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MEMORANDUM

TO: Ms. Susan Clippinger
City of Cambridge

FROM: William P. Mertz, PE
Paul Bakis
Vollmer Associates, LLP

DATE: December 9, 2005

RE: Blanchard Road Safety Study

Vollmer Associates LLP was contracted by the City of Cambridge to examine safety improvement alternatives on the section of Blanchard Road located between the intersections of Concord Avenue and Grove Street. The purpose of the study is to identify and evaluate alternative measures, including engineering modifications and traffic calming applications to reduce speeds on Blanchard Road. The objectives to be achieved include the following:

- reduce vehicle speeds
- reduce accident rate
- improve safety for all users and abutting residents
- improve accommodation for pedestrians and bicycles
- enhance street appearance

Existing Conditions

Blanchard Road begins at the intersection of Grove Street and continues in a generally north direction ending at Brighton Street at the Belmont town line. The focus of this study is on the southern section of Blanchard Road located between Grove Street and Concord Avenue, which is 2,100 feet in length. Blanchard Road is an urban collector providing access for the residences in the area to and from Concord Avenue. Blanchard Road is abutted by residential property, farmland and the Fresh Pond Golf Course. Speed limit signs of 30 mph are posted in each direction at the beginning of the project study area.

Based on plans provided by the City of Cambridge, Blanchard Road lies within a 40' right-of-way (ROW). The road provides a 28-foot travelway with a 12-foot lane and a 2-foot shoulder in each direction, separated by a double yellow centerline. No striped

cc: VA File 2004-207-01

bicycle lanes are provided. A sidewalk of variable width is provided on the easterly side from Grove Street to Glenn Road. From Glenn Road to Concord Avenue a variable width sidewalk is provided along the westerly side, as well. Based on GIS data provided by the City, the existing sidewalk does not meet ADA requirements. The existing roadway pavement shows signs of deterioration and is cracked throughout the study area.

Horizontal Alignment

A compound curve is located along the southern section of Blanchard Road approximately 350 feet from Grove Street. The curve is abutted by residential property on both sides of the road. Thick brush and tall trees also exist along both edges of roadway. Based on GIS data provided by the City, the curve is estimated to be a triple compound curve with approximate radii of 560 feet, 450 feet and 210 feet going from north to south respectively. The 560 foot and 450 foot radii meet AASHTO[1] guidelines for a 35 mph design speed, while the 210 foot radius only meets a 25 mph design speed.

Signing

Regulatory signing along Blanchard Road consists of two speed limit signs of 30 mph at each end of the study location. Curve warning signs are provided to alert motorists of the impending curve in each direction. Additionally, chevrons are provided through the curve in both directions. Locations of the existing signs are shown in Figures 12 and 13.

Issues and Concerns

Several issues and concerns have been raised by the community including roadway conditions, operations and safety. These issues include:

- Speeding - travel speeds greater than the posted speed limit.
- Accident Rate – frequency of accidents
- Type & Severity of accident – fatalities, injuries, damage to residential property
- Roadside Protection – pedestrian safety, residential property protection
- Pedestrian/Bicycle accommodations

[1] American Association of State Highway and Transportation Officials. (2001). A Policy on Geomertric Design or Highways and Streets. Washington D.C.

Data Collection and Findings

Travel Speed

Speed data was collected at five (5) locations along Blanchard Road. Data recorded at each location included 48 hours of data recorded on June 8, 2004 and June 9, 2004 in both the northbound and southbound direction. From this data, a speed profile of Blanchard Road along the curve was developed. Figure 1 shows the location of the data collection points. These locations include:

1. On the tangent piece, south of the curve
2. At the point of curvature at the south end of the curve
3. At the midpoint of the curve
4. At the point of tangency on the north end of the curve
5. On the tangent piece, north of the curve

A breakdown of the speed data is shown in Figures 2 through 11 showing the frequency of each speed range. The 85th percentile speed was used as the benchmark for analysis. The 85th percentile speed is the speed at or below which 85 percent of the traffic is traveling. It was determined that at four out of the five data collection locations, the 85th percentile speed was above the posted speed limit of 30 mph. In the northbound direction, the speed data shows the 85th percentile speed to be over the 30 mph speed limit approaching the curve before slowing to 30 mph at the beginning of the curve. Once in the curve, northbound vehicles accelerate to 35 mph at the midpoint of the curve then to 40 mph as vehicles proceed towards Concord Ave. In the southbound direction, the speed data shows the 85th percentile speed to be at 40 mph approaching the curve and continuing to over the 30 mph speed limit through the curve before reducing to 30 mph at the end of the curve. Once past the curve, the 85th percentile speed then increases to 35 mph. The speed data shows that northbound vehicles slow to negotiate the initial part of the curve before accelerating once into the curve. Southbound vehicles do not slow to properly negotiate the curve until after they are past the midpoint of the curve. A summary of the 85th percentile speed at each location is summarized in Table 1.

Table 1 – Existing 85th Percentile Speeds

Location	85th Percentile Speed (mph)	
	Northbound	Southbound
1 - Tangent, South of Curve	35	35
2 - Point of Curvature, South of Curve	30	30
3 - Midpoint of Curve	35	35
3 - Point of Tangency, North of Curve	40	40
5 - Tangent, North of Curve	40	40

Traffic Volumes

Using the speed data, traffic volumes were also compiled and are summarized in Table 2 below.

Table 2 – Traffic Volumes

	Direction	
	Northbound	Southbound
Average Daily Traffic	6650	6200
AM Peak Hour Volume	500	460
PM Peak Hour Volume	440	565

Accident History

Accident data was collected from the Massachusetts Highway Department (MHD) for the years 2000 through 2002. Over the three-year period, a total of 28 accidents occurred within the project area. After reviewing the data it was observed that there are no obvious environmental factors contributing to the accidents. Sixteen (16) of the 24 accidents, or 67%, occurred under daylight conditions, fifteen (15) of the 24 accidents, or 63%, occurred under clear conditions and 20 of the 24 accidents, or 83%, occurred on dry pavement. Using accident reports provided by the City, a more in depth breakdown of accidents, shown in Table 3, along the curve was also examined. Northbound accidents account for approximately 63% of total accidents along the curve. Eight percent of accidents along the curve resulted in injury, 21% resulted in substantial property damage (greater than $1,000) and 71% resulted in minor property damage (less than $1,000). While not noted in any of the accident reports, excessive speed is assumed to be a factor in some of the accidents and reported property damage.

Mitigation Measures

Mitigation alternatives were considered to reduce travel speeds, improve safety and enhance accommodations for pedestrians and bicycles. The alternatives considered short and long-term mitigation using both physical engineering modifications and traffic calming measures. Short term, or immediate mitigation measures, include superficial type improvements that are considered to be functionally effective, cost efficient and can be readily implemented in a few months. Long term measures include modifications to the existing roadway alignment and infrastructure, or new infrastructure that are considered to be functionally effective. However, these long term improvements would require further study and design development for incorporation into the City's capital programming for construction.

Table 3 - Accident Breakdown by Direction/Type/Severity

LOCATION	No. of Accidents	Type					Severity*		
		Rear End	Angle	Head-On	Fixed Object	Unknown	Injury	Damage >$1000	Damage <$1000
Blanchard Road/Concord Ave	13	2	5	0	1	5	1	3	9
Blanchard Road/Grove Street	1					1			1
South of Curve									
Northbound Direction	1		1				1		
Southbound Direction									
North of Curve									
Northbound Direction	2	1	1					1	1
Southbound Direction	2	1	1						2
Blanchard Road (Unknown Location/Direction)	2	2						1	1
Northbound Direction	2	1	1						2
Southbound Direction	1	1							1

* No fatalities were reported in the information reviewed by Vollmer. Damage not reported was assumed to have less than $1,000 worth of damage.

Direction Distribution

Northbound Travel:	63%
Southbound Travel:	37%

Severity Distribution

Injury:	8%
Damage >$1000:	21%
Damage <$1000:	71%

Short Term Improvements

Engineering Modifications

Signing

Signing modifications include the relocation of existing signs and installation of new signs to improve sight lines and visibility and reinforce advance warning. Signing improvements include:

- In the southbound direction, relocating the existing speed limit sign away from the Concord Avenue intersection would increase the line of sight to the sign for motorists turning onto Blanchard Road.
- Curve warning and supplemental speed signs (W1-1, W13-1) could be relocated a sufficient distance from the curve that will provide adequate deceleration length (30 mph to the advisory speed of 20 mph) at the approach to the curve. Based on driver perception and reaction time, a distance of 150 feet from the beginning of the curve would allow sufficient distance for a motorist to decelerate to the advisory speed of 20 mph. In the southbound direction, the existing curve warning sign is located approximately 350 feet from the beginning of the curve. Although this provides sufficient distance to decelerate to the advisory speed of 20 mph, it could be located in closer proximity to the curve. In the northbound direction, the existing curve warning sign is located approximately 75 feet from the beginning of the curve. This location does not provide sufficient distance to decelerate to the advisory speed of 20 mph. This sign is also located behind a utility pole and is not visible until the motorist is upon the sign. Relocating this sign to approximately 150 feet in advance of the curve will improve visibility and provide sufficient distance for deceleration. Signing modifications are shown on Figure 12.
- The installation of additional and larger chevrons would reinforce warning to the motorist of the impending curve. The existing chevrons are placed properly in accordance with MUTCD recommended spacing such that two chevrons be in the motorist's view throughout the curve. However, a study[2] showed that increasing the number of chevrons in view to three causes a slower travel speed through curves than if there were two chevrons. The study also developed recommended spacing of chevrons based on the radius of the curve. Using the existing curve radius data provided by the City and the spacing recommendations in the study, additional chevrons are recommended to be spaced approximately 40 feet apart along the 210 foot radius. The current number and location of the chevrons on

[2] Rose E. and Carlson P. 2004. Spacing Chevrons on Horizontal Curves. TRB 2005 Annual Meeting.

the larger curve are consistent with the study recommendations and require no change. The additional chevron locations are shown in Figure 13.

Clear Vegetation

The removal of excessive vegetation growth and overhang to improve sight distance along the roadway, particularly approaching and through the curved section is also recommended. Clearing/trimming along the roadway edge would also improve sight lines for signing and roadway lighting.

Traffic Calming Measures

Pavement Markings

Re-striping travel lanes would reinforce travel lane widths and highlight the curvature of the roadway. Two options were examined, re-striping the roadway using the current travel way width and shoulders and re-stripe the roadway with narrower lanes.

- Re-striping the travel lanes to the existing 12-foot lanes and two-foot shoulder widths would define the travel lanes and accent the curve. The current pavement markings, particularly the edge lines are faded in many places. The faded pavement markings can give the driver a false sense of lane and roadway width, inviting higher travel speeds.
- Re-striping travel lanes using two ten-foot travel lanes and two four-foot shoulders requires more caution by the driver to remain within the narrower travel lanes and could result in a lower speed. Expanding to four foot shoulders would also provide sufficient width for bike lanes.

Additional pavement markings such as “SLOW CURVE” placed on the pavement before the curve may also help call attention to the curvature of the roadway.

Raised / Reflective Pavement Markers

Raised / reflective pavement markers which are embedded in the pavement can be used to supplement the existing pavement markings to help define or delineate the curvature of the roadway. The reflective markers will enhance the visibility of the curve at night or in times when visibility is reduced due to weather conditions.

Raised Rumble Strips (Thermoplastic)

Rumble strips are measures that produce audible and vibratory effects to alert motorists to take greater care. Two case studies of installations in England were examined to determine the effectiveness of using ½-¾” high thermoplastic rumble

strips. The first case study[3] was conducted in a rural area, on a stretch of two-way roadway with a 30-mph speed limit. Before the installation, vehicles would travel between 45 and 50 mph. Upon installation the speeds were reduced to 32-37 mph. One month after installation however, speeds continued to rise to a level of 38-42 mph. It was noticed that after installation some motorists increased their speeds to minimize the effects of the rumble strips.

The second case study[4] was conducted in a residential area. The road contained street trees and sidewalks on both sides of the roadway. Table 4 shows the results of five (5) streets monitored before and after the installation of the thermoplastic strips. In each case, the rumble strips initially reduced speeds between two and six mph. However, it was noted in the case study that after a period of time, travel speeds returned to their original levels. The primary issues associated with rumble strips include noise, maintenance (damage due to snow plowing), and their impediment to other modes of travel, particularly bicycling and in-line skating.

Table 4 – Before & After 85th Percentile Speeds

Location	85th Percentile Speed (mph)	
	Before	After
Christchurch Road	36.4	31.4
Glenmore Road	39.6	35.2
New Road	45.2	38.9
Palmeria Road	37.6	35.0
Wendover Road	34.3	28.7

Long Term Improvements

Long term alternatives could have an impact on the existing 40-foot right-of-way. When examining long term improvements, impact to right-of-way was taken into account. Using the existing right of way, edge of road, and dwelling location information provided by the City, the approximate location of the right of way was located on a plan shown in Figure 14. After locating the approximate right of way on the plan, it was noted that some existing dwellings on the easterly side of Blanchard

[3] Wakefield Metropolitan District Council. 1994. *Traffic Calming in Practice.* Case Study 33, West Yorkshire: West Bretton

[4] Bexley London Borough. 1994. *Traffic Calming in Practice*. Case Study 60, Bexley, Christchurch Road Area

Road are located as close as 10 feet from the existing right of way and 20 feet from the existing edge of pavement.

Engineering Modifications

Geometric Improvements

Horizontal alignment alternatives to simplify the curve (reduce the number of compound curves), increase the radius of the non-conforming curve and to improve the transition ratio between compound curves were investigated and are discussed below.

Three replacement curves were examined as potential alternatives. These curves include a simple, compound, and spiral curve. The curves are selected to meet AASHTO design standards for 30-mph minimum design speed using a normal crown for low speed urban streets, avoid or minimize right of way impacts, and minimize encroachment on residential dwellings. The existing 28-foot travel way configuration, including two 12-foot travel lanes and two two-foot shoulders, was used in analyzing impacts to right-of-way and does not include sidewalks. Several constraints were identified when examining the three replacement curves and are shown on each figure referenced below. The constraints include maintaining the existing edge of road along the easterly side of the curve, maintaining the westerly edge of pavement along the right-of-way north of the curve, and maintaining edge the of pavement within the right-of way across driveways west of the curve. When the constraints could not be met, impacts to the constraints were minimized to the extent possible.

