRB) provides Level of Service (LOS) methodologies which enable engineers and planners to evaluate the overall performance of roadways and highways based on the physical characteristics of facilities. This allows for the evaluation of those facilities and offers a means for recognizing issues and planning, designing, implementing, and ultimately assessing improvements. Originally, level of service was developed for automotive traffic only, but with recent developments as part of the complete streets movement, the performance of infrastructure for alternative transportation modes have also started being assessed in this fashion. There are methodologies in HCM 2010 for bicycle traffic at signalized intersections, all-way stop-controlled intersections, roadway and highway segments, but as of yet, no bicycle level of service methodology exists for two-way stop-controlled intersections. This work attempts to fill this gap. The methodology utilized for this report includes video collection of sample two-way stop-controlled intersections throughout California, collection of survey responses from viewers of video, and linear regression of collected survey responses with physical

attributes of each sample intersection as the explanatory variables. Data was analyzed from both combined and individual street movements to determine the final equation set. The final methodology involves two separate procedures for major and minor streets at TWSC intersections. Final factors deemed significant in bicycle level of service analysis include sight distances, speed limits, presence of bus stops, presence and type of bicycle infrastructure, street widths and types of lanes present, pavement quality, and traffic flows.

Keywords: Highway Capacity Manual, Level of Service, HCM, Bicycle, Two Way Stop Controlled, Intersection

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CHAPTER 1: INTRODUCTION

There are many components to a transportation network. There are links and all manner of classifications within that category such as streets, highways, freeways, arterials, connectors, etc. Where the links meet, there are intersections, with varying level of traffic controls such as signalized, all-way stop control, TWSC, and roundabouts etc. There are the individual components that are part of these traffic controls as well. A traffic signal, a loop detector, or, perhaps, a video detection system. Each component is important for insuring that the network does not breakdown and each is part of that overall system. If one component fails then it is likely to cause other parts of the system to fail. If one route on a roadway network becomes congested, it is probable that the alternative pathways of travel on that network will also become congested as users try to find alternative paths to their destinations. To ensure that a network and its components function as smoothly as intended, a method must be determined to evaluate how well each is performing and to predict future performance.

Level of Service

The 2010 Highway Capacity Manual, published by the Transportation Research Board, outlines a methodology for evaluating transportation networks and determining how well each part is functioning with the idea of a “Level of Service”(*Highway capacity manual*, 2010). This is a grading system that considers the various qualities of a particular part of a network, such as a

roadway segment, for example, and assigns it a simple letter grade A through F (A being the best operating conditions and F being the worst). This method allows for a simple way to determine which components are in need of improvement and which are, or will be, functioning within acceptable parameters. The LOS system is a quantitative method for calculating the performance measures or quality of service of a transportation facility. The measures used to calculate the level of service are referred to as “service measures.” Due to extensive costs, roadways are not usually designed up to “A” level standards but may yet experience those conditions during off-peak periods.

Normally, the level of service evaluation is performed for a specific roadway or highway segment, intersection, or direction of travel. Usually the evaluation process examines each traffic movement at that facility individually to identify within the facility its strengths and weaknesses, then use that information to summarize the facility as a whole. Level of service is an important feature of a traffic impact study for future developments as it determines how well a particular transportation facility will work under a given flow rate. Usage of the LOS methodology or the level of service criteria can help a designing engineer determine how best to reasonably accommodate the increase in traffic flow and increase the level of service.

The LOS system is used to designate a physical measurement (e.g., density in case of automobiles on the freeway) that can map to human perception. The simple A through F result hides the complex nature behind the measurements. There are a number of inputs that go into the series of equations associated with

each facility. LOS is a step function which was devised as a way to quickly convey the conditions of a transportation facility to someone who was not familiar with the facility. However, it tends to oversimplify some aspects of the facility and may hide or exaggerate certain specific flaws in the facility. Some have criticized its use saying that it is not fully representative of the overall transportation network, but for the time being it is a well-accepted practice. One reason for this is because it makes for an easy way to communicate roadway performance to lay persons and decision makers that, despite their inability to fully comprehend the technical nature of the situation, are key stakeholders in addressing the transportation related issues.

Modes

There are different varieties of modes available for travelers to utilize in their travel. The most common of these include the automobile, walking, bicycle, and public transit. The level of service system requires different procedures and set of equations for each. This paper focuses primarily on level of service for bicycle mode choice.

Bicycles are often selected by travelers for a variety of different types of trips including commutes to school or work, recreation, shopping, errands, exercise, or social gatherings and events. Bicycles allow users to travel about five times faster (or more, depending on the cyclist) than an average pedestrian and can extend the range of a local trip. Cycling in the United States is currently less common than in other countries worldwide, but it is increasing in popularity due to a number of reasons both economic and political. Several cities, like Portland,

Oregon, are becoming increasingly famous for their bicycle friendly infrastructure and attractive locations for potential businesses and residents (*Highway capacity manual*, 2010).

The existing HCM bicycle level of service equations were developed from survey data on a series of existing bicycle paths. The routes and intersections selected where analyzed in terms of their physical dimensions, characteristics, and flow rates. Then volunteers were asked to give those routes and intersections a letter grade that reflected their own opinion of that facility. Then, the opinion surveys were used to create and calibrate the series of equations that are presented in the 2010 manual (Kang & Lee, 2012; Dowling et al, 2008). The idea being that these statistical models can now estimate what level of service the cyclists would claim to experience from a given bicycle facility.

Differences from Cyclist's Perception to Driver's Perception

Many measures that apply to vehicle level of service also apply to bicycle level of service, e.g., delay. Some measures, however, are different, like vehicle density, for example. Cyclists often travel very tightly packed in groups and even travel side by side. Unlike motorists, who experience a higher level of service when densities are low and distances between vehicles are very high, cyclists are more tolerant or even prefer higher densities. But, at the same time, faster cyclists often wish to, but may be unable to, pass slower groups of cyclists due to inadequate maneuvering room with a high density of cycling traffic. This kind of situation makes density a very unstable measure of level of service for bicycles. Capacity is also a difficult measure as it usually depends on the flow speed of the

traffic. Bicycle speeds vary from cyclist to cyclist, sometimes by up to four times the slower cyclist's speed. It has been noted that, when facilities become too congested, some less experienced cyclists will even dismount and start walking before the facility reaches capacity (*Highway capacity manual*, 2010).

Some factors have more weight in determining a cyclist's perceived level of service than a motorist's level of service. The pavement quality (and/or presence of roadway debris), for example, often affects a cyclist much more directly than the motorist both due to comfort and the likelihood of mechanical issues like the possibility of getting a flat tire. The percentage of heavy vehicles on a route also may impact cyclists' level of service significantly. Large vehicles can intimidate cyclists, especially when passing in close proximity with a high speed differential. The existence of on-street parking is important to cyclists as pedestrians become more likely to step into the cyclist's path of travel and drivers are more likely to open their doors into the bike lane. On street parking often forces cyclists to slow down and move closer to the main traffic flow in order to avoid a collision with the parking lane.

Environmental factors may play a much heavier role on cyclists' level of service than on motorized vehicle transit. Cyclists often feel more satisfied with a scenic area. This is where the cyclist's perception of safety plays a role as they do not have a locked door between them and someone else standing on a street corner. The weather is also a concern as cyclists are comparatively more concerned than motorists about wet and slick conditions.

Problem Statement

Among the existing modal choices, active modes of transportation, i.e., walking and bicycling, can provide significant benefits for physical well-being in addition to the environment. Increased bicycle usage also has the added benefit of making transit more attractive as a mode since a bicyclist can traverse significantly more distance to and from a transit stop compared to a pedestrian. Cycling is not only more economical but also is more equitable alternative to the automobile due to its affordability. In spite of the benefits mentioned here, there are significant challenges to widespread use of bicycles in the US. Infrastructure is designed largely for the automobile not only as the dominant mode but in some jurisdictions as the only mode of travel. In addition, bicycle users are more sensitive to inclement weather conditions and the environment, in general. Also, cyclists are more vulnerable on the road compared to drivers. These challenges to bicycle usage require that the needs of bicyclists on the road are adequately identified and addressed. A level of service (LOS) score can be a valuable tool to help traffic engineers and planners do just that. Although Dowling et al. (2008) tied the LOS measures for bicycle users to user satisfaction for street segments and signalized intersections, the concept is not well defined for some of the other facilities and one of the missing links is the LOS for bicycles at two-way stop-controlled (TWSC) intersections (Dowling et al, 2008). As of yet, there is no bicycle LOS method for TWSC intersections. The HCM states the following on the subject:

> *As of the publication date of this edition of the HCM, no methodology specific to bicyclists has been developed to assess the performance of bicyclists at TWSC intersections, as few data are available in the United States to support model calibration or LOS definitions*. (*Highway capacity manual*, 2010)

This study addresses these challenges and is organized as follows: the next chapter provides characteristics of the bicycle traffic followed by the data details. The chapter after that describes the statistical analysis of the data followed by results and conclusions.

CHAPTER 2: CHARACTERISTICS OF BICYCLE TRAFFIC

Demand Fluctuation

The amount of bicycle travel, and demand for bicycle facilities, varies significantly by time. Bicycle travel is heaviest on an average day during the morning and during the evening as people either commute or have the ability to partake in recreational activities. Bicycle travel is generally higher in the summer time of the year than in the winter as cyclists are exposed to the elements and experience a far lower comfort level when exposed to bad weather, low light levels for bad visibility, and extreme cold. Even over the course of a week, the number of cyclists on a roadway varies from day to day. See Figure 1 below which depicts fluctuations in time for bicycles reproduced from the HCM 2010 (*Highway capacity manual*, 2010)**.**

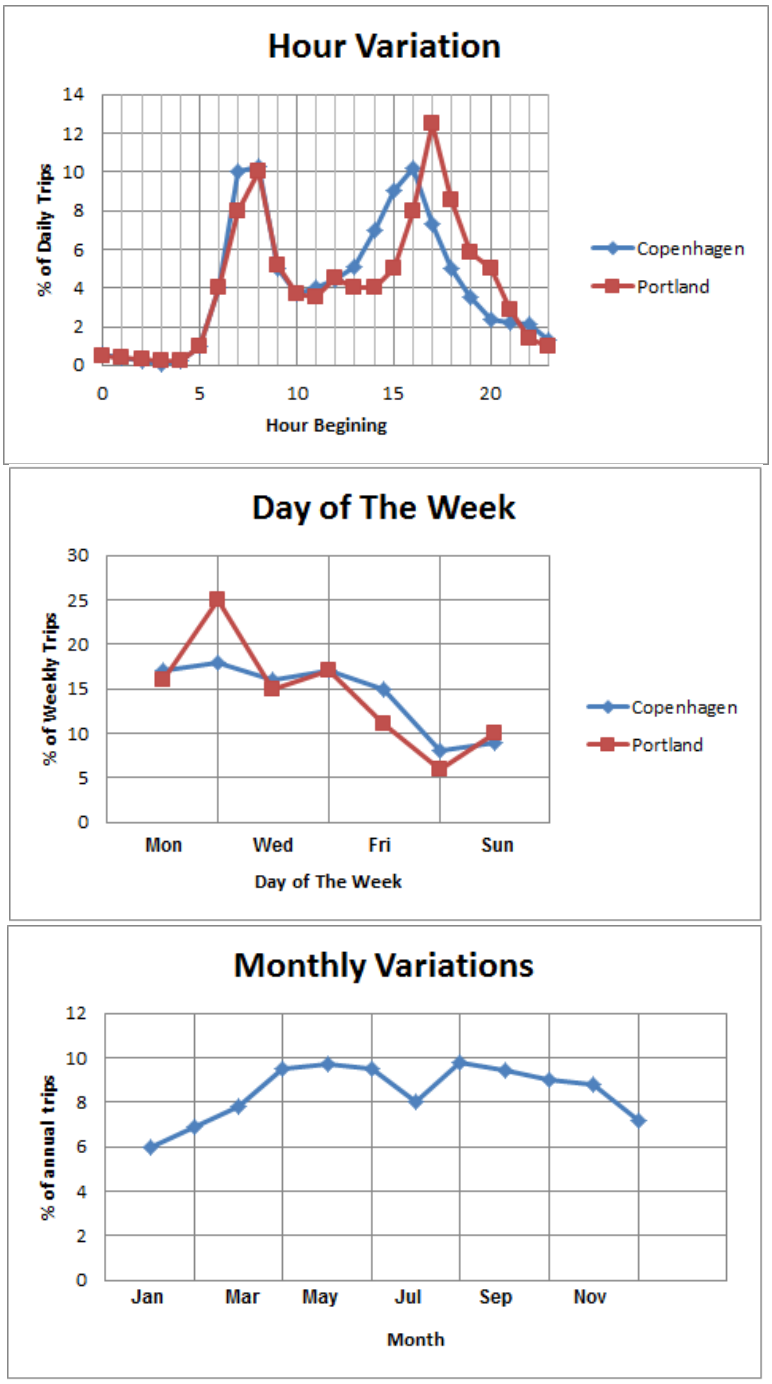

Figure 1: Portland, Oregon, and Copenhagen Travel Demand; (*Highway capacity manual*, 2010)

Paved Bicycle Facility Types

Bicycle facilities may or may not follow, or even be part of, the main roadway network. Those that are part of the existing roadway are considered on-street and those that are not part of the roadway are considered off-street. On-street facilities include (but are not limited to) shared lane paths (also known as Sharrows), bicycle lanes, shoulder bikeways, and bicycle tracks. In some cases a bicycle path may exist on a roadway, but may not be stripped or marked or may have some intermediate method of announcing the presence of cyclists. A class three bike path, for example, refers to a highway that has signage for a "Bike Route," but in which no roadway markings are present and cyclists are expected to ride in the primary travel lanes with other vehicles. For on-street facilities, cyclists share the roadway with motor vehicles but may or may not have separate lanes. These are fairly common in both rural and urban areas with low financial resources. Off-street facilities include sidepaths and exclusive bike pathways, usually offering bi-directional flow. Some facilities may be for bicycle use only whereas some allow for pedestrian travel on these paths, as well, however, such mixed use paths can cause congestion and safety issues when experiencing high flow volumes. Sidepaths in particular can also cause conflicts or concerns with adjacent properties, driveways, or intersecting roadways but the 2010 Highway Capacity Manual level of service methodology does not take this into account. Whatever facility type is utilized, all function with the primary purpose of transporting travelers from point A to point B and can either be constructed on or parallel to a normal vehicle roadway.

Bike Lane

Shared Lane (Sharrows)

Bike Track

Shoulder Bikeway

Exclusive Pathway

Side Path

Figure 2: Types of Common Bicycle Facilities

Interactions

The volumes of automobile and heavy vehicle flow on or adjacent to a bicycle pathway affect the ride quality of the cyclist. Parked vehicles increase the chances of bicycle collisions, not only with the parked vehicles or pedestrians, but with normal vehicle traffic as the existence of roadside parking often forces cyclists further into the lane of travel than they would otherwise go if no vehicles were parked. Turning vehicles often cross the path of cyclists and right turning vehicles especially often do not even notice the bicycle before cutting into its travel lane. The distance kept between a cyclist and a vehicle is a key aspect in a cyclists' view of the level of service of a facility as well as the speed of the passing vehicle. (On a side note: A proposed piece of legislation that is currently being supported, at the time of this paper being written, is to require vehicles on a roadway to keep a minimum of three feet away from cyclists. If this legislation were to be implemented (as it will be, starting September 2014, in California), and be enforced, the cyclists' level of service perception of each facility may automatically increase without actual physical improvement of the facility.) Transit vehicles such as buses react similarly with cyclists as heavy vehicles except that they often cut into bicycle travel paths in order to pick up or drop off passengers. This adds increasing delay and decreasing safety to the cyclist's ride quality. The 2010 Highway Capacity Manual does not yet account for this in its level of service methods (*Highway capacity manual*, 2010). In a related manner, transit that allows for a cyclist to bring his or her bike on board can extend the range, ease, and comfort of the ride and increase the perceived

level of service for a route. In reality, all of these play a role in the cyclists' perception of level of service with respect to vehicles.

Pedestrians also affect cyclists and usually add to the delay with their presence. Pedestrians often travel in groups, typically side by side, at low speeds and have a tendency to block cyclists travel path (even if against the law). They often are more maneuverable than bicycles in close quarters and act in unexpected ways when encountering a bicycle on the same pathway. Similar to motor vehicles, bicycles must yield to pedestrians and also wait for them to travel across their path when heading perpendicular to the bikeway.

Bicycle Flow

Bicycles tend to act in ways similar to motor vehicles, being legally obligated to adhere to the same rules and regulations. They operate in distinct lanes or paths with widths that are easily measured or determined and the capacity of the facility depends on the number of these lanes that are available. In general, a bicycle lane is around 3 to 5 feet in width but sizes do vary depending on a multitude of factors. (The American Association of State Highway Transportation Officials recommends 10 feet total width for off-street bike paths (Do, 2006). Shared lane facilities are the most common and usually only have one lane in each direction, but there are other paths that have bike shoulders, passing lanes, or tracks that bikes can take to increase their flow. Not all of these lanes may be in use for riders, however, so it may be difficult to determine which should be considered its own lane and which should not. Usually a field evaluation is in order when this ordeal is encountered. The HCM 2010 recommends three lane bike paths (two

one directional lanes and one passing lane) as being the most efficient bike path layout (*Highway capacity manual*, 2010). These offer increased maneuverability for cyclists (and pedestrians when allowed) to pass slower groups without conflict, which reduces delay and increases the safety of the path.

As with other vehicles, as the density of the cyclists becomes very large the average speed of the cyclist drops as congestion occurs. Collisions between cyclists are fairly frequent under these circumstances, but rarely do significant damage to person or property, unless a motor vehicle is involved. The majority of bicycle facilities in America are shared with motor vehicles and as the density of each increases, the delay of each increases.

The average free flow speed of the cyclist under ideal conditions also affects the flow significantly. The speed is affected by several factors including skill level, bicycle type, age, and physical capability. A road bike rider is more likely to travel at a faster rate than a mountain bike or “beach cruiser” rider. The personal characteristics of the bicycle and its rider affect the speed and flow just as much as the characteristics of a vehicle and its driver affect its speed and flow. (Note: Please recall that flow is in units of volume per time whereas speed is in units of distance per time.)

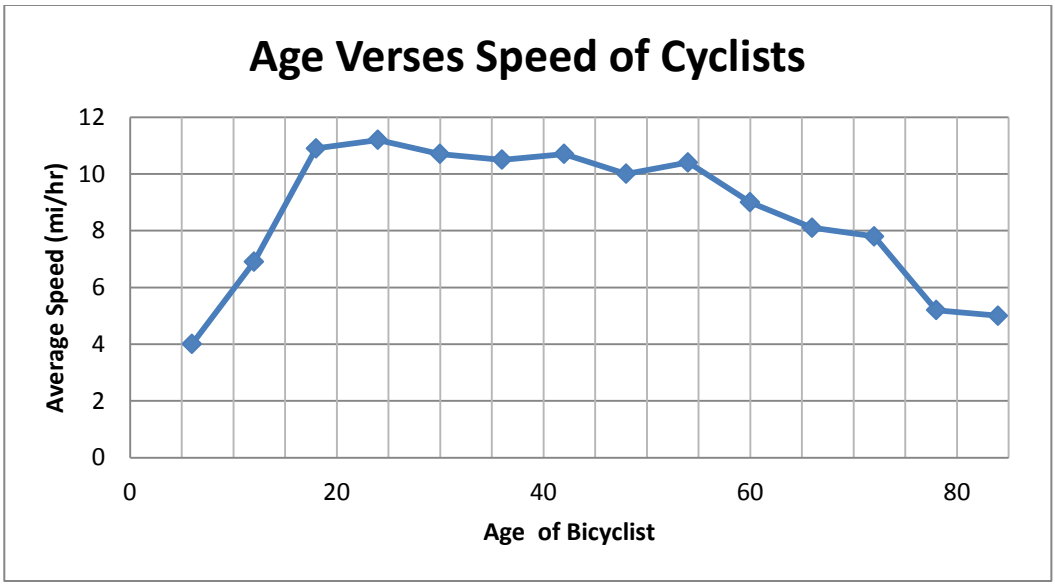

Figure 3: Age versus Speed of Cyclists (*Highway capacity manual*, 2010)

Flow rates for bicycles usually vary with time over the course of an hour and a day. As cyclists become more exhausted they typically slow down. The HCM usually recommends examining the peak 15 minute flow during the peak hour for measuring the level of service (*Highway capacity manual*, 2010). (If necessary, the peak hour factor can be used to obtain this value from an hourly rate. Peak hour factors typically range between 0.7 to 1 or 0.85 on average.)

Unfortunately, as highlighted above, the concept of capacity is not the best measurement for level of service or maximum bicycle flow rate. Capacity values depend on factors that have too much variation when applied to bicycles and cannot usually be trusted. The HCM suggests that capacity is only important when dealing with bicycles at signalized intersections but then offers a rule of thumb value of 1000 bicycles/hour/lane to use as a default and a saturation flow rate of 2000 bicycles/hour/lane (*Highway capacity manual*, 2010). This is

inconsistent as it claims individual evaluation to be important, then recommends ignoring it altogether in favor of a default value. Delay may serve as a better judgment characteristic than capacity for bicycles. Delay represents the overall travel time, an important factor both for the initial mode choice and for the facility, and accounts for the cyclist's willingness and patience with a system. A cyclist who experiences delay has to exert themselves more than a cyclist that does not experience delay. A cyclist that gets stopped at a traffic signal has to brake and then accelerate again as opposed to a cyclist who coasts through an intersection without extra effort because they were not required to stop. This plays an important part of the perceived satisfaction the cyclist experiences as the one who had to stop no doubt felt a little less happy with the facility than did the cyclist that was allowed to coast through unhindered. Even when the purpose of the bike rider is to exercise, unnecessary physical exertion caused by excess starting and stopping of a bicycle results in increased stress on the rider and decreases their satisfaction with the bicycle facility.

Delay actually may have some components because of this effect. A cyclist that has to start and stop several times along a route will probably feel more upset than a cyclist that only has to stop one or two times. A cyclist, like a normal vehicle driver, that has to wait a long time at an intersection will probably feel more upset than if they only had to wait a few seconds. This indicates that it is necessary to consider not only how long the total delay is in seconds, but also how many times the rider is required to stop. Not only would this apply to routes, but when analyzing a particular intersection the distance to nearby upstream and

downstream intersections or stops should be considered as well as their cycle lengths.

Bicycle level of service methodologies exist for signalized intersections, but not for the more common TWSC intersections. (A two-way stop-controlled intersection is a roadway intersection in which one or more direction of traffic flows pass through uninhibited while conflicting traffic flows are held back by a stop sign.)

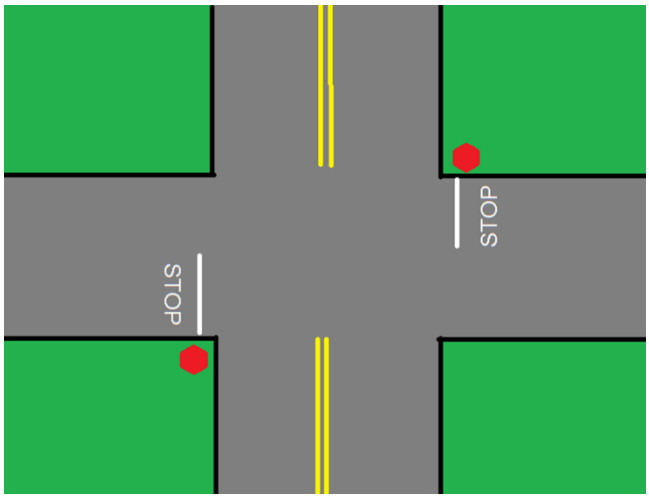

Figure 4: Diagram of Two-Way Stop-Controlled Intersection

TWSC intersections are critical and frequently encountered elements of a street network. One needs to address the LOS for bicyclists at these intersections to obtain a better assessment of the bicycle travel experience. The expansion of LOS procedures by incorporating this critical roadway element will help cities make street networks more bicycle friendly and lead to increased bicycle usage. Literature written about bicycle infrastructure reports significant evidence that providing adequate roadway designs and addressing the needs of bicyclists

leads to increased bicycle usage (Dill and Voros, 2007; Pucher, Dill, & Handy, 2010).

Increased bicycling can result in reduced greenhouse gas and pollutants being released into the environment. Bicycles are typically considered to be one of the most economical and sustainable modes of transportation. In addition to being an active mode of transportation they can enhance access to transit services at bus and rail stops. Commuters on bicycles can commute to transit centers located much farther than commuters who walk. Ultimately enhancing the multi modal LOS procedure with this crucial roadway element will make the HCM methodology more complete. Wider applications with a more complete methodology can allow communities to make better decisions with respect to the enhancements that are needed to improve user perception of bicycle facilities. A list of the necessary procedures for providing this level of service methodology is outlined in table 1 below.

Table 1: Goals

Goal
Collection of Data on Physical Characteristics of Sample Two-Way Stop-Controlled Intersections
Collection of Video Footage of Two-Way Stop-Controlled Intersection Turn Movements from Cyclist' Perspective
Collection of Video Footage of Signalized Intersection Turn Movements for Validation of Viewers Feedback
Collection of Video Viewer's Feedback as Perceived Level of Service Ratings
Consolidate Viewers Feedback into a Single Average LOS Score for Each Turn Movement
Split Data into Three Sets for Analysis: Major Street, Minor Street, and Combined
Perform Linear Regression on Data and Confirm with Reserved Survey Intersections
Provide details on significance of Results and Future Research Possibilities

Existing Level of Service Methodologies

The first step in developing a new level of service methodology is to examine the other methodologies that have already been created and to see what aspects may be important for TWSC (two-way stop-controlled) intersections. It is also possible that an already existing methodology for a similar manner of roadway configuration may work just as well for two-way stop-controlled intersections. This is something that should be tested with data collected from the field at two-way stop-controlled intersections (and is tested later on in this report). Brief descriptions of each method are outlined below. A much more detailed format for each level of service methodology is listed in the appendix.

Bicycle Level of Service for Signalized Intersections

Currently, the HCM requires intersection performance to be calculated individually for each intersection approach (direction of travel) unless otherwise stated (*Highway capacity manual*, 2010). Bicycles are assumed to travel in an on-street facility in the same direction as adjacent motor vehicles. The methodology looks at the intersection from the cyclists' point of view, as the data calibration for the model was done specifically from feedback of cyclists on selected real-life intersections.

There are three main steps in the bicycle level of service for a signalized intersection:

- Determine Bicycle Delay
- Determine Bicycle Level of Service Score for the Intersection
- Determine the Level of Service

These are done separately for each approach to the intersection and repeated for each approach of interest. If a bicycle lane or shoulder does not exist, the bicycle delay is assumed to be the same value for bicycles as it is for vehicles as they both use the same lane. This does cause some room for error as the presence of bicycles in the vehicle lane usually slows down the main traffic flow, so there may be increased delay that is not accounted for by the LOS calculation under these circumstances.

The last step is to use the above bicycle level of service score to look up the actual level of service in exhibit 18-5 from the HCM:

Table 2: LOS Criteria for Bicycles at Signalized Intersections: Exhibit 18-5 (*Highway capacity manual*, 2010)

LOS	LOS Score
A	<2.00
B	2.00 - 2.75
C	2.75 - 3.50
D	3.50 – 4.25
E	4.25 – 5.00
F	>5.00

For example, if $I_{b,int}$ was found to equal 3.76, that particular travel direction in the intersection would have a level of service rating "D." This would imply that modifications may be necessary to improve the experience for cyclists at such an intersection.

Something that is noteworthy in this approach is that, although the delay is calculated, it does not actually factor into the level of service calculation. This may or may not be a flaw in this particular methodology as a high level of delay in the field should indicate a lower level of service. As the HCM mentions, cyclists will not normally tolerate oversaturated conditions or areas with high delay and will select alternate routes or even ignore traffic laws in order to avoid unnecessary delays (*Highway capacity manual*, 2010). In general, most delay at a signalized intersection is caused by the signal itself. However, right turning vehicles also require cyclists to slow down in order to avoid a collision and cyclists are often delayed whether right turning vehicles are present or not simply because the cyclist has to check for them before entering an intersection. Large dips at intersections, common for streets with high quantities of drainage capacity, also are known to cause delay as cyclists must reduce speed in order

to safely pass over these hazards. However, these are not directly addressed in the signalized intersection methodology for bicycle level of service.

Two-way stop-controlled intersection bicycle behavior may function in similar respects to this particular level of service method. However, the HCM only looks at what it considers to be the effective bicycle widths without taking into consideration whether or not this space is shared by bicycles with other vehicles. Inexperienced cyclists are often not comfortable with riding in automotive traffic and even experienced cyclists prefer the safety of being separated (*Highway capacity manual*, 2010). The type of bicycle facility present is not reflected in this method. In addition, signalized intersection delay is estimated based off of the signal timing, but a TWSC intersection has no signal timing. Delay for a two-way stop-controlled intersection may be much more difficult to accurately estimate as it would depend on the individual intersection configuration, traffic flow, sight distance, and possibly other factors we would not normally consider. Another key element in the signalized intersection bicycle level of service methodology is the saturation flow rate. The saturation flow rate is the rate at which vehicles (bicycles in this case) traverse an intersection during a green signal with a full queue. It measures how many vehicles can go through an intersection under perfect conditions (never actually achieved in reality). This can be very difficult to determine as the saturation flow rate varies depending on the experience, age, and skill level of the cyclists (as mentioned in the previous sections). This may be another flaw for the signalized intersection level of service method.

Bicycle LOS at TWSC

As mentioned in the introduction, the HCM 2010 states the following in regards to two-way stop-controlled intersection bicycle level of service: "As of the publication date of this edition of the HCM, no methodology specific to bicyclists has been developed to assess the performance of bicyclists at TWSC intersections, as few data are available in the United States to support model calibration or LOS definitions" (*Highway capacity manual*, 2010). In other notes, the HCM mentions concerns with bicycle follow up times and headways as cyclists often ride side-by-side rather than single file as an automobile would. There has been some discussion as to whether it is best to model a bicycle more as a vehicle or as a pedestrian instead. (Note that the pedestrian method for level of service at a two-way stop-controlled intersection applies only to pedestrians crossing the major street because the delay for pedestrians crossing the minor street is assumed to be negligible as vehicles already have to stop and wait for conflicting flows to pass by.)

Bicycle Level of Service for All-Way Stop-Controlled Intersections

For all-way stop-controlled intersections, bicycles are modeled in exactly the same way as vehicles. The HCM recognizes that bicycles do not queue in a single file or linear fashion, but this fact is not reflected in the methodology chosen for LOS estimation (*Highway Capacity Manual*, 2010). It is stated in the HCM that bicycle delay will be slightly less than the vehicle delay because of this effect, but by exactly how much is unknown. The exception to this is with left turning bicycles who must queue with motorized vehicles in order to safely

complete their turns. In general, where bike lanes are present, bicycles are not delayed by other vehicles until they reach the stop bar and must wait for their turn to pass through the intersection. Bicycles can pass through an intersection at the same time as the adjacent vehicle traffic where bike lanes are present, so the bike lane, in effect, serves as an additional lane of traffic allowing multilane operations at the intersection. It has been observed that these effects may still occur in areas without a striped bike lane where bicycles simply pass vehicles on the right side, resulting in lower delay for the cyclists.

The methodology for bicycle level of service at all-way stop-controlled intersections is considerably longer than the methodology previously discussed for signalized intersections. The steps include the following:

- Convert movement demand volumes to flow rates
- Determine lane flow rates
- Determine geometry group for each approach
- Determine the saturation headway adjustments
- Determine initial departure headway
- Calculate initial degree of utilization
- Compute probability states
- Compute probability adjustment factors
- Compute saturation headways
- Compute departure headways
- Check for convergence

- Compute capacity
- Compute service times
- Compute control delay for each lane
- Compute control delay and determine level of service for each approach and the intersection
- Compute queue lengths

Please note that the HCM offers contradictory information between pages 20-3 and 20-19 and notes that the bicycle delay, capacity, and level of service may be inaccurate for all-way stop-controlled intersections because it uses the model primarily for vehicular behavior (*Highway capacity manual*, 2010).

This method of determining the level of service does account for directionality, but does not account for the existence of bicycle facilities. It is designed mainly for the determination of automobile level of service and may often present a poor representation of cycling level of service. It does not consider the pavement quality, the separation distance between cyclists and other vehicles, the lane widths, or most of the other factors that are important to a bicycle rider. In addition to not being responsive, this is a fairly complicated method to use, involving multiple iterations of probabilities for each approach and is not user-friendly. It is the calculation intensiveness with the ease of making an error along the way that disrupts the overall estimate of level of service. The all-way stop-

controlled intersection level of service methodology is highly flawed and does not represent a good model for two-way stop-controlled intersections.

Bicycle Level of Service for Urban Street Segments

Now let's examine the determination of bicycle level of service for urban street segments. This method also considers the directional movement of the cyclist at the intersection. The cyclist is assumed to travel in on-street facilities for this method and in the same direction as the adjacent vehicles. This method consists of the following steps depending on the specific information one is interested in:

- Determination of Bicycle Running Speed
- Determine Bicycle Delay at the Intersection
- Determine Bicycle Travel Speed
- Determine Bicycle Level of Service Score for the Intersection
- Determine Bicycle Level of Service Score for the Link
- Determine Level of Service Score for the Link
- Determine Bicycle Level of Service Score for the Segment
- Determine Segment Level of Service

One important part of this methodology that may be very useful for other bicycle level of service methodologies (including two-way stop-controlled intersections) is the use of pavement quality ratings as established by the Federal Highway Administration. A copy of the rating scale details is reproduced below from chapter 17 in the HCM 2010 (*Highway capacity manual*, 2010).

Table 3: Pavement Quality Ratings: Exhibit 17-7 (*Highway capacity manual*, 2010)

Pavement Condition Rating	Pavement Description	Motorized Vehicle Ride Quality and Traffic Speed
4 to 5	New or nearly new superior pavement. Free of cracks and patches	Good Ride
3 to 4	Flexible pavements may begin to show evidence of rutting and fine cracks. Rigid pavements may begin to show evidence of minor cracking	Good Ride
2 to 3	Flexible pavements may show rutting and extensive patching. Rigid pavements may have a few joint fractures, faulting, or cracking.	Acceptable ride for low-speed traffic but barely tolerable for high speed traffic
1 to 2	Distress occurs over 50% or more of the surface. Flexible pavement may have large potholes and deep cracks. Rigid pavement distress includes joint spalling patching and cracking.	Pavement deterioration affects the speed of free flow traffic. Ride quality not acceptable.
0 to 1	Distress occurs over 75% or more of the surface. Large potholes and deep cracks exist.	Passably only at reduced speed and considerable rider discomfort.

These methods do account for a variety of factors that influence cyclist perception of the true level of service experience, but rely on reaching out to other methods (such as signalized intersection level of service) to fill in missing pieces of the level of service puzzle. In a way, this is a wise thing to do as it breaks down the method into its individual components (intersection, street segment, another intersection, etc.), but at the same time it seems to almost lose

sight of the fact that it is all part of the same route. The final equation (step seven) combines all of the components into a single equation but only looks at a single route in a single direction. It does not account for bicycles that make a turn along the route. It also does not reflect bicycle facility type (apart from noting that it is assumed to be an on-street facility).

Bicycle Level of Service for Urban Street Facilities

Now we shall look at a level of service methodology that combines the above methods. Urban street facilities are also looked at in the individual direction of travel (Chapter 16 of the 2010 HCM) (*Highway capacity manual*, 2010). This method has only three steps although they require the other methods to be calculated before these can be completed:

- Determine the Bicycle Travel Speed
- Determine the Bicycle Level of Service Score
- Determine the Bicycle Level of Service

This method uses the bicycle travel speed (which, again, varies from cyclist to cyclist) and can offer different level of services for the same facility to different riders. It uses the level of service scores of the individual components that make up that facility (possibly including several intersections, when appropriate) and is more of a global level of service tool than a methodology for a specific site facility location. It would not be useful for two-way stop-controlled intersection analysis.

Bicycles Level of Service for Uninterrupted Flow Facilities

For uninterrupted traffic flow, there are three main types of facilities: freeways, multilane highways, and two lane highways. Bicycles are not allowed on freeways, however, and for a cyclist, multilane highways have much the same effect as a two-lane highway. This means that, essentially, there is only one form of uninterrupted flow methodology for bicycles.

The HCM lists the process as being five main steps, however, since one of the steps is simply to gather data, there are effectively only four steps (*Highway capacity manual*, 2010):

- Calculate the Directional Flow Rate in the Outside Lane
- Calculate the Effective Width
- Calculate the Effective Speed Factor
- Determine the Level of Service

This method takes into account the lane widths (including the shoulder), the motorized vehicle traffic, the number of directional lanes, the percentage of heavy vehicles, the speeds of the vehicles, roadside parking, and the pavement quality. As level of service methodologies go, this is one of the better ones as it accounts for numerous factors and is still fairly simple to use. Simplicity is an important factor in these models because, if a methodology is not simple, no one will want to use it and, if they do, the chances of the engineer using it incorrectly increase dramatically.

Automobile Level of Service for Two-Way Stop-Controlled Intersections

The methodology for automobile level of service at two-way stop-controlled intersections depends on a number of factors including intersection geometry, priority of movements, capacities, and delay. The steps for calculation involve the following:

- Determine and Label Movement Priorities
- Convert Movement Demand Volumes to Flow Rates
- Determine Conflicting Flow Rates
- Determine Critical Headways and Follow-up Headways
- Compute Potential Capacities
- Compute Movement Capacities by Rank
- Determine Capacity Adjustments
- Compute Movement Control Delay
- Compute Approach and Intersection Control Delay
- Compute the 95^{th} percentile queue lengths

This methodology examines each turn movement separately, ranking them in order of importance, and even considers whether or not the driver completes their movement in one or multiple stages. (For example, a scenario in which a driver pulls out from the minor street and seeks refuge in a center median on the major street before completing the turn would be considered a two stage movement.) Because this methodology considers each turn movement separately, turn designations are provided that may serve well for discussing and

analyzing bicycle level of service. The equations utilize the labeling shown in the diagram below which is taken from the HCM 2010 (exhibit 19-6).

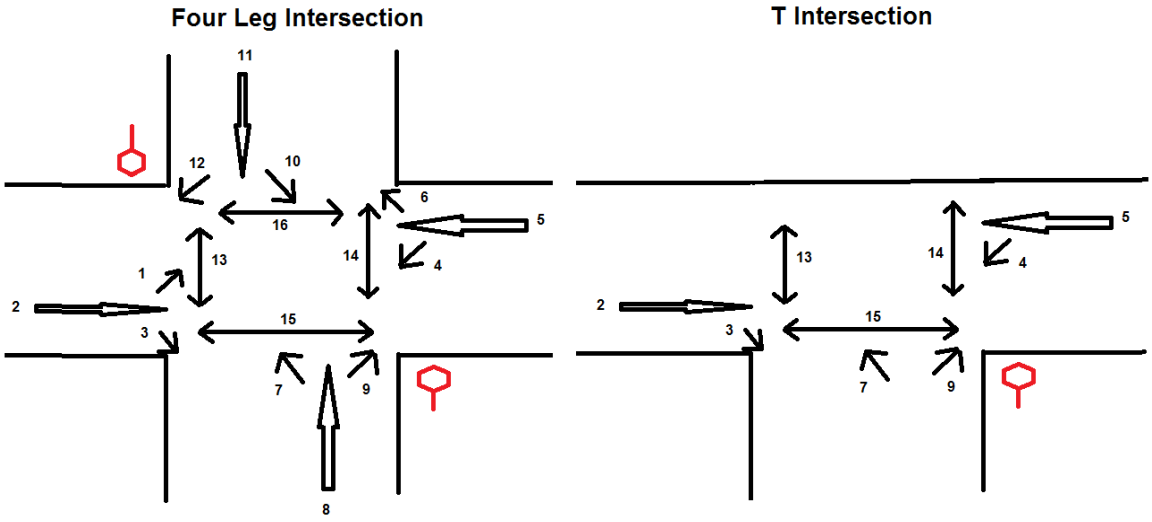

Figure 5: Two-Way Stop-Controlled Movement Diagram 1: Exhibit 19-6 (*Highway Capacity Manual*, 2010)

Notes: vc# = Conflicting Volume for # direction

v13 through v16 are pedestrian volumes

Step four in this method is to determine the critical and follow-up headways for the movements. These may not actually apply to bicycle level of service and may be an indication of a separate format being required for bicycle traffic. The effects of upstream signalized intersections are also accounted for, and may make the methodology much more accurate, but severally complicate the nature of the methodology and, unfortunately, inhibits the idea of being "user friendly." To make this procedure even more complex, it must also consider the effects of multiple stage movements (mentioned earlier in this paper) in which the act of

traversing a single intersection takes place in multiple phases. A positive aspect of this methodology is that it considers the effects of large curb returns, which is something very few methodologies do, even though such physical attributes are fairly common and can greatly affect a user's perception of the quality of an intersection or street segment.

CHAPTER 3: DATA COLLECTION AND PROCEDURES

After reviewing the methodologies that were developed for level of service, a list of common roadway elements that were anticipated to possibly have an effect on a cyclist's quality of service perception for an intersection was developed. The list is provided below.

Roadway Design and Environmental Characteristics Possibly Affecting Two-Way Stop-Controlled Intersection Bicycle Level of Service:

- Number/width of Lanes in each Direction
- Type of Bike Facilities present and in which direction/location at the intersection (Bike Lanes, Sharrows, Signage, etc.)
- Speed Limits (including estimates of bicycle speed)
- Volume of Traffic in each Direction (Vehicle, Bicycle, and Pedestrian)
- Number of Heavy Vehicles
- Grades in each direction
- Pavement Quality
- Presence of Bicycle/Pedestrian Detectors
- Ease of Use for Detection Devices
- Sight distances in each direction (intersection geometry)
- Presence of Shared Turn Lanes
- Presence of Dedicated Vehicular Lanes

- Presence of Hazards (Dips, storm drains, etc.)
- Proximity to nearest intersection, signalized or other, in each direction.
- Saturation flow rates
- Observed Delay
- Street Lighting
- ADA ramps or other accessibility elements (particularly important if off-road bike facilities)

Consideration in Data Collection Procedures

A noteworthy concept regarding methods for collecting data that was brought up by Dowling et al. (2008) was the issue of biased field ratings from cyclists (Dowling et al., 2008). Those present at an intersection will tend to rate it as higher than the real perception since the cyclists who like the locations will be over-represented at the intersection. Those who don't like the intersection will tend to avoid it. Therefore, in conducting field interviews for bicycle level of service data, only a skewed sample group is obtained. A better approach that is recommended is to video tape the intersection (from a cyclist's experience of passing through it) and then show the video to a group of people and have them rate the intersection from that. This method attempts to address any biased input that may otherwise be received.

Data Collection Methods

In early 2012, Kang et. al. (2012) conducted a survey of bicycle level of service similar to this one for bicycle level of service for rural roadways and did not attempt to obtain video recording (Kang & Lee, 2012). The method of data collection that was employed in this case was the simple one of stopping passing cyclists and asking them to rate the intersection. However, they did not use the regular A-F rating system and instead used an A-C grading rubric. This resulted in a less detailed level of service methodology than those reviewed previously in this thesis and provides less information to traffic engineers and planners. The overall accuracy of this particular research project is a matter of some dispute and it is believed that the methods used by Sprinkle Consulting in 2010 provide a better image of bicycle level of service.

Various methods of capturing video footage have been tried in the past for the Highway Capacity Manual (Dowling et al., 2008). The following is a list of various methods attempted by Sprinkle Consulting Inc. in coordination with the Florida Department of Transportation:

- Fixed Camera Mounted Roadside
- Moving Motor Vehicle Mounted Camera
- Bicycle Helmet Mounted Camera
- Suspended Mountain Bike with Frame Mounted Camera
- Front Suspended Tandem Bicycle with Rear Rider (Stoker) Operating a Camera Mounted on a Glidecam^{TM} Stabilization System
- Two-person Adult Tricycle with the Videographer in the Left Side Seat

- Viewpoint Bicycle with Front Rider (Stoker) Operating a Hand Held Camera

Figure 6: Semi-Tandem Bicycle Used for Previous Bicycle Level of Service Methodologies: Image courtesy of Sprinkle Consulting Inc.

For this research, initially an attempt was made to acquire and deploy a viewpoint style bicycle as recommended by Dowling et al. (2008) and Sprinkle Consulting for data collection. However, due to cost and availability concerns procurement of such a specialized bicycle was not feasible for this particular effort.

A compromise was made to obtain a regular tandem bicycle and attach a pole mounted camera in a position where the rear cyclist could operate the camera while the lead cyclist steers the bicycle. The bike used for data collection was a 2013 Kent Dual Drive as seen in the Figure 7.

Figure 7: Tandem Bicycle Used for Data Collection for Two-Way Stop-Controlled Intersections

The pole seen here mounted on the bicycle is an extendable monopod which, when in operation, extends up over the heads of the cyclists. This enables the camera to have a view of both the roadway and a live cyclist reacting to real-world conditions. A GoPro Hero3 action camera was attached to the monopod to capture video footage of various survey intersections in California. This camera was operated by the cyclist seated on the rear of the bicycle while the lead cyclist

steered and powered the bike. Please note that the lead cyclist did not wear a helmet in the video due to issues with blocking the camera's view, but the rear cyclist followed standard roadway safety procedures (including signaling to other vehicles for turns when appropriate). As mentioned in a previous section, some more experienced cyclists often ride in tightly packed groups. The effect of cyclists riding in close proximity to one another unfortunately cannot be adequately estimated from a camera mounted on this type of a bicycle due to the bulky and slow nature of the bike, making it difficult for the riders to keep up with other experienced cyclists. Any information obtained from these surveys will apply to bicycles traveling independently of one another rather than as a uniform group. The total equipment cost for this project was approximately $700.

In order for the data collection process to provide an accurate estimate of level of service, a range of sample data intersections from multiple cities, ideally in different regions would need to be collected.

Sample cities that were surveyed had to be relatively well used by cyclists in order to provide sufficient feedback for cycling facility performance. Communities with few bicycle facilities or accommodations will provide only poor information on how to adequately meet the needs of cyclists. The feedback may be offset by the fact that the riders don't have any point of reference for adequately designed intersection for bicyclists. Data collected must provide both good and bad feedback on bicycle facilities in order to be properly utilized. In order to meet this

objective, only areas that are nationally recognized as Bicycle Friendly Communities by the American League of Bicyclists were examined.

41 Intersections that have been surveyed for cyclist facilities and performance ratings are listed below. Copies of the original field data sheets can be found in the appendix. Please note that not all information regarding these intersections may be on these sheets and may be recorded elsewhere.

These intersections provide samples of several different varieties of bicycle facilities including, but not limited to, Shared Lane Markings, Bike Lanes, Bike Boulevards, Bikes May Use Full Lane Signs, Share the Road Signs, Separated Bike Lanes, and Bike Lanes with Parking Lanes. All sampled cities are in Southern California.

Sampled Two Way Stop-controlled Intersections:

- San Luis Obispo (14 TWSC intersections)
  - Broad Street/Chorro Street/ Sandercock Street
  - Broad Street/Islay Street
  - Cerro Romaldo/Patricia Drive
  - Grand Avenue/McCollum Street
  - Higuera Street/ Garden Street
  - Johnson Avenue/Sydney Street

- Los Osos Valley Road/ Diablo Drive
- Los Osos Valley Road/Prefumo Canyon Road
- Marsh Street/ Beach Street
- Monterey Street/Pepper Street
- Monterey Street/Toro Street
- Morro Street/ISlay Street
- Morro Street/ Pismo Street
- Tank Farm Road/Poinsettia Avenue

- Goleta/University of California Santa Barbara (5 TWSC Intersections)
  - Cathedral Oaks Road/Ellwood Ridge Road
  - Cathedral Oaks Road/North La Patera Lane
  - Cathedral Oaks Road/Placer Drive
  - Lagoon Road/ Harold Frank Road
  - North La Patera Lane/Covington Way

- Claremont (8 TWSC Intersections)
  - Baseline Road/Grand Avenue
  - Bonita Avenue/Cornell Avenue
  - Cambridge Avenue/Wharton Drive
  - College Avenue/2nd Street
  - College Avenue/4th Street
  - Mills Avenue/First Street

- Mountain Avenue/Butte Street
- Vanderbilt Avenue/Butte Street

- Riverside (7 TWSC Intersections)
  - California Avenue/Shelby Drive
  - Colorado Avenue/Dundee Road
  - Magnolia Avenue/Hoover Street
  - Victoria Avenue/Grace Street
  - Victoria Avenue/Saint Lawrence Street
  - Victoria Avenue/ Boundary Lane
  - West Linden Street/Douglass Avenue

- Irvine (5 TWSC Intersections)
  - Deerfield Avenue/Fawn Glen East
  - McGaw Avenue/Armstrong Avenue
  - Michelson Drive/Sequoia Tree Lane
  - Northwood/Savannah
  - Turtle Rock Drive/Sycamore Creek

To validate collected data and the methodology developed herein, two signalized intersections were also sampled and analyzed with the already established and accepted level of service methodology for bicycles at signalized intersections. These two intersections are also located in Claremont, California:

- Baseline Road/Mountain Avenue

- Claremont Boulevard/First Street

Videos of each of these intersections were made available online at: http://goo.gl/7fyp65 and online surveys were posted at: http://goo.gl/KYiwnN via which viewers could submit feedback from the videos. Once all field video was collected, the obtained video footage was compared with a series of video footage that had been captured by Sprinkle Consulting Inc. for use in the prior Transportation Research Board bicycle level of service methodologies development later adopted in the HCM 2010 (Dowling et al., 2008).

It was found from viewing these two groups of videos that the only noticeable difference was that in the camera view from the videos for two-way stop-controlled intersections, the back of the head of the lead cyclist was visible, whereas in Sprinkle Consulting Inc.'s videos the cyclist was behind the camera and not directly in view. However, this is a very minor discrepancy that should not severely influence the collected feedback either negatively or positively.

Potential Problems with the Data Collection Method

A problem with the data collection process involving video viewers, however, is that some aspects (such as pavement quality) may be downplayed in the received level of service feedback because a focus group that provides ratings from a safe and comfortable room does not experience the exact same elements that a cyclist would. Even aspects such as temperature and weather may play a role in the comfort level a cyclist feels with a particular intersection in addition to other more deterministic factors of traffic safety. A focus group may not fear

adjacent street traffic as much as a cyclist, and may even feel different levels of safety depending on the skill of the rider who captured the video footage. As Kang et al. described it: “They did not calibrate their video-based findings to bicyclists riding on the roadways, and they only validated viewpoints from still-standing respondents, i.e. not obtaining realistic perspectives of bicyclists.” Despite this drawback, this is the method that was used for previous bicycle LOS research and is the method that was determined for the project so as to best follow previously accepted practices. In the next chapter the survey data collected from respondents watching the videos were analyzed.

Another issue is that of bicycle delay. The HCM LOS methodology for signalized intersections estimates bicycle delay at the intersection based off of the signal timing. However, this delay factor is not included in the actual LOS estimation. The pedestrian LOS at signalized intersections computes ped delay and includes it in the LOS calculations. This indicates that delay may offer different levels of importance for bicycles than for pedestrians. For Two-Way Stop-Controlled Intersections, calculating bicycle delay was deemed to be extremely difficult to accurately model due to differences in cyclist behavior towards acceptable vehicle gap time. For this thesis, the focus was decided to be based on the non-delay aspects of bicycle LOS at TWSC intersections. Future research may provide more insight on the delay-based aspects of bicycle LOS at TWSC intersections.

CHAPTER 4: DATA ANALYSIS

The first step in the analysis was to make comparisons with existing procedures by inputting the physical characteristics data from this study to existing equations from the HCM 2010. This was done to assess the possibility that the LOS on two-way stop-controlled intersections is governed by the same or similar relationships as the signalized intersections. This assumption was likely to be incorrect, but the output from these equations was valuable to assess the usability of existing models as a starting point for this analysis.

Applying Signalized Intersection Models

The Signalized Intersection Method proposed in the Highway Capacity Manual 2010 (HCM 2010) utilizes the following formula:

$$I_{b,int} = 4.1324 + F_w + F_v$$

$$F_w = 0.0153W_{cd} - 0.2144W_t$$

$$F_v = 0.0066[v_{lt} + v_{th} + v_{rt}]/(4N_{th})$$

$$W_t = W_{ol} + W_{bl} + I_{pk}W_{os}^*$$

Where:

$I_{b,int}$ = bicycle LOS score for intersection

W_{cd} = curb-to-curb width of the cross street (ft)

W_t = total width of the outside through lane, bicycle lane, and paved shoulder (ft)

V_{lt} = left turn demand flow rate (veh/hr)

V_{th} = through demand flow rate (veh/hr)

V_{rt} = right turn demand flow rate (veh/hr)

Nth = Number of through lanes (shared or exclusive) (ln)

Wol = width of the outside lane (ft)

Wbl = width of the bicycle lane = 0 if bicycle lane not provided (ft)

Ipk = indicator variable for on street parking occupancy = 0 of p pk <0; 1 Otherwise

Wos = width of paved outside shoulder (ft)

Wos* = adjusted with of paved outside shoulder; if curb is present W os* = W os – 1.5>0;otherwise W os* = W os

Unfortunately, applying the signalized intersection equation resulted in almost all approaches to receive a level of service rating “A” for bicycle travel which does not match the collected survey data for the intersections. It was apparent from these results that there are significant differences between the relationships affecting signalized intersection LOS and those governing the bicyclist perceptions and hence the LOS at TWSC. A different LOS methodology may provide a closer formula set to use as a starting point for developing models for TWSC.

All-Way Stop-Controlled Intersections

Next the all-way stop-controlled bicycle level of service method was tested with the assumption that our survey intersections were all-way stop-controlled. A sample calculation for this application is also provided in the appendix. This method also provided significant differences between the expected level of service values and the survey responses indicating the need for model

estimation for the TWSC intersections. Examples of the results are shown in Figures 9 through 12 below.

Two-Way Stop-Controlled Automobile

In comparing bicycle LOS to automobile LOS at TWSC, there is a problem that presents itself. The Automobile LOS is based off of the delay experienced by the driver at the TWSC intersection and, as is mentioned earlier in this thesis, delay for bicyclists varies depending on behavior. This is, of course, also true for automobile drivers, but is more so for cyclists due to the increased level of risk involved if a collision were to occur. The overall effect of this is that automobile LOS and bicycle LOS cannot be accurately modeled using the same equations.

Methodology Comparison Figures

To better illustrate the findings from the series of calculations described above, a series of graphs were generated to provide a visual example of the findings. These graphs show the ratings these intersections would have provided for bicycle level of service if the sampled intersections were modeled as the type of intersection labeled on each graph. These are compared with the average survey responses that were obtained for each individual turn movement.

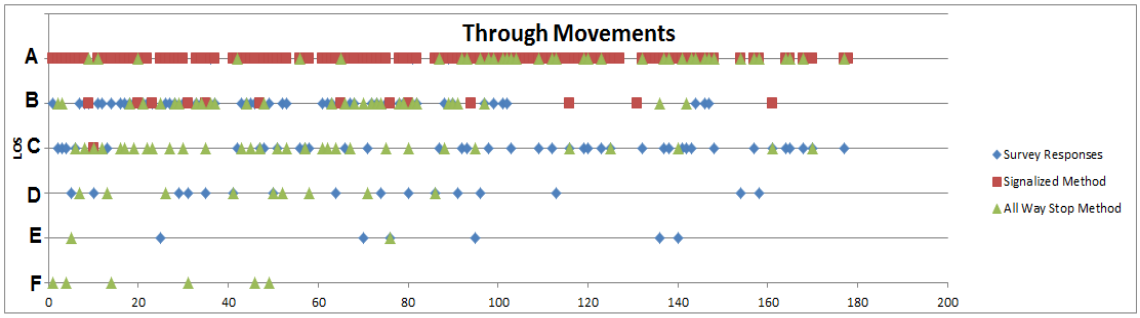

Figure 8: Through Movement Existing Methodology Comparison

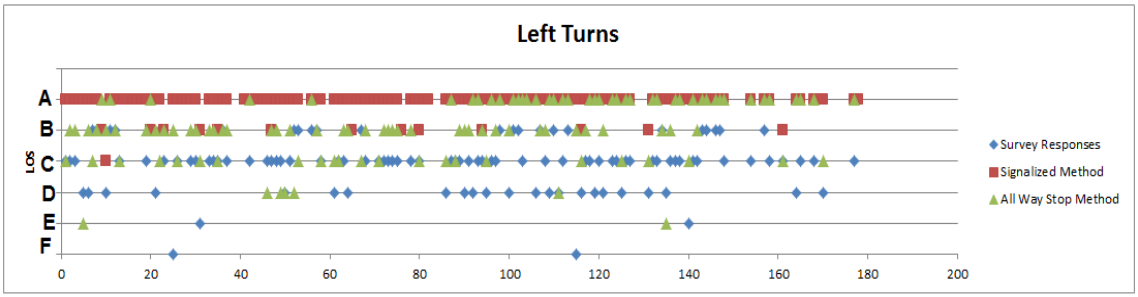

Figure 9: Left Turn Movement Existing Methodology Comparison

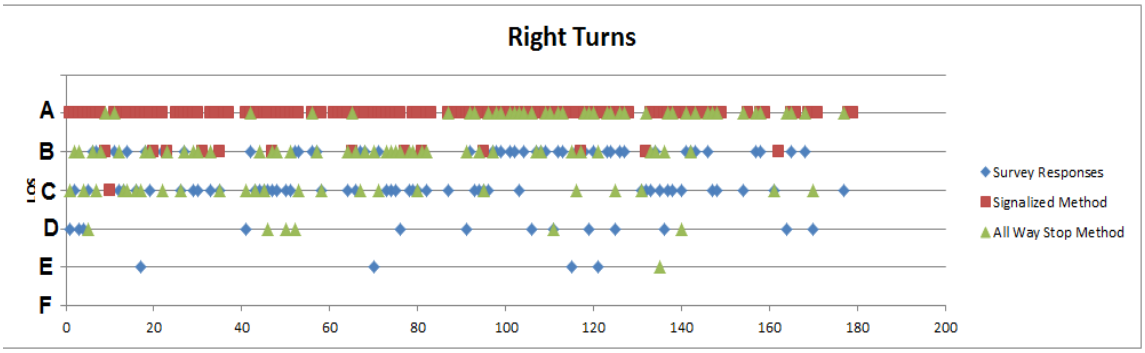

Figure 10: Right Turn Movement Existing Methodology Comparison

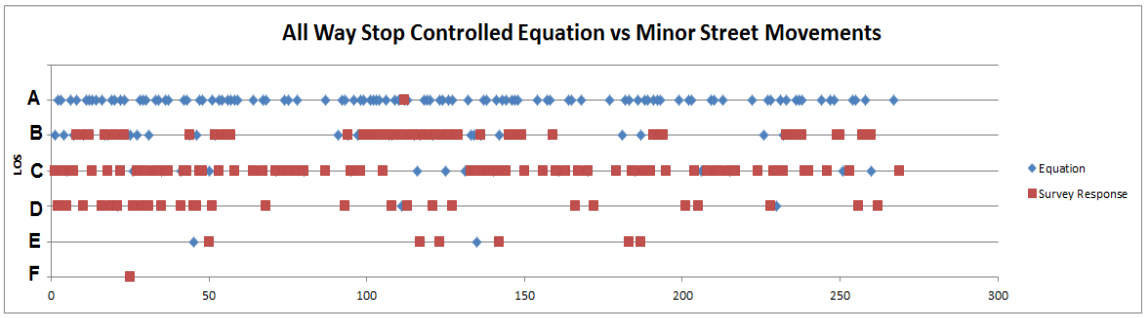

Figure 11: All-Way Stop-Controlled Equation vs. Minor Street Movements

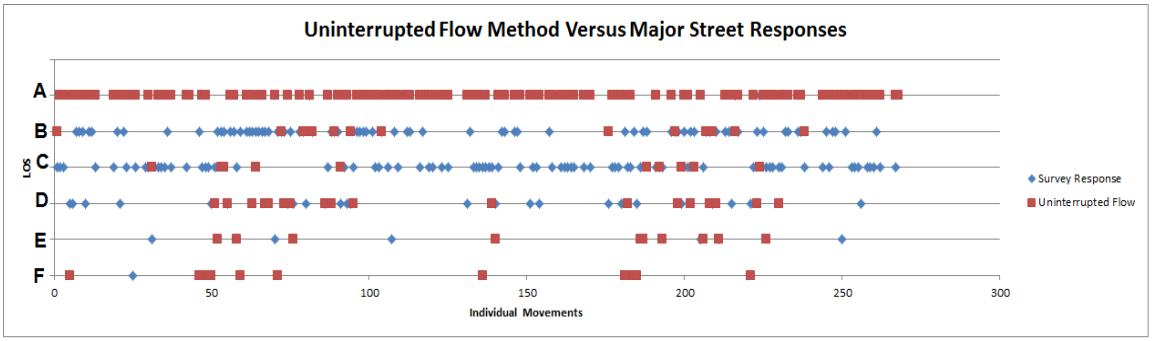

Figure 12: Uninterrupted Flow Equation vs. Major Street Movements

The next set of graphs compare the responses and the equations based off of an increasing (across the x-axis) difference in the ratings to see if there were any trends in why some turn movements had such significantly different values from the theoretical responses than did other turn movements.

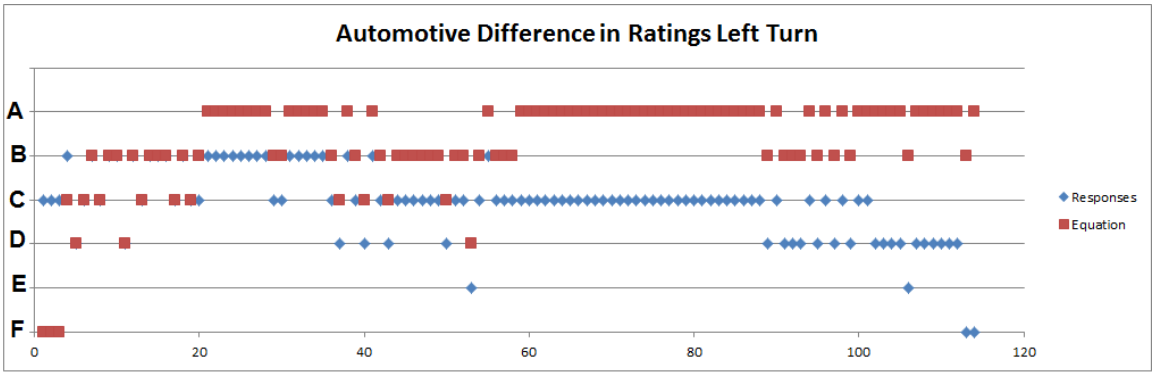

Figure 13: TWSC Automobile Method Left Turn

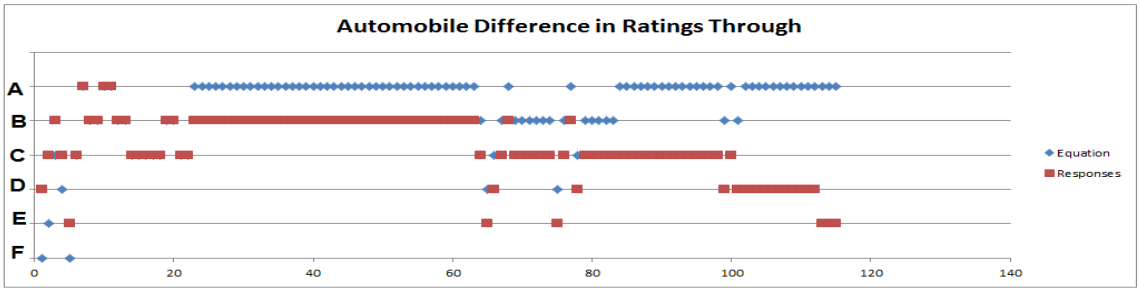

Figure 14: TWSC Automobile Method Through

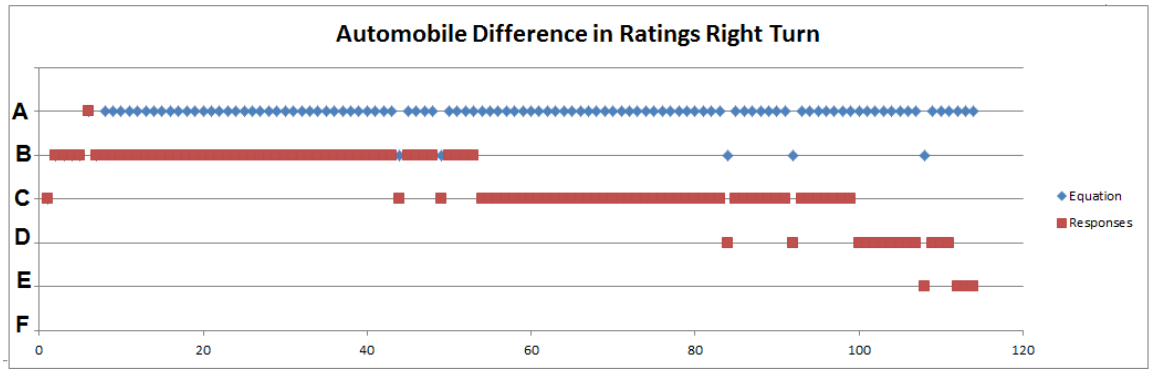

Figure 15: TWSC Automobile Method Right Turn

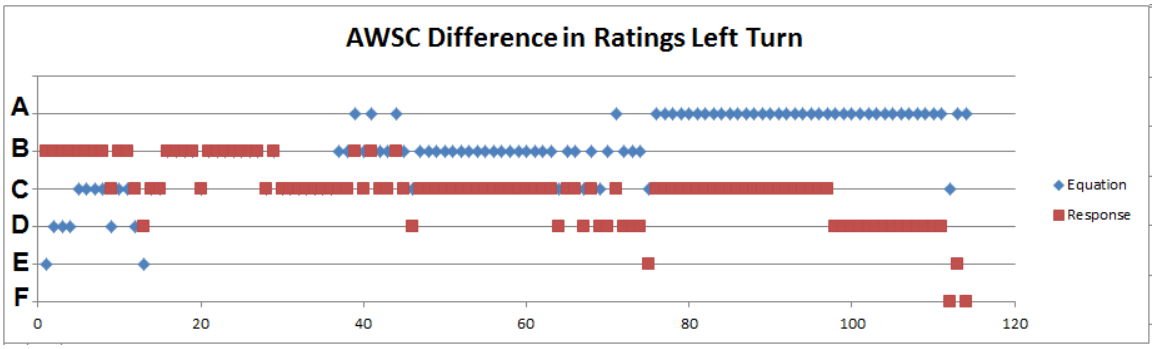

Figure 16: AWSC Automobile Method Left Turn

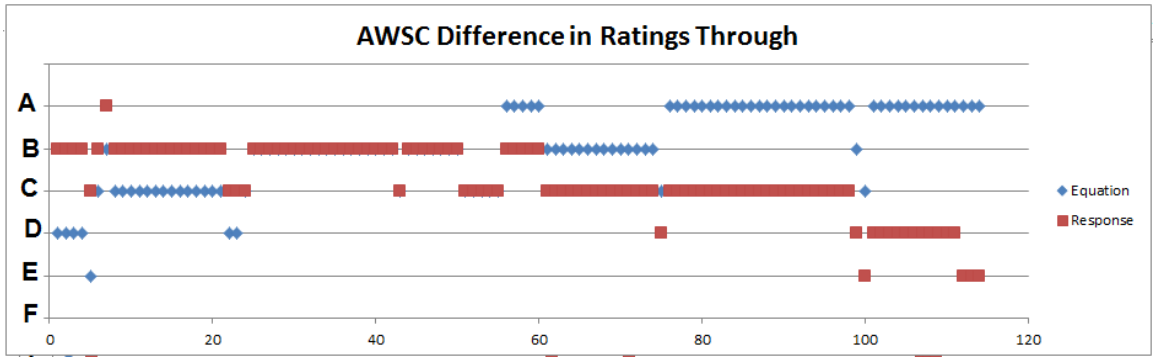

Figure 17: AWSC Automobile Method Through

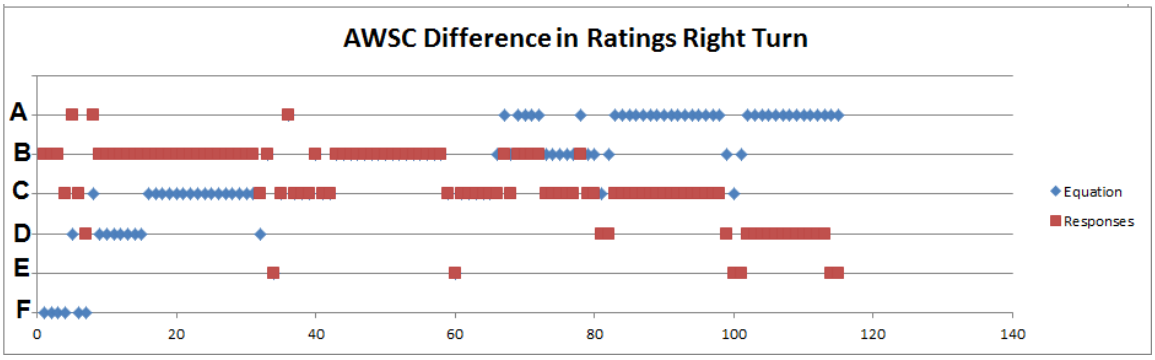

Figure 18: AWSC Automobile Method Right Turn

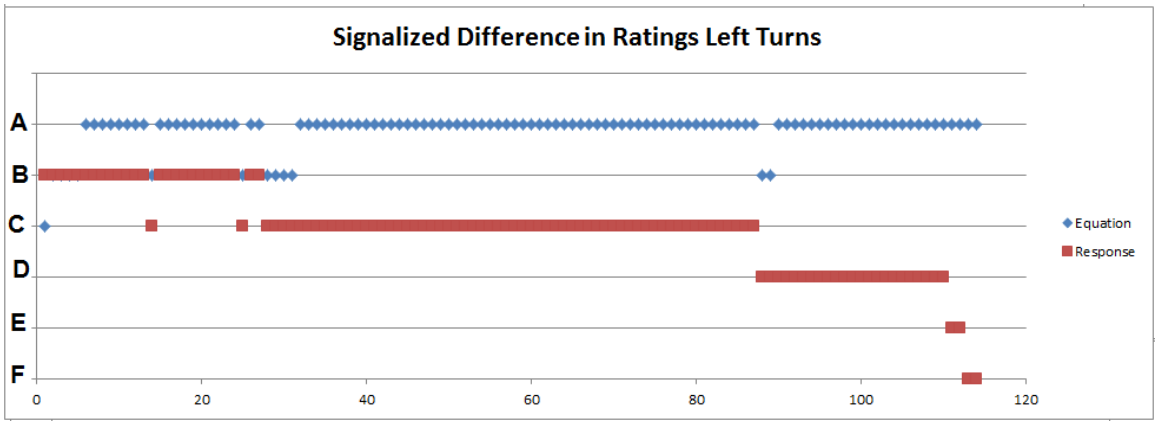

Figure 19: Signalized Automobile Method Left Turn

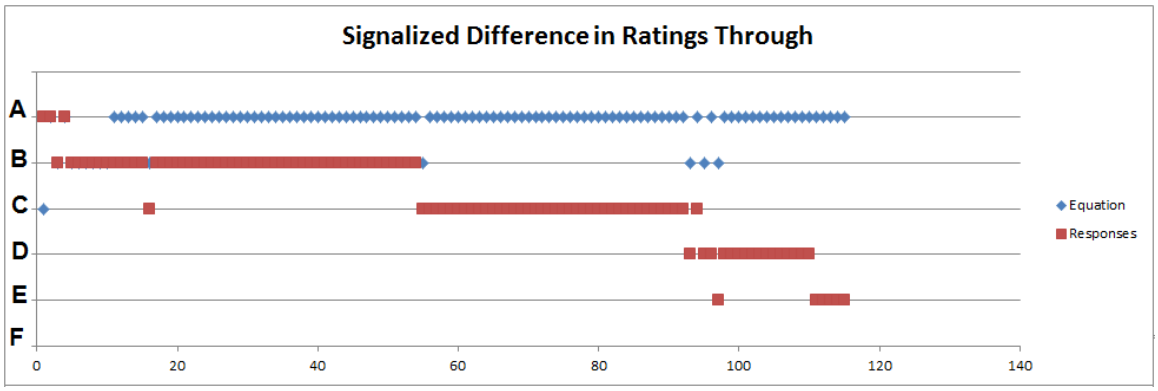

Figure 20: Signalized Automobile Method Through

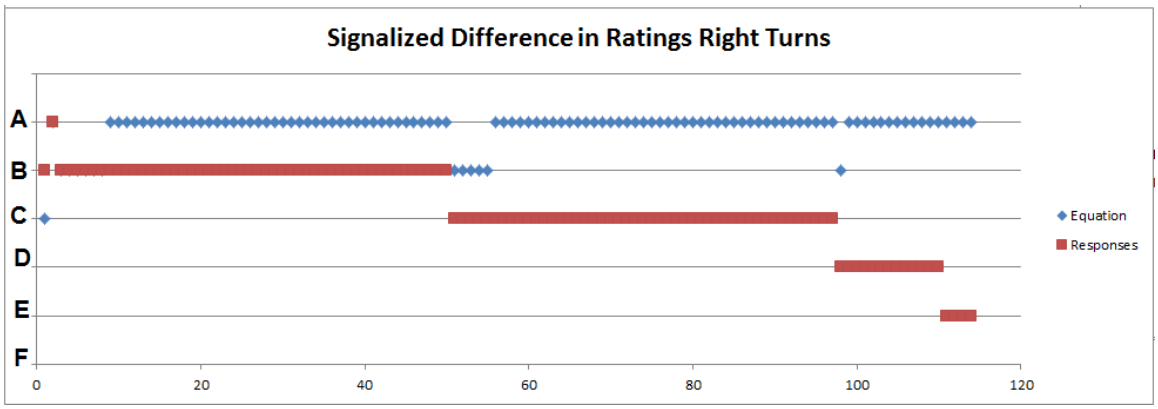

Figure 21: Signalized Automobile Method Right Turn

Validation of the Existing Signalized Intersection Methodology with Data from this Research

In order to validate the Level of Service methodology for two-way stop-controlled intersections, two signalized intersections were also included in the survey set and reviewed by the same feedback providers as all other two-way stop-control data. The bicycle level of service for signalized intersections is already established and documented in HCM 2010. The responses for the signalized intersections were compared to the estimated LOS through model from HCM 2010 to evaluate the fit. Collected responses were concluded to have insignificant differences between values and obtained response values. Sample calculations are provided in the appendix. Data listed in Table 4 is a simplified representation of the t tests and presents the results by overall intersection rather than by approach. Individual approach t tests were also calculated but provided similar results and are not reproduced below.

Table 4: Signalized Intersections Paired T Test Results

Intersection	Average Score from the Model	Average Score for Respondents	St Dev	T Value	P Value
Claremont/First	3.75	3.75	0.739	0.00	1.00
Baseline/Mnt	4.50	4.42	0.289	1.00	0.34

Further Considerations

Now let's examine a few of the characteristics that may affect a bicyclist's perception of two-way stop-controlled intersections. The first characteristic we will assess is sight distance. Cyclists feel more at-risk at intersections if they

have insufficient sight distance. It is not as much the sight *distance* they are really concerned about as the amount of time that they have after they first see another vehicle and before it could theoretically collide with them. This time can be approximated by taking the distance to the intersection from the point where a vehicle would first become visible to a bicycle and dividing that distance by the speed limit on the major road (of TWSC). This time can also be directly measured in the field with a stopwatch. To better clarify, please see Figure 13 below.

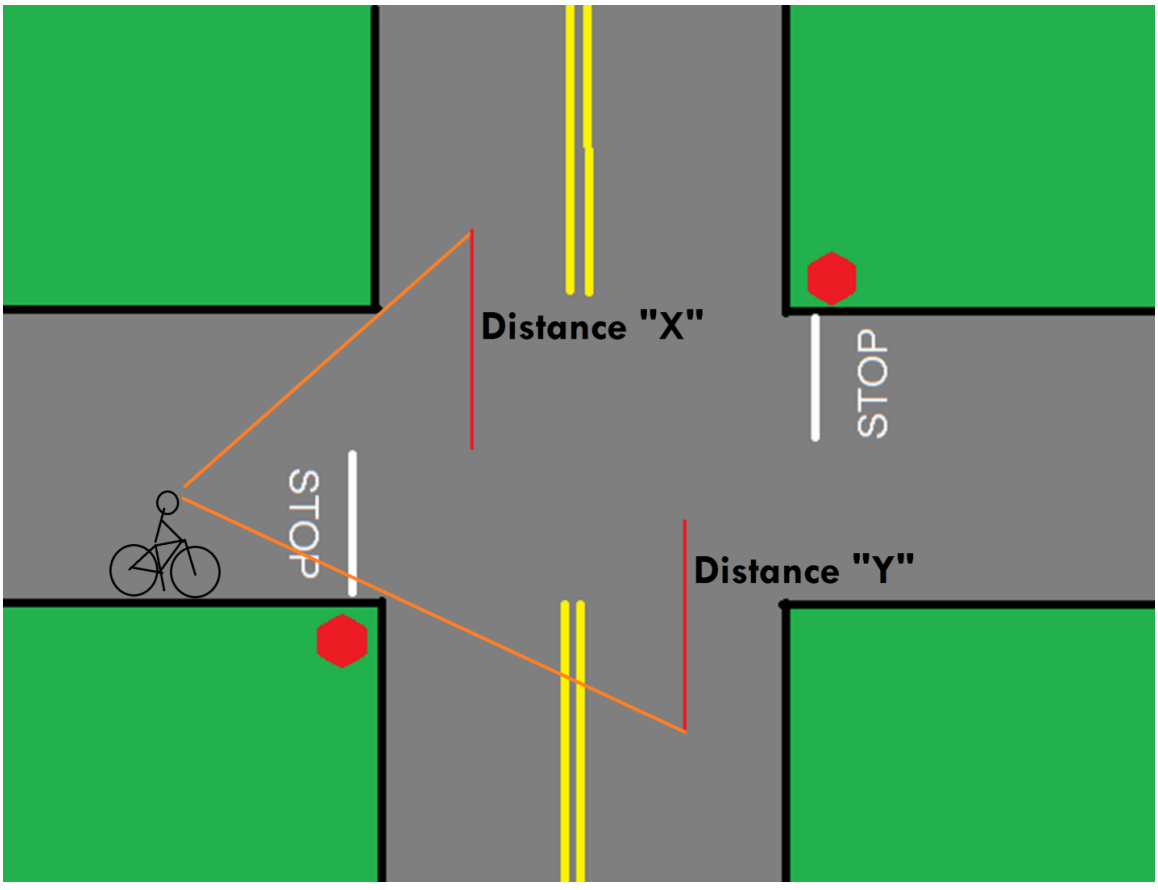

Figure 22: Sight Distance Diagram for TWSC Intersection Bicycle Approach

The orange lines represent the cyclist's line of sight and the red lines represent the distance a vehicle would have to travel in order to collide with the cyclist's own travel path. These distances (Distances "X" and "Y") can be easily obtained using simple geometry and then divided by the posted speed limit to provide the potential time before a collision.

Data analysis for past level of service equation development was performed using three different statistical methods: Linear Regression, Ordered Logit, or Ordered Probit models. However, it was concluded by the past research that "The results and interpretations […] were notably similar" (Kang & Lee, 2012) and "The choice between [methods] is typically an analyst's preference because [the chosen method] does not influence conclusions drawn from the model's results" (Kang & Lee, 2012). Similar effects were also noted by three other texts: Dowling et al., (2008), and Dixon, (1996), and Landis, (1997). Due to these conclusions, linear regression was decided to be the method of choice for TWSC intersection analysis.

The software selected for analysis of the data in this research paper was Minitab 16 (Minitab, 2013). Analysis was done considering each turn movement at the intersection as a separate data set. This was to keep the existing practice of using the final LOS model to estimate values for each individual bicycle movement. A list of all types of variables considered is the following:

- Individual Directional Traffic Counts (including bikes and pedestrian movements)

- Sight Distances
- Speed Limits (all directions)
- Widths of Individual Lanes
- Width of Bike Lanes (if present)
- Shared Lane Markings (categorical variable: present or not)
- Striped Parking Lane Adjacent to Bike Lane(categorical variable: present or not)
- Total Street Widths
- Bus Stop(s) Nearby (categorical variable: present or not)
- Percent Heavy Vehicle Traffic
- Grades/Slope of Roadway near Intersection
- On Street Parking Present (categorical variable: present or not) (Separate variables for major and minor roads)
- Bicycle Signage (categorical variable: present or not)
- Number of Lanes each Roadway
- Median/Barrier Near Intersection (categorical variable: present or not)
- Parking Allowed In Bike Lane (categorical variable: present or not)
- Signalized Intersection Nearby (categorical variable: present or not)
- Bicycle Boulevard (categorical variable: present or not)
- Pavement Quality (FHWA rating system)
- Designated Right Turn Lane (categorical variable: present or not)
- Designated Left Turn Lane (categorical variable: present or not)
- Center Storage Lane (categorical variable: present or not)

- Separated Bike Lane Present (categorical variable: present or not)
- One Way Street (categorical variable: present or not)
- Large Curb Return Radius (categorical variable)

In Minitab, data from each turn movement at each intersection was listed as a separate row of data. Survey responses on perceived level of service were averaged into a single value for each movement and recorded in a column with the row corresponding to the turn movement each represented. During the course of this project there were three different survey datasets that were collected. These datasets identify different stages of the research and the survey questionnaire went through minor modifications during each stage. The first data set “1” was collected from members of cycling clubs in Southern California, the second survey data set “2” was collected from Dr. Kimberley Mastako’s CE 421 Fall 2013 class, and the third set “3” was collected from the public via YouTube videos and a SurveyMonkey survey. Survey questions were the same in intent but were revised in wording in each of these datasets with the survey conducted via the online tool, Survey Monkey being the most reliable one. To use each data set, confirmation had to be made that the discrepancy between the responses in each survey type were minimal. Samples of each survey type are provided in the appendix. This was evaluated using a t-test and paired t-test in Minitab and the results are reproduced in Table 5 below:

Table 5: Paired T Test Results

Data Set A	Data Set B	T Value	P Value
2	**3**	**0.62**	**0.536**
1	**3**	**-0.82**	**0.415**
1	**2**	**-0.84**	**0.401**

In each situation, a large p-value (>0.1) would indicate that there is not a significant difference between the two survey datasets tested in each run. This essentially means that the three datasets were not statistically different from each other in terms of the respondent's average response to the LOS questions.

Separate tests were generated based on three sets of data: A set of turn movements originating from minor streets, a set of turn movements originating from major streets, and a combined data set that looked at all turn movements. This was meant to address the following concern: two-way stops may have two bicycle levels of service; one for the stopping street, the other for the through street. If the research chose to focus only on the stopping street bike LOS, it may ignore that there are also bicyclists on the through street with their own perceived LOS for the two-way stop intersection. This concern was conceived as a valid point that may imply that separate methodologies for different approaches within the same intersection may be most appropriate. The behavior of cyclists can be expected to differ significantly if their movement originated from the major or the minor street because of the difference in uncontrolled and controlled traffic flows that they are a part of. In order to test this hypothesis, the data were analyzed as three separate sets rather than just one.

The level of service scores where converted into numeric format where a score of “F” corresponded to a 0, and a score of “A” corresponded to a 5. This scaling is essentially the same as past level of service methodologies where a higher range was used (e.g., 0 to 35 or more).

When the tests were first run using multivariate linear regression in Minitab, the diagnostic tests resulted in violations of some assumptions. In a linear regression model there are four main assumptions that must be validated in order for the results to be accepted as accurate (Field & Miles, 2010):

- The residual errors must have constant (equal) variances
- The residual errors must follow a normal distribution
- The data must be independent in nature
- The response variable and the explanatory variables must be linearly related

In this scenario, the assumption was violated (as was determined from the patterns present in the residuals versus predicted values plot).

