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TRANSPORTATION FACILITY PLANNING

Waugh Chapel Road, Phase 2
Future Conditions and Recommendations

Waugh Chapel Road from Maytime Drive to Piney Orchard Parkway
Project Number H539600 Contract No. H539617

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EXECUTIVE SUMMARY

Anne Arundel County initiated the Waugh Chapel Road Phase 2 study to extend the Transportation Facility Plan for Waugh Chapel Road to Piney Orchard Parkway. Phase 1 of the study, H539611, encompassed the 1.1-mile segment from New Market Lane to Maytime Drive. Phase 2 extends the study area 1.8 miles to Piney Orchard Parkway. The primary purpose of Phase 2 is to identify existing geometric and operational deficiencies to evaluate alternatives to address concerns expressed by the public with side street access to Waugh Chapel Road. The study focuses on a multimodal, context-sensitive approach to identify and recommend improvements to the existing corridor that strike a balance between future vehicular traffic and pedestrian/bicyclists to enhance safety and connectivity for all modes of transportation.

This Future Conditions Report, which builds upon the March 2021 Existing Conditions Report, summarizes preferred alternative concepts and how they can address the purpose and need of the project as well as the process of developing, analyzing, and prioritizing improvement alternatives. The County will use the recommendations of this report to identify potential projects to move forward for implementation based on the County's priorities and funding opportunities.

The following summarizes the key findings (existing conditions) and recommendations based on the future (2045) conditions analysis for the Waugh Chapel Road study corridor:

- **Key Findings (Existing Conditions)**
  - The signalized study intersections along Waugh Chapel Road operate at level of service (LOS) E or worse for at least one of the AM or PM peak hours. For unsignalized and signalized intersections, traffic on the side streets experiences higher delays than the mainline traffic. The failing level of service may be influenced by the difficulty that the side street vehicles have in finding gaps to enter Waugh Chapel Road. The greatest delays were seen during the PM peak hour, where four unsignalized intersections and two signalized intersections experience LOS E or worse for intersection turning movements. The failing level of service for the unsignalized intersections is a result of the side streets waiting for gaps in traffic on Waugh Chapel Road. During the PM peak hour, the side streets at the signalized intersection at Strawberry Lake Way experience LOS of E with up to a minute of delay. The signalized intersection at Dairy Farm Road also has high side street delay during the PM peak hour and serves a high volume of left turning traffic from Dairy Farm Road that competes with green time needed on Waugh Chapel Road.
  - Existing collected 2020 traffic volumes at all the unsignalized intersections do not meet the warrants for a traffic signal. Further study is needed for these intersections, post-COVID.
  - Speeding in the corridor, based on the 85th percentile speeds, in conjunction with roadway horizontal and vertical alignments, may contribute to the challenges side street traffic experiences when trying to turn onto Waugh Chapel Road.
  - Reported crashes along the corridor are centered around the intersections and driveways. Angle and rear end crashes were higher near the signalized intersections. The intersections with the greatest crashes were Strawberry Lake Way (27 crashes), Dairy Farm Road (18 crashes), and Piney Orchard Parkway (13 crashes). These crashes were recorded during a 10.5 -year period. During the most recent 5-year data, Strawberry Lake Way was the only study intersection to experience four or more crashes in a given year (2017 and 2019).
  - The study area's extent along Waugh Chapel Road has sidewalks from Piney Orchard Parkway to Maytime Drive.

- Bicycle Lanes on Waugh Chapel Road between Piney Orchard Parkway and MD 3 were listed as a Tier II project in Anne Arundel County's 2013 Pedestrian and Bicycle Master Plan. The County records indicate that this is a "high stress" corridor for biking.

- **Recommendations Based on Future (2045) Conditions**
  - **Intersection Preferred Alternatives.** The recommended alternatives improve safety and access to and from Waugh Chapel Road and side streets at key study area intersections. These improvements address existing issues related to intersection sight distance and operations as well as potential future capacity issues, while also accommodating the needs of non-motorized road users.
    - Piney Orchard Road – modify westbound approach to accommodate dual right turn lanes
    - Casuarina Way – install a traffic signal
    - Old Waugh Chapel Road – install a roundabout
    - Seneca Drive – install a roundabout
    - Strawberry Lake Way – modify the northbound approach lane use and implement signal timing improvements
    - Summer Hill Drive – provide a left-turn acceleration lane
    - Fall Ridge Way – provide a left-turn acceleration lane
    - Autumn Gold Drive – install a roundabout (long-term)
  - **Corridor-wide.** Improving safety and reducing speeds along the corridor were key issues noted by the community. The recommendations in this study include removing the two-way left-turn lane where possible and installing raised medians to visually narrow the corridor.
  - **Multimodal.** While this portion of Waugh Chapel Road has continuous sidewalks along the north and south sides of the road, portions of the corridor have sidewalks below the County's current width. Dedicated bicycle facilities and shared-use paths are needed along Waugh Chapel Road to provide protection for bicyclists and connectivity for the bicycle network linking to the regional trail and transit system. These recommendations are consistent with the County's *2013 Pedestrian and Bicycle Master Plan*.
    - Cross-sections that include a buffered bike lane on both sides of Waugh Chapel Road, a shared use path on the south side of Waugh Chapel Road (eliminating existing gaps) and upgrading existing sidewalks on the north side of Waugh Chapel Road.
  - **Network Connectivity.** Continued growth in the western portion of the County will continue to place pressure on Waugh Chapel Road. In addition, this study highlights the effects of neighborhood development along the corridor that is not in alignment with the functional classification. Residents of these small neighborhoods that do not have alternative access points experience difficulty accessing Waugh Chapel Road. These two aspects place pressure on Waugh Chapel Road as well as Dairy Farm Road. The following are needed to address transportation constraints in Western Anne Arundel County:
    - Planning study of the area south of MD 32, north of Patuxent Road and between MD 3 and Piney Orchard Road to determine travel patterns and potential solutions to remove traffic from Dairy Farm Road and through traffic from Waugh Chapel Road. Due to the small intersection footprint and proximity of homes and driveways at the intersection of Waugh Chapel Road and Dairy Farm Road, the study team was not able to identify spot-specific improvements to address poor level of service under existing or future conditions; one of the goals of a network connectivity study is to alleviate issues at this intersection.

- From Move Anne Arundel!
  - Improvements to Conway and Patuxent Ridge Road between MD 3 and Piney Orchard Parkway
  - Extension of Evergreen Road to Piney Orchard Parkway to create a full street grid
  - Zonal Flex On-Demand Transit
  - Express service between Waugh Chapel and Parole Transit Center (Westfield Mall)
  - Expanded Transit amenities with adjacent bike racks in a consolidated area

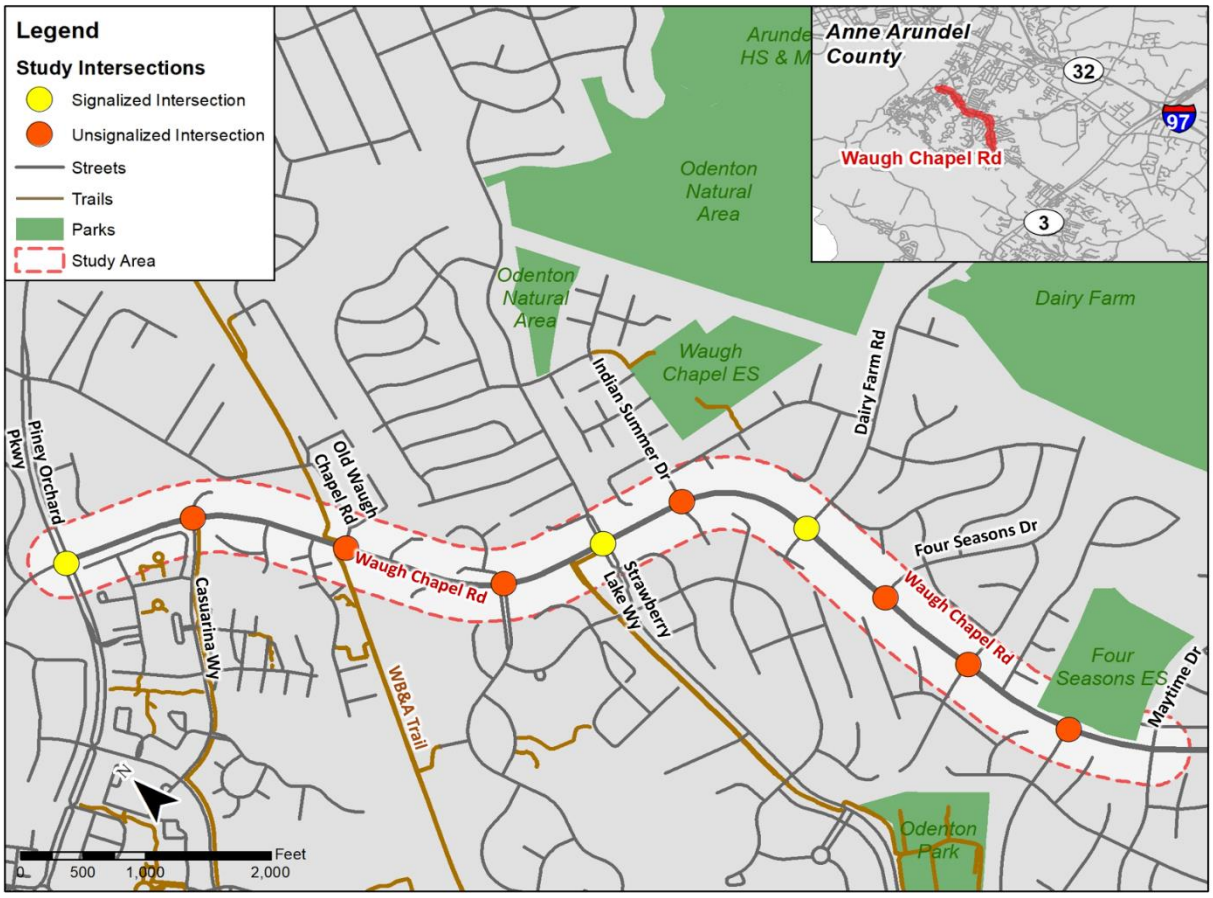
CHAPTER 1: BACKGROUND

Anne Arundel County initiated the Waugh Chapel Road Phase 2 study to identify intersection and roadway improvements that address existing geometric and operational deficiencies along Waugh Chapel Road from Maytime Drive to Piney Orchard Parkway. The *Move Anne Arundel!* County Transportation Plan identifies the Waugh Chapel Road area as a priority investment corridor. The plan notes that Waugh Chapel Road provides access to MD 3 from the west, and acknowledges access issues, such as difficulty making left turns into and out of side streets during peak hours.

The Waugh Chapel Road study area limits are shown in **Figure 1**. The limits total approximately 1.8-miles in length and include the following study intersections:

1. Waugh Chapel Road and Autumn Gold Drive (Unsignalized)
2. Waugh Chapel Road and Summer Hill Drive (Unsignalized)
3. Waugh Chapel Road and Four Seasons Drive (Unsignalized)
4. Waugh Chapel Road and Dairy Farm Road (Signalized)
5. Waugh Chapel Road and Indian Summer Drive (Unsignalized)
6. Waugh Chapel Road and Strawberry Lake Way (Signalized)
7. Waugh Chapel Road and Seneca Drive (Unsignalized)
8. Waugh Chapel Road and Old Waugh Chapel Road (Unsignalized)
9. Waugh Chapel Road and Casuarina Way (Unsignalized)
10. Waugh Chapel Road and Piney Orchard Parkway (Signalized)

Figure 1: Waugh Chapel Road Study Area



EXISTING CONDITIONS SUMMARY

The study team analyzed the existing roadway and intersection conditions within the study area to understand the needs and deficiencies for all roadway users. The Waugh Chapel Road Existing Conditions Report, dated March 2021, is provided in **Appendix A**. Key findings from the existing conditions analysis included:

- The signalized study intersections along Waugh Chapel Road operate at level of service (LOS) E or worse for at least one of the AM or PM peak hours. For unsignalized and signalized intersections, traffic on the side streets experiences higher delays than the mainline traffic. The failing level of service may be influenced by the difficulty that the side street vehicles have in finding gaps to enter Waugh Chapel Road. The greatest delays were seen during the PM peak hour, where four unsignalized intersections and two signalized intersections experience LOS E or worse for intersection turning movements. The failing level of service for the unsignalized intersections is a result of the side streets waiting for gaps in traffic on Waugh Chapel Road. During the PM peak hour, the side streets at the signalized intersection at Strawberry Lake Way experience LOS of E with up to a minute of delay. The signalized intersection at Dairy Farm Road also has high side street delay during the PM peak hour and serves a high volume of left turning traffic from Dairy Farm Road that competes with green time needed on Waugh Chapel Road.
- Existing collected 2020 traffic volumes at all the unsignalized intersections do not meet the warrants for a traffic signal. Further study is needed for these intersections, post-COVID.
- Speeding in the corridor, based on the 85th percentile speeds, in conjunction with roadway horizontal and vertical alignments, may contribute to the challenges side street traffic experiences when trying to turn onto Waugh Chapel Road.
- Reported crashes along the corridor are centered around the intersections and driveways. Angle and rear end crashes were higher near the signalized intersections. The intersections with the greatest crashes were Strawberry Lake Way (27 crashes), Dairy Farm Road (18 crashes), and Piney Orchard Parkway (13 crashes). These crashes were recorded during a 10.5 -year period. During the most recent 5-year data, Strawberry Lake Way was the only study intersection to experience four or more crashes in a given year (2017 and 2019). Crash experience at this intersection will be reviewed as part of the next phase of the study.
- The study area's extent along Waugh Chapel Road has a full connected sidewalk facility running from Piney Orchard Parkway to Maytime Drive.
- Bicycle Lanes on Waugh Chapel Road between Piney Orchard Parkway and MD 3 were listed as a Tier II project in Anne Arundel County's 2013 Pedestrian and Bicycle Master Plan. The County records indicate that this is a "high stress" corridor for biking.

FUTURE NO-BUILD CONDITIONS SUMMARY

The study team selected 2045 as the future analysis year to coincide with the Baltimore Metropolitan Council (BMC) Regional Travel Demand Model Version 44CI. The Waugh Chapel Road Future No-Build Conditions Report, dated May 2021, and provided in **Appendix B,** details the traffic forecasting methodology and Future No-Build Conditions traffic analysis results.

Existing (2020) and future (2045) ADT, AM and PM peak hour traffic volumes for each study intersection are depicted in **Figure 2** - **Figure 6**.

FUTURE NO-BUILD AND INTERSECTION DELAY AND LEVEL OF SERVICE

The 2045 future no-build conditions intersection delay and LOS are summarized in **Table 1:** 2045 Future No-Build Peak Hour Intersection Delay and LOS

Table 1: 2045 Future No-Build Peak Hour Intersection Delay and LOS

Study Intersection with Waugh Chapel Road	Traffic Control	Existing				Future No-Build			
		Weekday AM Peak Hour		Weekday PM Peak Hour		Weekday AM Peak Hour		Weekday PM Peak Hour	
		Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)	LOS
Piney Orchard Parkway	Signalized	85.8	F	53.7	D	71.8	E	28.4	C
Casuarina Way	Unsignalized*	31.6	D	40.4	E	41.5	E	59.7	F
Old Waugh Chapel Road	Unsignalized*	16.2	C	18.6	C	17.1	C	19.4	C
Seneca Drive	Unsignalized*	34.4	D	55.1	F	48.6	E	82.5	F
Strawberry Lake Way	Signalized	37.8	D	60.9	E	26.8	C	27.6	C
Indian Summer Drive	Unsignalized*	56.3	F	95.6	F	82.1	F	149.9	F
Dairy Farm Road	Signalized	63.8	E	73.8	E	20.2	C	24.3	C
Four Seasons Drive	Unsignalized*	15.9	C	24.8	C	17.0	C	27.1	D
Summer Hill Drive	Unsignalized*	43.3	E	158.4	F	54.8	F	272.1	F
Autumn Gold Drive	Unsignalized*	18.1	C	27.0	D	19.4	C	30.4	D

* Worst movement reported for unsignalized, stop-controlled intersections

Under future no-build conditions, the following approaches experience delay increases larger than forty percent during at least one of the peak hours when compared to the existing conditions:

- **Waugh Chapel Road and Autumn Gold Drive:** The northbound approach delay increases by 46% during the PM peak hour.
- **Waugh Chapel Road and Summer Hill Drive:** The northbound and southbound approach delay increases by 72% and 50%, respectively, during the PM peak hour.
- **Waugh Chapel Road and Four Seasons Drive:** The eastbound approach delay increases 72% and 50%, respectively, during the PM peak hour.
- **Waugh Chapel Road and Dairy Farm Road:** The eastbound approach delay increases by 50% during the PM peak hour. While with signal timing optimization, the overall intersection operates at LOS C, the northbound (Sage Drive) approach and the southbound left/through movement operate at LOS E in the AM and PM peak hour and the southbound queue extends beyond Winterhaven Drive.
- **Waugh Chapel Road and Indian Summer Drive:** The southbound approach delay increases by 46% and 57% during the AM and PM peak hour, respectively.
- **Waugh Chapel Road and Seneca Drive:** The northbound approach delay increases by 41% and 50% during the AM and PM peak hour, respectively.
- **Waugh Chapel Road and Casuarina Way:** During the PM peak hour, the northbound and southbound approach delay increases by 48% and 50%, respectively.

- **Waugh Chapel Road and Piney Orchard Parkway:** During the AM peak hour, the westbound and northbound approach delay increases by 43% and 53%, respectively. However, with signal timing optimization, the intersection will operate better than the existing conditions.

The following signalized intersection approaches experience decreases in delay in the future no-build condition when compared to the existing conditions, resulting from optimizing signal timing offsets and splits:

- **Waugh Chapel Road and Dairy Farm Road:** The westbound approach delay decreases by 4% during the AM peak hour.
- **Waugh Chapel Road and Strawberry Lake Way:** The eastbound approach delay decreases by 8% during the AM peak hour. The westbound approach delay decreases by 8% and 14% during the AM and PM peak hour, respectively.
- **Waugh Chapel Road and Piney Orchard Parkway:** The southbound approach delay decreases by 48% during the AM peak hour.

FUTURE NO-BUILD QUEUING

Under future no-build conditions, the following unsignalized intersection side street approaches experience queues (three to five vehicles) during the AM and/or PM peak hours during the 95th percentile based on Synchro HCM outputs. The 95th percentile queue is defined to be the queue length that has only a 5% probability of being exceeded during the analysis time period, thus representing the worst-case scenario. During field observations, queues were not observed along with the side street approaches.

- **Northbound Casuarina Way:** 4 vehicles during the AM and PM peak hours
- **Northbound Seneca Drive:** 5 vehicles during the AM peak hour and 4 vehicles during the PM peak hour
- **Southbound Indian Summer Drive:** 5 vehicles during the AM peak hour and 4 vehicles during the PM peak hour
- **Northbound Summer Hill Drive:** 4 vehicles during the PM peak hour

The following signalized intersection approaches experience long queues and/or turn lane blockages:

- **Waugh Chapel Road and Dairy Farm Road:** During the AM and PM peak hours, the westbound queue blocks the left-turn and right-turn lanes, and the southbound queue blocks the right-turn lane.
- **Waugh Chapel Road and Strawberry Lake Way:** During the AM and PM peak hours, the eastbound and westbound queues block the left-turn and right-turn lanes.
- **Waugh Chapel Road and Piney Orchard Parkway:** During the AM and PM peak hours, the westbound and northbound queues exceed capacity

Findings from the future no-build conditions analysis provided a basis for developing improvement alternatives that could accommodate anticipated vehicular traffic growth while serving the multimodal needs along Waugh Chapel Road.

Figure 2: 2020 and 2045 Directional Average Daily Traffic (ADT)

Figure 3: 2020-2045 AM Peak Hour Traffic Volumes - View 1

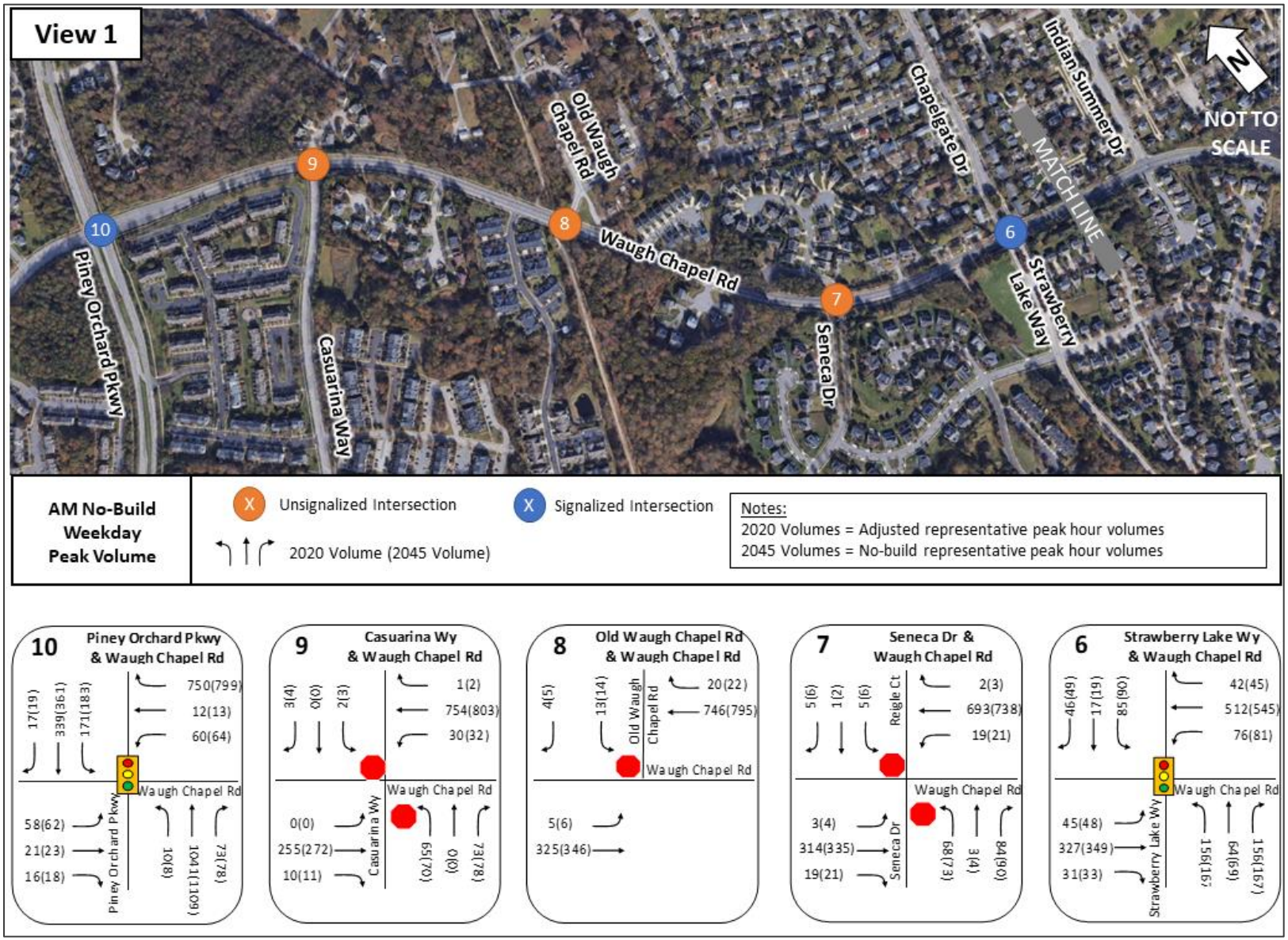


Figure 4: 2020-2045 AM Peak Hour Traffic Volumes - View 2

Figure 5: 2020-2045 PM Peak Hour Traffic Volumes - View 1

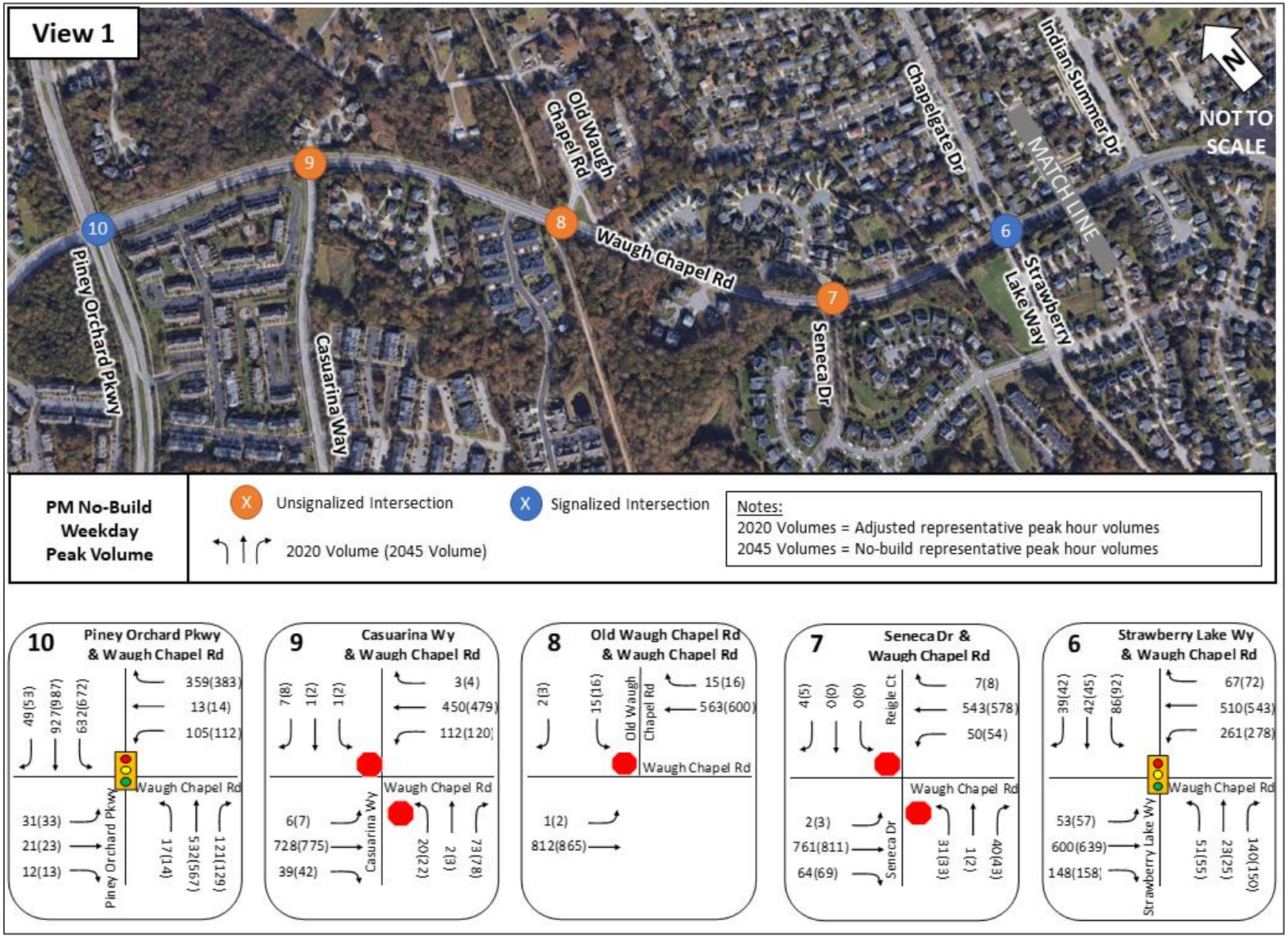


Figure 6: 2020-2045 PM Peak Hour Traffic Volumes - View 2

PUBLIC OUTREACH SUMMARY

An online survey was launched in June 2021 to collect feedback on traveler characteristics and existing traffic and safety issues within the study corridor. The survey was live for one month from June 11, 2021 to July 11, 2021 and consisted of an interactive map and survey. **Figure 7** summarizes the issues identified on the interactive map. The public noted mostly safety and multimodal concerns; congestion and parking issues encompassed less than twenty percent of the map markers. **Table 2** summarizes the top transportation priorities ranked by participants; safety for all users ranked the highest, while roadway elements, such as streetscape and on-street parking, ranked the lowest.

Figure 7: Public Outreach Map Marker Results

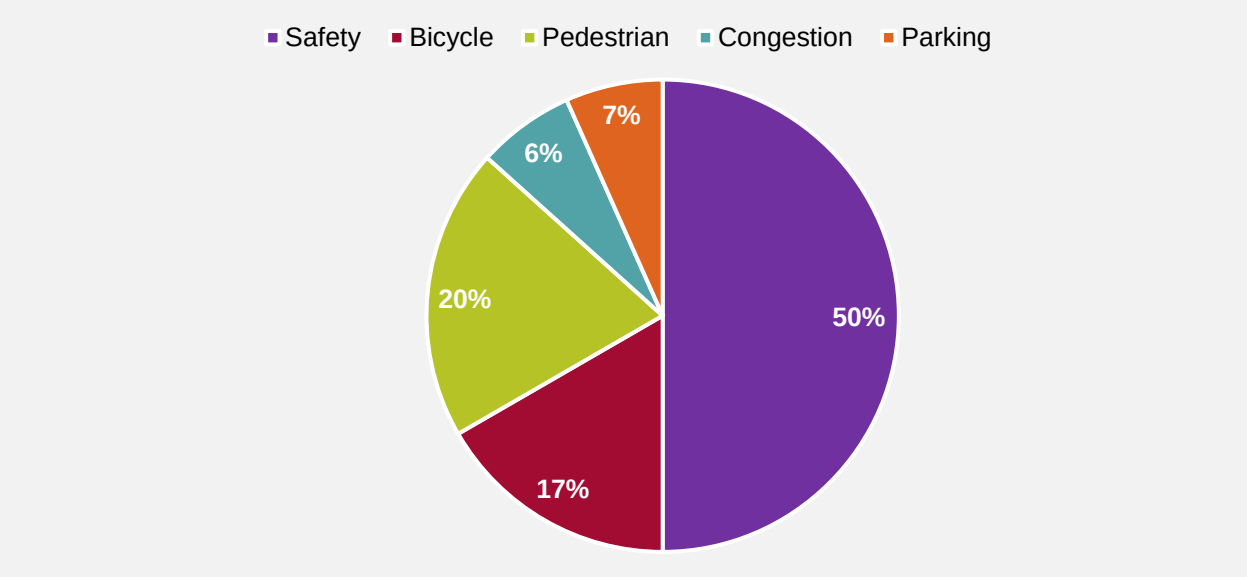


Table 2: Public Input Transportation Elements Survey Results

Rank	Transportation Element
#1	Vehicular Safety
#2	Bike/Ped Safety
#3	Traffic Operations
#4	Pedestrian Facilities
#5	Bike Facilities
#6	Lighting
#7	Access Management
#8	Streetscape
#9	On-Street Parking

CHAPTER 2: PURPOSE AND NEED STATEMENT

Based on the existing and future no-build conditions analyses, the study team identified the need to develop viable and cost-effective improvements to address traffic operations and heightened crash risk, while retaining the multimodal needs of the Waugh Chapel Road corridor. The purpose and need statement provide a basis for developing, screening, and analyzing alternative improvement concepts. The study team identified the purpose and need of the Waugh Chapel Road study is to:

- Improve access for side street traffic at intersections that experience excessive delay and heightened crash risk
- Reduce crash risk for all modes of transportation throughout the corridor
- Provide LOS D or better for vehicular traffic at study intersections in 2045 by improving operations, without adding through lanes to the Waugh Chapel Road mainline
- Reduce queuing and turn lane blockages
- Address geometric deficiencies at intersections and in mid-block areas that present difficulty in crossing or merging with traffic
- Provide a dedicated route for bicyclists and improve the bicycle level of traffic stress (LTS) along the length of Waugh Chapel Road
- Reduce crash risk for pedestrians and bicyclists crossing at intersections

CHAPTER 3: ALTERNATIVES CONCEPT SCREENING AND DEVELOPMENT

The *Move Anne Arundel!* County Transportation Plan states that improvements along Waugh Chapel Road must reflect the residential nature of the area, keep traffic at safe speeds, and reflect the sensitive environmental areas along the corridor. Intersection and roadway improvement concepts were developed to address safety, geometric, and operational deficiencies along the study corridor identified during the existing and future no-build conditions analyses, as well as documented by the public. The outcomes and findings from the alternative screening and analysis provided the basis for selecting preferred alternatives for the corridor for all roadway users.

Based on the screening results, final concepts were selected by the study team following feedback from the Waugh Chapel Road Transportation Advisory Committee (TAC). More detailed analysis, design, and cost estimates were developed for these preferred improvement projects, as summarized in **Chapter 4**.

INTERSECTION ALTERNATIVES

The study team analyzed up to three potential intersection improvement concepts at each location, consisting of the following:

- Turn lanes and/or other geometric improvements
- Signal phasing and timing adjustments
- New traffic signal or roundabout

While geometric and signal timing improvements are generally more cost-effective and easier to implement, new traffic signals and roundabouts can provide safety and operational benefits for all road users. Moreover, traffic signals and roundabouts can slow traffic, thus improving safety along the corridor for vulnerable road users. A roundabout, if designed appropriately, reduces the number of potential conflict points at an intersection and offers safety benefits to all road users, including bicyclists and pedestrians.

INTERSECTION CONCEPT SCREENING METHODOLOGY

The study team developed screening criteria for potential intersection and roadway improvement concepts with weighted importance assigned to each measure. The screening matrix was used as a tool to assess the relative ability of each alternative to address the issues identified in the purpose and need statement. The screening criteria and weighting (1=low; 5=high) are summarized in **Table 3**.

Table 3: Intersection Alternatives Screening Criteria

Screening Category		Category Weighting
Safety for All Users	Reduce Vehicular-Vehicular Conflicts	5
	Reduce Vehicular-Bike/Ped Conflicts	5
	Speed Management	5
	Lighting	5
Connectivity	Bike Access and Crossing	4
	Pedestrian Access and Crossing	4
	Ease of Access to/from Side Streets	3
Roadway	Streetscape	2
	Right-of-Way and Utility Relocation	2
Ease of Implementation		2
Level of Service (LOS) along Waugh Chapel Road		1

Each potential intersection alternative was analyzed using Synchro 10 to quantitatively evaluate the ease of access to/from side streets and level of service (LOS) along Waugh Chapel Road. SIDRA Intersection Version 9.0 was used to analyze traffic operations for potential roundabout concepts.

The Highway Capacity Manual (HCM) 6th Edition methodology was selected to analyze all signalized and unsignalized intersections. Where the HCM 6th Edition was not supported, the HCM 2000 methodology results were reported. The change in control delay (measured in seconds per vehicle) and LOS were calculated for each approach to compare traffic operations to no-build conditions. **Table 4** summarizes the LOS corresponding to the delay at unsignalized and signalized intersections, as specified in the HCM. The delay criteria for LOS differs slightly for unsignalized and signalized intersections due to driver expectations and behavior. For unsignalized intersections, the LOS analysis assumes that the traffic along Waugh Chapel Road is not affected by traffic on the side street.

Table 4: LOS and Delay Thresholds

Level of Service (LOS)	Signalized Delay (seconds)	Unsignalized Delay (seconds)	General Description
A	≤ 10.0	≤ 10.0	Free flow
B	> 10.0 to 20.0	> 10.0 to 15.0	Stable flow (slight delays)
C	> 20.0 to 35.0	> 15.0 to 25.0	Stable flow (acceptable delays)
D	> 35.0 to 55.0	> 25.0 to 35.0	Approaching unstable flow (tolerable delay, occasionally wait through more than one signal cycle before proceeding)
E	> 55.0 to 80.0	> 35.0 to 50.0	Unstable flow (intolerable delay)
F	≥ 80.0	≥ 50.0	Forced flow (congested and queues fail to clear)

SIGNAL WARRANT ANALYSIS

A signal warrant analysis was performed using the future 2045 traffic volumes at the following unsignalized intersections:

- Waugh Chapel Road and Casuarina Way
- Waugh Chapel Road and Old Waugh Chapel Road
- Waugh Chapel Road and Seneca Drive
- Waugh Chapel Road and Indian Summer Drive
- Waugh Chapel Road and Four Seasons Drive
- Waugh Chapel Road and Summer Hill Drive
- Waugh Chapel Road and Autumn Gold Drive

The Maryland MUTCD signal warrant analysis worksheets for each intersection are provided in **Appendix C**. At the intersection of Waugh Chapel Road and Casuarina Way, Warrant 1 – Eight- Hour Vehicular Volume, Condition B – Interruption of Continuous Traffic is met with 2045 traffic volumes. A traffic signal was not originally recommended, because this intersection is within 1,000 feet of the signalized intersection with Waugh Chapel Road and Piney Orchard Parkway. Later in the project, after further review and discussion with the County, based on the purpose of the study, installation of a traffic study was added to the list of recommendations.

CONCEPT SCREENING RESULTS

Table 5 summarizes the initial potential alternatives and respective screening matrix results at several of the study intersections. The detailed score calculations for the screening analysis are provided in **Appendix D.** The study team used the results of this initial screening to discuss the potential alternatives with stakeholders. There were no intersection-specific initial potential alternatives for a few of the study intersections, most of which will receive benefits from corridor and network recommendations.

Table 5: Initial Intersection Alternatives Concept Screening Summary

Intersection	Alternative	Safety for All Users	Connectivity	Roadway	Ease of Implementation	Level of Service along Waugh Chapel Road	Total Score
	Total Possible Points	**20**	**11**	**4**	**2**	**1**	**38**
10. Piney Orchard Parkway (Signalized)	No-Build	10.0	5.5	2.0	2.0	0.5	20.0
	Turn Lane Improvements (Dual WBR)	12.5	11.0	2.0	1.0	1.0	27.5
	Restrict Through Movements	15.0	11.0	2.0	0.0	1.0	29.0
	Restrict Left-Turn and Through Movements	15.0	11.0	2.0	0.0	1.0	29.0
	Roundabout	17.5	11.0	1.0	0.0	1.0	30.5
8. Old Waugh Chapel Road (Unsignalized)	No-Build	10.0	5.5	2.0	2.0	0.5	20.0
	Left-Turn Acceleration Lane	15.0	7.0	2.0	2.0	0.5	26.5
	Roundabout	17.5	11.0	1.0	0.0	0.0	29.5
7. Seneca Drive (Unsignalized)	No-Build	10.0	5.5	2.0	2.0	0.5	20.0
	Roundabout	17.5	11.0	1.0	0.0	0.0	29.5
6. Strawberry Lake Way (Signalized)	No-Build	10.0	5.5	2.0	2.0	0.5	20.0
	Signal Timing Improvements	12.5	11.0	2.0	1.0	0.5	27.0
	Turn Lane Improvements	10.0	7.0	0.0	0.0	0.5	17.5
	Roundabout	17.5	11.0	1.0	0.0	0.0	29.5
4. Dairy Farm Road (Signalized)	No-Build	10.0	5.5	2.0	2.0	0.5	20.0
	Signal Timing Improvements	10.0	7.0	2.0	1.0	0.0	20.0
	Turn Lane Modifications	10.0	7.0	2.0	0.0	0.5	19.5
	Restrict Sage Drive Through Movements	17.5	11.0	2.0	1.0	0.0	31.5
	Turn Lane Extension	7.5	3.0	2.0	0.0	0.0	12.5
	Roundabout	17.5	11.0	1.0	0.0	1.0	30.5
1. Autumn Gold Drive (Unsignalized)	No-Build	10.0	5.5	2.0	2.0	0.5	20.0
	Left-Turn Acceleration Lane	15.0	7.0	2.0	2.0	0.5	26.5
	Roundabout	17.5	11.0	1.0	0.0	0.0	29.5

Waugh Chapel Road at Unsignalized Intersections

To reduce delay and address inadequate gaps in traffic for left-turn movements during the future 2045 No-Build conditions peak hours, the study team considered the following alternatives at unsignalized intersections:

- Left-Turn Acceleration Lane
- Roundabout
- Traffic signal (where warranted)

Waugh Chapel Road at Signalized Intersections

Waugh Chapel Road at Piney Orchard Parkway

The Waugh Chapel Road/Piney Orchard Parkway intersection operates at LOS E and LOS C during the future 2045 No-Build conditions AM and PM peak hours, respectively. To address the excessive intersection control delay, the study team considered the following alternatives:

- Dual Westbound Right-Turn Lanes
- Alternative Intersection Designs
- Roundabout

Although the alternative intersection concepts provide a greater safety benefit by reducing vehicular conflict points, the study team concluded the dual westbound right-turn lanes result in acceptable traffic operations without restricting vehicular turning movements. The roundabout would reduce the number of conflict points and slow vehicular speeds at the intersection; however, the 180-foot diameter requires additional right-of-way.

Waugh Chapel Road at Strawberry Lake Way/Chapelgate Drive

The Waugh Chapel Road/Strawberry Lake Way intersection operates at LOS C during the future 2045 No-Build conditions AM and PM peak hours, however, the northbound approach experiences queuing beyond the available storage. To improve access to/from Strawberry Lake Way and Chapelgate Drive, the study team considered the following alternatives:

- Dedicated Left-Turn Lane, Shared Through/Right-Turn Lane
- Dedicated Left-Turn Lane, Through, Right-Turn Lane
- Roundabout

All alternatives reduce delay and queuing along the side streets during the peak hours. The roundabout would reduce the number of conflict points and slow vehicular speeds at the intersection; however, the 150-foot geometric footprint requires additional right-of-way.

Waugh Chapel Road at Dairy Farm Road

The Waugh Chapel Road/Dairy Farm Road intersection operates at LOS C during the future 2045 No-Build conditions AM and PM peak hours; however, the northbound (Sage Drive) approach and the southbound (Dairy Farm) through/left-turn lane operate as LOS E during both peak hours. During the PM peak hour, the southbound through/left-turn lane experiences queuing beyond the intersection at Winterhaven Drive. To improve access to/from Dairy Farm Road, the study team considered operational and geometric alternatives, with the goal of balancing competing needs while serving future traffic demand.

Table 6 summarizes the constraints for each alternative considered. Although modifications to the existing turn lanes would alleviate queuing along Dairy Farm Road and Waugh Chapel Road, right-of-way impacts and impacts to the proposed bike lane along Waugh Chapel Road are not favorable. As a result,

the study team recommends the Waugh Chapel Road/Dairy Farm Road intersection be further evaluated under a separate study.

Table 6: Dairy Farm Road Potential Alternatives

Alternative	Constraint
Signal Timing Modifications	Increases queuing along Waugh Chapel Road
Southbound Dual Left-Turn Lanes, Shared Through/Right-Turn Lane	Insufficient right-of-way along Dairy Farm Road to merge traffic
Right-Turn Lane Extensions	Impacts parking along Waugh Chapel Road and Dairy Farm Road, and impacts proposed bike lane along Waugh Chapel Road
Restrict Sage Drive Through Volumes	Not enough space within the intersection to accommodate concurrent left-turns
Roundabout	Impacts the right-of-way on all four corners of the intersection, which would require removal of four houses

CORRIDOR ALTERNATIVES

The study team reviewed geometric and multimodal improvements along Waugh Chapel Road to address safety concerns and improve bicycle and pedestrian connectivity.