- A simple curve, consisting of a constant radius, was designed at both 30 and 35-mph design speeds. The 30-mph simple curve alignment would result in minor impacts to abutting properties on the westerly side of the curve. It would also require shifting the roadway approximately three feet to the east whereby bringing the edge of pavement as close as ten feet to existing dwellings on the easterly side of Blanchard Road, but still within the existing right-of-way. The 35-mph simple curve would require a substantially larger radius and have a significant impact to the abutting properties on the westerly side of the curve. The 35-mph simple curve would not require shifting of the roadway to the east. The alignments and associated impacts are illustrated on Figures 15 and 16.
- A compound curve contains multiple constant radii within a curve. The compound curve alignment was designed for 25 and 30 mph. The 25 mph curve would use radii of 250 feet, 375 feet and 550 feet. These radii would meet AASHTO guidelines for 25-mph design speed using a normal crown. If the roadway was to be superelevated at 2 percent across the entire roadway cross section, these same radii would meet a 30 mph design speed. When using compound curves, it is also recommended by AASHTO that the ratio between curves be 1.5:1 with a maximum of 2:1. Under the existing compound curve, the 450-foot and 210 foot

radii produce a ratio of 2.1:1. The proposed radii produce a ratio of 1.5:1. The 30 mph curve would use radii of 350 feet and 450 feet. This produces a ratio of 1.3:1. The 30-mph compound curve alignment would result in significant impact to abutting properties on the westerly side of the curve. The compound curve would require minor shifting of less than one foot to the east. The alignments and associated impacts are illustrated in Figure 17 and 18.

- A spiral curve provides changing radii throughout a curve. The radii decrease to a minimum radius in the middle of the curve, then increase to the end of the curve. The spiral curve alignment was designed for a 30-mph design speed. The proposed alignment would result in significant impacts to the abutting properties on the westerly side of the curve. It would also require shifting the roadway approximately two feet to the east, bringing the edge of pavement to as close as 18 feet to existing dwellings on the easterly side of Blanchard Road but still within the existing right-of-way. The alignments and associated impacts are illustrated in Figure 19.

Roadside Barrier

The installation of a roadside barrier on the outside of the curve would protect pedestrians on the sidewalk as well as abutting property. The barrier would be approximately 675 feet in length and would need to be interrupted at driveways. The roadside barrier would be placed approximately two feet from the edge of pavement, resulting in the existing sidewalk being relocated/expanded to incorporate the space needed for pedestrian access. The barrier would also impact the sidewalks at driveway locations. Curved guardrail sections would need to be installed along the driveway entrance to avoid blunt end collisions. This would require re-routing the sidewalk onto what is currently private property. Recognizing that the aesthetic impacts are always a major issue with barriers, options other than MassHighway's Steel Beam GR, including wood are available, should the City and the community consider this to be a desirable alternative. Figure 20 shows the approximate barrier location along the curve.

<u>Traffic Calming Measures</u>

Vertical curbing/sidewalks

Roadway reconstruction to include vertical curbing and sidewalks would enhance the roadway environment but also better define the edge of road for vehicles. Defining edge of roadway through vertical curb and sidewalks will change the character of the roadway and give the appearance of an urban roadway. It will also give the appearance of a narrower travelway causing motorists to slow down. Sidewalks on both sides of the roadway would also improve accommodations for pedestrians. A

schematic cross-section of crosswalks on one and both sides of the road is shown in Figures 21 and 22.

Bicycle Lanes

Bicycle lanes would not only enhance the roadway environment for other users, but would also better define vehicle travel lanes. This alternative is recommended to be used in conjunction with narrow lanes and vertical curbing to optimize the effect on vehicle travel.

Crossing Islands

Crossing islands employ narrow travel lanes and raised center "islands" in the roadway to create a deflection in the travelway, causing motorists to slow down to navigate that section of roadway. Located at intersections, crossing islands can also provide a temporary pedestrian refuge for pedestrians crossing the street. Crossing islands are typically raised and constructed using vertical curb or mountable curb (for truck traffic on narrow roads).

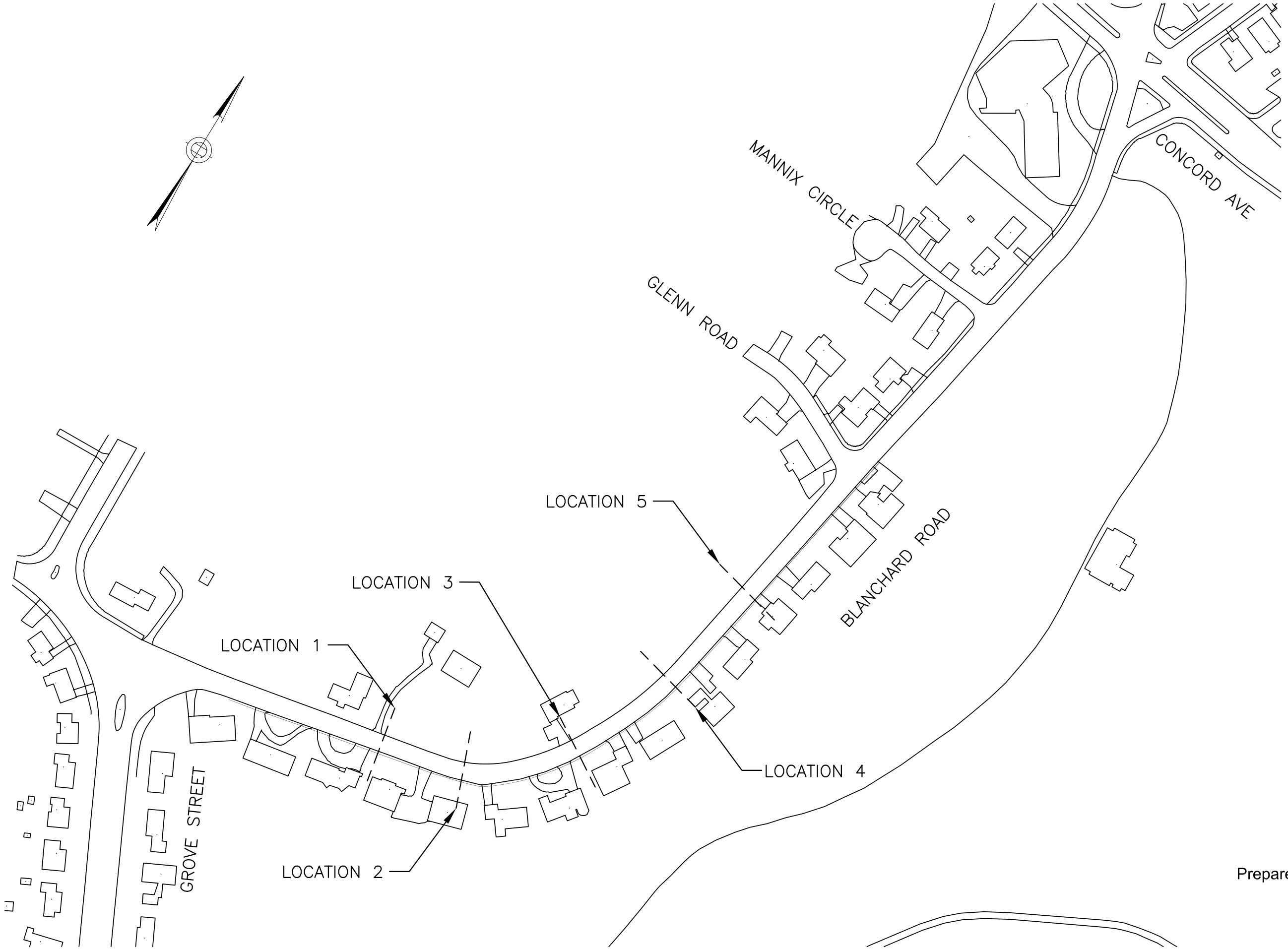
Construction of the crossing islands with bicycle lanes and sidewalks is feasible within the existing 40' right-of-way. A schematic cross section of a crossing island is shown in Figure 23. A plan view of a crossing island at the Glenn Road intersection is shown in Figure 24.

Roundabouts

Roundabouts utilize a raised circular center island to encourage motorists to reduce speeds in order to navigate the circle. Roundabouts are typically raised and constructed using vertical curb/mountable curb as well as a truck apron along narrow roads. Due to the size of the roundabout, additional right-of-way would likely be required. A schematic of a roundabout at the Glenn Road/Blanchard Road intersection is shown in Figure 25.

Figure 1

Speed Data Locations



Prepared by: VOLLMER ASSOCIATES LLP

Date: March 16, 2005

Figure 2
Location 1 - Tangent, South of Curve
Speed Data - Northbound 6/8/04 & 6/9/04 (miles per hour)

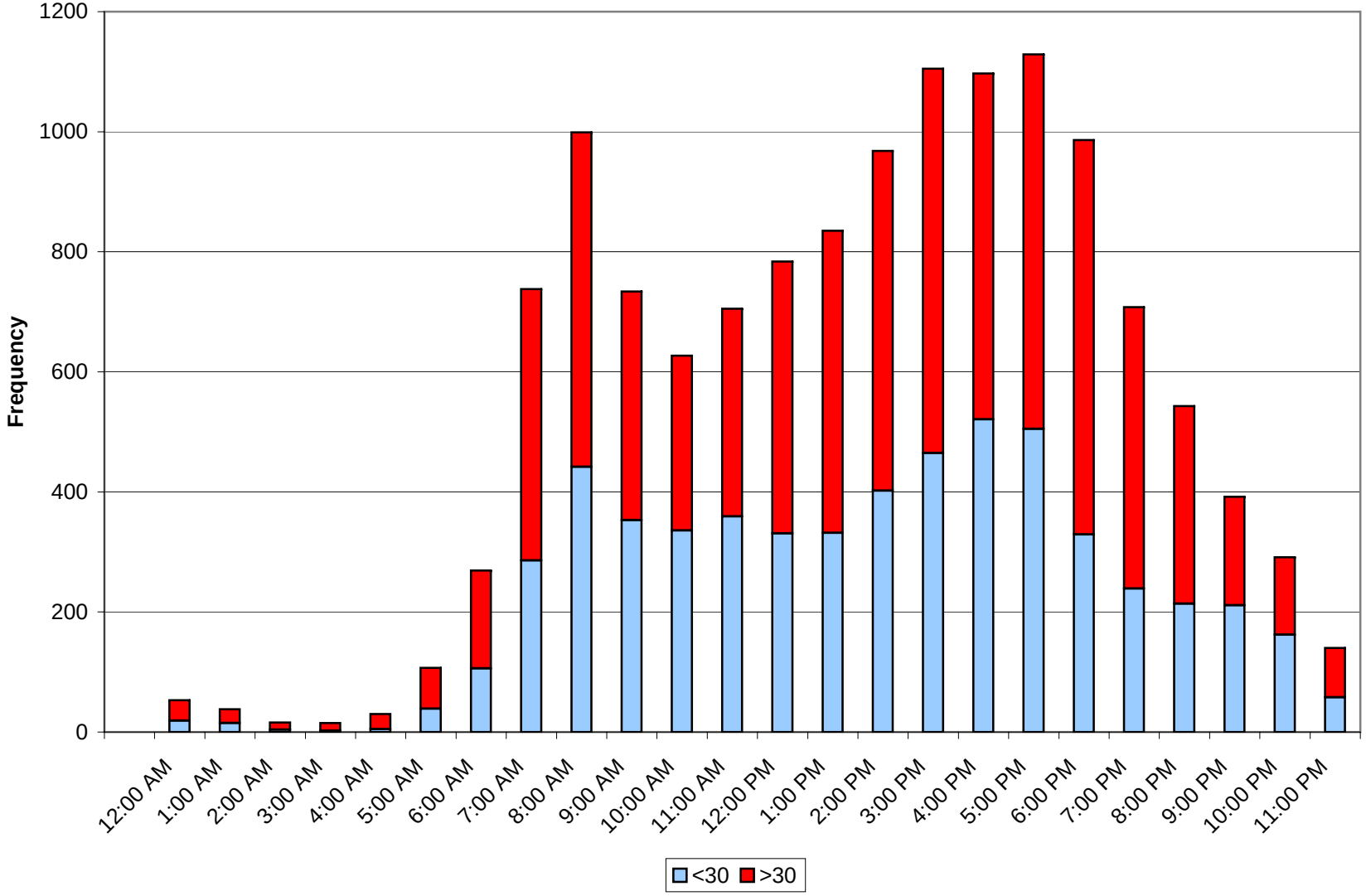


Figure 3
Location 1 - Tangent, South of Curve
Speed Data - Southbound 6/8/04 & 6/9/04 (miles per hour)

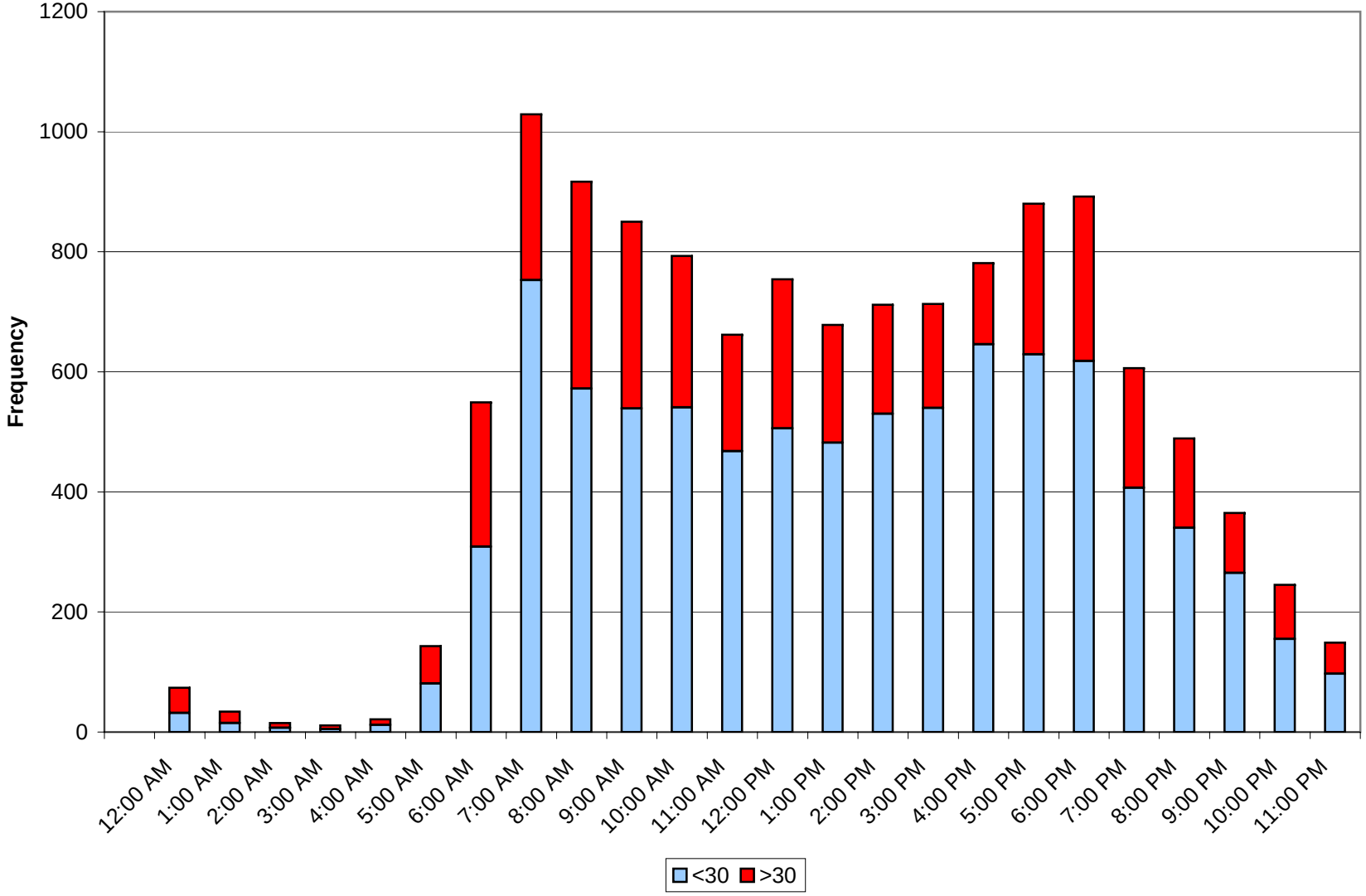


Figure 4
Location 2 - Point of Curvature, South of Curve
Speed Data - Northbound 6/8/04 & 6/9/04 (miles per hour)

