# IVY ROAD (US 250)

Albemarle County, Virginia

**August 2018**

**Prepared by**

Kimley»Horn

vhb

STARS

**Prepared for**

VDOT

VDOT

# Ivy Road (US 250)

## Albemarle County, Virginia

**August 2018**

**Prepared for**

**Prepared by**

# ABSTRACT

STARS (Strategically Targeted Affordable Roadway Solutions) is a program within the Virginia Department of Transportation (VDOT) aimed at critical safety and congestion hot spots throughout the Commonwealth. The study area for this STARS project is US 250 (Ivy Road) from US 29 Bypass (Monocan Trail Road) to Route 240 (Three Notch'd Road) located in Albemarle County, Virginia, to the west of Charlottesville. US 250 is a designated Corridor of Statewide Significance (CoSS) and a Mobility Enhancement Segment (MES).

Ivy Road is a minor arterial that is rural on the western end and urban on the eastern. The western (i.e., rural) part of the corridor is a typical two-lane unsignalized roadway and does not experience much congestion or delay. The eastern (i.e., urban) part of the corridor includes signalized intersections and does experience congestion. Most of the corridor is not anticipated to experience significant growth in traffic volumes or a considerable deterioration in operations in future years, except for the area in vicinity of the US 250/US 29 interchange.

Through operational, safety, and field analysis, the project team identified 12 hot spots on this corridor. Each hot spot faces operational and/or safety concerns. The team developed recommendations for each of the hot spot intersections and segments. These recommendations ranged from short-term to long-term implementation. Short-term improvements include optimizing signal timings, installing new signing or pavement markings, or trimming vegetation along the corridor. Long-term improvements include installing a left-turn lane, constructing a roundabout, or widening the roadway.

The intersection of Ivy Road and Three Notch'd Road is a source of congestion and crashes. The geometry of this intersection is unfavorable to drivers on Three Notch'd Road. Through the High Risk Rural Roads (HRRR) program, VDOT received funding to construct a roundabout at this location.

The segment between Farmington Drive and Canterbury Road / Old Garth Road experiences heavy congestion. The commuter traffic pattern makes this location an ideal candidate for a reversible lane concept. The proposed improvements for this hot spot segment include potential roadway widening and implementation of reversible travel lanes.

In addition to recommending spot-specific treatments at hot spot locations, the project team applied systemic templates to the entire corridor. The type and tier of systemic template to apply was determined based on the intersection geometry and safety-related factors.

All recommendations aim to improve both the operations and the safety of this corridor.

# TABLE OF CONTENTS

# APPENDICES

# 1 INTRODUCTION

STARS (Strategically Targeted Affordable Roadway Solutions) is a program within the Virginia Department of Transportation (VDOT) aimed at critical safety and congestion hot spots throughout the Commonwealth. The Transportation and Mobility Planning Division (TMPD), in partnership with the Traffic Engineering Division (TED), is leading the studies being prepared throughout the state for each hot spot. The main purpose of the STARS program is to unite planners, traffic engineers, safety engineers, and maintenance and operations staff to jointly identify cost-effective, quick to implement (24-month or less) improvements aimed at improving safety and reducing congestion. This program will allow VDOT to better incorporate operations and safety planning into the long-term process. It is important to note that the recommendations outlined in this report represent a list of improvements that could potentially be implemented. Inclusion in this report does not constitute a commitment or guarantee for implementation.

The recommendations outlined in this report are organized into one of three categories – short term, intermediate, and long-term. The short-term category is comprised of improvements that could be implemented by state/local forces or packaged together into a corridor-long contract. Examples of these types of improvements include cutting back foliage to improve visibility, replacing signage, retiming signals, upgrading pavement markings, construction of median islands, etc. The intermediate category consists of improvements that are candidates for funding under the Highway Safety Improvement Program (HSIP). Long-term improvements are generally more extensive in nature and, as such, are candidates for SmartScale funding versus state/local forces or HSIP funding. Improvements in the long-term category will need more extensive planning, environmental, and design work before implementation can be considered.

# 2 STUDY AREA AND METHODOLOGY

The project study area is US 250 (Ivy Road) from Route 29 Bypass (Monacan Trail Road) to Route 240 (Three Notch'd Road) in Albemarle County, Virginia. The study corridor is 7.13 miles in length and is shown in **Figure 2.1**.

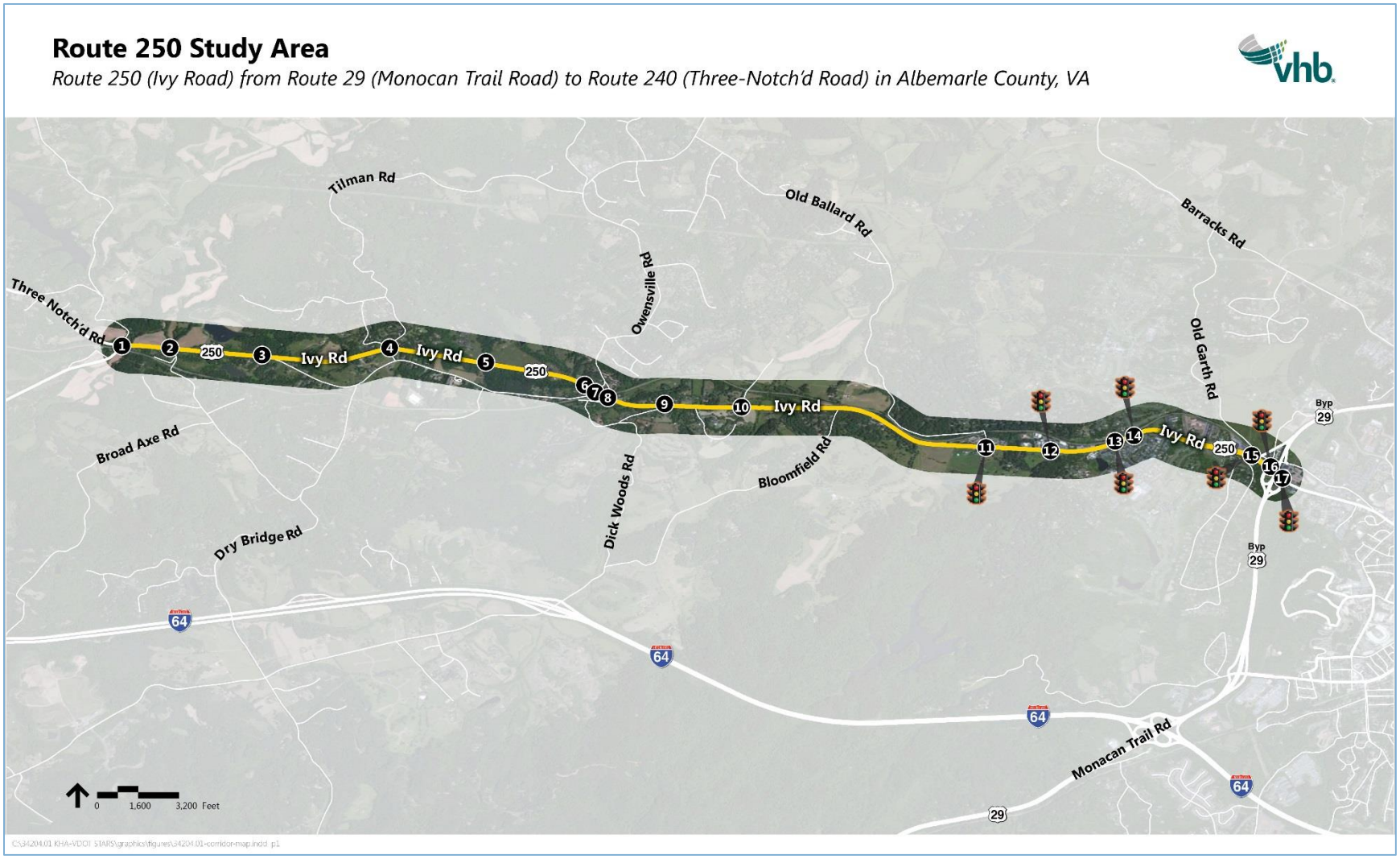



Figure 2.1 – Study Area

Through evaluation of crash locations, crash types, and other concerns, the study team identified the following hot spot locations, shown in **Figure 2.2**:

1. US 250 (Ivy Road) @ Route 240 (Three Notch'd Road)
2. US 250 (Ivy Road) @ Route 787 (Gillums Ridge Road)
3. US 250 (Ivy Road) @ Route 676 (Tilman Road)
4. US 250 (Ivy Road) @ Route 678 (Owensville Road)
5. US 250 (Ivy Road) between the C&O Railroad Overpass to Private Driveway
6. US 250 (Ivy Road) @ Broomley Road
7. US 250 (Ivy Road) between the East Entrance of UVA Northridge Medical Park and Broomley Road
8. US 250 (Ivy Road) @ UVA Northridge Medical Park
9. US 250 (Ivy Road) between Golf Course Drive / Colridge Drive and Bellair Exxon West Entrance
10. US 250 (Ivy Road) @ Route 846 (Canterbury Road / Old Garth Road)
11. US 250 (Ivy Road) @ US 29 Southbound Interchange
12. US 250 (Ivy Road) @ US 29 Northbound Interchange