Based on input from the public during the May 2021 TAC meeting, as well as the public input from the outreach survey, the study team focused on roadway improvements that would improve bicycle and pedestrian accommodations in the corridor and reduce speeding. Alternatives included:

- Removing the existing two-way turn lane where possible where there are long sections without driveways on both sides of Waugh Chapel Road
- Adding raised medians to visually narrow the width of the roadway and reduce speeding on Waugh Chapel Road
- Providing buffered bike lanes along both sides of Waugh Chapel Road to provide a higher level of comfort for bicyclists
- Eliminating gaps in the current shared use path to provide a continuous shared use path on the south side of Waugh Chapel Road

Roadway alternatives were screened qualitatively based on the accommodation within the existing cross section and available right-of-way. The preferred roadway cross section is presented in **Chapter 4**.

PARKING POCKETS

During the TAC meeting, residents indicated that the parking pockets between Summer Hill Drive and Dairy Farm Road were problematic. Most of them only accommodate one car and maneuvering into the spaces can be difficult, especially during peak periods. The study team considered the following alternatives for the existing parking:

- Maintain existing configuration
- Eliminate parking pockets and replace with grass buffer
- Eliminate parking pockets and replace with uniform asphalt shoulder

ACCESS REVIEW AND NETWORK CONNECTIONS

One of the catalysts for this study was to determine how best to improve access to Waugh Chapel Road from the side streets. This was based on community members expressing concerns about difficulties they experience turning onto Waugh Chapel Road.

The study team performed an access review for each side street in the corridor to evaluate access and connectivity, including alternative side street access in the corridor. **Figure 8** illustrates the existing access for each community along Waugh Chapel Road. The intersections shown in green have full access and alternative access routes to the corridor. As an example, Summer Hill Drive is a 4-way intersection with Waugh Chapel Road. To the north, vehicles can travel through the neighborhood to access Dairy Farm Road, which provides access to a signalized intersection at Waugh Chapel Road. On the south side of Summer Hill Drive, vehicles can travel through the neighborhood to access the traffic signal at Maytime Drive. The intersections shown in yellow represent locations where only neighborhoods on one side of Waugh Chapel Road have alternative access. For example, at Casuarina Way/Haymeadow Court, the community of Autumn Crest on Haymeadow Court does not have alternate access, but the Residences of Piney Orchard on Casuarina Way can travel southward to access Piney Orchard Parkway or Strawberry Lake Way. The intersections depicted in red represent locations where Waugh Chapel Road serves as the only access point to the community. All of the communities at the intersections in red (except Old Waugh Chapel Road) and the communities at the intersections depicted in yellow, that do not have alternative side street access, do not align with the functional classification of Waugh Chapel Road. As a minor arterial, “direct access to individual properties and neighborhoods is discouraged.”

The study team used the results of this analysis to develop the following alternatives:

- Rerouting traffic within communities to determine if the resulting traffic volumes would warrant a traffic signal
  - Even with this rerouting, the side street volumes were not high enough to warrant a traffic signal using the 2045 forecast volumes, except for the intersection with Casuarina Way/ Haymeadow Court.
- Adding turn restrictions into/out of side streets to funnel traffic through neighborhoods to load traffic at specific intersections is possible in some locations
  - This would increase traffic on narrow neighborhood streets with on-street parking, which would likely not be popular with residents.
  - Turn restrictions would be difficult to enforce, resulting in the need to install traffic islands or other geometric changes to restrict turns.
  - Even with this routing, intersections may not meet signal warrants and/or signalized intersections would be too closely spaced.
- Installing roundabouts would allow traffic from side streets to turn right, then use the roundabout to ‘turn left.’ Since Dairy Farm Road is a key intersection and source of congestion on the corridor, providing a roundabout east and west of Dairy Farm Road would be ideal. The study team reviewed each intersection to determine if a roundabout was feasible based on the geometry of the roundabout and the available property on the corners of the intersection. The intersections most likely able to accommodate a future roundabout, without removing houses on corner lots, include:
  - Seneca Drive/Riegle Court
  - Old Waugh Chapel Road

- Autumn Gold Drive

During the May 2021 TAC meeting, community representatives also expressed concern about congestion at the intersection of Dairy Farm Road with Waugh Chapel Road. As discussed earlier in this chapter, improvements at this intersection would impact homes in the vicinity. Peak hour volumes at this intersection indicate that Dairy Farm Road and Waugh Chapel Road both serve traffic beyond the study area. A larger scale study of this area is needed to determine how to potentially divert traffic away from this intersection, rather than make improvements to this geometrically constrained intersection.

Figure 8: Waugh Chapel Road Existing Access Review

CHAPTER 4: RECOMMENDATIONS

The potential alternatives identified in Chapter 3 were presented to the Waugh Chapel Road Transportation Advisory Committee (TAC) on February 28, 2022. After reviewing the results of the concept screening process, discussions with the County, and TAC comments, the study team identified the preferred intersection and corridor recommendations outlined in this Chapter.

INTERSECTION RECOMMENDATIONS

The preferred intersection alternatives are summarized in **Table 7** and depicted in **Figure 9** - **Figure 14**. The figures include a conceptual sketch, traffic operations and safety benefits summary, and planning-level costs, presented in 2022 dollars. The planning level cost estimate for the preferred intersection recommendations is approximately $9.8 million. The detailed breakdown for the cost estimate is provided in **Appendix F**.

Table 7: Study Intersection Recommendations

Intersection	Preferred Alternative
Piney Orchard Parkway (Signalized)	Turn Lane Modifications
Casuarina Way (Unsignalized)	Install Traffic Signal
Old Waugh Chapel Road (Unsignalized)	Roundabout
Seneca Drive (Unsignalized)	Roundabout
Strawberry Lake Way (Signalized)	Signal Timing Improvements and Turn Lane Modifications
Indian Summer Drive (Unsignalized)	No intersection-specific recommendation; see corridor improvements
Dairy Farm Road (Signalized)	Recommended for further study
Four Seasons Drive (Unsignalized)	No intersection-specific recommendation; see corridor improvements
Summer Hill Drive (Unsignalized)	No intersection-specific recommendation; see corridor improvements
Falls Ridge Way (Unsignalized)*	Left-Turn Acceleration Lane
Autumn Gold Drive (Unsignalized)	Long Term: Roundabout

* Review of intersection added during study

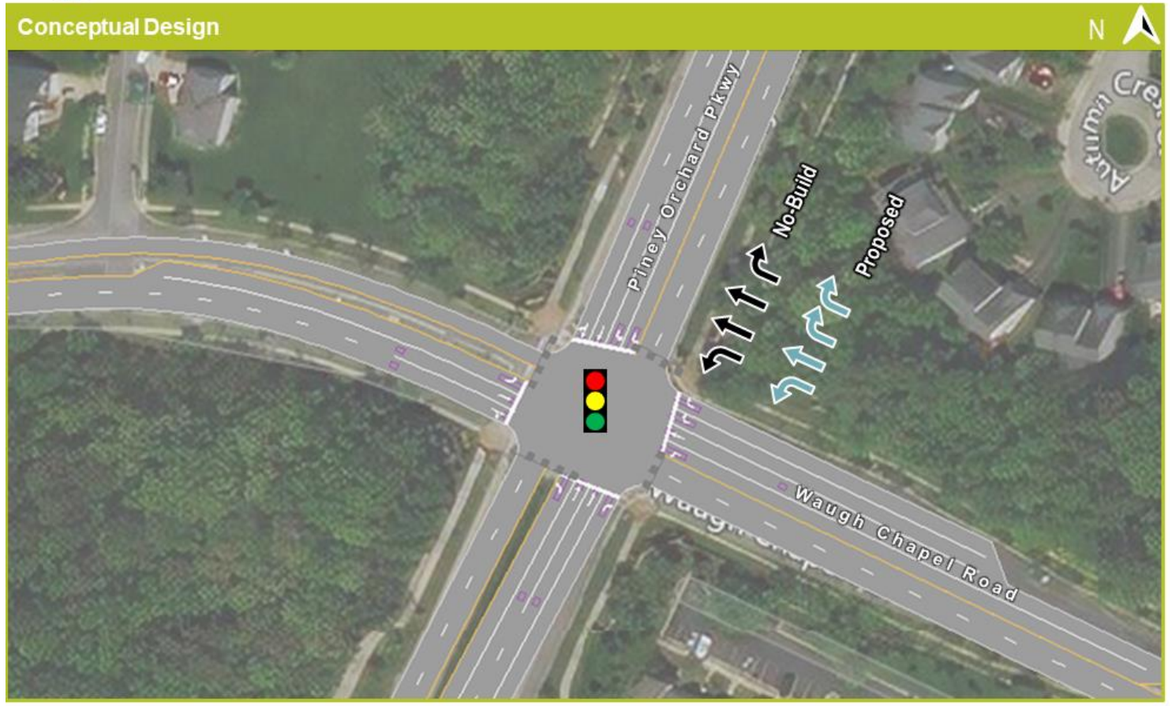
The intersection recommendations address the purpose and needs of the study as follows:

- Improving access for side street traffic that experiences excessive delay and heightened crash risks
- Improve side street level of service without adding through lanes to Waugh Chapel Road
- Reduce queuing and turn lane blockages
- Reduce crash risk for pedestrians and bicyclists crossing at intersections

Figure 9: Piney Orchard Parkway Turn Lane Modifications

Transportation Facility Planning **Waugh Chapel Road from Maytime Drive to Piney Orchard Parkway**
Waugh Chapel Road at Piney Orchard Parkway | Turn Lane Improvements

Conceptual Design



Planning Level Cost Estimate

Phase	Cost Estimate
Preliminary Engineering	$24,500
Right-of-Way and Utility Relocation	No Cost Anticipated
Construction	$163,400
Total	$187,900

Intersection Improvement Goal

Safety | Reduce Delay & Queue

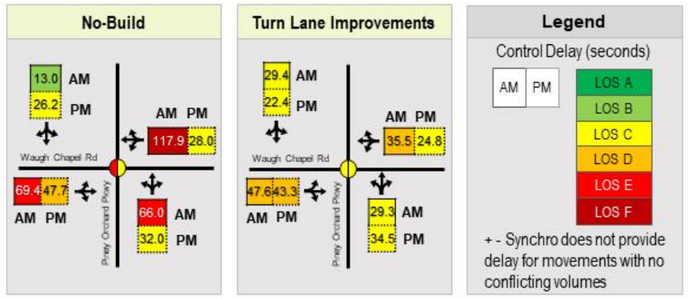
Description

The proposed improvement at the Piney Orchard Parkway intersection is to convert one westbound through lane to a right-turn lane. There are 799 and 383 westbound right-turning vehicles during the AM and PM peak hour, respectively. The turn lane improvements would:

- Maintain right-turn overlap and allow right turn on red from inside right-turn lane
- Reduce AM peak hour overall intersection delay from LOS F to LOS C
- Reduce westbound right-turn queue length

Traffic Operations Results

Control Delay



95th Percentile Queue Length

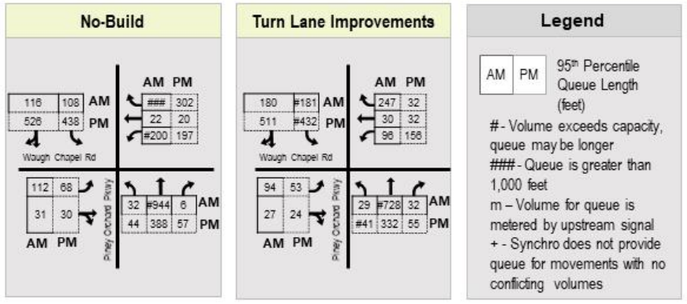


Figure 10: Casuarina Way Install Traffic Signal

Transportation Facility Planning **Waugh Chapel Road from Maytime Drive to Piney Orchard Parkway**
Waugh Chapel Road at Casuarina Way | Install Traffic Signal

Conceptual Design

Planning Level Cost Estimate

Phase	Cost Estimate
Preliminary Engineering	$53,500
Right-of-Way and Utility Relocation	No Cost Anticipated
Construction	$356,600
Total	$410,000

Intersection Improvement Goal

Reduce Delay & Queue Side Street Access

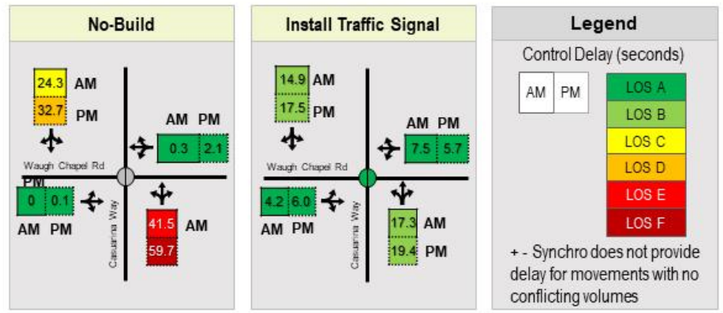
Description

The proposed improvement at the Casuarina Way intersection is to install a traffic signal. This proposed improvement will reduce delay and help side street traffic onto Waugh Chapel Road. The installation of a traffic signal would:

- ✓ Reduce delay and queue along Casuarina Way
- ✓ Improve side-street access

Traffic Operations Results

Control Delay



95th Percentile Queue Length

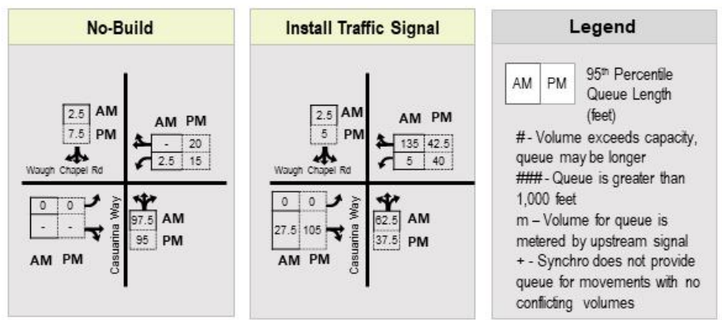


Figure 11: Old Waugh Chapel Road Roundabout

Transportation Facility Planning **Waugh Chapel Road from Maytime Drive to Piney Orchard Parkway**
Waugh Chapel Road at Old Waugh Chapel Road | Roundabout

Conceptual Design

Intersection Improvement Goal

Side Street Access

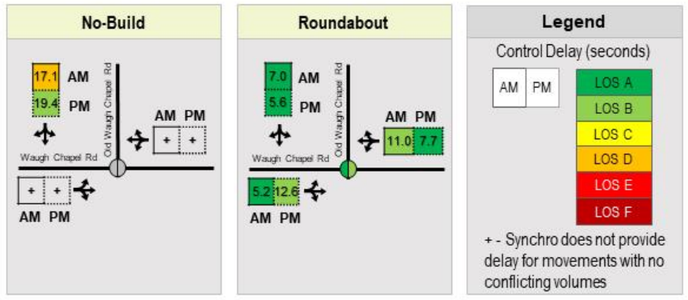
Description

The proposed improvement at the Old Waugh Chapel Road intersection is to convert the intersection into a roundabout. The roundabout has a 100' diameter with one circulating lane. The roundabout would:

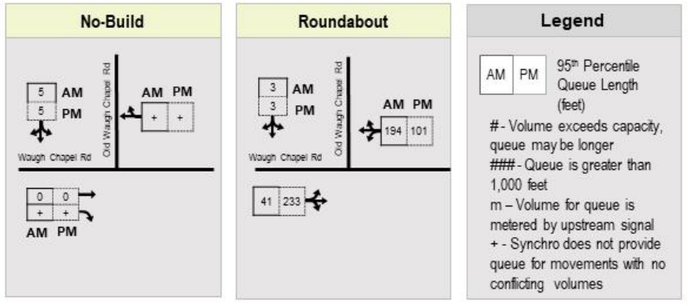
- Reduce delay and queuing along Old Waugh Chapel Road
- Improve WB&A Trail crossing alignment adjacent to the intersection
- Reduce the number of vehicular-vehicular conflict points at the intersection
- Reduce vehicular speeds along Waugh Chapel Road

Traffic Operations Results

Control Delay



95th Percentile Queue Length



Planning Level Cost Estimate

Phase	Cost Estimate
Preliminary Engineering	$239,000
Right-of-Way and Utility Relocation	$187,800
Construction	$1,690,000
Total	$2,116,800

Figure 12: Seneca Drive Roundabout

Transportation Facility Planning **Waugh Chapel Road from Maytime Drive to Piney Orchard Parkway**
Waugh Chapel Road at Seneca Drive | Roundabout

Conceptual Design

Planning Level Cost Estimate

Phase	Cost Estimate
Preliminary Engineering	$296,100
Right-of-Way and Utility Relocation	$149,600
Construction	$2,069,400
Total	$2,515,100

Intersection Improvement Goal

Side Street Access

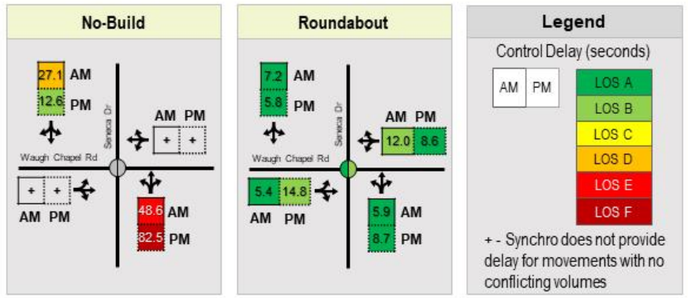
Description

The proposed improvement at the Seneca Drive intersection is to convert the intersection into a roundabout. The roundabout has a 100' diameter with one circulating lane. The roundabout would:

- ✓ Reduce delay and queuing along Seneca Drive during the AM and PM peak hours
- ✓ Reduce the number of vehicular-vehicular conflict points at the intersection
- ✓ Reduce vehicular speeds along Waugh Chapel Road

Traffic Operations Results

Control Delay



95th Percentile Queue Length

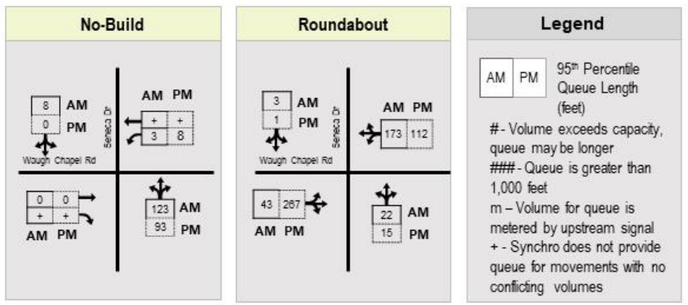


Figure 13: Strawberry Lake Way Turn Lane Modifications

Transportation Facility Planning **Waugh Chapel Road from Maytime Drive to Piney Orchard Parkway**
Waugh Chapel Road at Strawberry Lake Way / Chapelgate Drive | Signal Timing Improvements

Conceptual Design

Planning Level Cost Estimate

Phase	Cost Estimate
Preliminary Engineering	$20,000
Right-of-Way and Utility Relocation	No Cost Anticipated
Construction	$133,100
Total	$153,100

Intersection Improvement Goal

Safety | Reduce Delay & Queue

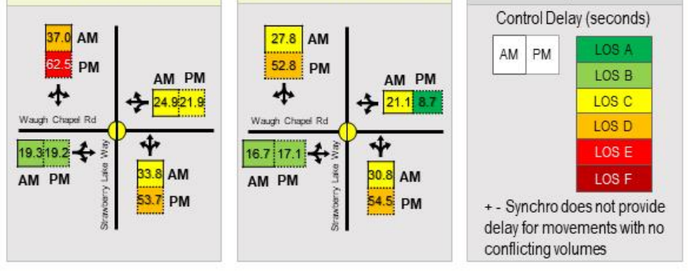
Description

The proposed improvement is to eliminate split phasing at the Strawberry Lake Way/Chapelgate Drive intersection. The improvement converts the northbound shared left/through lane into a dedicated left-turn lane so northbound and southbound left-turn movements may operate concurrently. The signal timing improvements would:

- Reduce the delay along Chapelgate Drive during the AM and PM peak hours
- Reduce queuing along Strawberry Lake Way and Chapelgate Drive during the AM and PM peak hours

Traffic Operations Results

Control Delay



95th Percentile Queue Length

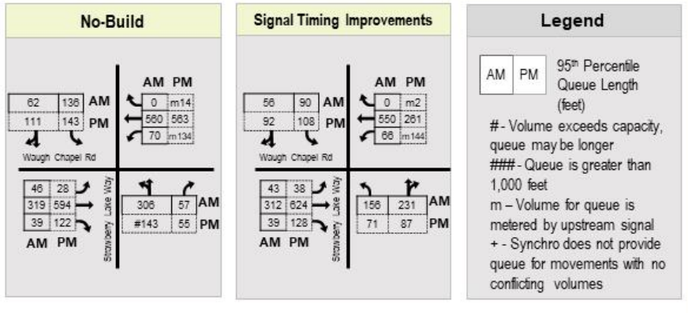


Figure 14: Autumn Gold Drive Roundabout

Transportation Facility Planning **Waugh Chapel Road from Maytime Drive to Piney Orchard Parkway**
Waugh Chapel Road at Autumn Gold Drive | Roundabout

Conceptual Design

Planning Level Cost Estimate

Phase	Cost Estimate
Preliminary Engineering	$489,900
Right-of-Way and Utility Relocation	$354,100
Construction	$3,455,100
Total	$4,299,100

Intersection Improvement Goal

Side Street Access

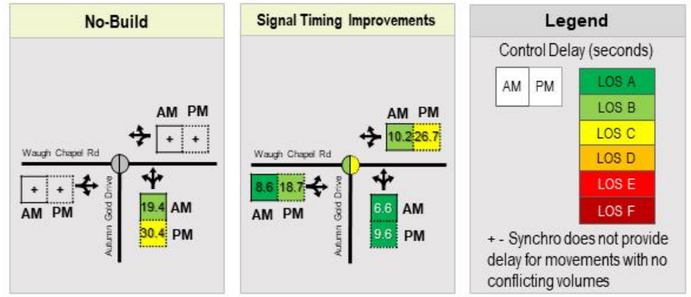
Description

The proposed improvement at the Autumn Gold Drive intersection is to convert the intersection into a roundabout. The roundabout has a 150' diameter with two circulating lanes. The roundabout would:

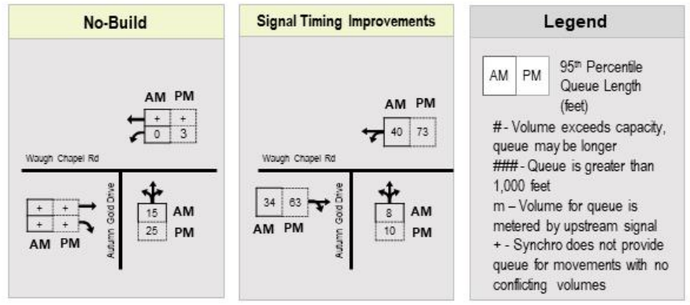
- Reduce delay and queuing on Autumn Gold Drive during the AM and PM peak hours
- Reduce the number of vehicular-vehicular conflict points at the intersection
- Reduce vehicular speeds along Waugh Chapel Road

Traffic Operations Results

Control Delay



95th Percentile Queue Length



FUTURE BUILD CONDITIONS TRAFFIC ANALYSIS RESULTS

Control delay (measured in seconds per vehicle) and 95th percentile queue length (measured in feet) were reported at each signalized and unsignalized intersection. Average queue length (measured in feet) outputted from SIDRA Intersection were reported for each roundabout.

Control Delay and Level of Service (LOS)

The 2045 future build conditions intersection delay and LOS are summarized in **Table 8** and depicted in **Figure 15** - **Figure 16**.

Table 8: 2045 Future Build Peak Hour Intersection Delay and LOS

Study Intersection	Weekday AM Peak Hour		Weekday PM Peak Hour	
	Delay (sec)	LOS	Delay (sec)	LOS
10. Piney Orchard Parkway (Signalized)	32.0	C	26.2	C
9. Casuarina Way (Signalized)	7.9	A	6.9	A
8. Old Waugh Chapel Road (Roundabout)	9.2	A	10.5	B
7. Seneca Drive (Roundabout)	9.3	A	12.0	B
6. Strawberry Lake Way (Signalized)	23.0	C	20.6	C
5. Indian Summer Drive (Unsignalized, Stop-Controlled)	82.1	**F**	149.9	**F**
4. Dairy Farm Road (Signalized)	20.2	C	24.3	C
3. Four Seasons Drive (Unsignalized, Stop-Controlled)	17.0	C	27.1	D
2. Summer Hill Drive (Unsignalized, Stop-Controlled)	54.8	**F**	272.1	**F**
1. Autumn Gold Drive (Roundabout)	9.3	A	22.6	C

* Worst movement reported for unsignalized, stop-controlled intersections

95th Percentile Queue Length

The 2045 future build conditions 95th percentile queue for each approach is depicted in **Figure 17** - **Figure 18**.

Figure 15: 2045 Future Build Conditions Peak Hour Approach Delay and LOS - View 1

Figure 16: 2045 Future Build Conditions Peak Hour Approach Delay and LOS - View 2

Figure 17: 2045 Future Build Conditions Peak Hour 95th Percentile Queue - View 1

Figure 18: 2045 Future Build Conditions Peak Hour 95th Percentile Queue - View 2

CORRIDOR RECOMMENDATIONS

The corridor recommendations were developed to compliment the *Anne Arundel County Pedestrian and Bicycle Master Plan 2013 Update* which identified the following projects within the Waugh Chapel Road study area:

- Bicycle Lanes from Piney Orchard Parkway to MD 3 (Tier II)
- Improved WB&A Trail Access near Old Waugh Chapel Road (Tier II).

The preferred recommendations are included in **Appendix E** and are shown on six separate sheets depicting the corridor from west to east. The intersection and roundabout recommendations, while discussed in the previous section, were also included in **Appendix E** to convey how these improvements could be incorporated into the overall corridor recommendations.

The preferred Waugh Chapel Road corridor recommendation provides improved pedestrian facilities and new bicycle accommodations for cyclists of all abilities, while incorporating traffic calming features to reduce speeding. The preferred corridor recommendations include:

- Install a 10-foot shared use path on the south side of Waugh Chapel Road
- Repurpose the existing roadway width to avoid utility and property impacts
- Provide 6-foot buffered bike lanes in both directions
- Upgrade existing 4-foot sidewalks to be 5 feet wide on the north side of Waugh Chapel Road
- Remove the existing two-way turn lane where possible, to reduce dangerous passing
- Add raised medians along Waugh Chapel Road to visually narrow the corridor and reduce speeding
    - Recommendations for raised medians were originally included for the following locations; however, the recommendations were removed due to the County's concerns about prior issues with raised medians in those locations. These locations could be evaluated in the future for potential raised medians.
        - Between Indian Summer Drive and Strawberry Lake Way
        - Between the Waugh Chapel Swim Club and Dairy Farm Road
        - Just east of the intersection with Four Seasons Drive
- Remove the parking pockets between Summer Hill Drive and Dairy Farm Road to better facilitate on-street parking

As noted in the previous section, there are three locations without intersection specific recommendations for which the corridor recommendations will serve to improve conditions at those locations. The buffered bike lanes and raised medians will alter the character of the corridor which should result in lower speeds along the corridor. The network recommendations outlined in the next section may also impact the volume of through traffic on Waugh Chapel Road. All of the intersections in the corridor will benefit from reduced speeds and lower volume of through traffic on Waugh Chapel Road.

The corridor recommendations address the purpose and needs of the study as follows:

- Reduce crash risk for all modes of transportation throughout the corridor
- Provide a dedicated route for bicyclists and improve the bicycle level of traffic stress (LTS) along the length of Waugh Chapel Road.

The planning level cost estimate for the preferred corridor recommendations is approximately $9.5 million. The detailed breakdown for the cost estimate is provided in **Appendix F**.

ADDITIONAL NETWORK RECOMMENDATIONS

This study identified the need for a study of Dairy Farm Road and its connections to MD 175 and Waugh Chapel Road, along with travel patterns in Odenton, MD. The forecast 2045 volumes and growth at Ft. Meade will continue to place pressure on Waugh Chapel Road.

The *Move Anne Arundel!* County Transportation Plan identifies the following long-term network improvements:

- Improvements to Conway and Patuxent Ridge Road between MD 3 and Piney Orchard Parkway
- Extension of Evergreen Road to Piney Orchard Parkway to create a full street grid

In addition, the plan identifies the following transit recommendations near the study area:

- Zonal Flex On-Demand Transit
- Express service between Waugh Chapel and Parole Transit Center (Westfield Mall)
- Expanded Transit amenities with adjacent bike racks in a consolidated area

The County will work to implement these recommendations in the future as funding is made available.

CHAPTER 5: NEXT STEPS

This study identified several improvements that could take place in the Waugh Chapel Road corridor between Maytime Drive and Piney Orchard Parkway. Some of those improvements can be implemented in the near-term, while others will require additional study and engineering design to move forward. The following chart shows improvement timeframes.

INTERSECTIONS

Near Term	
Piney Orchard Parkway	1) Modify intersection by converting one westbound through lane to a right turn lane. This will result in 2 right turn lanes from westbound Waugh Chapel Road to northbound Piney Orchard Parkway.
Casuarina Way	1) Conduct 13-hour traffic counts to verify volumes and prepare a traffic signal warrant analysis.
Strawberry Lake Way	1) Convert the northbound shared left/through lane to a dedicated left-turn lane and the right lane to a shared through/right turn lane. 2) Modify the signal operation to eliminate split phase so Strawberry Lake Way and Chapelgate Drive run concurrently.
Summer Hill Drive	Restripe the existing pavement to provide a left turn acceleration lane
Dairy Farm Road	1) Conduct a planning study of the area south of MD 32, north of Patuxent Road and between MD 3 and Piney Orchard Road to determine travel patterns and potential solutions to remove traffic from Dairy Farm Road and through traffic from Waugh Chapel Road.
Fall Ridge Way	Restripe the existing pavement to provide a left turn acceleration lane
Mid-Term	
Casuarina Way	1) Install a traffic signal
Old Waugh Chapel Road	1) Install a roundabout
Seneca Drive	1) Install a roundabout
Summer Hill Drive	1) Install left-turn acceleration lane as part of corridor improvements.
Fall Ridge Way	1) Install left-turn acceleration lane as part of corridor improvements.
Long Term	
Autumn Gold Drive	1) Install a roundabout

CORRIDOR

Near Term
Restripe the existing pavement to remove the existing two-way turn lane where there is no need for a two-way left turn lane.
Eliminate parking pockets between Summer Hill Drive and Dairy Farm Road and replace with uniform asphalt shoulder.
Mid-Term
Add raised medians to visually narrow the corridor and reduce speeding
Provide 6-foot buffered bike lanes in both directions
Long Term
Install a 10-foot shared use path on the south side of Waugh Chapel Road
Upgrade existing 4-foot sidewalks to be 5 feet wide on the north side of Waugh Chapel Road

NETWORK CONNECTIONS

As mentioned in the chart above, the study of the intersection with Dairy Farm Road and Waugh Chapel Road should be expanded to include a planning study of the area south of MD 32, north of Patuxent Road and between MD 3 and Piney Orchard Road to determine travel patterns and potential solutions to remove traffic from Dairy Farm Road and through traffic from Waugh Chapel Road.

In the coming years, the County will work to implement the network and transit-related recommendations from *Move Anne Arundel!*, including:

- Improvements to Conway and Patuxent Ridge Road between MD 3 and Piney Orchard Parkway
- Extension of Evergreen Road to Piney Orchard Parkway to create a full street grid
- Zonal Flex On-Demand Transit
- Express service between Waugh Chapel and Parole Transit Center (Westfield Mall)
- Expanded Transit amenities with adjacent bike racks in a consolidated area

APPENDICES

APPENDIX A: EXISTING CONDITIONS REPORT

APPENDIX B: FUTURE NO-BUILD CONDITIONS REPORT

APPENDIX C: MARYLAND MUTCD SIGNAL WARRANT ANALYSIS

APPENDIX D: CONCEPT SCREENING MATRIX

APPENDIX E: PREFERRED CORRIDOR RECOMMENDATIONS

APPENDIX F: PLANNING LEVEL COST ESTIMATES

APPENDIX G: TRAFFIC ANALYSIS RESULTS

TRANSPORTATION FACILITY PLANNING

Waugh Chapel Road, Phase 2
Future Conditions and Recommendations Appendix

Waugh Chapel Road from Maytime Drive to Piney Orchard Parkway
Project Number H539600 Contract No. H539617

prepared for:

prepared by:

Kimley»Horn

Appendix A

EXISTING CONDITIONS REPORT

DRAFT March 2021

TRANSPORTATION FACILITY PLANNING

WAUGH CHAPEL ROAD
Existing Conditions

Waugh Chapel Road from Maytime Drive to Piney Orchard Parkway
Project Number H539600 Contract No. H539617

prepared for:

ANNE ARUNDEL COUNTY MARYLAND

prepared by:

Kimley»Horn

Table of Contents

Appendix

Executive Summary

Anne Arundel County initiated the Waugh Chapel Road Phase 2 study to extend the Transportation Facility Plan for Waugh Chapel Road to Piney Orchard Parkway. Phase 1 of the study, H539611, encompassed the 1.1-mile segment from New Market Lane to Maytime Drive. Phase 2 extends the study area 1.8 miles to Piney Orchard Parkway. The primary purpose of Phase 2 to identify existing geometric and operational deficiencies to evaluate alternatives to address concerns expressed by the public with side street access to Waugh Chapel Road.

This Existing Conditions Report represents the first step in the study process.

The following summarizes the key findings of the existing conditions analysis for the Waugh Chapel Road study corridor:

- The signalized study intersections along Waugh Chapel Road operate at level of service (LOS) E or worse for at least one of the AM or PM peak hours. For unsignalized and signalized intersections, traffic on the side streets experiences higher delays than the mainline traffic. The failing level of service may be influenced by the difficulty that the side street vehicles have in finding gaps to enter Waugh Chapel Road. The greatest delays were seen during the PM peak hour, where four unsignalized intersections and two signalized intersections experience LOS E or worse for intersection turning movements.
- Existing collected 2020 traffic volumes at all the unsignalized intersections do not meet the warrants for a traffic signal. Further study is needed for these intersections, post-COVID.
- Speeding in the corridor, based on the 85th percentile speeds, in conjunction with roadway horizontal and vertical alignments, may contribute to the challenges side street traffic experiences when trying to turn onto Waugh Chapel Road.
- Reported crashes along the corridor are centered around the intersections and driveways. Angle and rear end crashes were higher near the signalized intersections. The intersections with the greatest crashes were Strawberry Lake Way (27 crashes), Dairy Farm Road (18 crashes), and Piney Orchard Parkway (13 crashes). These crashes were recorded during a 10.5 -year period. During the most recent 5-year data, Strawberry Lake Way was the only study intersection to experience four or more crashes in a given year (2017 and 2019).
- The study area's extent along Waugh Chapel Road has sidewalks from Piney Orchard Parkway to Maytime Drive.
- Bicycle Lanes on Waugh Chapel Road between Piney Orchard Parkway and MD 3 were listed as a Tier II project in Anne Arundel County's 2013 Pedestrian and Bicycle Master Plan. The County records indicate that this is a "high stress" corridor for biking.

Chapter 1 Project Background

INTRODUCTION

The primary purpose of this study is to identify existing geometric and operational deficiencies in order to evaluate alternatives to address concerns expressed by the public with side street access to Waugh Chapel Road. These alternatives will help address the difficulties experienced by road users on the side streets and improve safety while maintaining reasonable levels of service on Waugh Chapel Road and maintaining the character of the corridor.

This project will serve as an extension of the recently completed Transportation Facility Planning Study conducted for the portion of Waugh Chapel Road between Maytime Drive and New Market Lane. Due to the important function and connectivity that Waugh Chapel Road serves between MD 3 and points west in Odenton, the development taking place in and around the corridor, and the importance of non-motorized connectivity in this area, it was necessary to expand the study area to provide a holistic approach to consider existing and future needs.

Other previous studies examined for this area from a land use and planning and transportation perspective, included:

- Anne Arundel County Pedestrian/Bicycle Crossing Improvements Analysis: Washington, Baltimore, and Annapolis (WB&A) Trail Crossing, 2019
- Lot 29 Traffic Impact Study, 2017

This report documents the existing transportation conditions in the study area.

STUDY AREA

The study area is shown in **Figure 1**. The limits of the Waugh Chapel Road study corridor are from Maytime Drive to Piney Orchard Parkway. This 1.8-mile segment has ten intersections (three signalized and seven unsignalized). This report documents existing conditions along the Waugh Chapel Road corridor to understand the needs and deficiencies for all roadway users.

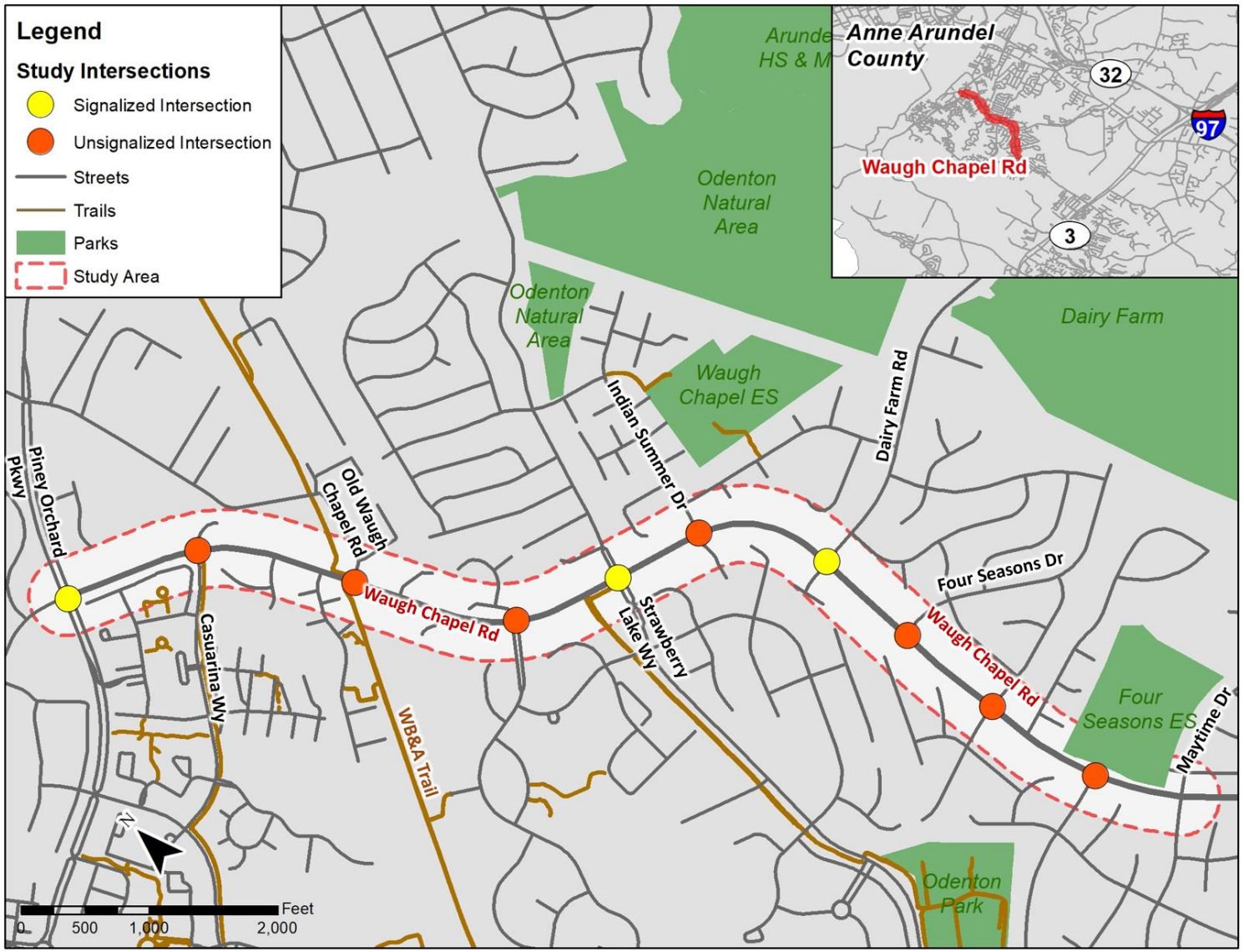


Figure 1: Study Area

STUDY INTERSECTIONS

The study area includes the following ten intersections:

1. Autumn Gold Drive and Waugh Chapel Road
2. Summer Hill Drive and Waugh Chapel Road
3. Four Seasons Drive and Waugh Chapel Road
4. Dairy Farm Road and Waugh Chapel Road
5. Indian Summer Drive and Waugh Chapel Road
6. Strawberry Lake Way and Waugh Chapel Road
7. Seneca Drive and Waugh Chapel Road
8. Old Waugh Chapel Road and Waugh Chapel Road
9. Casuarina Way and Waugh Chapel Road
10. Piney Orchard Parkway and Waugh Chapel Road

Figure 3 and **Figure 4** illustrate the locations of the study intersections and their associated lane designations and intersection traffic control. The traffic signals at the intersections of Piney Orchard Parkway/Waugh Chapel Road, Strawberry Lake Way/Waugh Chapel Road, and Dairy Farm Road/Waugh Chapel Road operate actuated-uncoordinated or actuated-coordinated depending on time of day. Depending on the peak hour, coodinated signals include Dairy Farm Road, Maytime Drive, and Strawberry Lake Way. Based on the signal timings the County provided, **Table 1** summarizes the assumptions made for each signal. The Max2 signal timings are time-of-day specific timings for Piney Orchard Parkway, as noted by the County. In general, the Max2 are used to accomdate school traffic. County signal timings can be found in **Appendix A**. The other seven intersections are stop-controlled on the side streets.

Table 1: Signal Time Assumptions

Type	AM Peak Hour	PM Peak Hour
Piney Orchard Parkway	▪ Actuated-Uncoordinated ▪ Max2 green for phase 7	▪ Actuated-Uncoordinated ▪ Max2 green for phase 5
Strawberry Lake Way	▪ Actuated-Uncoordinated	▪ Actuated-Coordinated ▪ Cycle length 130 seconds ▪ Offset 30 seconds
Dairy Farm Road	▪ Actuated-Coordinated ▪ Cycle length 120 seconds ▪ Offset 65 seconds	▪ Actuated-Coordinated ▪ Cycle length 130 seconds ▪ Offset 80 seconds

The only location with a pavement marking abnormality is at the WB&A trail crossing near the intersection of Waugh Chapel Road and Old Waugh Chapel Road (**Figure 2**). One of the left-turn pavement marking arrows from the two-way left turn arrow pavement markin still remains (the other is covered by the island). Since there is receiving lane, this arrow should be removed.

Figure 2: WB&A Trail Crossing

Figure 3: Study Intersection Lane Designation and Traffic Control – View 1

Figure 4: Study Intersection Lane Designation and Traffic Control - View 2

COMMUNITY AND DEVELOPMENT

Waugh Chapel Road is in the Odenton Small Area Plan portion of Anne Arundel County. **Figure 5** and **Figure 6** show the types of land uses that are present. The areas located adjacent to Waugh Chapel Road are primarily residential, including low to medium density multifamily dwellings. A bit further outside the study area contains schools, residential high density, commercial areas, and natural features such as parks.

The main schools within the vicinity of the study area are Four Seasons Elementary School (ES), Waugh Chapel ES, Arundel High School, Odenton Christian School, and the School of Incarnation.

The Odenton MARC Train Station is located west of the study area, approximately a 10-minute walk from the western most portion of the study area. Further west is the National Security Agency (NSA), the Tipton Airport, and Fort Meade.

