
Traffic Study

Forest Hill Avenue Widening

City of Richmond, Virginia

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INTRODUCTION

This report presents the results of a traffic study conducted for the widening of Forest Hill Avenue in the City of Richmond, Virginia. The 1 mile study corridor extends from eastern junction of Powhite Parkway (Route 76) at the northbound ramps to Hathaway Road in the City of Richmond, Virginia. The roadway is to be widened from a four lane to a five lane roadway. The analysis has been conducted for the traffic conditions in the Existing year 2009, the Build or the Opening year - 2011, and the Design year – 2030

The project site is shown in Figure 1.

The scope of this study includes the following tasks:

- Review historical traffic count data and other studies provided by the City of Richmond
- Conduct roadway inventory to collect the information regarding lane configuration of the study intersections, on-street parking and towing enforcement, and transit stops and shelters along the study roadway
- Review and document roadway inventory information
- Conduct two-way twenty four hour traffic classification counts at following two locations;
 - Between southbound Glyndon Lane and Willow Oaks Country Club entrance
 - Between Melbourne Drive and Hathaway Road
- Determine AM and PM peak hours from the 24 hour count data and collect turning movement counts at the following intersections;
 - Hathaway Road at Old Westham Road
 - Forest Hill Avenue at Hathaway Road
 - Forest Hill Avenue at Melbourne Drive
 - Forest Hill Avenue at Windsorview Drive
 - Forest Hill Avenue at Woodberry Lane
 - Forest Hill Avenue at Rettig Road
 - Forest Hill Avenue at Heartwood Road
 - Forest Hill Avenue at Willow Oaks Country Club entrance
 - Forest Hill Avenue at Glyndon Lane
 - Forest Hill Avenue at southbound Powhite Parkway ramps
 - Forest Hill Avenue at northbound Powhite Parkway ramps
- Conduct capacity analysis for the Existing, the Build, and the Design year peak hour traffic volume conditions.
- Determine storage length requirements for turn lane lengths based on intersection queues
- Develop recommendations for traffic signalization improvements
- Conduct signal warrant analysis for two locations along the study corridor for the opening and the design year
- Determine need for left and right-turn lanes
- Collect and analyze crash data along the study roadway

Report Purpose

The purpose of this report is to present the results of detailed capacity analyses of Forest Hill Avenue extending from the eastern junction of Powhite Parkway at the northbound ramps to Hathaway Road in the City of Richmond. The report also presents crash statistics by type and severity at each intersection located within the study corridor for the existing condition. The capacity analyses conducted include the existing and the future year traffic conditions for the AM and the PM peak hours. This report has been prepared in accordance with the following objectives:

- *Existing Conditions Analysis:* This analysis was conducted to determine the performance level of the roadway network for existing traffic conditions. The level of service provided by the study network under this condition is used as a baseline scenario for the future conditions.
- *2011 No Build Analysis:* The purpose of this analysis was to determine the performance level of the study network for traffic volume conditions in the year 2011 as though the study roadway is not modified. The results from this scenario will provide the baseline conditions of the study network in order to access the full impacts of the roadway modifications.
- *2011 Build Analysis:* This analysis is performed to evaluate the level of service experienced by the study network for 2011 traffic condition (based on regional growth) for various roadway modifications.
- *2030 Design Year No Build Analysis:* The purpose of the analysis of this scenario is to evaluate the level of service provided by the study network for the Design year, 2030, for No Build conditions only. As for 2011 No Build, this scenario will provide the baseline conditions of the study network in order to access the full impacts of the roadway modifications.
- *2030 Design Year Build Analysis:* This analysis is performed to evaluate the level of service experienced by the study network for 2030 traffic condition for various roadway modifications.

Executive Summary

Forest Hill Avenue is located in Richmond, Virginia. This approximately 0.8-mile section of the corridor is an undivided four-lane facility with primarily residential development on both sides of the roadway. On the western end of the study area, commercial developments with direct access points are on both sides of the roadway.

The proposed roadway improvements have been analyzed for the Opening year - 2011 and design year - 2030. The analysis is conducted in accordance with City of Richmond traffic analysis standards, through coordination with City staff. Additionally, Virginia Department of Transportation design standards were employed to assess many of the geometric requirements.

Site Location

This proposed project is located on a portion of the Forest Hill Avenue corridor that extends to the west of the City of Richmond, Virginia. This section of the corridor is adjacent to Powhite Parkway, which is a major facility for commuter traffic, that ultimately provide access to downtown Richmond and the surrounding suburbs, including Chesterfield County. The proposed site location and local traffic network is shown in Figure 1.

Key Findings

The overall performances of all intersections in the study network improve markedly during the AM and PM peak hours for Opening and Design year conditions due to the implementation of access management strategies. The focus for improvement is reserved mostly for the side-street movements, which currently experience considerable delay. The access modifications in the Build condition eliminate many of the capacity issues. There are however, individual approaches at few intersections that operate below acceptable levels of service. While this project addresses many capacity and safety issues, some operational issues remain, given the growth of traffic along the corridor and the consistent side-street demand.

Conclusions

The analysis of Existing, No-Build, and Build conditions has shown that existing operational issues within the network are exacerbated by an increase in background traffic. Traffic operations were found to be moderately improved from “no-build” conditions, by incorporating access management strategies and providing the suitable storage capacity. These strategies also rely on the installation of a traffic signal at the intersection of Forest Hill Avenue and Rettig Road, which will provide access for much of the diverted traffic. While the proposed configurations may not address every operational issue along this stretch of the corridor, many of the access, capacity, and safety issues are addressed to the extent possible.

Ultimately, right-of-way and intersection spacing will be a determining factor for the installation of some of the storage capacity improvements along the corridor; especially at the intersection of Forest Hill Avenue and Hathaway Road, which provides access to commercial developments on the north and south sides of the roadway. While improvements at this intersection were not evaluated in detail, it is anticipated that any increase in turn lane capacity will result in improved operations.

Recommendations

There are several capacity issues that can be addressed by the installation of left and right turn auxiliary lanes along the corridor. A turn lane analysis was conducted to reveal that right- and left-turn lanes are warranted and recommended at several intersections. At two of the intersections, the turn lane lengths were longer than the available spacing between intersections. Still, some benefit would still be gained through the addition of these improvements to the extent constructible.

Additionally, a traffic signal has been recommended at the intersection of Forest Hill Avenue and Rettig Road. While this intersection did not meet any of the applicable traffic signal warrants considered in the analysis, the recommendation of a traffic signal at this intersection has a pivotal role in promoting safe and efficient access for local traffic diverted by the implementation of access management strategies.

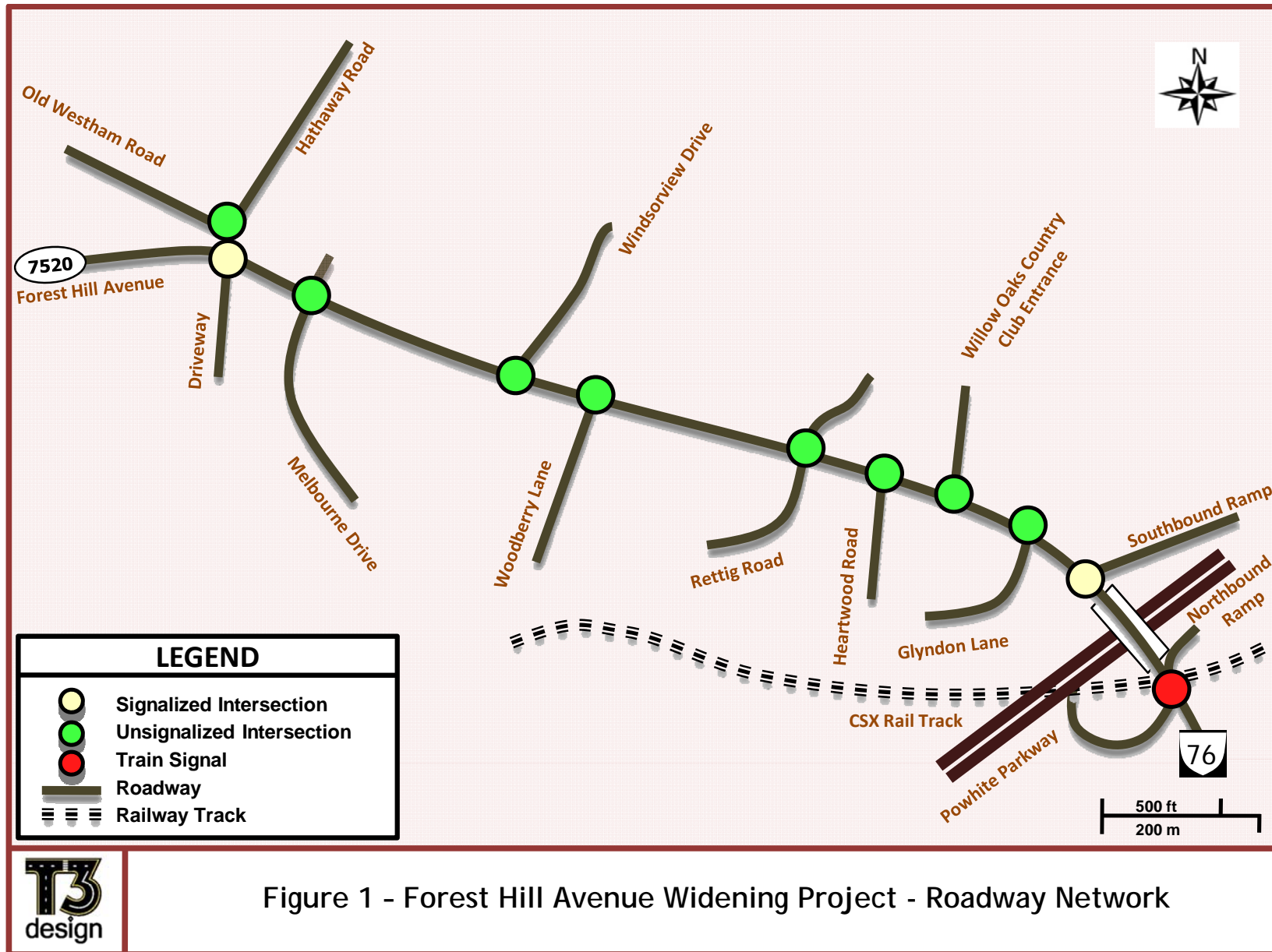


Figure 1 - Forest Hill Avenue Widening Project - Roadway Network



BACKGROUND INFORMATION

Existing Roadway Network

The study network consists of ten (10) intersections with various travel patterns, cross-sections, and functional classes. The characteristics of these roadways are described below, with details regarding their intersection geometries shown in Figure 2.

Forest Hill Avenue (VA Route 683) is an east-west roadway with its western end at Huguenot Road (VA Route 147) and its eastern terminus at West Commerce Road. Over a 1.6 miles stretch of its eastern end, Forest Hill Avenue overlaps with US Route 60 as Semmes Avenue. Within study limits, Forest Hill Avenue is a four-lane undivided roadway. This roadway has a bi-directional 2007 average annual daily traffic (AADT) volume of 27,000 vehicles per day (vpd). Within study limits the posted speed limit on Forest Hill Avenue is 40 mph.

Hathaway Road is a two lane undivided local roadway. To its south Hathaway road intersects with Forest Hill Avenue and provides access to various adjacent residential and commercial developments. To the north it intersects with Wallowa Road and extends as Longview Drive till its intersection with Rockfalls Drive/Riverside Drive. To the north of Riverside Drive, Longview Drive extends as Hill Drive and ends at Rockfalls Drive. Within study limits, the posted limit on Hathaway Road is 25 mph. This roadway has a 2007 AADT of 2,900 vpd.

Old Westham Road is a two lane undivided collector street and provides access to various residential developments in the area. To its east, Old Westham Road intersects with Hathaway Road and to its west it ends at Vesper Road. The posted speed limit along this roadway is 25 mph. The AADT is not reported for this roadway.

Melbourne Drive is an undivided local roadway that provides access to the adjacent residential developments to Forest Hill Avenue. To its northern end it intersects with Forest Hill Avenue and to its southern end it connects with Glyndon Lane. Melbourne Drive has the posted speed limit of 25 mph. The 2007 AADT is not reported for this roadway.

Woodberry Lane is a local street that runs north-south between Forest Hill Avenue and Glyndon Lane. It is an undivided lane with a posted speed limit of 25 mph. The AADT is not reported for this roadway.

Norcross Road is a local street that runs north-south, extending approximately 500 ft and connecting to Rettig Road on its southern end. It is an undivided lane with a posted speed limit of 25 mph. The AADT is not reported for this roadway. Although this was not a study intersection, changes to the access for this roadway were incorporated in the analysis assumptions.

Rettig Road is a two lane undivided roadway that runs north-south between Glyndon Avenue to its south and Westchester Road to its north. It provides access to the driveways of residential development along its stretch. The posted speed limit on Rettig Road is 25 mph. AADT is not published for this roadway.

Heartwood Road is an undivided local street that provides access to residential communities to Glyndon Lane to its south and Forest Hill Avenue to its North. The posted speed limit on this street is 25 mph. The 2007 AADT value is not reported for this roadway.

Glyndon Lane is a two lane undivided local street that provides access to a number of driveways and intersect with a number of streets along the study stretch. It intersects with Forest Hill Avenue to its east and Melbourne Avenue to its west. The posted speed limit along this road is 25 mph and 2007 AADT is 160 vpd.

Study Intersections

Forest Hill Avenue at Hathaway Road is a four-legged signalized intersection. On Forest Hill Avenue eastbound and westbound exclusive left-turn lanes operate with protected - permissive phases. Lane markings are present at all approaches of the intersection. Also, pedestrian crosswalks are provided at all approaches with pedestrian signal heads and pedestrian push buttons on all approaches to the intersection. Bus stops are located at 100 ft from the north-east and south-east corners of the intersection.

Forest Hill Avenue at Melbourne Drive is an unsignalized four-legged intersection. The northbound approach on Melbourne Drive is stop controlled and has a shared left-through-right lane. The southbound approach is a driveway to a shopping mall and the traffic movement through the driveway is also controlled by a stop sign. The eastbound approach to the intersection has two through lanes and a Two-Way-Left-Turn Lane (TWLTL) and the westbound approach has two through lanes and an exclusive left-turn lane.

Forest Hill Avenue at Windsorview Drive is an unsignalized T-intersection. The north approach to the intersection on Windsorview Drive is stop-controlled. The eastbound approach has a through lane and a shared left-through lane and the westbound approach has a through and a through-right lane. The southbound approach has a shared left-through-right turn lane. A bus stop is located to the north-east corner of the intersection. Moreover, no-parking signs are installed along east and west approaches of the intersection. No pedestrian crosswalks are provided at any approach of the intersection.

Forest Hill Avenue at Woodberry Lane is an unsignalized T-intersection. The south approach to the intersection at Windsorview Drive is stop-controlled. The eastbound approach to the intersection has a through and a through-right turn lane and the westbound approach has a through and a left-through lane. The northbound approach has a shared left-right turn lane. A bus-stop is located to the south-west corner of the intersection. Also, no-parking signs are installed along eastbound approach of the intersection. Pedestrian crosswalks are not provided at any approach of the intersection.

Forest Hill Avenue at Rettig Road is a four-legged stop-control intersection. The eastbound and westbound approaches have left-through and right-through lanes and the northbound and southbound approaches have shared left-through-right lanes. The bus stops are located at the north-east and south-west approaches of the intersection. Parking is not allowed at either approach to the intersection. Also, pedestrian crosswalks are not provided at any approach of the intersection.

Forest Hill Avenue at Heartwood Road is a stop-controlled T-intersection. The northbound approach to the intersection on Heartwood Road is stop-controlled. The eastbound approach has a through and through-right turn lane and the westbound approach has a through and a left-through lane. The northbound approach has a shared left-right lane. Pedestrian crosswalks are not provided at any approach to the intersection.

Forest Hill Avenue at Willow Oaks Country Club Entrance is a stop-controlled T-intersection. The traffic movement along the County Club entrance is stop-controlled. The left and right-turn movements from Willow Oaks Country Club Entrance are separated by an island. The pedestrian crosswalks are not provided at any approach to this intersection. Also, parking is prohibited along Willow Oaks Country Club Entrance.

Forest Hill Avenue at Glyndon Lane is a stop-control T-intersection. The traffic movement along Glyndon Lane is stop-controlled. The eastbound approach to the intersection has a through and a right-through lane and the westbound approach has a through lane and a left-through lane. Also, the westbound approach has a drop lane to merge traffic from southbound Powhite Parkway onto westbound Forest Hill Avenue. Pedestrian crosswalks are not provided at any approach to the intersection.

The intersection of Powhite Parkway (Route 76) southbound on-ramp and off-ramps with Forest Hill Avenue are signalized.

Old Westham Road is a service road two-lane collector which runs parallel to Forest Hill Avenue and intersects with Cherokee Road to its west. Old Westham Road extends to the south of the intersection and intersects with Forest Hill Avenue. The eastbound traffic movement along Old Westham Road is controlled by a stop sign and the northbound left-turn movement is controlled by a Yield sign.

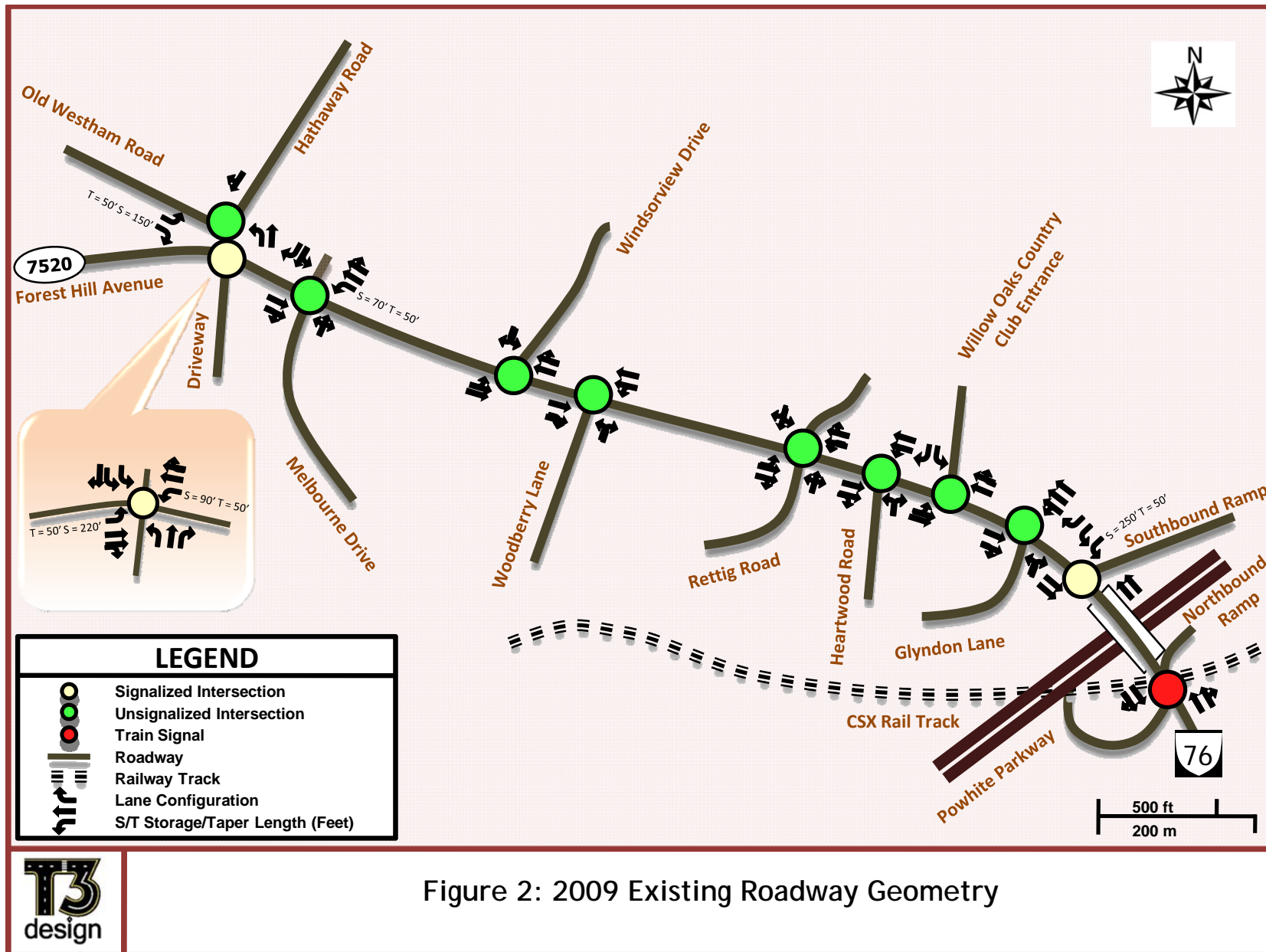


Figure 2: 2009 Existing Roadway Geometry



EXISTING CONDITIONS

Turning Movement Counts

Turning movement counts were conducted during the week of May 4 to May 8, 2009. Based on the 24-hr data provided by VDOT collected in 2007 on Forest Hill Avenue 0.61 mile east of Cherokee Road, the AM and PM peak periods were determined to be between 7:00 – 9:00 AM and 4:00 PM – 6:00 PM respectively. Two hour AM and two hour PM peak counts were conducted at the following intersections:

1. Hathaway Road at Old Westham Road
2. Forest Hill Avenue at Hathaway Road
3. Forest Hill Avenue at Melbourne Drive
4. Forest Hill Avenue at Woodberry Lane
5. Forest Hill Avenue at Heartwood Road
6. Forest Hill Avenue at Willow Oaks Country Club entrance
7. Forest Hill Avenue at Glyndon Lane
8. Forest Hill Avenue at southbound Powhite Parkway ramps
9. Forest Hill Avenue at northbound Powhite Parkway ramps

To conduct signal warrant analysis, twelve hour counts were collected at the following intersections:

1. Forest Hill Avenue at Rettig Road
2. Forest Hill Avenue at Windsorview Drive

Based on the collected data, AM and PM peak hours were determined to occur between 8:00 AM – 9:00 AM and 5:00 PM – 6:00 PM, respectively. The existing turning movement counts for the study intersections are depicted in Figure 7 and counts summaries are presented in Appendix B.

Twenty Four Hour (24-hr) Counts

In addition to turning movement counts, twenty four (24-hr) counts were also collected on Forest Hill Avenue at two different locations; between Melbourne Drive and Windsorview Drive and between Glyndon Lane and Willow Oaks Country Club Road. The 24-hr speed and vehicle classifications counts were collected in fifteen-minute time aggregate from 12:00 PM, May 05, 2009 to 12:00 PM, May 06, 2009. The 24-hr counts are compiled and presented in Appendix B.

Travel Time Runs

Travel time runs on Forest Hill Avenue were conducted on May 05, 2009 during the AM and PM peak hours. The travel time and vehicle location data was collected using GPS technology on a second by second basis. Also, a time-log was documented for each study intersection. During the AM peak hour, several runs were conducted in the eastbound and the westbound directions on Forest Hill Avenue from 8:00 AM to 9:00 AM. Similarly, during the PM peak hour several runs were conducted in the eastbound and the westbound directions on Forest Hill Avenue from 5:00 PM to 6:00 PM.

During the AM peak hour, the average time required to travel in the westbound direction between the Forest Hill Avenue and the Powhite Parkway NB On-ramp intersection and the Forest Hill Avenue and Hathaway Road intersection was 77 sec with an average vehicle speed of 46 mph. The average time required to travel on Forest Hill Avenue in the eastbound direction during the AM peak hour was 74 sec; with the average travel speed of 46 mph. A negligible difference in the travel time between the eastbound and westbound directions indicates a similar level of congestion in both directions on Forest Hill Avenue during the AM peak hour.

During the PM peak hour, the average time required to travel in the westbound direction between the Forest Hill Avenue and the Powhite Parkway NB on-ramp intersection and the Forest Hill Avenue and Hathaway Road intersection was 100 sec with the average vehicle speed of 37.5 mph; while, the average time required to travel on Forest Hill Avenue in the eastbound direction during the PM peak hour was 88 sec with the average travel speed of 41 mph. A slight difference in travel time for the two directions on Forest Hill Avenue indicates a higher level of congestion in the westbound direction in comparison to the eastbound direction during the PM peak hour. The travel time data also suggests more congestion or vehicle delay during the PM peak hour. The resulting travel time data can be found in Appendix C.

Crash Analysis

An analysis of crash data was conducted that included data compiled for the three-year period from January 2006 through December 2008. This crash data was specifically analyzed to reveal trends along the corridor and for various comparisons, including crash severity, yearly totals, and intersection totals. The crash analysis included an examination of crashes that occurred at the study intersections (using a 300' diameter) and throughout the entire corridor. The total number of crashes that occurred over the three-year period is 216 crashes. A total of 121 crashes occurred at intersections.

In Table 1, it is shown that the number of intersection crashes occurring during the three-year period follows a consistent pattern, with 43, 38, and 40 crashes occurring in 2006, 2007, and 2008, respectively. The highest number of crashes over the three years occurs at the intersection of Forest Hill Avenue and the Powhite Parkway SB Off-Ramp, which is more than twice the total number of crashes at the intersection with the second-highest frequency. Table 2 shows the totals for each intersection based on collision type where it can be seen that the predominant type of crash is rear-end, followed by angle crashes. The highest number of rear-end crashes at an unsignalized intersection is 9 crashes at the intersection of Forest Hill Avenue and Glyndon Lane. The two potential contributing factors for this may be the proximity of Glyndon Lane to the Powhite Parkway SB off-ramp and the absence of left turn storage lanes. There is also a consistent number of angle crashes along the corridor, which likely relate to the side-street delay and the limited number of mainline gaps. Two other notable crash types are the head-on collisions (10) and the sideswipe-same direction crashes. The absence of a median along the corridor may contribute to this.

Table 1 - Annual Crash Total by Intersection

Intersection	2006	2007	2008	Grand Total
Glyndon Lane	2	4	8	14
Hathaway Road	9	5	6	20
Heartwood Road	1	2	1	4
Melbourne Drive	1	1	5	7
Powhite Parkway	19	17	17	53
Rettig Road	4	4	3	11
Windsorview Drive	5	5		10
Woodberry Lane	2			2
Grand Total	43	38	40	121

Table 2 - Intersection Crashes by Type

Location	RE	ANG	HO	SSOD	SSSD	OTH	FOOR	DR	FOIR	N/C	TOT
Glyndon Lane	9	2	1			1	1				14
Hathaway Road	4	13	2	1							20
Heartwood Road	1	2			1						4
Melbourne Drive	3	1			3						7
Powwhite Parkway	27	12	4	1	3		3	1	1	1	53
Rettig Road	3	2	2		3	1					11
Windsorview Drive	5	2	1		1		1				10
Woodberry Lane	2										2
Grand Total	54	34	10	2	11	2	5	1	1	1	121

The annual crash summaries for the entire study area, based on crash type are summarized in Table 3. By far, the most predominant crash type for the study area is rear-end with a total of 98 crashes over the three year period. This crash type, which tends to occur at signalized intersections, shows its highest rate of occurrence at the intersection of Forest Hill Avenue and the Powwhite Parkway SB Off-Ramp. At the Glyndon Lane intersection six rear-end crashes occur in 2008. However, no more than three rear-end crashes occur at or in the vicinity of the intersections during the three-year period.

The second-highest occurrence of crashes for the entire study area is for the angle crash type, which is common at unsignalized intersections, especially along active corridors. A total of 54 angle crashes occurred along the corridor during the three-year period.

There was relatively an equal and notable number of head-on (16) and sideswipe-same direction (20) crashes within the study area, which is likely related to the absence of a median along the corridor. Additionally, the relatively straight alignment of the corridor may contribute to somewhat higher travel speeds.

Table 3 - Annual Crash Totals by Type for Study Area

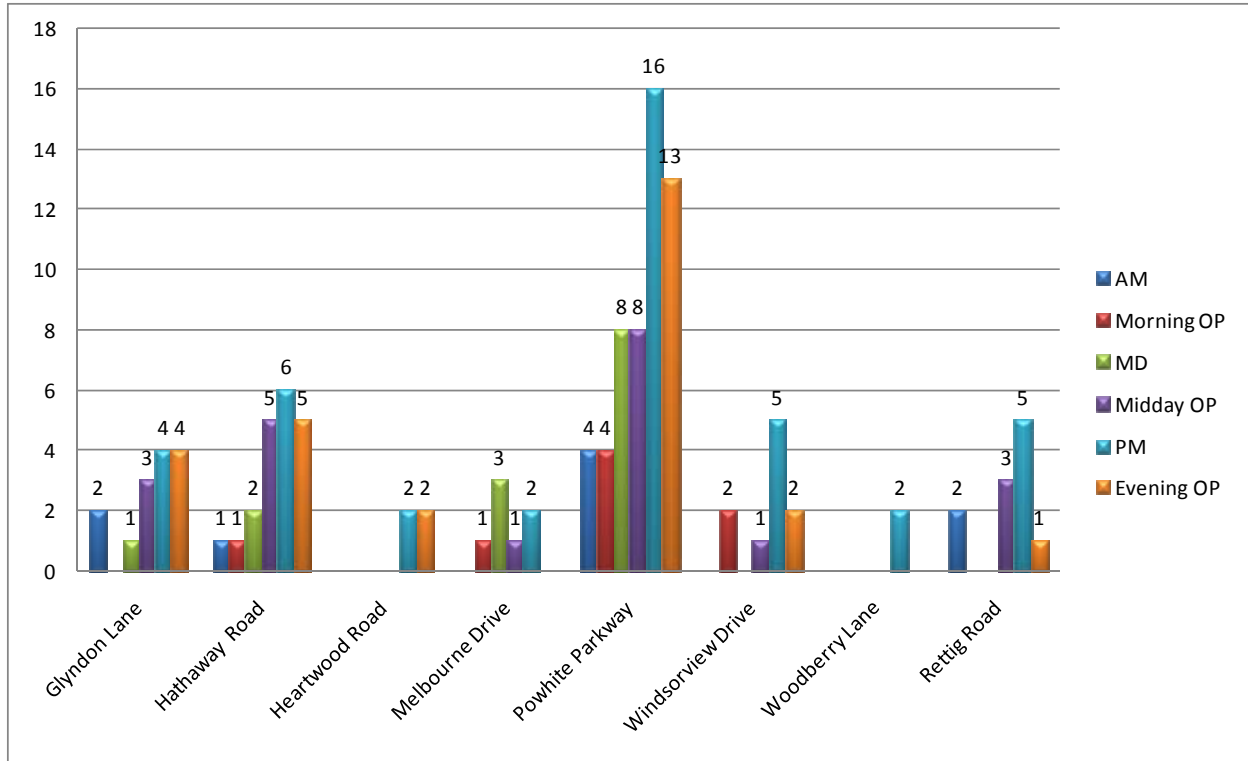
Location	RE	ANG	HO	SSOD	SSSD	OTH	FOOR	DR	FOIR	N/C	TOT
2006	26	19	9		7	1	5	1	1		69
Glyndon Ln.	3										3
Hathaway Rd.	2	7	1								10
Heartwood Rd.					1						1
Melbourne Dr.	1										1
Powwhite Pkwy.	15	10	6		4	1	5	1	1		43
Rettig Rd.	1	1	1		1						4
Windsorview Dr.	2	1	1		1						5
Woodberry Ln.	2										2
2007	38	19	2	3	6	2	4	1	2		77
Glyndon Ln.	2	1				1					4
Hathaway Rd.	3	4		1							8
Heartwood Rd.		2									2
Melbourne Dr.	1				1						2
Powwhite Pkwy.	28	10	2	1	4		3		2		50
Rettig Rd.	1	1			1	1					4
Windsorview Dr.	3	1		1			1	1			7
2008	34	16	5		7	2	4			2	70
Glyndon Ln.	6	2	1				1				10
Hathaway Rd.	2	5	2								9
Heartwood Rd.	2										2
Melbourne Dr.	3	1			2						6
Powwhite Pkwy.	18	8	1		4	2	3			2	38
Rettig Rd.	2		1		1						4
Windsorview Dr.	1										1
Grand Total	98	54	16	3	20	5	13	2	3	2	216

NOTE:

- RE - Rear end
- ANG - Angle
- HO - Head on
- SSOD - Sideswipe-opposite direction
- SSSD - Sideswipe-same direction
- OTH - Other
- FOOR - Fixed object-off road
- DR - Deer
- FOIR - Fixed object in road
- N/C - Non-collision

In examining the various time-periods throughout the day, the highest frequency intersection crashes occurs during the PM peak period. This is also the time-period that includes the highest volumes on Forest Hill Avenue. Second to the PM peak period is the Evening off-peak period. This reflects the potential of an expanded PM peak that lasts outside of the typical range. The AM peak period actually was among the time periods with the lowest occurrence of crashes. A graph summarizing the occurrence of crashes by time-period is shown in Figure 3.