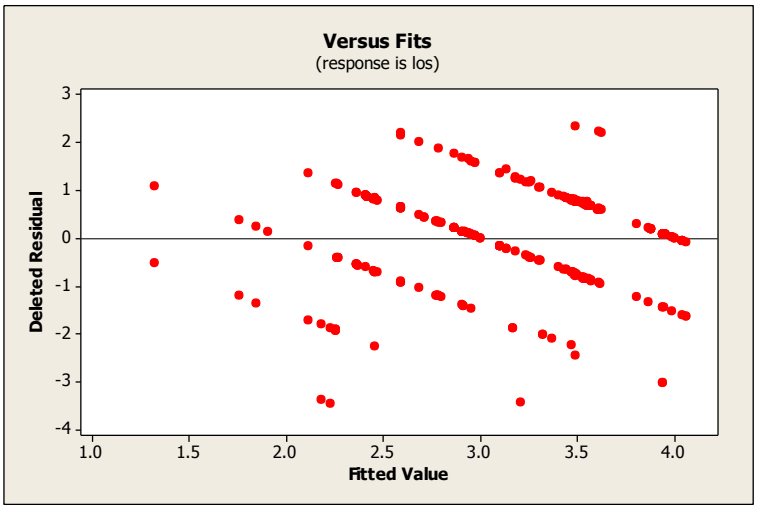

Figure 23: Original Residuals versus Predicted Values Plot

To help rectify the situation, the case was brought to the attention of Dr. John Walker in the Statistics Department at Cal Poly San Luis Obispo. He proposed taking the log (base 10) of the level of service scores and the traffic volumes to transform the data. Following the transformation the residual plot patterns were consistent with the assumptions for linear regression.

A large number of regression models were estimated for each of the three types of data sets and refined by using the "Best Subsets" feature on Minitab which calculates all possible arrangements of all variables and provides the standard deviations, R^2 adjusted, and error values for the different variable combinations; from which can be determined the optimal variables to be included in the model to provide the best fitted equation to the data. Once the variables that should be included are determined, a regression is run to provide the coefficients for those variables. These results are then, of course, checked for any violation of assumptions or possible presence of large error, such as effects of multicollinearity (in which the value of one explanatory variable deeply correlates with the value of another explanatory variable). Once all foreseeable causes of error have been rectified, the equation that is found to provide the best fit to the data is selected. This resulted in three equations from the three data sets.

The data sets that were used to generate the equations included the intersections from San Luis Obispo, Irvine, Riverside and Claremont. The data from Goleta was not used in the original equation generation but was instead

used to verify the accuracy of the estimated equations and validate the final results.

Expectations

I would expect, without having done the calculations, that the presence of bicycle signage, shared lane markings, or a bicycle boulevard would have a positive correlation with the level of service for bicycles as they alert motor vehicle drivers to the presence of bicycles and attempt to regulate both traffic forms in a safe manner. An increase in conflicting vehicle traffic along the roadway should correlate to a decrease in the LOS as situations typically become more hazardous to bicycles when more vehicles are present and delays are typically increased, as well. The presence of nearby bus stops should decrease the level of service as bicycles have to enter normal traffic lanes in order to maneuver around parked buses in the bike lane. This increases the likelihood of a bicycle being struck by a motor vehicle. Similar effects are expected where parking is allowed in the bike lane. LOS should increase with increasing sight distance and decrease with increasing speed limits as the reaction time for conflicting traffic is likely to be a factor. Pavement quality is expected to affect LOS and a good pavement should produce a higher LOS than a poor pavement. However, whether or not the video will effectively portray this is uncertain. Large street widths are expected to decrease the LOS as bicycles have further to travel across conflicting traffic flows in order to complete their movement. Medians, center storage lanes, and designated turn lanes are expected to increase the

LOS as they separate out some conflicting traffic and can provide refuge for bicycles during stages of their movement.

Resultant Equations

Each of the three final generated equations are outlined in Tables 6, 8 and 10 below. Also provided are suggested LOS ratings ranges that correspond to possible outputs from the equation. These do not necessarily have to be used, but do offer useful suggestions for practical use.

TWSC Combined LOS Resultant Equation

Table 6: Combined LOS Equation Coefficients

Term	Description	Coef	Standard Error Coef	T Stat	P Stat
Constant		0.3879	0.0604	6.4141	<0.0001
SD/(MJSL x 1.467)	SD = Sight Distance MJSL = Major Street Speed Limit	-0.0051	0.0043	-1.2077	0.028
MNSL	Minor Street Speed Limit	0.0044	0.0014	3.0516	0.003
PAV	Pavement Quality Score (see Table 3)	0.0054	0.0071	0.7579	0.049
SHAR	= 1 if Shared Lane Markings are Present Near Intersection; SHAR = 0 Otherwise	0.1342	0.0132	10.1346	<0.0001
SIGN	= 1 if Bicycle Signage is Present Near Intersection; SIGN = 0 Otherwise	0.0219	0.0091	2.4000	0.017
BB	= 1 if Bicycle Boulevard; BB = 0 Otherwise	0.1332	0.0190	7.0053	<0.0001
PBL	= 1 if Parking is Allowed in the Bike Lane; PBL = 0 Otherwise (and if no bike lane is present)	-0.0293	0.0171	-1.7099	0.088
WBL	Width of Bike Lane (feet)	0.0171	0.0015	10.8786	<0.0001
DRTL	= 1 if Designated Right Turn Lane is Present; DRTL = 0 Otherwise	-0.0009	0.0215	-0.0422	0.066
DLTL	= 1 if Designated Left Turn Lane is Present; DLTL = 0 Otherwise	-0.0285	0.0103	-2.7427	0.007
M	= 1 if Median or Barrier Present Near Intersection; M = 0 Otherwise	-0.0489	0.0112	-4.3578	<0.0001
MNW	Minor Street Curb to Curb Width (feet)	0.0015	0.0006	2.3890	0.018
LC	Log(Sum of peak hour traffic volumes conflicting with approach)	-0.0558	0.0140	-3.9671	<0.0001

R-Sq(adj) = 57.08%

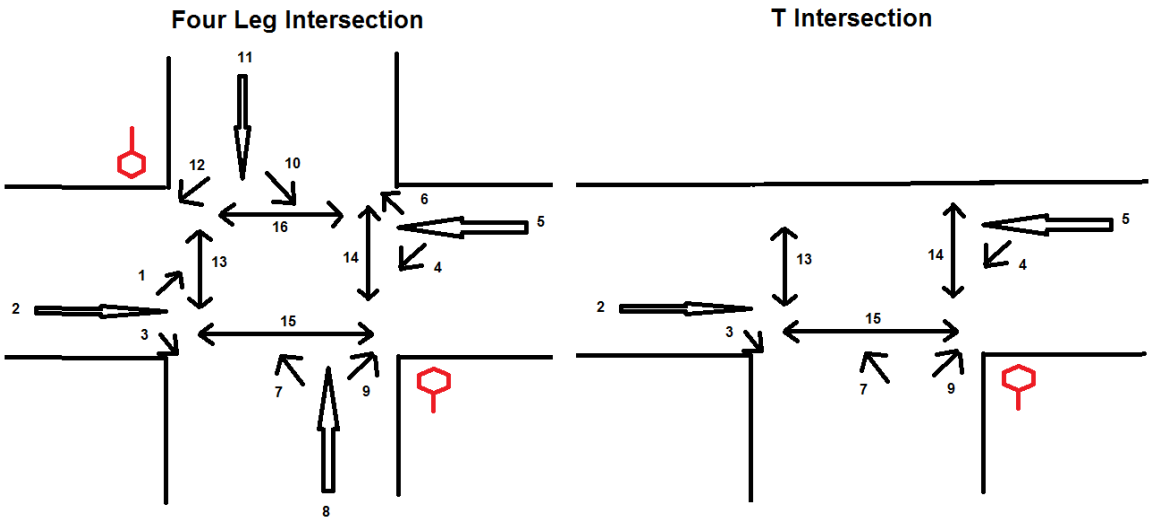

Figure 24: Combined Methodology Two-Way Stop-Controlled Movement

Diagram: Exhibit 19-6 (*Highway capacity manual*, 2010)

TWSC Major Street LOS Resultant Equation

Table 7: Major Street LOS Regression Coefficients

Term	Description	Coef	Standard Error Coef	T Stat	P Stat
Constant		2.9549	0.1218	2.0212	0.045
SD/(MJSL*1.467)	SD = Sight Distance MJSL = Major Street Speed Limit	0.0028	0.0060	0.4778	0.034
MNSL	Minor Street Speed Limit	0.0067	0.0020	3.2200	0.002
BS	1 if Bus Stop Present Near Intersection; BS = 0 Otherwise	0.0216	0.0155	1.3906	0.066
SHAR	= 1 if	0.1272	0.0191	6.6617	<0.0001

	Shared Lane Markings are Present Near Intersection; SHAR = 0 Otherwise				
SIGN	= 1 if Bicycle Signage is Present Near Intersection; SIGN = 0 Otherwise	0.0416	0.0134	3.0963	0.002
BB	= 1 if Bicycle Boulevard; BB = 0 Otherwise	0.1029	0.0308	3.3414	0.001
PBL	= 1 if Parking is Allowed in the Bike Lane; PBL = 0 Otherwise (and if no bike lane is present)	-0.0438	0.0236	-1.8566	0.065
OPMN	= 1 if Parking is Allowed on Minor Street; OPMN = 0 Otherwise	-0.0918	0.0252	-3.6428	<0.0001
WBL	Width of Bike Lane (feet)	0.0165	0.0024	6.7505	<0.0001
MNW	Minor Street Curb to Curb Width (feet)	0.0016	0.0009	1.6079	0.11
MJW	Major Street	0.0002	0.0005	0.4904	0.025

	Curb to Curb Width (feet)				
DRTL	= 1 if Designated Right Turn Lane is Present; DRTL = 0 Otherwise	-0.0134	0.0337	-0.3993	0.69
DLTL	= 1 if Designated Left Turn Lane is Present; DLTL = 0 Otherwise	-0.0378	0.0150	-2.5083	0.013
LM	Log(Sum of peak hour traffic volumes with direction of approach)	-0.1749	0.0896	-1.9506	0.053
LC	Log(Sum of peak hour traffic volumes conflicting with approach)	-0.7692	0.0636	-1.7159	0.088
PAV	Pavement Quality Score (see Table 3)	0.0135	0.0107	1.2636	0.008
M	= 1 if Median or Barrier Present Near Intersection; M = 0 Otherwise	-0.0525	0.0174	-3.0112	0.003

R-Sq(adj) = 58.93%

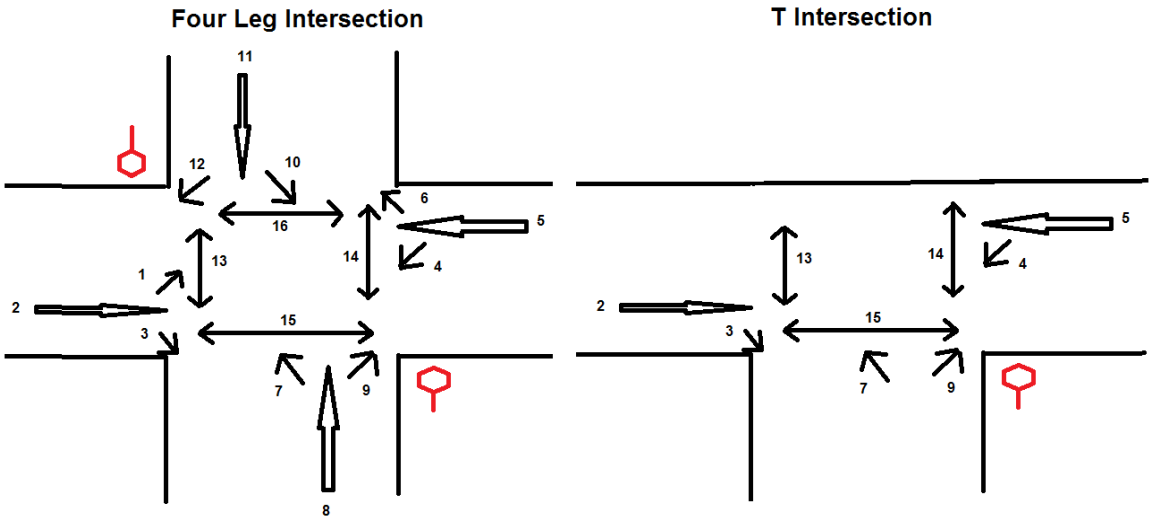

Figure 25: Major Methodology Two-Way Stop-Controlled Movement Diagram:

Exhibit 19-6 (*Highway capacity manual*, 2010)

TWSC Minor Street LOS Resultant Equation

Table 8: Minor Street LOS Regression Coefficients

Term	Description	Coef	Standard Error Coef	T Stat	P Stat
Constant		0.6187	0.1066	5.8020	<0.0001
SD/(MJSL x 1.467)	SD = Sight Distance MJSL = Major Street Speed Limit	-0.0040	0.0094	-0.4244	0.072
MNSL	Minor Street Speed Limit	0.0041	0.0029	1.4184	0.059
SHAR	= 1 if Shared Lane Markings are Present Near Intersection; SHAR = 0 Otherwise	0.1471	0.0189	7.7720	<0.0001
BB	= 1 if Bicycle Boulevard; BB = 0 Otherwise	0.1336	0.0292	4.5690	<0.0001
PBL	= 1 if Parking is Allowed in the Bike Lane; PBL = 0 Otherwise (and if no	-0.0805	0.0272	-2.9509	0.004

	bike lane is present)				
WBL	Width of Bike Lane (feet)	0.0195	0.0029	6.7374	<0.0001
LT	Log(Sum of peak hour traffic volumes for all approaches)	-0.0972	0.0332	-2.9236	0.004
LM	Log(Sum of peak hour traffic volumes with direction of approach)	0.0222	0.0268	0.8296	0.08
M	= 1 if Median or Barrier Present Near Intersection; M = 0 Otherwise	-0.0090	0.0196	-0.4575	0.048
MJW	Major Street Curb to Curb Width (feet)	-0.0011	0.0007	-1.5570	0.022
SLOPE	Steepest Grade Cyclist Encounters during Movement (integer)	0.0013	0.0030	0.4596	0.047
HV	Percent Heavy Vehicles	-0.0156	0.0027	-5.6652	<0.0001
CR	= 1 if Curb Return Radius >9 feet; CR = 0 if Curb Return Radius < 9 feet	-0.0308	0.0128	-2.3879	0.019

R-Sq(adj) = 56.70%

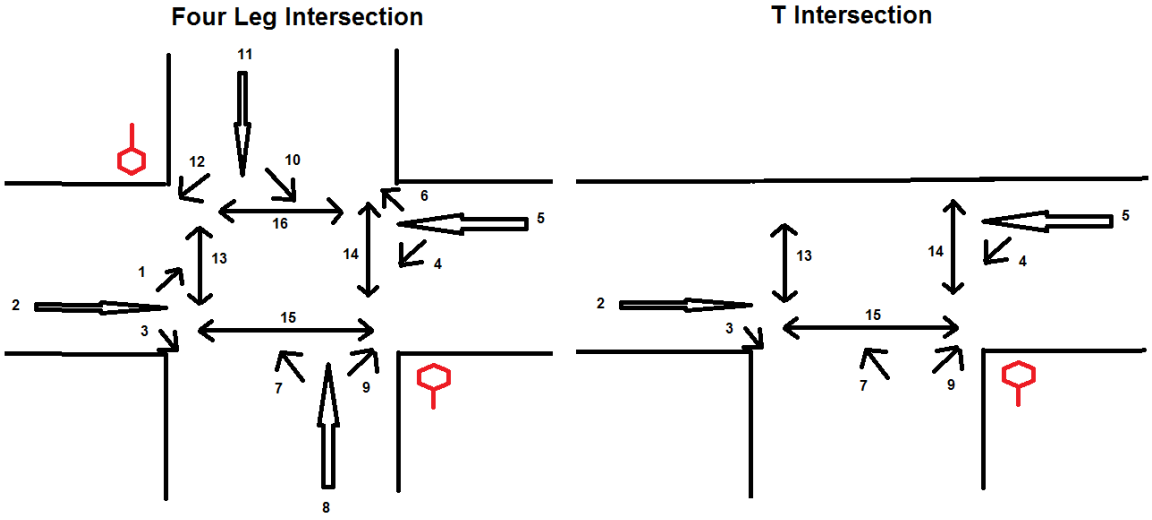

Figure 26: Minor Methodology Two-Way Stop-Controlled Movement Diagram:

Exhibit 19-6 (*Highway capacity manual*, 2010)

Comparative Evaluation of LOS Estimation at Approach Level vs. Aggregating All Approaches

Which method is better? It is recommended that the individual data equations are utilized due to the increased accuracy that these equations provide in estimating level of service values (note that these equations also have the slightly higher R^2 adjusted values and provide a better fit for the data). The other method, which provides a single equation for major and minor street movements separately is, perhaps, slightly simpler to use and may provide similar results to the individual data equations, but will probably not prove quite as accurate.

As may be seen in the above resultant equations, whether or not shared lane markings and signage are present at an intersection does affect the level of service. This will be a way that agencies in the future can improve the quality of their roadway networks. Somewhat surprisingly, the presence of a designated left turn lane does appear to have a negative impact on level of service. This may be because of the higher traffic volumes that correspond with roadways that require a designated left turn lane. Also, for major street level of service, the presence of a bus stop was correlated with higher level of service ratings than intersections that did not have a bus stop. This is likely an issue that is due to insufficient data on intersections with bus stops (only six sampled intersections had bus stops present). The presence of parking both on the major and minor roads was also found to be fairly significant, but in opposite ways. Parking on the minor roadways led to a lower level of service score, whereas parking on the major roadways led to a higher level of service score. This could be in part due to the speed of traffic being lower on the major roads that allowed parking or could

more likely be due to the fact that the traffic flows stayed farther away from the side of the road when parking was adjacent than when no parking was provided.

Another result was that bicyclists perceived the level of service to be higher if the intersection had a bicycle boulevard on it. A bicycle boulevard is defined by Walker et al. (2009) as “low volume and low speed streets that have been optimized for bicycle travel through treatments such as traffic calming and traffic reduction, signage and pavement markings, and intersection crossing treatments. These treatments allow through movements for cyclist while discouraging similar through trips by non-local motorized traffic.” Walker et al., 2009)

Figure 27: Bicycle Boulevard (*Walker et al.*, 2009)

This is another factor that can be considered by traffic engineers and planners to improve the level of service of roadway networks for bicycles in low traffic areas.

The data collected for this research was based on video based ratings. These videos were of sample intersections that were recorded at times that may not have been the peak hours for those specific intersections, but because traffic counts and video collection for each individual intersection occurred during approximately the same time of day, the data is reflective of the conditions that the roadway was experiencing during the survey time. The intersections themselves may have different actual levels of service during their own peak hour times, but because this research is to evaluate a level of service methodology and not the intersections themselves, this manner of data collection was deemed acceptable. Respondents to the surveys viewed the traffic volumes as a normal cyclist on the road would, that is by judging for themselves based on how many vehicles are present in the video as to what the relative traffic volumes were at the time of data collection. It is based on this perspective that respondents provided their responses.

Once all variables were entered into the Minitab 16 software, the computer analyzed the patterns to try to determine the best linear regression for the data. It provided, as can be seen in the results tables, different signs for the coefficients of the logs of the traffic volumes. This was done by the software to best enhance the relationship between the data and the best-fit equation. The significance of this is that the conflicting vehicle traffic flows and the vehicle traffic

flows that are traveling in the same direction as the bicycle experience different levels of significance in determining the overall LOS.

Physical aspects of the intersections that did not appear to influence the level of service equations included the width and number of the lanes, however, these qualities were most likely already accounted for by the curb-to-curb dimension variables (as was suggested by the diagnostic results). Also, the presence of a designated right turn only lane or a center storage lane was determined to be insignificant, as well. This may be because a bicycle has to deal with these traffic flows whether the designated lanes are present or not.

Sensitivity Analysis

This section presents the results from the equation (estimated bicycle LOS score) based on change in the major road conflicting automobile flow while all other variables are kept constant. This analysis is represented in order to clearly show the correspondence between the well-established automobile LOS methodology and the bicycle LOS methodology. Table 13 and Figure 25 clearly show that the LOS score decreases (i.e., LOS becomes worse as one would expect) for LOS the same way as the conflicting flows on the major street increased.

Table 9: Resulting Variation in Minor Approach Bicycle LOS Score Based on Increase in Conflicting Automobile Flow

Main Flow	Opposing Flow	Conflicting Flow	Log(Total Flow)	Log(Main Flow)	Log(los)	LOS
200	300	200	2.845098	2.30103	0.554265	3.58315
200	300	400	2.954243	2.30103	0.521827	3.325273
200	300	600	3.041393	2.30103	0.495926	3.132754
200	300	800	3.113943	2.30103	0.474364	2.981015
200	300	1200	3.230449	2.30103	0.439739	2.752572
200	300	2000	3.39794	2.30103	0.38996	2.454485

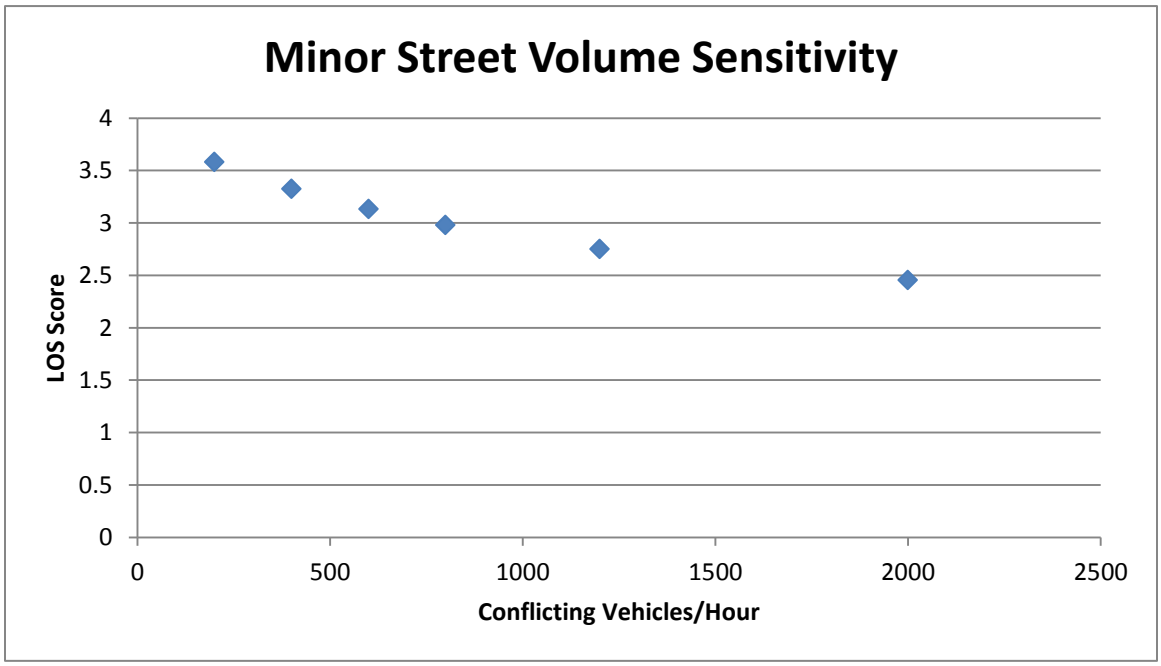

Figure 28: Minor Street Conflicting Volume Sensitivity

Goodness of Fit

The Goleta intersection user perception and intersection design data was used to statistically test if the LOS score from the equation for each approach was the same as the average of the ratings from all users. The analysis was conducted using a paired t-test. The results are shown in Table 12.

Table 10: Equation Paired T Test Results

Equation	Mean Difference	Std Dev	T Value	P Value
Major	**0.137**	**0.710**	**-0.90**	**0.378**
Minor	**0.143**	**0.535**	**-1.00**	**0.336**
Combined	**0.25**	**0.692**	**-2.17**	**0.037**

As you can see from the above results, the individual major and minor street equations provide a much better fit for the Goleta intersection turn movements than does the combined equation. This is one of the main reasons why the individual turn movement equations are being recommended by this report as the best methodology over the single combined equation.

Threshold Recommendation and Improving Goodness of Fit

To further show how well each equation fits its data set, a series of graphs are created below that show for each individual turn movement (on the x axis) what the equation predicts the level of service to be versus what the actual survey response was. Data for both Goleta validation intersections and other intersections are provided below in different formats. For each graph, the blue points represent the average of all survey respondents and the purple lines represent the numerical value directly provided by the equation. This time,

however, a threshold has been applied to convert the raw score into a LOS. The thresholds are provided in Tables 11 and 12. Note that these thresholds were used here to maximize the correspondence between the predicted and estimated LOS category. The author is aware of the concept of over-fitting in statistical modeling and these thresholds are not recommended for assigning LOS for all scenarios. If the proposed methodology is adopted as the standard bicycle LOS methodology for TWSC standard thresholds could be developed and adopted.

Table 11: TWSC Intersection Major Street Suggested LOS

RATE	LOS
5+	A
3.6 – 5.0	B
2.5 – 3.6	C
2.4 – 2.5	D
2.2 – 2.4	E
<2.2	F

Table 12: TWSC Intersection Minor Street Suggested LOS

RATE	LOS
4.8+	A
3.5 - 4.8	B
2.7 – 3.5	C
1.7 – 2.7	D
1.5 – 1.7	E
<1.5	F

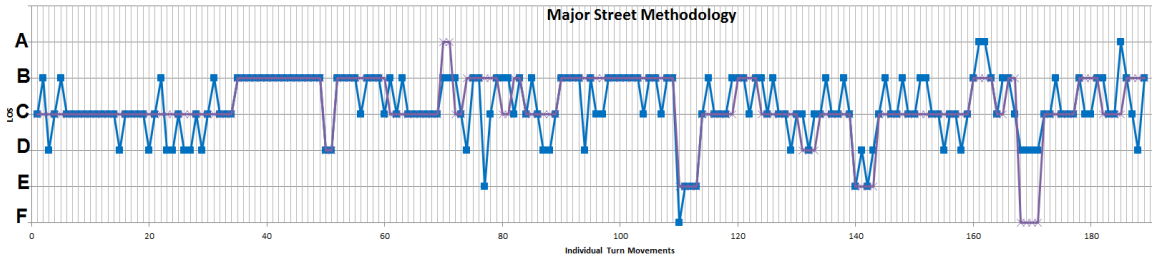

Figure 29: Major Street Equation

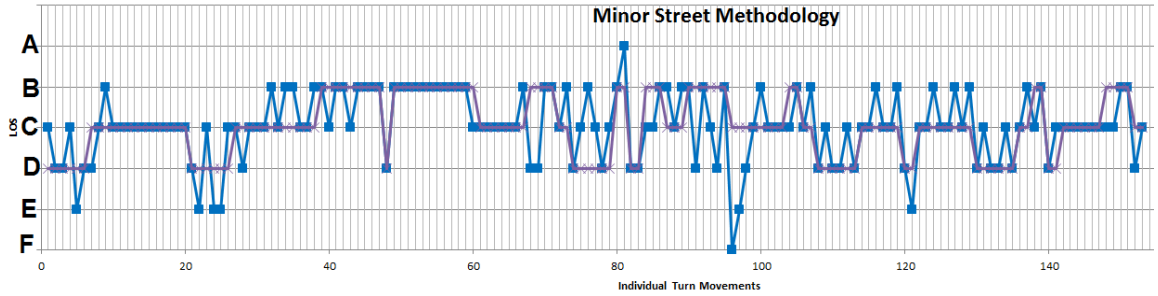

Figure 30: Minor Street Equation

Please note that for each of the above graphs, about the last fifth of the individual turn movements (x axis) are movements from Goleta, California which was used to help confirm the validity of the equations and were not considered during the original development of the equations. The Goleta data is reproduced alone below.

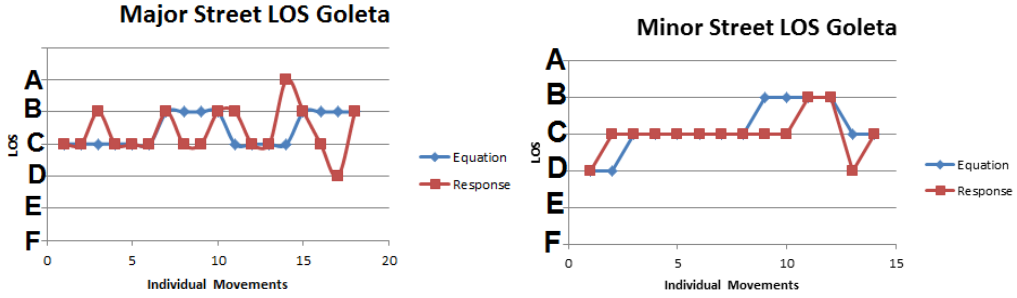

Figure 31: Goleta Comparison

Interesting Issues Affecting Bicycle Operation

Enforcement

From the field research, there were several concerns that presented themselves that were not included in previous research and could not be explored for this research either. For example, in multiple cases of the reviewed sample intersections, “No Parking Bike Lane” signs were posted on the sides of the street, but vehicles would ignore these signs and park in the bike lane anyway, forcing cyclists to leave the safety of their designated lane and enter the normal traffic lanes in order to get around them. This brings into play the importance of police enforcement in maintaining street facilities and level of service. Even if the facilities, such as signage and striping, from an engineering standpoint are present, they become meaningless if they are not enforced. This was discovered to be a very serious concern.

Figure 32: Trucks Parking in Bike Lane in Claremont, California

Not only parking laws were ignored, but normal traffic laws as well. Multiple times during the captured video that was shown to a review panel for feedback, vehicles break traffic laws to swerve around the cyclist on all sides in order to pass the slower cyclist while he is still traversing the intersection (even blocking off the oncoming traffic in order to complete their pass). Movements such as these are prohibited, but lack of enforcement and/or driver knowledge of rules of the road make such legal matters void in the field. This would lead to a lower level of comfort and safety as well as level of service for the cyclist, but cannot easily be addressed by good bicycle infrastructure without completely separating bicycles and other vehicular traffic.

Pavement Quality Discrepancy between Intersecting Roads

Another field condition that presented itself is that of inconsistent pavement quality. On many intersections one of the two intersecting roadways has a better pavement quality than the other intersecting roadway. This results in an opinion to average a pavement quality score approximately midway between the two individual roadway scores. For example, a roadway with a pavement quality corresponding to a level two, which intersects with a roadway with a pavement quality of a level four, will usually average to an overall pavement quality of approximately level three to the eye of the cyclist. This often appears to occur because the cyclist's movement across the intersection requires him or her to interact with both pavement qualities as they traverse the intersection.

Figure 33: Pavement Quality Discrepancy

Shared Lane Markings

A separate finding was that involving sharrows (shared-lane markings) and bike lanes. For small traffic volumes, painted sharrows were found to provide higher levels of service for cyclists than bike lanes. However, once motor vehicle traffic volumes became sizable (over approximately 160 vehicles per hour) bike lanes started becoming more and more desired by cyclists for adequate safety. This trend was determined from a combination of direct questioning on the internet surveys and manipulation of the overall LOS scores estimated by computer when traffic volumes and presence of sharrows are altered. The California Manual on Uniform Traffic Control Devices addresses this using the speed limit of the roadway, suggesting in Section 9C.07 that the Shared Lane Marking is used only on roadways with a speed limit of 35 miles per hour or lower (*California Manual on Uniform Traffic Control*, 2012). Signage alerting vehicles to the presence of

cyclists and improved pavement quality were both found to have a positive effect no matter what the traffic volumes were. Painted parking lanes placed between a bike lane and a curb were actually less desirable than just a lone bike lane UPON THE CONDITION that no parking was allowed in the bike lane and that this was properly enforced. If parking in the bike lane was allowed, then this provided a lower level of service than if there had been a separate striped parking lane.

When a roadway had no bicycle facilities on it but had on street parking, the level of service decreased significantly. From the reviewers' comments, this was primarily because of the lack of painted sharrows without which the cyclist is supposed to legally stay as far to the right as practical. However, on narrower streets, cyclists were at risk of hitting doors that open from adjacently parked vehicles and, if a door is open while a vehicle behind the approaching cyclist tries to pass the bicycle, the cyclist is forced to stop completely and wait for the other vehicles to complete their maneuvers. Very narrow streets make sharrows almost a necessity for bicycle safety even though the California Manual on Uniform Traffic Control Devices, 2012 states that sharrows should not be placed within 11 feet of the curb when on-street parking is present (*California Manual on Uniform Traffic Control*, 2012).

Medians

Previous research on medians has so far showed positive feedback on the presence of solid barriers in the center of the roadway. Dixon et al. (1996) stated the following:

"Medians Present: The medians must be restrictive, raised medians with or without turn bays. The presence of medians should be noted only if the medians are a dominant feature throughout the corridor segment or at least in those portions of the segment where vehicle turning movements are most frequent. These medians are considered a benefit to bicyclists because they limit left-turn conflicts. Turn lanes in a median can also be a benefit because they allow traffic flow to continue without backing up behind a turning vehicle. When this back-up occurs motorists are often tempted to use the bicycle lanes or paved shoulders to pass on the right. However, continuous turn lanes are not to be credited in this category because the benefit of reducing back-ups is greatly offset by the increase in turning movements at random locations." (Dixon, 1996)

However, in the survey information collected for this thesis the medians generally led to reduced sight distance. Planted or exceptionally raised medians in particular decreased the sight distance of cyclists approaching an intersection and made it difficult to see opposing traffic. This resulted in a decrease in level of service at intersections where a restrictive median is present (see results table listed above). This could be offset if medians and barriers ended about 200 feet or so before and intersection, so that cyclists could see traffic within that range,

but most of the locations observed had medians that went right up to the intersection before breaking. This posed problems especially on roadways with high speed and traffic volumes.

Figure 34: Median Presence in Riverside, California

CHAPTER 5: CONCLUSIONS AND SUBJECTS FOR FUTURE RESEARCH

Although all steps necessary to create a level of service model at TWSC intersections were undertaken (See Table 13 below), a key difference between this study and past Transportation Research Board research projects on level of service is the number and range of surveyed sites. Prior studies that have been conducted had significantly larger budgets and staff and were thus able to consider approximately double the number of surveyed locations and those locations were spaced over a greater geographical range that provides a more certain representation of the United States (and other parts of the world depending on the individual study) whereas data from this thesis was collected only in California. Future studies, like the one currently being developed by Kittelson & Associates for the HCM 2020, will probably benefit from having a larger number of sample intersections and a wider geographical range so as to make the resultant calculations more applicable for agencies in different locations. This is partially the reasoning for why the combined level of service method that was estimated in this research may not have provided an accurate evaluation technique for TWSC LOS. Such a system may only provide a "ball-park" estimate of the true level of service because only 34 intersections where actually used to create the model (with an additional 7 more to validate). There may be a significant amount of error in the model due to the relatively small number of sample survey intersections and future research could help to rectify this issue. In the meantime, the method of analyzing TWSC intersections using two different aspects (major and minor street turn movements) should serve as

the most accurate means of LOS estimation. Also, in addition to a wider range of survey intersections, it may be advisable to survey the same intersection at multiple times and under different traffic conditions. This may provide further insight on the effects of traffic volume on LOS.

Surveyed intersections in this research were all collected from areas that are recignised at a national level as being “bicycle friendly.” It may also prove valuable to survey some sites that are not bicycle friendly to see if there are differences in vehicle and bicycle behavior and/or LOS between the two types of areas. It is possible that the data collected for this research in terms of collected perception scores was skewed due to increased vehicular awareness and friendliness towards cyclists. This validation is a subject for future research.

Table 13: Goals Revisited

Goal	Completed?
Collection of Data on Physical Characteristics of Sample Two-Way Stop-Controlled Intersections	☑
Collection of Video Footage of Two-Way Stop-Controlled Intersection Turn Movements from Cyclist’ Perspective	☑
Collection of Video Footage of Signalized Intersection Turn Movements for Validation of Viewers Feedback	☑
Collection of Video Viewer’s Feedback as Perceived Level of Service Ratings	☑
Consolidate Viewers Feedback into a Single Average LOS Score for Each Turn Movement	☑
Split Data into Three Sets for Analysis: Major Street, Minor Street, and Combined	☑
Perform Linear Regression on Data and Confirm with Reserved Survey Intersections	☑
Provide details on significance of Results and Future Research Possibilities	☑

The resultant equations from this thesis and related insights provided about the other field observed variables such as medians, sharrows etc. should serve as a fair estimate of the bicycle level of service for TWSC intersections. Even within the data used in this study there is still significant variance in the level of service survey response data and the equations' fit, which indicates that there may be no perfect fit, and that the equations represent an estimate only, and that individual situations may offer actual field LOS that could not be fully predicted by such models. Other aspects that should be topics of future research include emerging technologies. For example, flashing lights that activate either by push button or other detection system that alert drivers to the presence of bicycles at an intersection. Such configurations are very rare at current conditions, but within the near future that may change. Technologies similar to bike boxes may also present themselves. Although the bike box itself is only for signalized intersections currently and would most likely serve little purpose at a two-way stop-controlled intersection, it is possible that a similar means of providing a safe haven for bicycle traffic at different types of intersections may be developed in the future. Painted bike lanes, for example, are slowly being introduced to areas of high bicycle incidents and could be subject to further review for level of service analyses.

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Appendix A

The following is a detailed list of the procedures for several related existing level of service methodologies.

Bicycle Level of Service for Signalized Intersections:

The first step (Determine Bicycle Delay) begins with determining the bicycle lane capacity. This is done using the following equation:

$C_b = (S_b \times g_b)/C$

Where

C_b = capacity of the bike lane (bicycles/hour)

S_b = saturation flow rate of the bicycle lane (default = 2,000 bicycles/hour)

g_b = effective green time for the bicycle lane

C = cycle length

(Source: HCM 2010)

S_b has been found in some areas to be as high as 2,600 bicycles per hour but the standard of 2,000 is recommended. If high levels of right turning vehicles are present, even this value may be unachievable in some locations. If possible, field conditions should be measured to determine the exact saturation flow rate of the site being evaluated. The saturation flow rate is the rate at which vehicles (bicycles in this case) traverse an intersection during a green light with a full queue. It measures how many vehicles can go through an intersection under perfect conditions (never actually achieved in reality).

The cycle length is the time the signal takes to go through a complete cycle (the time a bicycle would have to wait if it was stopped the moment the light turned red, plus the green time)

The effective green time is equal to the actual green time for the direction of travel of interest minus the combination of the time lost at the beginning of the cycle from cyclists starting back up and the time lost from cyclists slowing down as the light begins to turn yellow and/or red.

The second step in this procedure is to determine the bicycle delay using equation 18-79 from the HCM:

$$d_b = 0.5C(1-g_b/C)^2/[1-\min(v_{bic}/c_b, 1.0)g_b/C]$$

d_b = Bicycle Delay

v_{bic} = Bicycle Flow Rate (bicycles per hour)

The next step is to calculate the bicycle level of service score for the intersection. This is done using the following equations from HCM 2010:

$$I_{b,int} = 4.1324 + F_w + F_v$$

$$F_w = 0.0153W_{cd} - 0.2144W_t$$

$$F_v = 0.0066[v_{lt} + v_{th} + v_{rt}]/(4N_{th})$$

$$W_t = W_{ol} + W_{bl} + I_{pk}W_{os^*}$$

Where:

$I_{b,int}$ = bicycle LOS score for intersection

W_{cd} = curb-to-curb width of the cross street (ft)

W_t = total width of the outside through lane, bicycle lane, and paved shoulder (ft)

V_{lt} = left turn demand flow rate (veh/hr)

V_{th} = through demand flow rate (veh/hr)

V_{rt} = right turn demand flow rate (veh/hr)

N_{th} = Number of through lanes (shared or exclusive) (ln)

W_{ol} = width of the outside lane (ft)

W_{bl} = width of the bicycle lane = 0 if bicycle lane not provided (ft)

I_{pk} = indicator variable for on street parking occupancy = 0 of $p_{pk}<0$; 1 Otherwise

P_{pk} = proportion of on street parking occupied (decimal)

W_{os} = width of paved outside shoulder (ft)

W_{os^*} = adjusted with of paved outside shoulder; if curb is present $W_{os^*} = W_{os} - 1.5>0$; otherwise $W_{os^*} = W_{os}$

The last step is to use the above bicycle level of service score to look up the actual level of service in exhibit 18-5 from the HCM:

Table: Exhibit 18-5 from HCM 2010

LOS	LOS Score
A	<2.00
B	2.00 - 2.75
C	2.75 - 3.50
D	3.50 – 4.25
E	4.25 – 5.00
F	>5.00

Bicycle Level of Service for All Way Stop Controlled Intersections:

The first step is to convert the movement demand volume into a flow rate (remembering that the level of service is calculated for a specific vehicle movement).

$$v_i = V_i/PHF$$

where:

v_i = the demand flow rate for a movement (vehicles/ hour)

V_i = the demand volume for the movement (vehicles/hour)

PHF = Peak Hour Factor

The second step is determined if there are multiple lanes that travel in the same direction. If there is only one lane per movement, the first step values are equal to the second step values. Next, the geometry group for each approach must be determined. This is done using exhibit 20-10 of the HCM and our knowledge of the intersection's configuration.

Table: Exhibit 20-10 from HCM 2010

Intersection Configuration	Subject Approaches	Opposing Approaches	Conflicting Approaches	Geometry Group
Four leg or T	1	0 or 1	1	1
Four leg or T	1	0 or 1	2	2
Four leg or T	1	2	1	3a/4a
T	1	2	2	3b
Four leg	1	2	2	4b
Four leg or T	1 1 2 3 3 3	0 or 1 3 0,1,or 2 0 or 1 0 or 1 2 or 3	3 1 1 or 2 1 2 or 3 1	5
Four leg or T	1 1 1 2 2 3	3 2 3 3 0,1,2, or 3 2 or 3	2 3 3 1,2, or 3 3 2 or 3	6

The forth step involves calculating the saturation headway adjustments using equation 20-13.

$$H_{adj} = h_{lt,adj}P_{lt} + h_{rt}P_{rt} + h_{hv,adj}P_{hv}$$

Where:

H_{adj} = headway adjustment (s)

$H_{lt,adj}$ = headway adjustment for left turns(s)

$H_{rt,adj}$ = headway adjustment for right turns (s)

$H_{hv,adj}$ = headway adjustment for heavy vehicles (s)

P_{lt} = proportion of left turning vehicles in the lane

P_{rt} = proportion of right turning vehicles in the lane

P_{hv} = proportion of heavy vehicles in the lane

The adjustments listed here can be obtained from exhibit 20-11:

Table: Exhibit 20-11 from HCM 2010: Saturation Headway Adjustment

Group	1	2	3a	3b	4a	4b	5	6
Factor								
LT	0.2	0.2	0.2	0.2	0.2	0.2	0.5	0.5
RT	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.7	-0.7
HV	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7

Step five is the first part of an iterative process in which the departure headways are assumed to be 3.2 seconds until a more accurate estimate can be determined. Step six is to calculate the initial degree of utilization using equation 20-14:

$$X = vh_d/3600$$

Where

X = Degree of utilization

h_d = Assumed departure headway (step five)

v = Lane flow rate (step two)

Step seven is a complicated and fairly confusing one to understand at first glance. The probability state of each combination is found by multiplying all individual probabilities together. The individual probabilities can be determined using exhibits 20-12 and/or 20-13. It may be advisable to simply read the value from exhibit 20-13 if you are uncertain as to how best to utilize the data in exhibit 20-12.

J = O1(opposing approach, Lane 1), O2 (opposing approach, Lane 2), CL1 (conflicting left approach, Lane 1), CL2 (conflicting left approach, Lane 2), CR1 (conflicting right approach, Lane 1), and CR2 (conflicting right approach, Lane 2) for a two-lane, two-way AWSC intersection

$P(a_j)$ = probability of a_j, computed on the basis of Exhibit 20-12, where V_j is the lane flow rate

A_j = 1(indicating a vehicle present) or 0 (indicating no vehicle present in the lane) (values of a_j for each lane in each combination I are listed in Exhibit 20-13).

Table: Exhibit 20-12 from HCM 2010

A_j	V_j	$P(a_j)$
1	**0**	**0**
0	**0**	**1**
1	**>0**	**X_j**
0	**>0**	**$1 - x_j$**

Table: Exhibit 20-13 from HCM 2010

i	DOC Case	# Vehicles	Op Approach L1	Op App L2	Conf App L1	Conf App L2	Conf App R1	Conf App R2
1	1	0	0	0	0	0	0	0
2	2	1	1	0	0	0	0	0
3			0	1				
4	2	2	1	1	0	0	0	0
5	3	1	0	0	1	0	0	0
6					0	1	0	0
7					0	0	1	0
8					0	0	0	1
9	3	2	0	0	1	1	0	0
10					0	0	1	1
11	4	2	0	0	0	1	0	1
12			0	0	1	0	0	1
13			0	0	1	0	1	0
14			0	0	0	1	1	0
15			0	1	0	1	0	0
16			1	0	1	0	0	0
17			0	1	0	0	1	0
18			1	0	0	1	0	0
19			0	1	1	0	0	0
20			0	1	0	0	0	1
21			1	0	0	0	1	0
22			1	0	0	0	0	1
23	4	3	0	0	0	1	1	1
24			0	0	1	1	0	1
25			0	0	1	1	1	0
26			1	0	1	1	0	0
27			1	1	1	0	0	0
28			1	1	0	0	1	0
29			1	1	0	0	0	1
30			0	1	1	1	0	0
31			1	0	0	0	1	1
32			0	0	1	0	1	1
33			1	1	0	1	0	0
34			0	1	0	0	1	1
35	4	4	1	1	0	0	1	1
36			0	0	1	1	1	1
37			1	1	1	1	0	0
38	5	3	0	1	0	1	0	1
39			1	0	0	1	1	0
40			0	1	1	0	1	0

41			0	1	0	1	1	0
42			0	1	1	0	0	1
43			1	0	1	0	0	1
44			1	0	0	1	0	1
45			1	0	1	0	1	0
46	5	4	1	0	0	1	1	1
47			0	1	1	1	1	0
48			0	1	1	1	0	1
49			1	0	1	0	1	1
50			1	0	1	1	1	0
51			0	1	0	1	1	1
52			1	1	1	0	0	1
53			1	0	1	1	0	1
54			0	1	1	0	1	1
55			1	1	0	1	1	0
56			1	1	0	1	0	1
57			1	1	1	0	1	0
58	5	5	1	0	1	1	1	1
59			1	1	0	1	1	1
60			1	1	1	0	1	1
61			0	1	1	1	1	1
62			1	1	1	1	1	0
63			1	1	1	1	0	1
64	5	6	1	1	1	1	1	1

The probabilities of no opposing conflict, no conflict from the left, and no conflict from the right are computed using 1-(values from step six). Each of these are then used to calculate the probability of each scenario from the above table, usually through straight multiplication.

Step eight is to compute the probability adjustment factors using the values from step seven.

$$P(C_1) = P(1)$$

$$P(C_2) = \sum_{i=2}^{4} P(i)$$

$$P(C_3) = \sum_{i=5}^{10} P(i)$$

$$P(C_4) = \sum_{i=11}^{37} P(i)$$

$$P(C_5) = \sum_{i=38}^{64} P(i)$$

$$AdjP(1) = \alpha[P(C_2) + 2P(C_3) + 3P(C_4) + 4P(C_5)]/1$$

$$AdjP(2)\text{through } AdjP(4) = \alpha[P(C_3) + 2P(C_4) + 3P(C_5) - P(C_2)]/3$$

$$AdjP(5) \text{ through } AdjP(10) = \alpha[P(C_4) + 2P(C_5) - 3P(C_3)]/6$$

$$AdjP(11) \text{ through } AdjP(37) = \alpha[P(C_5) - 6P(C_4)]/27$$

$$AdjP(38) \text{ through } AdjP(64) = \alpha[10P(C_5)]/27$$

$$\alpha = 0.01 \text{ or } 0 \text{ if no correlation between saturation headways}$$

$$P'(i) = P(i) + AdjP(i)$$

Step nine is to compute the saturation headways using $h_{si} = h_{base} + h_{adj}$ and exhibit 20-14. **Table: Exhibit 20-14 from HCM 2010: Base Saturation Headways**

Case	# Veh	Gr 1	Gr 2	Gr 3a	Gr 3b	Gr 4a	Gr 4b	Gr 5	Gr 6
1	0	3.9	3.9	4	4.3	4	4.5	4.5	4.5
2	1	4.7	4.7	4.8	5.1	4.8	5.3	5.0	6.0
	2							6.2	6.8
	3+								7.4
3	1	5.8	5.8	5.9	6.2	5.9	6.4	6.4	6.6
	2							7.2	7.3
	3+								7.8
4	2	7	7	7.1	7.4	7.1	7.6	7.6	8.1
	3							7.8	8.7
	4							9.0	9.6
	5+								12.3
5	3	9.6	9.6	9.7	10	9.7	10.2	9.7	10
	4							9.7	11.1
	5							10	11.4
	6+							11.5	13.3

Step ten is to compute the departure headways. This is done with the following formula:

$$h_d = \sum_{i=1}^{64} P'(i) h_{is}$$

Step eleven is to check for convergence. Check the calculated h_d values from the last step with the initial assumed values in step 5. If there is a change bigger than 0.1 second, repeat procedures 5-10 until the values do not change significantly. (This may take a lot of work.)

Step twelve is to compute the capacity of each approach assuming that the flows are constant on the opposing and conflicting directions. The flow rate of the subject lane is increased and departure headways are computed for each approach with the degree of utilization set equal to 1.

Step thirteen is to determine the service times in order to calculate control delay.

$$t_s = h_d - m$$

t_s = service time

h_d = departure headway (step 10)

m = move up time (2.0sec for geo groups 1-4; 2.3 sec for geo groups 5-6)

Step fourteen is to compute control delay for each lane.

$$d = t_s + 900T[(x-1) + ((x-1)^2 + (h_d x/450T))^{0.5}] + 5$$

d = average control delay

$x = vh_d/3600$ = degree of utilization

t_s = service time (sec)

h_d = departure headway (sec)

T = length of analysis period (hour)

Step fifteen is to determine the control delay for each approach and find the level of service for each approach and the intersection as a whole.

$$d_{approach} = \sum d_i v_i / \sum v_i$$

$d_{approach}$ = control delay for each approach (sec/veh)

d_i = control delay for the lane (sec/veh)

v_i = flow rate for the lane i (veh/hr)

$$d_{intersection} = \sum d_{approach} V_i / \sum V_i$$

$d_{intersection}$ = control delay for the intersection

V_i = flow rate for the approach i

The level of service can then be determined from exhibit 20-2 and the above computed values.

Table: Exhibit 20-2 from HCM 2010

Control Delay (sec/veh)	LOS (v/c <1)
0-10	A
10-15	B
15 – 25	C
25-35	D
35-50	E
>50	F

If the volume to capacity ratio is greater than 1, the level of service is automatically an "F" grade.

The last step in the process applies more to automotives than to bicycles, but shall be included in these notes just for completeness. Step sixteen involves the computation of queue lengths.

$$Q_{95} = 900T[(x-1) + ((x-1)^2 + (h_d x/150T))^{0.5}] / h_d$$

Q_{95} =95th percentile queue (veh)

x = degree of utilization

h_d = departure headway (sec)

T = length of analysis period (hour)

Bicycle Level of Service for Urban Street Segments:

Step one is to determine the average running speed. This is best done in the field looking at the speed of cyclists between signalized intersections. If a speed cannot be determined, it is recommended that a speed of 15 mi/hr is used. Many factors influence bicycle speed including roadway volumes and conditions as well as cyclist demographics.

Step two is to determine bicycle delay at the intersection. This is done using one of three ways depending on the intersection configuration. If the intersection is uncontrolled, delay is assumed to be zero (although it may not be in reality). If the intersection is signalized or stop controlled, the delay is calculated in the same respective manner as listed in the previous sections of this paper. (See all way stop controlled intersections and/or signalized intersections.)

Step three is to determine the bicycle travel speed using a formula that accounts for downstream delay and the time required to travel through the length of the segment. This value is typically lower than the running speed. In general, we want this speed to be greater than 10 mi/hr. If it is less than 5, that suggests there is a problem with the street segment or the calculations.

$$S_{Tbseg} = 3600L/(5280t_{Rb} + 5280\ d_b)$$

S_{Tbseg} = travel speed of bicycles in through direction along the segment

L = segment length

t_{Rb} = segment running time of bicycles in through direction ($3600L/5280S_b$) (sec)

S_b = bicycle running speed (mi/hr) (step 1)

d_b = bicycle control delay (sec/bicycle)

Step four is to determine the bicycle level of service score for the intersection. This is done in the same manner as in the signalized intersection section of this paper and will not be repeated here. Step five is to determine the bicycle level of service score for the link.

$$I_{blink} = 0.76 + F_w + F_v + F_S + F_p$$

$$F_w = -0.005W_e^2$$

$$F_v = 0.507\ln(v_{ma}/4N_{th})$$

$$F_S = 0.199[1.1199\ln(S_{Ra} - 20) + 0.8103](1+0.1038P_{HVa})^2$$

$$F_p = 7.066/P_c^2$$

I_{blink} =bicycle level of service score for the link

F_w = cross section adjustment factor

F_v = motorized vehicle volume adjustment factor

F_S = motorized vehicle speed adjustment factor

F_P = pavement condition adjustment factor

W_e = effective width of outside through lane

V_{ma} = adjusted midsegment demand flow rate (veh/hr)

N_{th} = number of through lanes on the segment in the subject direction of travel

S_{Ra} = adjusted motorized vehicle running speed (mi/hr)

P_{HVa} = adjusted percent heavy vehicles in midsegment demand flow rate (%)

P_c = pavement condition rating (exhibit 17-7)

Table: Exhibit 17-7 from HCM 2010

Pavement Condition Rating	Pavement Description	Motorized Vehicle Ride Quality and Traffic Speed
4 to 5	New or nearly new superior pavement. Free of cracks and patches	Good Ride
3 to 4	Flexible pavements may begin to show evidence of rutting and fine cracks. Rigid pavements may begin to show evidence of minor cracking	Good Ride
2 to 3	Flexible pavments may show rutting and extensive patching. Rigid pavements may have a few joint fractures, faulting, or cracking.	Acceptable ride for low-speed traffic but barely tolerable for high speed traffic
1 to 2	Distress occurs over 50% or more of the surface. Flexible pavement may have large potholes and deep cracks. Rigid pavement distress includes joint spalling patching and cracking.	Pavement deterioration affects the speed of free flow traffic. Ride quality not acceptable.
0 to 1	Distress occurs over 75% or more of the surface. Large potholes and deep cracks exist.	Passably only at reduced speed and considerable rider discomfort.

Step six is to find the link level of service using the bicycle level of service score from step five. This is done using exhibit 17-4 reproduced here:

Table: Exhibit 17-4 from HCM 2010

Level of Service	Level of Service Score
A	<2.0
B	2.0-2.75
C	2.75-3.5
D	3.5-4.25
E	4.25-5
F	5<

There are conditions that go along with these values however. Please see the following exhibit 17-21 to check for special conditions.

Table: Exhibit 17-21 from HCM 2010

Condition	Variable When Condition Is Satisfied	Variable When Condition Is Not Satisfied
$P_{pk} = 0$	$W_t = W_{ol} + W_{bl} + W_{os^*}$	$W_t = W_{ol} + W_{bl}$
V_m>160 veh/hr or street is divided	$W_v = W_t$	$W_v = W_t(2\text{-}0.005v_m)$
$W_{bl}+W_{os^*}$<4 ft	$W_e = W_v - 10p_{pk}>0$	$W_e = W_v + W_{bl} + W_{os^*} - 20p_{pk}>0$
$V_m(1\text{-}0.01P_{hv})$<200 veh/hr and p_{hv}> 50%	$P_{hva} = 50\%$	$P_{hva} = P_{hv}$
S_r<21 mi/hr	$S_{Ra} = 21$ mi/hr	$S_{Ra} = S_R$
$V_m > 4\ N_{th}$	$V_{ma} = v_m$	$V_{ma} = 4N_{th}$

V_m = midsegment demand flow rate (veh/hr)

S_R = motorized vehicle running speed (mi/hr)

Step seven is to calculate the bicycle level of service score for the street segment.

$$I_{bseg} = 0.16I_{blink} + 0.011F_{bi}e^{Ibint} + [0.035N_{aps}/(L/5280)] + 2.85$$

I_{bseg} = bicycle level of service score for the segment

I_{blink} = bicycle level of service score for the link

F_{bi} = 1 if signalized intersection, =0 if two way stop controlled intersection

I_{bint} = bicycle level of service score for the intersection

N_{aps} = number of access point approaches on the right side in the subject direction of travel

Step eight is to simply plug the value obtained from step seven back into exhibit 17-4 (shown above in step six) to obtain the final level of service rating.

Bicycle Level of Service for Urban Street Facilities:

The first step, bicycle travel speed, is found using the following equation:

$$S_{TbF} = (\sum_{i=1}^{m} L_i)/(\sum_{i=1}^{m} L_i/S_{Tbsegi})$$

S_{TbF} =travel speed of through bicycles for the facility (mi/hr)

L_i = length of segment (ft)

M = number of segments on the facility

S_{Tbsegi} = travel speed of through bicycles for segment i

Step two is to determine the bicycle level of service score using the following:

$$I_{bF} = (\sum I_{bsegi} L_i)/\sum L_i$$

I_{bF} = bicycle level of service score for the facility

I_{bsegi} = bicycle level of service score for the segment i

L_i = length of segment (ft)

Step three is to simply plug the value obtained in step two into exhibit 17-4 to determine the level of service for the urban street facility.

Table: Exhibit 17-4 from HCM 2010

Level of Service	Level of Service Score
A	<2.0
B	2.0-2.75
C	2.75-3.5
D	3.5-4.25
E	4.25-5
F	5<

Bicycles Level of Service for Uninterrupted Flow Facilities:

The flow in the outside travel lane affects the perception of the cyclist and must be determined in the first step.

$$V_{OL} = V/(PHF \times N)$$

V_{OL} = directional demand flow rate in the outside lane (veh/hr)

V = hourly directional volume (veh/hr)

PHF = Peak Hour Factor

N = number of directional lanes (1 for two lane highways)

The second step is to calculate the effective width (factor) that is available to the bicycle. This depends on the outside through lane and the shoulder or bike lane. On highway parking, if present, reduces the effective width of the highway.

W_e = effective width

W_s = width of paved shoulder

If W_s >8ft: $W_e = W_v + W_s - (\%OHP \times 10\ ft)$

If 4ft <W_s< 8ft: $W_e = W_v + W_s - 2(\%OHP(2ft + W_s))$

If W_s<4 ft: $W_e = W_v + (\%OHP(2ft + W_s))$

If V> 160 veh/hr: $W_v = W_{OL} + W_s$

If V<160 veh/hr: $W_v = (W_{OL} + W_s) \times (2 - 0.005V)$

W_v = effective width as a function of traffic volume (ft)

W_{OL} = outside lane width

V = hourly directional volume

%OHP = percentage of segment with occupied on-highway parking (decimal)

Step three is to calculate the effective speed factor which represents the effects of motor vehicle speed on the cyclist quality of service.

$$S_t = 1.1199\ln(S_p - 20) + 0.8103$$

S_t = effective speed factor

S_p = posted speed limit (mi/hr)

The final step is to calculate and determine the bicycle level of service using the following equation and exhibit 15-4.

$$BLOS = 0.507\ln(V_{OL}) + 0.1999S_t(1+10.38HV)^2 + 7.066(1/P)^2 - 0.005W_e^2 + 0.057$$

BLOS = bicycle level of service score

HV = percentage of heavy vehicles (decimal)(max of 0.5 if V<200 veh/hr)

P = FHWA's 5 point pavement surface condition rating (see below chart)

Table: Exhibit 15-4 from HCM 2010

Level of Service	Level of Service Score
A	<1.5
B	1.5-2.5
C	2.5-3.5
D	3.5-4.5
E	4.5-5.5
F	5.5<

Table: FHWA Pavement Quality Ratings

Rating	Quality
1	Very Poor
2	Poor
3	Fair
4	Good
5	Very Good

Automobile Level of Service for Two Way Stop Controlled Intersections:

The first step is to determine the priority of each direction of travel. This is to allow the engineer to determine what are the most likely areas in an intersection to have conflicts arise. The priorities are listed in order below:

1. Left Turns from the Major Street
2. Right Turns from the Minor Street
3. U Turns from the Major Street
4. Through Movements from the Minor Street
5. Left Turns From the Minor Street
6. Any other Movement

Step two is to convert the movement demand volumes into flow rates. This is done simply by dividing the peak hour demand volume by the peak hour factor.

$$v_i = V_i/PHF$$

v_i = demand flow rate for movement i (veh/hr)

V_i = demand volume for movement i (veh/hr)

PHF = Peak Hour Factor

Step three is to determine conflicting flow rates for the movement of interest. These include pedestrian and bicycle flows, as well. The equations for some of these conflicting movements are listed below either because they are common and serve as a good example for calculating the conflicting rates of other directions or because some of the equations listed have unique multipliers that account for driver behavior. The equations utilize the labeling shown in the below diagram which is taken from the HCM 2010 (exhibit 19-6).

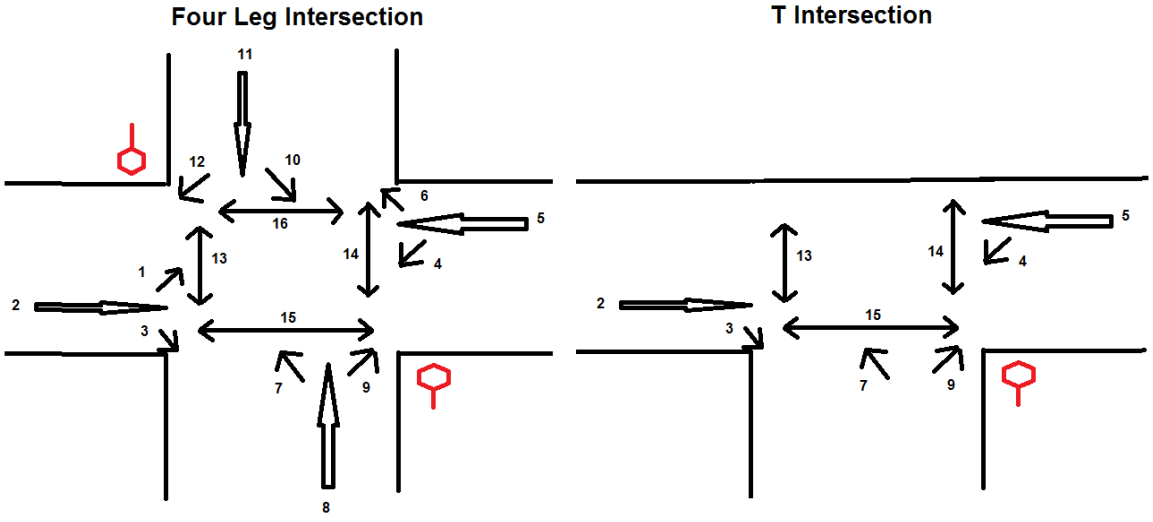


Figure: Exhibit 19-6 from HCM 2010

Notes: vc# = Conflicting Volume for # direction

vc#u = Conflicting Volume for U Turn from # direction

v13 through v16 are pedestrian volumes

vc1 = v5 + v6 + v16

vc4 = v2 + v3 + v15

For Two Lane Major Streets:

vc9 = v2 + 0.5v3 + v14 + v15

vc12 = v5 + 0.5v6 + v13 + v16

For Four Lane Major Streets:

vc9 = 0.5v2 + 0.5v3 + v14 + v15

vc12 = 0.5v5 +0.5v6 + v13 + v16

vc1u = v5 +v6

vc4u = v2 +v3

For Six Lane Major Streets:

$$Vc9 = 0.5v2 + 0.5v3 + v14 + v15$$

$$Vc12 = 0.5v5 + 0.5v6 + v13 + v16$$

$$Vc1u = 0.73v5 + 0.73\ v6$$

$$Vc4u = 0.73v2 + 0.73v3$$

Some other movements are more complicated and, in effect, take place in more than one phase. Vehicles crossing the intersection may enter an intersection and stay in the intersection for a length of time, waiting for an acceptable gap in conflicting traffic to complete their turn. This behavior results in multiple equations for what is essentially the same vehicular movement.

Note: vc$,# = Conflicting Flow in Phase $ and Direction #

$$vcI,8 = 2(v1 + v1u) + v2 + 0.5v3 + v15$$

$$vcII,8 = 2(v4 + v4u) + v5 + v6 + v16$$

$$vcI,11 = 2(v4 + v4u) + v5 + 0.5v6 + v16$$

$$vcII,11 = 2(v1 + v1u) + v2 + v3 + v15$$

For Two Lane Major Streets:

$$v_{cI,7} = 2v1 + v2 + 0.5 + v15$$

$$v_{cII,7} = 2v4 + v5 + 0.5v6 + 0.5v12 + 0.5v11 + v13$$

$$v_{cI,10} = 2v4 + v5 + 0.5v6 + v16$$

$$v_{cII,10} = 2v1 + v2 + 0.5v3 + 0.5v9 + 0.5v8 + v14$$

For Four Lane Major Streets:

$$v_{cI,7} = 2(v1 + v1u) + v2 + 0.5v3 + v15$$

$$v_{cII,7} = 2(v4 + v4u) + 0.5v5 + 0.5v11 + v13$$

$$v_{cI,10} = 2(v4 + v4u) + v5 + 0.5v6 + v16$$

$$v_{cII,10} = 2(v1 + v1u) + 0.5v2 + 0.5v9 + 0.5v8 + v14$$

For Six Lane Major Streets:

$$v_{cI,7} = 2(v1 + v1u) + v2 + 0.5v3 + v15$$

$$v_{cII,7} = 2(v4 + v4u) + 0.4v5 + 0.5v11 + v13$$

$$v_{cI,10} = 2(v4 + v4u) + v5 + 0.5v6 + v16$$

$$v_{cII,10} = 2(v1 + v1u)\ 0.4v2 + 0.5v8 + v14$$

Step four is to determine the critical and follow-up headways for the movements. The critical headway can be estimated using the following equation:

$$Tcx = tcbase + tcHV*PHV + tcg*G – t3LT$$

Where: tcx = critical headway for movement x (sec)

tcbase = base critical headway (from Exihibit 19-10 reproduced below from HCM 2010)

tcHV = Heavy Vehicle Factor (Equals 1 if major street has one lane in each direction; Equals 2 if major street has multiple lanes in each direction.)

PHV = Percent Heavy Vehicles (decimal)

tcg = Grade Factor (Equals 0.1 for movements 9 and 12; Equals 0.2 for movements 7, 8, 10, and 11)

G = Percent Grade (integer)

t3LT = Intersection Geometry Factor (0.7 if minor street left turn movement at T intersection; 0 for all other scenarios)

Table: Exhibit 19-10: Base Critical Headway

Vehicle Movement	Two Lanes	Four Lanes	Six Lanes
Left turn from major	4.1	4.1	5.3
U turn from major	NA	6.4 (wide) 6.9 (narrow)	5.6
Right Turn from minor	6.2	6.9	7.1
Through traffic on minor	1-stage: 6.5 2-stage, stage 1: 5.5 Stage 2: 5.5	1-stage: 6.5 2-stage, stage 1: 5.5 Stage 2: 5.5	1-stage: 6.5 2-stage, stage 1: 5.5 Stage 2: 5.5
Left turn from minor	1-stage: 7.1 2-stage, stage 1: 6.1 Stage 2: 6.1	1-stage: 7.5 2-stage, stage 1: 6.5 Stage 2: 6.5	1-stage: 6.4 2-stage, stage 1: 7.3 Stage 2: 6.7

The follow-up headway can be determined from a separate equation:

$$tfx = tfbase + tfHV*PHV$$

Where: tfx = follow-up headway for movement x (sec)

tfbase = base follow up headway (from Exhibit 19-11 reproduced below from HCM 2010)

tfHV = Heavy Vehicle Factor (Equals 0.9 if major street has one lane in each direction; Equals 1 otherwise)

PHV = Percent Heavy Vehicles for movement x

Table: Exhibit 19-11 from HCM 2010: Base Follow Up Headway

Vehicle Movement	2 Lanes	4 Lanes	6 Lanes
Left Turn from Major	2.2	2.2	3.1
U Turn from Major	NA	2.5(wide) 3.1(narrow)	2.3
Right Turn from minor	3.3	3.3	3.9
Through traffic on minor	4	4	4
Left Turn from minor	3.5	3.5	3.8

The fifth step in this procedure is to evaluate the potential capacities of the roadways. The capacities are determined from the following equation:

$$C_{p,x} = v_{c,x}[e^{-vc,xtc,x/3600}/(1-e^{-vc,xtf,x/3600})]$$

Where: $C_{p,x}$ = the potential capacity of movement x (veh/hr)

$V_{c,x}$ = the conflicting flow rate for movement x (veh/hr)

$t_{c,x}$ = the critical headway for the minor movement x (sec)

$t_{f,x}$ = the follow-up headway for the minor movement x (sec)

Now we get to the point where we must examine the effects of upstream signals or coordinated signals on our intersection. To make this procedure even more complex, we must remember to consider the effects of multiple stage movements (mentioned

earlier in this paper) in which the act of traversing a single intersection takes place in multiple phases. The proportion of time blocked is designated by $p_{x,\#}$. A list of which of these factors apply to what movement is detailed in Exhibit 19-12.

Table: Exhibit 19-12 from HCM 2010: Proportion Blocked for Movement

Movement	1 Stage	1st Stage	2nd Stage
1,1U	$P_{B,1}$	NA	NA
4,4U	$P_{B,4}$	NA	NA
7	$P_{B,7}$	$P_{B,4}$	$P_{B,1}$
8	$P_{B,8}$	$P_{B,4}$	$P_{B,1}$
9	$P_{B,9}$	NA	NA
10	$P_{B,10}$	$P_{B,1}$	$P_{B,4}$
11	P_{B11}	$P_{B,1}$	$P_{B,4}$
12	$P_{B,12}$	NA	NA

The conflicting flow for each movement during the period of time that is unblocked can be determined with the equation: $v_{c,u,x} = [v_{c,x} – 1.5v_{c,min}p_{b,x}]/[1 – p_{b,x}]$ However, this applies only if $v_{c,x}$ is greater than $1.5v_{c,min}p_{b,x}$ so that the numerator is positive. If this is not the case, then the conflicting flow is taken to be zero.

Note: $v_{c,u,x}$ = conflicting flow for movement x during the unblocked period (veh/hr)

$v_{c,x}$ = the total conflicting flow for movement x that was determined from step 3 above (veh/hr)

$v_{c,min}$ = minimum platooned flow rate (veh/hr); Equals 1000N

N = Number of through lanes in each direction on the major street

$p_{b,x}$ = the proportion of time the movement x is blocked by the major street platoon (Exhibit 19-12)

Now, with the upstream signal effects we use the following equations to determine the effective capacities of the intersection.

$$C_{p,x} = (1-p_{b,x})c_{t,x}$$

$$C_{t,x} = v_{c,u,x}[e^{-vc,u,xtc,x/3600}/(1-e^{-vc,u,xtf,x/3600})]$$

Where: $C_{p,x}$ = the potential capacity of movement x (veh/hr)

$p_{p,x}$ = the proportion of time that movement x is blocked by a platoon

$C_{r,x}$ = the capacity of movement x with unplatooned flow during the unblocked period

This equation is then used individually for all possible movements at the intersection. U-turn movements are considered with a few extra steps beyond this equation.

$$F_{1u} = p_{0,12} = 1- v_{12}/c_{m,12}$$

$$F_{4u} = p_{0,9} = 1 - v_9/c_{m,9}$$

Where:

F_{iu} = capacity adjustment factor for rank 2 major street u turn movements

$P_{0,j}$ = probability that conflicting rank 2 minor street right turn movment j will operate in a queue free state

V_j = flow rate of movement j

$C_{m,j}$ = capacity of movement j

J = 9 and 12 (minor street movements of rank 2)

The movement capacity for major street u turn movements is then computed with equation 19-40:

$$C_{m,ju} = (C_{P,JU})F_{JU}$$

Where:

$C_{m,ju}$ = movement capacity for movements 1u and 4u

$C_{p,ju}$ = potential capacity for movments 1u and 4u

F_{ju} = capacity adjustment factor for movements 1u and 4u

Since the left turn and u turn movments are typically conducted from the same lane, their shared lane capacity is computed with equation 19-41:

$$C_{sh} = \text{Sum}[v_y]/\text{Sum}[v_y/c_{m,y}]$$

Where: c_{SH} = the capacity of the shared lane (veh/hr)

v_y = flow rate of the y movement in the shared lane (veh/hr)

$c_{m,y}$ = movement capacity of the y movement in the shared lane (veh/hr)

If the major street has does not have a left lane that is a shared left turn and through lane or a designated left turn lane, then the probability of not having a queue build up in that lane is expressed as:

$$P_{o,j} = 1\text{-}v_j/c_{m,j}$$

Note: j usually equals 1 or 4

On the opposite scenario, if a left turn pocket or shared left turn lane exists, then the following equation is used to calculate the probability of having no queue waiting on the street:

$$P^*_{0,j} = 1 - (1\text{-}p_{0,j})[(nl +1)(1+x_{i,1+2}{}^{nl+1}/(1\text{-}x_{i,1+2}))\text{^}(1/2)]$$

$$X_{i,1+2} = v_{i1}/s_{i1} + v_{i2}/s_{i2}$$

Where:

$P_{0,j}$ = probability of queue free state for movement j assuming an exclusive left turn lane on the major street

J = 1 and 4 (major street turn movements)

I1 = 2 and 5 (major street through movements)

I2 = 3 and 6 (major street right turning movements)

$X_{i,1+2}$ = combined degree of saturation for the major street through and right turn movements

S_{i1} = saturation flow rate for the major street through movements (default assumed to be 1800 veh/hr, however, this parameter can be measured in the field

S_{i2} = saturation flow rate for the major right turn movements (default assumed to be 1500 veh/hr, however, this parameter can be measured in the field

V_{i1} = major street through movement (veh/hr)

V_{i2} = major street right turn flow rate (veh/hr) (0 if an exclusive right turn lane is provided)

N_l = storage places in the left turn pocket

For shared lanes, the equation becomes:

$$P^*_{0,j} = 1-(1-p_{0,j})/(1-x_{i,1+2})$$

Step eight is to compute the next rank of movement capacities. These are the minor street left and through movements which must yield to the major street movements. These capacities are determined from the product of all probabilities of the possible movements experiencing a queue free scenario.

$$F_k = \prod p_{o,j}$$

F_k = The capacity adjustment factor for all rank 3 movements

$p_{o'j}$ = The Probability that rank 2 movements will operate in a queue free manner to allow a break in traffic for movement 3 vehicles to complete their transgression of the intersection.

F_k is then multiplied by $C_{p,k}$ to obtain the adjusted capacity. If there is a two stage movement style action undertaken by a vehicle in the intersection for a rank 3 movement, then a different formula is used to calculate the adjusted capacity.

$$A = 1\text{-}0.32e^{-1.3(nm)^{\wedge}1/2} \text{ for } nm > 0$$

$$Y = [c_i - c_{m,x}]/(c_{II} - v_L - c_{m,x})$$

Where:

Nm = number of storage spaces in the median

C_j = movement capacity for the stage 1 process (veh/hr)

C_{II} = movement capacity for the stage 2 process (veh/hr)

V_l = major left turn or u turn flow rate, either $v_1 + v_{1u}$ or $v_4 + v_{4u}$ (veh/h)

$C_{m,x}$ = capacity of subject movement, considering the total conflicting flow rate for both stages of a two stage gap acceptance process

$$\text{For y not equal to 1: } c_t = a/(y^{nm+1}\text{-}1)[y(y^{nm}\text{-}1)(c_h\text{-}v_l)+(y\text{-}1)c_{m,x}]$$

$$\text{For y = 1: } c_t = a/(n_m + 1)[n_m(c_{II}\text{-}v_l)+_c m,x]$$

Step nine is to compute the rank 4 movement type capacities. Once again, these depend on the probability of operating in a queue free state, and, queuing in one traffic direction can induce queuing in one of the lesser priority travel directions so we have to be careful to account for multiple causes of vehicle delay from queuing.

$$P' = 0.65p'' - p''/(p''+3)+0.6(p'')^{(1/2)}$$

Where:

P' = adjustment to the major street left, minor street through impedance factor

P" = $(p_{0,j})(p_{0,k})$

$P_{0,j}$ = probability of a queue free state for the conflicting major street left turning traffic

$P_{0,k}$ = probability of a queue free state for the conflicting minor street crossing traffic

When determining p' for rank 4 movement 7 in equation 19-53:

P" = $(p_{0,1})(p_{0,4})(p_{0,11})$ Likewise when determining p' for rank 4 movement 10

P" = $(p_{0,1})(p_{0,4})(p_{0,8})$

The relationship between p' and p" can be determined graphically from Exhibit 19-14 of the HCM, reproduced below:

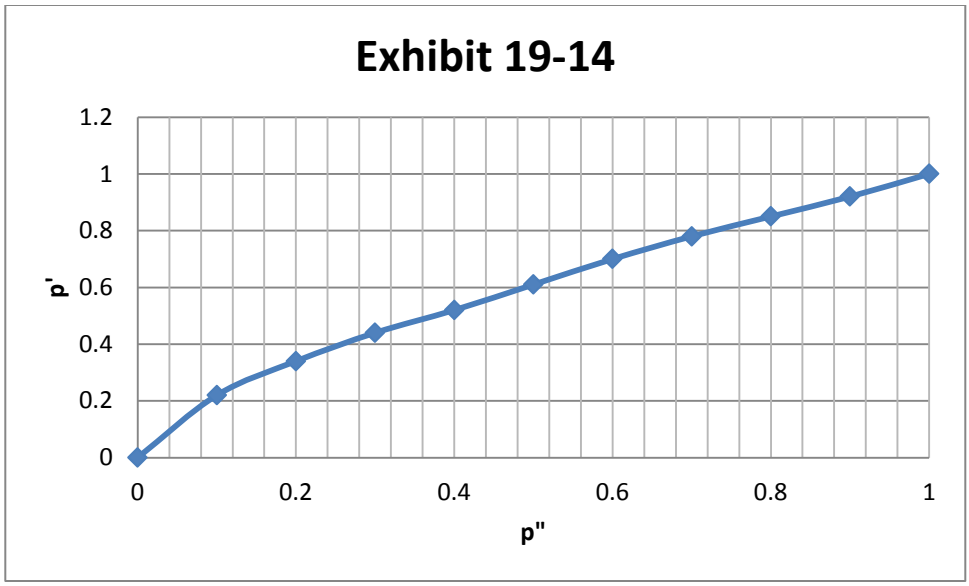


Figure 6: Exhibit 19-14 from HCM 2010

The adjustment factor $F_{p,l}$ is calculated by multiplying p' by $p_{0,j}$. $F_{p,l}$ is then multiplied by $C_{p,l}$ to determine the adjusted capacity for rank 4 movements. If a two stage behavior is observed, then the capacity must be calculated using a similar process from step eight (essentially the same set of equations).

$$A = 1\text{-}0.32e^{-1.3(nm)^{\wedge}(1/2)} \text{ for } nm > 0$$

$$Y = (c_i - c_{m,x})/(c_{II}\text{-}v_I\text{-}c_{m,x})$$

Where:

N_m = number of storage spaces in the median

C_i = movement capacity for the stage 1 process (veh/hr)

C_{II} = movement capacity for the stage 3 process (veh/hr)

V_I = major left turn or u turn flow rate, either $v_1 + v_{1u}$ or $v_4 + v_{4u}$ (veh/hr)

$C_{m,x}$ = capacity of subject movement, considering the total conflicting flow rate for both stages of a two stage gap acceptance process

$$\text{For y not equal to 1: } c_t = a/(y^{nm+1}-1)[y(y^{nm}-1)(c_{ll}-v_L)+(y-1)c_{m,x}]$$

$$\text{For y = 1: } c_t = a/(n_m + 1)[n_m(c_{ll}-v_L)+c_{m,x}]$$

Step ten is to perform the final capacity adjustments to the model. If different movements share the same lane, this must be accounted for using the equation:

$$C_{sh} = \text{Sum}[v_y]/\text{Sum}[v_y/c_{m,y}]$$

Where: c_{SH} = the capacity of the shared lane (veh/hr)

v_y = flow rate of the y movement in the shared lane (veh/hr)

$c_{m,y}$ = movement capacity of the y movement in the shared lane (veh/hr)

If a right turn lane has a flared style corner, this must also be accounted for in the queue length estimate.

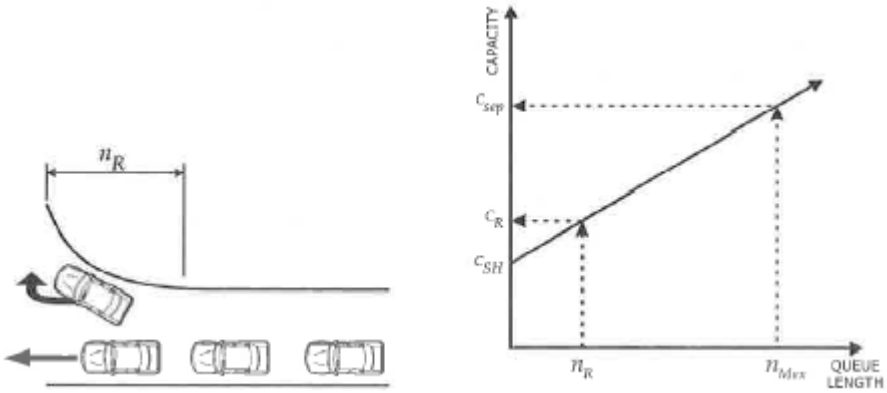


Figure: Exhibit 19-15 from HCM 2010

$$Q_{sep} = d_{sep}v_{sep}/3600$$

Q_{sep} = average queue length for the movement considered as a separate lane (veh/hr)

D_{sep} = control delay for the movement considered as a separate lane

V_{sep} = flow rate for the movement (veh/hr)

The next part of this procedure is to determine the necessary length of the vehicle storage area that is needed to allow for effective operation of the intersection.

$$N_{max} = Max[round(Q_{sep} + 1)]$$

Where:

Q_{sep} = average queue length for movement I considered as a separate lane

Round = round off operator, rounding the quantity in parentheses to the nearest integer

N_{Max} = length of the storage area such that the approach would operate as separate lanes

To compare, the capacity of an additional theoretical lane is then calculated to see how well the median storage area operates at containing vehicular flow.

$$C_{sep} = Min[c_r(1+v_{l+th}/v_r), c_{l+th}(1+v_r/v_{l+th})]$$

Where:

C_{sep} = sum of the capacities of the right turning traffic operating as a separate lane and the capacity of the other traffic in the right lane (upstream of the flare) operating in the separate lane (veh/hr)

C_r = capacity of the right turn movment (veh/hr)

C_{l+th} = capacity of the through and left turn movements as a shared lane (veh/hr)

V_r = right turn movement flow rate (veh/hr)

V_{l+th} = through and left turn movement combined flow rate (veh/hr)

Then the capacity of the lane is computed taking all of these above factors into account.

$$C_r = (c_{sep} - c_{sh})(n_r/n_{max}) + c_{sh} \text{ if } n_r < n_{max}$$

$$C_r = c_{sep} \text{ if } n_r > n_{max}$$

Where:

C_r = actual capacity of the flared lane (veh/hr)

C_{sep} = capacity of the lane if both storage areas were infinitely long

C_{sh} = capacity of the lane when all traffic is sharing one lane

N_r = actual storage are for right turning vehicles

The actual capacity c_{net} must be greater than c_{sh} but less than or equal to c_{sep}.

Step eleven is to calculate the movement control delay. This consist of the time a driver experiences in decelerating, waiting, and then accelerating again back to the free flow speed at the intersection. It is first calculated for the rank 2 through 4 movements using the following equation from the HCM:

$$D = 3600/c_{m,x} + 900T[(v_x/c_{m,x})-1+((v_x/c_{m,x}-1)^2+((3600/c_{m,x})(v_x/c_{m,x})/450T))^{(1/2)}] +5$$

Where:

D = control delay (s/veh)

V_x = flow rate for movement x (veh/hr)

$C_{m,x}$ = capacity of movement x (veh/hr)

T = analysis time period (=0.25 for 15 minute period)

Please note that the +5 on the end of this equation is to account for vehicle deceleration and acceleration. It is an assumed constant and may differ from the specific field scenario depending on the location. If possible, a field analysis of the intersection in question is desired to provide this constant, but it can be very difficult to estimate even in the field.