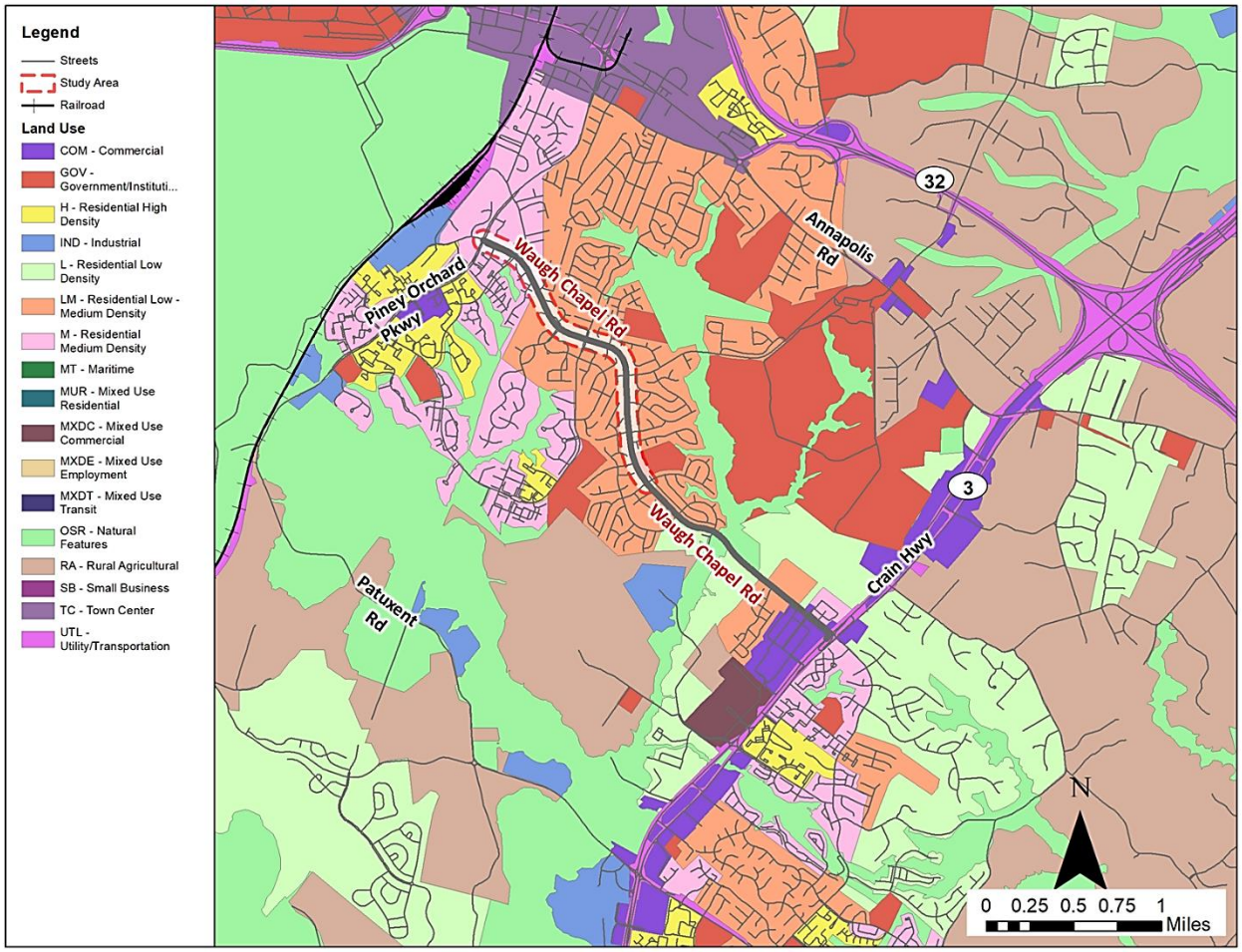


Figure 5. Existing Land Use

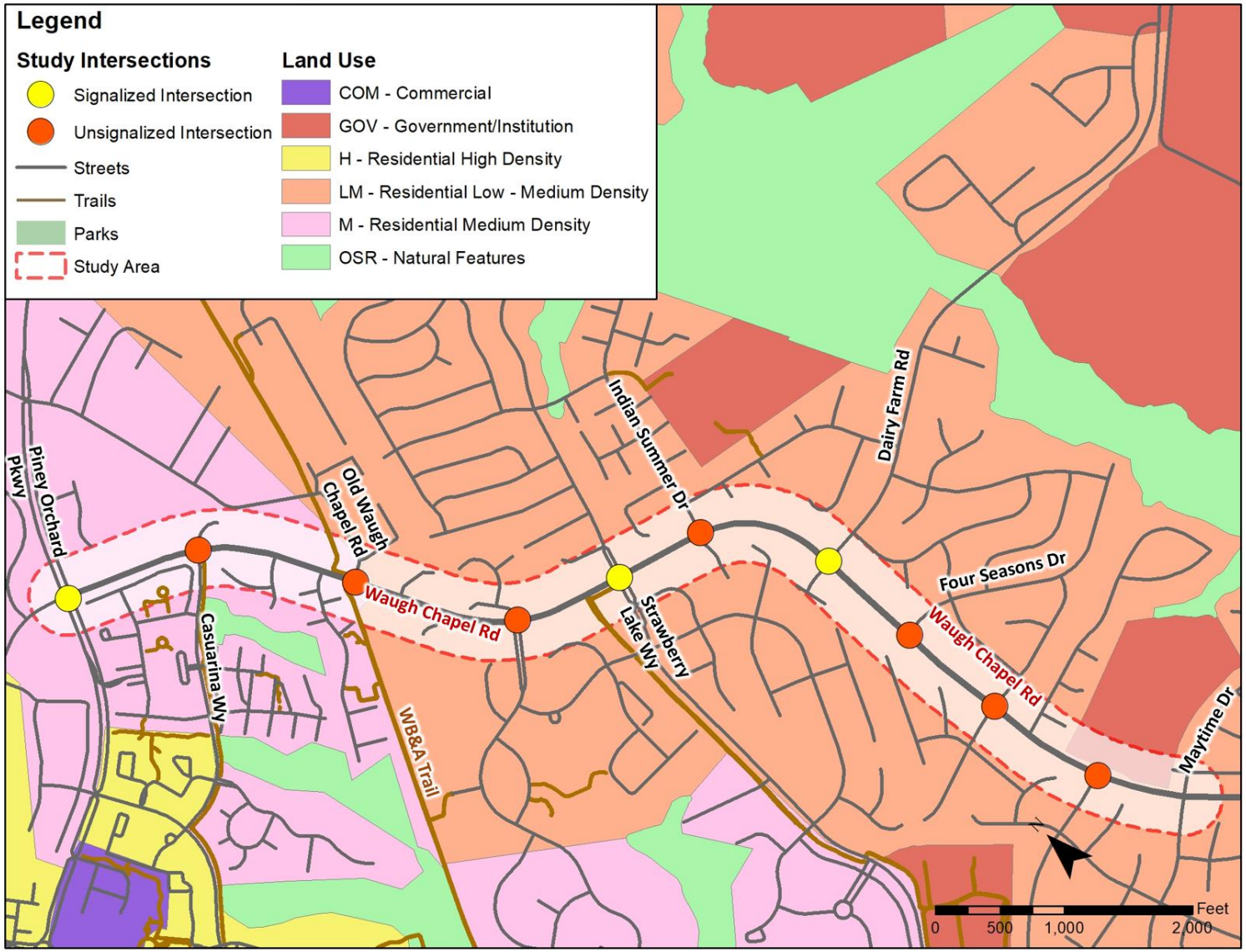


Figure 6. Existing Land Use (Study Corridor)

Chapter 2 Traffic Data Collection

The following is a summary of the data collected.

- 6-hour and 13-hour intersection turning movement count (TMC) data, including passenger vehicle, heavy vehicle, pedestrian, and bicycle counts
- 48-hour average daily traffic (ADT) volume, speed, and classification data for roadway segments
- Historical volumes
- Roadway geometrics data
- Traffic observations

2020 INTERSECTION COUNTS AND VOLUME

To conduct an analysis of existing conditions, traffic data was collected in November 2020 along the study corridor. **Table 2** summarizes the data collection locations and time periods.

Table 2: Data Collection Summary

<table>
<tr><th>Type</th><th>Location</th><th colspan="2">Data Collection Hours</th></tr>
<tr><td rowspan="4">6-hour TMC</td><td rowspan="2">Piney Orchard Parkway</td><td colspan="2">November 18, 2020</td></tr>
<tr><td rowspan="3">6:30 AM to 9:30 AM</td><td rowspan="3">4:30 PM to 7:30 PM</td></tr>
<tr><td>Strawberry Lake Way/Chapelgate Drive</td></tr>
<tr><td>Dairy Farm Road</td></tr>
<tr><td rowspan="7">13-hour TMC</td><td>Casuarina Way</td><td colspan="2" rowspan="7">November 18, 2020
6:00 AM to 7:00 PM</td></tr>
<tr><td>Old Waugh Chapel Road</td></tr>
<tr><td>Seneca Drive</td></tr>
<tr><td>Indian Summer Drive</td></tr>
<tr><td>Four Seasons Drive</td></tr>
<tr><td>Summer Hill Drive</td></tr>
<tr><td>Autumn Gold Drive</td></tr>
<tr><td rowspan="3">48-hour Tube Counts</td><td>Between Casuarina Way and Black Cherry Way</td><td colspan="2" rowspan="3">November 17, 2020 to November 19, 2020</td></tr>
<tr><td>Between Strawberry Way and Indian Summer Drive</td></tr>
<tr><td>Between Four Seasons Drive and Autumn Gold Drive</td></tr>
</table>

In order to validate the fall 2020 traffic counts, 6-hour TMC counts and 48-hour tube counts were collected for the intersection of Waugh Chapel Road and Maytime Drive to compare with the 2017 counts taken under Anne Arundel County Project H539611. The 2020 counts and 2017 counts were compared to determine the adjustment needed to account for any abnormalities in traffic volumes due to the COVID-19 pandemic.

The overall AM and PM peak hours of the study area were determined by reviewing the individual intersection data. The network 2017 AM peak hour was determined to be 7:15 AM to 8:15 AM, the network PM peak hour was determined to be 5:30 PM to 6:30 PM. The network 2020 AM peak hour was determined to be 7:45 AM to 8:45 AM and the network PM peak hour was determined to be 4:30 PM to 5:30 PM. In 2020, the network AM peak hour was 30 mins later than the 2017 network peak hour, which may be attributed to virtual school for Anne Arundel County Public Schools (School of the Incarnation is a private school, and students were in school). Moreover, the 2020 network PM peak hour was an entire

hour earlier than the 2017 network peak hour. Raw intersection count data for 2020 is provided in **Appendix A**.

In general, the differences between the 2017 and 2020 traffic counts were in line with the County's expectations, based on other areas in the County, with a significant decrease in the 2020 volumes due to the pandemic. There was an approximately 20 percent decrease in daily traffic for both westbound and eastbound Waugh Chapel Road near Maytime Drive, while during the peak hours it decreased as much as 80 percent for the side streets. **Figure 7** illustrates the daily volume trend for Waugh Chapel Road eastbound and westbound for the years 2017 and 2020. The TMC, ADT, and speed COVID-19 comparisons tables can be found in **Appendix B**.

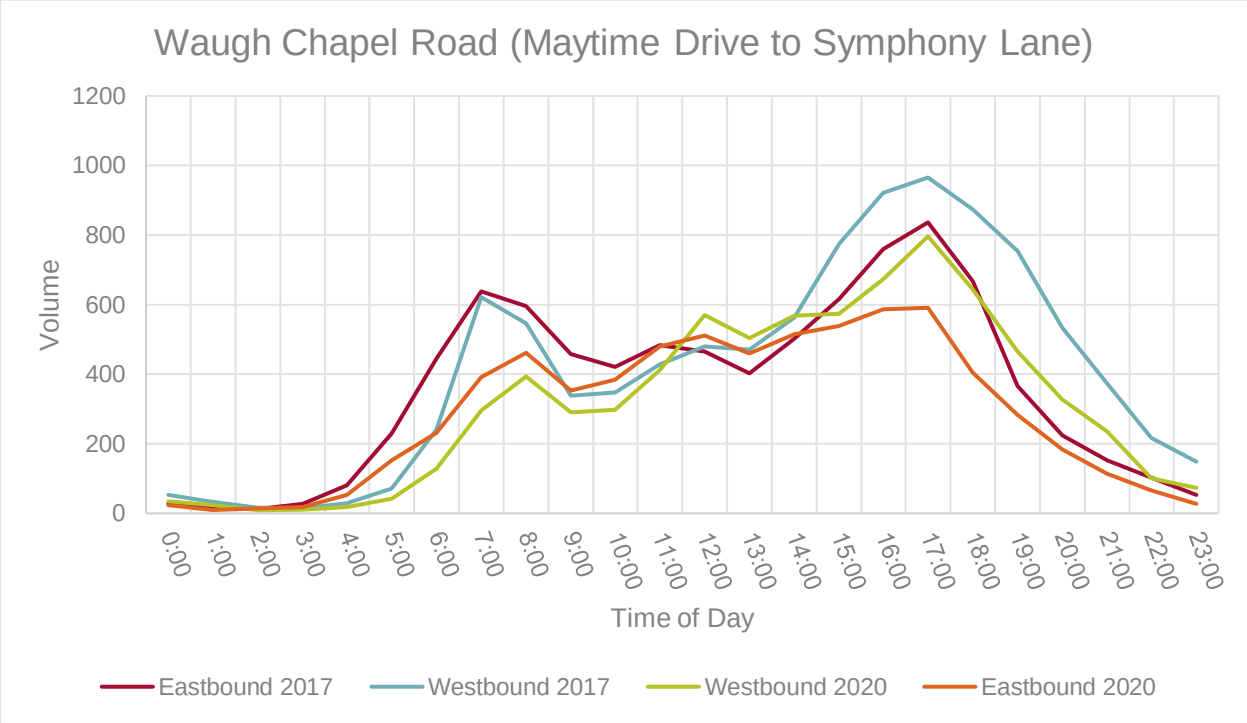
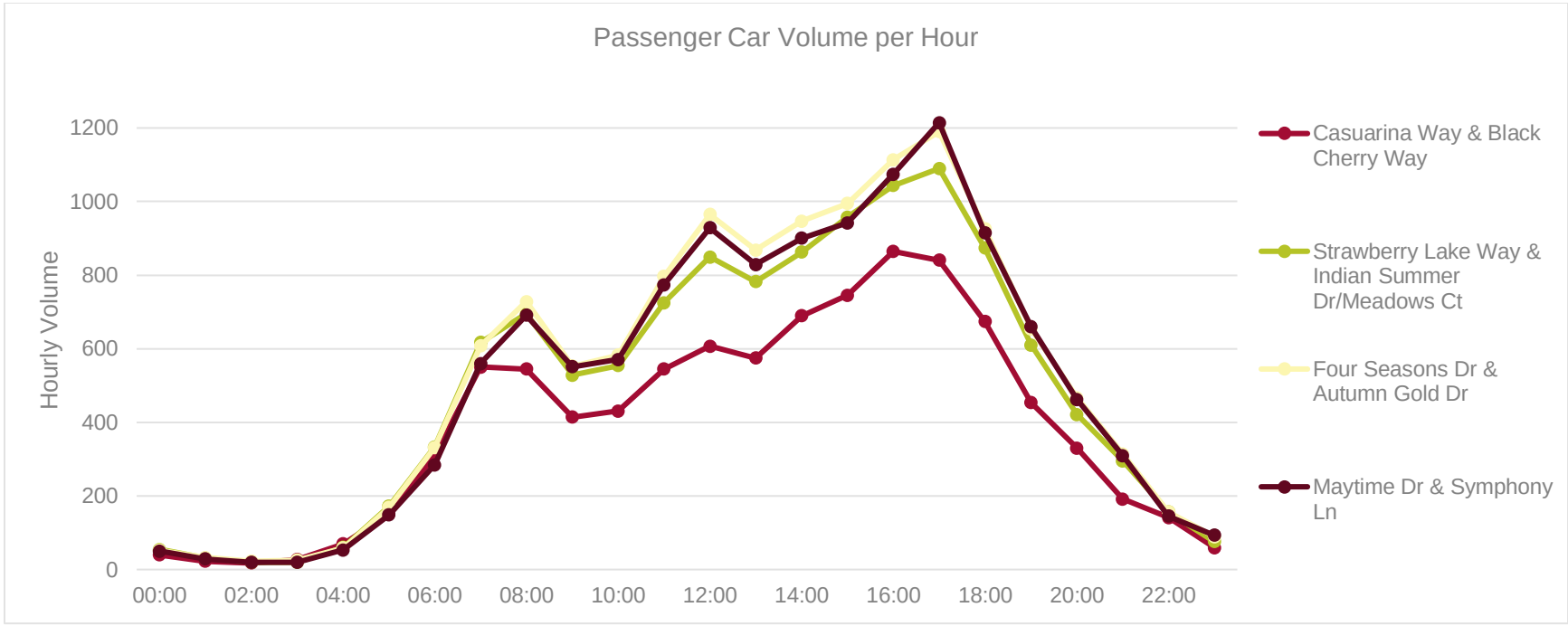


Figure 7. 2017 and 2020 Volumes by Time of Day (Waugh Chapel Road, Maytime Drive to Symphony Lane)

VEHICLE CLASSIFICATION

This section summarizes the 48-hour ADT volume and classification counts collected on November 2020. Non-heavy vehicle traffic volumes increased during the AM peak period of 7 AM to 9 AM, midday peak period of 11 AM to 1 PM, and PM peak period of 4 PM to 6PM. Heavy vehicle traffic was mostly concentrated around the 7 AM to 9 AM period and varied between 11 AM to 5PM. **Figure 8** summarizes the overall distribution between heavy and non-heavy vehicular volume. The full data of vehicle classification can be found in **Appendix A**.



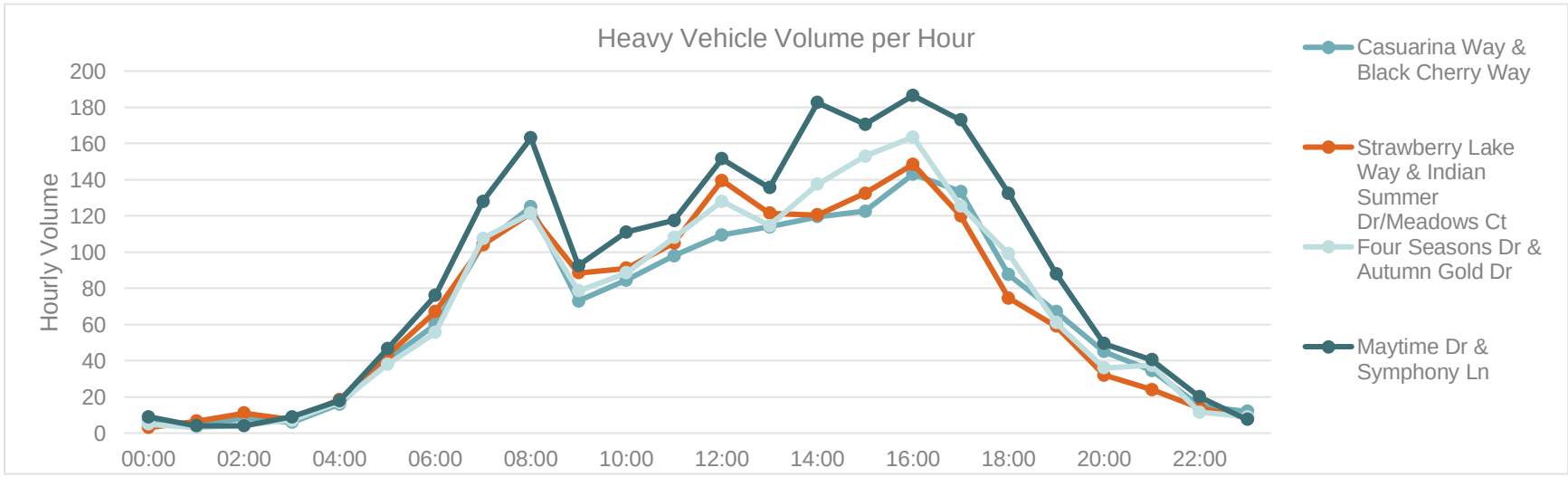


Figure 8: Volume and Classification

DEVELOPING ADJUSTED 2020 TURNING MOVEMENT COUNTS

In order to analyze the existing traffic conditions at a pre-COVID-19 pandemic state, we developed adjusted 2020 traffic counts. The methodology and the resulting adjusted TMC volumes were reviewed and approved by the County before moving forward with data analysis.

There were several sources used to develop the adjusted 2020 TMC intersection volumes. The main five sources were:

- Baltimore Metropolitan Council Travel Demand Model (BMC TDM), 2021 and 2045
- Anne Arundel County Pedestrian/Bicycle Crossing Improvements Analysis: WB&A Trail Crossing, 2019
- Lot 29 Traffic Impact Study, 2017
- Waugh Chapel Road Phase 1 Study, 2017
- ITE Trip Generation

The methodology to develop the adjusted volumes involved comparing the 2017 and 2020 counts, where available, and assuming the higher of the two counts. In most cases, the 2017 counts were significantly higher than the 2020 counts. The 2017 TIS counts were only available for five of the 10 study intersections. At intersections where there were no 2017 counts, side streets were assumed to retain the 2020 counts. The only location where volumes were calculated using the ITE Trip Generation's Single-Family Units rate was for Meadows Court at the intersection of Indian Summer Drive/Meadows Court and Waugh Chapel Road. Meadows Court is a cul-de-sac with 18 houses. The AM peak assumed three vehicles entering and 10 vehicles exiting, whereas the PM peak assumed 11 vehicles entering and seven exiting.

The next step in the methodology was to balance the traffic counts between the intersections. Volumes were increased in order to attain balance between vehicles existing an intersection and entering the adjacent intersection—they were not decreased. The 2020 counts at the intersections that did not have 2017 counts to compare were increased to reflect that the 2020 counts were lower than pre-COVID conditions. A few imbalances were maintained because there were additional side streets and driveways located between the study intersections that would have generated additional traffic flow. When balancing, the intersection with the highest volumes was Dairy Farm Road. This intersection influenced the through volume increases along Waugh Chapel Road in both AM and PM peak hours.

Through various iterations of volume balancing and adjustments, representative peak hour volumes for AM and PM were developed. The County's concurrence was important to verify the 2020 adjusted volumes along not only Waugh Chapel Road but the side streets as well.

Figure 9 and **Figure 10** illustrate the weekday adjusted 2020 peak hour traffic volume at the study intersections.

A summary of the weekday volumes is provided below.

Weekday Peak Hour Adjusted Volumes

- The representative AM peak hour starts between 7:00 AM and 7:15 AM, whereas the representative PM peak hour starts between 4:30 PM and 4:45 PM throughout the study corridor. No actual peak hours are stated for the adjusted 2020 volumes because sources with various peak hours were used to develop the volumes.
- During the AM peak period, volumes were greater going westbound throughout the corridor.

- During the PM peak period, volumes were higher going westbound for the most part east of Dairy Farm Road, whereas eastbound through traffic was higher from Piney Orchard Parkway to Indian Summer Drive.
- Peak hour volumes were more directional in the AM peak hour than the PM peak hour.
- The highest through volume on Waugh Chapel Road was 1022, traveling westbound at the intersection with Autumn Gold Drive during PM peak. This through volume was mainly driven by Dairy Farm Road. The highest left turn volume from Waugh Chapel Road was the eastbound left turn onto Dairy Farm Road, with a volume of 186 during the AM peak hour. Dairy Farm Road provides access to Route 175 and parallels Route 3 and Piney Orchard Parkway.
- The highest turning volumes from a side street onto Waugh Chapel Road were the left and right turns from Strawberry Lake Way with volumes of 156 and 156, respectively during the AM peak hour. Additionally, volumes turning left from Piney Orchard Parkway into Waugh Chapel Road were significant, with about 171 vehicles in the AM and 631 in the PM.

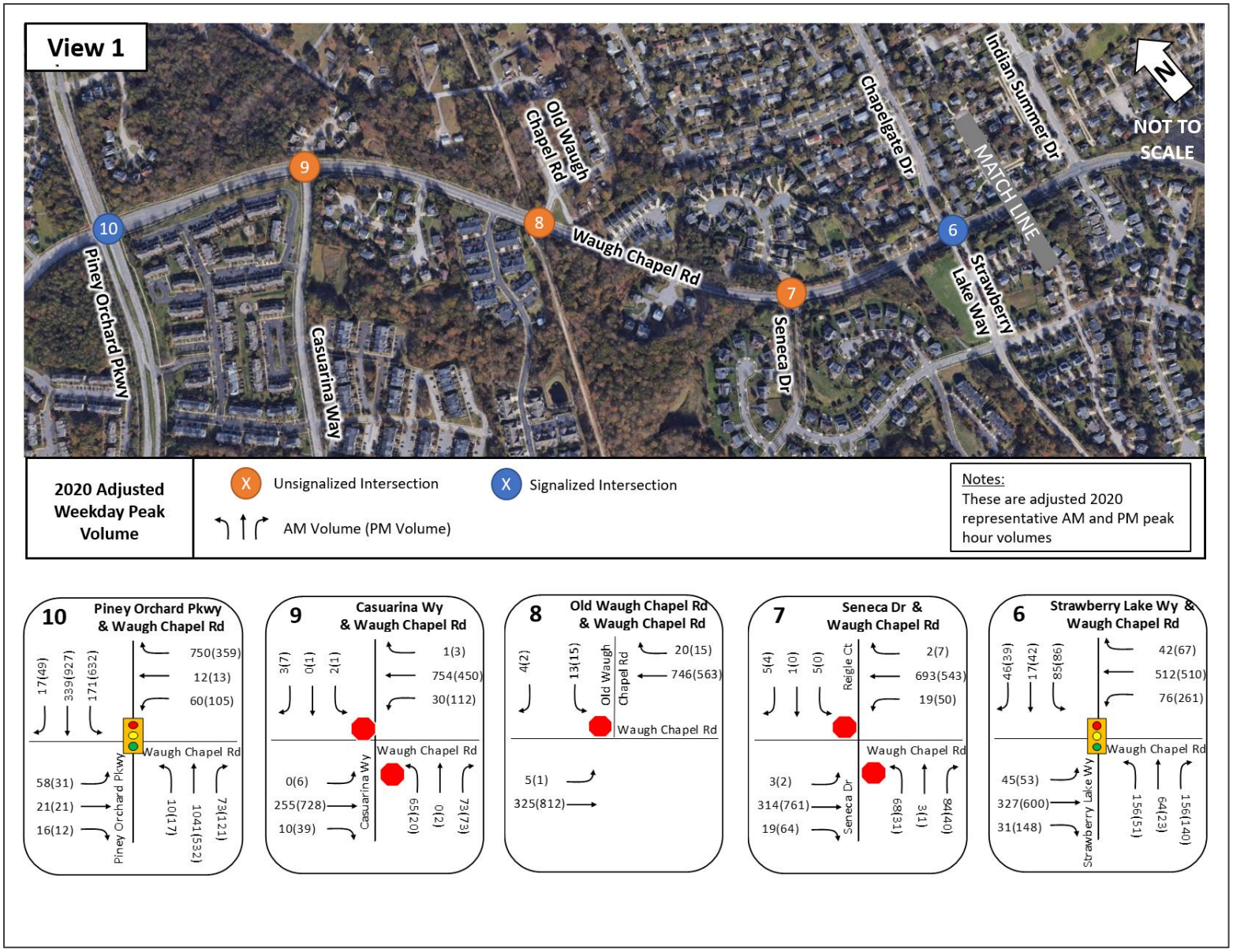


Figure 9. Adjusted 2020 Existing Weekday Peak Hour Volume- View 1

Figure 10. Adjusted 2020 Existing Weekday Peak Hour Volume- View 2

ROADWAY SEGMENT VOLUME SPEED AND CLASSIFICATION DATA

48-hour classification and speed data were collected from Tuesday to Thursday (November 17 to November 19, 2020) on Waugh Chapel Road at the following three locations:

1. Between Casuarina Way and Black Cherry Way
2. Between Strawberry Lake Way and Indian summer Drive
3. Between Four Seasons Drive and Autumn Gold Drive.

The average 24-hour un-adjusted volumes and 85th-percentile speeds over the two days are shown in **Figure 11**. The directional 24-hour volumes on Waugh Chapel Road range from approximately 5,200 vehicles to 7,500 vehicles. The average 85th-percentile speeds on Waugh Chapel Road over the two days are lower between Strawberry Lake Way and Indian Summer Drive than in the other tube count locations. Raw classification and speed data are provided in **Appendix A**.

The following is a summary of the un-adjusted ADT and speed data:

- PM peak period volumes are higher than AM peak period.
- The speeds are higher traveling eastbound on Waugh Chapel Road, east of Dairy Farm Road
- The greatest ADT values are seen east of Dairy Farm Road, where volumes are almost 100 vehicles more going westbound.
- The 85th percentile speeds at all segments in both directions exceed the posted speed limit of 35 miles per hour (mph).
- The percentage of traffic traveling faster than 50 mph varied throughout the study corridor. About 4 to 5 percent of total daily volumes were speeding over 50 mph between Four Seasons Drive and Symphony Lane and between Casuarina Way and Black Cherry Way. Only 1 percent of total daily volumes were speeding over 50 mph between Strawberry Lake Way and Indian Summer Drive.
- Speeding near Maytime Drive and Symphony Lane for 2020 was comparable to the 2017 speeding where about 3 to 4 percent of total daily volumes were over 50 mph.

Figure 11. Existing Average Daily Volumes and 85th Percentile Speed

HISTORICAL TRAFFIC DATA

To understand the changes in traffic volumes and patterns over time, annual average daily traffic (AADT) volumes were examined for 2010 through 2019—the most recent data available. AADTs are determined to provide an estimate of the daily bi-directional volumes at specific locations or along specific roadway corridors. AADT data was obtained from the Maryland Department of Transportation State Highway Administration (MDOT SHA) Statewide AADT Points website. A summary of the historical AADT volumes is provided in **Table 3**. The mainline Waugh Chapel Road AADT trend from 2012 to 2019 is illustrated in **Figure 12**.

Table 3: Historical AADT Data

Road	Annual Average Daily Traffic Volumes (vehicles per day)									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Waugh Chapel Road	18,441	18,522	17,500	17,541	17,492	17,953	18,870	19,321	19,152	19,650
Piney Orchard Parkway	25,152	24,750	24,551	24,602	24,850	25,501	25,992	26,960	26,721	27,842
Crain Highway (Route 3)	63,191	64,042	67,100	62,251	62,062	65,490	66,731	68,332	72,250	72,251

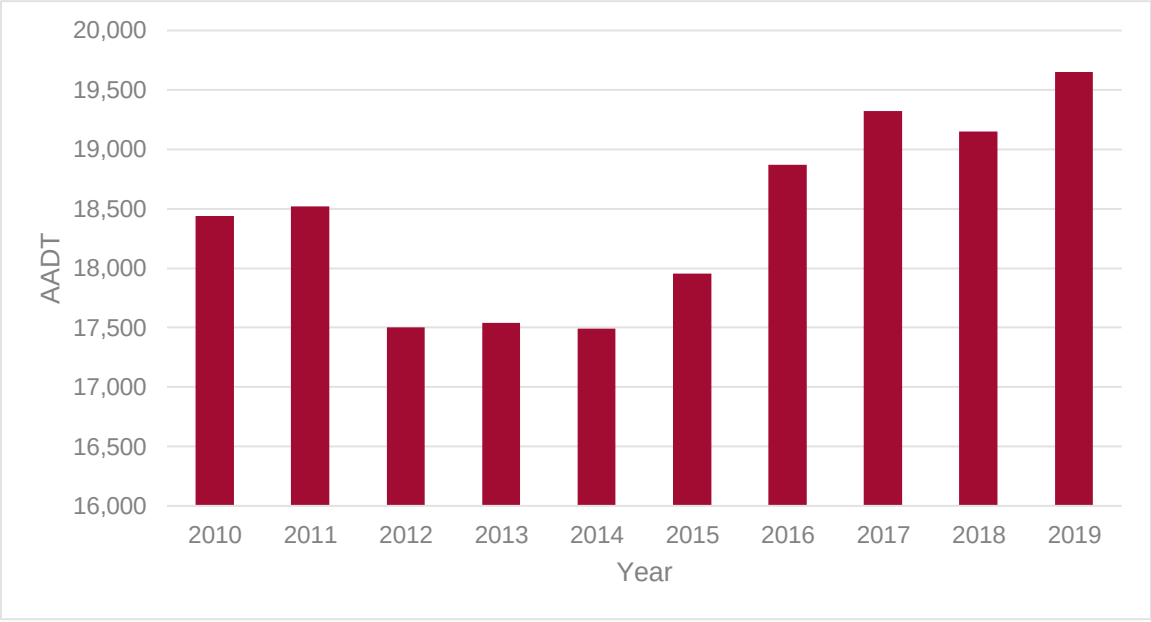


Figure 12: Historical Annual Average Daily Traffic Volumes for Waugh Chapel Road

The data shows that traffic volumes on Waugh Chapel Road remained steady until 2012 and 2013. The reconstruction of the MD 3/Waugh Chapel Road intersection may have contributed to the volume dip during that time. Traffic volumes began to show growth in 2015 and continued to grow through 2019.

OBSERVATIONS OF TRAFFIC AND SAFETY OPERATIONS

Field observations were conducted November 24 and December 8, 2020 as well as January 28, 2021. The field observations were focused on queue lengths and duration, traffic flow, and bicycle and pedestrian activities and facilities. Operational issues, driver behaviors, and pedestrian activity were documented. Information gathered during the field observations was used to validate outputs from traffic analysis software programs used to analyze existing conditions. Notable observations from the site visits are summarized below.

Traffic Operations and Traffic Control Devices

- Operational issues along the corridor were at a minimum; however, side street vehicles experience delays getting onto Waugh Chapel Road.
  - At the signalized intersection with Strawberry Lake Way/Chapelgate Drive, side street left turning and through traffic, as well as southbound right turning traffic, queued while waiting to be served by the signal. During some signal phases, particularly in the afternoon and the evening peak hour, these queues extended 6-8 vehicles back, even though there were very few through vehicles on Waugh Chapel Road.
  - At some of the unsignalized intersections where sight-distances are limited or affected by vegetation, parked cars, or entrance walls (see Chapter 3), drivers turning from the side streets onto the mainline were a bit hesitant.
- The distance between the travel way edge line and the face of curb (paved shoulder) is between 8 to 10 feet in some areas. During field observations, some vehicles used the shoulder as a right turn lane.
- There are several signposts without signs along the corridor. Most of these signs are on side streets; however, there are a few along Waugh Chapel Road at Strawberry Lake Way and Dairy Farm Road.
- The Keep Right signs at the trail crossing are mounted approximately 6” from the ground on plastic posts attached to the roadway and concrete island with rubber bases (see **Figure 13**). *Maryland Manual on Uniform Traffic Control Devices* (MDMUTCD) mounting height for these signs is 7 feet from bottom of sign.
- Several crosswalk pavement markings are faded.

Figure 13: Keep Right Sign

Safety Issues

- Speeding
  - The approximately half-mile distance between Seneca Drive and Casuarina Way is fairly straight and vehicles travelling this segment tend to reach speeds in excess of the posted 35 mph speed limit. The 85th percentile speeds, as shown in **Figure 11,** show that most vehicles are traveling at speeds greater than 40 mph. The posted speed limit is 35 mph. This was confirmed when performing field observations
- Sight Distance
  - The vertical stopping sight distance for westbound vehicles between Four Seasons Drive and Dairy Farm Road and between Piney Orchard Parkway and Casuarina Way appears to be challenging. There are advanced signal warning signs; however, vehicle speeds, parking maneuvers, and the vertical curve prior to Dairy Farm Road contribute to the need for drivers to be alert and attentive when travelling on this section of the corridor.
  - Side street intersection sight distance may be limited at the unsignalized intersections due to the existing roadway geometry and other obstructions including vegetation and parked cars. Potentially difficult turning movements were observed at Casuarina Way, Indian Summer Drive, Summer Hill Drive, Autumn Gold Drive, and Reigle Court.
- Parking
  - Parking is permitted along much of the corridor. On the north side of the corridor (westbound direction) between Summer Hill Drive and Dairy Farm Road, there are curb cuts for parking areas that accommodate 1 to 2 vehicles between the edge of pavement and the sidewalk. These areas provide additional parking for the homes along this section of Waugh Chapel Road as shown in **Figure 14**. Field observations showed some drivers making U-turns to exit the parking areas in order to travel eastbound on Waugh Chapel Road
  - Vehicles park on eastbound Waugh Chapel Road between Emerald Way and the trail (parking is permitted). Parking is not permitted east of the trail in the vicinity of the trail crossing (No Parking signs are present and appear to be effective)

Figure 14: Street Parking along Waugh Chapel Road

Multimodal Activity

- Pedestrians and Bicyclists
  - There are sidewalks present on both sides of the corridor. During field observations, pedestrians were observed walking throughout the corridor, as well as bicyclists. The paved shoulders in many segments of the corridor provide bicyclists with areas to ride. In areas with on-street parking, bicyclists must be cautious of parked vehicles.
  - The WB&A trail crosses Waugh Chapel Road east of the point where the trail actually meets Waugh Chapel Road from the north and the south. The crossing is signed and marked. During field observations, bicyclists tended to use the marked trail crossing; however, pedestrians primarily crossed Waugh Chapel Road on the west of Old Waugh Chapel Road (at the point where the north and south trail approaches meet Waugh Chapel Road). There is a short section of chain-linked fencing on the north side of Waugh Chapel Road to discourage bicyclists and pedestrians from crossing Waugh Chapel Road where the north approach of the trail meets Waugh Chapel Road.
- Transit
  - There are a signs along eastbound Waugh Chapel near Casuarina Way and the WB&A Trail crossing for CMRT Route M, which has been disbanded. There are signs along Piney Orchard Parkway, north and south of Waugh Chapel Road and on southbound Casuarina Way for “Anne Arundel County Bus Stop.” No buses were present along the corridor during field observations.

Chapter 3 Roadway Geometrics and Traffic Control Devices

Waugh Chapel Road is classified as a minor arterial and generally has one through lane in the east and westbound directions with exclusive turn lanes at some intersections along the corridor. Roadway geometric and traffic control device data was collected in mid-November 2020. Observations included the following:

- Travel lane width
- Roadway geometry analysis
  - Horizontal curve measured
  - Vertical curve measured
  - Sight distance measurements for the intersections

TRAVEL LANE AND SHOULDER WIDTHS

Travel lane, turn lane, and shoulder widths vary throughout the corridor. Through lanes generally measured 11 to 12 feet, while some turn lane widths are as narrow as 7.5 feet. The eastbound approach of Waugh Chapel Road at Summer Hill Drive has about a 7.5 ft wide right turn lane onto Summer Hill Drive. These narrow turn lanes can become an operational issue if drivers slow down to turn but do not fully enter the turn lane, thus partially remaining in the through lanes to make turns. This could potentially affect through traffic delay. Casuarina Way and Seneca Drive do not have right turn lanes along Waugh Chapel Road but have about an 8-foot shoulder on either side.

Most of the corridor has shoulders present that range from 2 feet to 15 feet. In most cases, the narrow shoulders are located along the eastbound direction of Waugh Chapel Road between Indian Summer Drive and Summer Hill Drive. There are no shoulders where right turn lanes are present. The wide shoulders are mostly present along the westbound Waugh Chapel Road direction where on-street parking is common. These shoulders in most cases are wide enough for a parked vehicle and a bicyclist.

ROADWAY GEOMETRIC ANALYSIS

Based on field driving tests including windshield tests and other observations, locations for further roadway geometric assessments were identified. Horizontal and vertical curve alignments, as well as, sight distances were analyzed for these locations as shown in **Table 4**.

Table 4: Roadway Geometric Analysis Locations

Roadway Geometric Analysis	Locations
Horizontal Curve	• Between Indian Summer Drive and Dairy Farm Road
Vertical Curve	• Westbound approaching Dairy Farm Road (between Four Seasons Drive and Dairy Farm Road) • Westbound approaching Piney Orchard
Intersection Sight Distance	• Casuarina Way • Indian Summer Drive • Summer Hill Drive • Autumn Gold Drive • Reigle Court

All assumptions were made from the American Association of State Highway and Transportation Officials (AASHTO) and the Anne Arundel County Design Manual:

- County topography at a 2-foot contours was used to calculate vertical curve estimates and to review sight lines, but further surveying would be required to make any design updates.
- Waugh Chapel Road is posted at 35 mph; however, 45 mph was used in the geometric analysis based on the average 85th percentile speed data collected.
- Stopping sight distance for AASHTO uses a driver's eye at 3.5 feet and an object at 2 feet, while Anne Arundel standards uses a driver's eye at 3.5 feet and an object at 0.5 feet.
- Intersection sight distance for AASHTO and Anne Arundel standards both use 3.5 feet for the driver's eye and object.
- Sight distances were taken 15 feet behind the main road curb return to align with Anne Arundel County standards. This is a conservative approach as AASHTO recommends 14.5 feet behind the edge of the traveled way.
- Roads were assumed to be at a grade less than 3 percent for the analysis of intersection and stopping sight distances.
- For horizontal curves, a 4 percent cross slope was assumed to determine the minimum allowable radius of 711 feet at a design speed of 45 mph.
- The intersection sight distance was analyzed for vehicles making left or right turns from side streets onto Waugh Chapel Road. The Anne Arundel standards were used in the graphics as they are more conservative than the AASHTO standards.

Table 5 shows the results of the analysis locations in relations to the standards. This table also includes an approximate available distance for the existing features that do not meet the standards at the 45 mph analysis speed. **Appendix C** provides the graphics and measurement used for the roadway geometric analysis.

Table 5: Roadway Geometry Analysis Results

Roadway Geometric Analysis	Location	AASHTO Required (ft)	Standards Met?	County Required (ft)	Standards Met?	Approximate Available Distance (ft)
Horizontal Curve - Minimum Radius	Between Indian Summer Drive and Dairy Farm Road	711	Yes	728	Yes	-
Vertical Curve - Stopping Sight Distance	Between Four Seasons Drive and Dairy Farm Road	360	No	400	No	350/300*
	Between Piney Orchard Parkway and Casuarina Way	360	No	400	No	350/300*
Intersection Sight Distance	Casuarina Way – Left Turn	500	No	670	No	350
	Casuarina Way – Right Turn	430	No	640	No	250
	Indian Summer Drive – Left Turn	500	Yes	670	Yes	-
	Indian Summer Drive – Right Turn	430	Yes	640	Yes	-
	Summer Hill Drive – Left Turn	500	Yes	670	Yes	-
	Summer Hill Drive – Right Turn	430	Yes	640	Yes	-
	Autumn Gold Drive – Left Turn	500	Yes	670	No	500
	Autumn Gold Drive – Right Turn	430	Yes	640	Yes	-
	Reigle Court – Left Turn	500	No	670	No	350
	Reigle Court – Right Turn	430	No	640	No	250

*first number is for AASHTO object height of 2', second number is for County object height of 0.5'

The minimum radius of any horizontal curve along the corridor was measured to be 831 feet located between Indian Summer Drive and Dairy Farm Road. This is greater than the minimum radius required by AASHTO and the County standards and suggests the horizontal geometry was originally designed to be near 45 to 50 mph.

The vertical curves were evaluated at two locations between Four Seasons Drive and Dairy Farm Road and between Piney Orchard Parkway and Casuarina Way. Both locations do not provide adequate stopping sight distance at the 45 mph analysis speed for AASHTO and County standards. For the existing geometry to meet the standards, the design speed would need to be near 35 mph for AASHTO, and 25 to 30 mph to meet County standards. The vertical curves limit the visibility of the northbound approaches to the signalized intersections at Dairy Farm Road and at Piney Orchard Parkway, potentially obscuring views of cars stopped at the signals.