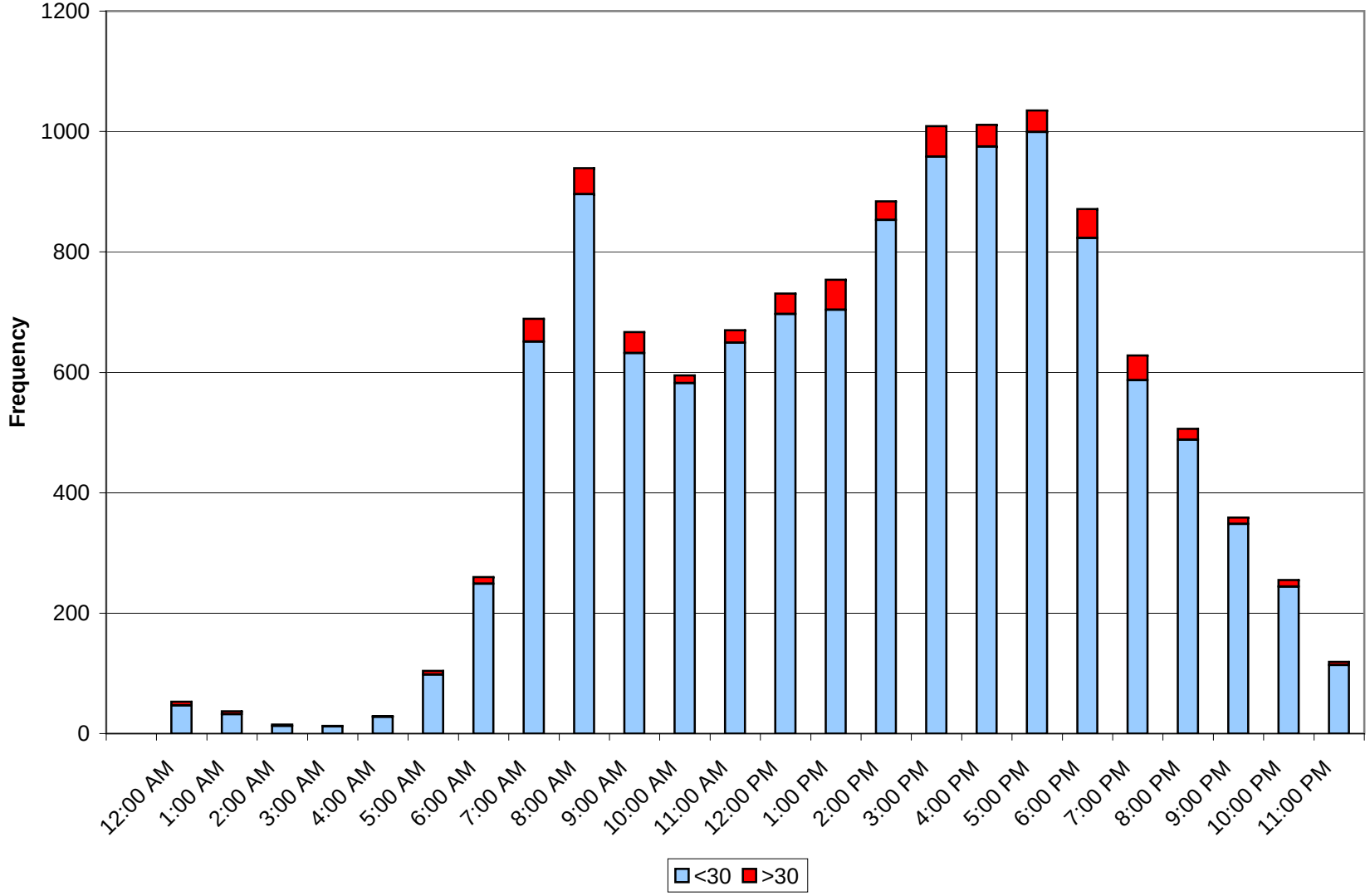


Figure 5
Location 2 - Point of Curvature, South of Curve
Speed Data - Southbound 6/8/04 & 6/9/04 (miles per hour)

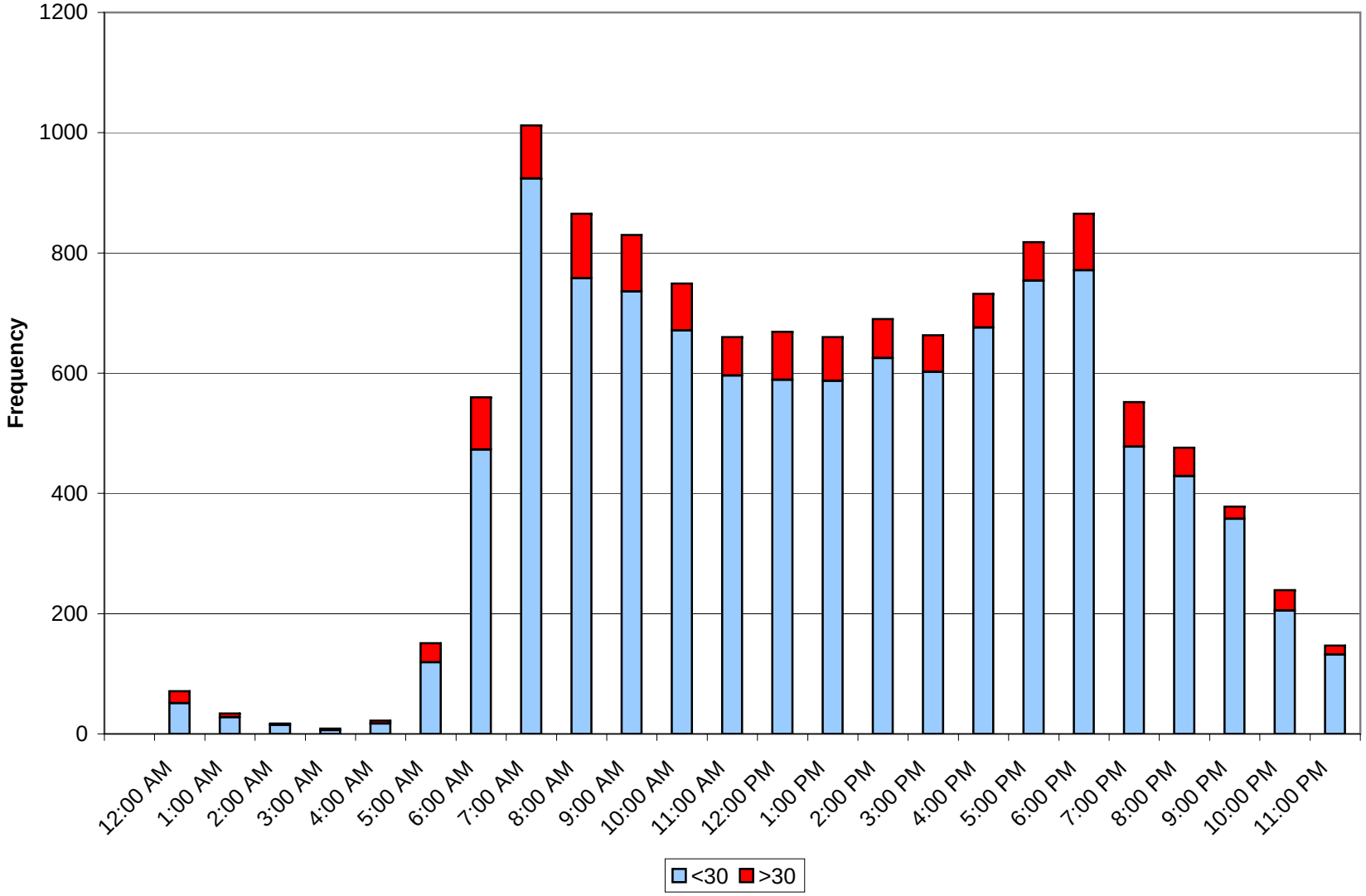


Figure 6
Location 3 - Midpoint of Curve
Speed Data - Northbound 6/8/04 & 6/9/04 (miles per hour)

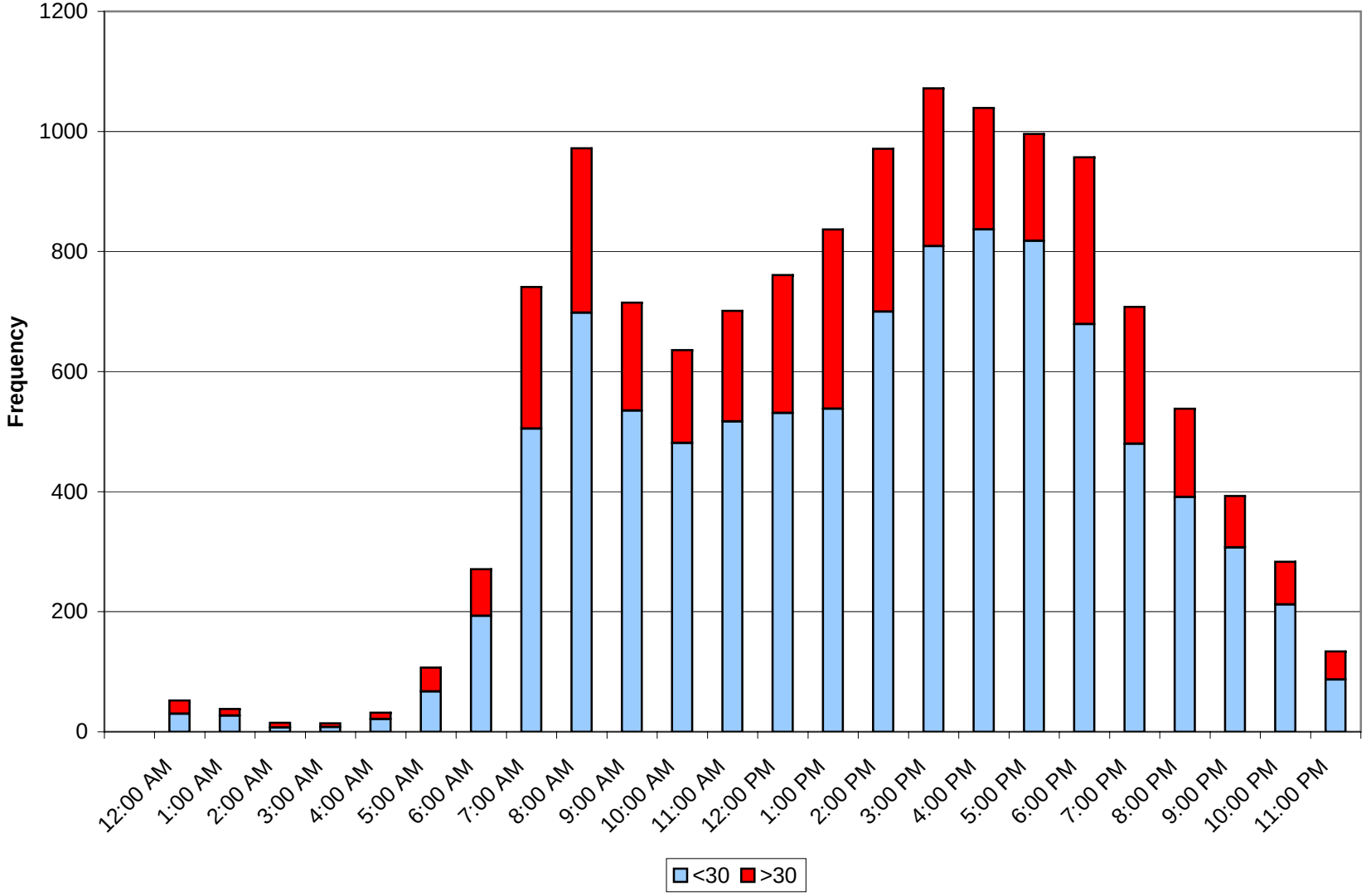


Figure 7
Location 3 - Midpoint of Curve
Speed Data - Southbound 6/8/04 & 6/9/04 (mph)