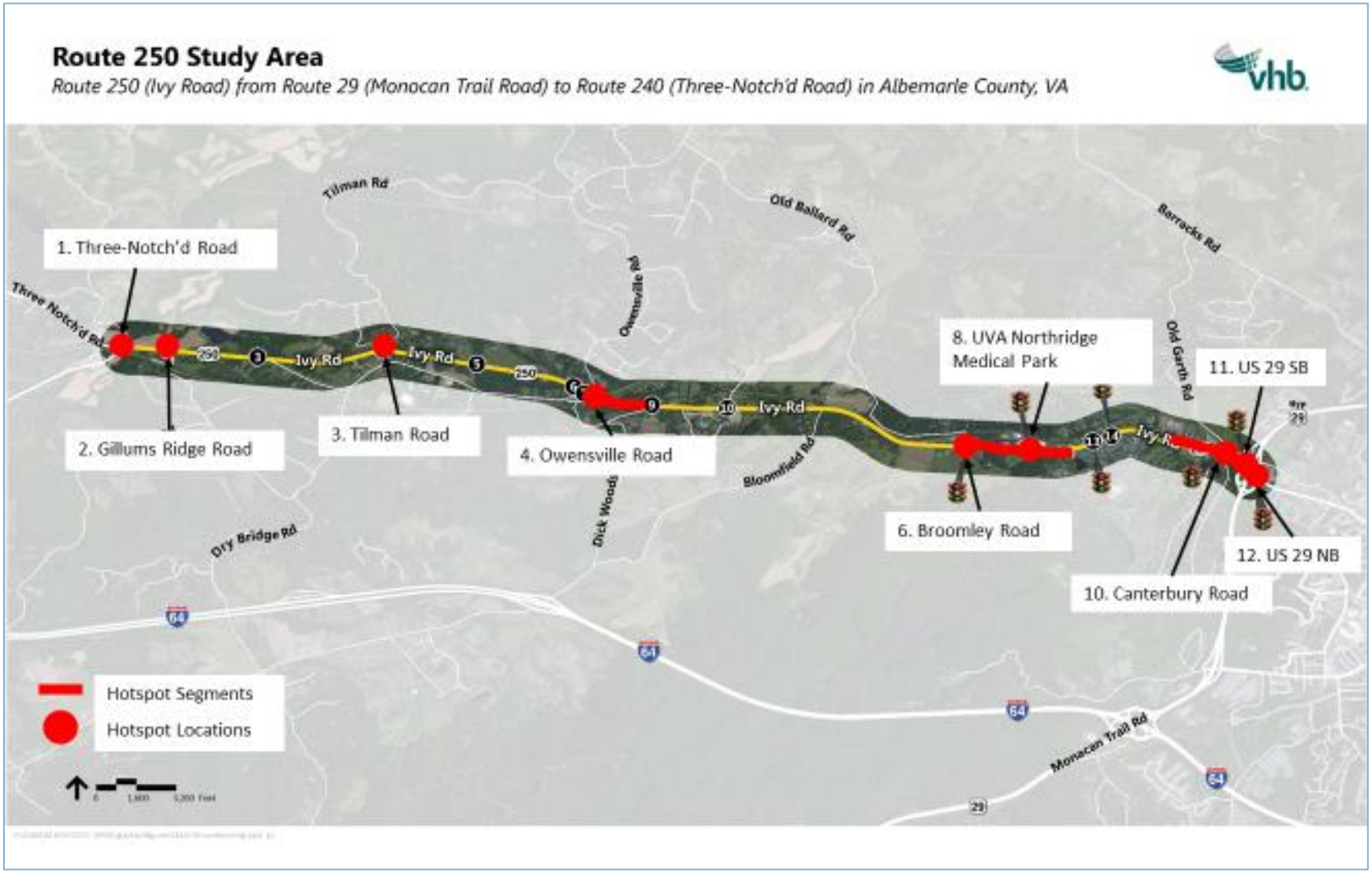



**Figure 2.2 – Hot Spot Locations**

## 2.1 Road Safety Assessment Workshop

The Road Safety Assessment Workshop for the study area was conducted on November 10, 2016 by the following members:

- Chris Daily and Noelle Wilcox, VHB
- Charles Proctor, VDOT Culpeper District – Planning
- Kevin McDermott, Albemarle County
- Adam Moore, VDOT Charlottesville
- Samuel Hayes, VDOT Central Office
- Ali Farhangi, VDOT – NWRO Traffic Engineering

The purpose of the field visit was to observe road user behaviors, site characteristics (road geometry, sight distances, clear zones, drainage, signing, lighting, and barriers), traffic characteristics (speeds, traffic mix, and peak volumes), surrounding land uses (existing traffic and pedestrian generators, driveways, and traffic patterns associated with the adjacent land uses), and link points to the adjacent transportation network (at-grade railway crossing, interchange ramps, and transit connections). During the field review, issues previously identified were verified, and additional potential safety issues were documented. Following the field review, the team assembled to review the information gathered and to identify possible measures to mitigate safety or operational concerns.

## 2.2 Findings Meetings

After developing preliminary improvement concepts, VHB held two separate findings meeting, one with the VDOT STARS stakeholder team and another with the US 250 West Task Force community group. The VDOT findings meeting occurred on October 23rd, 2018 at the Albemarle County Office Building. The findings presentation to the US 250 West Task Force occurred at their meeting on February 21st, 2018. Comments and suggestions from both meetings were thoroughly considered and included in the recommendations as appropriate.

# 3 Existing Conditions

## 3.1 Description of Study Area

Ivy Road, in Albemarle County, is classified as a rural minor arterial from Three Notch'd Road to Owensville Road. It is classified as an urban minor arterial from Owensville Road to the US 29 interchange, where it becomes a primary arterial. Ivy Road is a VDOT maintained road. The corridor is surrounded by predominately residential land uses, with commercial and institutional land uses in the urban portion of the study area, towards the eastern side. In addition to being a Corridor of Statewide Significance (CoSS), the rural segment of Ivy Road is also part of Virginia's new Arterial Preservation Network, a network of critical state highways designated for preservation and enhancement of capacity and safety. The eastern half (i.e., the urban portion east of Owensville Road) is a Mobility Enhancement Segment (MES). VDOT's goals are to promote safety and prioritize mainline (Ivy Road) through traffic along these corridors.

## 3.2 Geometric Conditions

To aid in identifying geometric inadequacies, VHB obtained the Roadware database from VDOT. This database contains crucial information such as lane widths, curve characteristics, and shoulder width. VHB

used the information in identifying any deficiencies in the roadway network and determining hot spot locations. Specific geometric characteristics are discussed where appropriate.

For most of the study area, Ivy Road is a two-lane undivided roadway with varying turn lane geometry. Between the UVA Northridge Medical Park entrance and Ednam Drive, a two-way left-turn lane is present. East of Canterbury Road, Ivy Road is a four-lane highway, divided by a 16-foot median. The study corridor runs east to west with intermediate horizontal curvature. It is on rolling terrain.

Curb and gutter is not present along much of the corridor. Curb and gutter is only found in four sections along the corridor:

1. Northern side of Ivy Road within proximity of the UVA Northridge Medical Park entrance (approximately 350 feet)
2. Southern side of Ivy Road between Ednam Center and Ednam Drive (approximately 0.33 miles)
3. Northern side of Ivy Road from Canterbury Road to the entrance for Atlantic Research Group (approximately 270 feet)
4. The median between Canterbury Road and the US 29 northbound interchange (approximately 0.23 miles)

Ditches are used for drainage along the rest of the study corridor.

Guardrail is placed intermittently along the study corridor totaling approximately 2.24 miles of guardrail.

## 3.3 Traffic Control Devices

On the rural, western side of the study area, intersections with Ivy Road are unsignalized and operate under stop control on the side streets (i.e., Ivy Road operates as free flow). Towards the eastern side of the study area (i.e., the urban portion), signalized intersections are frequent, with all seven major intersections being signalized. All signalized intersections on the corridor have mast arm-mounted signals. Most left-turn movements operate under protected/permissive conditions, with one exception: the westbound left-turn at the US 29 southbound interchange operates as protected only. VHB obtained traffic signal timing plan information from VDOT for all seven traffic signals on Ivy Road within the project area. This information was used for input in evaluating the existing traffic operations using Synchro and Highway Capacity Software. The signal timing plans received are included in **Appendix A**.

The speed limit ranges from 35 mph – 55 mph along the corridor. The posted speed limit for each section of Ivy Road is shown below in **Table** 3.1.

**Table 3.1 – Posted Speed Limits**

| From | To | Speed Limit, mph |
|---|---|---|
| Three Notch'd Road (West Project Limit) | Fields of Boaz Drive | 55 |
| Fields of Boaz Drive | West of Dick Woods Road | 35 |
| West of Dick Woods Road | East of Dick Woods Road | 45 |
| East of Dick Woods Road | West of Broomley Road | 55 |
| West of Broomley Road | Farmington Drive | 45 |
| Farmington Drive | US 29 Interchange (East Project Limit) | 35 |

A signal warrant analysis was conducted for Ivy Road at Tilman Road in June of 2016 by the Culpeper District Traffic Engineering team of VDOT. This intersection is currently stop-controlled on Tilman Road using two-section signal heads flashing yellow along Ivy Road and flashing red for the Tilman Road approaches. The signal warrant analysis concluded that the intersection of Ivy Road and Tilman Road did not meet the necessary warrants for installation of a traffic signal. Due to the low minor street approach volumes and types of crashes incurred, a signal is not warranted for the intersection of Ivy Road and Tilman Road. The completed signal warrant analysis is attached in **Appendix B** for reference.