Figure 3 - Occurrence of Intersection Crashes by Time of Day



A review of the annual occurrence of crashes based on severity for the intersections revealed that the highest occurrence was for property damage only crashes. A total of 87 crashes involving property damage only occurred at Forest Hill Avenue intersections. There were 26 crashes at corridor intersections involving a Type C injury, which is deemed a “possible injury”. The other injury types occurred in relatively small numbers. Type A involves an injury where a motorist or passenger is incapacitated; and Type B indicates a non-incapacitating crash. One fatality occurred at the intersection of Forest Hill Avenue and Hathaway Road. The only other fatality occurred near the SB off-ramp from Powhite Parkway, 0.8 miles from the corridor. These crashes are summarized in tabular and graphical formats in Table 4 and

Figure 4 for the intersections. Figure 5 expands this data to show the results by intersection. Lastly, Figure 6 summarizes these types for the entire study area.

Table 4 - Annual Occurrence of Fatality/Injury/Property Damage Crashes - Intersections

Location	Fatality Crashes	Type A Injured Crashes	Type B Injured Crashes	Type C Injured Crashes	PDO Crashes
2006	0	1	3	8	32
2007	0	2	2	11	25
2008	1	0	1	7	30
Grand Total	1	3	6	26	87

Figure 4 - Annual Occurrence of Fatality/Injury/Property Damage Crashes for All Intersections

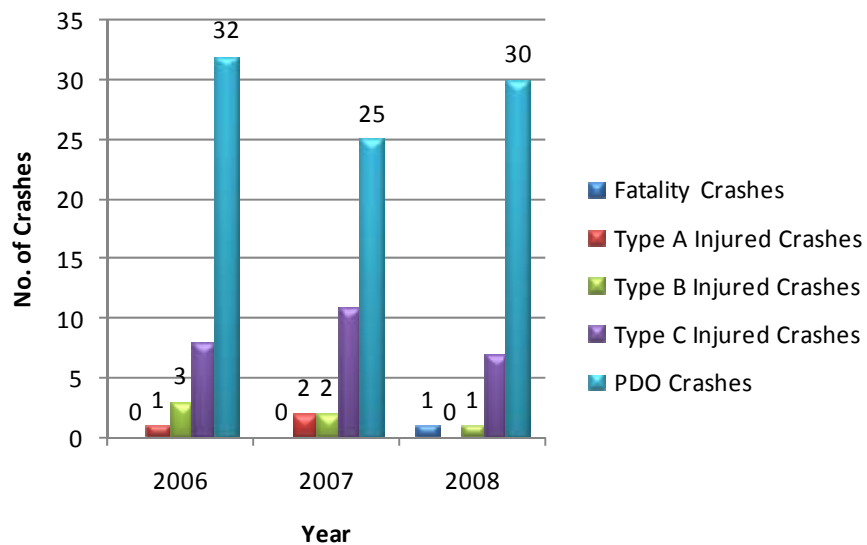


Figure 5 - Annual Occurrence of Fatality/Injury/Property Damage Crashes by Intersection

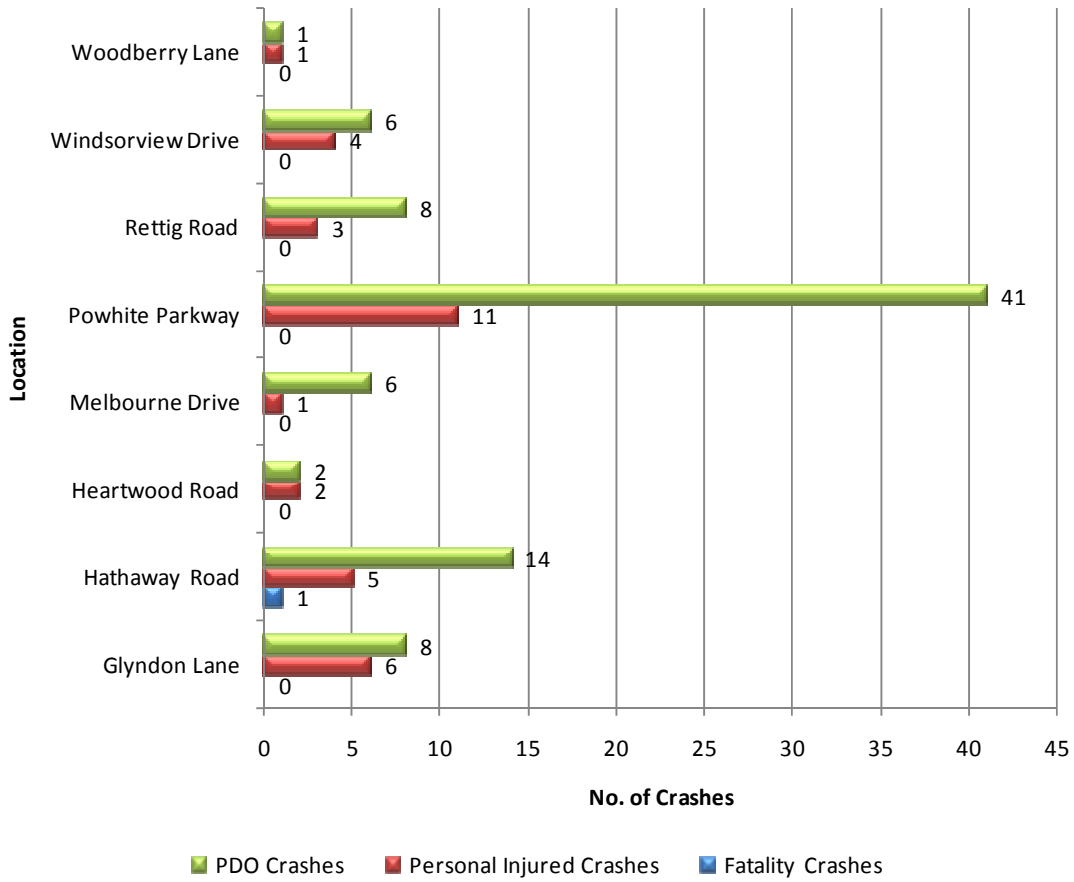
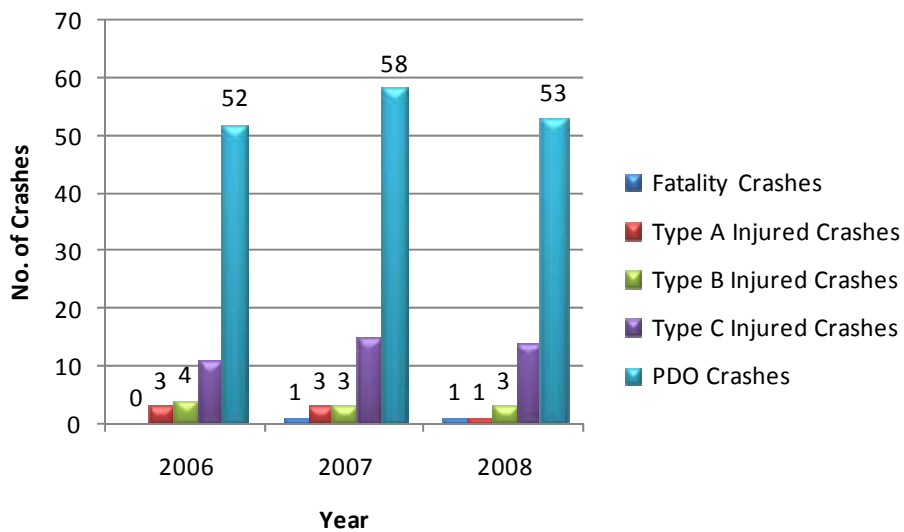


Figure 6 - Annual Occurrence of Fatality/Injury/Property Damage Crashes - Study Area



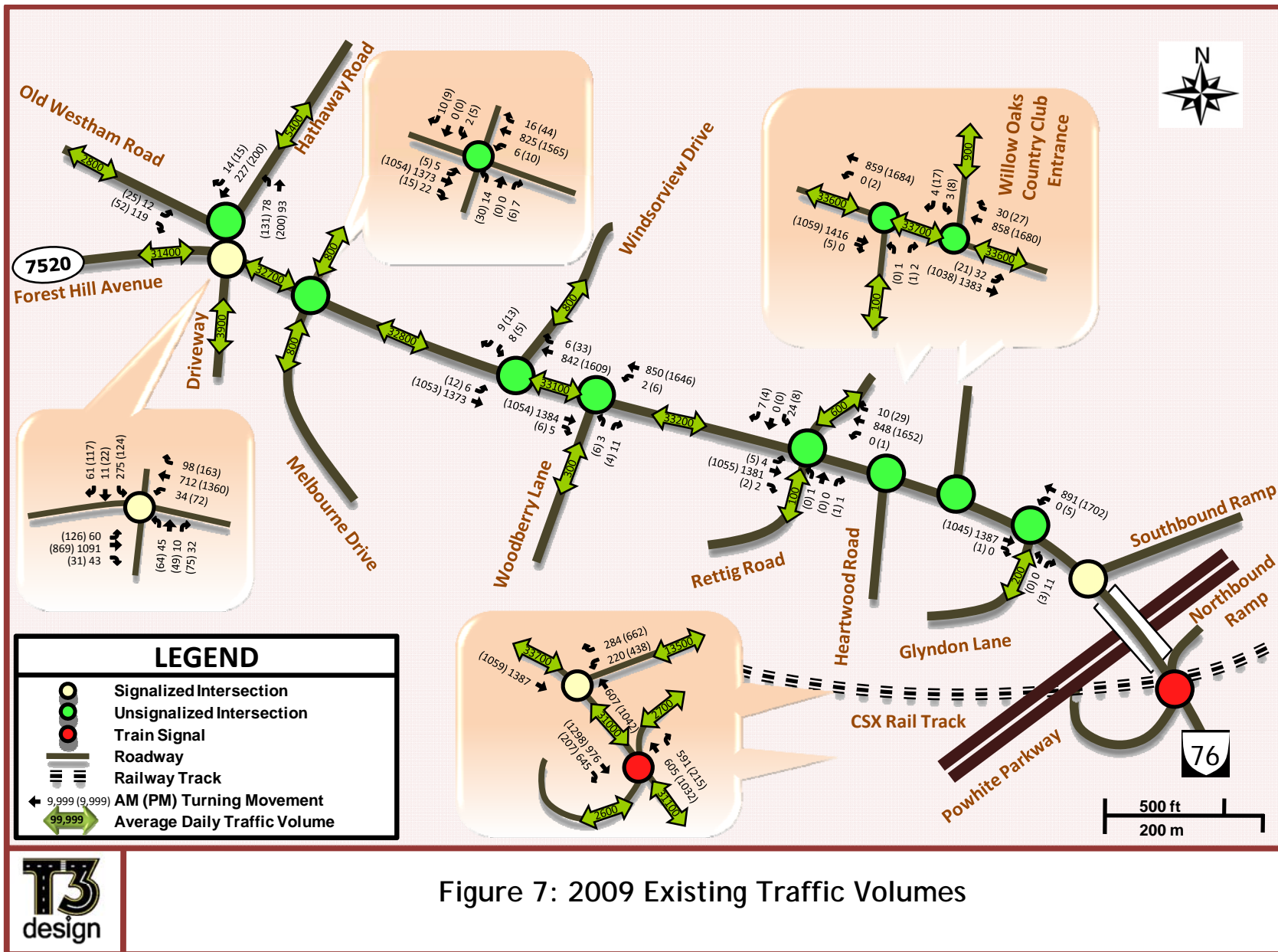


Figure 7: 2009 Existing Traffic Volumes



Capacity Analysis – Existing Conditions

Capacity analysis for the existing conditions was conducted using the methodologies defined in *Highway Capacity Manual (HCM 2000)*. The software program, Synchro Version 7.0, was used to conduct the analysis. Synchro reports operating conditions for each movement at signalized and unsignalized intersections in terms of Level of Service (LOS) and the corresponding control delays.

Level of service at an intersections is determined in terms of control delay per seconds and is expressed in grade letters between “A” through “F”; with LOS service “A” defining a free-flow condition and LOS “F” defining a spill back condition. HCM gives different LOS criteria based on control delay per second thresholds for signalized and unsignalized intersections. The LOS criteria as defined in HCM for unsignalized and signalized intersections are presented in Table 5 and LOS criteria are graphically presented in Figure 8.

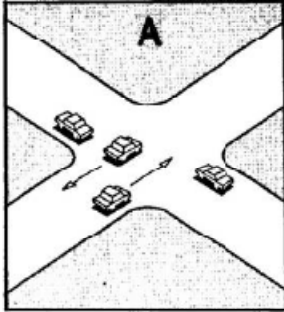
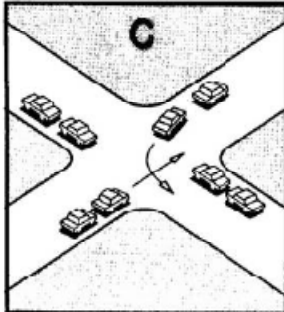
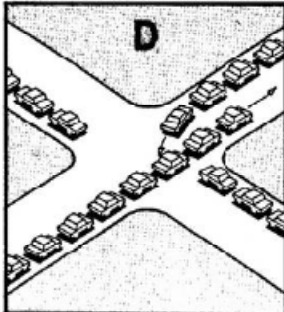
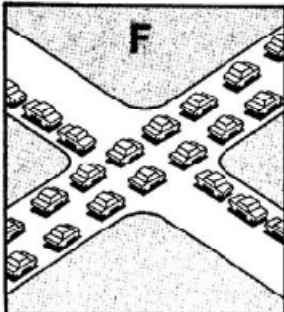
Table 5: LOS Criteria for Signalized and Unsignalized Intersections (HCM 2000)

Signalized Intersection		Unsignalized Intersection	
<u>LOS</u>	<u>Control Delay per Vehicle (seconds)</u>	<u>LOS</u>	<u>Control Delay per Vehicle (seconds)</u>
A	≤10	A	≤10
B	>10 and ≤20	B	>10 and ≤15
C	>20 and ≤35	C	>15 and ≤25
D	>35 and ≤55	D	>25 and ≤35
E	>55 and ≤80	E	>35 and ≤50
F	>80	F	>50

For the analysis of the study network, several assumptions have been applied based on the collected data, and information available from appropriate agencies. Following assumptions were made for different input parameters:

- Terrain – The terrain is assumed to be “level” based on field observations
- Heavy vehicle percentage – The AM and PM peak hours heavy vehicle percentages for each movement on each intersection were determined from the counts
- Peak Hour Factors (PHFs) – PHFs for AM and PM peak hours for each movement on each intersection were determined from the counts
- Lane Width - 12 ft standard lane width was considered for analysis
- Area type – The land use in the study area is a non-business district, considered as “other” in Synchro

Figure 8 - Level of Service (LOS) Descriptions

<u>LOS</u>	<u>Roadway Segments or Controlled Access Highways</u>	<u>Intersections</u>	
A	Free flow, low traffic density	No vehicle waits longer than one signal indication.	
B	Delay is not unreasonable, stable traffic flow	On a rare occasion, motorists wait through more than one signal indication	
C	Stable condition, movements somewhat restricted due to higher volumes, but not objectionable for motorists.	Intermittently, drivers wait through more than one signal indication and occasionally backups may develop behind left turning vehicles, traffic flow still stable and acceptable.	
D	Movements more restricted queues and delays may occur during short peaks, but lower demands occur often enough to permit clearing, thus preventing excessive backups.	Delays at intersections may become extensive with some, especially left-turning vehicles waiting two or more signal indications, but enough cycles with lower demand occur to permit periodic clearance, thus preventing excessive backups.	
E	Actual capacity of the roadway involves delay to all motorists due to congestion.	Very long queues may create lengthy delays, especially for left turning vehicles.	
F	Forced flow with demand volumes greater than capacity resulting in complete congestion. Volumes drop to zero in extreme cases.	Backups from locations downstream restrict or prevent movement of vehicles out of approach, creating a storage area during part or all of an hour.	

SOURCE: A Policy on Design of Design of Urban Highways and Arterial Streets - A material published in Highway Capacity Manual, National Academy of Sciences, 1965.

The results of the capacity analysis for 2009 Existing conditions are indicated in Table 6. It can be seen from the results table that all intersections operate at an acceptable LOS D or better during the AM peak hour. During the PM peak hour, all intersections operate at an acceptable LOS except for the intersection of Forest Hill Avenue and Powhite Parkway SB ramp. The analysis results however indicate that side streets at several unsignalized intersections operate below the acceptable levels of service and consequently experienced longer traffic delays. The intersections approaches experiencing unacceptable levels of service are discussed below:

Forest Hill Avenue at Melbourne Road – The northbound approach to this intersection operates at LOS “F” with significant delays both during the AM and PM peak hours and the southbound approach operates at LOS “F” during the PM peak hour. The north and south approaches to the intersection are stop-controlled and the vehicles on Melbourne Drive wait for a gap from the main street traffic to turn or cross Forest Hill Avenue which causes large delays and develop queue.

Forest Hill Avenue at Windsorview Drive – The southbound approach to this intersection operates at LOS “E” and “F” during the AM and PM peak hours respectively. The southbound approach on Windsorview Drive is stop-controlled and therefore, traffic on the side-street incurs high delays due to insufficient availability of gaps in traffic on Forest Hill Avenue.

Forest Hill Avenue at Woodberry Lane – The southbound approach of this intersection at Woodberry Lane is stop-controlled and it operates at LOS “F” with 54 sec of delay during the PM peak hour. The approach operates at an acceptable LOS during the AM peak hour.

Forest Hill Avenue at Rettig Road – The northbound approach to this intersection operates at LOS “F” both during the AM and PM peak hours. The southbound approach operates at LOS “F” during the PM peak hour with a significant delay of 419 sec. Both the northbound and southbound approaches on Rettig Road are stop-controlled.

Forest Hill Avenue at Heartwood Road – The northbound approach on Heartwood Road is stop-controlled and it operates at LOS E during the AM peak hour. The approach operates at an acceptable LOS B during the PM peak hour.

Forest Hill Avenue at Willow Oaks Country Club Entrance – The northbound approach to this intersection operates at an acceptable LOS F during the PM peak hour with 119 sec of delay. The northbound approach to this intersection is stop-controlled.

Forest Hill Avenue at Powhite Parkway Southbound Ramp – The southbound right-turn movement at this intersection operates at an unacceptable LOS “F” during the PM peak hour. The heavy right-turn movement from Powhite Parkway westbound/southbound off-ramp yields to eastbound through movement on Forest Hill Avenue and thus incurs significant delay.

Table 6: 2009 Existing Condition LOS Analysis Results

<u>INTERSECTION</u>	<u>TYPE OF CONTROL</u>	<u>MOVEMENT APPROACH</u>	<u>AM PEAK HOUR</u>		<u>PM PEAK HOUR</u>	
			<u>LEVEL OF SERVICE</u>	<u>DELAY (SEC/VEH)</u>	<u>LEVEL OF SERVICE</u>	<u>DELAY (SEC/VEH)</u>
1 Hathaway Rd Old Westham Rd	Unsignalized	EB LR	B	10.9	B	12.9
		EB Overall	B	10.9	B	12.9
		NB L	A	8	A	8.1
		NB T	A	0	A	0
		NB Overall	A	3.8	A	3.5
		SB LR	A	0	A	0
		SB Overall	A	0	A	0
		Intersection Overall	A	4.2	A	3.5
2 Hathaway Rd Forest Hill Ave	Signalized	EB L	A	8.6	D	35.8
		EB TR	B	16	B	16.8
		EB Overall	B	15.4	B	19.4
		WB L	B	10.8	B	10.1
		WB TR	B	16.1	C	27.5
		WB Overall	B	15.9	C	26.6
		NB L	D	40	D	39.9
		NB T	D	47.7	D	49.3
		NB R	D	46.7	D	46.7
		NB Overall	D	44	D	45.3
		SB L	C	34.7	D	38.3
		SB TR	D	42.3	D	50.7
		SB Overall	D	36.5	D	44.7
		Intersection Overall	B	19.6	C	27.8
3 Melbourne Rd Forest Hill Ave	Unsignalized	EB LT	A	0.5	A	1
		EB TR	A	0	A	0
		EB Overall	A	0.3	A	0.5
		WB L	B	14.2	B	11.4
		WB T	A	0	A	0
		WB TR	A	0	A	0
		WB Overall	B	0.2	A	0.1
		NB LTR	F	203.8	F	884.4
		NB Overall	F	203.8	F	884.4
		SB LT	F	92.2	F	439.9
		SB R	B	12.4	C	17.1
		SB Overall	C	23.9	F	187.1
Intersection Overall	A	4.1	C	20.6		

Table 6 -2009 Existing Condition LOS Analysis Results (Continued)

<u>INTERSECTION</u>	<u>TYPE OF CONTROL</u>	<u>MOVEMENT APPROACH</u>	<u>AM PEAK HOUR</u>		<u>PM PEAK HOUR</u>	
			<u>LEVEL OF SERVICE</u>	<u>DELAY (SEC/VEH)</u>	<u>LEVEL OF SERVICE</u>	<u>DELAY (SEC/VEH)</u>
4 Windsorview Dr Forest Hill Ave	Unsignalized	EB LT	A	0.7	A	2.2
		EB T	A	0	A	0
		EB Overall	A	0.2	A	0.8
		WB TR	A	0	A	0
		WB R	A	0	A	0
		WB Overall	A	0	A	0
		SB LR	E	44.3	F	90
		SB Overall	E	44.3	F	90
		Intersection Overall	A	0.7	A	1.2
5 Woodberry Ln Forest Hill Ave	Unsignalized	EB T	A	0	A	0
		EB TR	A	0	A	0
		EB Overall	A	0	A	0
		WB LT	A	0.6	A	0.7
		WB T	A	0	A	0
		WB Overall	A	0.2	A	0.2
		NB LR	D	33.8	F	53.8
		NB Overall	D	33.8	F	53.8
		Intersection Overall	A	0.5	A	0.4
6 Rettig Rd Forest Hill Ave	Unsignalized	EB LT	A	0.5	A	1.4
		EB TR	A	0	A	0
		EB Overall	A	0.2	A	0.7
		WB LT	A	0	A	0.2
		WB TR	A	0	A	0
		WB Overall	A	0	A	0.1
		NB LTR	F	70.8	B	13.2
		NB Overall	F	70.8	B	13.2
		SB LTR	F	99	F	415.5
SB Overall	F	99	F	415.5		
Intersection Overall	A	2.4	A	3.6		
7 Heartwood Rd Forest Hill Ave	Unsignalized	EB T	A	0	A	0
		EB TR	A	0	A	0
		EB Overall	A	0	A	0
		WB LT	A	0	A	0.2
		WB T	A	0	A	0
		WB Overall	A	0	A	0.1
		NB LR	E	47.1	B	12.7
		NB Overall	E	47.1	B	12.7
Intersection Overall	A	0.2	A	0.1		

Table 6 - 2009 Existing Condition LOS Analysis Results (Continued)

<u>INTERSECTION</u>	<u>TYPE OF CONTROL</u>	<u>MOVEMENT APPROACH</u>	<u>AM PEAK HOUR</u>		<u>PM PEAK HOUR</u>	
			<u>LEVEL OF SERVICE</u>	<u>DELAY (SEC/VEH)</u>	<u>LEVEL OF SERVICE</u>	<u>DELAY (SEC/VEH)</u>
8 Willow Oaks C.C. Entr. Forest Hill Ave	Unsignalized	EB LT	A	1.5	A	3.4
		EB T	A	0	A	0
		EB Overall	A	0.5	A	1.2
		WB TR	A	0	A	0
		WB R	A	0	A	0
		WB Overall	A	0	A	0
		SB LR	D	31.9	F	118.9
		SB Overall	D	31.9	F	118.9
		Intersection Overall	A	0.6	A	2.6
9 Glyndon Ln Forest Hill Ave	Unsignalized	EB T	A	0	A	0
		EB TR	A	0	A	0
		EB Overall	A	0	A	0
		WB LT	A	0	A	0.6
		WB T	A	0	A	0
		WB Overall	A	0	A	0.1
		NB LR	C	15.6	B	12.5
		NB Overall	C	15.6	B	12.5
		Intersection Overall	A	0.1	A	0.1
10 Southbound Ramp Forest Hill Ave	Signalized	EB T	A	4.6	A	7.4
		EB Overall	A	4.6	A	7.4
		WB T	A	3.4	A	8.1
		WB Overall	A	3.4	A	8.1
		SB L	D	46.7	B	19.2
		SB R	D	42.3	F	224.9
		SB Overall	D	44.5	F	145.2
		Intersection Overall	B	13.1	E	55.3
11 Northbound Ramp Forest Hill Ave	Unsignalized	No conflicting movements at this intersection.				

