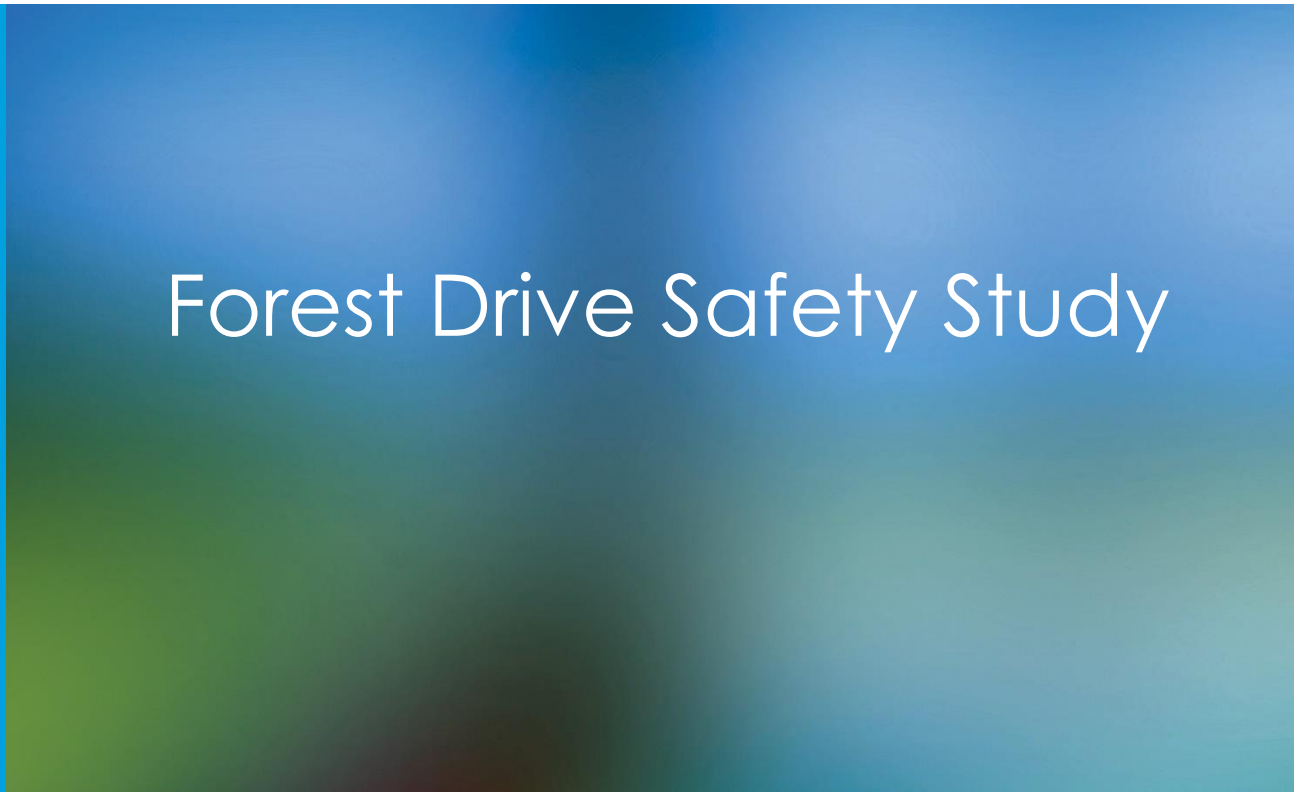
PREPARED BY

Mead & Hunt



Forest Drive Safety Study

July 27, 2023

Prepared For:

ANNE ARUNDEL COUNTY
MARYLAND

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Appendix

1. Executive Summary

Anne Arundel County initiated the Forest Drive Safety Study (H539622) to conduct a comprehensive safety review, analysis, and development of multimodal safety recommendations for the Forest Drive corridor. The study corridor is approximately 2.75-miles in length from Bywater Road to Arundel on the Bay Road.

This report summarizes existing conditions, data collection, historical and predictive crash analysis, public involvement, safety countermeasure recommendations, and project prioritization through cost / benefit analyses.

The following summarizes the key findings of the Forest Drive Safety Study:

- The study corridor is ranked in the top 10 for highest crash rate of all roads in Anne Arundel County.
- The study corridor crash rate exceeds statewide average for similar road types for total crashes, left turn, and pedestrian type crashes.
- The study corridor property damage only crash rate exceeds the statewide average for similar road types.
- Safety countermeasure recommendations were grouped by Short-, Mid-, and Long-Term scenarios based on cost and ease of implementation at each location.
- The recommended safety improvements include:
    - Speed limit reduction from 40- to 35-mph along Forest Drive and Bay Ridge Road to reduce the number and severity of crashes along the corridor.
    - Pedestrian safety improvements to provide new signalized crossings, improve the safety of existing crossings, bus stop relocations, and to trim back vegetation encroaching on sidewalks.
    - Traffic signal hardware upgrades to improve signal visibility and increase compliance.
    - Traffic signal phasing changes to reduce vehicle conflicts.
    - Driveway access modifications to reduce vehicle conflicts at unsignalized access points.
    - Signing and marking improvements to provide increased guidance through and approaching intersections.
- The capacity analysis results indicate that the proposed safety countermeasures would have no significant detrimental impact on traffic operations within the study area and all intersection will maintain acceptable Level of Service (LOS) D or better during the weekday AM and PM peak hours.
- The predictive safety analysis results indicate that the combined improvements in each scenario could reduce the number of crashes within the study area by 5.2% in the short-term, 14.2% in the mid-term, and 15.1% in the long-term.

Public outreach included an elected officials briefing and a working group meeting with community leaders. There was a one-month public comment period that included a public meeting. A total of 48 comments were received.

2. Introduction, Study Area, and Previous Studies

2.1 Introduction

The purpose of this study is to complete a comprehensive safety review, analysis, and the development of multimodal safety recommendations for the Forest Drive corridor. Recommendations will range from low-cost short-term, medium-cost mid-term, and high-cost long-term recommendations. Fundable projects will be identified to include in the Anne Arundel County Capital Improvement Projects (CIP) program.

2.2 Study Area

The study area is shown in Figure 2-1. The project limits are along Forest Drive/Bay Ridge Road and extend from Bywater Road southeast to Arundel on the Bay Road.

Forest Drive/Bay Ridge Road from Bywater Road to Arundel on the Bay Road is 2.75-miles in length and has been identified as a high crash corridor. The roadway is classified by the County as a major arterial with a four-lane to six-lane typical roadway section with auxiliary lanes at major intersections. The roadway typical section includes concrete curb and gutter with sidewalks/trails on both the north and south side of the roadway. Land use in the area consist mostly of commercial developments, Annapolis Middle School, residential/ housing developments, and undeveloped land.

There are 19 study intersections within the project limits. At the time of the study, 11 of these intersections were signalized, with a 12th signal under construction at the intersection of Forest Drive and Annapolis Neck Road/ Martha Court. This report will document existing conditions within the study area to understand the needs and deficiencies and propose safety improvements in accordance with goals of Vision Zero.

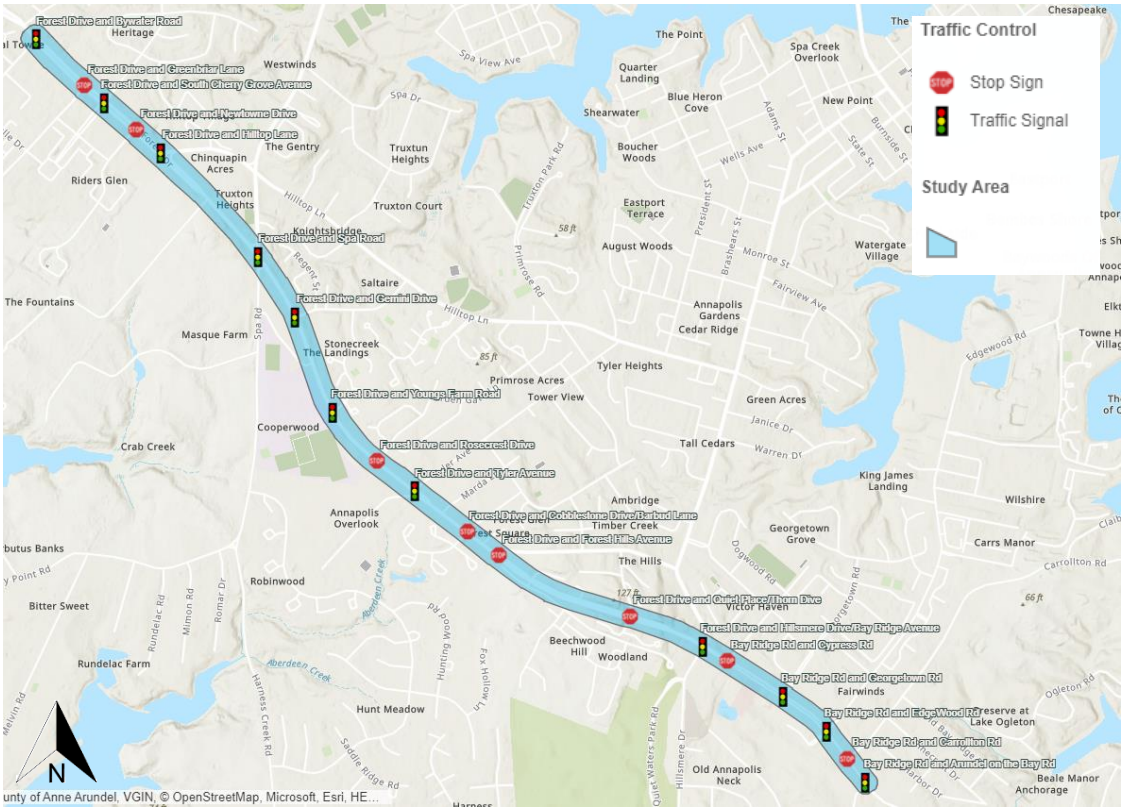


FIGURE 2-1: STUDY AREA

2.3 Study Intersections

The study area includes the following nineteen (19) intersections as well as the eighteen (18) roadway segments between each intersection:

- Bywater Road and Forest Drive (signal)
- Greenbriar Lane and Forest Drive
- South Cherry Grove Avenue and Forest Drive (signal)
- Newtowne Drive and Forest Drive
- Hilltop Lane and Forest Drive (signal)
- Spa Road and Forest Drive (signal)
- Gemini Drive and Forest Drive (signal)
- Youngs Farm Road and Forest Drive (signal)
- Rosecrest Drive and Forest Drive
- Tyler Avenue and Forest Drive (signal)
- Cobblestone Drive/Barbud Lane and Forest Drive
- Forest Hills Avenue and Forest Drive
- Quiet Waters/Thom Drive and Forest Drive
- Hillsmere Drive/Bay Ridge Avenue and Forest Drive (signal)
- Bay Ridge Road and Cypress Road
- Bay Ridge Road and Georgetown Road (signal)
- Bay Ridge Road and Edgewood Road (signal)
- Bay Ridge Road and Carrollton Road
- Bay Ridge Road and Arundel on the Bay Road (signal)

2.4 Previous Studies

Related studies and plans reviewed as part of this report include:

- Forest Drive at Hilltop Lane, rear end collisions – Technical Memo (dated June 26, 2013)
- Forest Drive Marking plans for Hilltop Lane – Triple Right Turns with “No Turn on Red” (constructed at the end of 2018)
- Major Intersections/Important Facilities (MIIF) Study (dated June 2016)
- Pedestrian Road Safety Audit- Forest Drive at South Cherry Grove Avenue and Forest Drive at Tyler Avenue Technical Memo (dated February 15, 2019)
- The Village at Providence Point, Right Turn Lane Analysis – Technical Memo (dated April 24, 2020)
- The Village at Providence Point, Right Turn Lane Analysis, Wells & Associates Letter to the City of Annapolis (dated September 21, 2020)

Recommendations from the studies listed above that were recently implemented prior to this study are as follows:

- The installation of a third right turn lane on Hilltop Lane with the No Turn on Red signs was installed.

Additionally, there are several developments occurring along the corridor and an adjacent Maryland Department of Transportation (MDOT) State Highway Administration (SHA) study / project at MD 665 at Chinquapin Round Road. These background projects include:

- LIDL – Annapolis (located on Bay Ridge Road at Georgetown Road)
- Village at Providence Point (located on Forest Drive near Spa Road)
    - Includes improvements at Forest Drive at Spa Road
- Primrose School (located near Hilltop Lane at MD 387 (Spa Road))
- Willow's (located near Forest Drive at Hilltop Lane)
- Bay Village (located near Forest Drive at Edgewood Road)
- MD 665 at Chinquapin Round Road Study led by MDOT SHA
    - This study is being closely coordinated with our study although the limits do not overlap.

3. Traffic Data Collection and Analysis

3.1 Traffic Data Collection

Traffic data was collected for the study that includes peak period weekday turning movement counts (TMC's) of vehicles, pedestrians, and cyclists at all study intersections, as well as 48-hour tube counts (vehicle classification and speed data) at three locations along the corridor. Traffic counts were collected in the spring and fall of 2022. Historical Annual Average Daily Traffic (AADT)[1] counts and TMC were compiled from MDOT SHA's AADT locator and MDOT SHA's Internet Traffic Monitoring System (I-TMS), respectively.

3.2 Traffic Volume Trends

The traffic volumes along Forest Drive and Bay Ridge Road vary along the length of the study corridor with the highest volumes west of Hilltop Lane (58,000 vehicles per day) and decreasing volumes to the south and east (30,000 vehicles per day). Figure 3-1 shows a map of the 2022 AADT volumes along Forest Drive and Bay Ridge Road.

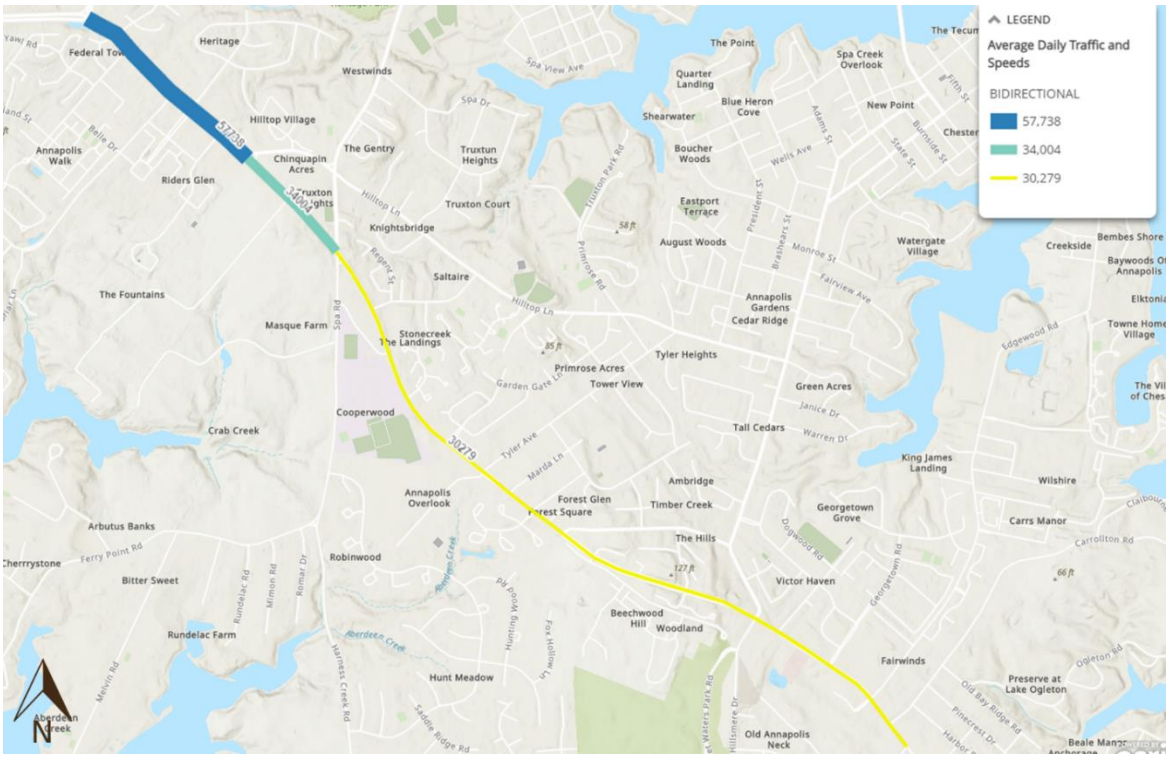


FIGURE 3-1: STUDY AREA AADT MAP

Weekday AM and PM peak hours along the corridor were determined based on the AADT and TMC counts. The AM peak hour is 8-9 AM and the PM peak hour is 4-5 PM. Traffic patterns during the peak hours are moderately directional with westbound traffic highest during the AM peak period and eastbound traffic highest in the PM peak period. Traffic volumes in the peak hour mirror the volume trends observed in the AADT volumes with peak direction traffic volumes of approximately 2,500 vehicles per hour in the west end of the study area and falling to nearly 1,000 vehicles per hour to the south and east. Refer to Appendix A for traffic counts and calculations. Existing Conditions (2022) intersection TMC's are shown in Figure 3-2 and Figure 3-3.

[1] Annual Average Daily Traffic (AADT) is the average 24-hr traffic volume for a given section of roadway over the course of a year.

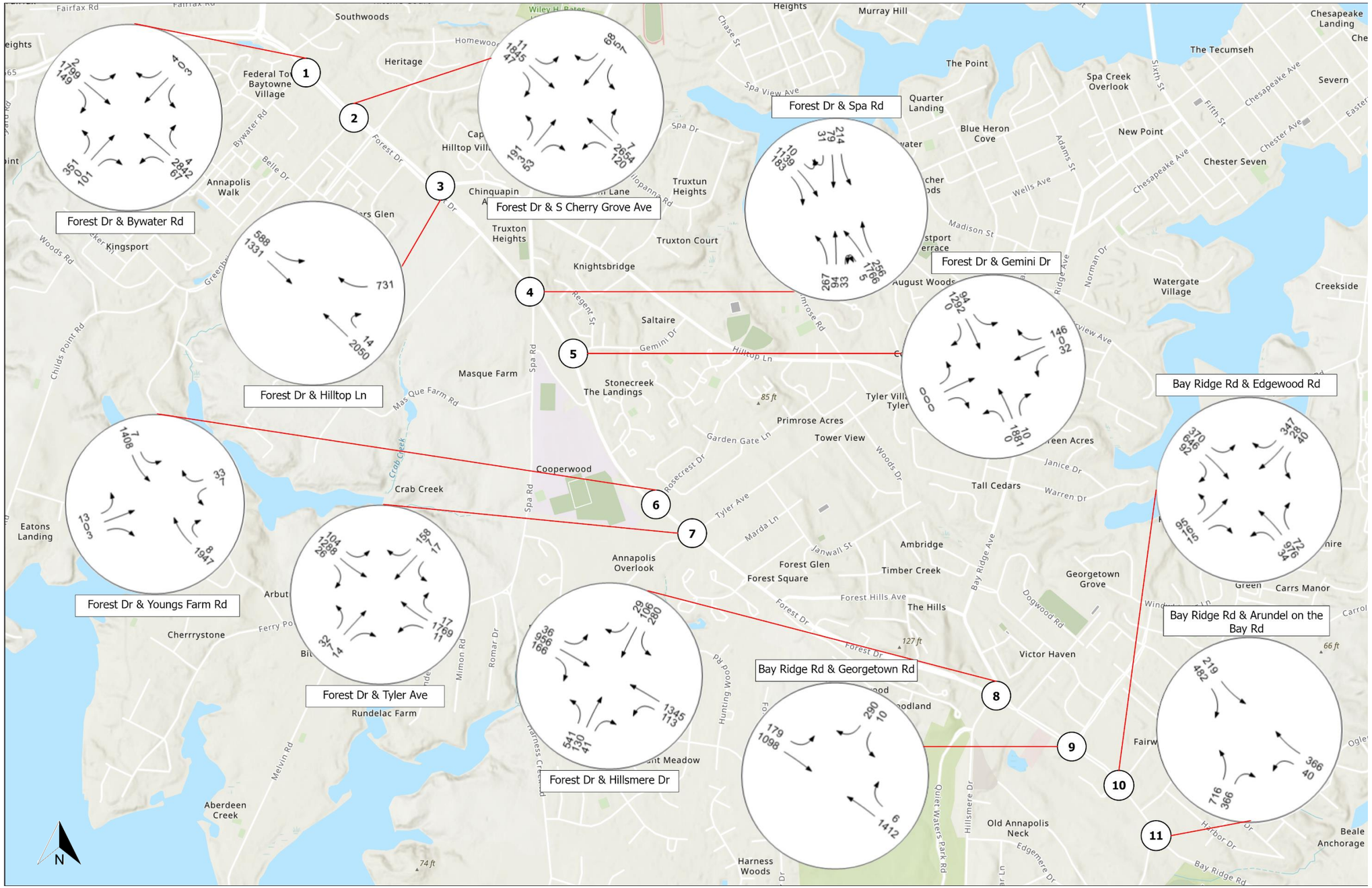


FIGURE 3-2: 2022 AM PEAK HOUR VOLUMES

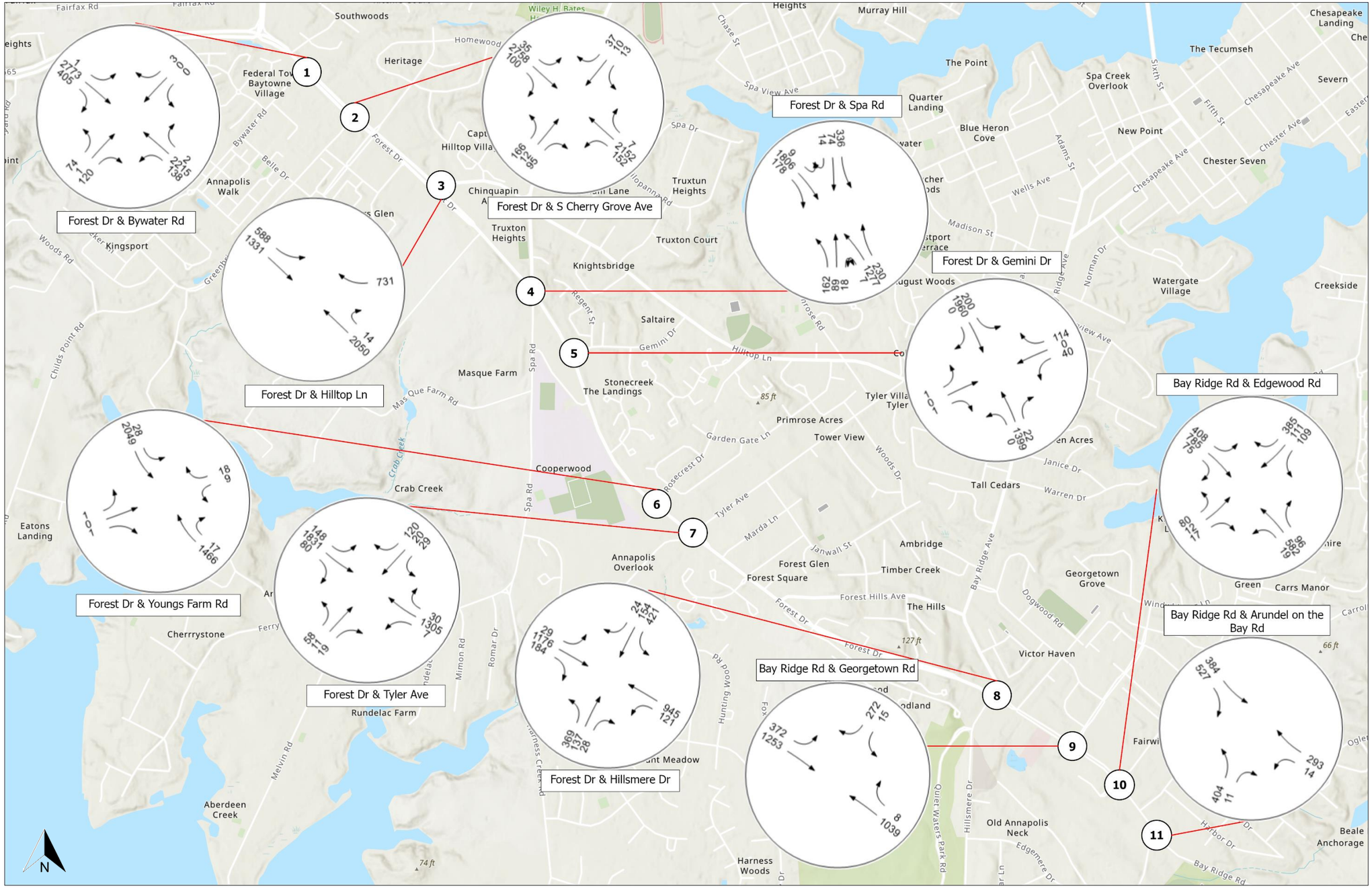


FIGURE 3-3: 2022 PM PEAK HOUR VOLUMES

To examine pre- and post-covid traffic volumes trends, 2017 turning movement counts were taken from the Forest Drive Sector Study and compared to the 2022 turning movement counts at the following locations:

- Forest Drive and Chinquapin Round Road
- Forest Drive and South Cherry Grove Avenue
- Forest Drive and Spa Road

The total volume of entering vehicles during the AM and PM peak hours (8:00-9:00 AM and 4:00-5:00 PM) were compared at each location. Figure 3-4 shows the comparison between the peak hour volume counts.