## 3.4 Traffic Conditions

The 2016 Average Annual Daily Traffic (AADT) on Ivy Road, as reported by Jurisdiction Report 02, was:

- **12,000 vehicles/day** from Three Notch'd Road (West Project Limit) to Dick Woods Road
- **13,000 vehicles/day** from Dick Woods Road to US 29 / Ivy Road (East Project Limit)

Per Jurisdiction Report 02, 2016 heavy vehicles are 2% on Ivy Road for the entire project segment.

Peak hour turning movement volume counts were conducted for 16 intersections along the study corridor by Peggy Malone & Associates on May 10-12, 2016. These turning movement counts were balanced and are presented for each intersection in their respective sections and summarized in **Appendix C.** Ivy Road experiences primarily commuter traffic, causing an average directional split of 3:1 in the eastbound and westbound directions during the AM and PM peak periods, respectively.

## 3.5 Traffic Operations

The following metrics were used to quantify the existing operations on Ivy Road:

- Queue length, expressed in feet and represented as the number of vehicles stopped in a lane behind the stop line, is a measure of the level of congestion on an intersection approach. Queue lengths were determined using Synchro.
- Vehicle delay, expressed as average delay (in seconds) per vehicle, is the time experienced by a driver exceeding the time required to travel at the desired speed. Reported per *Highway Capacity Manual* (HCM) 2000 methodology using Synchro.
- Level of service (LOS), expressed as a value A-F, is a qualitative representation of delay. LOS was calculated for each movement, approach, and intersection per *Highway Capacity Manual (HCM) 2000* methodology using Synchro.
- Volume to capacity (V:C) ratio is the ratio of the actual flow rate to the theoretical maximum capacity of the roadway segment or intersection. V:C ratio was determined using Highway Capacity Software (HCS) 2010.

The intersections along Ivy Road largely perform at an acceptable level of service, typically defined as LOS D or better. The intersection of Ivy Road and Three Notch'd Road, however, operates at LOS F in the AM peak hour due to the eastbound Three Notch'd Road through movement incurring heavy delay and long queues. Though still an acceptable level of service, the intersection of Ivy Road and Canterbury Road / Old Garth Road operates at LOS D in the AM peak hour.

Operational performance measures (queue length, vehicle delay, LOS, and V:C ratio) for each hot spot are presented in the corresponding hot spot section and are summarized in **Appendix D**. Full Synchro reports are provided in **Appendix E.**

To determine the V:C ratio of Ivy Road, VHB employed Highway Capacity Software (HCS) 2010. This software uses methodology of the *Highway Capacity Manual (HCM) 2010* to calculate the operations of a roadway and is comprised of several modules to evaluate various roadway configurations. To evaluate Ivy Road, the HCS 2010 two-lane module was used between Three Notch'd Road and Owensville Road as this segment experiences uninterrupted flow and is not affected by traffic signals. Between Owensville Road and the US 29 Interchange, signals are present that interrupt the flow of traffic and, for this reason, the HCS 2010 Streets module was applied for this segment. The volume to capacity ratios are shown on aerial graphics in **Appendix D** and the full HCS 2010 outputs are included in **Appendix F**. **Table 3.2** presents a summary of the volume to capacity ratios.

**Table 3.2 – Range of V:C Ratios along Corridor**

| Direction | Peak Hour | V:C Ratio |
|---|---|---|
| Eastbound | AM | 0.25-0.95 |
| | PM | 0.20-0.68 |
| Westbound | AM | 0.26-0.81 |
| | PM | 0.45-1.05 |

A volume to capacity ratio approaching or exceeding 1.0 represents congestion in that segment. Overall, the corridor performs with little to no congestion. The corridor does, however, experience congestion (i.e., V:C ratio approaches or exceeds 1.0) east of Farmington Drive in both directions. According to VDOT's TOSAM (*Traffic Operations and Safety Analysis Manual*), microsimulation traffic modeling software should be utilized for oversaturated conditions (V/C > 1.0); however, the oversaturated segment of Ivy Road is localized both spatially (westbound direction between Canterbury and Farmington) and temporally (PM peak hour). For these reasons, macroscopic traffic modeling software (Synchro and HCS) was determined to be sufficient to model conditions throughout the corridor.

## 3.6 Crash Analysis

Between the years 2011-2015, a total of 318 crashes were reported in the project study area. VHB obtained the FR 300 Crash Reports for all 318 crashes from VDOT to further analyze the possible causes and identify issues. The full FR 300 crash reports are attached in **Appendix G.**

Rear end crashes were the predominant crash type accounting for 46% of total crashes, followed by 20% angle crashes. **Figure 3.1** shows the crash type distribution and the lighting conditions associated with the crashes. Most crashes, 69%, happened in the daylight. Additionally, 81% of total crashes occurred on dry pavement. A diagram summary of the crash conditions is included in **Appendix H**.

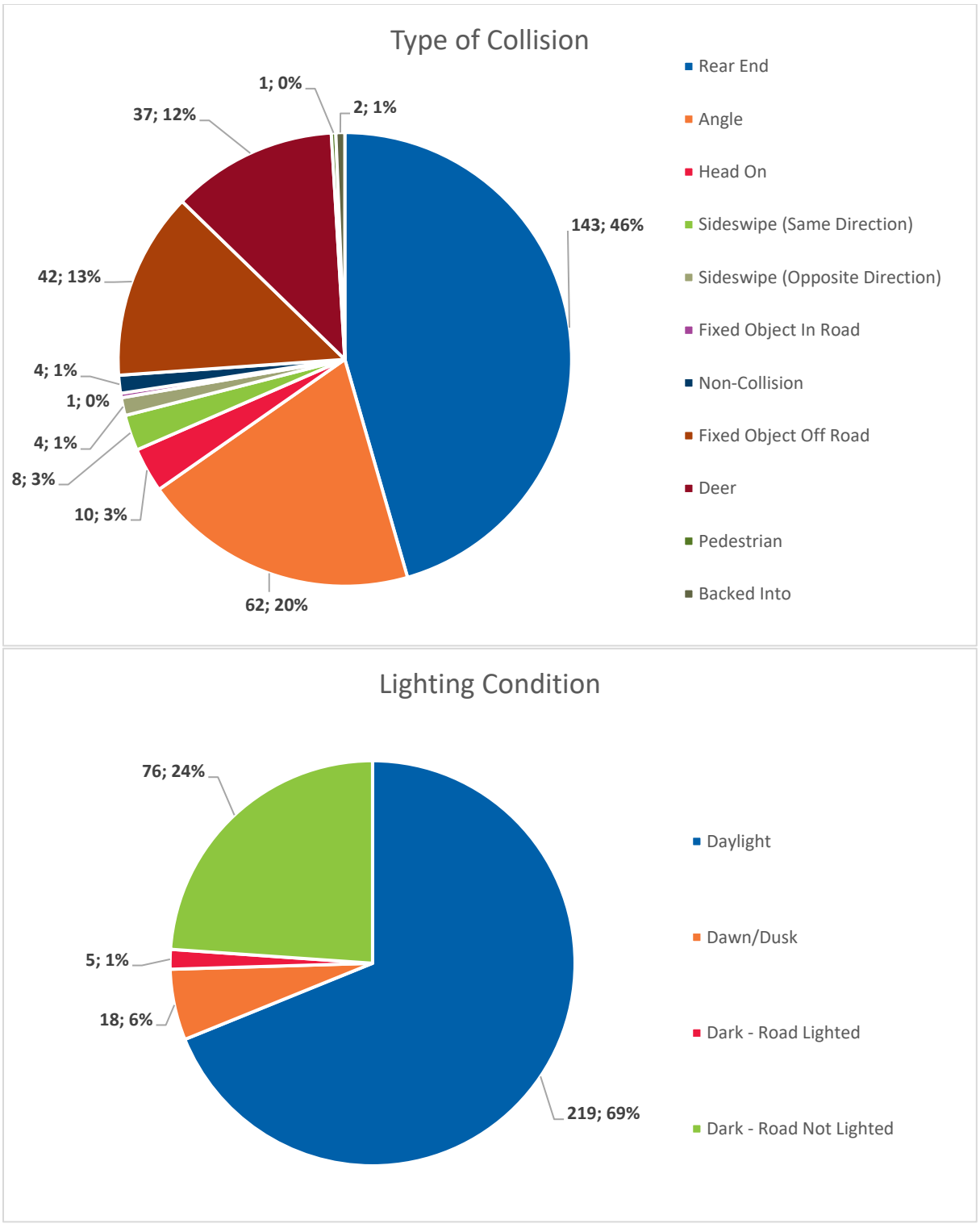



**Figure 3.1– Collision Type and Lighting Condition of 2011-2015 Crashes in the Study Area**

**Figures 3.2 and 3.3** present the crash severity and crash location, respectively. 75% of all crashes resulted in property damage only. There were two fatalities, one of which was a pedestrian struck by a westbound vehicle near the entrance to Volvo of Charlottesville. The second fatality was a senior driver turning left onto westbound Ivy Road from the northbound Tilman Road approach and struck by an eastbound vehicle.