Now the rank 1 movement control delay can be estimated using a separate equation:

$$D_{rank1} = (1-p^*_{0,j})d_{M,LT}(v_{i,1}/N)/(v_{i,1}+v_{i,2}) \text{ for } N>1$$

$$D_{rank1} = (1-p^*_{0,j})d_{M,LT} \text{ for } N = 1$$

Where:

D_{rank1} = delay to rank 1 vehicles (s/veh)

N = number of through lanes per direction on the major street

$P^*_{0,j}$ = proportion of rank 1 vehicles not blocked

$D_{M,LT}$ = delay to major left turning vehicles

$V_{i,1}$ = major street through vehicles in shared lane

$V_{i,2}$ = major street turning vehicles in shared lane

The twelfth step is to compute the approach and intersection control delay. These are handled respectively by the following two equations:

$$D_a = (d_r v_r+d_t v_t+d_l v_l)/(v_r+v_t+v_l)$$

$$D_i = (d_{a,1}v_{a,1}+d_{a,2}v_{a,2}+d_{a,3}v_{a,3}+d_{a,4}v_{a,4})/(v_{a,1}+v_{a,2}+v_{a,3}+v_{a,4})$$

Where:

D_a = control delay on the approach (s/veh)

D_r,d_t,d_l = computed control delay for the right turn, through and left turn movements

V_r,v_t,v_l = volume or flow rate of right turn, through, and left turn traffic on the approach

$D_{a,x}$ = control delay on approach x (s/veh)

$V_{a,x}$ = volume or flow rate on approach x (veh/hr)

.

Please note that the delay for all major street rank 1 movements is assumed to be zero seconds per vehicle. Total intersection delay is usually only used to compare the intersection in question to others similar to it or to evaluate different traffic control alternatives. Movement delays are, of course, used to determine the level of service rating from Exhibit 19-1 (reproduced below)

Table: Exhibit 19-1 from HCM 2010: LOS

Control Delay	v/c< 1	v/c>1
0-10	A	F
10-15	B	F
15-25	C	F
25-35	D	F
35-50	E	F
50+	F	F

Step thirteen is to compute the queue lengths. This is done for the estimated 95th percentile queue.

$$Q_{95} = 900T[(v_x/c_{m,x})-1+((v_x/c_{m,x} -1)^2+(3600/c_{m,x})(v_x/c_{m,x})/150T)^{0.5}](c_{m,x}/3600)$$

Where:

Q_{95} = 95th percentile queue (veh)

V_x = flow rate for movement x

$C_{m,x}$ = capacity of movement x

T = analysis time period

Appendix B

Sample calculations for comparing existing level of service methodologies with collected survey responses are provided in the following.

Signalized Intersection:

Intersection: West Linden Street and Douglass Avenue, Riverside California

Signalized Intersection Method- Eastbound Through Movement

Lane width = 18’

No bike lane or shoulder present.

Wt = 18’ + 0’

Total Width = 36’

Fw = 0.0153*36’ – 0.2144*18’ = -3.4922

Vleft = 0

Vthrough = 107 veh/hr

Vright = 19 veh/hr

Nlanes = 1

Fv = 0.0066*(107 + 19 + 0)/(4*1) = 0.051975

Ib,int = 4.1324 + 0.051975 – 3.4922 = 0.676088

LOS = A

LOS obtained from survey = E

Answers do not match.

All Way Stop Controlled Intersection:

Sample Calculation:

Intersection: West Linden Street and Douglass Avenue, Riverside California

All Way Stop Controlled Intersection Method- Eastbound Through Movement

$$Vi = V/PHF$$

$$107/0.85 = 125.8$$

Group Geometry = Group 1for this movement

$$Plt = 0.0$$

$$Prt = 0.15$$

$$Phv = 0.03$$

$$Hlt = 0.2$$

$$Hrt = -0.7$$

$$Hhv = 1.7$$

$$Hadj = Plt * Hlt + Prt * Hrt + Phv * Hhv = 5.01$$

$$X = vh_d/3600$$

$$X = 125.8 * 3.2 /3600 = 0.1119$$

$$His = Hbase + Hadj$$

(skipping writing out the individual probability iteration which was done in Microsoft Excel)

Hbase = 3.9 for Group 1

His = 5.01 + 3.9 = 8.91

Hd ~ His

Ts = Hd – m

m = 2

Ts = 8.91 – 2 = 6.91

$$d = t_s + 900T[(x-1) + ((x-1)^2 + (h_d x/450T))^{0.5}] + 5$$

T = 1

$$d = 6.91 + 900 * [(0.1119-1) + ((0.1119-1)^2 + (8.91 * 0.1119/450))^{0.5}] + 5 = 13.03$$

Number of Lanes = 1

Movement LOS = B

Average Reviewers' LOS = E

Answers Do Not Match

Uninterrupted Flow Facilities:

Intersection: West Linden Street and Douglass Avenue, Riverside California

Uninterrupted Flow Facility Method- Eastbound Through Movement

$$V_{OL} = V/(PHF \times N)$$

$$107/(0.85*1) = 125.8 \text{ veh/hr}$$

If V> 160 veh/hr: $W_v = W_{OL} + W_s$

If V<160 veh/hr: $W_v = (W_{OL} + W_s) \times (2- 0.005V)$

$$W_{OL} = 18'$$

$$W_s = 0$$

$$_{Wv}\ 18' *(2-0.005(125.8)) = 26.37$$

If W_s<4 ft: $W_e = W_v +(\%OHP(2ft + W_s))$

%OHP = 100% at this intersection

$$26.37 + 1(2) = 28.37 = W_e$$

$$S_t = 1.1199\ln(S_p - 20) + 0.8103$$

$$S_p = 30$$

$$1.1199\ln(30-20) + 0.8103 = 3.389 = S_t$$

$$BLOS = 0.507\ln(V_{OL}) + 0.1999S_t(1+10.38HV)^2 + 7.066(1/P)^2 - 0.005W_e^2 + 0.057$$

$$HV = 0.03$$

$$P = 2$$

$$0.507\ln(125.8) + 0.1999(3.389)(1 + 10.38(0.03))^2 + 7.066(1/2)^2 - 0.005(28.37)^2 + 0.057$$

$$= 1.4158$$

$$LOS = A$$

Survey LOS = E

Answers do not match.

Automobile Level of Service Methodology:

Intersection: West Linden Street and Douglass Avenue, Riverside California

Two Way Stop Controlled Intersection Automotive Method- Eastbound Through Movement

$$Vi = V/PHF$$

$$107/0.85 = 125.8$$

Conflicting Volume for Major Street Through Movement = 0 veh/hr

$$Tcx = Tc,base + Tc,HV*PHV + Tc,g*G - T3LT$$

$$Tc,base = 4.1$$

$$Tc,HV = 1$$

PHV = 0.03

Tc,g = 0

T3LT = 0

Tcx = 4.1 + 1*0.03 = 4.13

tfx = tfbase + tfHV*PHV

tfbase = 2.2

tfHV = 0.9

PHV = 0.03

tfx = 2.2 + 0.9*0.03 = 2.227

$$C_{p,x} = v_{c,x}[e^{-vc,xtc,x/3600}/(1-e^{-vc,u,xtf,x/3600})]$$

Vc,x = 0 ~ 1

$$Cp,x = 1*(e^{-1*4.13/3600}/(1-e^{-1*2.227/3600})) = 1615 \text{ veh/hr}$$

No nearby signals at this location.

$$D = 3600/c_{m,x} + 900T[(v_x/c_{m,x})-1+((v_x/c_{m,x}-1)^2+((3600/c_{m,x})(v_x/c_{m,x})/450T))^{(1/2)}] +5$$

Where:

D = control delay (s/veh)

V_x = flow rate for movement x (veh/hr)

$C_{m,x}$ = capacity of movement x (veh/hr)

T = analysis time period (=0.25 for 15 minute period)

T = 1 hr

Cp,x ~ Cm,x

$$d = (3600/1615) + 900*1*[(125.8/1615) - 1 + ((125.8/1615 - 1)^2 + (3600/1615)*(125.8/1615)/(450*1))^{(1/2)}] + 5 = 7.41724$$

LOS = A

Average Survey Response LOS from our Data Collection = E

Answers do not match.

Appendix C

The following is a sample calculation for data validation of collected responses by comparing accepted signalized intersection level of service equations to collected signalized intersection level of services.

Intersection: Claremont Boulevard and First Street, Claremont, California

Signalized Intersection Method- Southbound Through Movement

Lane width = 12’

No bike lane or shoulder present.

Wt = 12’ + 0’

Total Width = 87’

Fw = 0.0153*87’ – 0.2144*12’ = -1.2417

Vleft = 4

Vthrough = 203 veh/hr

Vright = 26 veh/hr

Nlanes = 2

Fv = 0.0066*(4 + 203 + 26)/(4*2) = 0.192225

Ib,int = 4.1324 + 0.192225 – 1.2417 = 3.082925

LOS = C

Average LOS Survey Score = C

Survey Average Appears Approximately Valid.

Appendix D

The following is a list of American League of Bicyclists approved Bicycle Friendly Communities and Universities for 2012. All sites surveyed in this report were selected from this list.

Current Bicycle Friendly Communities 2012

Click on the name of the community to learn more

Community	State	Award Level	Population	Fall 2012
Boulder	CO	Platinum	101,500	
Davis	CA	Platinum	63,722	
Portland	OR	Platinum	533,492	
Breckenridge	CO	Gold	4,540	
Corvallis	OR	Gold	53,165	
Durango	CO	Gold	16,887	
Eugene	OR	Gold	142,681	
Fort Collins	CO	Gold	118,652	
Jackson and Teton County	WY	Gold	18,251	
Madison	WI	Gold	221,551	
Minneapolis	MN	Gold	379,499	
Missoula	MT	Gold	66,788	
Palo Alto	CA	Gold	64,403	
San Francisco	CA	Gold	739,426	
Scottsdale	AZ	Gold	217,385	
Seattle	WA	Gold	563,374	
Stanford University	CA	Gold	13,315	
Steamboat Springs	CO	Gold	12,088	
Tucson & East Pima Region	AZ	Gold	512,023	
Ada County	ID	Silver	392,365	Moved Up
Ann Arbor	MI	Silver	114,028	
Arcata	CA	Silver	17,321	
Arlington	VA	Silver	210,280	
Aspen	CO	Silver	6,100	
Austin	TX	Silver	681,804	
Bellingham	WA	Silver	73,460	
Bend	OR	Silver	80,995	
Bloomington	IN	Silver	69,107	
Boston	MA	Silver	645,169	
Bozeman	MT	Silver	37,280	New
Burlington	VT	Silver	42,417	
Charlottesville	VA	Silver	43,475	
Carrboro	NC	Silver	18,162	
Chicago	IL	Silver	2,896,016	
Chico	CA	Silver	79,000	Moved Up
Claremont	CA	Silver	36,612	Moved Up
Colorado Springs	CO	Silver	360,890	
Columbia	MO	Silver	102,324	

Current Bicycle Friendly Communities 2012

Community	State	Award Level	Population	Fall 2012
Denver	CO	Silver	598,707	
Evanston	IL	Silver	74,486	New
Flagstaff	AZ	Silver	57,391	
Folsom	CA	Silver	63,960	Moved Up
Gainesville	FL	Silver	117,182	
Gunnison	CO	Silver	5,854	
Hilton Head Island	SC	Silver	33,862	
La Crosse	WI	Silver	51,818	
Long Beach	CA	Silver	466,520	
Longmont	CO	Silver	87,461	
Mountain View	CA	Silver	70,708	Moved Up
New York	NY	Silver	8,143,197	
Olympia	WA	Silver	44,460	
Park City and Snyderville Basin	UT	Silver	20,671	
Philadelphia	PA	Silver	1,454,382	Moved Up
Port Townsend	WA	Silver	8,334	
Presidio of San Francisco	CA	Silver	3,000	
Redmond	WA	Silver	49,637	
Sacramento	CA	Silver	456,394	
Salt Lake City	UT	Silver	181,743	
San Luis Obispo	CA	Silver	43,766	
Santa Cruz	CA	Silver	54,593	
Sisters	OR	Silver	1,925	
Tempe	AZ	Silver	172,589	
Venice	FL	Silver	22,146	New
Washington	DC	Silver	599,657	
Wood River Valley	ID	Silver	12,506	
Alameda	CA	Bronze	73,812	
Albany	OR	Bronze	48,770	
Albuquerque	NM	Bronze	448,607	
Alexandria	VA	Bronze	140,024	
Anchorage	AK	Bronze	284,994	
Arlington	MA	Bronze	42,844	
Arvada	CO	Bronze	107,050	
Ashland	OR	Bronze	19,522	
Asheville	NC	Bronze	83,393	
Athens-Clarke County	GA	Bronze	115,000	
Auburn	AL	Bronze	52,205	
Bainbridge Island	WA	Bronze	20,300	
Baltimore	MD	Bronze	631,000	

Current Bicycle Friendly Communities 2012

Community	State	Award Level	Population	Fall 2012
Baton Rouge	LA	Bronze	428,360	
Beaverton	OR	Bronze	79,350	
Bemidji	MN	Bronze	13,431	New
Bentonville	AR	Bronze	35,301	New
Bethesda	MD	Bronze	57,319	New
Billings	MT	Bronze	100,147	
Boca Raton	FL	Bronze	83,960	
Brentwood	CA	Bronze	40,007	
Brunswick	ME	Bronze	21,820	
Calistoga	CA	Bronze	5,300	
Carbondale	CO	Bronze	5,196	
Carmel	IN	Bronze	70,000	
Cary	NC	Bronze	119,745	
Castle Rock	CO	Bronze	50,028	New
Cedar Falls	IA	Bronze	36,145	
Cedar Rapids	IA	Bronze	12,6498	
Chandler	AZ	Bronze	252,257	
Chapel Hill	NC	Bronze	55,616	
Charleston	SC	Bronze	124,000	
Charlotte	NC	Bronze	648,387	
Chattanooga	TN	Bronze	167,674	
Cincinnati	OH	Bronze	297,000	
Coeur d'Alene	ID	Bronze	41,983	
Columbia	SC	Bronze	116,278	
Columbus	IN	Bronze	44,061	
Columbus	OH	Bronze	748,000	
Concord	NH	Bronze	43,225	
Conway	AR	Bronze	59,511	
Cottonwood	AZ	Bronze	12,426	
Cupertino	CA	Bronze	50,479	
Davidson	NC	Bronze	10,300	
Dayton	OH	Bronze	154,200	
Decatur	GA	Bronze	19,335	New
Des Moines	IA	Bronze	203,433	
Durham	NC	Bronze	212,789	
Eau Claire	WI	Bronze	101,353	
Emeryville	CA	Bronze	10,080	New
Fayetteville	AR	Bronze	67,158	
Fitchburg	WI	Bronze	25,260	New
Fort Wayne	IN	Bronze	253,691	

Current Bicycle Friendly Communities 2012

Community	State	Award Level	Population	Fall 2012
Franklin	PA	Bronze	7,212	
Frederick	MD	Bronze	65,239	
Fresno	CA	Bronze	500,121	
Gilbert	AZ	Bronze	196,000	
Golden	CO	Bronze	18,026	
Goshen	IN	Bronze	31,719	
Grand Rapids	MI	Bronze	688,937	
Greater Mankato	MN	Bronze	52,703	
Greensboro	NC	Bronze	258,671	
Greenville	SC	Bronze	57,400	
Gresham	OR	Bronze	101,537	
Harrisonburg	VA	Bronze	48,814	
Hoboken	NJ	Bronze	50,005	New
Houghton	MI	Bronze	8,238	
Huntington Beach	CA	Bronze	202,250	
Indianapolis & Marion County	IN	Bronze	872,842	
Iowa City	IA	Bronze	65,219	
Irvine	CA	Bronze	186,220	
Juneau	AK	Bronze	30,711	
Kansas City	MO	Bronze	482,228	
Keene	NH	Bronze	24,769	
Knoxville	TN	Bronze	177,646	
Lakeland	FL	Bronze	97,422	New
Lakewood	CO	Bronze	146,000	
Lansing	MI	Bronze	111,304	
Las Cruces	NM	Bronze	92,235	
Lawrence	KS	Bronze	88,664	
Lee's Summit	MO	Bronze	92,188	New
Lewes	DE	Bronze	2,747	
Lexington-Fayette County	KY	Bronze	246,800	
Lincoln	NE	Bronze	258,379	
Los Altos	CA	Bronze	27,483	
Los Angeles	CA	Bronze	3,792,621	New
Louisville	KY	Bronze	700,030	
Manhattan	KS	Bronze	52,281	
Marquette	MI	Bronze	21,000	
Menlo Park	CA	Bronze	30,648	
Mesa	AZ	Bronze	437,454	
Miami	FL	Bronze	418,480	New
Midland	MI	Bronze	41,863	New

Current Bicycle Friendly Communities 2012

Community	State	Award Level	Population	Fall 2012
Milwaukee	WI	Bronze	554,965	
Morgantown	WV	Bronze	29,660	
Napa	CA	Bronze	75,000	
Naperville	IL	Bronze	128,358	
Nashville-Davidson County	TN	Bronze	601,222	New
Newark	DE	Bronze	29,886	
New Orleans	LA	Bronze	343,829	
Norman	OK	Bronze	112,551	
North Little Rock	AR	Bronze	60,433	
Northampton	MA	Bronze	28,978	
Oakland	CA	Bronze	365,875	
Ocean City	NJ	Bronze	11,701	New
Oceanside	CA	Bronze	174,925	
Omaha	NE	Bronze	408,958	
Orange County	CA	Bronze	3,010,232	New
Orlando	FL	Bronze	205,648	
Oxford	MS	Bronze	16,727	
Pittsburgh	PA	Bronze	316,718	
Portage	MI	Bronze	46,143	
Provo	UT	Bronze	117,489	New
Raleigh	NC	Bronze	405,612	
Redding	CA	Bronze	89,470	
Reno-Sparks Washoe County	NV	Bronze	421,407	
Richmond	VA	Bronze	205,533	New
Ridgeland	MS	Bronze	22,809	
River Falls	WI	Bronze	15,308	New
Riverside	CA	Bronze	311,575	
Roanoke	VA	Bronze	94,911	
Rochester	MN	Bronze	102,437	
Rochester	NY	Bronze	210,565	New
Rock Hill	SC	Bronze	66,154	New
Rockville	MD	Bronze	61,209	New
Roseville	CA	Bronze	109,154	
Roswell	GA	Bronze	85,920	
Saint Paul	MN	Bronze	281,244	
Salem	OR	Bronze	152,239	
San Antonio	TX	Bronze	1,144,646	
San Jose	CA	Bronze	912,332	
Sanibel	FL	Bronze	6,064	
Santa Clara	CA	Bronze	110,376	

Current Bicycle Friendly Communities 2012

Community	State	Award Level	Population	Fall 2012
Santa Fe	NM	Bronze	67,947	
Santa Monica	CA	Bronze	87,400	
Schaumburg	IL	Bronze	73,346	
Sedona	AZ	Bronze	10,192	
Shawnee	KS	Bronze	57,628	
Sheboygan County	WI	Bronze	115,507	
Shorewood	WI	Bronze	13,267	
Simsbury	CT	Bronze	23,256	
Sioux Falls	SD	Bronze	154,000	
Sitka	AK	Bronze	8,883	
Snohomish	WA	Bronze	9,098	
Sonoma	CA	Bronze	9,128	
Somerville	MA	Bronze	77,478	
South Bend	IN	Bronze	100,842	
South Lake Tahoe	CA	Bronze	23,609	
South Sioux City	NE	Bronze	11,925	
South Windsor	CT	Bronze	24,409	
Spartanburg	SC	Bronze	39,487	
Spokane	WA	Bronze	204,428	
Springfield	MO	Bronze	156,206	
State College - Centre Region	PA	Bronze	92,096	
Stillwater	OK	Bronze	45,688	New
St. Louis	MO	Bronze	350,759	
St. Petersburg	FL	Bronze	249,090	
Summit County	CO	Bronze	29,626	
Sunnyvale	CA	Bronze	131,760	
Tacoma	WA	Bronze	198,387	
Tallahassee	FL	Bronze	176,336	
The Woodlands Township	TX	Bronze	97,023	
Thousand Oaks	CA	Bronze	127,644	
Tybee Island	GA	Bronze	3,713	
Traverse City	MI	Bronze	14,532	
Tulsa	OK	Bronze	384,037	
University Heights	IA	Bronze	1,051	
Urbana	IL	Bronze	40,550	
Vail	CO	Bronze	4,806	
Vancouver	WA	Bronze	156,600	
Westerville	OH	Bronze	36,120	New
West Windsor	NJ	Bronze	27,165	
Wilmington	NC	Bronze	101,353	

Current Bicycle Friendly Communities 2012

Community	State	Award Level	Population	Fall 2012
Windsor	CA	Bronze	26,801	New

Current Bicycle Friendly Universities
Spring 2013

Go to bikeleague.org/programs/bicyclefriendlyamerica/ to learn more about these universities

College/ University Name	Award	Location	Spring 2013
Stanford University	Platinum	Stanford, CA	
Portland State University	Gold	Portland, OR	Moved Up
University of California	Gold	Davis, CA	
University of California	Gold	Santa Barbara, CA	
Boise State University	Silver	Boise, ID	
California State University	Silver	Long Beach, CA	
Colorado State University	Silver	Fort Collins, CO	
Georgia Institute of Technology	Silver	Atlanta, GA	
Harvard University	Silver	Cambridge, MA	New
Lincoln Memorial University	Silver	Harrogate, TN	New
Northern Arizona University	Silver	Flagstaff, AZ	
Oregon State University	Silver	Corvallis, OR	
University of Arizona	Silver	Tucson, AZ	
University of California	Silver	Irvine, CA	
University of California	Silver	Berkeley, CA	New
University of Maryland	Silver	College Park, MD	
University of Minnesota	Silver	Twin Cities, MN	
University of Nebraska	Silver	Lincoln, NE	New
University of Oregon	Silver	Eugene, OR	
University of Utah	Silver	Salt Lake City, UT	
University of Washington	Silver	Seattle, WA	
University of Wisconsin	Silver	Madison, WI	
Virginia Commonwealth University	Silver	Richmond, VA	
California Institute of Technology	Bronze	Pasadena, CA	New
Chatham University	Bronze	Pittsburgh, PA	
Clemson University	Bronze	Clemson, SC	New
Cornell University	Bronze	Ithaca, NY	
Duke University	Bronze	Durham, NC	
Eastern Mennonite University	Bronze	Harrisonburg, VA	
Emory University	Bronze	Atlanta, GA	

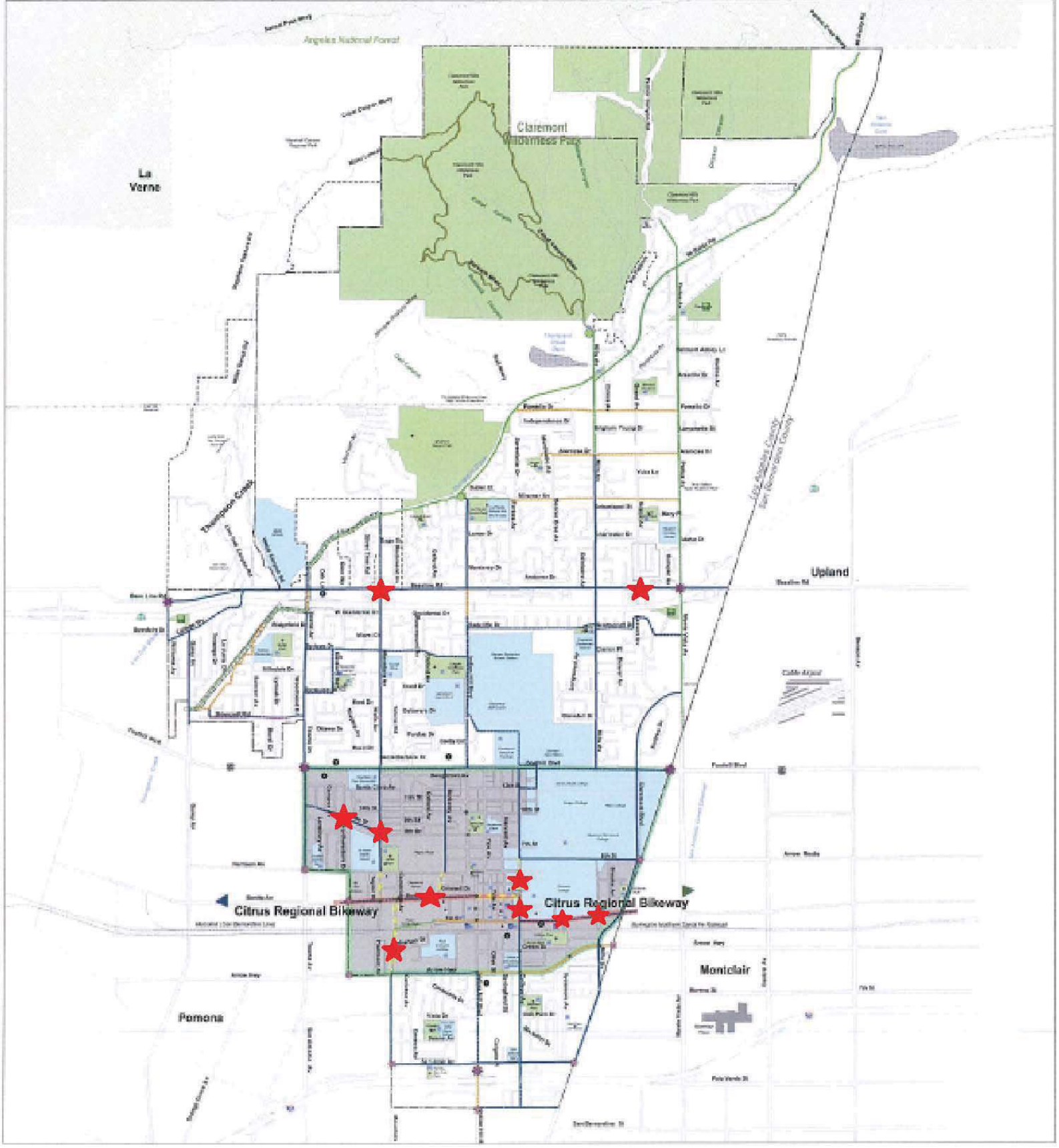
Current Bicycle Friendly Universities
Spring 2013

Go to bikeleague.org/programs/bicyclefriendlyamerica/ to learn more about these universities

College/ University Name	Award	Location	Spring 2013
George Mason University	Bronze	Fairfax, VA	
Gustavus Adolphus College	Bronze	Saint Peter. MA	New
Indiana University	Bronze	Bloomington, IN	
James Madison University	Bronze	Harrisonburg, VA	New
Michigan State University	Bronze	East Lansing, MI	
Michigan Technological University	Bronze	Houghton, MI	New
New Mexico State University	Bronze	Las Cruces, NM	New
North Carolina State University	Bronze	Raleigh, NC	
Ohio State University	Bronze	Columbus, OH	
Old Dominion University	Bronze	Norfolk, VA	New
Pennsylvania State University	Bronze	University Park, PA	
Princeton University	Bronze	Princeton, NJ	
Rochester Institute of Technology	Bronze	Rochester, NY	
State University of New York	Bronze	Buffalo, NY	
University of California	Bronze	Los Angeles, CA	
University of Denver	Bronze	Denver, CO	
University of Illinois	Bronze	Champaign, IL	
University of Kentucky	Bronze	Lexington, KY	
University of Miami	Bronze	Coral Gables, FL	
University of Michigan	Bronze	Ann Arbor, MI	
University of Michigan	Bronze	Flint, MI	New
University of New England	Bronze	Biddeford, ME	New
University of North Carolina	Bronze	Greensboro, NC	
University of North Carolina	Bronze	Wilmington, NC	
University of South Carolina	Bronze	Columbia, SC	
University of Vermont	Bronze	Burlington, VT	
Virginia Tech	Bronze	Blacksburg, VA	New
Yale University	Bronze	New Haven, CT	

Appendix E

The following images are maps of the selected survey sites shown on the official Bike Maps of the cities selected for data collection. These maps are the ones submitted to the American League of Bicyclists by the individual communities at the time of application for 2012 recognition as Bicycle Friendly Communities. Locations of selected survey intersections are denoted by a large star.



Bike Facilities

Bikeways

- Bike Path (Class I)
- Proposed Bike Path (Class I)
- Bike Lane (Class II)
- Proposed Bike Lane (Class II)
- Bike Lane (Class III)
- Proposed Bike Lane (Class II)
- Citrus Regional Bikeway
- Bike Priority Zone
- Bike Parking
- Bike Lockers
- Bike Station

Park Trails

- Claremont Hillside Wilderness Park Trail
- Trail Staging Area/ Trail Parking

Base Map Features

- Claremont City Boundary
- Claremont Sphere of Influence

Park and School Facilities

- Parks
- Proposed Park
- Schools
- Los Angeles National Forest
- Proposed Sharrow

- Major Gateway
- Secondary Gateway
- Proposed Bike Detection

Mixed Use Areas

1. Peppertree Square Mixed Use
2. Transportation Oriented Development
3. Old School House/Hotel/Office Mixed Use
4. Foothill Boulevard Corridor Mixed Use
5. Base Line Road/Towne Avenue Mixed Use

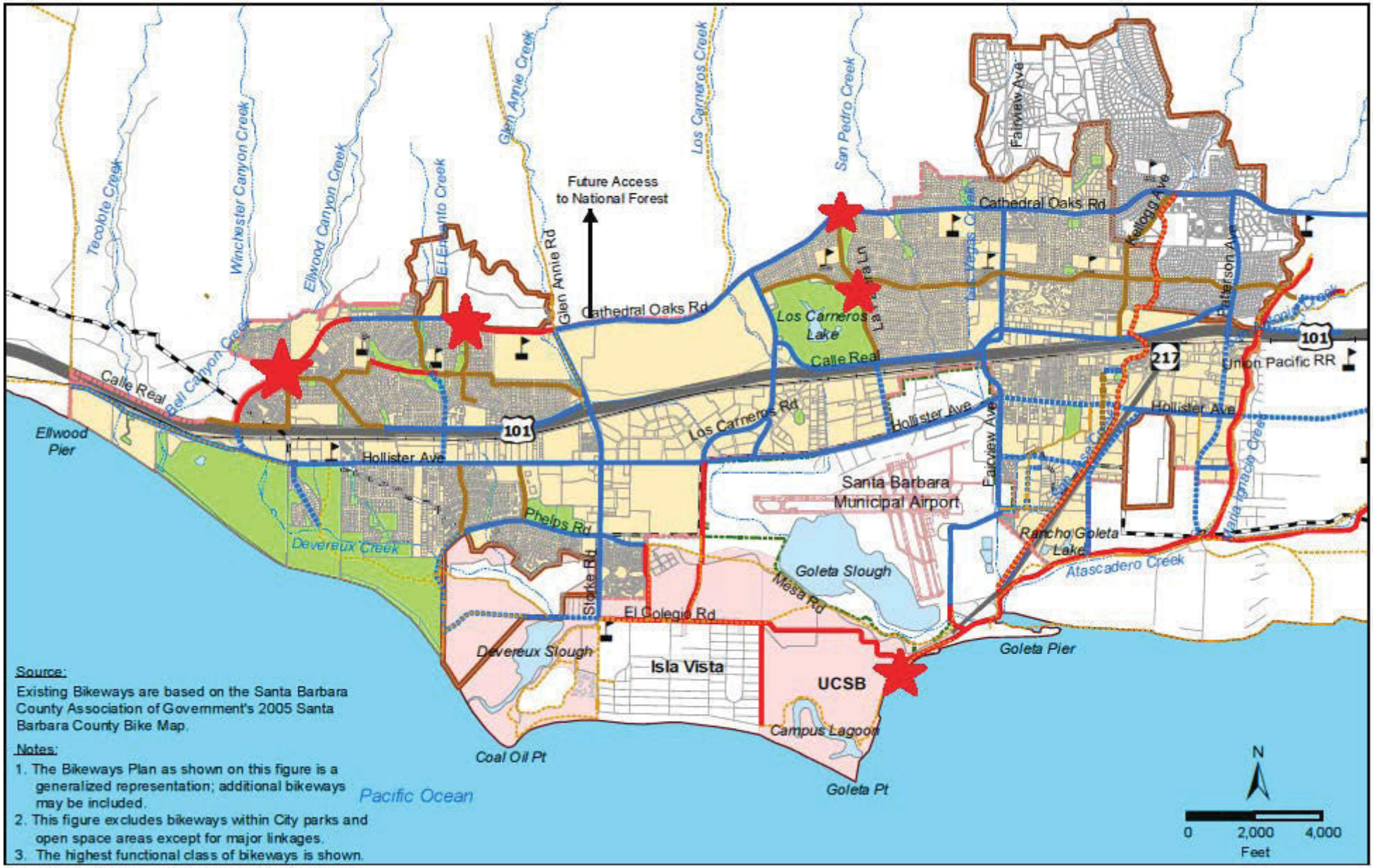
- Community Center
- Post Office
- City Hall
- Library
- Cemetery
- Garner House
- Claremont Depot

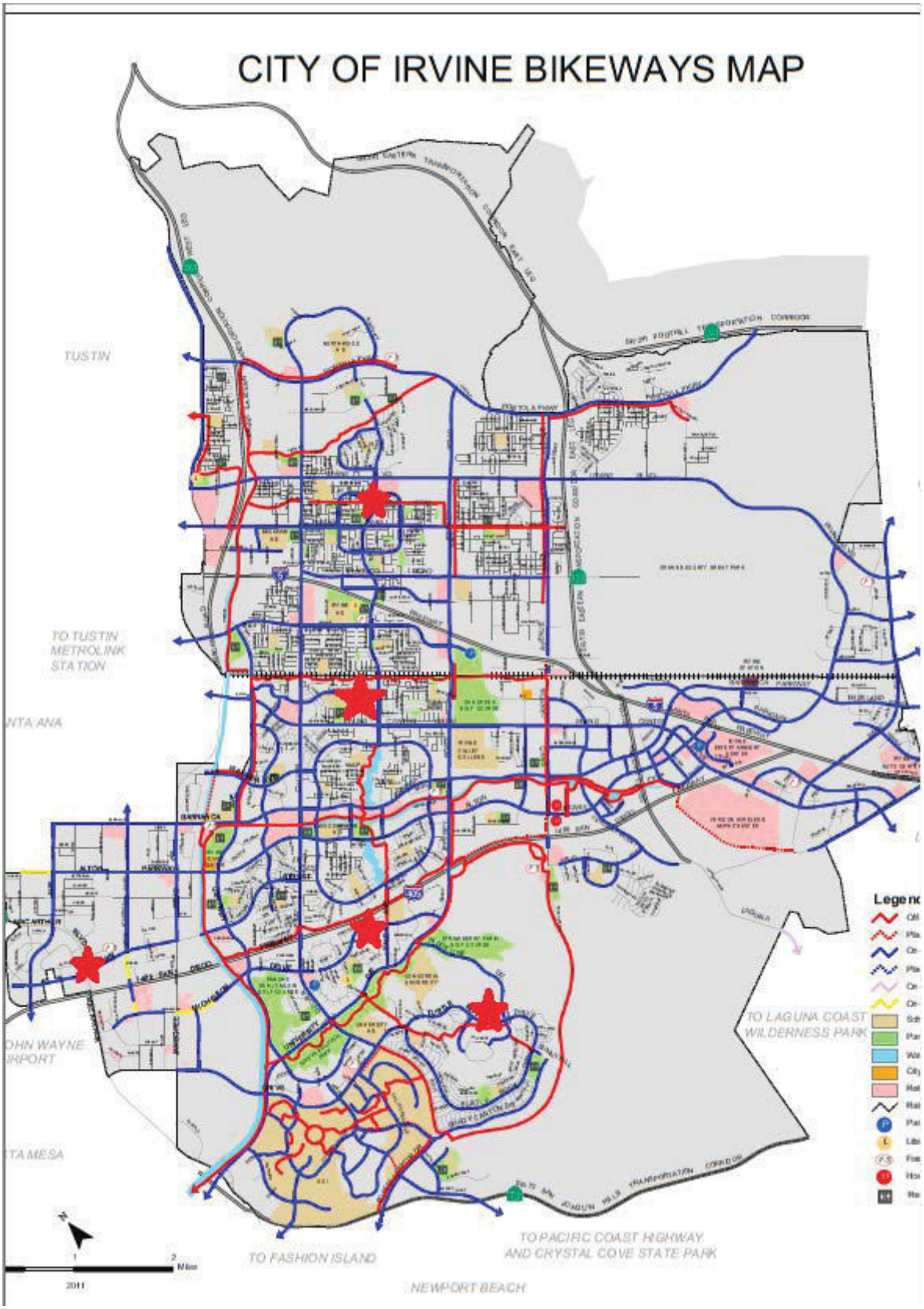
claremont · california · 1887 ·

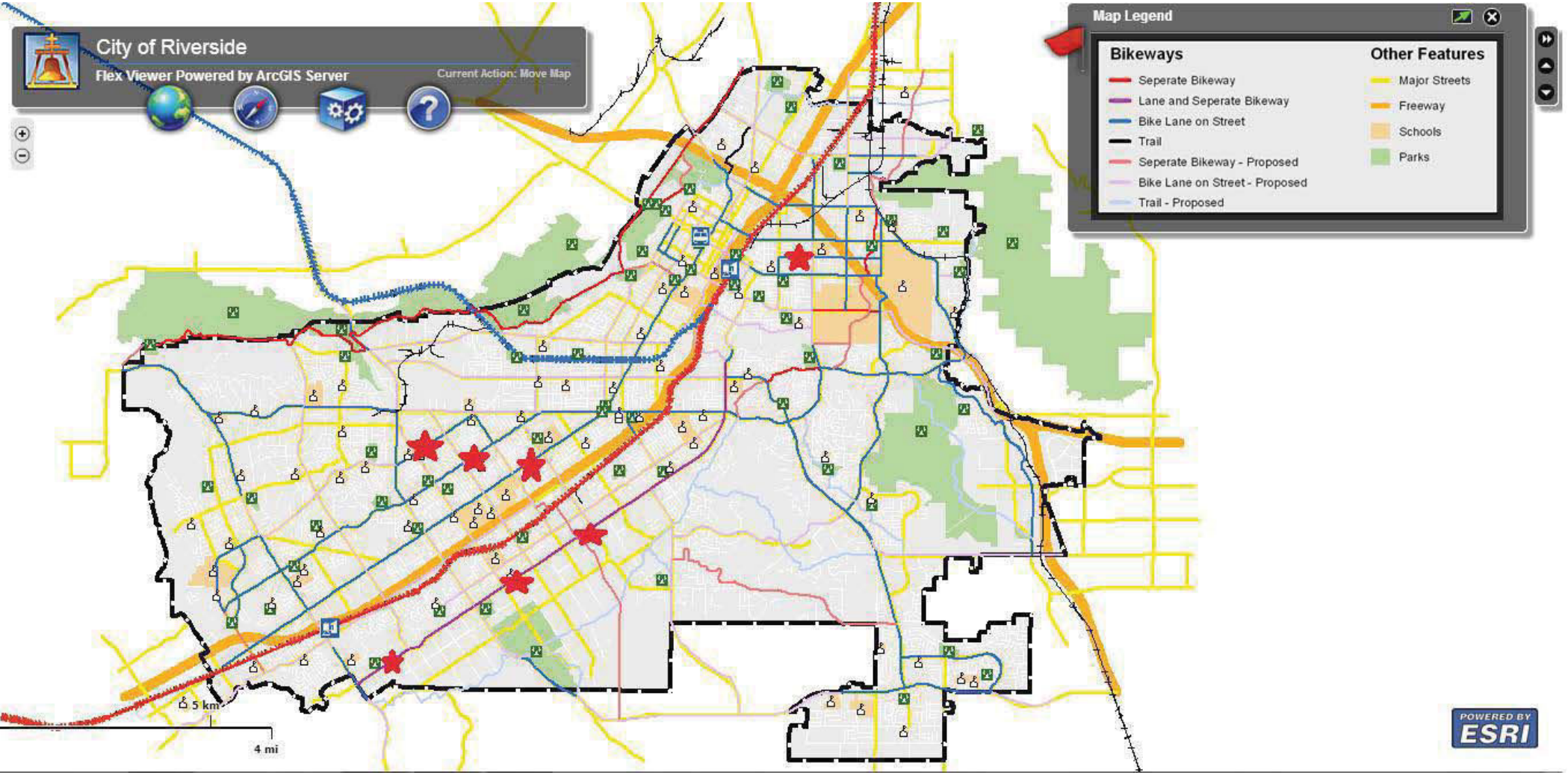
Bike Plan

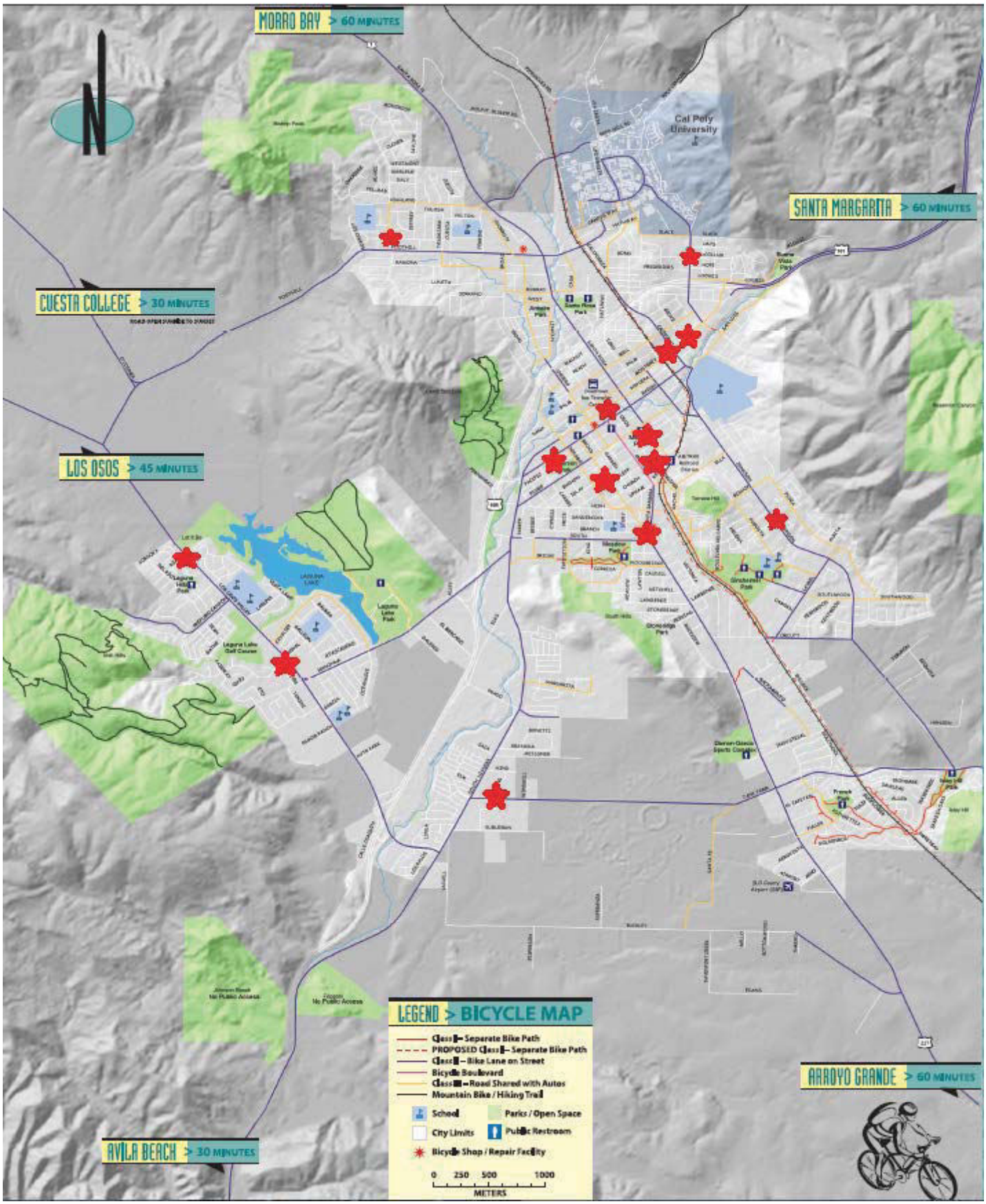
UPDATED: APRIL 2011

CLAREMONT BICYCLE PLAN


Future Access to National Forest
Cathedral Oaks Rd
Los Carneros Lake
Calle Real
Hollister Ave
Los Carneros Rd
Fairview Ave
Santa Barbara Municipal Airport
Rancho Goleta Lake
Goleta Slough
Atascadero Creek
Union Pacific RR
101
217
Ellwood Pier
Devereux Creek
Phelps Rd
Storke Rd
El Colegio Rd
Mesa Rd
Devereux Slough
Isla Vista
UCSB
Campus Lagoon
Goleta Pier
Coal Oil Pt
Goleta Pt
Pacific Ocean
Tecolote Creek
Winchester Canyon Creek
Ellwood Canyon Creek
El Encanto Creek
Glen Annie Creek
Los Carneros Creek
San Pedro Creek
Bell Canyon Creek
Maria Ignacia Creek
Source:
Existing Bikeways are based on the Santa Barbara County Association of Government's 2005 Santa Barbara County Bike Map.
Notes:
1. The Bikeways Plan as shown on this figure is a generalized representation; additional bikeways may be included.
2. This figure excludes bikeways within City parks and open space areas except for major linkages.
3. The highest functional class of bikeways is shown.
N
0
2,000
4,000
Feet


CITY OF IRVINE BIKEWAYS MAP
TUSTIN
TO TUSTIN METROLINK STATION
NTA ANA
OHN WAYNE IRPORT
TA MESA
TO FASHION ISLAND
NEWPORT BEACH
TO PACIFIC COAST HIGHWAY AND CRYSTAL COVE STATE PARK
TO LAGUNA COAST WILDERNESS PARK
Legend
2011


City of Riverside
Flex Viewer Powered by ArcGIS Server
Current Action: Move Map
Map Legend
Bikeways
Seperate Bikeway
Lane and Seperate Bikeway
Bike Lane on Street
Trail
Seperate Bikeway - Proposed
Bike Lane on Street - Proposed
Trail - Proposed
Other Features
Major Streets
Freeway
Schools
Parks
5 km
4 mi
POWERED BY ESRI


MORRO BAY > 60 MINUTES
SANTA MARGARITA > 60 MINUTES
CUESTA COLLEGE > 30 MINUTES
LOS OSOS > 45 MINUTES
AVILA BEACH > 30 MINUTES
ARROYO GRANDE > 60 MINUTES
Cal Poly University
LEGEND > BICYCLE MAP
Class I – Separate Bike Path
PROPOSED Class I – Separate Bike Path
Class II – Bike Lane on Street
Bicycle Boulevard
Class III – Road Shared with Autos
Mountain Bike / Hiking Trail
School
Parks / Open Space
City Limits
Public Restroom
Bicycle Shop / Repair Facility
0 250 500 1000
METERS

Appendix F

The following are the scanned field data collection pages collected on-site at each survey location.

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: College Avenue / Fourth Street

City: Claremont

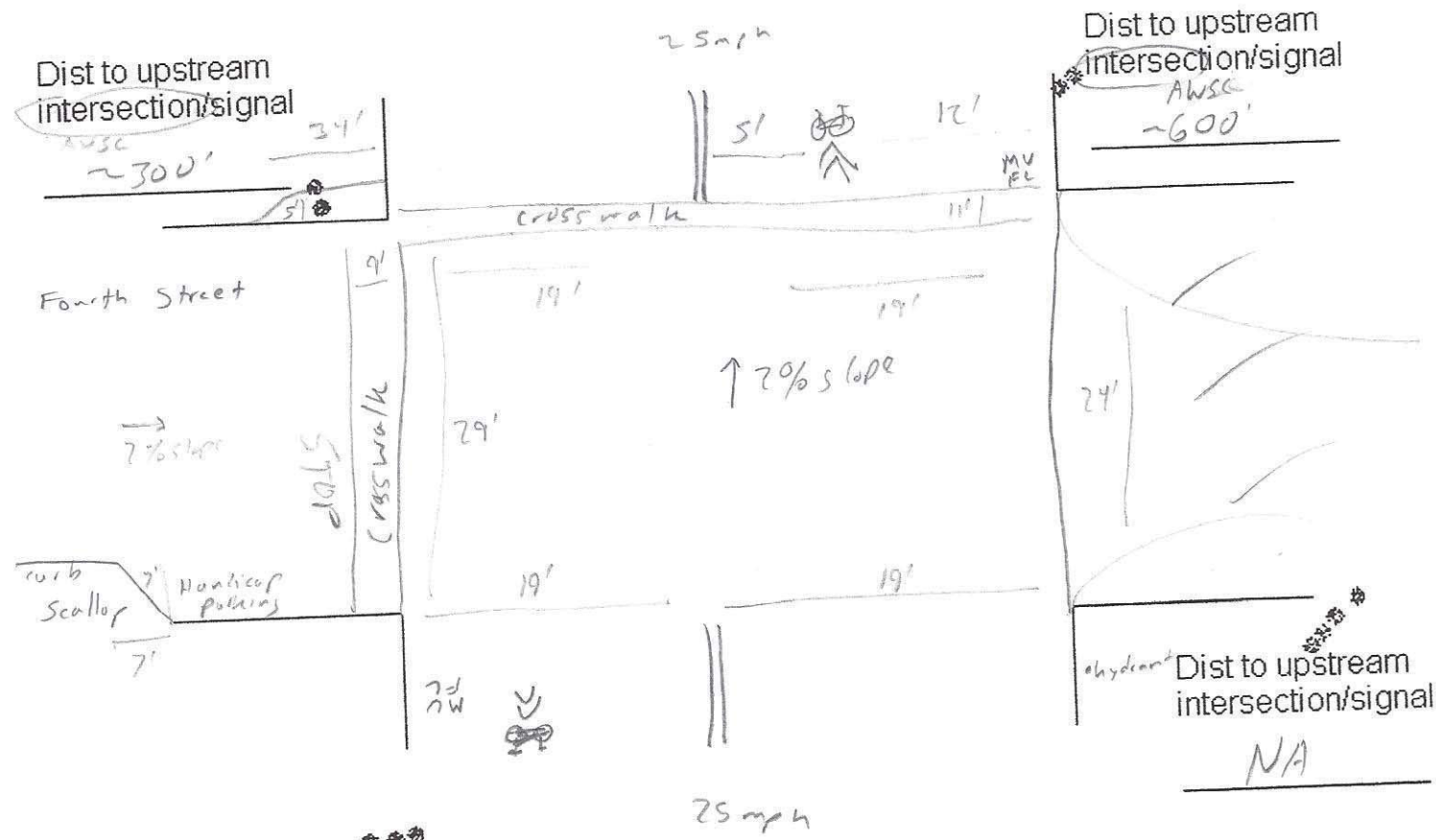
Location: (Southern CA) Northern CA Central CA Other

Intersection Type: (T) +

Data Collection Time: 8:00 - 9:00

Intersection Geometry:

North Arrow:



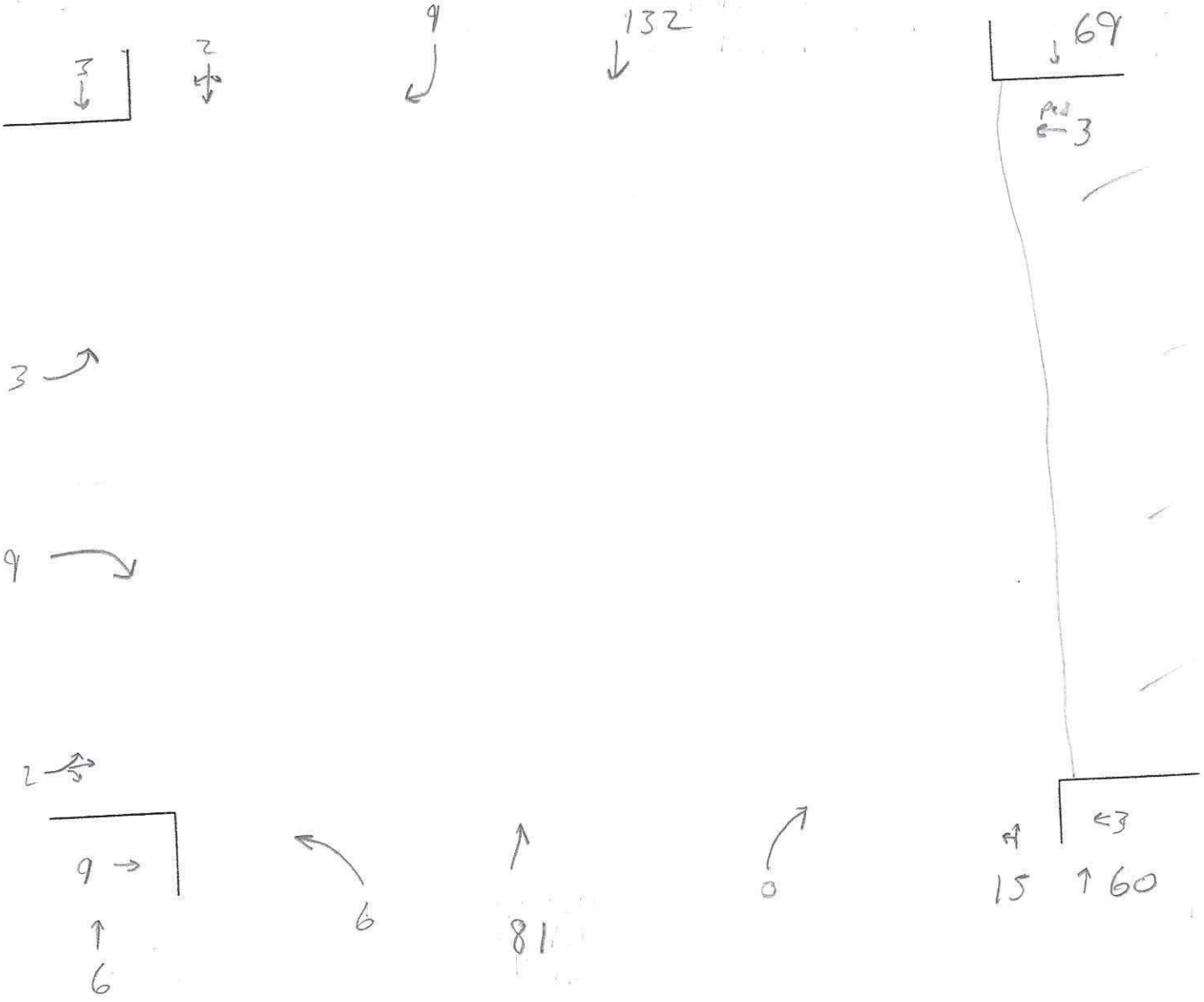
Comments: Normally, Fourth Street does go through as a four way intersection; But it is temporarily blocked off for long term construction. Sharrows! May use Full lane Signs. Parking allowed along street side. Pedestrians seperated from Street by large hedge (~20')

Nathan Johnston

Intersection: College Avenue / Fourth Street

Time Period: 8:00 - 9:00

Volumes:



Cal Poly San Luis Obispo

Nathan Johnston

Intersection: College Avenue / Fourth Street

Heavy Vehicles:

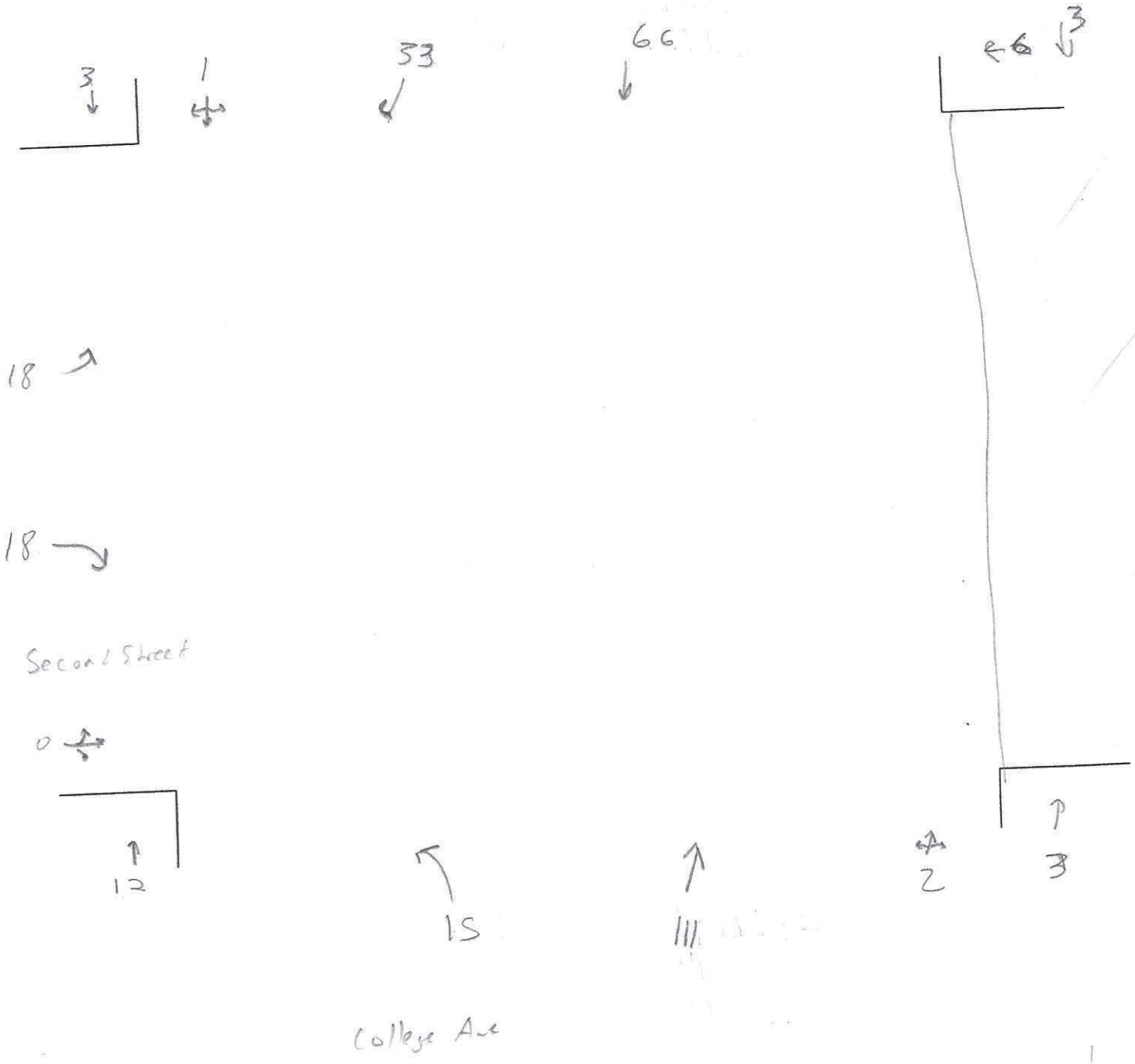
Comments: Trash trucks, Construction trucks, and normal tractor trailers. College is an approved truck route through the city.
Fourth Street has trees that inhibit large vehicles.

Nathan Johnston

Intersection: College Avenue / Second Street

Time Period: 9:10 - 10:10

Volumes:

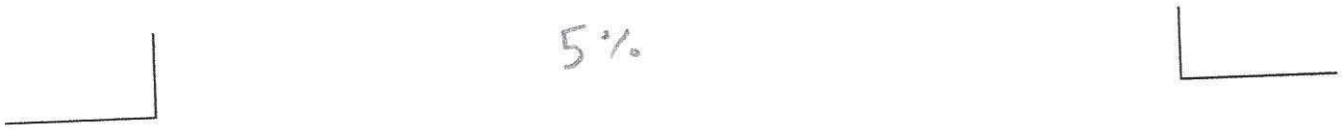


Nathan Johnston

Cal Poly San Luis Obispo

Intersection: College Avenue / Second Street

Heavy Vehicles:



3%

Second Street

Comments: Post office on Second Street

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: College Avenue/ Second Street

City: Claremont

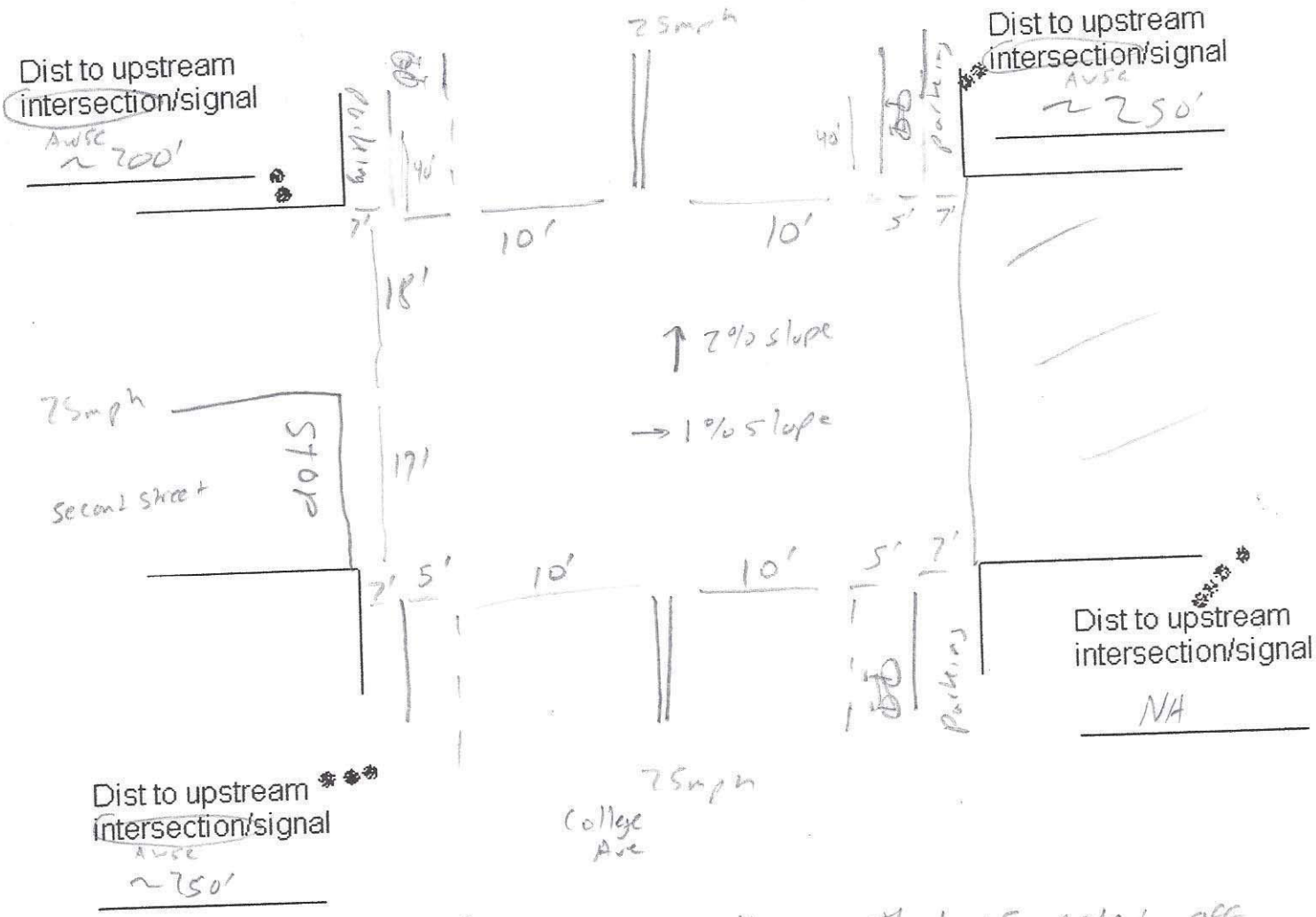
Location: (Southern CA) Northern CA Central CA Other

Intersection Type: (T) +

Data Collection Time: 9:10 - 10:10

Intersection Geometry:

North Arrow:



Comments: there is a walkway that is gated off on east side of street. Bike and parking lanes painted on college. On north side, parking lane ends 40' north of intersection. (Not the case on south side) No parking w/in 40' of intersection on college due to red curb in any case.

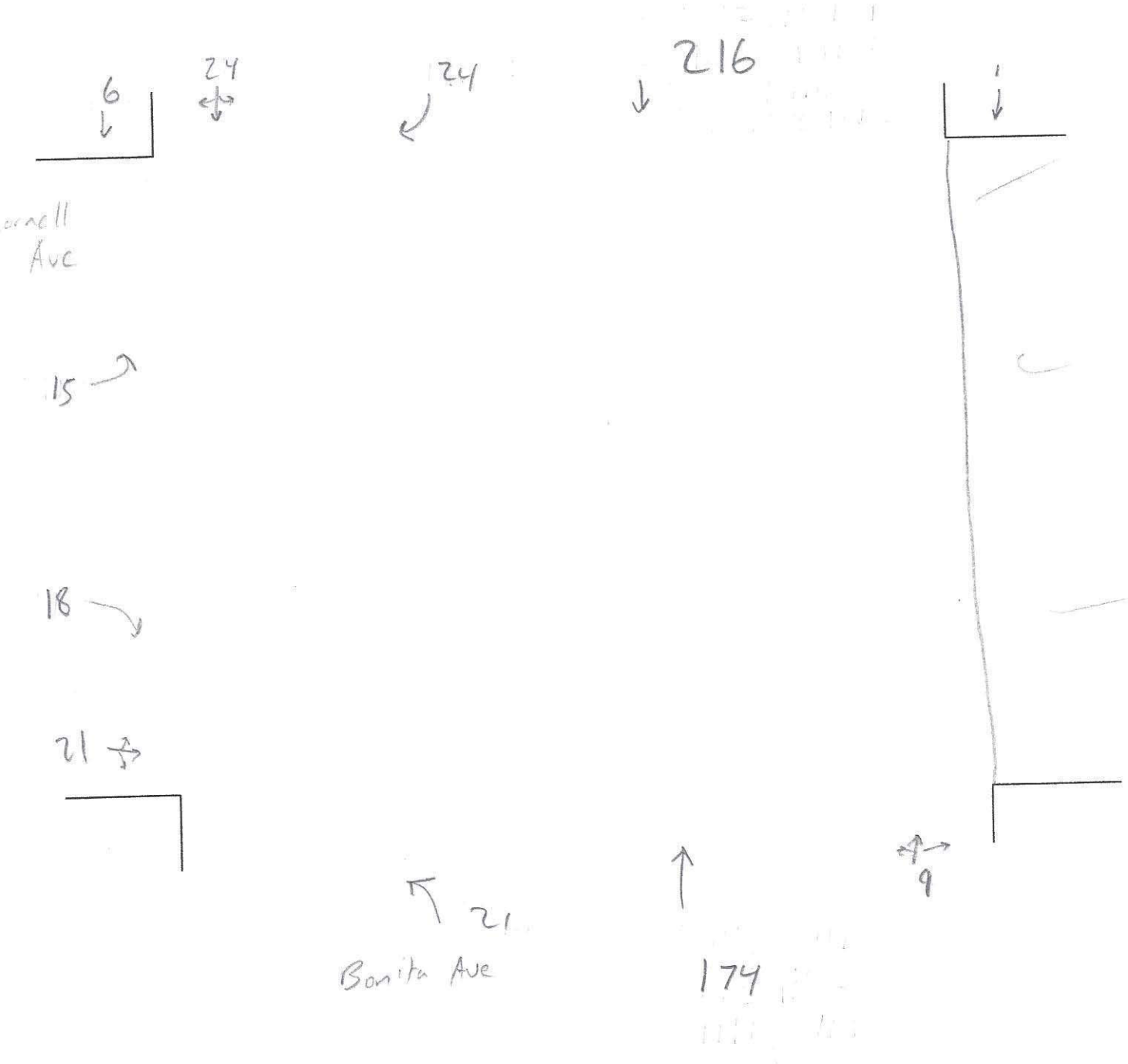
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Cornell Avenue / Bonita Avenue

Time Period: 10:20 - 11:20 7/5/13

Volumes:



Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Bonita Avenue / Cornell Avenue

Heavy Vehicles:

Comments: Coincidence that there is the same fire station adjacent to police station

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Bonita Avenue / Cornell Avenue

City: Claremont

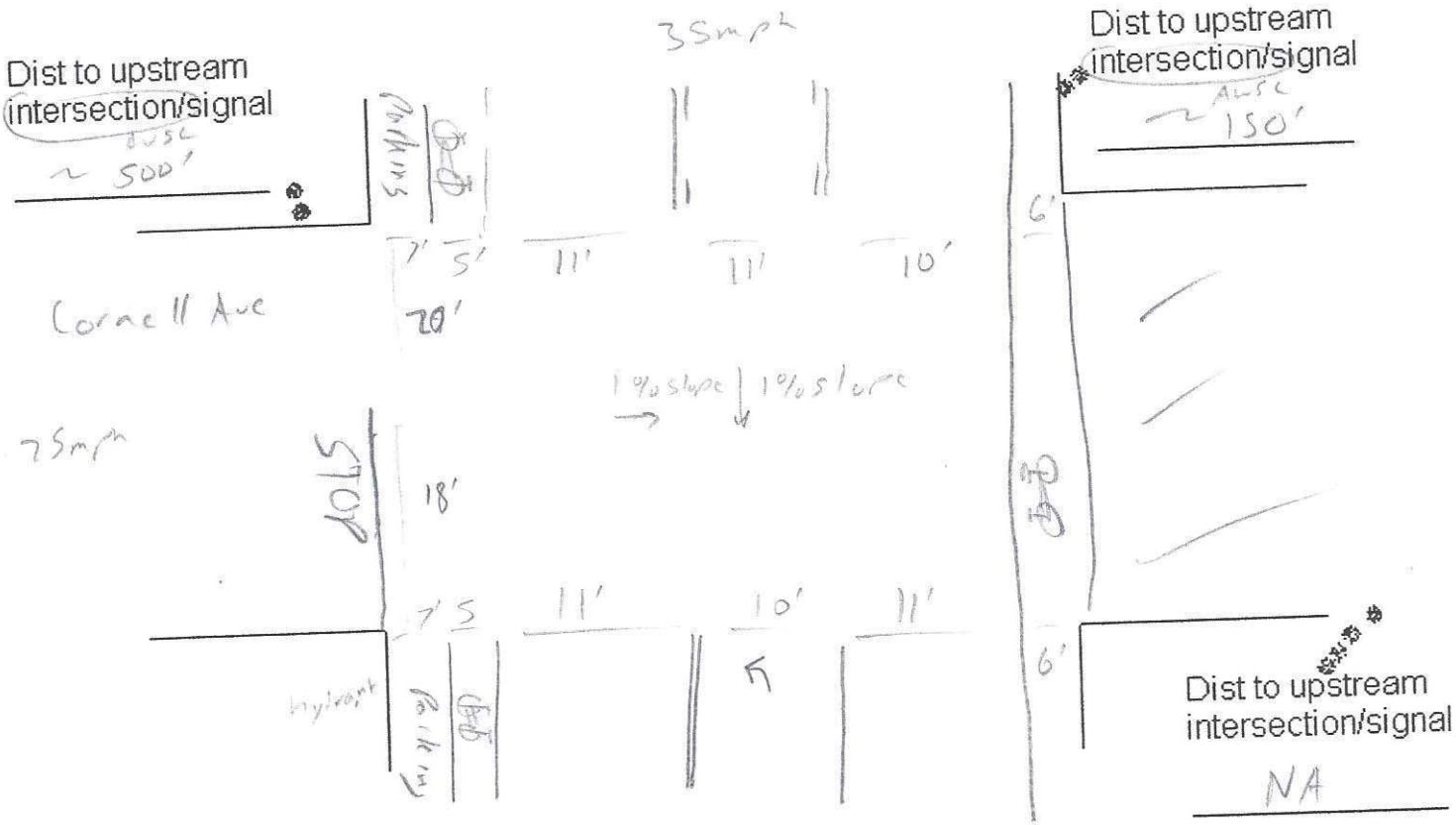
Location: (Southern CA) Northern CA Central CA Other

Intersection Type: (T) +

Data Collection Time: 10:20 - 11:20 7/5/13 (Friday)

Intersection Geometry:

North Arrow:



Comments: Police Station on South West Corner

Bike Corridor - Citrus Bikeway. (Signage)

Bike lanes set back 30' from intersection.

No parking Bike lane Signs on North Side of Street.

1

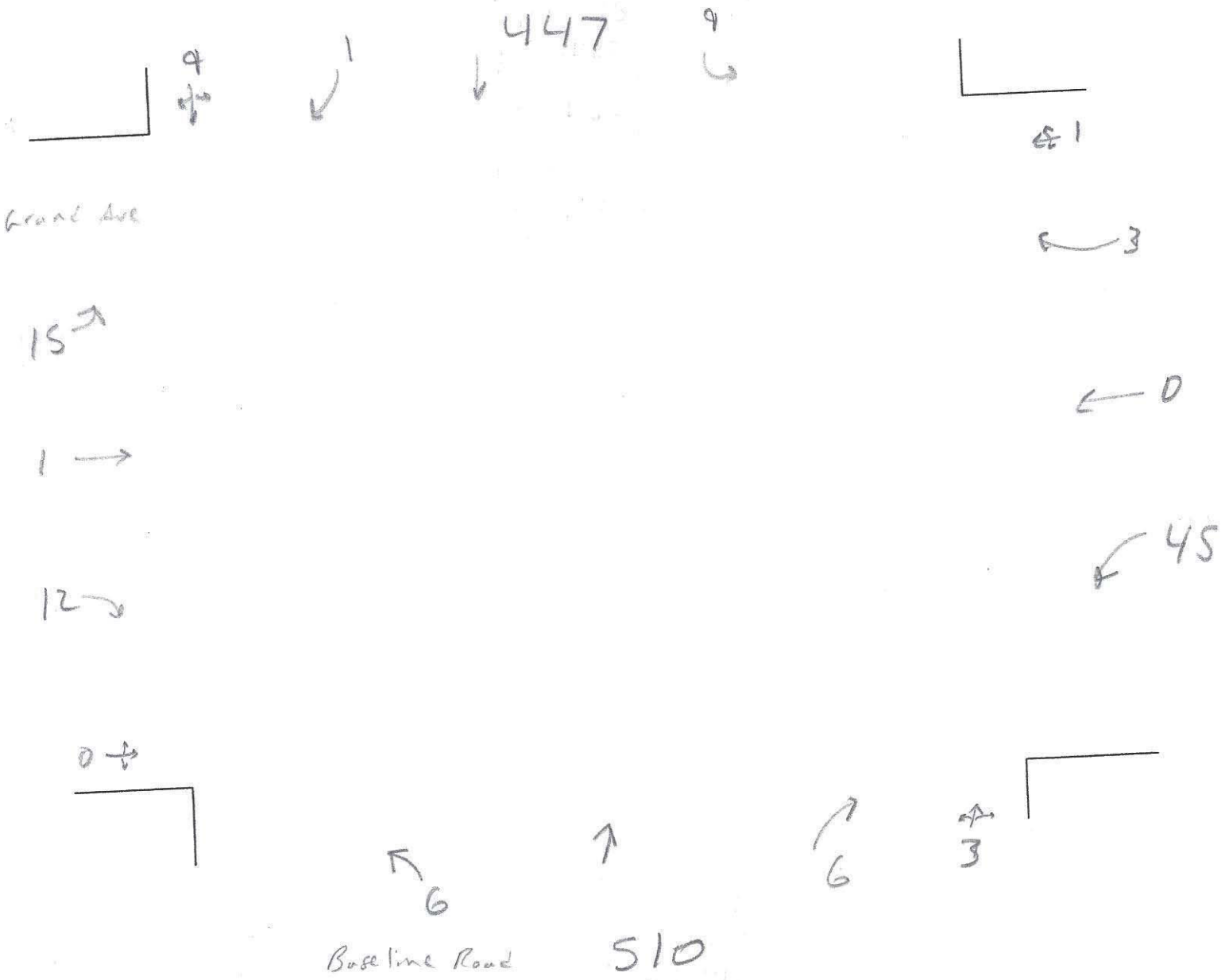
Cal Poly San Luis Obispo

Nathan Johnston

Intersection: Baseline Road / Grand Avenue

Time Period: 11:30-12:30 7/5/13

Volumes:



Cal Poly San Luis Obispo

Nathan Johnston

Intersection: Baseline Road / Grand. Ave

Heavy Vehicles:

3%

1%

3%

Comments: Baseline is old state Route 30 & is established truck route.

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Baseline Road / Grand Avenue

City: Claremont

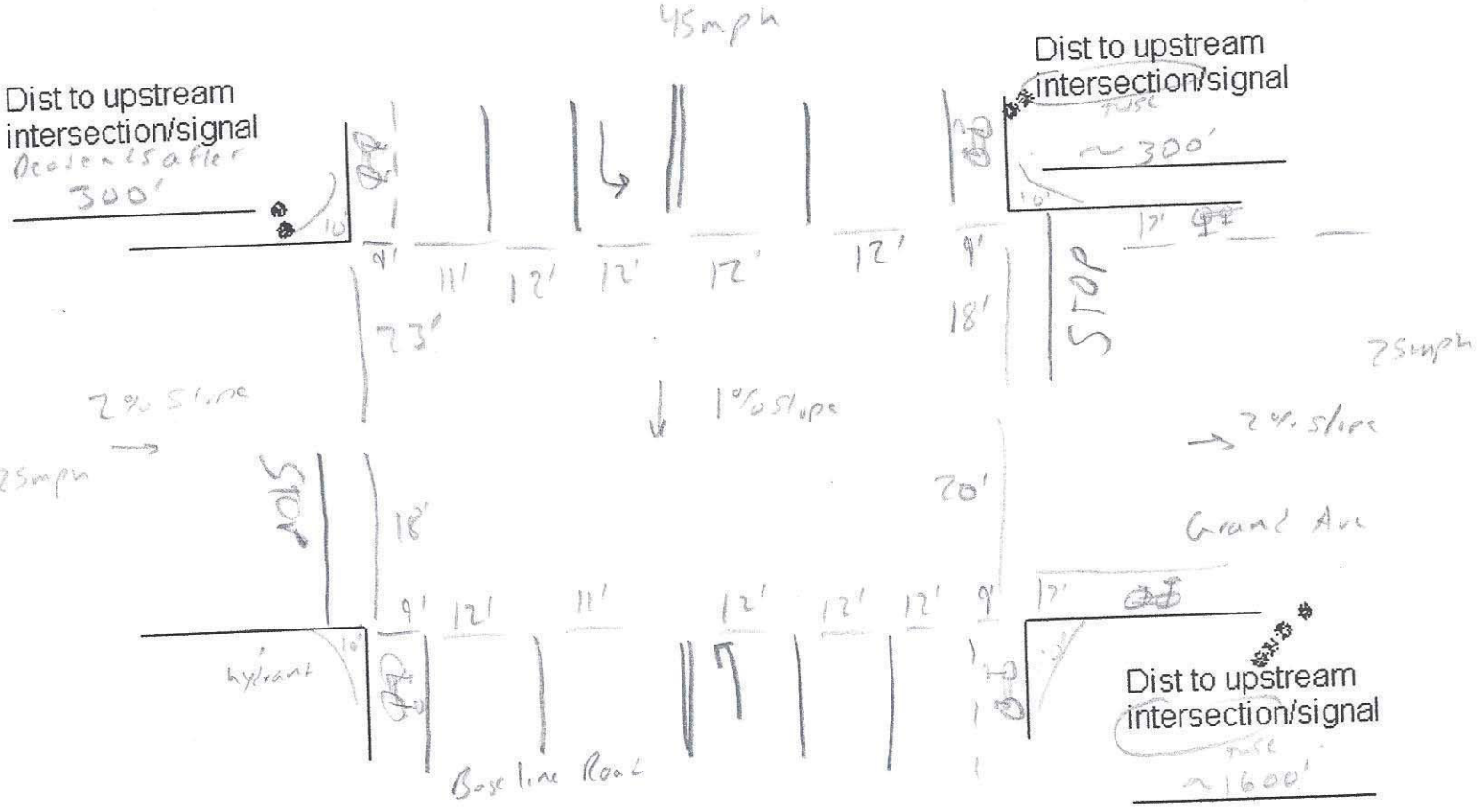
Location: (Southern CA) Northern CA Central CA Other

Intersection Type: T (+)

Data Collection Time: 11:30-12:30 7/5/13

Intersection Geometry:

North Arrow:



Comments: Church on S.E. corner. Apartment complex entrance on Grand South side. Parking allowed in bike lane. Faded bike lanes on North Grand. Was center divider but it is too faded not to be seen

Cal Poly San Luis Obispo

Nathan Johnston

Intersection: Butte Street / Vanderbilt Ave

City: Claremont

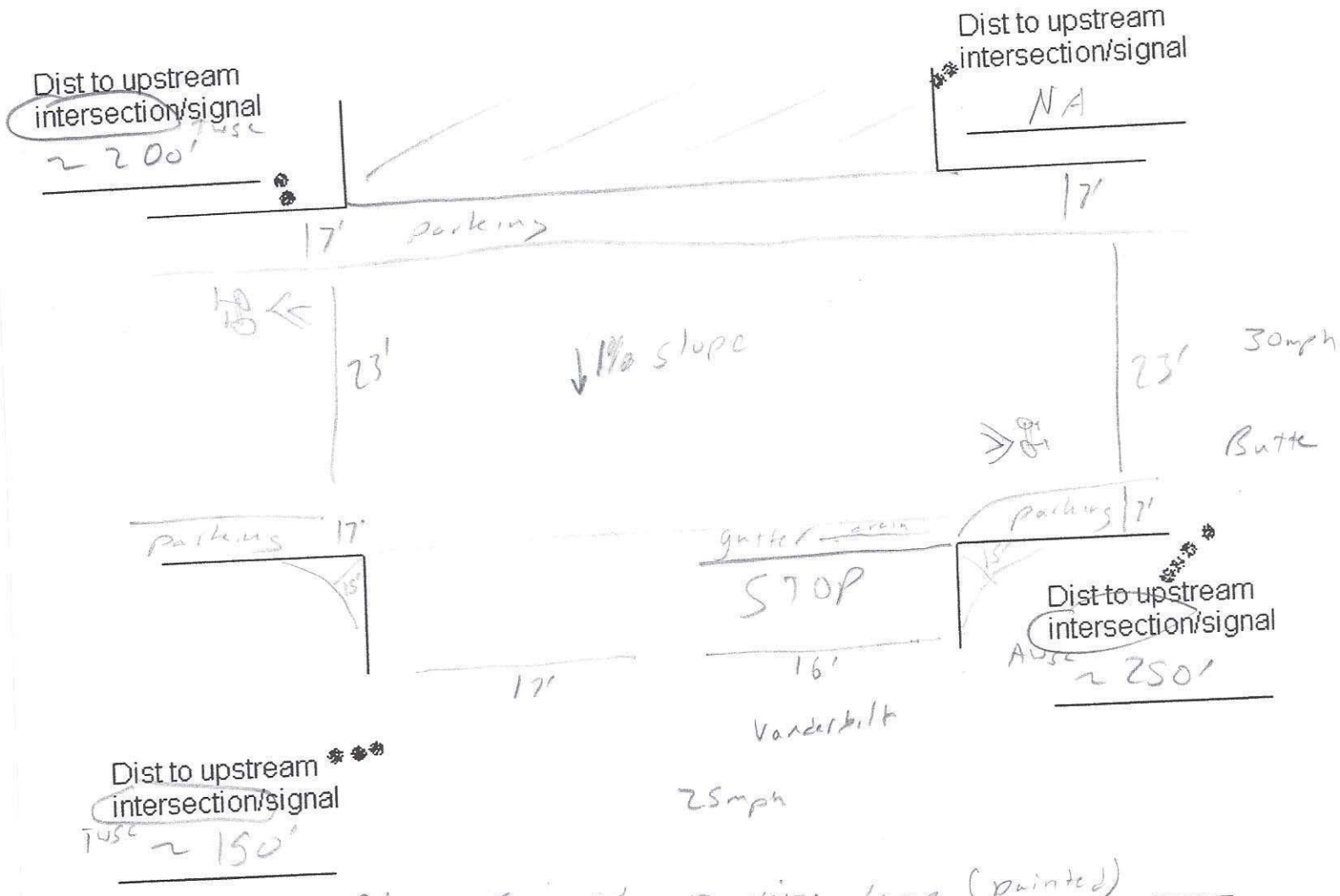
Location: (Southern CA) Northern CA Central CA Other

Intersection Type: (T) +

Data Collection Time: 8:30 - 9:30

Intersection Geometry:

North Arrow:



Comments: Sharrows and parking lane (painted) gutter along part of north side.