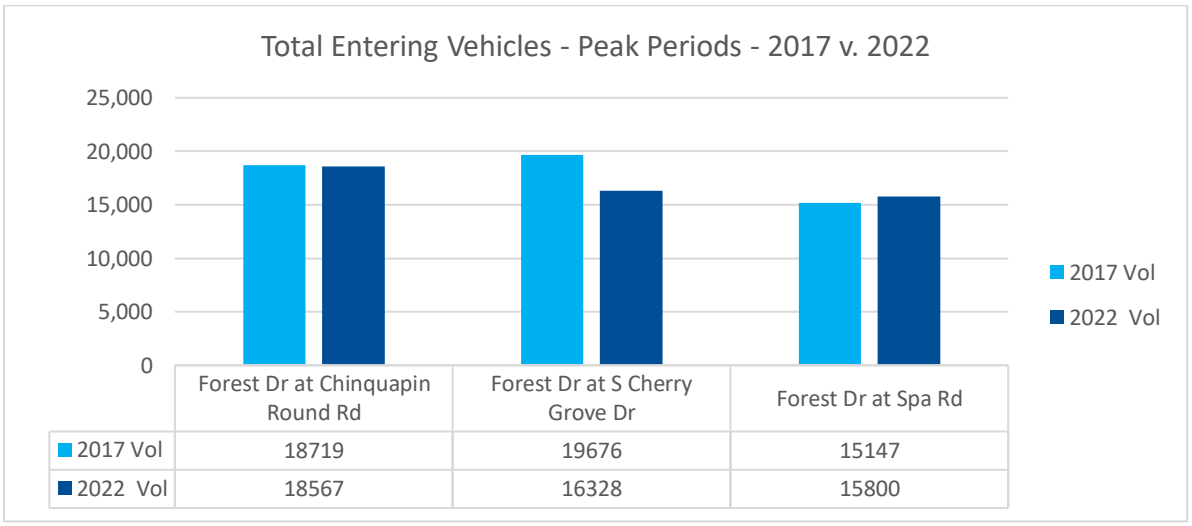


FIGURE 3-4: PEAK HOUR VOLUME COMPARISON

The intersections at Chinquapin Round Road and Spa Road show little change between pre-and post-covid volumes, with relative difference of -0.8% and +4.3% respectively. The intersection of South Cherry Grove Road shows the highest reduction from pre-covid volumes with a -17.0% reduction in vehicular volumes.

The average 24-hr volumes from the 2017 and 2022 48-hour tube counts were compared at the following two locations along the corridor:

- Between Hilltop Lane and Spa Road (11/7-8/2017)
- West of Hillsmere Drive/Bay Ridge Avenue (9/5-6/2018)

Figure 3-5 shows the comparison of the 48-hour counts.

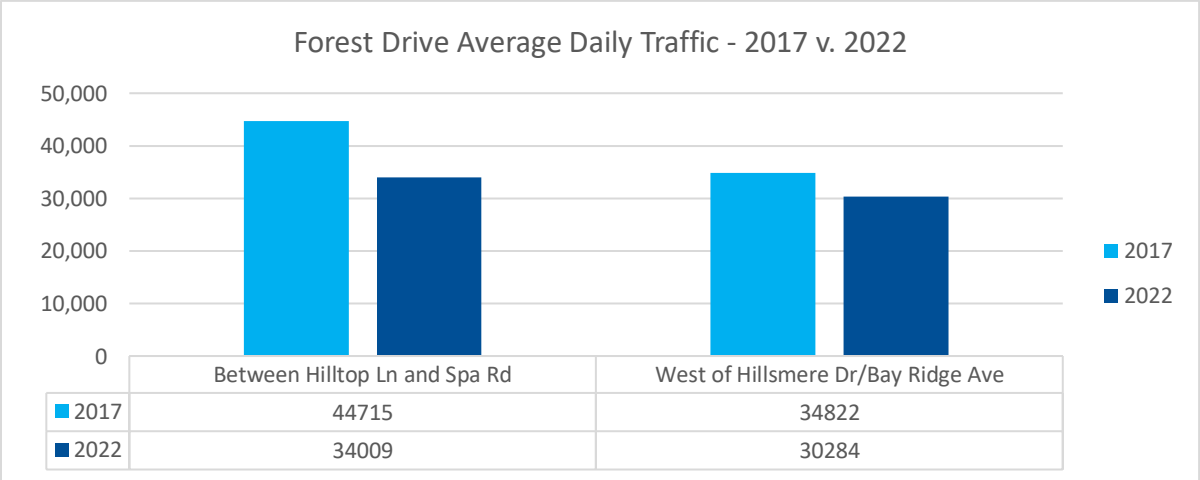


FIGURE 3-5: AVERAGE DAILY TRAFFIC (ADT) VOLUME COMPARISON

Both segments show a reduction from pre-covid ADT, with a 23.9% reduction in the segment between Hilltop Lane and Spa Road and a 13.0% reduction in the segment west of Hillsmere Drive/Bay Ridge Avenue.

3.3 Growth Rate Comparison

A horizon year of 2025 was selected to evaluate the potential impacts on traffic operations from the implementation of the recommended safety improvements. 2025 was selected as a future opening year in which many of the short- and mid-term safety improvements could be constructed by, and conservatively considers the potential increases in local and regional traffic due to background developments.

To determine an acceptable growth rate for volumes in the study area for the 2025 horizon year, historical growth rates were compared to forecasted growth rates. Historical trends were calculated from AADT data obtained from MDOT SHA's AADT locator and forecasted growth rates were extracted from the Baltimore Metropolitan Council Regional Travel Demand Model (BMC). Historical annual growth rates on Forest Drive (between 2011 to 2018) are shown in Table 3-1. Table 3-2 shows future annual growth projections based on 2021 and 2045 AADT volumes from the BMC model. Note that the 2045 BMC model run was used for the future year annual growth rate comparison due to increased uncertainty in short-term forecasting model trends relative to the base year 2021.

TABLE 3-1: ANNUAL GROWTH RATES FROM HISTORICAL AADT'S ON FOREST DRIVE

Year	Between Hilltop Lane to Spa Road	Annual Growth Rate %	West of Tyler Avenue	Annual Growth Rate %	East of Tyler Avenue	Annual Growth Rate %
2011	35,530	-	28,140	-	37,790	-
2012	36,241	2.0%	27,921	-0.8%	37,491	-0.8%
2013	36,312	0.2%	27,982	0.2%	37,572	0.2%
2014	33,510	-7.7%	29,040	3.8%	34,910	-7.1%
2015	34,381	2.6%	31,110	7.1%	35,821	2.6%
2016	35,032	1.9%	31,701	1.9%	36,502	1.9%
2017	42,460	21.2%	32,462	2.4%	42,000	15.1%
2018	42,081	-0.9%	32,200	-0.8%	41,321	-1.6%
Average		2.8%		2.0%		1.5%
Single Value Average		2.4%				

TABLE 3-2: BMC AADT VOLUMES AND ANNUAL GROWTH RATES

Segment	2021 AADT Volumes	2045 AADT Volumes	Annual Growth Rate %
Chinquapin Round Rd to Bywater Rd	55,700	57,900	0.17%
Greenbriar Ln to Hilltop Ln	50,500	52,700	0.18%
Crystal Spring Farm Rd to Spa Rd	50,400	51,900	0.12%
W of Tyler Ave	30,100	28,800	-0.18%
E of Tyler Ave	24,300	24,900	0.10%
W of Bay Ridge Ave	24,700	25,200	0.08%
Average			**0.08%**

The average annual growth rate from the BMC model was 0.08% compared to a historical average annual growth rate of 2.4%. This data was discussed with the County, and it was recommended to use an annual

growth rate of 1.1% per year to grow the base year counts to the opening year of 2025. The 1.1% growth rate represents a conservative growth rate that balances historical trends with future travel demand model projections. Refer to Appendix A for traffic counts and calculations.

3.4 Vehicle Classification

Vehicle classification data was collected with the 2022 48-hour tube counts on Forest Drive at the following locations:

- East of Bywater Road
- East of Hilltop Lane
- East of Hillsmere Drive/Bay Ridge Avenue

Figure 3-6, Figure 3-7, and Figure 3-8, as well as Table 3-3 show the hourly volume by time of day for cars, buses, and heavy vehicles at each location.

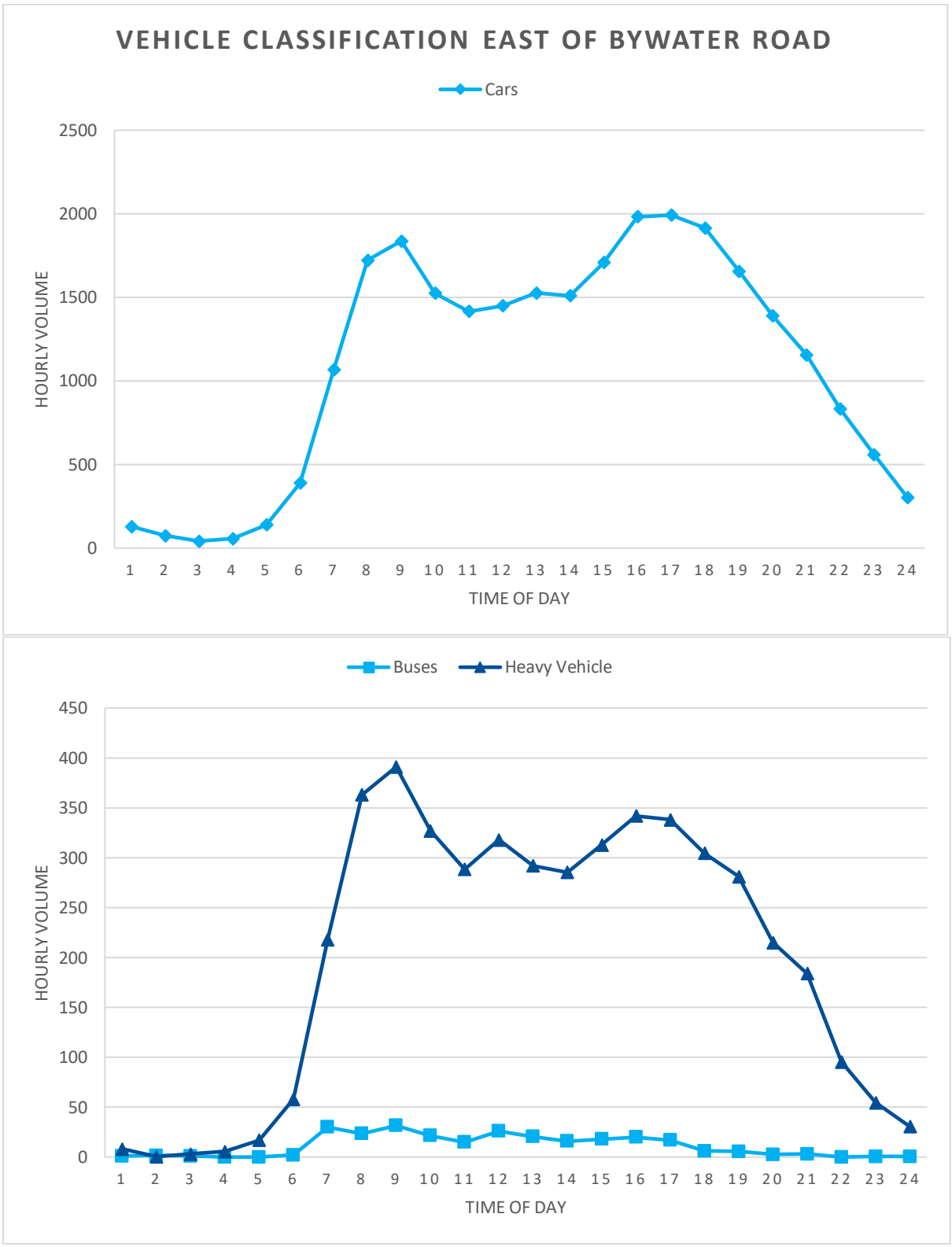


FIGURE 3-6: VEHICLE CLASSIFICATION EAST OF BYWATER ROAD

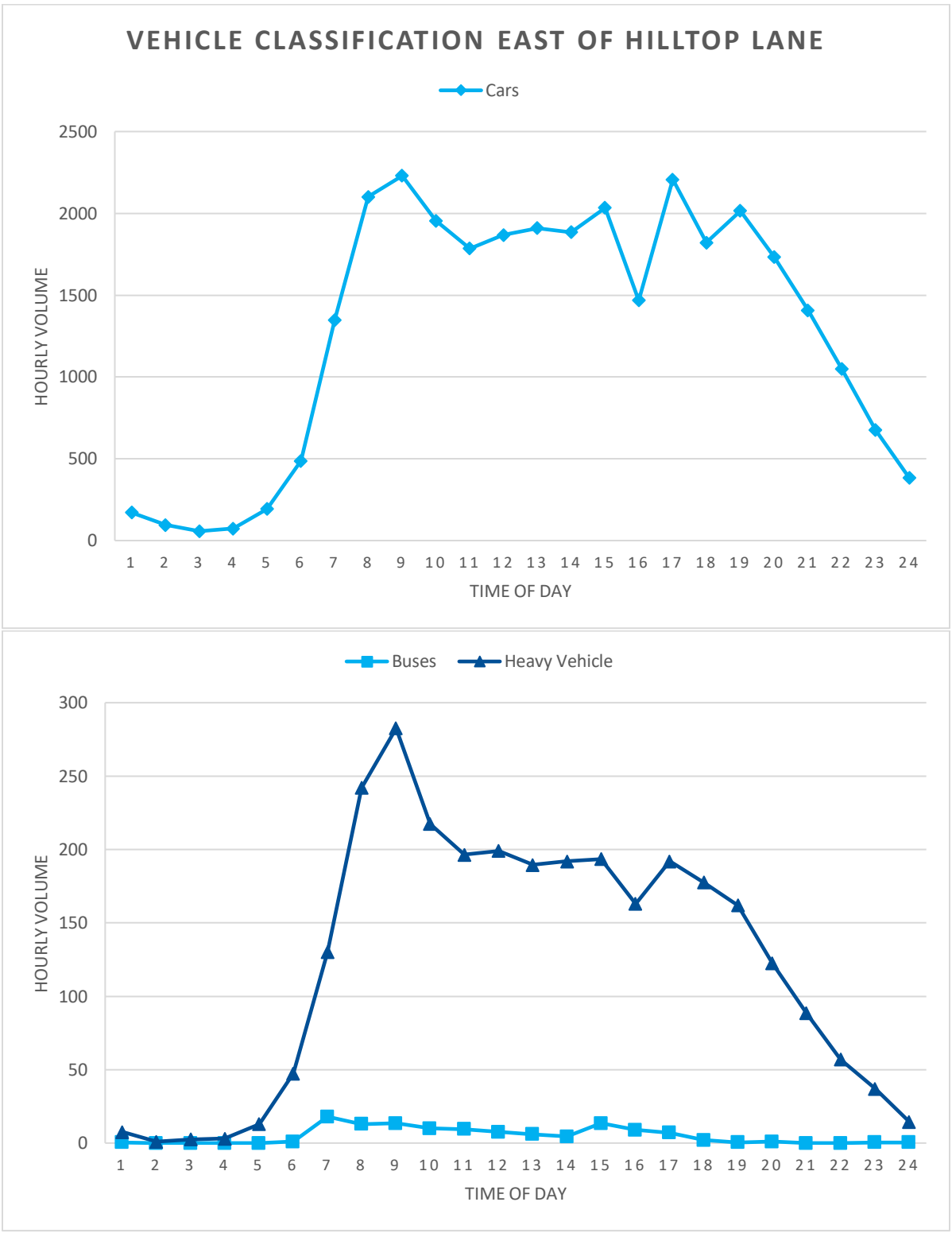


FIGURE 3-7: VEHICLE CLASSIFICATION EAST OF HILLTOP LANE

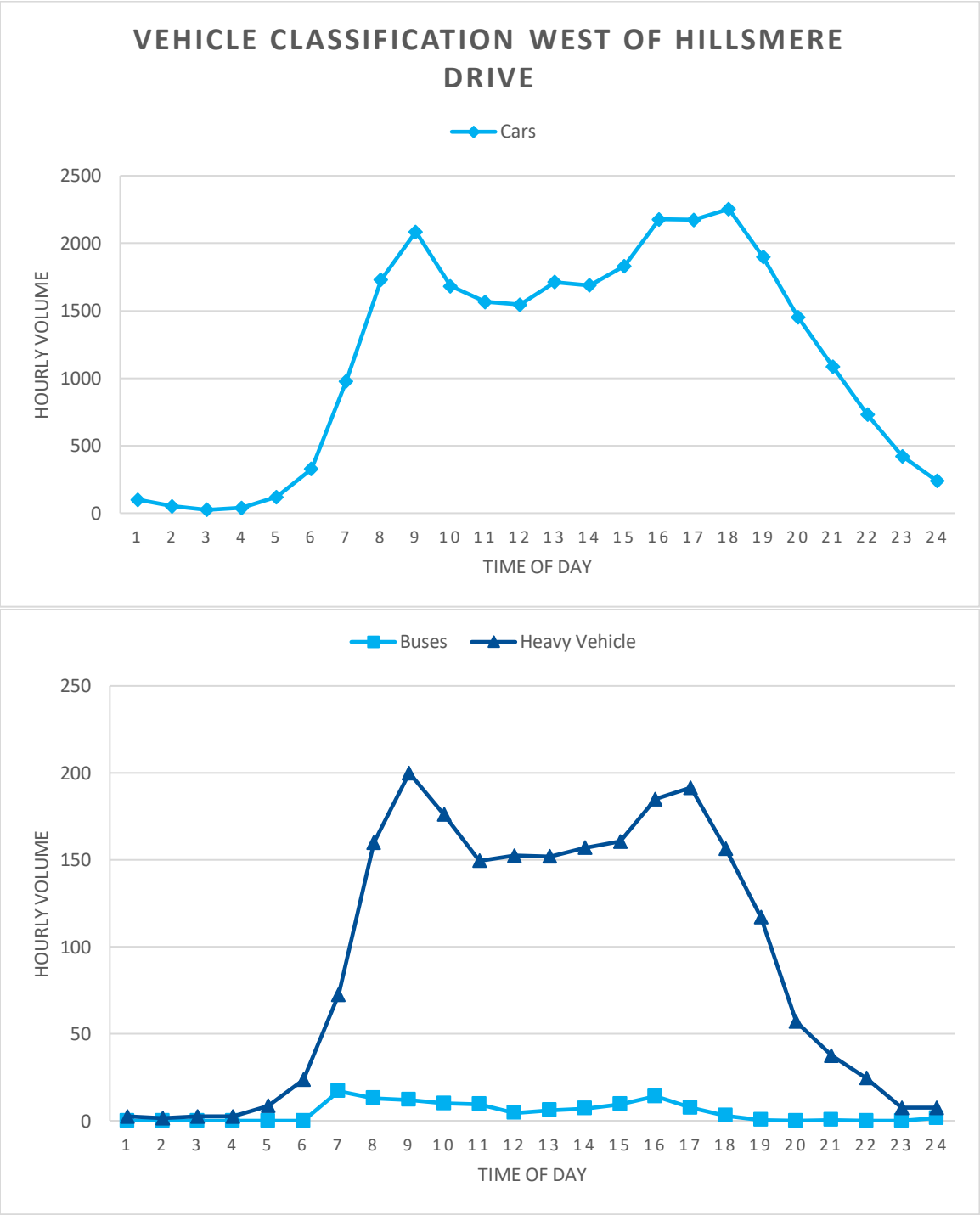


FIGURE 3-8: VEHICLE CLASSIFICATION WEST OF HILLSMERE DRIVE

TABLE 3-3: PERCENT VEHICLE TYPE ALONG FOREST DRIVE

Vehicle Type	East of Bywater Rd		East of Hilltop Lane		West of Hillsmere Dr/Bay Ridge Ave.	
	Eastbound	Westbound	Eastbound	Westbound	Eastbound	Westbound
Cars	90.8%	91.9%	90.6%	91.7%	92.4%	92.2%
Buses	0.43%	0.48%	0.46%	0.20%	0.28%	0.49%
Heavy Veh.	8.8%	7.6%	9.0%	8.1%	7.3%	7.3%

The data shows that the dominant mode of travel on this corridor is cars. Peaks in car traffic volumes can be seen between 7 – 9 AM in the morning peak and between 4 – 7 PM in the evening peak. Heavy vehicle traffic followed a similar trend to car traffic, with a peak between 7 – 9 AM and consistent volume for the rest of the day. Bus traffic increased from non-zero volume in the morning peak and remained consistent until 10 PM, at the end of the service period.

3.5 Roadway Segment Speed Data

The posted speed limit on Forest Drive and Bay Ridge Road is 40 mph along the entire project corridor. Refer to the Forest Drive existing plans in Appendix B for the exact location of the existing speed limit signs.

Speed data was collected with the 2022 tube counts on Forest Drive at the following locations:

- East of Bywater Road
- East of Hilltop Lane
- East of Hillsmere Drive/Bay Ridge Avenue

Data was collected for all vehicles as part of the 24-hour tube counts. Figure 3-9, Figure 3-10, Figure 3-11, as well as Table 3-4 show the speed distribution at each location and the measured pace[2], mean speed[3] and 85th percentile speed[4] at each location.