The intersection sight distance was measured at unsignalized locations that were observed during the field driving tests to have limited sight lines. The analysis based on a 45 mph speed along with field observations contributed to the following results:

- Casuarina Way
  - Right and left turn movements' sight distance limited by the existing grading behind the curb
  - Landscaping near brick sign further reduces sight distance
  - Existing trees and potential for parked cars near the intersection may also reduce sight distance (no parked cars observed)
- Indian Summer Drive
  - Right and left turn movements' sight distance is adequate
  - Left turn movement sight distance may be limited by parked cars north of the intersection (no parked cars observed)
- Summer Hill Drive
  - Westbound right and eastbound left turn movements' sight distance is adequate
  - Existing trees may limit sight distance for the eastbound left turn movement
  - Existing trees and potential for parked cars past near the intersection may also reduce sight distance (no parked cars observed)
- Autumn Gold Drive
  - Right turn movement's sight distance is adequate
  - Left turn movement's sight distance is limited by the existing grading of the roadway
  - Existing trees and potential for parked cars south of the intersection may also reduce sight distance (no parked cars observed)
- Reigle Court
  - Right and left turn movements' sight distance limited by the existing grading behind the curb
  - Existing vegetation and potential for parked cars near the intersection further reduce sight distance (no parked cars observed)

Chapter 4 Traffic Operations Evaluation

MEASURES OF EFFECTIVENESS

Traffic analysis was performed using Synchro 10, a macroscopic analysis tool that uses Highway Capacity Manual (HCM) methodologies to calculate operational performance at signalized and unsignalized intersections. The following measures of effectiveness (MOE) were considered for this study:

- Movement/approach/overall intersection delay
- Movement/approach/overall intersection Level of Service (LOS)
- 95th percentile movement/approach queues, based on Synchro HCM outputs

The Highway Capacity Manual (HCM) defines LOS for signalized and unsignalized intersections as a function of average vehicle control delay. LOS may be calculated per movement or per approach for any intersection configuration, but overall intersection LOS is defined for signalized and all-way stop-controlled intersections only. Overall intersection LOS is not reported for unsignalized, stop-controlled intersections. **Table 6** and **Table 7** summarize the different LOS designations for both signalized and unsignalized intersections, respectively, based on vehicle delay. The existing conditions LOS, delay, and queuing analyses for the AM and PM peak hours are discussed in the following sections.

Table 6: LOS and Delay Thresholds, Signalized Intersections

Level of Service (LOS)	Average Control 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 and queues fail to clear)

Table 7: LOS and Delay Thresholds, Unsignalized Intersections

Level of Service (LOS)	Average Control Delay (seconds)
A	$0 - 10$
B	$> 10 - 15$
C	$> 15 - 25$
D	$> 25 - 35$
E	$> 35 - 50$
F	> 50

In addition to the LOS and delay, 95th percentile queues per movement were evaluated. 95th percentile queues are particularly useful for traffic operations evaluation, as they represent the maximum queue lengths that are anticipated for 95 percent of the time at each location while removing potential outliers that may skew the analysis results. It is assumed an average vehicle is 25 feet when analyzing queues.

TRAFFIC OPERATIONAL RESULTS

Synchro Results

The existing conditions overall intersection delay and LOS outputs are summarized in **Table 8**. The existing conditions delay and LOS by movement is provided in Synchro HCM reports in **Appendix D**.

Table 8. Existing (2017) Peak Hour Intersection Delay and LOS

Intersection	Traffic Control	Weekday AM Peak Hour		Weekday PM Peak Hour	
		Delay (sec)	LOS	Delay (sec)	LOS
Waugh Chapel Road and Piney Orchard Parkway	Signalized	85.8	**F**	53.7	D
Waugh Chapel Road and Casuarina Way	Unsignalized*	31.6	D	40.4	**E**
Waugh Chapel Road and Old Waugh Chapel Road	Unsignalized*	16.2	C	18.6	C
Waugh Chapel Road and Seneca Drive	Unsignalized*	34.4	D	55.1	**F**
Waugh Chapel Road and Strawberry Lake Way	Signalized	37.8	D	60.9	**E**
Waugh Chapel Road and Indian Summer Drive	Unsignalized*	56.3	**F**	95.6	**F**
Waugh Chapel Road and Dairy Farm Road	Signalized	63.8	**E**	73.8	**E**
Waugh Chapel Road and Four Seasons Drive	Unsignalized*	15.9	C	24.8	C
Waugh Chapel Road and Summer Hill Drive	Unsignalized*	43.3	**E**	158.4	**F**
Waugh Chapel Road and Autumn Gold Drive	Unsignalized*	18.1	C	27	D

* Worst movement was reported for unsignalized, stop-controlled intersections

As shown in **Table 8** and **Appendix D,** the signalized intersections experience an LOS E or worse for at least one of the peak hours. At all intersections, the side street traffic experiences the greatest delays for unsignalized and signalized intersections. The side street traffic often finds it difficult to turn out of the streets because of the high through traffic in the Waugh Chapel Road mainline.

The eastbound and westbound Waugh Chapel Road movements all operate at a LOS D or better at all intersections except Waugh Chapel Road and Piney Orchard Parkway. At this signalized intersection, the major street is Piney Orchard Parkway and the minor street is Waugh Chapel Road. For this reason, the signals timings prioritize Piney Orchard Parkway over Waugh Chapel Road. In the AM peak period, the adjusted volumes indicate the westbound right turn volume at this intersection is about 750 vehicles. Though this movement operates with an overlap during the southbound left turn phase and operates split phase with eastbound Waugh Chapel Road, this right turn experiences about 85.8 seconds of delay with about 1,100 feet of queuing. In the PM peak period, this intersection operates at a LOS D or better for all movements.

For the signalized intersection at Waugh Chapel Road and Strawberry Lake Way, the AM peak hour operates at a LOS D or better for all movements. The greatest delays are experienced during the PM peak hour where the northbound and southbound through-left movements experience LOS of E with up to a minute of delay. The side streets at this intersection operate split phase and have a significant amount of left and right turn volumes.

The last signalized intersection is at the Waugh Chapel Road and Dairy Farm Road intersection, the highest delays are along the northbound and southbound through-left movements. The volumes for these movements were minimal in both AM and PM peak hour for the through volumes, ranging from one to two vehicles. Whereas, the southbound left turns experience adjusted volumes as high as 177 or 264 in the AM and PM peak hours, respectively. The northbound and southbound movements operate split phase. Because the through lanes are shared lanes with the left turning movement, the through volumes, although very low, experience high delays. Both these movements in the peak hours experience a LOS of E.

Out of all the unsignalized intersections, the highest delays were seen during the PM peak hours. Below is a summary by peak hour highlighting the side street movements with LOS E or worse:

AM Peak Hour

- Indian Summer Drive: Southbound (LOS F, 56.3 seconds)
- Summer Hill Drive: Northbound (LOS E, 43.3 seconds)

PM Peak Hour

- Casuarina Way: Northbound (LOS E, 40.4 seconds)
- Seneca Drive: Northbound (LOS F, 55.1 seconds)
- Indian Summer Drive: Southbound (LOS F, 95.6 seconds)
- Summer Hill Drive: Northbound (LOS F, 158.4 seconds)
- Summer Hill Drive: Southbound (LOS F, 73.9 seconds)

The 95th percentile queue length for each movement at the study intersections was reported and compared with available storage for turn lanes and between adjacent intersections. During the AM peak, there were two locations where the westbound right turn queues exceeded the storage length: 1) Dairy Farm Road and 2) Piney Orchard Parkway. During the PM peak, at the intersection with Dairy Farm Road, both the westbound right and southbound right queues exceeded the storage length.

The results of delay by approach at each intersection are summarized in **Figure 15**, **Figure 16** and in the full summary table and results for delay/LOS and 95th percentile queues are **Appendix D**.

Figure 15: Existing Conditions Synchro Results – View 1

Figure 16: Existing Conditions Synchro Results – View 2

SIGNAL WARRANT ANALYSIS

A high-level signal warrant analysis was performed for the unsignalized intersections along Waugh Chapel Road. All eight signal warrant criteria were evaluated based on the actual counts collected in November 2020 (not the adjusted 2020 representative counts) and crash data provided by Maryland SHA. These eight warrants can be found in **Appendix D**. All warrants were checked for a 35-mph posted speed limit, as well as, speeds traveling faster than 40 mph. Warrants were analyzed based on the number of lanes per direction along major and minor streets.

Based on Warrant 1: Eight-Hour Vehicular Volume, the unsignalized intersection at Waugh Chapel Road and Casuarina Way met the signal warrant for Condition B at the 80% volume level. According to the MUTCD guidelines, signal warrant Condition B can be used for locations where major street traffic is so heavy that traffic on the minor street suffers excessive delay or conflicts in entering or crossing the major street. Moreover, because the prevailing speeds exceed 40 mph for Waugh Chapel Road, Condition B at an 80% volume level was evaluated. This intersection is about 1,000 feet east of Piney Orchard Parkway and provides access to a residential community south of the intersection.

No other unsignalized intersections met the signal warrants because of the low volumes on the side streets. The number of crashes per year at all of the intersections are such that they do not meet the crash experience warrant. Pedestrian volumes are low and there are no observed school crossing activities directly at the study intersections (*note to County: please check school route, may need to modify this*). It is recommended that further signal warrant analysis be done at these unsignalized intersections post-COVID. The signal warrant guidelines and calculated volumes can be found in **Appendix D**.

Chapter 5 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 observation in the field. The previous study referenced in this section is the Anne Arundel County Pedestrian/Bicycle Crossing Improvements Analysis for the WB&A Trail Crossing (2019). The following sections provide details and maps pertaining to the various modes.

PEDESTRIAN AND BICYCLE FACILITIES

The 2013 Pedestrian and Bicycle Master Plan (PBMP), which was created as an update to the 2003 Pedestrian and Bicycle Master Plan, identifies improvement opportunities that increase the potential for safe trip-making by walking and bicycling. These opportunities include both infrastructure and non-infrastructure improvements that are sorted by a tier ranking system. The following summarizes conditions of bicycle and pedestrian facilities in the study area.

Sidewalks

Policy outlined in the 2013 PBMP stresses the importance of prioritizing sidewalk improvements to ensure that streets have sidewalks on at least one side of the street. As shown in **Figure 18**, sidewalks are continuous along Waugh Chapel Road in the study area, ranging from 4 to 5 feet throughout the corridor. There are no existing gaps in the pedestrian network.

The WB&A Trail, Gambrills-Odenton Recreational Council (GORC) Park, and Four Seasons Elementary School near Maytime Drive are the main pedestrian attractors near the study area.

Table 9 provides a summary of the locations and conditions of the marked crosswalks. **Figure 19** and **Figure 20** summarize the total pedestrian counts during the representative peak hours. The peak hour pedestrian counts for each of the study intersections were compiled for this study, therefore, the peak hours are referred to as "representative peak hours". Pedestrian volumes were low at the study intersections during the AM and PM peak periods. The highest pedestrian activities occurred at the intersection of Waugh Chapel Road and Old Waugh Chapel Road, which is adjacent to the WB&A trail crossing. There were eight pedestrians counted during the AM peak period and 13 pedestrians counted during the PM peak period. The full pedestrian counts at each intersection can be found in **Appendix A**.

Table 9: Summary of Existing Marked Crosswalks

Intersection along Waugh Chapel Road	Type	Legs with Marked Crosswalk	Marked Crosswalk Condition	Curb Ramps	Push Buttons
Piney Orchard Parkway	Signalized	All	Faded	Yes	Yes
Casuarina Way	Unsignalized	South	Faded, no inner striping	Yes	N/A
Old Waugh Chapel Road	Unsignalized	North	Slightly faded, no inner striping	Yes	N/A
Seneca Drive	Unsignalized	None	-	Yes	N/A
Strawberry Lake Way	Signalized	All	Good	Yes	Yes
Indian Summer Drive	Unsignalized	None	-	Yes	N/A
Dairy Farm Road	Signalized	West, North	Slightly faded	Yes	Yes
Four Seasons Drive	Unsignalized	North	Faded	Yes	N/A
Summer Hill Drive	Unsignalized	None	-	Yes	N/A
Autumn Gold Drive	Unsignalized	None	-	Yes	N/A

Bicycle Facilities

This section describes the facilities and condition of biking in the study area. The bicycle facilities in the study area are the shoulders on both sides of the roadway that are, for the most part, wide enough to accommodate both bicycles and parked vehicles. **Figure 17** shows an example of where there is street parking and a wide shoulder. The shoulders range from 2 to 15 feet wide. The only location where the shoulder is less than 8 feet and unable to accommodate street parking is in the eastbound direction between Indian Summer Drive and Summer Hill Drive. At intersection approaches, the shoulder often becomes an additional turn lane. **Figure 18** shows the type of bicycle facilities in the study area. The study area does not have any roadway signs indicating shared use roads or bike lanes. **Figure 21** and **Figure 22** summarize the total bicycle counts during the representative peak hours. The peak hour bicycle counts for each of the study intersections were compiled, therefore, the peak hour is referred to as the "representative peak hour". There were no more than four bicyclists counted at any given intersection during the AM or PM peak period. The full bicycle counts at each intersection can be found in **Appendix A**.

Constructing Waugh Chapel Road bicycle lanes from Piney Orchard Parkway to MD 3 was listed as a tier two project in the 2013 PBMP. Waugh Chapel Road was described as a feasible route for bicycle lanes.

Figure 17: Street Parking Lane

Trails

There are three main trails along the study area. The WB&A Trail and two unnamed trails, one parallel Casuarina Way and another parallel to Strawberry Lake Way. The trails can be accessed from Waugh Chapel Road and connect users to various surrounding neighborhoods, downtown Odenton, shopping centers, and the Piney Orchard Nature Trail. The WB&A Trail crosses Waugh Chapel Road at Old Waugh Chapel Road. The at-grade crossing is currently unsignalized with a median refugee area. The County recently (after November 2020) installed Rectangular Rapid Flashing Beacons at the WB&A trail crossing. The 2013 PBMP identified WB&A trail access improvement to enhance access to WB&A Trail where Old Waugh Chapel Road bridge crosses the trail.

TRANSIT

Transit and School Bus Routes

Although there is no fixed-route local or regional bus service in the area, the Crofton Connector provides Monday through Friday service between the Odenton Maryland Area Regional Commuter (MARC) station and Crofton Country Club, using Waugh Chapel Road for a portion of the route.

Waugh Chapel Road also serves a few school bus routes.

MARC Station

The Odenton MARC train station is located approximately 0.3 miles from the Piney Orchard Parkway intersection, the western terminus of the Waugh Chapel study area. The Odenton station provides daily train service to various locations, including Washington, DC's Union Station and Baltimore's Penn Station, via the Penn Line. It a popular commuter route, with parking at the Odenton station often beyond capacity.

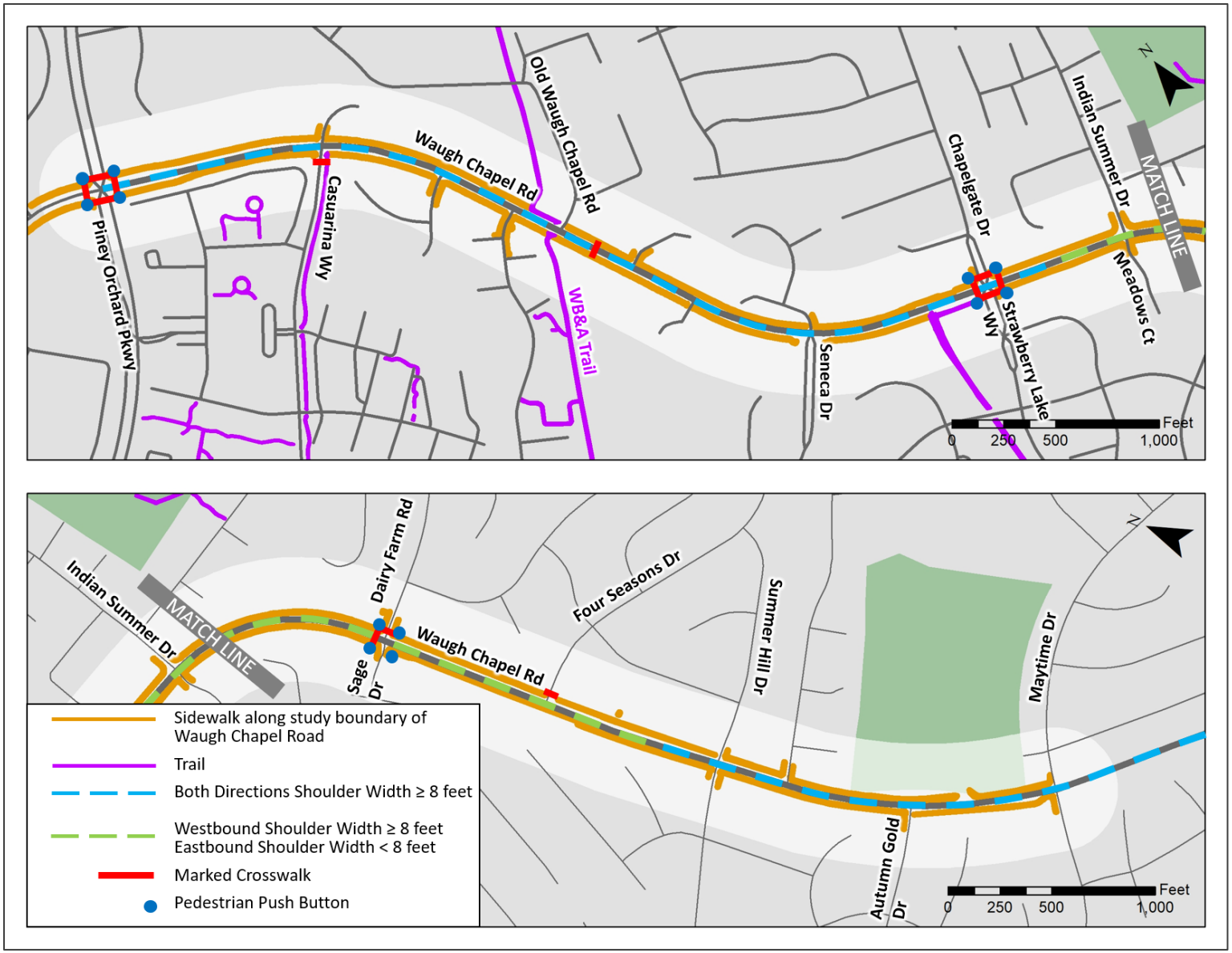


Figure 18: Existing Bicycle and Pedestrian Facilities

Figure 19. Pedestrian Counts – View 1

Figure 20. Pedestrian Counts – View 2

Figure 21. Bicycle Counts – View 1

Figure 22. Bicycle Counts – View 2

Chapter 6 Crash Data Summary

CRASH DATA

Crash data was used to evaluate safety conditions and crash patterns throughout the study area. This data was obtained from MDOT SHA. The data includes a 10.5-year period for crashes from January 1, 2010 to July 30, 2020 by mile marker. The crash analysis included segments of Waugh Chapel Road from Piney Orchard Parkway to Maytime Drive. According to the crash data, Piney Orchard Parkway represents mile marker 3.3 between the years 2010 and 2013 and changed to mile marker 3.2 from year 2013 to present day. The estimated adjustment of 0.1-mile marker value was made when summarizing the crash data throughout the study corridor.

COLLISION FREQUENCY AND SEVERITY

Between January 2010 and July 2020, there were 151 total crashes in the study corridor. A summary of the crashes by year and by injury is shown in **Table 10**. There were no fatalities during the study period but more than a third of the crashes resulted in injuries.

Table 10: Crash Severity by Year

Year	Fatalities	Injuries	No Injuries	Total
2010	0	8	11	19
2011	0	6	8	14
2012	0	4	3	7
2013	0	3	9	12
2014	0	9	16	25
2015	0	5	6	11
2016	0	6	6	12
2017	0	2	15	17
2018	0	8	11	19
2019	0	4	7	11
2020*	0	3	1	4
Total	0	58	93	151

Note: 2020 data is partial and only through July 30, 2020

Table 11 summarizes the number of crashes associated with each study intersection by year. Crashes within 0.10-miles or 500 feet of an intersection were associated with the intersection, which is the average standard distance of a storage lane or influence area of an intersection. The top intersections with the most crashes recorded within the influence area of the intersection were (1) Strawberry Lake Way, (2) Dairy Farm Road, (3) Piney Orchard Parkway, and (4) Maytime Drive. Overall, when comparing the most recent full year crash data (2019) to the previous year's data (2018), Strawberry Lake Way and Piney Orchard Parkway experienced an increase in crashes in 2019 from 2018. Aside from those two intersections, the yearly data does not show an apparent increase in crashes in the past 5-years for all the study intersections. Strawberry Lake Way is the only intersection that experienced greater than four crashes in the past 5-year period.

Table 11: Crash Frequency per Study Intersection by Year

Year	Piney Orchard Parkway	Casuarina Way	Old Waugh Chapel Road	Seneca Drive	Strawberry Lake Way	Indian Summer Drive	Dairy Farm Road	Four Seasons Drive	Summer Hill Drive	Autumn Gold Drive	Maytime Drive
2010	2	1	0	0	2	0	3	1	0	1	3
2011	0	0	0	0	3	1	0	1	1	0	1
2012	0	0	0	0	3	0	0	1	0	0	1
2013	1	0	0	0	2	0	1	1	1	1	0
2014	2	1	1	0	3	0	5	1	0	0	1
2015	3	0	0	2	1	0	2	0	0	0	0
2016	1	0	1	0	2	1	1	0	1	0	1
2017	0	0	0	0	5	1	1	2	1	0	1
2018	1	1	1	0	2	0	2	0	0	0	3
2019	3	0	0	0	4	0	2	0	0	0	1
2020*	0	1	1	0	0	0	1	0	0	0	0
Total	**13**	**4**	**4**	**2**	**27**	**3**	**18**	**7**	**4**	**2**	**12**

Note: 2020 data is partial and only through July 30, 2020

COLLISION TYPES

Figure 23 shows the overall crash quantities per mile marker along Waugh Chapel Road. **Figure 24** show the overall crash trends along 0.2-mile segments in Waugh Chapel Road. It is important to note that the high crash locations in **Figure 23** are different from those identified in **Figure 24** because one quantifies crashes by mile marker points and the other by 0.2-mile segments. 0.2-mile (about 1,060 feet) segments were used as the distance to capture the general influence area of a full intersection. Generally, crashes between 250 feet to 500 feet from the center of the intersection are associated with the given intersection. Therefore, a 0.2-mile segmentation was used to best capture a full extent of an intersection. Using the provided SHA data, 0.2-mile segments were created starting from the western most available crash data point.

High crash locations are shown in **Figure 23** by mile marker point. There were three main mile marker locations that experienced the highest number of crashes. The mile marker with the highest crashes was at the center of Dairy Farm Road intersection, the center of intersection of Piney Orchard Parkway, and the center of intersection of Maytime Drive. These three locations are signalized intersections, with Dairy Farm Road and Piney Orchard Parkway having the highest volumes in the study area. These mile markers identify specific point locations that experienced high crashes and not the entirety of the intersection's influence area. The overall intersection influence area crash number is found in **Table 11**.

Figure 24 shows high crash 0.2-mile segments in histogram bar charts. When analyzing the crash trends by 0.2-mile segments, there are two locations with the highest crashes. The first 0.2-mile segment is between Seneca Drive and just east of Strawberry Lake Way, with almost 40 crashes total. According to the SHA crash records, half of the crashes were recorded as rear end crashes, 13 percent were angled crashes, 13 percent involved parked vehicles, and the rest were sideswipe, fixed object, head on, and left turns. This segment includes the signalized intersection of Strawberry Lake Way which may attribute to the high number of rear end crashes in this segment. The second 0.2-mile segment is between Chapel Hill Boulevard and east of Dairy Farm Road, with 25 crashes. Almost half the crashes were rear end crashes, the rest being angle, left turn, sideswipe, fixed object, and other. This segment also includes a signalized intersection at Dairy Farm Road, which attributes to the high number of rear end crashes.

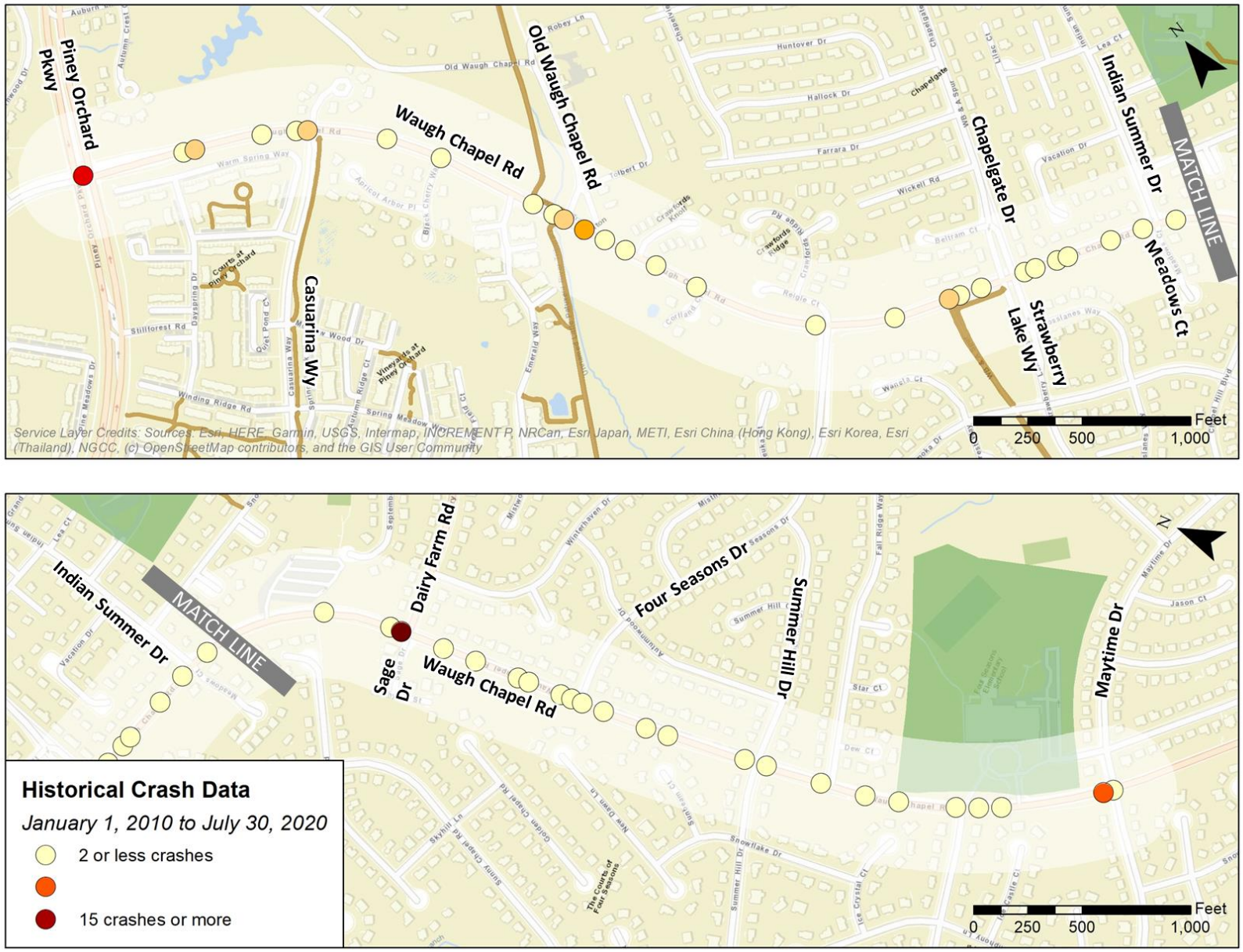


Figure 23: Historical Crash Data by Mile Marker

Figure 24: Collision Types along Waugh Chapel Road by 0.2-Mile Segments

Along the corridor, there were three total bicycle crashes, two between Indian Summer Drive and Strawberry Lake Way, and one by Maytime Drive. There were none located near the WB&A trail crossing, but this location had the highest number of fixed object crashes in the study area. The trail crossing consists of flexible posts and a median on Waugh Chapel Road to provide bicyclists and pedestrians a refuge island mid-crossing. **Figure 25** shows the refuge island.

Figure 25: WB&A Trail Crossing Refuge Island

Figure 26 through **Figure 31** summarize the overall crash trends by crash type, severity, peak period, day of week, light condition, and road condition. Overall, the most prevalent crash types were rear end crashes (49 percent), angle crashes (12 percent), and fixed object (11 percent). Out of the 151 crashes, 62 percent resulted in non-injuries. Majority of the crashes occurred during non-peak times (54 percent), during the day (70 percent), and on dry roadway conditions (79 percent). The raw crashes and detailed tables summarizing the crashes by year can be found in **Appendix E**.

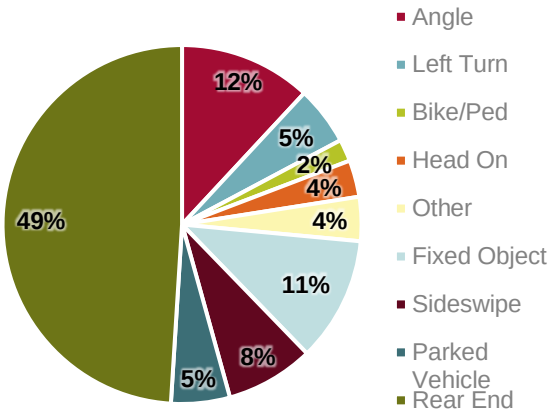


Figure 26: Overall Study Area Crash Types

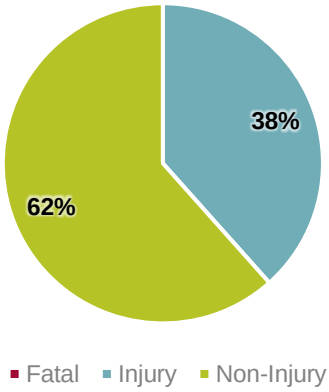


Figure 27: Overall Study Area Crash Severity

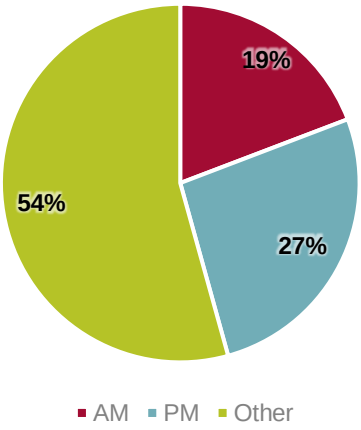


Figure 28: Overall Study Area Crash Peak Period

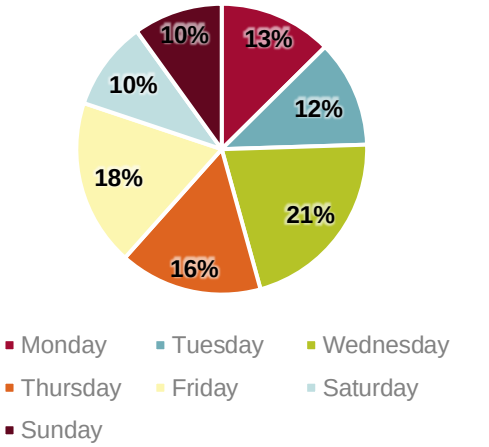


Figure 29: Overall Study Area Crash Day of Week

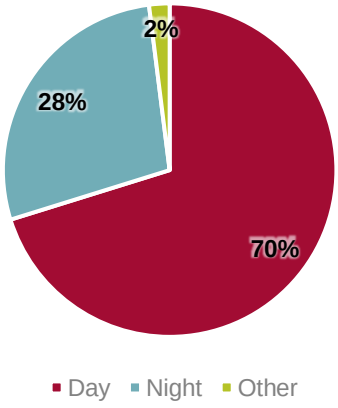


Figure 30: Overall Study Area Crash Light Conditions

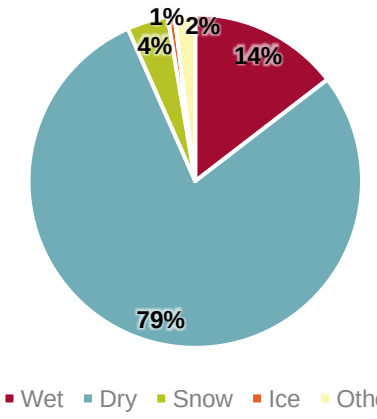


Figure 31: Overall Study Area Crash Road Condition

Chapter 7 Findings and Next Steps

SUMMARY OF FINDINGS

The following summarizes the key findings of the existing conditions analysis for the Waugh Chapel Road study corridor:

- The signalized study intersections along Waugh Chapel Road operate at level of service (LOS) E or worse for at least one of the AM or PM peak hours. For unsignalized and signalized intersections, traffic on the side streets experiences higher delays than the mainline traffic. The failing level of service may be influenced by the difficulty that the side street vehicles have in finding gaps to enter Waugh Chapel Road. The greatest delays were seen during the PM peak hour, where four unsignalized intersections and two signalized intersections experience LOS E or worse for intersection turning movements.
- Existing collected 2020 traffic volumes at all the unsignalized intersections do not meet the warrants for a traffic signal. Further study is needed for these intersections, post-COVID.
- Speeding in the corridor, based on the 85th percentile speeds, in conjunction with roadway horizontal and vertical alignments, may contribute to the challenges side street traffic experiences when trying to turn onto Waugh Chapel Road.
- Reported crashes along the corridor are centered around the intersections and driveways. Angle and rear end crashes were higher near the signalized intersections. The intersections with the greatest crashes were Strawberry Lake Way (27 crashes), Dairy Farm Road (18 crashes), and Piney Orchard Parkway (13 crashes). These crashes were recorded during a 10.5 -year period. During the most recent 5-year data, Strawberry Lake Way was the only study intersection to experience four or more crashes in a given year (2017 and 2019). Crash experience at this intersection will be reviewed as part of the next phase of the study.
- The study area's extent along Waugh Chapel Road has a full connected sidewalk facility running from Piney Orchard Parkway to Maytime Drive.
- Bicycle Lanes on Waugh Chapel Road between Piney Orchard Parkway and MD 3 were listed as a Tier II project in Anne Arundel County's 2013 Pedestrian and Bicycle Master Plan. The County records indicate that this is a "high stress" corridor for biking.

NEXT STEPS

Following the final existing conditions report, the study team will develop future volumes for the study corridor. The team will then work with the County and the community to develop evaluation metrics and begin to develop concepts for improvements to address deficiencies along the study corridor.

Appendix B

FUTURE NO-BUILD CONDITIONS REPORT

DRAFT May 2021

TRANSPORTATION FACILITY PLANNING

WAUGH CHAPEL ROAD
No-Build Conditions

Waugh Chapel Road from Maytime Drive to Piney Orchard Parkway
Project Number H539600 Contract No. H539617

prepared for:

ANNE ARUNDEL COUNTY MARYLAND

prepared by:

Kimley»Horn

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APPENDIX

Chapter 1 Future No-Build Conditions

This chapter documents the future (2045) traffic volume forecast and no-build conditions traffic operations analysis. The study team selected 2045 as the future analysis year to coincide with the Baltimore Metropolitan Council (BMC) Regional Travel Demand Model Version 44C, hereafter referred to as the BMC Model. The future traffic volumes will be used to identify future traffic operational issues and needs during weekday AM and PM peak hours. Findings from the no-build conditions analysis will provide a basis for developing improvement alternatives that could accommodate anticipated vehicular traffic growth while serving the multimodal needs along Waugh Chapel Road.

TRAFFIC FORECASTING

The study team obtained outputs from the BMC Model from Anne Arundel County, which included future year data from 2045 for the AM (6:30-9:30am), midday (9:30am-3:30pm), PM (3:30-6:30pm), and night (6:30pm-6:30am) peak hours. After reviewing the projected land use assignments and volumes within the model, the study team projected traffic growth rate(s) within the study corridor, including major crossing and parallel roadways. **Table 1** summarizes the daily and peak hour projected linear growth rates along Waugh Chapel Road. Growth rates for other segments and approaches within the study area are provided in **Appendix A**.

Table 1: Waugh Chapel Road Projected BMC Model Growth Rates

Peak Hour	AM (6:30-9:30am)	Mid-Day (9:30am-3:30pm)	PM (3:30-6:30pm)	Night (6:30pm-6:30am)	Daily
Growth Rate (2020-2045)	-0.9%	-0.2%	-0.6%	-0.3%	-0.5%

According to the BMC model, yearly volume projections were resulting in negative growth values from 2020-2045. Upon further review of the model, the study team determined that a large traffic analysis zone (TAZ) included centroid connectors to MD 3 and Waugh Chapel Road. MD 3 is improved in the 2045 scenario and has increased capacity, which attracts more traffic within the model. In lieu of performing extensive modeling work to update the model links and assignments, the projected growth rates for each TAZ surrounding the study area was reviewed to approximate the vehicular growth along Waugh Chapel Road. The study team worked with the Anne Arundel County Office of Transportation to determine an appropriate growth rate (0.25%), which considers minor changes in population, household, and employment growth within the area.

Kimley-Horn forecasted the existing intersection traffic volumes within the study area using the approved 0.25% annual traffic growth rate. Because there are no other known planned developments in the vicinity of the corridor, no additional background traffic was added to the future 2045 traffic volumes. **Figure 1** - **Figure 5** depict the existing (2020) and future (2045) ADT, AM and PM peak hour traffic volumes for each study intersection.

Figure 1. 2020 and 2045 Directional Average Daily Traffic (ADT)

Figure 2. 2020-2045 AM Peak Hour Traffic Volumes - View 1

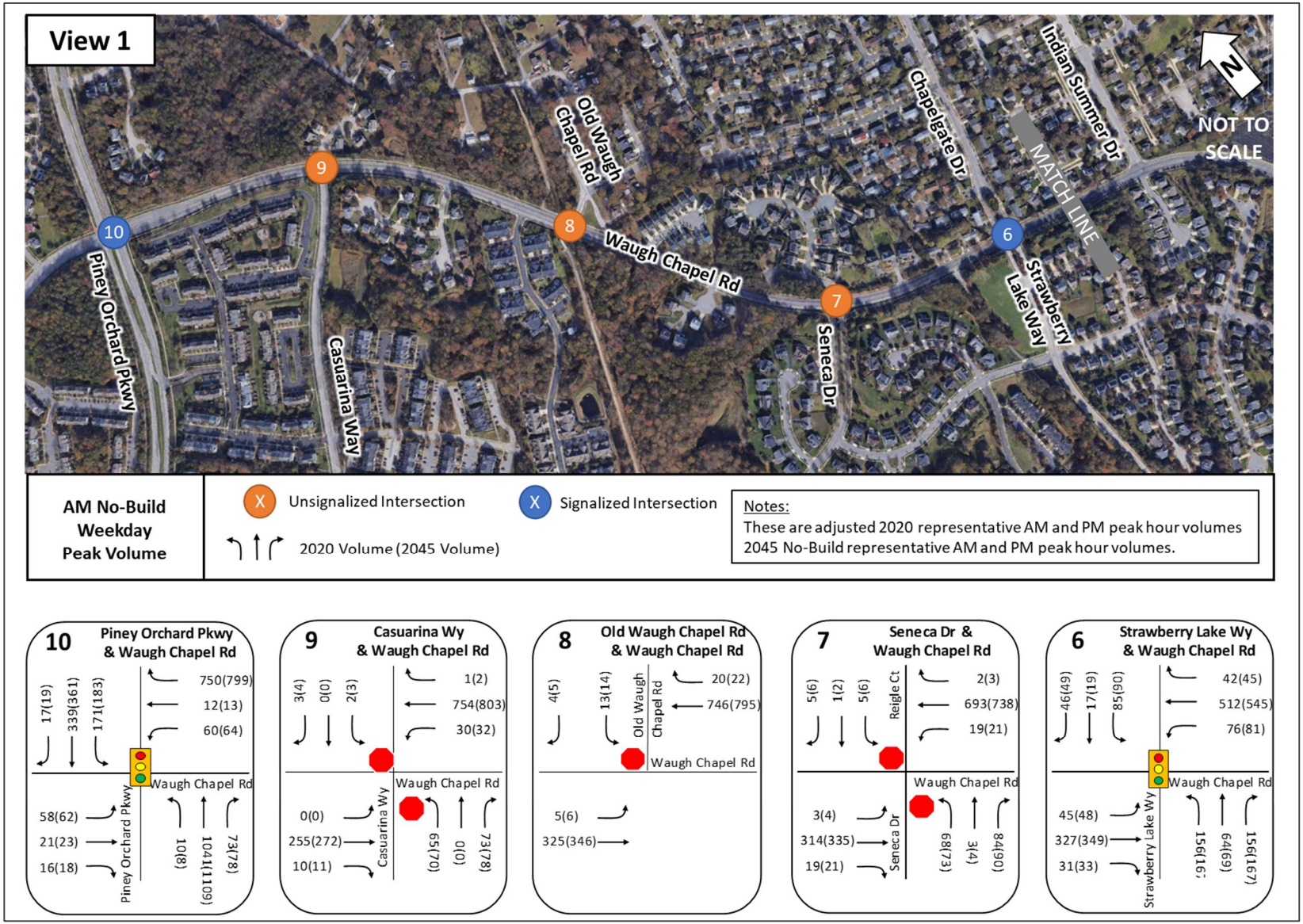


Figure 3. 2020-2045 AM Peak Hour Traffic Volumes - View 2

Figure 4. PM No-Build Weekday Peak Hour Volumes - View 1

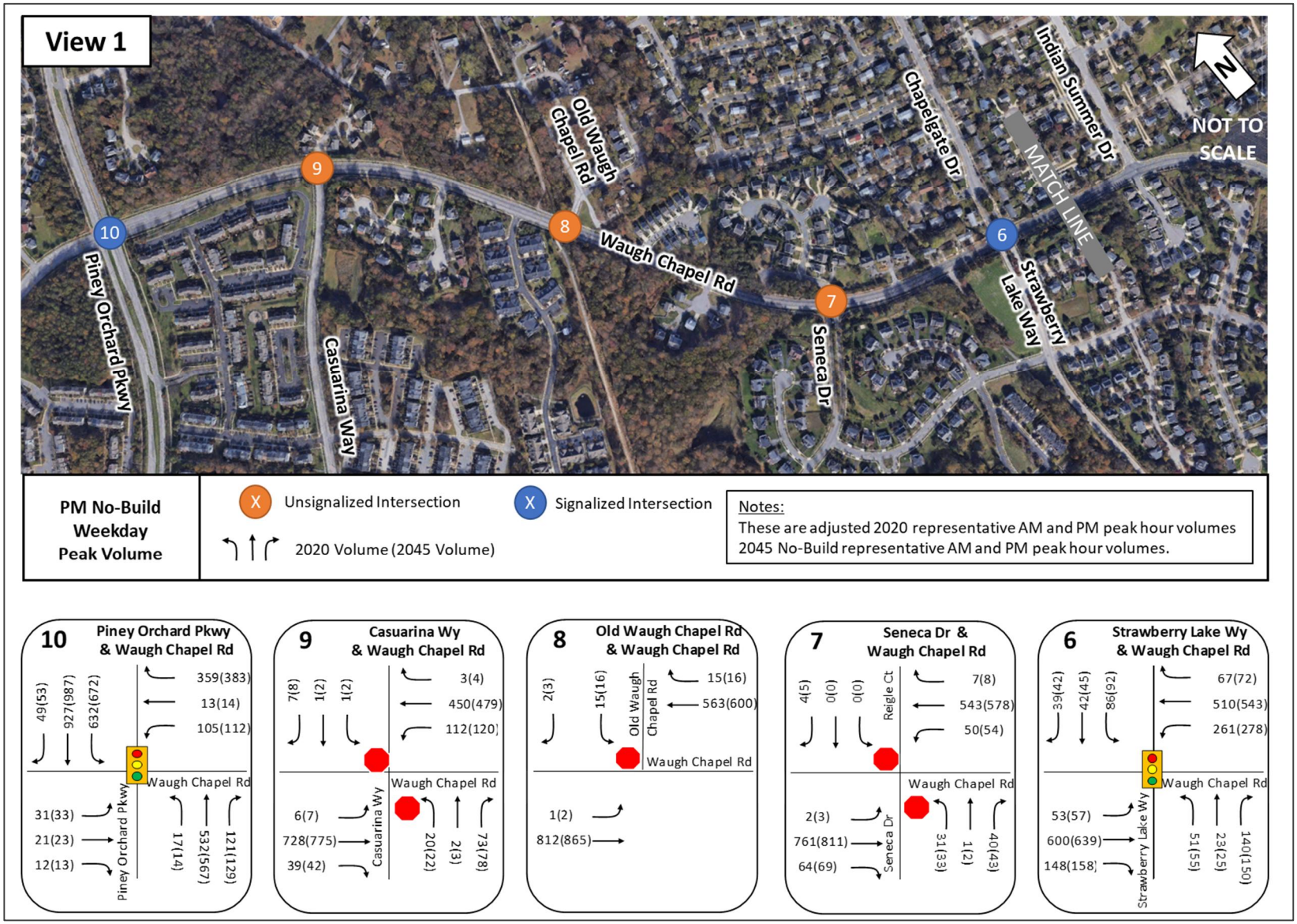


Figure 5. 2020-2045 PM Peak Hour Traffic Volumes - View 2

TRAFFIC OPERATIONAL ASSUMPTIONS AND RESULTS

The existing conditions AM and PM peak hour Synchro files were used as the basis to develop the no-build models. For each signalized study intersection, cycle lengths were assumed consistent with existing conditions, and traffic signal splits and offsets were optimized to accommodate growth along Waugh Chapel Road. Synchro HCM reports, which summarize signal timing parameters, delay, and LOS, and 95th percentile queue by movement, are provided in **Appendix B**.