Cal Poly San Luis Obispo

Nathan Johnston

Intersection: Butte Street / Vanderbilt Ave

Time Period: 8:30 - 9:30

Volumes:

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Vanderbilt Ave / Butte Street

Heavy Vehicles:

0% HV

Butte

0% HV

Vanderbilt

Comments: Residential neighborhood; No RVs allowed from view of street. Small homes - no place to store RVs.

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Cambridge Ave / Wharton Drive

City: Claremont

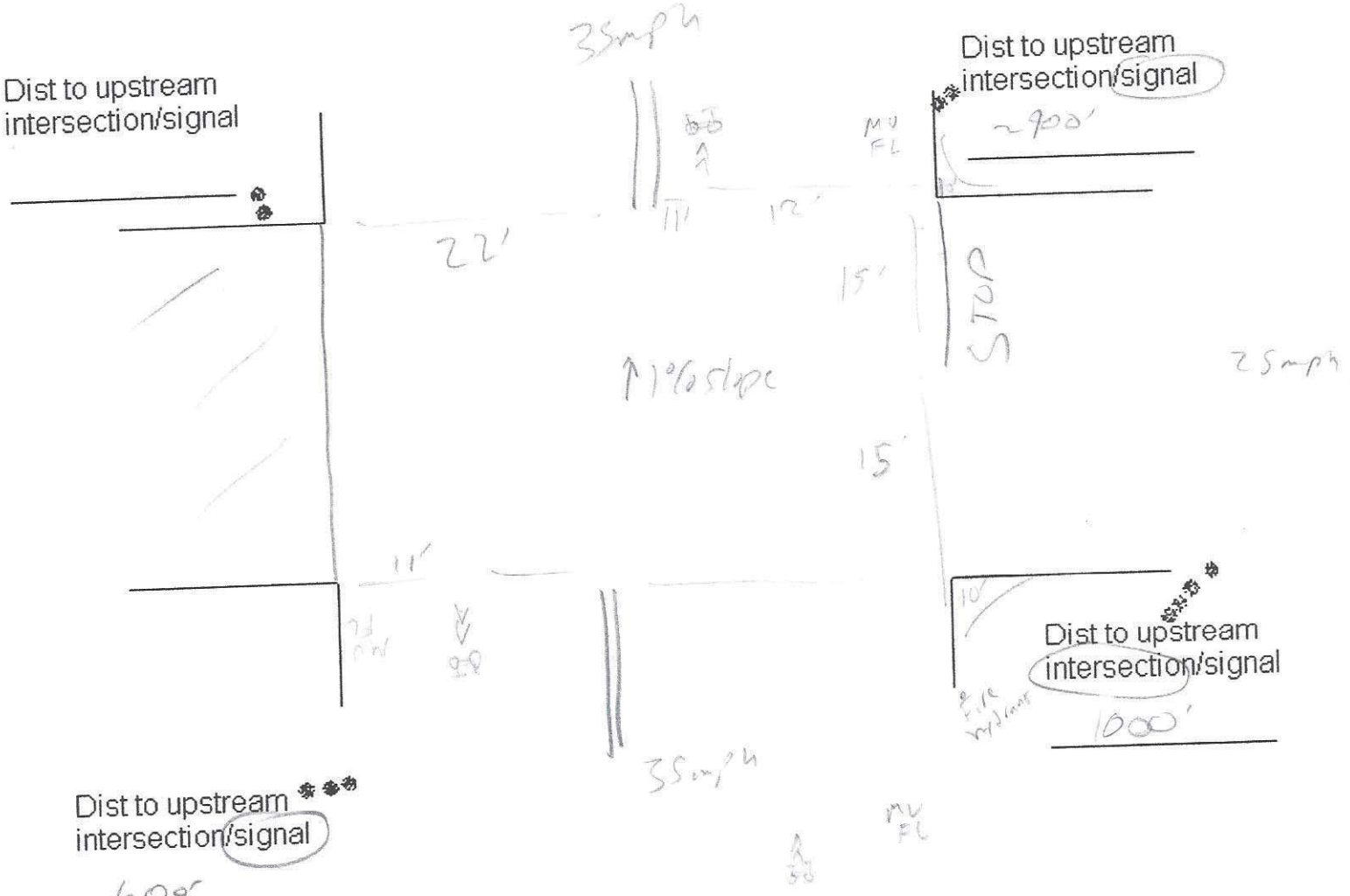
Location: Southern CA Northern CA Central CA Other

Intersection Type: T +

Data Collection Time: 9:50 - 10:50

Intersection Geometry:

North Arrow: ↑



Comments: Sharrows & Bikes Max use Full lane signs every ~150' Railroad Crossing about 500' to north on Cambridge

Parking allowed on all sides of intersection except by hydrant

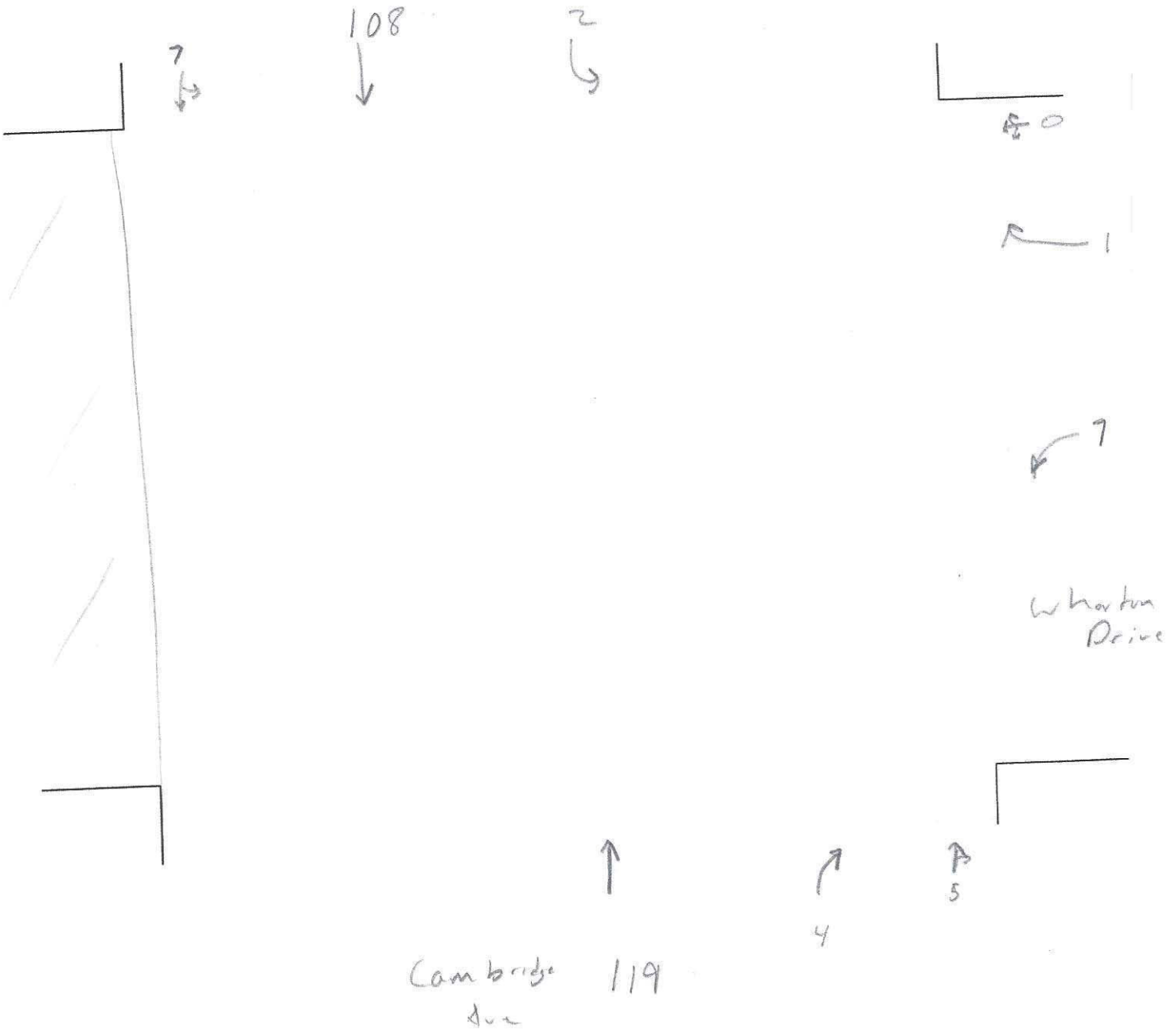
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Cambridge Ave / Wharton Drive

Time Period: 9:50 - 10:50

Volumes:

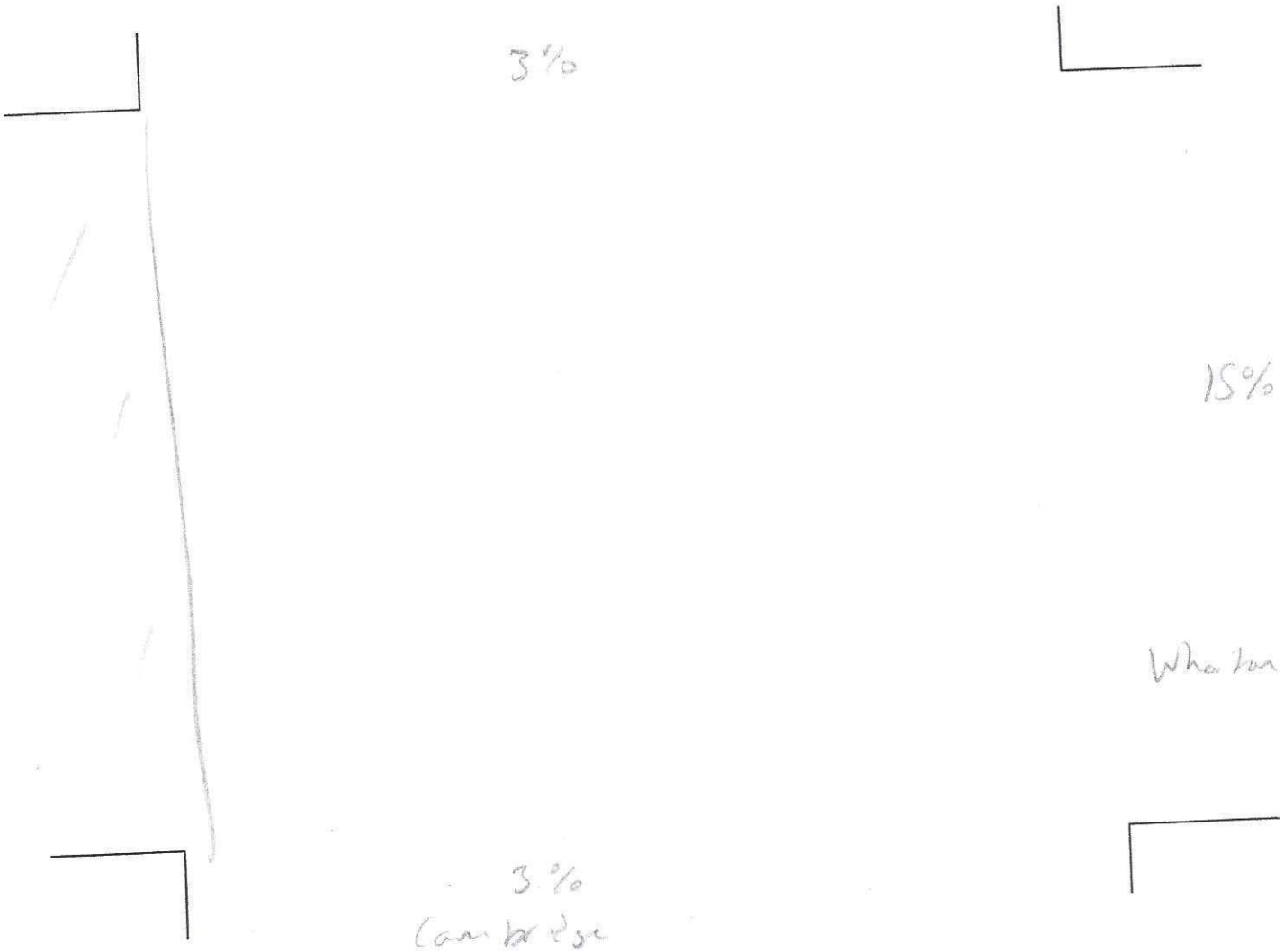


Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Cambridge Ave / Wharton Drive

Heavy Vehicles:



Comments: Truck center located on Wharton Drive
distribution

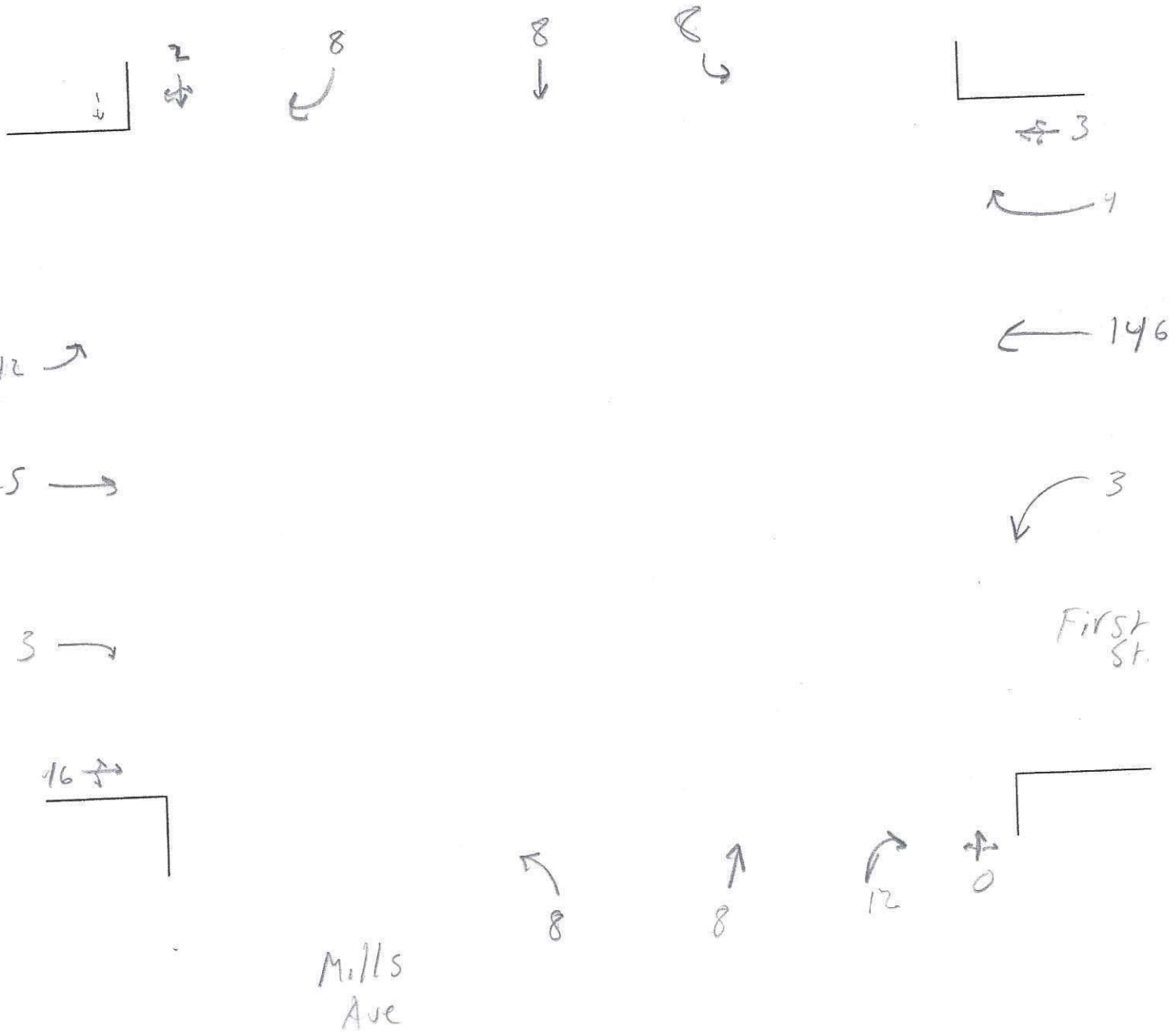
Cal Poly San Luis Obispo

Nathan Johnston

Intersection: First Street / Mills Ave

Time Period: 11:00 - 12:00

Volumes:



Nathan Johnston

Cal Poly San Luis Obispo

Intersection: First Street / Mills Ave

Heavy Vehicles:

1% HV

7%

7% HV

First St.

2% HV

Mills Ave

Comments: Bus route along 1st street Both directions

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: First Street / Mills Ave

City: Claremont

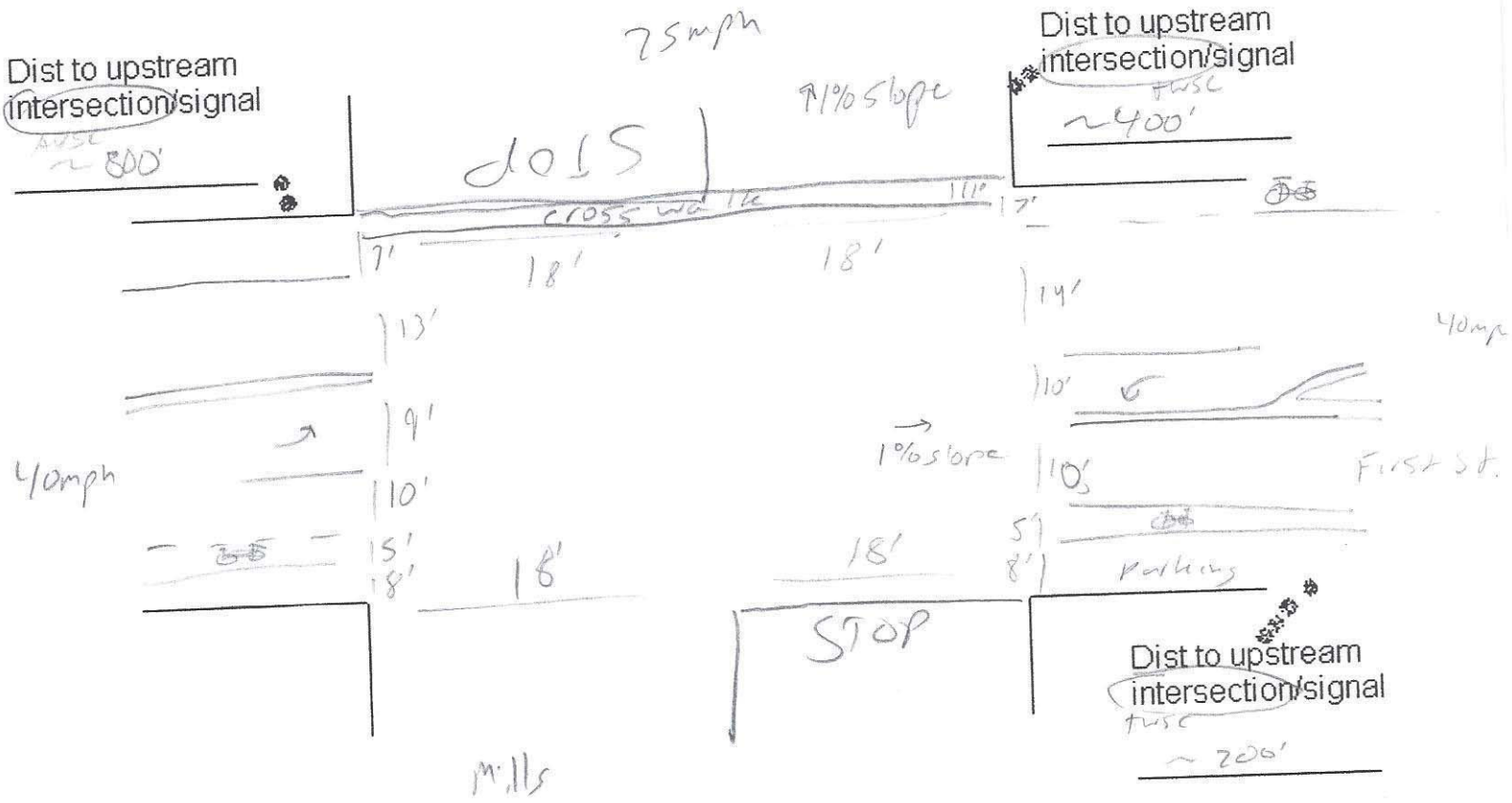
Location: (Southern CA) Northern CA Central CA Other

Intersection Type: T (+)

Data Collection Time: 11:00 - 12:00

Intersection Geometry:

North Arrow: ↑



Dist to upstream intersection/signal

Not a through Street ~150'

Comments: South side Los school Admin buildings

Pomona college. Cars come & go from there

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Mountain Avenue / Buttie Street / 8th Street

City: Claremont

Location: (Southern CA) Northern CA Central CA Other

Intersection Type: T (+)

Data Collection Time: 10:00 - 11:00 Tues 7/23/13

Intersection Geometry:

North Arrow:

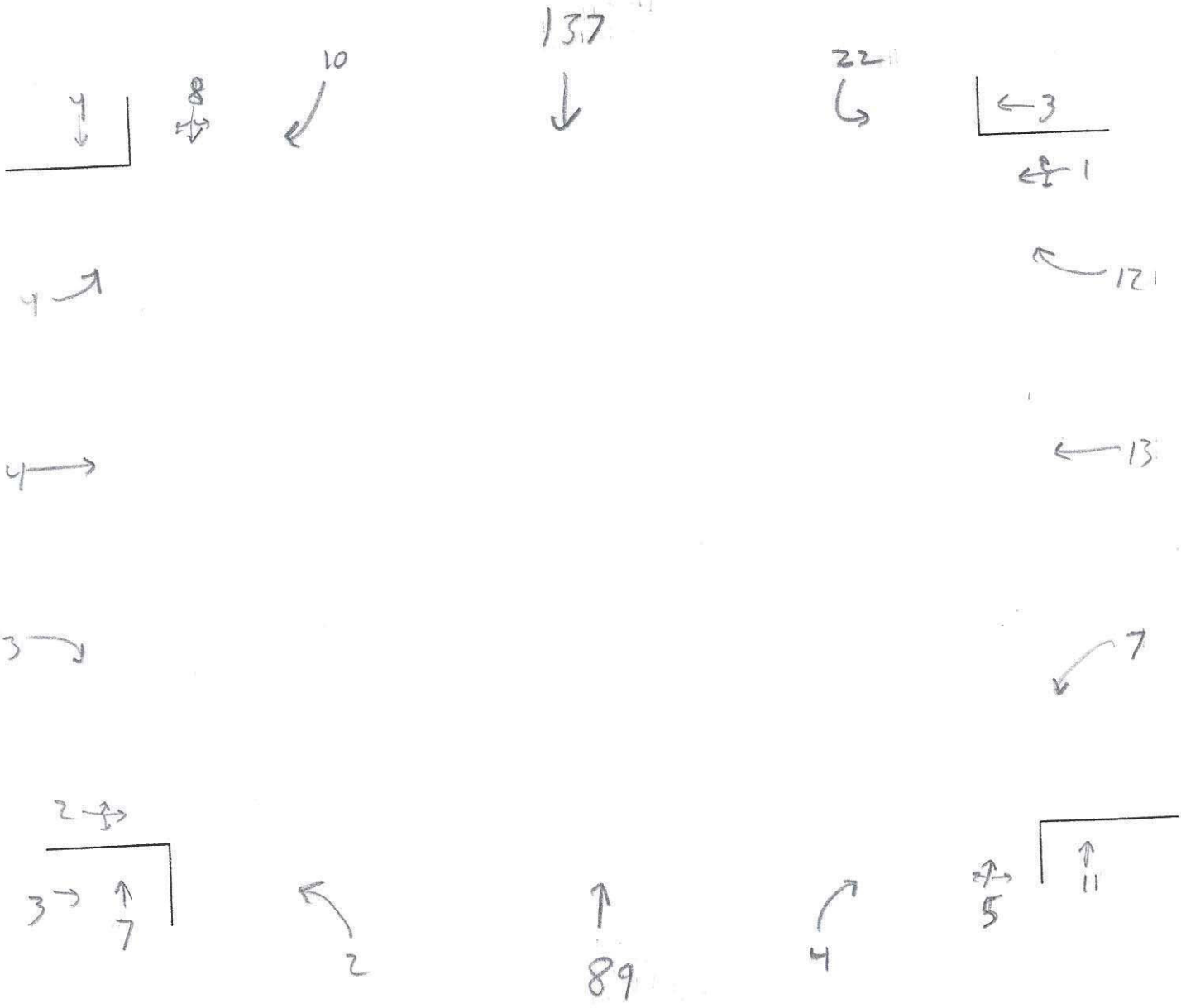
Comments: Sharrows + bike lanes w/ stripped on street parking. Bike priority zone signage. Poor quality 4 intersection offset by ~30'

Nathan Johnston

Intersection: Mountain Ave / Butte Street / 8th Street

Time Period: 10:00 - 11:00

Volumes:



Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Mountain Avenue / Butte Street / 8th Street

Heavy Vehicles:

↓ 4% HV

← 1% HV

→ 1% HV

↑ 4% HV

Comments: School a few blocks away on mountain = Buses.

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Lagoon Road / Harold Frank Road

City: Goleta (UCSB)

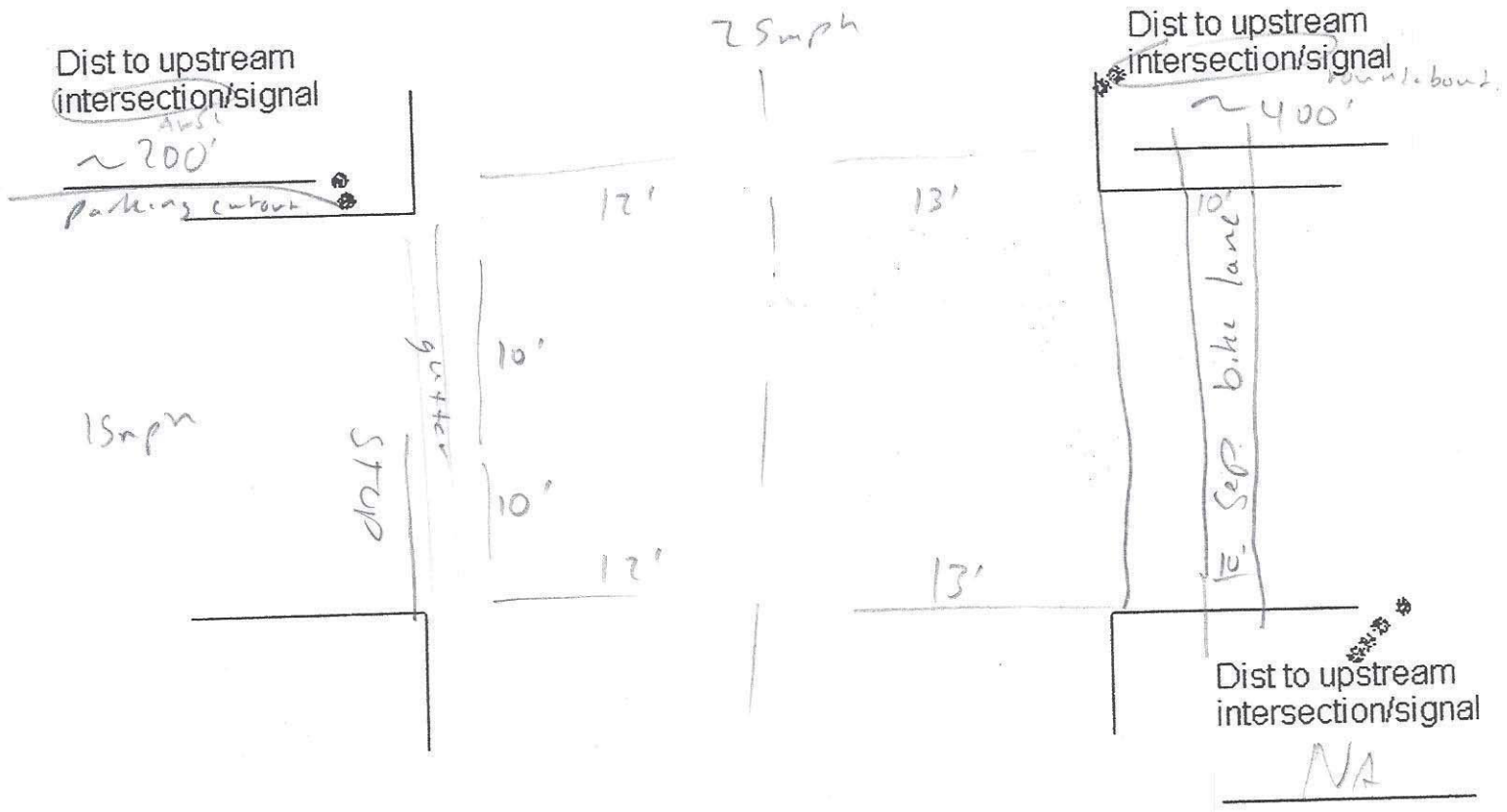
Location: Southern CA Northern CA (Central CA) Other

Intersection Type: (T) +

Data Collection Time: 1:45 - 2:45 7/26/13 Friday

Intersection Geometry:

North Arrow:



Comments: Pavement quality = 2 Signage Present

Bikes are mainly seperated.

No parking on major. Minor has cutout parking

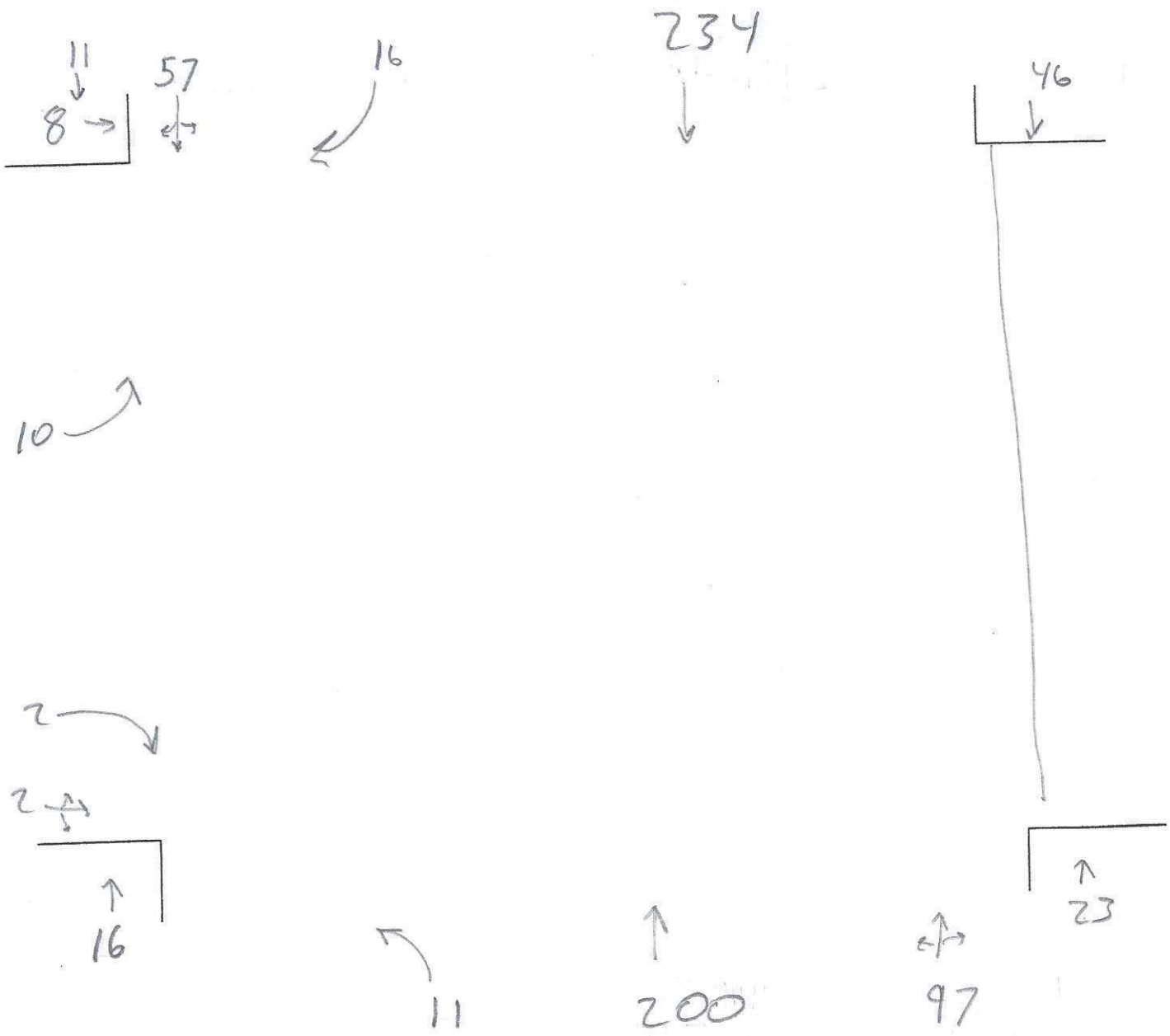
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Lagoon Road / Harold Frank Road

Time Period: 1:45 - 2:45

Volumes:

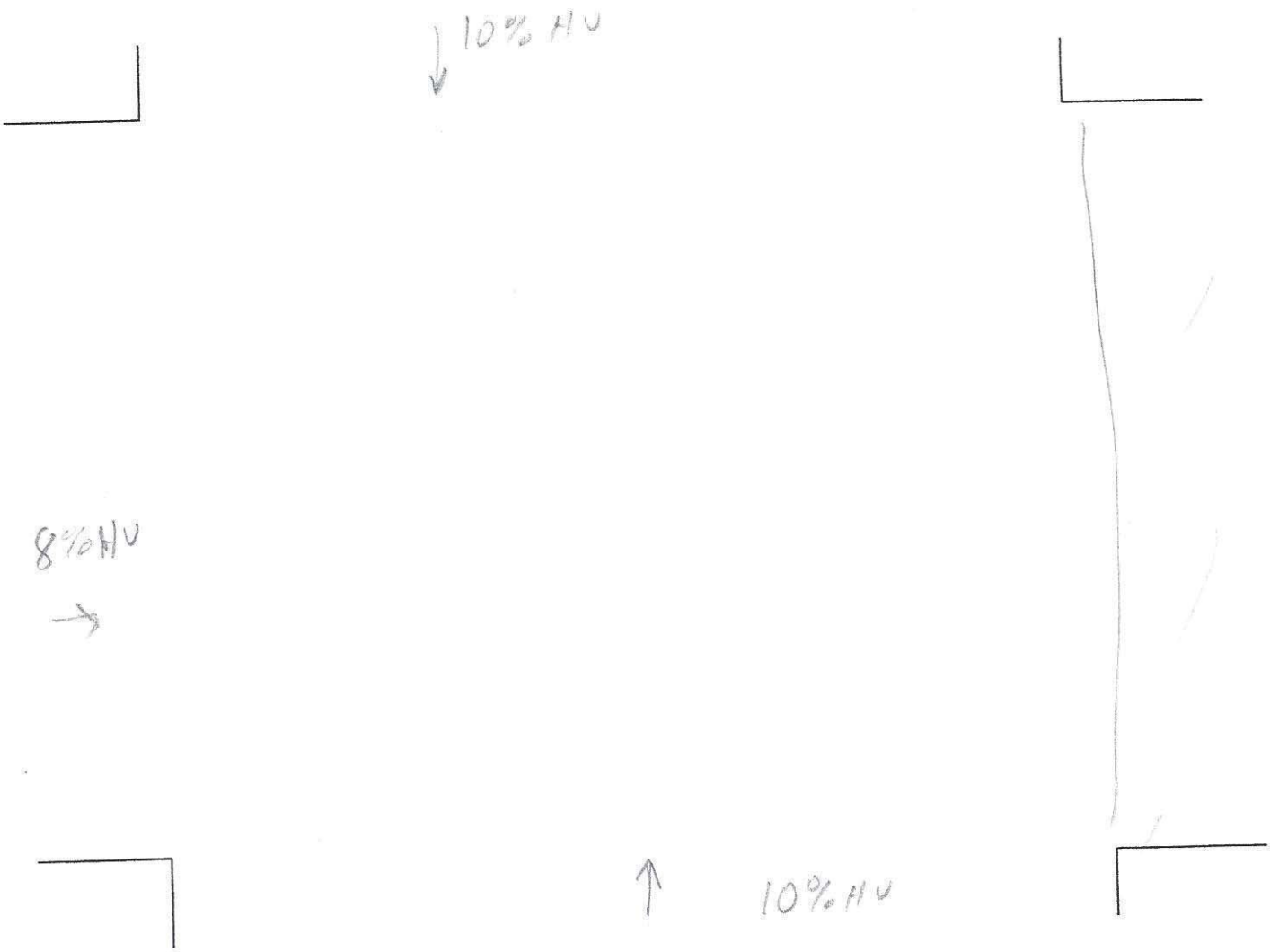


Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Lagoon Road / Harold Frank Road

Heavy Vehicles:



Comments:

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: North La Patera Lane / Covington Way

City: Goleta

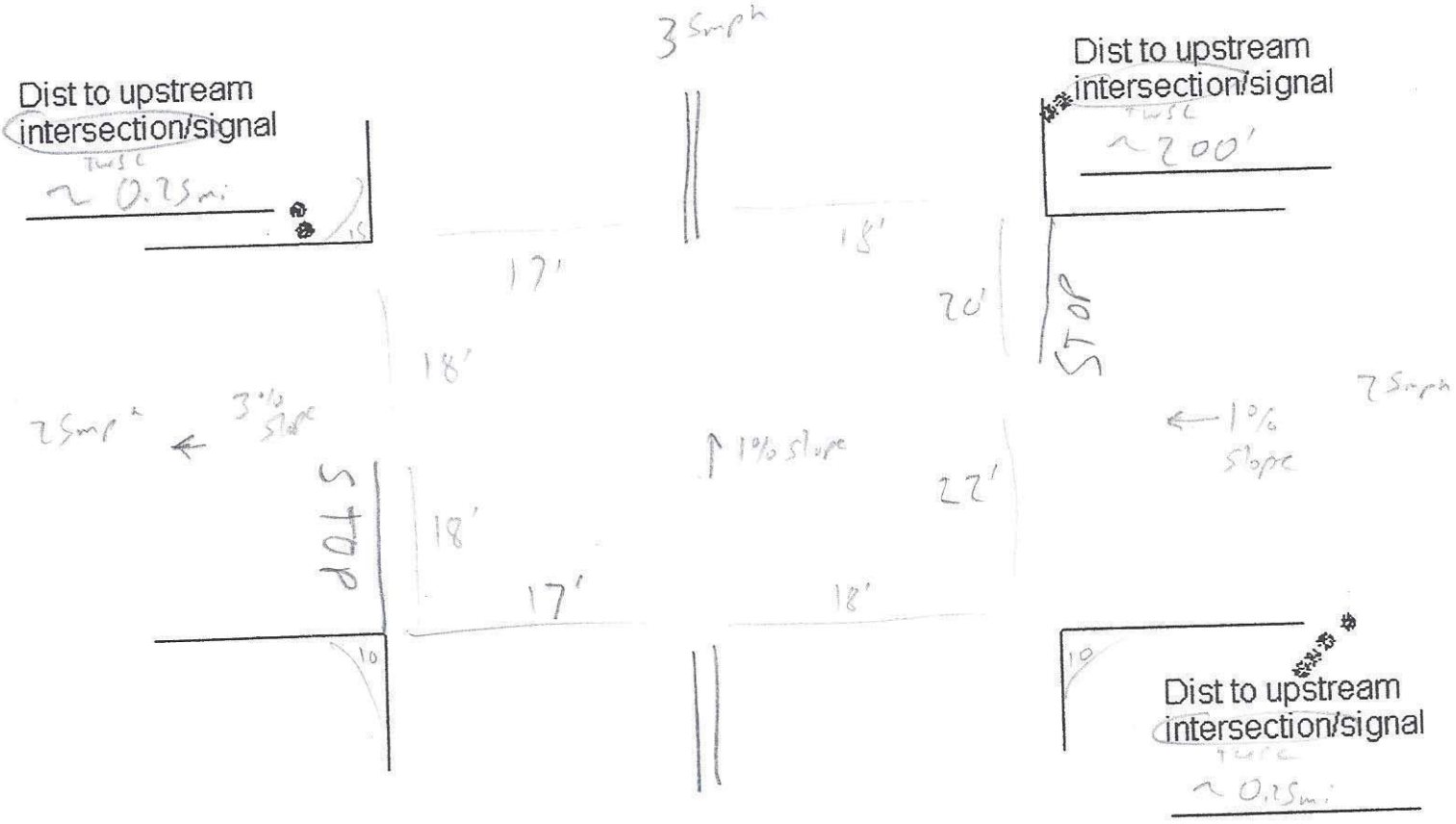
Location: Southern CA Northern CA (Central CA) Other

Intersection Type: T (+)

Data Collection Time: 9:00-10:00 7/26/13 Friday

Intersection Geometry:

North Arrow: 1



Comments: School Signage. Pavement quality 4

On street parking allways.

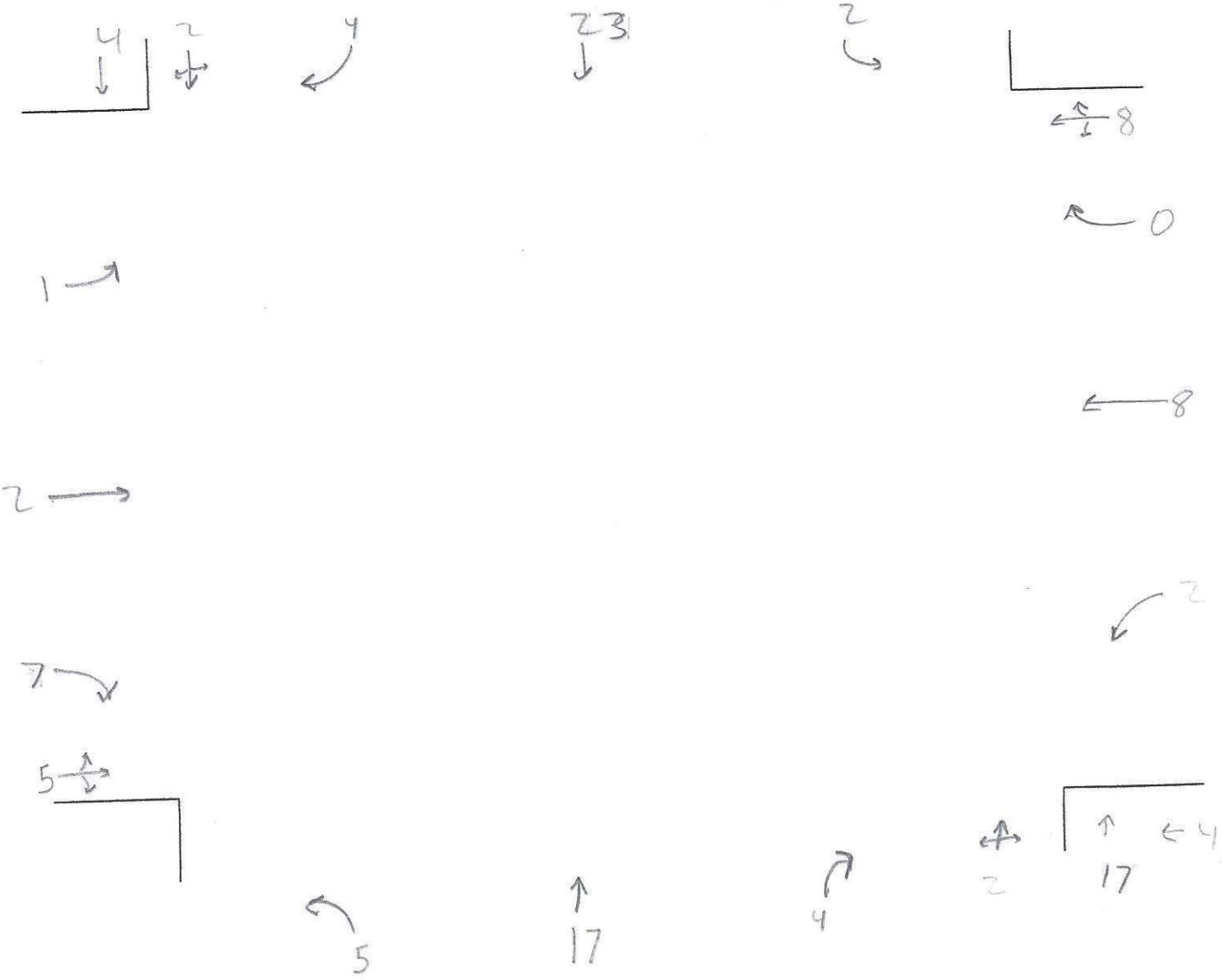
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: N. La Patera Lane / Covington Way

Time Period: 9:00 - 10:00

Volumes:

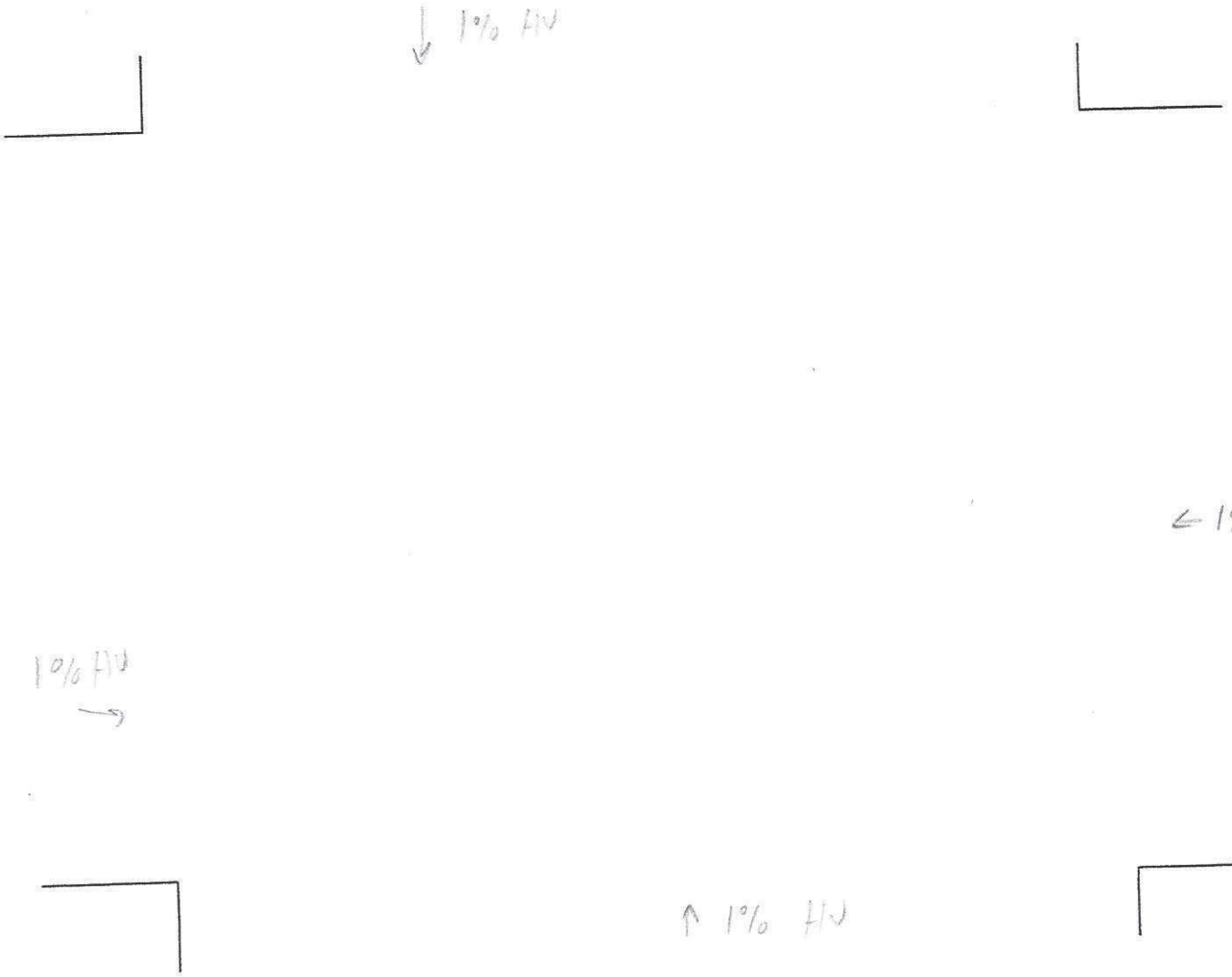


Nathan Johnston

Cal Poly San Luis Obispo

Intersection: N. La Patera Lane / Covington Way

Heavy Vehicles:



Comments:

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Cathedral Oaks Road / North La Patera Lane

City: Goleta

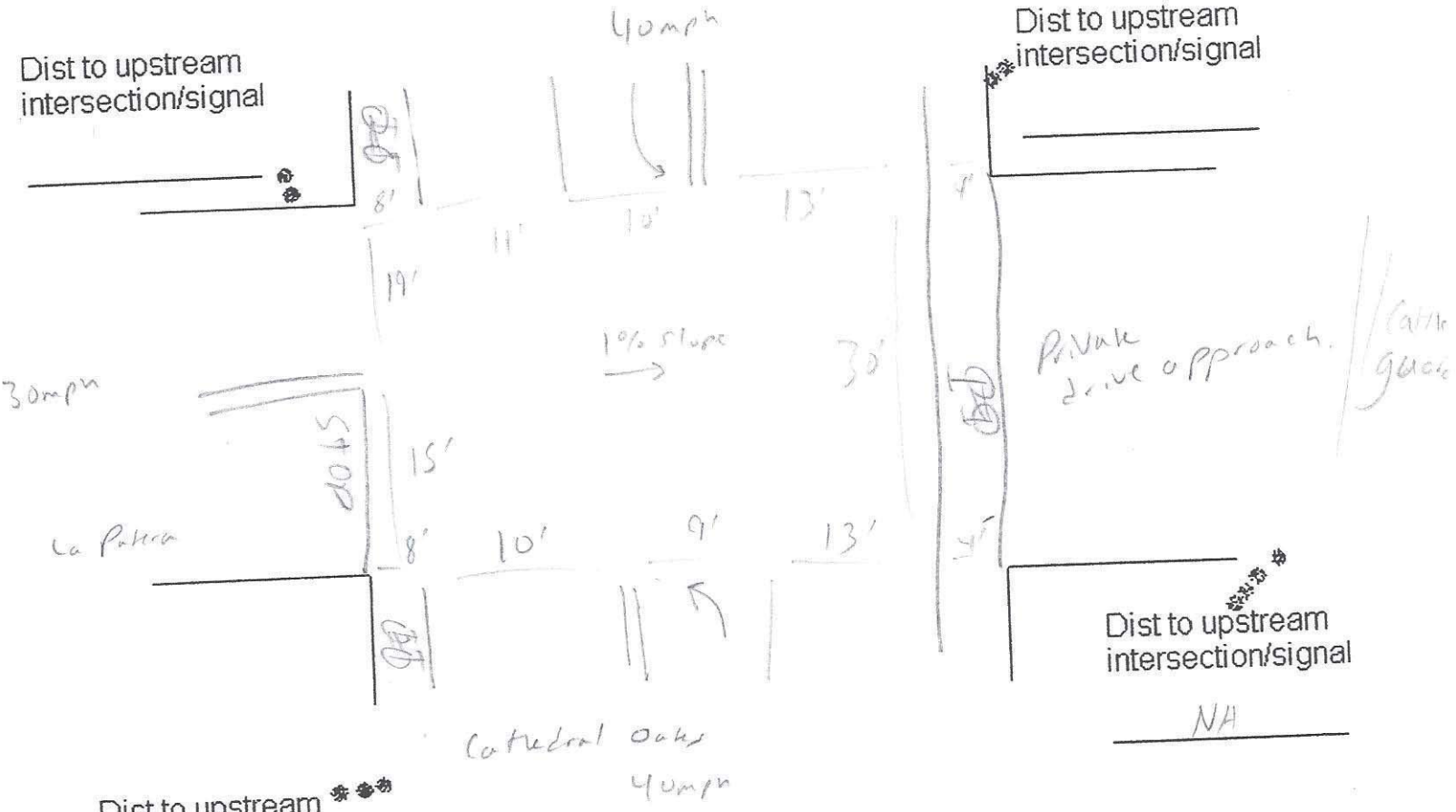
Location: Southern CA Northern CA Central CA Other

Intersection Type: T +

Data Collection Time: 10:05 - 11:05 7/26/13 Friday

Intersection Geometry:

North Arrow:



Comments: Pavement quality = 4 Signage present

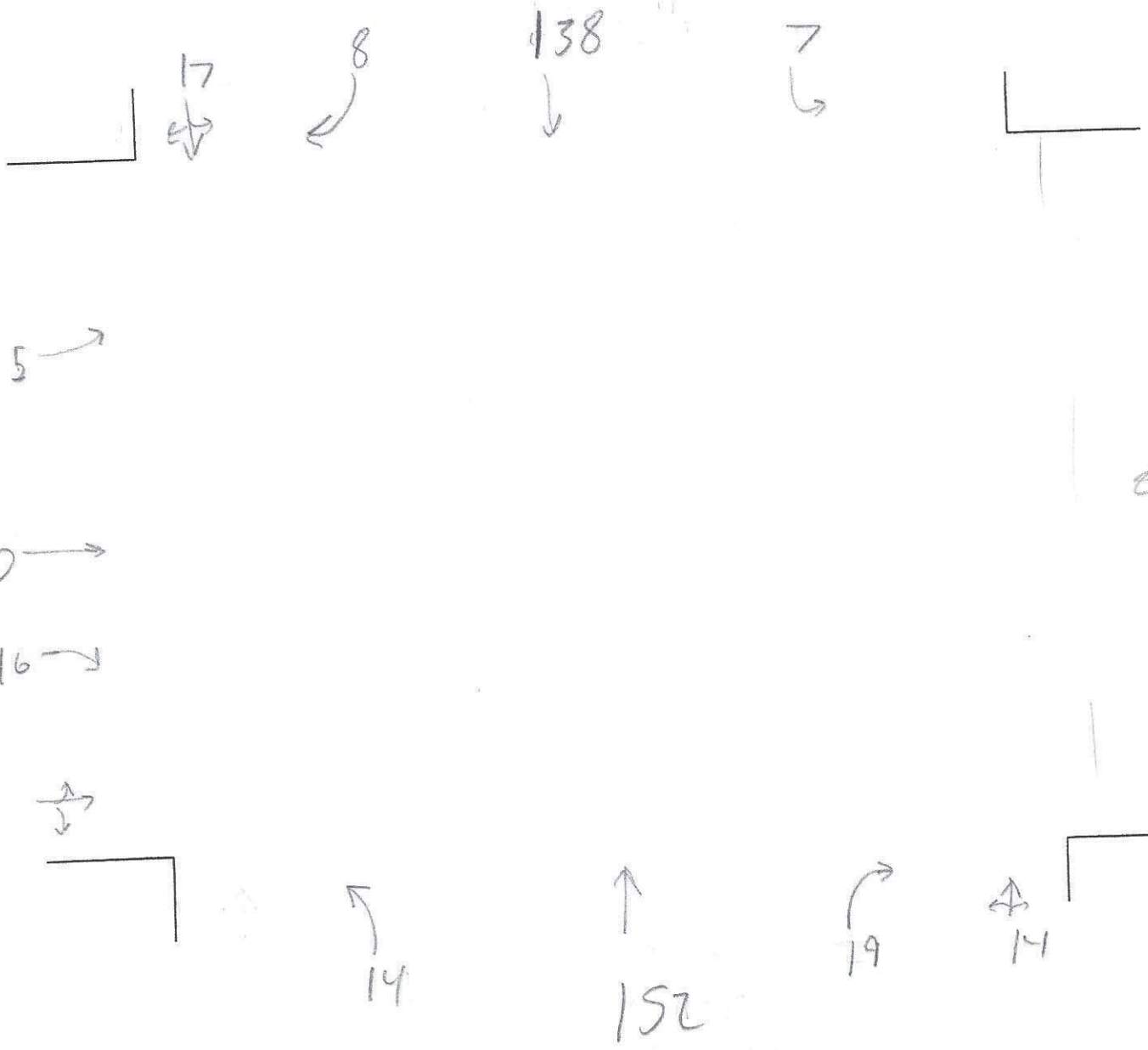
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Cathedral Oaks Road / La Patera Lane

Time Period: 10:05 - 11:05

Volumes:



Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Cathedral Oaks Road / N. La Patera Lane

Heavy Vehicles:

↓ 8% HV

← 4% HV

2% HV →

↑ 7% HV

Comments:

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Cathedral Oaks Road/ Placer Drive

City: Goleta

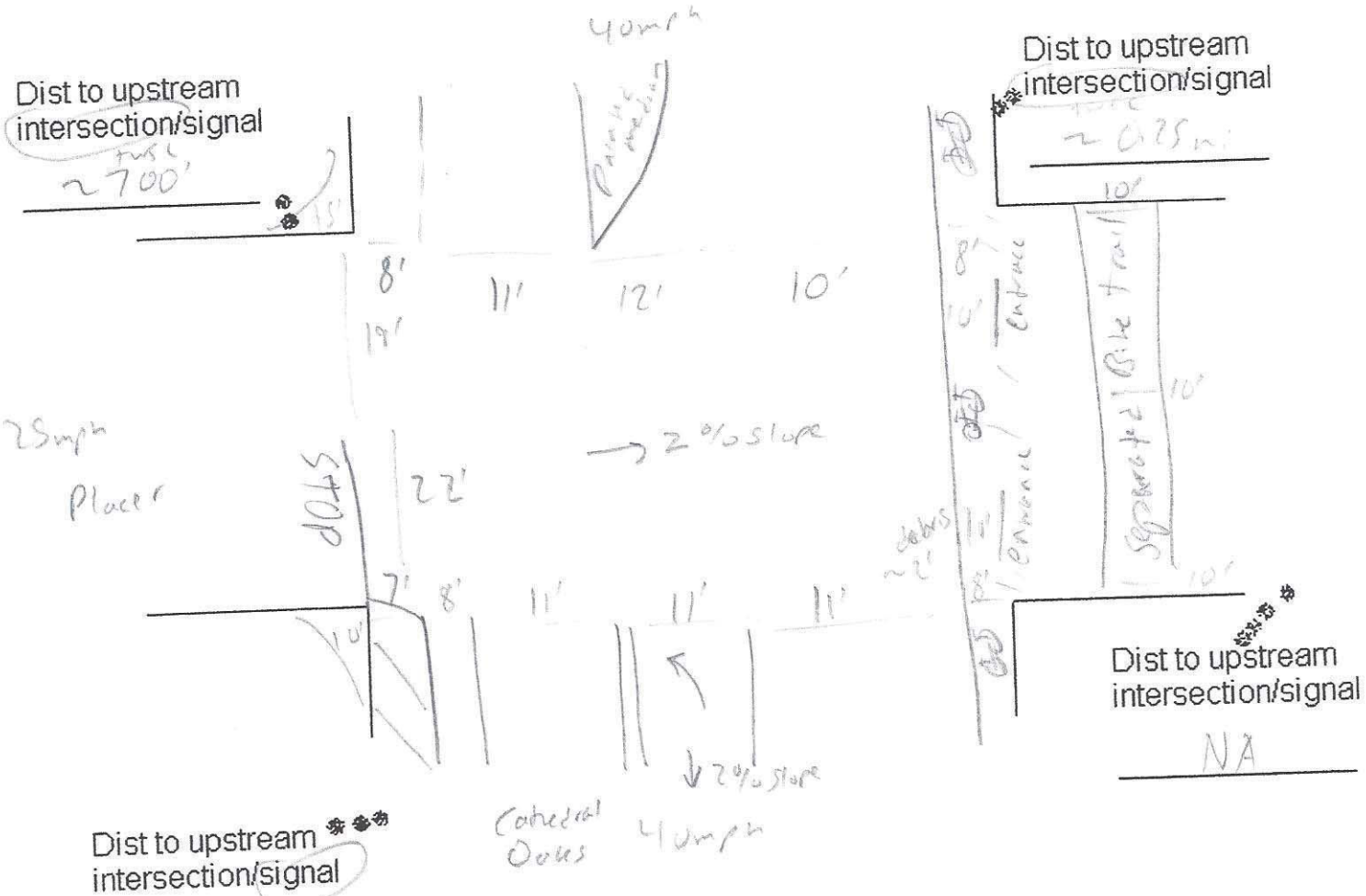
Location: Southern CA Northern CA (Central CA) Other

Intersection Type: (T) +

Data Collection Time: 11:15 - 12:15 7/26/13 Friday

Intersection Geometry:

North Arrow: →



Comments: School on Placer ~1200' away.

Pave quality ~2 Signage present.

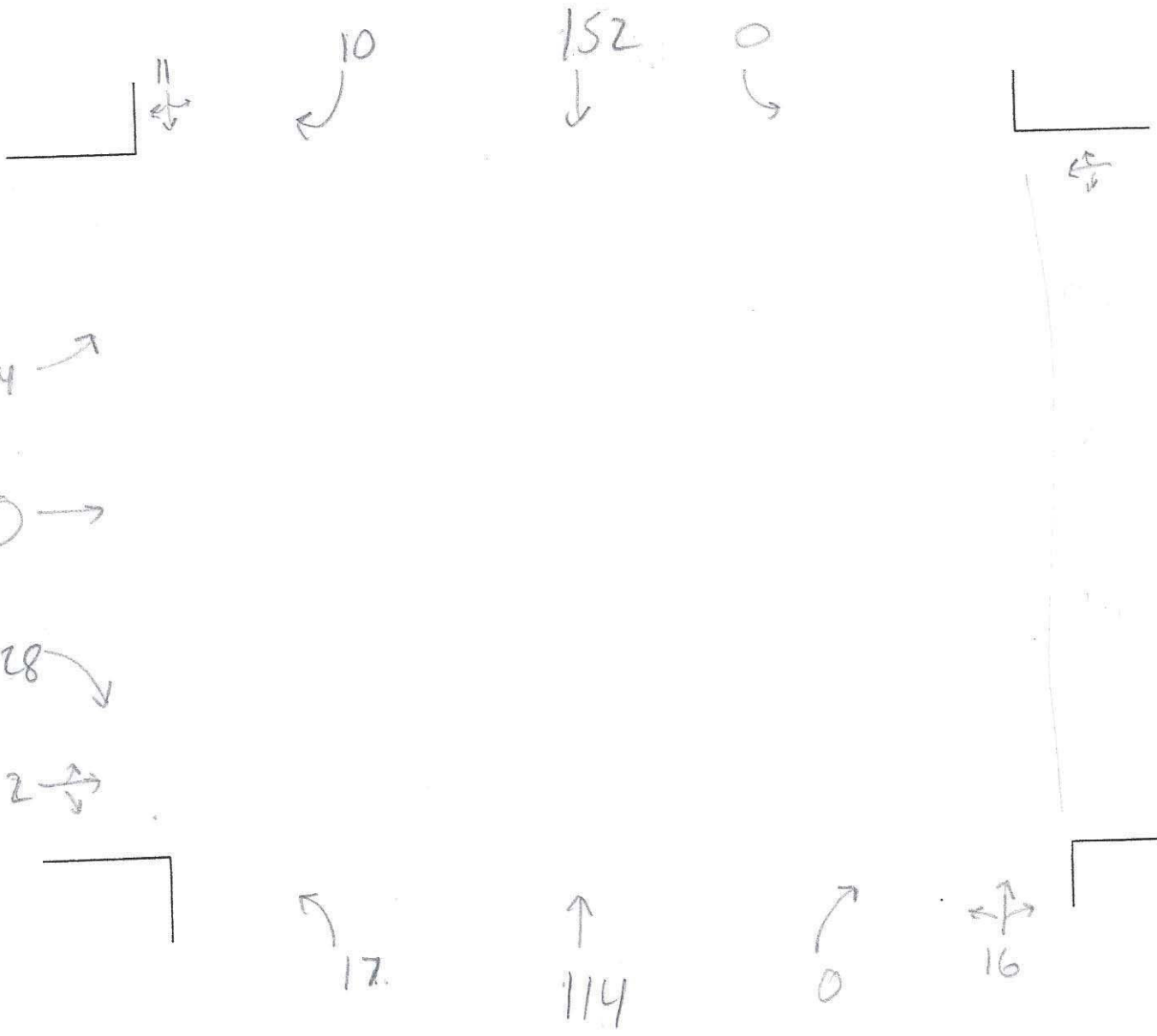
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Cathedral Oaks Road / Placer Drive

Time Period: 11:15 - 12:15

Volumes:



Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Cathedral Oaks Road/Placer Drive

Heavy Vehicles:

Comments: School on Placer

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Cathedral Oaks Road / Ellwood Ridge Road

City: Goleta

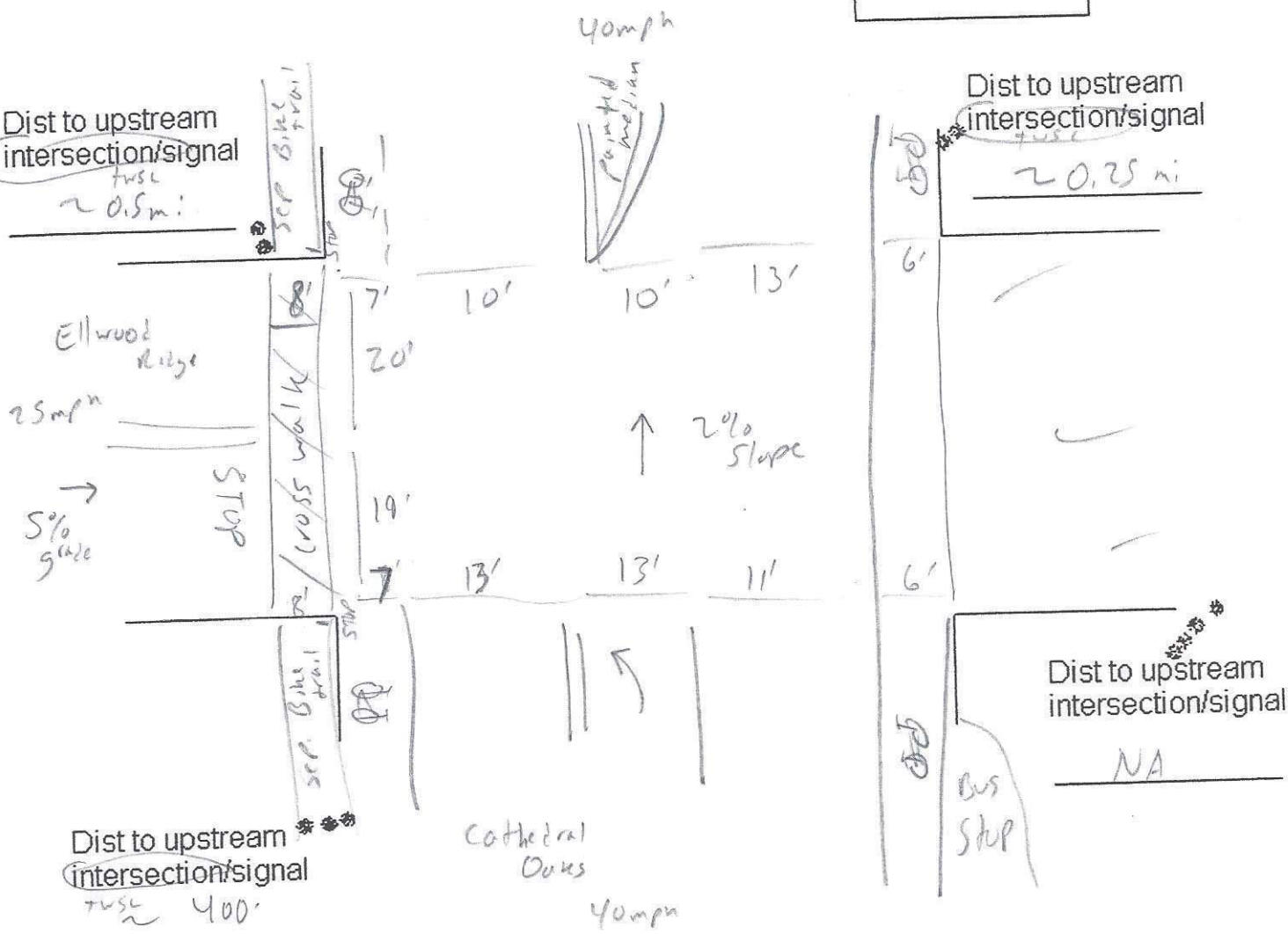
Location: Southern CA Northern CA (Central CA) Other

Intersection Type: (T) +

Data Collection Time: 12:30 - 1:30 7/26/13 Friday

Intersection Geometry:

North Arrow:



Comments: Pavement Quality = 3 Signage present

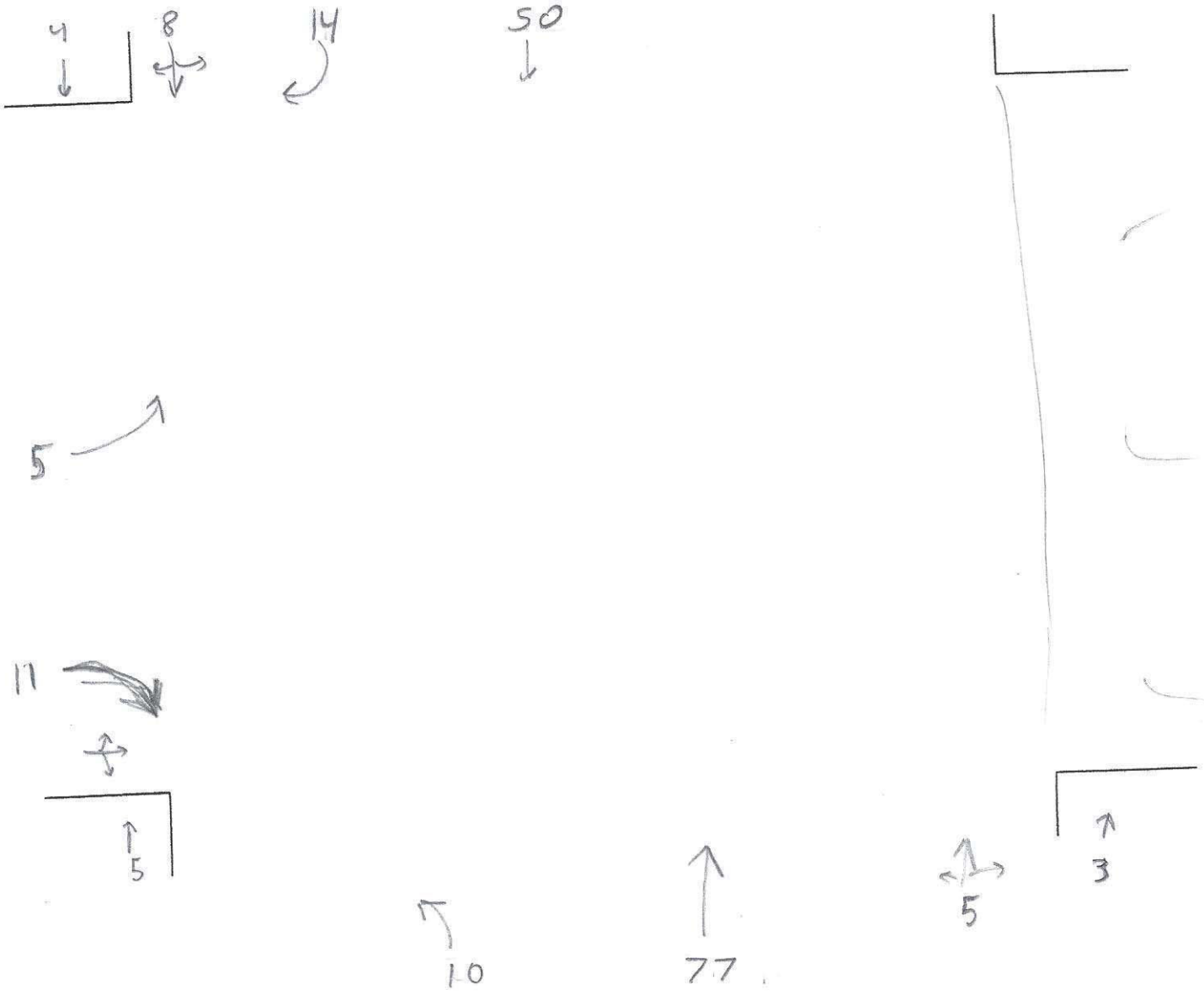
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Cathedral Oaks Road / Ellwood Ridge Road

Time Period: 12:30 - 1:30

Volumes:



Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Cathedral Oaks Road / Ellwood Ridge Road.

Heavy Vehicles:

↓ 6% HV

25% HV
→

↑ 4% HV

Comments: Ellwood doesn't go through, but leads to a well used canyon w/ heavy vehicles.

...on

...n: Northwood / Savannah

Irvine

Location: (Southern CA) Northern CA Central CA Other

Intersection Type: T (+)

Data Collection Time: 10:00 - 11:00 7/20/13 Sat

Intersection Geometry:

North Arrow: ↑

Dist to upstream intersection/signal

~701'

Comments: School Signage (nearby) Pavement quality: 5

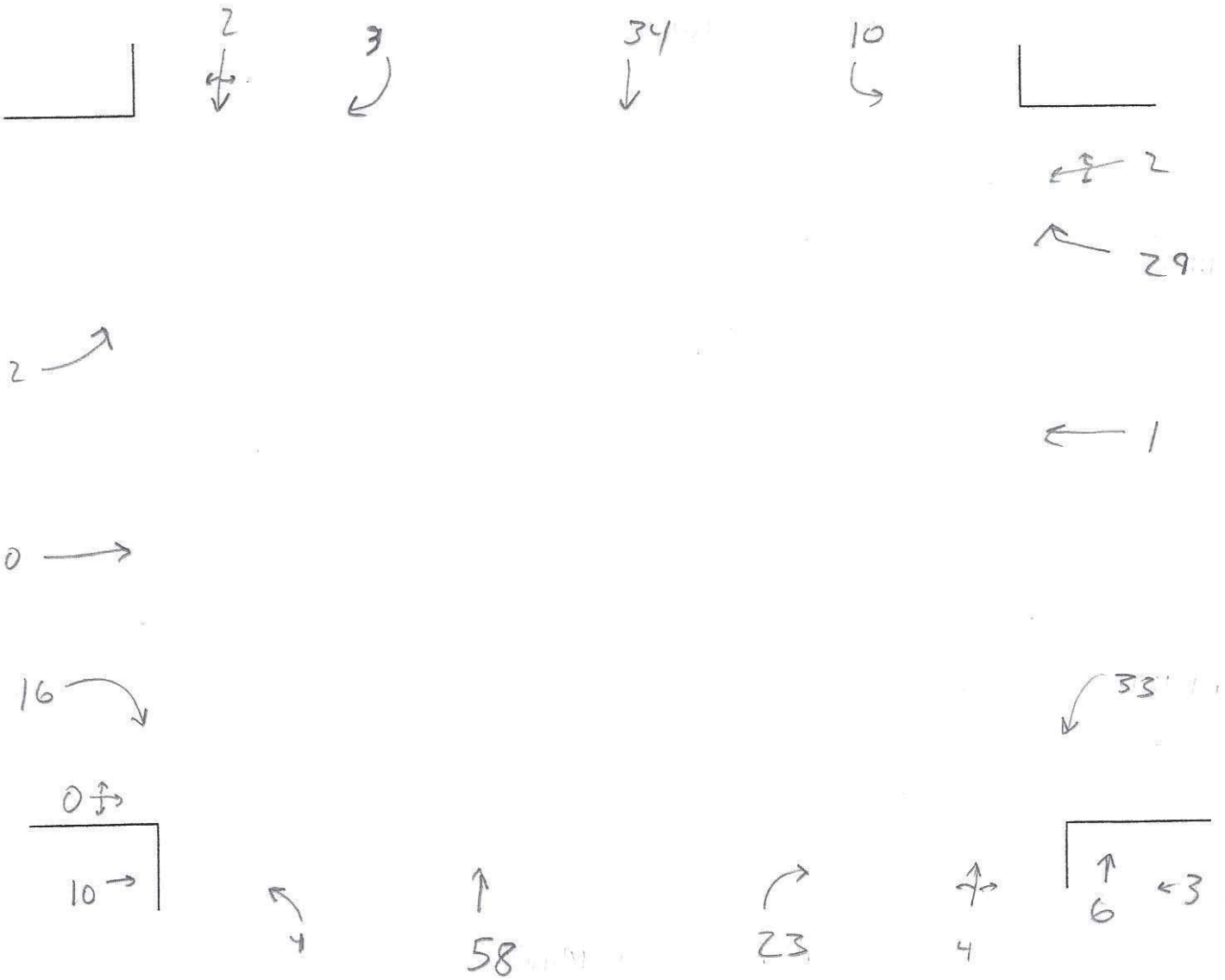
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Northwood / Savannah

Time Period: 10:00 - 11:00

Volumes:

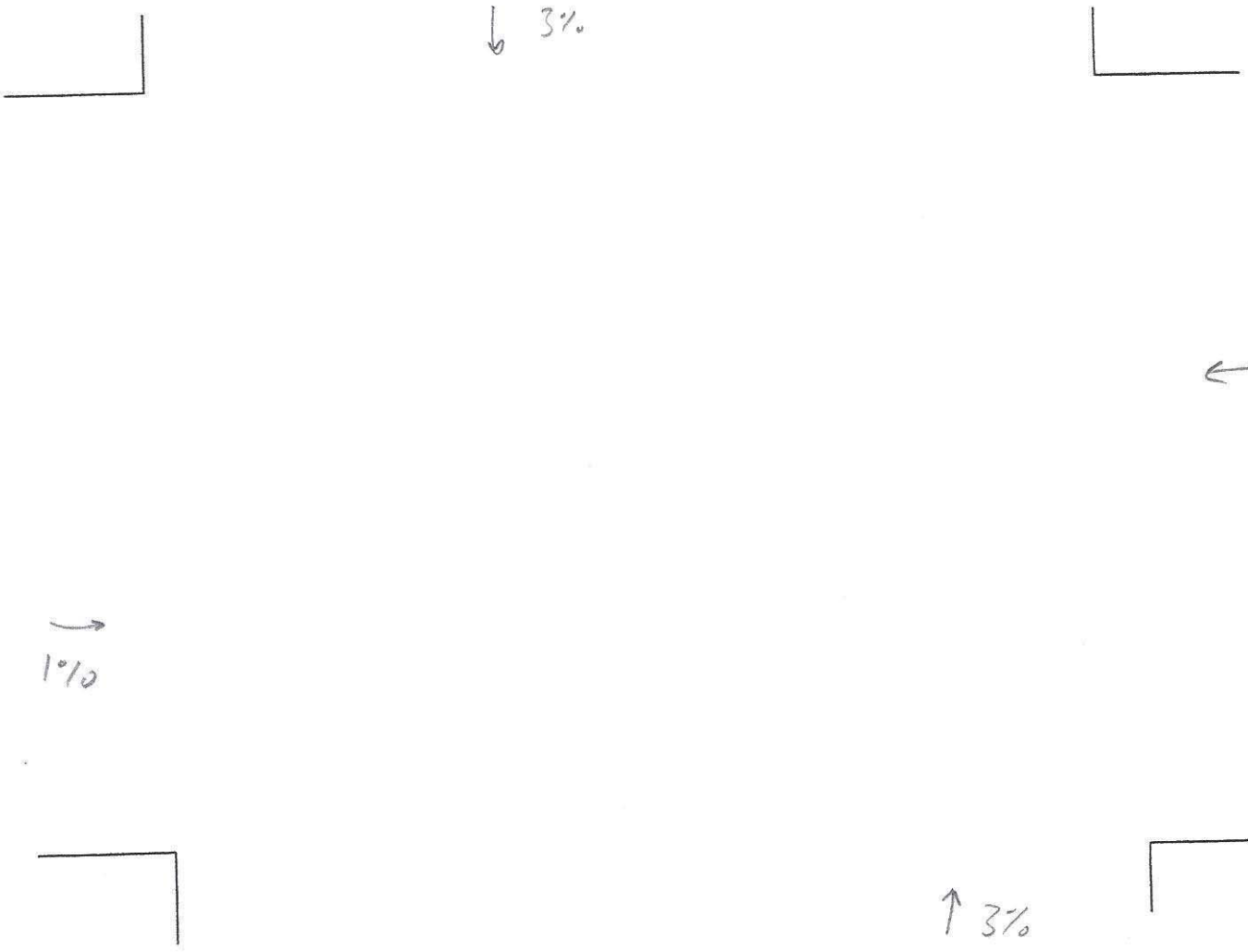


Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Northwood / Savannah

Heavy Vehicles:



Comments:

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Deerfield / Fawn Glen East

City: Irvine

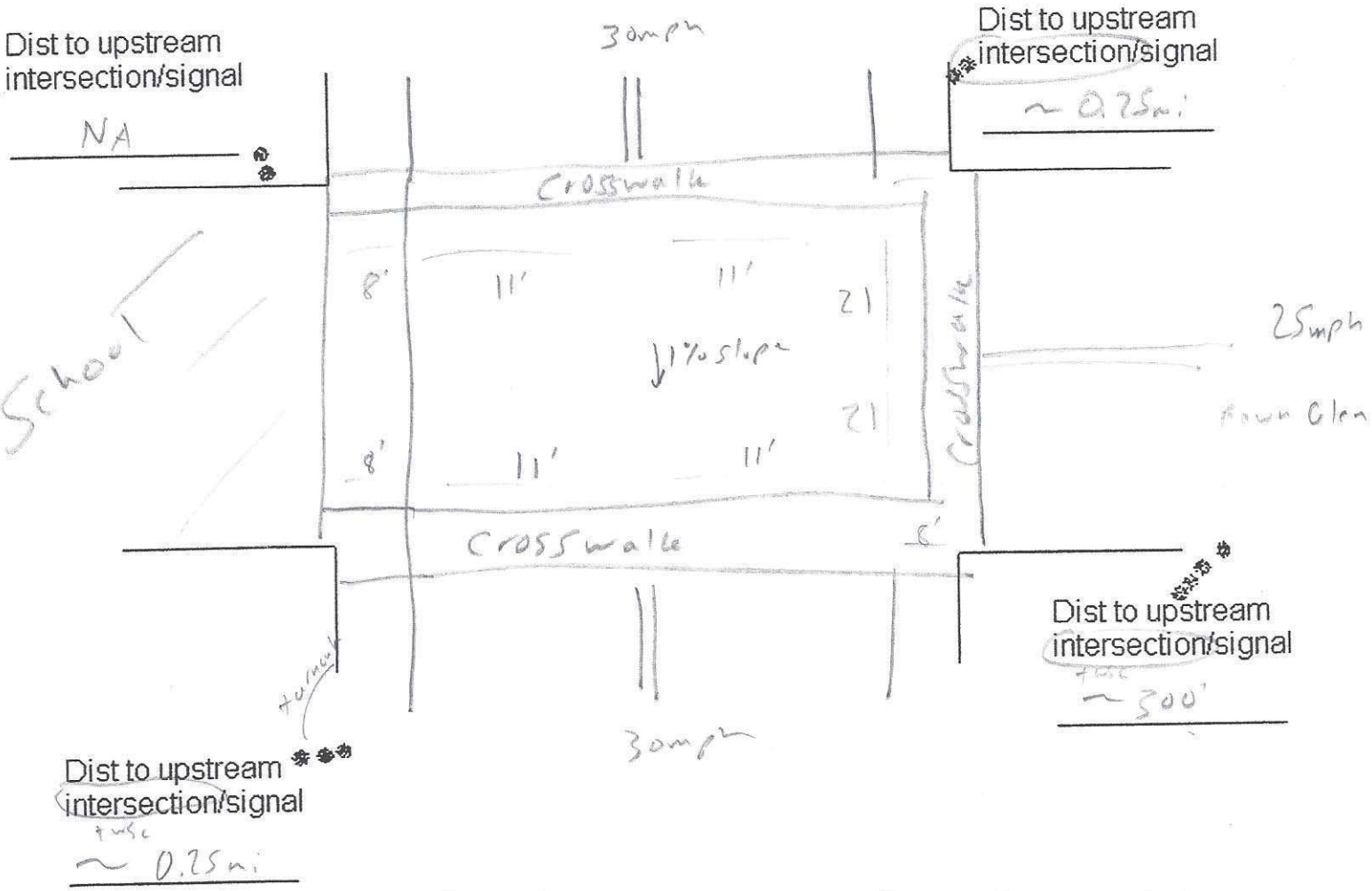
Location: (Southern CA) Northern CA Central CA Other

Intersection Type: (T) +

Data Collection Time: 11:20 - 12:20

Intersection Geometry:

North Arrow:



Comments: School adjacent No parking in bike lanes. Pave quality 3 No signage

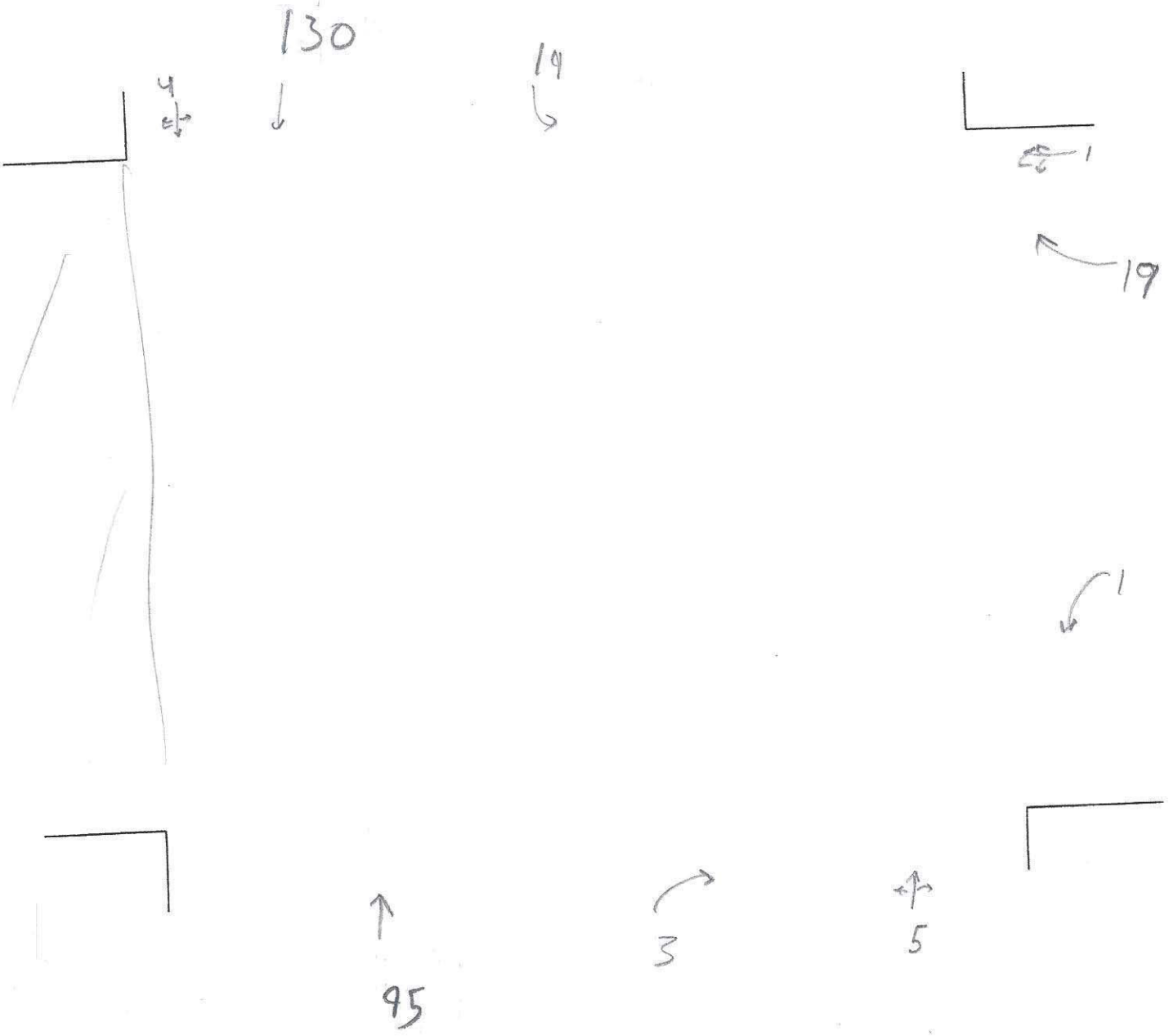
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Deerfield / Town Glen East

Time Period: 11:20-12:20

Volumes:



Cal Poly San Luis Obispo

Nathan Johnston

Intersection: Deerfield / Fawn Glen East

Heavy Vehicles:

Comments:

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: McGaw Ave / Armstrong Street

City: Irvine

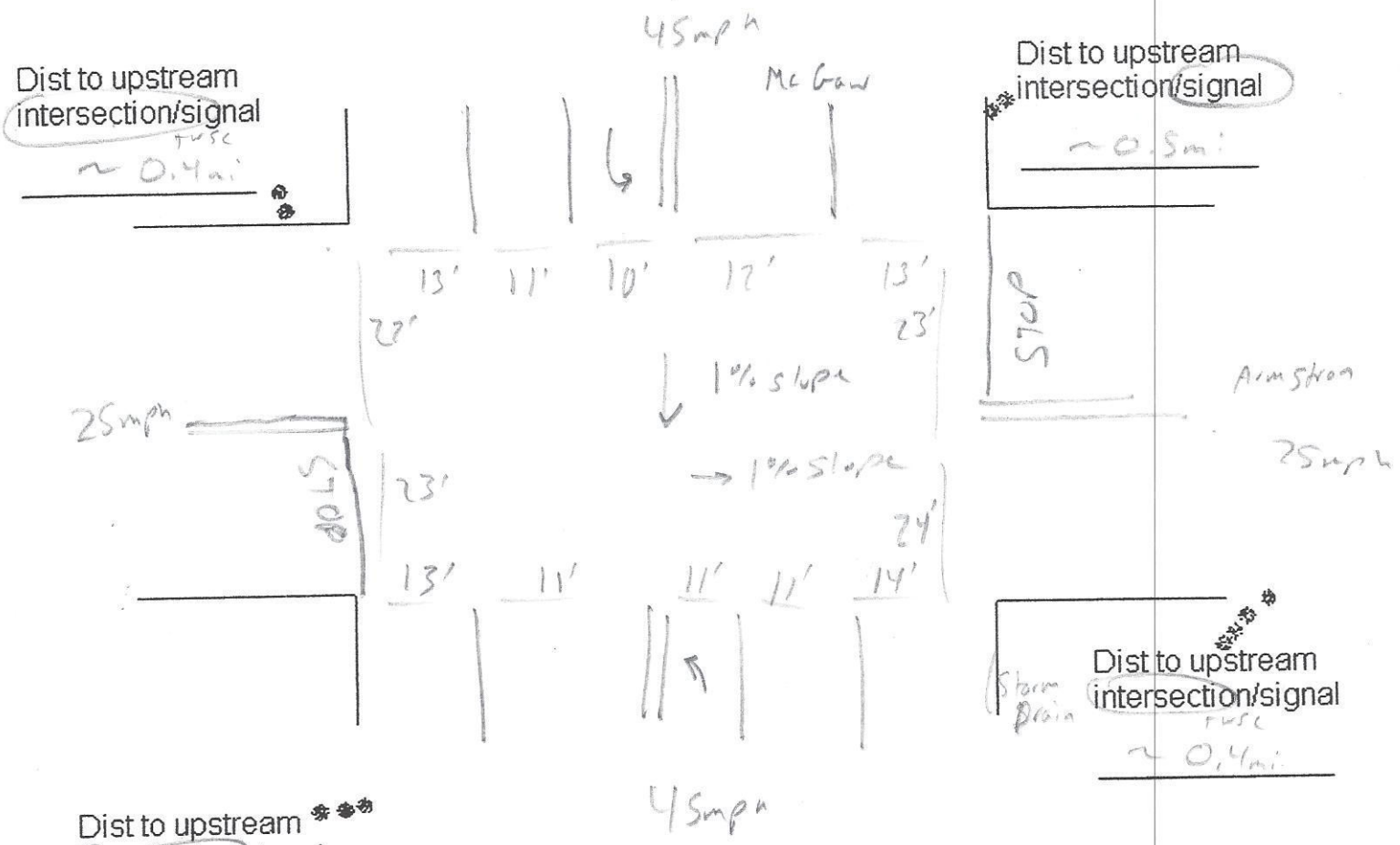
Location: (Southern CA) Northern CA Central CA Other

Intersection Type: T +

Data Collection Time: 12:30-1:30 7/20/13 Sat

Intersection Geometry:

North Arrow:



Comments: No bike lanes pavement quality = 4

no signage.