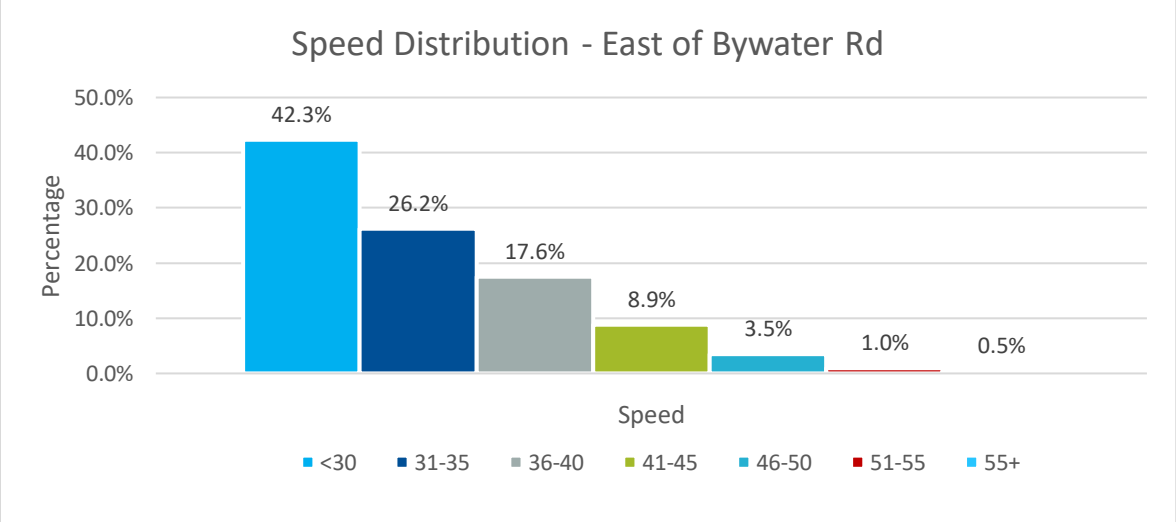


FIGURE 3-9: SPEED DISTRIBUTION EAST OF BYWATER ROAD

[2] The 10-mph pace is the range of speeds containing the highest percentage of vehicles recorded.
[3] Mean speed is the summation of the instantaneous speeds at a specific location of vehicles divided by the number of vehicles observed. It is a common measure of central tendency.
[4] The 85th percentile is the speed at or below which 85% of vehicles travel.

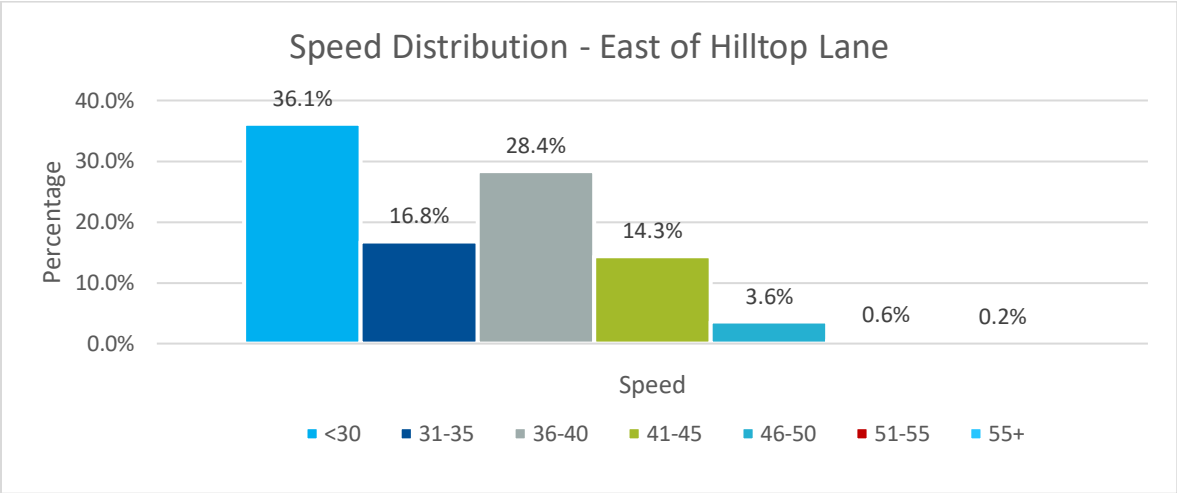


FIGURE 3-10: SPEED DISTRIBUTION EAST OF HILLTOP LANE

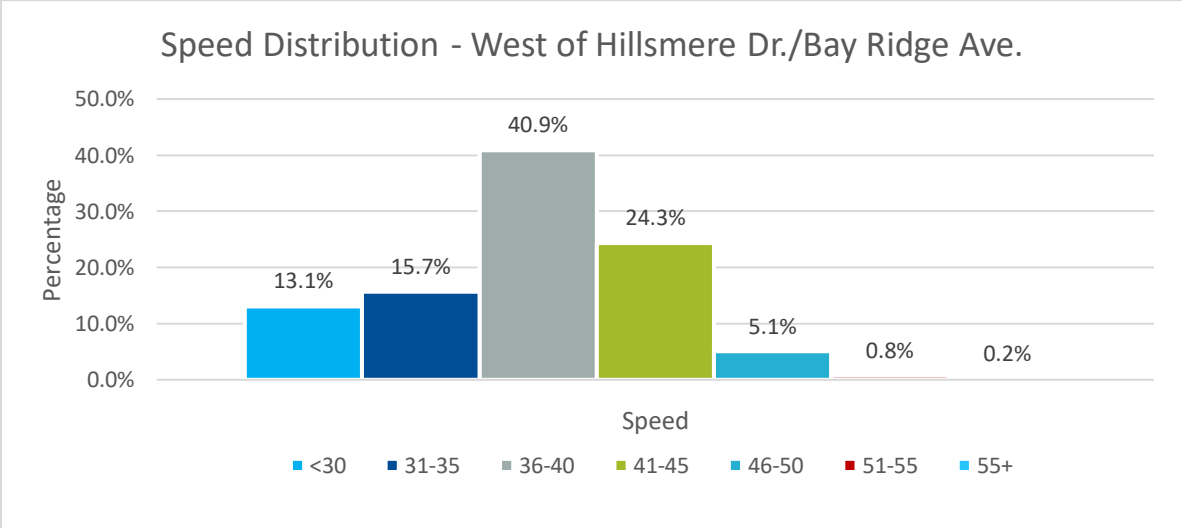


FIGURE 3-11: SPEED DISTRIBUTION WEST OF HILLSMERE DRIVE

TABLE 3-4: VEHICULAR SPEEDS ON FOREST DRIVE

Measurement	East of Bywater Rd		East of Hilltop Lane		West of Hillsmere Dr/Bay Ridge Ave.	
	Eastbound	Westbound	Eastbound	Westbound	Eastbound	Westbound
Mean Speed (Average)	27 mph	29 mph	35 mph	25 mph	34 mph	38 mph
10 MPH Pace Speed	31-40 mph	31-40 mph	31-40 mph	36-45 mph	36-45 mph	36-45 mph
85th Percentile Speed	38 mph	40 mph	41 mph	40 mph	42 mph	43 mph

4. Roadway Geometrics, Traffic Control Devices and Observations

4.1 Roadway Geometrics

Forest Drive is classified as a principal arterial west of Cherry Grove Avenue and transitions to a minor arterial east of Cherry Grove Avenue which continues east along Bay Ridge Road. Bay Ridge Road and Forest Drive have a 4-lane section east of Hilltop Lane and 5- to 6-lane section west of Hilltop Lane to Bywater Road. Auxiliary lanes are present throughout the study area. The posted speed limit is 40 mph. The roadway typical section includes concrete curb and gutter with sidewalks/trails on both the north and south side of the roadway. Table 4-1 below outlines the roadway characteristics on Forest Drive.

TABLE 4-1: ROADWAY CHARACTERISTICS

From	To	Through Lanes (total both dir.)	Highway (Divided/ Not Divided)	Access (none, partial[5], full[6])
Bywater Rd.	S. Cherry Grove Ave.	6	Divided	Partial
S Cherry Grove Ave.	Crystal Springs Farm Rd.	5	Divided	Partial
Crystal Springs Farm Rd.	Forest Hills Ave.	4	Undivided	Full
Forest Hills Ave.	Hillsmere Drive/ Bay Ridge Ave.	4	Divided	Partial
Hillsmere Drive/ Bay Ridge Ave.	Arundel on the Bay Road	4	Undivided	Full

4.2 Traffic Control Devices

Lane configurations at all signalized study intersections are shown in Figure 4-1. The number of through lanes in each direction of Forest Drive is three lanes west of Hilltop Lane and two lanes to the east. Each intersection provides left turn lanes with permissive, protected-permissive, or protected only left turn phasing. The presence of right turn lanes varies throughout the corridor as well as the presence of yield controlled channelized right turns. Side street signal phasing is predominately split due to unbalanced traffic patterns in which one approach volume is significantly higher than the opposing, or skewed intersection geometry requiring additional phasing protection.

Traffic signals along Forest Drive and Bay Ridge Road previously operated using adaptive control[7] but were then converted to a fixed-pattern schedule in April of 2022. Signals in the corridor are currently in the process of being upgraded to a new system.

[5] Partial access refers to left turn prohibitions at unsignalized driveways and roadways along a particular segment.
[6] Full access refers to no turn prohibitions along a particular segment.
[7] Adaptive signal timing adjusts the timing of green, yellow, and red time to accommodate changing traffic patterns.

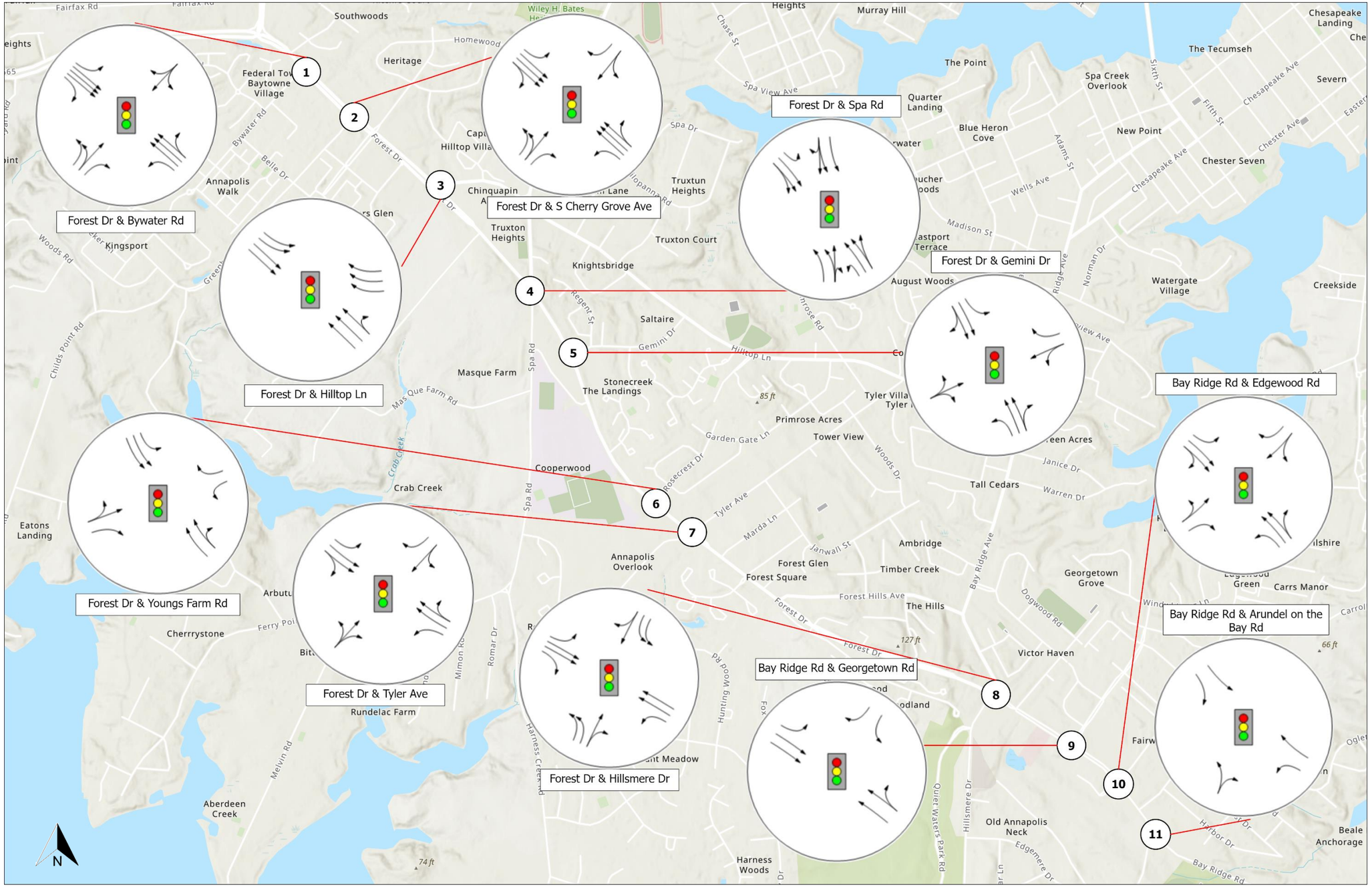


FIGURE 4-1: LANE CONFIGURATION AT SIGNALIZED INTERSECTIONS

4.3 Field Observations

A field review was conducted on July 14, 2022, during the AM peak from 8 – 9 AM and during the PM peak from 4 – 5 PM. Below is a list of field observations:

Forest Drive & Bywater Road - Intersection

- Signing and Pavement Markings:
  - Existing foliage blocks signing in the westbound direction at firehouse signal.
- Sight Distance, Obstructions, Objects within Clear Zone:
  - Westbound left has limited sight distance for vehicles turning left from Forest Drive when vehicles are present in the opposite direction due to the offset lanes.
  - Left turn lanes on Forest Drive are not aligned with each other limiting sight distance.
  - There is a pedestrian-scale light pole approximately 3' from the face of curb along the south side of Forest Drive.
- Traffic Operations:
  - During the PM westbound lefts receive very few gaps and are not able to clear the signal cycle.
  - Westbound vehicles observed blocking Firehouse driveway (see photo below).

Forest Drive at Greenbriar Lane– Intersection

- Sight Distance Limitations:
  - Median foliage along Forest Drive limits the view of opposing traffic (westbound vehicles) from the eastbound left turn lane at Greenbriar Lane. It should be noted that this is a general field observation and specific measurements were not taken as part of this study.

Forest Drive & South Cherry Grove - Intersection

- Sight Distance Limitations:
    - Sight distance is limited for eastbound and westbound left turns from Forest Drive when vehicles are present in the opposing left turn lane due to offset left turn lanes. It should be noted that this is a general field observation and specific measurements were not taken as part of this study.
- Traffic Operations:
    - Westbound left turn queue spills back into the through lane, and queues do not clear in one signal cycle.

Forest Drive & Spa Road - Intersection

- Traffic Operations:
    - Westbound Forest Drive queue spills back through Gemini Drive and Youngs Farm Road.

Forest Drive & Tyler Avenue - Intersection

- Traffic Operations
    - The offset nature of the north and south legs of Tyler Avenue, along with the concurrent side-street phasing, create some variation in the vehicle paths taken by left-turning vehicles when opposing left-turning vehicles are present.

Forest Drive & Barbud Lane/Cobblestone Drive - Intersection

- Sight Distance Limitations:
    - The northbound approach has limited sight distance looking left (for conflicting eastbound traffic) due to the grade / vegetation located on the south side of Forest Drive. It should be noted that this is a general field observation and specific measurements were not taken as part of this study.

Forest Drive & Hillsmere Drive/Bay Ridge Road - Intersection

- Traffic Operations:
    - Southbound left turns from Bay Ridge Avenue cross over the double yellow line into the left turn lane on Forest Drive.

General Observations

- Minimal pedestrian activity observed during field visit. Pedestrian and bicycle volumes from field counts are shown in section 6.1.

5. Traffic Operations Evaluation

5.1 Methodology and Metrics Evaluated

All signalized study intersections were coded into Synchro 11 to evaluate traffic operations. Synchro is a deterministic and macroscopic signal analysis computer software program that models street networks and traffic signal systems. Geometric data such as number of lanes, lane configuration, storage lengths, tapers, and distances between intersections were inputted into the Synchro network. Additionally, existing signal timings and phasing were obtained from the Anne Arundel County Department of Public Works and coded into the Synchro traffic model along with traffic volumes.

Intersection capacity analyses were performed using the industry standard HCM methodology[8]. Synchro implements HCM methods of analysis, which were used for the intersection capacity analysis of all study intersections during weekday AM and PM peak hours. Performance measures of effectiveness from the Synchro model include level of service (LOS), volume-to-capacity (v/c) ratio, and average vehicle delay.

The original scope only listed the 8 signalized intersections between Bywater and Hillsmere/Bay Ridge for developing existing and opening year volume sets. We also initially did not have counts at many of the unsignalized intersections, so the Synchro model was created for signalized intersections only. This study was not intended to be a detailed capacity analysis effort and signalized intersections are typically the constraining points along a corridor. Although long side street delay can contribute to safety concerns, those would be found via the field observations and / or observed crash patterns.

Key performance measures are defined as follows:

- Level of Service (LOS) is a qualitative measure describing operational conditions of an intersection or any other transportation facility. LOS measures the quality of traffic service and may be determined for intersections on the basis of delay, and volume to capacity (v/c) ratio. At intersections, LOS is a letter designation that corresponds to a certain range of roadway operating conditions. The levels of service range from ‘A’ to ‘F,’ with ‘A’ indicating the best operating conditions and ‘F’ indicating the worst, or a failing, operating condition.
- The volume-to-capacity ratio (v/c ratio) is the ratio of current flow rate to the capacity of the intersection. This ratio is often used to determine how sufficient capacity is at a given intersection. Generally speaking, a ratio of 1.0 indicates that the intersection is operating at capacity. A ratio of greater than 1.0 indicates that the facility is operating above capacity as the number of vehicles exceeds the roadway capacity.
- Delay (Control delay) is the portion of average delay per vehicle attributed to traffic signal operation for signalized intersections. Table 5-1 summarizes the LOS thresholds for signalized intersections based on vehicle delay.

[8] The HCM is a Transportation Research Board (TRB) publication.

TABLE 5-1: LOS AND DELAY THRESHOLDS, SIGNALIZED INTERSECTIONS

Level of Service (LOS)	Average Delay (seconds)	General Description
A	≤ 10	Free flow
B	> 10 - 20	Stable flow (slight delays)
C	> 20 - 35	Stable flow (acceptable delays)
D	> 35 - 55	Approaching unstable flow (tolerable delay, occasionally wait through more than one signal cycle before proceeding)
E	> 55 - 80	Unstable flow (intolerable delay)
F	> 80	Forced flow (congested with excessive queueing)

5.2 Volume Development

The opening year was defined as a timeline for completing short-term improvements that may be recommended in this report. To develop the 2022 and 2025 opening year traffic volumes the historical and new traffic volumes were compared, adjusted, and balanced to establish the existing 2022 volumes. A future growth rate of 1.1% was applied to the 2022 volumes for three years to arrive at the 2025 opening year traffic volumes.

5.3 Capacity Analysis

The overall intersection capacity analysis results for Existing Conditions and future year 2025 No Build alternatives are presented in Table 5-2. More detailed movement level HCM results are available in Appendix C.

TABLE 5-2: EXISTING AND FUTURE NO BUILD CAPACITY ANALYSIS SUMMARY TABLE – AM (PM)

ID	Intersection	Traffic Control	Existing Conditions		2025 No Build	
			LOS	Delay (sec)	LOS	Delay (sec)
1	Forest Drive & Bywater Road	Signal	B (B)	16.8 (17.9)	B (B)	17.6 (15.4)
2	Forest Drive & S. Cherry Grove Ave.	Signal	B (B)	14.4 (18.3)	B (C)	15.8 (20.5)
3	Forest Drive & Hilltop Lane	Signal	B (B)	17.2 (16.3)	B (B)	17.4 (16.7)
4	Forest Drive & Spa Road	Signal	D (D)	35.4 (36.7)	D (D)	41.9 (42.2)
5	Forest Drive & Gemini Drive	Signal	B (A)	13.2 (7.3)	B (A)	14.2 (7.8)
6	Forest Drive & Youngs Farm Road	Signal	A (A)	4.7 (4.5)	A (A)	4.8 (4.8)
7	Forest Drive & Tyler Avenue	Signal	B (A)	13.2 (9.9)	B (B)	14.3 (10.4)
8	Forest Dr.& Hillsmere Dr./Bay Ridge Ave.	Signal	D (D)	38.6 (50.2)	D (D)	39.3 (56.5)
9	Bay Ridge Road & Georgetown Road	Signal	A (A)	6.7 (6.6)	A (A)	7.7 (7.9)
10	Edgewood Road & Bay Ridge Road	Signal	C (C)	21.0 (21.4)	C (C)	22.7 (25.6)
11	Arundel on the Bay Rd & Bay Ridge Rd	Signal	B (B)	16.3 (16.3)	C (C)	24.9 (31.0)

The capacity analysis results under Existing Conditions shows that all intersections operate with LOS D or better in the AM and PM peak hours.

The capacity analysis results under 2025 No Build conditions show that all intersections operate with a LOS D or better in the AM or PM peak hours. There is generally a slight increase in the delay experienced in both peaks in the future year due to the increased traffic volumes.

The Existing and 2025 No Build alternatives serve as a baseline for which to compare and identify operational impacts associated with the recommended improvements discussed in subsequent sections.

6. Multimodal Transportation

This chapter describes the existing conditions of the study area related to the connectivity and conditions of pedestrian and bicycle facilities and public transportation. The information presented in this chapter is based on a combination of sources including previous studies, Geographic Information Systems (GIS) from Anne Arundel County, and visual observations in the field. The following sections provide details and maps pertaining to the various modes of travel.

6.1 Pedestrian and Bicycle Facilities

Figure 6-1 and Figure 6-2 show the pedestrian and bicycle facilities within the Forest Drive/ Bay Ridge Road study area. All pedestrian and bicycle data were obtained from the Anne Arundel County open data portal. Dedicated pedestrian facilities are available along the entire study corridor. Sidewalks are present and continuous on both sides of Forest Drive and Bay Ridge Road for the length of the study area. Sidewalks along some sections of the corridor are narrow, overgrown, and lack buffers from adjacent vehicular traffic. Pedestrian signals are provided at each signalized intersection with curb ramps at all signalized crossings and crosswalks present on at least 3 legs of all signalized intersections. No bike lanes are provided along Forest Drive and Bay Ridge Road within the study limits. A shared-use path is provided along the south side of Forest Drive from Bywater Road to Hilltop Lane. Figure 6-3 also shows proposed bicycle infrastructure along or intersecting the corridor from other studies or projects from the City or County.

Figure 6-4 and Figure 6-5, respectively, show the daily pedestrian volumes and daily pedestrian conflicts[9]. Pedestrian conflicts are a consideration in the selection of intersections at which improvements will be prioritized. The pedestrian volumes represent the total entering volume, which is the sum of pedestrian volumes on all legs of the intersection over a 24-hr period. The intersection of Forest Drive and Youngs Farm Road has the highest daily pedestrian volume, with 268 pedestrians per day (ppd). The intersection with the highest pedestrian vehicle volume conflicts is at Forest Drive and Tyler Avenue followed closely by Forest Drive at Youngs Farm Road. In total, seven (7) study intersection have greater than 100 daily entering pedestrians:

- Bywater Road at Forest Drive (158-ppd)
- Gemini Drive at Forest Drive (185-ppd)
- Youngs Farm Road at Forest Drive (268-ppd)
- Rosecrest Drive at Forest Drive (109-ppd)
- Tyler Avenue at Forest Drive (197-ppd)
- Hillsmere Drive at Forest Drive (107-ppd)
- Cypress Road at Bay Ridge Road (126-ppd)

Figure 6-6 shows the daily bicycle volumes in the study area and Figure 6-7 shows the Bicycle Level of Traffic Stress (LTS) in the study area. The intersection with the highest number of bicycles is Bay Ridge Road at Carrollton Road (62-bicyclists per day). The intersections experiencing the highest number of daily bicycles are located at the eastern end of the study area. Bicycle LTS is a method for assessing the

[9] Pedestrian conflicts were calculated by multiplying the pedestrian volume by the conflicting vehicular volume. The pedestrian conflict metric is commonly used to identify locations where the magnitude of pedestrian and vehicle volumes are highest and where the highest pedestrian exposure is present.