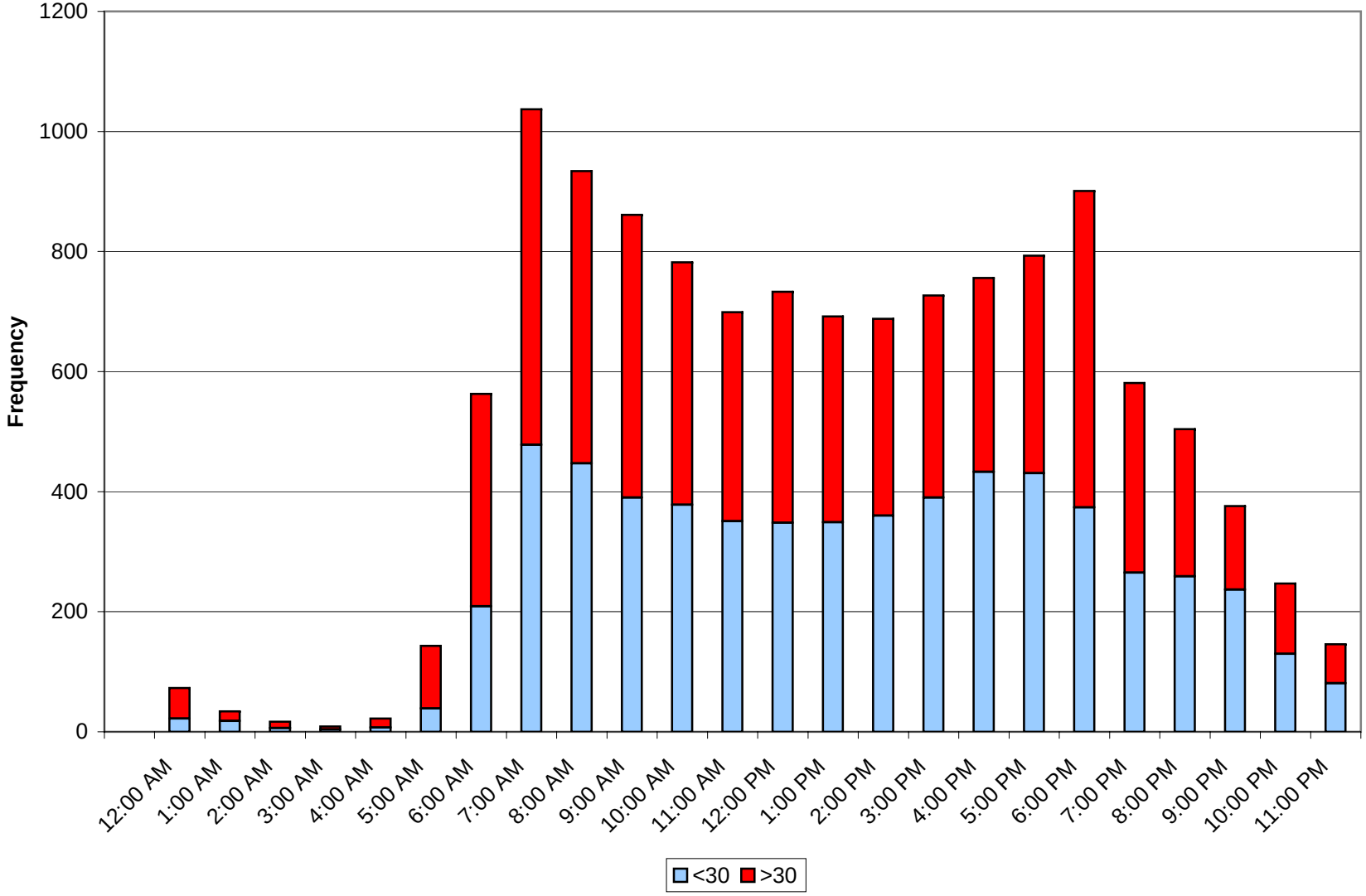


Figure 8
Location 4 - Point of Tangency, North of Curve
Speed Data - Northbound 6/8/04 & 6/9/04 (miles per hour)

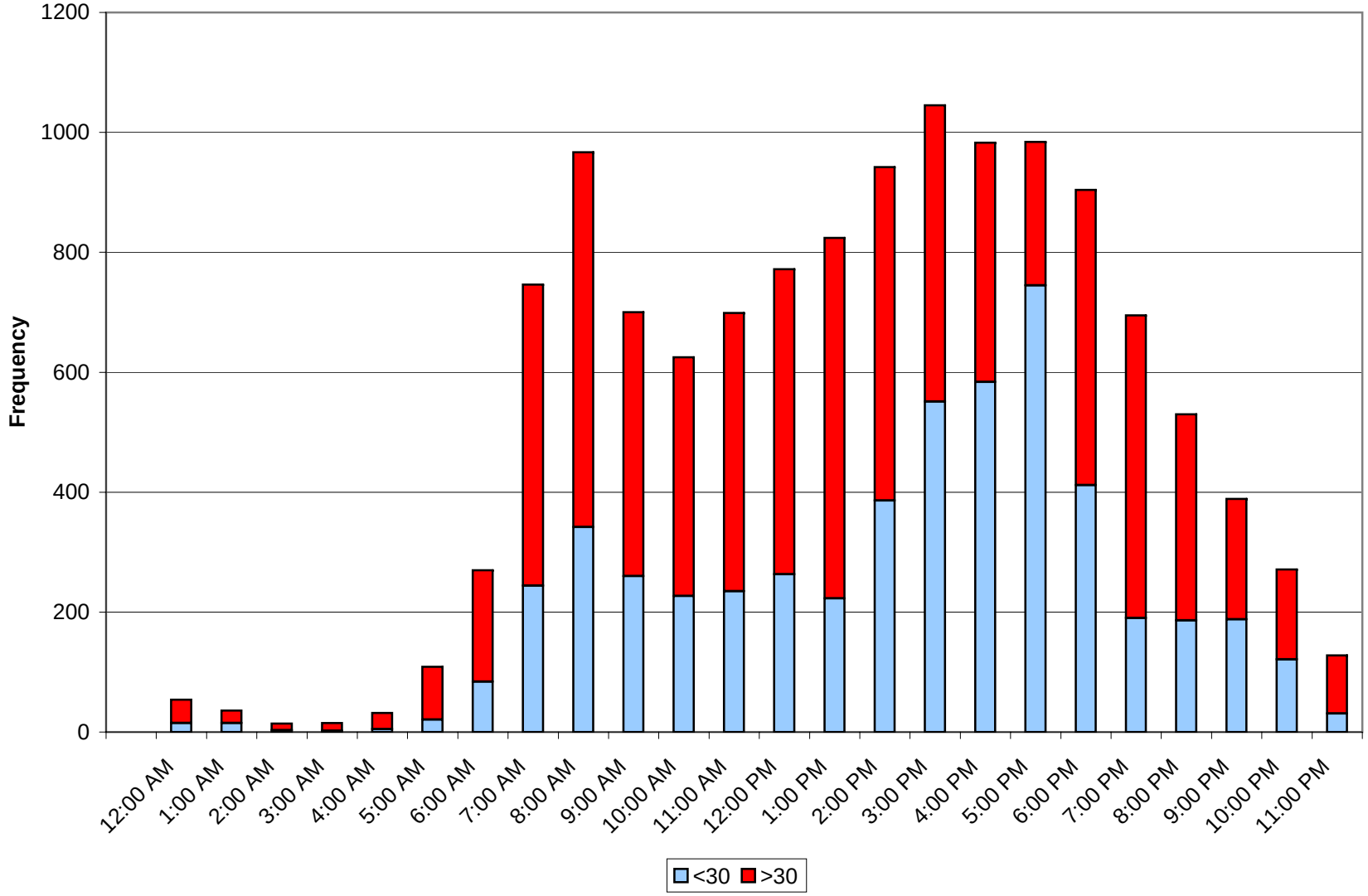


Figure 9
Location 4 - Point of Tangency, North of Curve
Speed Data - Southbound 6/8/04 & 6/9/04 (miles per hour)

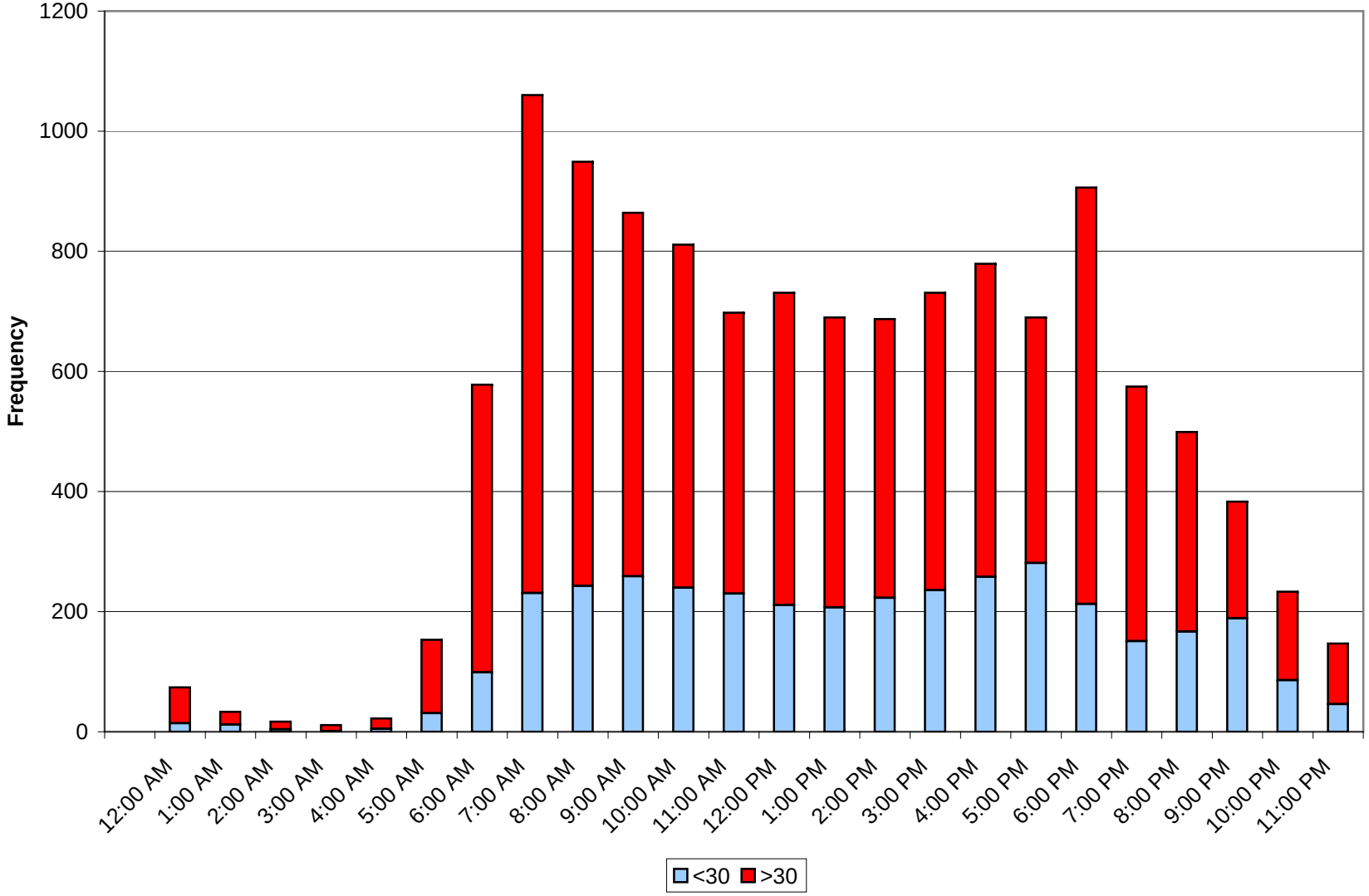


Figure - 10
Location 5 - Tangent, North of Curve
Speed Data - Northbound 6/8/04 & 6/9/04 (miles per hour)

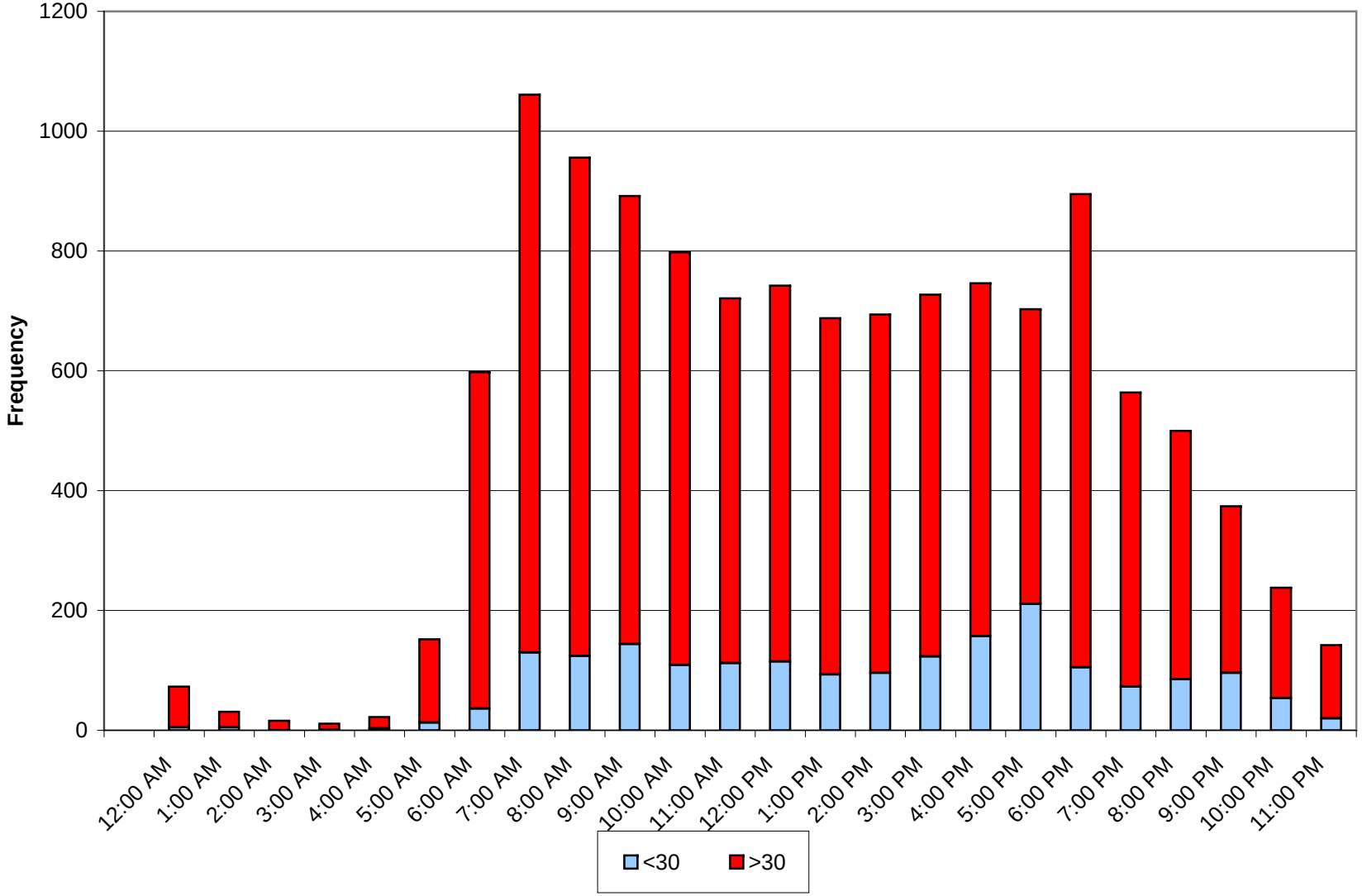


Figure 11
Location 5 - Tangent, North of Curve
Speed Data - Southbound 6/8/04 & 6/9/04 (miles per hour)