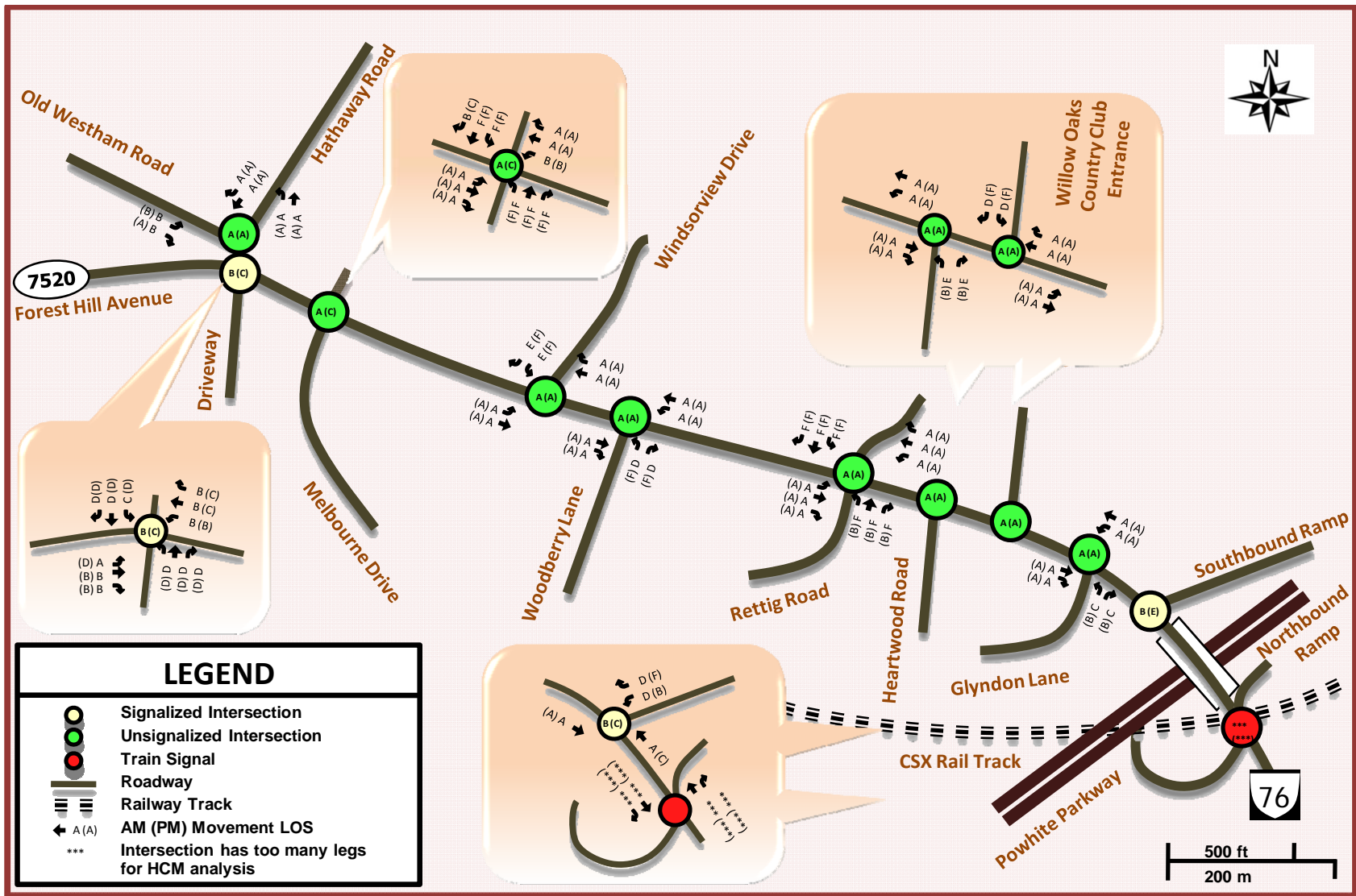


Figure 9: 2009 Existing Level of Service (LOS)



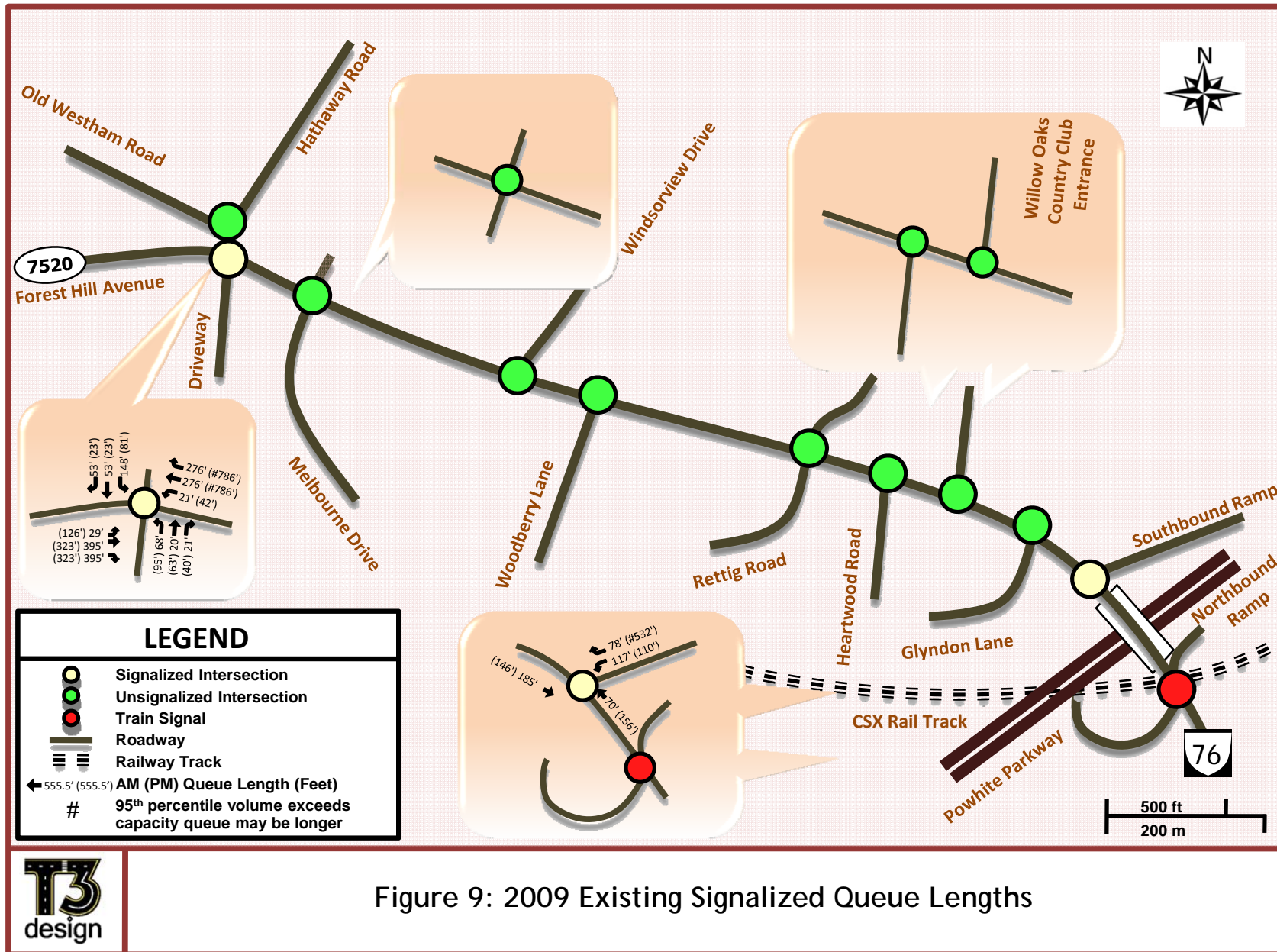


Figure 9: 2009 Existing Signalized Queue Lengths



Queue Length Analysis – Existing Conditions

A queue length analysis was conducted for the study intersections. Table 7 presents the results of the queuing analysis for the Existing traffic conditions. The results are reported for the maximum of the AM or PM peak hour volumes. The shaded cell in the table reports the AM peak hour volume. Also, in the table below, the queue length results are reported for the approaches at the study intersections that are expected to impact operations for adjacent intersections or driveways. For the remaining approaches, the queue lengths are discussed.

Table 7 - Queuing Analysis Results - Existing Condition

Intersection	Control Type	Movement	Peak Hour Volume (vph)	95th Percentile Queue length (ft)
Hathaway Rd at Old Westham Rd		NB L	131	10
Forest Hill Avenue at Hathaway Rd	Signalized	EB L	126	126
		EB TR	1134	395
		WB L	72	42
		WB TR	1523	786
		NB L	64	95
		NB T	49	63
		NB R	75	40
		SB L	275	148
		SB TR	139	23
Forest Hill Avenue at Melbourne Dr		WB L	10	2
Forest Hill Avenue at SB Off-Ramp	Signalized	SB L	438	110
		SB R	662	532
		EB T	1387	185
		WB T	1042	156

Hathaway Road at Old Westham Road – The 95th percentile queue length for the northbound left-turn movement is reported to be 10 ft which is within the existing available storage length of 40ft. Therefore, the queue for the northbound approach does not impact traffic on Forest Hill Avenue. The maximum queue lengths for the eastbound left and right turning movements at this intersection are reported to be 17 ft which occurs during the AM peak hour. For the southbound approach a “zero” queue length is reported during the AM and PM peak hour.

Forest Hill Avenue at Hathaway Road – At the intersection of Forest Hill Avenue and Hathaway Road, a 95th percentile queue length of 126 ft is reported for the eastbound left-turning movement which is within the existing storage length of 220 ft. For the eastbound through-right movement, a 95th percentile queue length of 395 ft was reported which extends beyond the driveway to the shopping center located south of Forest Hill Avenue and also partially blocks access to Gravel Hill Road.

For the westbound left-turning movement, a 95th percentile queue length of 42 ft was reported which is within than the existing available storage length of 90 ft. However, during the PM peak hour, for the westbound through movement a 95th percentile queue length of 786 ft. was reported, which extends well

beyond the intersection and blocks the northbound and southbound movements at Melbourne Drive and the other accesses located on the north side of Forest Hill Avenue.

For the northbound left, through, and right-turning movements, the 95th percentile queue lengths are reported to be 95 ft, 63 ft, and 40 ft, respectively, which are within than the available storage length of 140 ft. For the southbound left and through-right turning movements, the 95th percentile queue lengths are reported to be 148 ft and 23 ft, respectively. The 148-ft queue length for the southbound left-turning movement exceeds the storage length of 50 ft available at this approach. The queue length for the southbound left-turning movement at the intersection is reported for the AM peak hour traffic condition. Synchro reports that during the AM peak hour, the 95th percentile volume for the southbound left-turning movement exceeds capacity and therefore, the queue is expected to be longer than the reported queue length.

Forest Hill Avenue at Melbourne Drive – For the westbound left-turning movement at this intersection, the maximum queue length of 2 ft is reported which is within the available storage length of 70 ft. Since, the eastbound and westbound through movement operates freely at the intersection of Forest Hill Avenue and Melbourne Drive, minimal queue lengths are reported for these approaches. The maximum queue length of 162 ft is reported for the northbound left-through-right, movement; and 27 ft and 3 ft are reported for the southbound left and through-right movements, respectively.

Forest Hill Avenue at Windsorview Drive The eastbound and westbound approaches at this intersection operate freely therefore, “zero” or minimal queues are reported for these approaches. For the southbound left-right movement, a 95th percentile queue length of 32 ft is reported.

Forest Hill Avenue at Woodberry Lane – The eastbound and westbound approaches at this intersection operate freely, therefore “zero” or minimal queues are reported for these approaches. For the northbound left-right movement, a maximum queue length of 18 ft is reported during the AM peak hour.

Forest Hill Avenue at Rettig Road – Like the other unsignalized intersections, the eastbound and westbound approaches at this intersection operate freely; therefore “zero” or minimal queues are reported for these approaches. For the northbound and southbound left-through-right movement, the maximum queue lengths of 10 ft and 70 ft were reported, respectively.

Forest Hill Avenue at Heartwood Road – The eastbound and westbound approaches at this intersection operate freely; therefore “zero” or minimal queues were reported for these approaches. For the northbound shared left and right-movement, a 95th percentile queue length of 7 ft is reported.

Forest Hill Avenue at Willow Oaks Country Club Entrance – The eastbound and westbound approaches at this intersection operate freely, therefore “zero” or minimal queues are reported for these approaches. For the southbound left and right-turn movements, a 95th percentile queue length of 52 ft is reported.

Forest Hill Avenue at Glyndon Lane – The eastbound and westbound approaches at this intersection operate freely, therefore zero or minimal queues are reported for these approaches. For the northbound shared left and right-turn movement, a 95th percentile queue length of 4 ft is reported.

Forest Hill Avenue at Powhite Parkway SB On/Off Ramps –The queuing analysis results for the southbound right-turning movement at the intersection of Forest Hill Avenue and Powhite Parkway SB off-ramp indicated a 95th percentile queue length of 532 ft. Synchro reports that the 95th percentile volume for this movement exceeds capacity and the queue is expected to be longer than the reported queue length of 532 ft. Based on the available storage length of 180 ft on Forest Hill Avenue, the queue is expected to extend onto the SB off-ramp.

ANALYSIS OF FUTURE CONDITIONS

Traffic Growth Rate

Traffic volumes are expected to increase between the Existing year 2009 and the Build year 2011. Similarly, the traffic volumes are also expected to increase between the Build and the Design years. To account for the future peak hour traffic volumes, a traffic growth rate has been applied to the Existing year traffic volumes.

The projected growth rates on Forest Hill Avenue was estimated based on historical AADT data published by VDOT, historical AADT data provided by Statewide Planning System (SPS), and AADT data from the Richmond Regional Model.

City of Richmond Regional Model

Based on the projected traffic volumes from the City of Richmond Regional Model an average annual growth rates for the Opening and Design years for Forest Hill Avenue were estimated. On Forest Hill Avenue the Regional model indicated a slight decline in traffic growth between 1 to 2 percent on the study segment. Since, the City of Richmond Regional model provided a negative trend in traffic growth between the Existing and the future analysis years, the traffic growth rates from the City of Richmond Regional model were not used to project the Existing traffic volumes for the future analysis years.

Demographic Data

The City of Richmond use inputs of projected households, population, and employment data by sub-areas called Traffic Analysis Zones (TAZs). This demographic data was analyzed for TAZs adjacent to the study segment and randomly in the broader surrounding area to estimate the growth in the number of household and employments. The analysis indicated a 1.5 percent and 0.9 percent increase in the numbers of households and employments between years 2000 and 2011 respectively and a 1.3 percent and 0.8 percent increase in the numbers of households and employment respectively between 2011 and 2031.

Historical AADT Data

The source for the historical AADT data was the VDOT published data available for 2005, 2006, and 2007 and the Statewide Planning System (SPS) database. The SPS database had AADT information for historical years ranging from 1973 to 2007. Based on historical traffic volume information regression models for different periods between 1973 and 2007 were developed and growth rates were estimated from each model. The growth rate estimates from the regression models are indicated in Table 8.

Table 8: Traffic Growth Rates from Historical Traffic Volume Data

Data Between		Annual Growth Rate
1973	2007	1.13%
1993	2003	2.75%
2005	2007	5.44%
1993	2007	1.39%
1998	2007	0.46%

A review of traffic growth rate estimates based on the Richmond Regional Model suggests a slight decline of 1% to 2% in traffic volume on the study segment; however the traffic growth rate estimates from historical AADT data and demographic data suggest a slight increase in traffic volume ranging from

0.46% to 5.4% on Forest Hill Avenue study segment. As 0.46 percent is considered too low, 5.4% is considered too high to apply to the existing traffic volumes on Forest Hill Avenue. Since the timeframe of 1993 to 2007 represents a recent period that encompasses a broad range of positive and negative growth in the past 15 years, it was decided to use 1.39% growth rate for traffic projection on Forest Hill Avenue and side streets for the Build and the Design Years.

Traffic Forecasting Methodology

Future traffic volumes were projected for the 2011 – Build year, and the Design year of 2030 using a 1.39 percent average annual growth rate. The peak hour traffic volumes were developed by applying the above annual growth rate to the 2009 (Existing) intersection turning movement volumes of the study intersections and compounding annually using the methodology with parameters defined below:

$$V_{Future\ Year} = V_{2008} \times (1 + i)^n$$

Where, $V_{Future\ Year}$ = Analysis year future background traffic volume;

V_{2008} = 2008 existing traffic volume;

i = growth rate (%); and

n = number of years.

Figure 10 and Figure 11 indicate peak hour traffic volumes for the Opening year and the Design year, respectively.

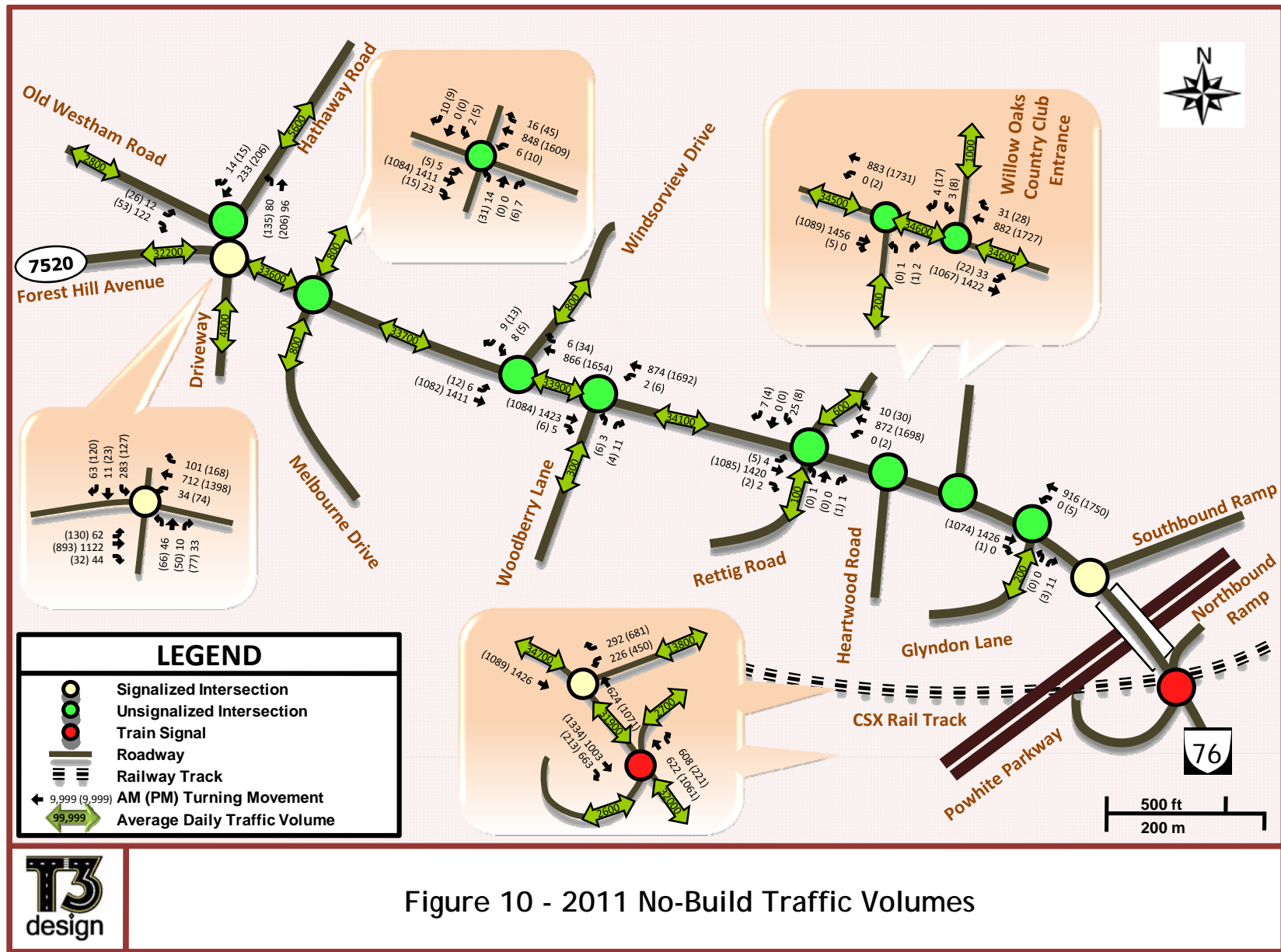


Figure 10 - 2011 No-Build Traffic Volumes



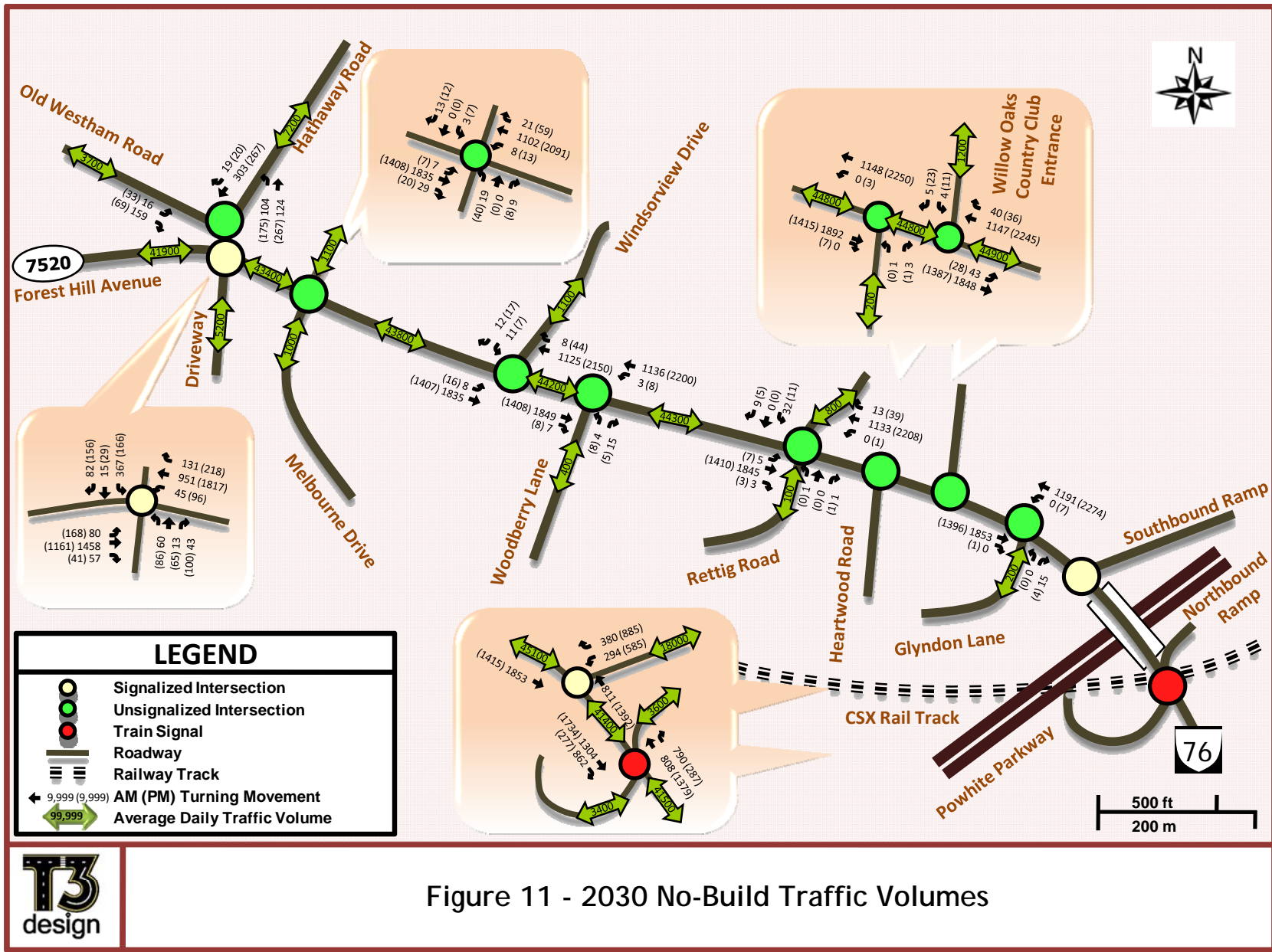


Figure 11 - 2030 No-Build Traffic Volumes



Traffic Signal Warrant Analysis – Existing & No-Build Conditions

Selection of Analysis Intersections

The Forest Hill Avenue widening project includes conducting up to two signal warrant analyses within the study corridor for both the opening year, 2011, and the design year, 2030. The signal warrant analyses require eight to twelve hours turning movement counts data collection at the proposed locations. Twelve hour Turning Movement Counts were collected at the Forest Hill Avenue intersections at Rettig Road and Windsorview Road for the purpose of performing a traffic signal warrant analysis for each of these intersections. The selection of these two intersections for analysis was based on the following factors:

1. Side streets delays at intersections in the Existing 2009 scenario, and the opening and design year No-Build scenarios;
2. Crash history at the intersections, including angled crashes that could be deemed correctable by a traffic signal installation;
3. Peak hour traffic volumes from side streets;
4. Heavy vehicle percentage; and
5. Constructability factors, such as traffic signal spacing.

Based on the above criteria, the intersections of Forest Hill Avenue at Rettig Road and Forest Hill Avenue at Windsorview Drive were selected for traffic signal warrant analyses. At the Rettig Road intersection, 12 total crashes occurred during the three-year period from 2006 to 2008, including two angled crashes. A total of 13 crashes occurred during the same three-year period, including two angled crashes, at the Windsorview Drive intersection. In addition, the capacity analyses also indicate that the side streets at both intersections operate at unacceptable level of service E or F during the Existing Year, Opening Year No-Build, and Design Year No-Build scenarios for both AM and PM peak periods.

The other two intersections that qualified for traffic signal warrant analyses based on either high numbers of crashes or higher side street delays were Forest Hill Avenue at Glyndon Lane and Forest Hill Avenue at Melbourne Drive. The intersection of Forest Hill Avenue at Glyndon Lane had 17 crashes during the past three years including three angled crashes. However, the capacity analyses indicate that this intersection operates at acceptable LOS in the Existing Year, Opening Year No-Build, and the Design Year No-Build scenarios during the AM and PM peak hours.

The intersection of Forest Hill Avenue at Melbourne Drive has high side street delays and operates at unacceptable LOS in the Existing Year, Opening Year No-Build, and Design Year No-Build scenarios. A total of nine crashes occurred during the past three years at this intersection, including one angled crashes, which is lower than the numbers of “correctable” crashes at the Forest Hill Avenue intersections at Rettig Road and Windsorview Drive. Also, the signalized intersection of Forest Hill Avenue at Hathaway Road is located at approximately 250 ft east of this intersection and experiences queuing during the PM peak hours in the westbound direction.

Signal Warrant Analysis Results – Existing and No-Build Conditions

As prescribed in the Manual on Uniform Traffic Control Devices, 2003 Edition (MUTCD), the determination of whether to pursue the installation of a traffic signal should be based on an evaluation of traffic conditions, pedestrian characteristics, and the physical characteristics of a location. The traffic signal warrants contained within the MUTCD consist of a list of factors to be used, when applicable, to determine whether consideration should be given to the installation of a traffic signal. There are eight warrants provided by the MUTCD. The following warrants were found to be applicable to this corridor:

1. Warrant 1 – Eight-Hour Vehicular Volume
2. Warrant 2 – Four-Hour Vehicular Volume
3. Warrant 3 – Peak Hour

The traffic signal warrant analyses conducted for the intersections of Forest Hill Avenue and Rettig Road and Forest Hill Avenue at Windsorview Road found that no warrants are met for the Existing Year. To assess a “worst-case” scenario, no right-turn volume reductions were applied.

Capacity Analysis – No Build Traffic Conditions

Capacity analyses were performed with the intent to provide insight into the level of operation of the transportation network under future traffic conditions without the proposed project. The No-Build operations for the study intersections were analyzed using Synchro™ version 7, which is based on the 2000 Highway Capacity Manual (HCM) methodologies. The assumptions considered for this analysis include a 12-ft standard lane width, peak hour factors for each intersection approach derived from existing (2009) traffic counts, non-central business district area type, and the heavy vehicle percentage is based on existing (2009) traffic counts.

Capacity Analysis - 2011 Opening Year No-Build Traffic Conditions

Table 9 summarizes the level of service results of the study network for 2011 No-Build traffic conditions. Since the planned improvements for the corridor will all take place in the Build Condition, the analysis performed for the 2011 No-Build scenario is based on the (2009) existing geometry. The lane group LOS results are detailed in Figure 12.

The analysis reveals that for the AM and PM peak periods the operations of the study intersections were reflective of whether the intersection were signalized. For example, during the AM peak hour, the operations at the unsignalized intersections consisted of significant side-street delay. At the Forest Hill Avenue intersections of Melbourne Drive/Parking Lot, Woodberry Lane, Rettig Road, and Heartwood Road the side-street approach experience LOS E or LOS F. Although, these results reflect the approaches being over capacity, the degree of unacceptable approach delay ranged from 36.3 sec/veh at Woodberry Lane (NB) to 124.9 sec/veh at Rettig Road (SB). In these cases, the heavy demand and free-flow operations of the mainline significantly limit the acceptable gaps for side-street traffic. It is important to note that the side-street traffic volumes at the unsignalized intersections are significantly less than the mainline volumes, with the highest stop-controlled side-street approach volume being 32 vph.

At the signalized intersection of Forest Hill Avenue and Hathaway Drive, the side-street approaches also experience a disproportionate amount of delay due to mainline demand. However, the northbound and southbound approaches at this intersection experience 43.4 sec/veh and 38.2 sec/veh of delay, respectively, operating both at LOS D during the AM peak hour. At the signalized intersection of Forest Hill Avenue and the Powhite Parkway Southbound off-ramp the southbound approach also operates at a LOS D (39.4 sec/veh).

During the PM peak hour, the conditions experienced during the AM peak hour are exacerbated by a moderately higher and less directional traffic demand on Forest Hill Avenue. The delays for the side-street approach were determined to be significantly higher than during the AM peak hour. Each of the unsignalized intersections on Forest Hill Avenue have side-street approaches that operate at LOS E or LOS F, with the exception of the intersections at Heartwood Road and Glyndon Lane, which have no left-turn egress movements (due to a volume of 0 vph). These unacceptable approach delays range from 58.9 sec/veh at Woodberry Lane (NB) to 353.7 sec/veh at Rettig Road (SB).

At the signalized intersection of Forest Hill Avenue and Hathaway Road, both side-street approaches (NB and SB) experience a LOS D. The delays for the northbound and southbound approaches are 44.6 sec/veh and 43.1 sec/veh, respectively. At the intersection of Forest Hill Avenue and Powhite Parkway Southbound off-ramp, the southbound approach operates at a LOS C during the PM peak hour. The demand for this approach is significantly greater than during the AM given the time-of-day traffic patterns. However, the PM peak hour cycle length of 60 seconds, as opposed to 110 seconds during the AM peak, allows for more efficient operations despite the change in demand.

Capacity Analysis - 2030 Design Year No-Build Traffic Conditions

The level of service results for the study network for 2030 No-Build traffic conditions are summarized in Table 10. Similar to the 2011 No-Build geometry, the analysis performed for the 2030 No-Build scenario uses the (2009) existing geometry. The lane group LOS results are detailed in Figure 13.

The results of the analysis indicate that the growth in demand along Forest Hill Avenue, further exacerbates the congestion experienced by the stop-controlled side-street traffic. During the AM peak hour, the side-street delays become considerably high for some approaches, while others remain consistent with what was experienced in the 2011 No-Build condition. Some of the more notable instances of considerable delay along Forest Hill Avenue include the northbound approach at Melbourne Drive (903.5 sec/veh), the southbound approach at Rettig Road (781.7 sec/veh), and the northbound approach at Rettig Road (290.0 sec/veh). Most of the other intersections with unacceptable side-street LOS have an approximate range of approach delay between 1.5 to 2 minutes.

For the side-street approaches with significant approach delay, the approach volumes are substantially lower than the mainline volumes, despite the LOS E and LOS F results. At the intersection of Forest Hill Avenue and Melbourne Drive the northbound approach with 903.5 sec/veh of delay serves left-turn and right-turn volumes of 14 vph and 7 vph, respectively. The southbound approach at the intersection of Forest Hill Avenue and Rettig Road, which experiences a delay of 781.7 sec/veh serves left-turn and right-turn volumes of 32 vph and 9 vph, respectively. However, during the AM peak period on Forest Hill Avenue the eastbound demand increases by approximately 400 vph, while the westbound demand increases by approximately 300 vph.

At the signalized intersections along Forest Hill Avenue, the operations are similar to the AM operations in the 2011 No-Build scenario. Despite the increase in demand on the mainline, the intersection of Forest Hill Avenue and Hathaway Road operates at an acceptable LOS C, with both side-street approaches operating at LOS D. This is consistent with the operations at the intersection of Forest Hill Avenue and Powhite Parkway Southbound off-ramp, where the overall intersection operates at LOS B. The SB Off Ramp approach operates at LOS D (37.2 sec/veh).

During the PM peak hour, the conditions along the corridor become significantly more congested, with both signalized intersections have some approaches that operate at LOS E or LOS F. The signalized intersection of the Forest Hill Avenue and Hathaway Road, the westbound and southbound approaches operate at LOS F and LOS E, respectively. Based on several volume adjustment factors, the westbound through (WBT) volume of 1817 vph becomes a lane group flow of 2149 vph, which exceeds the lane group capacity of 1924 vph. As a result, the volume-to-capacity ratio (V/C) is 1.12. The southbound approach operates at a LOS E, with 56.1 sec/veh of delay.