"bikeability" of a roadway network. Different variables are used to calculate the LTS, including:

- The presence and type of bicycle facility
- Roadway speed limit
- Number of through lanes/ traffic volume

The Level of Traffic Stress (LTS) (scale "1" to "4") is a measure for assessing the quality of the roadway network for its comfort with various bicycle users. The lower the LTS score, the more inviting the bicycle facility is for more audiences. Bicycle LTS definitions and thresholds are provided by the Mineta Transportation Institute, Report 11-19, which was adapted by MDOT for Maryland roadways in 2022. The Forest Dr study area is primarily a LTS 4, the poorest grade, with a few blocks at the western end of the study area classified as a LTS 1 due to the presence of a shared use path. Facilities that are classified as a LTS 4 are intended/ targeted for strong bicyclists that are comfortable biking on the same facility as high volumes of vehicle traffic. Table 6-1 shows each bicycle LTS definition and examples of bicycle facilities that correspond to each level.

TABLE 6-1: MARYLAND BICYCLE LTS DEFINITIONS (MDOT)

LTS	Target Audience	Bicycle Facility Types
0	All ages and abilities	Rail-trails, shared-use paths
1	Almost everyone	Protected bikeways, sidepaths
2	Interested but concerned	Bike lanes, bike boulevards
3	Enthused and confident	Bike lanes, shared lanes, shoulders
4	Strong and fearless	No bike facility or bike lane on a major roadway
5	Bicycle Access Prohibited	Bicycle access is prohibited by managing roadway agency

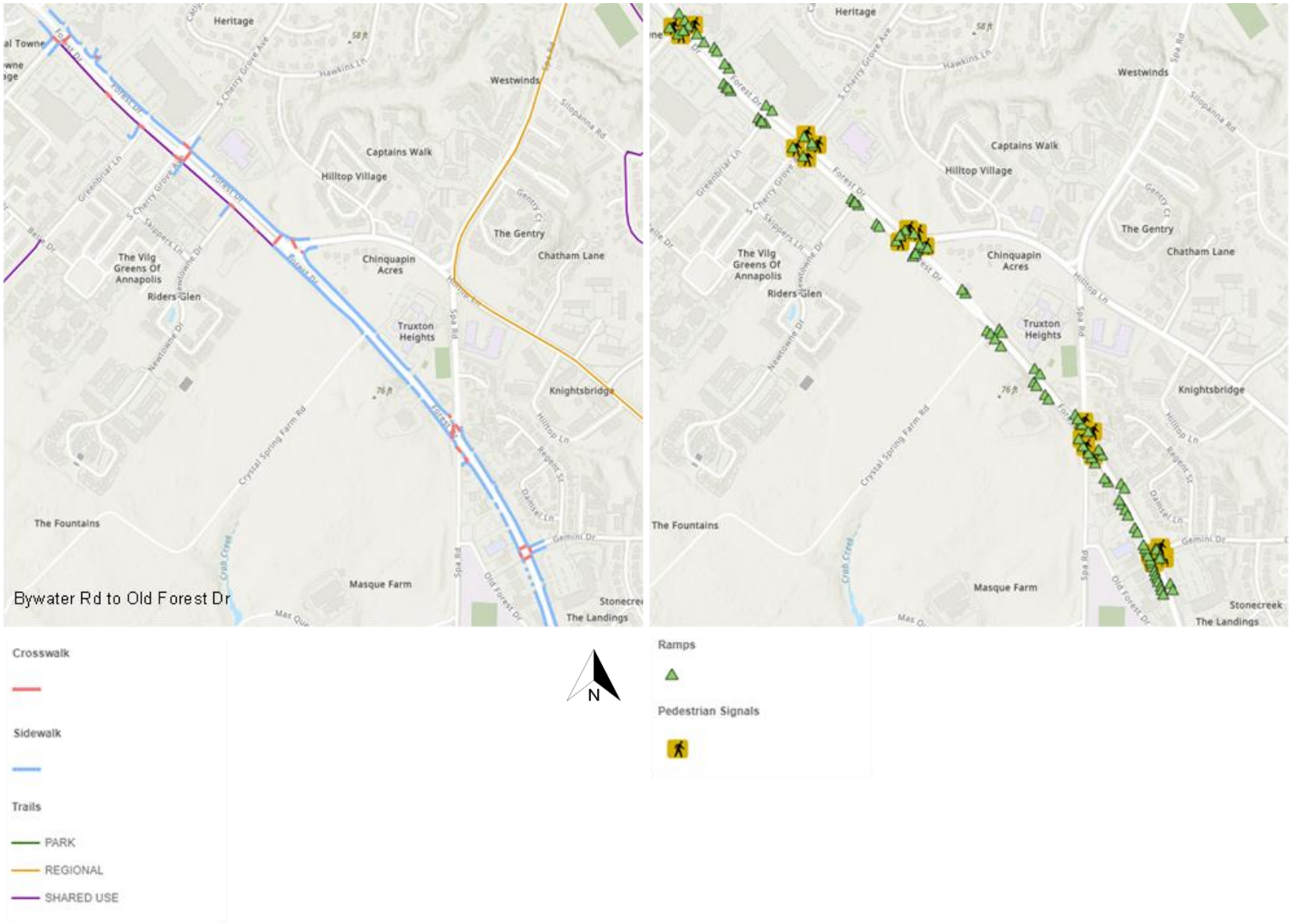


FIGURE 6-1: PEDESTRIAN INFRASTRUCTURE

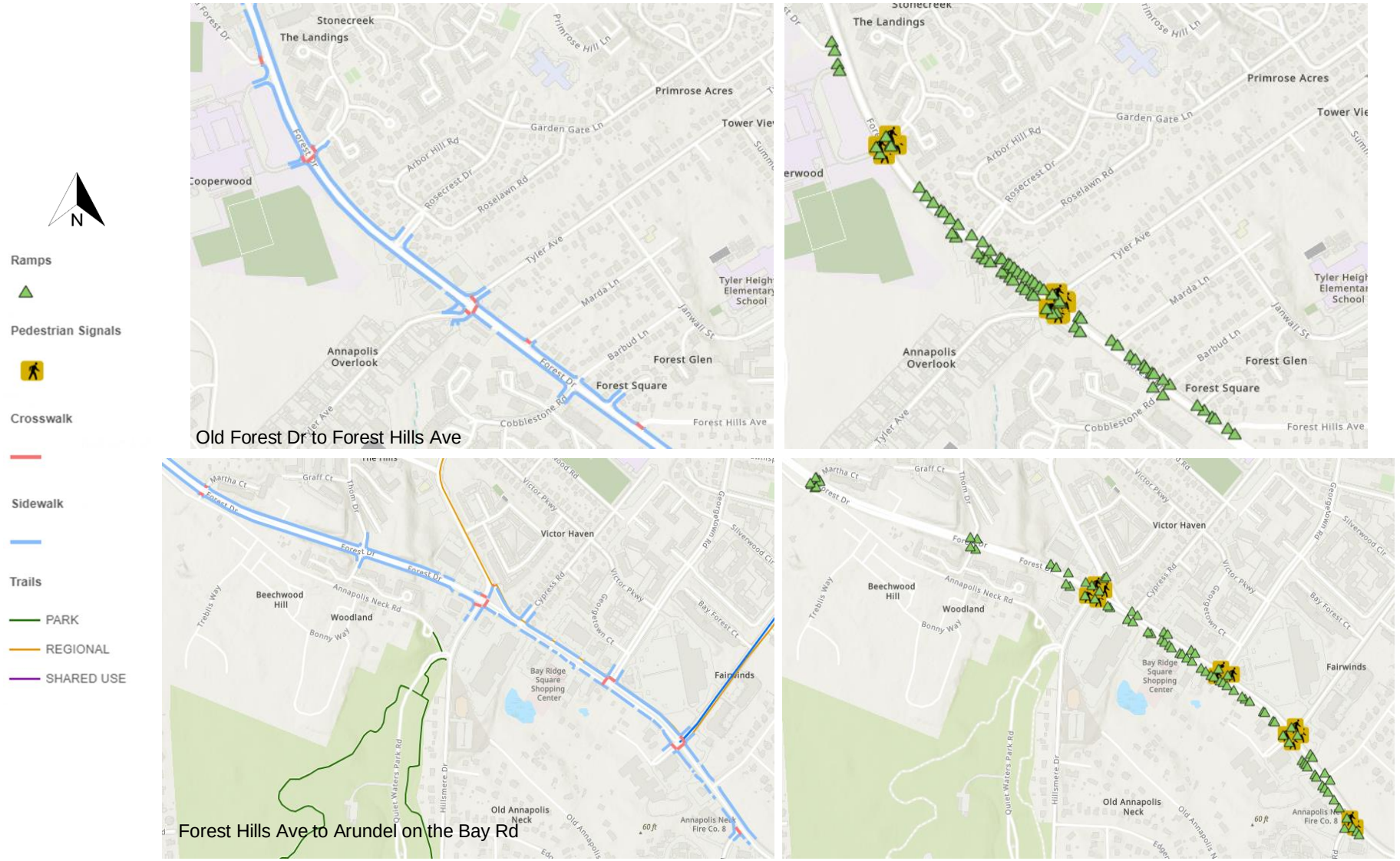
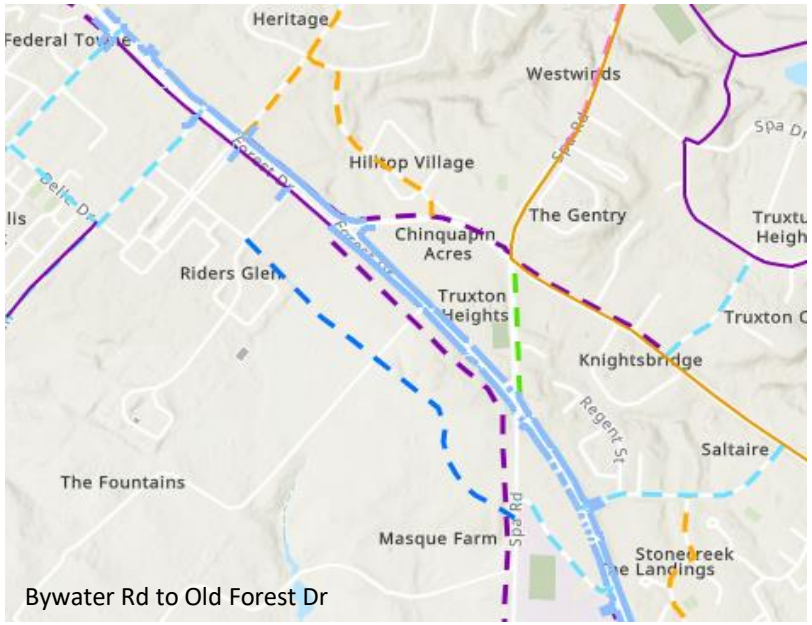
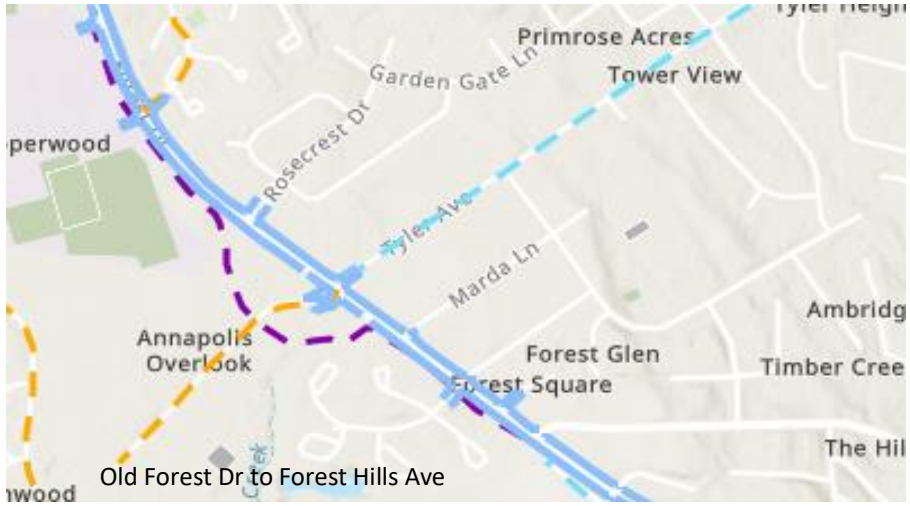
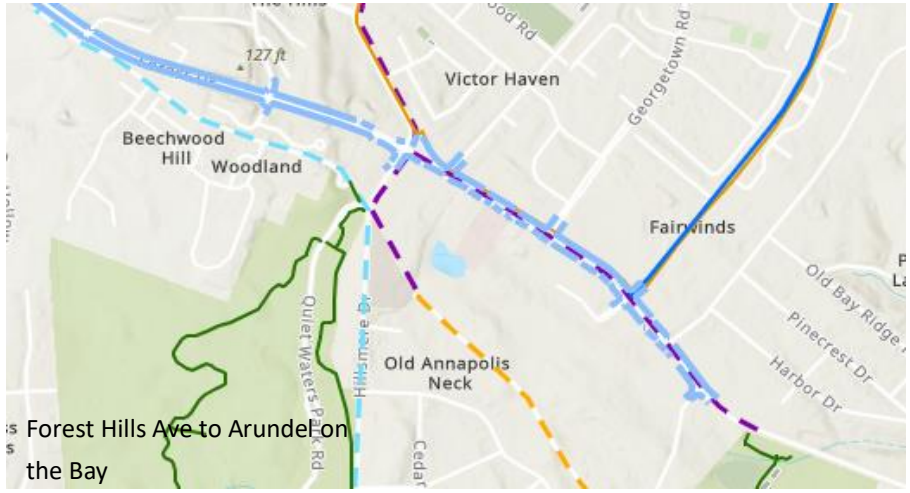