Control Delay and Level of Service

The 2045 no-build conditions intersection delay and LOS are summarized in **Table 2** and depicted in **Figure 6** - **Figure 7**.

Table 2. No-Build (2045) Peak Hour Intersection Delay and LOS

Study Intersection with Waugh Chapel Road	Traffic Control	Weekday AM Peak Hour		Weekday PM Peak Hour	
		Delay (sec)	LOS	Delay (sec)	LOS
Piney Orchard Parkway	Signalized	71.8	**E**	28.4	C
Casuarina Way	Unsignalized*	41.5	**E**	59.7	**F**
Old Waugh Chapel Road	Unsignalized*	17.1	C	19.4	C
Seneca Drive	Unsignalized*	48.6	**E**	82.5	**F**
Strawberry Lake Way	Signalized	26.8	C	27.6	C
Indian Summer Drive	Unsignalized*	82.1	**F**	149.9	**F**
Dairy Farm Road	Signalized	20.2	C	24.3	C
Four Seasons Drive	Unsignalized*	17.0	C	27.1	D
Summer Hill Drive	Unsignalized*	54.8	**F**	272.1	**F**
Autumn Gold Drive	Unsignalized*	19.4	C	30.4	D

* Worst movement reported for unsignalized, stop-controlled intersections

Under no-build conditions, the following approaches experience delay increases larger than forty percent during at least one of the peak hours:

- **Waugh Chapel Road and Autumn Gold Drive:** The northbound approach delay increases by 46% during the PM peak hour.
- **Waugh Chapel Road and Summer Hill Drive:** The northbound and southbound approach delay increases by 72% and 50%, respectively, during the PM peak hour.
- **Waugh Chapel Road and Four Seasons Drive:** The eastbound approach delay increases 72% and 50%, respectively, during the PM peak hour.
- **Waugh Chapel Road and Dairy Farm Road:** The eastbound approach delay increases by 50% during the PM peak hour.

- **Waugh Chapel Road and Indian Summer Drive:** The southbound approach delay increases by 46% and 57% during the AM and PM peak hour, respectively.
- **Waugh Chapel Road and Seneca Drive:** The northbound approach delay increases by 41% and 50% during the AM and PM peak hour, respectively.
- **Waugh Chapel Road and Casuarina Way:** During the PM peak hour, the northbound and southbound approach delay increases by 48% and 50%, respectively.
- **Waugh Chapel Road and Piney Orchard Parkway:** During the AM peak hour, the westbound and northbound approach delay increases by 43% and 53%, respectively.

The following signalized intersection approaches experience decreases in delay, resulting from optimizing signal timing offsets and splits:

- **Waugh Chapel Road and Dairy Farm Road:** The westbound approach delay decreases by 4% during the AM peak hour.
- **Waugh Chapel Road and Strawberry Lake Way:** The eastbound approach delay decreases by 8% during the AM peak hour. The westbound approach delay decreases by 8% and 14% during the AM and PM peak hour, respectively.
- **Waugh Chapel Road and Piney Orchard Parkway:** The southbound approach delay decreases by 48% during the AM peak hour.

95th Percentile Queue Results

The 2045 no-build conditions 95th percentile queue for each approach is depicted in **Figure 8** - **Figure 9**. Under no-build conditions, the following unsignalized intersection side street approaches experience long queues (approximately three or more vehicles) during the AM and/or PM peak hours:

- Northbound Casuarina Way during the AM and PM peak hour
- Northbound Seneca Drive during the AM and PM peak hours
- Southbound Indian Summer Drive during the AM and PM peak hours
- Northbound Summer Hill Drive during the PM peak hour

The following signalized intersection approaches experience long queues and/or turn lane blockages:

- **Waugh Chapel Road and Dairy Farm Road:** During the AM and PM peak hours, the westbound queue blocks the left-turn and right-turn lanes, and the southbound queue blocks the right-turn lane.
- **Waugh Chapel Road and Strawberry Lake Way:** During the AM and PM peak hours, the eastbound and westbound queues block the left-turn and right-turn lanes.
- **Waugh Chapel Road and Piney Orchard Parkway:** During the AM and PM peak hours, the westbound and northbound queues exceed capacity

Figure 6. 2045 No-Build Peak Hour Approach Delay and LOS - View 1

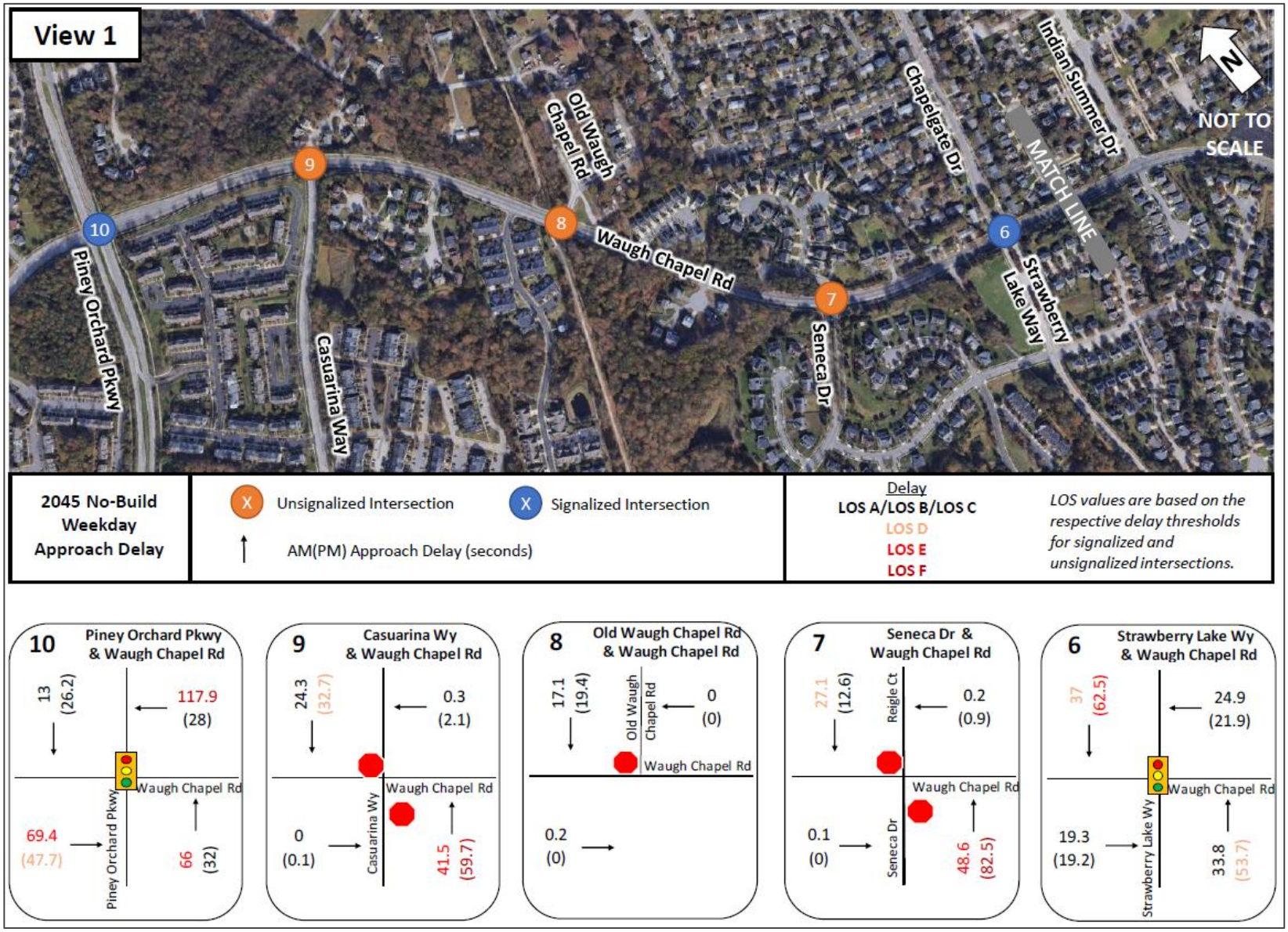


Figure 7. 2045 No-Build Peak Hour Approach Delay and LOS - View 2

Figure 8. 2045 No-Build Peak Hour 95th Percentile Queue - View 1

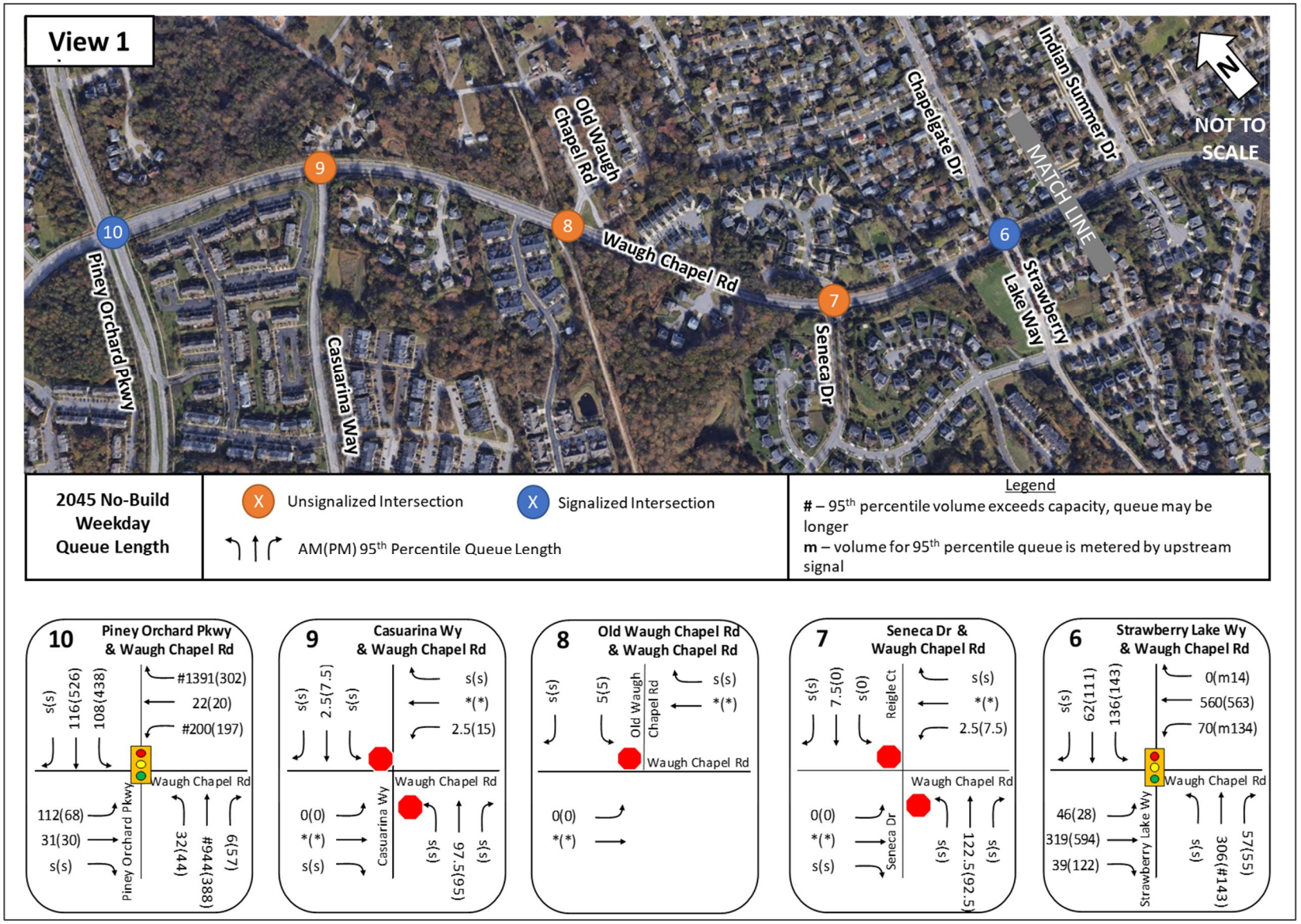


Figure 9. 2045 No-Build Peak Hour 95th Percentile Queue - View 2

Chapter 2 Purpose and Need Statement

Based on the existing and no-build conditions analyses, the study team identified the need to develop viable and cost-effective improvements to address traffic operations and heightened crash risk, while retaining the multimodal needs of the Waugh Chapel Road corridor. The purpose and need statement provides a basis for developing, screening, and analyzing alternative improvement concepts. The study team identified the need to improve the following:

- To improve access for side street traffic at intersections that experience excessive delay and heightened crash risk
- To reduce crash risk for all modes of transportation at the intersections
- To provide LOS D or better for vehicular traffic at study intersections in 2045 by improving operations, without adding through lanes to the Waugh Chapel Road mainline
- To improve queuing and reduce turn lane blockages
- To address geometric deficiencies at intersections and in mid-block areas that present difficulty in crossing or merging with traffic.
- To provide a dedicated route for bicyclists and improve the level of traffic stress (LTS) along the length of Waugh Chapel Road
- To reduce crash risk for pedestrians and bicyclists crossing at intersections

Appendix C

MARYLAND MUTCD SIGNAL WARRANT ANALYSIS

15-Min Total Intersection Volume Starting with Corresponding 15-Min Interval														
Start Time	**Casuarina Way**		**Old Waugh Chapel**		**Seneca Drive**		**Indian Summer**		**Four Seasons Drive**		**Summer Hill Drive**		**Autumn Gold Drive**	
Direction and Street	**Both Major**	**Max Minor**	**Both Major**	**Max Minor**	**Both Major**	**Max Minor**	**Both Major**	**Max Minor**	**Both Major**	**Max Minor**	**Both Major**	**Max Minor**	**Both Major**	**Max Minor**
6:00 AM	53	9	59	1	55	1	59	3	54	1	53	3	52	1
6:15 AM	82	7	88	1	80	1	75	6	78	1	81	1	76	8
6:30 AM	107	13	115	1	107	1	104	8	116	0	108	4	102	10
6:45 AM	121	20	127	1	109	1	119	8	118	4	123	2	118	4
7:00 AM	123	11	130	1	125	1	148	5	134	2	129	2	126	6
7:15 AM	132	24	132	2	129	2	143	12	127	2	131	3	137	5
7:30 AM	171	17	177	2	162	2	200	6	192	4	192	5	188	13
7:45 AM	184	22	196	2	191	2	212	9	225	3	226	6	222	10
8:00 AM	180	16	181	4	180	4	201	15	235	2	228	6	223	10
8:15 AM	173	24	192	2	188	2	217	5	215	3	215	6	212	7
8:30 AM	162	24	181	5	185	5	221	9	227	2	223	3	232	7
8:45 AM	146	21	154	4	146	4	187	12	195	2	190	5	194	5
9:00 AM	140	13	148	2	143	2	171	3	164	1	169	0	171	4
9:15 AM	133	8	137	0	137	0	169	11	166	3	166	0	161	2
9:30 AM	119	15	127	3	120	3	170	5	162	3	157	3	158	3
9:45 AM	92	16	105	1	106	1	148	7	145	3	156	1	148	4
10:00 AM	125	10	132	3	136	3	172	4	162	2	171	3	171	5
10:15 AM	107	8	113	1	119	1	145	8	161	2	155	5	163	2
10:30 AM	126	11	127	2	130	2	167	9	182	3	181	4	175	3
10:45 AM	133	12	148	1	147	1	190	3	176	4	177	2	178	4
11:00 AM	140	9	140	4	135	4	173	15	182	3	193	3	199	3
11:15 AM	145	15	156	2	159	2	209	3	211	2	219	6	217	7
11:30 AM	168	11	178	2	166	2	216	9	229	2	228	5	239	6
11:45 AM	190	10	191	3	190	3	251	7	264	1	261	2	269	5
12:00 PM	169	21	188	2	199	2	258	13	277	4	280	4	291	8
12:15 PM	192	15	185	3	192	3	251	11	276	5	287	5	291	6
12:30 PM	179	18	185	3	186	3	244	9	253	0	245	6	247	2
12:45 PM	197	19	205	5	211	5	260	11	271	4	288	4	299	7
1:00 PM	169	19	183	3	178	3	242	6	266	4	260	4	268	4
1:15 PM	184	16	198	2	216	2	283	6	291	4	288	6	291	1
1:30 PM	163	17	169	3	168	3	223	8	248	0	237	6	253	5
1:45 PM	168	12	182	3	177	3	223	10	243	4	255	2	249	8
2:00 PM	208	9	203	1	213	1	220	5	237	4	246	1	248	3
2:15 PM	194	18	206	3	208	3	284	6	295	3	274	5	282	1
2:30 PM	210	16	215	2	207	2	252	6	252	3	270	3	275	3
2:45 PM	224	19	231	2	242	2	286	2	317	5	307	4	313	4
3:00 PM	217	15	221	2	224	2	275	4	268	5	271	6	276	2
3:15 PM	221	18	226	3	229	3	261	10	288	2	288	0	285	2
3:30 PM	239	19	247	8	244	8	301	11	290	1	299	3	276	11
3:45 PM	242	22	262	3	263	3	326	13	341	1	351	5	341	4
4:00 PM	252	17	263	4	257	4	320	14	342	1	331	1	326	3
4:15 PM	272	15	269	5	279	5	303	12	302	1	309	4	300	3
4:30 PM	225	22	243	1	237	1	294	6	330	2	324	5	338	5
4:45 PM	268	21	277	1	279	1	310	8	298	2	314	5	316	9
5:00 PM	269	23	264	1	277	1	315	16	349	4	345	4	351	7
5:15 PM	220	18	230	1	228	1	302	12	324	5	349	6	375	12
5:30 PM	234	16	238	6	246	6	287	16	244	5	293	12	296	6
5:45 PM	257	13	256	2	257	2	360	3	369	1	346	6	333	9
6:00 PM	215	16	219	4	227	4	282	9	275	7	287	4	286	2
6:15 PM	185	9	186	5	195	5	258	9	248	1	257	1	264	5
6:30 PM	194	16	200	3	197	3	252	6	266	0	272	3	273	3
6:45 PM	159	9	170	0	167	0	203	6	226	4	225	3	233	4
Total 13 hr Volume	**9178**	**814**	**9555**	**131**	**9548**	**131**	**11742**	**430**	**12106**	**137**	**12230**	**198**	**12307**	**273**
Average Volume per Hour	**706**	**63**	**735**	**10**	**734**	**10**	**903**	**33**	**931**	**11**	**941**	**15**	**947**	**21**

Signal Warrant Analysis was based on the collected November 2020 Data. It is recommended traffic counts to be re-collected in the future when traffic conditions return to normal.

Warrant 1: Eight-Hour Vehicular Volume														
Condition A: 100%	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
Condition A: 80%	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
Condition A: 70%	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
Condition A: 56%	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
Condition B: 100%	N	N	N	N	N	N	Y	N	Y	N	Y	N	Y	N
Condition B: 80%	Y	Y	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
Condition B: 70%	Y	Y	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
Condition B: 56%	Y	Y	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
Meet Signal Warrant?	**Condition B (80%)**		No		No		No		No		No		No	

Warrant 2: Four-Hour Vehicular Volume	N minor street volumes too low	N minor street volumes too low	N minor street volumes too low	N minor street volumes too low	N minor street volumes too low	N minor street volumes too low	N minor street volumes too low
Warrant 3: Peak Hour	N minor street volumes too low	N minor street volumes too low	N minor street volumes too low	N minor street volumes too low	N minor street volumes too low	N minor street volumes too low	N minor street volumes too low
Warrant 4: Pedestrian Volume	N Pedestrian volumes too low	N Pedestrian volumes too low	N Pedestrian volumes too low	N Pedestrian volumes too low	N Pedestrian volumes too low	N Pedestrian volumes too low	N Pedestrian volumes too low
Warrant 5: School Crossing	November 2020 volumes were inconclusive due to schools not operating on normal schedules						
Warrant 6: Coordinated Signal System	November 2020 volumes were inconclusive due to signal timings not operating on normal schedules						
Warrant 7: Crash Experience	N less than five crashes reported at intersection a	N less than five crashes reported at intersection a	N less than five crashes reported at intersection a	N less than five crashes reported at intersection a	N less than five crashes reported at intersection a	N less than five crashes reported at intersection a	N less than five crashes reported at intersection a
Warrant 8: Roadway Network	N with a 0.25% yearly increase, projected volumes do not meet threshold	N with a 0.25% yearly increase, projected volumes do not meet threshold	N with a 0.25% yearly increase, projected volumes do not meet threshold	N with a 0.25% yearly increase, projected volumes do not meet threshold	N with a 0.25% yearly increase, projected volumes do not meet threshold	N with a 0.25% yearly increase, projected volumes do not meet threshold	N with a 0.25% yearly increase, projected volumes do not meet threshold

Appendix D

CONCEPT SCREENING MATRIX

Transportation Facility Planning Waugh Chapel Road Phase 2 Alternatives Screening Matrix

	Alternatives		Safety for All Users				Connectivity			Roadway				Total Score	Rank
			Reduce Vehicular-Vehicular Conflicts	Reduce Vehicular-Bike/Ped Conflicts	Speed Management	Lighting	Bike Access and Crossing	Pedestrian Access and Crossing	Ease of Access to/from Side Streets	Streetscape	R/W and Utility Relocation	Ease of Implementation	Level of Service along Waugh Chapel Road		
	Category Weighting		*5*	*5*	*5*	*5*	*4*	*4*	*3*	*2*	*2*	*2*	*1*		
			Effect	Effect	Effect	Effect	Effect	Effect	Effect	Effect	Effect	Effect	Effect		
Study Intersections															
10. Piney Orchard Parkway and Waugh Chapel Road (Signalized)	Alternative A	No-Build	0	0	0	0	0	0	0	0	0	+	0	20.0	5.0
			2.5	*2.5*	*2.5*	*2.5*	*2.0*	*2.0*	*1.5*	*1.0*	*1.0*	*2.0*	*0.5*		
	Alternative B	Turn Lane Improvements (Dual WBR)	0	+	0	0	+	+	+	0	0	0	+	27.5	4.0
			2.5	*5.0*	*2.5*	*2.5*	*4.0*	*4.0*	*3.0*	*1.0*	*1.0*	*1.0*	*1.0*		
	Alternative C	Restrict Through Movements	+	+	0	0	+	+	+	0	0	-	+	29.0	2.0
			5.0	*5.0*	*2.5*	*2.5*	*4.0*	*4.0*	*3.0*	*1.0*	*1.0*	*0.0*	*1.0*		
	Alternative D	Restrict Left-Turn and Through Movements	+	+	0	0	+	+	+	0	0	-	+	29.0	2.0
			5.0	*5.0*	*2.5*	*2.5*	*4.0*	*4.0*	*3.0*	*1.0*	*1.0*	*0.0*	*1.0*		
	Alternative E	Roundabout	+	+	+	0	+	+	+	0	-	-	+	30.5	1.0
			5.0	*5.0*	*5.0*	*2.5*	*4.0*	*4.0*	*3.0*	*1.0*	*0.0*	*0.0*	*1.0*		
8. Old Waugh Chapel Road and Waugh Chapel Road (Unsignalized)	Alternative A	No-Build	0	0	0	0	0	0	0	0	0	+	0	20.0	2.0
			2.5	*2.5*	*2.5*	*2.5*	*2.0*	*2.0*	*1.5*	*1.0*	*1.0*	*2.0*	*0.5*		
	Alternative B	Left-Turn Acceleration Lane	+	0	+	0	0	0	+	0	0	+	0	26.5	1.0
			5.0	*2.5*	*5.0*	*2.5*	*2.0*	*2.0*	*3.0*	*1.0*	*1.0*	*2.0*	*0.5*		
	Alternative C	Roundabout	+	+	+	0	+	+	+	0	-	-	-	29.5	1.0
			5.0	*5.0*	*5.0*	*2.5*	*4.0*	*4.0*	*3.0*	*1.0*	*0.0*	*0.0*	*0.0*		
7. Seneca Drive and Waugh Chapel Road (Unsignalized)	Alternative A	No-Build	0	0	0	0	0	0	0	0	0	+	0	20.0	2.0
			2.5	*2.5*	*2.5*	*2.5*	*2.0*	*2.0*	*1.5*	*1.0*	*1.0*	*2.0*	*0.5*		
	Alternative B	Roundabout	+	+	+	0	+	+	+	0	-	-	-	29.5	1.0
			5.0	*5.0*	*5.0*	*2.5*	*4.0*	*4.0*	*3.0*	*1.0*	*0.0*	*0.0*	*0.0*		
6. Strawberry Lake Way and Waugh Chapel Road (Signalized)	Alternative A	No-Build	0	0	0	0	0	0	0	0	0	+	0	20.0	3.0
			2.5	*2.5*	*2.5*	*2.5*	*2.0*	*2.0*	*1.5*	*1.0*	*1.0*	*2.0*	*0.5*		
	Alternative B	Signal Timing Improvements	0	+	0	0	+	+	+	0	0	0	0	27.0	2.0
			2.50	*5.00*	*2.50*	*2.50*	*4.00*	*4.00*	*3.00*	*1.00*	*1.00*	*1.00*	*0.50*		
	Alternative C	Turn Lane Improvements	0	0	0	0	0	0	+	-	-	-	0	17.5	4.0
			2.5	*2.5*	*2.5*	*2.5*	*2.0*	*2.0*	*3.0*	*0.0*	*0.0*	*0.0*	*0.5*		
	Alternative D	Roundabout	+	+	+	0	+	+	+	0	-	-	-	29.5	1.0
			5.0	*5.0*	*5.0*	*2.5*	*4.0*	*4.0*	*3.0*	*1.0*	*0.0*	*0.0*	*0.0*		
4. Dairy Farm Road and Waugh Chapel Road (Signalized)	Alternative A	No-Build	0	0	0	0	0	0	0	0	0	+	0	20.0	2.0
			2.5	*2.5*	*2.5*	*2.5*	*2.0*	*2.0*	*1.5*	*1.0*	*1.0*	*2.0*	*0.5*		
	Alternative B	Signal Timing Improvements (Adjust Splits)	0	0	0	0	0	0	+	0	0	0	-	20.0	2.0
			2.5	*2.5*	*2.5*	*2.5*	*2.0*	*2.0*	*3.0*	*1.0*	*1.0*	*1.0*	*0.0*		
	Alternative C	Turn Lane Modifications	0	0	0	0	0	0	+	0	0	-	0	19.5	3.0
			2.5	*2.5*	*2.5*	*2.5*	*2.0*	*2.0*	*3.0*	*1.0*	*1.0*	*0.0*	*0.5*		
	Alternative D	Restrict Sage Drive Through Movements	+	+	+	0	+	+	+	0	0	0	-	31.5	1.0
			5.0	*5.0*	*5.0*	*2.5*	*4.0*	*4.0*	*3.0*	*1.0*	*1.0*	*1.0*	*0.0*		
	Alternative E	Turn Lane Extensions	0	-	0	0	-	-	+	0	0	-	-	12.5	4.0
			2.5	*0.0*	*2.5*	*2.5*	*0.0*	*0.0*	*3.0*	*1.0*	*1.0*	*0.0*	*0.0*		
	Alternative F	Roundabout	+	+	+	0	+	+	+	0	-	-	+	30.5	2.0
			5.0	*5.0*	*5.0*	*2.5*	*4.0*	*4.0*	*3.0*	*1.0*	*0.0*	*0.0*	*1.0*		
1. Autumn Gold Drive and Waugh Chapel Road (Unsignalized)	Alternative A	No-Build	0	0	0	0	0	0	0	0	0	+	0	20.0	2.0
			2.5	*2.5*	*2.5*	*2.5*	*2.0*	*2.0*	*1.5*	*1.0*	*1.0*	*2.0*	*0.5*		
	Alternative B	Left-Turn Acceleration Lane	+	0	+	0	0	0	+	0	0	+	0	26.5	1.0
			5.0	*2.5*	*5.0*	*2.5*	*2.0*	*2.0*	*3.0*	*1.0*	*1.0*	*2.0*	*0.5*		
	Alternative C	Roundabout	+	+	+	0	+	+	+	0	-	-	-	29.5	1.0
			5.0	*5.0*	*5.0*	*2.5*	*4.0*	*4.0*	*3.0*	*1.0*	*0.0*	*0.0*	*0.0*		

Appendix E

PREFERRED CORRIDOR RECOMMENDATIONS

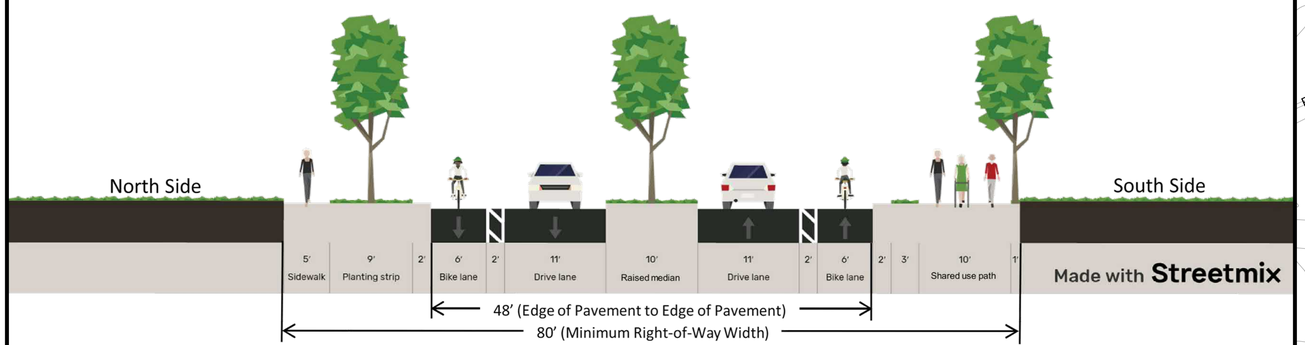
LEGEND

- SIGNALIZED INTERSECTION
- PROPERTY LINE
- SHARED USE PATH
- RAISED MEDIAN

NORTH

GRAPHIC SCALE IN FEET
0 25 50 100

CROSS SECTION



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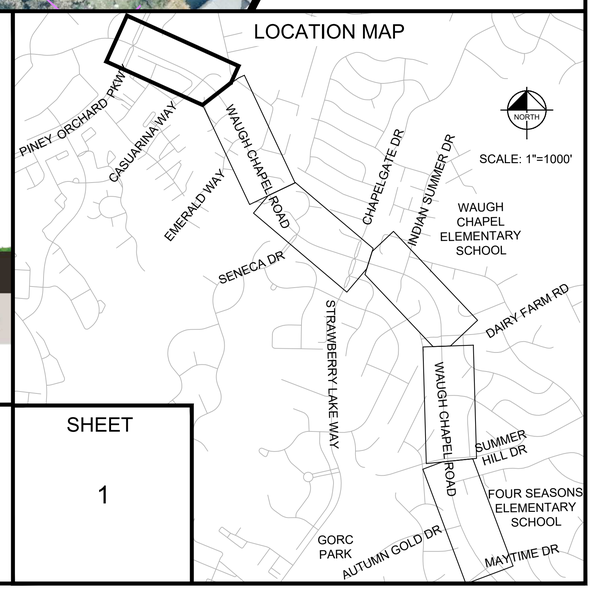


ANNE ARUNDEL COUNTY MARYLAND

Kimley»Horn

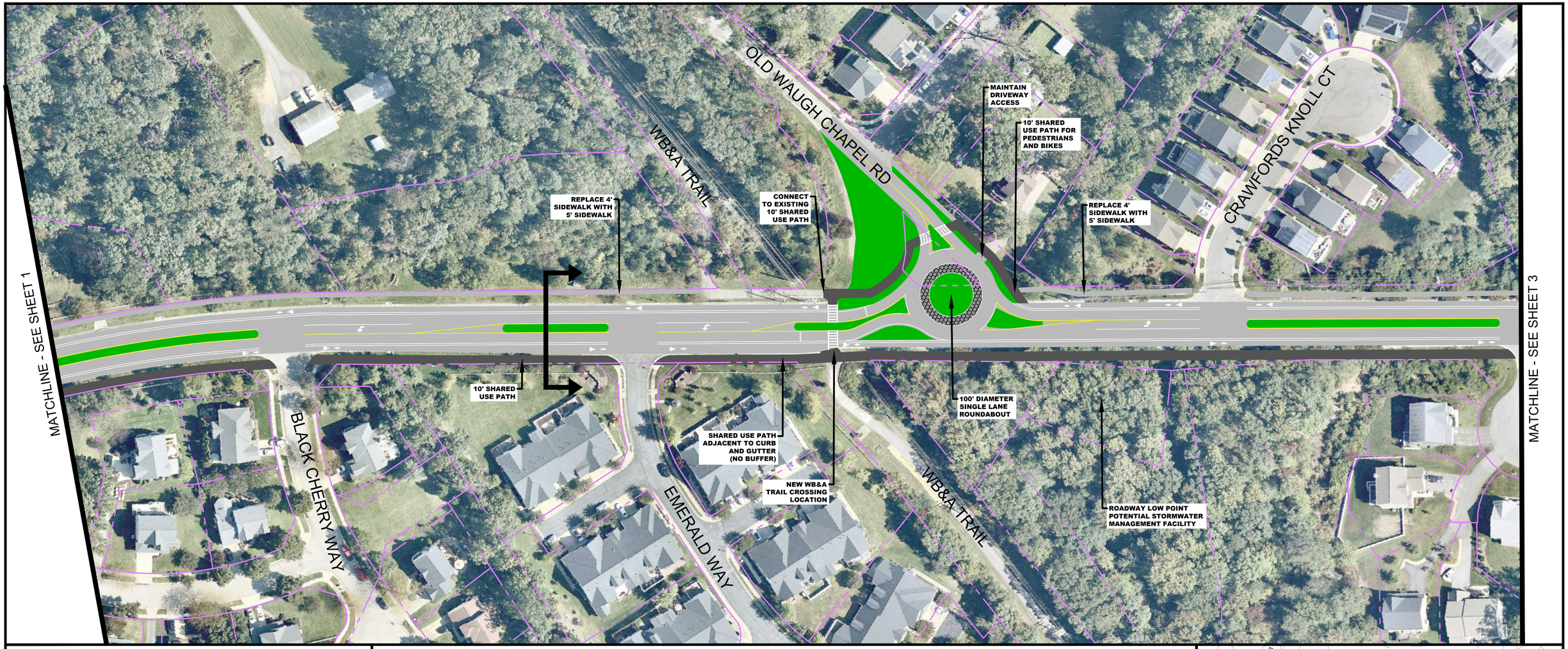
WAUGH CHAPEL ROAD

PINEY ORCHARD PARKWAY TO MAYTIME DRIVE

PREFERRED CORRIDOR RECOMMENDATIONS

SHEET

1



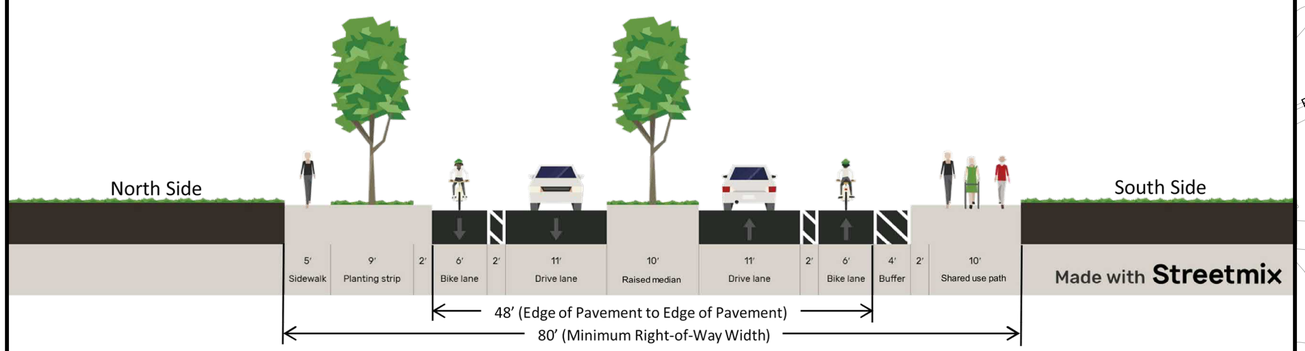
LEGEND

- SIGNALIZED INTERSECTION
- PROPERTY LINE
- SHARED USE PATH
- RAISED MEDIAN

NORTH

GRAPHIC SCALE IN FEET
0 25 50 100

CROSS SECTION



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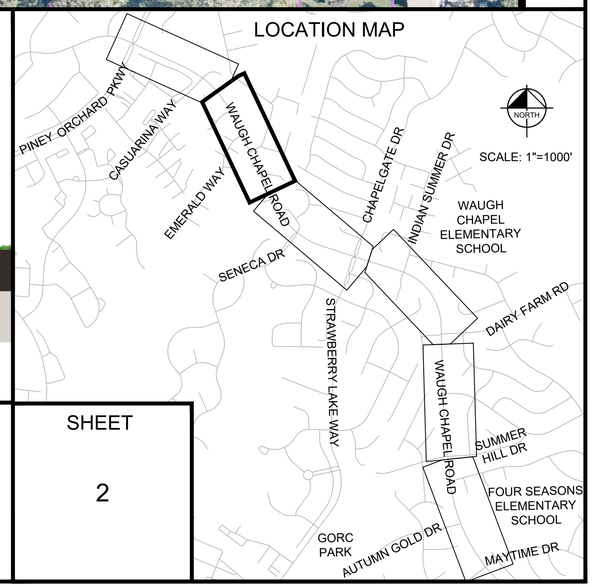


ANNE ARUNDEL COUNTY MARYLAND

Kimley»Horn

WAUGH CHAPEL ROAD

PINEY ORCHARD PARKWAY TO MAYTIME DRIVE

PREFERRED CORRIDOR RECOMMENDATIONS

SHEET

2

MATCHLINE - SEE SHEET 2

MATCHLINE - SEE SHEET 4

CORTLAND CT

REIGLE CT

CHAPEL-GATE DR

STRAWBERRY LAKE WAY

SENECA DR

EXISTING GRADE MAY MAKE ROUNDABOUT CONNECTION CHALLENGING

10' SHARED USE PATH FOR PEDESTRIANS AND BIKES

REPLACE 4' SIDEWALK WITH 5' SIDEWALK

EXISTING SHARED USE PATH

10' SHARED USE PATH

EXISTING STRAWBERRY LAKE WAY TRAIL

100' DIAMETER SINGLE LANE ROUNDABOUT

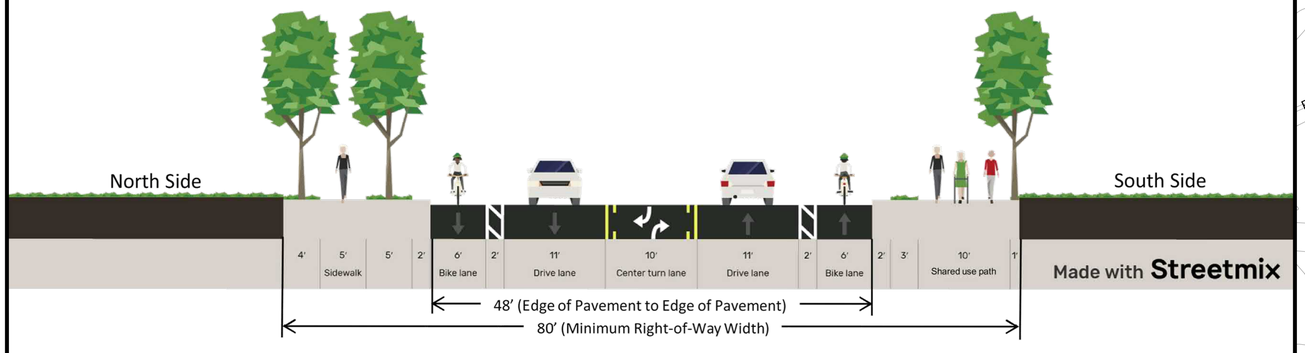
LEGEND

- SIGNALIZED INTERSECTION
- PROPERTY LINE
- SHARED USE PATH
- RAISED MEDIAN

NORTH

GRAPHIC SCALE IN FEET
0 25 50 100

CROSS SECTION



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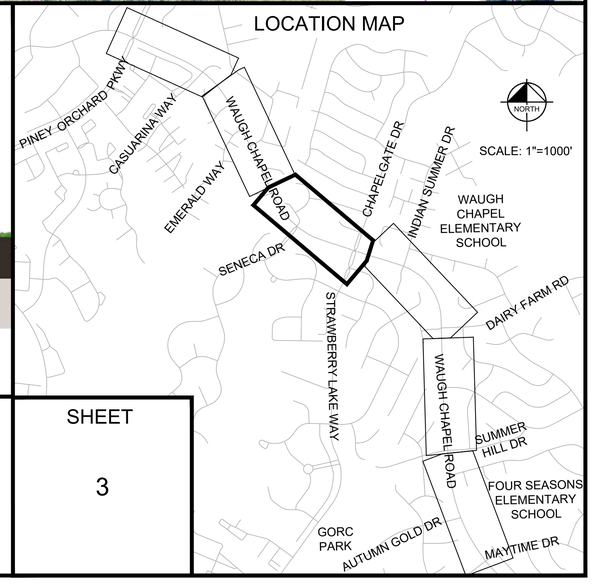