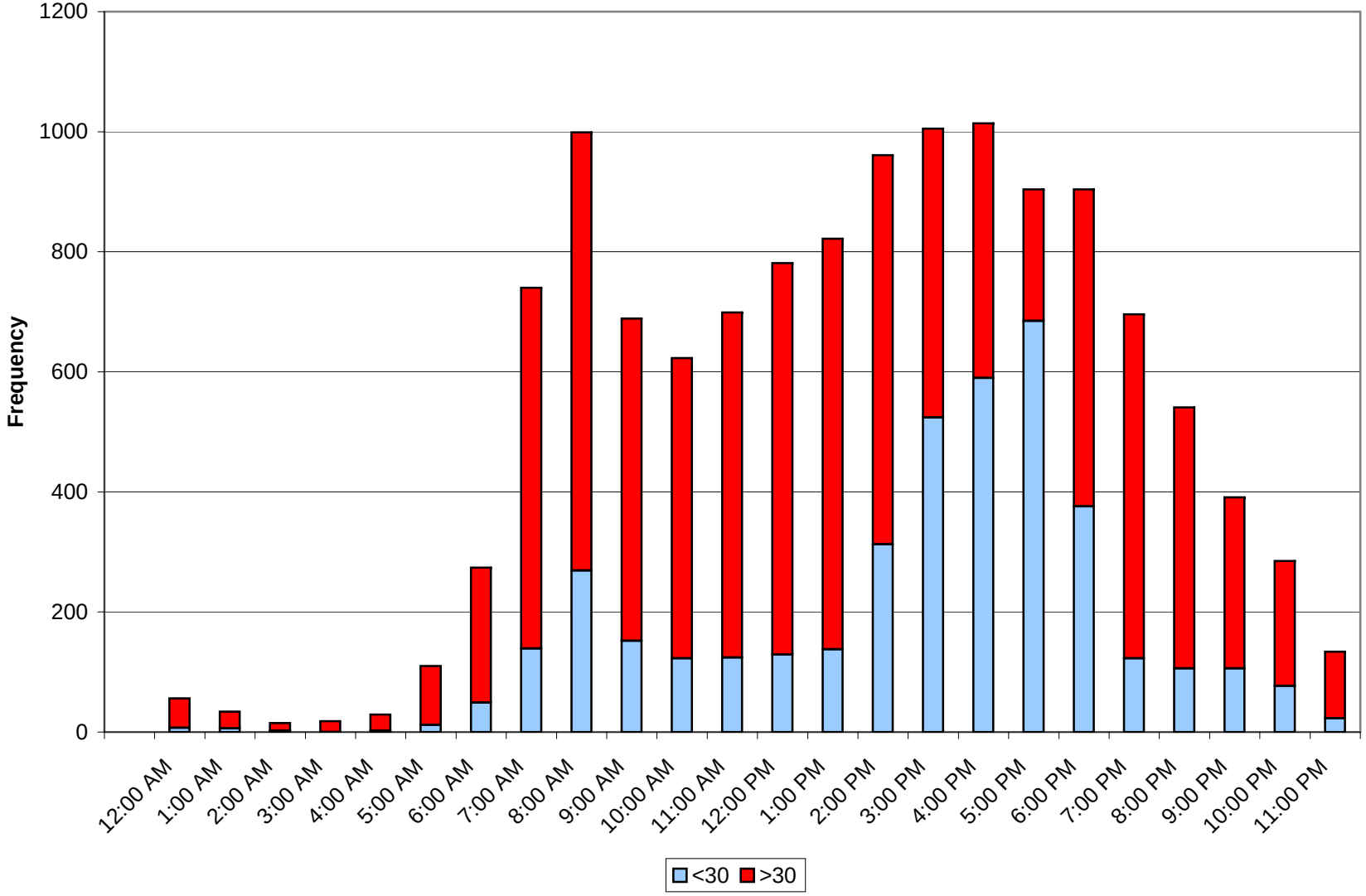


Figure 12

Proposed Signing Location

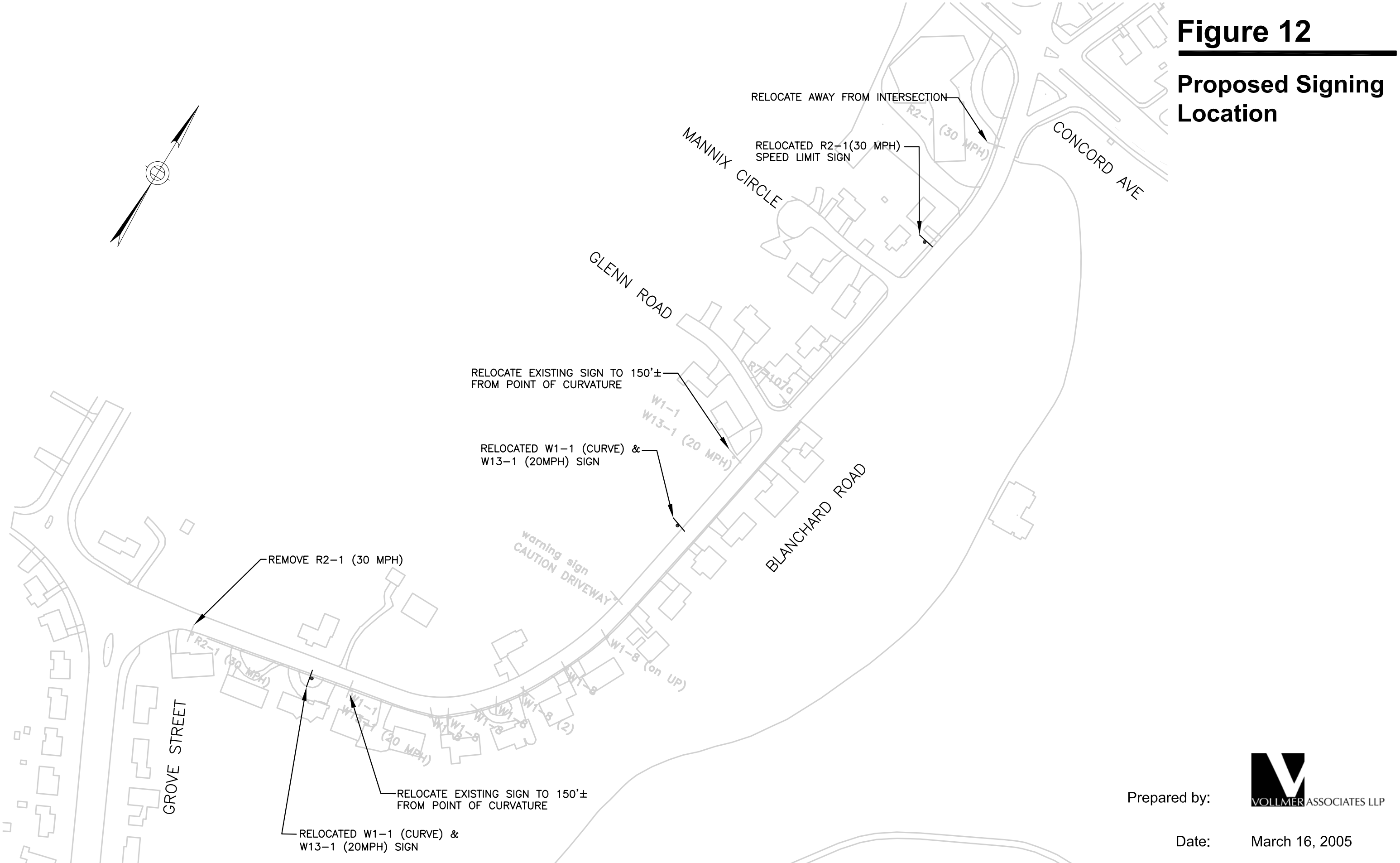


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Figure 13

Proposed Chevron Signing Location

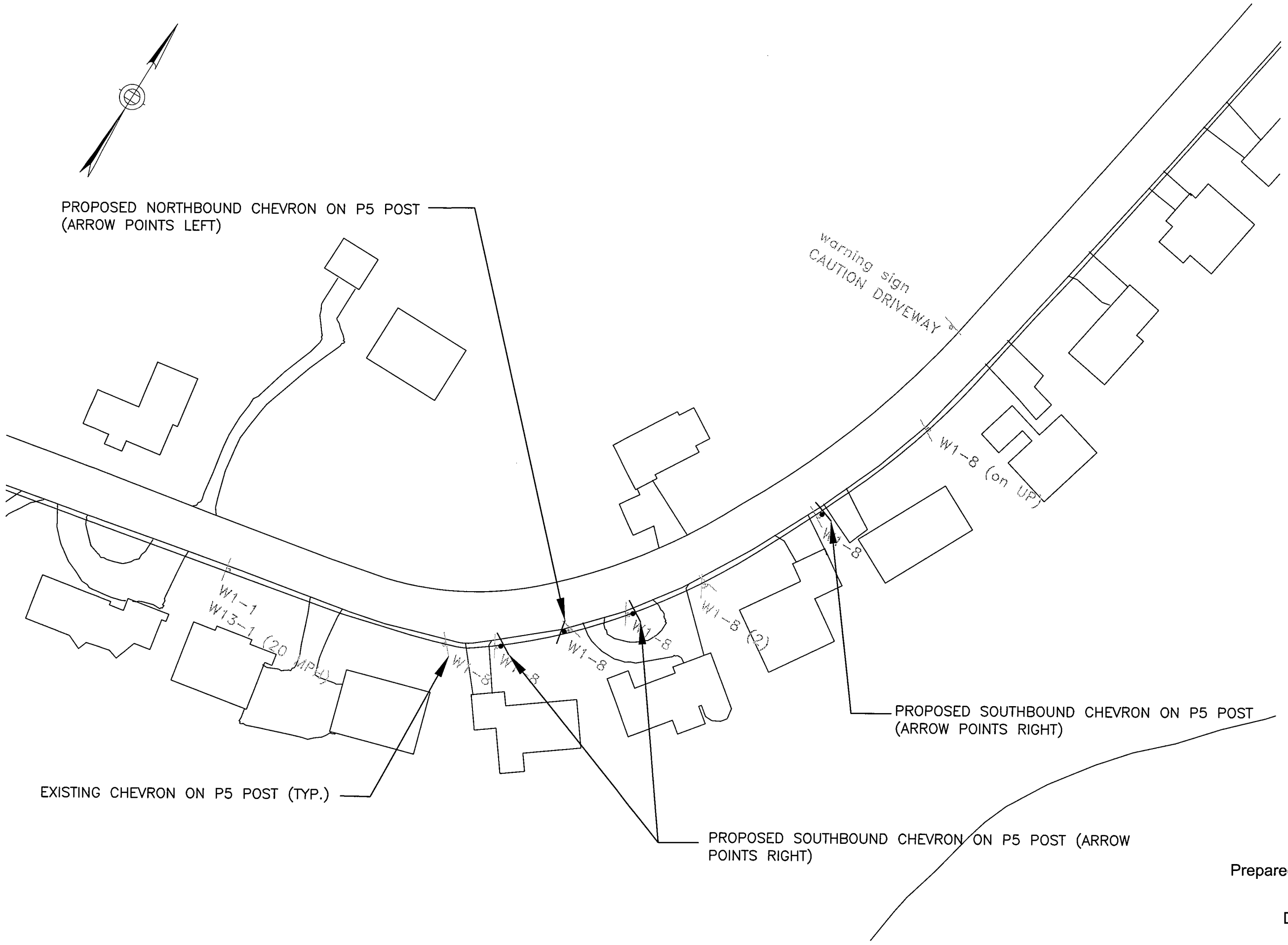

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Figure 14

Blanchard Road Right-of-Way

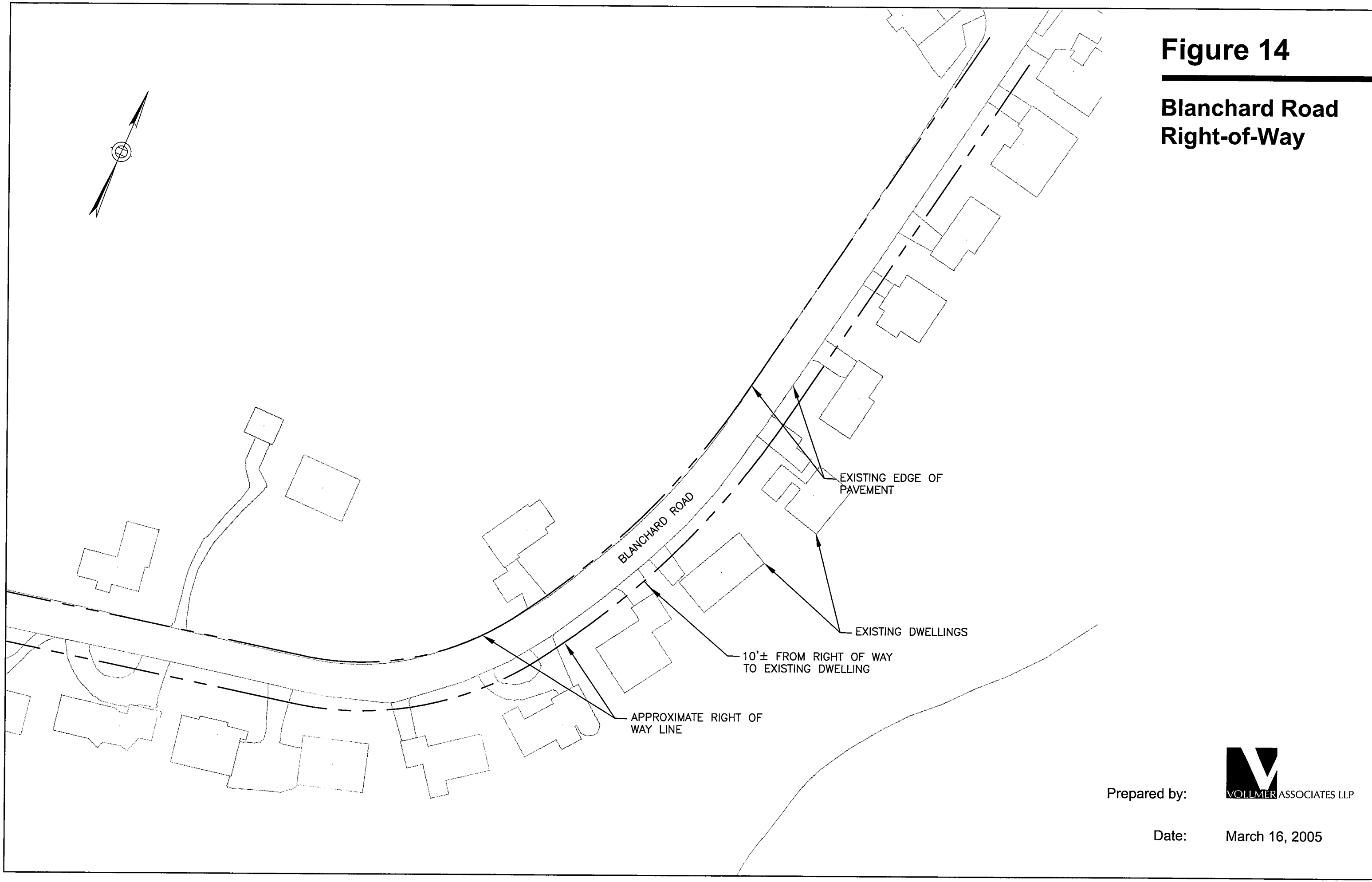

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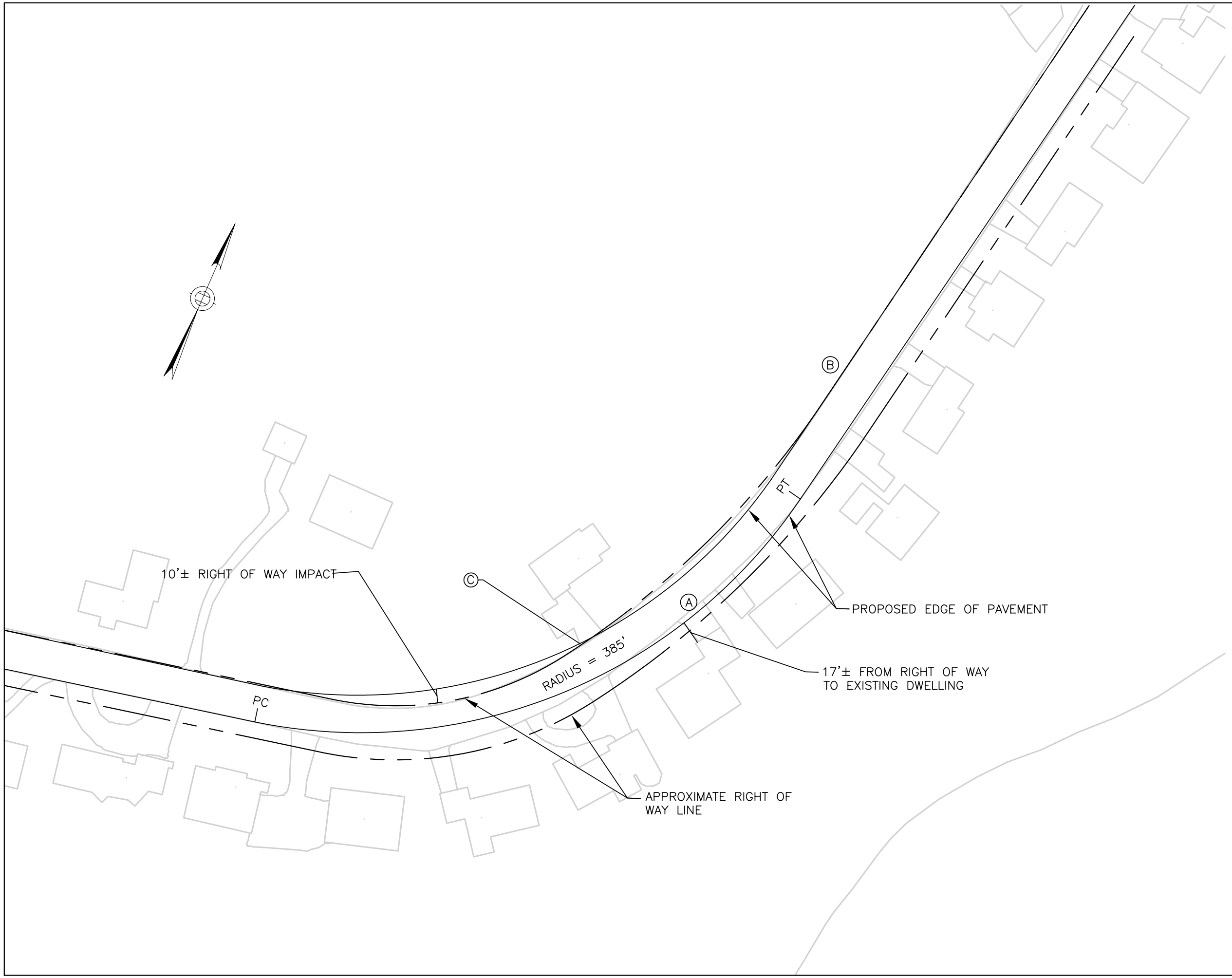
Figure 15

Simple Curve
30 mph Design Speed



CONSTRAINTS:

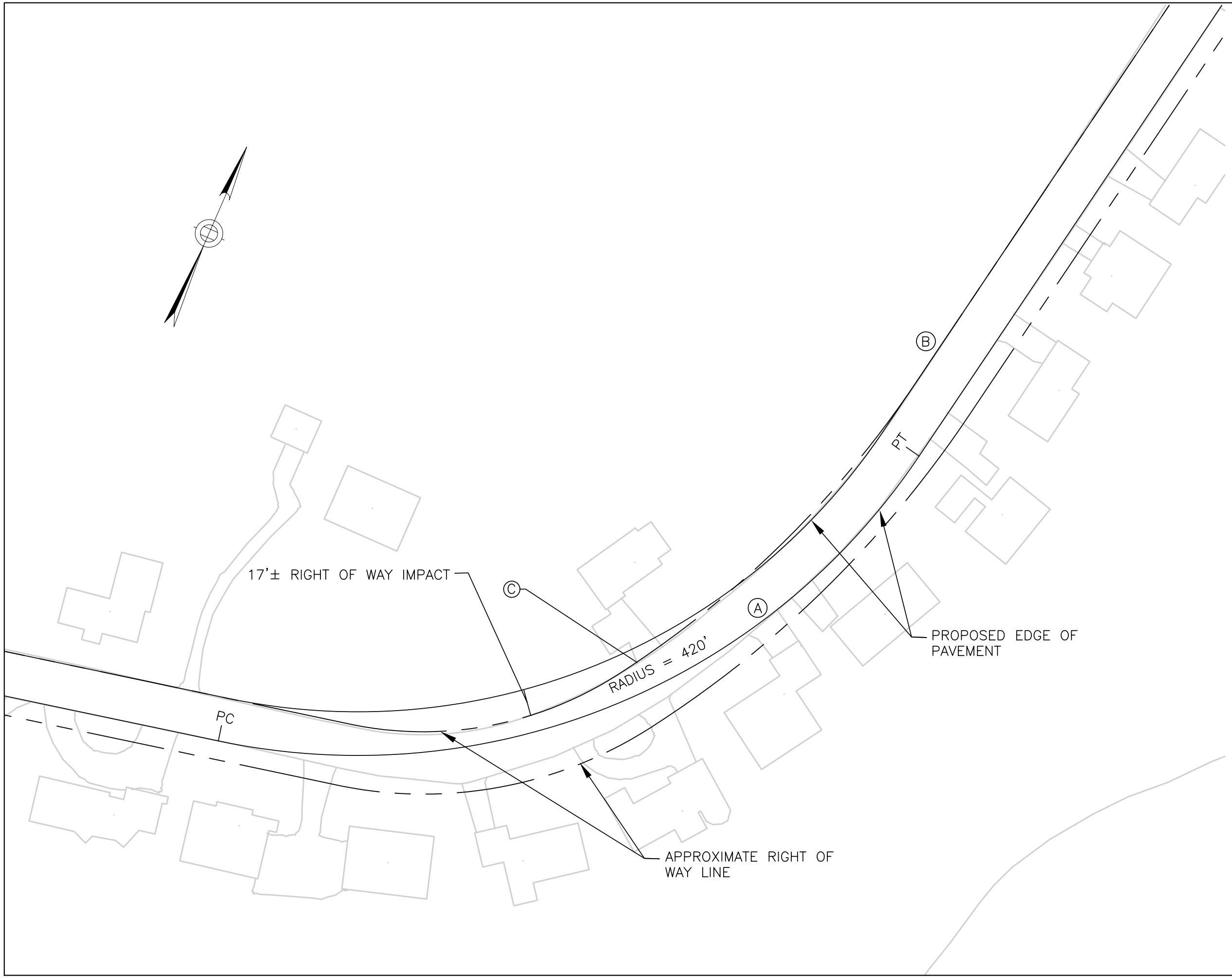
- (A) MAINTAIN EXISTING EDGE OF PAVEMENT
- (B) MAINTAIN TANGENT ALONG RIGHT-OF-WAY NORTH OF CURVE
- (C) MAINTAIN EDGE OF PAVEMENT WITHIN RIGHT OF WAY AT DRIVEWAY