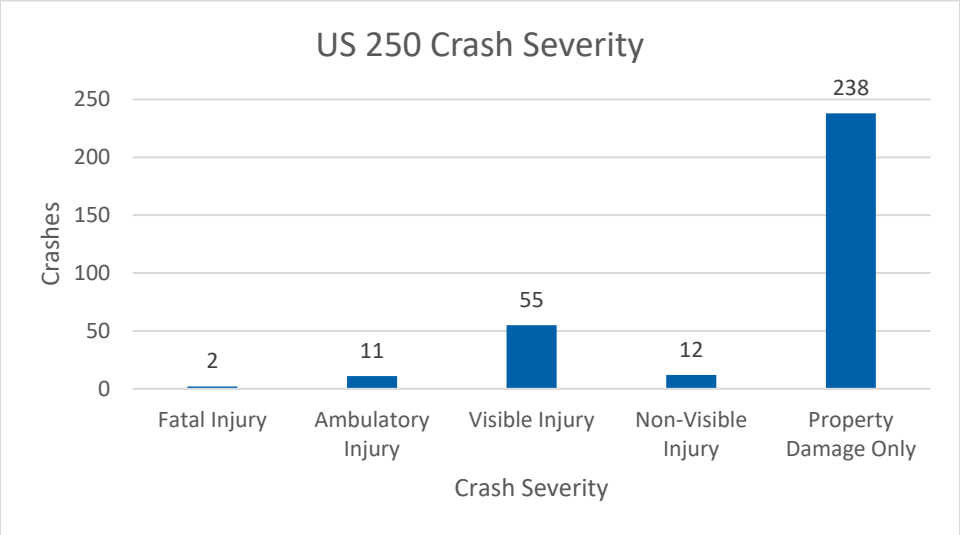



**Figure 3.2 – Crash Severity**

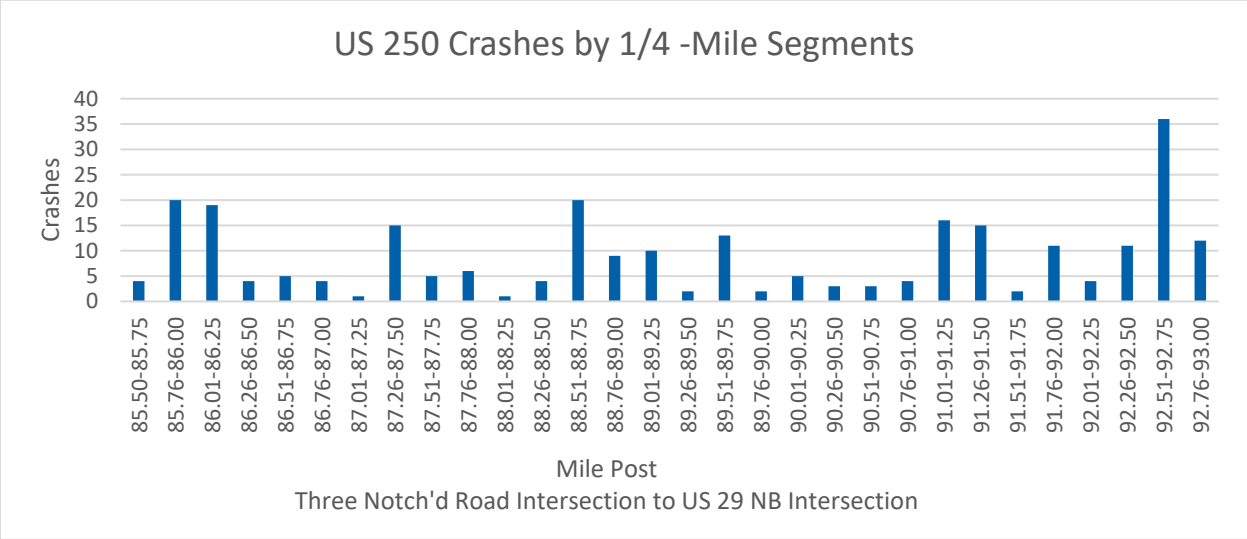



**Figure 3.3 – Crash Location (Mile Post)**

**Figures 3.4 to 3.7** break down the timing of the crashes by year, month, day of the week, and time of day. An overall increase in crashes is seen from 2011 to 2015. Crashes most commonly occurred between 3PM and 6PM.

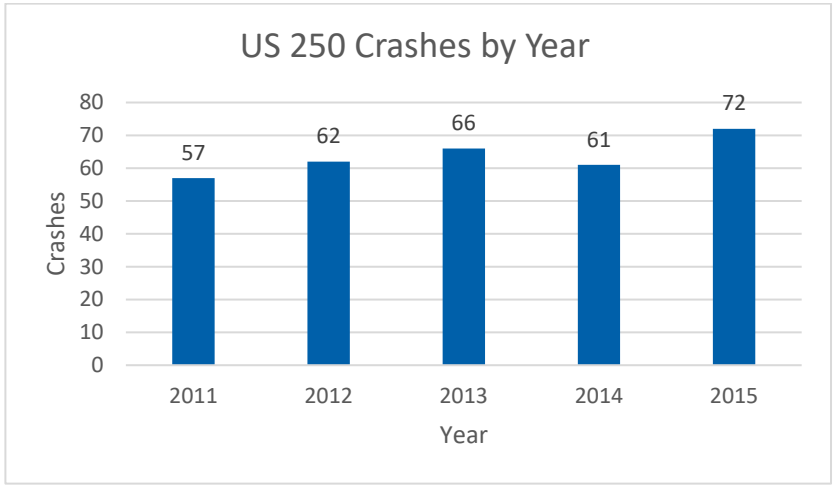



**Figure 3.4 – Crash Year**

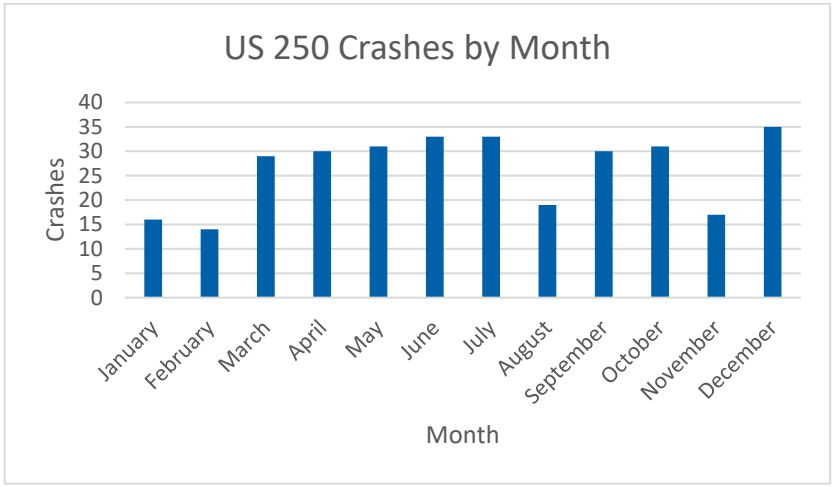



**Figure 3.5 – Crash Month**

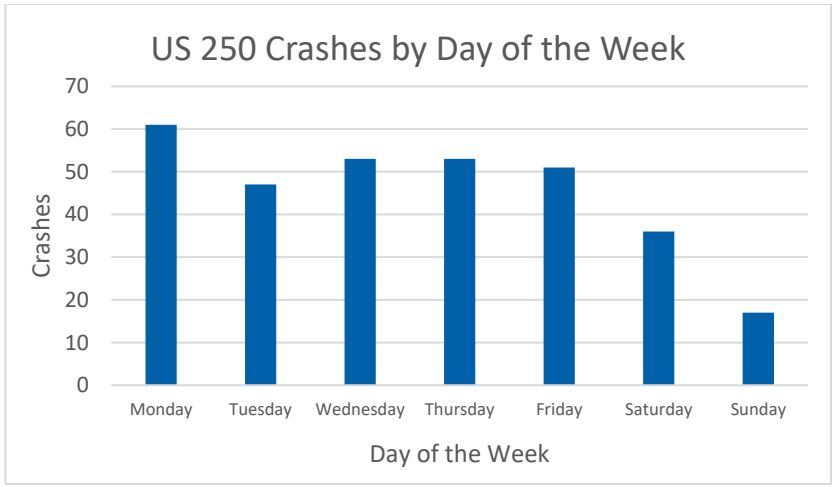



**Figure 3.6 – Crash Day**

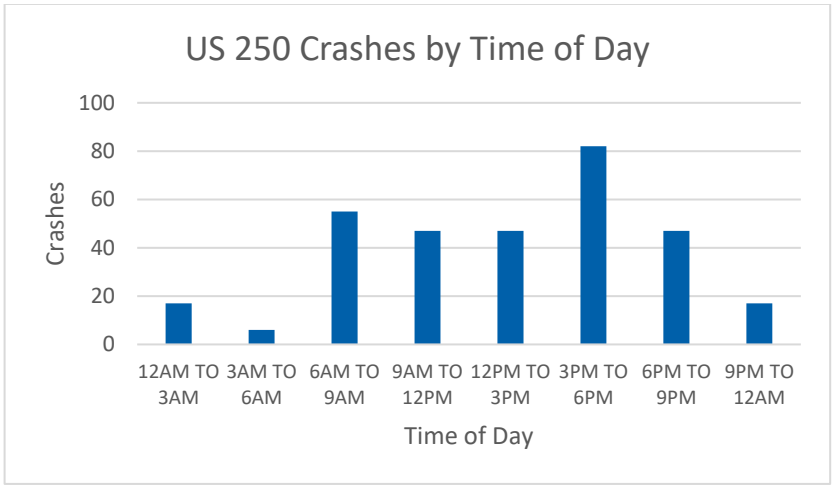



**Figure 3.7 – Crash Time**

A summary of crashes by intersection is shown in **Appendix H**. **Appendix H** also contains a heat proximity crash map of the corridor used to determine the hot spot locations as well as figures that display the crashes by crash type and crash conditions. Collision diagrams for each hot spot location are attached in **Appendix I**.