FIGURE 6-2: PEDESTRIAN INFRASTRUCTURE







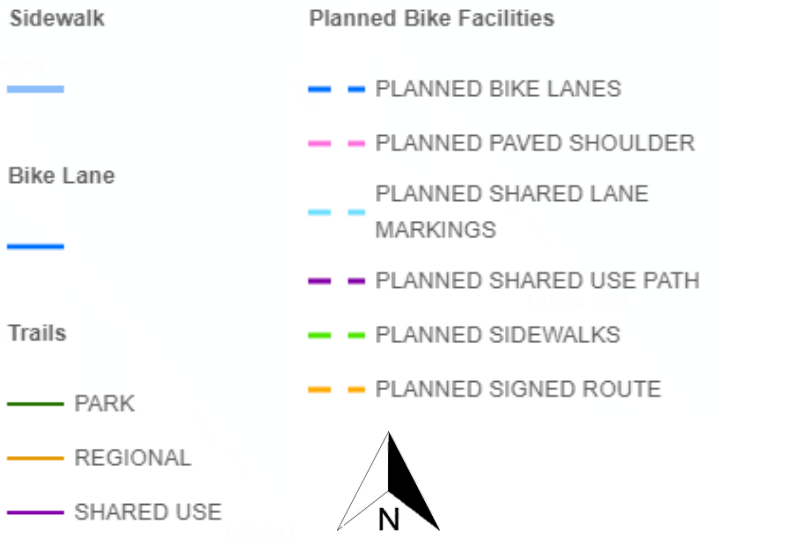


FIGURE 6-3: EXISTING AND PROPOSED BICYCLE INFRASTRUCTURE

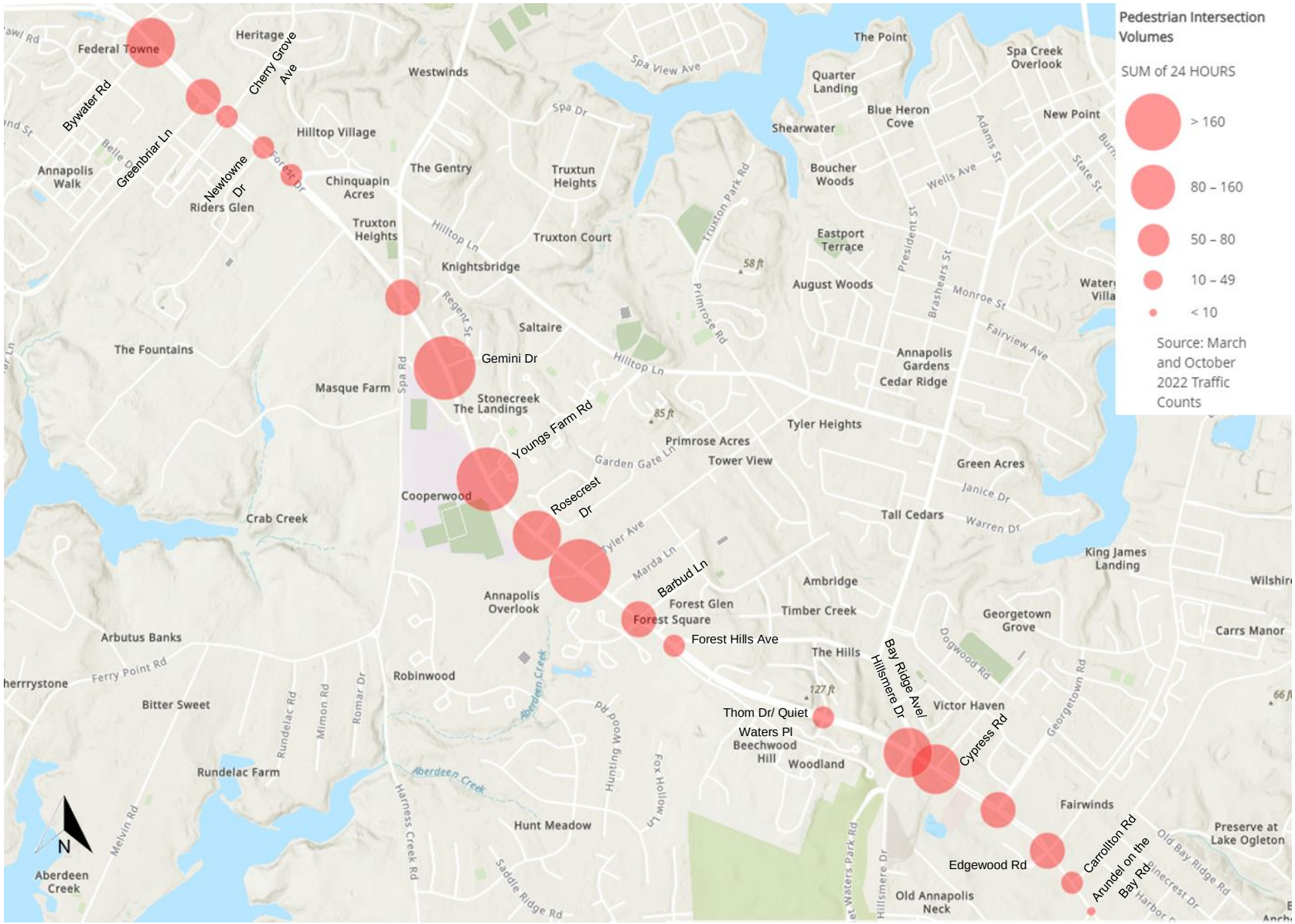


FIGURE 6-4: INTERSECTION PEDESTRIAN VOLUMES

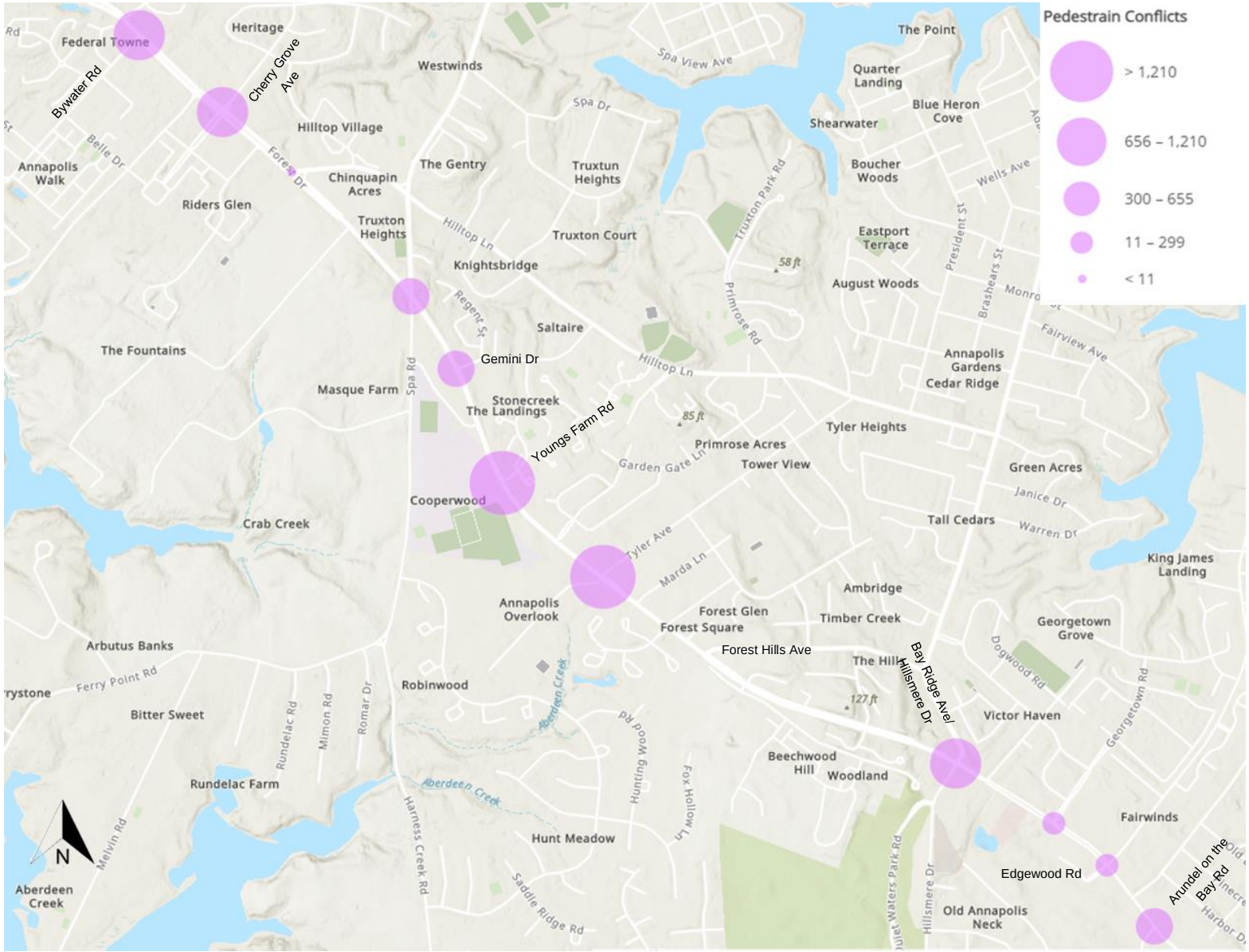


FIGURE 6-5: INTERSECTION PEDESTRIAN CONFLICTS

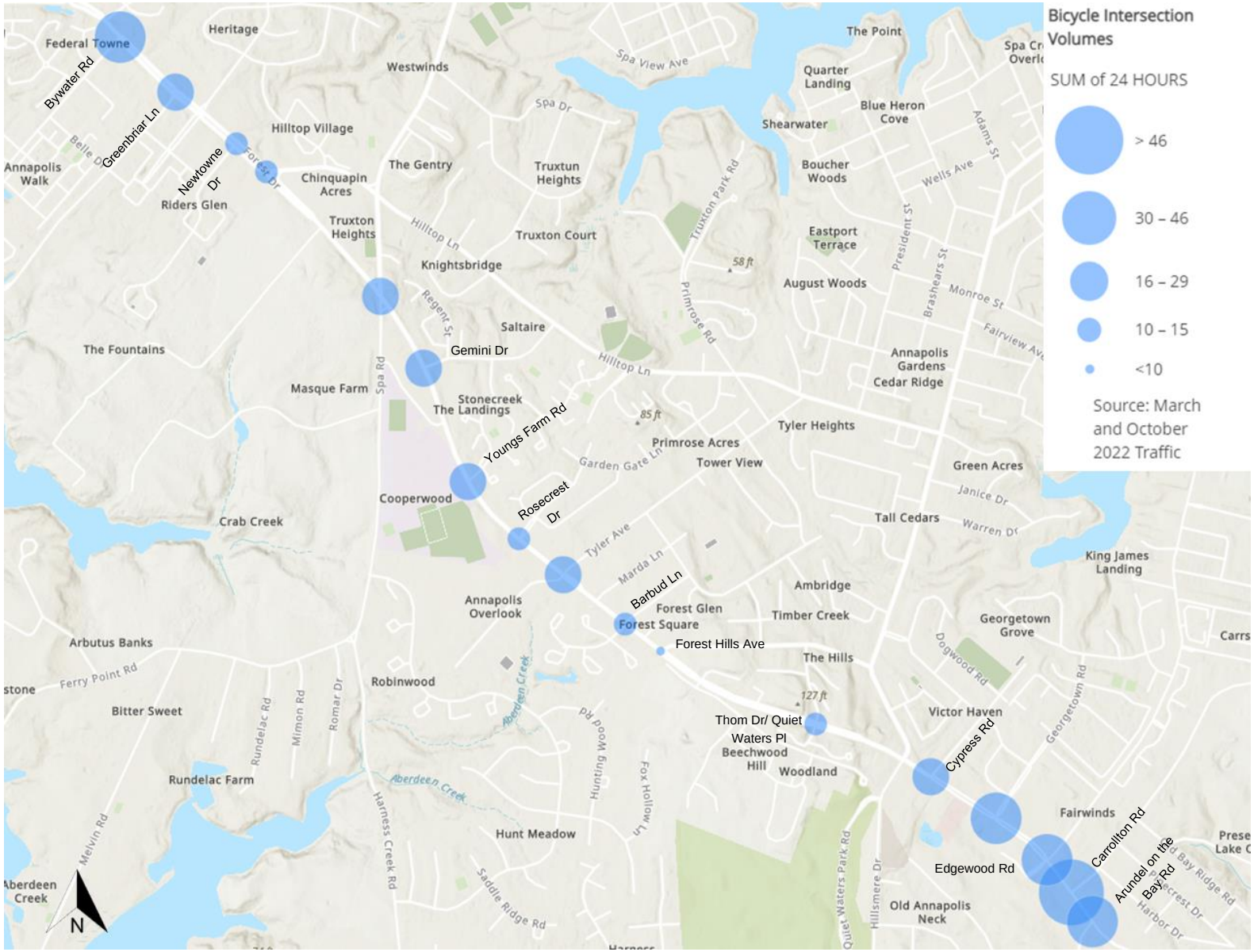


FIGURE 6-6: INTERSECTION BICYCLE VOLUMES

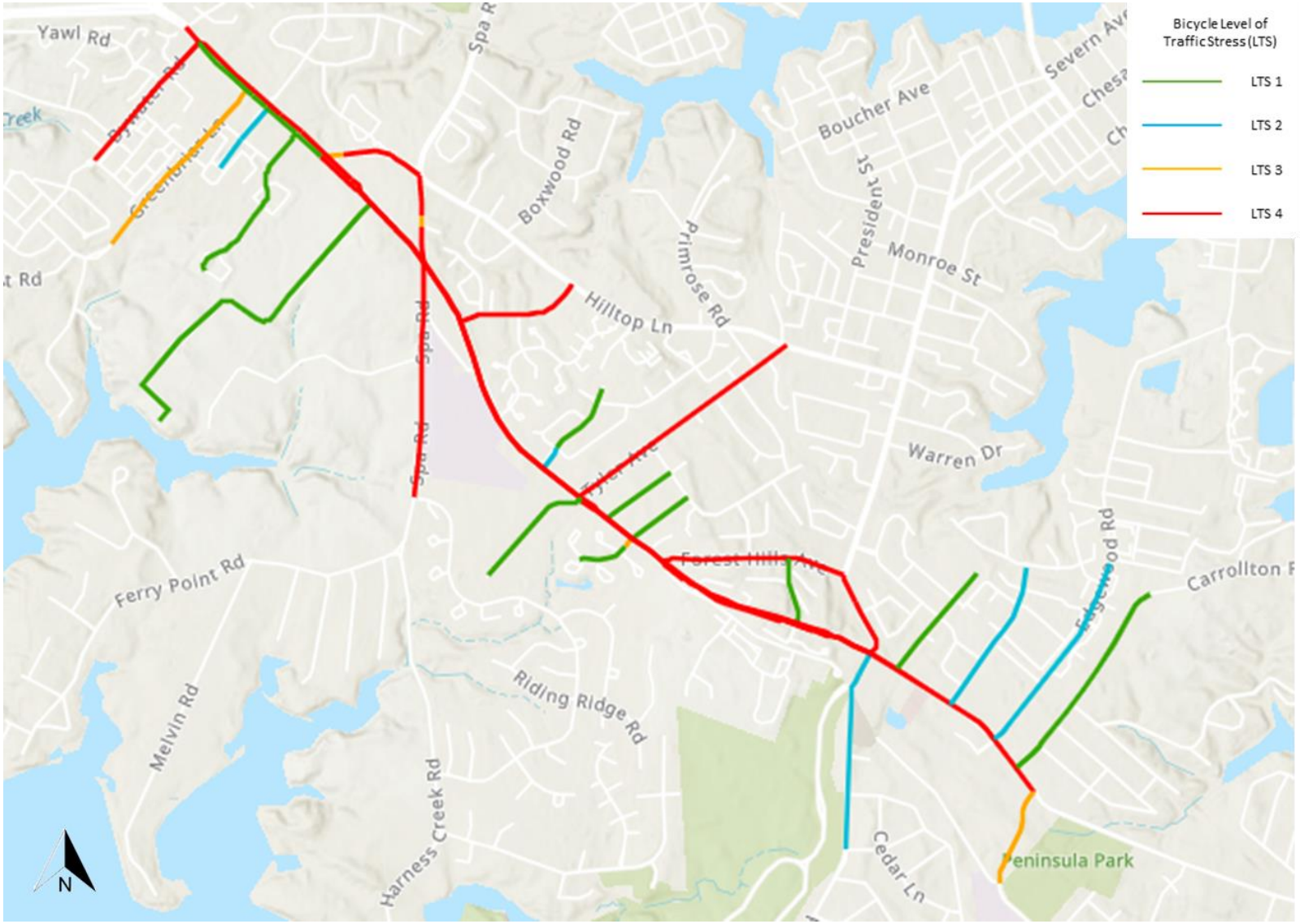


FIGURE 6-7: BICYCLE LEVEL OF TRAFFIC STRESS

6.2 Transit Facilities

There are four transit routes that run along the Forest Drive corridor, operated by the City of Annapolis. The four routes are:

- **Orange**: The Orange Route operates Monday through Friday from Downtown Annapolis to Forest Dr via Spa Rd; this route is a loop that begins and ends at the West and Calvert stop. The Orange Route operates from 5:30 AM to 6:52 PM, with a single bus on the route throughout the day. The bus on this route operates on a 45-minute headway.
- **Red**: The Red Route operates Monday through Friday, with modified service on Saturday, from the Westfield Mall to Eastport via Admiral Dr and Hilltop Ln. This route is only on the Forest Dr study area for a few blocks. The Red Route operates from 5:30 AM to 6:55 PM, with two buses on the route throughout the day. The buses on this route operate on a 30-minute headway.
    - Modified Saturday service begins at 8:00 AM eastbound and 7:30 westbound, and service runs until 6:55 PM. Saturday service operates on a 1-hour headway.
- **Brown**: The Brown Route operates Monday through Friday, with modified service on Saturday, from the Westfield Mall to Eastport via Forest Drive. The Brown Route operates from 5:30 AM to 6:53 PM, with two buses on the route throughout the day. The buses on this route operate on a 45-minute headway.
    - Modified Saturday service begins at 7:15 AM and runs until 7:08 PM. Saturday service operates on a 45-minute headway.
- **Purple**: The Purple Route operates Monday through Saturday, with modified service on Sundays and holidays, from the Westfield Mall to Eastport via Annapolis Towne Center and Church Circle. The Purple “South” route runs along the Forest Drive study area, which begins and ends at the Eastport Shopping Center. This route operates from 6:57 AM to 10:39 AM, with a single bus on the route throughout the day. The bus on this route operates on a 75-minute headway.
    - Modified Sunday service begins at 7:00 AM at the Westfield Mall and runs until 8:09 PM, terminating at the Eastport Shopping Center. The bus on this route operates on a 45-minute headway.

Figure 6-8 shows the transit routes and stops present in the study area.

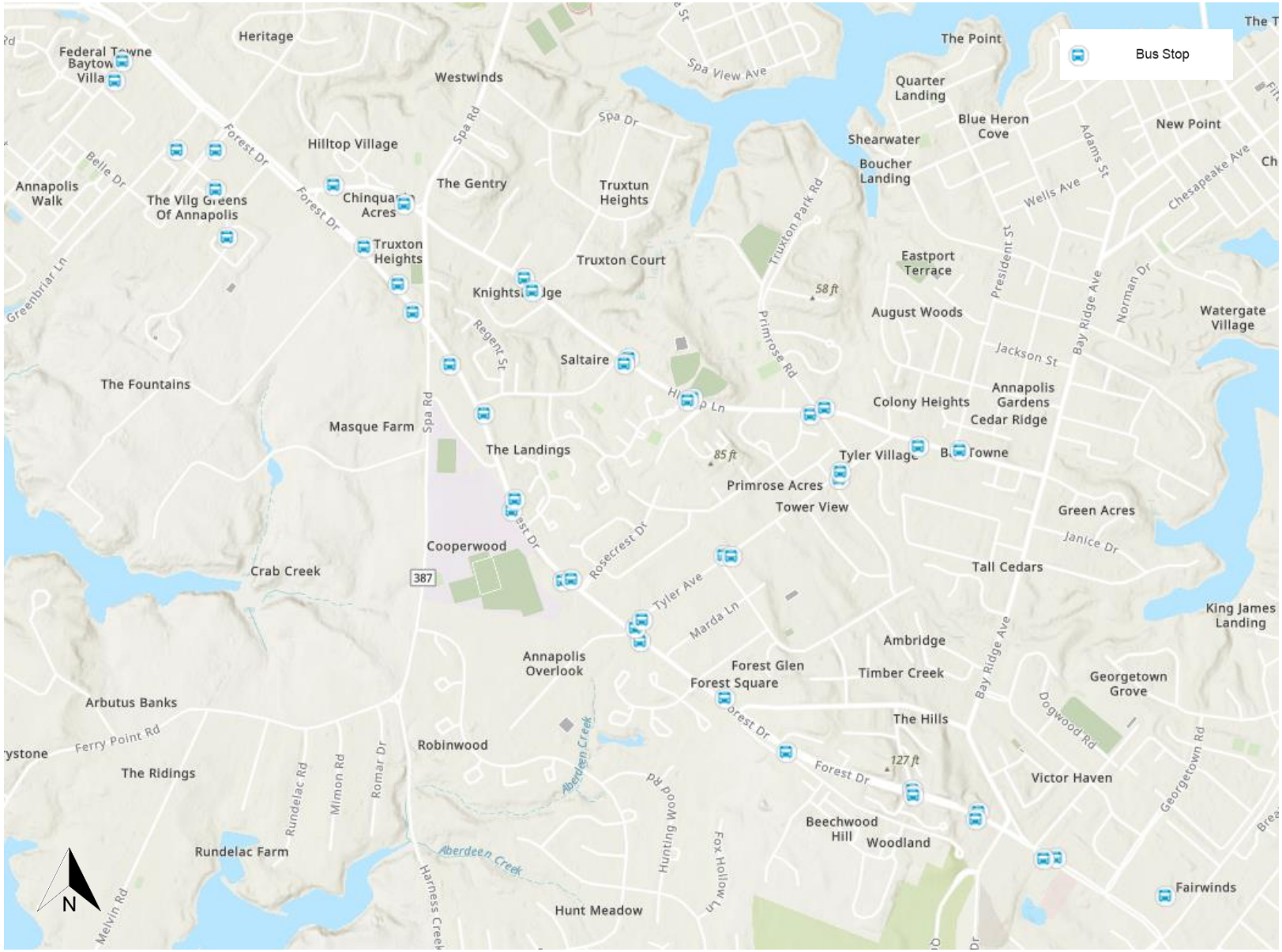


FIGURE 6-8: BUS STOPS IN STUDY AREA

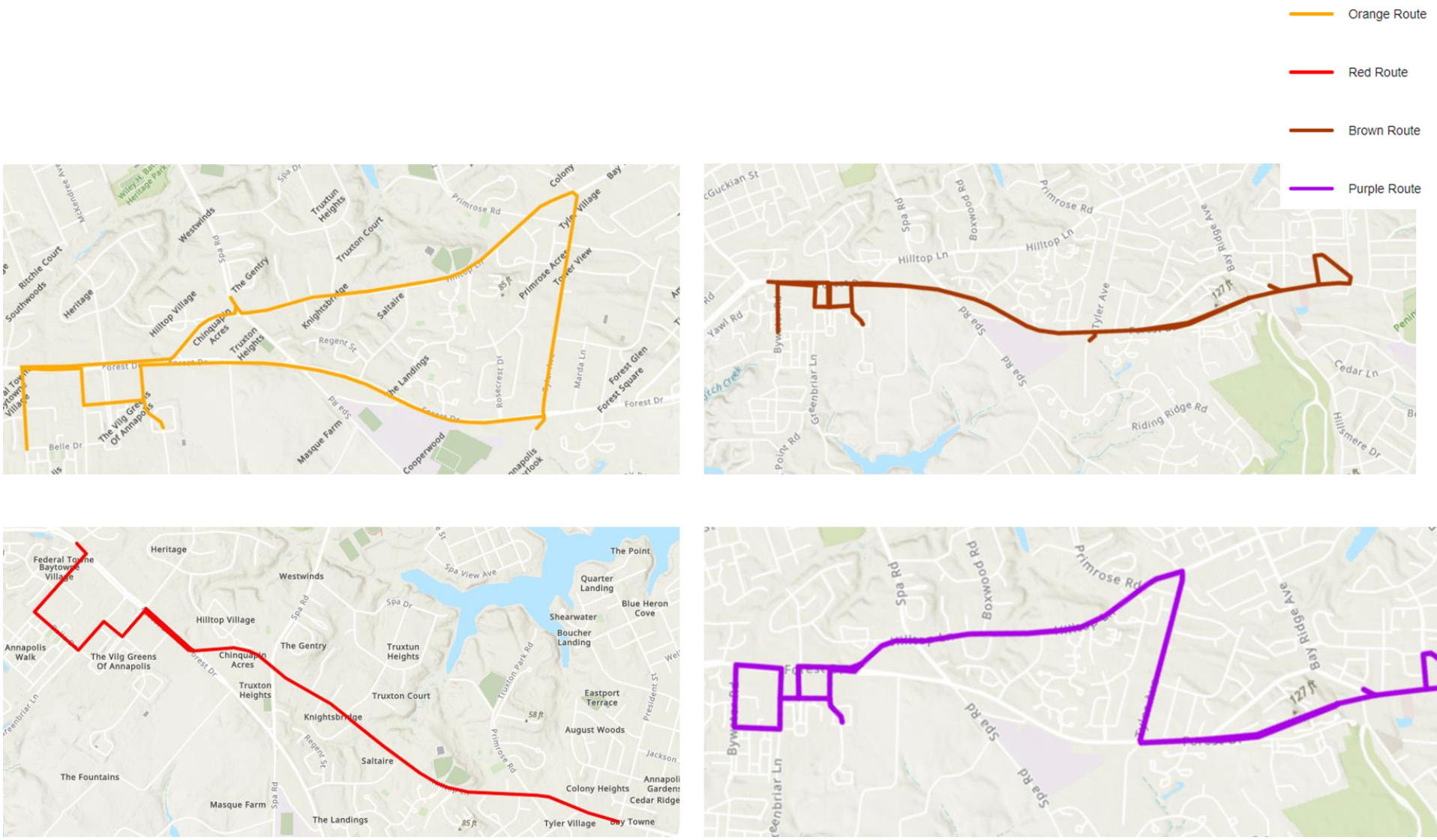


FIGURE 6-9: TRANSIT ROUTES IN STUDY AREA

7. Crash Data Summary

7.1 Crash Data

Crash data was used to evaluate safety conditions and crash patterns throughout the study area. This data was obtained from Maryland Department of Transportation (MDOT) State Highway Administration (SHA). The data includes a five-year period of crashes from January 1, 2016, to December 31, 2020. The crash data includes both intersections and road segment crashes on Forest Drive and Bay Ridge Road beginning the intersection of Forest Drive and Bywater Road and ending at the intersection of Forest Drive and Arundel on the Bay Road.

7.2 Crash Data Statistics

Between January 2016 and December 2020, there were a total of 570 crashes in the study corridor. The five-year period to analyze crash data was based on the latest available data at the time of this study. A summary of the crashes by year and by severity level for the corridor and the individual intersections is shown in Table 7-1.

TABLE 7-1: CRASHES BY YEAR AND SEVERITY LEVEL FOR THE STUDY AREA

Year	Fatal	Injury	Property Damage Only	Total
2016	0	28	47	75
2017	0	43	53	96
2018	0	41	42	83
2019	0	21	41	62
2020	0	26	38	64
Total	**0**	**236**	**334**	**570**

There were no fatalities during the study period, but 236 crashes resulted in at least one injury, which is 41% of the total number of crashes. While there were no fatalities in the years of provided data, the project team was made aware of recent fatalities in early 2023.

The following crash statistics along Forest Drive and Bay Ridge Road significantly exceed statewide average crash rates for similar roadway types:

- Total Crashes
- Property Damage Only
- Left Turn Crashes
- Pedestrian Crashes

Refer to Figure 7-1 through Figure 7-6 for more information. Intersection specific crash trends are displayed in Figure 7-8.