ANNE ARUNDEL COUNTY MARYLAND

Kimley»Horn

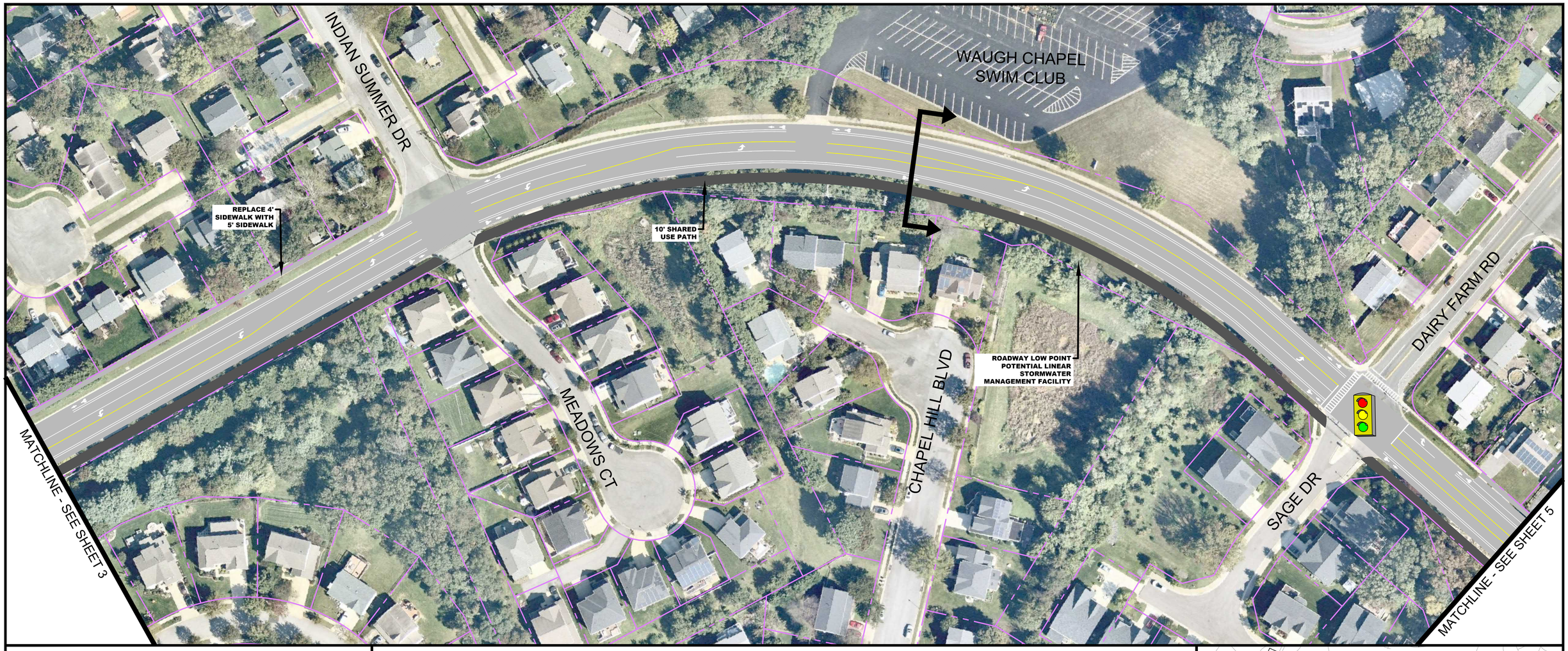
WAUGH CHAPEL ROAD

PINEY ORCHARD PARKWAY TO MAYTIME DRIVE

PREFERRED CORRIDOR RECOMMENDATIONS

SHEET

3



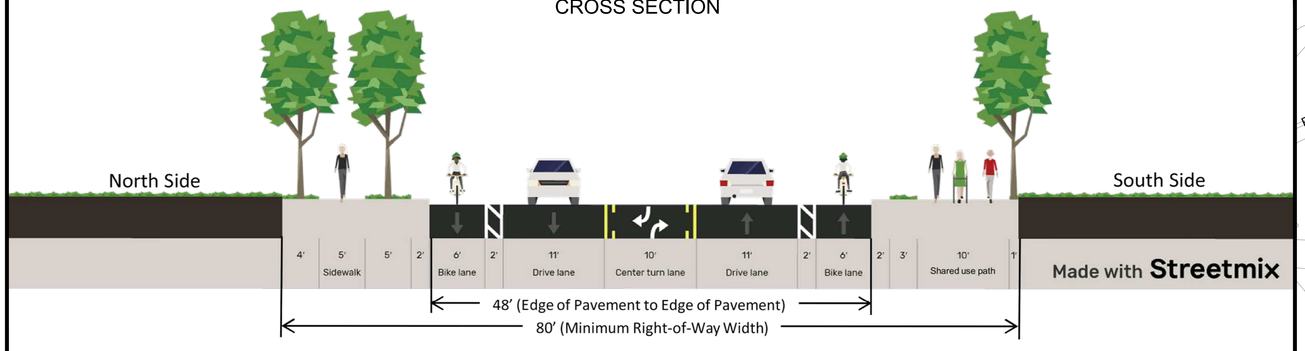
LEGEND

- SIGNALIZED INTERSECTION
- PROPERTY LINE
- SHARED USE PATH
- RAISED MEDIAN

NORTH

GRAPHIC SCALE IN FEET
0 25 50 100

CROSS SECTION



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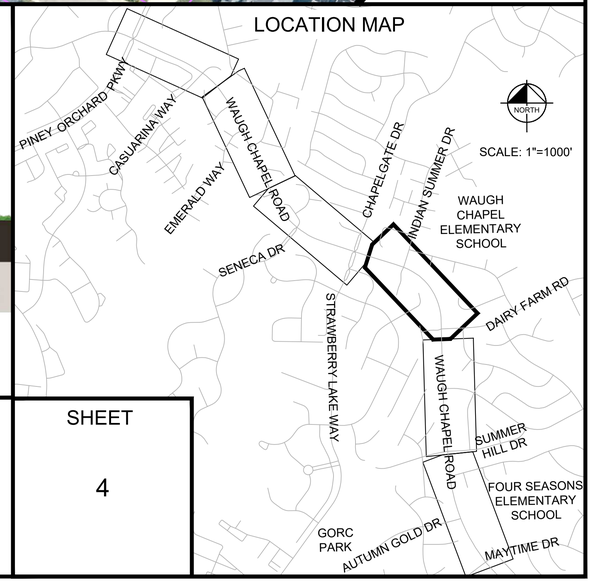


ANNE ARUNDEL COUNTY MARYLAND

Kimley»Horn

WAUGH CHAPEL ROAD

PINEY ORCHARD PARKWAY TO MAYTIME DRIVE

PREFERRED CORRIDOR RECOMMENDATIONS

SHEET

4

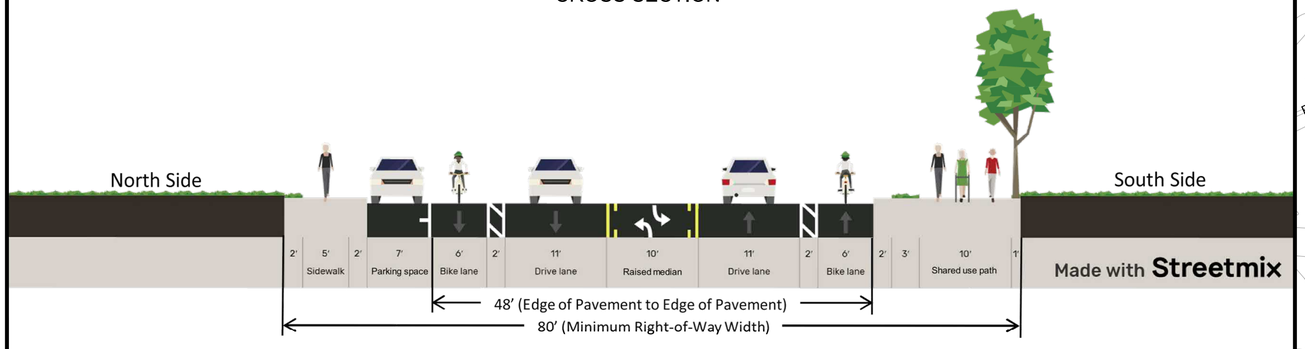
LEGEND

- SIGNALIZED INTERSECTION
- PROPERTY LINE
- SHARED USE PATH
- RAISED MEDIAN

NORTH

GRAPHIC SCALE IN FEET
0 25 50 100

CROSS SECTION



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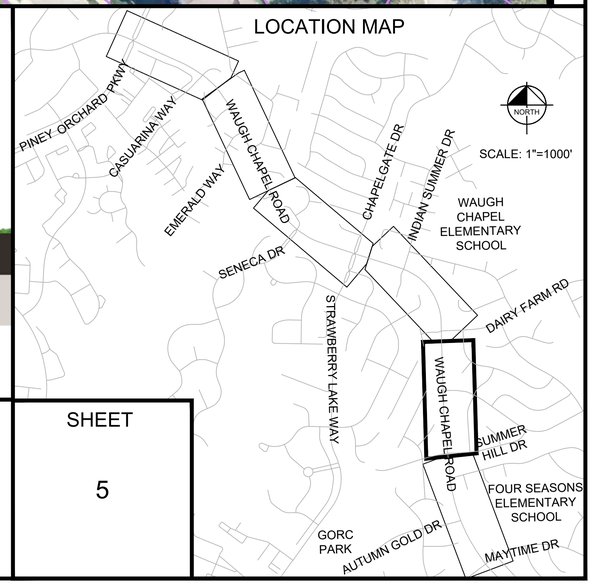


ANNE ARUNDEL COUNTY MARYLAND

Kimley»Horn

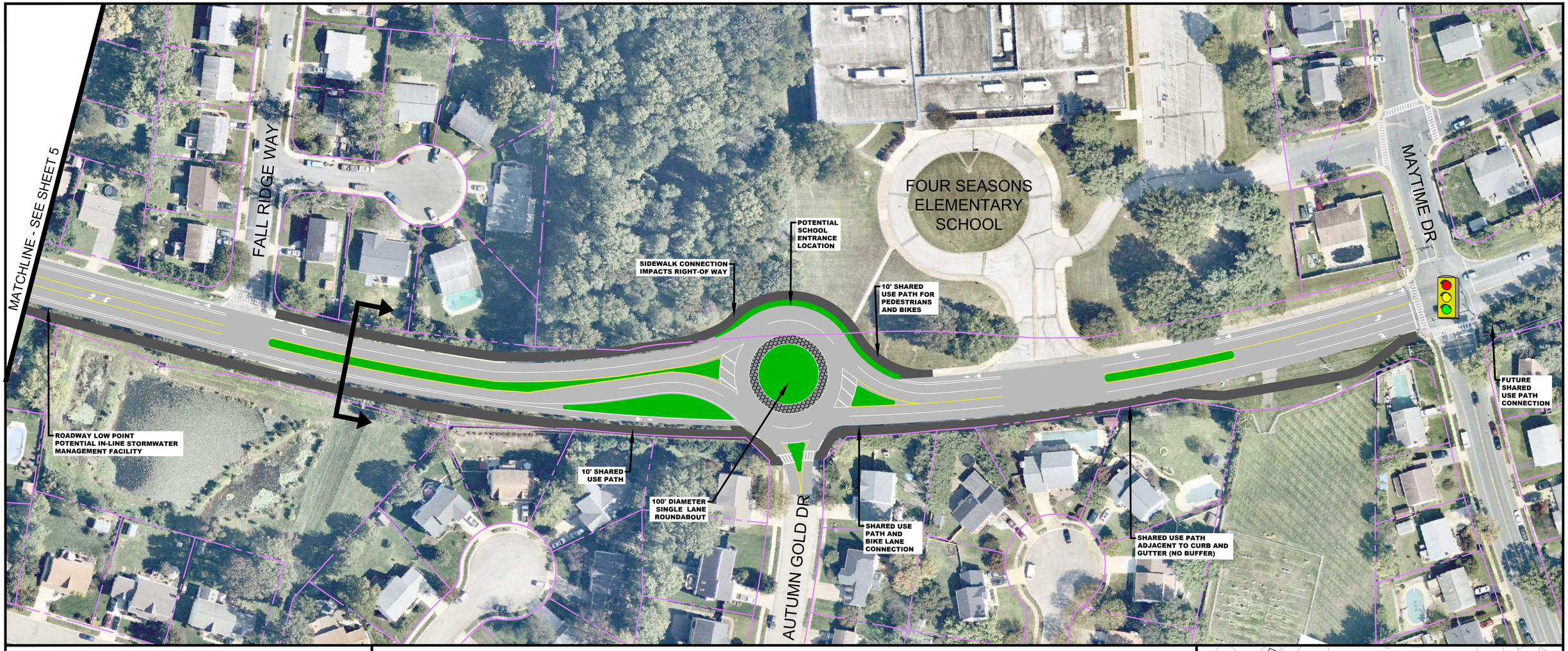
WAUGH CHAPEL ROAD

PINEY ORCHARD PARKWAY TO MAYTIME DRIVE

PREFERRED CORRIDOR RECOMMENDATIONS

SHEET

5



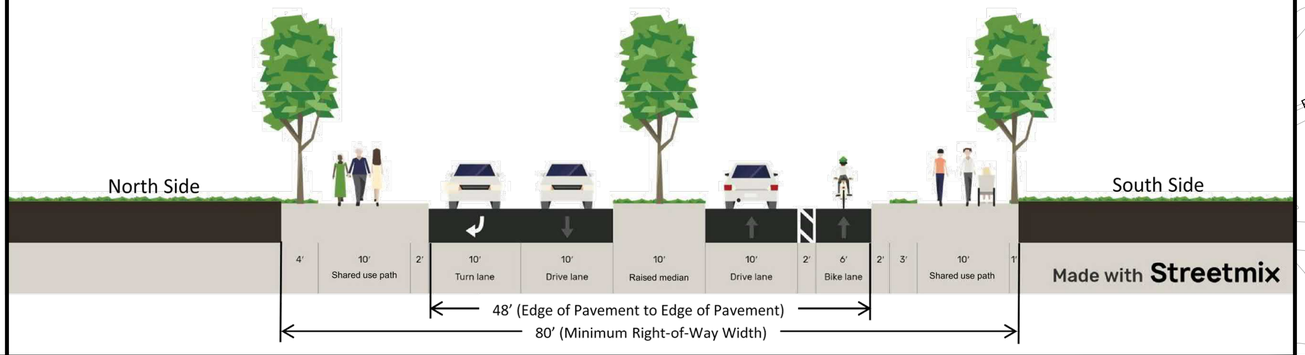
LEGEND

- SIGNALIZED INTERSECTION
- PROPERTY LINE
- SHARED USE PATH
- RAISED MEDIAN

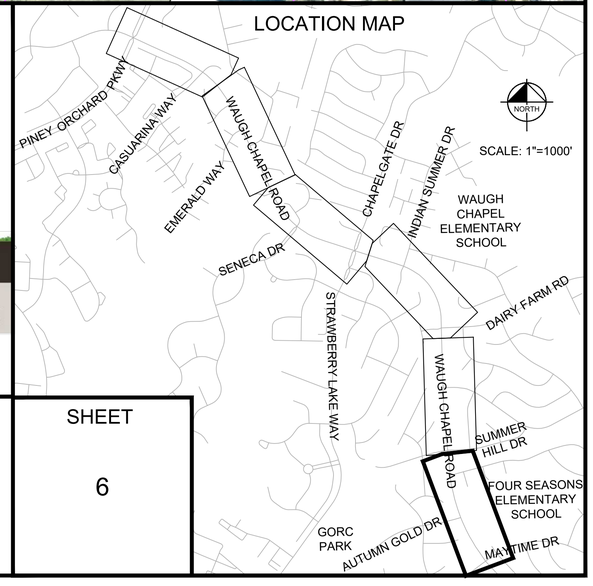
NORTH

GRAPHIC SCALE IN FEET
0 25 50 100

CROSS SECTION



LOCATION MAP



ANNE ARUNDEL COUNTY MARYLAND

Kimley»Horn

WAUGH CHAPEL ROAD

PINEY ORCHARD PARKWAY TO MAYTIME DRIVE

PREFERRED CORRIDOR RECOMMENDATIONS

SHEET

6

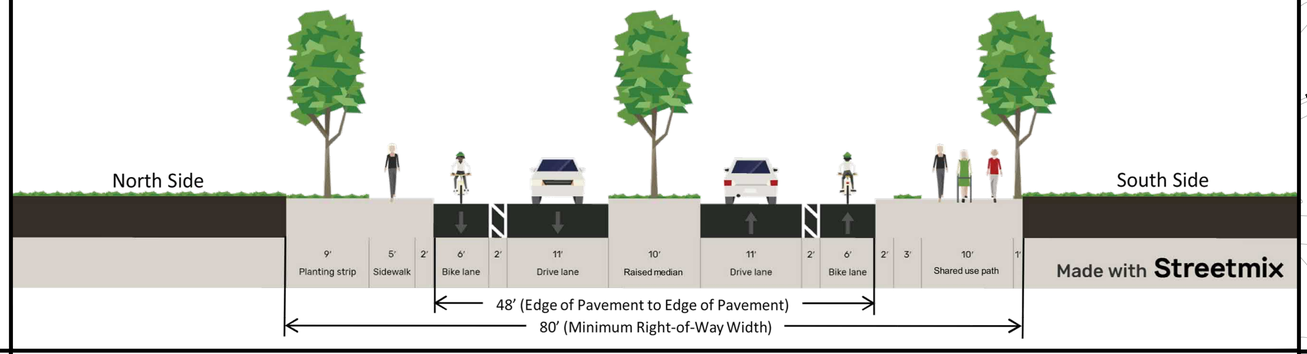
LEGEND

- SIGNALIZED INTERSECTION
- PROPERTY LINE
- SHARED USE PATH
- RAISED MEDIAN

NORTH

GRAPHIC SCALE IN FEET
0 25 50 100

CROSS SECTION



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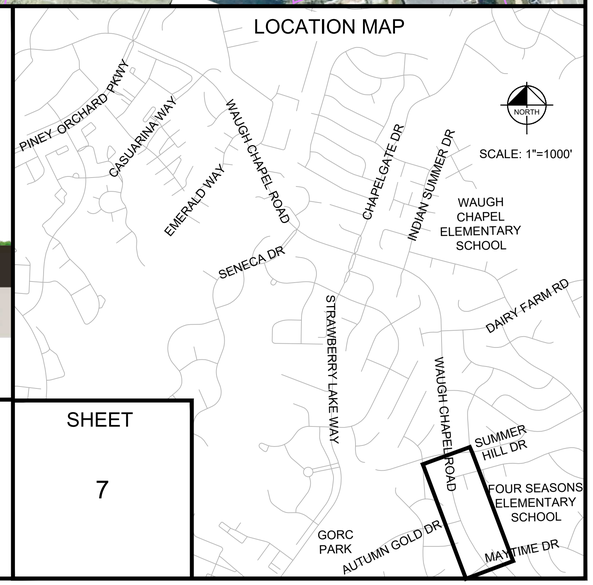

ANNE ARUNDEL COUNTY MARYLAND

Kimley»Horn

WAUGH CHAPEL ROAD

PINEY ORCHARD PARKWAY TO MAYTIME DRIVE

ALTERNATIVE CORRIDOR RECOMMENDATION
WITH LEFT TURN ACCELERATION LANE AT FALL RIDGE WAY

SHEET

7

Appendix F

PLANNING LEVEL COST ESTIMATES

WAUGH CHAPEL ROAD - CORRIDOR CONCEPT PLANNING QUANTITIES AND COSTS					
ITEM DESCRIPTION	UNITS	QUANTITY	UNIT PRICE	TOTAL PRICE	ASSUMPTIONS
CONSTRUCTION ITEMS					
MOBILIZATION	LS	1	$206,925.00	$206,900.00	*5% of construction items*
MAINTENANCE OF TRAFFIC	LS	1	$413,850.00	$413,900.00	*10% of construction items*
CONSTRUCTION SURVEYING	LS	1	$82,770.00	$82,800.00	*2% of construction items*
CLEARING & GRUBBING	LS	1	$100,000.00	$100,000.00	*Price assumes clearing and grubbing for the sections where the shared use path is added*
EARTHWORK	CY	9899	$40.00	$396,000.00	*Quantity assumes 30 SF of earthwork for the length of the improvements*
EROSION AND SEDIMENT CONTROL	EA	60	$800.00	$48,000.00	*Price includes inlet protection increased to include incidental E&S items (silt fence, tree protection, etc.)*
REMOVAL OF PAVEMENT	CY	590	$50.00	$29,500.00	*Quantity assumes an existing pavement depth of 1 foot*
LANDSCAPING	SF	15938	$4.00	$63,800.00	*Price assumes minimal trees and shrubs with mostly grass*
DRAINAGE IMPROVEMENTS	LF	10	$5,000.00	$50,000.00	*Quantity based on assumed drainage structures needed and price includes pipe connections*
STORMWATER MANAGEMENT	EA	3	$50,000.00	$150,000.00	*Quantity assumes ~1 small BMP per outfall*
MILL PAVEMENT	SY	52293	$6.00	$313,800.00	*Price includes 2" of mill of the road surface*
ROADWAY PAVEMENT (SURFACE)	TON	6275	$120.00	$753,000.00	*Price assumes asphalt pavement includeing 2"*
ROADWAY PAVEMENT (FULL DEPTH)	TON	1782	$120.00	$213,900.00	*Price assumes asphalt pavement includeing 2" surface, 6" base, and 8" aggregate*
SHARED USE PATH PAVEMENT	TON	6148	$120.00	$737,800.00	*Price assumes asphalt pavement with 2" of surface and 8" of aggregate and a width of 10'*
SIDEWALK PAVEMENT	SF	26298	$8.00	$210,400.00	*Price assumes 5' wide and 5" thick concrete pavement*
CURB	LF	6185	$25.00	$154,600.00	*Price assumes standard curb*
CURB RAMPS	EA	34	$4,000.00	$136,000.00	*Price assumes standard curb ramp*
HANDRAIL	LF	400	$150.00	$60,000.00	*Price assumes standard handrail at locations where slopes may be steep*
PAVEMENT MARKINGS (LINES)	LF	54077	$8.00	$432,600.00	*Price assumes 5"standard pavement markings for all lane divides*
PAVEMENT MARKINGS (SYMBOLS OR MESSAGES)	EA	115	$500.00	$57,500.00	*Quantity includes estimate of bike lane and roadway marking symbols*
SIGNAGE	EA	36	$250.00	$8,900.00	*Quantity assumes 2 new signs every 500 feet of improvements*
LIGHTING	EA	45	$5,000.00	$222,700.00	*Quantity assumes 1 new light pole every 200 feet of improvments*
OTHER ITEMS					
SURVEY	LS	1	$338,900.00	$338,900.00	*7% of construction items*
UTILITY RELOCATIONS	LS	1	$484,200.00	$484,200.00	*10% of construction items*
RIGHT-OF-WAY OR PERMANENT EASEMENT	SF	4960	$20.00	$99,200.00	*Quantity assumes permanent easements may be needed at select locations to avoid utilites*
TEMPORARY EASEMENT	SF	61560	$5.00	$307,800.00	*Quantity assumes temporary easments may be needed for slope grading during construction*
ENGINEERING DESIGN	LS	1	$726,300.00	$726,300.00	*15% of construction items*
CONSTRUCTION MANAGEMENT	LS	1	$484,200.00	$484,200.00	*10% of construction items*
ADMINISTRATIVE COSTS	LS	1	$29,100.00	$29,100.00	*4% of engineering design costs*
SUB TOTAL				$7,311,800.00	
CONTINGENCY		30%		$2,193,500.00	
TOTAL				$9,505,300.00	Price excludes intersection improvements

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WAUGH CHAPEL ROAD - PINEY ORCHARD PARKWAY SIGNAL PLANNING QUANTITIES AND COSTS					
ITEM DESCRIPTION	UNITS	QUANTITY	UNIT PRICE	TOTAL PRICE	ASSUMPTIONS
TRAFFIC SIGNAL MAST ARM	EA	1	$22,000.00	$22,000	*Price based on steel pole with a single 50 foot mast arm*
FOUNDATION	EA	1	$10,000.00	$10,000	*Price based on 5 CY of concrete per foundation at $1,600 per CY*
DETECTION	EA	1	$10,000.00	$10,000	*Price based on detection for each approach*
CONDUIT	LF	250	$50.00	$12,500	*Quantity based on geometry and layout of the intersection and signal*
CABLE	LF	1280	$5.00	$6,400	*Quantity based on geometry and layout of the intersection and signal*
JUNCTION BOX	EA	1	$1,000.00	$1,000	*Quantity assumes 1 for each corner with a new pole*
TRAFFIC SIGNAL HEAD	EA	3	$500.00	$1,500	*Quantity assumes 2 for each side street approach and 3 for the main line approaches*
PAVEMENT MARKINGS (LINES)	LF	1100	$8.00	$8,800.00	*Price assumes standard pavement markings for all lane divides*
PAVEMENT MARKINGS (SYMBOLS OR MESSAGES)	EA	6	$500.00	$3,000.00	*Quantity includes estimate of bike lane and roadway marking symbols*
SIGNAGE	EA	3	$250.00	$800.00	*Quantity assumes 1 sign on the approach and 2 signal mounted signs*
MILL PAVEMENT	SY	967	$6.00	$5,800.00	*Price includes 2" of mill of the road surface*
ROADWAY PAVEMENT (SURFACE)	TON	116	$120.00	$13,900.00	*Price assumes asphalt pavement includeing 2"*
OTHER CONSTRUCTION COSTS	LS	1	$30,000.00	$30,000	*Price includes mobilization and maintenance of traffic*
CONSTRUCTION COST	LS	1	$125,700.00	$163,400	*30% contingency*
ENGINEERING DESIGN	LS	1	$24,500.00	$24,500	*15% of construction cost, includes survey*
TOTAL				$187,900	

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WAUGH CHAPEL ROAD - CASUARINA WAY SIGNAL PLANNING QUANTITIES AND COSTS					
ITEM DESCRIPTION	UNITS	QUANTITY	UNIT PRICE	TOTAL PRICE	ASSUMPTIONS
TRAFFIC SIGNAL MAST ARM	EA	4	$22,000.00	$88,000.00	*Price based on steel pole with a single 50 foot mast arm*
FOUNDATION	EA	4	$10,000.00	$40,000.00	*Price based on 5 CY of concrete per foundation at $1,600 per CY*
CONTROLLER AND CABINET	EA	1	$15,000.00	$15,000.00	*Price based on ground mounted cabinet and other controller items*
DETECTION	EA	4	$10,000.00	$40,000.00	*Price based on detection for each approach*
CONDUIT	LF	350	$50.00	$17,500.00	*Quantity based on geometry and layout of the intersection and signal*
CABLE	LF	2100	$5.00	$10,500.00	*Quantity based on geometry and layout of the intersection and signal*
JUNCTION BOX	EA	4	$1,000.00	$4,000.00	*Quantity assumes 1 for each corner with a new pole*
TRAFFIC SIGNAL HEAD	EA	10	$500.00	$5,000.00	*Quantity assumes 2 for each side street approach and 3 for the main line approaches*
PAVEMENT MARKINGS (LINES)	LF	345	$8.00	$2,800.00	*Quantity includes only intersection stop bars and crosswalk pavement markings*
SIGNAGE	EA	6	$250.00	$1,500.00	*Quantity assumes 2 signs on the approach and 4 signal mounted signs*
OTHER CONSTRUCTION COSTS	LS	1	$50,000.00	$50,000.00	*Price includes mobilization and maintenance of traffic*
CONSTRUCTION COST	LS	1	$274,300.00	$356,600.00	*30% contingency*
ENGINEERING DESIGN	LS	1	$53,500.00	$53,500.00	*15% of construction cost, includes survey*
TOTAL				$410,100.00	

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WAUGH CHAPEL ROAD - OLD WAUGH CHAPEL ROAD ROUNDABOUT PLANNING QUANTITIES AND COSTS					
ITEM DESCRIPTION	UNITS	QUANTITY	UNIT PRICE	TOTAL PRICE	ASSUMPTIONS
CONSTRUCTION ITEMS					
MOBILIZATION	LS	1	$46,425.00	$46,400.00	*5% of construction items*
MAINTENANCE OF TRAFFIC	LS	1	$92,850.00	$92,900.00	*10% of construction items*
CONSTRUCTION SURVEYING	LS	1	$18,570.00	$18,600.00	*2% of construction items*
CLEARING & GRUBBING	LS	1	$20,000.00	$20,000.00	*Price assumes minimal clearing and grubbing*
EARTHWORK	CY	2135	$40.00	$85,400.00	*Quantity assumes 2 feet of earthwork for the total area of roadway improvements*
EROSION AND SEDIMENT CONTROL	EA	6	$500.00	$3,000.00	*Price includes inlet protection increased to include incidental E&S items (silt fence, tree protection, etc.)*
REMOVAL OF PAVEMENT	CY	1097	$50.00	$54,800.00	*Quantity assumes an existing pavement depth of 1 foot*
LANDSCAPING	SF	13222	$4.00	$52,900.00	*Price assumes minimal trees and shrubs with mostly grass*
DRAINAGE IMPROVEMENTS	EA	6	$5,000.00	$30,000.00	*Quantity based on assumed drainage structures needed and price includes pipe connections*
STORMWATER MANAGEMENT	EA	1	$50,000.00	$50,000.00	*Quantity assumes ~1 small BMP per outfall*
ROADWAY PAVEMENT (FULL DEPTH)	TON	3074	$120.00	$368,900.00	*Price assumes asphalt pavement includeing 2" surface, 6" base, and 8" aggregate*
SHARED USE PATH PAVEMENT	TON	435	$120.00	$52,200.00	*Price assumes asphalt pavement with 2" of surface and 8" of aggregate and a width of 10'*
MOUNTABLE CONCRETE APRON	SF	1823	$25.00	$45,600.00	*Price includes mountable apron 7" concrete pavement with 8" aggregate*
SIDEWALK PAVEMENT	SF	2708	$8.00	$21,700.00	*Price assumes 5' wide and 5" thick concrete pavement*
CURB AND GUTTER	LF	977	$30.00	$29,300.00	*Price assumes standard curb and gutter*
CURB RAMPS	EA	8	$4,000.00	$32,000.00	*Price assumes standard curb ramp*
HANDRAIL	LF	250	$150.00	$37,500.00	*Price assumes standard handrail at locations where slopes may be steep*
PAVEMENT MARKINGS (LINES)	LF	2648	$8.00	$21,200.00	*Price assumes 5"standard pavement markings for all lane divides*
PAVEMENT MARKINGS (SYMBOLS OR MESSAGES)	EA	5	$500.00	$2,500.00	*Quantity includes estimate of bike lane and roadway marking symbols*
SIGNAGE	EA	6	$250.00	$1,500.00	*Quantity assumes 2 new signs per approach*
LIGHTING	EA	4	$5,000.00	$20,000.00	*Quantity based on assumed light poles needed and price includes lighting connections*
OTHER ITEMS					
SURVEY	LS	1	$76,000.00	$76,000.00	*7% of construction items*
UTILITY RELOCATIONS	LS	1	$108,600.00	$108,600.00	*10% of construction items*
RIGHT-OF-WAY OR PERMANENT EASEMENT	SF	3208	$20.00	$64,200.00	*Quantity assumes minor permanent easements may be needed at select locations to avoid utilites*
TEMPORARY EASEMENT	SF	3000	$5.00	$15,000.00	*Quantity assumes minor temporary easments may be needed for slope grading during construction*
ENGINEERING DESIGN	LS	1	$163,000.00	$163,000.00	*15% of construction items*
CONSTRUCTION MANAGEMENT	LS	1	$108,600.00	$108,600.00	*10% of construction items*
ADMINISTRATIVE COSTS	LS	1	$6,500.00	$6,500.00	*4% of engineering design costs*
SUB TOTAL				$1,628,300.00	
CONTINGENCY		30%		$488,500.00	
TOTAL				$2,116,800.00	Price excludes intersection improvements

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WAUGH CHAPEL ROAD - SENECA DRIVE ROUNDABOUT PLANNING QUANTITIES AND COSTS					
ITEM DESCRIPTION	UNITS	QUANTITY	UNIT PRICE	TOTAL PRICE	ASSUMPTIONS
CONSTRUCTION ITEMS					
MOBILIZATION	LS	1	$57,535.00	$57,500.00	*5% of construction items*
MAINTENANCE OF TRAFFIC	LS	1	$115,070.00	$115,100.00	*10% of construction items*
CONSTRUCTION SURVEYING	LS	1	$23,014.00	$23,000.00	*2% of construction items*
CLEARING & GRUBBING	LS	1	$30,000.00	$30,000.00	*Price assumes minimal clearing and grubbing*
EARTHWORK	CY	2382	$40.00	$95,300.00	*Quantity assumes 3 feet of earthwork for the total area of roadway improvements*
EROSION AND SEDIMENT CONTROL	EA	500	$300.00	$150,000.00	*Price includes inlet protection increased to include incidental E&S items (silt fence, tree protection, etc.)*
REMOVAL OF PAVEMENT	CY	783	$50.00	$39,100.00	*Quantity assumes an existing pavement depth of 1 foot*
LANDSCAPING	SF	3765	$4.00	$15,100.00	*Price assumes minimal trees and shrubs with mostly grass*
DRAINAGE IMPROVEMENTS	EA	8	$5,000.00	$40,000.00	*Quantity based on assumed drainage structures needed and price includes pipe connections*
STORMWATER MANAGEMENT	EA	1	$50,000.00	$50,000.00	*Quantity assumes ~1 small BMP per outfall*
ROADWAY PAVEMENT (FULL DEPTH)	TON	4574	$120.00	$548,900.00	*Price assumes asphalt pavement includeing 2" surface, 6" base, and 8" aggregate*
SHARED USE PATH PAVEMENT	TON	326	$120.00	$39,100.00	*Price assumes asphalt pavement with 2" of surface and 8" of aggregate and a width of 10'*
MOUNTABLE CONCRETE APRON	SF	1823	$25.00	$45,600.00	*Price includes mountable apron 7" concrete pavement with 8" aggregate*
SIDEWALK PAVEMENT	SF	880	$8.00	$7,000.00	*Price assumes 5' wide and 5" thick concrete pavement*
CURB AND GUTTER	LF	890	$30.00	$26,700.00	*Price assumes standard curb and gutter*
CURB RAMPS	EA	6	$4,000.00	$24,000.00	*Price assumes standard curb ramp*
PAVEMENT MARKINGS (LINES)	LF	1988	$8.00	$15,900.00	*Price assumes 5"standard pavement markings for all lane divides*
PAVEMENT MARKINGS (SYMBOLS OR MESSAGES)	EA	4	$500.00	$2,000.00	*Quantity includes estimate of bike lane and roadway marking symbols*
SIGNAGE	EA	8	$250.00	$2,000.00	*Quantity assumes 2 new signs per approach*
LIGHTING	EA	4	$5,000.00	$20,000.00	*Quantity based on assumed light poles needed and price includes lighting connections*
OTHER ITEMS					
SURVEY	LS	1	$94,200.00	$94,200.00	*7% of construction items*
UTILITY RELOCATIONS	LS	1	$134,600.00	$134,600.00	*10% of construction items*
RIGHT-OF-WAY OR PERMANENT EASEMENT	SF	500	$20.00	$10,000.00	*Quantity assumes minor permanent easements may be needed at select locations to avoid utilites*
TEMPORARY EASEMENT	SF	1000	$5.00	$5,000.00	*Quantity assumes minor temporary easments may be needed for slope grading during construction*
ENGINEERING DESIGN	LS	1	$201,900.00	$201,900.00	*15% of construction items*
CONSTRUCTION MANAGEMENT	LS	1	$134,600.00	$134,600.00	*10% of construction items*
ADMINISTRATIVE COSTS	LS	1	$8,100.00	$8,100.00	*4% of engineering design costs*
SUB TOTAL				$1,934,700.00	
CONTINGENCY		30%		$580,400.00	
TOTAL				$2,515,100.00	Price excludes intersection improvements

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WAUGH CHAPEL ROAD - STRAWBERRY LAKE WAY SIGNAL PLANNING QUANTITIES AND COSTS					
ITEM DESCRIPTION	UNITS	QUANTITY	UNIT PRICE	TOTAL PRICE	ASSUMPTIONS
TRAFFIC SIGNAL MAST ARM	EA	1	$22,000.00	$22,000	*Price based on steel pole with a single 50 foot mast arm*
FOUNDATION	EA	1	$10,000.00	$10,000	*Price based on 5 CY of concrete per foundation at $1,600 per CY*
DETECTION	EA	1	$10,000.00	$10,000	*Price based on detection for each approach*
CONDUIT	LF	200	$50.00	$10,000	*Quantity based on geometry and layout of the intersection and signal*
CABLE	LF	1080	$5.00	$5,400	*Quantity based on geometry and layout of the intersection and signal*
JUNCTION BOX	EA	1	$1,000.00	$1,000	*Quantity assumes 1 for each corner with a new pole*
TRAFFIC SIGNAL HEAD	EA	2	$500.00	$1,000	*Quantity assumes 2 for each side street approach and 3 for the main line approaches*
PAVEMENT MARKINGS (LINES)	LF	255	$8.00	$2,000.00	*Price assumes standard pavement markings for all lane divides*
PAVEMENT MARKINGS (SYMBOLS OR MESSAGES)	EA	2	$500.00	$1,000.00	*Quantity includes estimate of bike lane and roadway marking symbols*
SIGNAGE	EA	2	$250.00	$500.00	*Quantity assumes 2 signal mounted signs*
MILL PAVEMENT	SY	469	$6.00	$2,800.00	*Price includes 2" of mill of the road surface*
ROADWAY PAVEMENT (SURFACE)	TON	56	$120.00	$6,700.00	*Price assumes asphalt pavement includeing 2"*
OTHER CONSTRUCTION COSTS	LS	1	$30,000.00	$30,000	*Price includes mobilization and maintenance of traffic*
CONSTRUCTION COST	LS	1	$102,400.00	$133,100	*30% contingency*
ENGINEERING DESIGN	LS	1	$20,000.00	$20,000	*15% of construction cost, includes survey*
TOTAL				$153,100	

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WAUGH CHAPEL ROAD - FALL RIDGE WAY ACCELERATION LANE PLANNING QUANTITIES AND COSTS					
ITEM DESCRIPTION	UNITS	QUANTITY	UNIT PRICE	TOTAL PRICE	ASSUMPTIONS
PAVEMENT MARKINGS (LINES)	LF	3557	$8.00	$28,500.00	*Price assumes standard pavement markings for all lane divides*
PAVEMENT MARKINGS (SYMBOLS OR MESSAGES)	EA	5	$500.00	$2,500.00	*Quantity includes estimate of bike lane and roadway marking symbols*
SIGNAGE	EA	2	$250.00	$500.00	*Quantity assumes 2 signs*
MILL PAVEMENT	SY	3013	$6.00	$18,100.00	*Price includes 2" of mill of the road surface*
ROADWAY PAVEMENT (SURFACE)	TON	362	$120.00	$43,400.00	*Price assumes asphalt pavement includeing 2"*
OTHER CONSTRUCTION COSTS	LS	1	$15,000.00	$15,000	*Price includes mobilization and maintenance of traffic*
CONSTRUCTION COST	LS	1	$140,400.00	$140,400	*30% contingency*
ENGINEERING DESIGN	LS	1	$21,100.00	$21,100	*15% of construction cost, includes survey*
TOTAL				$161,500	

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WAUGH CHAPEL ROAD - AUTUMN GOLD DRIVE ROUNDABOUT PLANNING QUANTITIES AND COSTS					
ITEM DESCRIPTION	UNITS	QUANTITY	UNIT PRICE	TOTAL PRICE	ASSUMPTIONS
CONSTRUCTION ITEMS					
MOBILIZATION	LS	1	$95,165.00	$95,200.00	*5% of construction items*
MAINTENANCE OF TRAFFIC	LS	1	$190,330.00	$190,300.00	*10% of construction items*
CONSTRUCTION SURVEYING	LS	1	$38,066.00	$38,100.00	*2% of construction items*
CLEARING & GRUBBING	LS	1	$30,000.00	$30,000.00	*Price assumes clearing and grubbing*
EARTHWORK	CY	5251	$40.00	$210,000.00	*Quantity assumes 3 feet of earthwork for the total area of roadway improvements*
EROSION AND SEDIMENT CONTROL	EA	6	$500.00	$3,000.00	*Price includes inlet protection increased to include incidental E&S items (silt fence, tree protection, etc.)*
REMOVAL OF PAVEMENT	CY	1161	$50.00	$58,000.00	*Quantity assumes an existing pavement depth of 1 foot*
LANDSCAPING	SF	10281	$4.00	$41,100.00	*Price assumes minimal trees and shrubs with mostly grass*
DRAINAGE IMPROVEMENTS	EA	6	$5,000.00	$30,000.00	*Quantity based on assumed drainage structures needed and price includes pipe connections*
STORMWATER MANAGEMENT	EA	1	$50,000.00	$50,000.00	*Quantity assumes ~1 small BMP per outfall*
ROADWAY PAVEMENT (FULL DEPTH)	TON	10082	$120.00	$1,209,800.00	*Price assumes asphalt pavement includeing 2" surface, 6" base, and 8" aggregate*
SHARED USE PATH PAVEMENT	TON	758	$120.00	$90,900.00	*Price assumes asphalt pavement with 2" of surface and 8" of aggregate and a width of 10'*
MOUNTABLE CONCRETE APRON	SF	2388	$25.00	$59,700.00	*Price includes mountable apron 7" concrete pavement with 8" aggregate*
CURB AND GUTTER	LF	1841	$30.00	$55,200.00	*Price assumes standard curb and gutter*
CURB RAMPS	EA	4	$4,000.00	$16,000.00	*Price assumes standard curb ramp*
PAVEMENT MARKINGS (LINES)	LF	3141	$8.00	$25,100.00	*Price assumes 5"standard pavement markings for all lane divides*
PAVEMENT MARKINGS (SYMBOLS OR MESSAGES)	EA	6	$500.00	$3,000.00	*Quantity includes estimate of bike lane and roadway marking symbols*
SIGNAGE	EA	6	$250.00	$1,500.00	*Quantity assumes 2 new signs per approach*
LIGHTING	EA	4	$5,000.00	$20,000.00	*Quantity based on assumed light poles needed and price includes lighting connections*
OTHER ITEMS					
SURVEY	LS	1	$155,900.00	$155,900.00	*7% of construction items*
UTILITY RELOCATIONS	LS	1	$111,300.00	$111,300.00	*5% of construction items*
RIGHT-OF-WAY OR PERMANENT EASEMENT	SF	11202	$20.00	$224,000.00	*Quantity assumes minor permanent easements may be needed at select locations to avoid utilites*
TEMPORARY EASEMENT	SF	3765	$5.00	$18,800.00	*Quantity assumes minor temporary easments may be needed for slope grading during construction*
ENGINEERING DESIGN	LS	1	$334,000.00	$334,000.00	*15% of construction items*
CONSTRUCTION MANAGEMENT	LS	1	$222,700.00	$222,700.00	*10% of construction items*
ADMINISTRATIVE COSTS	LS	1	$13,400.00	$13,400.00	*4% of engineering design costs*
SUB TOTAL				$3,307,000.00	
CONTINGENCY		30%		$992,100.00	
TOTAL				$4,299,100.00	Price excludes intersection improvements