Each VDOT District creates a "Top 100" list of 100 intersections and 100 miles of roadway segment that present the greatest safety or operational concerns. For years 2011-2015, VDOT Culpeper district identified the following three intersections and three segments on Ivy Road for their "Top 100" list:

| Intersection or Segment | Ranking |
|---|---|
| Ivy Road and Three Notch'd Road | 17 |
| Ivy Road and Gillums Ridge Road | 55 |
| Ivy Road and Ivy Depot Road | 66 |
| Ivy Road between Ednam Drive and UVA Northridge Medical Park Entrance | 113 |
| Ivy Road between UVA Northridge Medical Park Entrance and Broomley Road | 146 |
| Ivy Road between Atlantic Research Group Entrance and Birdwood Drive | 159 |

# 4 TRAFFIC FORECASTING

For the long-term improvements, it is necessary to understand the impact that the project will have on traffic operations in the Build year (i.e., the year the project is completed). Thus, traffic must be forecasted to a final Build year, assumed to be 2025 for the long-term improvements recommended in this study.

Through conversations with the VDOT District Planner, VHB determined that historical Average Annual Daily Traffic (AADT) volumes provided by VDOT were suitable for use in determining an appropriate growth factor for the corridor. The VDOT AADTs from 2001-2015 were analyzed and are presented in **Figure 4.1**.

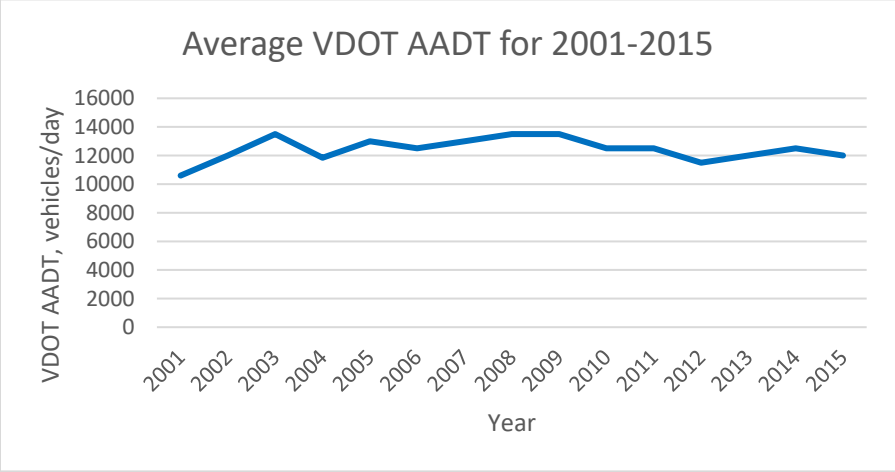



**Figure 4.1 – Average VDOT AADTs for 2001-2015 on Ivy Road**

The historical AADT volumes reveal little variance. Similarly, there are no known developments that will significantly influence the traffic volumes within the project area. Therefore, a growth rate of 0% was assumed for most of the corridor. This growth rate assumption was verified with VDOT.

Though a 0% growth rate was assumed for most of the corridor, a higher growth rate was assumed on the east end of the project area in proximity to the interchange (i.e., Ivy Road and Canterbury Road / Old Garth Road; Ivy Road and the US 29 interchange). For the area near the interchange, an annual growth rate of 1% was applied. The 1% growth rate was applied as a conservative estimate to account for additional development occurring east of the interchange. Any development east of the interchange is likely to create additional traffic through this interchange access point to US 29.

The Future (2025) traffic volumes are presented in **Appendix J**.

Using the forecasted traffic volumes, VHB performed a Synchro analysis of the 2025 No-Build Conditions near the interchange. Each intersection worsens under 2025 No-Build Conditions. **Table 4.1** presents a comparison of the delay and LOS experienced for the movements, approaches, and intersections under 2016 Existing Conditions and 2025 No-Build Conditions.

Table 4.1 – Operational Performance of 2025 No-Build Conditions

| | | 2016 Existing Conditions | | | | | | 2025 No-Build Conditions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Delay (s/veh) | LOS | Delay (s/veh) | LOS | Intersection Delay (s) | Intersection LOS | Delay (s/veh) | LOS | Delay (s/veh) | LOS | Intersection Delay (s) | Intersection LOS |
| **Ivy Road at Canterbury Road / Old Garth Road** | | | | | | | | | | | | | |
| Ivy Road EB | Left | 33.4/18.9 | C/B | 22.7/ 16.2 | C/B | **28.3/29.4** | **C/C** | 56.4/39.3 | E/D | 32.4/ 24.8 | C/C | **39.0/37.7** | **D/D** |
| | Through | 16.5/14.7 | B/B | | | | | 18.4/16.6 | B/B | | | | |
| | Right | 8.3/8.5 | A/A | | | | | 8.4/9.0 | A/A | | | | |
| Old Garth Road SB | L/T | 47.7/63.5 | D/E | 32.5/ 47.9 | C/C | | | 49.6/72.3 | D/E | 32.4/ 49.6 | C/D | | |
| | Right | 30.4/44.9 | C/D | | | | | 29.9/45.2 | C/D | | | | |
| Ivy Road WB | Left | 10.1/11.7 | B/B | 33.0/ 29.4 | C/C | | | 10.2/14.8 | B/B | 56.3/ 44.1 | F/D | | |
| | T/R | 33.5/30.2 | C/C | | | | | 57.2/45.5 | E/D | | | | |
| Canterbury Road NB | L/T | 45.0/51.3 | D/D | 44.4/ 50.6 | D/D | | | 44.9/50.1 | D/D | 44.3/ 49.5 | D/D | | |
| | Right | 43.6/49.9 | D/D | | | | | 43.4/48.9 | D/D | | | | |
| **Ivy Road at US 29 Southbound Interchange** | | | | | | | | | | | | | |
| Ivy Road EB | Through | 2.2/23.0 | A/C | 4.9/ 18.8 | A/B | **5.1/30.2** | **A/C** | 2.3/25.8 | A/C | 1.9/ 50.4 | A/D | **5.4/31.7** | **A/C** |
| | Right | 0.8/72.6 | A/E | | | | | 0.7/80.2 | A/F | | | | |
| US 29 NB Ramp | Left | 47.9/51.7 | D/D | 3.8/ 10.5 | A/A | | | 48.1/51.7 | D/D | 3.8/ 10.8 | A/B | | |
| | Right | 0.1/0.1 | A/A | | | | | 0.1/0.1 | A/A | | | | |
| Ivy Road WB | Left | 44.3/51.3 | D/D | 8.8/ 21.7 | A/C | | | 45.8/49.1 | D/D | 9.6/ 20.9 | A/C | | |
| | Through | 3.6/2.0 | A/A | | | | | 4.1/2.1 | A/A | | | | |
| **Ivy Road at US 29 Northbound Interchange** | | | | | | | | | | | | | |
| Ivy Road EB | Through | 15.8/2.2 | B/A | 15.7/ 1.8 | B/A | **21.4/12.1** | **C/B** | 17.3/2.7 | B/A | 16.8/ 2.1 | B/A | **21.5/12.5** | **C/B** |
| | Right | 15.4/0.8 | B/A | | | | | 15.6/0.8 | B/A | | | | |
| US 29 NB Ramp | Left | 33.2/44.3 | C/D | 29.7/ 41.5 | C/D | | | 32.2/43.8 | C/D | 28.7/ 40.9 | C/D | | |
| | Right | 25.9/36.7 | C/D | | | | | 24.9/36.0 | C/D | | | | |
| Ivy Road WB | Left | 10.8/4.9 | B/A | 10.9/ 6.5 | B/A | | | 12.1/5.3 | B/A | 12.1/ 7.3 | B/A | | |
| | Through | 10.9/6.6 | B/A | | | | | 12.1/7.4 | B/A | | | | |

# 5 SYSTEMIC ANALYSIS

## 5.1 Introduction and Methodology

In addition to locating hot spots for site specific improvements, the project team employed a systemic approach. The systemic approach consists of proactively addressing potential risk factors even where no crashes have yet occurred. Such risk factors may include lack of adherence to MUTCD standards as well as higher risk factors, such as speeding.