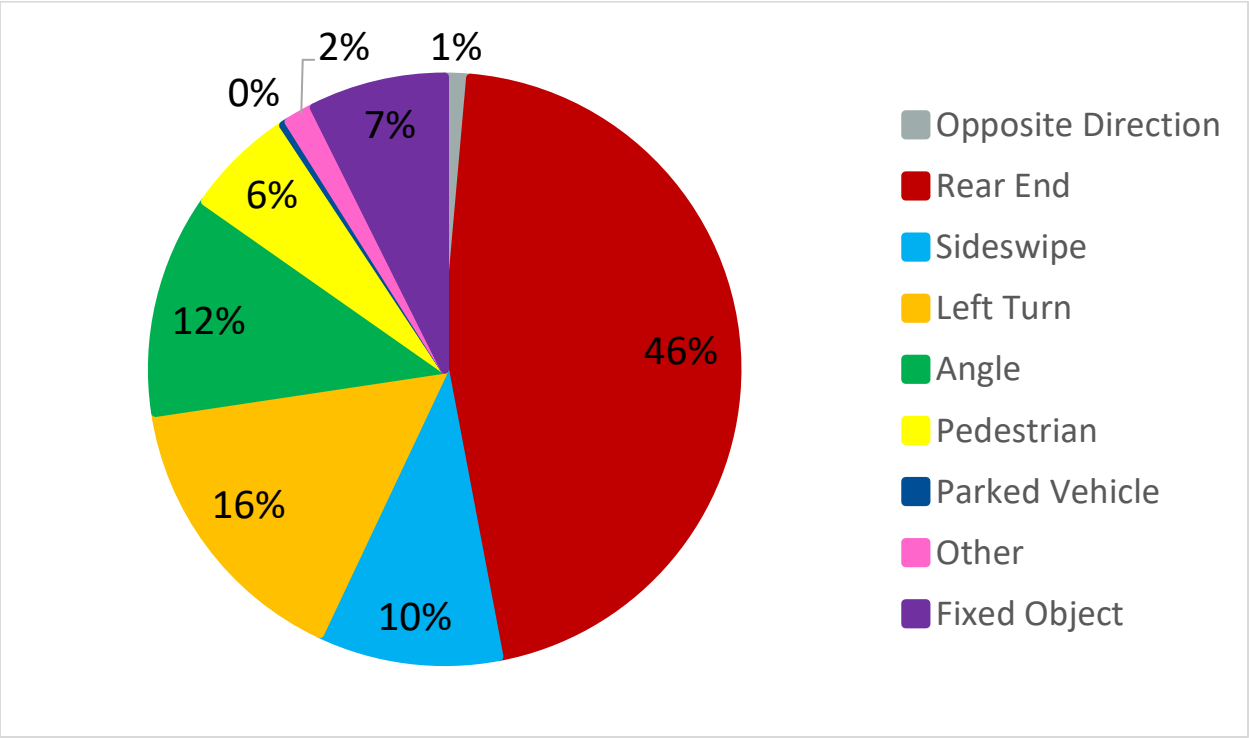


FIGURE 7-1: CRASH BREAKDOWN BY CRASH TYPE

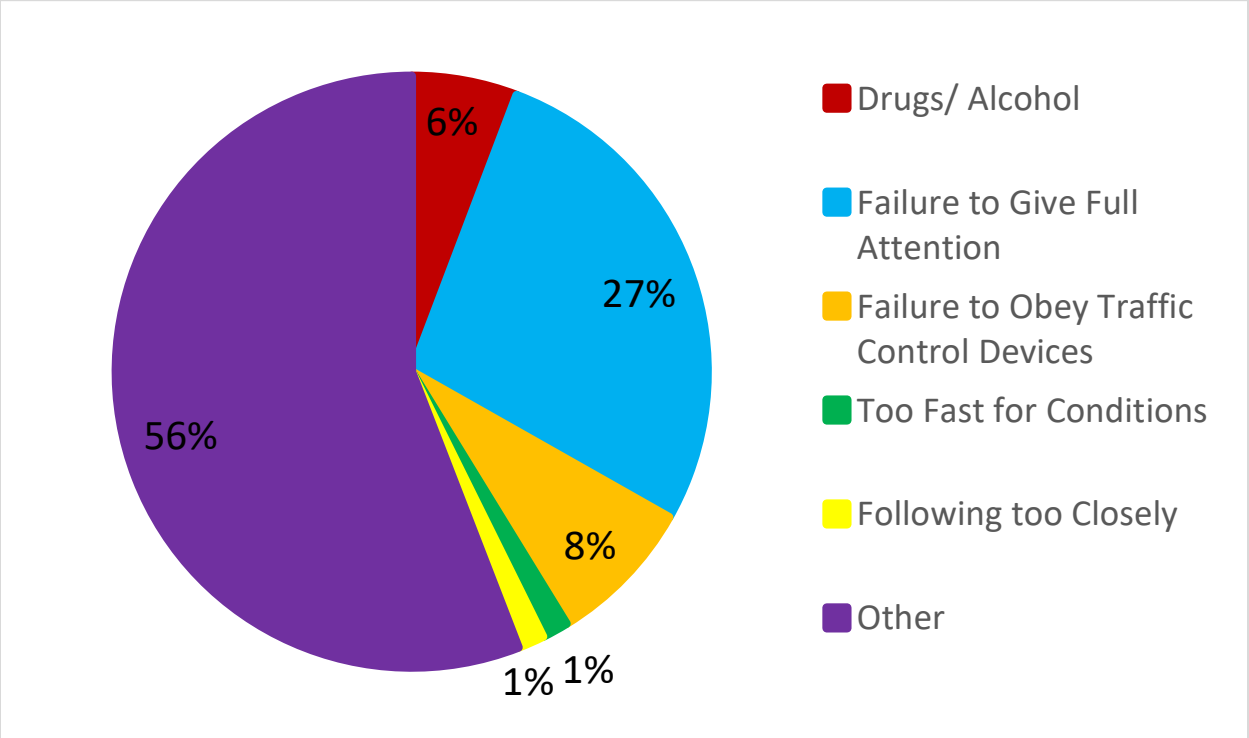


FIGURE 7-2: CRASH BREAKDOWN BY MAIN CONTRIBUTING FACTOR

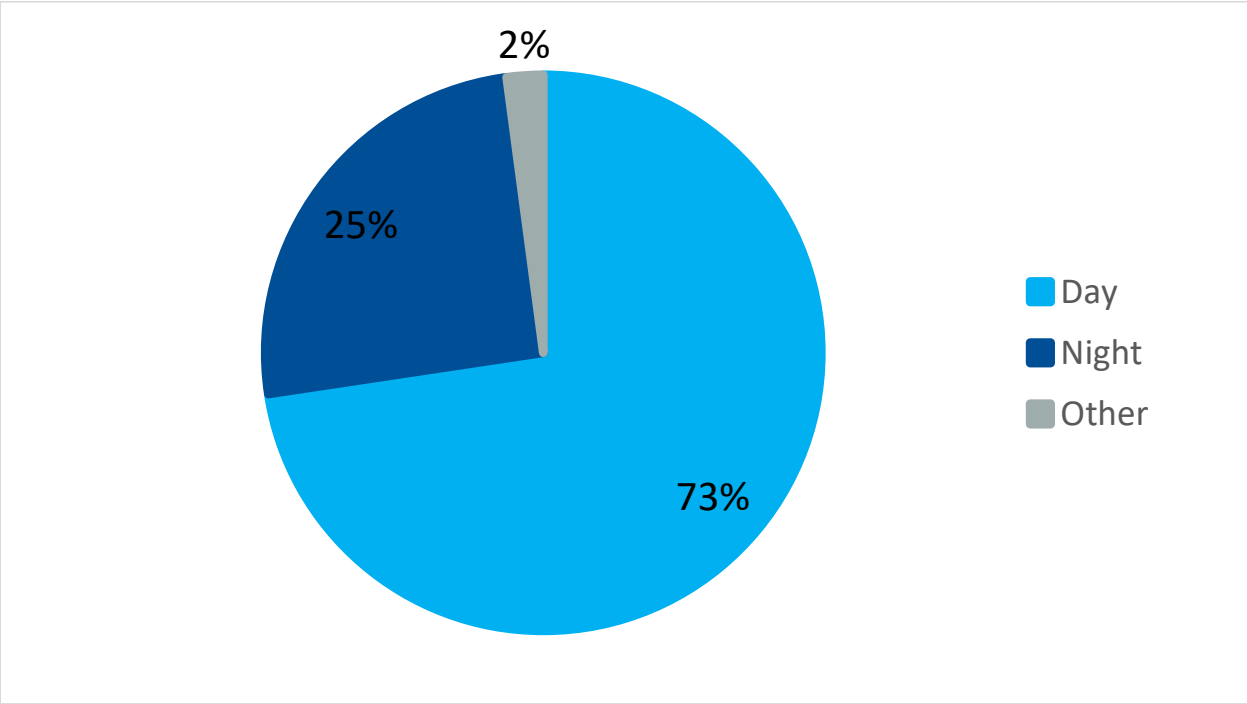


FIGURE 7-3: CRASH BREAKDOWN BY LIGHTING CONDITION

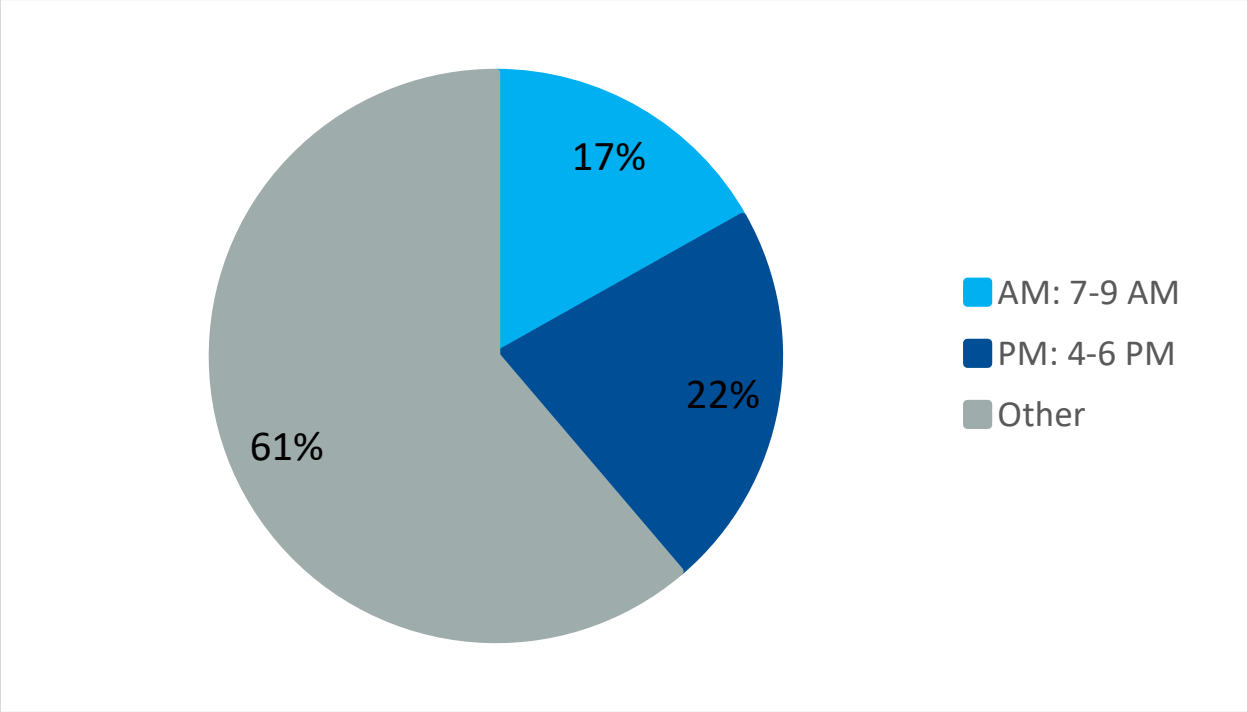


FIGURE 7-4: CRASH BREAKDOWN BY PEAK PERIOD

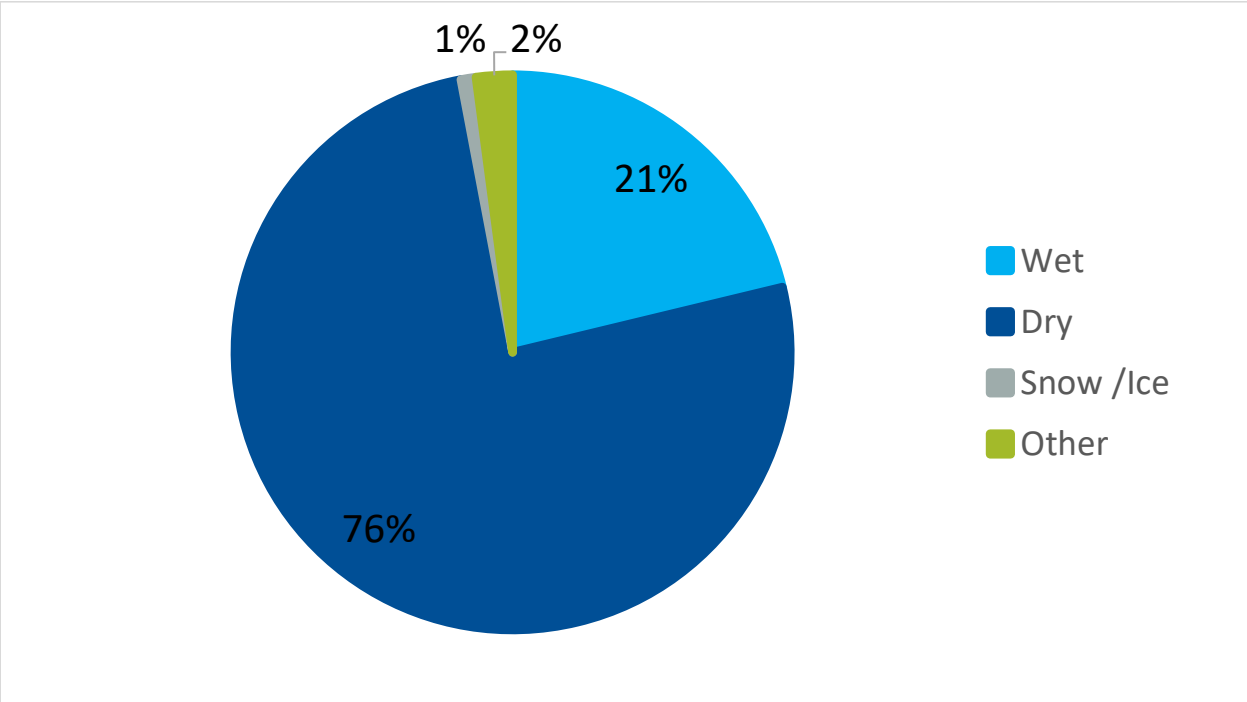


FIGURE 7-5: CRASH BREAKDOWN BY ROADWAY CONDITION

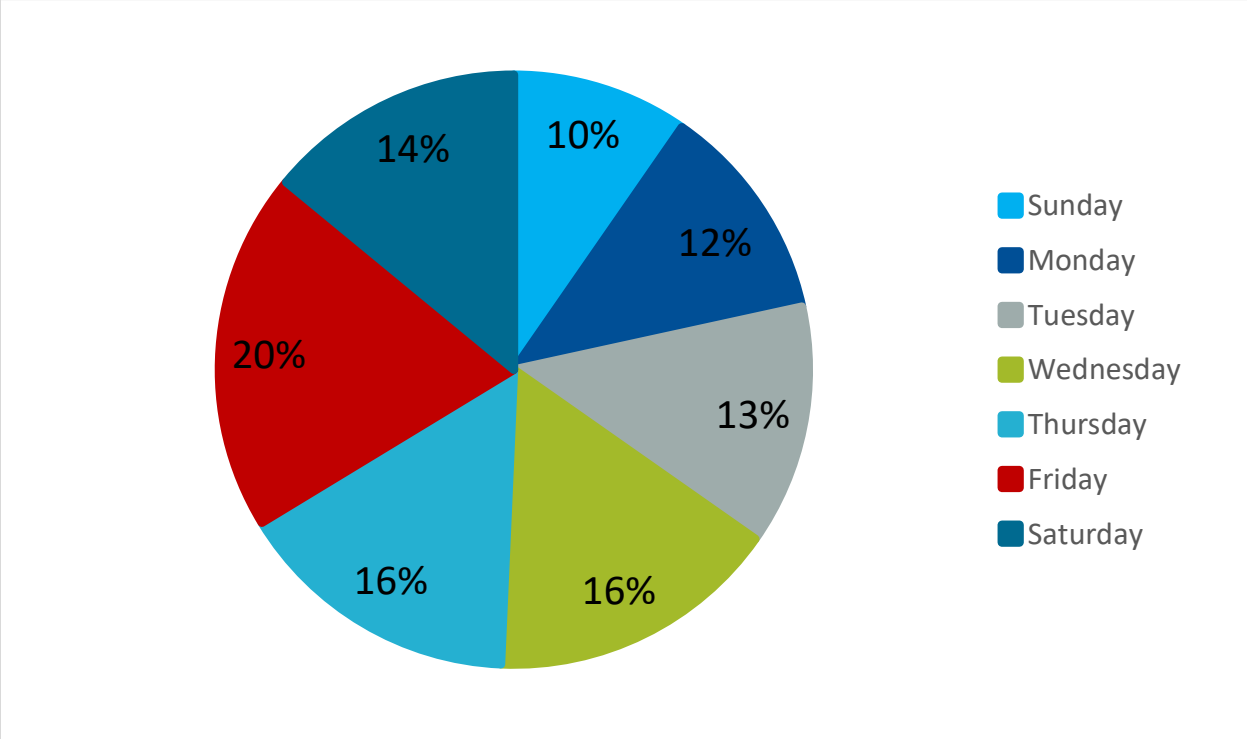


FIGURE 7-6: CRASH BREAKDOWN BY DAY OF WEEK

TABLE 7-2: INTERSECTION CRASH TOTALS BY YEAR

Year	Bywater Road	Green Briar Lane	S Cherry Grove Ave	Newtowne Drive	Hilltop Lane	Spa Road	Gemini Drive	Youngs Farm Road	Rosecrest Drive
2016	12	0	18	1	13	6	6	0	0
2017	11	1	11	1	27	6	6	5	0
2018	13	1	16	1	22	7	2	2	0
2019	8	0	9	1	8	8	4	2	1
2020	10	1	10	0	7	12	4	3	0
TOTAL	54	3	64	4	77	39	22	12	1

Year	Tyler Ave	Barbud Lane	Forest Hills Ave	Thom Dr/Quiet Waters Pl	Hillsmere Dr/Bay Ridge Rd.	Cypress Road	Georgetown Road	Edgewood Road	Carrollton Road	Arundel on the Bay Road
2016	6	0	1	2	5	1	0	2	0	2
2017	7	1	3	1	6	3	2	3	1	1
2018	3	3	2	0	4	1	5	0	0	1
2019	5	1	2	0	8	1	1	2	1	0
2020	8	1	0	0	6	0	1	1	0	0
TOTAL	29	6	8	3	29	6	9	8	2	4

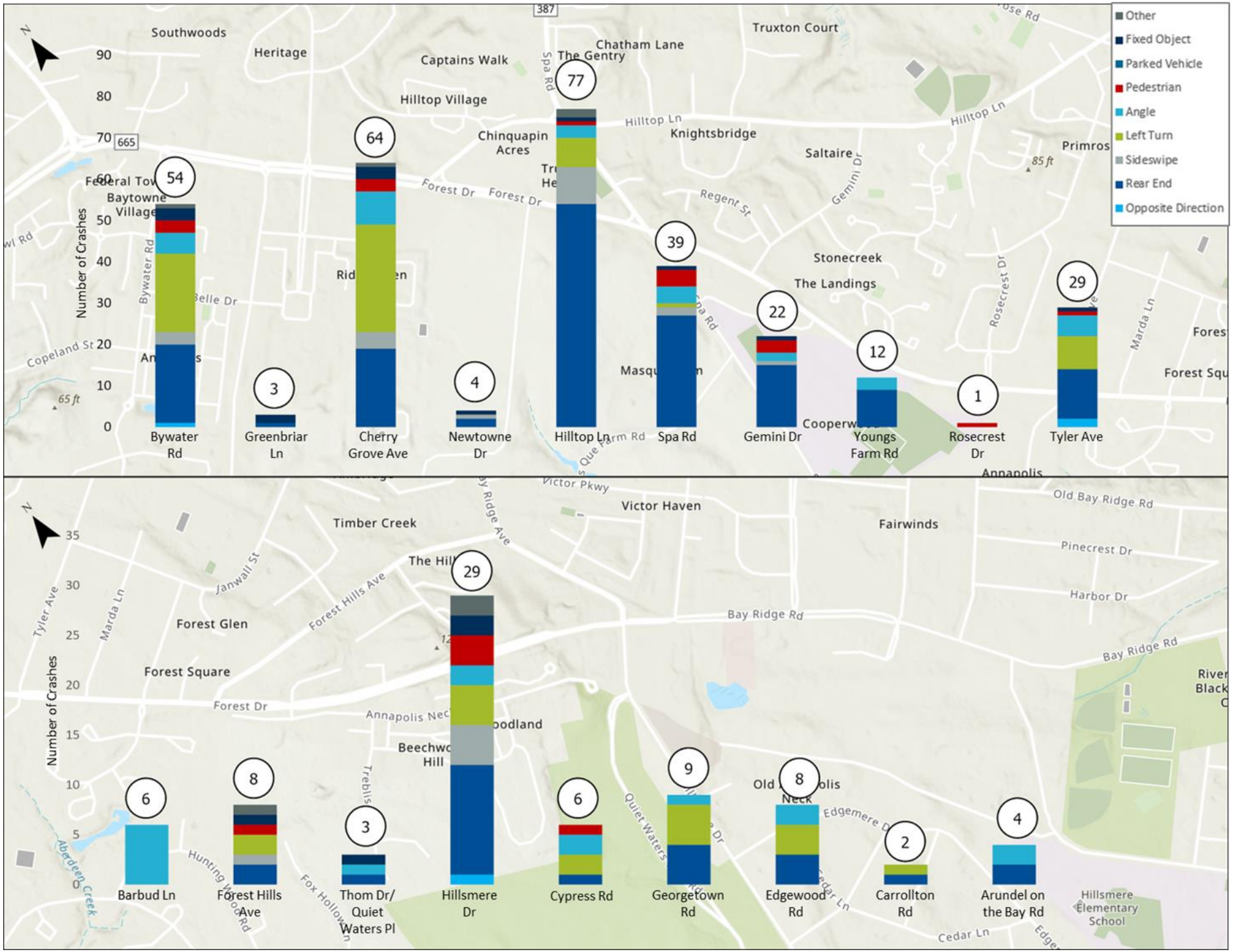


FIGURE 7-7: INTERSECTION CRASH TRENDS

7.3 County Crash Rate Comparison

A crash rate[10] comparison was made between Forest Drive/ Bay Ridge Road and compared with similar roadways within Anne Arundel County. After reviewing various county roadways within Anne Arundel County, the following list of similar roadways was developed. Table 7-3 shows the selected roadways as well as their characteristics. The roads listed are four-lane roads, but the rankings are shown for all roadway types (4-lane facilities and other facility sizes).

TABLE 7-3: COUNTY ROADS (ANNE ARUNDEL COUNTY) WITH SIMILAR ROADWAY CHARACTERISTICS

Roadway	From	To	Through Lanes (total both dir.)	Highway (Divided/ Not Divided)	Access (none, partial, full)	Posted speed Limit (mph)	Roadway Functional Classification
Riva Rd..	West St.	Harry S Truman Pkwy.	5	Undivided	Full	35/40	Minor Arterial
Bestgate Rd.	Generals Hwy.	Lawrence Ave.	4/5	Divided/ Undivided	Partial/ Full	30/40	Minor Arterial
Jennifer Rd	West St.	Admiral Dr.	5	Undivided	Full	30/40	Minor Arterial
Town Center Blvd.	Cannon Ridge Dr.	Annapolis Rd.	4	Divided	Partial	35	Minor Arterial
Piney Orchard Pkwy.	Annapolis Rd	Stream Valley Dr.	4/5	Divided/ Undivided	Partial/ Full	35/40	Minor Arterial

Anne Arundel County Department of Public Works (DPW) recently ranked all county owned roadways based upon a calculated crash rate and categorized by the number of lanes (i.e., 2-lane vs. 4-lane) using data from 2017 to 2020 (four years of data). A comparison of Forest Drive and Bay Ridge Road along with the similar roadways listed above is displayed in Table 7-4.

TABLE 7-4: CRASH RATES ON COUNTY ROADS (ANNE ARUNDEL COUNTY)

Roadway	No. of Crashes "C"	Road Length (miles) "L"	AADT (4yr avg) "V"	Crash Rate per million vehicle miles traveled (VMT)	Anne Arundel County Ranking	Anne Arundel County Ranking (4-thru lanes)
Jennifer Road	92	1.35	5,416	861.83	1	1
Forest Drive	***357***	***2.42***	***38,588***	***261.61***	***9***	***3***
Riva Road	197	2.61	36,390	142.23	36	6
Bestgate Road	59	2.44	25,411	65.18	75	16
Piney Orchard Pkwy	128	4.66	31,118	60.46	77	17
Town Center Blvd.	16	3.44	6,960	45.77	83	19
Bay Ridge Road	***42***	***1.95***	***36,380***	***40.55***	***84***	***20***
Countywide Average	-	-	-	149.31 (161.38*)	-	-

*County Roads with 4 through lanes

- Forest Drive (Chinquapin Round Road to Hillsmere Drive/Bay Ridge Avenue)
  - 9th highest crash rate of all County roads

[10] Crash data is commonly reported as a rate to remove statistical bias from the data due to segment length and traffic volume so that different locations can be compared. Crash rates in this section are defined as the number of crashes per million vehicle miles travelled.

- 3rd highest crash rate for County roads with four (4) through lanes.
- Well over county wide average.

- Bay Ridge Road (east of Hillsmere Drive)
  - Crash rate is under county wide average.

8. Improvement Development and Analysis

8.1 Improvement Recommendations

Safety improvements were developed along the corridor based upon field observations, data collection, and a thorough review of the crash data and trends. Improvements were grouped by Short-, Mid-, and Long-Term scenarios based on cost and ease of implementation. The timeline to secure funding and complete further design and construction for each scenario are:

- Short-term: < 3 years
- Mid-term: 3 to 5 years
- Long-term: 5+ years

The most common types of safety countermeasures recommended throughout the study area are summarized in Figure 8-1. These improvements were tailored to address current crash trends that significantly exceeded statewide averages including total number of crashes, left turn crashes, and pedestrian crashes. Additional safety improvements were recommended as needed to address acute issues at certain intersections or roadway segments.

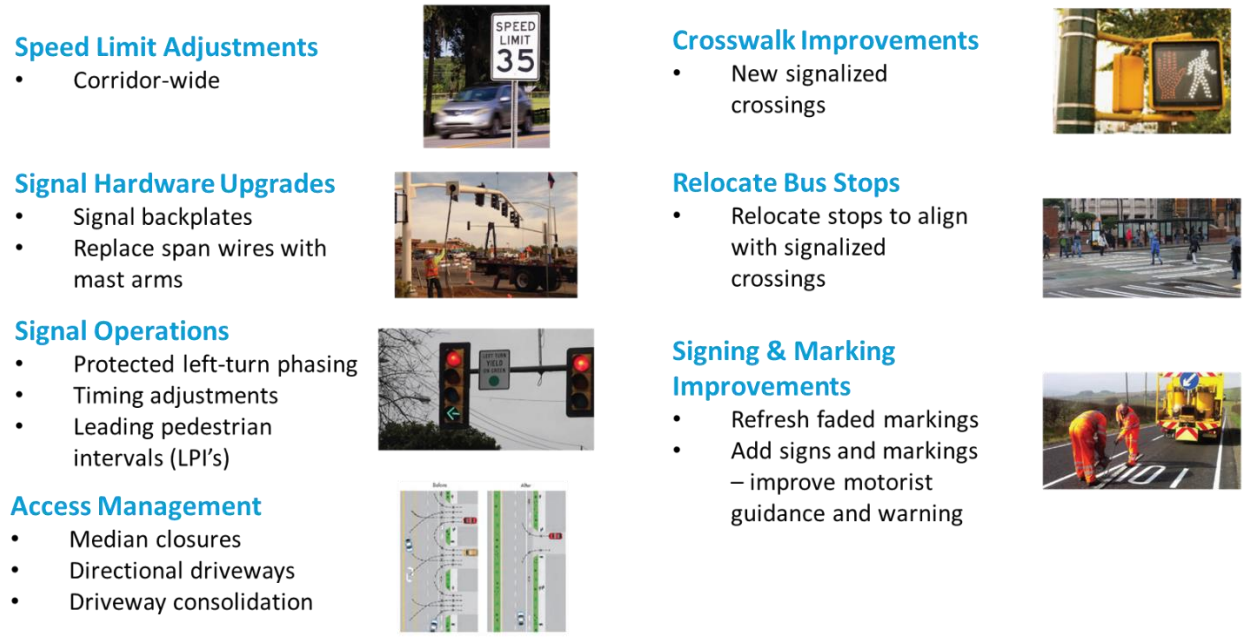


FIGURE 8-1: SAFETY IMPROVEMENT TOOLBOX

Corridor wide analysis was conducted to reevaluate the current speed limit on Forest Drive and Bay Ridge Road of 40-mph using USLIMITS2. USLIMITS2 is a web-based tool designed to help practitioners set reasonable, safe, and consistent speed limits for specific segments of roads. USLIMITS2 can provide an objective second opinion and increase confidence in speed limit setting decisions.