At the intersection of Forest Hill Avenue and Powhite Parkway Southbound off-ramp, the westbound approach degrades to LOS E given the increase in demand on Forest Hill Avenue. Based on a volume of 1392 vph and a peak hour factor (PHF) of 0.91, the adjusted flow rate for this approach is 1530 vph which exceeds the lane group capacity of 1460 vph. A primary influence on this lane group capacity is the proportion of the green-time allocated to Forest Hill Avenue in the traffic signal timing plan, which is less

than the proportion of green-time allocated to the Southbound off-ramp approach during the AM peak period. Even with a slightly greater proportion of green-time, the Southbound off-ramp approach also experiences a LOS E (62.7 sec/veh), given the relatively high SBR volume of 885 vph entering Forest Hill Avenue.

The operations at the unsignalized intersections during the PM peak reflect conditions significantly worse than the AM peak period operations. The Synchro™ traffic modeling analysis results include an “error message” for some of the stop-controlled approaches, indicating that the delay is too significant to calculate. These results occur for the northbound approach at Melbourne Drive, the southbound approach at Rettig Road, and the southbound approach at the Willow Oaks Country Club Entrance. During the PM peak the only stop-controlled approaches that do not experience and unacceptable LOS E or LOS F are the northbound approaches at the Forest Hill Avenue intersections of Heartwood Road and Glyndon Lane, with have no left-turn movements from the side-streets.

Table 9: 2011 No-Build LOS Analysis Results

<u>INTERSECTION</u>	<u>TYPE OF CONTROL</u>	<u>MOVEMENT APPROACH</u>	<u>AM PEAK HOUR</u>		<u>PM PEAK HOUR</u>	
			<u>LEVEL OF SERVICE</u>	<u>DELAY (SEC/VEH)</u>	<u>LEVEL OF SERVICE</u>	<u>DELAY (SEC/VEH)</u>
1 Hathaway Rd Old Westham Rd	Unsignalized	EB LR	B	11	B	13.2
		EB Overall	B	11	B	13.2
		NB L	A	8	A	8.2
		NB T	A	0	A	0
		NB Overall	A	3.8	A	3.5
		SB LR	A	0	A	0
		SB Overall	A	0	A	0
		Intersection Overall	A	4.2	A	3.5
2 Hathaway Rd Forest Hill Ave	Signalized	EB L	A	8.3	D	36.5
		EB T	B	16.2	B	18.4
		EB Overall	B	15.5	C	20.9
		WB L	B	10.1	B	11.3
		WB TR	B	15.6	C	32.9
		WB Overall	B	15.3	C	31.8
		NB L	D	39.5	D	38.6
		NB LT	D	47.1	D	49.5
		NB R	D	46.2	D	46.6
		NB Overall	D	43.5	D	44.9
		SB L	D	36.6	D	36.3
		SB TR	D	43.8	D	50.1
		SB Overall	D	38.2	D	43.5
Intersection Overall	B	19.7	C	30.7		
3 Melbourne Rd Forest Hill Ave	Unsignalized	EB LT	A	0.6	A	1.1
		EB TR	A	0	A	0
		EB Overall	A	0.3	A	0.5
		WB L	B	14.7	B	11.7
		WB T	A	0	A	0
		WB TR	A	0	A	0
		WB Overall	A	0.2	A	0.1
		NB LTR	F	265.7	F	439.4
		NB Overall	F	265.7	F	439.4
		SB LT	F	104.6	F	557.4
		SB R	B	12.6	C	17.6
SB Overall	D	25.8	F	234.6		
Intersection Overall	A	5.1	A	7.4		

Table 9: 2011 No-Build LOS Analysis Results (Continued)

INTERSECTION	TYPE OF CONTROL	MOVEMENT APPROACH	AM PEAK HOUR		PM PEAK HOUR	
			LEVEL OF SERVICE	DELAY (SEC/VEH)	LEVEL OF SERVICE	DELAY (SEC/VEH)
4 Windsorview Dr Forest Hill Ave	Unsignalized	EB LT	A	0.7	A	2.3
		EB T	A	0	A	0
		EB Overall	A	0.2	A	0.8
		WB TR	A	0	A	0
		WB R	A	0	A	0
		WB Overall	A	0	A	0
		SB LR	E	48.4	F	109.1
		SB Overall	E	48.4	F	109.1
		Intersection Overall	A	0.7	A	1.2
5 Woodberry Ln Forest Hill Ave	Unsignalized	EB T	A	0	A	0
		EB TR	A	0	A	0
		EB Overall	A	0	A	0
		WB LT	A	0.6	A	0.7
		WB T	A	0	A	0
		WB Overall	A	0.2	A	0.2
		NB LR	E	36.3	F	58.9
		NB Overall	E	36.3	F	58.9
		Intersection Overall	A	0.5	A	0.5
6 Rettig Rd Forest Hill Ave	Unsignalized	EB LT	A	0.5	A	1.9
		EB TR	A	0	A	0
		EB Overall	A	0.2	A	1
		WB LT	A	0	A	0.2
		WB TR	A	0	A	0
		WB Overall	A	0	A	0.1
		NB LTR	F	78.9	B	13.4
		NB Overall	F	78.9	B	13.4
		SB LTR	F	124.9	F	850.2
SB Overall	F	124.9	F	850.2		
Intersection Overall	A	3	A	6.9		
7 Heartwood Rd Forest Hill Ave	Unsignalized	EB T	A	0	A	0
		EB TR	A	0	A	0
		EB Overall	A	0	A	0
		WB LT	A	0	A	0.2
		WB T	A	0	A	0
		WB Overall	A	0	A	0.1
		NB LR	F	52.2	B	12.9
		NB Overall	F	52.2	B	12.9
		Intersection Overall	A	0.2	A	0.1

Table 9: 2011 No-Build LOS Analysis Results (Continued)

INTERSECTION	TYPE OF CONTROL	MOVEMENT APPROACH	AM PEAK HOUR		PM PEAK HOUR	
			LEVEL OF SERVICE	DELAY (SEC/VEH)	LEVEL OF SERVICE	DELAY (SEC/VEH)
8 Willow Oaks C.C. Entr. Forest Hill Ave	Unsignalized	EB LT	A	1.6	A	4.7
		EB T	A	0	A	0
		EB Overall	A	0.6	A	1.6
		WB TR	A	0	A	0
		WB R	A	0	A	0
		WB Overall	A	0	A	0
		SB LR	D	34.5	F	270.4
		SB Overall	D	34.5	F	270.4
		Intersection Overall	A	0.6	A	5.3
9 Glyndon Ln Forest Hill Ave	Unsignalized	EB T	A	0	A	0
		EB TR	A	0	A	0
		EB Overall	A	0	A	0
		WB LT	A	0	A	0.6
		WB T	A	0	A	0
		WB Overall	A	0	A	0.1
		NB LR	C	15.9	B	12.7
		NB Overall	C	15.9	B	12.7
		Intersection Overall	A	0.1	A	0.1
10 Southbound Ramp Forest Hill Ave	Signalized	EB T	A	7.1	A	18.4
		EB Overall	A	7.1	A	18.4
		WB T	A	5.3	A	22
		WB Overall	A	5.3	A	22
		SB L	D	39.8	A	10
		SB R	D	40.5	C	28.7
		SB Overall	D	40.2	C	21.5
				Intersection Overall	B	13.9
11 Northbound Ramp Forest Hill Ave *** Intersection has too many legs for HCM analysis.	Unsignalized	EB T	***	***	***	***
		EB TR	***	***	***	***
		EB Overall	***	***	***	***
		WB T	***	***	***	***
		WB TR	***	***	***	***
		WB Overall	***	***	***	***
				Intersection Overall	***	***

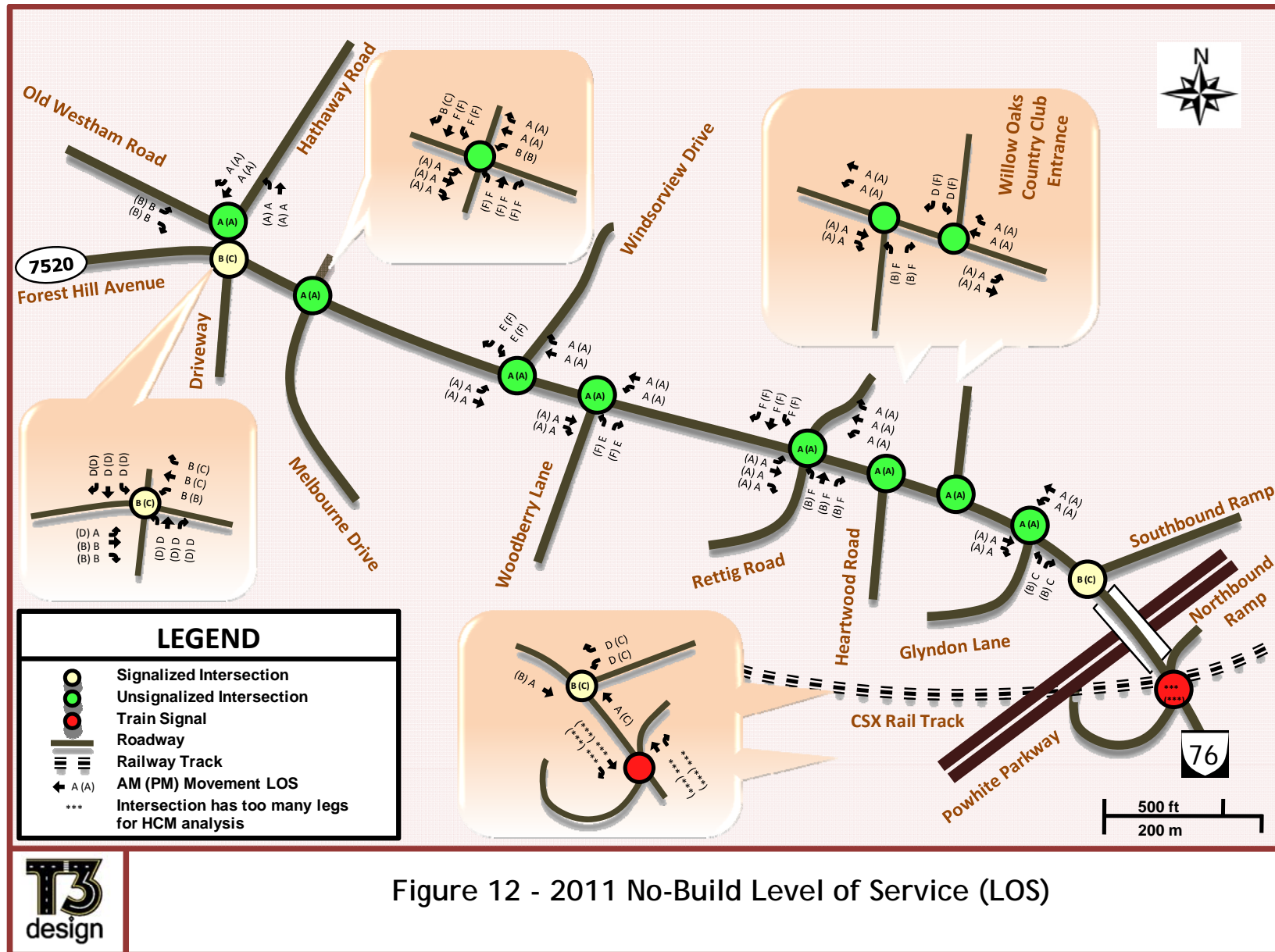


Table 10: 2030 No-Build LOS Analysis Results

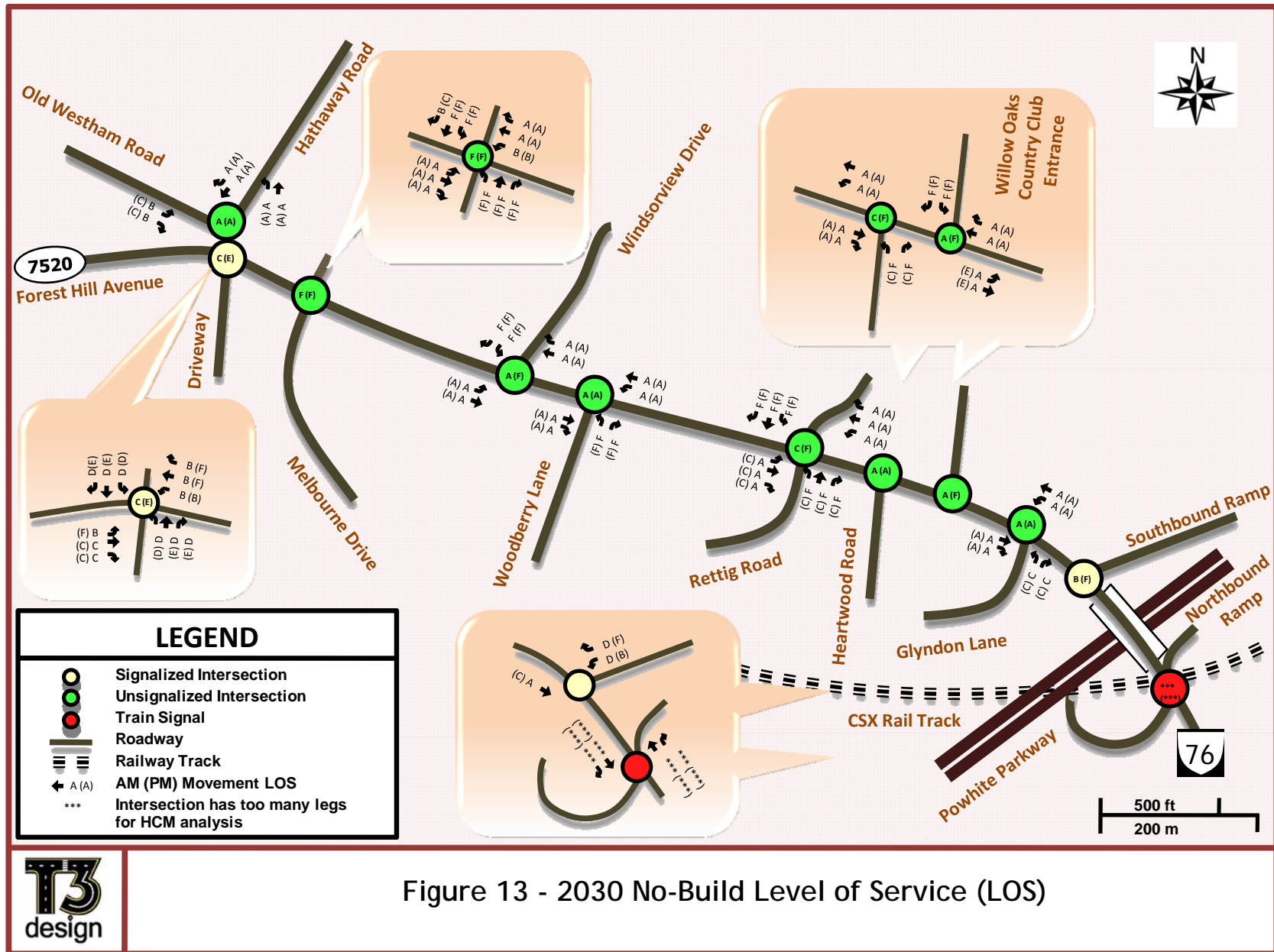
INTERSECTION	TYPE OF CONTROL	MOVEMENT APPROACH	AM PEAK HOUR		PM PEAK HOUR	
			LEVEL OF SERVICE	DELAY (SEC/VEH)	LEVEL OF SERVICE	DELAY (SEC/VEH)
1 Hathaway Rd Old Westham Rd	Unsignalized	EB LR	B	12.5	C	17
		EB Overall	B	12.5	C	17
		NB L	A	8.3	A	8.6
		NB T	A	0	A	0
		NB Overall	A	3.9	A	3.7
		SB LR	A	0	A	0
		SB Overall	A	0	A	0
		Intersection Overall	A	4.7	A	4.1
2 Hathaway Rd Forest Hill Ave	Signalized	EB L	B	12.5	F	113.6
		EB T	C	21.7	C	22.7
		EB Overall	C	20.9	D	35
		WB L	B	16.2	B	16.4
		WB TR	B	19.2	F	92.2
		WB Overall	B	19	F	88.1
		NB L	D	39.1	D	50.5
		NB LT	D	46.9	E	57.7
		NB R	D	45.7	E	56.2
		NB Overall	D	43.1	D	54.8
		SB L	D	38.7	D	45.4
		SB TR	D	44	E	66.5
		SB Overall	D	39.9	E	56.2
		Intersection Overall	C	23.8	E	65.2
3 Melbourne Rd Forest Hill Ave	Unsignalized	EB LT	A	1.3	A	3.3
		EB TR	A	0	A	0
		EB Overall	A	0.7	A	1.6
		WB L	B	28.5	C	15.9
		WB T	A	0	A	0
		WB TR	A	0	A	0
		WB Overall	B	0.3	A	0.1
		NB LTR	F	Err	F	Err
		NB Overall	F	Err	F	Err
		SB LT	F	1140.4	F	Err
		SB R	B	14.8	C	24.5
SB Overall	F	197.6	F	4151.1		
Intersection Overall	F	135.3	F	244.9		

Table 10: 2030 No-Build LOS Analysis Results (Continued)

INTERSECTION	TYPE OF CONTROL	MOVEMENT APPROACH	AM PEAK HOUR		PM PEAK HOUR	
			LEVEL OF SERVICE	DELAY (SEC/VEH)	LEVEL OF SERVICE	DELAY (SEC/VEH)
4 Windsorview Dr Forest Hill Ave	Unsignalized	EB LT	A	1.3	A	6.3
		EB T	A	0	A	0
		EB Overall	A	0.4	A	2.2
		WB TR	A	0	A	0
		WB R	A	0	A	0
		WB Overall	A	0	A	0
		SB LR	F	632.8	F	Err
		SB Overall	F	632.8	F	Err
		Intersection Overall	A	7.7	F	97.4
5 Woodberry Ln Forest Hill Ave	Unsignalized	EB T	A	0	A	0
		EB TR	A	0	A	0
		EB Overall	A	0	A	0
		WB LT	A	1.4	A	1.5
		WB T	A	0	A	0
		WB Overall	A	0.5	A	0.5
		NB LR	F	130.8	F	251.3
		NB Overall	F	130.8	F	251.3
		Intersection Overall	A	1.9	A	1.7
6 Rettig Rd Forest Hill Ave	Unsignalized	EB LT	A	1	C	18.2
		EB TR	A	0	A	0
		EB Overall	A	0.5	A	9.1
		WB LT	A	0	A	0.5
		WB TR	A	0	A	0
		WB Overall	A	0	A	0.3
		NB LTR	F	356	C	16.2
		NB Overall	F	356	C	16.2
		SB LTR	F	971.2	F	Err
SB Overall	F	971.2	F	Err		
		Intersection Overall	C	21	F	80.5
7 Heartwood Rd Forest Hill Ave	Unsignalized	EB T	A	0	A	0
		EB TR	A	0	A	0
		EB Overall	A	0	A	0
		WB LT	A	0	A	0.4
		WB T	A	0	A	0
		WB Overall	A	0	A	0.1
		NB LR	F	146.2	C	15.3
		NB Overall	F	146.2	C	15.3
		Intersection Overall	A	0.4	A	0.1

Table 10: 2030 No-Build LOS Analysis Results (Continued)

INTERSECTION	TYPE OF CONTROL	MOVEMENT APPROACH	AM PEAK HOUR		PM PEAK HOUR	
			LEVEL OF SERVICE	DELAY (SEC/VEH)	LEVEL OF SERVICE	DELAY (SEC/VEH)
8 Willow Oaks C.C. Entr. Forest Hill Ave	Unsignalized	EB LT	A	3	E	37.9
		EB T	A	0	A	0
		EB Overall	A	1.1	B	13.3
		WB TR	A	0	A	0
		WB R	A	0	A	0
		WB Overall	A	0	A	0
		SB LR	F	127.6	F	Err
		SB Overall	F	127.6	F	Err
		Intersection Overall	A	1.6	F	185.6
9 Glyndon Ln Forest Hill Ave	Unsignalized	EB T	A	0	A	0
		EB TR	A	0	A	0
		EB Overall	A	0	A	0
		WB LT	A	0	A	1.1
		WB T	A	0	A	0
		WB Overall	A	0.1	A	0.2
		NB LR	C	21.3	C	15
		NB Overall	C	21.3	C	15
		Intersection Overall	A	0.1	A	0.2
10 Southbound Ramp Forest Hill Ave	Signalized	EB T	B	14.3	C	33.1
		EB Overall	B	14.3	C	33.1
		WB T	A	9	E	60.7
		WB Overall	A	9	E	60.7
		SB L	C	34.1	B	12.8
		SB R	D	41	F	94.3
		SB Overall	D	37.6	E	62.7
		Intersection Overall	B	18.1	D	52.4
11 Northbound Ramp Forest Hill Ave *** Intersection has too many legs for HCM analysis.	Unsignalized	EB T	***	***	***	***
		EB TR	***	***	***	***
		EB Overall	***	***	***	***
		WB T	***	***	***	***
		WB TR	***	***	***	***
		WB Overall	***	***	***	***
		Intersection Overall	***	***	***	***



Queue Length Analysis - 2011 Opening Year No-Build

The results of the queue length analysis for the 2011 No-Build condition are presented in Table 11. The 95th percentile queue lengths shown represent the maximum queue length independent of peak hour. The shaded values in the Peak Hour Volume column indicate the AM peak hour volume. Otherwise, the volumes in this column represent PM peak hour volumes.

Table 11 - Queuing Analysis Results - 2011 No Build Condition

Intersection	Control Type	Movement	Peak Hour Volume (vph)	95th Percentile Queue length (ft)
Hathaway Rd at Old Westham Rd	Unsignalized	NB L	135	11
		EB L	130	129
Forest Hill Avenue at Hathaway Rd	Signalized	EB TR	1166	415
		WB L	74	46
		WB TR	1566	869
		NB L	66	96
		NB T	50	63
		NB R	77	39
		SB L	283	165
		SB TR	143	22
Forest Hill Avenue at Melbourne Dr	Unsignalized	WB L	10	2
Forest Hill Avenue at SB Off-Ramp	Signalized	SB L	450	77
		SB R	681	443
		EB T	1426	359
		WB T	1071	283

Hathaway Road at Old Westham Road – The 95th percentile queue length for the northbound left-turn movement is reported to be 11 ft which is within the existing available storage length of 40ft. The maximum queue lengths for the eastbound left and right turning movements at this intersection are reported to both be 18 ft which occurs during the AM peak hour. For the southbound approach “zero” queue lengths are reported during the AM and PM peak hours.

Forest Hill Avenue at Hathaway Road – At the Forest Hill Avenue and Hathaway Road intersection, a 95th percentile queue length of 129 ft is reported for the eastbound left-turning movement which is within the existing storage length of 220 ft. For the eastbound through-right movement, a 95th percentile queue length of 415 ft was reported, which extends beyond the driveway to the shopping center on the south side of Forest Hill Avenue and also blocks access to Gravel Hill Road.

For the westbound left-turning movement, a 95th percentile queue length of 74 ft is reported which is within the existing available storage length of 90 ft. Similar to the Existing condition, a significantly long queue of 869 ft is reported for the westbound through movement in the 2011 No-Build condition. This long queue on the westbound approach is expected to extend beyond the upstream intersection and block northbound and southbound movements at Melbourne Drive and also other accesses on the north side of Forest Hill Avenue.

For the northbound left, through, and right-turning movements, the 95th percentile queue lengths were reported to be 96 ft, 63 ft, and 39 ft, respectively, which are within the minimum available storage length of 140 ft. For the southbound left and through-right turning movements, the 95th percentile queue lengths were reported to be 165 ft and 22 ft, respectively. The 165 ft queue length for the southbound left-turning movement exceeds the available storage length of 50 ft at this approach. The queue length for the southbound left-turning movement at the intersection was reported for the AM peak hour traffic condition. Synchro reports that during the AM peak hour, the 95th percentile volume for the southbound left-turning movement exceeds capacity and therefore, the queue is expected to be longer than the reported queue length.

Forest Hill Avenue at Melbourne Drive – The 95th percentile queue length for the westbound left-turning movement at this intersection remains same in the No-Build condition as in the Existing condition. The 2 ft long queue at this approach is within the available storage length of 70 ft. Since, the eastbound and westbound traffic have free movements at this intersection, minimal queue lengths were reported for these approaches. For the northbound shared left-through-right movement, a maximum queue of 176 ft was reported; and for the southbound left and through-right movements 95th percentile queue lengths of 30 ft and 3 ft, respectively were reported.

Forest Hill Avenue at Windsorview Drive The eastbound and westbound approaches at this intersection operate freely, therefore “zero” or minimal queues were reported for these approaches. For the southbound shared left and right turn movements, a 95th percentile queue length of 35 ft was reported.

Forest Hill Avenue at Woodberry Lane – The eastbound and westbound approaches at this intersection operate freely, therefore “zero” or minimal queues are reported for these approaches. For the northbound left-right turn movement, a maximum queue length of 20 ft is reported during the AM peak hour.

Forest Hill Avenue at Rettig Road – Like other unsignalized intersections, the eastbound and westbound approaches at this intersection operate freely; therefore “zero” or minimal queues are reported for these approaches. For the northbound and southbound left-through-right movements, the maximum queue lengths of 11 ft and 82 ft were reported, respectively.

Forest Hill Avenue at Heartwood Road – The eastbound and westbound approaches at this intersection operate freely’ therefore “zero” or minimal queues are reported for these approaches. For the northbound shared left and right-turn movement, a 95th percentile queue length of 7 ft was reported.

Forest Hill Avenue at Willow Oaks Country Club Entrance – The eastbound and westbound approaches at this intersection operate freely, therefore “zero” or minimal queues are reported for these approaches. For the southbound left and right-turn movements, a 95th percentile queue length of 57 ft was reported.

Forest Hill Avenue at Glyndon Lane – The eastbound and westbound approaches at this intersection operate freely, therefore “zero” or minimal queues were reported for these approaches. For the northbound shared left and right-turn movement, a 95th percentile queue length of 4 ft was reported.

Forest Hill Avenue at Powhite Parkway SB On/Off Ramps –The queuing analysis results for the southbound right-turning movement at the intersection of Forest Hill Avenue and Powhite Parkway SB off-ramp indicated a 95th percentile queue length of 443 ft. Synchro reports that the 95th percentile volume for this movement exceeds capacity and the queue is expected to be longer than the reported queue length of 443 ft. Based on the available storage length of 180 ft on Forest Hill Avenue, the queue is expected to extend on the SB off-ramp. For the eastbound through movement, the 95th percentile queue length is reported to be 359 ft which is expected to extend beyond the upstream intersection of Forest Hill Avenue and Glyndon Lane.

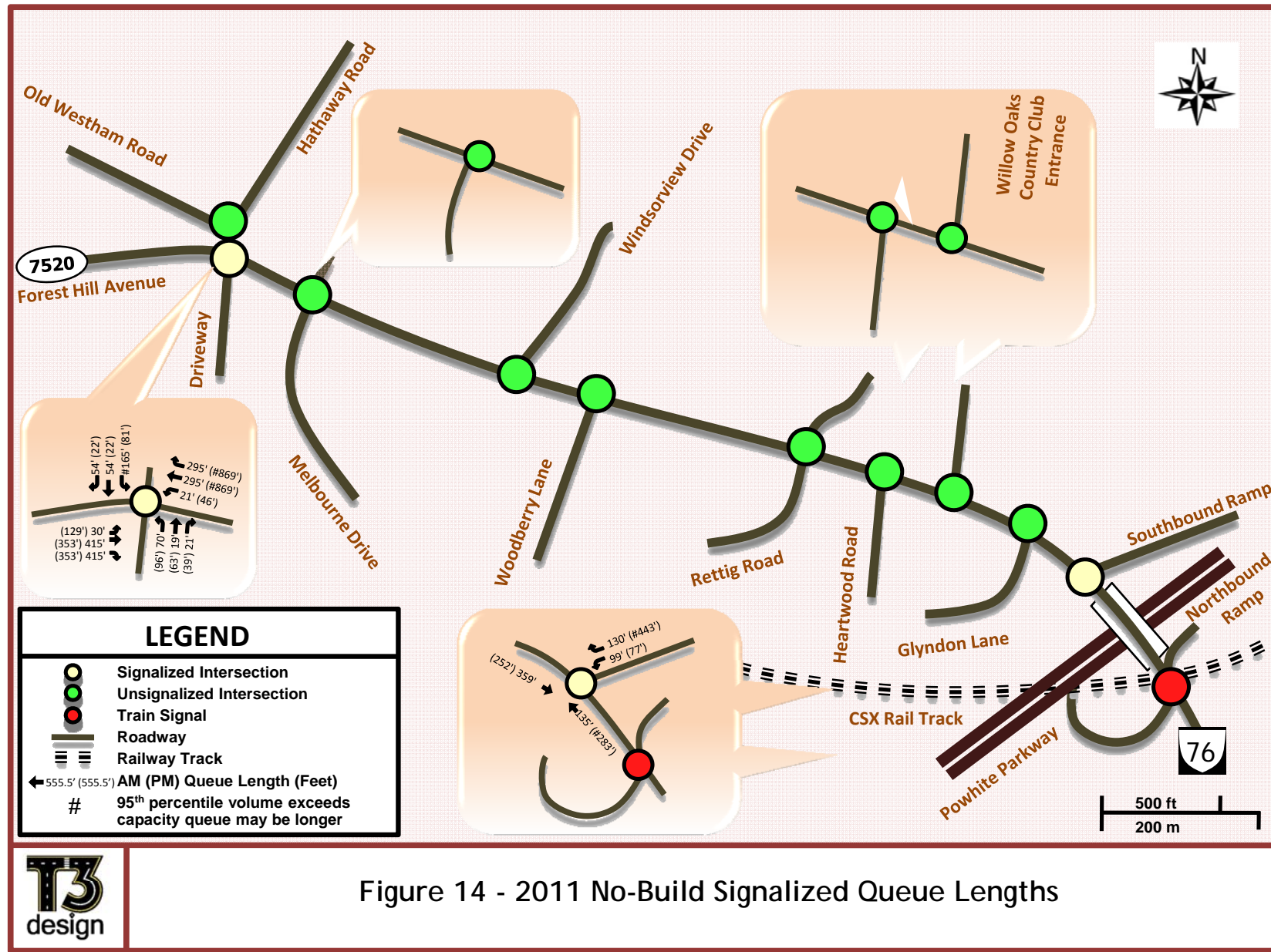


Figure 14 - 2011 No-Build Signalized Queue Lengths



Queue Length Analysis – 2030 Design Year No-Build

The queuing analysis results for the 2030 No-Build condition are presented in Table 12. The peak hour volumes that are shaded represent AM peak hour conditions.