The project team applied the methodology created for the VDOT Corridor Safety Audit (CSA) for the Corridors of Statewide Significance (CoSS) program, which provides geometry-specific systemic templates for use at intersections and corridor segments. These templates have three tiers of recommendations. Tier 1 is simply to bring the intersection or segment up to the standards outlined in the *Manual on Uniform Traffic Control Devices* (MUTCD). Tiers 2 and 3 are for use where more or higher risk factors are present. Three attributes constitute the use of a Tier 2 or Tier 3 template: identification of systemic risk factors, crash history, and high Potential for Safety Improvement (PSI). If two of these three attributes are identified at the location, the geometrically-appropriate Tier 2 template should be applied. If all three attributes are present, the geometrically-appropriate Tier 3 template should be applied. Locations with high Potential for Safety Improvement (PSI) values were determined by VDOT's 2011-2015 top 100 lists previously discussed. **Appendix K** includes all systemic templates developed by the VDOT CSA for CoSS.

## 5.2 Application of Systemic Templates

**Figure 5.1** and **Figure 5.2** present the proposed application locations of the systemic templates. The project team chose the appropriate application tier for each template location based on the criteria stated above. The systemic templates are further discussed in each respective section.

The costs to apply the systemic templates to the corridor are presented in **Table 5.1** below. The cost estimates assume a uniform application of the templates and installation of all new signs and pavement markings. The actual costs for each application may vary depending on the state of compliance already present. Almost all the systemic template improvements are pavement marking and signage modifications that can be completed in one of the following manners: be implemented in the next scheduled paving cycle, be accomplished by state forces, be completed as part of the larger improvement projects proposed in this report. Scheduling implementation of the systemic templates as part of either routine repaving or new construction will mitigate mobilization costs, and the material/labor costs of the templates is minimal compared to the cost of repaving or new construction.