USLIMITS2 was developed based on research through National Cooperative Highway Research Program (NCHRP) Project 3-67 and considers all major factors used by practitioners to make engineering judgment in determining an appropriate speed limit. This includes operating speed (50th and 85th percentile), annual

average daily traffic, roadway characteristics and geometric conditions, level of development in the area around the road, crash and injury rates, presence of on-street parking, and extent of ped/bike activity, as well as several others depending on the road type. Additionally, reduced speed limits are a known Vision Zero countermeasure that reduce the severity of crashes particularly for vulnerable road users such as pedestrians and bicyclists.

This data was input for three segments of Forest Drive and Bay Ridge Road along the west, central, and east portions of the study area. The results of the USLIMITS2 analysis revealed that the speed limit through the study area is recommended to be 35-mph on the east segment and 30-mph for the central and western portions of the corridor. USLIMITS2 worksheets are available in Appendix D. Additionally, the National Association of City Transportation Officials (NACTO), has published guidance, *City Limits*, which provides technical and policy guidance on setting safe speed limits of city streets. This guidance document provides tools for setting speeds on major street corridors. The Safe Speed Study methodology analyzes conflict density and activity level, among other contextual factors, to determine the speed limit that will best minimize the risk of a person being killed or seriously injured. The Forest Drive corridor has High Conflict Density and Moderate Activity, which supports a speed limit of 20-mph based on NACTO's risk matrix.

Based on engineering judgement, speed limits on adjacent segments of Forest Dr and Bay Ridge Ave, the high number of rear-end, left turn, and pedestrian crash statistics (which are well above statewide averages), and the need to balance vehicular mobility with safety for all roadway users, the speed limit through the study area is recommended to be decreased to 35-mph.

With any speed reduction, the proper speed management tools are needed to reduce the overall number of vehicles exceeding the target speed and the even more dangerous high-end speeders. These tools include signing and markings, design and operations changes to make the street "self-enforcing", automated enforcement, and messaging and education.

One operational change recommended as part of this study is optimizing the traffic signal progression along the corridor to encourage compliance with the new posted speed limit. An overall optimization of the corridor may be beneficial to both safety and traffic operations. As part of the optimization process, Leading Pedestrian Intervals (LPI) should be considered at intersections with high pedestrian and bicycle volumes, or with vulnerable roadway users. The County should re-evaluate the speed limit post implementation to determine the improvement's success on reducing incidents and severity, and whether additional speed limit modifications or additional speed management tools are necessary.

To address the statistically high number of left turn crashes in the study area, left turn phasing at each signalized intersection along Forest Drive and Bay Ridge Road was reevaluated using the MDOT SHA left turn phasing selection guidelines. This analysis was requested by TED to confirm if the current phasing at each intersection is appropriate. The selection guidelines consider traffic volume conflicts, crash statistics, and intersection sight distance constraints. The recommended phasing ranges in level of control from permissive (yield), protected-permissive (arrow then yield), and protected only (arrow). The results from the selection screening guidelines are summarized in Table 8-1.

TABLE 8-1: LEFT TURN SELECTION RESULTS

Intersection	Direction	Guideline Finding	Existing Phasing	Study Recommendation
Bywater Rd	EB	Permissive	Protected-Permissive	No Change
	WB	Protected	Protected-Permissive	Protected
South Cherry Grove	EB	Protected	Protected-Permissive	Protected
	WB	Protected	Protected-Permissive	Protected
Hilltop Ln	EB	Protected	Protected	No Change
	WB	-	-	-
Spa Rd	EB	Permissive	Permissive	No Change
	WB	Permissive	Permissive	No Change
Gemini Dr	EB	Protected-Permissive	Protected-Permissive	No Change
	WB	Permissive	Protected-Permissive	No Change
Youngs Farm Rd	EB	Permissive	Protected-Permissive	No Change
	WB	-	-	-
Tyler Ave	EB	Protected-Permissive	Protected-Permissive	No Change
	WB	Permissive	Protected-Permissive	No Change
Bay Ridge Ave / Hillsmere Dr	EB	Permissive	Protected-Permissive	No Change
	WB	Protected-Permissive	Protected-Permissive	No Change
Georgetown Rd	EB	Permissive	Protected-Permissive	No Change
	WB	-	-	-
Edgewood Rd	EB	Protected-Permissive	Protected-Permissive	No Change
	WB	Permissive	Protected-Permissive	No Change
Arundel on the Bay Rd	EB	-	-	-
	WB	Permissive	Permissive	No Change

The findings from the MDOT SHA left turn selection flow chart revealed that the majority of the intersections currently operate with left turn phasing that is equal to or more protected than that recommended by the flowchart. Upgrades are recommended for the westbound left turn at Bywater Road and the eastbound and westbound left turns at South Cherry Grove where the existing left turn phasing was less protected than the flow chart finding.

Additional corridor-wide improvements include:

- Signal hardware upgrades to install backplates and replace span wires with mast arms to improve the visibility and compliance with traffic signals.
- A thorough corridor audit to determine signage and marking compliance with the Maryland Manual on Uniform Traffic Control Devices (MdMUTCD)[11].
- Access control recommendations to reduce driveway density and conflict points where feasible.

The detailed recommended improvements at each intersection and segment by implementation time frame are presented below. The recommendation improvement matrix and concept roll maps are attached in Appendix F.

[11] The MUTCD is the national set of traffic control device standards and guidance promulgated by Federal Highway Administration (FHWA) rulemaking on December 16, 2009. The Maryland Manual on Uniform Traffic Control Devices (MdMUTCD) is the state's adopted version from the FHWA version, and the most recent state version is dated 2011.

Forest Drive at Bywater Road (Intersection)

- Short-Term
    - Install protected-only left turn phasing westbound to improve protection based on SHA left turn selection criteria.
    - Review signal clearance intervals.
    - Install backplates on signal heads to improve signal visibility.
    - Clear brush on south side west of the intersection to improve sight distance.
    - Install larger speed limit sign eastbound in accordance with MdMUTCD to improve visibility.
    - Install No Turn on Red for northbound right turn.
- Mid-Term
    - Add new marked and signalized pedestrian crossing on the north leg of Bywater Road.

Forest Drive: Bywater Road to Greenbriar Lane (Segment)

- Short-Term
    - Upgrade driveway control at Annapolis Market Place (south side) from yield-control to stop-control.
    - Trim vegetation blocking westernmost office driveway (north side) stop sign and install stop lines.

Forest Drive at Greenbriar Lane (Intersection)

- No improvements recommended at this location.

Forest Drive: Greenbriar Lane to South Cherry Grove Avenue (Segment)

- Short-Term
    - Trim and maintain foliage along median to improve sight distance visibility for mainline left turns and side street egress. Can consider removing vegetation at this intersection.

Forest Drive at South Cherry Grove Avenue (Intersection)

- Short-Term
    - Install protected-only left turn phasing eastbound and westbound to improve protection based on SHA left turn selection criteria.
    - Review signal clearance intervals.
    - Install backplates on signal heads to improve signal visibility.
    - Revise signal timing to increase service time for westbound left-turn movement.
    - Install high visibility (hatched) crosswalk pavement markings on all legs of intersection.
- Mid-Term
    - Provide more green time to the westbound left turn movement and extend the westbound left turn storage to reduce queue spillback likelihood.

  The Mid-term improvements noted above at Forest Drive at South Cherry Grove Avenue are shown in the concepts provided in Appendix B.

Forest Drive: South Cherry Grove Avenue to Newtowne Drive (Segment)

- Short-Term
    - Install an advanced lane use sign overhead eastbound along Forest Drive near Newtowne Dr to notify motorists earlier of the downstream left turn only lanes to Hilltop Lane.

Forest Drive at Hilltop Lane (Intersection)

- Short-Term
    - Install backplates on signal heads to improve signal visibility.
    - Improve pavement markings with lane extension lines for better guidance for motorists making left or right turns.
- Mid-Term
    - Install new mast arm to align signal heads within the intersection and improve visibility.
    - Create an advanced lane use sign eastbound along Forest Drive to notify motorists of the downstream left turn only lanes to Hilltop Lane.
- Long-Term
    - Install a curb continuous through Forest Drive to provide a continuous green intersection such that eastbound traffic does not stop. This option would be contingent on the Hilltop Trail and Pedestrian bridge/underpass project and would provide travel time/delay savings and safety benefit.

The Long-term improvements noted above at Forest Drive at Hilltop Lane are shown in the concepts provided in Appendix B.

Forest Drive: Hilltop Lane to Spa Road (Segment)

- No improvements recommended at this location.

Forest Drive at Spa Road (Intersection)

- Short-Term
    - Install backplates on signal heads to improve signal visibility.
    - Install high visibility (hatched) crosswalk pavement markings on all existing marked legs (north, south, and west legs) of the intersection.
    - Re-align the west leg crossing of Forest Drive to reduce crossing distance and pedestrian exposure.
    - Install TWLTL pavement markings.
- Mid-Term
    - Address pedestrian safety on north leg by reducing radii on the northeast corner. This improvement shortens the crossing distance and slows vehicular right turn movements.
    - Signalize the channelized right turn movements to protect pedestrians.
    - Re-align crosswalks to be perpendicular to curb lines to further reduce pedestrian crossing distance and exposure.

The Mid-term improvements noted above at Forest Drive at Spa Road are shown in the concepts provided in Appendix B.

- Long-Term
    - Alternative intersection configuration with re-aligned offset “T” intersections to correct side street skew. Skewed intersections result in longer crossing distances for pedestrians and facilitate higher speed turning movements by vehicles. Correcting skewed intersections provides safer crossing conditions for pedestrians of all abilities, as well as improving operations at the intersection and removing channelized right turns.

The Long-term improvements noted above at Forest Drive at Spa Road are shown in the concepts provided in Appendix B.

Forest Drive: Spa Road to Gemini Drive (Segment)

- Mid-Term
    - Turn movement restrictions (e.g., Left-Out restriction) and driveway consolidations for businesses along this section with access to Old Forest Drive, Spa Road, and/or Gemini Dr. Access restrictions reduce conflict points and improve safety for motorists and pedestrians.

Forest Drive at Gemini Drive (Intersection)

- Short-Term
    - Install backplates on signal heads to improve signal visibility.
    - Review signal clearance intervals.
    - Clear brush on the north corner of the intersection to improve sight distance.

Forest Drive: Gemini Drive to Youngs Farm Road (Segment)

- Mid-Term
    - Access management restrictions (e.g., Left-Out restriction) and consolidations for businesses along this section with access to Old Forest Drive. Access restrictions reduce conflict points and improve safety for motorists and pedestrians.

Forest Drive at Youngs Farm Road (Intersection)

- Short-Term
    - Install backplates on signal heads to improve signal visibility.
    - Review signal clearance intervals.
    - Clear brush on the north side of Forest Drive east of the intersection to improve sight distance (maintenance).
    - Install TWLTL signs and pavement markings.
- Mid-Term
    - Add new marked and signalized pedestrian crossing on the west leg of Forest Drive.

Forest Drive: Youngs Farm Road to Rosecrest Drive (Segment)

- Install TWLTL signs and pavement markings.

Forest Drive at Rosecrest Drive (Intersection)

- Short-Term
    - Improve pavement markings (add stop bar) and crosswalk markings (completely faded) on the side street.
    - Install TWLTL signs and pavement markings.

Forest Drive: Rosecrest Drive to Tyler Avenue (Segment)

- Short-Term
    - Upgrade westbound school advance sign (S1-1) to fluorescent yellow green in accordance with latest MdMUTCD standards.
    - Install TWLTL signs and pavement markings.
- Mid-Term
    - Use access management to control driveway alignments and widths as access restrictions reduce conflict points and improve safety for motorists and pedestrians. Consider left-out

restrictions.

- Permanent closure of self-closed curb cuts on northside and rebuilding of curb and sidewalk.

Forest Drive at Tyler Avenue (Intersection)

- Short-Term
  - Install backplates on signal heads to improve signal visibility.
  - Improve pavement markings and lane use signs on the side streets to improve lane use guidance.
  - Install split-phasing on side-streets to increase side-street movement protection.
- Mid-Term
  - Add new marked and signalized pedestrian crossing on the west leg of Forest Drive.
  - Install new mast arm to align signal heads within the intersection and improve visibility.
- Long-Term
  - Modify the Tyler Avenue alignment north of Forest Dr to reduce approach skew and offset. Skewed intersections result in longer crossing distances for pedestrians and facilitate higher speed turning movements by vehicles. Correcting skewed intersections provides safer crossing conditions for pedestrians of all abilities (no concept provided).

Forest Drive: Tyler Avenue to Barbud Lane/Cobblestone Drive (Segment)

- No improvements recommended at this location.

Forest Drive at Barbud Lane/Cobblestone Drive (Intersection)

- Short-Term
  - Clear vegetation / foliage to improve intersection sight triangle on the south leg.
  - Upgrade westbound school advance sign (S1-1) to fluorescent yellow green in accordance with latest MdMUTCD standards.
- Mid-Term
  - South leg median nose does not provide sufficient width for peds/bikes crossing south leg. The side street median should be modified to accommodate a continuous pedestrian path through the intersection.

Forest Drive: Barbud Lane/Cobblestone Drive to Forest Hills Avenue (Segment)

- Short-Term
  - Consolidate/shift bus stops to new signal at Martha Ct/Annapolis Neck Rd or Tyler Avenue. Locating bus stops at intersections can reduce the likelihood of crossing away from marked crosswalks.

Forest Drive at Forest Hills Avenue (Intersection)

- Short-Term
  - Refresh faded crosswalk and stop bar markings.

Forest Drive: Forest Hills Avenue to Thom Drive / Quiet Waters Place (Segment)

- Short-Term
  - Trim vegetation encroaching over sidewalks.

Forest Drive at Thom Drive / Quiet Waters Place (Intersection)

- Short-Term
    - Consolidate/shift bus stops to new signal at Martha Ct/Annapolis Neck Rd. Locating bus stops at intersections can reduce the likelihood of crossing away from marked crosswalks.

Forest Drive: Drive / Quiet Waters Place to Hillsmere Drive / Bay Ridge Avenue (Segment)

- Short-Term
    - Trim and maintain vegetation encroaching over sidewalks.

Forest Drive at Hillsmere Drive / Bay Ridge Avenue (Intersection)

- Short-Term
    - Install backplates on signal heads to improve signal visibility.
    - Update lane use signs and markings through intersection (add lane extension lines on dual lefts) for improved guidance.
    - Adjust stop bar locations on Forest Drive to reduce encroachment.
    - Change yield control on right turn spur westbound to stop control and provide rumble strips and advance warnings.
    - Re-stripe faded crossing markings on westbound right spur.
    - Install Leading Pedestrian Intervals (LPI) to allow pedestrians to establish their presence within the crosswalk prior to vehicles green indication.
    - Consider enhanced pedestrian signage.
- Mid-Term
    - Add new marked and signalized pedestrian crossing on the west leg of Forest Drive.
    - Upgrade curb ramps to meet ADA requirements and realign crossings with curb ramps while also avoiding utilities (e.g., storm drains).
    - Tighten curb radii on SW corner to reduce pedestrian exposure and slow turning vehicles.
    - Eliminate westbound slip right turn and add a right turn lane.

  The Mid-term improvements noted above at Forest Drive at Hillsmere Drive / Bay Ridge Avenue are shown in the concepts provided in Appendix B.

Bay Ridge Road: Hillsmere Drive / Bay Ridge Avenue to Cypress Road (Segment)

- No improvements recommended at this location.

Bay Ridge Road at Cypress Road (Intersection)

- Short-Term
    - Conduct detailed evaluation for removing bollards on Victor Parkway to allow access to/from Cypress Rd and Georgetown Rd signal. The evaluation would include meeting with the community to discuss feasibility, impacts, and alternative possible measures. The access modification to Victor Pkwy will require additional study to determine potential impacts.
- Mid-Term
    - Install a median on Bay Ridge Road to prohibit left turns and through movements from Cypress Road, as well as restricting the through and left turning movement from the driveway on the south side of the intersection. Access restrictions reduce conflict points and improve safety for motorists and pedestrians.

Bay Ridge Road: Cypress Road to Georgetown Road (Segment)

- Short-Term
    - Relocate Bus stops to signal at Georgetown Rd. Locating bus stops at intersections can reduce the likelihood of crossings away from marked crosswalks.
    - Install TWLTL signs and pavement markings.
- Mid-Term
    - Consolidate driveways and reduce widths of those remaining. Such access restrictions reduce conflict points and improve safety for motorists and pedestrians.
    - Install High-Intensity Activated crossWalK (HAWK) signal with marked crossing on Bay Ridge Road for a mid-block crossing between Cypress Road and Georgetown Road

Bay Ridge Road at Georgetown Road (Intersection)

- Short-Term
    - Install backplates on signal heads to improve signal visibility.
    - Install Leading Pedestrian Intervals (LPI) to allow pedestrians to establish their presence within the crosswalk prior to vehicles green indication.
- Mid-Term
    - Add new marked and signalized pedestrian crossing on the east leg of Bay Ridge Road (to be provided by developer).

Bay Ridge Road: Georgetown Road to Edgewood Road (Segment)

- No improvements recommended at this location.

Bay Ridge Road at Edgewood Road (Intersection)

- Short-Term
    - Install backplates on signal heads to improve signal visibility.
    - Change eastbound left-turn phasing to Protected Only
    - Re-stripe faded crossing markings on southwest intersection approach leg.
    - Re-stripe faded crossing markings on the northeast intersection approach leg. Coordinate with the City of Annapolis to consider removing the stamped brick crosswalk and providing high-visibility hatched crosswalk.

Bay Ridge Road: Edgewood Road to Carrollton Road (Segment)

- No improvements recommended at this location.

Bay Ridge Road at Carrollton Road (Intersection)

- No improvements recommended at this location.

Bay Ridge Road: Carrollton Road to Arundel on the Bay Road (Segment)

- No improvements recommended at this location.

Bay Ridge Road at Arundel on the Bay Road (Intersection)

- Short-Term
    - Install backplates on signal heads to improve signal visibility.
    - Re-stripe faded crossing markings on southwest intersection approach leg.

- Mid-Term
    - Tighten curb radii particularly on the SW corner to reduce crossing distance and slow vehicle turning speeds.
    - Add new marked and signalized pedestrian crossing on the east leg of Bay Ridge Road.

  The Mid-term improvements noted above at Bay Ridge Road at Arundel on the Bay Road are shown in the concepts provided in Appendix B.

8.2 Predictive Safety Analysis

A predictive safety analysis was performed to estimate the reduction of expected crash frequencies provided by the recommend safety countermeasures described in Section 8.1. The analysis was performed using a spreadsheet-based tools developed by the Texas A&M University Transportation Institute, based on the Highway Safety Manual (HSM) 1st Ed, Vol. 2, Chapter 12: Predictive Method for Urban and Suburban Arterials and NCHRP 17-58 (for six-lane arterials).

The tool analyzes intersections and non-intersection segments and calculates an expected annual average crash frequency. The tool requires input data for the characteristics of the roadway segments such as: number of lanes/typical section, AADT, presence of lighting and automated speed enforcement, posted speed, and the number of observed crashes. For intersections, additional data required for the analysis includes: the intersection control type, AADT of both major and minor streets phasing for left turns, right turn on red conditions, volume of pedestrian crossings, and the presence of pedestrian generators within 1,000 ft of the intersection.

The expected average crash frequency under Existing Conditions for fatal/ injury and property damage only severities are shown for intersections in Table 8-2, and for segments in Table 8-3. To estimate the effect of the proposed countermeasures, crash modification factors (CMF) were applied to the existing expected crash frequencies. Some CMFs could be implicitly applied through the spreadsheet inputs, such as prohibition of right turns on red and changes to left turn phasing. The others were applied to the calculated crash frequencies. CMFs were selected by searching treatments on U.S. Department of Transportation Federal Highway Administration's (FHWA's) CMF Clearinghouse and applying the CMF which best matched the studied treatment from which the CMF was developed. For mid- and long-term mitigation, it was assumed that the short-term treatments had already been implemented, and the CMFs were therefore applied in conjunction with the additional mitigation CMFs.

The HSM recommends that no more than three CMFs be applied to a single location, as not to overestimate the effect of multiple treatments applied at the same time. Therefore, each stage of mitigation was limited to three CMFs, and the most impactful CMFs were selected. In the mid- and long- term mitigation scenarios, CMFs from the short-term were only overwritten if the additional mitigation had a greater impact than already applied CMF. The estimated expected crash frequencies and reduction compared to existing conditions for each stage of mitigation are shown for intersections in Table 8-2, and for segments in Table 8-3. Values are shown for all locations for all phases, even if no countermeasures are proposed at that location in each phase. In the following tables, fatal and injury is written as F+I and property damage only is written as PDO.