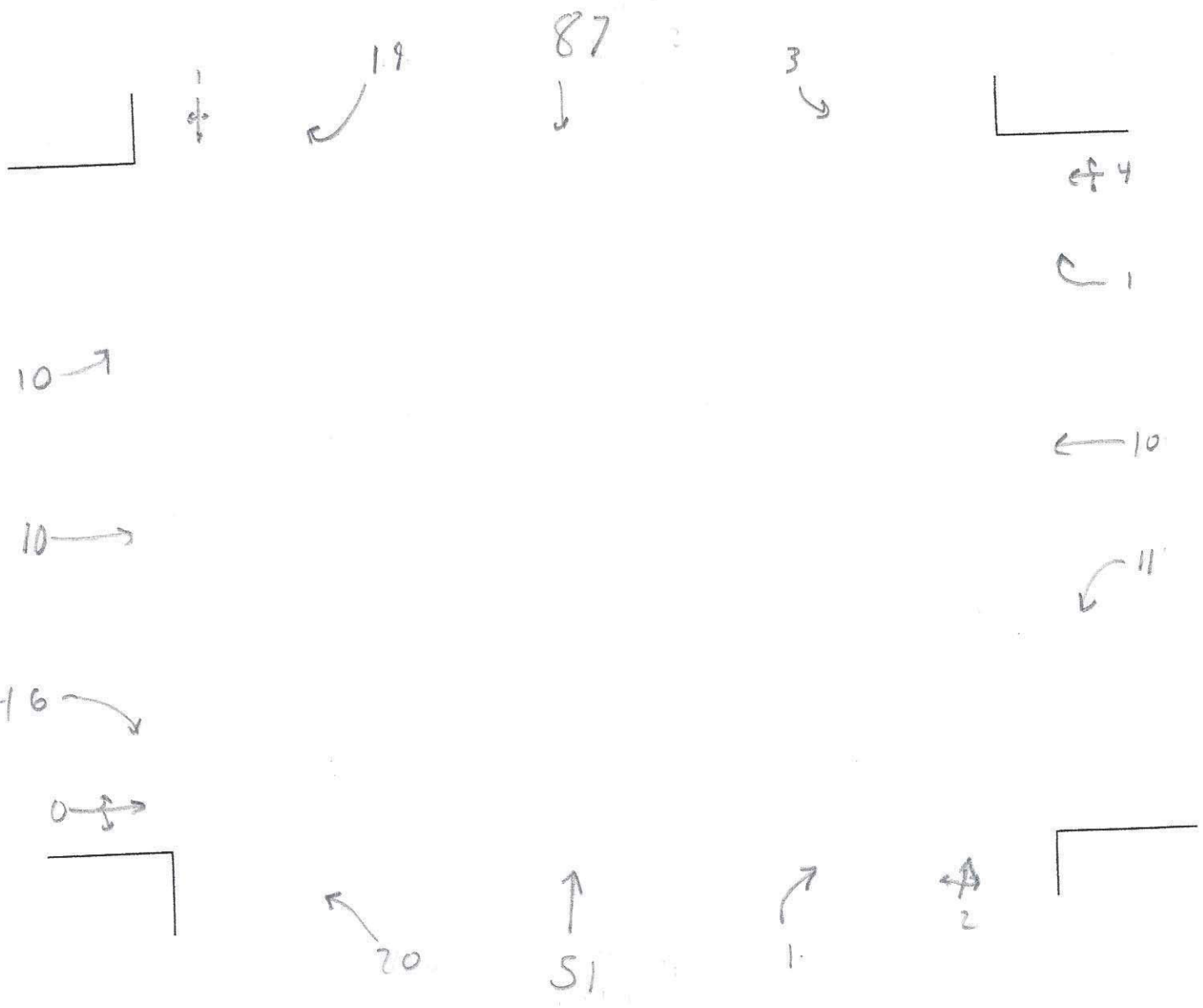
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: McGraw / Armstrong Street

Time Period: 12:30-1:30

Volumes:



Nathan Johnston

Cal Poly San Luis Obispo

Intersection: McCaw / Armstrong Street

Heavy Vehicles:

Comments:

Cal Poly San Luis Obispo

Nathan Johnston

Intersection: Michelson / Sequoia Tree Lane

City: Irvine

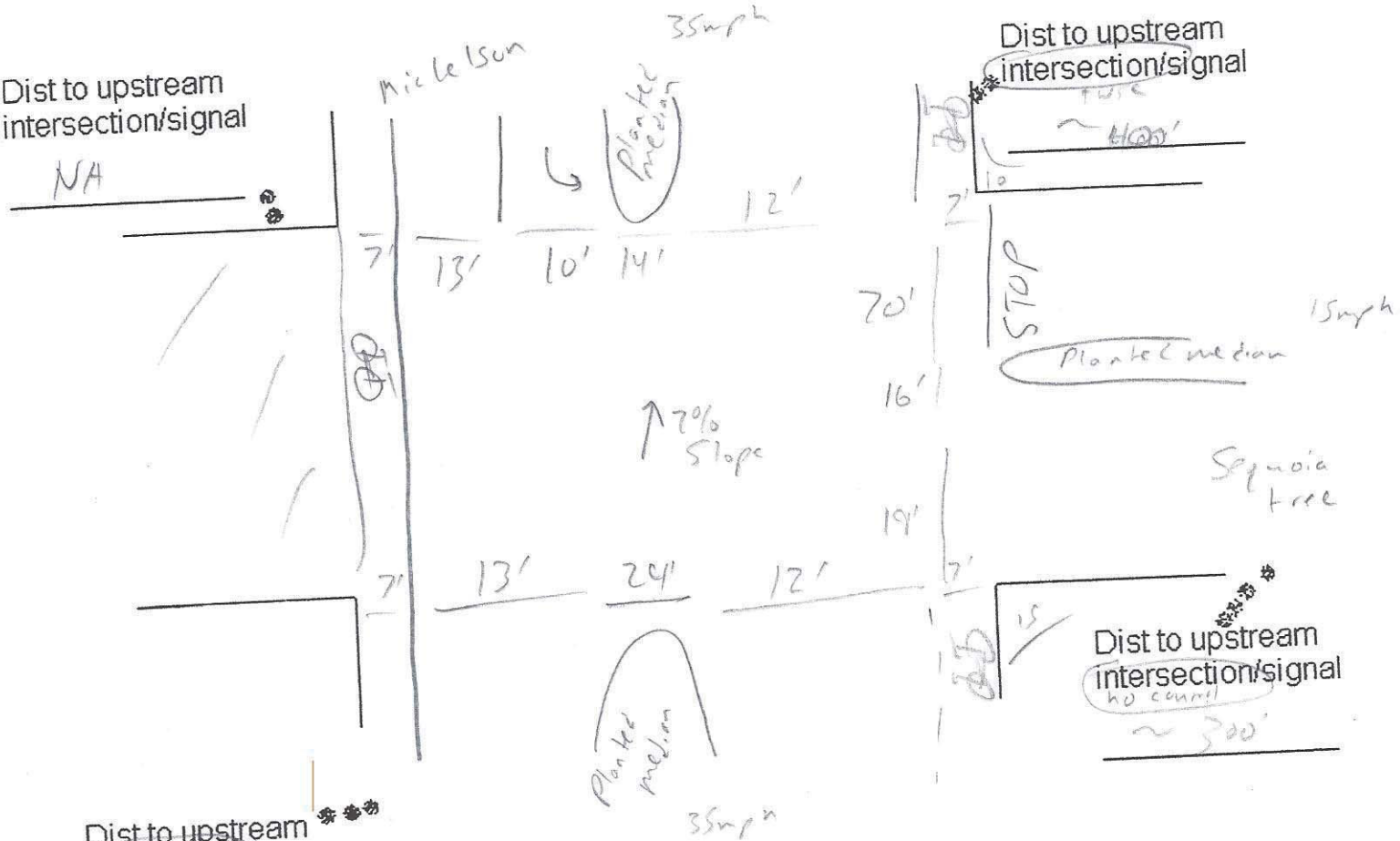
Location: (Southern CA) Northern CA Central CA Other

Intersection Type: T +

Data Collection Time: 1:40 - 2:40 7/20/13 Sat

Intersection Geometry:

North Arrow:



Comments: Pave quality 4 No Parking on Michelson

no Signage

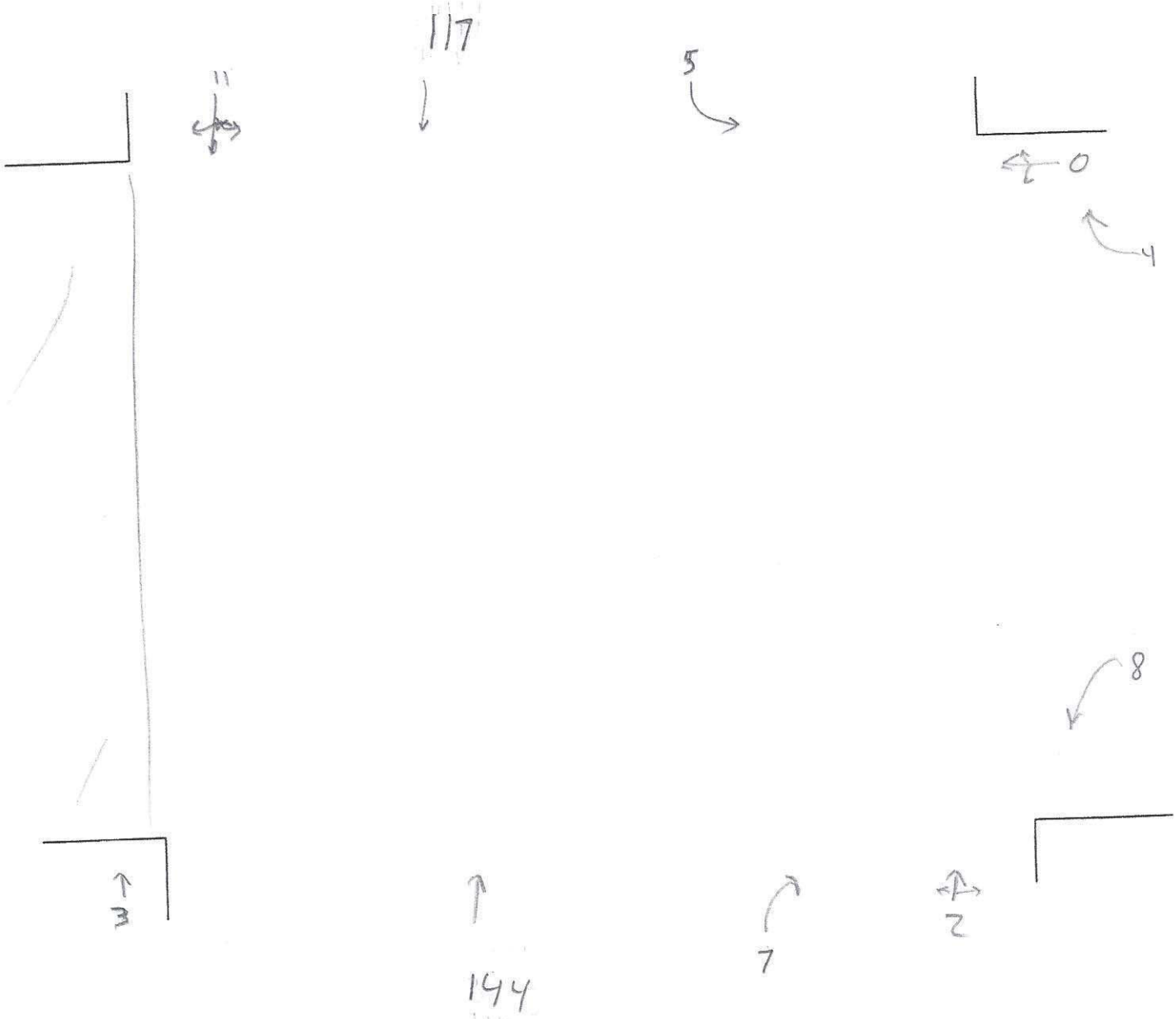
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Michelson / Sequoia Tree lane

Time Period: 1:40 - 2:40

Volumes:

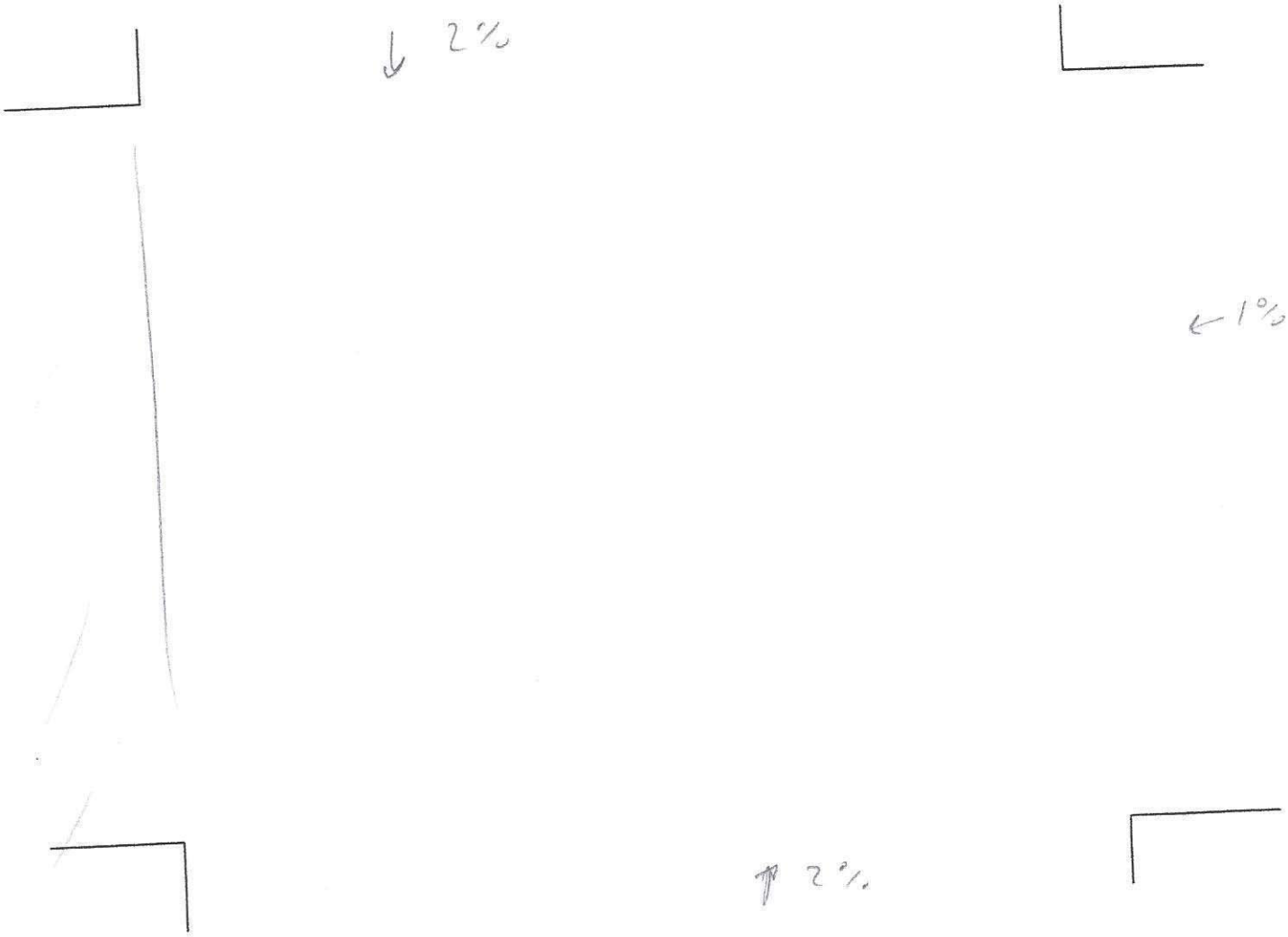


Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Michelson / Sequoia Tree Lane

Heavy Vehicles:



Comments:

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Turtle Rock Drive / Sycamore Creek

City: Irvine

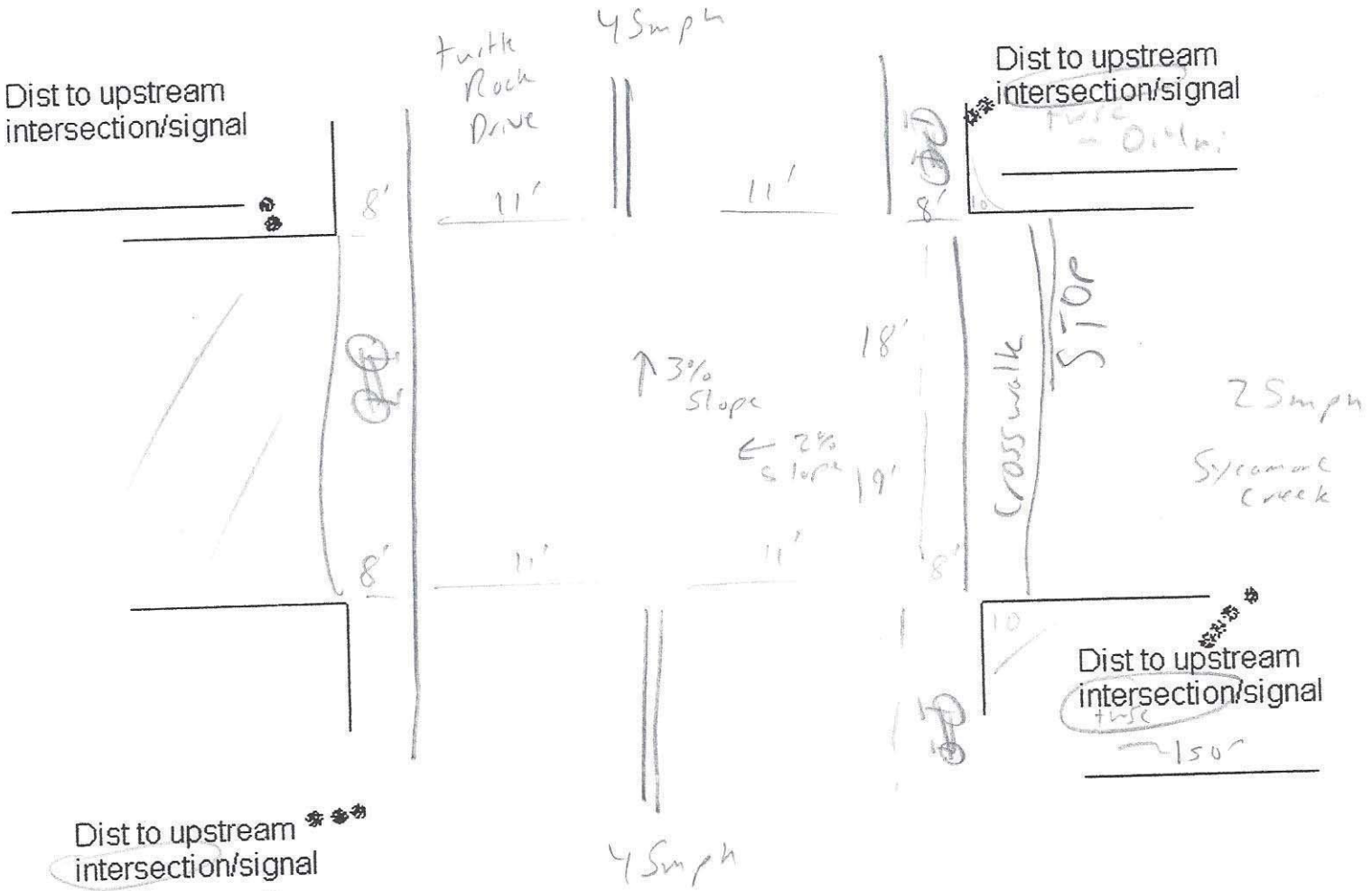
Location: (Southern CA) Northern CA Central CA Other

Intersection Type: (T) +

Data Collection Time: 2:50 - 3:50 7/20/13 Sat

Intersection Geometry:

North Arrow:



Comments: Par quality = 4 No signage.

No parking on major.

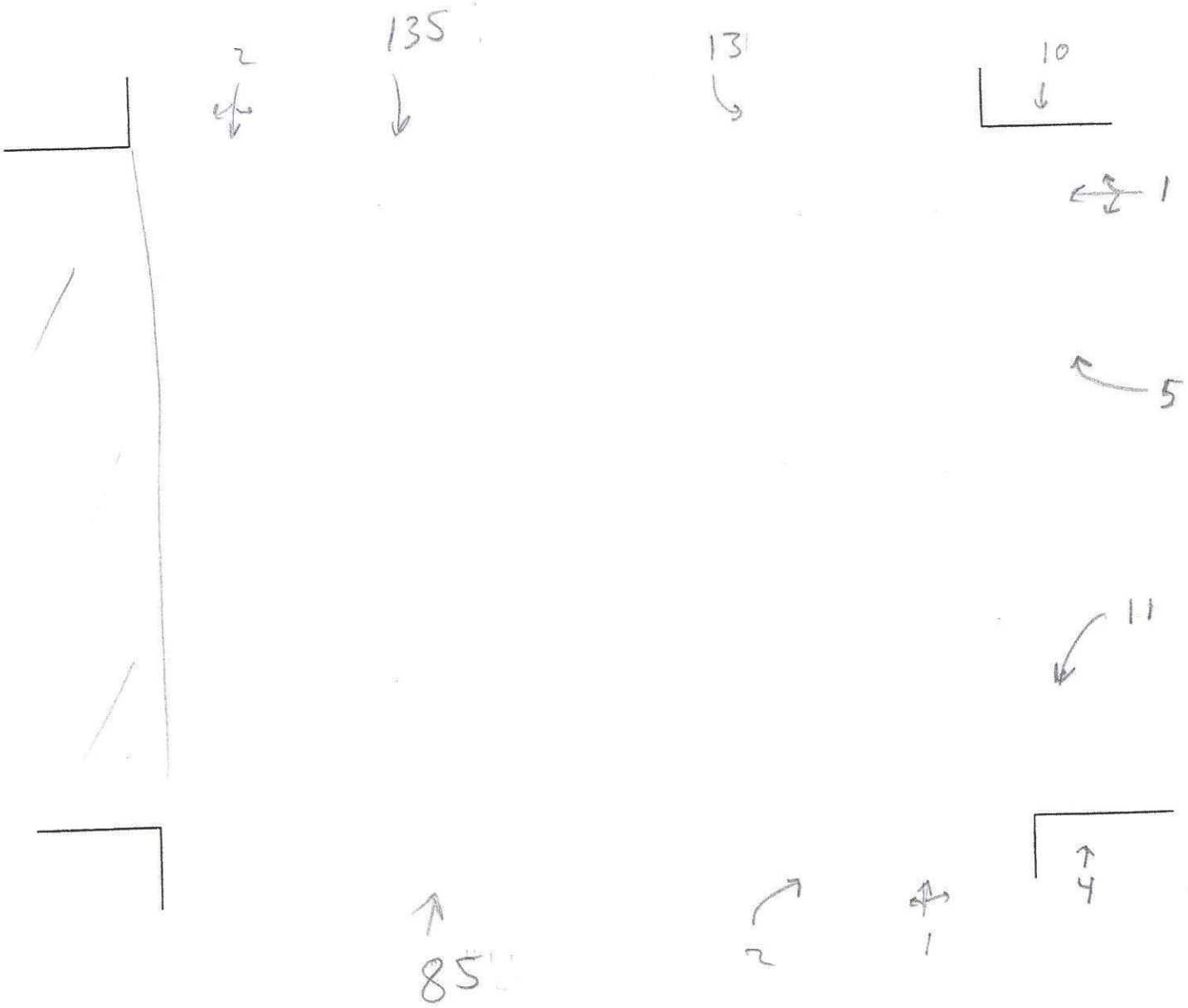
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Turtle Rock Drive / Sycamore Creek

Time Period: 2:50 - 3:50

Volumes:

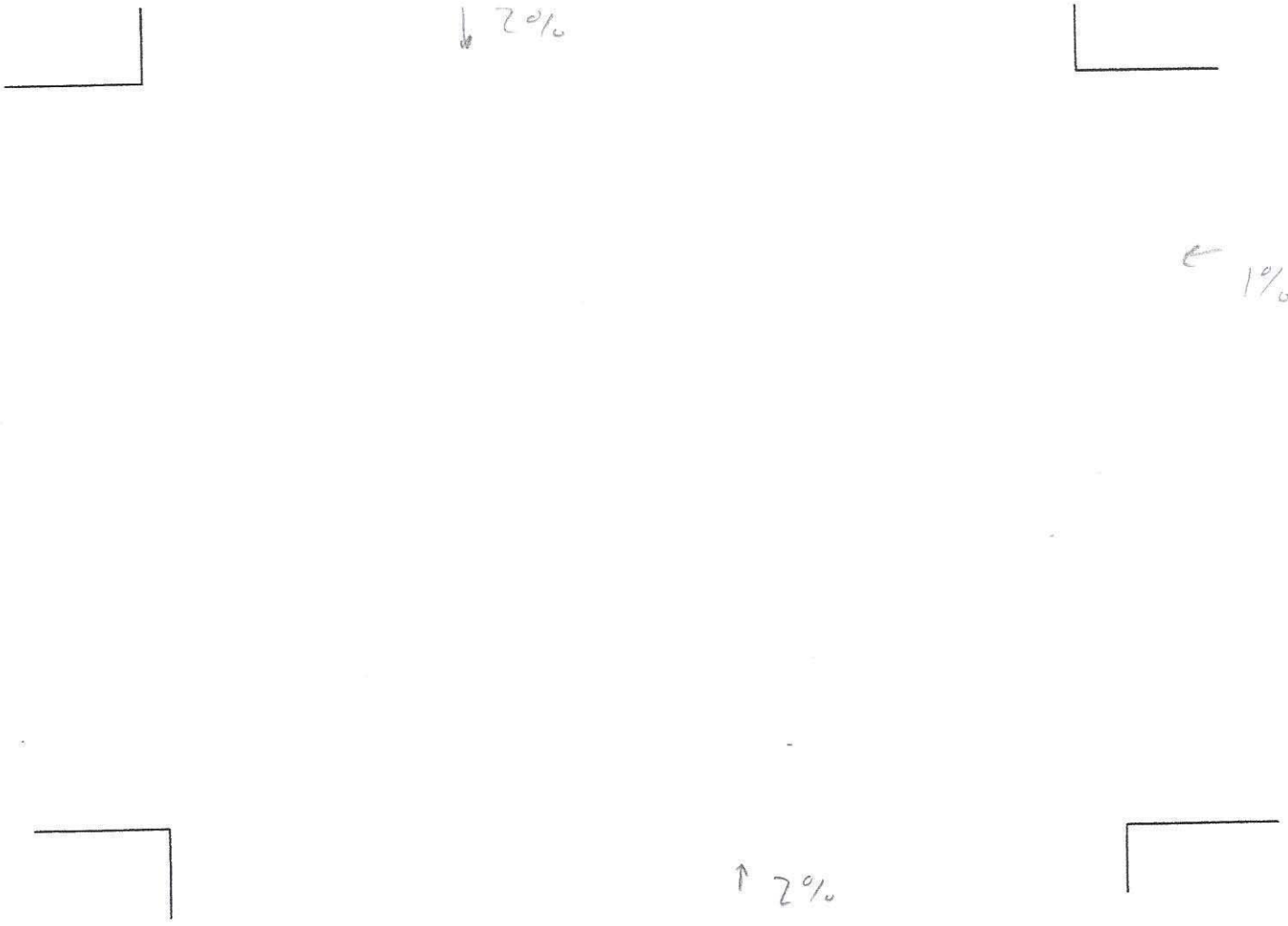


Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Turtle Rock Drive / Sycamore Creek

Heavy Vehicles:



Comments:

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: West Linden Street / Douglass Avenue

City: Riverside

Location: (Southern CA) Northern CA Central CA Other

Intersection Type: (T) +

Data Collection Time: 1:50-2:50 7/16/15 Tues

Intersection Geometry:

North Arrow: ←

Dist to upstream intersection/signal AVSC ~400'

Comments: Pavement quality = 2 Onstreet parking on all sides No signage

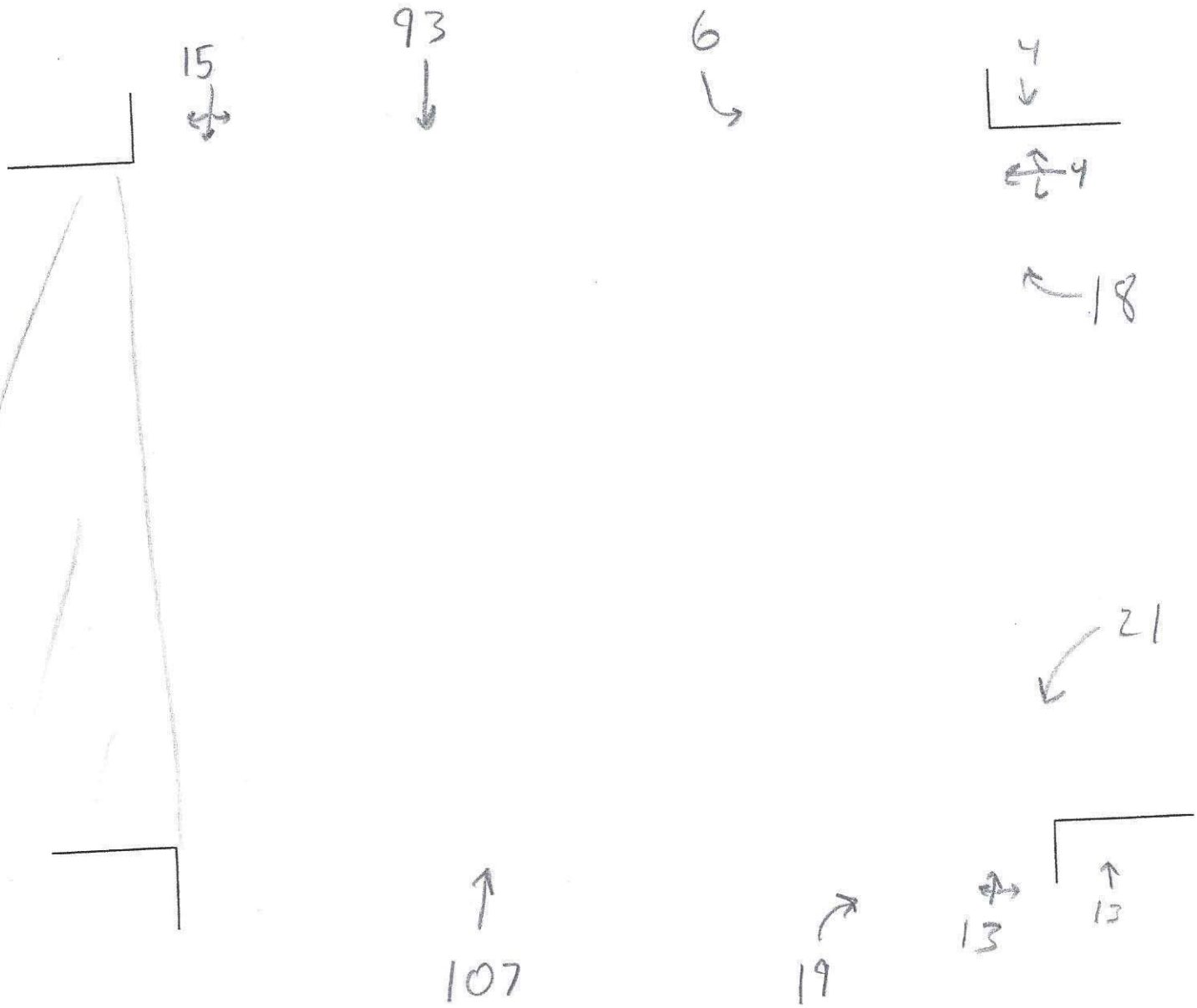
Cal Poly San Luis Obispo

Nathan Johnston

Intersection: W Linden Street / Douglass Avenue

Time Period: 1:50-2:50 7/16/13 Tues

Volumes:



Cal Poly San Luis Obispo

Nathan Johnston

Intersection: W Linden Street / Douglass Avenue

Heavy Vehicles:

Comments:

Cal Poly San Luis Obispo

Nathan Johnston

Intersection: Victoria Ave / Grace Street

City: Riverside

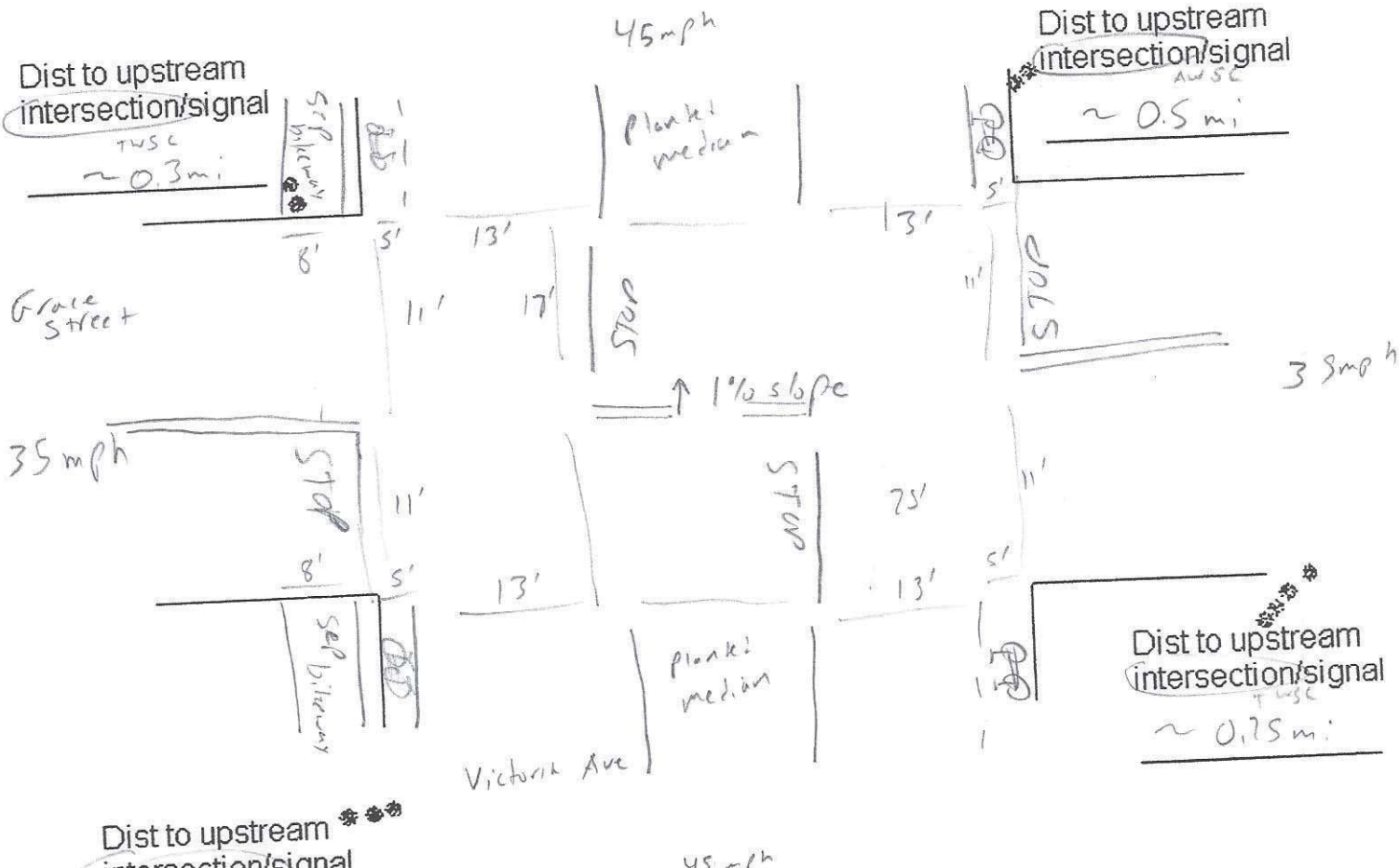
Location: (Southern CA) Northern CA Central CA Other

Intersection Type: T (+)

Data Collection Time: 8:00-9:00 7/16/13 Tues

Intersection Geometry:

North Arrow:



Comments: Onstreet and Separated bikelanes median planter center divider. Signage upstream, but not @ immediate intersection.

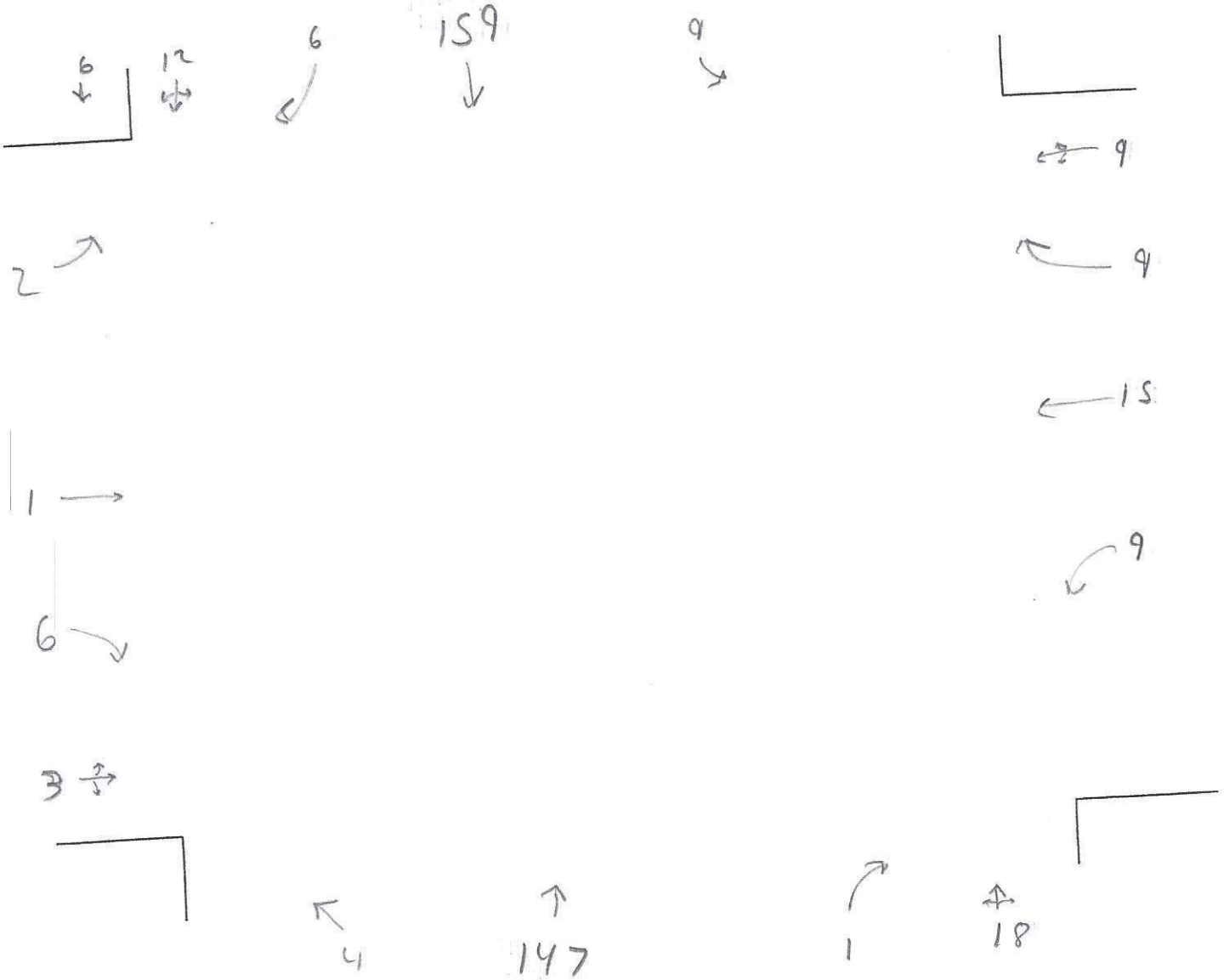
Cal Poly San Luis Obispo

Nathan Johnston

Intersection: Victoria Avenue/ Grace Street

Time Period: 8:00-9:00

Volumes:

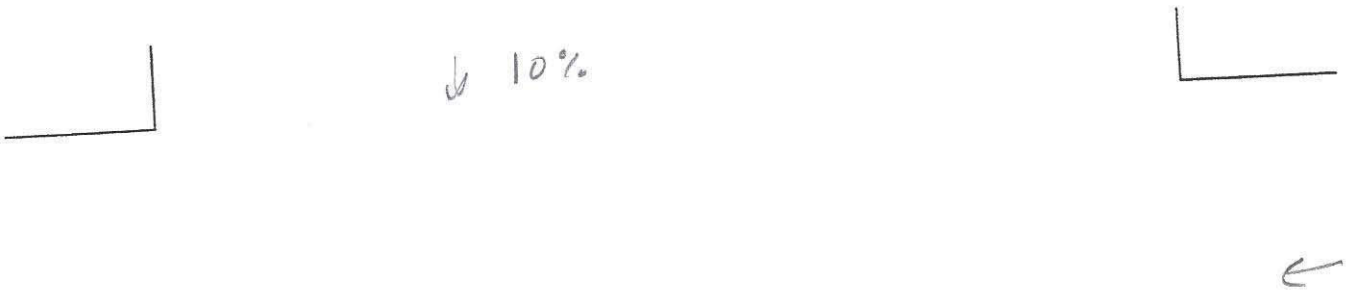


Cal Poly San Luis Obispo

Nathan Johnston

Intersection: Victoria Ave / Grace Street

Heavy Vehicles:



Comments: Quite a few large vehicles

Cal Poly San Luis Obispo

Nathan Johnston

Intersection: Victoria Avenue / Saint Lawerence Street

City: Riverside

Location: (Southern CA) Northern CA Central CA Other

Intersection Type: (T) +

Data Collection Time: 9:05 - 10:05 7/16/13 Tues

Intersection Geometry:

North Arrow:

Comments: Signage present Pavement Quality 3
No parking in bike lanes Planted median

Cal Poly San Luis Obispo

Nathan Johnston

Intersection: Victoria Avenue / Saint Lawerence Street

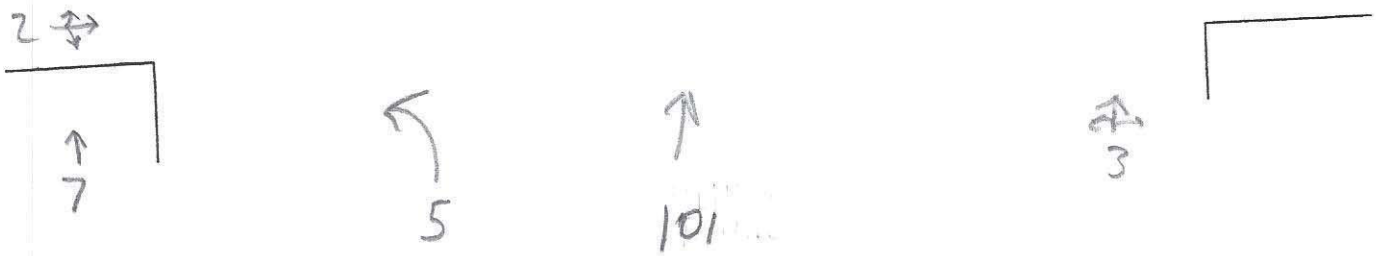
Time Period: 9:05 - 10:05

Volumes:

6

Little to no traffic

4



Cal Poly San Luis Obispo

Nathan Johnston

Intersection: Victoria Ave / Saint Lawrence Street

Heavy Vehicles:

Comments:

Cal Poly San Luis Obispo

Nathan Johnston

Intersection: Victoria Avenue / Boundary Lane

City: Riverside

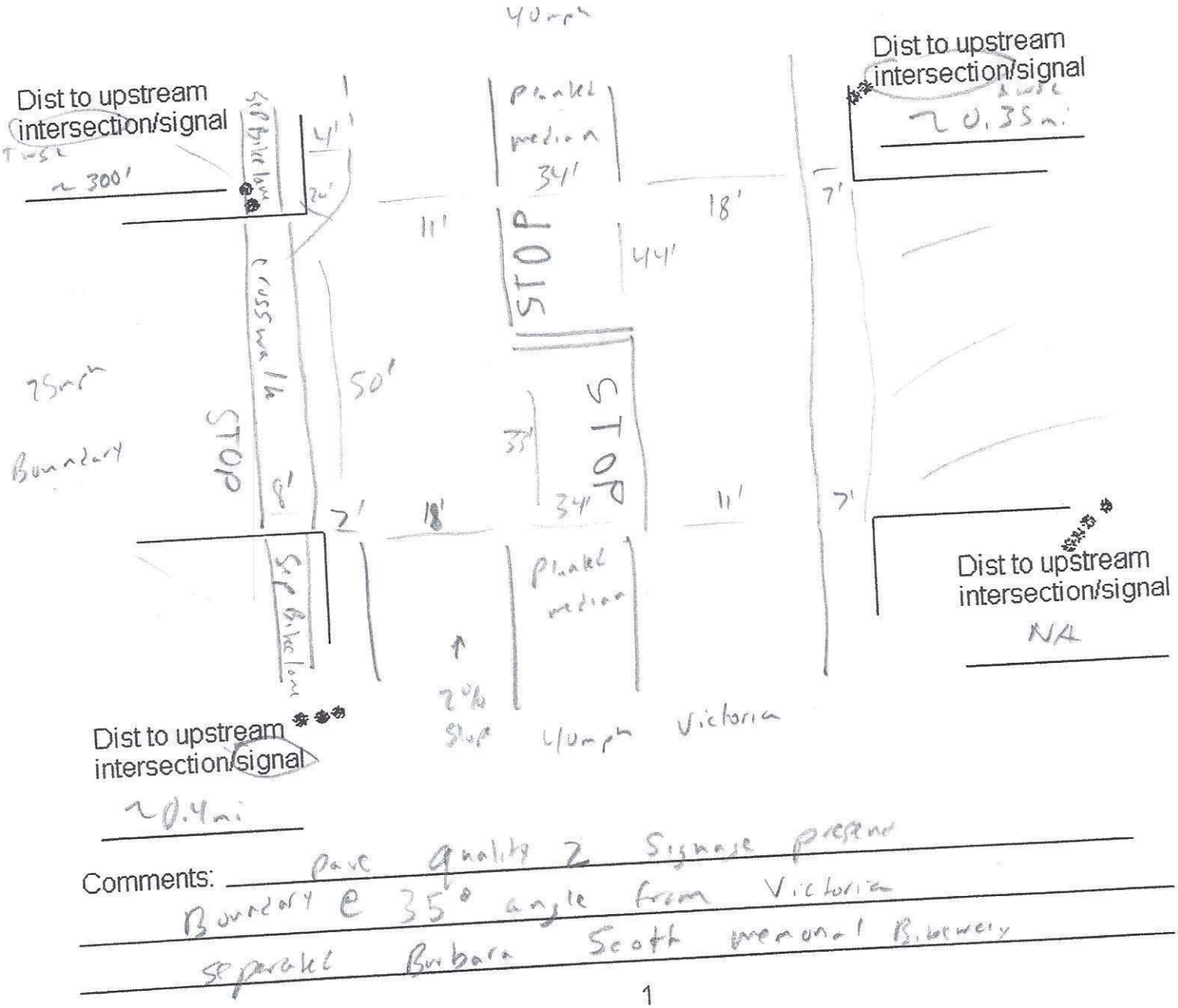
Location: (Southern CA) Northern CA Central CA Other

Intersection Type: (T) +

Data Collection Time: 10:10 - 11:10 7/16/13 Tues

Intersection Geometry:

North Arrow:



Comments: Poor quality 2 Signage present

Boundary @ 35° angle from Victoria

separate Barbara Scott memorial Bikeway

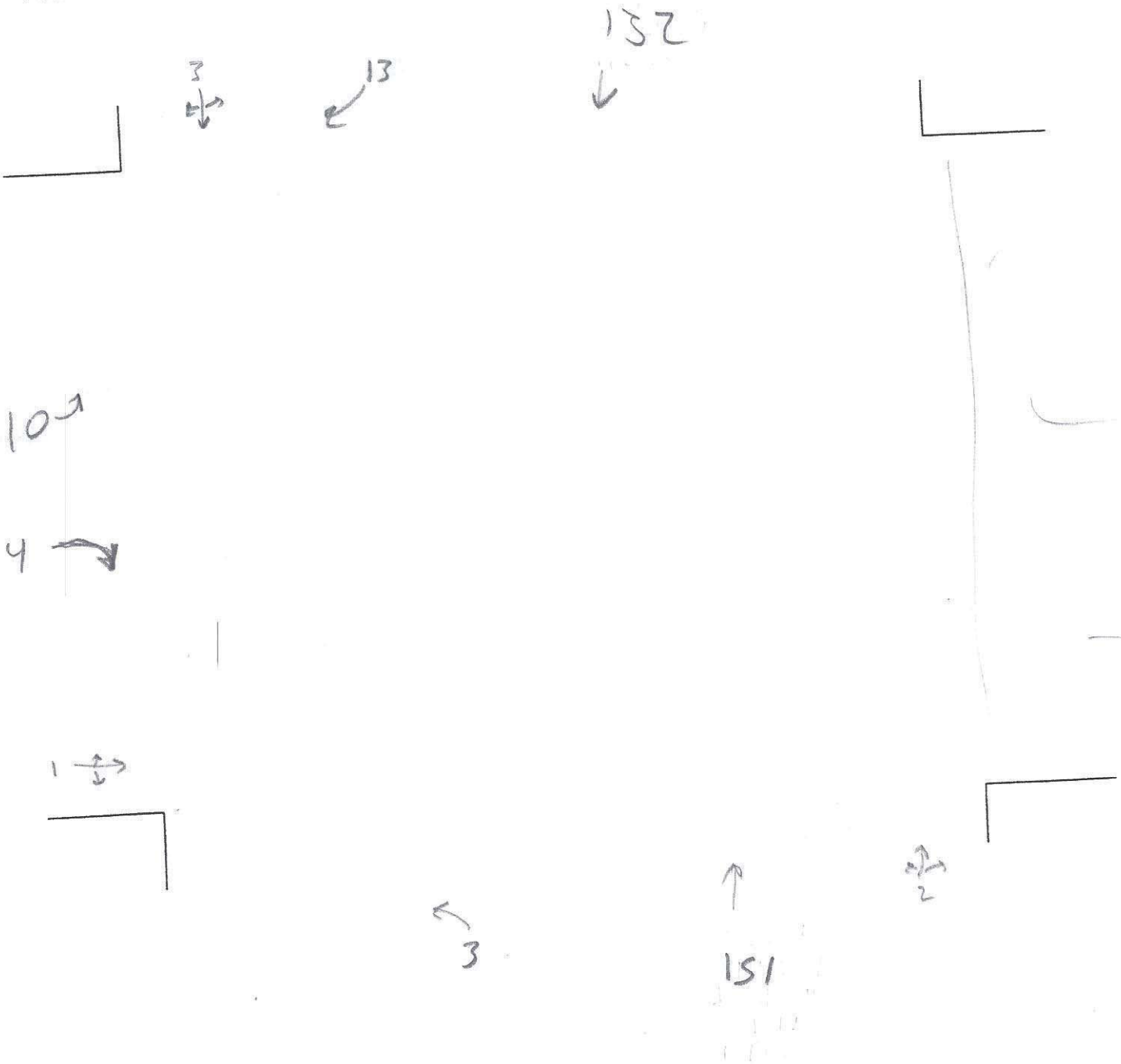
Cal Poly San Luis Obispo

Nathan Johnston

Intersection: Victoria Avenue / Boundary Lane

Time Period: 10:10 - 11:10

Volumes:



Cal Poly San Luis Obispo

Nathan Johnston

Intersection: Victoria Avenue/Boundary Lane

Heavy Vehicles:

Comments:

Cal Poly San Luis Obispo

Nathan Johnston

Intersection: Colorado Avenue / Dundee Road

City: Riverside

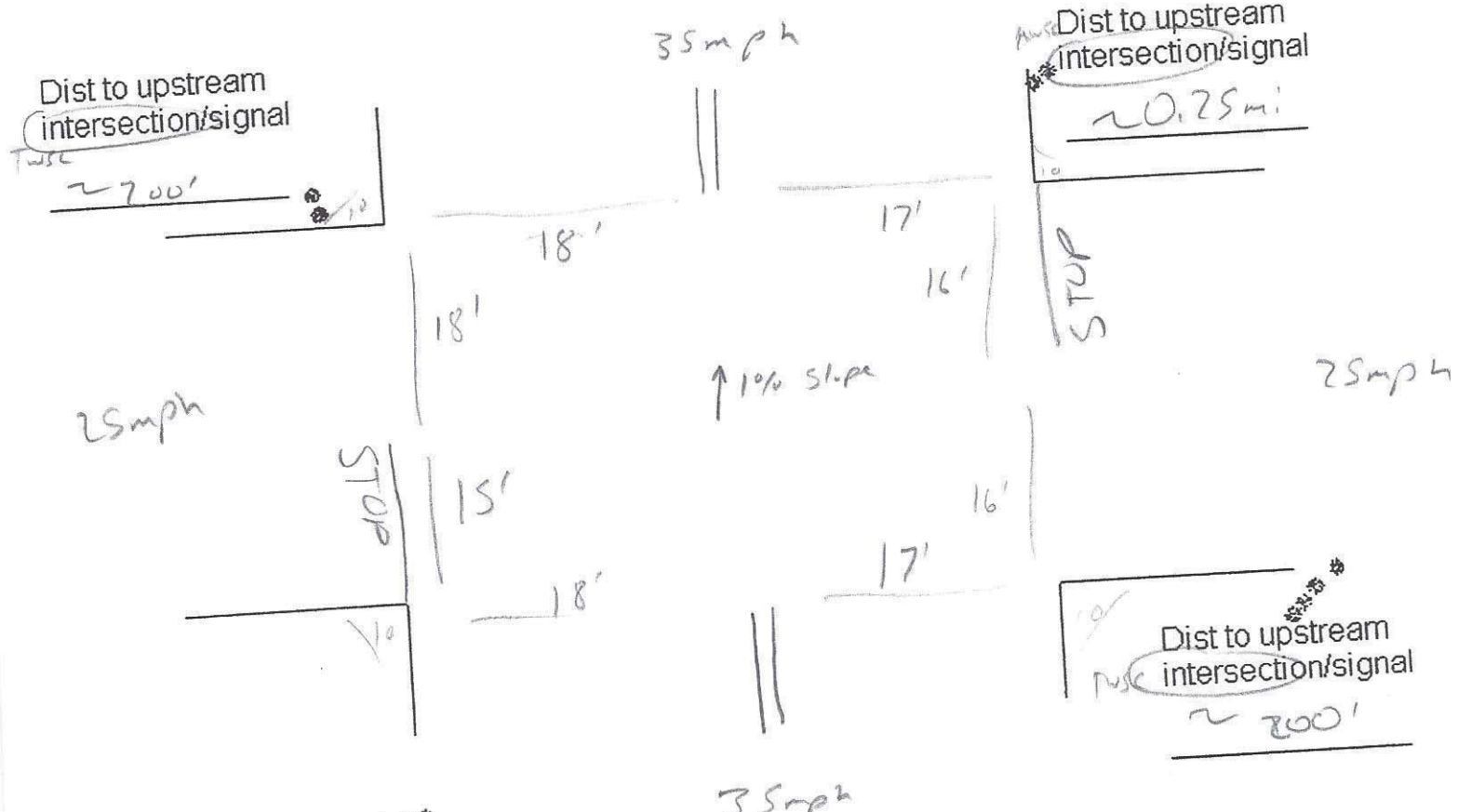
Location: (Southern CA) Northern CA Central CA Other

Intersection Type: T (+)

Data Collection Time: 11:15-12:15 7/16/13 Tues

Intersection Geometry:

North Arrow:



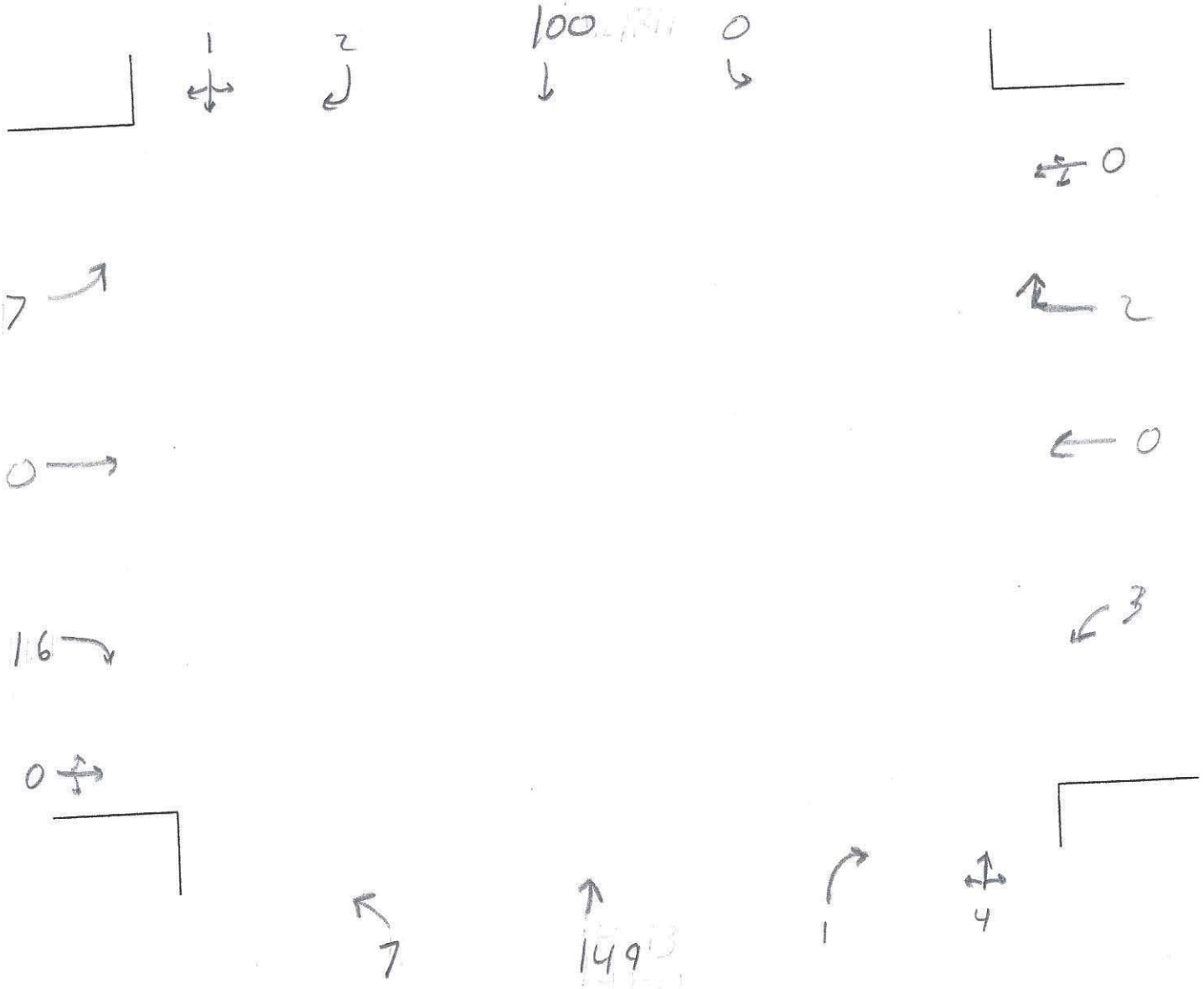
Comments:

Nathan Johnston

Intersection: Colorado Avenue / Dundee Road

Time Period: 11:15 - 12:15

Volumes:

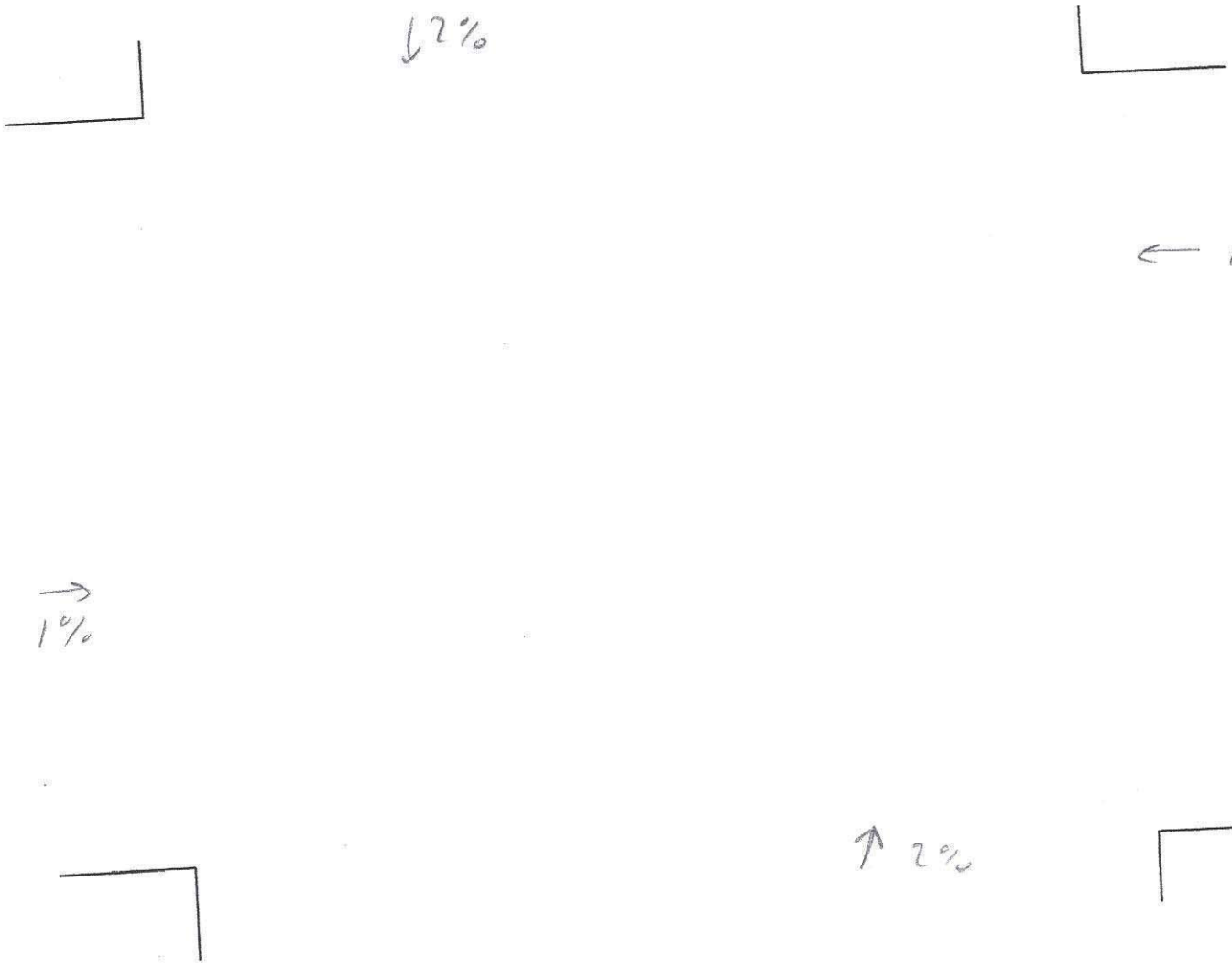


Cal Poly San Luis Obispo

Nathan Johnston

Intersection: Colorado Avenue / Dundee Road

Heavy Vehicles:



Comments:

Cal Poly San Luis Obispo

Nathan Johnston

Intersection: California Avenue / Shelby Drive

City: Riverside

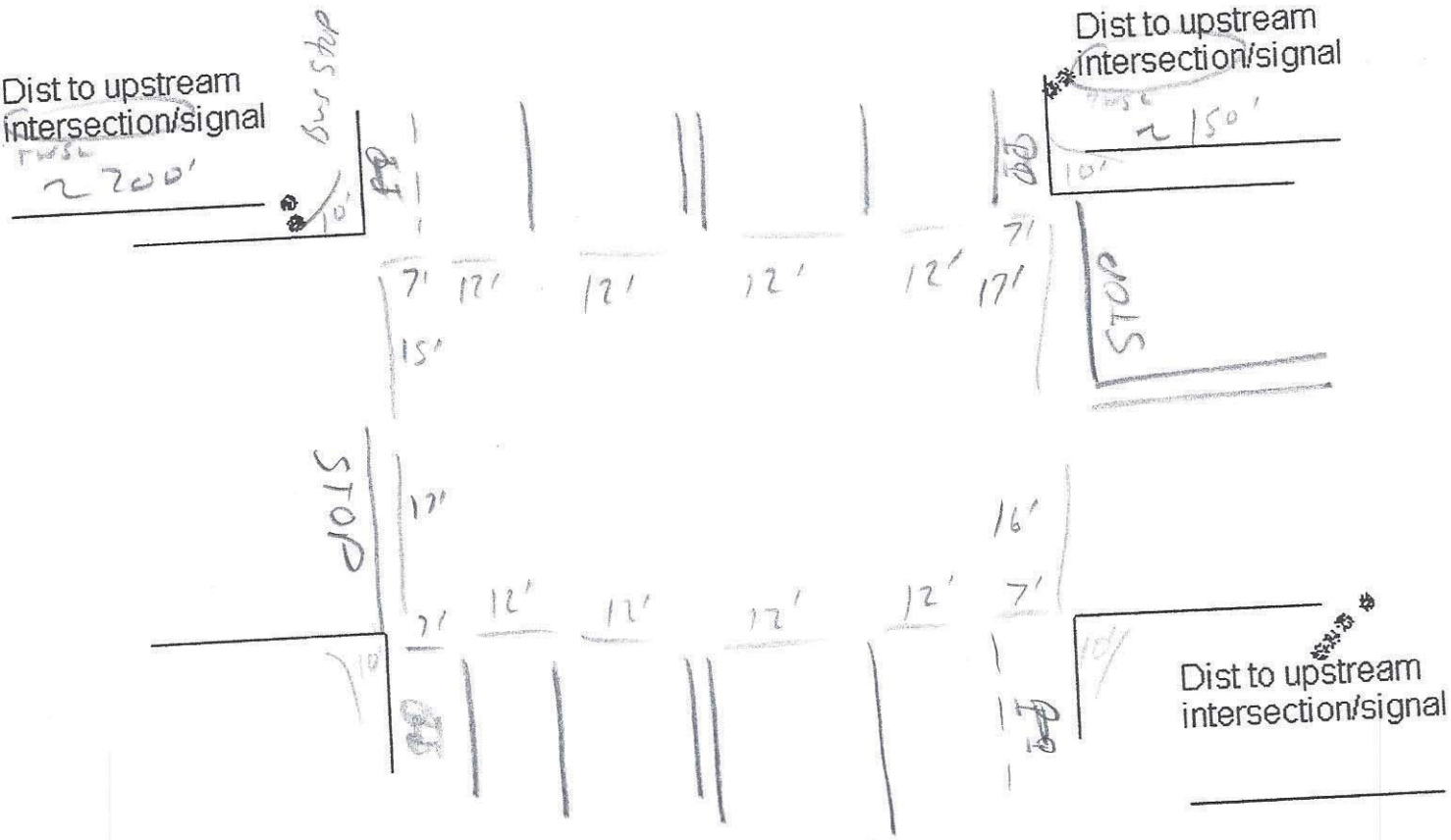
Location: Southern CA Northern CA Central CA Other

Intersection Type: T +

Data Collection Time: 12:20-1:20 7/16/13 Tues

Intersection Geometry:

North Arrow: ↖



Comments: Shelby Streets offset by ~15'

Pavement quality 3 No signage.

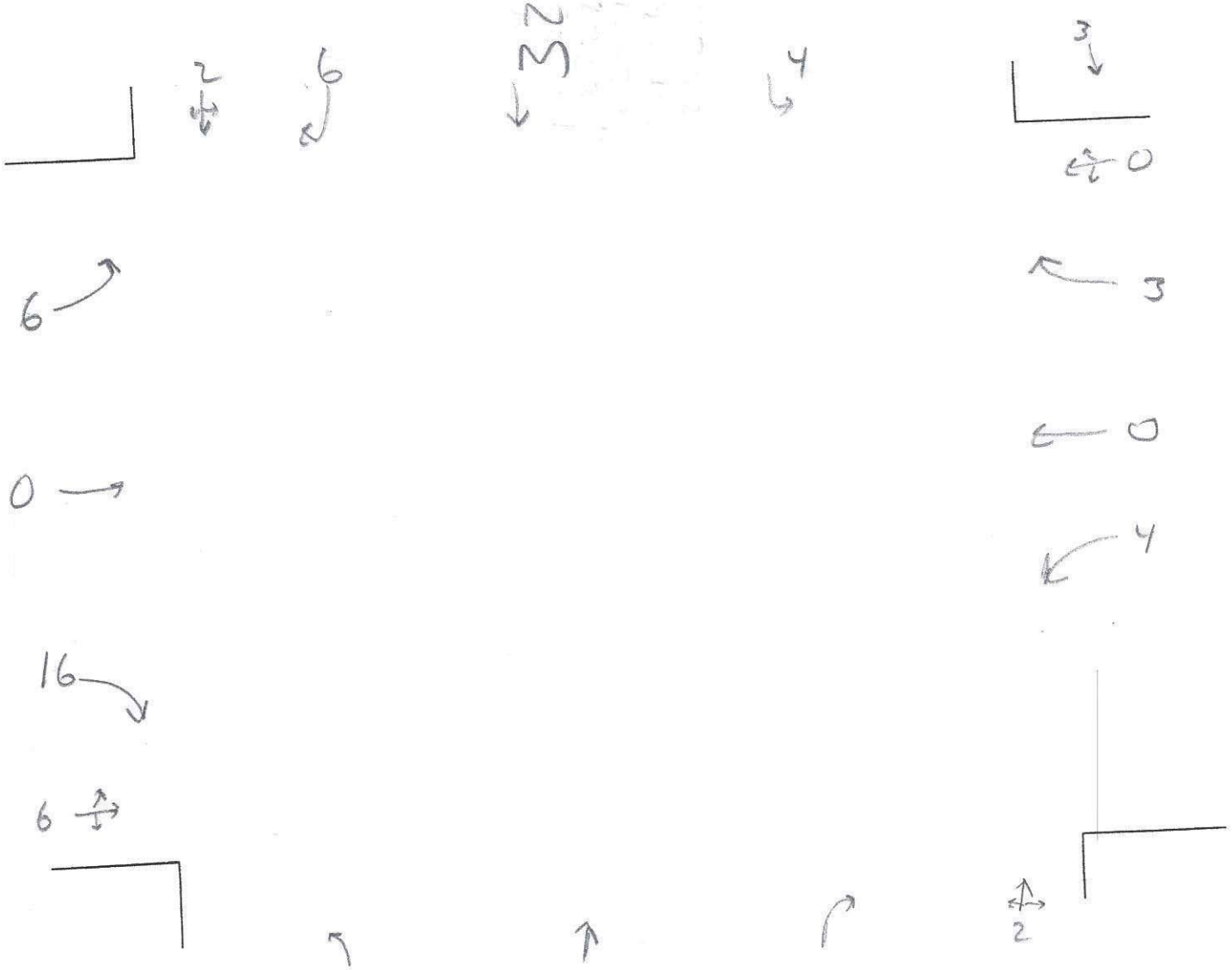
Cal Poly San Luis Obispo

Nathan Johnston

Intersection: California Avenue / Shelby Drive

Time Period: 12:20 – 1:20

Volumes:



Cal Poly San Luis Obispo

Nathan Johnston

Intersection: California Ave / Shelby Drive

Heavy Vehicles:

Comments:

Cal Poly San Luis Obispo

Nathan Johnston

Intersection: Magnolia Avenue / Hoover Street

City: Riverside

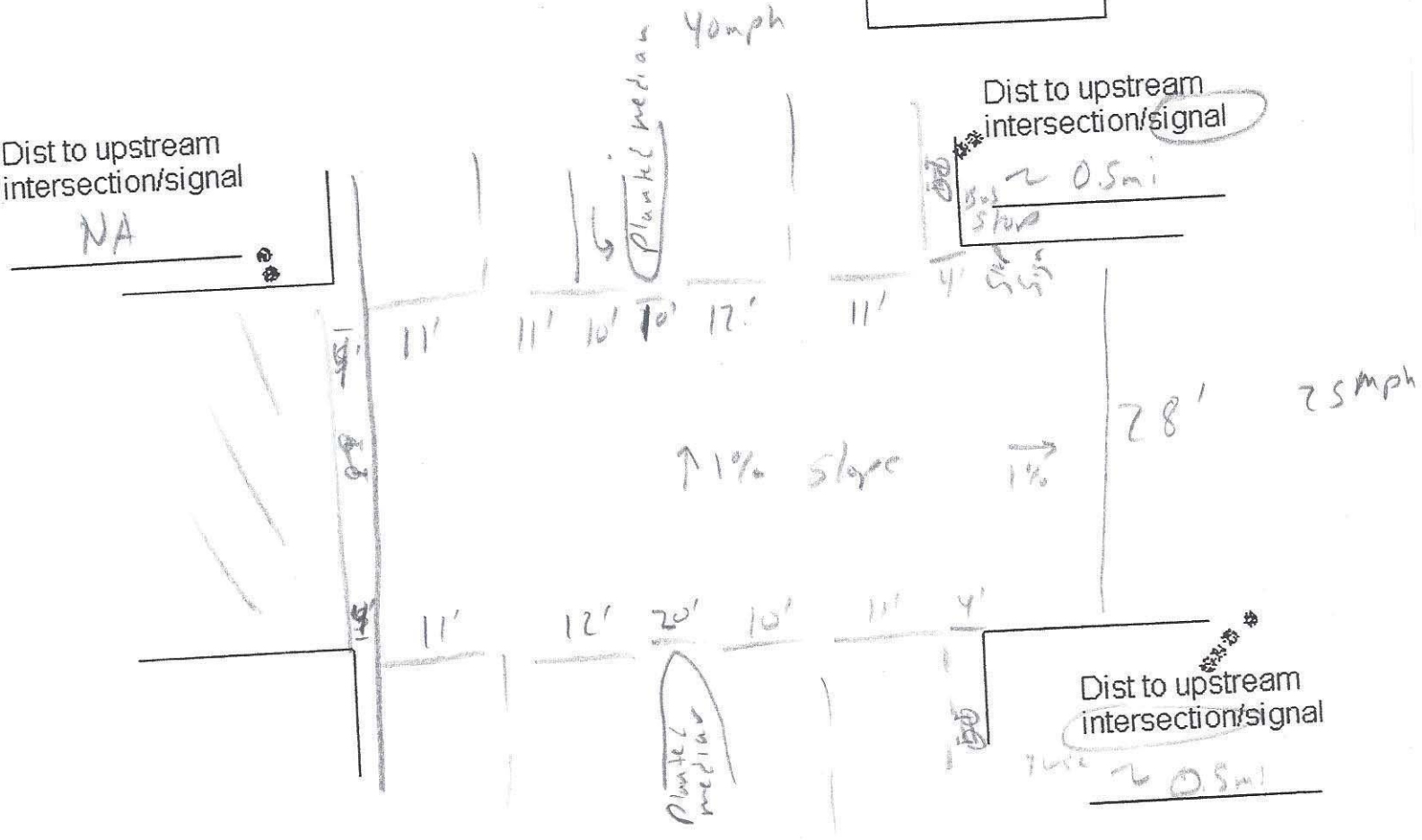
Location: (Southern CA) Northern CA Central CA Other

Intersection Type: (T) +

Data Collection Time: 1:30 - 2:30 7/16/15

Intersection Geometry:

North Arrow: ↑



Comments: No parking on magnolia East side has mountable curb. Pave quality = 3 No signage.