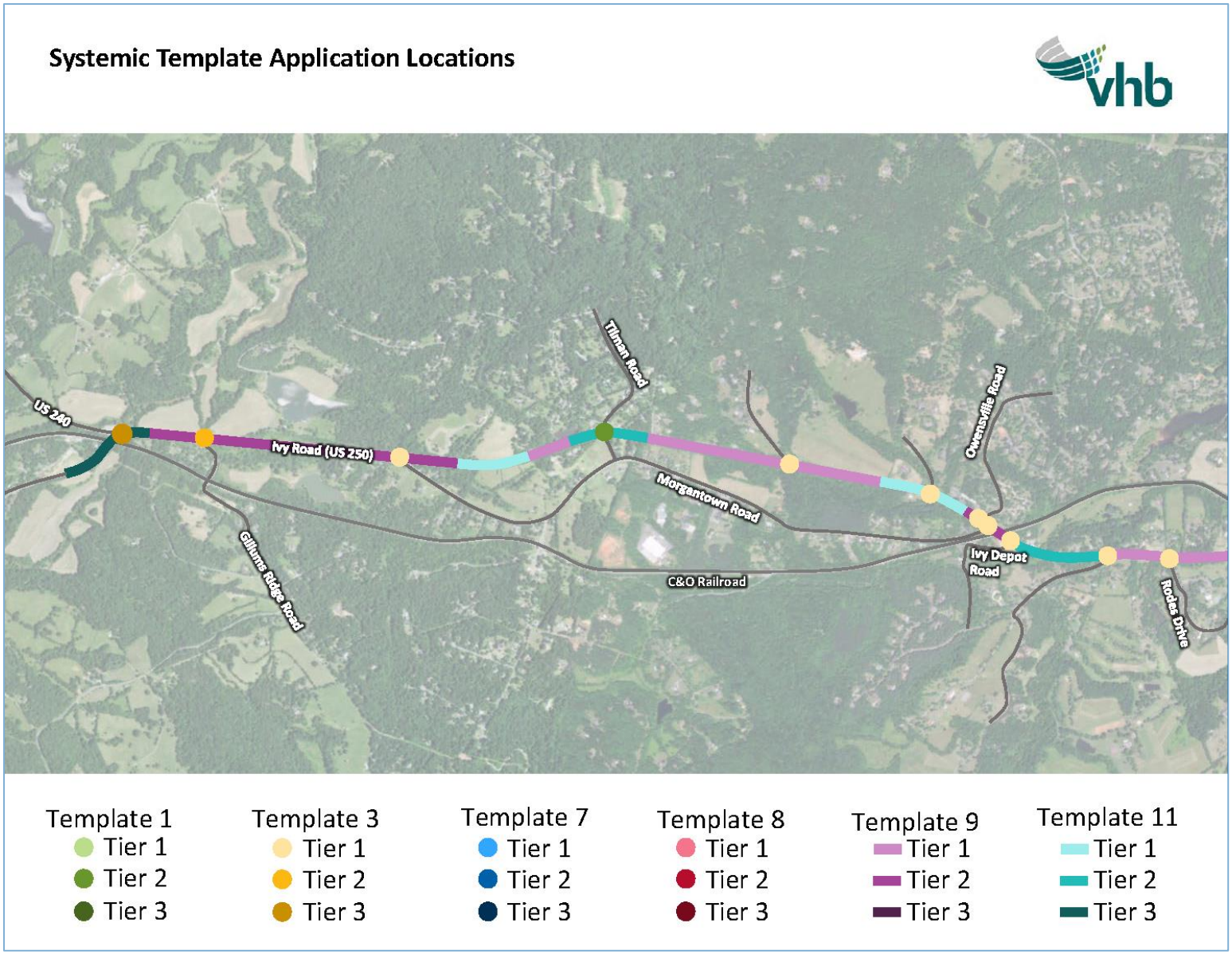



Figure 5.1 – Systemic Template Application Locations, West of West Leigh Drive

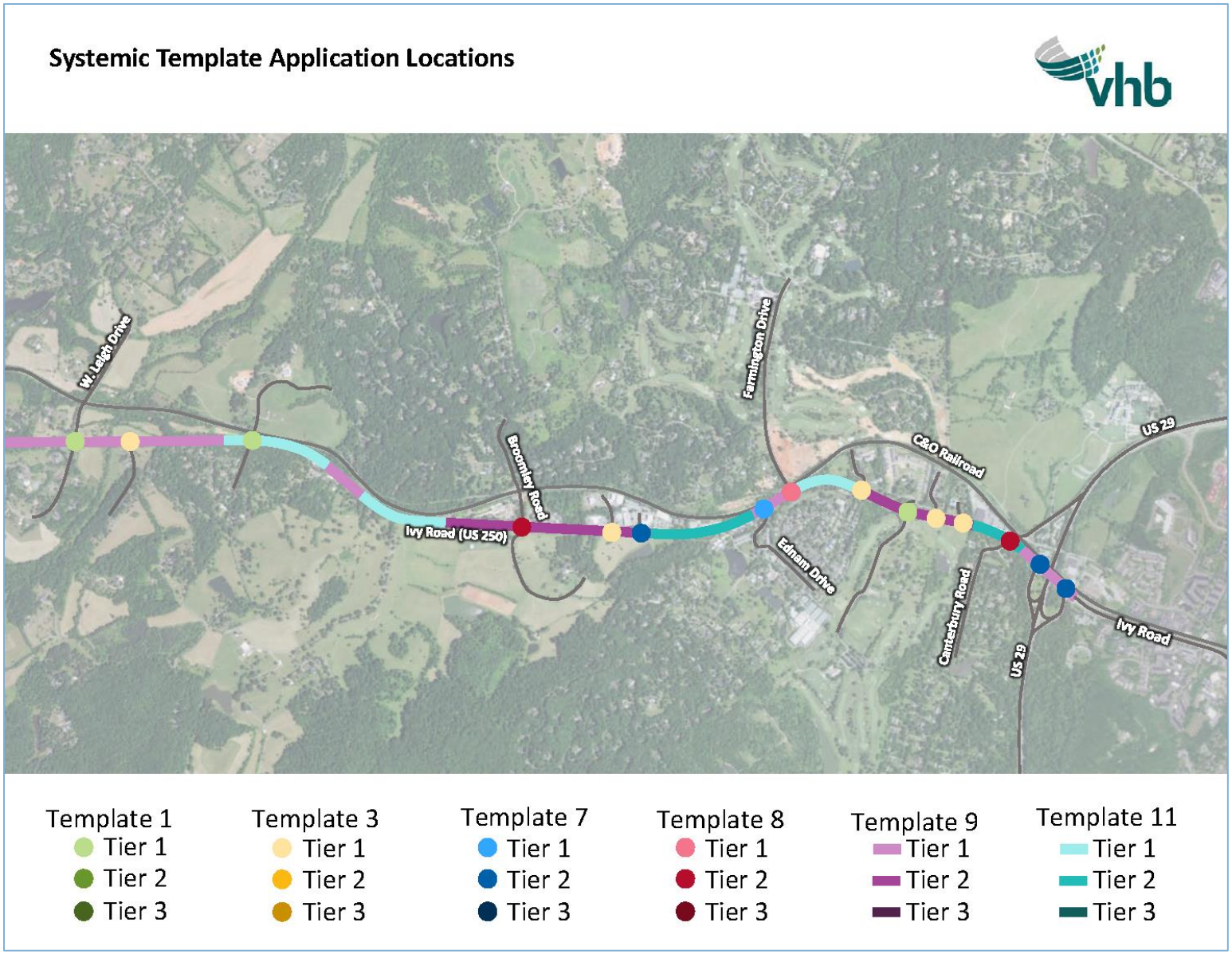



Figure 5.2 – Systemic Template Application Locations, East of West Leigh Drive

Table 5.1 – Systemic Template Application Costs

| Template | Cost per Template | Number or Miles of Template Application | Total Corridor Cost |
|---|---|---|---|
| **Template 1** | | | |
| Tier 1 | $ 14,985.06 | 3 | **$ 44,955.18** |
| Tier 2 | $ 25,401.43 | 1 | **$ 25,401.43** |
| Tier 3 | $ 35,212.53 | 0 | **$ -** |
| **Template 3** | | | |
| Tier 1 | $ 13,074.30 | 13 | **$ 169,965.88** |
| Tier 2 | $ 22,542.81 | 1 | **$ 22,542.81** |
| Tier 3 | $ 27,733.43 | 1 | **$ 27,733.43** |
| **Template 7** | | | |
| Tier 1 | $ 11,763.25 | 1 | **$ 11,763.25** |
| Tier 2 | $ 27,194.93 | 3 | **$ 81,584.78** |
| Tier 3 | $ 43,101.62 | 0 | **$ -** |
| **Template 8** | | | |
| Tier 1 | $ 41,842.08 | 1 | **$ 41,842.08** |
| Tier 2 | $ 64,559.00 | 2 | **$ 129,117.99** |
| Tier 3 | $ 73,608.35 | 0 | **$ -** |
| **Template 9** | | | |
| Tier 1 | $ 65,270.60/mile | 4.25 miles | **$ 277,400.05** |
| Tier 2 | $ 74,487.35/mile | 2.88 miles | **$ 214,523.57** |
| Tier 3 | $ 83,357.75/mile | 0 miles | **$ -** |
| **Template 11** | | | |
| Tier 1 | $ 8,847.40 | 5 | **$ 44,236.98** |
| Tier 2 | $ 15,058.27 | 4 | **$ 60,233.08** |
| Tier 3 | $ 23,637.14 | 1 | **$ 23,637.14** |
| **Corridor Total = $ 1,174,900** | | | |

# 6 BENEFIT-COST ANALYSIS METHODOLOGY

## 6.1 Introduction

To prioritize the hot spot alternative solutions proposed in this report, VHB quantified the benefits and costs of each set of solutions. Each set of solutions provides a combination of safety and operational benefits via the reduction in crash risk and the reduction of delay, respectively. These benefits were monetized to develop a benefit/cost ratio for each solution set. The benefit/cost ratio was computed using a 20-year present value for both benefits and costs. Detailed costs, summarized 20-year benefits and cost, and B/C is included with each alternative set, and a corridor prioritization matrix is included at the end of this report.

## 6.2 Cost Analysis

VHB developed and refined improvement costs using several VDOT tools. VHB first developed a range of costs for each recommended improvement using a combination of VDOT's Transportation and Mobility Planning Division (TMPD) cost estimation tool and VDOT construction district bid item averages. VHB then refined costs using VDOT's Planning Cost Estimate Spreadsheet (PCES) and bid item cost take-offs. Finally, VHB developed 20-year present value project costs using 20-year cash flows sourced from PCES construction, preliminary engineering, and right of way, and VDOT's HSIP Safety Improvement Proposal service life and annual maintenance values. VHB then calculated the B/C ratio for each alternative set using 20-year present value benefit and cost values.

## 6.3 Benefit Analysis

VHB developed improvement benefits from a combination of safety and operational benefits. Safety improvements have an associated reduction in crashes called a crash modification factor (CMF). A CMF is a percentage of applicable crashes (specific to crash type and severity) that will be treated by the safety improvement. The quantifiable impact of CMFs on crash reduction is monetized using the Federal Highway Administration's (FHWA) crash costs. Crash costs vary by type and severity of crash, and include not only immediate damages but also the loss of economic potential due to injuries and fatalities.

Using VDOT's HSIP Safety Improvement Proposal Spreadsheet, VHB carefully applied CMFs obtained from the CMF Clearinghouse to the proposed alternative solutions. A common error with the application of CMFs is overestimating safety improvement by applying overlapping CMFs that treat the same crash type. To avoid this issue, VHB removed a treated crash category from the crash inventory after applying a CMF. For example, the first CMF applied targets angle crashes of all severities. After recording the present value of the CMF 20-year safety benefit (calculated in the HSIP Tool), VHB removes all angle crashes before applying a second CMF targeting all crashes of all severities. The safety benefit for the alternative set equals the sum of present value 20-year safety benefits for the CMFs applied for that alternative.

The monetary benefit of operational improvements is the reduction of traffic delay, and thus the saving of user time. FHWA has assigned monetary values to travel time in its Tool for Operations Benefit/Cost (TOPS-BC). Business and shipping travel time (2017 $34.44/hour) is valued twice as much as personal travel time (2017 $17.22/hour). VHB assumed an equal distribution of trip purpose and thus utilized a weighted monetary travel time value of $28.70/hour. Operational benefit equals the 20-year present value of the annual monetary savings due to the delay reduction from the alternative set. Total alternative benefit equals the sum of 20-year safety and operational benefits.

# 7 HOT SPOTS

## 7.1 Ivy Road (US 250) at Three Notch'd Road

### 7.1.1 Intersection Description and Geometric Conditions

At Three Notch'd Road, Ivy Road (US 250) becomes Rockfish Gap Turnpike (US 250) and creates a channelized T-intersection with Three Notch'd Road. Browns Gap Turnpike also intersects at this location, but must use Three Notch'd Road to access Ivy Road. This intersection is unsignalized. Both Ivy Road and Three Notch'd Road are classified as rural minor arterials at this location. Three Notch'd Road provides access to Crozet, VA. Rockfish Gap Turnpike also provides access to Crozet, VA as well as Interstate 64. Ivy Road provides access to various residential, commercial, and institutional land uses. Browns Gap Turnpike provides residential access. No pedestrian facilities (i.e., crosswalks or sidewalks) are provided.

Three Notch'd Road and Ivy Road are both two-lane undivided roadways. This intersection operates with the use of a channelization island. No roadway lighting is provided at this intersection. All approaches are on level terrain. Ivy Road experiences a significant change in horizontal alignment at this intersection with a curve radius of 384 feet. The lane use at this intersection is as follows:

- Ivy Road (US 250) westbound: 1 shared through/right-turn lane
- Rockfish Gap Turnpike (US 250) northbound: 1 shared left-turn/through lane
- Three Notch'd Road eastbound: 1 through lane, 1 channelized right-turn lane

### 7.1.2 Traffic Control Devices

This intersection is unsignalized, and Ivy Road is free-flowing. Three Notch'd Road is given a stop sign and stop bar for both movements.

### 7.1.3 Traffic Conditions

The posted speed limit on Ivy Road (US 250) is 55 mph. On Three Notch'd Road, a speed limit of 45 mph is posted. The 2016 VDOT Average Annual Daily Traffic (AADT) is as follows:

- Ivy Road (US 250 east of Three Notch'd Road): **12,000 vehicles/day**
- Rockfish Gap Turnpike (US 250 south of Three Notch'd Road): **9,800 vehicles/day**
- Three Notch'd Road: **6,000 vehicles/day**

The peak hour turning movement volumes as well as the intersection performance measures, are shown in **Figure 7.1** below.

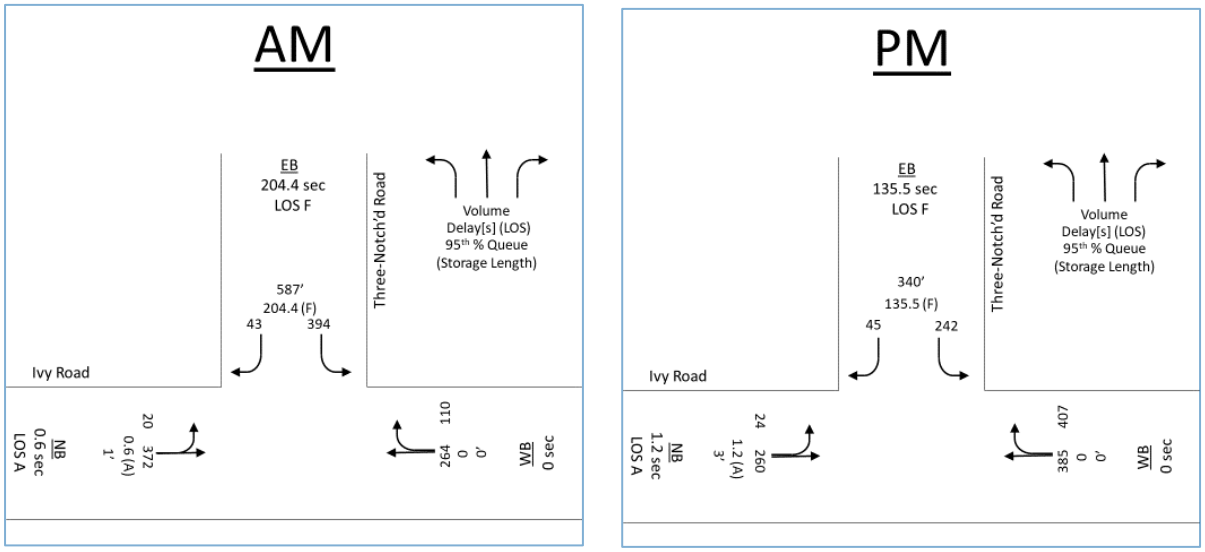



**Figure 7.1 – Traffic Conditions at Ivy Road and Three Notch'd Road**

The left-turning movement from Three Notch'd Road to eastbound Ivy Road experiences heavy delay and operates at LOS F in both the AM and PM peak hours. Thus, extensive queues are experienced on Three Notch'd Road. The Ivy Road approaches experience minimal to no delay.