Table 12 - Queuing Analysis Results - 2030 No-Build Condition

Intersection	Control Type	Movement	Peak Hour Volume (vph)	95th Percentile Queue length (ft)
Hathaway Rd at Old Westham Rd		NB L	175	16
Forest Hill Avenue at Hathaway Rd	Signalized	EB L	168	274
		EB TR	1515	714
		WB L	96	61
		WB TR	2035	1425
		NB L	86	141
		NB T	65	92
		NB R	100	86
		SB L	367	243
		SB TR	185	67
Forest Hill Avenue at Melbourne Dr		WB L	13	3
Forest Hill Avenue at SB Off-Ramp	Signalized	SB L	585	128
		SB R	885	805
		EB T	1853	626
		WB T	1392	575

Hathaway Road at Old Westham Road – The 95th percentile queue length for the northbound left-turn movement is reported to be 16 ft which is within the existing available storage length of 40ft. The maximum queue lengths for the eastbound left and right turning movements at this intersection are reported to be 29 ft which occurs during the AM peak hour. For the southbound approach a “zero” queue length was reported during the AM and PM peak hour.

Forest Hill Avenue at Hathaway Road – At the Forest Hill Avenue and Hathaway Road intersection, a 95th percentile queue length of 274 ft was reported for the eastbound left-turning movement, which is slightly longer than the existing storage length of 220 ft. For this movement, Synchro reported that the

volume exceeds capacity and the queue length is expected to be longer than the reported queue length. The “effective storage length” available for the eastbound left-turning movement at the Forest Hill Avenue and Hathaway intersection is 245 ft. For the eastbound through-right movement, the 95th percentile queue length of 714 ft was reported, which similar to the Existing and 2011 No-Build conditions, extends beyond the driveway to the shopping center on the south side of Forest Hill Avenue and also blocks access to Gravel Hill Road.

For the westbound left-turning movement, a 95th percentile queue length of 61 ft is reported, which is within the existing available storage length of 90 ft. Similar to the Existing and 2011 No-Build conditions, for the 2030 No-Build condition a significantly long queue of 1,425 ft is reported for the westbound through movement. This long queue on the westbound approach is expected to extend beyond the upstream intersections of Forest Hill Avenue at Melbourne Drive, Windsorview Drive, and Woodberry Lane.

For the northbound left, through, and right-turning movement, the 95th percentile queue lengths are reported to be 141 ft, 92 ft, and 86 ft, respectively which could be accommodated within the available storage length of 140 ft. For the southbound left and through-right turning movements, the 95th percentile queue lengths are reported to be 243 ft and 67 ft, respectively. The 243 ft queue length for the southbound left-turning movement exceeds the available storage length of 50 ft at this approach. The queue length for the southbound left-turning movement at the intersection is reported for the AM peak hour traffic condition. Synchro reports that during the AM peak hour, the 95th percentile volume for the southbound left-turning movement exceeds capacity and therefore, the queue is expected to be longer than the reported queue length.

Forest Hill Avenue at Melbourne Drive – The 95th percentile queue length for the westbound left-turning movement at this intersection is reported to be 3 ft which is within the available storage length of 70 ft. Since, the eastbound and westbound traffic have free movements at this intersection, minimal queue lengths were reported for these approaches. For the northbound shared left-through-right movement and for the southbound left and through movements, Synchro reported an error which indicates the queues are expected to be very long at these approaches.

Forest Hill Avenue at Windsorview Drive – The eastbound and westbound approaches at this intersection operate freely, therefore “zero” or minimal queues were reported for these approaches. For the southbound shared left and right turn movements, the 95th percentile queue length of 130 ft was reported.

Forest Hill Avenue at Woodberry Lane – The eastbound and westbound approaches at this intersection operate freely therefore, zero or minimal queues are reported for these approaches. For the northbound left-right turn movement, a maximum queue length of 71 ft was reported during the AM peak hour.

Forest Hill Avenue at Rettig Road – Similar to other unsignalized intersections, the eastbound and westbound approaches at this intersection operate freely, therefore, “zero” or minimal queues are reported for these approaches. For the northbound shared left-through-right movement, a maximum queue length of 29 ft was reported during the AM peak hour. For the southbound shared left-through-right movement Synchro reported a 195-ft 95th percentile queue length during the AM peak hour and an reported an error for the PM peak hour queue length indicating a long queue on the southbound approach of Rettig Road.

Forest Hill Avenue at Heartwood Road – The eastbound and westbound approaches at this intersection operate freely, therefore “zero” or minimal queues are reported for these approaches. For the northbound shared left and right-turn movement, a 95th percentile queue length of 20 ft was reported.

Forest Hill Avenue at Willow Oaks Country Club Entrance – For the eastbound through-right movement, a 95th percentile queue length of 20 ft was reported. For the westbound approach a “zero” queue length was reported. For the southbound left and right-turn movements, a 95th percentile queue length of 38 ft was reported for the AM peak hour and an error was reported for the PM peak hour indicating a significantly long queue for the southbound approach of this intersection.

Forest Hill Avenue at Glyndon Lane – The eastbound and westbound approaches at this intersection operate freely therefore, “zero” or minimal queues were reported for these approaches. For the northbound shared left and right-turn movement, a maximum 95th percentile queue length of 7 ft was reported.

Forest Hill Avenue at Powhite Parkway SB On/Off Ramps –The queuing analysis results for the southbound right-turning movement at the intersection of Forest Hill Avenue and Powhite Parkway SB off-ramp indicate a 95th percentile queue length of 850 ft. Synchro reports that the 95th percentile volume for this movement exceeds capacity and the queue is expected to be longer than the reported queue length. Based on the available storage length of 180 ft on Forest Hill Avenue, the queue is expected to extend onto the SB off-ramp. Also, for the southbound left-turning movement a 95th percentile queue length of 128 ft was reported which extends close to the toll both on the ramp.

For the eastbound through movement, a 95th percentile queue length of 626 ft was reported, which is expected to extend beyond the upstream intersection of Forest Hill Avenue and Glyndon Lane during the AM peak hour. A 95th percentile queue of 575 ft was reported for the westbound through movement which extends beyond the northbound on-ramp to Powhite Parkway and is also expected to block the upstream intersection of Forest Hill Avenue and Fairlee Road.

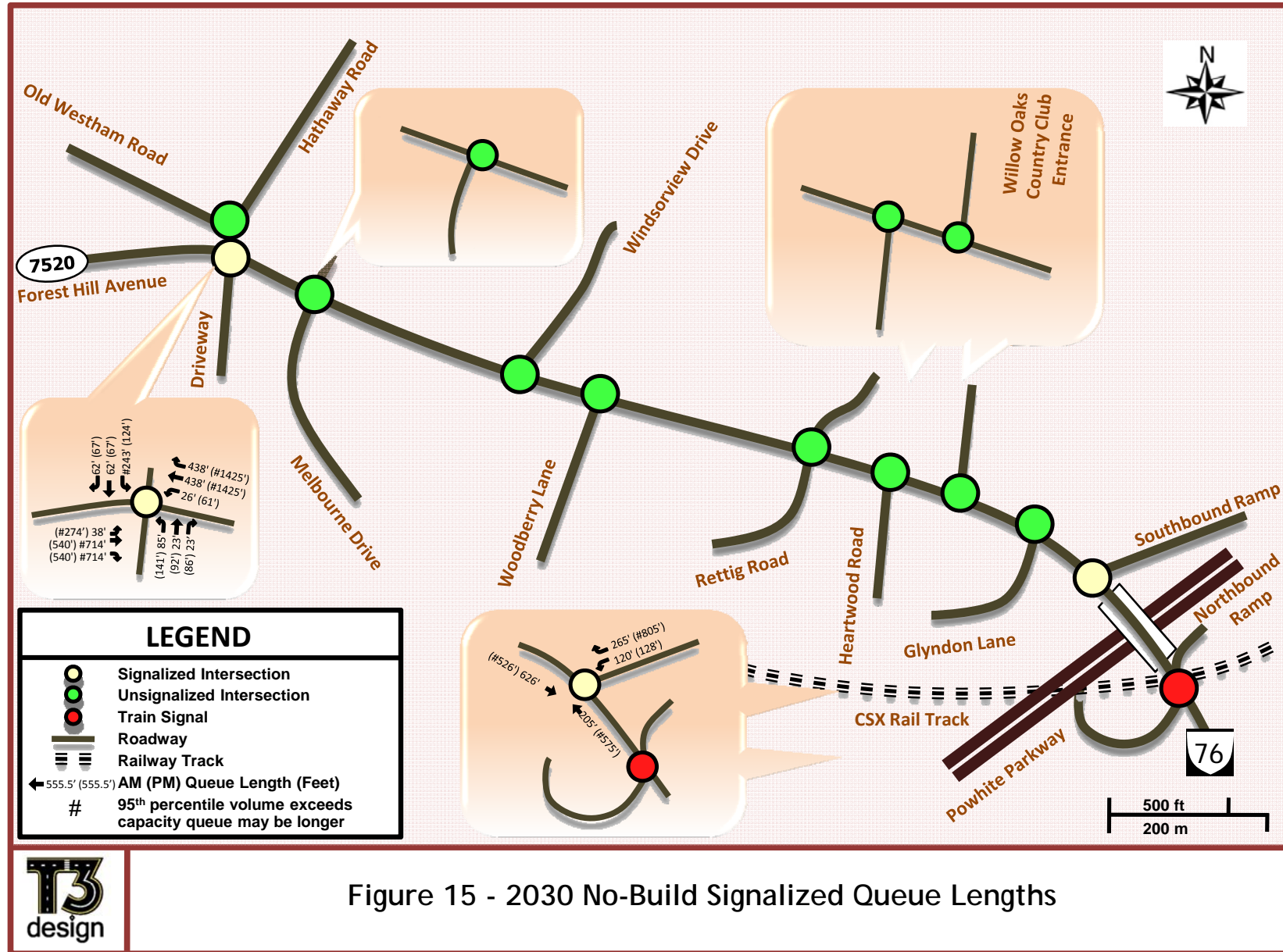


Figure 15 - 2030 No-Build Signalized Queue Lengths

Future Build Network Configurations

Description of Future Roadway Network

Several configurations were considered for this corridor to provide the highest level of operations, including the calming of traffic through the area, a reduction of vehicular conflicts, and an increase in operational efficiency. These configurations explored the modification of several side-street approaches using access management strategies, such as to right-in/out only operations, street closures (i.e., cul-de-sac), and internal traffic diversions. The various configurations considered are listed in Table 13.

Table 13 - Alternative Build Configurations

Intersection	Existing Configuration	Configuration 1A1	Configuration 1A2 (modified)	Configuration 1B1	Configuration 1B2 (modified)	Configuration 2A1	Configuration 2A2 (modified)
Powhite Pkwy	Full Access	Full Access	Full Access	Full Access	Full Access	Full Access	Full Access
Glyndon Ave.	Full Access	Right-in/out	Cul-de-sac	Right-in/out	Cul-de-sac	Right-in/out	Cul-de-sac
Willow Oaks Country Club Entr.	Full Access	Full Access	Full Access	Right-in/out, EBL in; SBL use the internal connection to Rettig to make a SBL	Right-in/out, EBL in; SBL use the internal connection to Rettig to make a SBL	Right-in/out, EBL in; SBL use the internal connection to Rettig to make a SBL	Right-in/out, EBL in; SBL use the internal connection to Rettig to make a SBL
Heartwood Rd.	Full Access	Right-in/out	Right-in/out	Right-in/out	Right-in/out	Right-in/out	Right-in/out
Rettig Rd.	Full Access	Full Access	Full Access	Full Access	Full Access	Full Access	Full Access
Norcross Rd.	Full Access	Right-in/out	Right-in/out	Right-in/out	Right-in/out	Cul-de-sac	Cul-de-sac
Woodberry Ln.	Full Access	Full Access (WBL but no EBU or EBL)	Full Access (WBL but no EBU or EBL)	Full Access (WBL but no EBU or EBL)	Full Access (WBL but no EBU or EBL)	Full Access (WBL but no EBU or EBL)	Full Access (WBL but no EBU or EBL)
Windsorview Dr.	Full Access	Full Access (EBL but no WBU or WBL)	Full Access (EBL but no WBU or WBL)	Full Access (EBL but no WBU or WBL)	Full Access (EBL but no WBU or WBL)	Full Access (EBL but no WBU or WBL)	Full Access (EBL but no WBU or WBL)
Melbourne Dr.	Full Access	Full Access	Full Access	Full Access	Full Access	Right-in/out, divert all left turning traffic to Hathaway	Right-in/out, divert all left turning traffic to Hathaway
Hathaway Rd./Old Westham Rd.	Full Access	Full Access	Full Access	Full Access	Full Access	Full Access	Full Access

Configuration 1A1

In this corridor configuration, the Forest Hill Avenue intersections at Glyndon Avenue, Heartwood Road, and Norcross Road are modified to “right in/out only” operation. The left turn egress from each of these intersections was diverted to the NBL movement at Rettig Road. Likewise the WBL ingress movements at each of these intersections were also diverted to the WBL movement at the intersection of Forest Hill Avenue and Rettig Road.

The Forest Hill Avenue intersections at Woodberry Lane and Windsorview Drive allow access to all ingress and egress movements. However, at Woodberry Lane an eastbound U-turn (EBU) movement will not be permitted. Likewise, at the intersection of Forest Hill Avenue and Windsorview Drive a westbound U-turn (WBU) will not be permitted. These restrictions limit the intersection operations to through movements and ingress/egress movements.

Configuration 1A2

This corridor configuration is similar to “Configuration 1A1”, but includes the closure of the side-street approach at the intersection of Forest Hill Avenue and Glyndon Avenue. This resulted in the diversion of all traffic from Glyndon Avenue to other side-streets. The northbound right (NBR) movement at Glyndon Lane was diverted to Heartwood Road, which is the adjacent intersection to the west. All left-turning traffic at from each of the modified intersections was diverted to the intersection of Rettig Road, as in “Configuration 1A1”.

Configuration 1B1

Although the Willow Oaks Country Club Entrance has full access in “Configuration 1A1” and “Configuration 1A2”, the left-turn egress from the southbound approach is prohibited in this configuration. This movement is diverted and added to the southbound left (SBL) movement at the intersection of Forest Hill Avenue and Rettig Road.

The remaining operations for this configuration are identical to “Configuration 1A1”, including the modification of the side-street approaches at Glyndon Avenue, Heartwood Road, and Norcross Road to “right in/out only” operation and the prohibition of U-turns at Woodberry Lane and Windsorview Drive. The traffic diversions related to these modifications are identical to “Configuration 1A1”.

Configuration 1B2

Much like the difference between “Configuration 1A1” and “Configuration 1A2”, the difference between “Configuration 1B1” and “Configuration 1B2” is the closure of Glyndon Avenue and the diversion of the right-turning traffic from the northbound approach to Heartwood Road. The remaining modifications result in the diversions identified in previous configurations.

Configuration 2A1

In “Configuration 2A1” the northbound side-street approach from Norcross is closed, and its traffic diverted to its intersection with Rettig Road approximately 450 feet from Forest Hill Avenue. Norcross Road is accessed by four residential driveways to single-family homes, making the volume of the diversion substantially low.

An additional feature of this corridor configuration is the modification of the northbound approach at Melbourne Drive to “right-in/out only” operation and the diversion of all left turning traffic to the intersection of Forest Hill Avenue and Hathaway Road. The diversion of the left-turn ingress and egress at Melbourne Drive to Hathaway Road will be through a newly-constructed internal roadway connection.

All other approach modifications and diversions are identical to those in “Configuration 1B1”. These include the Forest Hill Avenue intersections at Glyndon Avenue, the Willow Oaks Country Club Entrance, and Heartwood Road.

Configuration 2A2

This corridor configuration is similar to “Configuration 2A1”, but includes the closure of the side-street approach at the intersection of Forest Hill Avenue and Glyndon Avenue. This resulted in the diversion of the northbound right (NBR) movement at Glyndon Lane to Heartwood Road. The left-turning traffic from this intersection was diverted to the intersection of Rettig Road.

Selection of Ultimate Build Configuration

Configuration 2A1 was selected as the “ultimate” Build configuration for more detailed documentation in the report. However, the results for all configurations are included in the Appendix of this report. In the selection of the “ultimate” configuration, the traffic operations were the primary factor for which a comparison of the configurations was conducted. The specific operational characteristics focused on:

- Overall intersection and approach LOS in the 2030 Build condition.
- Operations at the intersection of Forest Hill Avenue and Melbourne Road based on changes in access in the 2030 Build condition.
- Operations at the intersection of Forest Hill Avenue and Rettig Road in the 2030 Build condition.
- Operations at the intersection of Forest Hill Avenue and the Willow Oaks Country Club Entrance in the 2030 Build condition.

For any remaining characteristics, the differences in conditions were considered negligible. However, there are several factors that influenced the operations, such as the diversion of traffic due to access management strategies and the warrant of exclusive storage lanes for corridor left and right turning movements.

Overall LOS (2030 Build)

With respect to the overall intersection LOS for each of the configurations, the only notable differences were at the intersections of Forest Hill Avenue and Melbourne Road and Forest Hill Avenue and Rettig Road. The comparisons at both of these intersections are discussed below.

Traffic Operations (2030 Build) –Forest Hill Avenue and Melbourne Road

At the intersection of Forest Hill Avenue and Melbourne Road the overall intersection LOS is unacceptable (LOS F) during the PM peak hour for Configurations 1A1, 1A2, 1B1, and 1B2. When considering the intersection approaches, the mainline (Forest Hill Avenue) approaches are operating at LOS A, in each of these cases, except for the WB approach in Configuration 1A1, which operates at LOS C during the AM peak period. For these configurations, the overall intersection LOS F is driven by the side-street delay, which is substantially high during both the AM and PM peak hours. In this regard, the difference between these four configurations and the remaining two configurations (i.e., 2A1, 2A2) does not appear to be substantive. The side-street delays for Configurations 2A1 and 2A2 at the intersection of Forest Hill Avenue and Melbourne Road are equally substantial.

Traffic Operations (2030 Build) - Forest Hill Avenue and Rettig Road

For the intersection of Forest Hill Avenue and Rettig Road, the only configuration that experiences an unacceptable level of service is Configuration 2A1, which experiences an overall intersection LOS E during the PM peak hour. This not only encompasses unacceptable LOS for the side-street approaches, but also the westbound mainline approach. The primary difference between Configurations 2A1 and 2A2 is the warranting of the WBL lane at this intersection. The WBL lane is not warranted for Configuration 2A1 based on the volume for this movement being 12 vph. Conversely, the WBL lane is warranted for Configuration 2A2, which has a volume of 20 vph. Although this difference in volume between the two configurations is relatively minor, this difference determines the warranting of the WBL lane, which ultimately impacts the overall intersection operations. Thus, for these criteria, Configuration 2A1 represents a “worst case” for one of the primary access points to the corridor.

Traffic Operations (2030 Build) - Forest Hill Avenue and Willow Oaks Country Club Entrance

For Configurations 1B1, 1B2, 2A1, and 2A2 the access at the intersection of Forest Hill Avenue and the Willow Oaks Country Club Entrance is modified. For Configurations 1B1 and 1B2, the egress from the Willow Oaks Country Club is restricted to a right-out only movement. However, the EBL is permitted for the ingress movement. For Configurations 2A1 and 2A2, the access for the Willow Oaks Country Club entrance is restricted to right-in/out access. The left turn movements at this intersection access the site through Rettig Road. Each of these scenarios operates at an overall acceptable LOS. For Configurations 1A1 and 1A2, the level of service for the southbound approach is LOS F during the PM peak. For these configurations, all movements are permitted, including the left turn ingress and egress. The Willow Oaks Country Club entrance is located approximately 150 ft from the end of the merge lane for WB Forest Hill Avenue traffic from the Powwhite Parkway.

Although Configurations 1A1 and 1A2 represent “worst-case” operations for this intersection, it was determined that one of the other configurations should be considered as the “ultimate” configuration, since the modification in access is consistent with purpose of the project to incorporate access management strategies, and the fact that the side-street operations for Configurations 1A1 and 1A2 duplicate the Existing Conditions. Furthermore, it would be more beneficial to assess the impact of the diversion on the intersection of Forest Hill Avenue and Rettig Road than to further explore what is an existing condition at the entrance.

The traffic volumes for Configuration 2A1 for the 2011 Opening and 2030 Design Years are depicted in Figure 16 and Figure 17.

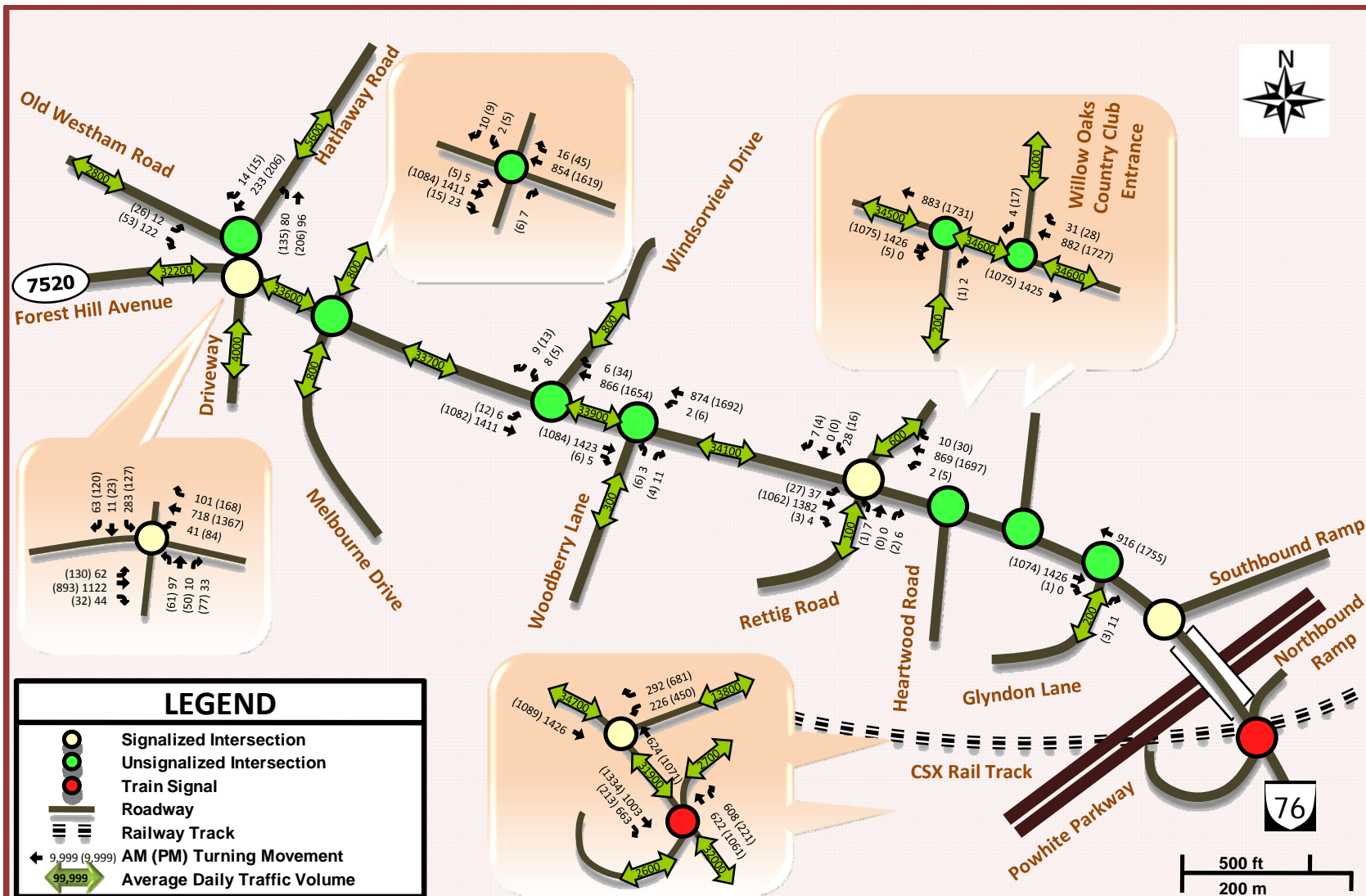


Figure 16 - 2011 -Build 2A1 Traffic Volumes



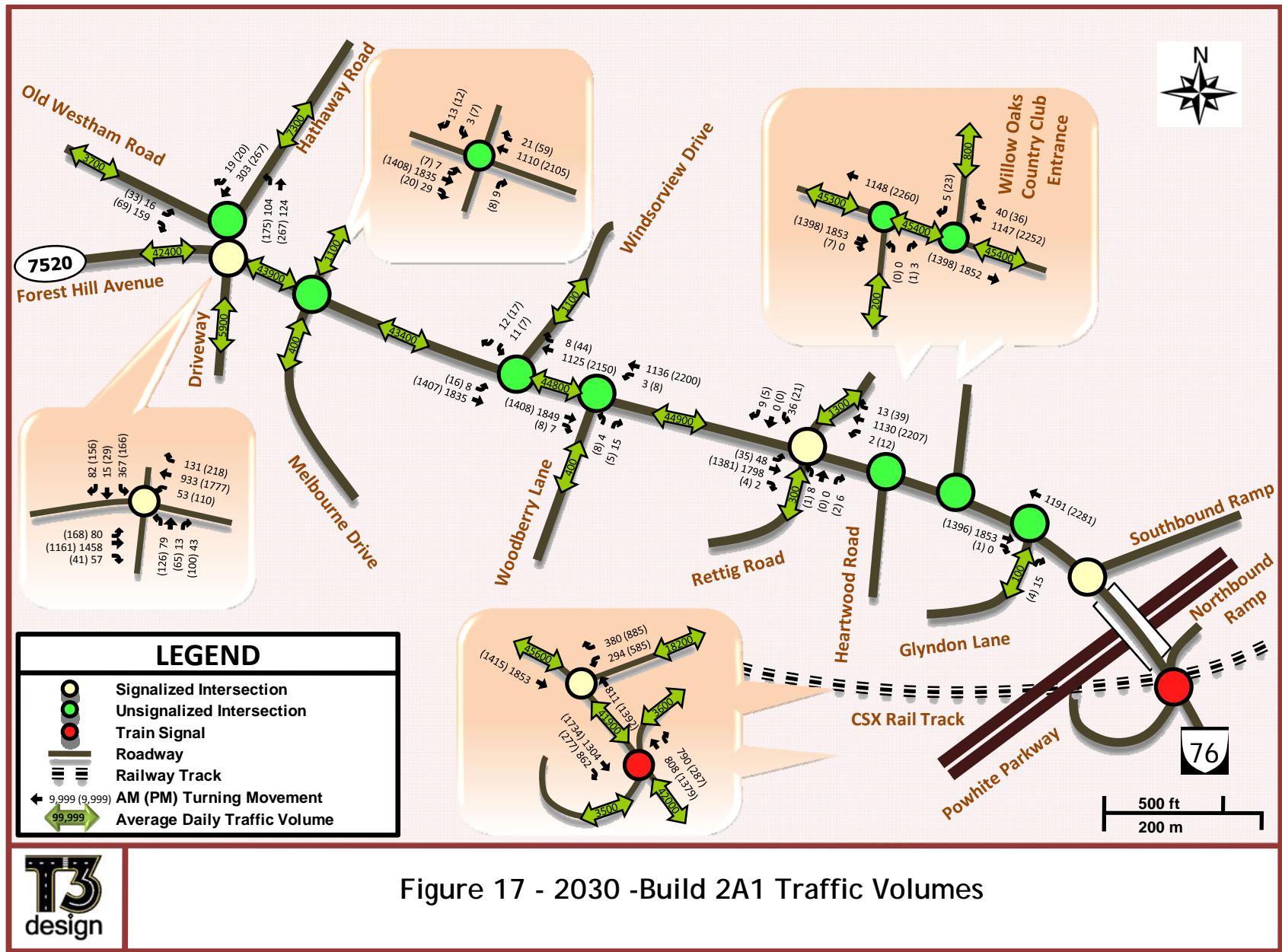


Figure 17 - 2030 -Build 2A1 Traffic Volumes



Traffic Signal Warrant Analysis – 2011 and 2030 Build Conditions

Signal Warrant Analysis Results – Build Conditions

As prescribed in the Manual on Uniform Traffic Control Devices, 2003 Edition (MUTCD), the determination of whether to pursue the installation of a traffic signal should be based on an evaluation of traffic conditions, pedestrian characteristics, and the physical characteristics of a location. The traffic signal warrants contained within the MUTCD consist of a list of factors to be used, when applicable, to determine whether consideration should be given to the installation of a traffic signal. There are eight warrants provided by the MUTCD. The following warrants were found to be applicable to this corridor:

1. Warrant 1 – Eight-Hour Vehicular Volume
2. Warrant 2 – Four-Hour Vehicular Volume
3. Warrant 3 – Peak Hour

The traffic signal warrant analyses conducted for the intersections of Forest Hill Avenue and Rettig Road and Forest Hill Avenue at Windsorview Road found that no warrants are met for the Build Opening and Design years. To assess a “worst-case” scenario, no right-turn volume reductions were applied.

Capacity Analysis - 2011 Opening Build 2A1 Traffic Conditions

Table 14 summarizes the level of service results of the study network for 2011 Build traffic conditions for Configuration 2A1. The lane group LOS results are detailed in Figure 18. Both the table and figure indicate that the corridor overall experiences acceptable LOS and relatively efficient traffic operations, with the exception of two side-street approach movements.

At the signalized intersection of Forest Hill Avenue and Hathaway Road and the offset intersection of Hathaway Road and Old Westham Road, the AM peak hour results indicated an overall intersection LOS C and LOS A, respectively. For the PM peak hour, the overall intersection LOS at the intersection of Hathaway Road and Old Westham Road remains at LOS A, while the intersection of Forest Hill Avenue and Hathaway Road operates at LOS D.

At the intersection of Forest Hill Avenue and Melbourne Road, the overall intersection LOS for the AM and PM peak hours are LOS A. However, the southbound approach from the shopping center on the north side of the corridor experiences a LOS F (112.2 sec/veh). While the northbound approach operates with a right-in/out configuration, left turn movements are still permitted for the southbound approach (including a left-turn ingress from Forest Hill Avenue). The delay experienced by the SBL movement is the primary contributor to the southbound approach LOS.