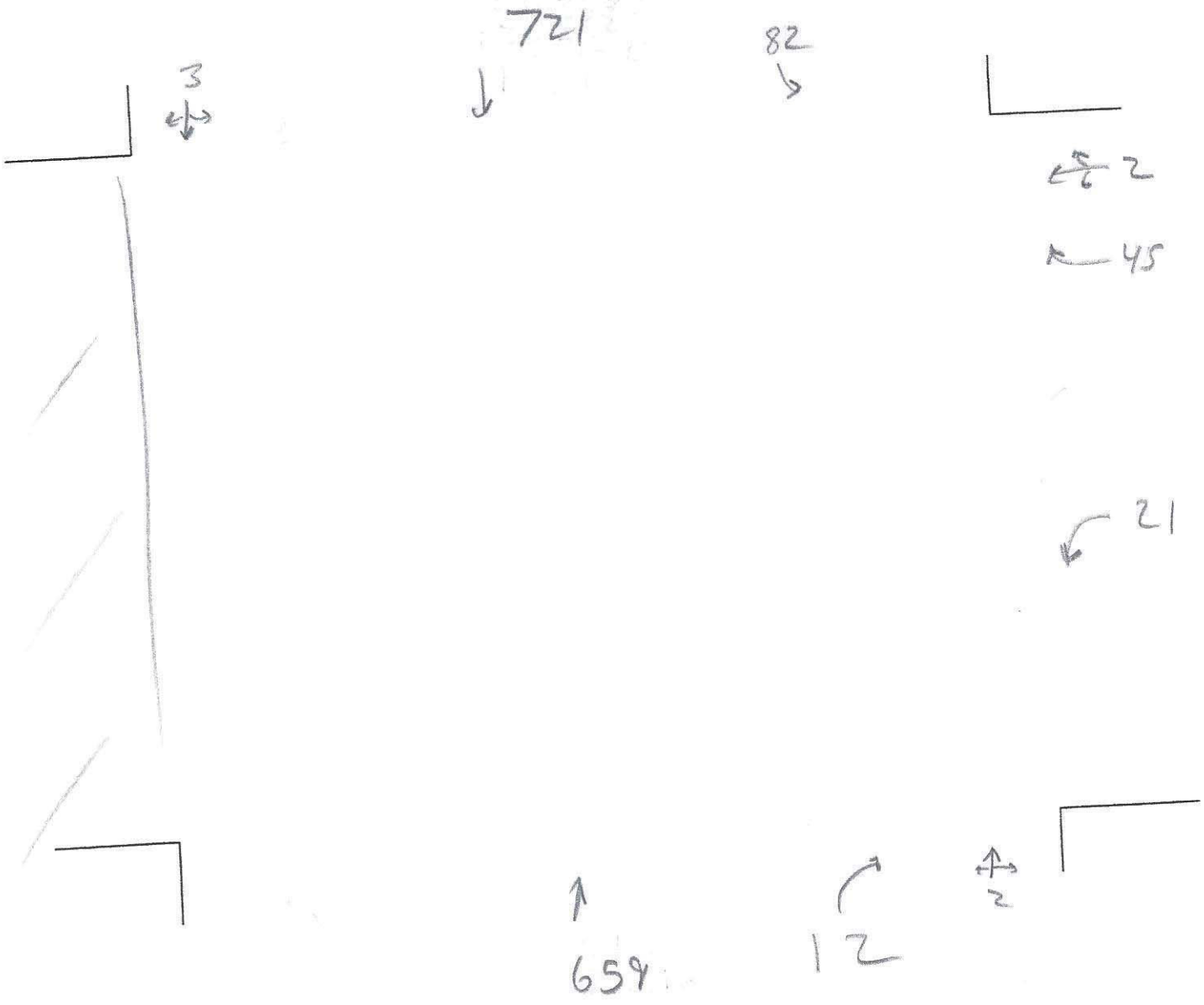
Cal Poly San Luis Obispo

Nathan Johnston

Intersection: Magnolia Avenue / Hoover Street

Time Period: 1:30-2:30

Volumes:

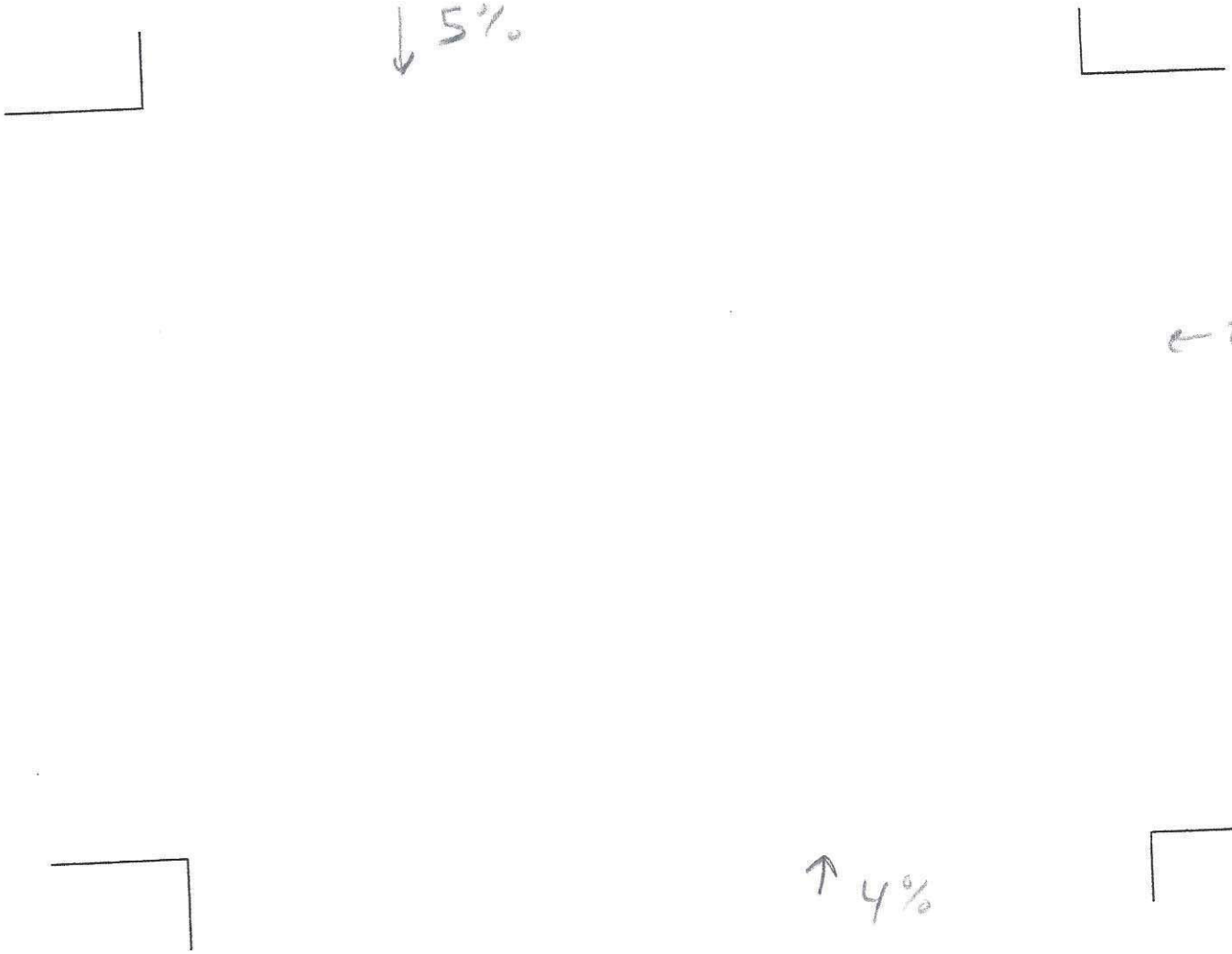


Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Magnolia Avenue / Hoover Street

Heavy Vehicles:



Comments:

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Los Osos Valley Road / Diablo Drive

City: San Luis Obispo

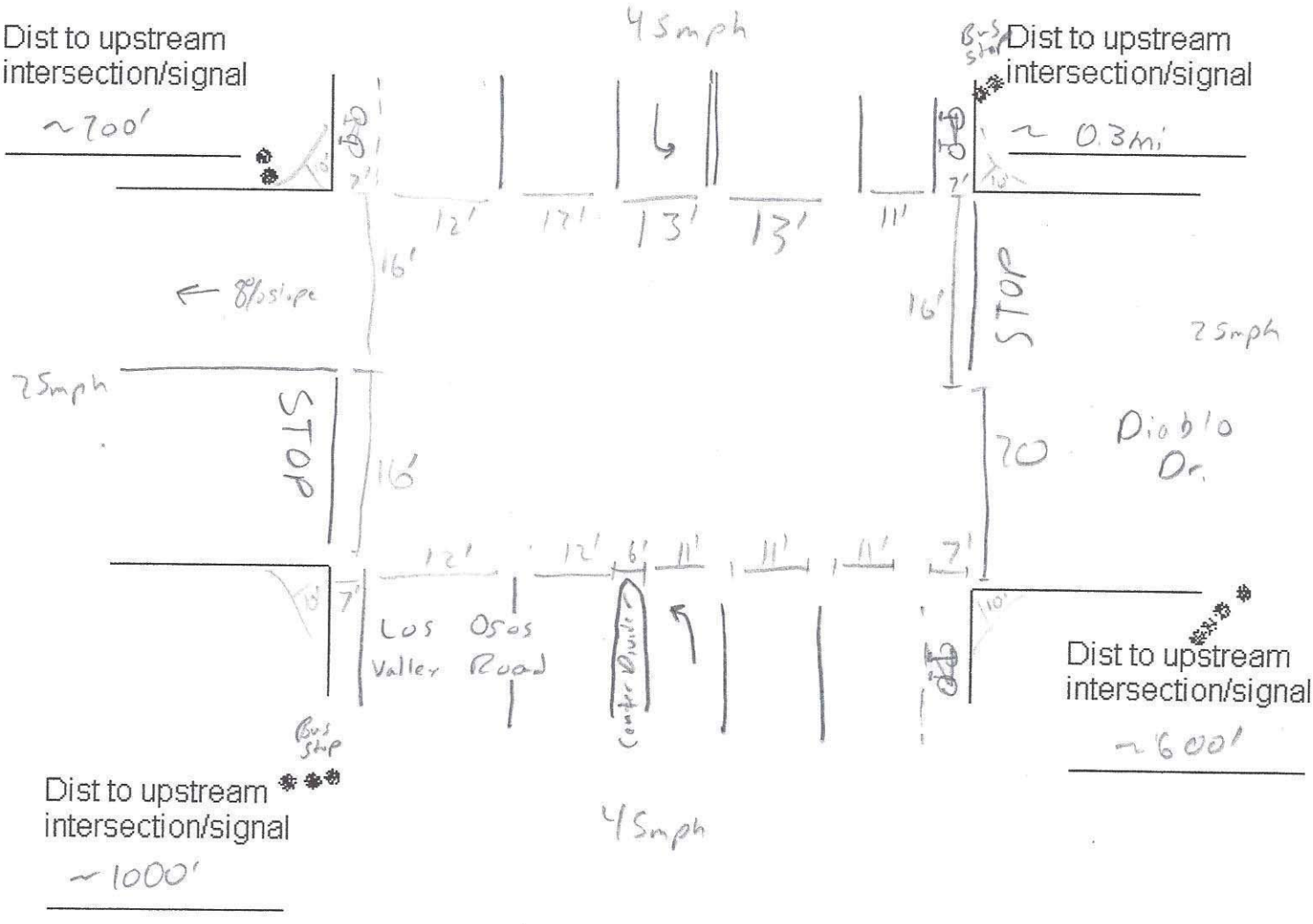
Location: Southern CA Northern CA Central CA Other

Intersection Type: T +

Data Collection Time: 9:00 - 10:00 Weds 6/19/13

Intersection Geometry:

North Arrow:



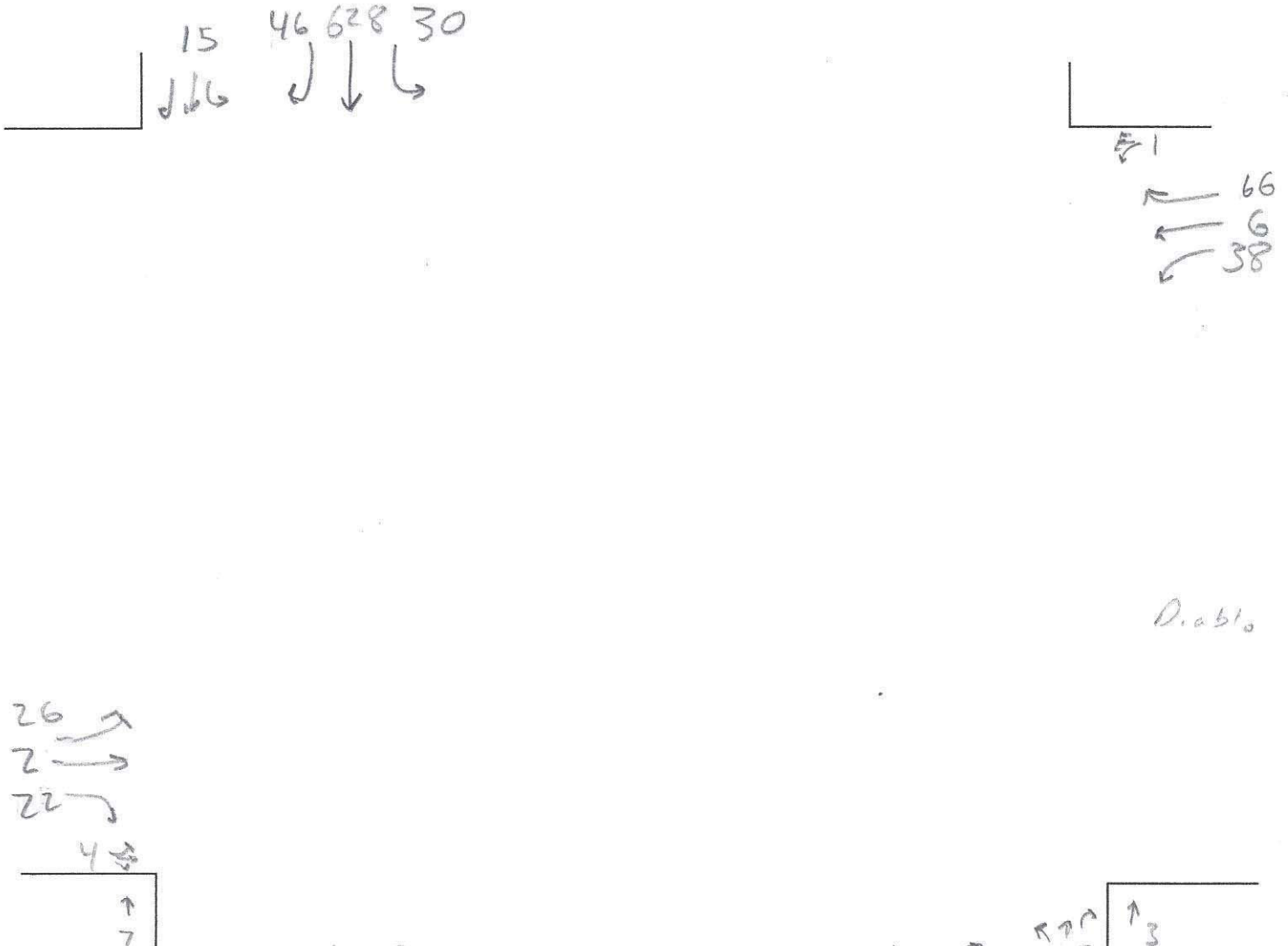
Comments: Diablo EB is set back about 20 feet from LOVR for stop bar. Provides space for cyclists to enter.

Nathan Johnston Cal Poly San Luis Obispo

Intersection: Los Osos Valley Road / Diablo Dr.

Time Period: 9:00 - 10:00

Volumes:



Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Los Osos Valley Road / Diablo Drive

Heavy Vehicles:

↓ 9%

7%
←

7%
→

Diablo

LOVR

12%
↑

Comments: Diablo had RV traffic

Nathan Johnston Cal Poly San Luis Obispo

Intersection: Grand Ave / McCollum St.

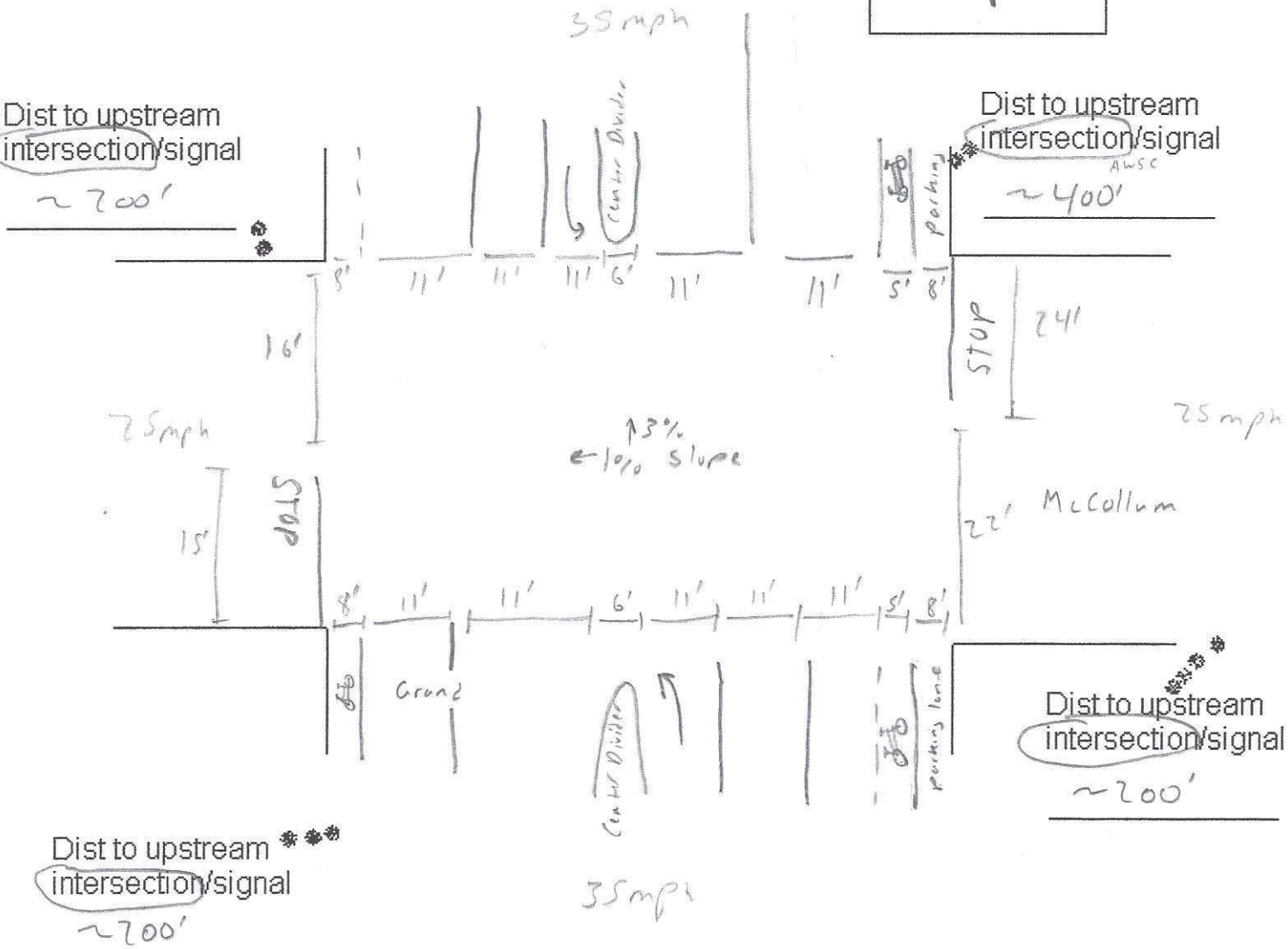
City: San Luis Obispo

Location: Southern CA Northern CA (Central CA) Other

Intersection Type: T (+)

Data Collection Time: 7:40 - 8:40 Weds 6/19/13

Intersection Geometry: North Arrow:

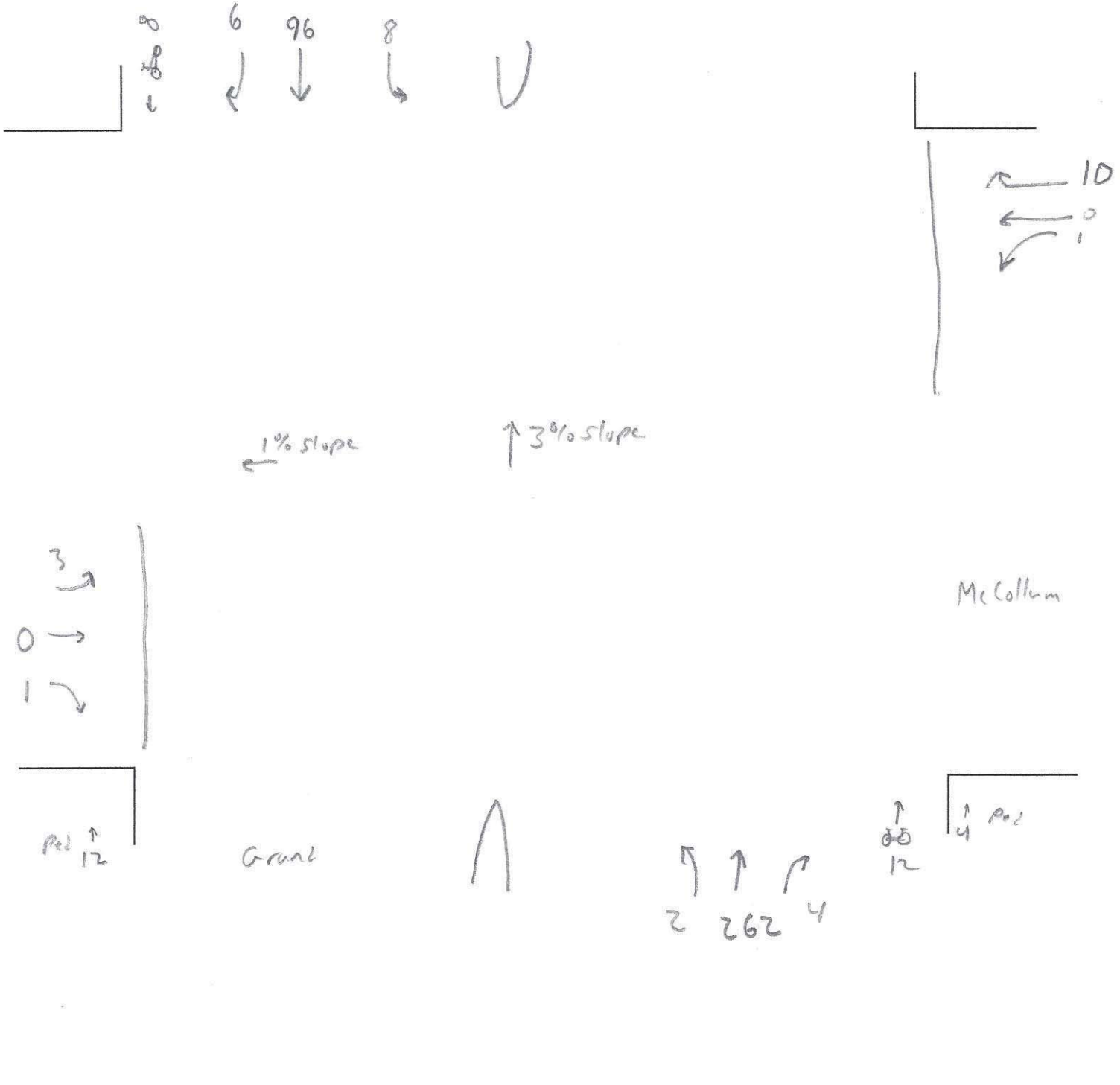


Comments:

Intersection: Grand Ave / McCollum St.

Time Period: 7:40 - 8:40 · Weds 6/19/13

Volumes:

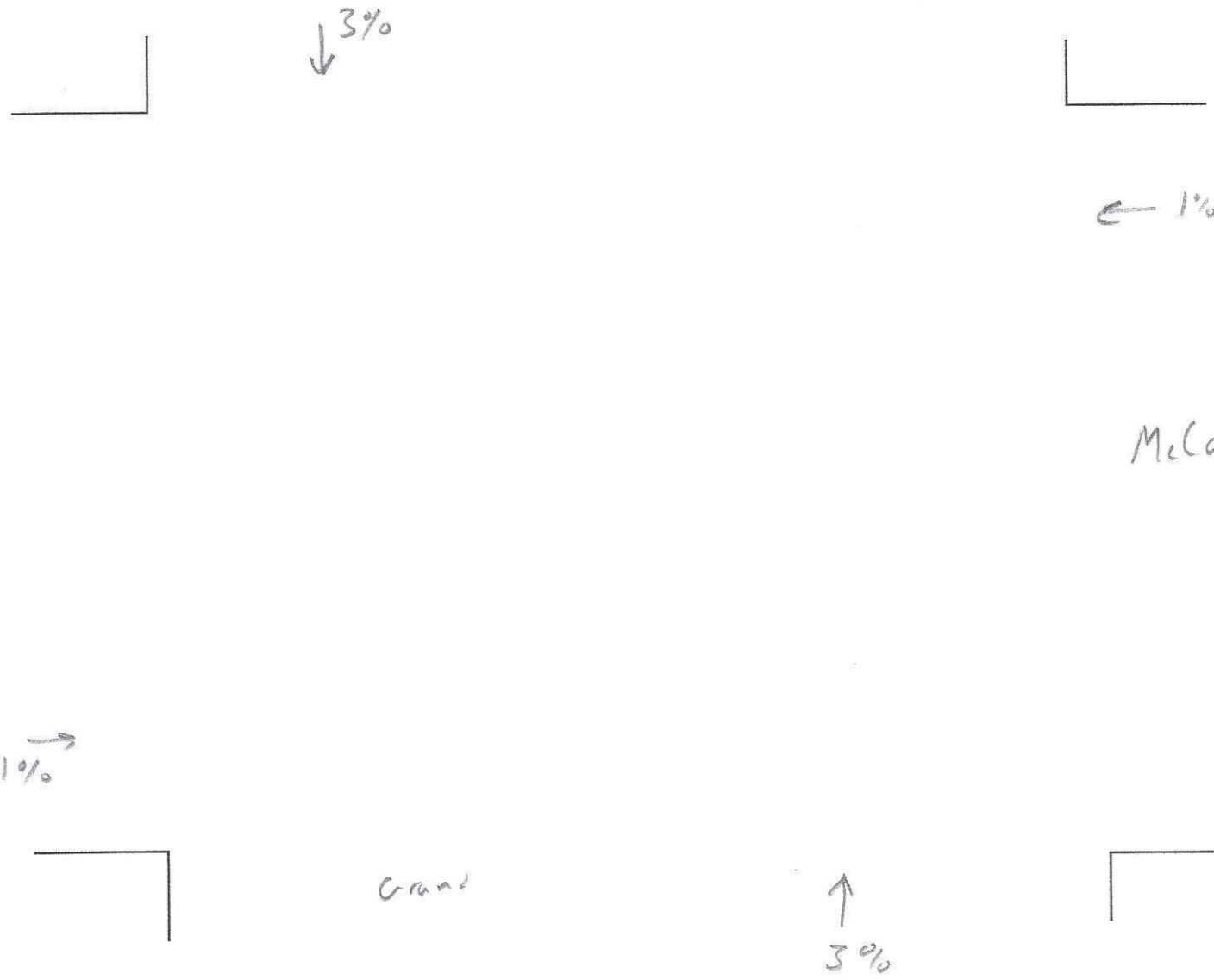


Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Grand Ave / McCollum st

Heavy Vehicles:



Comments:

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Patricia Dr / Cerro Romaldo Ave

City: San Luis Obispo

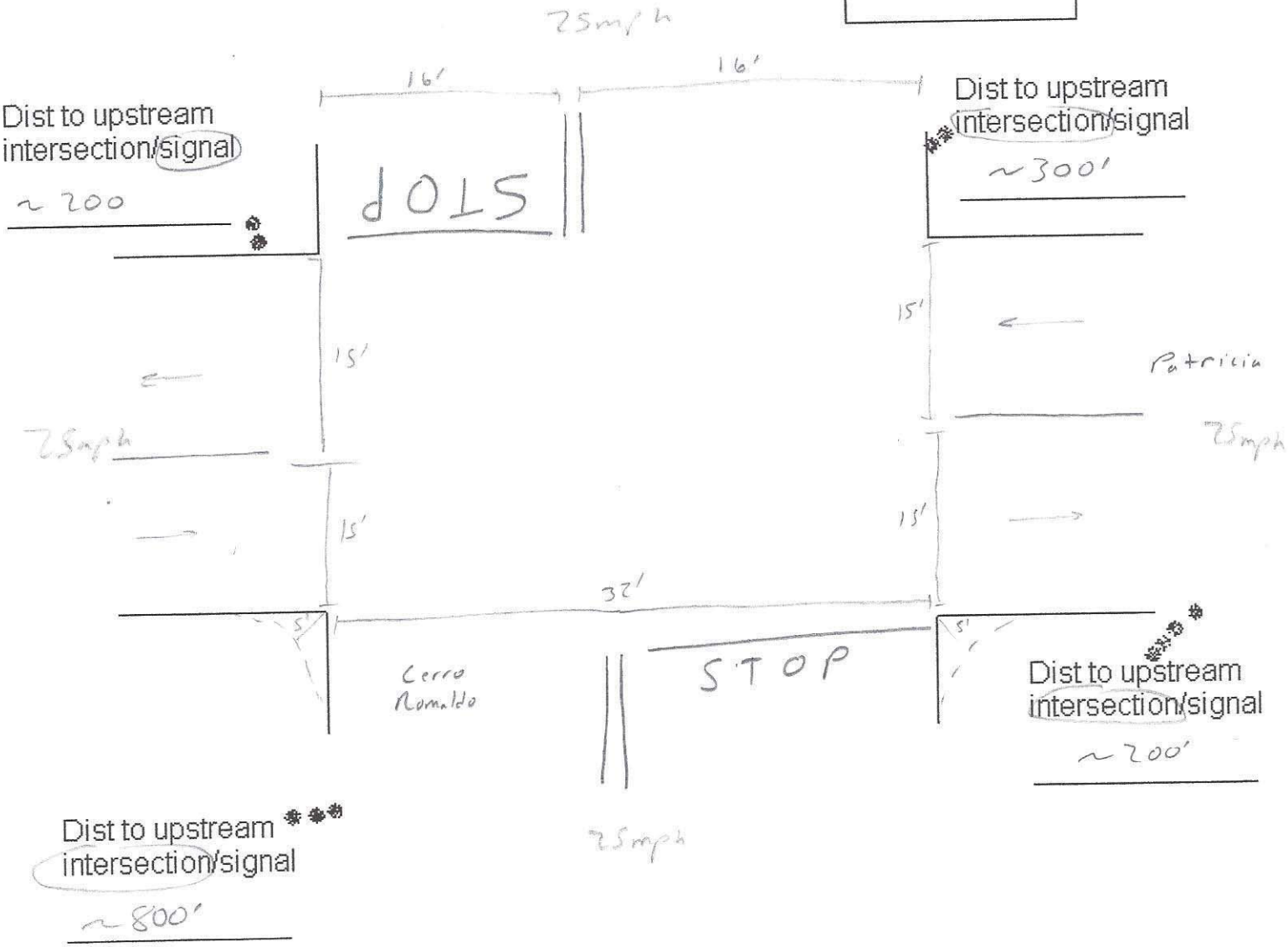
Location: Southern CA Northern CA (Central CA) Other

Intersection Type: T (+)

Data Collection Time: Weds 6/19/13 ~6:30am start

Intersection Geometry:

North Arrow:



Comments:

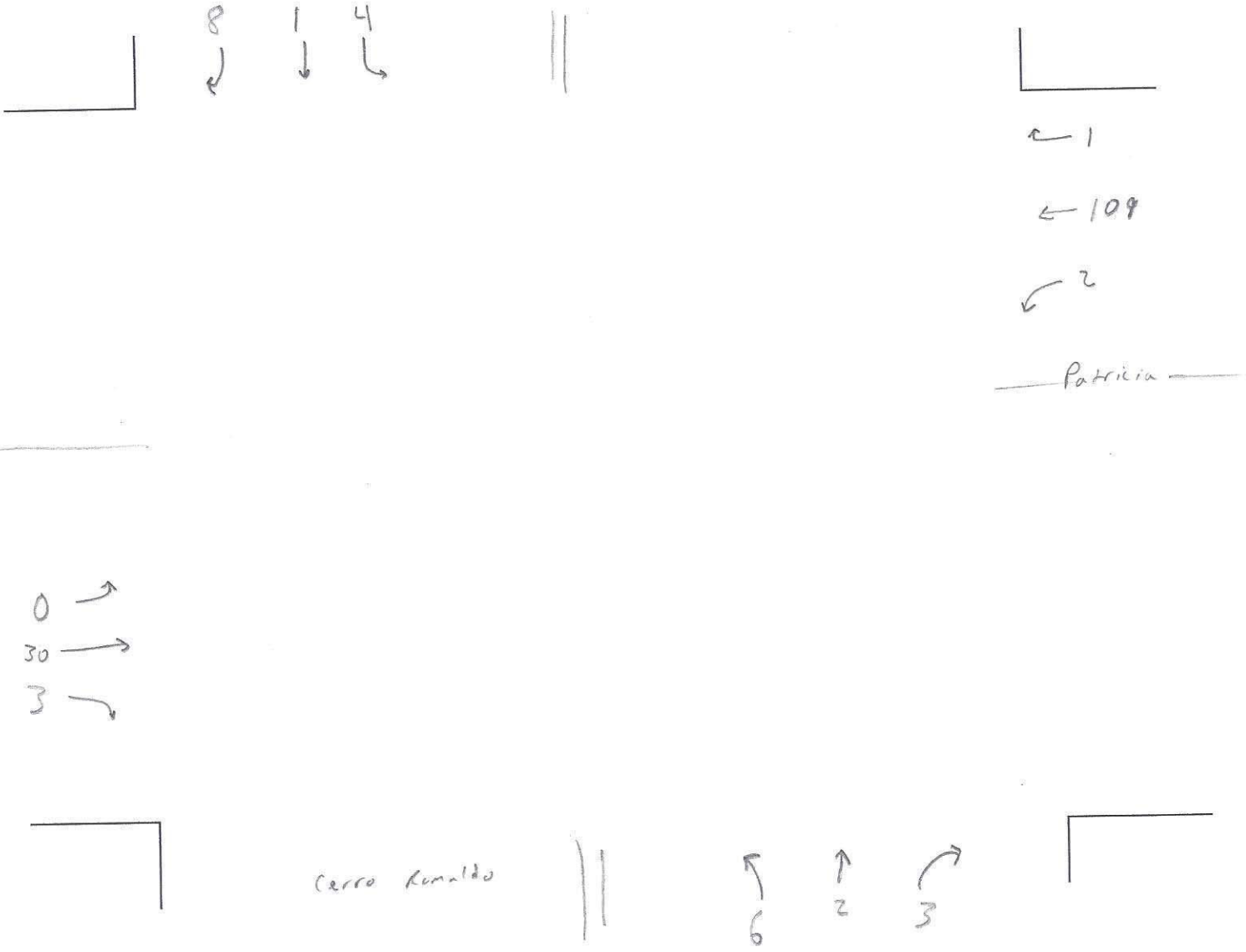
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Patricia Dr. / Cerro Romaldo

Time Period: 6:30-7:30 am Weds

Volumes:

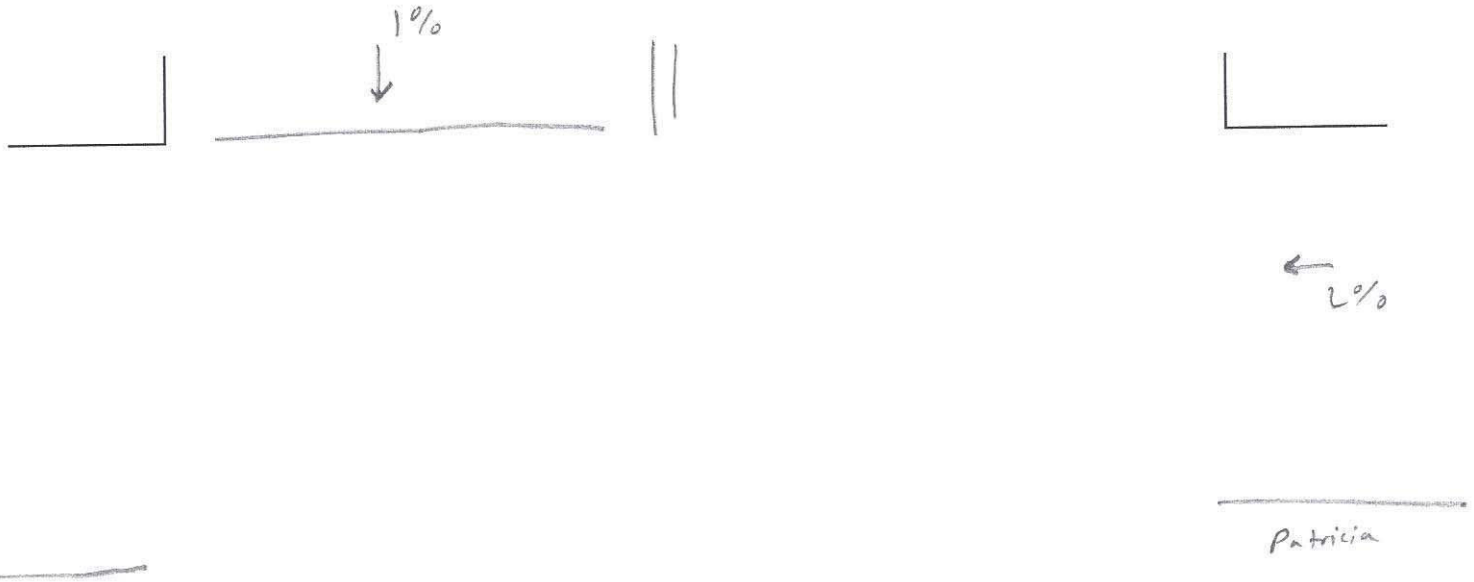


Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Patricia Dr / Cerro Romaldo

Heavy Vehicles:



Comments: Near residential neighborhood. Only heavy vehicles were school buses.

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Prefumo Canyon Road / Los Osos Valley Road

City: San Luis Obispo

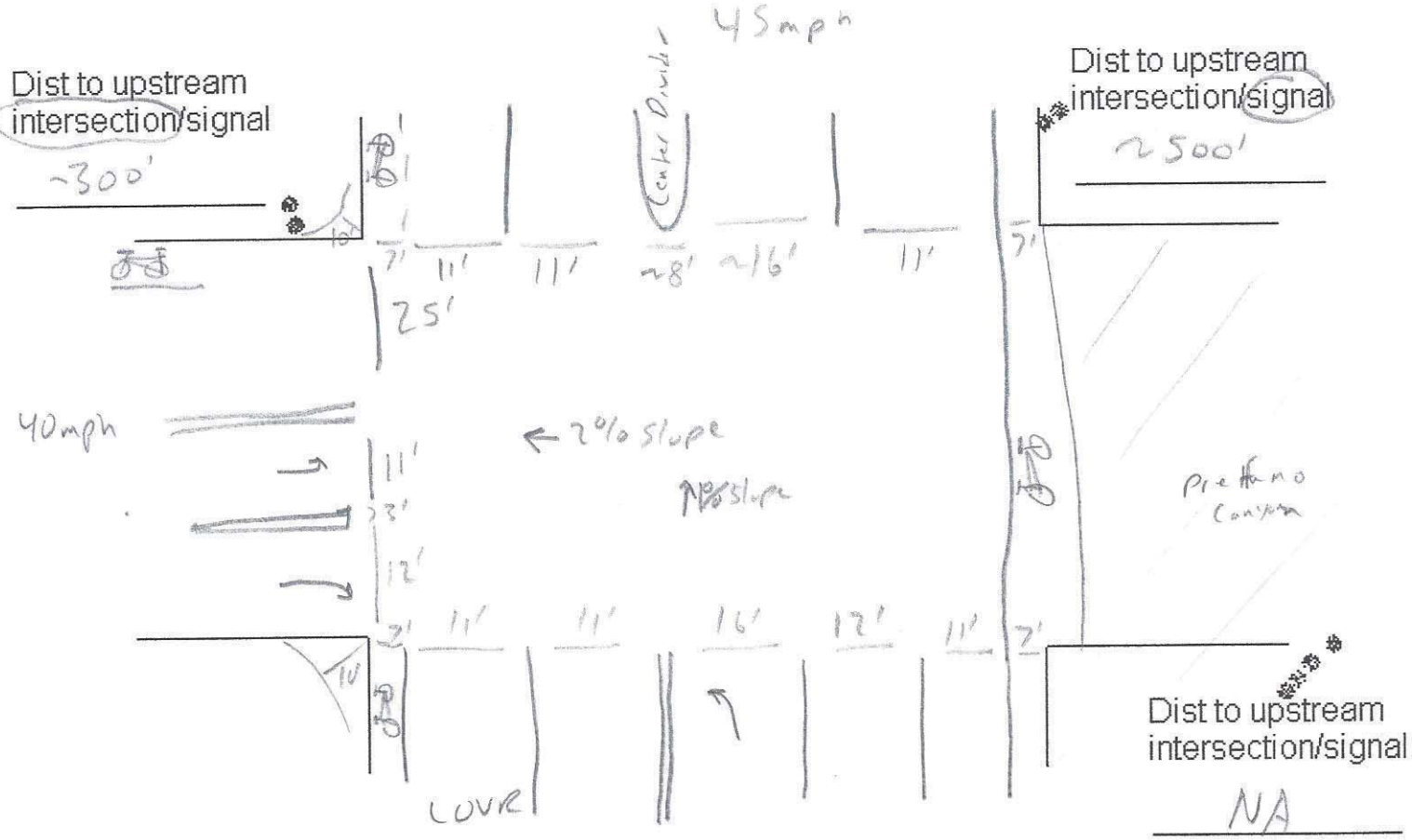
Location: Southern CA Northern CA (Central CA) Other

Intersection Type: (T) +

Data Collection Time: 10:10 – 11:10

Intersection Geometry:

North Arrow:



Comments: WB bike lane Doesn't become visible for 50' after intersection. North Center Divider merges into NB #1 lane reducing to 12' later.

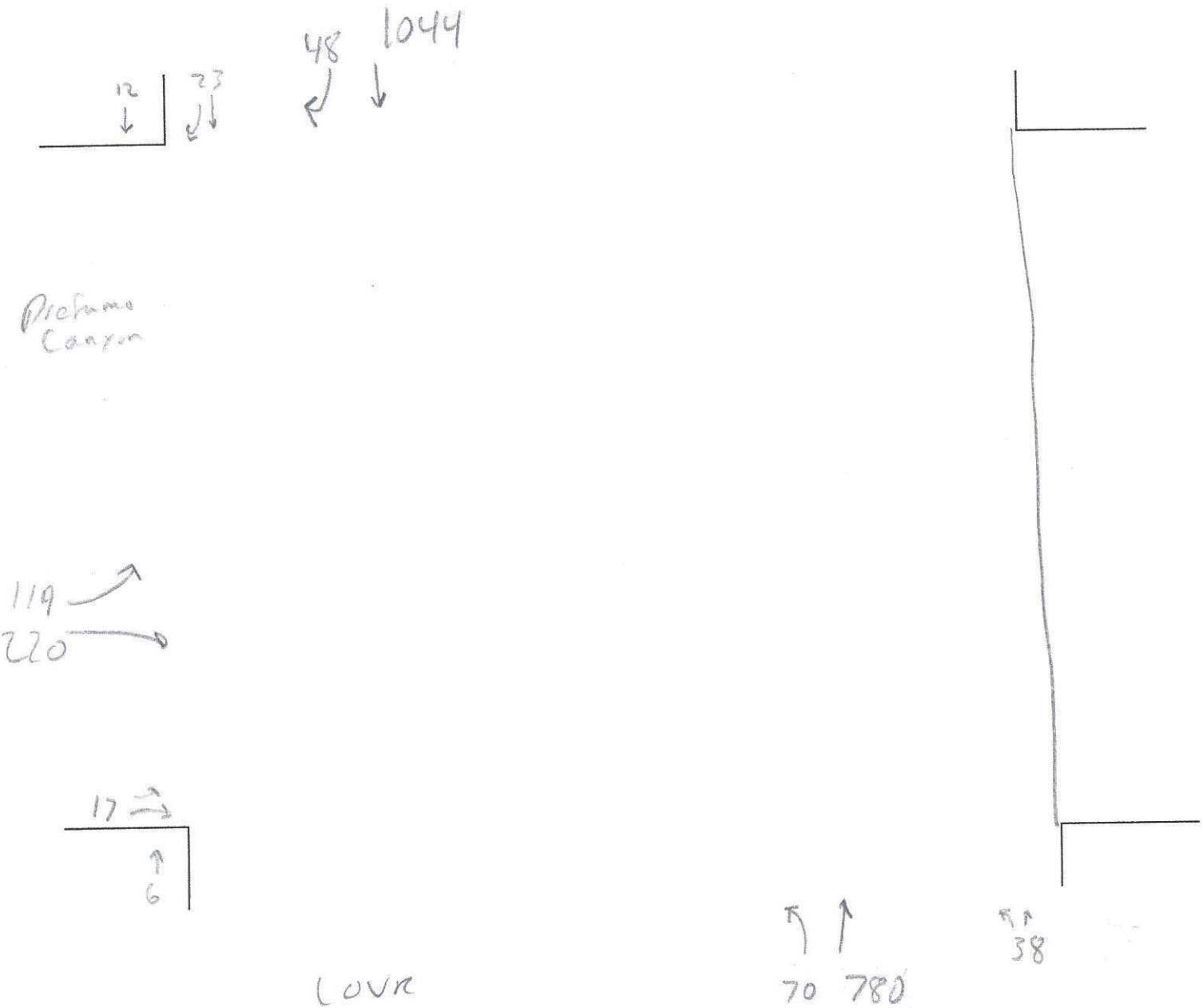
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: LOVR / Prefumo Canyon Road

Time Period: 10:10 - 11:10

Volumes:

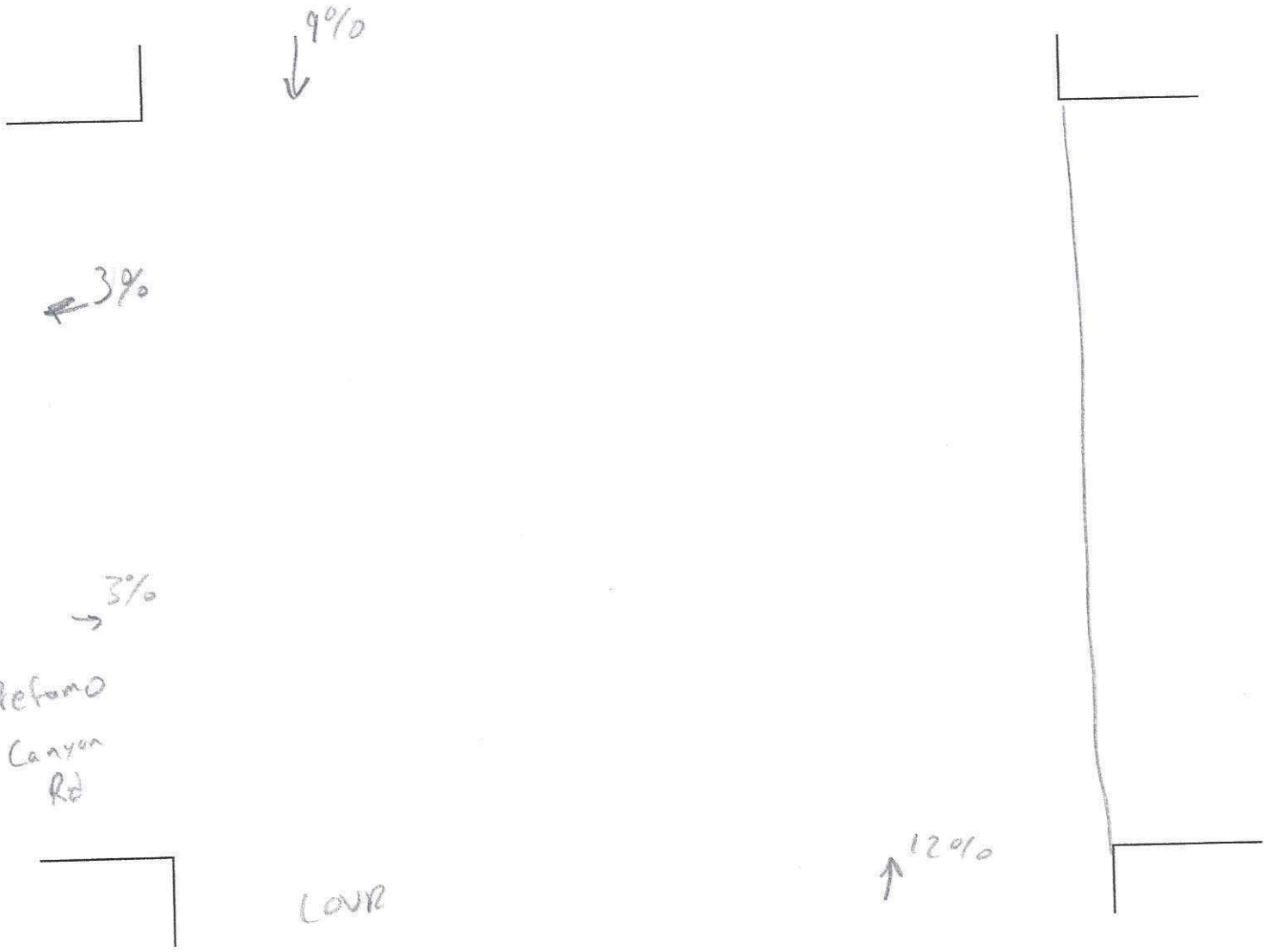


Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Los Osos Valley Road / Prefumo Canyon Road

Heavy Vehicles:



Comments:

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Tank Farm Road / Long Street

City: San Luis Obispo

Location: Southern CA Northern CA (Central CA) Other

Intersection Type: T (+)

Data Collection Time: 11:30 - 12:30 Wed 6/19/13

Intersection Geometry:

North Arrow:

Comments: Very Windy.

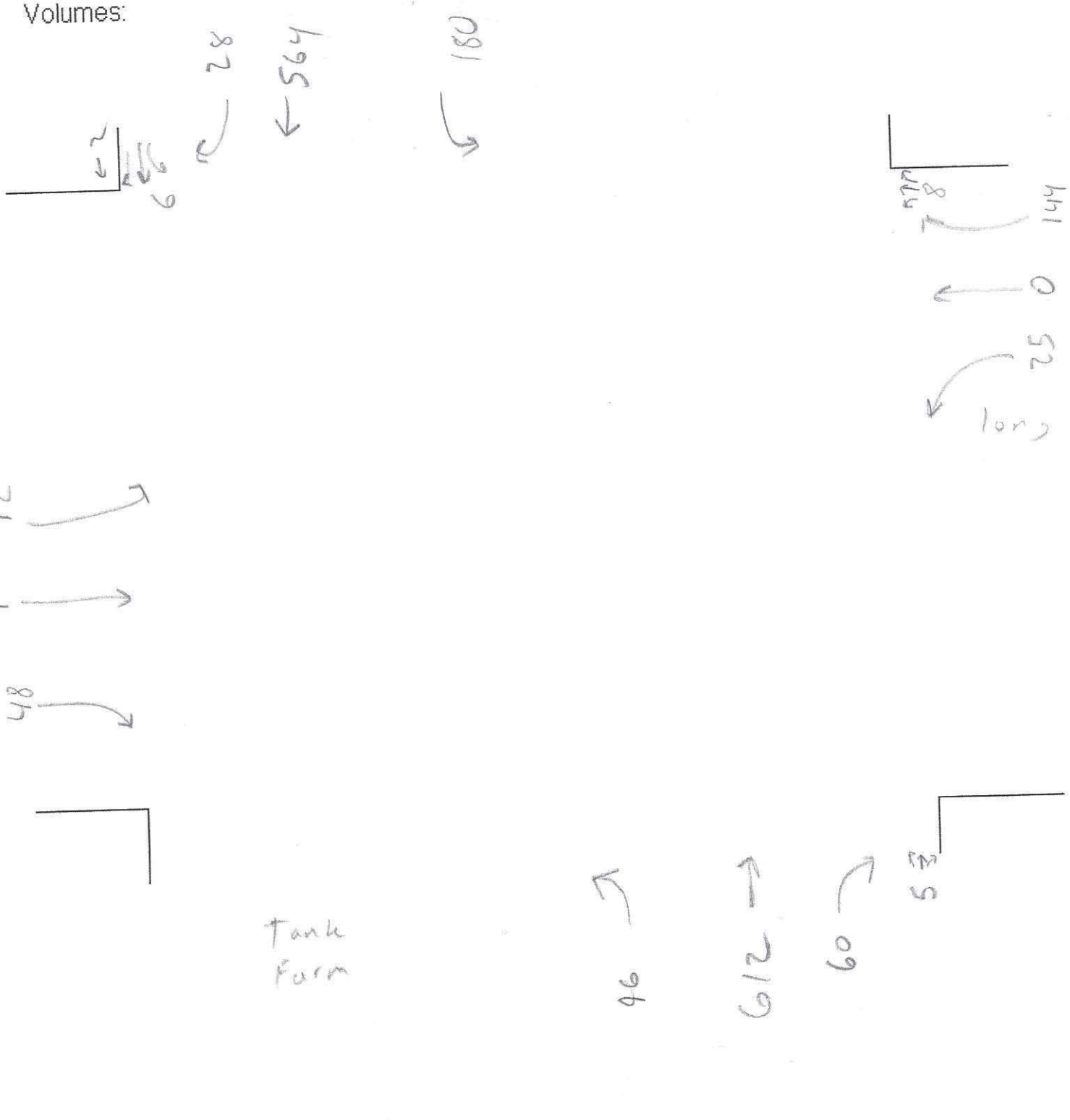
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Tank Farm Road/ Long Street

Time Period: 11:30-12:30 Weds 6/19/13

Volumes:

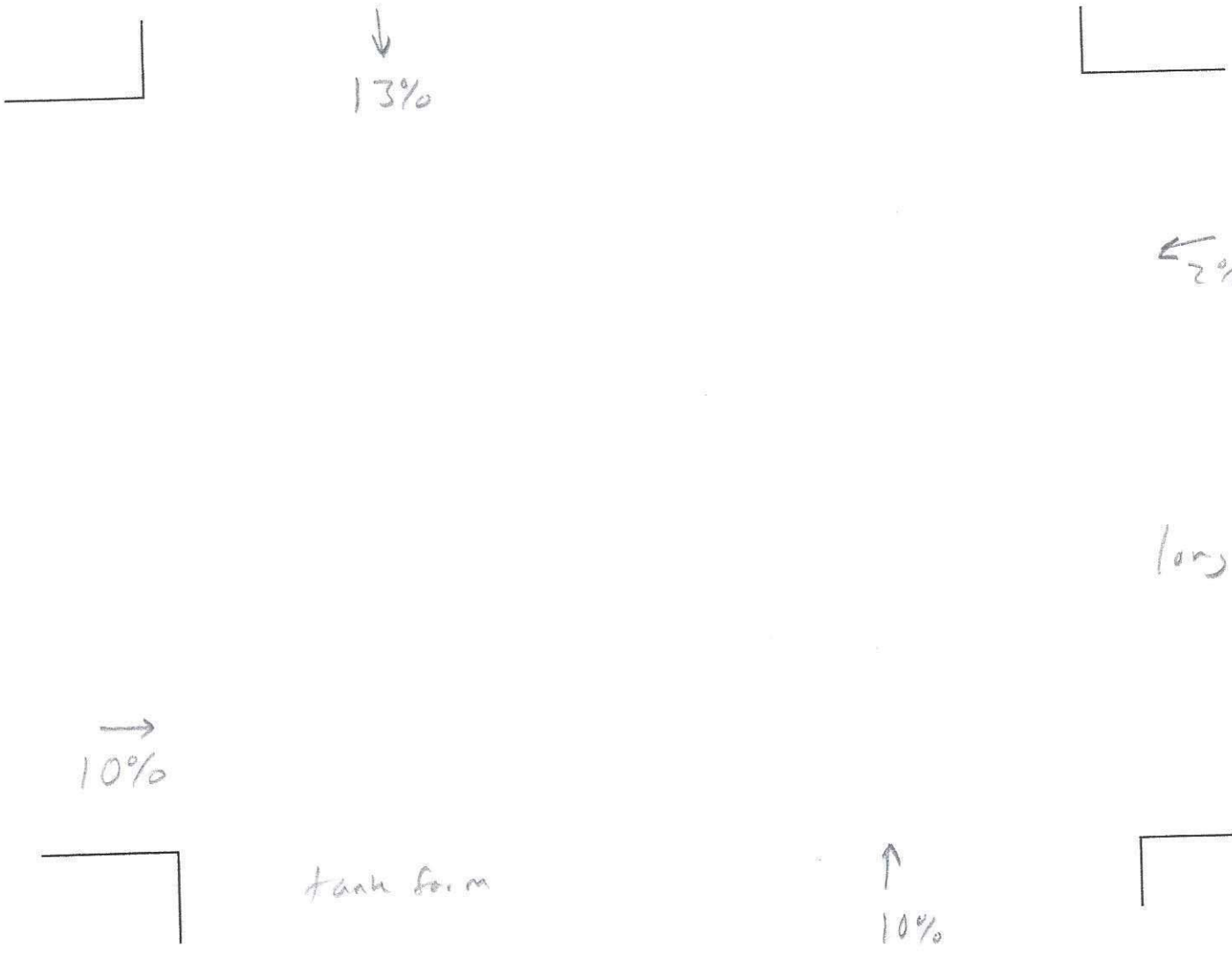


Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Tank Farm Road / Long Street

Heavy Vehicles:



Comments:

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Johnson Ave / Sydney Street

City: San Luis Obispo

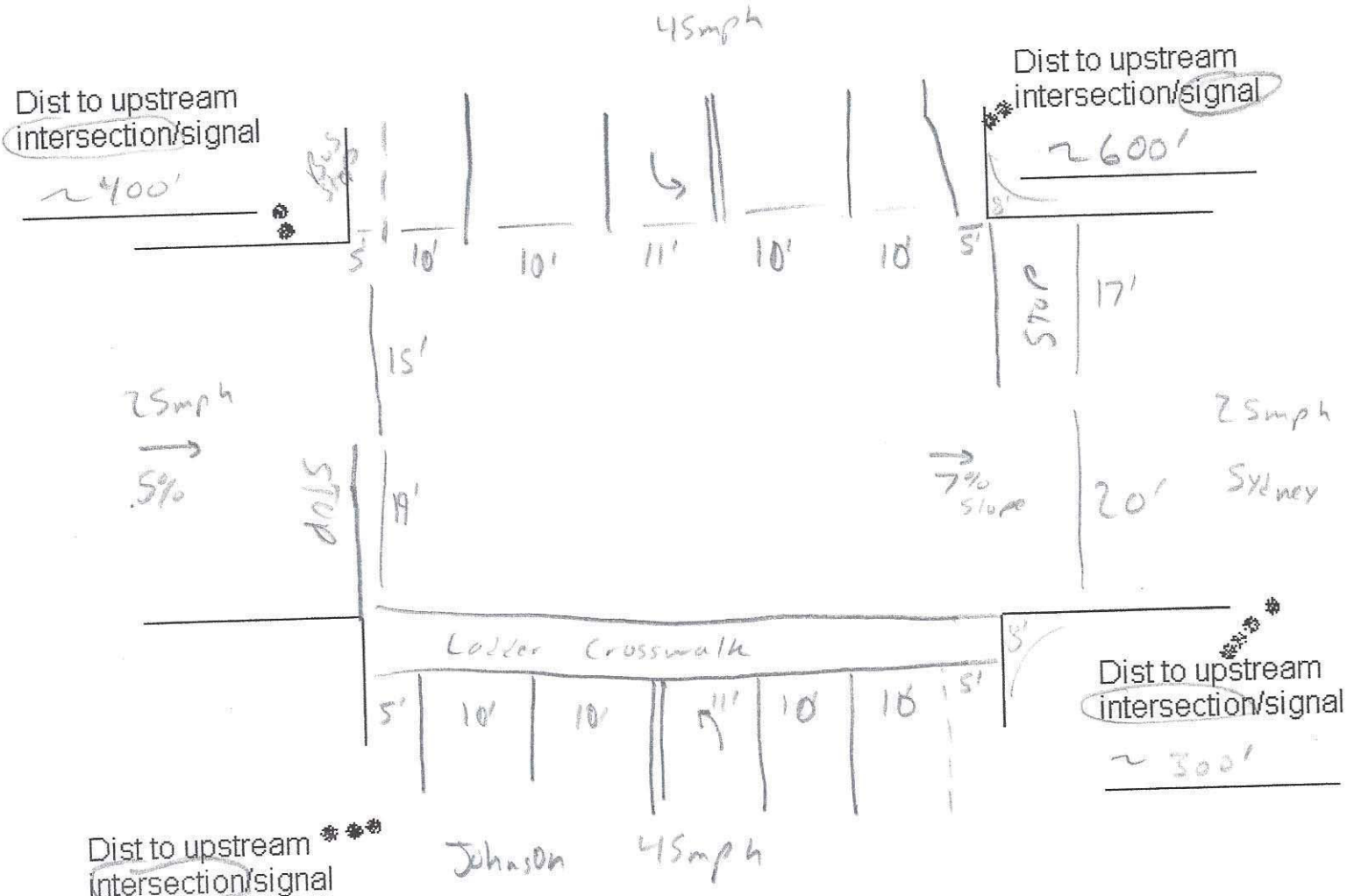
Location: Southern CA Northern CA (Central CA) Other

Intersection Type: T (+)

Data Collection Time: 12:50 - 1:50

Intersection Geometry:

North Arrow:



Comments: NB expands to include parking lane after 100'

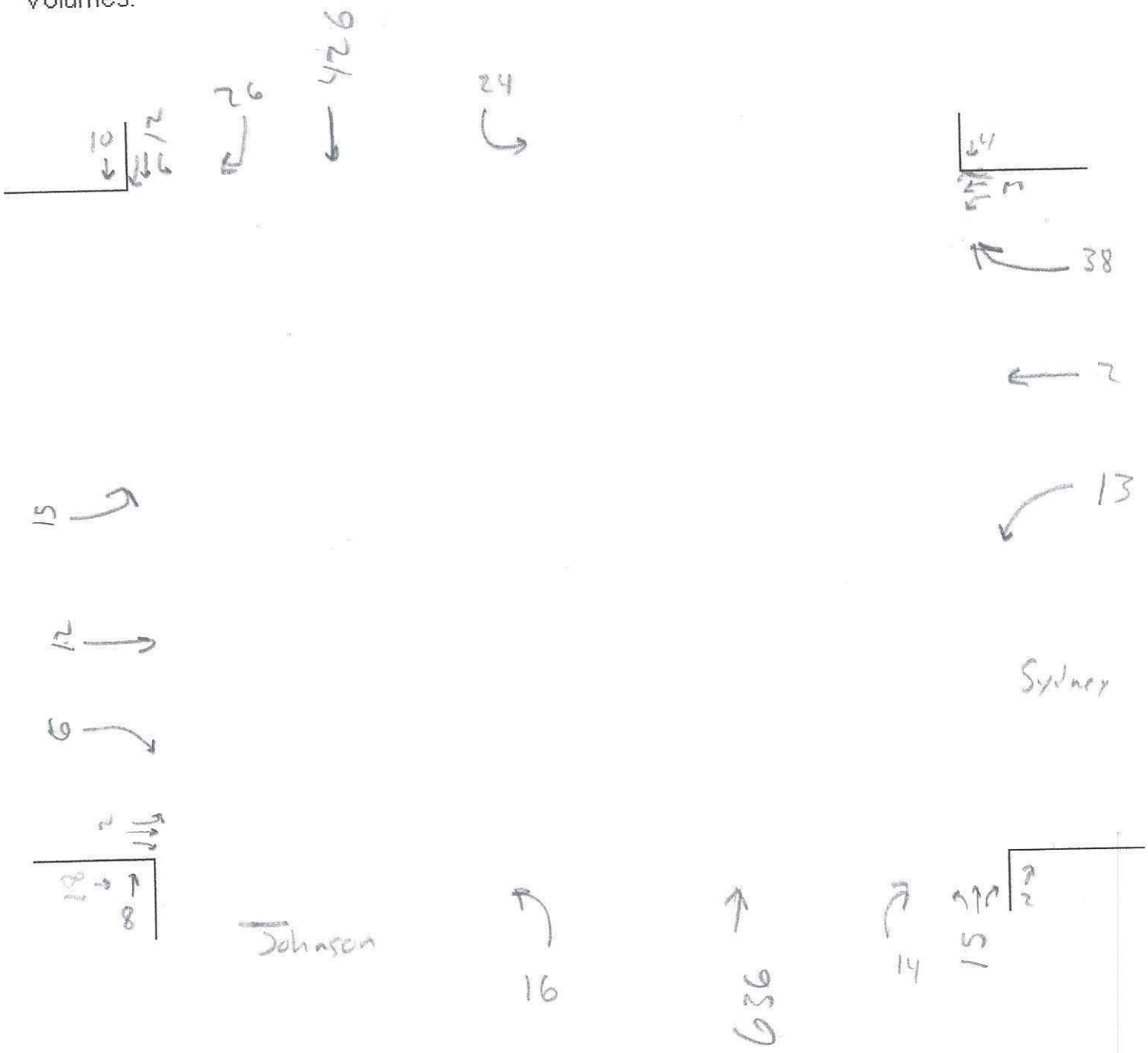
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Johnson Ave / Sydney Street

Time Period: 12:30-1:30

Volumes:

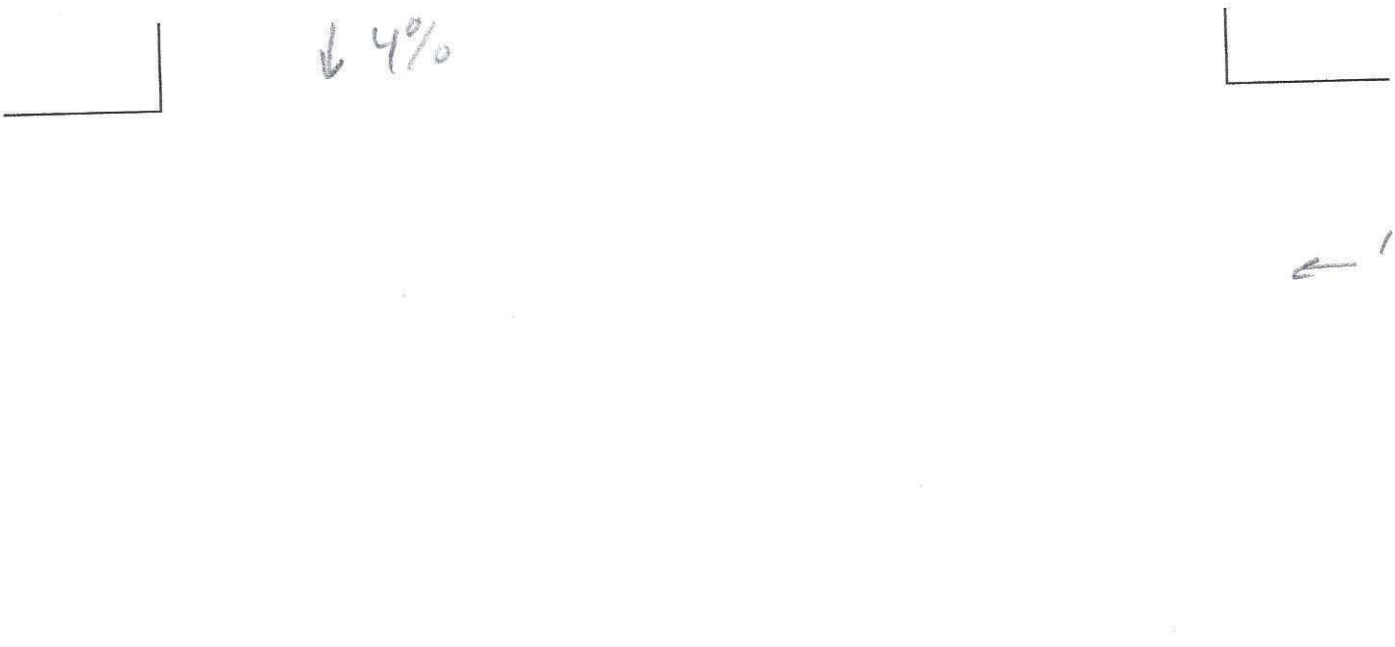


Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Johnson Ave / Sydney Street

Heavy Vehicles:



Comments: Sydney is a residential while Johnson is a heavier route

Cal Poly San Luis Obispo

Nathan Johnston

Intersection: Monterey Street / Toro Street

City: San Luis Obispo

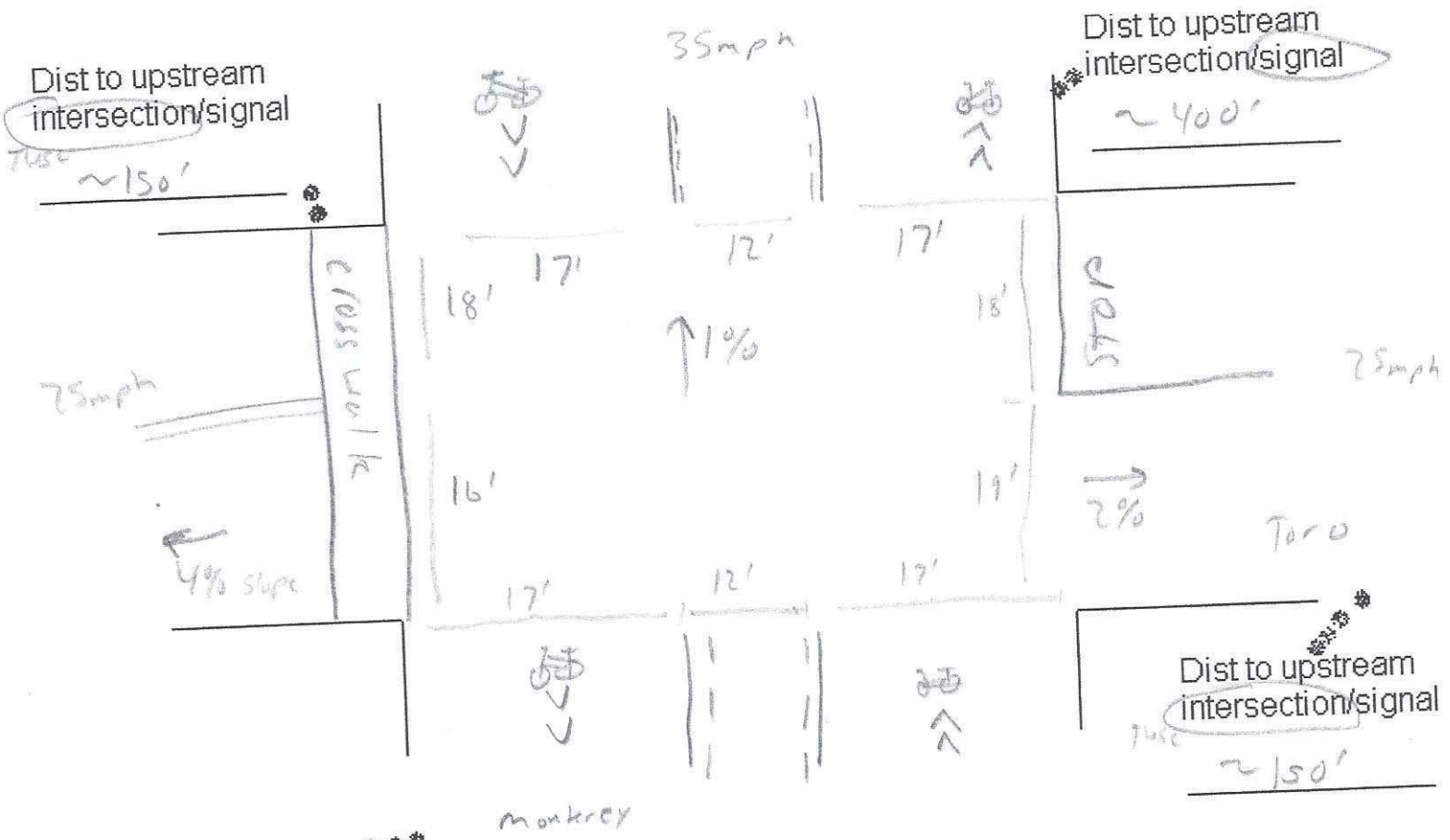
Location: Southern CA Northern CA (Central CA) Other

Intersection Type: T (+)

Data Collection Time: 1:40 - 2:40 Weds 6/19/13

Intersection Geometry:

North Arrow:



Comments: Sharrows! Parking parallel gutter about 80' from intersection each way. 7 manholes in intersection

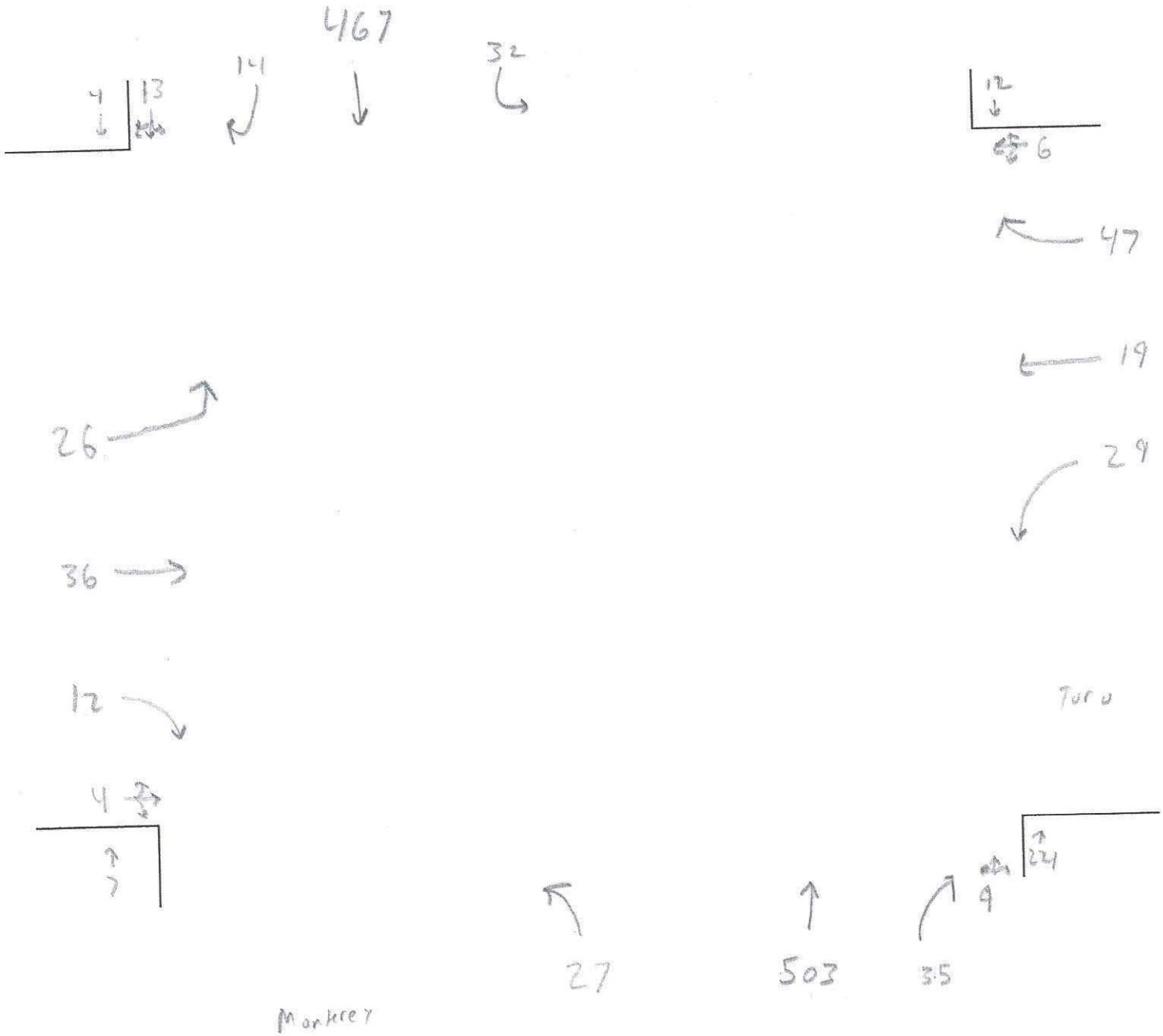
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Monterey Street / Toro Street

Time Period: 1:40 - 2:40

Volumes:



Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Monterey Street / Toro Street

Heavy Vehicles:

Comments:

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Monterey Street / Pepper Street

City: San Luis Obispo

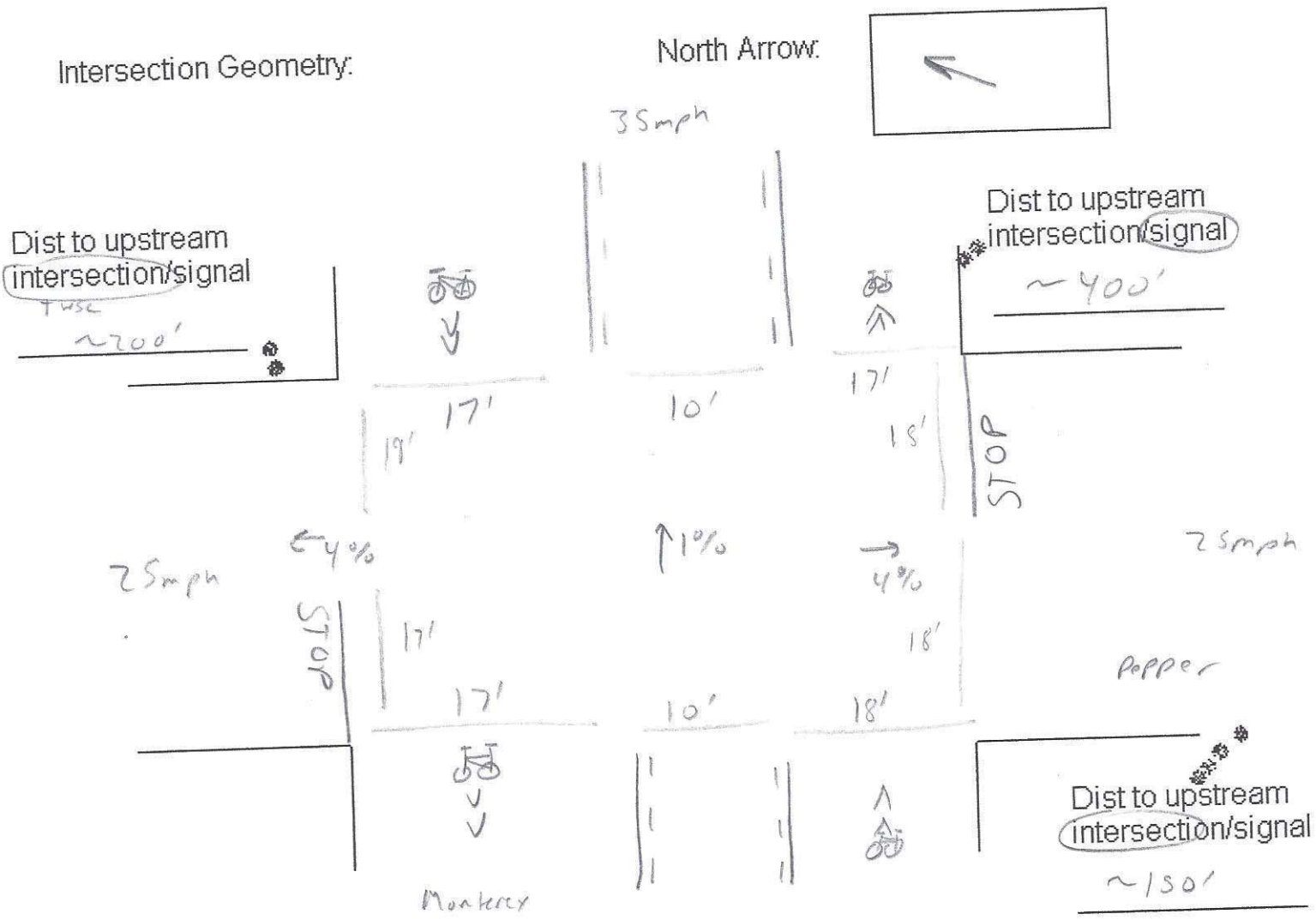
Location: Southern CA Northern CA (Central CA) Other

Intersection Type: T +

Data Collection Time: 2:50 - 3:50 Weds 6/19/13

Intersection Geometry:

North Arrow:



Comments: Sharrows / Share the Road Signs

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Monterey Street / Pepper

Heavy Vehicles:

Comments:

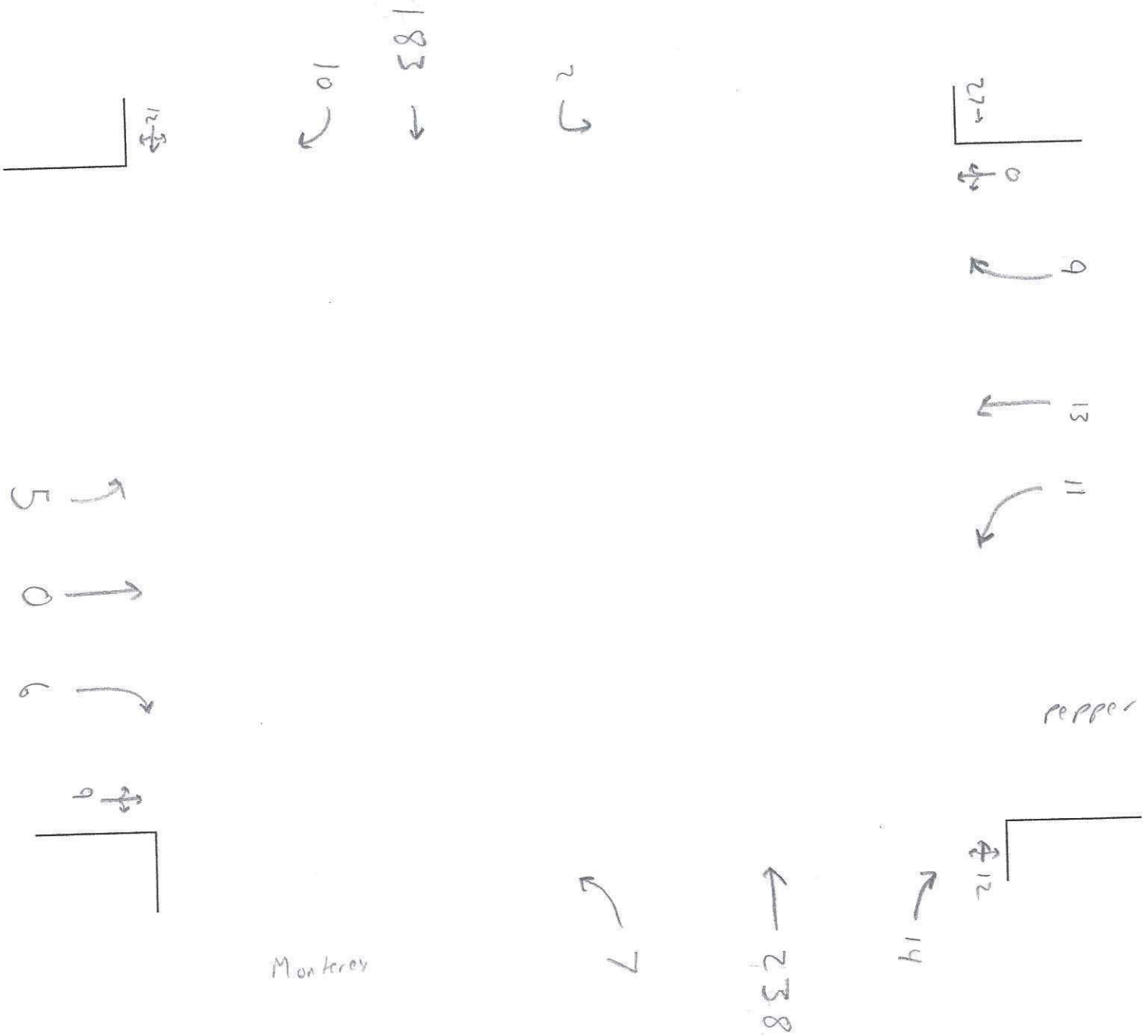
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Monterey Street / Pepper Street

Time Period: 2:50 - 3:50

Volumes:



Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Morro Street / Pismo Street

City: San Luis Obispo

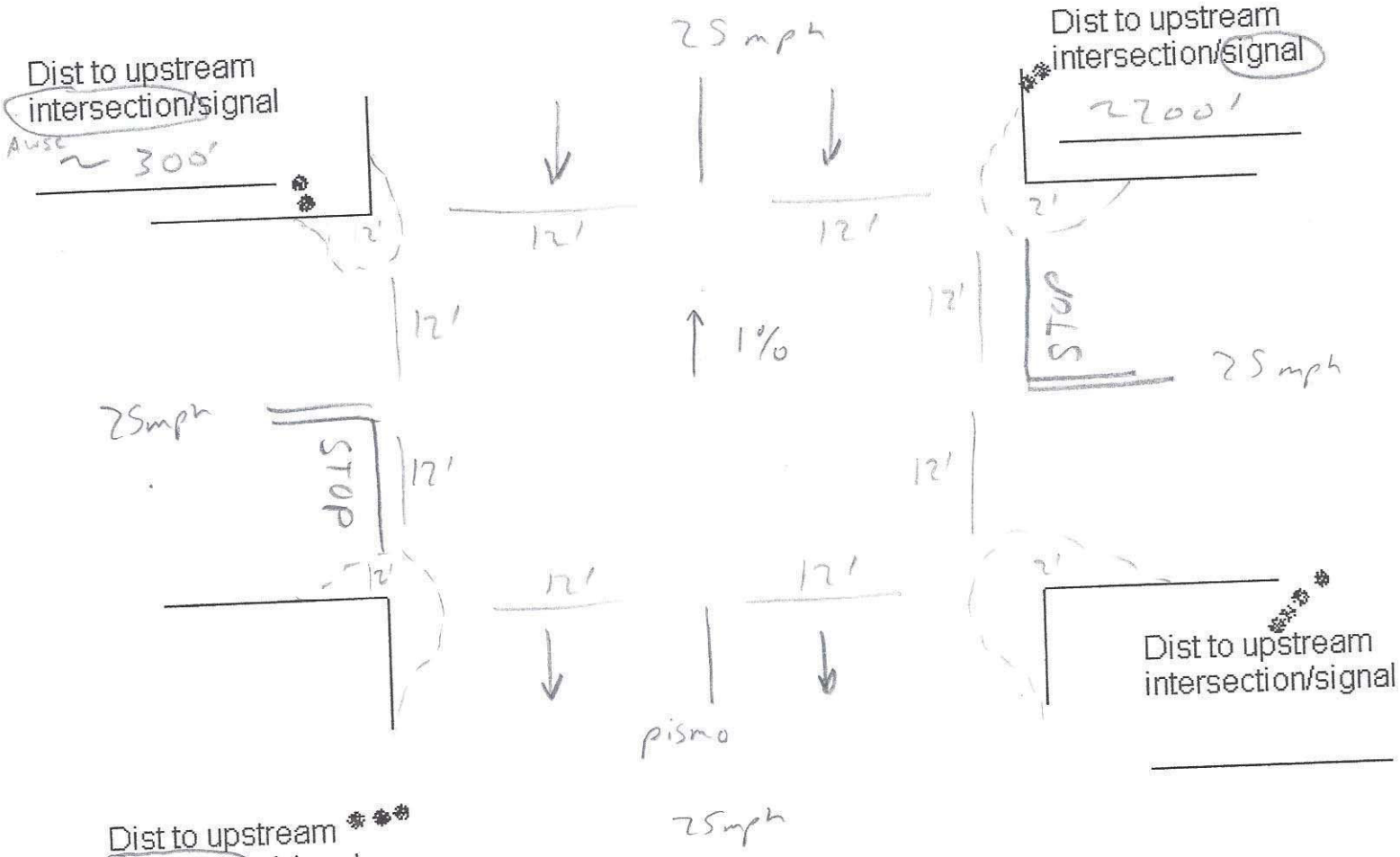
Location: Southern CA Northern CA (Central CA) Other

Intersection Type: T +

Data Collection Time: 3:55 - 4:55

Intersection Geometry:

North Arrow: ↑



Comments: Bike Boulevard; Pismo one directional traffic only

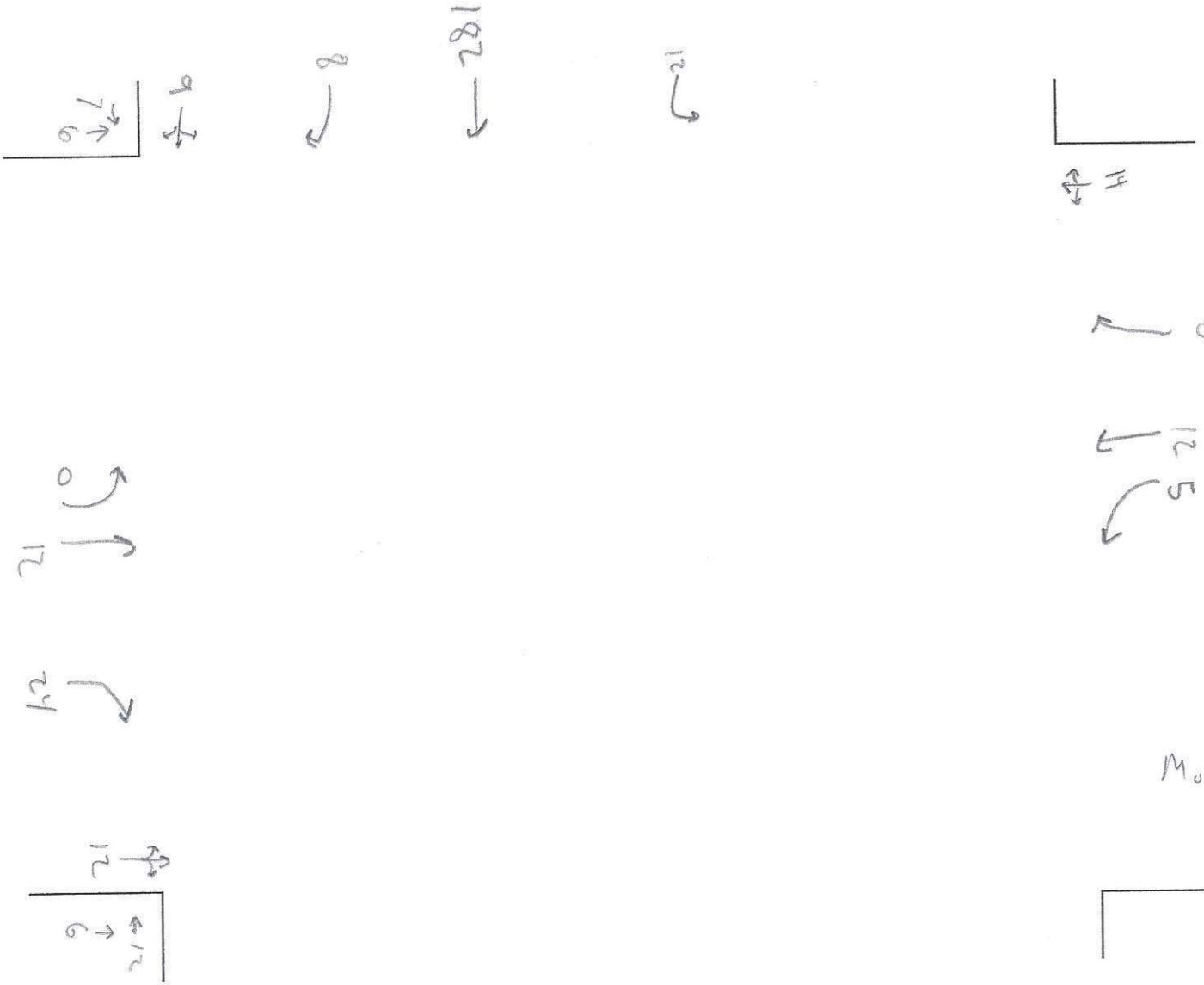
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Pismo Street / Morro Street

Time Period: 3:55 - 4:55

Volumes:



Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Pismo Street / Murro Street

Heavy Vehicles:

Comments: Very Few heavy vehicles.