TABLE 8-2: EXPECTED AVERAGE CRASH FREQUENCY REDUCTION - INTERSECTIONS

Intersection	Expected Average Crash Frequency (Crashes/Yr)								Reduction from Existing Crash Frequency		
	Existing Conditions		Short Term Mitigation		Mid Term Mitigation		Long Term Mititgation		Short-Term	Mid-Term	Long-Term
	F+I	PDO	F+I	PDO	F+I	PDO	F+I	PDO			
Forest Dr at Bywater Rd	4.59	4.5	3.7	4.1	3.5	3.8	3.5	3.8	14.9%	19.3%	19.3%
Forest Dr at Greenbriar Ln	0.74	1.1	0.7	1.1	0.7	1.1	0.7	1.1	0.0%	0.0%	0.0%
Forest Dr at S Cherry Grove Ln	4.79	5.4	4.3	5.0	4.0	4.7	4.0	4.7	8.9%	14.5%	14.5%
Forest Dr at Newtowne Dr	0.84	1.1	0.8	1.1	0.8	1.1	0.8	1.1	0.0%	0.0%	0.0%
Forest Dr at Hilltop Ln	4.97	8.4	4.9	8.3	4.6	8.1	4.3	7.8	1.2%	5.3%	8.8%
Forest Dr at Spa Rd	2.80	5.1	2.6	4.7	2.4	4.5	2.0	4.8	7.7%	13.1%	13.9%
Forest Dr at Gemini Dr	1.50	3.1	1.2	2.7	1.2	2.7	1.2	2.7	13.9%	13.9%	13.9%
Forest Dr at Youngs Farm Rd	1.24	2.3	1.0	2.0	0.9	2.1	0.9	2.1	12.7%	14.7%	14.7%
Forest Dr at Rosecrest Dr	0.53	0.8	0.5	0.8	0.5	0.8	0.5	0.8	5.2%	5.2%	5.2%
Forest Dr at Tyler Ave	2.32	4.4	2.2	4.1	2.0	3.8	1.8	3.4	6.3%	12.4%	22.6%
Forest Dr at Barbud Ln/Cobblestone Drive	0.93	1.4	0.8	1.4	0.8	1.3	0.8	1.3	8.1%	9.6%	9.6%
Forest Dr at Forest Hills Ave	0.69	1.3	0.7	1.3	0.7	1.3	0.7	1.3	3.1%	3.1%	3.1%
Forest Dr at Thom Dr	0.47	0.7	0.5	0.7	0.5	0.7	0.5	0.7	0.6%	0.6%	0.6%
Forest Dr at Hillsmere Dr	2.00	3.9	1.9	3.6	1.6	3.1	1.6	3.1	7.5%	19.2%	19.2%
Bay Ridge Rd at Cypress Rd	0.68	1.0	0.6	0.9	0.4	0.6	0.4	0.6	13.1%	43.2%	43.2%
Bay Ridge Rd at Georgetown Rd	0.94	2.0	0.8	1.8	0.8	1.6	0.8	1.6	10.4%	20.2%	20.2%
Bay Ridge Rd at Edgewood Rd	1.04	2.1	1.0	2.0	1.0	2.0	1.0	2.0	3.6%	3.6%	3.6%
Bay Ridge Rd at Carrollton Rd	0.71	1.1	0.7	1.1	0.7	1.1	0.7	1.1	0.0%	0.0%	0.0%
Bay Ridge Rd at Arundel on the Bay Rd	0.85	1.9	0.8	1.8	0.7	1.5	0.7	1.5	2.0%	17.9%	17.9%

TABLE 8-3: EXPECTED AVERAGE CRASH FREQUENCY REDUCTION - SEGMENTS

Segment	Length (mi)	Expected Average Crash Frequency (Crashes/Year)								Reduction from Existing Crash Frequency		
		Existing Conditions		Short Term Mitigation		Mid Term Mitigation		Long Term Mititgation		Short-Term	Mid-Term	Long-Term
		F+I	PDO	F+I	PDO	F+I	PDO	F+I	PDO			
Bywater Rd to Greenbriar Ln	0.16	0.9	1.9	0.9	1.9	0.9	1.9	0.9	1.9	2.9%	2.9%	2.9%
Greenbriar Ln to S Cherry Grove Rd	0.07	0.7	1.1	0.7	1.1	0.7	1.1	0.7	1.1	3.6%	3.6%	3.6%
S Cherry Grove Rd to Newtowne Rd	0.09	0.8	1.3	0.7	1.2	0.7	1.2	0.7	1.2	7.0%	7.0%	7.0%
Newtowne Rd to Hilltop Ln	0.07	0.5	1.3	0.5	1.3	0.5	1.3	0.5	1.3	6.1%	6.1%	6.1%
Hilltop Ln to Spa Rd	0.31	1.2	3.3	1.2	3.3	1.2	3.3	1.2	3.3	0.0%	0.0%	0.0%
Spa Rd to Gemini Dr	0.16	1.1	3.3	1.1	3.3	0.8	2.4	0.8	2.4	0.0%	27.5%	27.5%
Gemini Dr to Youngs Farm Rd	0.24	1.6	4.7	1.6	4.7	1.2	3.4	1.2	3.4	0.0%	26.5%	26.5%
Youngs Farm Rd to Rosecrest Dr	0.15	0.4	1.3	0.4	1.3	0.4	1.3	0.4	1.3	0.0%	0.0%	0.0%
Rosecrest Dr to Tyler Ave	0.10	1.5	4.2	1.3	4.1	0.5	1.6	0.5	1.6	5.5%	62.9%	62.9%
Tyler Ave to Cobblestone Dr/Barbud Ln	0.15	0.8	2.3	0.8	2.3	0.8	2.3	0.8	2.3	0.0%	0.0%	0.0%
Cobblestone Dr to Forest Hills Ave	0.09	0.4	1.1	0.4	1.1	0.4	1.1	0.4	1.1	0.0%	0.5%	0.5%
Forest Hills Ave to Thom Dr	0.35	0.5	1.7	0.5	1.7	0.5	1.7	0.5	1.7	2.5%	2.5%	2.5%
Thom Dr to Hillsmere Dr/Bay Ridge Ave	0.19	0.6	1.8	0.6	1.8	0.6	1.8	0.6	1.8	0.5%	0.5%	0.5%
Hillsmere Dr/Bay Ridge Ave to Cypress Rd	0.06	0.2	0.5	0.2	0.5	0.2	0.5	0.2	0.5	0.0%	0.0%	0.0%
Cypress Rd to Georgetown Rd	0.15	0.7	2.0	0.7	2.0	0.4	1.1	0.4	1.1	0.5%	44.5%	44.5%
Georgetown Rd to Edgewood Rd	0.12	0.3	0.9	0.3	0.9	0.3	0.9	0.3	0.9	0.0%	0.0%	0.0%
Edgewood Rd to Carrollton Rd	0.07	0.3	0.9	0.3	0.9	0.3	0.9	0.3	0.9	0.0%	0.0%	0.0%
Carrollton Rd to Arundel on the Bay Rd	0.07	0.3	0.8	0.3	0.8	0.3	0.8	0.3	0.8	0.0%	0.0%	0.0%

8.3 Operational Impact Analysis

To identify any potential impacts to traffic operations associated with the safety countermeasures, the recommended improvements were coded into Synchro to perform capacity analysis. The capacity analysis results for the 2025 Build alternatives with safety countermeasures are shown in Figure 8-1 relative to the 2025 No Build for comparison.

The results of the capacity analysis reveal that all intersections are expected to continue to maintain acceptable LOS D or better with the improvements recommended under the short-, mid-, and long-term scenarios. Additionally, the poorest performing intersection, Forest Drive at Spa Road, would be expected to see operational improvements associated with offset “T” intersection modifications recommended in the long-term scenario.

The findings from the capacity analysis indicate that the safety countermeasures recommended in the report would not result in significant degradation of traffic operations along Forest Drive and Bay Ridge Road or their side street approaches.

TABLE 8-2: FUTURE BUILD CAPACITY ANALYSIS SUMMARY TABLE - AM (PM)

ID	Intersection	2025 No Build			2025 Build Short-Term			2025 Build Mid-Term			2025 Build Long-Term		
		Delay	LOS	V/C	Delay	LOS	V/C	Delay	LOS	V/C	Delay	LOS	V/C
1	Bywater Road & Forest Drive	17.8 (16.2)	B (B)	0.89 (0.83)	19.8 (25.0)	B (C)	0.89 (0.91)	19.8 (25.0)	B (C)	0.89 (0.91)	No Additional Recommendations		
2	South Cherry Grove & Forest Drive	16.3 (22.8)	B (C)	0.80 (0.91)	17.7 (30.8)	B (C)	0.80 (0.94)	17.7 (30.8)	B (C)	0.80 (0.94)	No Additional Recommendations		
3	Forest Drive & Hilltop Lane	17.2 (16.4)	B (B)	0.75 (0.73)	17.2 (16.4)	B (B)	0.75 (0.73)	17.1 (16.3)	B (B)	0.75 (0.73)	18.7 (15.6)	B (B)	0.75 (0.73)
4	Spa Road & Forest Drive	42.4 (41.9)	D (D)	0.98 (0.97)	41.6 (41.6)	D (D)	1.00 (0.99)	42.0 (41.3)	D (D)	1.00 (0.99)	See nodes 51 & 52		
5	Gemini Drive & Forest Drive	14.2 (8.9)	B (A)	0.76 (0.74)	No Additional Recommendations			15.6 (8.6)	B (A)	0.76 (0.74)	No Additional Recommendations		
6	Youngs Farm Road & Forest Drive	4.8 (5.3)	A (A)	0.71 (0.73)	5.9 (5.4)	A (A)	0.71 (0.73)	5.4 (5.1)	A (A)	0.71 (0.73)	No Additional Recommendations		
7	Tyler Avenue & Forest Drive	12.9 (10.9)	B (B)	0.75 (0.77)	14.4 (16.4)	B (B)	0.77 (0.83)	12.8 (15.7)	B (B)	0.77 (0.83)	13.9 (16.2)	B (B)	0.77 (0.83)
8	Hillsmere Drive/Bay Ridge Avenue & Forest Drive	35.5 (37.9)	D (D)	0.85 (0.79)	32.6 (34.7)	C (C)	0.84 (0.79)	34.2 (36.1)	C (D)	0.84 (0.79)	No Additional Recommendations		
9	Bay Ridge Road & Georgetown Road	13.1 (13.2)	B (B)	0.71 (0.75)	11.5 (13.0)	B (B)	0.71 (0.75)	11.6 (13.8)	B (B)	0.71 (0.75)	No Additional Recommendations		
10	Edgewood Road & Bay Ridge Road	31.2 (25.3)	C (C)	0.83 (0.79)	35.7 (32.4)	D (C)	0.78 (0.70)	No Additional Recommendations			No Additional Recommendations		
11	Arundel on the Bay Road & Bay Ridge Road	21.6 (13.3)	C (B)	0.81 (0.58)	21.7 (13.3)	C (B)	0.81 (0.58)	21.6 (12.9)	C (B)	0.81 (0.58)	No Additional Recommendations		
4A	Forest Drive & Spa Rd (west)	Not Applicable			Not Applicable			Not Applicable			19.8 (13.1)	B (B)	0.96 (0.83)
4B	Forest Drive & Spa Rd (east)	Not Applicable			Not Applicable			Not Applicable			20.3 (15.4)	C (B)	0.82 (0.88)

8.4 Cost Estimates

Planning-level construction costs were estimated for each improvement. The planning-level construction costs are reported as a high-level construction cost estimate to design and to build each set of safety countermeasures, considering any right-of-way needs, utility relocation, and other factors that can have outsized impacts on construction costs. Note that these costs are subject to significant changes based on the final design of the project. Quantities were estimated for each countermeasure and unit costs were applied to develop planning-level construction costs. Unit costs and quantity estimates for each improvement scenario can be found in Appendix E.

8.5 Benefit / Cost Analysis

A Benefit/ Cost (B/C) analysis was performed for each proposed improvement for the short-, mid- and long-term scenarios. This analysis compares a planning-level cost estimate for an improvement to the cost savings from the expected reduction in each crash occurrence. The B/C analysis was performed for individual intersections as well as segments between intersections.

MDOT SHA has a standard Benefit-Cost Analysis Tool that was used for the benefit to cost ratio calculation. The Benefit-Cost analysis spreadsheet tool is designed for computing and comparing benefits and costs of a project. For the Forest Drive study area, the construction costs were compared to the benefit from the reduction in crashes and did not incorporate any potential operational benefits as those were not the focus of this study. The accident cost data was obtained from the National Safety Council for fatal, injury, and property damage only crashes.

Several key assumptions were necessary in order to compute the B/C ratio. These assumptions include the following:

- Project Life Span – 5, 10, and 20 years (based on the improvement scenario)
- Annual Traffic Growth Factor – 1.1
- Salvage Value – 0%
- Annual Inflation Rate – 2.10%
- Annual Discount Rate – 2.32%
- Crash Cost Data (in 2020 dollars)
    - Fatal - $1,750,000
    - Injury - $101,000
    - Property Damage Only - $12,800
- No-Build Operations and Maintenance Cost – 15%
- Operation Cost (Project Life Span) – 10%

The results of the B/C analysis are displayed in Table 8-5 through Table 8-7 based on the scenario. A higher B/C ratio indicates which proposed improvements should be prioritized for implementation in the study area. The lowest-cost alternative does not always have the highest B/C ratio; if a higher-cost project provides a significant crash reduction/ other safety improvement, it can have a high B/C ratio.

TABLE 8-5: SHORT-TERM RECOMMENDATION B/C ANALYSIS RESULTS

Rank	Intersection/Section	Cost Estimate	B/C
1	Rosecrest Drive to Tyler Avenue	**$600**	**82.9**
2	Newtowne Dr. To Hilltop Lane	**$400**	**41.4**
3	Cypress Road	**$1,300**	**31.6**
4	Barbud Lane to Forest Hills Avenue	**$100**	**21.3**
5	Gemini Drive	**$11,700**	**10.0**
6	Bywater Road	**$38,300**	**8.9**
7	Georgetown Road	**$7,200**	**7.6**
8	Youngs Farm Road	**$11,700**	**7.3**
9	Hillsmere Drive/ Bay Ridge Road	**$11,500**	**7.2**
10	Hilltop Lane	**$5,500**	**5.8**
11	Barbud Lane/Cobblestone Drive	**$6,800**	**5.8**
12	S. Cherry Grove Avenue	**$38,500**	**5.6**
13	Rosecrest Drive	**$3,600**	**4.0**
14	Forest Hills Avenue	**$3,100**	**3.8**
15	Spa Road	**$31,700**	**3.7**
16	Tyler Avenue	**$31,700**	**2.5**
17	Greenbriar to S. Cherry Grove	**$6,500**	**2.2**
18	Bywater to Greenbriar	**$7,100**	**2.1**
19	Arundel On the Bay Road	**$7,700**	**1.3**
20	Forest Hills Avenue to Thom Drive/Quiet Waters Place	**$6,500**	**1.2**
21	S Cherry Grove to Newtowne Dr.	**$26,000**	**1.1**
22	Edgewood Road	**$33,100**	**0.6**
23	Thom Drive/Quiet Waters Pl to Hillsmere Dr/Bay Ridge Rd	**$6,500**	**0.3**
24	Cypress Road to Georgetown Rd	**$7,000**	**0.3**
25	Thom Drive/ Quiet Waters Place	**$9,400**	**0.2**

TABLE 8-6: MID-TERM RECOMMENDATION B/C ANALYSIS RESULTS

Rank	Intersection/Section	Cost Estimate	B/C
1	Rosecrest Drive to Tyler Avenue	**$16,000**	**69.0**
2	Gemini Drive to Youngs Farm Road	**$5,500**	**67.5**
3	Spa Road to Gemini Drive	**$11,700**	**22.9**
4	Bywater Road	**$34,900**	**5.6**
5	Georgetown Road	**$36,500**	**2.8**
6	Arundel On the Bay Road	**$52,600**	**2.8**
7	Cypress Road	**$55,500**	**2.2**
8	Barbud Lane/Cobblestone Drive	**$7,200**	**1.6**
9	Cypress Road to Georgetown Rd	**$165,600**	**1.4**
10	Spa Road	**$184,100**	**0.9**
11	S. Cherry Grove Avenue	**$270,700**	**0.8**
12	Hillsmere Drive/ Bay Ridge Road	**$358,500**	**0.7**
13	Hilltop Lane	**$325,400**	**0.7**
14	Youngs Farm Road	**$37,800**	**0.6**
15	Tyler Avenue	**$362,200**	**0.4**

TABLE 8-7: LONG-TERM RECOMMENDATION B/C ANALYSIS RESULTS

Rank	Intersection	Cost Estimate	B/C
1	Hilltop Lane	**$298,200**	**1.1**
2	Tyler Avenue	**$327,600**	**1.1**
3	Spa Road	**$2,111,900**	**0.37**

9. Public Outreach

Public outreach included an elected officials briefing, a working group meeting with community leaders, and a public meeting with an approximately one-month comment period. The outreach events consisted of the following:

- Elected Officials Briefing – February 17, 2023
- Community Leaders Working Group Presentation – February 28, 2023
- Public Meeting – March 30, 2023

The Elected Officials meeting was held of February 17, 2023, and was attended by the County Department of Public Works, Office of Transportation, County Executive's Office, City of Annapolis, Annapolis City Council Wards 3,4,5,7,8, and District 6 County Council. It provided an overview of the project purpose and schedule, study area description, other ongoing projects in the corridor, safety improvement option screening process, crash pattern findings, safety improvement toolbox, concept development examples, guide to the interactive web map from the project webpage, and the schedule of public outreach and next steps.

The Community Leaders Working Group presentation was held on February 28, 2023, and was attended by 29 people, which included many of the same attendees as the Elected Officials meeting as well as other stakeholders including those representing homeowner's associations, special interest groups, and more. It had a similar agenda to the Elected Officials meeting. Even though the agenda was similar to the elected officials briefing, it was intended to share some refined information, get initial feedback from community representatives on draft recommendations, and kick off outreach to the general public.

The virtual outreach process began 2-weeks prior to the public meeting and stayed open 2-weeks after the public meeting, closing on April 14, 2023. Project material including a link to the project website and project maps, recordings, and transcripts from the Working Group Meeting, along with other information about the comment period, were posted on the County's website.

The Public Meeting was held on March 30, 2023. There were 24 attendees from the general public. The public meeting had a presentation similar to those given to the Elected Officials / Community Leaders Working Group on loop, roll maps of the corridor showing the short-term, mid-term, and long-term improvements, and concept layouts on boards showing some of the more major geometric changes at intersections along the corridor.

Public comments were summarized and are included in Appendix G. These comments included comments received via email, comments on the comment cards provided at the public meeting, and comments posted on the concept layout boards/roll maps during the public meeting. A pie chart categorizing the comments by type is shown below in Figure 9-1. There were at total of 48 comments received.

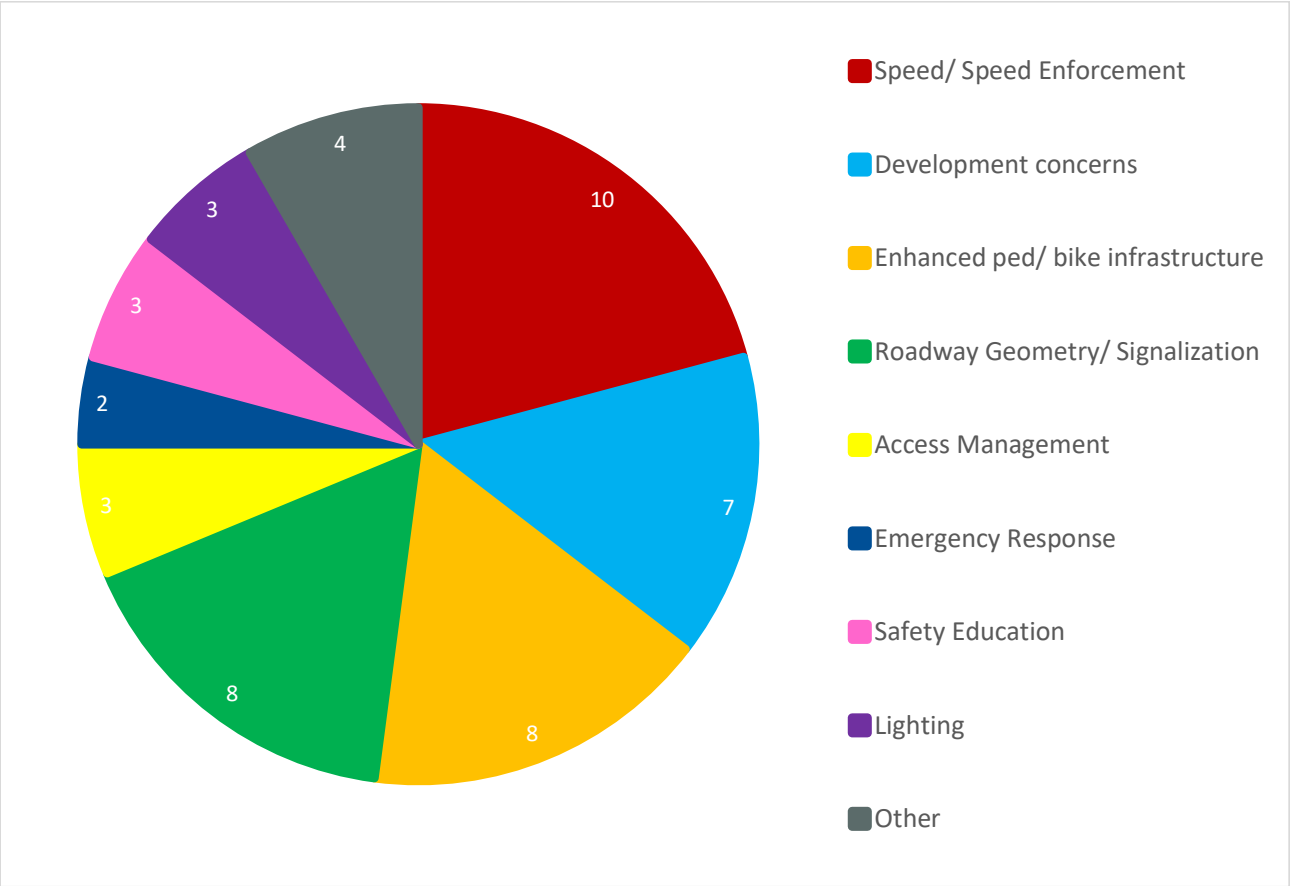


FIGURE 9-1: PUBLIC COMMENTS BY CATEGORY

10. Summary, Findings, Recommendations, and Next Steps

This study provides a comprehensive multi-modal transportation safety review along the 2.75-mi Forest Drive study corridor from Bywater Road to Arundel on the Bay Road in Anne Arundel County, MD. The study documents existing infrastructure, traffic operations, and a thorough review and analysis of historical crash data and trends. Findings from the existing conditions safety review include:

- The traffic volumes along Forest Drive and Bay Ridge Road vary along the length of the study corridor with the highest volumes west of Hilltop Lane (58,000 vehicles per day) and decreasing volumes to the south and east (30,000 vehicles per day).
- Between January 2016 and December 2020, there were a total of 570 crashes in the study corridor.
- There were no fatalities[12] during the study period, but 236 crashes resulted in at least one injury, which is 41% of the total number of crashes.
- The study corridor is ranked in the top 10 for highest crash rate of all roads in Anne Arundel County.
- The study corridor significantly exceeds statewide crash rates for total crashes, property damage only, left turn, and pedestrian type crashes.

Based on the findings from the safety review, industry best practices, and discussions with community stakeholder groups and various public agencies, multimodal safety recommendations were developed for the Forest Drive study corridor. The recommendations were grouped into short-, mid-, and long-term alternatives when considering cost and schedule requirements for further study, design, and construction. The recommended safety improvements include, but are not limit to:

- Speed limit reduction along Forest Drive and Bay Ridge Road from 40-mph to 35-mph to reduce the number and severity of crashes along the corridor
- Pedestrian improvements to provide new signalized crossings, improve the safety of existing crossings, bus stop relocations, and to trim back vegetation encroaching on sidewalks
- Traffic signal hardware upgrades to improve signal visibility and increase compliance
- Traffic signal phasing changes to reduce vehicle conflicts
- Access management to reduce vehicle conflicts at unsignalized access points
- Signing and marking improvements to provide increased guidance through and approaching intersections

Further evaluation was conducted on the safety improvement recommendations to identify any detrimental impacts on traffic operations. Additionally, predictive crash reduction analyses and planning-level cost estimation was performed for the purposes of a benefit / cost analysis which can be a useful metric for agencies to refer to when prioritizing safety improvement recommendations. Findings from the safety recommendation analysis include:

- The capacity analysis results indicate that the proposed safety improvements would have no significant detrimental impact on traffic operations within the study area and all intersections will

[12] While there were no fatalities in the years of provided data, the project team was made aware of recent fatalities in early 2023.

maintain acceptable Level of Service (LOS) D or better during the weekday AM and PM peak hours.

- The predictive safety analysis results indicate that the combined improvements in each scenario could reduce the number of crashes within the study area by 5.2% in the short-term, 14.2% in the mid-term, and 15.1% in the long-term.

The safety recommendations included in this study will be considered for implementation along the Forest Drive corridor to improve the safety of all roadway users in accordance with Vision Zero. Anne Arundel County will consider the findings from this study to prioritize project implementation, fundings sources, and to identify improvement for further study and design. Some of the smaller short-term recommendations may be able to be addressed with County DPW's maintenance budget, while other larger projects may need to find grant funding and/or be budgeted into the County's CIP Program. Some improvements recommended in this study will require further coordination between Anne Arundel County, MDOT SHA, City of Annapolis, and/or stakeholders from local businesses and the public.