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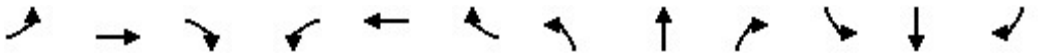
Appendix G

TRAFFIC ANALYSIS RESULTS



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	62	23	18	64	13	799	8	1109	78	183	361	19
Future Volume (vph)	62	23	18	64	13	799	8	1109	78	183	361	19
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)	5.0	5.0		5.0	5.0	5.0	5.0	5.5	5.5	5.0	5.5	
Lane Util. Factor	1.00	0.95		1.00	1.00	0.88	1.00	0.95	1.00	0.97	0.95	
Frpb, ped/bikes	1.00	0.99		1.00	1.00	1.00	1.00	1.00	0.98	1.00	1.00	
Flpb, ped/bikes	1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
Frt	1.00	0.93		1.00	1.00	0.85	1.00	1.00	0.85	1.00	0.99	
Flt Protected	0.95	1.00		0.95	1.00	1.00	0.95	1.00	1.00	0.95	1.00	
Satd. Flow (prot)	1770	3284		1770	1863	2787	1766	3539	1545	3433	3508	
Flt Permitted	0.95	1.00		0.95	1.00	1.00	0.95	1.00	1.00	0.95	1.00	
Satd. Flow (perm)	1770	3284		1770	1863	2787	1766	3539	1545	3433	3508	
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	67	25	20	70	14	868	9	1205	85	199	392	21
RTOR Reduction (vph)	0	18	0	0	0	378	0	0	47	0	2	0
Lane Group Flow (vph)	67	27	0	70	14	490	9	1205	38	199	411	0
Confl. Peds. (#/hr)			1	1			2		2	2		2
Turn Type	Split	NA		Split	NA	pm+ov	Prot	NA	Perm	Prot	NA	
Protected Phases	8	8		7	7	5	1	6		5	2	
Permitted Phases						7			6			
Actuated Green, G (s)	10.2	10.2		21.2	21.2	29.7	0.5	49.7	49.7	8.5	57.7	
Effective Green, g (s)	10.2	10.2		21.2	21.2	29.7	0.5	49.7	49.7	8.5	57.7	
Actuated g/C Ratio	0.09	0.09		0.19	0.19	0.27	0.00	0.45	0.45	0.08	0.52	
Clearance Time (s)	5.0	5.0		5.0	5.0	5.0	5.0	5.5	5.5	5.0	5.5	
Vehicle Extension (s)	3.0	3.0		3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	
Lane Grp Cap (vph)	163	304		340	358	878	8	1597	697	265	1838	
v/s Ratio Prot	c0.04	0.01		0.04	0.01	c0.04	0.01	c0.34		c0.06	0.12	
v/s Ratio Perm						0.13			0.02			
v/c Ratio	0.41	0.09		0.21	0.04	0.56	1.12	0.75	0.06	0.75	0.22	
Uniform Delay, d1	47.1	45.7		37.4	36.2	34.6	54.8	25.1	17.0	49.8	14.1	
Progression Factor	1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
Incremental Delay, d2	1.7	0.1		0.3	0.0	0.8	366.8	2.1	0.0	11.3	0.1	
Delay (s)	48.8	45.8		37.7	36.2	35.3	421.6	27.2	17.0	61.1	14.2	
Level of Service	D	D		D	D	D	F	C	B	E	B	
Approach Delay (s)		47.6			35.5			29.3			29.4	
Approach LOS		D			D			C			C	

Intersection Summary			
HCM 2000 Control Delay	32.0	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.69		
Actuated Cycle Length (s)	110.1	Sum of lost time (s)	20.5
Intersection Capacity Utilization	75.0%	ICU Level of Service	D
Analysis Period (min)	15		

c Critical Lane Group

Lane Group	EBL	EBT	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT
Lane Group Flow (vph)	67	45	70	14	868	9	1205	85	199	413
v/c Ratio	0.33	0.11	0.20	0.04	0.68	0.17	0.80	0.12	0.72	0.21
Control Delay	50.8	29.4	40.1	38.5	15.7	67.9	33.5	5.2	67.0	16.5
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	50.8	29.4	40.1	38.5	15.7	67.9	33.5	5.2	67.0	16.5
Queue Length 50th (ft)	45	8	41	8	117	6	358	0	71	68
Queue Length 95th (ft)	94	27	96	30	247	29	#728	32	#181	180
Internal Link Dist (ft)		467		569			669			625
Turn Bay Length (ft)	290		395		250	200		510	550	
Base Capacity (vph)	556	1045	574	604	1339	53	1740	806	278	2030
Starvation Cap Reductn	0	0	0	0	0	0	0	0	0	0
Spillback Cap Reductn	0	0	0	0	0	0	0	0	0	0
Storage Cap Reductn	0	0	0	0	0	0	0	0	0	0
Reduced v/c Ratio	0.12	0.04	0.12	0.02	0.65	0.17	0.69	0.11	0.72	0.20

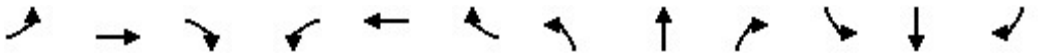
Intersection Summary

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	62	23	18	64	13	799	8	1109	78	183	361	19
Future Volume (vph)	62	23	18	64	13	799	8	1109	78	183	361	19
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)	5.0	5.0		5.0	5.0	5.0	5.0	5.5	5.5	5.0	5.5	
Lane Util. Factor	1.00	0.95		1.00	1.00	0.88	1.00	0.95	1.00	0.97	0.95	
Frpb, ped/bikes	1.00	0.99		1.00	1.00	1.00	1.00	1.00	0.98	1.00	1.00	
Flpb, ped/bikes	1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
Frt	1.00	0.93		1.00	1.00	0.85	1.00	1.00	0.85	1.00	0.99	
Flt Protected	0.95	1.00		0.95	1.00	1.00	0.95	1.00	1.00	0.95	1.00	
Satd. Flow (prot)	1770	3284		1768	1863	2787	1766	3539	1546	3433	3508	
Flt Permitted	0.75	1.00		0.69	1.00	1.00	0.95	1.00	1.00	0.95	1.00	
Satd. Flow (perm)	1394	3284		1286	1863	2787	1766	3539	1546	3433	3508	
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	67	25	20	70	14	868	9	1205	85	199	392	21
RTOR Reduction (vph)	0	17	0	0	0	546	0	0	46	0	2	0
Lane Group Flow (vph)	67	28	0	70	14	322	9	1205	39	199	411	0
Confl. Peds. (#/hr)			1	1			2		2	2		2
Turn Type	pm+pt	NA		pm+pt	NA	Prot	Prot	NA	Perm	Prot	NA	
Protected Phases	8	3		4	7	7	1	6		5	2	
Permitted Phases	3			7					6			
Actuated Green, G (s)	27.5	17.7		29.3	18.6	18.6	0.4	48.9	48.9	8.7	57.2	
Effective Green, g (s)	27.5	17.7		29.3	18.6	18.6	0.4	48.9	48.9	8.7	57.2	
Actuated g/C Ratio	0.26	0.17		0.28	0.17	0.17	0.00	0.46	0.46	0.08	0.54	
Clearance Time (s)	5.0	5.0		5.0	5.0	5.0	5.0	5.5	5.5	5.0	5.5	
Vehicle Extension (s)	3.0	3.0		3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	
Lane Grp Cap (vph)	394	545		402	325	486	6	1624	709	280	1884	
v/s Ratio Prot	0.02	0.01		c0.02	0.01	c0.12	0.01	c0.34		c0.06	0.12	
v/s Ratio Perm	0.03			0.03					0.03			
v/c Ratio	0.17	0.05		0.17	0.04	0.66	1.50	0.74	0.06	0.71	0.22	
Uniform Delay, d1	30.5	37.3		29.1	36.5	41.0	53.0	23.6	16.0	47.7	12.9	
Progression Factor	1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
Incremental Delay, d2	0.2	0.0		0.2	0.1	3.4	576.3	1.9	0.0	8.2	0.1	
Delay (s)	30.7	37.4		29.3	36.6	44.4	629.4	25.5	16.0	55.9	13.0	
Level of Service	C	D		C	D	D	F	C	B	E	B	
Approach Delay (s)		33.4			43.2			29.1			26.9	
Approach LOS		C			D			C			C	

Intersection Summary			
HCM 2000 Control Delay	33.3	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.66		
Actuated Cycle Length (s)	106.5	Sum of lost time (s)	20.5
Intersection Capacity Utilization	75.0%	ICU Level of Service	D
Analysis Period (min)	15		

c Critical Lane Group



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	33	23	13	112	14	383	14	567	129	672	987	53
Future Volume (vph)	33	23	13	112	14	383	14	567	129	672	987	53
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)	5.0	5.0		5.0	5.0	5.0	5.0	5.5	5.5	5.0	5.5	
Lane Util. Factor	1.00	0.95		1.00	1.00	0.88	1.00	0.95	1.00	0.97	0.95	
Frpb, ped/bikes	1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
Flpb, ped/bikes	1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
Frt	1.00	0.95		1.00	1.00	0.85	1.00	1.00	0.85	1.00	0.99	
Flt Protected	0.95	1.00		0.95	1.00	1.00	0.95	1.00	1.00	0.95	1.00	
Satd. Flow (prot)	1770	3333		1770	1863	2787	1770	3539	1583	3433	3508	
Flt Permitted	0.95	1.00		0.95	1.00	1.00	0.95	1.00	1.00	0.95	1.00	
Satd. Flow (perm)	1770	3333		1770	1863	2787	1770	3539	1583	3433	3508	
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	36	25	14	122	15	416	15	616	140	730	1073	58
RTOR Reduction (vph)	0	13	0	0	0	242	0	0	99	0	2	0
Lane Group Flow (vph)	36	26	0	122	15	174	15	616	41	730	1129	0
Confl. Peds. (#/hr)			1	1			1					1
Turn Type	Split	NA		Split	NA	pm+ov	Prot	NA	Perm	Prot	NA	
Protected Phases	8	8		7	7	5	1	6		5	2	
Permitted Phases						7			6			
Actuated Green, G (s)	9.3	9.3		12.9	12.9	42.7	1.0	29.8	29.8	29.8	58.6	
Effective Green, g (s)	9.3	9.3		12.9	12.9	42.7	1.0	29.8	29.8	29.8	58.6	
Actuated g/C Ratio	0.09	0.09		0.13	0.13	0.42	0.01	0.29	0.29	0.29	0.57	
Clearance Time (s)	5.0	5.0		5.0	5.0	5.0	5.0	5.5	5.5	5.0	5.5	
Vehicle Extension (s)	3.0	3.0		3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	
Lane Grp Cap (vph)	160	303		223	234	1299	17	1030	461	1000	2009	
v/s Ratio Prot	c0.02	0.01		c0.07	0.01	0.04	0.01	0.17		c0.21	c0.32	
v/s Ratio Perm						0.02			0.03			
v/c Ratio	0.23	0.09		0.55	0.06	0.13	0.88	0.60	0.09	0.73	0.56	
Uniform Delay, d1	43.2	42.6		42.0	39.4	18.4	50.6	31.1	26.4	32.6	13.8	
Progression Factor	1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
Incremental Delay, d2	0.7	0.1		2.7	0.1	0.0	159.7	0.9	0.1	2.7	0.4	
Delay (s)	43.9	42.7		44.7	39.5	18.4	210.3	32.1	26.5	35.3	14.1	
Level of Service	D	D		D	D	B	F	C	C	D	B	
Approach Delay (s)		43.3			24.8			34.5			22.4	
Approach LOS		D			C			C			C	

Intersection Summary			
HCM 2000 Control Delay	26.2	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.60		
Actuated Cycle Length (s)	102.3	Sum of lost time (s)	20.5
Intersection Capacity Utilization	65.8%	ICU Level of Service	C
Analysis Period (min)	15		

c Critical Lane Group

Lane Group	EBL	EBT	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT
Lane Group Flow (vph)	36	39	122	15	416	15	616	140	730	1131
v/c Ratio	0.19	0.10	0.53	0.06	0.27	0.27	0.65	0.26	0.70	0.54
Control Delay	42.8	29.1	50.7	41.6	2.4	66.1	38.1	7.7	37.5	17.4
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	42.8	29.1	50.7	41.6	2.4	66.1	38.1	7.7	37.5	17.4
Queue Length 50th (ft)	21	7	69	8	0	9	173	0	198	181
Queue Length 95th (ft)	53	24	156	32	32	#41	332	55	#432	511
Internal Link Dist (ft)		467		567			669			625
Turn Bay Length (ft)	290		395		250	200		510	550	
Base Capacity (vph)	574	1090	592	623	1571	55	1018	555	1042	2096
Starvation Cap Reductn	0	0	0	0	0	0	0	0	0	0
Spillback Cap Reductn	0	0	0	0	0	0	0	0	0	0
Storage Cap Reductn	0	0	0	0	0	0	0	0	0	0
Reduced v/c Ratio	0.06	0.04	0.21	0.02	0.26	0.27	0.61	0.25	0.70	0.54

Intersection Summary

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	33	23	13	112	14	383	14	567	129	672	987	53
Future Volume (vph)	33	23	13	112	14	383	14	567	129	672	987	53
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)	4.5	5.0		4.5	5.0	5.0	5.0	5.5	5.5	5.0	5.5	
Lane Util. Factor	1.00	0.95		1.00	1.00	0.88	1.00	0.95	1.00	0.97	0.95	
Frpb, ped/bikes	1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
Flpb, ped/bikes	1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
Frt	1.00	0.95		1.00	1.00	0.85	1.00	1.00	0.85	1.00	0.99	
Flt Protected	0.95	1.00		0.95	1.00	1.00	0.95	1.00	1.00	0.95	1.00	
Satd. Flow (prot)	1770	3333		1769	1863	2787	1769	3539	1583	3433	3508	
Flt Permitted	0.75	1.00		0.44	1.00	1.00	0.95	1.00	1.00	0.95	1.00	
Satd. Flow (perm)	1393	3333		823	1863	2787	1769	3539	1583	3433	3508	
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	36	25	14	122	15	416	15	616	140	730	1073	58
RTOR Reduction (vph)	0	13	0	0	0	357	0	0	93	0	2	0
Lane Group Flow (vph)	36	26	0	122	15	59	15	616	47	730	1129	0
Confl. Peds. (#/hr)			1	1			1					1
Turn Type	pm+pt	NA		pm+pt	NA	Prot	Prot	NA	Perm	Prot	NA	
Protected Phases	8	3		4	7	7	1	6		5	2	
Permitted Phases	3			7					6			
Actuated Green, G (s)	11.0	6.9		21.9	13.3	13.3	0.4	31.2	31.2	25.2	56.0	
Effective Green, g (s)	11.0	6.9		21.9	13.3	13.3	0.4	31.2	31.2	25.2	56.0	
Actuated g/C Ratio	0.12	0.07		0.23	0.14	0.14	0.00	0.33	0.33	0.27	0.60	
Clearance Time (s)	4.5	5.0		4.5	5.0	5.0	5.0	5.5	5.5	5.0	5.5	
Vehicle Extension (s)	3.0	3.0		3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	
Lane Grp Cap (vph)	179	245		298	264	395	7	1177	526	922	2094	
v/s Ratio Prot	0.01	0.01		c0.05	0.01	0.02	0.01	0.17		c0.21	c0.32	
v/s Ratio Perm	0.01			c0.05					0.03			
v/c Ratio	0.20	0.11		0.41	0.06	0.15	2.14	0.52	0.09	0.79	0.54	
Uniform Delay, d1	37.3	40.6		29.7	34.8	35.3	46.7	25.3	21.5	31.9	11.2	
Progression Factor	1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
Incremental Delay, d2	0.6	0.2		0.9	0.1	0.2	817.6	0.4	0.1	4.7	0.3	
Delay (s)	37.9	40.8		30.6	34.9	35.5	864.3	25.7	21.6	36.6	11.5	
Level of Service	D	D		C	C	D	F	C	C	D	B	
Approach Delay (s)		39.4			34.4			41.3			21.3	
Approach LOS		D			C			D			C	

Intersection Summary			
HCM 2000 Control Delay	28.7	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.63		
Actuated Cycle Length (s)	93.8	Sum of lost time (s)	20.0
Intersection Capacity Utilization	65.8%	ICU Level of Service	C
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	0	272	11	32	803	2	70	0	78	3	0	4
Future Volume (veh/h)	0	272	11	32	803	2	70	0	78	3	0	4
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach		No			No			No			No	
Adj Sat Flow, veh/h/ln	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h	0	296	12	35	873	2	76	0	85	3	0	4
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	170	1072	43	728	1120	3	222	21	133	197	39	153
Arrive On Green	0.00	0.60	0.60	0.60	0.60	0.60	0.16	0.00	0.16	0.16	0.00	0.16
Sat Flow, veh/h	634	1785	72	1071	1865	4	594	130	809	461	239	933
Grp Volume(v), veh/h	0	0	308	35	0	875	161	0	0	7	0	0
Grp Sat Flow(s),veh/h/ln	634	0	1857	1071	0	1870	1532	0	0	1632	0	0
Q Serve(g_s), s	0.0	0.0	3.4	0.7	0.0	14.9	3.0	0.0	0.0	0.0	0.0	0.0
Cycle Q Clear(g_c), s	0.0	0.0	3.4	4.1	0.0	14.9	4.1	0.0	0.0	0.1	0.0	0.0
Prop In Lane	1.00		0.04	1.00		0.00	0.47		0.53	0.43		0.57
Lane Grp Cap(c), veh/h	170	0	1116	728	0	1123	376	0	0	389	0	0
V/C Ratio(X)	0.00	0.00	0.28	0.05	0.00	0.78	0.43	0.00	0.00	0.02	0.00	0.00
Avail Cap(c_a), veh/h	1057	0	3718	2229	0	3743	1013	0	0	1007	0	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	0.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	0.00	1.00	0.00	0.00
Uniform Delay (d), s/veh	0.0	0.0	4.1	5.0	0.0	6.4	16.5	0.0	0.0	14.9	0.0	0.0
Incr Delay (d2), s/veh	0.0	0.0	0.1	0.0	0.0	1.2	0.8	0.0	0.0	0.0	0.0	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(95%),veh/ln	0.0	0.0	1.1	0.2	0.0	5.4	2.5	0.0	0.0	0.1	0.0	0.0
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh	0.0	0.0	4.2	5.1	0.0	7.6	17.3	0.0	0.0	14.9	0.0	0.0
LnGrp LOS	A	A	A	A	A	A	B	A	A	B	A	A
Approach Vol, veh/h		308			910			161			7	
Approach Delay, s/veh		4.2			7.5			17.3			14.9	
Approach LOS		A			A			B			B	

Timer - Assigned Phs		2		4		6		8				
Phs Duration (G+Y+Rc), s		12.0		30.5		12.0		30.5				
Change Period (Y+Rc), s		5.0		5.0		5.0		5.0				
Max Green Setting (Gmax), s		25.0		85.0		25.0		85.0				
Max Q Clear Time (g_c+I1), s		6.1		5.4		2.1		16.9				
Green Ext Time (p_c), s		0.9		2.0		0.0		8.6				

Intersection Summary												
HCM 6th Ctrl Delay			7.9									
HCM 6th LOS			A									

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	7	775	42	120	479	4	22	3	78	2	2	8
Future Volume (veh/h)	7	775	42	120	479	4	22	3	78	2	2	8
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach		No			No			No			No	
Adj Sat Flow, veh/h/ln	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h	8	842	46	130	521	4	24	3	85	2	2	9
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	617	1152	63	372	1215	9	126	18	146	106	48	137
Arrive On Green	0.66	0.66	0.66	0.66	0.66	0.66	0.12	0.12	0.12	0.12	0.12	0.12
Sat Flow, veh/h	878	1757	96	626	1854	14	231	149	1197	108	391	1123
Grp Volume(v), veh/h	8	0	888	130	0	525	112	0	0	13	0	0
Grp Sat Flow(s),veh/h/ln	878	0	1853	626	0	1868	1578	0	0	1622	0	0
Q Serve(g_s), s	0.2	0.0	14.2	7.8	0.0	6.0	1.3	0.0	0.0	0.0	0.0	0.0
Cycle Q Clear(g_c), s	6.2	0.0	14.2	22.0	0.0	6.0	3.0	0.0	0.0	0.3	0.0	0.0
Prop In Lane	1.00		0.05	1.00		0.01	0.21		0.76	0.15		0.69
Lane Grp Cap(c), veh/h	617	0	1215	372	0	1224	290	0	0	290	0	0
V/C Ratio(X)	0.01	0.00	0.73	0.35	0.00	0.43	0.39	0.00	0.00	0.04	0.00	0.00
Avail Cap(c_a), veh/h	1782	0	3674	1203	0	3703	825	0	0	834	0	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	0.00	1.00	0.00	0.00
Uniform Delay (d), s/veh	5.2	0.0	5.1	12.4	0.0	3.7	18.6	0.0	0.0	17.4	0.0	0.0
Incr Delay (d2), s/veh	0.0	0.0	0.9	0.6	0.0	0.2	0.8	0.0	0.0	0.1	0.0	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(95%),veh/ln	0.0	0.0	4.2	1.6	0.0	1.7	1.9	0.0	0.0	0.2	0.0	0.0
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh	5.2	0.0	6.0	13.0	0.0	3.9	19.4	0.0	0.0	17.5	0.0	0.0
LnGrp LOS	A	A	A	B	A	A	B	A	A	B	A	A
Approach Vol, veh/h		896			655			112			13	
Approach Delay, s/veh		6.0			5.7			19.4			17.5	
Approach LOS		A			A			B			B	

Timer - Assigned Phs		2		4		6		8				
Phs Duration (G+Y+Rc), s		10.5		34.4		10.5		34.4				
Change Period (Y+Rc), s		5.0		5.0		5.0		5.0				
Max Green Setting (Gmax), s		21.0		89.0		21.0		89.0				
Max Q Clear Time (g_c+I1), s		5.0		16.2		2.3		24.0				
Green Ext Time (p_c), s		0.5		8.8		0.0		5.4				

Intersection Summary												
HCM 6th Ctrl Delay			6.9									
HCM 6th LOS			A									

INTERSECTION SUMMARY

Site: 1 [Seneca Drive AM (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

Intersection Performance - Hourly Values				
Performance Measure	**Vehicles**		**Persons**	
Travel Speed (Average)	32.7	mph	32.7	mph
Travel Distance (Total)	894.4	veh-mi/h	1073.3	pers-mi/h
Travel Time (Total)	27.3	veh-h/h	32.8	pers-h/h
Desired Speed (Program)	40.0	mph		
Speed Efficiency	0.82			
Travel Time Index	7.98			
Congestion Coefficient	1.22			
Demand Flows (Total)	1416	veh/h	1700	pers/h
Percent Heavy Vehicles (Demand)	2.0	%		
Degree of Saturation	0.671			
Practical Spare Capacity	26.7	%		
Effective Intersection Capacity	2111	veh/h		
Control Delay (Total)	3.68	veh-h/h	4.41	pers-h/h
Control Delay (Average)	9.3	sec	9.3	sec
Control Delay (Worst Lane)	12.0	sec		
Control Delay (Worst Movement)	12.0	sec	12.0	sec
Geometric Delay (Average)	0.0	sec		
Stop-Line Delay (Average)	9.3	sec		
Idling Time (Average)	6.9	sec		
Intersection Level of Service (LOS)	LOS A			
95% Back of Queue - Vehicles (Worst Lane)	6.8	veh		
95% Back of Queue - Distance (Worst Lane)	173.1	ft		
Ave. Queue Storage Ratio (Worst Lane)	0.04			
Total Effective Stops	341	veh/h	409	pers/h
Effective Stop Rate	0.24		0.24	
Proportion Queued	0.42		0.42	
Performance Index	50.9		50.9	
Cost (Total)	560.79	$/h	560.79	$/h
Fuel Consumption (Total)	34.4	gal/h		
Carbon Dioxide (Total)	307.5	kg/h		
Hydrocarbons (Total)	0.027	kg/h		
Carbon Monoxide (Total)	0.389	kg/h		
NOx (Total)	0.359	kg/h		

Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: Same as Sign Control.
Intersection LOS value for Vehicles is based on average delay for all vehicle movements.
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Geometric Delay is not included).
Queue Model: HCM Queue Formula.
Site Model Variability Index (Iterations 3 to N): 0.0 %
Number of Iterations: 3 (Maximum: 10)
Largest change in Lane Degrees of Saturation for the last three Flow-Capacity Iterations: 100.0% 94.7% 0.0%

Intersection Performance - Annual Values				
Performance Measure	**Vehicles**		**Persons**	
Demand Flows (Total)	679,826	veh/y	815,791	pers/y
Delay	1,764	veh-h/y	2,117	pers-h/y
Effective Stops	163,481	veh/y	196,177	pers/y
Travel Distance	429,327	veh-mi/y	515,193	pers-mi/y
Travel Time	13,113	veh-h/y	15,735	pers-h/y

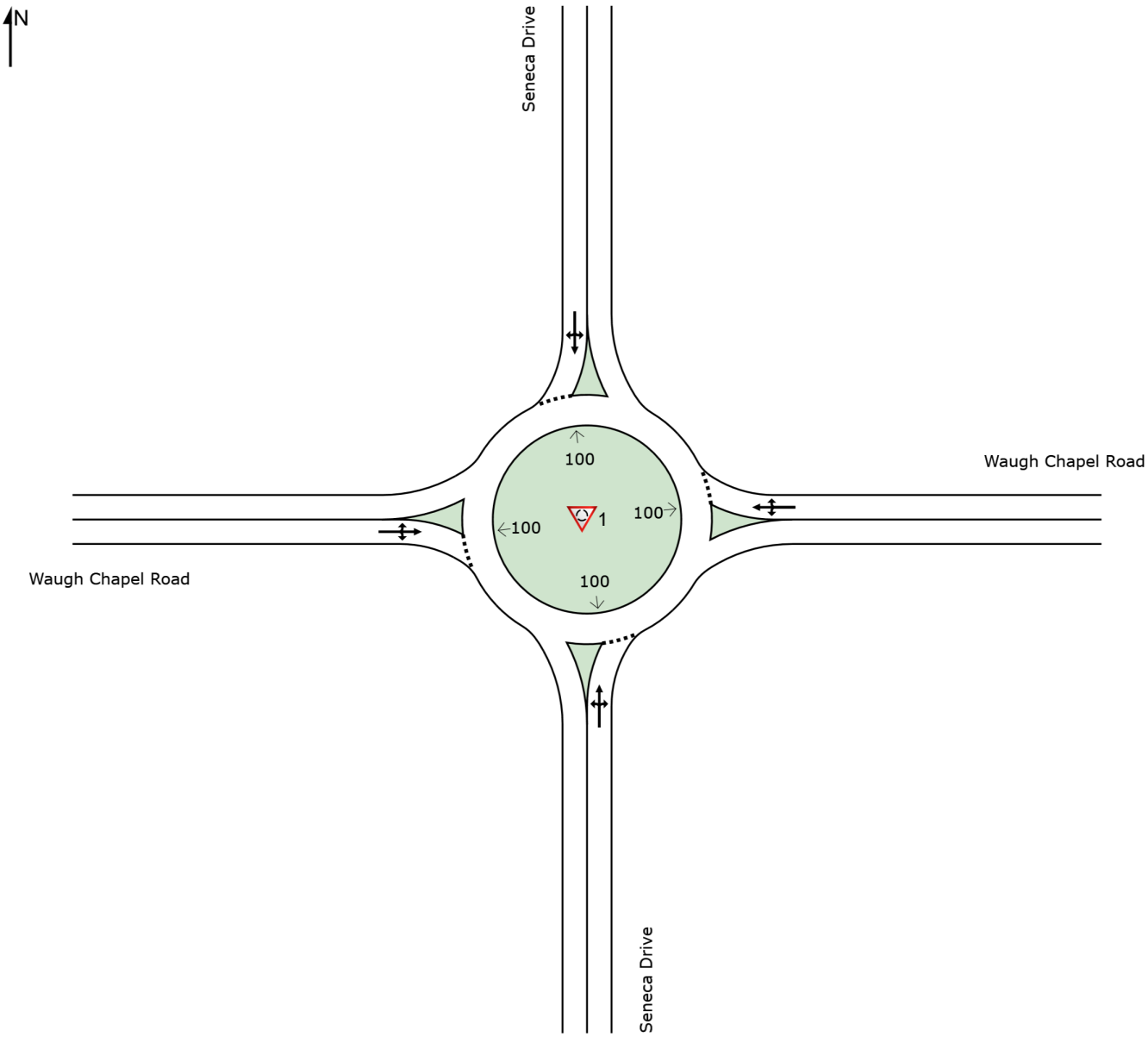
Cost	269,181	$/y	269,181	$/y
Fuel Consumption	16,505	gal/y		
Carbon Dioxide	147,599	kg/y		
Hydrocarbons	13	kg/y		
Carbon Monoxide	187	kg/y		
NOx	172	kg/y		

SITE LAYOUT

Site: 1 [Seneca Drive AM (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

Layout pictures are schematic functional drawings reflecting input data. They are not design drawings.



MOVEMENT SUMMARY

Site: 1 [Seneca Drive AM (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

Vehicle Movement Performance

Mov ID	Turn	INPUT VOLUMES [Total veh/h	HV] %	DEMAND FLOWS [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	Dist] ft	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed mph
South: Seneca Drive														
3	L2	73	2.0	79	2.0	0.198	5.9	LOS A	0.9	22.5	0.51	0.42	0.51	33.5
8	T1	4	2.0	4	2.0	0.198	5.9	LOS A	0.9	22.5	0.51	0.42	0.51	33.5
18	R2	90	2.0	98	2.0	0.198	5.9	LOS A	0.9	22.5	0.51	0.42	0.51	32.5
Approach		167	2.0	182	2.0	0.198	5.9	LOS A	0.9	22.5	0.51	0.42	0.51	33.0
East: Waugh Chapel Road														
1	L2	21	2.0	23	2.0	0.671	12.0	LOS B	6.8	173.1	0.52	0.28	0.52	31.8
6	T1	738	2.0	802	2.0	0.671	12.0	LOS B	6.8	173.1	0.52	0.28	0.52	31.8
16	R2	3	2.0	3	2.0	0.671	12.0	LOS B	6.8	173.1	0.52	0.28	0.52	30.9
Approach		762	2.0	828	2.0	0.671	12.0	LOS B	6.8	173.1	0.52	0.28	0.52	31.8
North: Seneca Drive														
7	L2	6	2.0	7	2.0	0.029	7.2	LOS A	0.1	2.6	0.63	0.58	0.63	32.9
4	T1	2	2.0	2	2.0	0.029	7.2	LOS A	0.1	2.6	0.63	0.58	0.63	32.9
14	R2	6	2.0	7	2.0	0.029	7.2	LOS A	0.1	2.6	0.63	0.58	0.63	32.0
Approach		14	2.0	15	2.0	0.029	7.2	LOS A	0.1	2.6	0.63	0.58	0.63	32.5
West: Waugh Chapel Road														
5	L2	4	2.0	4	2.0	0.299	5.4	LOS A	1.7	43.4	0.16	0.05	0.16	35.1
2	T1	335	2.0	364	2.0	0.299	5.4	LOS A	1.7	43.4	0.16	0.05	0.16	35.0
12	R2	21	2.0	23	2.0	0.299	5.4	LOS A	1.7	43.4	0.16	0.05	0.16	34.0
Approach		360	2.0	391	2.0	0.299	5.4	LOS A	1.7	43.4	0.16	0.05	0.16	34.9
All Vehicles		1303	2.0	1416	2.0	0.671	9.3	LOS A	6.8	173.1	0.42	0.24	0.42	32.7

Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: Same as Sign Control.
Vehicle movement LOS values are based on average delay and v/c ratio (degree of saturation) per movement.
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Intersection and Approach LOS values are based on average delay for all movements (v/c not used as specified in HCM 6).
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Geometric Delay is not included).
Queue Model: HCM Queue Formula.
Gap-Acceptance Capacity: Traditional M1.
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

INTERSECTION SUMMARY

Site: 1 [Seneca Drive PM (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

Intersection Performance - Hourly Values				
Performance Measure	**Vehicles**		**Persons**	
Travel Speed (Average)	31.6	mph	31.6	mph
Travel Distance (Total)	1103.5	veh-mi/h	1324.2	pers-mi/h
Travel Time (Total)	34.9	veh-h/h	41.9	pers-h/h
Desired Speed (Program)	40.0	mph		
Speed Efficiency	0.79			
Travel Time Index	7.67			
Congestion Coefficient	1.27			
Demand Flows (Total)	1748	veh/h	2097	pers/h
Percent Heavy Vehicles (Demand)	2.0	%		
Degree of Saturation	0.756			
Practical Spare Capacity	12.5	%		
Effective Intersection Capacity	2313	veh/h		
Control Delay (Total)	5.83	veh-h/h	6.99	pers-h/h
Control Delay (Average)	12.0	sec	12.0	sec
Control Delay (Worst Lane)	14.8	sec		
Control Delay (Worst Movement)	14.8	sec	14.8	sec
Geometric Delay (Average)	0.0	sec		
Stop-Line Delay (Average)	12.0	sec		
Idling Time (Average)	9.4	sec		
Intersection Level of Service (LOS)	LOS B			
95% Back of Queue - Vehicles (Worst Lane)	10.1	veh		
95% Back of Queue - Distance (Worst Lane)	257.1	ft		
Ave. Queue Storage Ratio (Worst Lane)	0.06			
Total Effective Stops	386	veh/h	464	pers/h
Effective Stop Rate	0.22		0.22	
Proportion Queued	0.44		0.44	
Performance Index	72.2		72.2	
Cost (Total)	710.52	$/h	710.52	$/h
Fuel Consumption (Total)	42.8	gal/h		
Carbon Dioxide (Total)	382.4	kg/h		
Hydrocarbons (Total)	0.034	kg/h		
Carbon Monoxide (Total)	0.483	kg/h		
NOx (Total)	0.444	kg/h		

Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: Same as Sign Control.
Intersection LOS value for Vehicles is based on average delay for all vehicle movements.
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Geometric Delay is not included).
Queue Model: HCM Queue Formula.
Site Model Variability Index (Iterations 3 to N): 0.0 %
Number of Iterations: 3 (Maximum: 10)
Largest change in Lane Degrees of Saturation for the last three Flow-Capacity Iterations: 100.0% 94.6% 0.0%

Intersection Performance - Annual Values				
Performance Measure	**Vehicles**		**Persons**	
Demand Flows (Total)	838,957	veh/y	1,006,748	pers/y
Delay	2,796	veh-h/y	3,356	pers-h/y
Effective Stops	185,512	veh/y	222,614	pers/y
Travel Distance	529,661	veh-mi/y	635,594	pers-mi/y
Travel Time	16,760	veh-h/y	20,112	pers-h/y

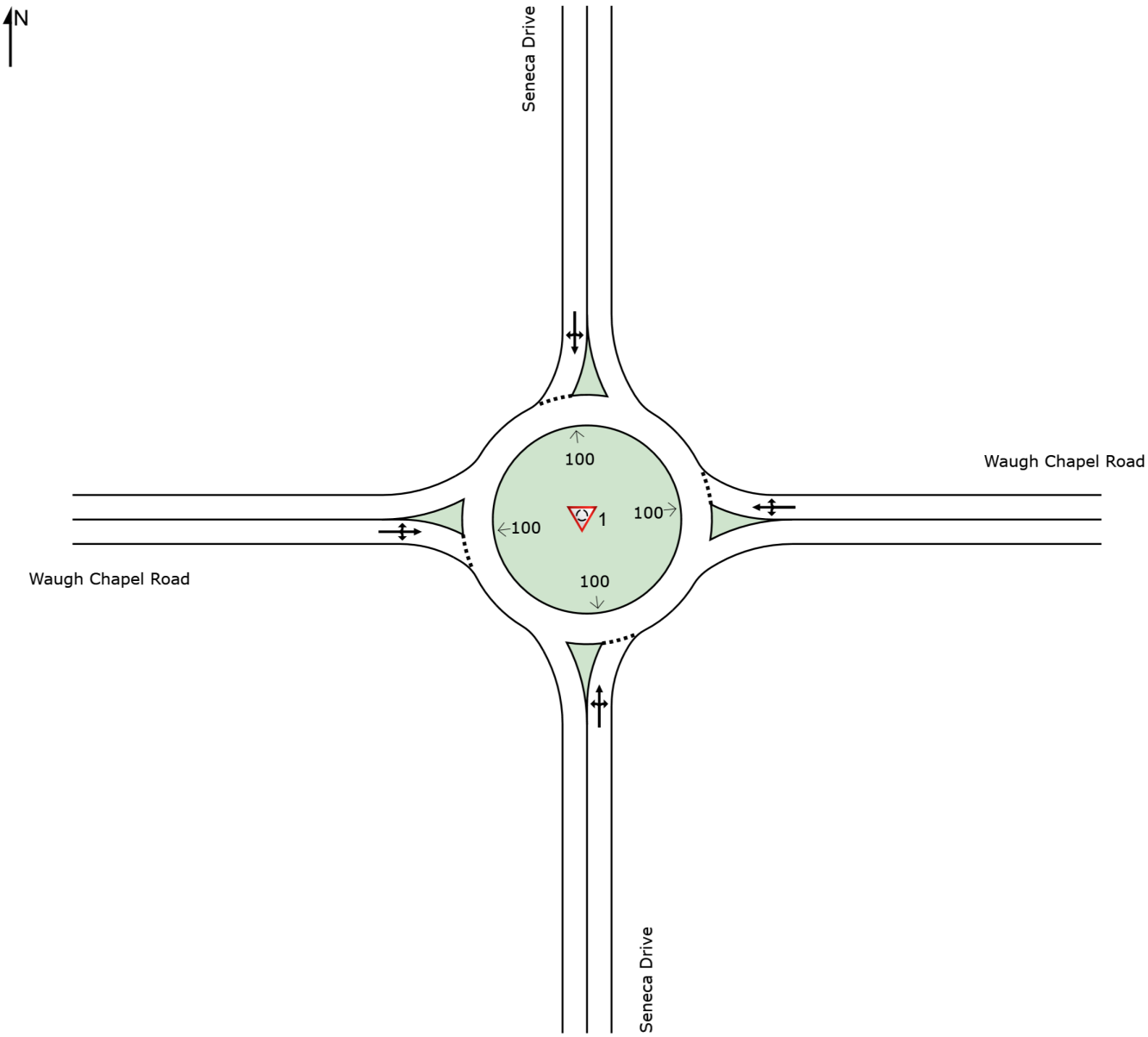
Cost	341,051	$/y	341,051 $/y
Fuel Consumption	20,525	gal/y	
Carbon Dioxide	183,546	kg/y	
Hydrocarbons	16	kg/y	
Carbon Monoxide	232	kg/y	
NOx	213	kg/y	

SITE LAYOUT

Site: 1 [Seneca Drive PM (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

Layout pictures are schematic functional drawings reflecting input data. They are not design drawings.