Prepared by: VOLLMER ASSOCIATES LLP

Date: March 16, 2005

Figure 16

Simple Curve 35 mph Design Speed



CONSTRAINTS:

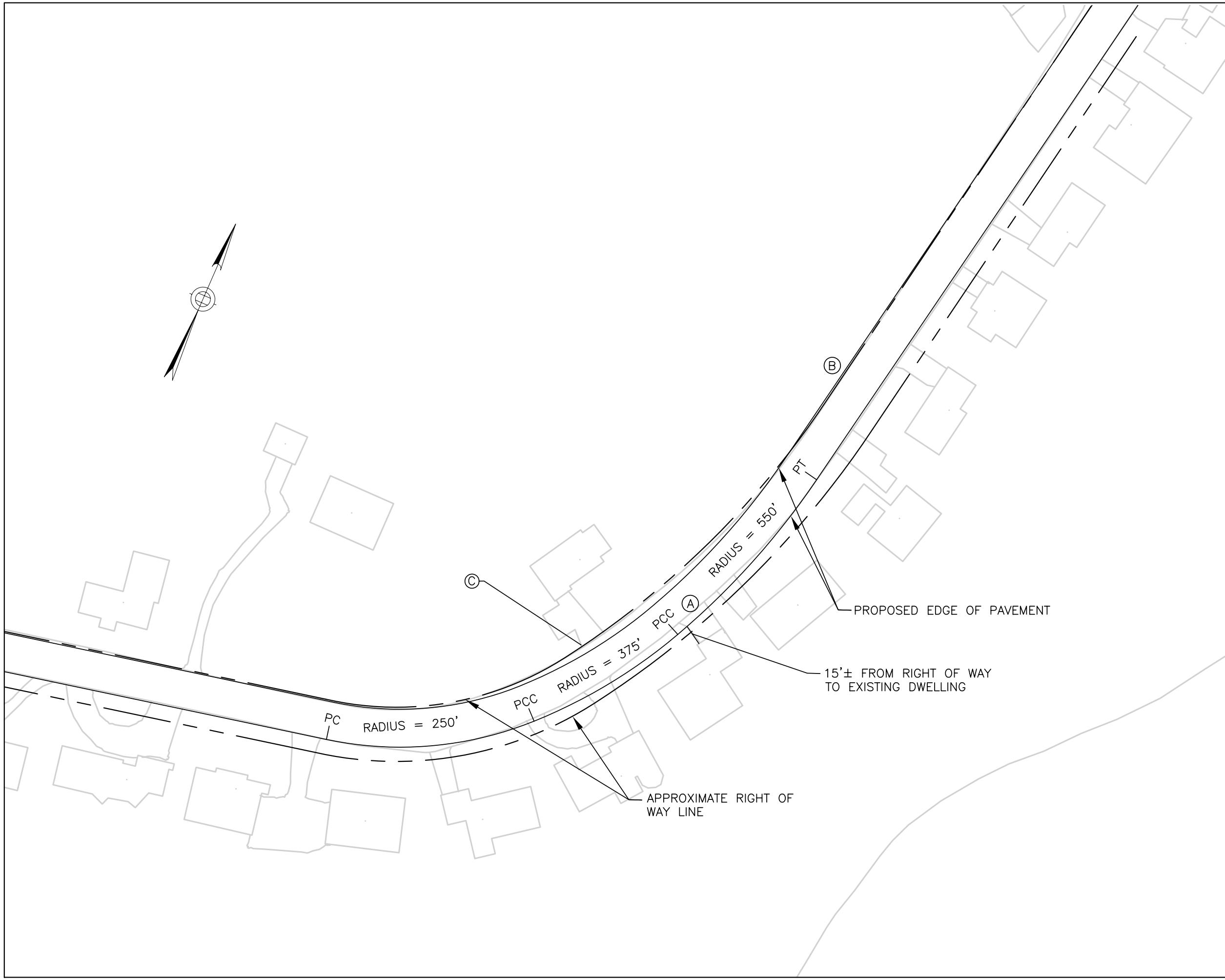
- (A) MAINTAIN EXISTING EDGE OF PAVEMENT
- (B) MAINTAIN TANGENT ALONG RIGHT-OF-WAY NORTH OF CURVE
- (C) MAINTAIN EDGE OF PAVEMENT WITHIN RIGHT OF WAY AT DRIVEWAY

Prepared by: VOLLMER ASSOCIATES LLP

Date: March 16, 2005

Figure 17

Compound Curve 25 mph Design Speed



CONSTRAINTS:

- (A) MAINTAIN EXISTING EDGE OF PAVEMENT
- (B) MAINTAIN TANGENT ALONG RIGHT-OF-WAY NORTH OF CURVE
- (C) MAINTAIN EDGE OF PAVEMENT WITHIN RIGHT OF WAY AT DRIVEWAY

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Date: December 8, 2005

Figure 18

Compound Curve 30 mph Design Speed

CONSTRAINTS:

Ⓐ MAINTAIN EXISTING EDGE OF PAVEMENT

Ⓑ MAINTAIN TANGENT ALONG RIGHT-OF-WAY NORTH OF CURVE

Ⓒ MAINTAIN EDGE OF PAVEMENT WITHIN RIGHT OF WAY AT DRIVEWAY

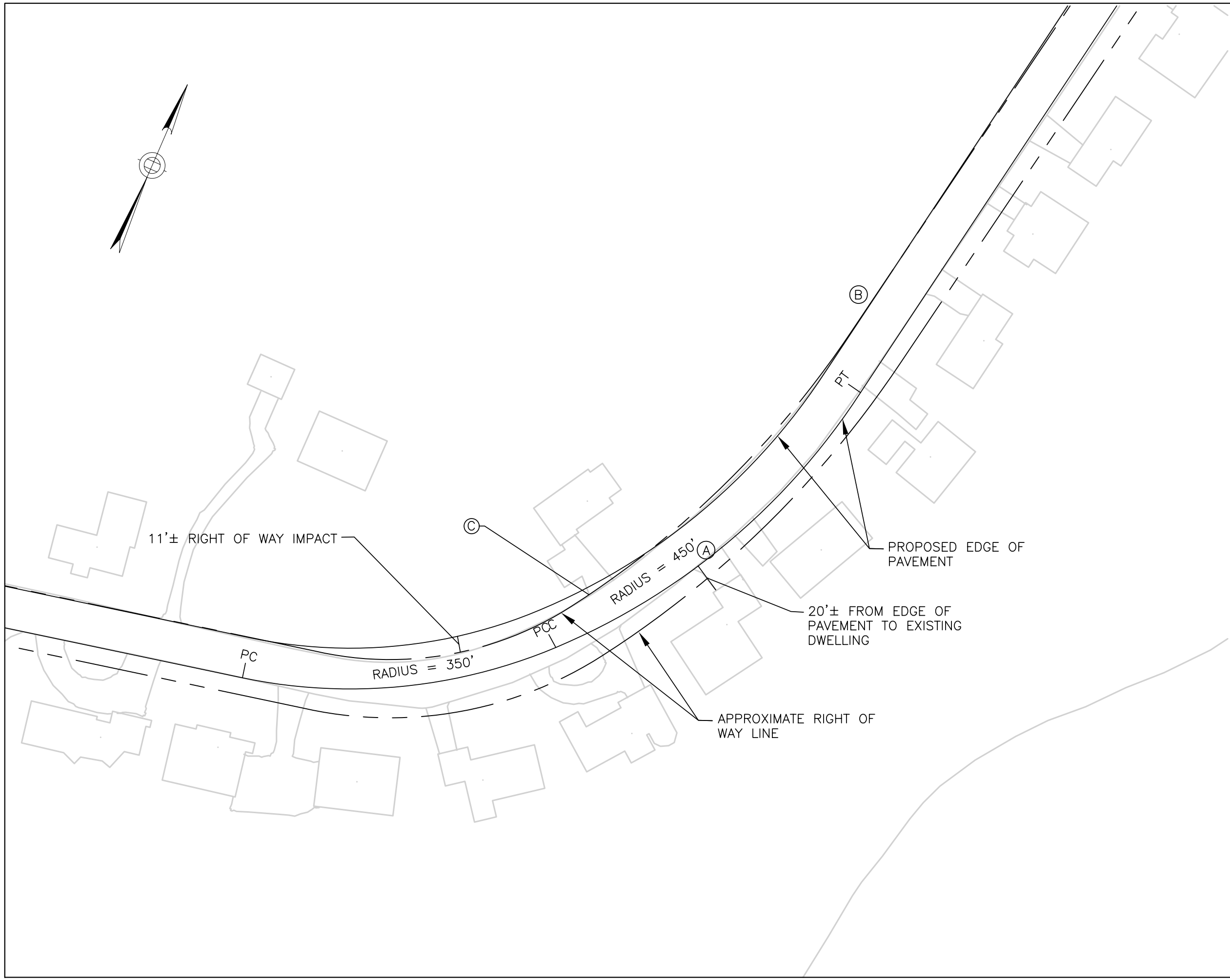

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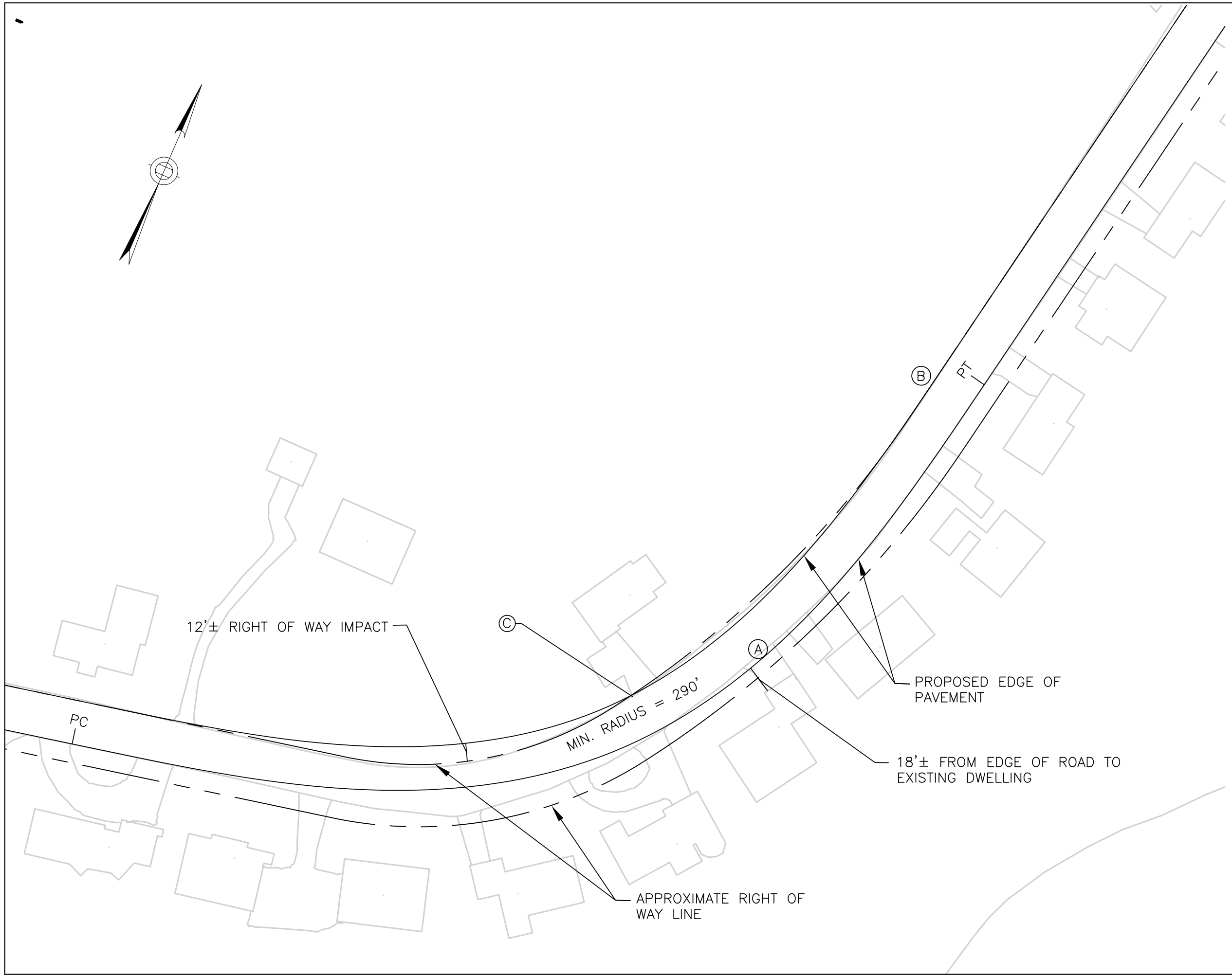
Figure 19

Spiral Curve 30 mph Design Speed



CONSTRAINTS:

- (A) MAINTAIN EXISTING EDGE OF PAVEMENT
- (B) MAINTAIN TANGENT ALONG RIGHT-OF-WAY NORTH OF CURVE
- (C) MAINTAIN EDGE OF PAVEMENT WITHIN RIGHT OF WAY AT DRIVEWAY