Cal Poly San Luis Obispo

Nathan Johnston

Intersection: Higuera Street / Garden Street

City: San Luis Obispo

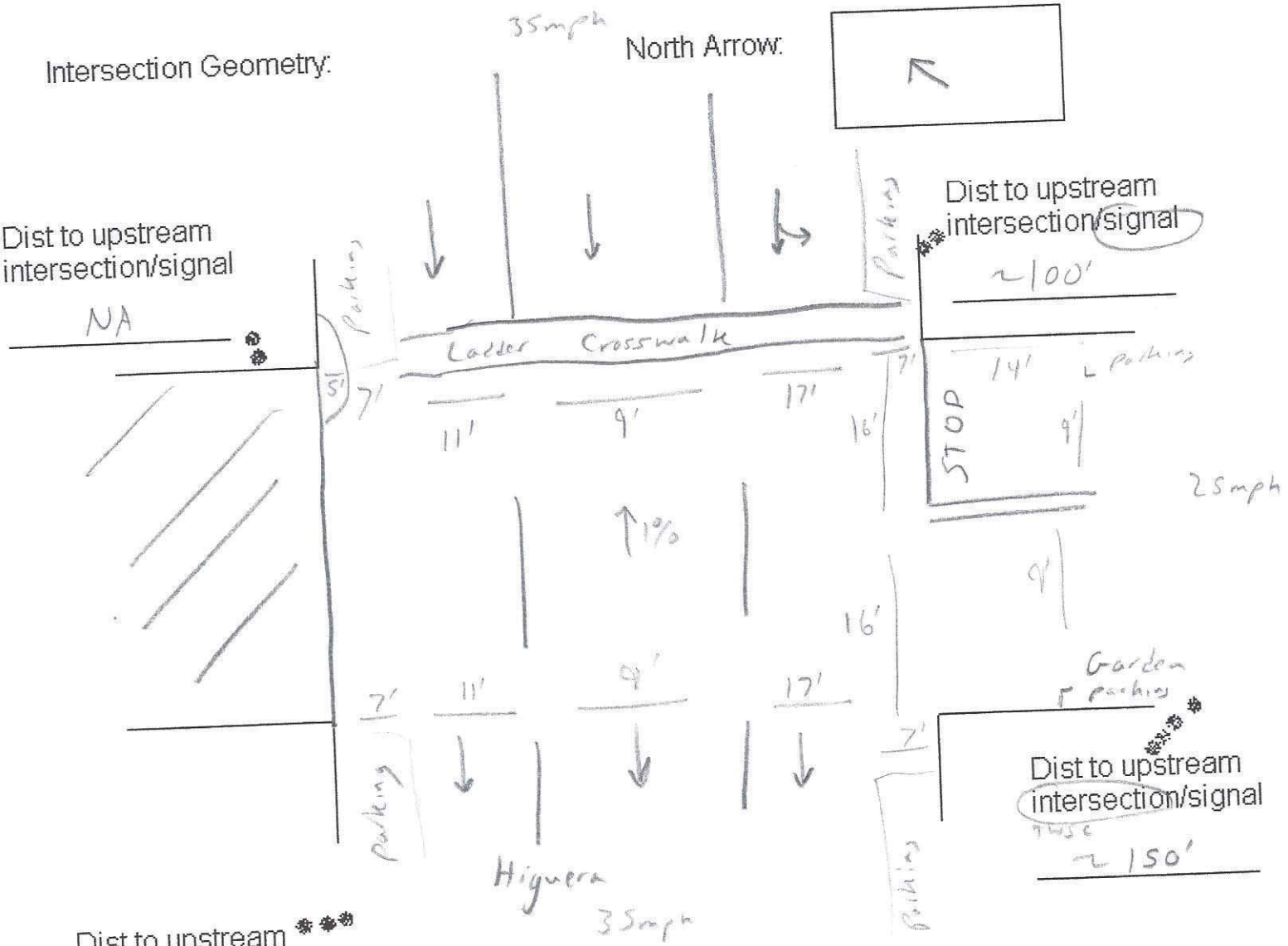
Location: Southern CA Northern CA (Central CA) Other

Intersection Type: (T) +

Data Collection Time: 5:05 - 6:05 Wed 6/19/13

Intersection Geometry:

North Arrow:



Comments: West side of crosswalk has 5' outcrop for traffic calming.

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Higuera Street / Garden Street

Heavy Vehicles:

Comments: Very urban area.

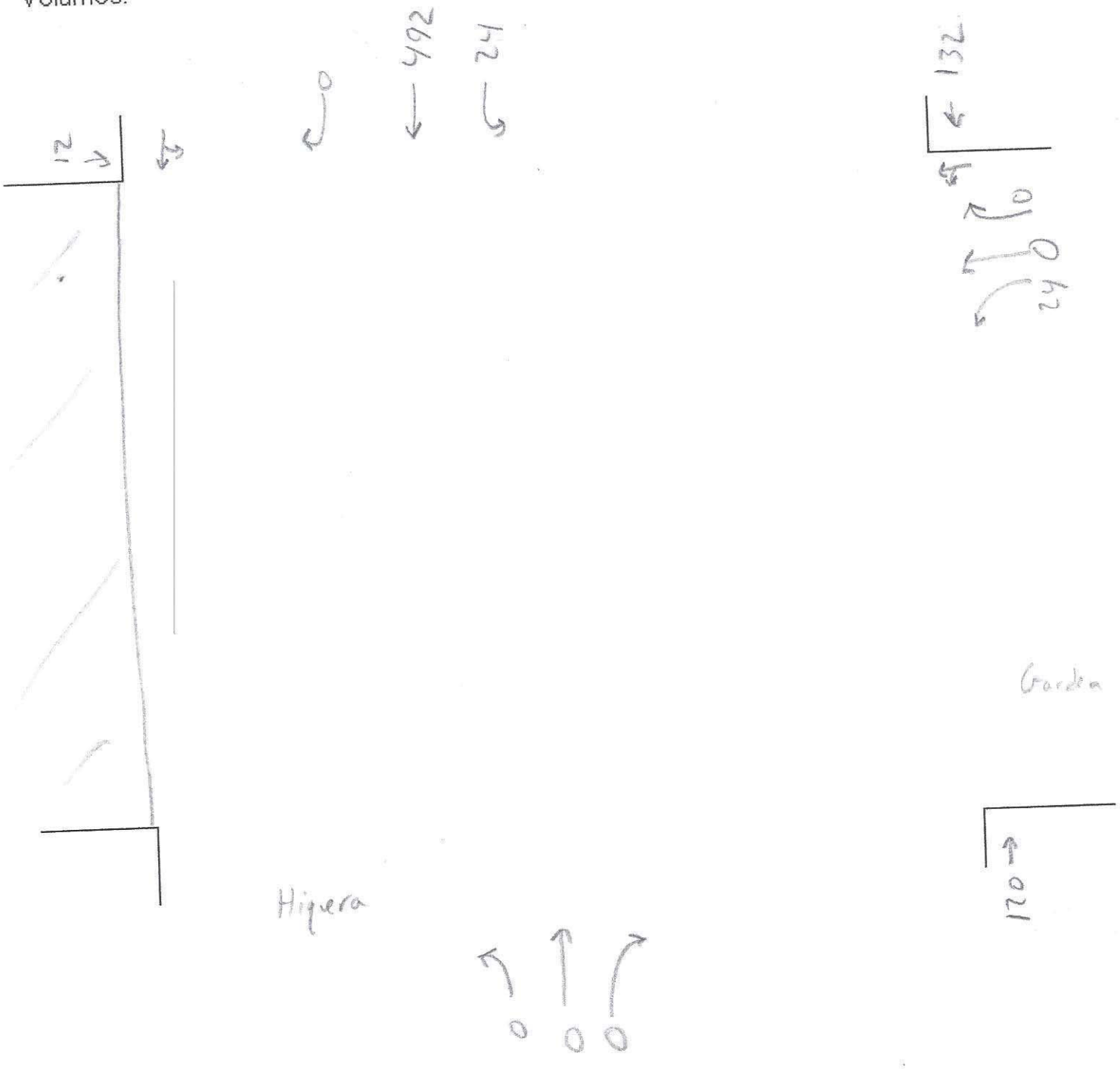
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Higuera Street / Garden Street

Time Period: 5:05 - 6:05 Weds 6/19/13

Volumes:



Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Morro Street / Islay Street

City: San Luis Obispo

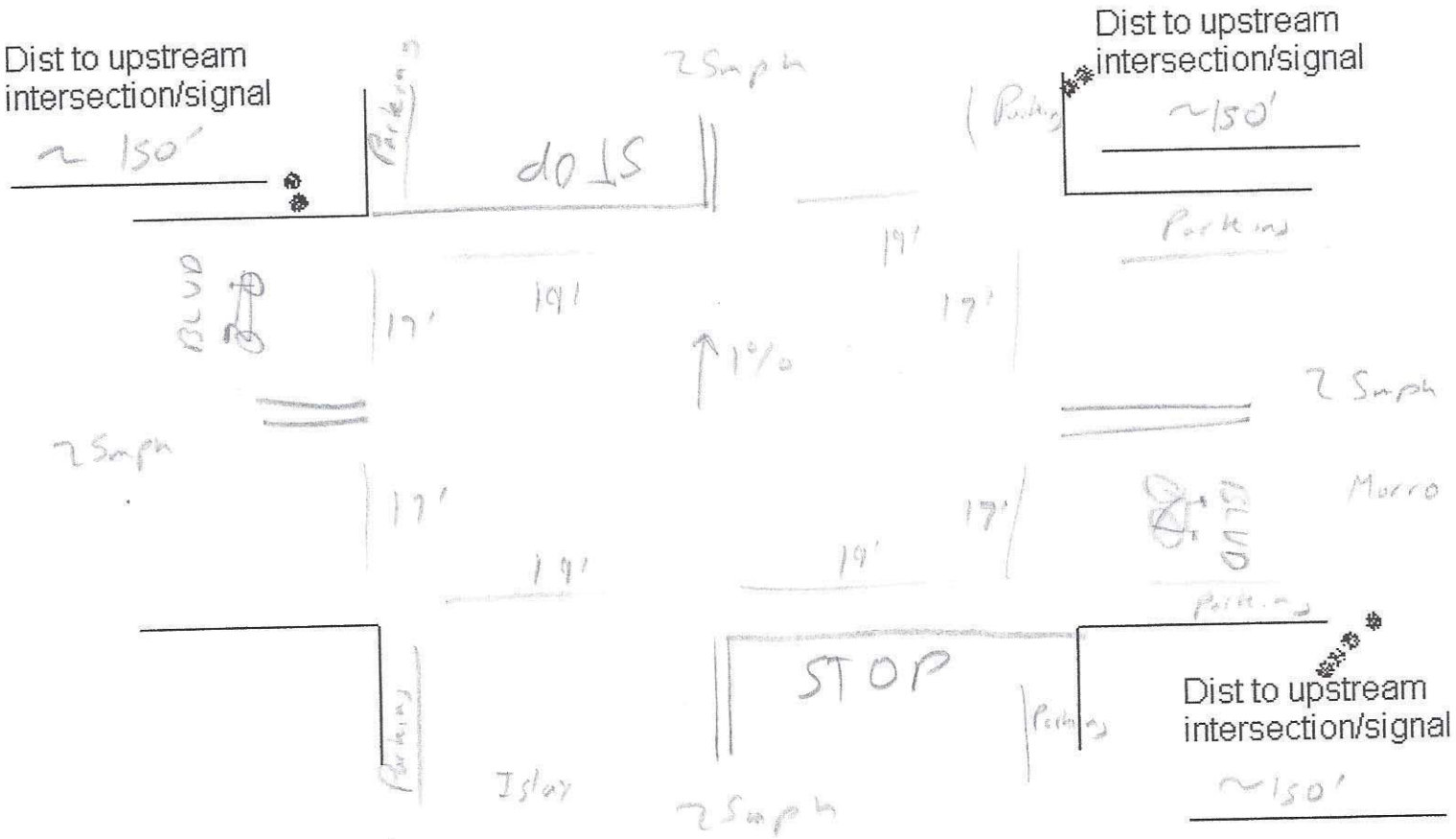
Location: Southern CA Northern CA Central CA Other

Intersection Type: T +

Data Collection Time: 6:10 - 7:10

Intersection Geometry:

North Arrow:



Comments: Morro is Bicycle Boulevard

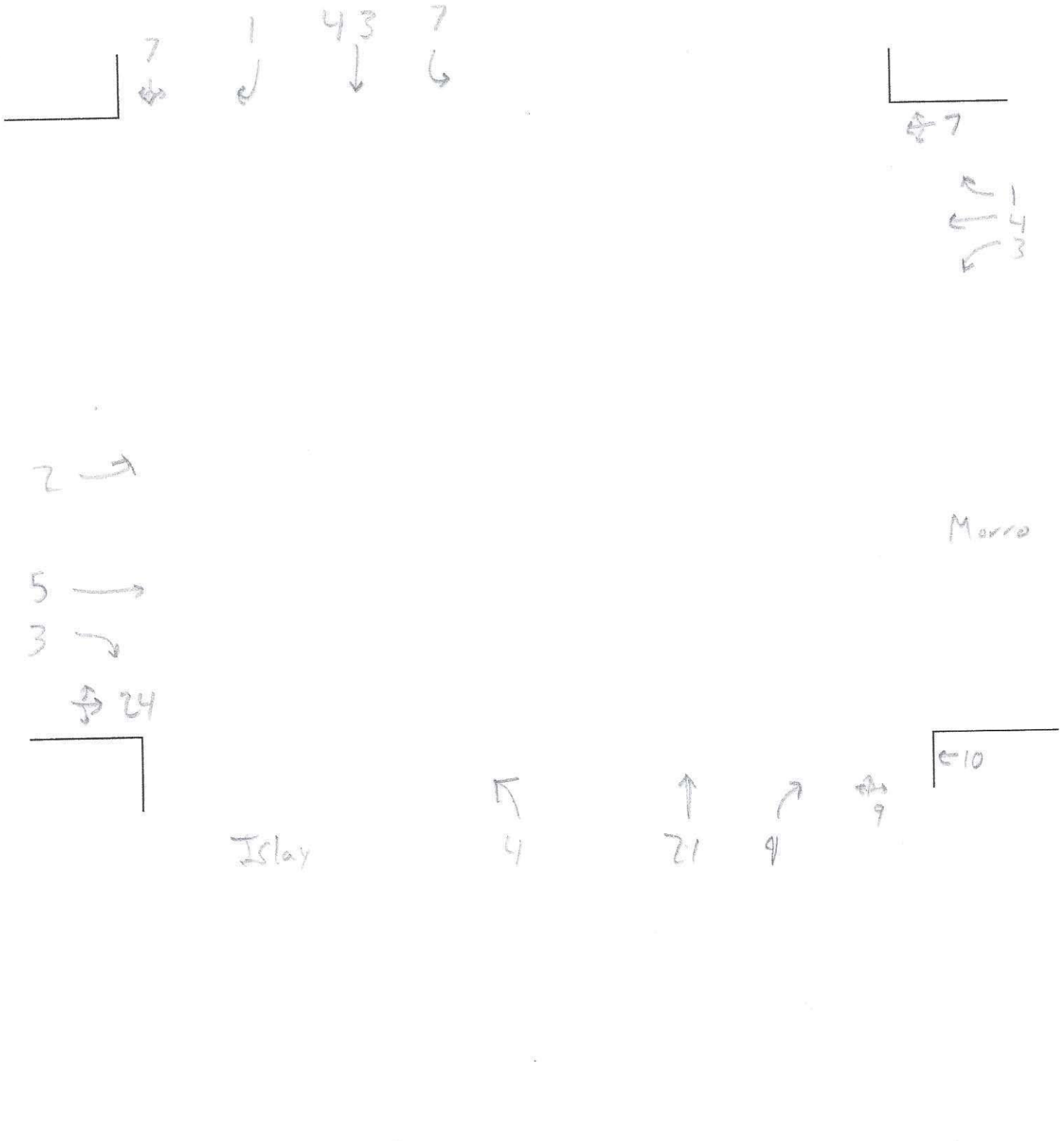
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Morro Street / Islay Street

Time Period: 6:10 - 7:10

Volumes:



Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Morro Street / Islay Street

Heavy Vehicles:

Comments: Large Vehicles Cannot navigate Morro traffic
Calming measures upstream.

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Broad Street / Islay Street

City: San Luis Obispo

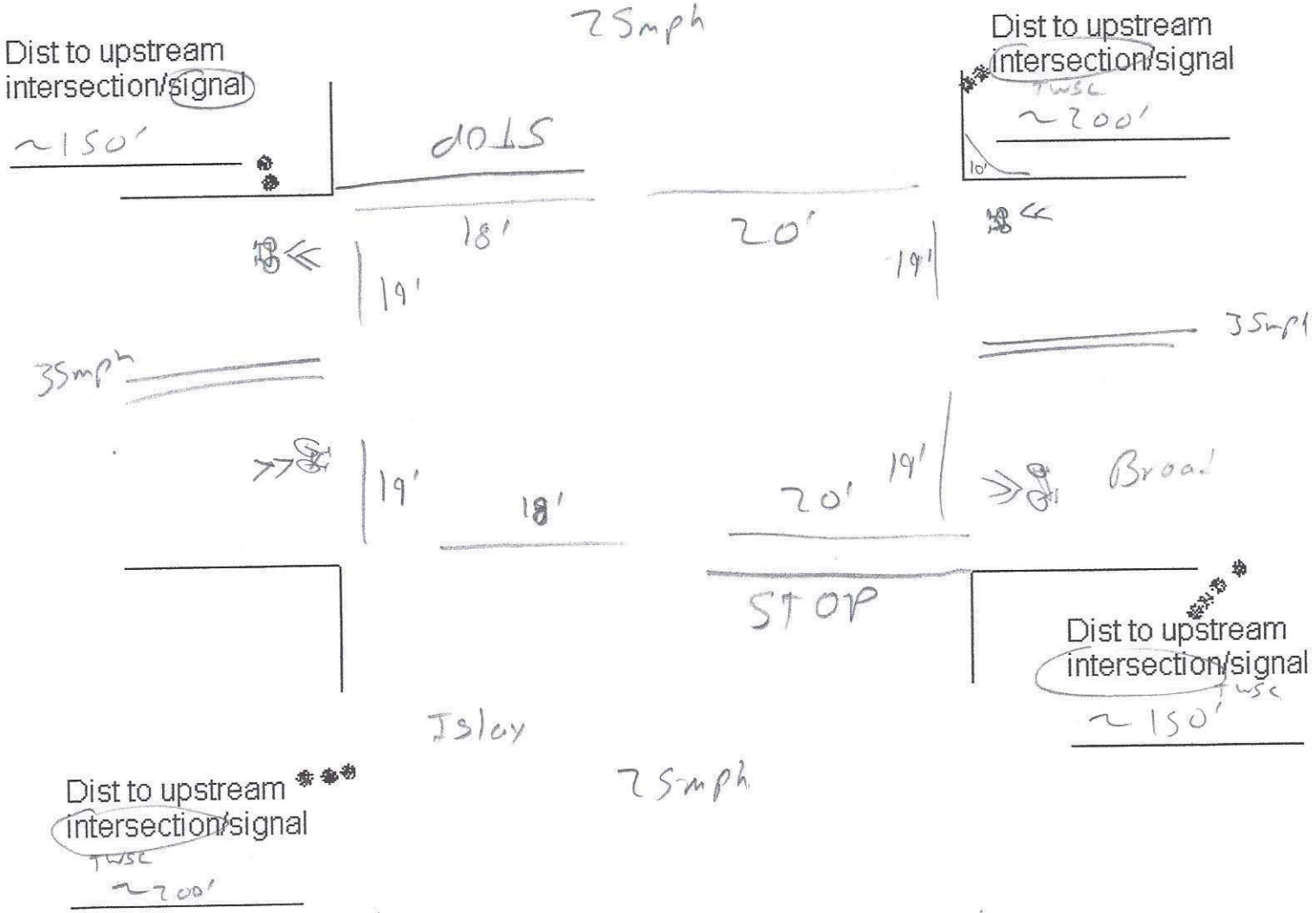
Location: Southern CA Northern CA Central CA Other

Intersection Type: T +

Data Collection Time: 7:15 - 8:15 pm Weds 6/19/13

Intersection Geometry:

North Arrow:



Comments: Sharrows; Broad has speeders that go up to 10+ the speed limit

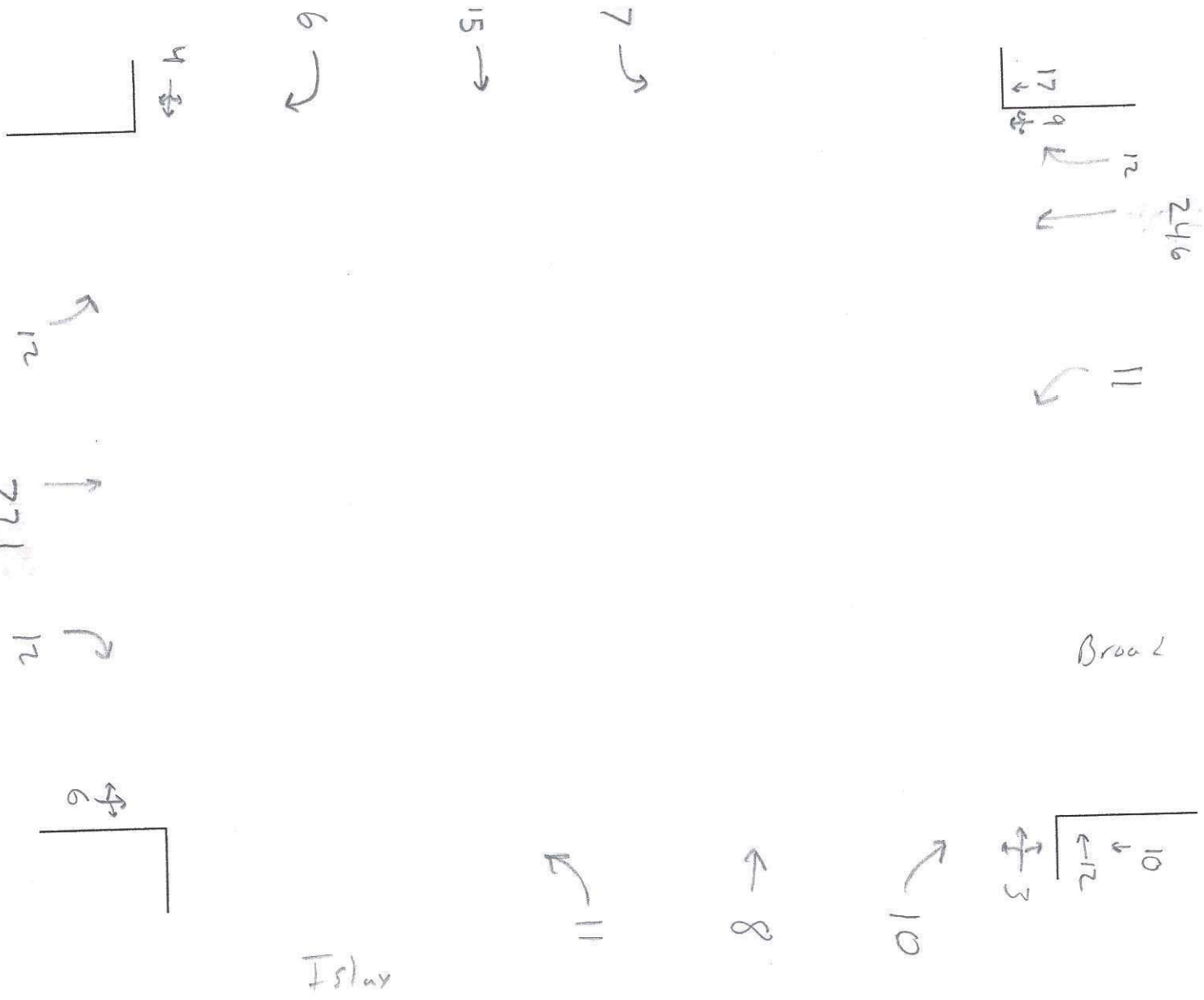
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Broad Street / Islay Street

Time Period: 7:15 - 8:15

Volumes:

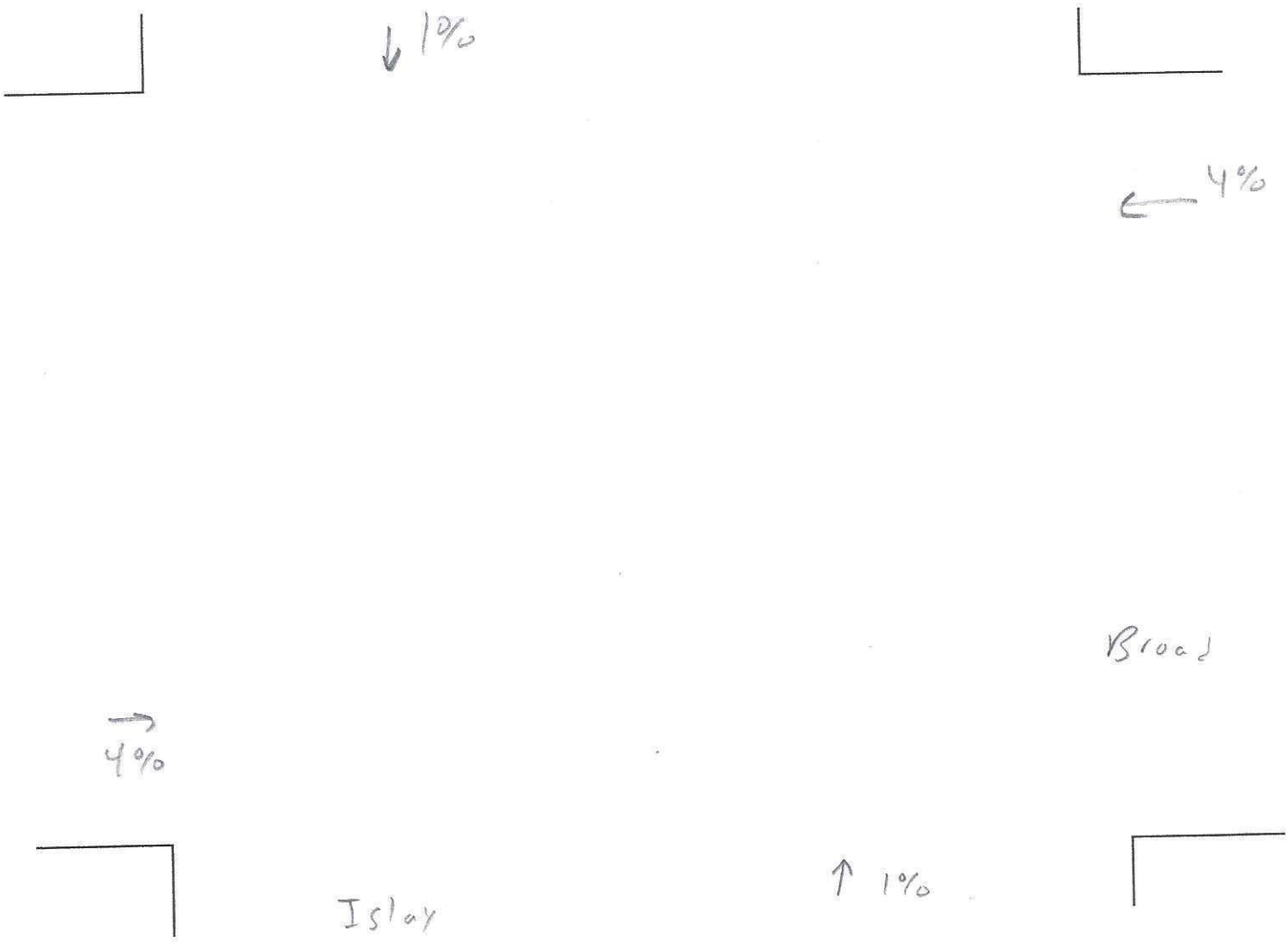


Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Broad Street / Islay Street

Heavy Vehicles:



Comments:

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Broad Street / Churro Street / Sandercock Street

City: San Luis Obispo

Location: Southern CA Northern CA (Central CA) Other

Intersection Type: T (+)

Data Collection Time: 7:30-8:30 6/18/13 Tues

Intersection Geometry:

North Arrow:

Comments: Churro & Sandercock Stretch to 45° angle Westward after intersection

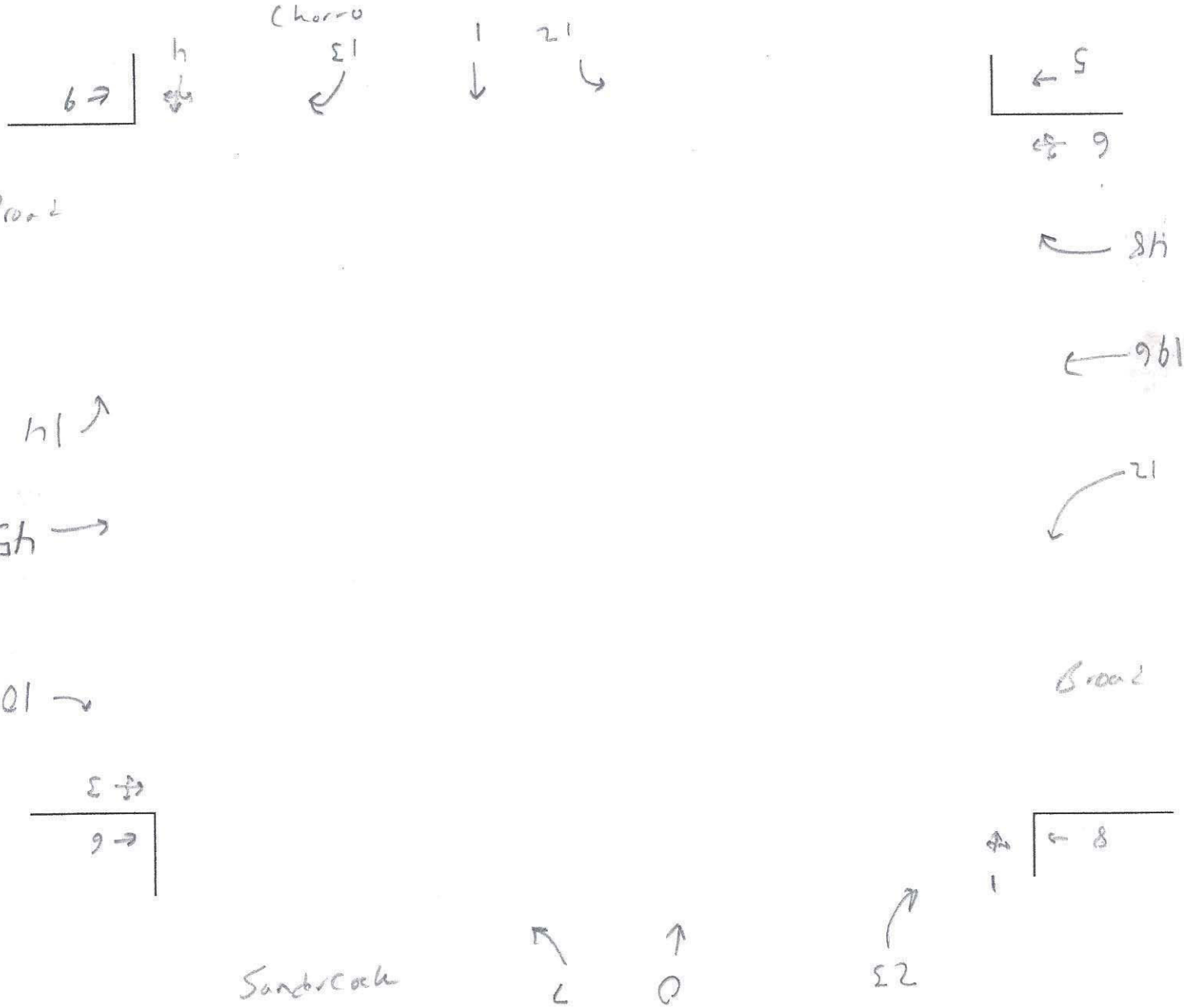
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Broad Street / Chorro Street / Sandercock Street

Time Period: 7:30 - 8:30 6/18/13

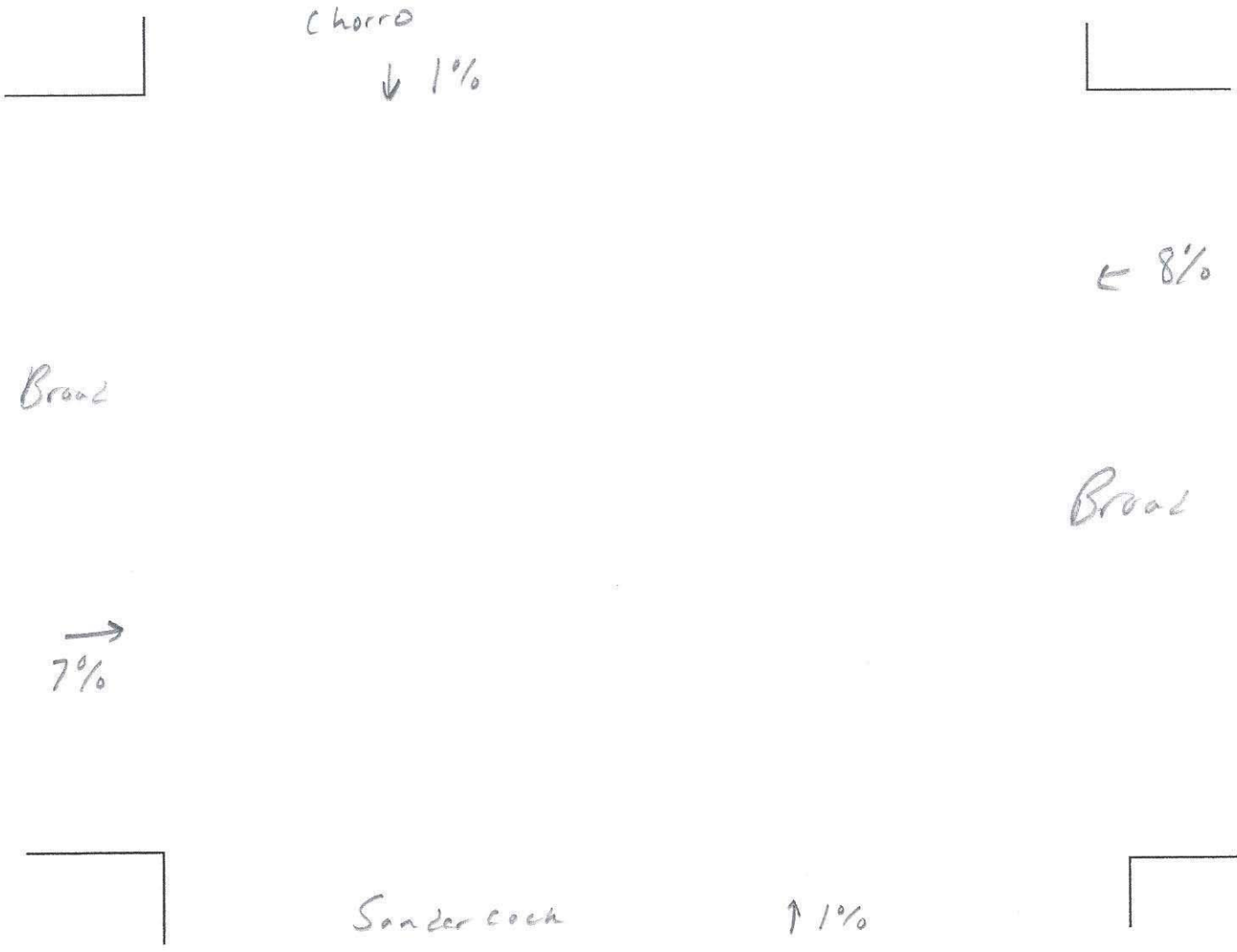
Volumes:



Nathan Johnston Cal Poly San Luis Obispo

Intersection: Broad Street / Chorro Street / Sandercock Street

Heavy Vehicles:



Comments:

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Marsh Street / Beach Street

City: San Luis Obispo

Location: Southern CA Northern CA (Central CA) Other

Intersection Type: (T) +

Data Collection Time: 8:50 - 9:50 6/18/13 Tues

Intersection Geometry:

North Arrow: ↑

Dist to upstream intersection/signal: NA

Dist to upstream intersection/signal: ~300'

Dist to upstream intersection/signal: ~150'

Dist to upstream intersection/signal: ~400'

Comments: Marsh is a one directional Street

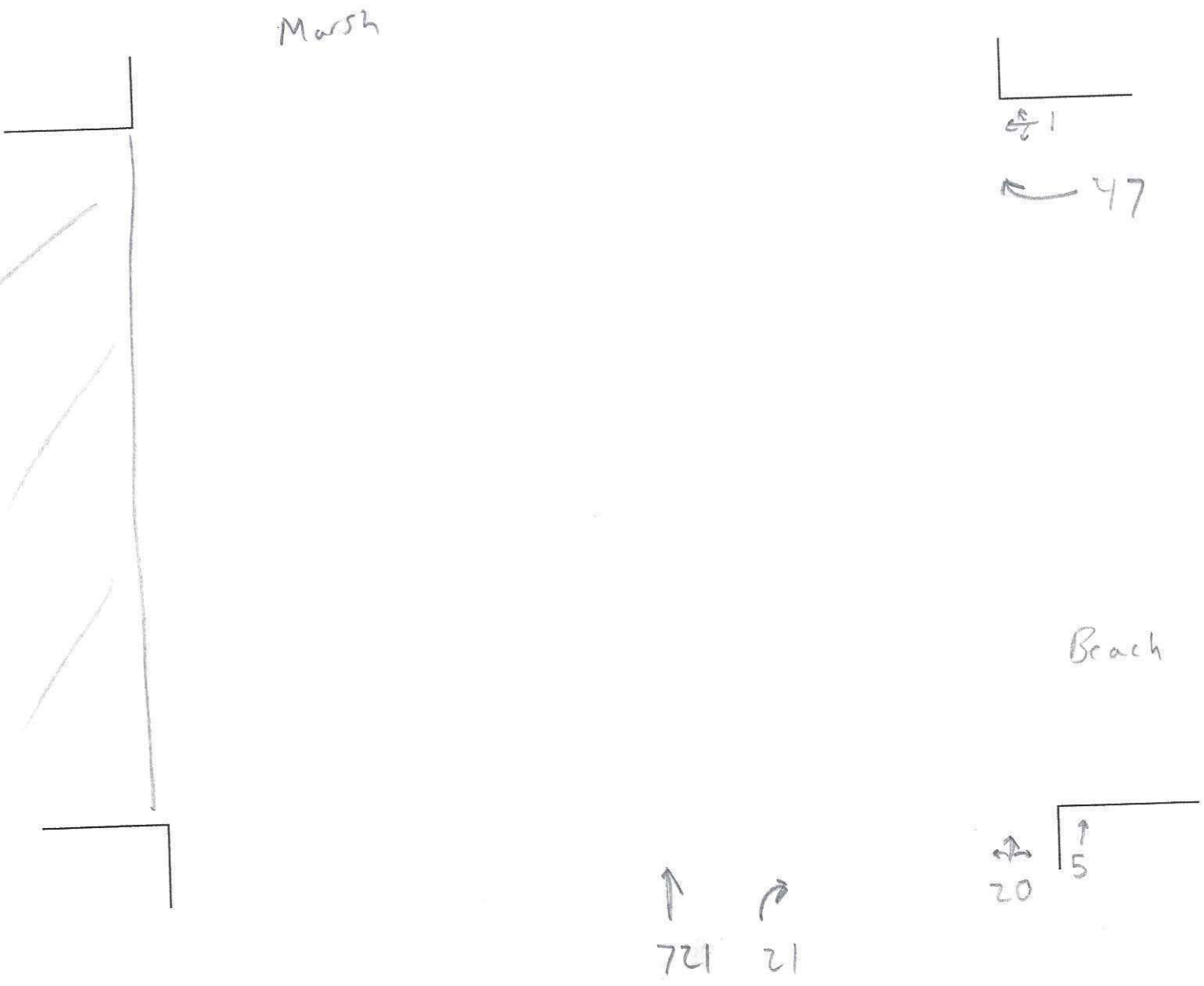
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Marsh Street / Beach Street

Time Period: 8:50 – 9:50 6/18/13

Volumes:

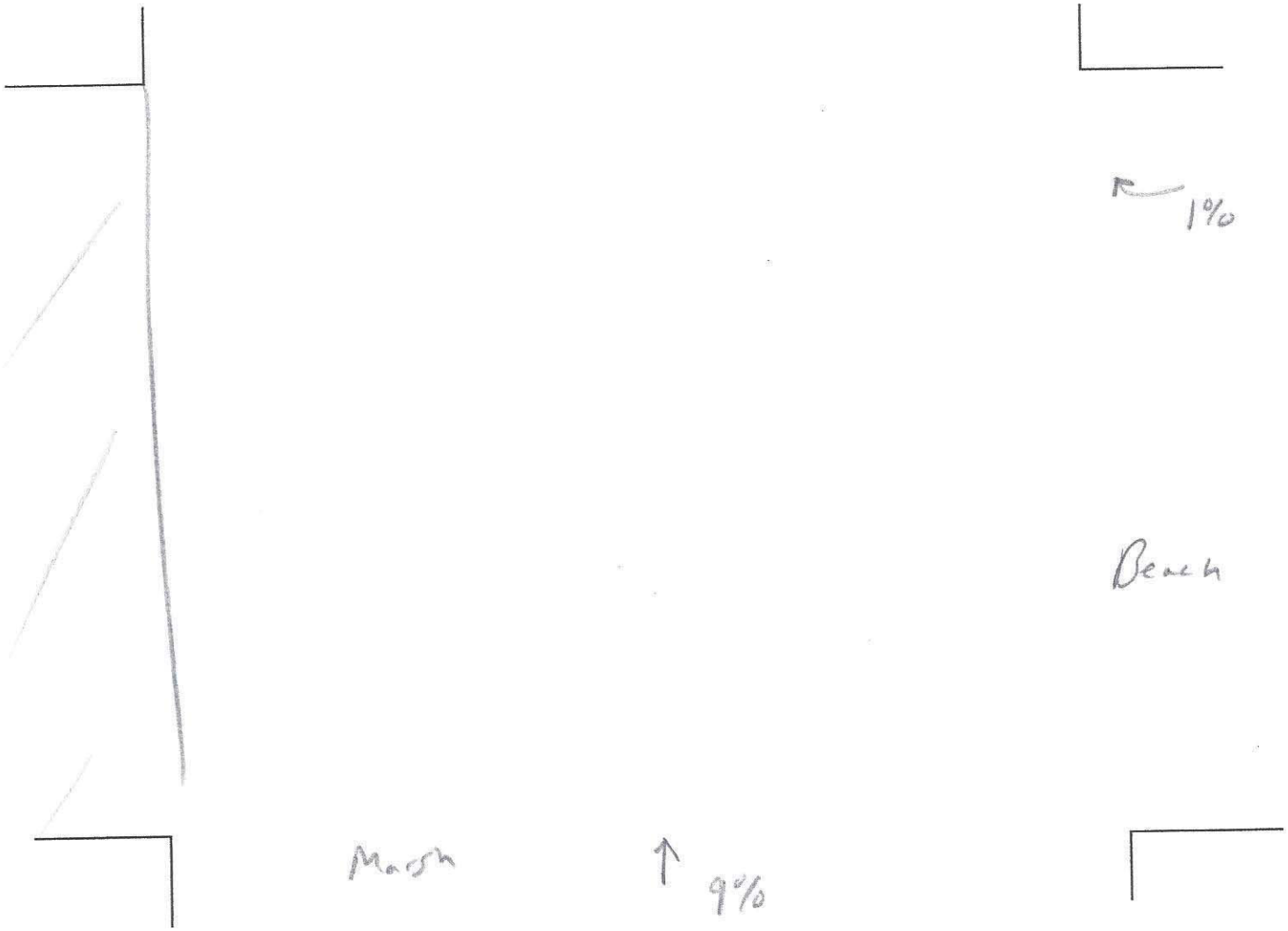


Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Marsh Street / Beach Street

Heavy Vehicles:



Comments:

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Claremont Boulevard / First Street

City: Claremont

Location: (Southern CA) Northern CA Central CA Other

Intersection Type: ~~T~~ + Signalized

Data Collection Time: 2:00 - 3:00 pm

Intersection Geometry:

North Arrow:

Comments: Pavement = 4 Quality

Parking allowed on Claremont bike lane, not First Street.

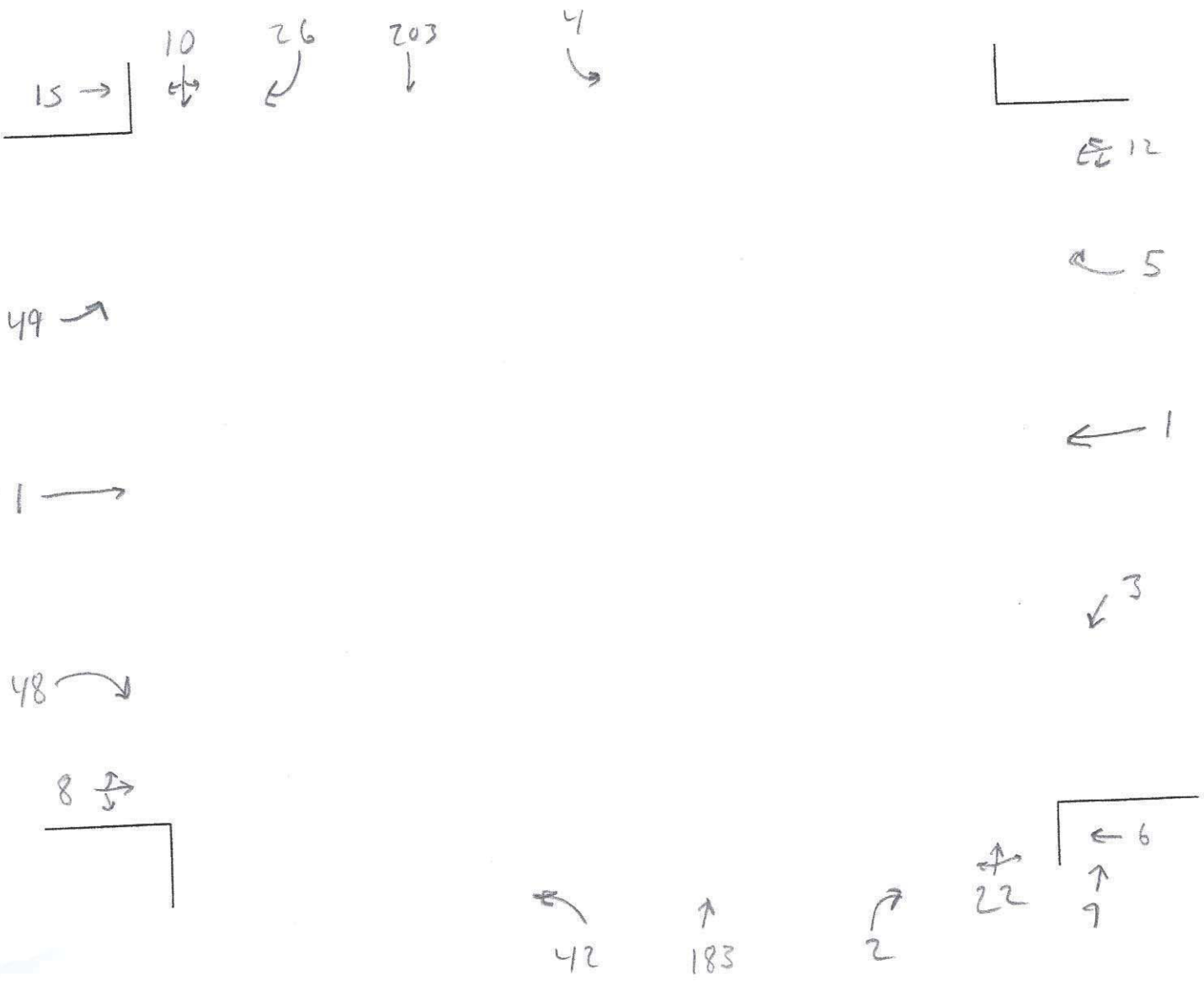
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Claremont Blvd / First Street

Time Period: 2:00-3:00

Volumes:



HV: 7%

Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Claremont Blvd / First Street

Heavy Vehicles:

Comments: East 1st street dead ends after a short ways.

Cal Poly San Luis Obispo

Nathan Johnston

Intersection: Baseline Road / Mountain Avenue

City: Claremont

Location: (Southern CA) Northern CA Central CA Other

Intersection Type: ~~T~~ + Signalized

Data Collection Time: 3:10 - 4:10

Intersection Geometry:

North Arrow:

Comments: Pavement = 3 approaches are red curbed

Parking allowed in bike lanes

Bike detection present (cameras)

1 HV ≈ 5%

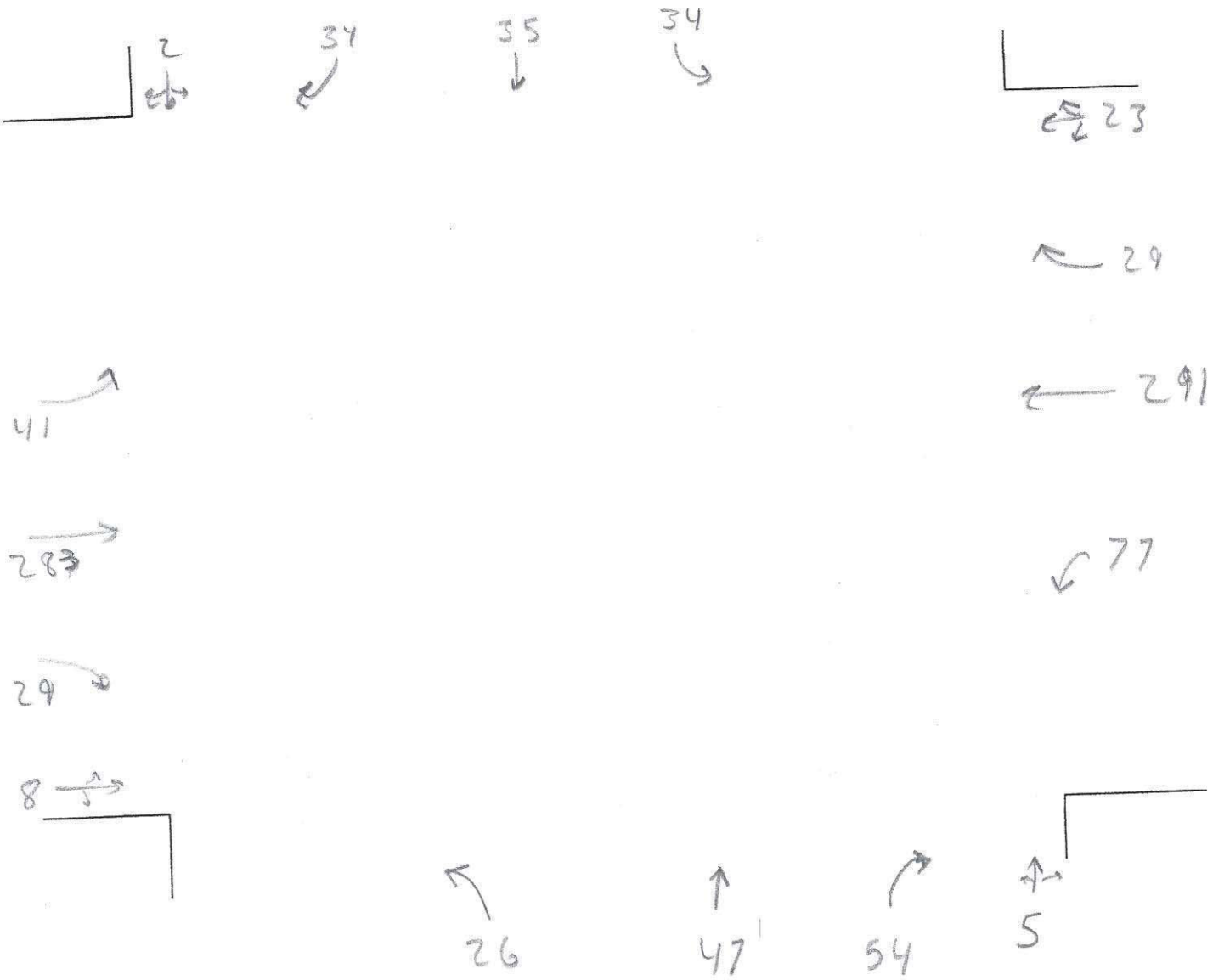
Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Mountain Avenue / Baseline Road

Time Period: 3:10 - 4:10

Volumes:



Nathan Johnston

Cal Poly San Luis Obispo

Intersection: Mountain Avenue/Baseline Road

Heavy Vehicles:

Comments: North Mountain is residential area, mainly.

Appendix G

The following is a summary of the collected field data sheets (please note that not all information from the sheets may be listed here, but the majority is).

Nathan Johnston
Anurag Pande

City	Intersection	Time	Day	Intersection Type	Major	Minor	Major Speed limit	Minor Speed Limit	Nearby signal conflict?	Bus Stop Nearby?	Pavement Quality
San Luis Obispo	Los Osos Valley Road/ Diablo Drive	9-10	Weds	+	LOVR	Diablo	45	25	No	Yes	2
Silver	Grand Avenue/McCollum Street	7:40-8:40	Weds	+	Grand	McCollum	35	25	No	No	3
	Patricia Drive/ Cerro Romaldo Avenue	6:30-7:30	Weds	+	Patricia	Cerro Romaldo	25	25	Yes	No	3
	Los Osos Valley Road/ Prefumo Canyon Drive	10:10-11:10	Weds	T	LOVR	Prefumo Canyon	45	40	No	No	3
	Tank Farm Road/Long Street	11:30-12:30	Weds	+	Tank Farm	Long	50	25	No	No	3
	Johnson Avenue/Sydney Street	12:50-1:50	Weds	+	Johnson	Sydney	45	25	No	Yes	3
	Monterey Street/ Toro Street	1:40-2:40	Weds	+	Monterey	Toro	35	25	No	No	3
	Monterey Street/ Pepper Street	2:50-3:50	Weds	+	Monterey	Pepper	35	25	No	No	3
	Morro Street/Pismo Street	3:55-4:55	Weds	+	Pismo	Morro	25	25	Yes	No	3
	Higuera Street/Garden Street	5:05-6:05	Weds	T	Higuera	Garden	35	25	Yes	No	3
	Morro Street/Islay Street	6:10-7:10	Weds	+	Morro	Islay	25	25	No	No	3
	Broad Street/ Islay Street	7:15-8:15	Weds	+	Broad	Islay	35	25	No	No	4
	Broad Street/ Chorro Street/Sandercock Street	7:30-8:30	Tues	+	Broad	Chorro/Sandercock	40	25	No	No	3
	Marsh Street/Beach Street	8:50-9:50	Tues	T	Marsh	Beach	35	25	No	No	3
Claremont	College Avenue/Fourth Street	8:00-9:00	Friday	T	College	Fourth	25	25	No	No	3
Silver	College Avenue/Second Street	9:10-10:10	Friday	T	College	Second	25	25	No	No	3
	Bonita Avenue/Cornell Avenue	10:20-11:20	Friday	T	Bonita	Cornell	35	25	No	No	4
	Baseline Road/Grand Ave	11:30-12:30	Friday	+	Baseline	Grand	45	25	No	No	3
	Butte Street/ Vanderbilt Avenue	8:30-9:30	Tues	T	Butte	Vanderbilt	30	25	No	No	4
	Cambridge Avenue/Wharton Drive	9:50-10:50	Tues	T	Cambridge	Wharton	35	25	No	No	3
	First Street/Mills Avenue	11:00-12:00	Tues	+	First	Mills	40	25	No	Yes	4
	Mountain Avenue/Butte Street/8th Street	10:00-11:00	Tues	+	Mountain	Butte/8th	40	25	No	No	4
Riverside	West Linden Street/ Douglass Avenue	2:50-3:50	Tues	T	West Linden	Douglass	30	25	No	No	2
Bronze	Victoria Avenue/Grace Street	8:00-9:00	Tues	+	Victoria	Grace	45	35	No	No	3
	Victoria Avenue/Saint Lawerence Street	9:05-10:05	Tues	T	Victoria	Saint Lawerence	45	30	No	No	3
	Victoria Avenue/Boundary Lane	10:10-11:10	Tues	T	Victoria	Boundary	40	25	No	No	2
	Colorado Avenue/Dundee Road	11:15-12:15	Tues	+	Colorado	Dundee	35	25	No	No	3
	California Avenue/Shelby Drive	12:20-1:20	Tues	+	California	Shelby	45	25	No	Yes	3
	Magnolia Avenue/Hoover Street	1:30-2:30	Tues	T	Magnolia	Hoover	40	25	No	Yes	3
Irvine	Northwood/Savannah	10:00-11:00	Sat	+	Northwood	Savannah	35	25	No	No	5
Bronze	Deerfield/Fawn Glen East	11:20-12:20	Sat	T	Deerfield	Fawn Glen East	30	25	No	Yes	3
	McGaw Avenue/Armstrong Street	12:30-1:30	Sat	+	McGaw	Armstrong	45	25	No	No	4
	Michelson/Sequoia Tree Lane	1:40-2:40	Sat	T	Michelson	Sequoia Tree	35	25	No	No	4
	Turtle Rock Drive/Sycamore Creek	2:50-3:50	Sat	T	Turtle Rock	Sycamore Creek	45	25	No	No	4

City	Intersection	Time	Day	Intersection Type	Major	Minor	Major Speed limit	Minor Speed Limit	Nearby signal conflict?	Bus Stop Nearby?	Pavement Quality
Goleta/Santa Barbara	Lagoon Road/Harold Frank Road	1:45-2:45	Friday	T	Lagoon	Harold Frank	25	15	No	No	2
Gold	North La Patera Lane/Covington Way	9:00-10:00	Friday	+	La Patera	Covington	35	25	No	No	4
	Cathedral Oaks Road/North La Patera Lane	10:05-11:05	Friday	+	Cathedral Oaks	La Patera	40	30	No	No	4
	Cathedral Oaks Road/Placer Drive	11:15-12:15	Friday	T	Cathedral Oaks	Placer	40	25	No	No	2
	Cathedral Oaks Road/Ellwood Ridge Road	12:30-1:30	Friday	T	Cathedral Oaks	Ellwood Ridge	40	25	No	Yes	3
Claremont	Claremont Boulevard/First Street	2:00-3:00	Tues	Signalized	Claremont	First	40	35	No	No	4
Signalized Intersections	Baseline Road/Mountain Avenue	3:10-4:10	Tues	Signalized	Baseline	Mountain	45	45	No	No	3

Sharrows?	Signage?	Bike Boulevard?	Bike Lane?	Separated Bike Lane?	Stripped Parking Lane?	Parking in Bike Lane?	If no stripped parking lane On Street Parking Major?	On Street Parking Minor	Bike Lane Size if present 1 (ft)	Bike Lane Size if present 2 (ft)	
No	No	No	Yes	No	No	No	No	Yes	7		7
No	No	No	Yes	No	Yes	No	No	Yes	8		5
No	No	No	No	No	No	No	Yes	Yes	0		0
No	No	No	Yes	No	No	No	No	Yes	7		7
No	No	No	Yes	No	No	No	No	Yes	5		5
No	No	No	Yes	No	Yes	No	No	Yes	5		5
Yes	Yes	No	No	No	No	No	Yes	Yes	0		0
Yes	Yes	No	No	No	No	No	Yes	Yes	0		0
No	Yes	Yes	No	No	No	No	Yes	Yes	0		0
No	No	No	No	No	Yes	No	Yes	Yes	0		0
No	Yes	Yes	No	No	Yes	No	Yes	Yes	0		0
Yes	No	No	No	No	No	No	Yes	Yes	0		0
No	No	No	Yes	No	No	No	Yes	Yes	5		5
No	Yes	No	Yes	No	Yes	No	Yes	Yes	5		0
Yes	Yes	No	No	No	No	No	Yes	Yes	0		0
No	Yes	No	Yes	No	Yes	No	Yes	Yes	7		7
No	Yes	No	Yes	No	Yes	No	Yes	Yes	7		6
No	No	No	Yes	No	No	Yes	Yes	Yes	9		9
Yes	Yes	No	No	No	Yes	No	Yes	Yes	0		0
Yes	Yes	No	No	No	No	No	Yes	Yes	0		0
No	Yes	No	Yes	No	Yes	No	Yes	Yes	7		5
Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	5		5
No	No	No	No	No	No	No	Yes	Yes	0		0
No	Yes	No	Yes	Yes	No	No	No	Yes	5		5
No	Yes	No	Yes	Yes	No	No	No	Yes	8		5
No	Yes	No	Yes	Yes	No	No	Yes	Yes	8		7
No	No	No	No	No	No	No	Yes	Yes	0		0
No	No	No	Yes	No	No	No	No	Yes	7		7
No	No	No	Yes	No	No	No	No	Yes	4		4
No	No	No	Yes	No	No	No	No	Yes	8		8
No	No	No	Yes	No	No	No	No	Yes	8		8
No	No	No	No	No	No	No	No	No	0		0
No	No	No	Yes	No	No	No	No	No	7		7
No	No	No	Yes	No	No	No	No	Yes	8		8

Sharrows?	Signage?	Bike Boulevard?	Bike Lane?	Separated Bike Lane?	Stripped Parking Lane?	Parking in Bike Lane?	On Street Parking Major?	On Street Parking Minor	Bike Lane Size if present 1 (ft)	Bike Lane Size if present 2 (ft)	
No	Yes	No	No	Yes	No	No	No	Yes	10		0
No	Yes	No	No	No	No	No	Yes	Yes	0		0
No	Yes	No	Yes	No	No	No	No	Yes	8		4
No	Yes	No	Yes	Yes	No	No	No	Yes	10		8
No	Yes	No	Yes	Yes	No	No	No	No	8		6
No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	7		5
No	No	No	Yes	No	No	Yes	Yes	Yes	7		4

Number of through lanes major street (both ways)	Designated Right Turn Lane?	Designated Left Turn lane?	Center Storage Lane?	Median?	One Way Street?	Number of lanes minor street	Large Curb Return?
4	No	Yes	No	Yes	No	2	Yes
4	No	Yes	No	Yes	No	2	No
2	No	No	No	No	No	2	No
4	No	Yes	No	Yes	No	3	Yes
4	No	Yes	No	Yes	No	2	Yes
4	No	Yes	No	No	No	2	No
2	No	No	Yes	No	No	2	No
2	No	No	Yes	No	No	2	No
2	No	No	No	No	Yes	2	Yes-traffic calming
3	No	No	No	No	Yes	2	No
2	No	No	No	No	No	2	No
2	No	No	No	No	No	2	No
3	Yes	Yes	Yes	No	No	2	No
3	No	No	No	No	Yes	2	No
2	No	No	No	No	No	2	Yes
2	No	No	No	No	No	2	No
2	No	Yes	Yes	No	No	2	No
4	No	Yes	No	No	No	2	Yes
2	No	No	No	No	No	2	Yes
2	No	No	No	No	No	2	Yes
2	No	Yes	No	No	No	2	No
2	No	No	Yes	No	No	2	No
2	No	No	No	No	No	2	No
2	No	No	Yes	Yes	No	2	No
2	No	No	Yes	Yes	No	2	No
2	No	No	Yes	Yes	No	2	Yes
2	No	No	No	No	No	2	Yes
4	No	No	No	No	No	2	Yes
4	No	Yes	No	Yes	No	2	No
2	No	Yes	No	Yes	No	2	Yes
2	No	No	No	No	No	2	No
4	No	Yes	No	No	No	2	No
2	No	No	No	Yes	No	2	Yes
2	No	No	No	No	No	2	Yes

Number of through lanes major street (both ways)	Designated Right Turn Lane?	Designated Left Turn lane?	Center Storage Lane?	Median?	One Way Street?	Number of lanes minor street	Large Curb Return?
2	No	No	No	No	No	2	No
2	No	No	No	No	No	2	Yes
2	No	Yes	No	No	No	2	No
2	No	Yes	No	Yes	No	2	Yes
2	No	Yes	No	Yes	No	2	No
4	Yes	Yes	No	Yes	No	4	No
4	Yes	Yes	No	Yes	No	3	No

Percent Grade				Volumes (/hr)					
Major street Slope 1	Major Street Slope 2	Minor Street Slope 1	Minor Street Slope 2	Major street 1 Left Turn	Major Street 1 Through	Major Street 1 Right Turn	Major Street 1 Bikes	Major Street 1 Peds	
0	0	8	0	30	628	46	15	0	
-3	3	-1	1	8	96	6	8	0	
-1	1	-2	2	2	108	1	0	0	
0	0	-2	2	0	1044	48	23	12	
-1	1	0	0	180	216	28	6	2	
-2	3	5	-7	24	193	26	12	14	
-1	1	2	4	32	215	14	13	16	
-1	1	4	4	2	183	10	12	27	
-1	0	0	0	12	182	8	9	7	
-1	0	0	0	24	492	0	0	132	
0	0	-1	1	3	4	1	7	10	
0	0	0	0	12	122	12	6	0	
1	1	-2	1	14	453	10	3	15	
1	0	-2	2	0	721	21	20	5	
-2	2	2	0	0	132	9	2	72	
-2	2	0	0	0	66	33	1	6	
1	-1	1	0	0	216	24	24	7	
1	-1	2	-2	9	447	1	9	0	
0	0	0	0	9	30	0	3	0	
-1	1	0	0	2	108	0	7	0	
1	-1	-1	0	12	125	3	16	0	
-2	2	0	0	22	137	10	8	4	
0	0	0	0	6	93	0	15	4	
-1	1	0	0	9	159	6	12	6	
0	0	0	0	0	127	4	5	0	
-2	2	0	0	0	132	13	3	0	
-1	1	0	0	0	100	2	1	0	
0	0	0	0	4	321	6	2	3	
-1	1	0	0	82	721	0	3	0	
1	-1	0	0	10	34	3	2	0	
1	-1	0	0	19	130	0	4	0	
1	-1	1	-1	3	87	19	1	0	
-2	2	0	0	5	117	0	11	0	
-3	3	2	0	13	135	0	2	10	

Major street Slope 1	Major Street Slope 2	Minor Street Slope 1	Minor Street Slope 2	Major street 1 Left Turn	Major Street 1 Through	Major Street 1 Right Turn	Major Street 1 Bikes	Major Street 1 Peds
0	0	0	0	0	234	16	57	57
-1	1	-3	-1	2	23	4	2	4
0	0	1	-1	7	138	8	17	2
0	-2	2	-2	0	152	10	11	0
-2	2	5	0	0	50	14	8	4
-2	2	1	-1	4	203	26	10	0
2	-2	-2	2	41	283	29	8	0

Movement Number	1	2	3	
If separated bike lane:	right turn onto bike lane from minor 1	left turn onto bike lane from minor 1	through along major 1	through along major 2
	13	14	15	16

Major Street 2 Left Turn	Major Street 2 Through	Major Street 2 Right Turn	Major Street 2 Bikes	Major Street 2 Peds	Minor street 1 Left Turn	Minor Street 1 Through	Minor Street 1 Right Turn	Minor Street 1 Bikes
168	732	57	23		10	26	2	22	4
2	262	4	12		16	3	0	1	0
0	30	3	0		0	4	1	8	0
70	780	0	38		6	119	0	220	17
96	211	60	5		0	12	1	48	0
16	252	14	15		10	15	12	6	2
27	201	35	9		31	26	36	12	4
7	238	14	12		0	5	0	6	9
0	0	0	0		12	0	12	24	12
0	0	0	0		120	24	0	0	0
2	5	3	24		0	7	43	1	7
11	246	12	9		27	7	15	6	4
12	196	48	6		13	12	1	13	4
0	0	0	0		0	0	0	47	1
6	81	0	15		66	3	0	9	2
15	111	0	2		15	18	0	18	0
21	174	0	9		0	15	0	18	21
6	510	6	3		0	15	1	12	0
0	23	12	5		5	8	0	7	4
0	119	4	5		0	7	0	1	0
3	146	4	3		0	8	8	8	2
2	89	4	5		18	4	14	13	2
0	107	19	13		13	21	0	18	4
4	147	1	18		0	2	1	6	3
5	101	0	3		7	6	0	4	2
3	151	0	2		0	10	0	4	1
7	149	1	4		0	7	0	16	0
10	325	7	2		0	6	0	16	6
0	659	12	2		0	21	0	45	2
4	58	23	4		6	2	0	16	0
0	95	3	5		0	1	0	19	1
20	51	1	2		0	10	10	46	0
0	144	7	2		3	8	0	4	0
0	85	2	1		4	11	0	5	1

Major Street 2 Left Turn	Major Street 2 Through	Major Street 2 Right Turn	Major Street 2 Bikes	Major Street 2 Peds	Minor street 1 Left Turn	Minor Street 1 Through	Minor Street 1 Right Turn	Minor Street 1 Bikes
11	200	0	97		39	10	0	2	2
5	17	4	2		17	1	2	7	5
14	152	19	14		1	5	0	16	0
17	114	0	16		0	4	0	28	2
10	77	0	5		8	5	0	11	0
42	183	2	22		9	49	1	48	8
77	291	29	23		0	34	35	34	2
4	5	6				7	8	9	

right turn along major 1	right turn along major 2	left turn along major 1	left turn along major 2	right turn onto bike lane from minor 2	left turn onto bike lane from minor 2
17	18	19	20	21	22

Minor Street 1 Peds	Minor Street 2 Left Turn	Minor Street 2 Through	Minor Street 2 Right Turn	Minor Street 2 Bikes	Minor Street 2 Peds	HV Major 1	HV Major 2	HV minor 1	HV minor 2
0	38	6	66	1	0	9	12	2	2
0	1	0	10	0	0	3	3	1	1
0	6	2	3	0	0	2	2	1	1
0	0	0	0	0	0	9	12	3	3
0	25	0	144	8	0	13	10	10	2
18	13	2	38	3	0	4	4	1	1
0	29	19	47	6	0	9	11	3	2
0	11	13	9	0	0	4	5	1	1
6	5	12	0	14	0	1	0	1	1
0	0	0	0	0	12	3	0	2	0
0	4	21	9	9	0	0	0	1	1
0	11	8	10	3	12	4	4	1	1
0	7	0	23	1	0	7	8	1	1
0	0	0	0	0	0	9	0	1	0
9	0	0	0	0	6	5	5	1	0
0	0	0	0	0	0	5	5	3	0
0	0	0	0	0	0	3	3	3	0
0	45	0	3	1	0	3	3	1	1
0	0	0	0	0	0	1	1	1	0
0	0	0	0	0	0	3	3	15	0
1	8	8	12	0	0	7	7	1	2
3	7	13	12	1	3	4	4	1	1
0	0	0	0	0	0	3	3	2	0
0	9	15	9	9	0	10	9	7	7
0	0	0	0	0	0	4	4	3	0
0	0	0	0	0	0	3	3	1	0
0	3	0	2	0	0	2	2	1	1
0	4	0	3	0	0	3	3	1	1
0	0	0	0	0	0	5	4	2	0
10	33	1	29	2	3	3	3	1	1
0	0	0	0	0	0	2	2	1	0
0	11	10	1	4	0	6	6	5	5
0	0	0	0	0	0	2	2	1	0
0	0	0	0	0	0	2	2	1	0

Minor Street 1 Peds	Minor Street 2 Left Turn	Minor Street 2 Through	Minor Street 2 Right Turn	Minor Street 2 Bikes	Minor Street 2 Peds	HV Major 1	HV Major 2	HV minor 1	HV minor 2
8	0	0	0	0	0	10	10	8	0
0	2	8	0	8	4	1	1	1	1
0	7	4	0	0	0	8	7	2	4
0	0	0	0	0	0	3	3	3	0
0	0	0	0	0	0	6	4	25	0
0	3	1	5	12	6	7	7	7	2
0	26	47	54	5	0	5	5	4	2
	10	11	12						

Average Rating Movement	1	2	3	4
C	B	D	C	
C	C	C	C	
C	C	D	C	
	C	D	C	
D	D	C	D	
D	C	B	C	
B	B	B	B	
B	B	B	B	
B	B	B		
D	D			
B	B	B	B	
B	B	C	B	
C	C	C	C	
	B	B		
	B	C	D	
	B	E	C	
	B	B	C	
C	B	C	D	
B	B			
D	B			
B	B	B	B	
C	B	B	C	
F	E			
C	B	C	C	
	B	B	C	
	B		C	
C	D	C	C	
C	B	C	C	
E	D			
C	B	C	C	
C	B			
C	D	C	C	
B	A			
C	B			

	1	2	3	4
	D	D	D	
C	C	B	C	
	B	C	C	
	B	C	C	
	B	C	D	
C	C	C	B	
B	A	A	B	

5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
B	C	C	D	D	C	E	D										
C	C	D	C	B	C	C	C										
C	C	C	C	C	C	C	C										
B		C		C													
D	C	D	E	C	E	E	C										
C	C	C	D	C	C	C	B										
B	B	C	B	B	C	C	B										
B	B	B	C	B	B	C	B										
			B	B	B	B											
		D															
C	B	B	B	B	B	B	B										
C	B	B	B	B	B	B	C										
C	C	C	C	C	C	C	C										
				B													
B		D		D													
B		B		B													
B		C		B													
D	C	D	C	B	C	D	C										
B	B	B		A													
C	C	D		D													
B	B	C	C	B	B	C	B										
B	B	B	D	B	C	D	B										
E	E	F		E													
C	B	D	C	B	C	C	C	A	B	C	C	B	C	C	C	C	C
B		C		B				B	C	B	B	C			C		
B	C	C		B				B	B	B	B	C			D		
D	C	D	C	D	D	C	D										
B	C	C	C	B	C	C	B										
E	D	D		E													
B	C	C	C	B	C	C	B										
B	C	C		B													
D	C	D	C	D	D	C	D										
A	B	C		B													
B	C	C		B													
5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
D		D		C					A	A							
C	C	C	C	C	C	C	C										
B		C		C													
A		B		B			C	C	B	B	C			C			
B		D		C			C	D	B	B	C			C			
B	A	B	A	A	C	C	C										
A	B	B	B	B	B	B	B										

Appendix H

The following pages are sample public survey sheets upon which cyclist perception scores were collected by in-person interviews with video recording viewers. Please note that not all data pages collected are included in this appendix due to the large volume of data collected. A summary of all data collected is also included in this appendix to address the excluded data pages.

Intersection: Broad / Islay SLO

Scores: (A=Best F=Worst)

Right Turn	Through	Left Turn
C	B	B
C	D - cars share	B
B-	C - (light needed)	B
B	C- "	C

Comments: Cars parked on street, bushes obstruct view
Streets is not busy, Bike Sharrow road,
Street in poor repair
* Sharing a road with moving cars & parked cars is not good.