At the intersection of Forest Hill Avenue and Windsorview Drive, all approaches, as well as the overall intersection, operate at LOS D or better during the AM and PM peak periods. This intersection operates with full access, allowing all movements except a WBL or WBU movement. Additionally, the intersection of Forest Hill Avenue and Woodberry is a similarly configured T-intersection that allows for full access, with the exception of an EBL or EBU movement. However, the NB approach (side-street) at this intersection experiences a LOS E (43.9 sec/veh). Both intersections operate at overall LOS A during both peak periods.

As a signalized intersection, the intersection of Forest Hill Avenue and Rettig Road operates at overall intersection LOS A during both the AM and PM peak hours. The signalization of this intersection has led to significant improvements in operations, especially given the diversion of traffic due to access management along the corridor. All approaches, except the SB approach during the PM peak, operate at

LOS C or better. The SB approach operates at LOS D during the PM peak hour. This intersection is proposed to operate with a simple two-phase operation and cycle lengths of 80 seconds and 90 seconds, during the AM and PM peak hours, respectively.

In Configuration 2A1, the Forest Hill Avenue intersections at Heartwood Road, Willow Oaks Country Club, and Glyndon Lane all operate with a right-in/out configuration for the side-streets. Thus, the number of conflicts is significantly reduced, which leads to overall intersection LOS A for all three intersections for both the AM and PM peak hour. All approaches operate at LOS D or better.

At the intersection of Forest Hill Avenue and the Powhite Parkway SB Ramp, the overall intersection operates at LOS B and LOS C during the AM and PM peak hours, respectively. During both peak hours all approaches operate at LOS C or better, except the southbound ramp approach during the AM peak period, which operates at LOS D (39.2 sec/veh).

Capacity Analysis - 2030 Design Year Build 2A1 Traffic Conditions

The level of service results for the study network for 2030 Build 2A1 traffic conditions are summarized in Table 15. The lane group LOS results are detailed in Figure 19. These results reveal that the increase in demand along Forest Hill Avenue has a more significant impact on the operations at several of the study intersections.

At the signalized intersection of Forest Hill Avenue and Hathaway Road, the southbound approach is the only approach that operates at worse than LOS D conditions. This approach operates at a LOS D (71.3 sec/veh), which is certain to impact the operations at the intersection of Hathaway Road and Old Westham Road. However, the side-street approach of Old Westham Road operates at LOS C or better during the AM and PM peak hours. This is attributable to the fact that the EBR movement for this approach consists of 90% of the approach volume.

The intersection of Forest Hill Avenue and Melbourne Road operates at overall intersection LOS A for both the AM and PM peak hours, which is primarily driven by the mainline operations. The unacceptable LOS is experienced by the southbound approach during the AM and PM peak hour are LOS E (39.2 sec/veh) and LOS (985.5 sec/veh), respectively. The southbound approach is an egress from a shopping center north of the corridor. While the south leg operates with a right-in/out configuration, the north leg operates with full ingress/egress (including left turns).

The Forest Hill Avenue intersections at Windsorview Drive and Woodberry Lane are offset T-intersections approximately 300 ft apart. The intersection of Forest Hill Avenue and Windsorview Drive operates with an overall intersection LOS A during both the AM and PM peak hours. All approaches operate at LOS C or better. However, at the intersection of Forest Hill Avenue and Woodberry Lane, the northbound approach operates at LOS F during both the AM (144.7 sec/veh) and PM (293.6 sec/veh) peak hours. Still, the northbound approach volumes are relatively low during the AM (19 vph) and PM (13 vph) peak hours.

At the intersection of Forest Hill Avenue and Rettig Road, the AM peak hour operates relatively efficiently, with all approaches operating at LOS C or better. However, during the PM peak hour both side-street approaches operate at LOS E. Additionally, the WB approach operates at LOS F (98.5 sec). Although the signalization of this intersection provides a remedial approach to addressing the delay, the traffic volumes on Forest Hill Avenue demand a substantial portion of green-time. Additionally, the absence of a WBL lane reduces the capacity of the westbound approach. An exclusive WBL is warranted in Configuration 2A2. With the addition of a WBL lane and permissive/protected phasing, this intersection can operate with acceptable LOS for all approaches.

In Configuration 2A1, the Forest Hill Avenue intersections at Heartwood Road, Willow Oaks Country Club, and Glyndon Lane all operate with a right-in/out configuration for the side-streets. Thus, the number of conflicts is significantly reduced, which leads to overall intersection LOS A for all three intersections for both the AM and PM peak hour. All approaches operate at LOS D or better.

At the intersection of Forest Hill Avenue and the Powhite Parkway SB Ramp, the overall intersection operates at LOS B during both the AM and PM peak hours. During both peak hours all approaches operate at LOS C or better.

Table 14: 2011 Build 2A1 LOS Analysis Results

INTERSECTION	TYPE OF CONTROL	MOVEMENT APPROACH	AM PEAK HOUR		PM PEAK HOUR	
			LEVEL OF SERVICE	DELAY (SEC/VEH)	LEVEL OF SERVICE	DELAY (SEC/VEH)
1 Hathaway Rd Old Westham Rd	Unsignalized	EB L	B	11.0	B	13.2
		EBR	B	11.0	B	13.2
		EB Overall	B	11.0	B	13.2
		NB L	A	8.0	A	8.2
		NB T	A	0.0	A	0.0
		NB Overall	A	3.8	A	3.5
		SB TR	A	0.0	A	0.0
		SB Overall	A	0.0	A	0.0
		Intersection Overall	A	4.2	A	3.5
2 Hathaway Rd Forest Hill Ave	Signalized	EB L	A	8.8	D	35.9
		EB TR	B	17.3	C	21.4
		EB Overall	B	16.5	C	23.4
		WB L	B	11.0	B	13.3
		WB TR	B	16.3	D	39.5
		WB Overall	B	16.0	D	37.9
		NB L	D	49.0	D	53.9
		NB T	D	46.8	D	48.4
		NB R	D	45.9	D	45.7
		NB Overall	D	47.6	D	49.9
		SB L	D	53.0	D	49.4
		SB TR	D	43.6	D	50.7
		SB Overall	D	50.8	D	50.1
Intersection Overall	C	22.5	D	35.7		
3 Melbourne Rd Forest Hill Ave	Unsignalized	EB LT	A	0.6	A	1.1
		EB R	A	0.0	A	0.0
		EB Overall	A	0.2	A	0.0
		WB T	A	0.0	A	0.0
		WB R	A	0.0	A	0.0
		WB Overall	A	0.0	A	0.0
		NB R	B	10.2	A	9.4
		NB Overall	B	10.2	A	9.4
		SB L	F	52.9	F	253.5
		SB R	B	12.4	C	17.2
		SB Overall	C	18.2	F	112.2
Intersection Overall	A	0.4	A	0.9		

Table 14: 2011 Build 2A1 LOS Analysis Results (Continued)

<u>INTERSECTION</u>	<u>TYPE OF CONTROL</u>	<u>MOVEMENT APPROACH</u>	<u>AM PEAK HOUR</u>		<u>PM PEAK HOUR</u>	
			<u>LEVEL OF SERVICE</u>	<u>DELAY (SEC/VEH)</u>	<u>LEVEL OF SERVICE</u>	<u>DELAY (SEC/VEH)</u>
4 Windsorview Dr Forest Hill Ave	Unsignalized	EB L	B	10.7	B	14.7
		EB T	A	0.0	A	0.0
		EB Overall	A	0.1	A	0.0
		WB T	A	0.0	A	0.0
		WB R	A	0.0	A	0.0
		WB Overall	A	0.0	A	0.0
		SB LR	D	27.7	C	17.8
		SB Overall	D	27.7	C	17.8
		Intersection Overall	A	0.4	A	0.3
5 Woodberry Ln Forest Hill Ave	Unsignalized	EB T	A	0.0	A	0.0
		EB TR	A	0.0	A	0.0
		EB Overall	A	0.0	A	0.0
		WB LT	A	0.6	A	0.7
		WB T	A	0.0	A	0.0
		WB Overall	A	0.0	A	0.2
		NB LR	D	35.0	E	43.9
		NB Overall	D	35.0	E	43.9
		Intersection Overall	A	0.5	A	0.4
6 Rettig Rd Forest Hill Ave	Signalized	EB L	A	4.4	A	6.8
		EB TR	A	5.9	A	3.3
		EB Overall	A	5.8	A	3.4
		WB LT	A	4.5	A	5.9
		WB TR	A	3.1	A	2.1
		WB Overall	A	4.5	A	5.9
		NB LTR	C	26.8	C	34.0
		NB Overall	A	26.8	C	34.0
		SB LTR	C	27.0	D	37.4
		SB Overall	C	27.0	D	37.4
		Intersection Overall	A	6.2	A	5.3
7 Heartwood Rd Forest Hill Ave	Unsignalized	EB T	A	0.0	A	0.0
		EB TR	A	0.0	A	0.0
		EB Overall	A	0.0	A	0.0
		WB T	A	0.0	A	0.0
		WB Overall	A	0.0	A	0.0
		NB R	A	9.5	B	10.4
		NB Overall	A	9.5	B	10.4
		Intersection Overall	A	0.0	A	0.0

Table 14: 2011 Build 2A1 LOS Analysis Results (Continued)

INTERSECTION	TYPE OF CONTROL	MOVEMENT APPROACH	AM PEAK HOUR		PM PEAK HOUR	
			LEVEL OF SERVICE	DELAY (SEC/VEH)	LEVEL OF SERVICE	DELAY (SEC/VEH)
8 Willow Oaks C.C. Entr. Forest Hill Ave	Unsignalized	EB T	A	0.0	A	0.0
		EB Overall	A	0.0	A	0.0
		WB T	A	0.0	A	0.0
		WB R	A	0.0	A	0.0
		WB Overall	A	0.0	A	0.0
		SB R	B	11.0	B	10.2
		SB Overall	B	11.0	B	10.2
		Intersection Overall	A	0.1	A	0.1
9 Glyndon Ln Forest Hill Ave	Unsignalized	EB T	A	0.0	A	0.0
		EB TR	A	0.0	A	0.0
		EB Overall	A	0.0	A	0.0
		WB T	A	0.0	A	0.0
		WB Overall	A	0.0	A	0.0
		NB R	A	9.6	B	11.3
		NB Overall	A	9.6	B	11.3
		Intersection Overall	A	0.1	A	0.0
10 Southbound Ramp Forest Hill Ave	Signalized	EB T	A	7.2	B	18.4
		EB Overall	A	7.2	B	18.4
		WB T	A	5.4	C	22.0
		WB Overall	A	5.4	C	22.0
		SB L	D	39.5	A	10.0
		SB R	D	38.9	C	28.7
		SB Overall	D	39.2	C	21.5
		Intersection Overall	B	13.8	C	20.6
11 Northbound Ramp Forest Hill Ave	Unsignalized	No conflicting movements at this intersection.				

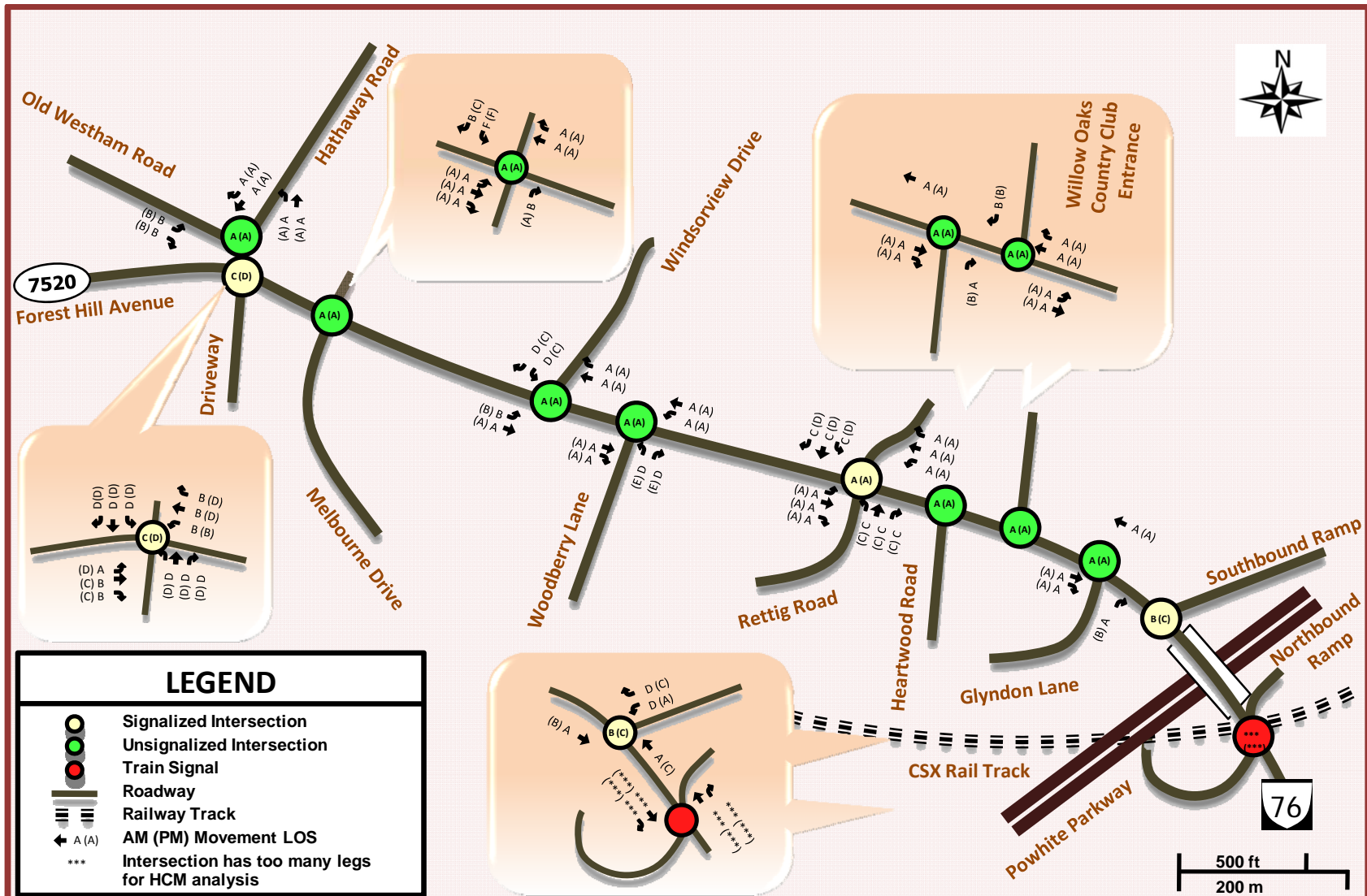


Figure 18 - 2011 Build 2A1 Level of Service (LOS)



Table 15: 2030 Build 2A1 LOS Analysis Results

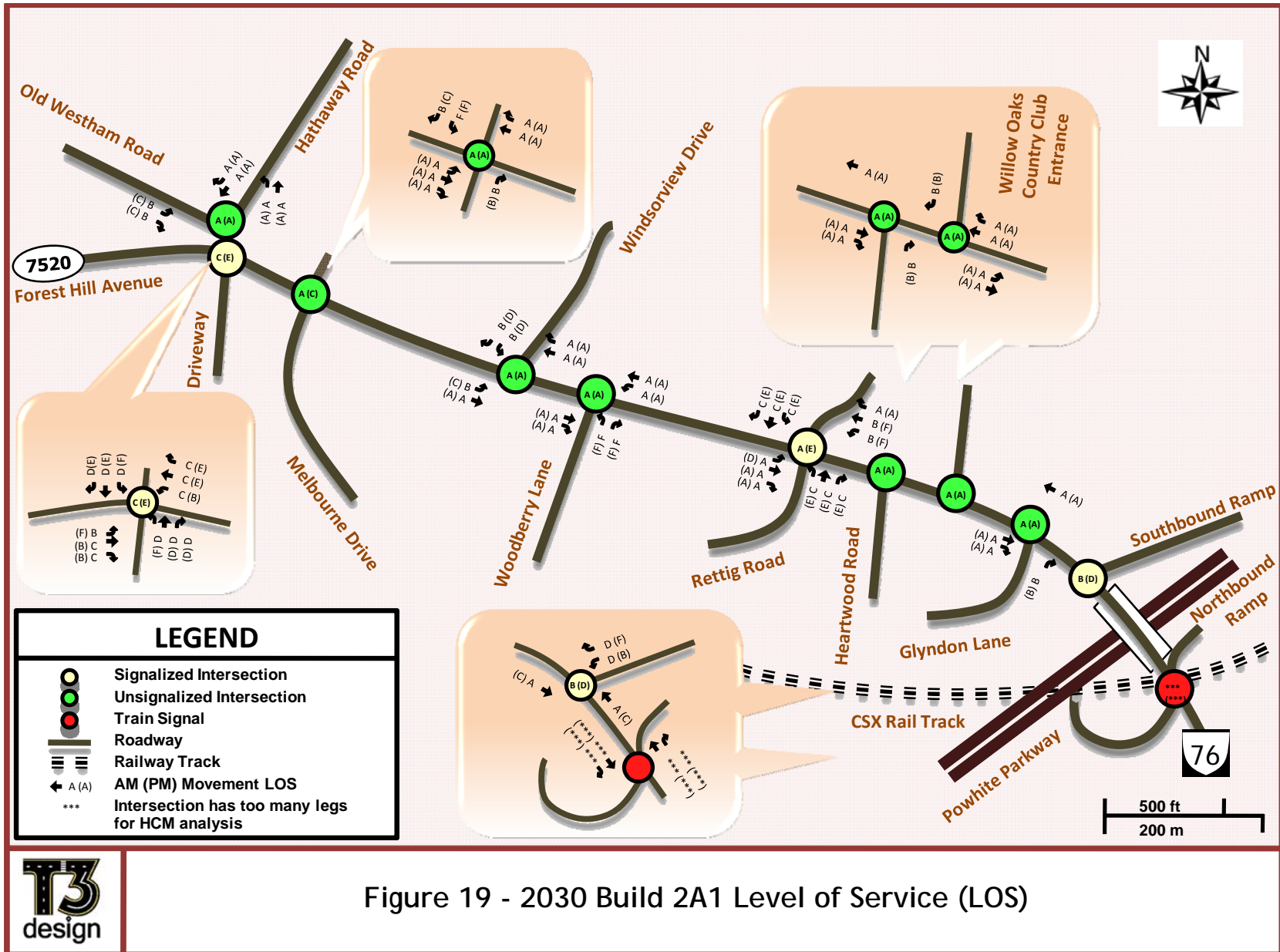
<u>INTERSECTION</u>	<u>TYPE OF CONTROL</u>	<u>MOVEMENT APPROACH</u>	<u>AM PEAK HOUR</u>		<u>PM PEAK HOUR</u>	
			<u>LEVEL OF SERVICE</u>	<u>DELAY (SEC/VEH)</u>	<u>LEVEL OF SERVICE</u>	<u>DELAY (SEC/VEH)</u>
1 Hathaway Rd Old Westham Rd	Unsignalized	EB L	B	12.5	C	17.0
		EBR	B	12.5	C	17.0
		EB Overall	B	12.5	C	17.0
		NB L	A	8.3	A	8.6
		NB T	A	0.0	A	0.0
		NB Overall	A	3.9	A	3.7
		SB TR	A	0.0	A	0.0
		SB Overall	A	0.0	A	0.0
		Intersection Overall	A	4.7	A	4.1
2 Hathaway Rd Forest Hill Ave	Signalized	EB L	B	15.1	F	85.2
		EB TR	C	23.2	B	17.5
		EB Overall	C	22.5	C	26.7
		WB L	C	22.0	B	17.1
		WB TR	C	22.3	E	75.4
		WB Overall	C	22.3	E	71.8
		NB L	D	41.2	F	118.1
		NB T	D	48.9	D	54.7
		NB R	D	45.1	D	47.7
		NB Overall	D	43.7	E	78.8
		SB L	D	53.3	F	121.8
		SB TR	D	42.2	E	63.7
		SB Overall	D	50.8	F	92.0
Intersection Overall	C	27.3	E	60.4		
3 Melbourne Rd Forest Hill Ave	Unsignalized	EB LT	A	1.1	A	3.0
		EB R	A	0.0	A	0.0
		EB Overall	A	0.4	A	1.0
		WB T	A	0.0	A	0.0
		WB R	A	0.0	A	0.0
		WB Overall	A	0.0	A	0.0
		NB R	B	10.9	B	10.3
		NB Overall	B	10.9	B	10.3
		SB L	F	166.5	F	2278.0
		SB R	B	14.5	C	23.7
		SB Overall	E	39.2	F	956.4
Intersection Overall	A	0.8	A	7.2		

Table 15: 2030 Build 2A1 LOS Analysis Results (Continued)

<u>INTERSECTION</u>	<u>TYPE OF CONTROL</u>	<u>MOVEMENT APPROACH</u>	<u>AM PEAK HOUR</u>		<u>PM PEAK HOUR</u>	
			<u>LEVEL OF SERVICE</u>	<u>DELAY (SEC/VEH)</u>	<u>LEVEL OF SERVICE</u>	<u>DELAY (SEC/VEH)</u>
4 Windsorview Dr Forest Hill Ave	Unsignalized	EB L	B	10.6	C	21.2
		EB T	A	0.0	A	0.0
		EB Overall	A	0.1	A	0.4
		WB T	A	0.0	A	0.0
		WB R	A	0.0	A	0.0
		WB Overall	A	0.0	A	0.0
		SB LR	B	11.8	C	29.0
		SB Overall	B	11.8	C	29.0
		Intersection Overall	A	0.2	A	0.5
5 Woodberry Ln Forest Hill Ave		EB TR	A	0.0	A	0.0
		EB Overall	A	0.0	A	0.0
		WB LT	A	1.4	A	1.5
		WB Overall	A	0.5	A	0.5
		NB LR	F	144.7	F	293.6
		NB Overall	F	144.7	F	293.6
		Intersection Overall	A	2.1	A	1.9
6 Rettig Rd Forest Hill Ave	Signalized	EB L	A	9.9	D	41.5
		EB TR	A	9.4	A	3.6
		EB Overall	A	9.5	A	5.5
		WB LT	B	19.4	F	100.3
		WB R	A	9.9	A	5.5
		WB Overall	B	19.3	F	98.5
		NB LTR	C	29.4	E	56.1
		NB Overall	C	29.4	E	56.1
		SB LTR	C	29.4	E	60.3
		SB Overall	C	29.4	E	60.3
				Intersection Overall	B	13.8
7 Heartwood Rd Forest Hill Ave		EB TR	A	0.0	A	0.0
		EB Overall	A	0.0	A	0.0
		WB T	A	0.0	A	0.0
		WB Overall	A	0.0	A	0.0
		NB R	B	11.1	B	11.7
		NB Overall	B	11.1	B	11.7
				Intersection Overall	A	0.0

Table 15: 2030 Build 2A1 LOS Analysis Results

<u>INTERSECTION</u>	<u>TYPE OF CONTROL</u>	<u>MOVEMENT APPROACH</u>	<u>AM PEAK HOUR</u>		<u>PM PEAK HOUR</u>	
			<u>LEVEL OF SERVICE</u>	<u>DELAY (SEC/VEH)</u>	<u>LEVEL OF SERVICE</u>	<u>DELAY (SEC/VEH)</u>
8 Willow Oaks C.C. Entr. Forest Hill Ave	Unsignalized	EB T	A	0.0	A	0.0
		EB Overall	A	0.0	A	0.0
		WB T	A	0.0	A	0.0
		WB R	A	0.0	A	0.0
		WB Overall	A	0.0	A	0.0
		SBR	B	11.8	C	11.2
		SB Overall	B	11.8	C	11.2
		Intersection Overall	A	0.1	A	0.2
9 Glyndon Ln Forest Hill Ave	Unsignalized	EB TR	A	0.0	A	0.0
		EB Overall	A	0.0	A	0.0
		WB T	A	0.0	A	0.0
		WB Overall	A	0.0	A	0.0
		NB R	B	12.7	B	11.7
		NB Overall	B	12.7	B	11.7
		Intersection Overall	A	0.1	A	0.0
10 Southbound Ramp Forest Hill Ave	Signalized	EB T	A	9.0	A	21.7
		EB Overall	A	9.0	A	21.7
		WB T	A	5.7	B	28.3
		WB Overall	A	5.7	B	28.3
		SB L	D	42.1	B	16.2
		SB R	D	51.4	F	165.3
		SB Overall	C	46.8	F	107.5
		Intersection Overall	B	16.5	D	53.5
11 Northbound Ramp Forest Hill Ave	Unsignalized	No conflicting movements at this intersection.				



GEOMETRIC REQUIREMENTS - 2011 & 2030 BUILD CONDITIONS

Queue Length Analysis - 2011 Opening Year Build 2A1 Condition

Based on the capacity analysis results Configuration 2A1 is selected to represent the “ultimate” scenario for the Build Condition. This section discusses the queuing analysis results for each traffic movement at the study intersections as reported by Synchro. Table 16 presents the results of queuing analysis for the 2011 Build condition for Configuration 2A1. As in the No-Build condition, the queue length represents the maximum of the AM or PM peak hour volume for each movement. The shaded cells in the table reflect the AM peak hour volume.

Hathaway Road at Old Westham Road – The 95th queue length for the northbound left-turn movement was reported to be 11 ft which is within the available storage length of 40ft. The maximum queue lengths for the eastbound left and right turning movements at this intersection are reported to be 18 ft which occurs during the AM peak hour. For the southbound approach a “zero” queue length is reported during the AM and PM peak hour.

Forest Hill Avenue at Hathaway Road – At the Forest Hill Avenue and Hathaway Road intersection, a 95th percentile queue length of 131 ft is reported for the eastbound left-turning movement, which is within the existing storage length of 220 ft. For the eastbound through-right movement, a 95th percentile queue length of 426 ft is reported which extends beyond the driveway to the shopping center located south of Forest Hill Avenue and also blocks access to Gravel Hill Road.

For the westbound left-turning movement, a 95th percentile queue length of 56 ft is reported which is within the existing available storage length of 90 ft. For the eastbound through movement, a significantly long queue of 906 ft is reported. The queue on the westbound approach is expected to extend beyond the upstream intersection and block the movement of the northbound and southbound vehicles at Melbourne Drive and also other accesses to the north of Forest Hill Avenue.

For the northbound left, through, and right-turning movements, the 95th percentile queue lengths are reported to be 156 ft, 63 ft, and 39 ft, respectively. The queue length for the northbound left-turn movement is expected to extend beyond the available storage length of 140 ft. For the southbound left and through-right turning movements, the 95th percentile queue lengths are reported to be 154 ft and 22 ft, respectively. The 154 ft queue length for the southbound left-turning movement exceeds the available storage length of 50 ft at this approach. The queue length for the southbound left-turning movement at the intersection is reported for the AM peak hour traffic condition.

Forest Hill Avenue at Melbourne Drive – The 95th percentile queue length for the westbound and eastbound right-turning movements at this intersection are reported to be “zero”. The turn lane warrant analysis per The *VDOT Road Design Manual* requires a full length storage right-turn lane for the westbound right-turning movement and a taper for the eastbound right-turning movement based on peak hour right-turning volumes and the opposing approach volumes; however, the Synchro reported “zero” queue lengths for these movements. Since, the eastbound and westbound traffic have free movements at this intersection, minimal queue lengths were reported for the through movements at these approaches. For the northbound shared through-right movement, a maximum queue of 7 ft was reported; and for the southbound right and shared through-left movements 95th percentile queue lengths of 4 ft were reported.

Forest Hill Avenue at Windsorview Drive The eastbound and westbound approaches at this intersection operate freely therefore, “zero” or minimal queues are reported for these approaches. For the southbound shared left and right turn movements, a 95th percentile queue length of 7 ft was reported.

Forest Hill Avenue at Woodberry Lane – The eastbound and westbound approaches at this intersection operate freely; therefore “zero” or minimal queues are reported for these approaches. For the northbound left-right turn movement, a maximum queue length of 19 ft is reported during the AM peak hour.

Forest Hill Avenue at Rettig Road – For the Build 2A1 configuration, the intersection of Forest Hill Avenue and Rettig Road is signalized; therefore the queue lengths were reported for all movements at the intersection. For the eastbound left- and shared through-right movements, 95th percentile queue lengths of 16 ft and 240 ft, respectively, were reported for the AM peak hour.

For the westbound right-turn movement and a shared left-through movement, 95th percentile queue lengths of 10 ft and 386 ft, respectively, were reported. The queue length of 386 ft for the westbound left-through movement is expected to extend beyond the upstream intersection of Forest Hill Avenue and Heartwood Road. For the shared left-through-right movements for the northbound and southbound approaches of this intersection, 95th percentile queue lengths of 39 ft and 41 ft, respectively, were reported for the AM peak hour.

Forest Hill Avenue at Heartwood Road – The 95th percentile queue lengths are reported to be “zero” for all movements at this intersection.

Forest Hill Avenue at Willow Oaks Country Club Entrance – Due to a revised lane configuration for the Build condition, all approaches at this intersection are expected to have “zero” or minimal queue lengths at this intersection.

Forest Hill Avenue at Glyndon Lane – The 95th percentile queue lengths are reported to be “zero” for all movements at this intersection.

Forest Hill Avenue at Powhite Parkway SB On/Off Ramps –The queuing analysis results for the southbound right-turning movement at the intersection of Forest Hill Avenue and Powhite Parkway SB off-ramp indicate a 95th percentile queue length of 443 ft. Synchro reports that the 95th percentile volume for this movement exceeds capacity and the queue is expected to be longer than the reported queue length of 443 ft. Though, for the Build condition a full length right-turn storage lane is warranted for the westbound approach of the Forest Hill Avenue and Willow Oaks Country Club Entrance, a relatively small proportion of off-ramp traffic is expected to enter the Country Club entrance. Furthermore, the majority of the off-ramp traffic volume would have to yield to the westbound through movement. Based on the available storage length of 180 ft on Forest Hill Avenue, the queue is expected to extend on the SB off-ramp.

For the eastbound through movement, the 95th percentile queue length is reported to be 335 ft which is expected to extend beyond the upstream intersection of Forest Hill Avenue and Glyndon Lane.