MOVEMENT SUMMARY

Site: 1 [Seneca Drive PM (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

Vehicle Movement Performance

Mov ID	Turn	INPUT VOLUMES [Total veh/h	HV] %	DEMAND FLOWS [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	Dist] ft	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed mph
South: Seneca Drive														
3	L2	33	2.0	36	2.0	0.158	8.7	LOS A	0.6	15.2	0.66	0.66	0.66	32.2
8	T1	2	2.0	2	2.0	0.158	8.7	LOS A	0.6	15.2	0.66	0.66	0.66	32.1
18	R2	43	2.0	47	2.0	0.158	8.7	LOS A	0.6	15.2	0.66	0.66	0.66	31.3
Approach		78	2.0	85	2.0	0.158	8.7	LOS A	0.6	15.2	0.66	0.66	0.66	31.7
East: Waugh Chapel Road														
1	L2	54	2.0	59	2.0	0.537	8.6	LOS A	4.4	112.4	0.27	0.11	0.27	33.2
6	T1	578	2.0	628	2.0	0.537	8.6	LOS A	4.4	112.4	0.27	0.11	0.27	33.2
16	R2	8	2.0	9	2.0	0.537	8.6	LOS A	4.4	112.4	0.27	0.11	0.27	32.2
Approach		640	2.0	696	2.0	0.537	8.6	LOS A	4.4	112.4	0.27	0.11	0.27	33.2
North: Seneca Drive														
7	L2	1	2.0	1	2.0	0.012	5.8	LOS A	0.0	1.1	0.59	0.46	0.59	34.4
4	T1	1	2.0	1	2.0	0.012	5.8	LOS A	0.0	1.1	0.59	0.46	0.59	34.3
14	R2	5	2.0	5	2.0	0.012	5.8	LOS A	0.0	1.1	0.59	0.46	0.59	33.3
Approach		7	2.0	8	2.0	0.012	5.8	LOS A	0.0	1.1	0.59	0.46	0.59	33.6
West: Waugh Chapel Road														
5	L2	3	2.0	3	2.0	0.756	14.8	LOS B	10.1	257.1	0.55	0.26	0.55	30.7
2	T1	811	2.0	882	2.0	0.756	14.8	LOS B	10.1	257.1	0.55	0.26	0.55	30.6
12	R2	69	2.0	75	2.0	0.756	14.8	LOS B	10.1	257.1	0.55	0.26	0.55	29.8
Approach		883	2.0	960	2.0	0.756	14.8	LOS B	10.1	257.1	0.55	0.26	0.55	30.5
All Vehicles		1608	2.0	1748	2.0	0.756	12.0	LOS B	10.1	257.1	0.44	0.22	0.44	31.6

Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: Same as Sign Control.
Vehicle movement LOS values are based on average delay and v/c ratio (degree of saturation) per movement.
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Intersection and Approach LOS values are based on average delay for all movements (v/c not used as specified in HCM 6).
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Geometric Delay is not included).
Queue Model: HCM Queue Formula.
Gap-Acceptance Capacity: Traditional M1.
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

INTERSECTION SUMMARY

Site: 1 [Old Waugh Chapel AM (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

Intersection Performance - Hourly Values				
Performance Measure	**Vehicles**		**Persons**	
Travel Speed (Average)	33.0	mph	33.0	mph
Travel Distance (Total)	815.4	veh-mi/h	978.5	pers-mi/h
Travel Time (Total)	24.7	veh-h/h	29.6	pers-h/h
Desired Speed (Program)	40.0	mph		
Speed Efficiency	0.83			
Travel Time Index	8.06			
Congestion Coefficient	1.21			
Demand Flows (Total)	1291	veh/h	1550	pers/h
Percent Heavy Vehicles (Demand)	2.0	%		
Degree of Saturation	0.661			
Practical Spare Capacity	28.6	%		
Effective Intersection Capacity	1954	veh/h		
Control Delay (Total)	3.32	veh-h/h	3.98	pers-h/h
Control Delay (Average)	9.2	sec	9.2	sec
Control Delay (Worst Lane)	11.0	sec		
Control Delay (Worst Movement)	11.0	sec	11.0	sec
Geometric Delay (Average)	0.0	sec		
Stop-Line Delay (Average)	9.2	sec		
Idling Time (Average)	8.5	sec		
Intersection Level of Service (LOS)	LOS A			
95% Back of Queue - Vehicles (Worst Lane)	7.6	veh		
95% Back of Queue - Distance (Worst Lane)	193.6	ft		
Ave. Queue Storage Ratio (Worst Lane)	0.05			
Total Effective Stops	44	veh/h	52	pers/h
Effective Stop Rate	0.03		0.03	
Proportion Queued	0.13		0.13	
Performance Index	39.1		39.1	
Cost (Total)	501.59	$/h	501.59	$/h
Fuel Consumption (Total)	30.1	gal/h		
Carbon Dioxide (Total)	269.0	kg/h		
Hydrocarbons (Total)	0.023	kg/h		
Carbon Monoxide (Total)	0.342	kg/h		
NOx (Total)	0.306	kg/h		

Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: Same as Sign Control.
Intersection LOS value for Vehicles is based on average delay for all vehicle movements.
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Geometric Delay is not included).
Queue Model: HCM Queue Formula.
Site Model Variability Index (Iterations 3 to N): 0.0 %
Number of Iterations: 3 (Maximum: 10)
Largest change in Lane Degrees of Saturation for the last three Flow-Capacity Iterations: 100.0% 94.5% 0.0%

Intersection Performance - Annual Values				
Performance Measure	**Vehicles**		**Persons**	
Demand Flows (Total)	619,826	veh/y	743,791	pers/y
Delay	1,593	veh-h/y	1,911	pers-h/y
Effective Stops	20,901	veh/y	25,081	pers/y
Travel Distance	391,400	veh-mi/y	469,680	pers-mi/y
Travel Time	11,852	veh-h/y	14,223	pers-h/y

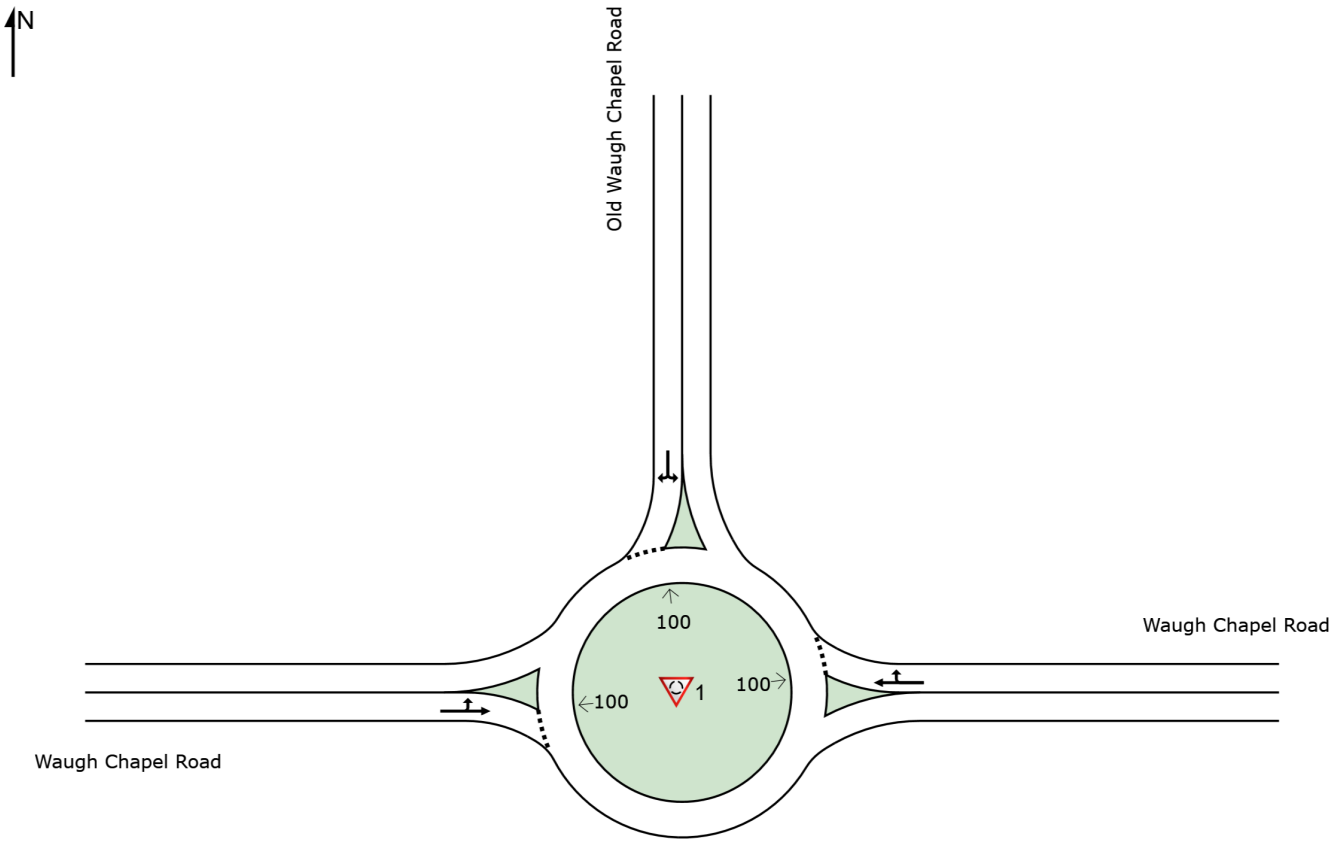
Cost	240,764	$/y	240,764	$/y
Fuel Consumption	14,434	gal/y		
Carbon Dioxide	129,098	kg/y		
Hydrocarbons	11	kg/y		
Carbon Monoxide	164	kg/y		
NOx	147	kg/y		

SITE LAYOUT

Site: 1 [Old Waugh Chapel AM (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

Layout pictures are schematic functional drawings reflecting input data. They are not design drawings.



MOVEMENT SUMMARY

Site: 1 [Old Waugh Chapel AM (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

Vehicle Movement Performance

Mov ID	Turn	INPUT VOLUMES [Total veh/h	HV] %	DEMAND FLOWS [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	Dist] ft	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed mph
East: Waugh Chapel Road														
6	T1	795	2.0	864	2.0	0.661	11.0	LOS B	7.6	193.6	0.13	0.02	0.13	32.2
16	R2	22	2.0	24	2.0	0.661	11.0	LOS B	7.6	193.6	0.13	0.02	0.13	31.4
Approach		817	2.0	888	2.0	0.661	11.0	LOS B	7.6	193.6	0.13	0.02	0.13	32.2
North: Old Waugh Chapel Road														
7	L2	14	2.0	15	2.0	0.038	7.0	LOS A	0.1	3.5	0.63	0.58	0.63	32.3
14	R2	5	2.0	5	2.0	0.038	7.0	LOS A	0.1	3.5	0.63	0.58	0.63	31.3
Approach		19	2.0	21	2.0	0.038	7.0	LOS A	0.1	3.5	0.63	0.58	0.63	32.0
West: Waugh Chapel Road														
5	L2	6	2.0	7	2.0	0.287	5.2	LOS A	1.6	41.5	0.10	0.03	0.10	35.2
2	T1	346	2.0	376	2.0	0.287	5.2	LOS A	1.6	41.5	0.10	0.03	0.10	35.1
Approach		352	2.0	383	2.0	0.287	5.2	LOS A	1.6	41.5	0.10	0.03	0.10	35.1
All Vehicles		1188	2.0	1291	2.0	0.661	9.2	LOS A	7.6	193.6	0.13	0.03	0.13	33.0

Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: Same as Sign Control.
Vehicle movement LOS values are based on average delay and v/c ratio (degree of saturation) per movement.
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Intersection and Approach LOS values are based on average delay for all movements (v/c not used as specified in HCM 6).
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Geometric Delay is not included).
Queue Model: HCM Queue Formula.
Gap-Acceptance Capacity: Traditional M1.
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

INTERSECTION SUMMARY

Site: 1 [Old Waugh Chapel PM (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

Intersection Performance - Hourly Values				
Performance Measure	**Vehicles**		**Persons**	
Travel Speed (Average)	32.5	mph	32.5	mph
Travel Distance (Total)	1031.1	veh-mi/h	1237.3	pers-mi/h
Travel Time (Total)	31.8	veh-h/h	38.1	pers-h/h
Desired Speed (Program)	40.0	mph		
Speed Efficiency	0.81			
Travel Time Index	7.91			
Congestion Coefficient	1.23			
Demand Flows (Total)	1633	veh/h	1959	pers/h
Percent Heavy Vehicles (Demand)	2.0	%		
Degree of Saturation	0.709			
Practical Spare Capacity	19.8	%		
Effective Intersection Capacity	2302	veh/h		
Control Delay (Total)	4.76	veh-h/h	5.71	pers-h/h
Control Delay (Average)	10.5	sec	10.5	sec
Control Delay (Worst Lane)	12.6	sec		
Control Delay (Worst Movement)	12.6	sec	12.6	sec
Geometric Delay (Average)	0.0	sec		
Stop-Line Delay (Average)	10.5	sec		
Idling Time (Average)	9.4	sec		
Intersection Level of Service (LOS)	LOS B			
95% Back of Queue - Vehicles (Worst Lane)	9.2	veh		
95% Back of Queue - Distance (Worst Lane)	233.2	ft		
Ave. Queue Storage Ratio (Worst Lane)	0.06			
Total Effective Stops	83	veh/h	99	pers/h
Effective Stop Rate	0.05		0.05	
Proportion Queued	0.17		0.17	
Performance Index	52.3		52.3	
Cost (Total)	643.49	$/h	643.49	$/h
Fuel Consumption (Total)	38.3	gal/h		
Carbon Dioxide (Total)	343.0	kg/h		
Hydrocarbons (Total)	0.030	kg/h		
Carbon Monoxide (Total)	0.435	kg/h		
NOx (Total)	0.390	kg/h		

Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: Same as Sign Control.
Intersection LOS value for Vehicles is based on average delay for all vehicle movements.
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Geometric Delay is not included).
Queue Model: HCM Queue Formula.
Site Model Variability Index (Iterations 3 to N): 0.0 %
Number of Iterations: 3 (Maximum: 10)
Largest change in Lane Degrees of Saturation for the last three Flow-Capacity Iterations: 100.0% 93.1% 0.0%

Intersection Performance - Annual Values				
Performance Measure	**Vehicles**		**Persons**	
Demand Flows (Total)	783,652	veh/y	940,383	pers/y
Delay	2,285	veh-h/y	2,742	pers-h/y
Effective Stops	39,607	veh/y	47,528	pers/y
Travel Distance	494,904	veh-mi/y	593,885	pers-mi/y
Travel Time	15,247	veh-h/y	18,297	pers-h/y

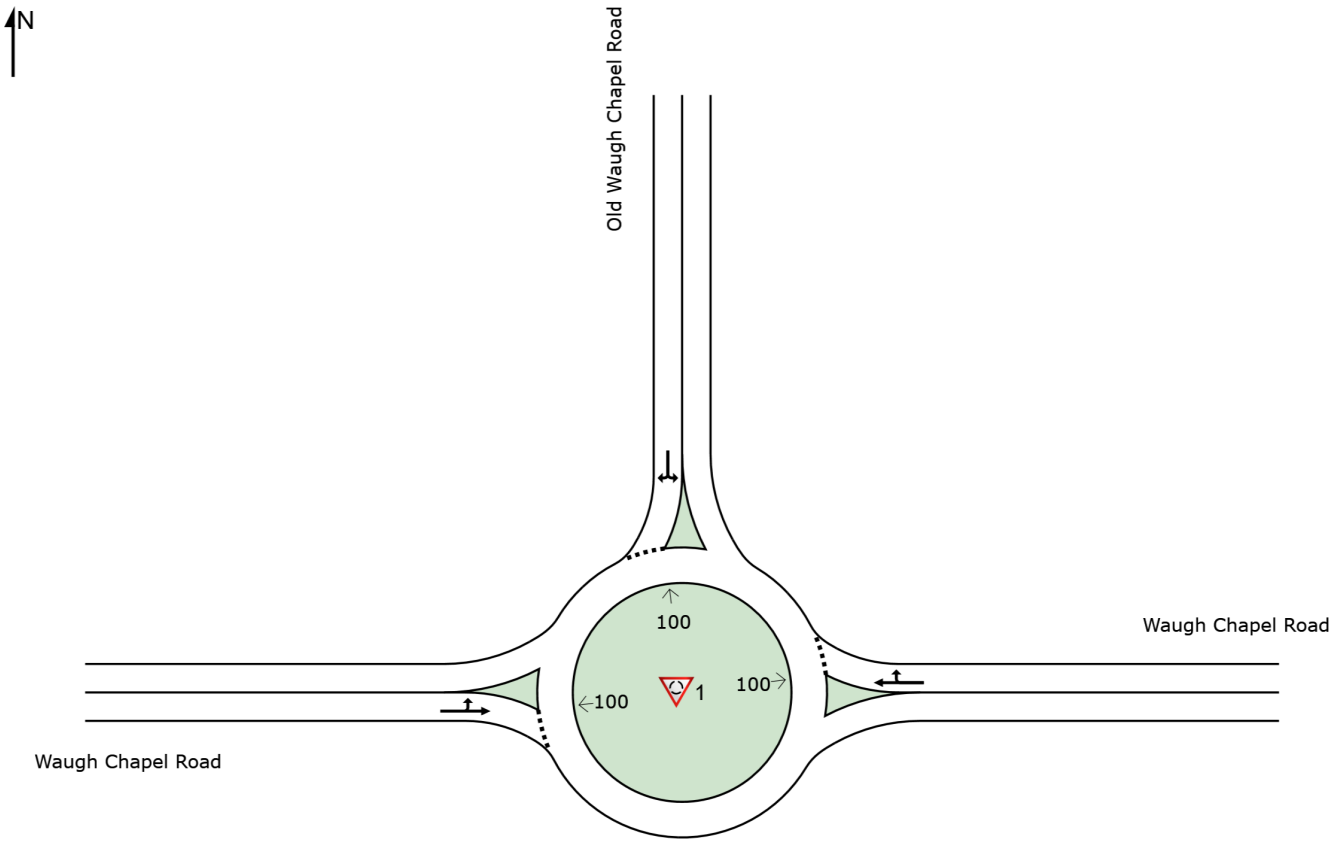
Cost	308,877	$/y	308,877	$/y
Fuel Consumption	18,407	gal/y		
Carbon Dioxide	164,623	kg/y		
Hydrocarbons	14	kg/y		
Carbon Monoxide	209	kg/y		
NOx	187	kg/y		

SITE LAYOUT

Site: 1 [Old Waugh Chapel PM (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

Layout pictures are schematic functional drawings reflecting input data. They are not design drawings.



MOVEMENT SUMMARY

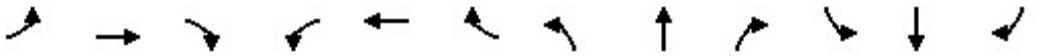
Site: 1 [Old Waugh Chapel PM (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

Vehicle Movement Performance

Mov ID	Turn	INPUT VOLUMES [Total veh/h	HV] %	DEMAND FLOWS [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	Dist] ft	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed mph
East: Waugh Chapel Road														
6	T1	600	2.0	652	2.0	0.496	7.7	LOS A	4.0	100.7	0.04	0.01	0.04	33.8
16	R2	16	2.0	17	2.0	0.496	7.7	LOS A	4.0	100.7	0.04	0.01	0.04	32.9
Approach		616	2.0	670	2.0	0.496	7.7	LOS A	4.0	100.7	0.04	0.01	0.04	33.8
North: Old Waugh Chapel Road														
7	L2	16	2.0	17	2.0	0.030	5.6	LOS A	0.1	2.9	0.57	0.47	0.57	32.7
14	R2	3	2.0	3	2.0	0.030	5.6	LOS A	0.1	2.9	0.57	0.47	0.57	31.7
Approach		19	2.0	21	2.0	0.030	5.6	LOS A	0.1	2.9	0.57	0.47	0.57	32.5
West: Waugh Chapel Road														
5	L2	2	2.0	2	2.0	0.709	12.6	LOS B	9.2	233.2	0.25	0.07	0.25	31.6
2	T1	865	2.0	940	2.0	0.709	12.6	LOS B	9.2	233.2	0.25	0.07	0.25	31.6
Approach		867	2.0	942	2.0	0.709	12.6	LOS B	9.2	233.2	0.25	0.07	0.25	31.6
All Vehicles		1502	2.0	1633	2.0	0.709	10.5	LOS B	9.2	233.2	0.17	0.05	0.17	32.5

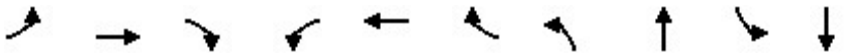
Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: Same as Sign Control.
Vehicle movement LOS values are based on average delay and v/c ratio (degree of saturation) per movement.
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Intersection and Approach LOS values are based on average delay for all movements (v/c not used as specified in HCM 6).
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Geometric Delay is not included).
Queue Model: HCM Queue Formula.
Gap-Acceptance Capacity: Traditional M1.
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	48	349	33	81	545	45	167	69	167	90	19	49
Future Volume (vph)	48	349	33	81	545	45	167	69	167	90	19	49
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0		5.0	5.0	
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00	1.00	
Frpb, ped/bikes	1.00	1.00	0.98	1.00	1.00	1.00	1.00	1.00		1.00	1.00	
Flpb, ped/bikes	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00	1.00	
Frt	1.00	1.00	0.85	1.00	1.00	0.85	1.00	0.89		1.00	0.89	
Flt Protected	0.95	1.00	1.00	0.95	1.00	1.00	0.95	1.00		0.95	1.00	
Satd. Flow (prot)	1770	1863	1544	1768	1863	1583	1770	1665		1770	1663	
Flt Permitted	0.22	1.00	1.00	0.42	1.00	1.00	0.71	1.00		0.36	1.00	
Satd. Flow (perm)	414	1863	1544	790	1863	1583	1320	1665		661	1663	
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	52	379	36	88	592	49	182	75	182	98	21	53
RTOR Reduction (vph)	0	0	0	0	0	28	0	68	0	0	46	0
Lane Group Flow (vph)	52	379	36	88	592	21	182	189	0	98	28	0
Confl. Peds. (#/hr)			3	3								
Turn Type	pm+pt	NA	Perm	pm+pt	NA	Perm	D.P+P	NA		D.P+P	NA	
Protected Phases	5	2		1	6		3	8		7	4	
Permitted Phases	2		2	6		6	4			8		
Actuated Green, G (s)	40.9	37.1	37.1	40.9	37.1	37.1	24.0	15.9		24.0	11.2	
Effective Green, g (s)	40.9	37.1	37.1	40.9	37.1	37.1	24.0	15.9		24.0	11.2	
Actuated g/C Ratio	0.48	0.44	0.44	0.48	0.44	0.44	0.28	0.19		0.28	0.13	
Clearance Time (s)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0		5.0	5.0	
Vehicle Extension (s)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0		3.0	3.0	
Lane Grp Cap (vph)	260	814	674	424	814	691	440	311		292	219	
v/s Ratio Prot	0.01	0.20		c0.01	c0.32		c0.06	c0.11		0.03	0.02	
v/s Ratio Perm	0.09		0.02	0.09		0.01	0.05			0.06		
v/c Ratio	0.20	0.47	0.05	0.21	0.73	0.03	0.41	0.61		0.34	0.13	
Uniform Delay, d1	13.9	16.9	13.8	12.4	19.7	13.6	24.3	31.6		23.4	32.5	
Progression Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00	1.00	
Incremental Delay, d2	0.4	0.4	0.0	0.2	3.3	0.0	0.6	3.3		0.7	0.3	
Delay (s)	14.3	17.3	13.8	12.6	23.0	13.7	25.0	35.0		24.1	32.8	
Level of Service	B	B	B	B	C	B	C	C		C	C	
Approach Delay (s)		16.7			21.1			30.8			27.8	
Approach LOS		B			C			C			C	

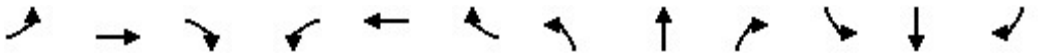
Intersection Summary			
HCM 2000 Control Delay	23.0	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.64		
Actuated Cycle Length (s)	84.9	Sum of lost time (s)	20.0
Intersection Capacity Utilization	67.6%	ICU Level of Service	C
Analysis Period (min)	15		

c Critical Lane Group



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	SBL	SBT
Lane Group Flow (vph)	52	379	36	88	592	49	182	257	98	74
v/c Ratio	0.18	0.46	0.05	0.20	0.72	0.06	0.41	0.67	0.30	0.24
Control Delay	13.9	22.0	18.2	13.8	28.6	0.2	24.7	34.4	23.5	17.8
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	13.9	22.0	18.2	13.8	28.6	0.2	24.7	34.4	23.5	17.8
Queue Length 50th (ft)	12	141	11	21	257	0	65	81	33	9
Queue Length 95th (ft)	43	312	39	66	550	0	156	231	90	56
Internal Link Dist (ft)		791			637			380		430
Turn Bay Length (ft)	100		180	100		150				
Base Capacity (vph)	294	1324	1095	451	1324	1154	638	643	588	648
Starvation Cap Reductn	0	0	0	0	0	0	0	0	0	0
Spillback Cap Reductn	0	0	0	0	0	0	0	0	0	0
Storage Cap Reductn	0	0	0	0	0	0	0	0	0	0
Reduced v/c Ratio	0.18	0.29	0.03	0.20	0.45	0.04	0.29	0.40	0.17	0.11

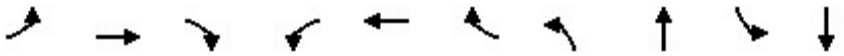
Intersection Summary



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	57	639	158	278	543	72	55	25	150	92	45	42
Future Volume (vph)	57	639	158	278	543	72	55	25	150	92	45	42
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0		4.5	5.0	
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00	1.00	
Frpb, ped/bikes	1.00	1.00	0.97	1.00	1.00	0.98	1.00	1.00		1.00	0.99	
Flpb, ped/bikes	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00	1.00	
Frt	1.00	1.00	0.85	1.00	1.00	0.85	1.00	0.87		1.00	0.93	
Flt Protected	0.95	1.00	1.00	0.95	1.00	1.00	0.95	1.00		0.95	1.00	
Satd. Flow (prot)	1769	1863	1542	1770	1863	1546	1768	1623		1770	1709	
Flt Permitted	0.39	1.00	1.00	0.24	1.00	1.00	0.63	1.00		0.33	1.00	
Satd. Flow (perm)	732	1863	1542	455	1863	1546	1178	1623		616	1709	
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	62	695	172	302	590	78	60	27	163	100	49	46
RTOR Reduction (vph)	0	0	0	0	0	26	0	148	0	0	29	0
Lane Group Flow (vph)	62	695	172	302	590	52	60	42	0	100	66	0
Confl. Peds. (#/hr)	2		3	3		2	1					1
Turn Type	pm+pt	NA	Perm	pm+pt	NA	Perm	D.P+P	NA		D.P+P	NA	
Protected Phases	5	2		1	6		3	8		7	4	
Permitted Phases	2		2	6		6	4			8		
Actuated Green, G (s)	81.5	78.3	78.3	94.3	86.1	86.1	20.7	12.1		21.2	15.4	
Effective Green, g (s)	81.5	78.3	78.3	94.3	86.1	86.1	20.7	12.1		21.2	15.4	
Actuated g/C Ratio	0.63	0.60	0.60	0.73	0.66	0.66	0.16	0.09		0.16	0.12	
Clearance Time (s)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0		4.5	5.0	
Vehicle Extension (s)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0		3.0	3.0	
Lane Grp Cap (vph)	484	1122	928	441	1233	1023	211	151		181	202	
v/s Ratio Prot	0.00	0.37		c0.06	0.32		0.01	0.03		c0.04	0.04	
v/s Ratio Perm	0.08		0.11	c0.44		0.03	0.03			c0.05		
v/c Ratio	0.13	0.62	0.19	0.68	0.48	0.05	0.28	0.28		0.55	0.33	
Uniform Delay, d1	9.7	16.4	11.6	12.7	10.9	7.7	49.4	54.9		48.5	52.5	
Progression Factor	1.00	1.00	1.00	1.23	0.25	1.00	1.00	1.00		1.00	1.00	
Incremental Delay, d2	0.1	2.6	0.4	3.2	1.0	0.1	0.7	1.0		3.6	0.9	
Delay (s)	9.8	19.0	12.0	18.9	3.7	7.7	50.2	55.9		52.1	53.5	
Level of Service	A	B	B	B	A	A	D	E		D	D	
Approach Delay (s)		17.1			8.7			54.5			52.8	
Approach LOS		B			A			D			D	

Intersection Summary			
HCM 2000 Control Delay	20.6	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.68		
Actuated Cycle Length (s)	130.0	Sum of lost time (s)	20.0
Intersection Capacity Utilization	80.9%	ICU Level of Service	D
Analysis Period (min)	15		

c Critical Lane Group



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	SBL	SBT
Lane Group Flow (vph)	62	695	172	302	590	78	60	190	100	95
v/c Ratio	0.12	0.61	0.18	0.68	0.47	0.07	0.28	0.66	0.56	0.41
Control Delay	7.6	20.6	13.4	16.1	3.9	0.3	45.5	22.6	54.8	39.1
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	7.6	20.6	13.4	16.1	3.9	0.3	45.5	22.6	54.8	39.1
Queue Length 50th (ft)	12	322	56	29	43	0	44	22	75	51
Queue Length 95th (ft)	38	624	128	m#144	261	m2	71	87	108	92
Internal Link Dist (ft)		791			637			380		430
Turn Bay Length (ft)	100		180	100		150				
Base Capacity (vph)	499	1135	939	444	1261	1091	508	701	184	406
Starvation Cap Reductn	0	0	0	0	0	0	0	0	0	0
Spillback Cap Reductn	0	0	0	0	0	0	0	0	0	0
Storage Cap Reductn	0	0	0	0	0	0	0	0	0	0
Reduced v/c Ratio	0.12	0.61	0.18	0.68	0.47	0.07	0.12	0.27	0.54	0.23

Intersection Summary

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.
m Volume for 95th percentile queue is metered by upstream signal.

MOVEMENT SUMMARY

Site: 1 [Autumn Gold Drive PM (2 Lane) (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

Vehicle Movement Performance

Mov ID	Turn	INPUT VOLUMES [Total veh/h	HV] %	DEMAND FLOWS [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	Dist] ft	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed mph
South: Autumn Gold Drive														
3	L2	25	2.0	27	2.0	0.108	9.6	LOS A	0.4	9.8	0.70	0.70	0.70	31.5
18	R2	19	2.0	21	2.0	0.108	9.6	LOS A	0.4	9.8	0.70	0.70	0.70	30.6
Approach		44	2.0	48	2.0	0.108	9.6	LOS A	0.4	9.8	0.70	0.70	0.70	31.1
East: Waugh Chapel Road														
1	L2	18	2.0	20	2.0	0.443	7.0	LOS A	2.9	73.5	0.16	0.05	0.16	34.2
6	T1	1088	2.0	1183	2.0	0.443	7.0	LOS A	2.9	73.5	0.16	0.05	0.16	34.2
Approach		1106	2.0	1202	2.0	0.443	7.0	LOS A	2.9	73.5	0.16	0.05	0.16	34.2
West: Waugh Chapel Road														
2	T1	985	2.0	1071	2.0	0.405	6.4	LOS A	2.5	63.5	0.13	0.04	0.13	34.5
12	R2	33	2.0	36	2.0	0.405	6.4	LOS A	2.5	63.5	0.13	0.04	0.13	33.4
Approach		1018	2.0	1107	2.0	0.405	6.4	LOS A	2.5	63.5	0.13	0.04	0.13	34.5
All Vehicles		2168	2.0	2357	2.0	0.443	6.8	LOS A	2.9	73.5	0.16	0.06	0.16	34.2

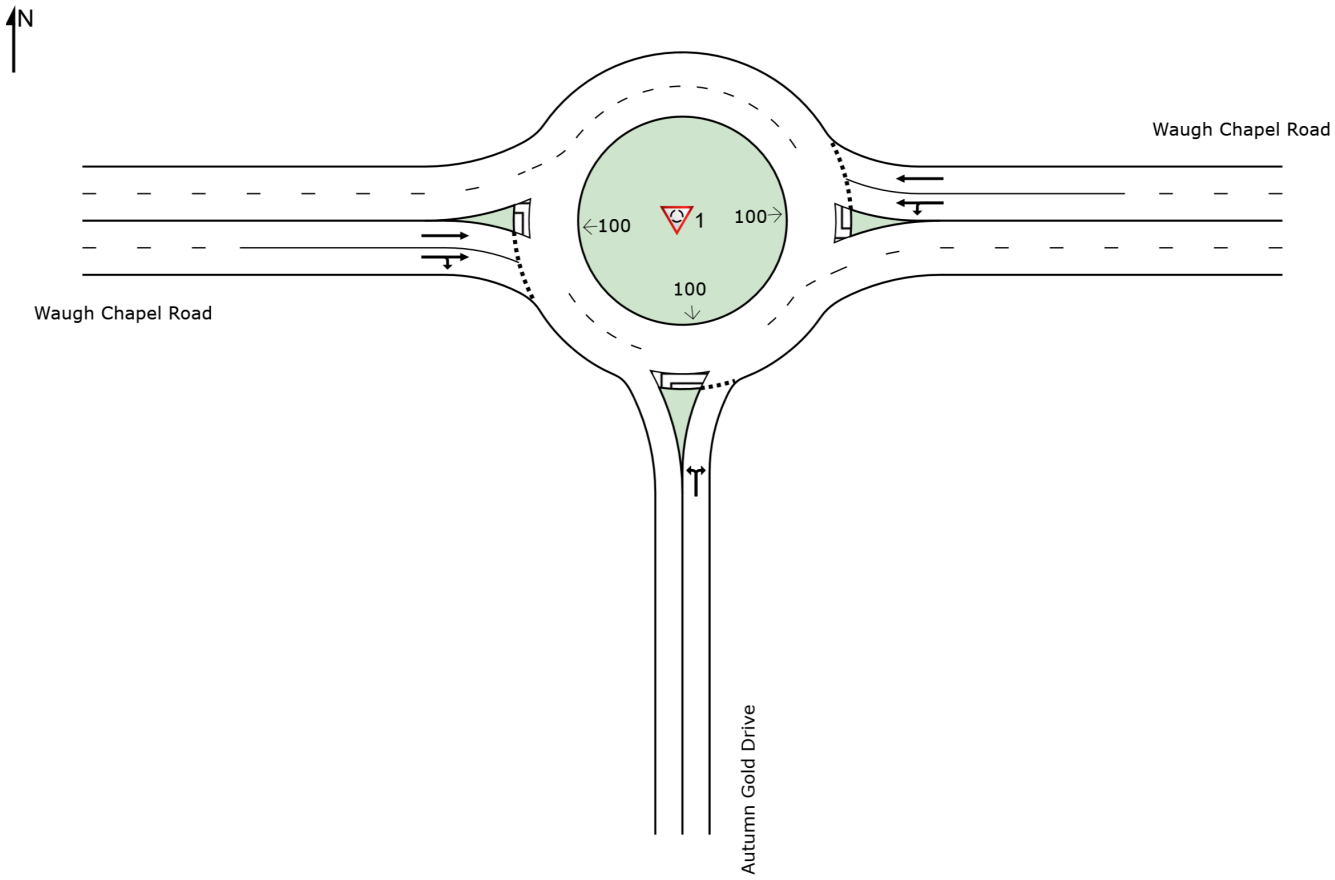
Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: Same as Sign Control.
Vehicle movement LOS values are based on average delay and v/c ratio (degree of saturation) per movement.
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Intersection and Approach LOS values are based on average delay for all movements (v/c not used as specified in HCM 6).
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Geometric Delay is not included).
Queue Model: HCM Queue Formula.
Gap-Acceptance Capacity: Traditional M1.
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

SITE LAYOUT

Site: 1 [Autumn Gold Drive PM (2 Lane) (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

Layout pictures are schematic functional drawings reflecting input data. They are not design drawings.



INTERSECTION SUMMARY

Site: 1 [Autumn Gold Drive PM (2 Lane) (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

Intersection Performance - Hourly Values				
Performance Measure	**Vehicles**		**Persons**	
Travel Speed (Average)	34.2	mph	34.2	mph
Travel Distance (Total)	1488.1	veh-mi/h	1785.8	pers-mi/h
Travel Time (Total)	43.5	veh-h/h	52.1	pers-h/h
Desired Speed (Program)	40.0	mph		
Speed Efficiency	0.86			
Travel Time Index	8.40			
Congestion Coefficient	1.17			
Demand Flows (Total)	2357	veh/h	2828	pers/h
Percent Heavy Vehicles (Demand)	2.0	%		
Degree of Saturation	0.443			
Practical Spare Capacity	92.0	%		
Effective Intersection Capacity	5322	veh/h		
Control Delay (Total)	4.43	veh-h/h	5.31	pers-h/h
Control Delay (Average)	6.8	sec	6.8	sec
Control Delay (Worst Lane)	9.6	sec		
Control Delay (Worst Movement)	9.6	sec	9.6	sec
Geometric Delay (Average)	0.0	sec		
Stop-Line Delay (Average)	6.8	sec		
Idling Time (Average)	5.8	sec		
Intersection Level of Service (LOS)	LOS A			
95% Back of Queue - Vehicles (Worst Lane)	2.9	veh		
95% Back of Queue - Distance (Worst Lane)	73.5	ft		
Ave. Queue Storage Ratio (Worst Lane)	0.02			
Total Effective Stops	137	veh/h	165	pers/h
Effective Stop Rate	0.06		0.06	
Proportion Queued	0.16		0.16	
Performance Index	51.7		51.7	
Cost (Total)	891.30	$/h	891.30	$/h
Fuel Consumption (Total)	54.6	gal/h		
Carbon Dioxide (Total)	488.0	kg/h		
Hydrocarbons (Total)	0.042	kg/h		
Carbon Monoxide (Total)	0.623	kg/h		
NOx (Total)	0.559	kg/h		

Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: Same as Sign Control.
Intersection LOS value for Vehicles is based on average delay for all vehicle movements.
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Geometric Delay is not included).
Queue Model: HCM Queue Formula.
Site Model Variability Index (Iterations 3 to N): 0.0 %
Number of Iterations: 3 (Maximum: 10)
Largest change in Lane Degrees of Saturation for the last three Flow-Capacity Iterations: 100.0% 95.6% 0.0%

Intersection Performance - Annual Values				
Performance Measure	**Vehicles**		**Persons**	
Demand Flows (Total)	1,131,131	veh/y	1,357,357	pers/y
Delay	2,126	veh-h/y	2,551	pers-h/y
Effective Stops	65,986	veh/y	79,184	pers/y
Travel Distance	714,311	veh-mi/y	857,174	pers-mi/y
Travel Time	20,858	veh-h/y	25,029	pers-h/y

Cost	427,823	$/y	427,823	$/y
Fuel Consumption	26,188	gal/y		
Carbon Dioxide	234,218	kg/y		
Hydrocarbons	20	kg/y		
Carbon Monoxide	299	kg/y		
NOx	269	kg/y		

MOVEMENT SUMMARY

Site: 1 [Autumn Gold Drive AM (2 Lane) (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

Vehicle Movement Performance

Mov ID	Turn	INPUT VOLUMES [Total veh/h	HV] %	DEMAND FLOWS [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	Dist] ft	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed mph
South: Autumn Gold Drive														
3	L2	33	2.0	36	2.0	0.084	6.6	LOS A	0.3	8.1	0.61	0.58	0.61	32.6
18	R2	16	2.0	17	2.0	0.084	6.6	LOS A	0.3	8.1	0.61	0.58	0.61	31.6
Approach		49	2.0	53	2.0	0.084	6.6	LOS A	0.3	8.1	0.61	0.58	0.61	32.3
East: Waugh Chapel Road														
1	L2	6	2.0	7	2.0	0.298	5.3	LOS A	1.6	39.7	0.15	0.05	0.15	35.1
6	T1	732	2.0	796	2.0	0.298	5.3	LOS A	1.6	39.7	0.15	0.05	0.15	35.1
Approach		738	2.0	802	2.0	0.298	5.3	LOS A	1.6	39.7	0.15	0.05	0.15	35.1
West: Waugh Chapel Road														
2	T1	667	2.0	725	2.0	0.266	4.9	LOS A	1.4	34.5	0.05	0.01	0.05	35.3
12	R2	11	2.0	12	2.0	0.266	4.9	LOS A	1.4	34.5	0.05	0.01	0.05	34.2
Approach		678	2.0	737	2.0	0.266	4.9	LOS A	1.4	34.5	0.05	0.01	0.05	35.3
All Vehicles		1465	2.0	1592	2.0	0.298	5.1	LOS A	1.6	39.7	0.12	0.05	0.12	35.1

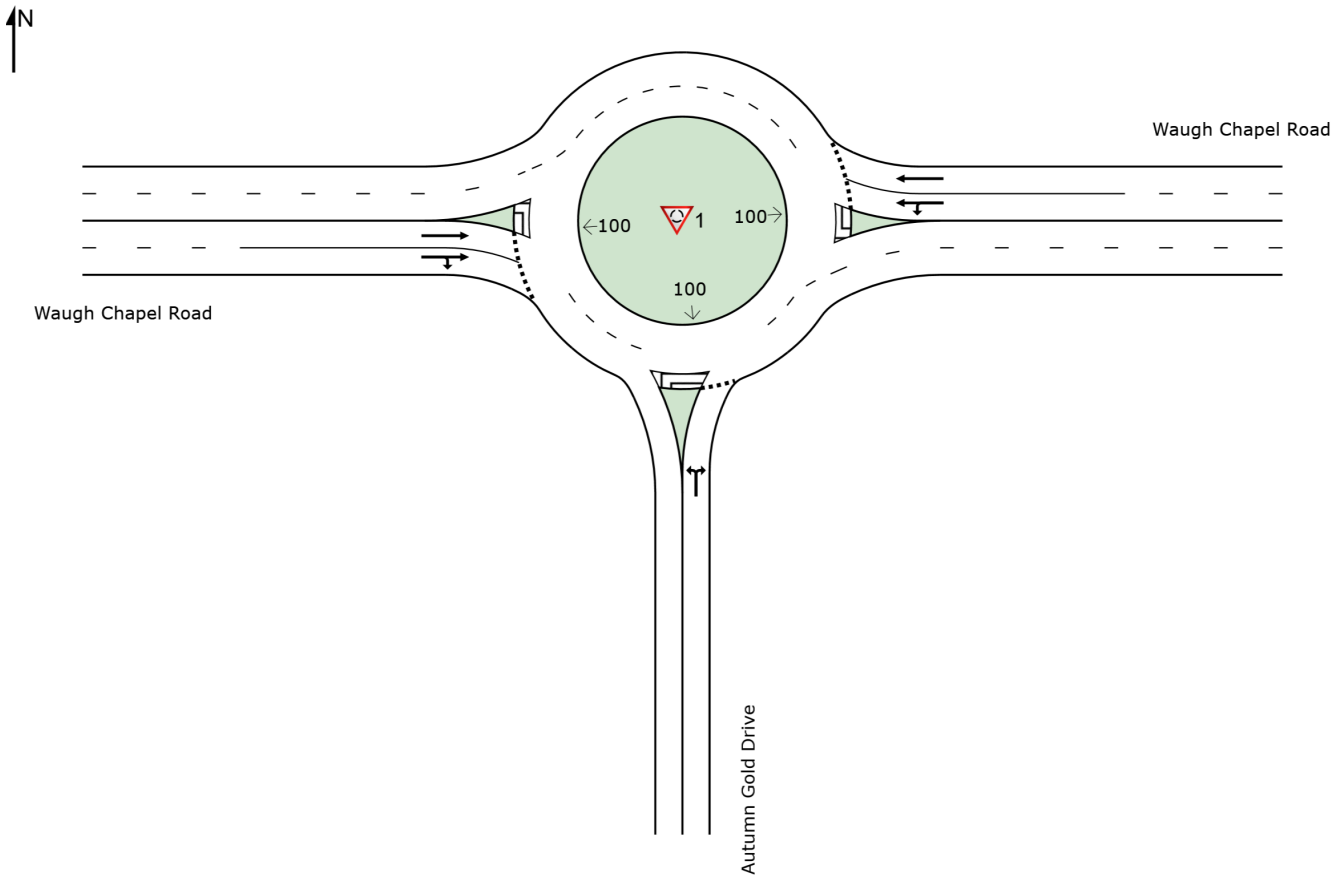
Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: Same as Sign Control.
Vehicle movement LOS values are based on average delay and v/c ratio (degree of saturation) per movement.
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Intersection and Approach LOS values are based on average delay for all movements (v/c not used as specified in HCM 6).
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Geometric Delay is not included).
Queue Model: HCM Queue Formula.
Gap-Acceptance Capacity: Traditional M1.
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

SITE LAYOUT

Site: 1 [Autumn Gold Drive AM (2 Lane) (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

Layout pictures are schematic functional drawings reflecting input data. They are not design drawings.



INTERSECTION SUMMARY

Site: 1 [Autumn Gold Drive AM (2 Lane) (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

Intersection Performance - Hourly Values				
Performance Measure	**Vehicles**		**Persons**	
Travel Speed (Average)	35.1	mph	35.1	mph
Travel Distance (Total)	1005.9	veh-mi/h	1207.1	pers-mi/h
Travel Time (Total)	28.7	veh-h/h	34.4	pers-h/h
Desired Speed (Program)	40.0	mph		
Speed Efficiency	0.88			
Travel Time Index	8.64			
Congestion Coefficient	1.14			
Demand Flows (Total)	1592	veh/h	1911	pers/h
Percent Heavy Vehicles (Demand)	2.0	%		
Degree of Saturation	0.298			
Practical Spare Capacity	185.4	%		
Effective Intersection Capacity	5346	veh/h		
Control Delay (Total)	2.27	veh-h/h	2.73	pers-h/h
Control Delay (Average)	5.1	sec	5.1	sec
Control Delay (Worst Lane)	6.6	sec		
Control Delay (Worst Movement)	6.6	sec	6.6	sec
Geometric Delay (Average)	0.0	sec		
Stop-Line Delay (Average)	5.1	sec		
Idling Time (Average)	4.4	sec		
Intersection Level of Service (LOS)	LOS A			
95% Back of Queue - Vehicles (Worst Lane)	1.6	veh		
95% Back of Queue - Distance (Worst Lane)	39.7	ft		
Ave. Queue Storage Ratio (Worst Lane)	0.01			
Total Effective Stops	81	veh/h	98	pers/h
Effective Stop Rate	0.05		0.05	
Proportion Queued	0.12		0.12	
Performance Index	33.1		33.1	
Cost (Total)	590.90	$/h	590.90	$/h
Fuel Consumption (Total)	36.6	gal/h		
Carbon Dioxide (Total)	326.9	kg/h		
Hydrocarbons (Total)	0.028	kg/h		
Carbon Monoxide (Total)	0.418	kg/h		
NOx (Total)	0.375	kg/h		

Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: Same as Sign Control.
Intersection LOS value for Vehicles is based on average delay for all vehicle movements.
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Geometric Delay is not included).
Queue Model: HCM Queue Formula.
Site Model Variability Index (Iterations 3 to N): 0.0 %
Number of Iterations: 3 (Maximum: 10)
Largest change in Lane Degrees of Saturation for the last three Flow-Capacity Iterations: 100.0% 93.6% 0.0%

Intersection Performance - Annual Values				
Performance Measure	**Vehicles**		**Persons**	
Demand Flows (Total)	764,348	veh/y	917,217	pers/y
Delay	1,092	veh-h/y	1,310	pers-h/y
Effective Stops	39,018	veh/y	46,822	pers/y
Travel Distance	482,844	veh-mi/y	579,412	pers-mi/y
Travel Time	13,759	veh-h/y	16,511	pers-h/y

Cost	283,633	$/y	283,633 $/y
Fuel Consumption	17,544	gal/y	
Carbon Dioxide	156,917	kg/y	
Hydrocarbons	14	kg/y	
Carbon Monoxide	201	kg/y	
NOx	180	kg/y	