Intersection: Chorro Broad / Sander cock

Scores: (A=Best F=Worst)

Right Turn	Through	Left Turn
C-	C- } not designed for bikes	C
C-	C-	C+
C	D	C
C	C	C

Comments: The Bike lane is helpful - but the other lanes should be sharrows.

Intersection: Gardens / Higuera

Scores: (A=Best F=Worst)

Right Turn	Through	Left Turn
	C	D → cross 3 lanes
		C

Comments: Streets are narrow - Not Sharrow - Yikes!
- Cars parked along the side

Intersection: Cathedral Oaks Rd. & Placer Drive. Goleta

Scores: (A=Best F=Worst)

Right Turn	Through	Left Turn
B	A	B
C	B	C

Comments: Nice - wide bike lanes.

Intersection: Cathedral Oaks Rd. & Placer Dr. Bike Trail

Scores: (A=Best F=Worst)

Right Turn	Through	Left Turn
C	C	
C	C	
B *		
B *		

Comments: * The score would be higher if the bike-lane was maintained. Trees block the view; the pavement is cracked.

Intersection: N. La Patera Lane & Covington Way

Scores: (A=Best F=Worst)

Right Turn	Through	Left Turn
E	D	E
C	E	E
D	E	D
D	D	D

Comments: Cyclist must share narrow road with motorist & parked cars.

Intersection: Broad & ISLAY SLO

Scores: (A=Best F=Worst)

A
B
C
D
E
F

Right Turn	Through	Left Turn
C-	B	B
C+	B	C+
C-	B	B
B	B	B

Comments: Sharrow makes up for narrow lanes
Parked cars are a problem

Intersection: Chorro / Broad / Sandercock streets SLO

Scores: (A=Best F=Worst)

Right Turn	Through	Left Turn
D C-	C	C
D C-	C	C
D C-	C	C
C	C	C

Comments: SIDE STREET SHOULD BE A Sharrow

Intersection: CALDERA Higuera

Scores: (A=Best F=Worst)

Right Turn	Through	Left Turn
	C- D	D
		C- D
		A
		A

Comments: SHOULD BE A Sharrow

Intersection: Grand & McCullom SLO

Scores: (A=Best F=Worst)

Right Turn	Through	Left Turn
C	C	D
B	C	C
C	C	C
C	C	C

Comments: Island blocks line of sight
Lack of signage.

Intersection: VOHNSON / SYDNEY SLO

Scores: (A=Best F=Worst)

Right Turn	Through	Left Turn
B	C	C
C	C	D
C	C	C
C	C	C

Comments: Poor visibility due to some bushes

Intersection: Diablo Street Los Osos Valley Rd SLO

Scores: (A=Best F=Worst)

Right Turn	Through	Left Turn
D	D	C
C	D	C
D	C	D
C	C	C

Comments: Poor Positing of bus stops
Center median block vis
Bus stop blocks one turn sel

Appendix I

The following is a sample survey response that was provided by a Cal Poly Student in Dr. Mastako's CE 421 Class.

#3

COMPLETE

Collector: Web Link (Web Link)
Started: Monday, November 04, 2013 5:35:04 PM
Last Modified: Monday, November 04, 2013 5:45:06 PM
Time Spent: 00:10:01
IP Address: [redacted]

PAGE 1

Q1: **Please rate your own personal level of experience cycling on a scale of 1 to 5; 5 being very experienced and 1 being not at all experienced.**	4- Experienced Biker
Q2: **For low speed and low traffic roads, do you prefer:**	Bike Lanes with Parking Adjacent?
Q3: **Please view each of the videos at http://goo.gl/7fyp65 and rate each movement from a cyclist's perspective in the order shown in the video. If fewer movements occur in the video than are listed below, simply leave the extra options blank. What we are looking for in your response is how well the intersection design addresses the needs of the cyclist. It is recommended that you fill this out while you are watching the video rather than after you have completed the video. Please select the intersection you are viewing here:**	2: Deerfield/Fawn Glen East

Q4: **You will now be asked to provide two separate values for each turn movement shown in the video. The first concerns the safety level of the cyclist and the second concerns how well the roadway infrastructure present helps the cyclist. Provide safety ratings in question numbers 4, 5, and 6 and the infrastructure ratings in questions 7, 8, and 9 below: Please rate each movement below in the order shown in the video in terms of how safe the cyclist is on this road.**

	1st Right Turn Shown	2nd Right Turn Shown	3rd Right Turn Shown	4th Right Turn Shown
Right Turns	A. Little to no danger for the cyclist	B. Minor danger to the cyclist, but experienced cyclists would not be concerned		

Q5: **Through Movements**

	1st Through Movement	2nd Through Movement	3rd Through Movement	4th Through Movement
Throughs	A. Little to no danger for the cyclist	C. Some danger to the cyclist, but most bicycle riders would attempt the movement		

Q6: **Left Turns**

	1st Left Turn Shown	2nd Left Turn Shown	3rd Left Turn Shown	4th Left Turn Shown
Left Turns	B. Minor danger to the cyclist, but experienced cyclists would not be concerned	C. Some danger to the cyclist, but most bicycle riders would attempt the movement		

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Q7: Below is the beginning of the second set of responses mentioned in the introduction to question 4. These relate to how well you think the bicycle infrastructure present at the intersection (bike lanes, signage, speed limit, etc.) helps the cyclist. Please note that some of the videos are of intersections with no bicycle facilities present. You may take this into consideration when rating them. Please rate each movement below in the order shown in the video in terms of how well the roadway design helps the cyclist on this road.

	1st Right Turn Shown	2nd Right Turn Shown	3rd Right Turn Shown	4th Right Turn Shown
Right Turns	A. Great improvement for the cyclist from a standard roadway; inexperienced cyclists would not be concerned	D. Lack of bike lanes or extremely narrow bike lanes; cyclists of all levels of experience would be uncomfortable		

Q8: Through Movements

	1st Through Movement	2nd Through Movement	3rd Through Movement	4th Through Movement
Throughs	A. Great improvement for the cyclist from a standard roadway; inexperienced cyclists would not be concerned	B. Some improvement for the cyclist from a standard roadway; inexperienced cyclists would be mildly concerned		

Q9: Left Turns

	1st Left Turn Shown	2nd Left Turn Shown	3rd Left Turn Shown	4th Left Turn Shown
Left Turns	B. Some improvement for the cyclist from a standard roadway; inexperienced cyclists would be mildly concerned	C. An average roadway with bike lanes adjacent to vehicular traffic; inexperienced cyclists would be gravely concerned		

Q10: Do you have any thoughts or comments on the intersection and/or videos? If so, please enter them here. This could include your thoughts on the type of infrastructure present or needed at a particular intersection, the quality of a roadway, comments on why the video does or does not give a good representation of field conditions, why you rated a particular movement the way you did, why you are confused over something, etc. This is a free section where you can provide open feedback.

Unprotected left turn is always going to have some sort of danger present.

Appendix J

The following is a sample survey response that was provided by a member of the general public.

Two Way Stop Controlled Intersections

#1

COMPLETE

Collector: Web Link (Web Link)
Started: Sunday, November 17, 2013 5:20:58 PM
Last Modified: Sunday, November 17, 2013 5:25:23 PM
Time Spent: 00:04:24
IP Address: [redacted]

PAGE 1

Q1: **Informed Consent Form INFORMED CONSENT TO PARTICIPATE IN A RESEARCH PROJECT, "Development of a Bicycle Level of Service Methodology for Two Way Stop Controlled Intersections" A research project on the level of service provided to bicyclists is being conducted by Dr. Anurag Pande in the Department of Civil Engineering at Cal Poly, San Luis Obispo. The purpose of the study is to develop a methodology to predict how well bicycle infrastructure at this particular type of intersection affects a cyclist's ride experience and perception of safety. You are being asked to take part in this study by watching a short video of an intersection recorded from a cyclist's point of view and rate each viewed turn movement on an onlinesurvey. Your participation will take approximately10 minutes. Please be aware that you are not required to participate in this research and you may discontinue your participation at any time without penalty. You may also omit any items on the questionnaire(s) you prefer not to answer. Your responses will be provided anonymously to protect your privacy. There are no risks anticipated with participation in this research. Potential benefits include improved roadway infrastructure for bicycle use. If you have questions regarding this study or would like to be informed of the results when the study is completed, please feel free to contact Dr. Anurag Pande at apande@calpoly.edu. If you have concerns regarding the manner in which the study is conducted, you may contact Dr. Steve Davis, Chair of the Cal Poly Human Subjects Committee, at (805) 756-2754, sdavis@calpoly.edu, or Dr. Dean Wendt, Interim Dean of Research, at (805) 756-1508, dwendt@calpoly.edu. If you agree to voluntarily participate in this research project as described, please indicate your agreement by completing and submitting the following questionnaire. Please print a copy of this consent form NOW for your reference, and thank you for your participation in this research.**	Yes, I Volunteer

PAGE 2

Q2: **Please indicate your approximate age.**	40-65
Q3: **Please rate your own personal level of experience cycling on a scale of 1 to 5; 5 being very experienced and 1 being not at all experienced.**	5- Highly Experienced Biker

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Q4: Please view each of the videos at http://goo.gl/7fyp65 and rate each movement from a cyclist's perspective in the order shown in the video. If fewer movements occur in the video than are listed below, simply leave the extra options blank. What we are looking for in your response is how well the intersection design addresses the needs of the cyclist. It is recommended that you fill this out while you are watching the video rather than after you have completed the video. Please select the intersection you are viewing here:

11: Victoria/Boundary

Q5: You will now be asked to provide two separate values for each turn movement shown in the video. The first concerns the safety level of the cyclist and the second concerns how well the roadway infrastructure present helps the cyclist. Provide safety ratings in question numbers 4, 5, and 6 and the infrastructure ratings in questions 7, 8, and 9 below: Please rate each movement below in the order shown in the video in terms of how safe the cyclist is on this road.

	1st Right Turn Shown	2nd Right Turn Shown	3rd Right Turn Shown	4th Right Turn Shown
Right Turns	B. Minor danger to the cyclist, but experienced cyclists would not be concerned	C. Some danger to the cyclist, but most bicycle riders would attempt the movement		

Q6: Through Movements

	1st Through Movement	2nd Through Movement	3rd Through Movement	4th Through Movement
Throughs	B. Minor danger to the cyclist, but experienced cyclists would not be concerned	B. Minor danger to the cyclist, but experienced cyclists would not be concerned		

Q7: Left Turns

	1st Left Turn Shown	2nd Left Turn Shown	3rd Left Turn Shown	4th Left Turn Shown
Left Turns	C. Some danger to the cyclist, but most bicycle riders would attempt the movement	C. Some danger to the cyclist, but most bicycle riders would attempt the movement		

Q8: Below is the beginning of the second set of responses mentioned in the introduction to question 4. These relate to how well you think the bicycle infrastructure present at the intersection (bike lanes, signage, speed limit, etc.) helps the cyclist. Please note that some of the videos are of intersections with no bicycle facilities present. You may take this into consideration when rating them. Please rate each movement below in the order shown in the video in terms of how well the roadway design helps the cyclist on this road.

	1st Right Turn Shown	2nd Right Turn Shown	3rd Right Turn Shown	4th Right Turn Shown
Right Turns	B. Some improvement for the cyclist from a standard roadway; inexperienced cyclists would be mildly concerned	B. Some improvement for the cyclist from a standard roadway; inexperienced cyclists would be mildly concerned		

Q9: Through Movements

	1st Through Movement	2nd Through Movement	3rd Through Movement	4th Through Movement
Throughs	A. Great improvement for the cyclist from a standard roadway; inexperienced cyclists would not be concerned	B. Some improvement for the cyclist from a standard roadway; inexperienced cyclists would be mildly concerned		

Q10: Left Turns

	1st Left Turn Shown	2nd Left Turn Shown	3rd Left Turn Shown	4th Left Turn Shown
Left Turns	B. Some improvement for the cyclist from a standard roadway; inexperienced cyclists would be mildly concerned	C. An average roadway with bike lanes adjacent to vehicular traffic; inexperienced cyclists would be gravely concerned		

Q11: Do you have any thoughts or comments on the intersection and/or videos? If so, please enter them here. This could include your thoughts on the type of infrastructure present or needed at a particular intersection, the quality of a roadway, comments on why the video does or does not give a good representation of field conditions, why you rated a particular movement the way you did, why you are confused over something, etc. This is a free section where you can provide open feedback.

The split roadway design is rather unusual. Also, the separated bike lane is nice, but may provide problems with turning cars. (and other bikes).

Appendix K

The following is a summary of the collected level of service feedback based on the experience of the providers.

		Medium Experience				Low Experience				High Experience				Average			
	Intersection	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn
San Luis Obispo	Los Osos Valley Road/ Diablo Drive	1	9	8	7	1	9	8	7	1	9	8	7	1	9	8	7
		2	6	11	1	2	6	11	1	2	6	11	1	2	6	11	1
Silver		3	12	2	10	3	12	2	10	3	12	2	10	3	12	2	10
		4	3	5	4	4	3	5	4	4	3	5	4	4	3	5	4
	Bus Stop	1 Score	D	D	D	1 Score	C	D	C	1 Score	D	C	C	1 Score	D	D	C
	Island	2	C	F	C	2	B	D	C	2	C	C	D	2	C	E	C
		3	D	B	C	3	C	B	C	3	D	C	C	3	D	B	C
		4	E	B	C	4	C	B	C	4	C	C	C	4	D	B	C
	Grand Avenue/McCollum Street	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn
		1	9	8	7	1	9	8	7	1	9	8	7	1	9	8	7
		2	6	11	1	2	6	11	1	2	6	11	1	2	6	11	1
	Island Blocks Sight	3	12	2	10	3	12	2	10	3	12	2	10	3	12	2	10
		4	3	5	4	4	3	5	4	4	3	5	4	4	3	5	4
		1 Score	B	C	C	1 Score	B	D	D	1 Score	C	C	D	1 Score	B	C	D
		2	C	C	C	2	C	D	D	2	B	C	C	2	C	C	C
		3	C	C	C	3	D	B	C	3	C	C	C	3	C	C	C
		4	B	D	D	4	C	B	C	4	C	C	C	4	C	C	C
	Patricia Drive/ Cerro Romaldo Avenue	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn
		1	3	2	1	1	3	2	1	1	3	2	1	1	3	2	1
		2	9	5	10	2	9	5	10	2	9	5	10	2	9	5	10
		3	6	8	4	3	6	8	4	3	6	8	4	3	6	8	4
		4	12	11	7	4	12	11	7	4	12	11	7	4	12	11	7
		1 Score	D	D	C	1 Score	D	C	C	1 Score	D	C	C	1 Score	D	C	C
		2	C	D	C	2	C	C	C	2	C	C	C	2	C	C	C
		3	B	C	D	3	C	C	C	3	C	C	C	3	C	C	C
		4	C	D	C	4	C	C	C	4	C	C	C	4	C	C	C
	Los Osos Valley Road/ Prefumo Canyon Drive	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn
		1	9	5	4	1	9	5	4	1	9	5	4	1	9	5	4
		2	3	2	7	2	3	2	7	2	3	2	7	2	3	2	7
		3				3				3				3			
		4				4				4				4			
		1 Score	D	D	D	1 Score	B	A	C	1 Score	C	B	C	1 Score	C	B	C
		2	E	D	C	2	B	B	B	2	C	C	D	2	D	C	C
		3				3				3				3			
		4				4				4				4			
	Tank Farm Road/Long Street	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn
		1	12	11	10	1	12	11	10	1	12	11	10	1	12	11	10
		2	3	8	4	2	3	8	4	2	3	8	4	2	3	8	4
		3	9	5	7	3	9	5	7	3	9	5	7	3	9	5	7
		4	6	2	1	4	6	2	1	4	6	2	1	4	6	2	1
		1 Score	D	F	F	1 Score	B	D	D	1 Score	B	C	D	1 Score	C	E	E
		2	C	F	E	2	C	D	C	2	C	C	D	2	C	E	D
		3	D	E	E	3	B	B	D	3	B	B	D	3	C	D	D
		4	C	D	E	4	C	B	D	4	C	B	D	4	C	D	D
	Johnson Avenue/Sydney Street	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn
		1	12	11	10	1	12	11	10	1	12	11	10	1	12	11	10
		2	3	8	1	2	3	8	1	2	3	8	1	2	3	8	1
		3	9	2	4	3	9	2	4	3	9	2	4	3	9	2	4
		4	6	5	7	4	6	5	7	4	6	5	7	4	6	5	7
		1 Score	C	D	D	1 Score	A	C	C	1 Score	B	C	C	1 Score	B	C	C
		2	B	E	D	2	B	C	C	2	C	C	D	2	B	D	D
		3	D	C	D	3	B	B	C	3	C	C	C	3	C	C	C
		4	D	D	D	4	B	B	C	4	C	C	C	4	C	C	C
	Monterey Street/ Toro Street	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn
		1	9	8	7	1	9	8	7	1	9	8	7	1	9	8	7
		2	6	11	1	2	6	11	1	2	6	11	1	2	6	11	1
		3	12	2	10	3	12	2	10	3	12	2	10	3	12	2	10
		4	3	5	4	4	3	5	4	4	3	5	4	4	3	5	4
		1 Score	B	A	C	1 Score	B	C	C	1 Score	C	C	C	1 Score	B	B	C
		2	B	B	A	2	B	C	B	2	B	C	B	2	B	C	B
		3	B	B	C	3	B	B	C	3	C	B	C	3	B	B	C
		4	C	B	B	4	B	B	B	4	B	B	B	4	B	B	B

		Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn
	Monterey Street/ Pepper Street	1	9	8	7	1	9	8	7	1	9	8	7	1	9	8	7
		2	6	11	1	2	6	11	1	2	6	11	1	2	6	11	1
		3	12	2	10	3	12	2	10	3	12	2	10	3	12	2	10
		4	3	5	4	4	3	5	4	4	3	5	4	4	3	5	4
		1 Score	B	C	B	1 Score	B	C	B	1 Score	B	C	C	1 Score	B	C	B
		2	B	C	A	2	B	C	B	2	C	C	B	2	B	C	B
		3	B	B	B	3	B	B	B	3	C	B	C	3	B	B	B
		4	B	B	B	4	B	B	B	4	C	B	B	4	B	B	B
	Morro Street/Pismo Street	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn
		1	9	11	10	1	9	11	10	1	9	11	10	1	9	11	10
		2	3	8	1	2	3	8	1	2	3	8	1	2	3	8	1
		3		2		3		2		3		2		3		2	
		4				4				4				4			
		1 Score	B	A	B	1 Score	B	B	B	1 Score	B	B	B	1 Score	B	B	B
		2	A	A	A	2	B	B	B	2	B	B	B	2	B	B	B
		3		A		3		B		3		B		3		B	
		4				4				4				4			
	Higuera Street/Garden Street	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn
		1		2	7	1		2	7	1		2	7	1		2	7
		2			1	2			1	2			1	2			1
		3				3				3				3			
	Too Narrow	4				4				4				4			
	Parking																
		1 Score		D	D	1 Score		C	D	1 Score		D	D	1 Score		D	D
		2			D	2			C	2			D	2			D
		3				3				3				3			
		4				4				4				4			
	Morro Street/Islay Street	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn
		1	12	11	10	1	12	11	10	1	12	11	10	1	12	11	10
		2	3	8	4	2	3	8	4	2	3	8	4	2	3	8	4
		3	9	5	7	3	9	5	7	3	9	5	7	3	9	5	7
		4	6	2	1	4	6	2	1	4	6	2	1	4	6	2	1
		1 Score	B	A	A	1 Score	B	C	B	1 Score	B	B	B	1 Score	B	B	B
		2	A	A	A	2	C	C	C	2	C	B	C	2	B	B	B
		3	B	A	A	3	B	B	B	3	B	C	B	3	B	C	B
		4	A	A	A	4	C	B	C	4	C	C	C	4	B	B	B
	Broad Street/ Islay Street	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn
		1	3	2	1	1	3	2	1	1	3	2	1	1	3	2	1
		2	12	5	7	2	12	5	7	2	12	5	7	2	12	5	7
		3	6	8	4	3	6	8	4	3	6	8	4	3	6	8	4
	Sight distance	4	9	11	10	4	9	11	10	4	9	11	10	4	9	11	10
		1 Score	B	B	B	1 Score	C	B	B	1 Score	C	B	B	1 Score	C	B	B
		2	B	B	B	2	C	D	B	2	C	B	B	2	C	C	B
		3	B	B	C	3	B	C	B	3	C	B	B	3	B	B	B
		4	C	B	B	4	B	C	C	4	B	B	B	4	B	B	B
	Broad Street/ Chorro Street/Sandercock Street	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn
		1	9	8	7	1	9	8	7	1	9	8	7	1	9	8	7
		2	3	11	4	2	3	11	4	2	3	11	4	2	3	11	4
		3	12	5	10	3	12	5	10	3	12	5	10	3	12	5	10
		4	6	2	1	4	6	2	1	4	6	2	1	4	6	2	1
		1 Score	B	C	C	1 Score	C	C	C	1 Score	D	C	C	1 Score	C	C	C
		2	C	D	C	2	C	C	C	2	D	C	C	2	C	C	C
		3	C	C	C	3	C	D	C	3	D	C	C	3	C	C	C
		4	C	C	C	4	C	C	C	4	C	C	C	4	C	C	C
	Marsh Street/Beach Street	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn
		1	3	2		1	3	2		1	3	2		1	3	2	
		2	9			2	9			2	9			2	9		
		3				3				3				3			
		4				4				4				4			
		1 Score	B	B		1 Score	B	B		1 Score	C	B		1 Score	B	B	
		2	B			2	B			2	B			2	B		
		3				3				3				3			
		4				4				4				4			
Claremont	College Avenue/Fourth Street	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn	Movement	Right Turn	Through	Left Turn
		1	3	5	4	1	3	5	4	1	3	5	4	1	3	5	4

		2		9	2	7	2		9	2	7	2		9	2	7	2		9	2	7
		3					3					3					3				
		4					4					4					4				
		1 Score	B	B	B		1 Score	C	C	E		1 Score	C	B	E		1 Score	C	B	D	
		2	B	B	B		2	E	C	E		2	E	B	E		2	D	B	D	
		3					3					3					3				
		4					4					4					4				
Silver	College Avenue/Second Street	Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn	
		1		9	5	7	1		9	5	7	1		9	5	7	1		9	5	7
		2		3	2	4	2		3	2	4	2		3	2	4	2		3	2	4
		3					3					3					3				
		4					4					4					4				
		1 Score	B	B	B		1 Score	B	B	B		1 Score	C	B	C		1 Score	B	B	B	
		2	C	B	C		2	F	B	D		2	F	B	C		2	E	B	C	
		3					3					3					3				
		4					4					4					4				
	Bonita Avenue/Cornell Avenue	Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn	
		1		3	5	4	1		3	5	4	1		3	5	4	1		3	5	4
		2		9	2	7	2		9	2	7	2		9	2	7	2		9	2	7
		3					3					3					3				
		4					4					4					4				
		1 Score	A	A	B		1 Score	B	B	C		1 Score	B	B	C		1 Score	B	B	C	
		2	B	A	C		2	B	B	C		2	B	B	C		2	B	B	C	
		3					3					3					3				
		4					4					4					4				
	Baseline Road/Grand Ave	Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn	
		1		9	8	7	1		9	8	7	1		9	8	7	1		9	8	7
		2		6	11	1	2		6	11	1	2		6	11	1	2		6	11	1
		3		12	2	10	3		12	2	10	3		12	2	10	3		12	2	10
		4		3	5	4	4		3	5	4	4		3	5	4	4		3	5	4
		1 Score	B	C	D		1 Score	B	C	D		1 Score	B	C	C		1 Score	B	C	D	
		2	D	D	C		2	C	D	C		2	B	C	C		2	C	D	C	
		3	D	C	C		3	C	B	C		3	B	B	C		3	C	B	C	
		4	C	E	D		4	C	D	D		4	B	B	C		4	C	D	D	
	Butte Street/ Vanderbilt Avenue	Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn	
		1		6	2	1	1		6	2	1	1		6	2	1	1		6	2	1
		2		9	5	7	2		9	5	7	2		9	5	7	2		9	5	7
		3					3					3					3				
		4					4					4					4				
		1 Score	A	A	A		1 Score	B	B	C		1 Score	B	B	B		1 Score	B	B	B	
		2	A	A	A		2	A	B	B		2	B	B	B		2	A	B	B	
		3					3					3					3				
		4					4					4					4				
	Cambridge Avenue/Wharton Drive	Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn	
		1		6	2	1	1		6	2	1	1		6	2	1	1		6	2	1
		2		9	5	7	2		9	5	7	2		9	5	7	2		9	5	7
		3					3					3					3				
		4					4					4					4				
		1 Score	C	B	C		1 Score	C	C	E		1 Score	C	B	E		1 Score	C	B	D	
		2	C	C	C		2	E	C	E		2	E	B	E		2	D	C	D	
		3					3					3					3				
		4					4					4					4				
	First Street/Mills Avenue	Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn	
		1		3	2	1	1		3	2	1	1		3	2	1	1		3	2	1
		2		12	5	7	2		12	5	7	2		12	5	7	2		12	5	7
	Bus Stops	3		6	8	4	3		6	8	4	3		6	8	4	3		6	8	4
		4		9	11	10	4		9	11	10	4		9	11	10	4		9	11	10
		1 Score	B	B	B		1 Score	B	B	C		1 Score	B	B	B		1 Score	B	B	B	
		2	B	B	B		2	B	C	B		2	B	B	C		2	B	B	C	
		3	A	B	B		3	C	C	C		3	B	C	B		3	B	C	B	
		4	B	B	B		4	B	C	B		4	B	C	C		4	B	C	B	
	Mountain Avenue/Butte Street/8th Street	Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn	
		1		9	8	7	1		9	8	7	1		9	8	7	1		9	8	7
		2		6	11	1	2		6	11	1	2		6	11	1	2		6	11	1

		3		12	2	10	3		12	2	10	3		12	2	10	3		12	2	10
		4		3	5	4	4		3	5	4	4		3	5	4	4		3	5	4
		1 Score	B	D	C		1 Score	B	D	B		1 Score	A	D	B		1 Score	B	D	B	
		2	B	D	C		2	C	D	C		2	B	D	B		2	B	D	C	
		3	B	C	C		3	B	B	C		3	B	B	B		3	B	B	C	
		4	B	B	D		4	B	B	B		4	A	B	B		4	B	B	C	
Riverside	West Linden Street/ Douglass Avenue	Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn	
		1		9	2	7	1		9	2	7	1		9	2	7	1		9	2	7
		2		6	5	1	2		6	5	1	2		6	5	1	2		6	5	1
		3					3					3					3				
		4					4					4					4				
	Too Narrow Parking	1 Score	E	D	F		1 Score	E	E	E		1 Score	F	E	F		1 Score	E	E	F	
		2	D	D	E		2	E	E	F		2	F	E	F		2	E	E	F	
		3					3					3					3				
		4					4					4					4				
Bronze	Victoria Avenue/Grace Street	Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn	
		1		9	8	7	1		9	8	7	1		9	8	7	1		9	8	7
		2		3	11	10	2		3	11	10	2		3	11	10	2		3	11	10
		3		12	2	1	3		12	2	1	3		12	2	1	3		12	2	1
		4		6	5	4	4		6	5	4	4		6	5	4	4		6	5	4
				22	19	17			22	19	17			22	19	17			22	19	17
				15	20	NO 13			15	20	NO 13			15	20	NO 13			15	20	NO 13
				16	18				16	18				16	18				16	18	
				14	21				14	21				14	21				14	21	
		1 Score	B	C	D		1 Score	B	D	D		1 Score	B	C	C		1 Score	B	C	D	
		2	B	C	C		2	D	D	B		2	C	C	C		2	C	C	C	
		3	B	B	C		3	D	C	C		3	B	B	B		3	C	B	C	
		4	B	B	B		4	B	D	D		4	C	B	C		4	B	C	C	
			C	C	A			B	C	C			C	C	B			C	C	B	
			B	B	A			D	D	A			C	D	A			C	C	A	
			A	C				F	D				D	C				C	C		
			A	C				C	C				C	C				B	C		
	Victoria Avenue/Saint Lawerence Street	Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn	
		1		9	2	7	1		9	2	7	1		9	2	7	1		9	2	7
		2		3	5	4	2		3	5	4	2		3	5	4	2		3	5	4
		3					3					3					3				
		4					4					4					4				
				17	14				17	14				17	14				17	14	
				13	20				13	20				13	20				13	20	
				15					15					15					15		
				16					16					16					16		
		1 Score	B	B	C		1 Score	B	C	C		1 Score	B	B	B		1 Score	B	B	C	
		2	B	B	C		2	C	B	C		2	B	B	B		2	B	B	C	
		3					3					3					3				
		4					4					4					4				
			B	B				C	C				C	C				C	C		
			A	B				B	C				C	D				B	C		
			A					C					C					B			
			A					C					D					B			
	Victoria Avenue/Boundary Lane	Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn	
		1		9	5	7	1		9	5	7	1		9	5	7	1		9	5	7
		2		6	2	4	2		6	2	4	2		6	2	4	2		6	2	4
		3					3					3					3				
		4					4					4					4				
				13	15				13	15				13	15				13	15	
				14	20				14	20				14	20				14	20	
				17					17					17					17		
				16					16					16					16		
		1 Score	B	B	D		1 Score	B	B	B		1 Score	B	A	C		1 Score	B	B	C	
		2	C	B	C		2	D	B	D		2	B	B	C		2	C	B	C	
		3					3					3					3				
		4					4					4					4				
			B	B				B	B				B	B				B	B		
			B	C				B	D				C	D				B	D		
			B					D					C					C			
			B					B					B					B			
	Colorado Avenue/Dundee Road	Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn	
		1		12	11	10	1		12	11	10	1		12	11	10	1		12	11	10
		2		3	8	4	2		3	8	4	2		3	8	4	2		3	8	4
		3		9	5	7	3		9	5	7	3		9	5	7	3		9	5	7

		4		6	2	1	4		6	2	1	4		6	2	1	4		6	2	1
	No Bike Lanes																				
		1 Score	B	C	C		1 Score	E	C	D		1 Score	D	D	D		1 Score	D	C	D	
		2	C	C	C		2	C	C	C		2	D	D	D		2	C	C	C	
		3	C	C	C		3	E	E	D		3	D	D	D		3	D	D	D	
		4	C	C	C		4	C	E	C		4	D	D	D		4	C	D	C	
	California Avenue/Shelby Drive	Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn	
		1		9	8	7	1		9	8	7	1		9	8	7	1		9	8	7
		2		6	11	1	2		6	11	1	2		6	11	1	2		6	11	1
		3		12	2	10	3		12	2	10	3		12	2	10	3		12	2	10
	High Traffic	4		3	5	4	4		3	5	4	4		3	5	4	4		3	5	4
	Narrow Minor Street																				
		1 Score	B	D	D		1 Score	B	C	B		1 Score	B	C	C		1 Score	B	C	C	
		2	C	D	D		2	C	C	C		2	B	C	C		2	C	C	C	
		3	C	C	D		3	B	B	B		3	B	B	C		3	B	B	C	
		4	C	C	D		4	C	B	C		4	C	B	C		4	C	B	C	
	Magnolia Avenue/Hoover Street	Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn	
		1		9	2	7	1		9	2	7	1		9	2	7	1		9	2	7
		2		6	5	1	2		6	5	1	2		6	5	1	2		6	5	1
		3					3					3					3				
	Median	4					4					4					4				
	Small Bike Lane																				
	Bad Pavement	1 Score	F	E	D		1 Score	D	E	D		1 Score	C	C	D		1 Score	E	D	D	
	High Volume	2	E	E	E		2	C	E	E		2	D	D	D		2	D	E	E	
		3					3					3					3				
		4					4					4					4				
Irvine	Northwood/Savannah	Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn	
		1	12	11	10		1	12	11	10		1	12	11	10		1	12	11	10	
		2	3	8	4		2	3	8	4		2	3	8	4		2	3	8	4	
		3	9	5	7		3	9	5	7		3	9	5	7		3	9	5	7	
	Bus Stop	4	6	2	1		4	6	2	1		4	6	2	1		4	6	2	1	
		1 Score	B	B	B		1 Score	B	C	C		1 Score	C	C	C		1 Score	B	C	C	
		2	B	B	B		2	E	C	C		2	B	C	C		2	C	C	C	
		3	B	A	B		3	B	B	E		3	C	B	C		3	B	B	C	
		4	B	A	B		4	E	B	E		4	B	B	C		4	C	B	C	
Bronze	Deerfield/Fawn Glen East	Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn	
		1		9	5	7	1		9	5	7	1		9	5	7	1		9	5	7
		2		6	2	1	2		6	2	1	2		6	2	1	2		6	2	1
		3					3					3					3				
		4					4					4					4				
		1 Score	B	B	C		1 Score	B	B	B		1 Score	B	B	C		1 Score	B	B	C	
		2	C	C	B		2	C	B	C		2	C	B	C		2	C	B	C	
		3					3					3					3				
		4					4					4					4				
	McGaw Avenue/Armstrong Street	Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn	
		1	12	11	10		1	12	11	10		1	12	11	10		1	12	11	10	
		2	3	8	4		2	3	8	4		2	3	8	4		2	3	8	4	
		3	9	5	7		3	9	5	7		3	9	5	7		3	9	5	7	
		4	6	2	1		4	6	2	1		4	6	2	1		4	6	2	1	
		1 Score	D	D	D		1 Score	E	C	E		1 Score	C	C	D		1 Score	D	C	D	
		2	D	D	D		2	C	C	C		2	C	C	C		2	C	C	C	
		3	D	E	D		3	E	E	C		3	C	C	D		3	D	D	D	
		4	D	E	D		4	C	E	C		4	C	C	C		4	C	D	C	
	Michelson/Sequoia Tree Lane	Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn	
		1		9	2	7	1		9	2	7	1		9	2	7	1		9	2	7
		2		6	5	1	2		6	5	1	2		6	5	1	2		6	5	1
		3					3					3					3				
		4					4					4					4				
		1 Score	B	A	B		1 Score	B	B	C		1 Score	B	A	C		1 Score	B	A	C	
		2	B	A	B		2	B	B	B		2	B	A	B		2	B	A	B	
		3					3					3					3				
		4					4					4					4				
	Turtle Rock Drive/Sycamore Creek	Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn		Movement	Right Turn	Through	Left Turn	
		1		9	2	7	1		9	2	7	1		9	2	7	1		9	2	7
City	Intersection	2		6	5	1	2		6	5	1	2		6	5	1	2		6	5	1
		3					3					3					3				
		4					4					4					4				

		1 Score	C		C		D			1 Score	B		B		C			1 Score	B		B		B			1 Score	B		B		C		
		2	C		C		C			2	C		B		C			2	B		B		B			2	C		B		C		
		3								3								3								3								
		4								4								4								4								
Goleta/Santa Barbara	Lagoon Road/Harold Frank Road	Movement	Right Turn		Through		Left Turn			Movement	Right Turn		Through		Left Turn			Movement	Right Turn		Through		Left Turn			Movement	Right Turn		Through		Left Turn		
		1			9		5		7	1			9		5		7	1			9		5		7	1			9		5		7
		2			3		2		4	2			3		2		4	2			3		2		4	2			3		2		4
		3								3								3								3								
		4								4								4								4								
					15								15								15								15				
					16								16								16								16				
		1 Score	C		D		E			1 Score	D		D		D			1 Score	C		C		C			1 Score	C		D		D		
		2	D		E		E			2	D		D		D			2	C		C		C			2	D		D		D		
		3								3								3								3								
		4								4								4								4								
			A								A								A								A							
			A								A								A								A							
Gold	North La Patera Lane/Covington Way	Movement	Right Turn		Through		Left Turn			Movement	Right Turn		Through		Left Turn			Movement	Right Turn		Through		Left Turn			Movement	Right Turn		Through		Left Turn		
		1		12		11		10		1		12		11		10		1		12		11		10		1		12		11		10	
		2		3		8		4		2		3		8		4		2		3		8		4		2		3		8		4	
		3		9		5		7		3		9		5		7		3		9		5		7		3		9		5		7	
		4		6		2		1		4		6		2		1		4		6		2		1		4		6		2		1	
		1 Score	B		B		B			1 Score	E		D		E			1 Score	C		C		C			1 Score	C		C		C		
		2	A		B		B			2	C		E		E			2	C		B		C			2	B		C		C		
		3	B		B		B			3	D		E		D			3	C		C		C			3	C		C		C		
		4	B		B		B			4	D		D		D			4	C		C		C			4	C		C		C		
	Cathedral Oaks Road/North La Patera Lane	Movement	Right Turn		Through		Left Turn			Movement	Right Turn		Through		Left Turn			Movement	Right Turn		Through		Left Turn			Movement	Right Turn		Through		Left Turn		
		1			9		5		7	1			9		5		7	1			9		5		7	1			9		5		7
		2			3		2		4	2			3		2		4	2			3		2		4	2			3		2		4
		3								3								3								3								
		4								4								4								4								
		1 Score	C		C		D			1 Score	C		B		C			1 Score	B		B		C			1 Score	C		B		C		
		2	C		C		D			2	E		B		C			2	C		B		C			2	C		B		C		
		3								3								3								3								
		4								4								4								4								
	Cathedral Oaks Road/Placer Drive	Movement	Right Turn		Through		Left Turn			Movement	Right Turn		Through		Left Turn			Movement	Right Turn		Through		Left Turn			Movement	Right Turn		Through		Left Turn		
		1			9		5		7	1			9		5		7	1			9		5		7	1			9		5		7
		2			3		2		4	2			3		2		4	2			3		2		4	2			3		2		4
		3								3								3								3								
		4								4								4								4								
				14		17						14		17						14		17						14		17			
				13		20						13		20						13		20						13		20			
				15								15								15								15					
				16								16								16								16					
		1 Score	C		C		D			1 Score	B		A		B			1 Score	B		A		B			1 Score	B		A		B		
		2	C		C		D			2	C		B		C			2	B		A		B			2	C		B		C		
		3								3								3								3								
		4								4								4								4								
			C		C						C		C						C		D						C		C			
			C		C						C		C						C		D						C		C			
			A								B								B								B							
			A								B								B								B							
	Cathedral Oaks Road/Ellwood Ridge Road	Movement	Right Turn		Through		Left Turn			Movement	Right Turn		Through		Left Turn			Movement	Right Turn		Through		Left Turn			Movement	Right Turn		Through		Left Turn		
		1			3		5		4	1			3		5		4	1			3		5		4	1			3		5		4
		2			9		2		7	2			9		2		7	2			9		2		7	2			9		2		7
		3								3								3								3								
		4								4								4								4								
				16		13						16		13						16		13						16		13			

| | | |

Appendix L

The following are the Minitab outputs for the final equations. Results for the tests that were conducted prior to these being determined are not included due to the sheer volume of that data.

Major Street Equation:

Best Subsets Regression: log los versus SD/SL(ft/s), Minor Speed , ...

Response is log los
185 cases used, 3 cases contain missing values

Vars	R-Sq	R-Sq(adj)	Mallows Cp	S	SD/SL(ft/s)	Minor Stop?	Bus Stop?	Shared Lane?	Bike Lane?	Bike Parking?	Bike Signal?	Bike Sensor?	Bike Left Turn?	Bike Lane 1 (ft)	Pair Speed (mph)	Minor Speed (mph)	Designated Right Turn?	Low Volume?	Average Queue?	Median Lane?	Center Storage?	Large Curb Return?
1	13.1	12.6	106.5	0.12255				X														
1	8.7	8.2	121.1	0.12563															X			
2	24.5	23.6	70.9	0.11458				X				X										
2	22.3	21.5	78.0	0.11619				X											X			
3	29.4	28.3	56.5	0.11106				X				X							X			
3	29.2	28.1	57.2	0.11122			X				X							X				
4	33.6	32.1	44.8	0.10804			X		X		X						X					
4	33.5	32.1	44.9	0.10807			X		X		X							X				
5	38.3	36.6	31.0	0.10438			X		X	X	X							X				
5	38.2	36.5	31.4	0.10448			X		X	X	X						X					
6	41.3	39.3	23.2	0.10212			X		X	X	X		X						X			
6	40.5	38.5	25.9	0.10284			X	X	X	X	X								X			
7	43.5	41.2	18.1	0.10053			X		X	X	X	X	X						X			
7	43.1	40.8	19.4	0.10088			X	X	X	X	X	X							X			
8	45.8	43.4	12.2	0.098666			X	X	X	X	X	X	X						X			
8	44.2	41.7	17.5	0.10011			X		X	X	X	X	X						X	X		
9	46.5	43.8	12.0	0.098334	X		X	X	X	X	X	X	X						X			
9	46.4	43.7	12.3	0.098404			X	X	X	X	X	X	X						X	X		
10	47.0	44.0	12.3	0.098141	X	X	X	X	X	X	X	X	X						X			
10	47.0	44.0	12.3	0.098144	X		X	X	X	X	X	X	X						X	X		
11	47.8	44.4	11.8	0.097729	X	X	X	X	X	X	X	X	X						X	X		
11	47.7	44.4	12.1	0.097804	X	X	X	X	X	X	X	X	X						X			
12	48.4	44.8	11.7	0.097405	X	X	X	X	X	X	X	X	X						X	X		
12	48.0	44.4	12.9	0.097753	X	X	X	X	X	X	X	X	X						X			

| | | |

```
  9
  9
 10
 10
 11
 11
 12
 12  X
 13
 13
 14
 14
 15
 15  X
 16
 16
 17
 17
 18
 18
 19
 19  X
 20  X
```

General Regression Analysis: log los versus SD/SL(ft/s), Minor Speed , ...

Regression Equation

log los = 0.246338 + 0.00288919 SD/SL(ft/s) + 0.00670291 Minor Speed Limit + 0.0216336 Bus Stop Nearby? + 0.127253 Sharrows? + 0.0416489 Signage? + 0.10298 Bike Boulevard? - 0.0438672 Parking in Bike Lane? - 0.0918312 On Street Parking Minor + 0.0165426 Bike Lane Size if present 1 (ft + 0.00160144 minor street total width + 0.000279196 major street total width - 0.0134926 Designated Right Turn Lane? - 0.0378084 Designated Left Turn lane? + 0.23736 log total - 0.174947 log main - 0.109256 log conflict + 0.0135567 Pavement Quality - 0.05259 Median?

163 cases used, 3 cases contain missing values

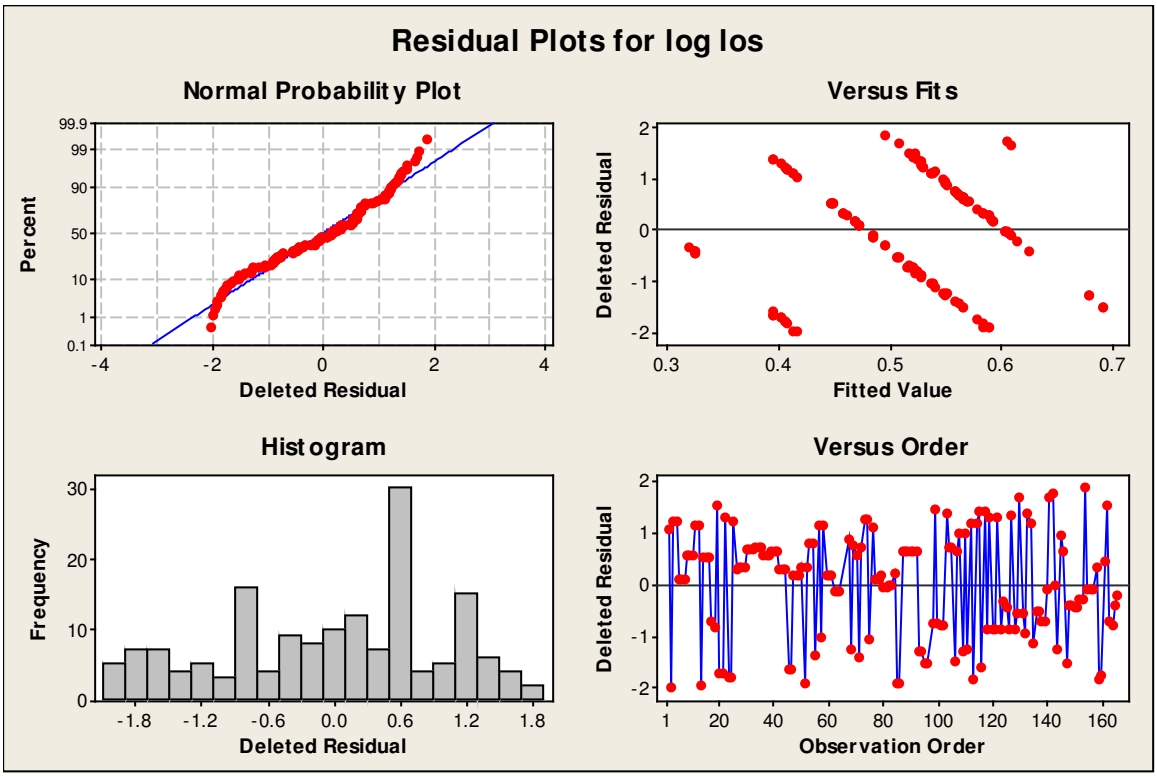
Coefficients

Term	Coef	SE Coef	T	P
Constant	0.246338	0.121873	2.02126	0.045
SD/SL(ft/s)	0.002889	0.006047	0.47781	0.634
Minor Speed Limit	0.006703	0.002082	3.22003	0.002
Bus Stop Nearby?	0.021634	0.015557	1.39063	0.166
Sharrows?	0.127253	0.019102	6.66179	0.000
Signage?	0.041649	0.013451	3.09635	0.002
Bike Boulevard?	0.102980	0.030819	3.34148	0.001
Parking in Bike Lane?	-0.043867	0.023627	-1.85666	0.065
On Street Parking Minor	-0.091831	0.025209	-3.64282	0.000
Bike Lane Size if present 1 (ft	0.016543	0.002451	6.75058	0.000
minor street total width	0.001601	0.000996	1.60791	0.110
major street total width	0.000279	0.000569	0.49040	0.625
Designated Right Turn Lane?	-0.013493	0.033785	-0.39937	0.690
Designated Left Turn lane?	-0.037808	0.015073	-2.50838	0.013
log total	0.237360	0.148192	1.60170	0.111
log main	-0.174947	0.089688	-1.95062	0.053
log conflict	-0.109256	0.063670	-1.71599	0.088

```
Pavement Quality                 0.013557  0.010728   1.26367  0.208
Median?                         -0.052590  0.017464  -3.01125  0.003

Term                                      95% CI              VIF
Constant                       ( 0.005446,  0.487230)
SD/SL(ft/s)                    (-0.009063,  0.014841)    1.752
Minor Speed Limit              ( 0.002588,  0.010817)    2.148
Bus Stop Nearby?               (-0.009115,  0.052383)    2.003
Sharrows?                      ( 0.089497,  0.165009)    2.574
Signage?                       ( 0.015062,  0.068236)    2.022
Bike Boulevard?                ( 0.042065,  0.163895)    2.215
Parking in Bike Lane?          (-0.090568,  0.002833)    1.302
On Street Parking Minor        (-0.141658, -0.042004)    1.636
Bike Lane Size if present 1 (ft ( 0.011699,  0.021386)    3.391
minor street total width       (-0.000367,  0.003570)    2.330
major street total width       (-0.000846,  0.001405)    4.244
Designated Right Turn Lane?    (-0.080271,  0.053286)    1.809
Designated Left Turn lane?     (-0.067601, -0.008016)    2.408
log total                      (-0.055553,  0.530272)  108.907
log main                       (-0.352222,  0.002328)   46.260
log conflict                   (-0.235104,  0.016591)   25.668
Pavement Quality               (-0.007648,  0.034761)    2.325
Median?                        (-0.087110, -0.018070)    2.899


Summary of Model

S = 0.0603852     R-Sq = 63.49%        R-Sq(adj) = 58.93%
PRESS = 0.654235  R-Sq(pred) = 54.51%


Analysis of Variance

Source                           DF   Seq SS    Adj SS    Adj MS        F
Regression                       18  0.91307  0.913075  0.050726  13.9115
  SD/SL(ft/s)                     1  0.00974  0.000832  0.000832   0.2283
  Minor Speed Limit               1  0.05069  0.037808  0.037808  10.3686
  Bus Stop Nearby?                1  0.04432  0.007052  0.007052   1.9339
  Sharrows?                       1  0.16081  0.161824  0.161824  44.3795
  Signage?                        1  0.11150  0.034959  0.034959   9.5874
  Bike Boulevard?                 1  0.03965  0.040714  0.040714  11.1655
  Parking in Bike Lane?           1  0.00090  0.012570  0.012570   3.4472
  On Street Parking Minor         1  0.09718  0.048388  0.048388  13.2701
  Bike Lane Size if present 1 (ft 1  0.19542  0.166166  0.166166  45.5703
  minor street total width        1  0.03054  0.009427  0.009427   2.5854
  major street total width        1  0.03545  0.000877  0.000877   0.2405
  Designated Right Turn Lane?     1  0.00003  0.000582  0.000582   0.1595
  Designated Left Turn lane?      1  0.01966  0.022943  0.022943   6.2920
  log total                       1  0.04662  0.009355  0.009355   2.5655
  log main                        1  0.00133  0.013874  0.013874   3.8049
  log conflict                    1  0.01257  0.010737  0.010737   2.9446
  Pavement Quality                1  0.02358  0.005823  0.005823   1.5969
  Median?                         1  0.03306  0.033064  0.033064   9.0676
Error                            144  0.52508  0.525077  0.003646
  Lack-of-Fit                     53  0.18349  0.183488  0.003462   0.9223
  Pure Error                      91  0.34159  0.341588  0.003754
Total                            162  1.43815

Source                                P
Regression                     0.000000
  SD/SL(ft/s)                  0.633511
  Minor Speed Limit            0.001584
  Bus Stop Nearby?             0.166483
```

```
  Sharrows?                          0.000000
  Signage?                           0.002355
  Bike Boulevard?                    0.001062
  Parking in Bike Lane?              0.065403
  On Street Parking Minor            0.000376
  Bike Lane Size if present 1 (ft    0.000000
  minor street total width           0.110045
  major street total width           0.624598
  Designated Right Turn Lane?        0.690214
  Designated Left Turn lane?         0.013237
  log total                          0.111413
  log main                           0.053044
  log conflict                       0.088315
  Pavement Quality                   0.208391
  Median?                            0.003074
Error
  Lack-of-Fit                        0.620608
  Pure Error
Total


Fits and Diagnostics for Unusual Observations


No unusual observations
```

Residual Plots for log los



Minor Street Equation:

Best Subsets Regression: log los versus SD/SL(ft/s), Minor Speed , ...

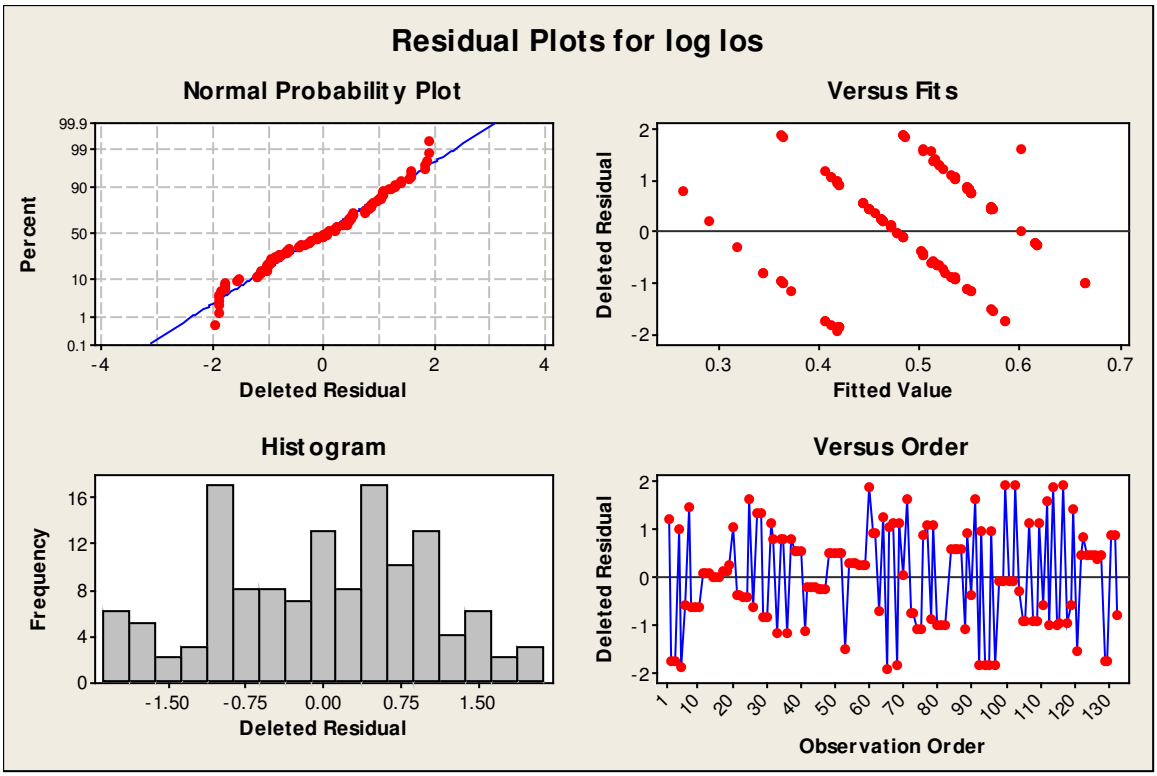
```
Response is log los
151 cases used, 1 cases contain missing values
```

Vars	R-Sq	R-Sq(adj)	Mallows Cp	S	SD/SL(ft/s)	Minor Speed	Bike Lane	Parking	Bike Speed	Sep Left	Shoulder Width	Bike Lane	Pavement Quality	Long Term Cong	Major Left Turn Lane	Major Thru Lane	On Street Parking	On Street Parking	Large Curb Radius	Hv
1	8.8	8.2	68.0	0.13483								X								
1	8.5	7.8	68.9	0.13510					X											
2	15.9	14.8	53.2	0.12990								X								X
2	15.7	14.6	53.8	0.13008					X											X
3	19.3	17.6	47.4	0.12773		X						X								X
3	18.9	17.3	48.2	0.12801		X			X											X
4	24.7	22.7	36.4	0.12374		X	X		X	X										
4	24.3	22.2	37.6	0.12413		X			X			X								X
5	29.4	26.9	27.5	0.12028		X	X		X	X				X						
5	28.8	26.4	28.8	0.12074		X	X		X	X										X
6	32.4	29.5	22.5	0.11812		X	X		X	X				X				X		
6	31.5	28.6	24.6	0.11891		X	X		X			X		X				X		
7	35.2	32.0	17.9	0.11605	X	X			X	X					X	X				X
7	34.7	31.5	19.1	0.11651		X	X	X	X	X				X				X		
8	36.8	33.2	16.1	0.11503	X	X			X	X					X	X			X	X
8	36.3	32.7	17.3	0.11546		X	X	X	X	X				X				X		X
9	38.0	34.1	15.1	0.11426		X	X	X	X	X				X				X		X
9	38.0	34.1	15.2	0.11428	X	X	X	X	X	X		X		X						X
10	40.3	36.1	11.7	0.11253	X	X	X	X	X	X	X		X	X						X
10	40.3	36.0	11.8	0.11255	X	X	X	X	X	X		X		X	X					X
11	41.5	36.8	11.0	0.11184	X	X	X	X	X	X	X		X	X	X					X
11	41.2	36.5	11.7	0.11214	X	X	X	X	X	X	X			X	X			X		X
12	42.3	37.3	11.1	0.11146	X	X	X	X	X	X	X		X	X	X			X		X
12	42.3	37.2	11.2	0.11149	X	X	X	X	X	X	X		X	X	X				X	X

| | | |

```
S = 0.0653847     R-Sq = 61.00%        R-Sq(adj) = 56.70%
PRESS = 0.626982  R-Sq(pred) = 51.53%


Analysis of Variance

Source                              DF   Seq SS    Adj SS    Adj MS        F
Regression                          13  0.78905  0.789053  0.060696  14.1975
  SD/SL(ft/s)                        1  0.00308  0.000770  0.000770   0.1802
  Minor Speed Limit                  1  0.00006  0.008601  0.008601   2.0119
  Sharrows?                          1  0.09949  0.258243  0.258243  60.4054
  Bike Boulevard?                    1  0.14251  0.089248  0.089248  20.8759
  Parking in Bike Lane?              1  0.01478  0.037227  0.037227   8.7078
  Bike Lane Size if present 1 (ft    1  0.22411  0.194061  0.194061  45.3927
  log total                          1  0.09318  0.036544  0.036544   8.5479
  log main                           1  0.02147  0.002943  0.002943   0.6883
  Median?                            1  0.02942  0.000895  0.000895   0.2093
  major street total width           1  0.00029  0.010364  0.010364   2.4243
  SLOPE TRANSITION                   1  0.00054  0.000903  0.000903   0.2112
  HV                                 1  0.13574  0.137210  0.137210  32.0946
  Large Curb Return?                 1  0.02438  0.024379  0.024379   5.7025
Error                              118  0.50447  0.504468  0.004275
  Lack-of-Fit                       38  0.17296  0.172955  0.004551   1.0983
  Pure Error                        80  0.33151  0.331513  0.004144
Total                              131  1.29352

Source                                P
Regression                         0.000000
  SD/SL(ft/s)                      0.672006
  Minor Speed Limit                0.158709
  Sharrows?                        0.000000
  Bike Boulevard?                  0.000012
  Parking in Bike Lane?            0.003823
  Bike Lane Size if present 1 (ft  0.000000
  log total                        0.004148
  log main                         0.408413
  Median?                          0.648127
  major street total width         0.122147
  SLOPE TRANSITION                 0.646641
  HV                               0.000000
  Large Curb Return?               0.018528
Error
  Lack-of-Fit                      0.355647
  Pure Error
Total


Fits and Diagnostics for Unusual Observations

Obs   log los       Fit     SE Fit    Residual   St Resid
 72  0.301030  0.343148  0.0388121  -0.0421181  -0.800432    X
 73  0.301030  0.343148  0.0388121  -0.0421181  -0.800432    X
104  0.301030  0.317540  0.0376274  -0.0165103  -0.308760    X
123  0.301030  0.263566  0.0461600   0.0374637   0.809016    X

X denotes an observation whose X value gives it large leverage.
```

Residual Plots for log los



Combined Data Equation:

Best Subsets Regression: log los versus SD/SL(ft/s), Minor Speed , ...

```
Response is log los
334 cases used, 4 cases contain missing values

                                                  B
                                                  i
                                                  k
                                                  e
                                                    D
                                                  L e D
                                                  a s e
                                                  n i s   m
                                                  e g i   i
                                                    n g   n
                                                P S a n   o
                                                a i t a   r
                                                r z e t
                                                k e d e   s
                                    M           i     d   t
                                    i P         n i R     r
                                    n a       B g f i L   e
                                    o v       i     g e   e
                                    r e       k i p h f   t
                                      m       e n r t t     l
                                S S e           e       t o
                                D p n       B B s T T   o g
                                / e t S     o i e u u   t
```

Vars	R-Sq	R-Sq(adj)	Mallows Cp	S	S e h S u k n r r a c L d Q a i l e t n n M l o (u r g e e w f L a r n v L 1 L l d w f t i l o a a a a n l i l / m i w g r n (n a d i s i t s e d e f e e n t c) t y ? ? ? ? t ? ? ? h t
1	9.9	9.6	129.8	0.13112	X
1	6.8	6.5	145.7	0.13336	X
2	17.1	16.6	95.0	0.12595	X X
2	16.8	16.3	96.5	0.12618	X X
3	20.9	20.2	77.3	0.12317	X X X
3	20.3	19.6	80.7	0.12368	X X X
4	25.2	24.3	57.5	0.11998	X X X X
4	23.2	22.2	68.0	0.12161	X X X X
5	27.7	26.6	47.0	0.11818	X X X X X
5	27.6	26.5	47.2	0.11821	X X X X X
6	30.8	29.5	33.0	0.11576	X X X X X X
6	30.5	29.2	34.5	0.11601	X X X X X X
7	32.3	30.9	27.1	0.11463	X X X X X X X
7	32.3	30.9	27.1	0.11464	X X X X X X X
8	33.9	32.3	21.0	0.11346	X X X X X X X X
8	33.8	32.2	21.8	0.11358	X X X X X X X X
9	35.1	33.3	16.9	0.11260	X X X X X X X X X
9	35.0	33.2	17.4	0.11268	X X X X X X X X X X
10	35.9	33.9	15.0	0.11209	X X X X X X X X X X
10	35.7	33.8	15.8	0.11223	X X X X X X X X X X
11	36.7	34.6	12.7	0.11153	X X X X X X X X X X
11	36.5	34.3	14.1	0.11178	X X X X X X X X X X X
12	37.2	34.9	12.2	0.11127	X X X X X X X X X X X
12	36.8	34.4	14.6	0.11170	X X X X X X X X X X X X
13	37.3	34.7	14.0	0.11141	X X X X X X X X X X X X X

General Regression Analysis: log los versus SD/SL(ft/s), Minor Speed , ...

Regression Equation

log los = 0.38792 - 0.00519421 SD/SL(ft/s) + 0.00443366 Minor Speed Limit + 0.00542615 Pavement Quality + 0.134263 Sharrows? + 0.0219049 Signage? + 0.133279 Bike Boulevard? - 0.0293113 Parking in Bike Lane? + 0.0171677 Bike Lane Size if present 1 (ft - 0.000908334 Designated Right Turn Lane? - 0.0284958 Designated Left Turn lane? - 0.0489385 Median? + 0.00155394 minor street total width - 0.0558096 log conflict

283 cases used, 4 cases contain missing values

Coefficients

Term	Coef	SE Coef	T	P
Constant	0.387920	0.0604794	6.4141	0.000
SD/SL(ft/s)	-0.005194	0.0043009	-1.2077	0.228
Minor Speed Limit	0.004434	0.0014529	3.0516	0.003
Pavement Quality	0.005426	0.0071595	0.7579	0.449
Sharrows?	0.134263	0.0132480	10.1346	0.000
Signage?	0.021905	0.0091271	2.4000	0.017
Bike Boulevard?	0.133279	0.0190255	7.0053	0.000
Parking in Bike Lane?	-0.029311	0.0171419	-1.7099	0.088

Bike Lane Size if present 1 (ft	0.017168	0.0015781	10.8786	0.000
Designated Right Turn Lane?	-0.000908	0.0215296	-0.0422	0.966
Designated Left Turn lane?	-0.028496	0.0103896	-2.7427	0.007
Median?	-0.048939	0.0112300	-4.3578	0.000
minor street total width	0.001554	0.0006505	2.3890	0.018
log conflict	-0.055810	0.0140681	-3.9671	0.000

Term	95% CI		VIF
Constant	(0.268847,	0.506993)	
SD/SL(ft/s)	(-0.013662,	0.003274)	1.54680
Minor Speed Limit	(0.001573,	0.007294)	1.72373
Pavement Quality	(-0.008670,	0.019522)	1.90245
Sharrows?	(0.108180,	0.160346)	2.13560
Signage?	(0.003935,	0.039875)	1.66025
Bike Boulevard?	(0.095822,	0.170737)	1.45249
Parking in Bike Lane?	(-0.063061,	0.004438)	1.32638
Bike Lane Size if present 1 (ft	(0.014061,	0.020275)	2.49603
Designated Right Turn Lane?	(-0.043296,	0.041480)	1.50466
Designated Left Turn lane?	(-0.048951,	-0.008041)	2.10756
Median?	(-0.071048,	-0.026829)	2.10432
minor street total width	(0.000273,	0.002835)	1.59391
log conflict	(-0.083507,	-0.028112)	2.23475

Summary of Model

S = 0.0594975 R-Sq = 59.05% R-Sq(adj) = 57.08%
PRESS = 1.04677 R-Sq(pred) = 54.99%

Analysis of Variance

Source	DF	Seq SS	Adj SS	Adj MS	F
Regression	13	1.37342	1.37342	0.105647	29.844
SD/SL(ft/s)	1	0.02513	0.00516	0.005163	1.459
Minor Speed Limit	1	0.02635	0.03296	0.032965	9.312
Pavement Quality	1	0.10355	0.00203	0.002033	0.574
Sharrows?	1	0.31694	0.36359	0.363586	102.709
Signage?	1	0.23354	0.02039	0.020390	5.760
Bike Boulevard?	1	0.11571	0.17372	0.173721	49.074
Parking in Bike Lane?	1	0.01256	0.01035	0.010350	2.924
Bike Lane Size if present 1 (ft	1	0.30166	0.41893	0.418931	118.344
Designated Right Turn Lane?	1	0.00505	0.00001	0.000006	0.002
Designated Left Turn lane?	1	0.08730	0.02663	0.026630	7.523
Median?	1	0.04934	0.06723	0.067226	18.991
minor street total width	1	0.04058	0.02020	0.020204	5.707
log conflict	1	0.05571	0.05571	0.055711	15.738
Error	269	0.95225	0.95225	0.003540	
Lack-of-Fit	93	0.32956	0.32956	0.003544	1.002
Pure Error	176	0.62268	0.62268	0.003538	
Total	282	2.32566			

Source	P
Regression	0.000000
SD/SL(ft/s)	0.228224
Minor Speed Limit	0.002504
Pavement Quality	0.449177
Sharrows?	0.000000
Signage?	0.017076
Bike Boulevard?	0.000000
Parking in Bike Lane?	0.088435
Bike Lane Size if present 1 (ft	0.000000
Designated Right Turn Lane?	0.966378

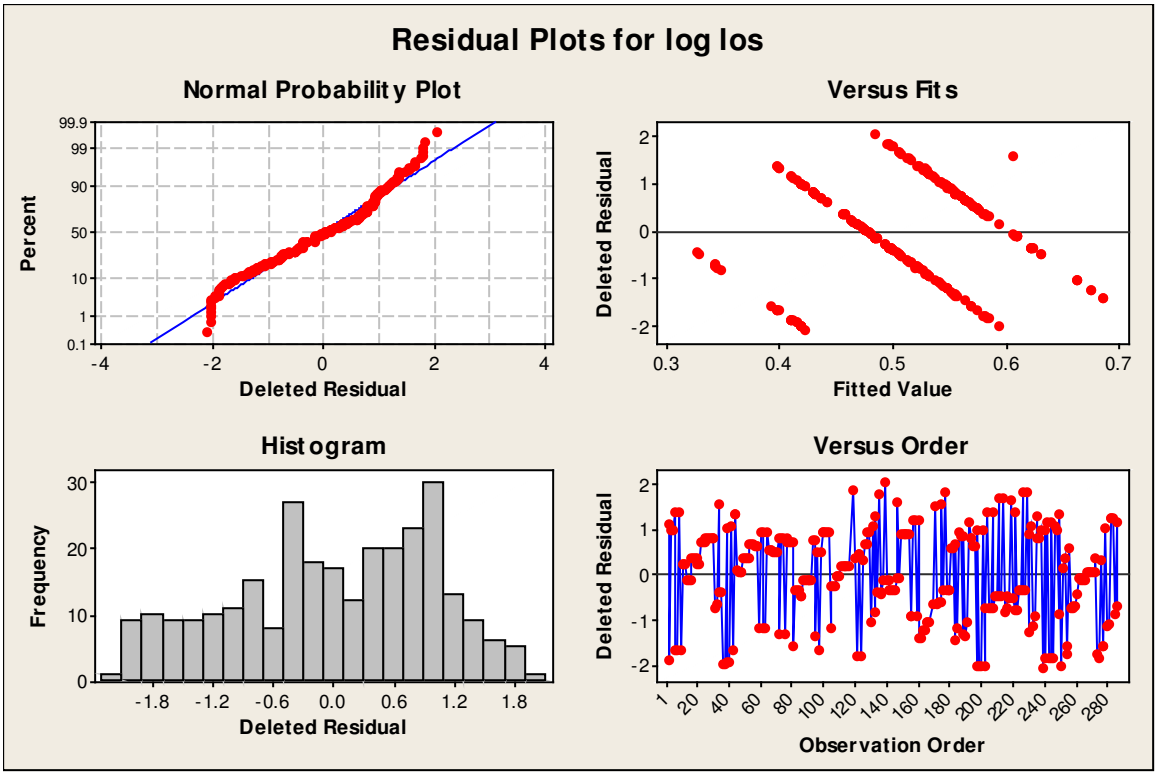
```
  Designated Left Turn lane?       0.006502
  Median?                          0.000019
  minor street total width         0.017583
  log conflict                     0.000093
Error
  Lack-of-Fit                      0.488995
  Pure Error
Total
```

Fits and Diagnostics for Unusual Observations

Obs	log los	Fit	SE Fit	Residual	St Resid	
36	0.301030	0.418256	0.0103601	-0.117226	-2.00083	R
37	0.301030	0.418256	0.0103601	-0.117226	-2.00083	R
139	0.602060	0.484634	0.0154310	0.117426	2.04355	R
197	0.301030	0.419139	0.0097034	-0.118109	-2.01204	R
199	0.301030	0.419139	0.0097034	-0.118109	-2.01204	R
200	0.301030	0.419139	0.0097034	-0.118109	-2.01204	R
202	0.301030	0.419139	0.0097034	-0.118109	-2.01204	R
239	0.301030	0.421978	0.0138906	-0.120948	-2.09060	R
251	0.477121	0.593898	0.0131798	-0.116777	-2.01272	R

R denotes an observation with a large standardized residual.

Residual Plots for log los



Appendix M

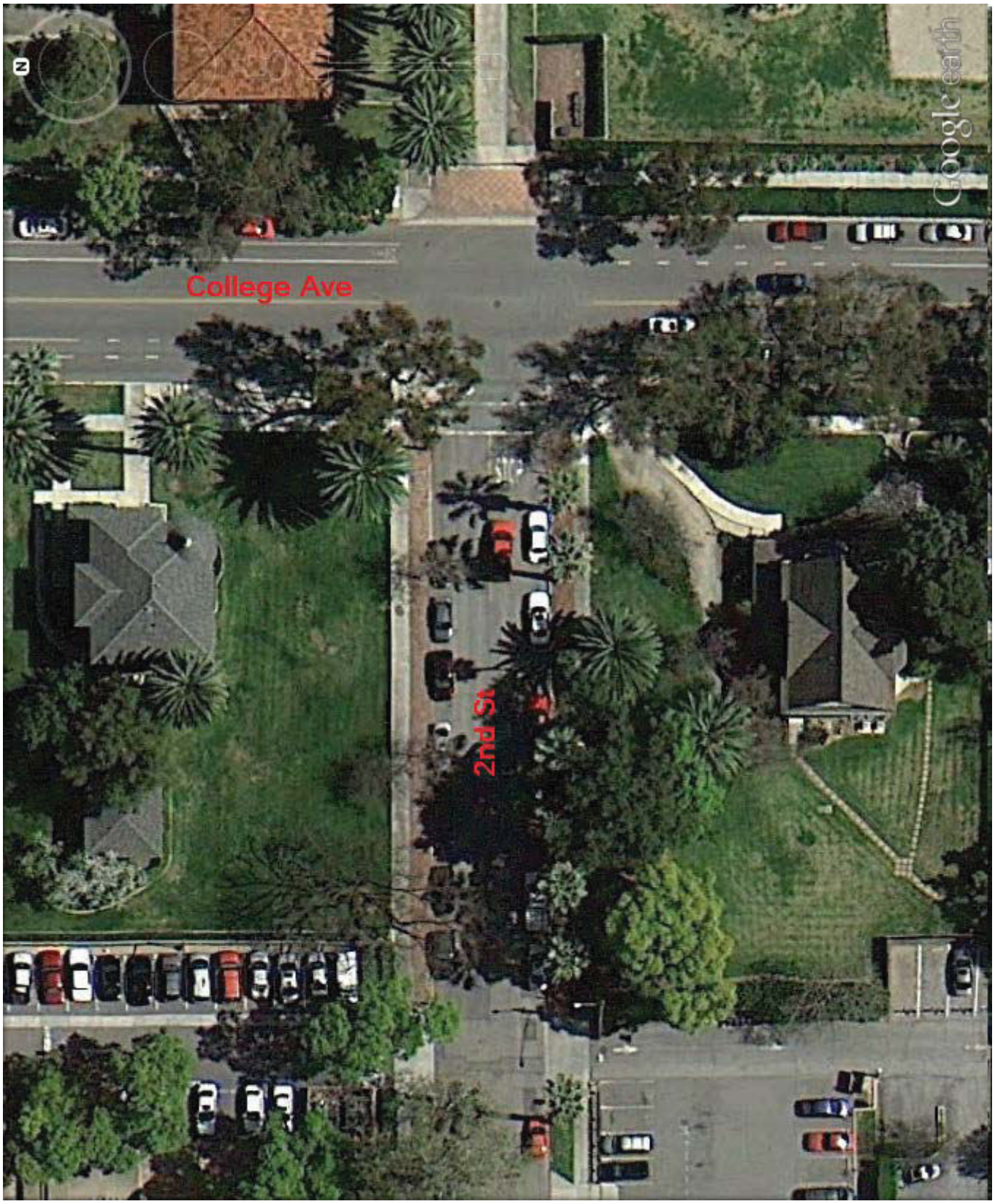
The following images are Google Earth™ screen shots of each surveyed intersection to clarify any confusion with the crude field drawings shown in the field data sheets provided in the above section. Please note that these images are only updated to the most recent Google Earth feed and some intersection images are out of date and do not show all current bicycle facilities present.

Claremont Sites

Butte St
Mountain Ave
Google Earth

Mills Ave
First St
Google earth

College Ave
4th St
Google earth


College Ave
2nd St
Google earth

Claremont Blvd
First St.
© 2013 Google
Google earth

Wharton Dr
Cambridge Ave
Google earth

Vanderbilt
Butte St
Google Earth

Cornell Dr
Bonita Ave
Google earth

Mountain Ave
Baseline Rd
N

N
Grand Ave
Baseline Rd

Goleta Sites

N
Covington Wy
N La Patera
Google earth

Harold Frank
Lagoon Rd
Google earth

Cathedral Oaks Rd
Placer Dr
Google Earth

N
Cathedral Oaks Rd
N La Patera
Google earth

Cathedral Oaks Rd
Ellwood Ridge Rd
Google earth

Irvine Sites

N
Turtle Rock Dr
Sycamore Creek
STOP
Turtle Rock Trail
© 2013 Google
Google earth

Savannah
Northwood
© 2013 Google
Google Earth

Michelson
Sequoia Tree Ln
Google earth

McGaw
Armstrong
STOP
STOP
Google earth

Deerfield Ave
Fawn Glen E
STOP
Sunflower
© 2013 Google

Riverside Sites

West Linden Ave
Douglass
STOP
© 2013 Google
Google earth

Saint Lawrence St
Victoria
STOP
Google earth

Grace St
Victoria
© 2013 Google
Google earth

Boundary Ln
Victoria Ave
Google Earth

Magnolia Ave
Hoover St
© 2013 Google
Google earth

Dundee
Colorado
Google earth

Shelby
California
©2013 Google
Google earth

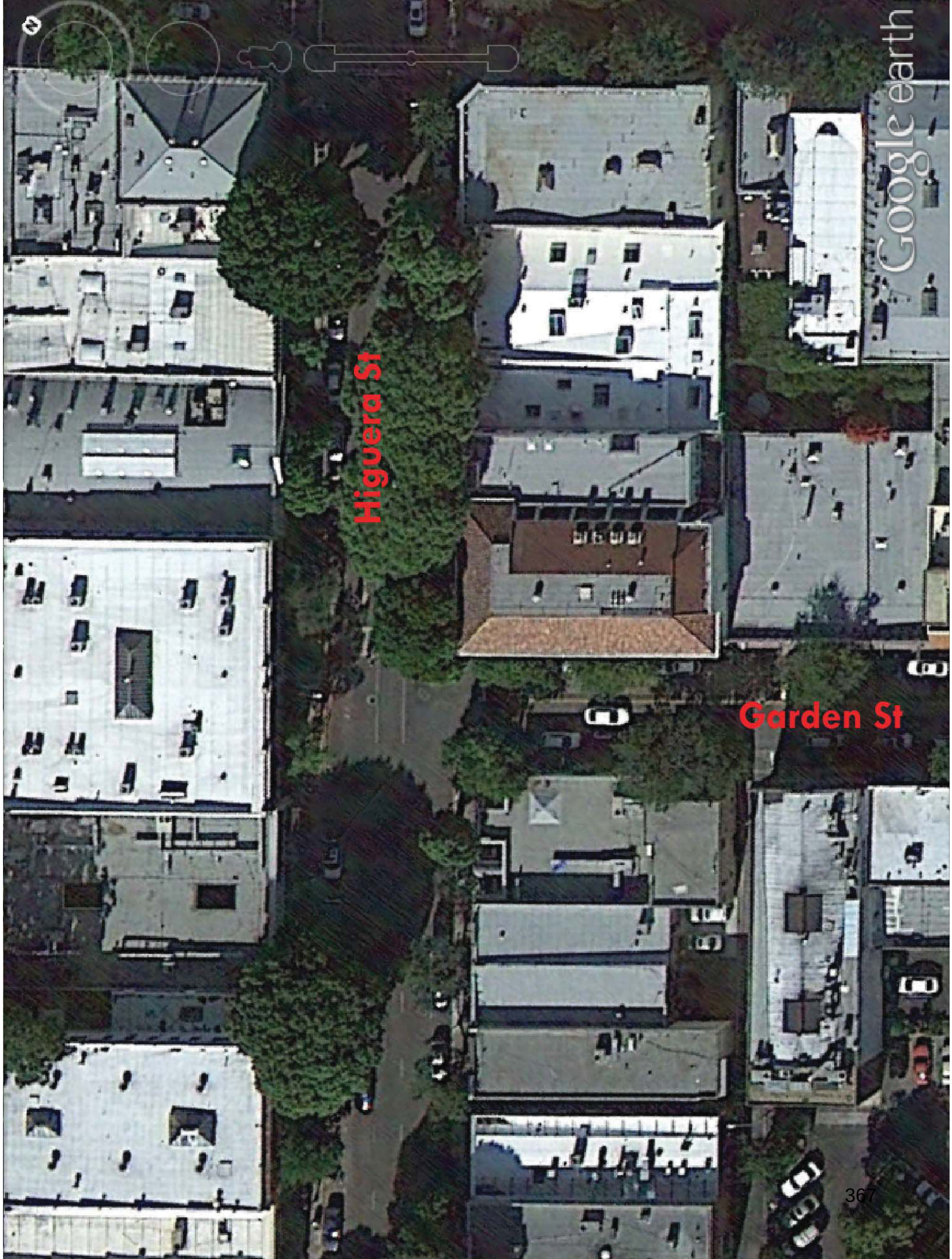
San Luis Obispo Sites

Broad
Chorro
Sandercock
Google earth

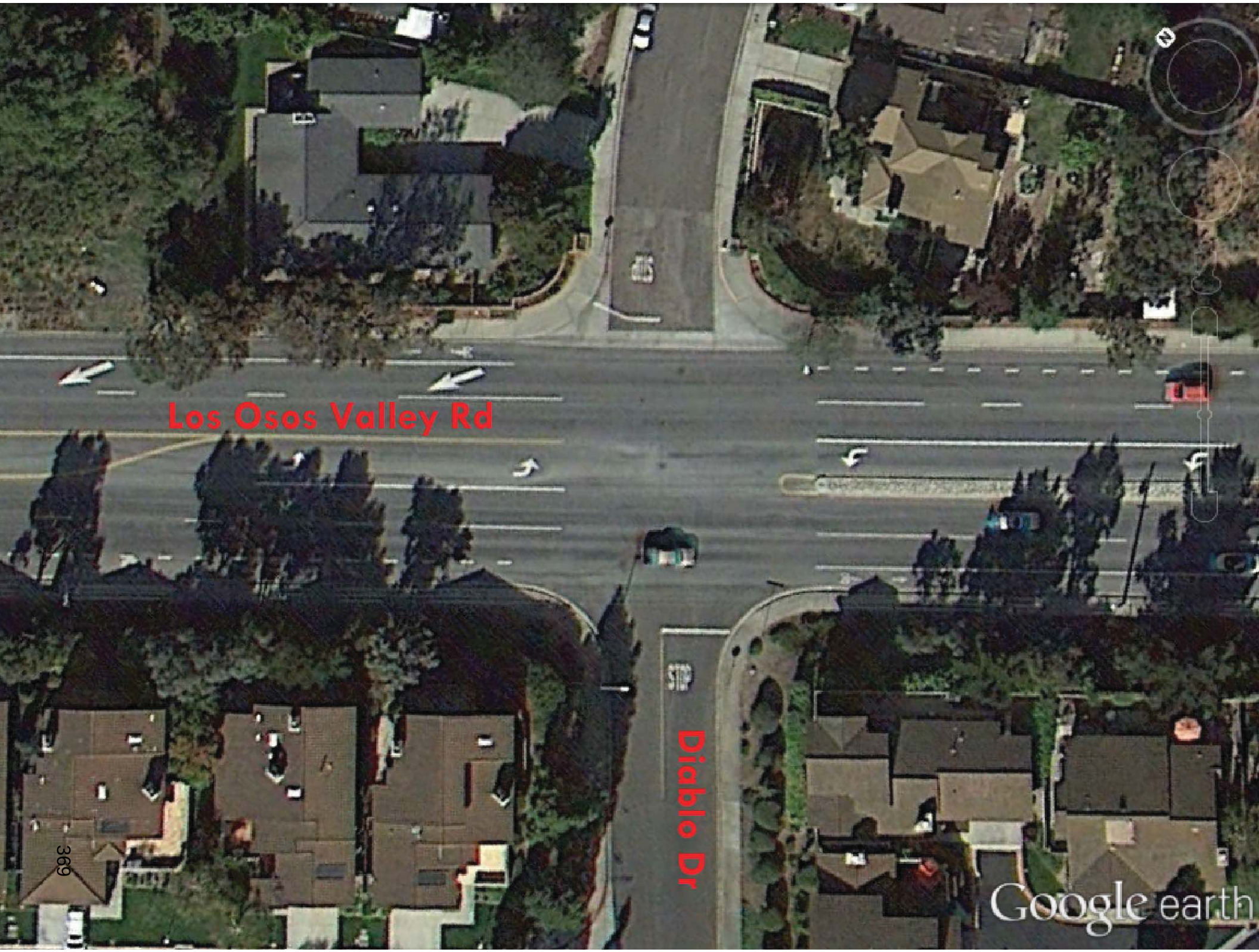
Islay
Broad
Google earth

Cerro Romauldo
Patricia Dr.
Google earth

McCollum St
Grand Ave
STOP
© 2013 Google
Google earth


Higuera St
Garden St
Google earth

Sydney
Johnson
Google earth
© 2013 Google


Los Osos Valley Rd
Diablo Dr
STOP
369
Google earth

Los Osos Valley Road
Perfumo Canyon Rd
Google earth

Marsh St
Beach St
Google earth

Monterey
Pepper St
Google earth

Monterrey
Toro St
Google earth

Islay
Morro
Google earth
© 2013 Google

Pismo
Morro
Google earth

Long St
Tank Farm
Google earth

Appendix N

The following is a poster that was drawn up requesting volunteers to provide feedback on the collected videos.

Help CAL POLY Develop A System For Improving Intersections To Accomodate Bicycle Traffic

We Need Your Opinion On Two Way Stop Controlled Intersections

Simply Watch a Video on Youtube and Submit a Simple Response Survey- Its Easy!

Video: http://goo.gl/7fyp65
Survey: http://goo.gl/KYiwnN

Video: http://goo.gl/7fyp65
Survey: http://goo.gl/KYiwnN

Video: http://goo.gl/7fyp65
Survey: http://goo.gl/KYiwnN

Video: http://goo.gl/7fyp65
Survey: http://goo.gl/KYiwnN

Video: http://goo.gl/7fyp65
Survey: http://goo.gl/KYiwnN

Video: http://goo.gl/7fyp65
Survey: http://goo.gl/KYiwnN

Video: http://goo.gl/7fyp65
Survey: http://goo.gl/KYiwnN

Video: http://goo.gl/7fyp65
Survey: http://goo.gl/KYiwnN

Video: http://goo.gl/7fyp65
Survey: http://goo.gl/KYiwnN

Video: http://goo.gl/7fyp65
Survey: http://goo.gl/KYiwnN

Video: http://goo.gl/7fyp65
Survey: http://goo.gl/KYiwnN

Video: http://goo.gl/7fyp65
Survey: http://goo.gl/KYiwnN