Table 16: Queuing Analysis Results - 2011 Build 2A1 Configuration

Intersection	Control Type	Movement	Peak Hour Volume (vph)	95th Percentile Queue length (ft)
Hathaway Rd at Old Westham Rd	Unsignalized	NBL	135	11
Forest Hill Avenue at Hathaway Rd	Signalized	EB L	130	131
		EB TR	1166	426
		WB L	84	56
		WBTR	1535	904
		NB L	97	125
		NB T	50	63
		NB R	77	39
		SB L	283	154
Forest Hill Avenue at Melbourne Dr	Unsignalized	WBR	45	0
		EB R	15	0
Forest Hill Avenue at Windsorview Dr	Unsignalized	EB L	12	5
		WB R	34	0
Forest Hill Avenue at Rettig Rd	Signalized	EB L	37	16
		EB TR	1386	240
		WBR	30	10
		WB LT	1727	386
		NB LTR	13	39
		SB LTR	35	41
Forest Hill Avenue at Willow Oaks C.C. Ent	Unsignalized	WB R	31	0
Forest Hill Avenue at SB Off-Ramp	Signalized	SB L	484	77
		SB R	765	443
		EBT	1426	335
		WBT	1071	283

Queue Length Analysis - 2030 Design Year Build 2A1 Condition

Table 17 presents the results of queuing analysis for the 2030 Build 2A1 condition. Similar to the No-Build condition, the queue length based on the higher of the AM and PM peak hour volume for each movement is reported. The shaded cell in the table reports the AM peak hour volume. Also, for several turning movements the 50th percentile queue length is greater than the 95th percentile queue length, in which case the maximum queue length is reported. The 50th percentile queue length is indicated in bold.

Hathaway Road at Old Westham Road – The 95th percentile queue length for the northbound left-turn movement is reported to be 16 ft which is within the available storage length of 40ft. The maximum queue lengths for the eastbound left and right turning movements at this intersection are reported to be 29 ft which occurs during the AM peak hour. For the southbound approach a “zero” queue length is reported during the AM and PM peak hour.

Forest Hill Avenue at Hathaway Road – At the Forest Hill Avenue and Hathaway Road intersection, a 95th percentile queue length of 258 ft is reported for the eastbound left-turning movement, which exceeds the existing storage length of 220 ft. For the eastbound through-right movement, a 95th percentile queue length of 642 ft is reported, which extends beyond the driveway of the shopping center located on the south side of Forest Hill Avenue and also blocks access to Gravel Hill Road.

For the westbound left-turning movement, a 95th percentile queue length of 62 ft is reported, which is within the existing available storage length of 90 ft. For the eastbound through movement, a significantly long queue of 1,195 ft is reported. The queue on the westbound approach is expected to extend beyond the upstream intersection and block the movement of the northbound and southbound vehicles at Melbourne Drive and also other accesses to the north of Forest Hill Avenue.

For the northbound left, through, and right-turning movements, the 95th or 50th percentile queue lengths are reported to be 148 ft, 105 ft, and 77 ft, respectively. The queue length for the northbound left-turn movement is expected to extend beyond the available storage length of 140 ft. For the southbound left and through-right turning movements, the 95th percentile queue lengths are reported to be 199 ft and 141 ft, respectively. The 199 ft queue length for the southbound left-turning movement exceeds the available storage length of 50 ft at this approach. The queue length for the southbound left-turning movement at the intersection was reported for the AM peak hour traffic condition.

Forest Hill Avenue at Melbourne Drive – The 95th percentile queue length for the westbound and eastbound right-turning movements at this intersection are reported to be “zero”. The turn lane warrant analysis per the *VDOT Road Design Manual* requires a full-length right-turn lane for the westbound right-turning movement and a taper for the eastbound right-turning movement, based on peak hour right-turning volumes and the opposing approach volumes, however, Synchro reports “zero” queue lengths for these movements. Since, the eastbound and westbound traffic have free movements at this intersection, minimal queue lengths are reported for the through movements for these approaches. For the northbound shared through-right movement, a maximum queue of 4 ft was reported and for the southbound right and shared through-left movements 95th percentile queue lengths of 64 ft and 6 ft, respectively, were reported.

Table 17: Queuing Analysis Results - 2011 Build 2A1 Configuration

Intersection		Movement	Peak Hour Volume (vph)	95th/50th Percentile Queue Length (ft)
Hathaway Rd at Old Westham Rd	Unsignalized	NBL	175	16
Forest Hill Avenue at Hathaway Rd	Signalized	EB L	168	258
		EB TR	1515	642
		WB L	110	62
		WB TR	1995	1321
		NB L	126	148
		NB T	65	105
		NB R	100	77
		SBR	156	141
Forest Hill Avenue at Melbourne Dr.	Unsignalized	WB R	59	0
		EB R	29	0
Forest Hill Avenue at Windsorview	Unsignalized	EB L	16	11
		WBR	44	0
Forest Hill Avenue at Rettig Rd	Signalized	EB L	48	18
		EB TR	1800	421
		WBR	39	21
		WB LT	2219	1456
		NB LTR	14	49
		SB LTR	45	52
Forest Hill Avenue at Oaks C.C. Ent.	Unsignalized	WB R	40	0
Forest Hill Avenue at SB Off-Ramp	Signalized	SB L	585	147
		SB R	885	862
		EBT	1853	406
		WBT	1392	514

Forest Hill Avenue at Windsorview Drive The eastbound and westbound approaches at this intersection operate freely, therefore “zero” or minimal queues are reported for these approaches. For the southbound shared left and right turn movements, a 95th percentile queue length of 18 ft was reported.

Forest Hill Avenue at Woodberry Lane – The eastbound and westbound approaches at this intersection operate freely, therefore “zero” or minimal queues are reported for these approaches. For the northbound left-right turn movement, a maximum queue length of 75 ft was reported during the AM peak hour.

Forest Hill Avenue at Rettig Road – For the Build 2A1 condition, the intersection of Forest Hill Avenue and Rettig Road is signalized; therefore the queue lengths are reported for all movements at the intersection. For the eastbound left-turning and shared through-right movements, 95th percentile queue lengths of 18 ft and 421 ft, respectively were reported for the AM peak hour.

For the westbound right-turning movement and a shared left-through movement, 95th percentile queue lengths of 21 ft and 1,456 ft, respectively, were reported. The queue length of 1,456 ft for the westbound left-through movement is expected to extend beyond the upstream intersections to the Powhite Parkway ramps. For the shared left-through-right turning movements at the northbound and southbound approaches of this intersection, 95th percentile queue lengths of 49 ft and 52 ft, respectively were reported for the AM peak hour.

Forest Hill Avenue at Heartwood Road – The 95th percentile queue lengths were reported to be “zero” for all movements at this intersection.

Forest Hill Avenue at Willow Oaks Country Club Entrance – Due to a revised lane configuration for the Build condition, the eastbound and westbound movements on Forest Hill Avenue are reported to have “zero” queue lengths. The 95th percentile queue length for the southbound right-turning movement was reported to be 12 ft.

Forest Hill Avenue at Glyndon Lane – The 95th percentile queue lengths are reported to be “zero” for the eastbound and westbound through movements and 7 ft for the southbound right-turning movement.

Forest Hill Avenue at Powhite Parkway SB On/Off Ramps –The queuing analysis results for the southbound right-turning movement at the intersection of Forest Hill Avenue and Powhite Parkway SB off-ramp indicate a 95th percentile queue length of 862 ft. Synchro reports that the 95th percentile volume for this movement exceeds capacity and the queue is expected to be longer than the reported queue length of 862 ft.

For the Build condition, a “taper” was added at the westbound approach of the Forest Hill Avenue and Willow Oaks Country Club entrance, a relatively low percentage of the off-ramp volume is expected to enter the Country Club entrance and a majority of the off-ramp traffic volume would yield to the westbound through movement. Based on the available storage length of 180 ft on Forest Hill Avenue, the queue is expected to extend on the SB off-ramp.

For the eastbound through movement, the 95th percentile queue length was reported to be 406 ft which is expected to extend beyond the upstream intersection of Forest Hill Avenue and Glyndon Lane.

Turn Lane Analysis - 2011 & 2030 Opening Year Build Condition

Turn-Lane Warrant Analysis

Storage lanes for the left and right-turn movements are provided to reduce impedance between the lower-speed turning vehicles and higher-speed through vehicles. This improves the safety and operational capacity for the through vehicles on an arterial. The decision to provide exclusive left and right-turn lanes at an intersection is based on the volume of the turning vehicles and opposing traffic.

This section of the report presents the results for the left and right-turn lane warrant analyses conducted for 2011 and 2030 Build conditions. The analyses were conducted based on *VDOT Road Design Manual* (Rev. 1/07). The manual provides separate analysis methodologies for the left and right-turn warrant analyses for a two-lane and four lane highways.

Left-Turn Lane Warrant Analysis:

Figure 20 illustrates curves for left-turn storage lane warrant analysis on a four lane highway. It can be seen from the figure that the storage length requirements for the left-turn lanes vary based on the left-turning volume and opposing traffic. Table 18 indicates the results for the left-turn lane warrant analysis conducted for the 2011 Build year for all configurations.

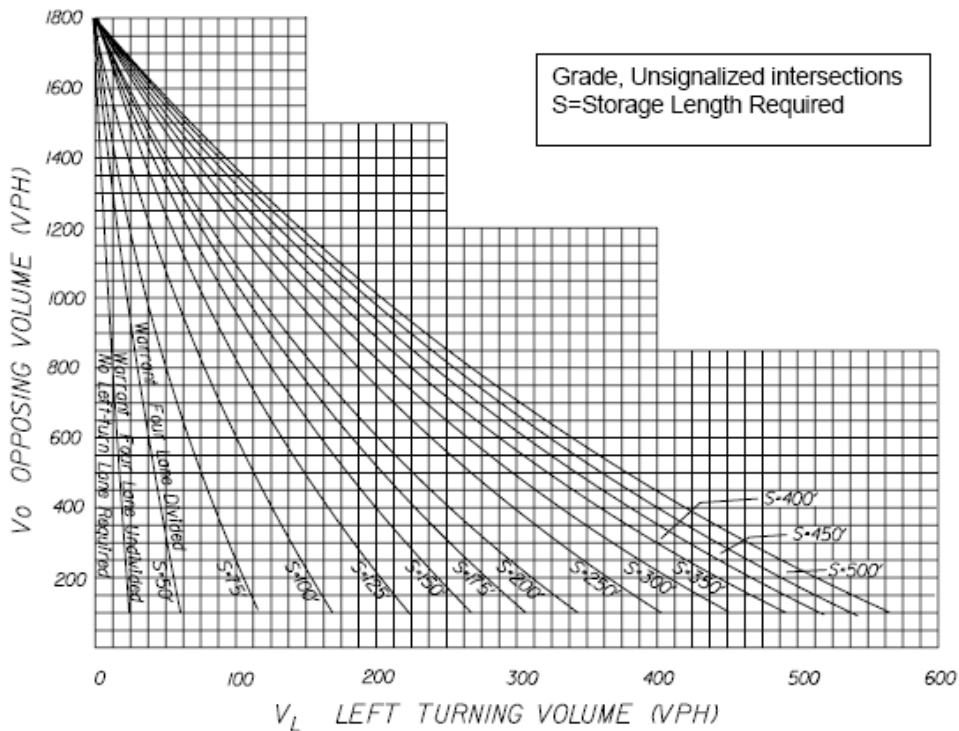


Figure 20 - Warrant for Left-Turn Storage Lanes on Four Lane Highways (Source: VDOT Roadway Design Manual)

Table 18: Left-Turn Lane Storage Lengths - 2011 Build Condition

Movement	Configuration	Left Turn Volume (vph)	Opposing Volume (vph)	Storage Length (ft)
EBL at Windsorview Dr	1A1	12	1688	125
EBL at Willow Oaks CC		22	1760	500
EBL at Windsorview Dr	1A2	12	1688	125
EBL at Willow Oaks CC		22	1760	500
EBL at Windsorview Dr	1B1	12	1688	125
EBL at Willow Oaks CC		22	1760	500
EBL at Windsorview Dr	1B2	12	1688	125
EBL at Willow Oaks CC		22	1760	500
EBL at Windsorview Dr	2A1	12	1688	125
EBL at Rettig Rd		27	1732	500
EBL at Windsorview Dr	2A2	12	1688	125
EBL at Rettig Rd		27	1736	500

As indicated in the table, for the 2011 future Build condition, left-turn storage lengths of 125 ft and 500 ft are warranted for the eastbound left-turning movements at the intersection of Forest Hill Avenue and Windsorview Drive and the intersection of Forest Hill Avenue and the Willow Oaks Country Club entrance, respectively. The storage lengths are warranted for PM peak hour volume and the length requirement remains same for all 2011 Build configurations.

Table 19 indicates results for the left-turn lane warrant analysis for 2030 Build condition. Due to an increase in left-turning and opposing traffic volumes, the storage length requirement for the eastbound left-turning movement at the Forest Hill Avenue and Windsorview Drive intersection increases to 500 ft compared to 125 ft required for the 2011 Build condition. For the eastbound left-turning movement at the Forest Hill Avenue and Willow Oaks Country Club intersection, the storage length requirements of 500 ft remains same for the 2030 Build Conditions as for 2011 Build condition. Moreover, for the 2030 Build condition, a left-turn storage length of 75 ft is also warranted for the westbound left-turning movement at the intersection of Forest Hill Avenue and Rettig Road. Similar to the 2011 Build condition, the storage lengths are warranted for the PM peak hour volume only and the storage length requirements at these locations remain same for all configurations.

Table 19: Left-Turn Lane Storage Lengths - 2030 Build Condition

Movement	Configuration	Left Turn Volume (vph)	Opposing Volume (vph)	Storage Length (ft)
EBL at Windsorview Dr	1A1	16	2194	500
EBL at Willow Oaks CC		28	2288	500
EBL at Windsorview Dr	1A2	16	2194	500
EBL at Willow Oaks CC		28	2288	500
WBL at Rettig Rd		20	1419	75
EBL at Windsorview Dr	1B1	16	2194	500
EBL at Willow Oaks CC		28	2288	500
EBL at Windsorview Dr	1B2	16	2194	500
EBL at Willow Oaks CC		28	2288	500
WBL at Rettig Rd		20	1419	75
EBL at Windsorview Dr	2A1	16	2194	500
EBL at Rettig Rd		35	2257	500
EBL at Windsorview Dr	2A2	16	2194	500
EBL at Rettig Rd		35	2257	500
WBL at Rettig Rd		20	1419	75

Right-Turn Lane Warrant Analysis:

The right-turn lane warrant analysis methodology given in the VDOT Roadway Design Manual warrants a radius, taper, or full length turn lane based on the peak hour right-turning volume and total approach volume. The right-turn lane warrant analysis curves are shown in Figure 21. The manual requires that the turn-lane storage lengths be provided based on the queuing analysis results.

Table 20 summarizes the right-turn adjustments for the 2011 Build condition. As shown in the table, the westbound right-turning traffic volume at the intersection of Forest Hill Avenue and Melbourne Drive requires a full storage and taper length for 2011 Build traffic condition for all configurations. The eastbound and westbound right-turning movements at all other intersections on Forest Hill Avenue either require a radius or a taper treatment. The full storage length for the westbound right-turning traffic volume at the intersection of Forest Hill Avenue and Melbourne Drive is required for the PM peak hour traffic volume. For the AM peak hour volume, a radius or a taper is required for the eastbound and westbound right-turning movements at all intersections on Forest Hill Avenue.

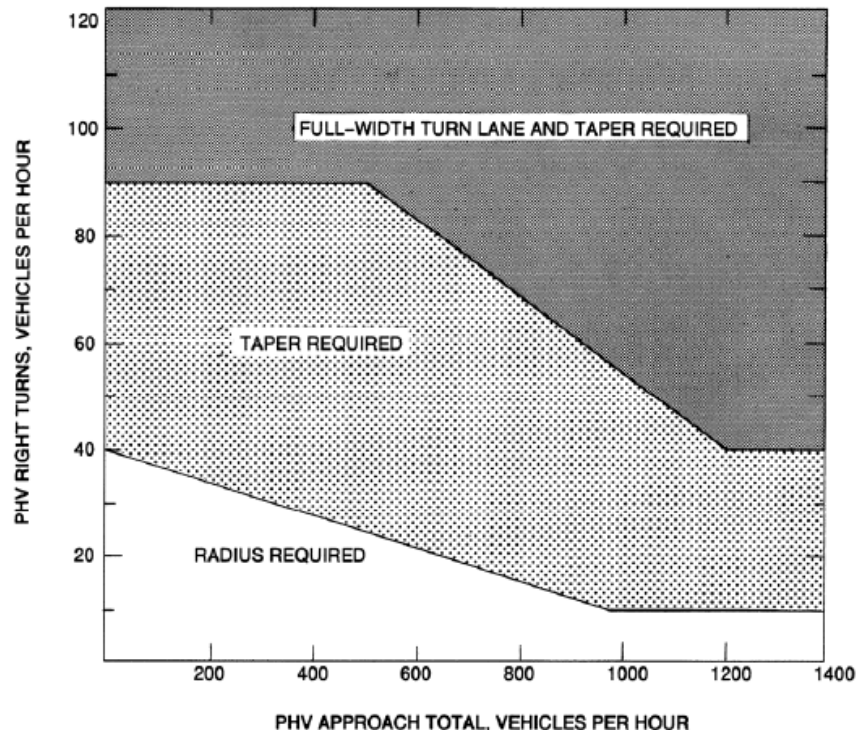


Figure 21 - AASHTO Right Turn Lane Requirements

Table 20: Right-Turn Adjustments - 2011 Build Condition

Right Turn	Build Configuration	Right Turn Volume (vph)	Approach Volume (vph)	Warrant
EBR at Melbourne Dr	1A1/1A2/1B1/1B2/2A1/2A2	15	1104	Taper
WBR at Melbourne Dr	1A1/1A2/1B1/1B2/2A1/2A2	45	1664	Full
WBR at Windsorview Dr	1A1/1A2/1B1/1B2/2A1/2A2	34	1688	Taper
EBR at Woodberry Ln	1A1/1A2/1B1/1B2/2A1/2A2	6	1090	Radius
EBR at Rettig Rd	1A1/1A2/1B1/1B2	2	1092	Radius
EBR at Rettig Rd	2A1/2A2	3	1092	Radius
WBR at Rettig Rd	1A1/1A2/1B1/1B2/2A1/2A2	30	1736	Taper
EBR at Heartwood Rd	1A1	5	1094	Radius
EBR at Heartwood Rd	1A2	6	1094	Radius
EBR at Heartwood Rd	1B1	5	1102	Radius
EBR at Heartwood Rd	1B2	6	1102	Radius
EBR at Heartwood Rd	2A1	5	1080	Radius
EBR at Heartwood Rd	2A2	6	1080	Radius
WBR at Willow Oaks CC	1A1/1A2/1B1/1B2/2A1/2A2	28	1760	Taper
EBR at Glyndon	1A1/1B1/2A1	1	1075	Radius

Table 21 presents right-turn adjustments on Forest Hill Avenue for the 2030 Build condition. The analysis results require full storage and taper lengths for the westbound right-turning movements at the intersection of Forest Hill Avenue and Melbourne Drive and Forest Hill Avenue and Windsorview Drive based on the PM peak hour traffic. Similar to the 2011 Build condition, the eastbound and westbound right-turning movements at all other intersections on Forest Hill Avenue require a radius or taper treatment.

Table 21: Right-Turn Adjustments - 2030 Build Condition

Right Turn	Build Configuration	Right Turn Volume	Approach Volume	Warrant
EBR at Melbourne Dr	1A1/1A2/1B1/1B2/2A1/2A2	20	1435	Taper
WBR at Melbourne Dr	1A1/1A2/1B1/1B2/2A1/2A2	59	2163	Full
WBR at Windsorview Dr	1A1/1A2/1B1/1B2/2A1/2A2	44	2194	Full
EBR at Woodberry Ln	1A1/1A2/1B1/1B2/2A1/2A2	8	1416	Radius
EBR at Rettig Rd	1A1/1A2/1B1/1B2	3	1419	Radius
EBR at Rettig Rd	2A1/2A2	4	1419	Radius
WBR at Rettig Rd	1A1/1A2/1B1/1B2/2A2	39	2257	Taper
EBR at Heartwood Rd	1A1	7	1422	Radius
EBR at Heartwood Rd	1A2	8	1422	Radius
EBR at Heartwood Rd	1B1	7	1432	Radius
EBR at Heartwood Rd	1B2	8	1432	Radius
EBR at Heartwood Rd	2A1	7	1404	Radius
EBR at Heartwood Rd	2A2	6	1080	Radius
WBR at Willow Oaks CC	1A1/1A2/1B1/1B2/2A1/2A2	36	2288	Taper
EBR at Glyndon	1A1/1B1/2A1	1	1398	Radius

Storage Length Requirements - 2011 Opening Year Build Condition

In the preceding sections of the report queue lengths have been discussed based on the capacity analysis and turn lane lengths have been discussed based on the Turn Lane Warrant analysis per the *VDOT Road Design Manual*. This section of the report recommends and discusses left and right-turn lane requirements based on the results of the capacity analysis and turn lane warrant requirements. Table 22 indicates total storage length requirements for the left and right turning lanes.

As per the AASHTO Green Book (2004), where full length storage is required, auxiliary lane lengths should be based on the sum of its three components: 1) entering taper, 2) deceleration length, 3) storage length. For the 2011 Build condition, the storage lengths for the left and right turning lanes are recommended based on the maximum of the 95th percentile queue length requirements or Turn Lane Warrant analysis requirements.

For the deceleration length and taper length, VDOT defines its standards based on the AASHTO standards. The standard deceleration lengths provided by VDOT are based on the roadway design speed. VDOT states that these deceleration lengths are desirable and the use of shorter deceleration lengths may require a design waiver. VDOT also provides standard taper length of 180 ft (for taper length to roadway width ratio of 15:1) or 100 ft (for taper length to roadway width ratio of 8:1). In Table 22, a deceleration length of 340 ft is recommended based on a design speed of 45 mph and a taper length of 180 for the taper length to roadway width ratio of 15:1. It should be noted that for a 100 ft taper length VDOT standards require a longer deceleration length as compared to the deceleration length when a 180 ft taper is provided.

Forest Hill Avenue at Hathaway Road – Storage lengths of 131 ft and 56 ft for the eastbound and westbound left-turning lanes, respectively, are desired based on the queuing analysis results. The total lengths 651 ft and 576 ft are required for the eastbound and westbound left-turning lanes, respectively, which includes 340 ft of deceleration length and 180 ft of taper length. However, as shown in the table, the required lengths of the turn lanes cannot be accommodated within the available spacing between the intersection of Forest Hill Avenue and Hathaway Road and the respective upstream intersections. In this case, shorter deceleration lengths are needed which may require a design waiver.

Forest Hill Avenue at Melbourne Drive - The 95th percentile queue length for the eastbound right-turn movement was reported to be “zero” at this intersection. However, the Turn Lane Warrant analysis requires a “taper” for the eastbound right-turning movement. Per VDOT standards, a taper length of 180 ft or 100 ft could be provided based on the right-of-way constraints. A comparison of 180 ft taper length and a 100 ft taper length concludes that a 100 ft taper is preferred at urban intersections where right-of-way constraints exists.

For the westbound right-turn lane, the results of the Turn Lane Warrant analysis require a full storage length. The capacity analysis results however, reported a “zero” queue length for this movement. Based on the VDOT standards for an unsignalized intersection, a minimum storage length of 50 ft is recommended. Including the deceleration length and the taper length, a total length of 570 ft is required for the westbound right-tuning lane. Right-of-way constraints may exist for the provision of a full length right-turn lane for the westbound right-turn movement.

Table 22: Recommended Lengths for Left and Right Turn Lanes - 2011 Build 2A1 Configuration

Intersection	Movement	95/50th Percentile Queue Length (ft)	Turn Lane Warrant Analysis Requirement	Desired Storage Length (ft)	Deceleration Length (ft)	Taper Length (ft)	Total Length (ft)	Distance to the Upstream Intersection (ft)
Forest Hill Avenue at Hathaway Road	EB L	131	-	131	340	180	651	350
	WB L	56	-	56	340	180	576	230
Forest Hill Avenue at Melbourne Dr.	EB R	0	Taper	-	-	180 (100)	-	230
	WB R	0	Full Storage	50	340	180	570	860
Forest Hill Avenue at Windsorview Dr.	EB L	5	125' Storage	125	340	180	645	860
	WB R	0	Taper	-	-	180	-	1000
Forest Hill Avenue at Rettig Rd	EB L	16	500' Storage	500	340	180	1020	800
	WB R	10	Taper	10	340-	180	530	540
Forest Hill Avenue at Willow Oaks C.C. Ent.	WB R	0	Taper	-	-	180		500

Forest Hill Avenue at Windsorview Drive - The Turn Lane Warrant analysis results require a 125 ft storage length for the eastbound left-turn movement at the Forest Hill Avenue and Windsorview Drive intersection. Including the deceleration length and the taper length, a total length of 645 ft is required for the eastbound left-turning lane. For the westbound right-turn movement, the capacity analysis results report a “zero” queue length. The Turn Lane Warrant analysis requires a taper for this movement, therefore, per VDOT standards, a taper length of 180 ft is recommended for the westbound right-turning movement.

Forest Hill Avenue at Rettig Road – For the eastbound left-turning movement, the capacity analysis results reported a 16 ft queue length. However, the Turn Lane Warrant analysis results required a 500 ft storage length. The sum of the storage, deceleration, and taper length equals a 1020 ft length for the eastbound left turn lane. As indicated in Table 22, the desired left-turn lane extends to the upstream intersection of Forest Hill Avenue and Woodberry Lane. For a shorter deceleration length, a design waiver may be required.

A storage length of 10 ft is required based on the 95th percentile queuing analysis results for the westbound right-turning movement at the Forest Hill Avenue and Rettig Road intersection. Including the deceleration and taper length a westbound right-turn lane of 530 ft is required.

Forest Hill Avenue at Willow Oaks C.C. Entrance - The Turn Lane Warrant analysis requires a taper for the westbound right-turning movement at the Forest Hill Avenue and Willow Oaks C.C. entrance. A 180 ft of taper length is recommended based on VDOT standards. If a 180 ft of taper is provided for the westbound right-turning movement, it would merge with the existing receiving lane provided for the southbound off-ramp traffic from Powhite Parkway.

Storage Length Requirements - 2030 Design Year Build Condition

This section of the report recommends and discusses left and right-turn lane requirements based on the results of the capacity analysis and turn lane warrant requirements for the 2030 Build Condition. Table 23 indicates total storage length requirements for the left and right turning lanes.

Forest Hill Avenue at Hathaway Road – Storage lengths of 258 ft and 62 ft for the eastbound and westbound left-turning lanes, respectively, are desired based on the queuing analysis results. Total lengths of 778 ft and 582 ft are required for the eastbound and westbound left-turning lanes, respectively, which includes 340 ft of deceleration length and 180 ft of taper length. However, as shown in the table, the required lengths of these turning lanes cannot be accommodated within the available spacing between the intersection of Forest Hill Avenue and Hathaway Road and the respective upstream intersections. In this case, shorter deceleration lengths are needed which may require a design waiver.

Forest Hill Avenue at Melbourne Drive - The 95th percentile queue length for the eastbound right-turn movement is reported to be “zero” at this intersection. However, the Turn Lane Warrant analysis requires a taper for the eastbound right-turning movement. Per VDOT standards, a taper length of 180 ft or 100 ft could be provided based on the right-of-way constraints. A comparison of 180 ft taper length and a 100 ft taper length states that a 100 ft taper is preferred at urban intersections where the right-of-way constraints exists.

For the westbound right-turn lane, the results of the Turn Lane Warrant analysis require a full storage length. The capacity analysis results for the 2030 Build condition however, reported a “zero” queue length for this movement. Based on VDOT standards for an unsignalized intersection, a minimum storage length of 50 ft is recommended. Including the deceleration length and the taper length, a total length of 570 ft is required for the westbound right-turning lane. Right-of-way constraints may exist for the provision of a full length right-turn lane for the westbound right-turning movement.

Forest Hill Avenue at Windsorview Drive - The Turn Lane Warrant analysis required a 500 ft storage length for the eastbound left-turning movement at the Forest Hill Avenue and Windsorview Drive intersection. Including the deceleration length and the taper length, a total length of 1,020 ft is required for the eastbound left-tuning lane. The 1,020 ft storage length for the eastbound left-turning movement at the Forest Hill Avenue and Windsorview Drive intersection extends beyond the upstream intersection of Forest Hill Avenue and Melbourne Drive. To provide shorter deceleration length a design waiver may be required. For the westbound right-turning movement, the capacity analysis results reported a “zero” queue length. The Turn Lane Warrant analysis required a full storage lane for this movement. Based on the VDOT standards for an unsignalized intersection, a minimum storage length of 50 ft is recommended. Including the deceleration length and the taper length, a total storage length of 570 ft is required for the westbound right-tuning lane.

Forest Hill Avenue at Rettig Road – For the eastbound left-turning movement, the capacity analysis results reported an 18 ft queue length. However, the Turn Lane Warrant analysis requires a 500 ft storage length. The storage, deceleration, and taper length add up to 1020 ft for the eastbound left turning lane. As indicated in Table 23, the desired left-turn lane extends to the upstream intersection of Forest Hill Avenue and Woodberry Lane. For a shorter deceleration length, a design waiver may be required.

A storage length of 21 ft is required based on the 95th percentile queuing analysis for the westbound right-turning movement at the Forest Hill Avenue and Rettig Road intersection. Including the deceleration and taper length a westbound right-turn lane of 541 ft is required.

Forest Hill Avenue at Willow Oaks Country Club Entrance - The Turn Lane Warrant analysis required a taper for the westbound right-turning movement on Forest Hill Avenue at the Willow Oaks Country Club entrance. A 180 ft of taper length is recommended based on VDOT standards. The 180 ft taper for the westbound right-turning movement at the Willow Oaks Country Club entrance merges with the receiving lane on Forest Hill Avenue for the southbound off-ramp right-turning traffic from Powhite Parkway.