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Figure 20

Proposed Guardrail Location

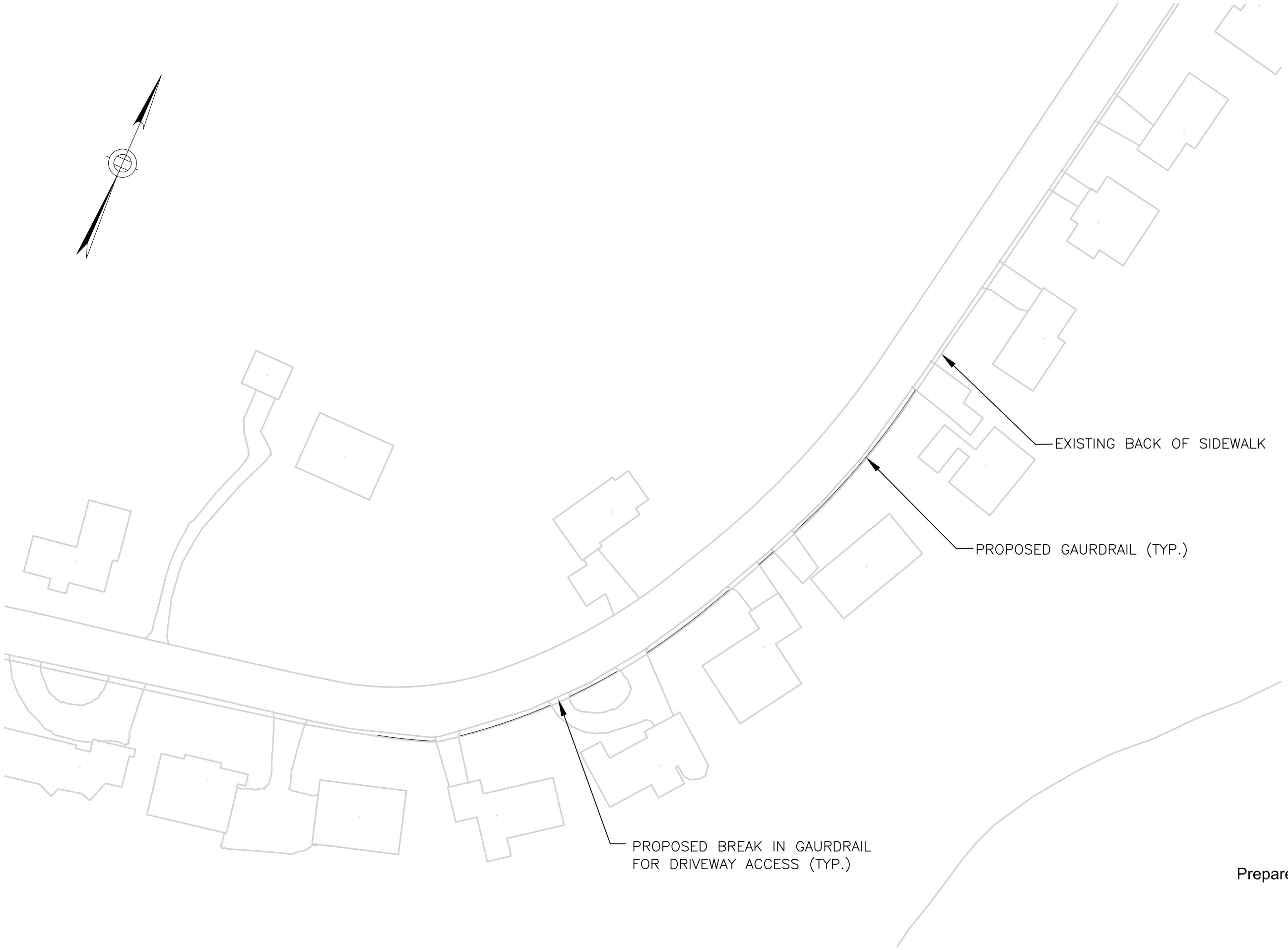

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Figure 21

One 10' Sidewalk Schematic Cross Section

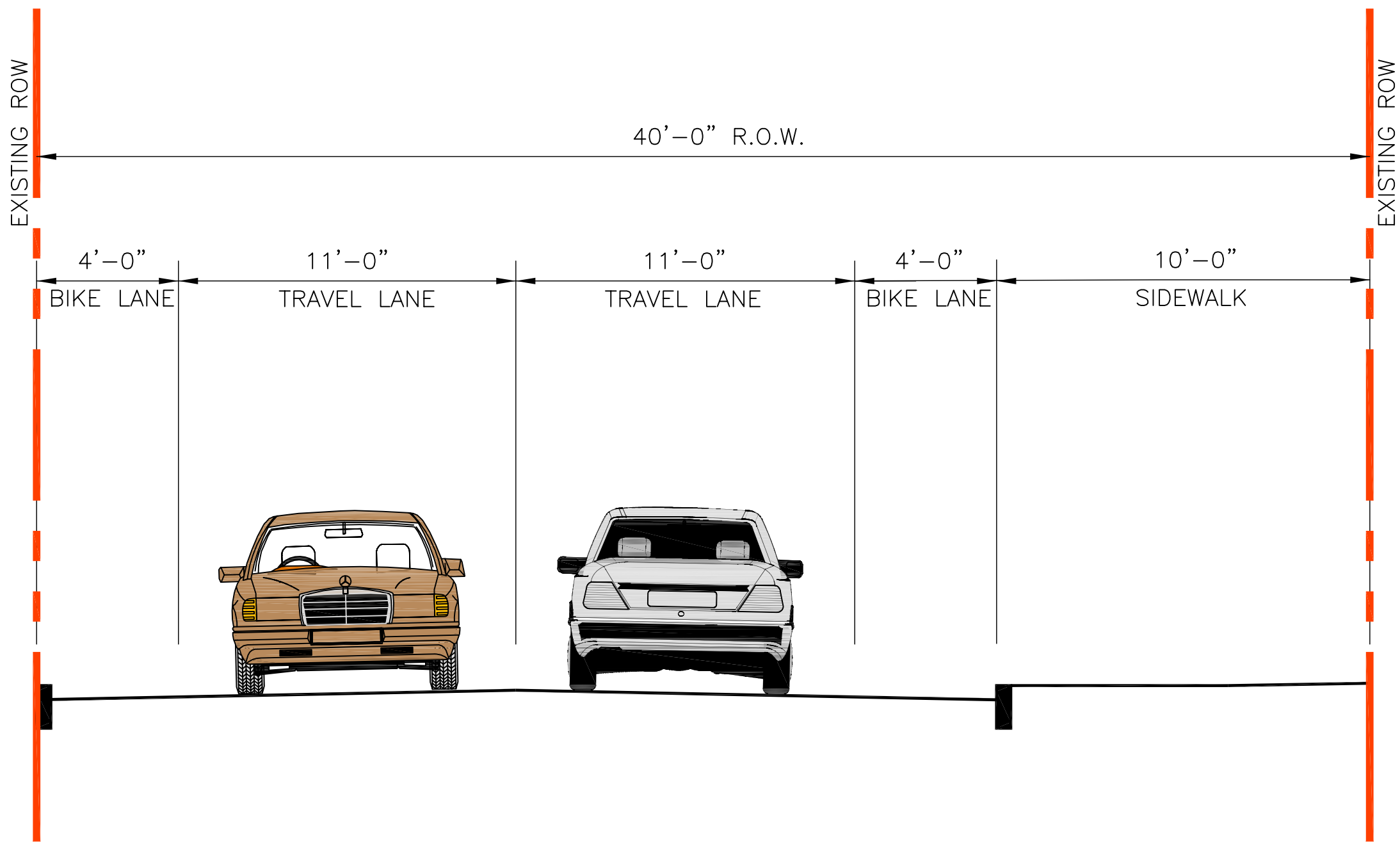

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Figure 22

Two 5' Sidewalks Schematic Cross Section

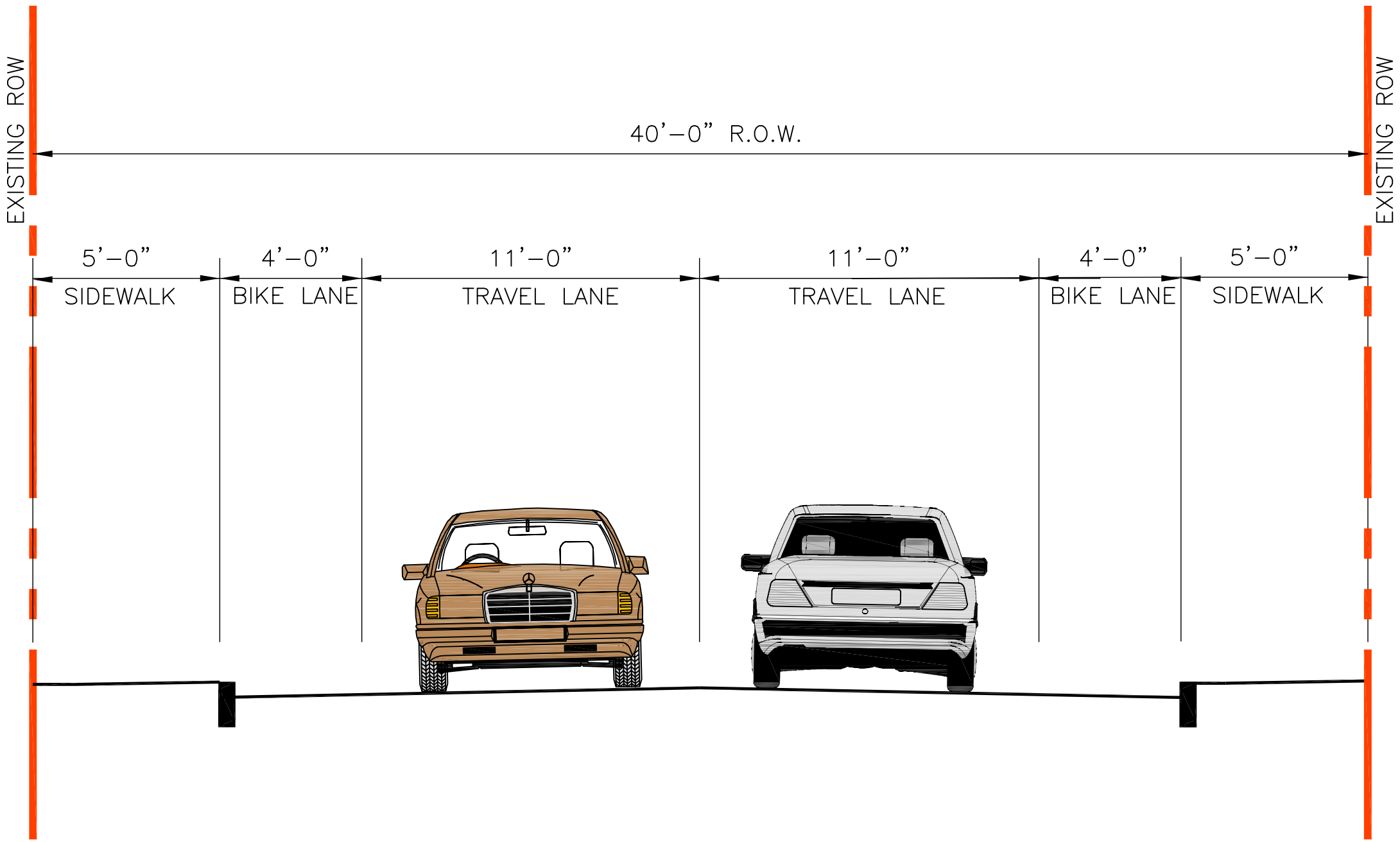

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Figure 23

Crossing Island Schematic Cross Section

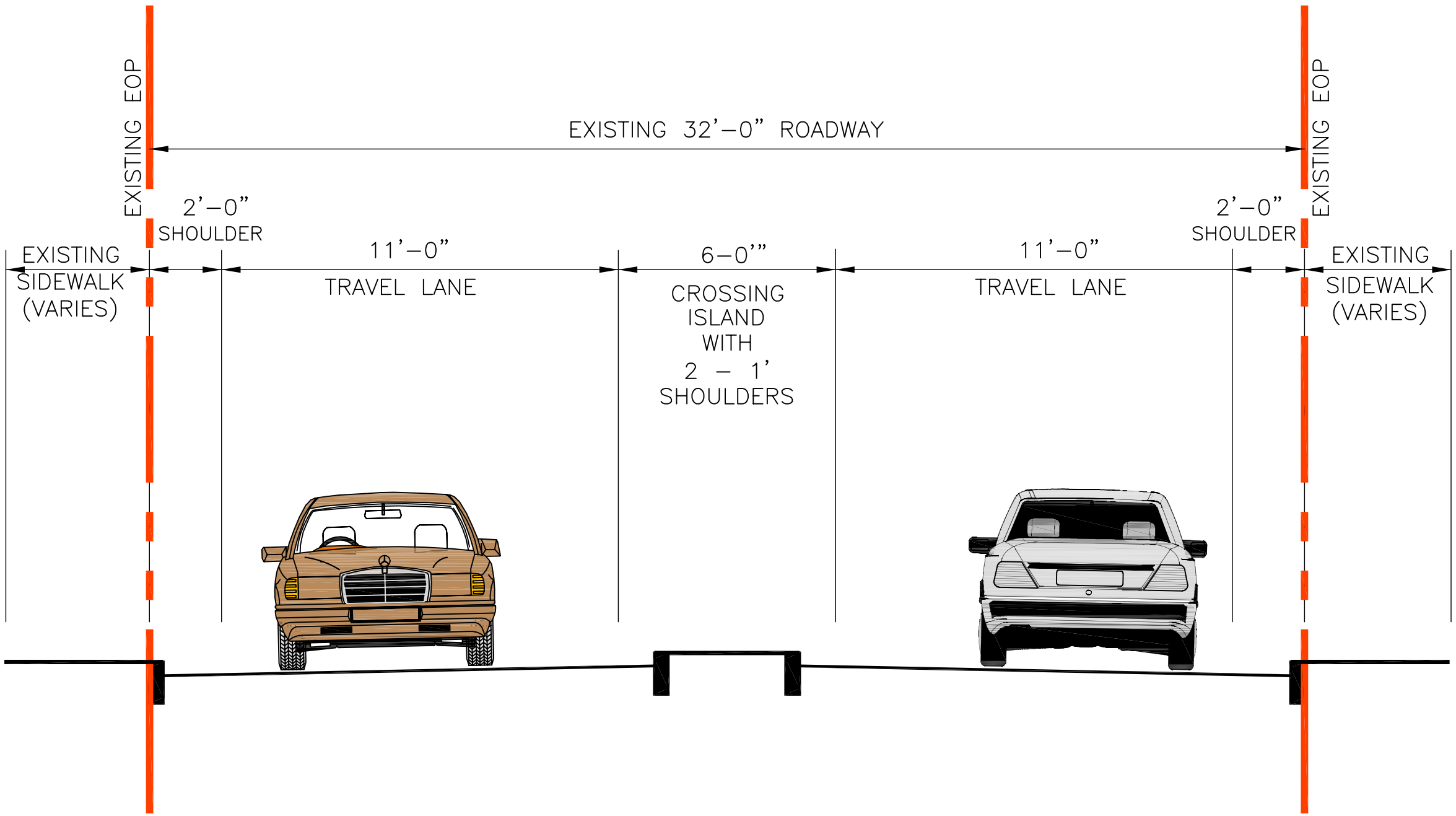

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Figure 24

Crossing Island at Glenn Road

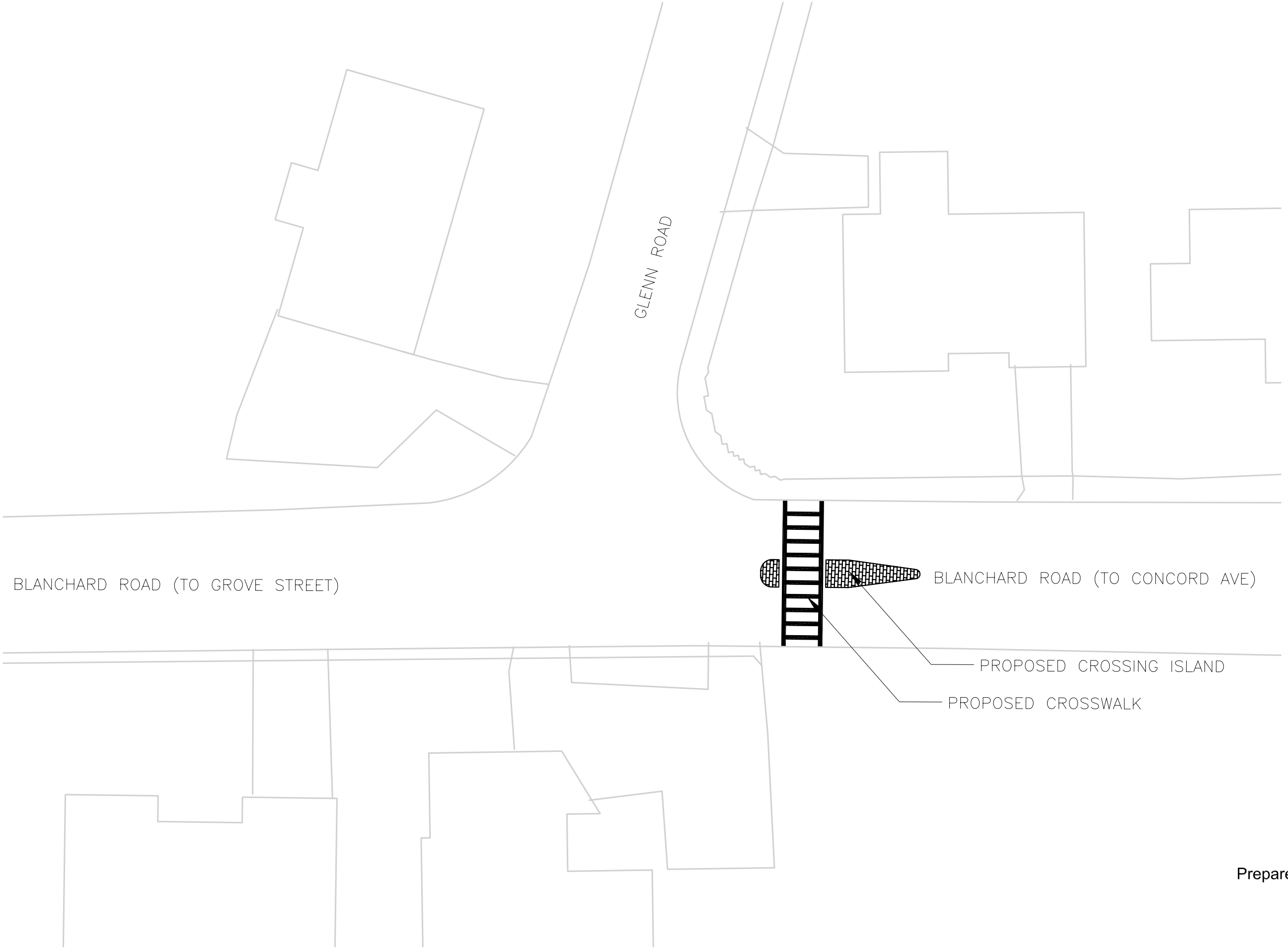

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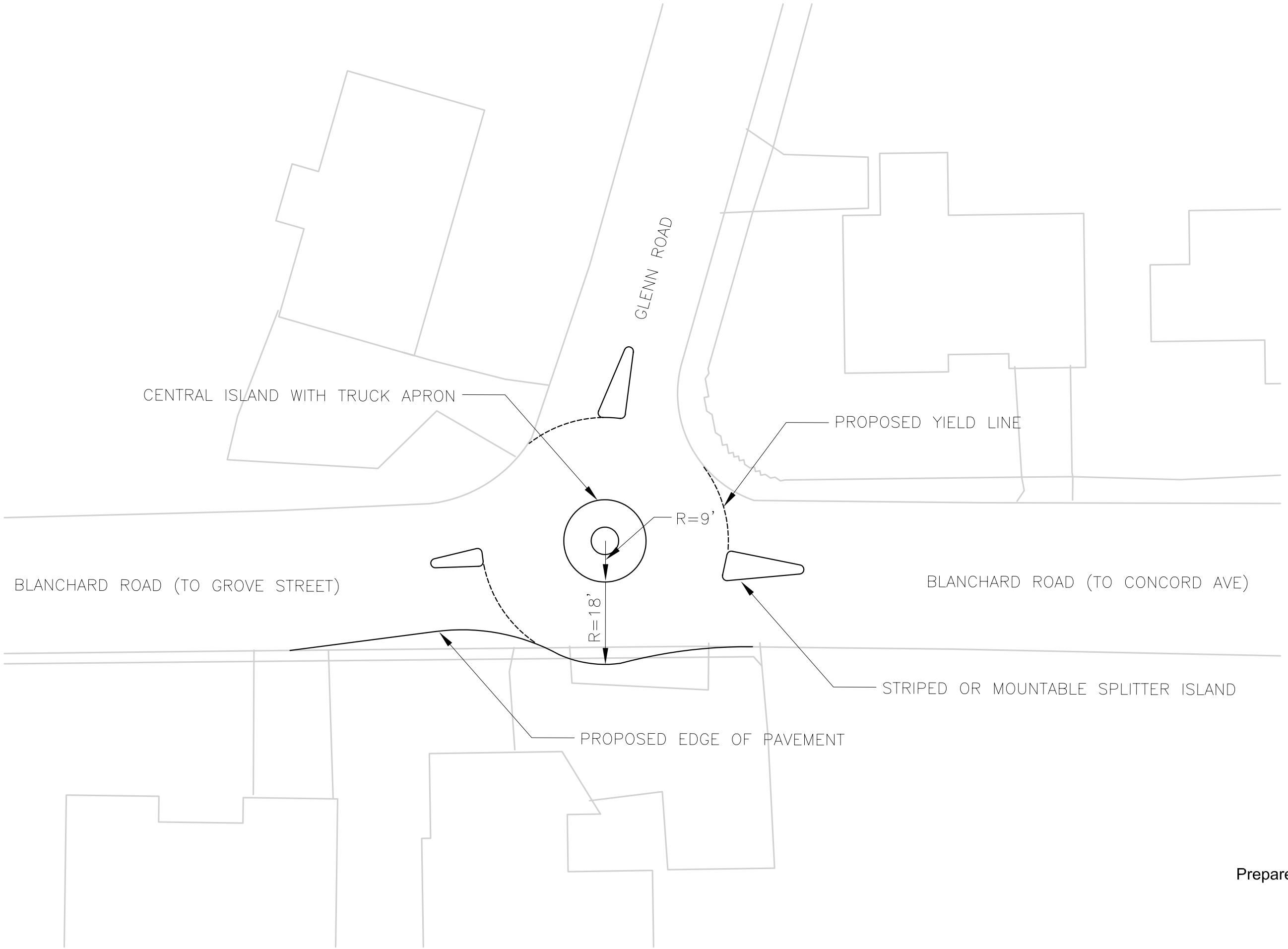
Figure 25

Roundabout at Glenn Road



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