Table 23: Recommended Lengths for Left and Right Turn Lanes - 2030 Build 2A1 Configuration

Intersection	Movement	95/50th Percentile Queue Length (ft)	Turn Lane Warrant Analysis Requirement	Desired Storage Length (ft)	Deceleration Length (ft)	Taper Length (ft)	Total Length (ft)	Distance to the Upstream Intersection (ft)
Forest Hill Avenue at Hathaway Road	EB L	258	-	258	340	180	778	350
	WB L	62	-	62	340	180	582	230
Forest Hill Avenue at Melbourne Dr.	EB R	0	Taper	-	-	180	-	230
	WB R	0	Full Storage	50	340	180	570	860
Forest Hill Avenue at Windsorview Dr.	EB L	11	500' Storage	500	340	180	1020	860
	WB R	0	Full Storage	50	340	180	570	1000
Forest Hill Avenue at Rettig Rd	EB L	18	500' Storage	500	340	180	1020	800
	WB R	21	Full Storage	21	340	180	541	540
Willow Oaks C.C. Ent.	WB R	0	Taper	-	-	180		500

Environmental Analysis - 2030 Design Year Build Condition

An environmental analysis was conducted that analyzes the ultimate scenario (i.e., Configuration 2A1 – 2030 Design Year) for fuel consumption and emissions. The analysis was conducted using CORSIM traffic modeling software and included an analysis spanning 12 hours. The 12 hours of projected traffic data were developed by using 24-hour automatic traffic recorder (ATR) data that was collected along the corridor. The turning movement volumes were projected over 12 hours using the percent difference between the peak hours and the other hours of the day, using the ATR data.

The environmental analysis revealed that a total of approximately 1270 gallons and 1130 gallons of fuel were consumed for the 12-hour period in the westbound and eastbound directions, respectively, along the entire corridor. Although the volumes in the westbound and eastbound direction are nearly balanced when totaling the AM and PM peak period, the westbound direction has the highest hourly total volume, becoming as high as 1700 vph in the vicinity of Glyndon Lane during the PM peak hour. This is reflected in the higher overall fuel consumption for the westbound direction. The fuel consumptions for individual hours have been aggregated and summarized for the westbound and eastbound segments in Table 24 and Table 25, respectively.

Table 24 - 12 Hour Fuel Consumption (Westbound Segment)

2030 2A1	FUEL CONSUMPTION - ALL VEHICLE TYPES (GALLONS)												
FOREST HILL AVE. WB SEGMENT	HR 1	HR 2	HR 3	HR 4	HR 5	HR 6	HR 7	HR 8	HR 9	HR 10	HR 11	HR 12	TOT
Powhite Pkwy NB On Ramp to Powhite Pkwy SB Off Ramp	2.5	5.1	3.5	2.6	2.8	4.0	10.1	10.3	12.8	15.0	16.2	10.3	95.1
Powhite Pkwy SB Off Ramp to Glyndon Ln	6.9	11.3	8.9	7.2	7.7	9.7	20.9	20.7	21.6	23.8	25.6	20.8	185.0
Glyndon Ln to Willow Oaks Country Club	4.2	8.2	5.9	4.5	4.9	6.5	15.2	15.7	16.9	18.9	20.4	15.5	136.8
Willow Oaks Country Club to Heartwood Rd	2.1	3.6	2.8	2.2	2.4	2.9	6.1	6.3	6.9	8.5	9.0	6.2	58.9
Heartwood Rd to Retting Rd	4.0	8.3	5.3	3.7	3.9	5.2	14.2	14.4	14.6	18.0	20.0	12.9	124.4
Retting Rd to Woodberry Ln	8.9	15.4	10.9	8.0	8.5	10.8	22.3	22.9	23.0	26.8	29.5	21.8	208.8
Woodberry Ln to Windsorview Dr	2.1	3.8	2.7	2.1	2.3	2.8	7.0	6.8	7.4	9.3	10.2	6.9	63.4
Windsorview Dr to Melbourne Dr	6.8	12.0	8.6	6.5	7.0	8.8	24.8	23.5	24.2	35.9	44.5	24.2	226.8
Melbourne Dr to Hathaway Rd	4.5	10.5	6.4	4.3	4.7	6.9	21.7	20.0	19.7	24.0	28.5	19.6	170.8
CORRIDOR TOTAL	41.9	78.1	55.0	41.1	44.1	57.6	142.3	140.5	147.2	180.2	203.9	138.1	1270.1

Table 25 - 12 Hour Fuel Consumption (Eastbound Segment)

2030 2A1	FUEL CONSUMPTION - ALL VEHICLE TYPES (GALLONS)												TOT
FOREST HILL AVE. EB SEGMENT	HR 1	HR 2	HR 3	HR 4	HR 5	HR 6	HR 7	HR 8	HR 9	HR 10	HR 11	HR 12	TOT
Hathway Rd to Melbourne Dr	11.2	19.9	14.3	10.3	11.6	14.9	11.0	10.1	9.9	11.4	12.1	9.9	146.6
Melbourne Dr to Windsorview Dr	13.3	22.8	17.3	12.8	13.9	17.8	12.9	11.4	11.9	13.4	14.2	11.5	173.1
Windsorview Dr to Woodberry Ln	4.0	6.9	5.4	4.0	4.2	5.2	4.0	3.7	4.0	4.1	4.8	3.7	54.0
Woodberry Ln to Retting Rd	13.3	25.2	17.4	12.3	13.6	17.8	12.3	11.9	13.7	15.4	17.1	11.7	181.7
Retting Rd to Heartwood Rd	9.6	16.6	11.6	8.1	9.0	11.5	8.0	7.8	9.4	10.4	11.2	7.8	120.9
Heartwood Rd to Willow Oaks Country Club	3.7	6.3	4.7	3.5	3.8	4.8	3.3	3.0	3.4	3.6	3.9	3.0	46.9
Willow Oaks Country Club to Glyndon Ln	2.0	4.0	2.6	1.9	2.1	2.8	2.0	1.7	2.1	2.8	3.4	1.8	29.2
Glyndon Ln to Powhite Pkwy SB Off Ramp	5.7	13.5	9.3	6.4	7.3	11.6	10.5	9.8	10.9	13.1	14.3	9.8	122.2
Powhite Pkwy SB Off Ramp to Powhite Pkwy NB On Ramp	14.7	29.8	20.9	15.9	17.4	23.1	21.7	20.6	20.7	23.2	24.9	20.6	253.6
CORRIDOR TOTAL	77.5	145.1	103.5	75.2	83.1	109.4	85.6	80.1	86.0	97.2	105.8	79.8	1128.2

The emission of carbon monoxide (CO) was also tabulated in units of grams for the entire corridor, as well as individual segments. Carbon monoxide is one of three emissions that evaluated as part of the environmental analysis, which also includes hydrocarbons (HC) and nitrogen oxide (NO). The result of the analysis for CO emissions is shown in Table 26. This shows the total emissions for the westbound segment of the corridor. The eastbound CO emissions are summarized in Table 27.

Table 26: Carbon Monoxide Emissions (WB Segment)

2030 2A1	CARBON MONOXIDE (CO) EMISSION - ALL VEHICLE TYPES (GRAMS)												TOT
FOREST HILL AVE. WB SEGMENT	HR 1	HR 2	HR 3	HR 4	HR 5	HR 6	HR 7	HR 8	HR 9	HR 10	HR 11	HR 12	TOT
Powhite Parkway NB On Ramp to Powhite Parkway SB Off Ramp	10.7	11.6	11.4	9.3	9.5	11.5	11.2	11.3	12.6	12.7	13.2	11.9	136.9
Powhite Parkway SB Off Ramp to Glyndon Lane	23.0	22.3	23.1	23.8	24.3	23.5	26.1	23.7	23.4	22.9	23.0	24.2	283.3
Glyndon Lane to Willow Oaks Country Club	20.6	23.7	21.3	21.6	21.8	21.9	27.0	27.8	28.3	28.0	28.5	27.8	298.3
Willow Oaks Country Club to Heartwood Road	13.8	14.6	14.6	15.5	15.1	15.2	14.7	14.5	14.1	12.5	12.8	14.6	172.0
Heartwood Road to Retting Road	11.0	13.8	11.6	12.1	11.4	11.7	14.2	15.1	15.6	16.7	16.6	14.6	164.4
Retting Road to Woodberry Lane	33.1	36.5	33.0	30.3	27.8	31.7	31.8	32.6	30.6	33.3	35.0	31.0	386.8
Woodberry Lane to Windsorview Drive	6.3	7.3	6.0	7.2	6.1	6.5	8.2	8.0	7.6	8.7	8.7	8.0	88.6
Windsorview Drive to Melbourne Drive	22.0	23.9	20.4	18.5	20.0	21.7	26.5	25.5	24.3	29.9	33.5	25.9	292.1
Melbourne Drive to Hathaway Road	8.5	13.1	10.3	9.1	10.3	10.8	19.5	17.7	17.5	19.6	21.9	17.2	175.7
CORRIDOR TOTAL	149.0	166.8	151.7	147.5	146.2	154.6	179.3	176.2	174.0	184.4	193.3	175.1	1998.1

Table 27: Carbon Monoxide Emissions (EB Segment)

2030 2A1	CARBON MONOXIDE (CO) EMISSION - ALL VEHICLE TYPES (GRAMS)												TOT
FOREST HILL AVE. EB SEGMENT	HR 1	HR 2	HR 3	HR 4	HR 5	HR 6	HR 7	HR 8	HR 9	HR 10	HR 11	HR 12	TOT
Hathway Road to Melbourne Drive	24.0	25.5	24.0	22.6	22.8	24.0	22.6	23.2	23.0	23.5	21.4	24.3	280.9
Melbourne Drive to Windsorview Drive	35.4	35.7	35.4	33.8	32.6	36.4	34.8	31.6	33.6	33.2	30.7	35.4	408.7
Windsorview Drive to Woodberry Lane	6.6	6.9	7.4	6.5	6.3	6.5	6.9	7.0	8.1	7.0	6.8	7.4	83.4
Woodberry Lane to Retting Road	20.3	22.6	22.6	20.3	20.1	21.8	21.5	21.4	23.1	23.0	23.9	20.6	261.2
Retting Road to Heartwood Road	19.6	21.2	18.6	16.1	16.1	17.1	16.4	17.8	20.6	21.1	20.6	16.8	222.0
Heartwood Road to Willow Oaks Country Club	9.7	10.2	9.1	8.5	8.6	8.6	8.1	9.0	10.0	10.6	10.1	8.4	111.1
Willow Oaks Country Club to Glyndon Lane	8.3	8.8	7.3	7.5	8.1	7.4	7.1	7.6	8.9	8.3	8.2	7.2	94.7
Glyndon Lane to Powwhite Parkway SB Off Ramp	7.5	10.4	10.0	8.4	8.6	11.3	13.4	12.0	12.6	14.5	16.0	12.3	136.8
Powwhite Parkway SB Off Ramp to Powwhite Parkway NB On Ramp	16.4	19.0	18.6	19.0	18.5	19.5	25.5	24.4	23.4	23.8	23.8	25.1	257.1
CORRIDOR TOTAL	147.8	160.4	153.0	142.8	141.7	152.7	156.3	154.1	163.2	165.0	161.4	157.5	1855.8

The emission of hydrocarbons (HC) was also tabulated in units of grams for the corridor and individual segments. The results of the analysis for HC emissions are shown in Table 26. This shows that the total of emissions for the westbound segment of the corridor equals 108 grams of hydrocarbons. The total eastbound emissions, which are summarized in Table 29 indicates that approximately 100 grams of hydrocarbons are emitted for the eastbound segment of Forest Hill Drive.

Table 28: Hydrocarbon Emissions (WB Segment)

2030 2A1	HYDROCARBONS (HC) EMISSION - ALL VEHICLE TYPES (GRAMS)												TOT
FOREST HILL AVE. WB SEGMENT	HR 1	HR 2	HR 3	HR 4	HR 5	HR 6	HR 7	HR 8	HR 9	HR 10	HR 11	HR 12	TOT
Powwhite Pkwy NB On Ramp to Powwhite Pkwy SB Off Ramp	0.6	0.7	0.6	0.5	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.7	8.0
Powwhite Pkwy SB Off Ramp to Glyndon Ln	1.1	1.1	1.1	1.1	1.2	1.1	1.3	1.1	1.1	1.1	1.1	1.2	13.6
Glyndon Ln to Willow Oaks Country Club	1.1	1.2	1.1	1.1	1.1	1.1	1.4	1.4	1.4	1.4	1.5	1.4	15.3
Willow Oaks Country Club to Heartwood Rd	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.8	9.2
Heartwood Rd to Retting Rd	0.6	0.8	0.7	0.7	0.6	0.7	0.8	0.8	0.9	0.9	0.9	0.8	9.3
Retting Rd to Woodberry Ln	1.7	1.9	1.7	1.6	1.5	1.7	1.7	1.7	1.6	1.8	1.9	1.6	20.5
Woodberry Ln to Windsorview Dr	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.5	0.5	0.5	5.1
Windsorview Dr to Melbourne Dr	1.3	1.3	1.2	1.1	1.2	1.2	1.5	1.5	1.4	1.8	2.0	1.5	16.9
Melbourne Dr to Hathaway Rd	0.5	0.8	0.6	0.5	0.6	0.6	1.1	1.0	1.0	1.1	1.3	1.0	10.3
CORRIDOR TOTAL	8.0	9.0	8.1	7.9	7.9	8.3	9.7	9.5	9.4	10.1	10.6	9.4	108.0

Table 29: Hydrocarbon Emissions (EB Segment)

2030 2A1	HYDROCARBONS (HC) EMISSION - ALL VEHICLE TYPES (GRAMS)												
FOREST HILL AVE. EB SEGMENT	HR 1	HR 2	HR 3	HR 4	HR 5	HR 6	HR 7	HR 8	HR 9	HR 10	HR 11	HR 12	TOT
Hathway Rd to Melbourne Dr	1.2	1.2	1.2	1.1	1.1	1.2	1.1	1.1	1.1	1.1	1.0	1.2	13.6
Melbourne Dr to Windsorview Dr	1.9	2.0	1.9	1.9	1.8	2.0	1.9	1.7	1.8	1.8	1.7	1.9	22.4
Windsorview Dr to Woodberry Ln	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4	4.8
Woodberry Ln to Retting Rd	1.2	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.3	1.3	1.4	1.2	15.1
Retting Rd to Heartwood Rd	1.0	1.1	0.9	0.8	0.8	0.9	0.8	0.9	1.0	1.1	1.0	0.9	11.2
Heartwood Rd to Willow Oaks Country Club	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.5	6.2
Willow Oaks Country Club to Glyndon Ln	0.5	0.5	0.4	0.5	0.5	0.4	0.4	0.5	0.5	0.5	0.5	0.4	5.7
Glyndon Ln to Powhite Pkwy SB Off Ramp	0.4	0.6	0.6	0.5	0.5	0.7	0.8	0.7	0.8	0.9	1.0	0.7	8.2
Powhite Pkwy SB Off Ramp to Powhite Pkwy NB On Ramp	0.9	1.0	1.0	1.0	1.0	1.0	1.3	1.2	1.2	1.2	1.2	1.2	13.0
CORRIDOR TOTAL	8.0	8.7	8.3	7.8	7.7	8.3	8.4	8.3	8.8	8.9	8.7	8.4	100.2

The emission of nitrogen oxide (NO) was also tabulated in units of grams for the corridor and individual segments. The results of the analysis for NO emissions are shown in Table 30. This shows that the total of emissions for the westbound segment of the corridor equals approximately 270 grams of nitrogen oxide. The total eastbound emissions, which are summarized in Table 31 indicates that approximately 260 grams of nitrogen oxide are emitted for the eastbound segment of Forest Hill Drive.

Table 30: Nitrogen Oxide Emissions (WB Segment)

2030 2A1	NITROGEN OXIDE (NO) EMISSION - ALL VEHICLE TYPES (GRAMS)												
FOREST HILL AVE. WB SEGMENT	HR 1	HR 2	HR 3	HR 4	HR 5	HR 6	HR 7	HR 8	HR 9	HR 10	HR 11	HR 12	TOT
Powhite Pkwy NB On Ramp to Powhite Pkwy SB Off Ramp	1.5	1.5	1.5	1.3	1.3	1.6	1.5	1.5	1.7	1.7	1.7	1.6	18.3
Powhite Pkwy SB Off Ramp to Glyndon Ln	2.9	2.9	3.0	3.0	3.1	3.0	3.5	3.1	3.1	3.0	3.0	3.2	36.8
Glyndon Ln to Willow Oaks Country Club	2.8	3.3	2.9	2.9	3.0	2.9	3.7	3.9	3.9	3.9	4.0	3.8	41.0
Willow Oaks Country Club to Heartwood Rd	1.8	1.9	1.9	2.0	2.0	2.0	1.9	1.9	1.9	1.7	1.7	1.9	22.6
Heartwood Rd to Retting Rd	1.5	1.8	1.5	1.6	1.5	1.6	1.9	2.0	2.1	2.3	2.2	1.9	22.0
Retting Rd to Woodberry Ln	4.5	4.9	4.5	4.1	3.7	4.3	4.3	4.4	4.1	4.5	4.7	4.1	52.1
Woodberry Ln to Windsorview Dr	0.9	1.0	0.8	1.0	0.9	0.9	1.1	1.1	1.0	1.2	1.2	1.1	12.2
Windsorview Dr to Melbourne Dr	3.0	3.2	2.8	2.6	2.8	3.0	3.6	3.4	3.3	4.0	4.5	3.5	39.8
Melbourne Dr to Hathaway Rd	1.1	1.7	1.4	1.2	1.4	1.4	2.7	2.4	2.4	2.7	3.0	2.3	23.9
CORRIDOR TOTAL	20.0	22.3	20.3	19.9	19.7	20.6	24.1	23.7	23.5	25.0	26.2	23.5	268.7

Table 31: Nitrogen Oxide Emissions (EB Segment)

2030 2A1 FOREST HILL AVE. EB SEGMENT	NITROGEN OXIDE (NO) EMISSION - ALL VEHICLE TYPES (GRAMS)												TOT
	HR 1	HR 2	HR 3	HR 4	HR 5	HR 6	HR 7	HR 8	HR 9	HR 10	HR 11	HR 12	
Hathway Rd to Melbourne Dr	3.2	3.4	3.2	3.0	3.0	3.2	2.9	3.0	3.0	3.1	2.8	3.2	37.0
Melbourne Dr to Windsorview Dr	4.8	4.9	4.8	4.7	4.5	5.0	4.7	4.3	4.6	4.5	4.2	4.8	55.8
Windsorview Dr to Woodberry Ln	0.9	0.9	1.0	0.9	0.9	0.9	0.9	1.0	1.1	1.0	0.9	1.0	11.5
Woodberry Ln to Retting Rd	2.7	3.1	3.1	2.8	2.8	3.0	2.9	2.9	3.1	3.1	3.3	2.8	35.4
Retting Rd to Heartwood Rd	2.6	2.8	2.5	2.2	2.1	2.3	2.2	2.3	2.8	2.8	2.8	2.2	29.7
Heartwood Rd to Willow Oaks Country Club	1.4	1.4	1.3	1.2	1.2	1.2	1.1	1.3	1.4	1.5	1.4	1.2	15.5
Willow Oaks Country Club to Glyndon Ln	1.1	1.2	1.0	1.0	1.1	1.0	1.0	1.0	1.2	1.1	1.1	1.0	12.8
Glyndon Ln to Powhite Pkwy SB Off Ramp	1.0	1.4	1.4	1.1	1.2	1.5	1.8	1.6	1.6	2.0	2.2	1.7	18.5
Powhite Pkwy SB Off Ramp to Powhite Pkwy NB On Ramp	2.2	2.6	2.5	2.6	2.5	2.7	3.4	3.3	3.2	3.2	3.2	3.4	34.8
CORRIDOR TOTAL	20.0	21.7	20.7	19.4	19.2	20.8	21.0	20.6	22.0	22.3	21.8	21.2	250.9

Intelligent Transportation Systems – Railroad Crossing

The intersection of Forest Hill Avenue and the Northbound Powhite Parkway Off-Ramp includes a ramp access to and from northbound Powhite Parkway, within an intersection that also includes an at-grade highway-rail crossing and an intersecting residential street (i.e., Fairlee Road) approximately 250 ft from the intersection. An aerial depiction of this intersection (courtesy of Bing™) is shown in Figure 22. Additional perspectives of the highway-rail intersection are shown in Figure 23.

Figure 22 - Aerial View of Highway-Rail Intersection at Forest Hill Avenue and NB Powhite Parkway Ramps



Figure 23 - At-Grade View to the North and South along the CSX Rail Tracks



A proposed upgrade to the highway-rail crossing signal includes the installation of four-quadrant (quad) gates which, unlike conventional gates, ensure the complete closure of the highway-rail intersection during actuation and prevent motorists from driving through/around the closed gates. A 2007 report published by the UC Berkeley Traffic Safety Center’s Institute of Transportation Studies evaluated the State of California’s at-grade crossing for a five-year period from 2000 through 2004; and found that “73% of the crashes occurred at crossing equipped with gates. A total of 27% involved vehicles that had driven around or through lowered gates.”

The report recommends quad gates as one of four measures (including long-arm gates, medians, and photo enforcement) for preventing motorists from going through/around the crossing gates. At the existing crossing, long-arm gates and medians have been implemented at the crossing. These can be seen in Figure 24.

Figure 24 - Highway-Rail Crossing at Forest Hill Avenue and Powhite Parkway NB Ramps



The UC Berkley Traffic Safety Center report describes a four-quadrant gate system as: “consist of a series of automatic flashing-light signals and gates where the gates extend across both the approach and departure side of roadway lanes where they cross the tracks. Unlike two-quadrant gate systems, four-quadrant gates provide additional visual constraint and inhibit nearly all traffic movements over the crossing after the gates have been lowered.”

Four Quadrant Gate Systems - Cost

The cost of a quad gate system can be considered in terms of the capital and operations and maintenance (O&M) cost. This system differs from conventional crossings in relation to the additional cost of maintaining the additional circuitry required to prevent the trapping of vehicles within the intersection. The UC Berkley Traffic Safety Center report estimates the cost per crossing ranging from \$125,000 to \$300,000; however “[f]or a single track crossing, the cost to upgrade from a passive crossing or 2-quad gate to a four-quad gate was given by Burlington Northern Santa Fe Railroad (BNSF) as ‘well over \$300,000.’

The U.S. Department of Transportation’s (USDOT) Research and Innovative Technology Administration published unit cost estimates for the roadside equipment included for the installation of a quad gate system using 1995 as the dollar year. The equipment cost was estimated to be between \$174,000 and \$206,500. This data also includes annual operations and maintenance costs, which range from approximately \$7,000 to \$8,000. This data is summarized in Table 32.

Table 32: RITA ITS Costs: Unit Costs (Adjusted)-Equipment Costs for Roadside Rail Crossing

Unit Costs (Adjusted)				
Equipment Costs for Roadside Rail Crossing (R-RC)				
Unit Cost Element	Life Years	Capital Cost \$K, 2007 Dollars (Source Year)	O&M Cost \$K/year, Dollars (Source Year)	Description
Rail Crossing 4-Quad Gate, Signals	20	115 - 130 (1995)	4.25 - 3.5 (1995)	Gates and signals.
Rail Crossing Train Detector	20	16 – 21.5 (1995)	0.77 - 1.03 (1995)	Train detector circuitry and communication line from intelligent interface controller (IIC) to wayside interface equipment (WIE). Assume two track crossing with two 0.5 mile communication lines.
Rail Crossing Controller	10	8 - 10 (1995)	0.4 - 0.5 (1995)	Intelligent interface controller (IIC).
Rail Crossing Pedestrian Warning Signal, Gates	20	10 - 15 (1995)	0.2 - 0.3 (1995)	Pedestrian warning signal and gates.
Rail Crossing Trapped Vehicle Detector	10	25 - 30 (1995)	1.25 - 1.5 (1995)	Entrapped vehicle detection camera, with poles and controller.

Note: Equipment list adjusted to 2007 dollars. The date in parentheses under the capital cost value and O&M cost value represents the dollar year from which the cost value was adjusted. All costs are in \$K.

Design and Architecture

According to the Innovation Deserving Exploratory Analysis Program’s (IDEA) High Speed Rail Program, one critical component to a quad gate system is an open architecture that allows for the implementation of this system at a pre-existing crossing. The open architecture is specifically crucial for the communication of the controller with existing and/or retrofitted detection devices. The IDEA report basically identifies key components to a quad gate system: programmable controller, inductive and radar-based vehicle presence detectors, modular device interfaces, and external vital software. The report

continues further to describe the three key components for the system controller, which include software configurability, open architecture, and modular design.

One of the primary functions of the quad gate controller is to monitor the highway-rail intersection for stopped vehicles. The quad gate controller is able to control the operation of the gates based on the presence of a vehicle. The detection of this vehicle is via the implemented detection technology (i.e., video image processor, inductive loops, radar) which communicates with the controller.

Since the ability to delay the closure of the exit gates to allow for the trapped vehicle to clear the intersection is the primary safety element, there are certain features of the controller that must be specified, including continuous status updates, status logging, periodic self-tests, and detection verification.

Sources:

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RECOMMENDED IMPROVEMENTS

Proposed Improvements

The analyses of the study network for the no-build and build scenarios for the analysis years of 2011, and 2030 revealed the overall operation of the network will be improved through the implementation of access management strategies. These strategies include changes in access along the corridor, which would result in the elimination of several side-street movements (particularly left turns) and the rerouting of these movements to intersections where more efficient access may be provided. This also incorporates the recommended installation of a traffic signal at Rettig Road to promote safe and efficient access to the corridor, and contribute to the “calming” of Forest Hill Avenue traffic.

As noted in the report none of the analyzed traffic signal warrants were met for the No-Build or Build conditions. Still, the installation of a traffic signal is considered to be an integral element in the improvement in traffic operations along the corridor.

The installation of right- and left-turn lanes is recommended at several intersections along the corridor. A turn lane analysis was conducted for both the 2011 Opening and 2030 Design year conditions. The required storage capacities for the Design year (2030) were also incorporated in the Opening year (2011) traffic analysis.

Installation of Traffic Signal at Forest Hill Avenue and Rettig Road

As noted above, the MUTCD Warrants 1, 2, and 3 were not met for the consideration of a traffic signal installation at Forest Hill Avenue and Rettig Road. Still, the installation of a traffic signal at this intersection is seen as an instrumental element of the project. This traffic signal would be consistent with the need to provide gaps in mainline traffic, manage speeds, and provide accessibility for local side-street traffic.

The installation of a traffic signal at this location would consist of typical concurrent and mainline and side-street phases, with the addition of an EBL protective/permissive phase. During the AM peak hour, this traffic signal would operate with all approaches having a LOS C or better. During the PM peak hour, the operations are constrained by the WBL movement (12 vph), which does not have an auxiliary lane and conflict with a considerable volume of opposing eastbound traffic (1420 vph). This movement alone drives an unacceptable overall LOS E for the intersection. Although a left-turn lane may be unconventional for such a low left turn volume, its installation would bring the intersection to acceptable LOS.

Turn Lane Recommendations

As discussed in previous sections, the installation of turn lanes is warranted at several intersections along the corridor. The most significant challenge for these recommendations is the required length for many of the auxiliary lanes based on VDOT standards. In several cases, the recommended lengths cannot be provided, given the spacing between intersections. This occurs at the following intersections:

- Windsorview Drive – EBL (1020-ft storage vs. 860-ft intersection spacing)
- Rettig Road – EBL (1020-ft storage vs. 800-ft intersection spacing)

In these two cases, design waivers may be required for the provision of left turn lanes that are shorter than those recommended by VDOT standards. It should be noted the turn lane warrant analysis was conducted for the intersection of Forest Hill Avenue and Rettig Road as an unsignalized intersection. With the signalization of this intersection, the storage requirements for the EBL would likely be reduced.

At the signalized intersection of Forest Hill Avenue and Hathaway Road, there are movements which currently do not have storage capacity, for which capacity would be recommended based on AASHTO standards. These movements include the SBR movement with a PM peak hour volume of 156 vph and a shared through-right configuration and the WBR, which has AM and PM peak hour volumes of 131 vph and 218 vph, respectively. Based on AASHTO standards, a minimum right turn volume of 100 vph warrants consideration for right-turn storage capacity. Even though this would improve intersection operations, there appear to be right-of-way constraints at this intersection that might make the implementation of these improvements costly and time-consuming.

Access Management Strategies

Each of the six proposed corridor configurations represents an approach to access management that serves to promote safe and efficient access to the corridor. In some cases, this is accomplished by restricting low-volume side-streets approaches to right-in/out configuration and eliminating access at locations. This led to diversions of relatively low volumes of local traffic being diverted to adjacent access points (i.e., Rettig Road), which makes the installation of a traffic signal at Rettig Road an integral component of the access management strategy. This approach leads to a marked improvement of side-street operations when compared to No-Build conditions.

Traffic Signal Configuration at Forest Hill Avenue and Hathaway Road

The intersections of Forest Hill Avenue and Hathaway Road and Old Westham Road and Hathaway Road are separated by 50 ft; however the intersection at Old Westham Road is unsignalized. Both intersections were evaluated as being signalized with a common controller, using Configuration 2A1. It was found that for the year 2030 the intersection of Old Westham Road and Hathaway Road operates with acceptable levels of service for all approaches during both the AM and PM peaks as a signalized intersection. The southbound approach at the intersection of Forest Hill Avenue and Hathaway Road for both peak hours operates at LOS F, which can be anticipated to impact the operations at Old Westham Road. The resulting Synchro reports are included in Appendix N.

Intelligent Transportation Systems – Railroad Crossing

At the existing highway-rail crossing at Forest Hill Avenue and the Northbound Powhite Parkway Off-Ramp, the design consists of long-arm gates and medians, which are two measures that are designed to prohibit vehicles traveling through/around the closed gates. Motorists attempting this maneuver would need to drive over the existing median, which may not be an effective deterrent for larger passenger vehicles and trucks.

The upgrade of this intersection to a quad gate system is recommended with many of the requirements discussed in the report for the controller operations, including an open architecture design that allows for integration with various detection technologies and potentially existing roadside equipment. Given the current pavement condition and the relatively high traffic volumes (due to the ramps), it is recommended that video or radar detection be explored to limit the level of maintenance required by inductive (i.e., in-pavement) loops.

Principal Study Findings

Conclusions

The analysis of Existing, No-Build, and Build conditions has shown that existing operational issues within the network are exacerbated by an increase in background traffic. Traffic operations were found to be moderately improved from “no-build” conditions, by incorporating access management strategies and providing the suitable storage capacity. These strategies also rely on the installation of a traffic signal at the intersection of Forest Hill Avenue and Rettig Road, which will provide access for much of the diverted traffic. While the proposed configurations may not address every operational issue along this stretch of the corridor, many of the access, capacity, and safety issues are addressed to the extent possible.

Ultimately, right-of-way and intersection spacing will be a determining factor for the installation of some of the storage capacity improvements along the corridor; especially at the intersection of Forest Hill Avenue and Hathaway Road, which provides access to commercial developments on the north and south sides of the roadway. While improvements at this intersection were not evaluated in detail, it is anticipated that any increase in turn lane capacity will result in improved operations.