### 7.1.4 Crash Analysis

Crash data for a five-year study period, 2011-2015, was collected and analyzed. **Table 7.1** provides a summary of crash data at the subject intersection.

**Table 7.1 – Crash Summary at Ivy Road and Three Notch'd Road**

| Year | Peak | | Lighting Condition | | | | Pavement | | Type of Collision | | | | | | | | | | Severity | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AM (6-10) | PM (3-7) | Day | Dawn /Dusk | Dark - Road Lighted | Dark - Road Not Lighted | Dry | Wet | RE | A | HO | SS | SO | FI | NC | FO | D | BI | K | A | B | C | PDO | |
| 2011 | 0 | 3 | 3 | 0 | 0 | 0 | 3 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | **3** |
| 2012 | 2 | 2 | 2 | 1 | 0 | 4 | 7 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 1 | 0 | 6 | **7** |
| 2013 | 2 | 4 | 7 | 0 | 0 | 3 | 6 | 4 | 1 | 4 | 2 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 3 | 0 | 6 | **10** |
| 2014 | 1 | 3 | 2 | 1 | 0 | 3 | 3 | 3 | 0 | 3 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 4 | **6** |
| 2015 | 0 | 4 | 6 | 0 | 0 | 7 | 10 | 3 | 2 | 7 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 0 | 2 | 2 | 0 | 9 | **13** |
| **Total** | **5** | **16** | **20** | **2** | **0** | **17** | **29** | **10** | **4** | **18** | **4** | **1** | **0** | **1** | **0** | **10** | **1** | **0** | **0** | **4** | **8** | **1** | **26** | **39** |
| % | 13% | 41% | 51% | 5% | 0% | 44% | 74% | 26% | 10% | 45% | 10% | 3% | 0% | 3% | 0% | 25% | 3% | 0% | 0% | 10% | 20% | 3% | 67% | |

RE = Rear End; A = Angle; HO = Head On; SS = Sideswipe Same Direction; SO = Sideswipe Opposite Direction; FI = Fixed Object in Road; NC = Non-Collision; FO = Fixed Object Off Road; D = Deer; BI = Backed Into

A summary of crashes by lighting conditions and type of collision is shown below in **Figure 7.2**.

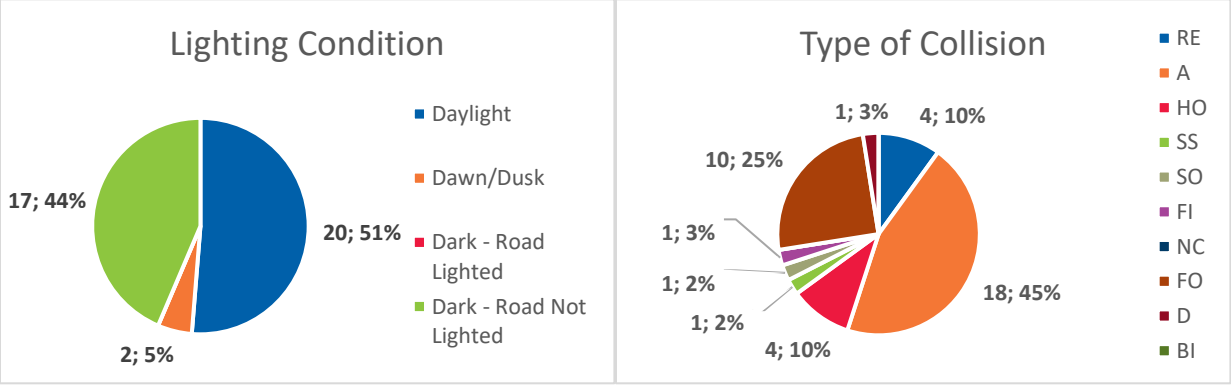



**Figure 7.2 – Lighting Condition and Collision Type at Ivy Road and Three Notch'd Road**

A significant portion of crashes at this intersection occurred in the dark with no roadway lighting. Seven out of the 10 fixed object - off road crashes occurred at dark. These crashes accounted for half of the ambulatory injury crashes. Of the ten total fixed object - off road crashes, four cite a "bank or ledge" as the first harmful crash event, and another three cite "guardrail." Two of these crashes were caused by avoiding an animal and seven were caused by failure to maintain proper control.

Angle crashes were predominant at this intersection. Of the 17 angle crashes documented, five occurred in the darkness. 13 of the angle crashes were caused by an eastbound vehicle on Three Notch'd Road turning onto eastbound Ivy Road and colliding with a westbound vehicle on Ivy Road.

Many of the crashes that occurred at this intersection were of higher severity than property damage only. Four ambulatory and eight visible injury crashes were documented between 2011 and 2015.

This intersection and the use of the channelization island may confuse drivers. One crash was caused by a southbound vehicle on Ivy Road turning right on the south side of the channelization island that is meant to receive the northbound left-turning vehicles.

## 7.1.5 Roadway Safety Assessment

### *7.1.5.1 Safety Issues and Contributing Factors*

#### EASTBOUND/WESTBOUND ANGLE

Three Notch'd Road eastbound vehicles, going straight onto eastbound Ivy Road, commonly collided with Ivy Road westbound/southbound through traffic. This type of crash occurred 14 times and may be attributed to the following safety issues and contributing factors:

- The angle at which the Three Notch'd Road approach intersects with Ivy Road makes completing the eastbound Three Notch'd Road turning movement more difficult than if the intersection were at a right angle, especially in rural conditions. The eastbound Three Notch'd Road lane looks straight onto the westbound Ivy Road lane, and so the eastbound vehicle may perceive a westbound vehicle as farther away than they are and cannot easily tell the speed at which the opposing vehicle is traveling.
- Six of these crashes occurred in dark, unlit conditions. The confusing geometry of this intersection makes it more difficult to navigate under dark conditions, especially for drivers unfamiliar with the intersection.
- Due to the geometry of the road (i.e., Ivy Road continues directly onto Three Notch'd Road by continuing straight but vehicles must turn to continue onto Ivy Road), Three Notch'd Road vehicles may assume that westbound Ivy Road vehicles are going straight rather than turning to continue onto Ivy Road.
- Eight drivers stated that they were unaware of the stop sign and, therefore, did not stop. The geometry of the intersection (i.e., Three Notch'd Road's straight alignment with Ivy Road) gives the illusion that Three Notch'd Road and Ivy Road are the same road. This may create the perception that there is no need to stop before proceeding onto Ivy Road. Additionally, the stop sign is in the channelization island and set back from the stop bar, potentially contributing to its non-notice by drivers.

#### FIXED OBJECT – OFF ROAD

Half of the fixed object – off road crashes were in the westbound/southbound direction on Ivy Road. In total, 10 fixed object – off road crashes occurred and may be attributed to the following safety issues and contributing factors:

- All but one fixed object – off road crash along Ivy Road occurred in the darkness. The curve is not properly delineated and can be difficult to identify in the darkness. This is accompanied by a distracting number of other signs and unclear intersection geometry.
- The curve radius is not adequate for the posted speed limit. A curve radius of 384 feet warrants a speed limit of only 35 mph. Though there is an advisory speed of 35 mph, drivers are not likely to follow this advisory speed and will continue to go at or above the posted speed limit (i.e., 55 mph).
- There is a narrow shoulder on the west side of southbound US 250 (Rockfish Gap Turnpike). This, combined with the lack of edge line warning (i.e., rumble stripes) does not allow drivers to easily recover if they cross the marked edge line.
- Since roadway signs cannot be easily placed on the bridge, both warning and guide signs are condensed to the area just before the bridge on the westbound Ivy Road approach. This number of signs may be overwhelming to the driver, especially at nighttime since all signs are retroreflective. This overload of information is distracting to the drivers and the signs are not properly spaced.

#### NORTHBOUND LEFT-TURN

These three crashes occurred between northbound Ivy Road left-turning vehicles and westbound/southbound Ivy Road through vehicles. They may be attributed to the following safety issues and contributing factors:

- Due to high traffic volumes at this intersection, there may be a lack of adequate gaps in the westbound/southbound Ivy Road traffic. These drivers are pressured to take smaller gaps since there is no left-turn lane and they are stopping traffic until they can turn.
- By nature of the curve, there may not be adequate sight distance for the northbound vehicles to see the opposing traffic on Ivy Road. The vegetation on the inner radius of the curve may further diminish the already inadequate sight distance. This makes it difficult for the northbound left-turning vehicles to see oncoming vehicles and safely make the left turn.
- The unconventional use of the channelization island at this intersection may make it difficult for the left-turning vehicles to distinguish where to turn left. This confusion may contribute to these crashes.

#### EASTBOUND REAR END

Three rear end crashes occurred on Three Notch'd Road at the approach to turn left onto eastbound Ivy Road. These crashes may be attributed to the following safety issues and contributing factors:

- Vehicles follow too closely and do not have enough time to stop when the driver realizes the car in front has stopped at the stop sign. Drivers may not be aware of the stop sign and may not be prepared for the vehicle in front to stop. Drivers of these crashes noted that they thought the vehicle in front had already left the intersection and were moving forward.

### *7.1.5.2 Suggestions and Opportunities for Improvement*

#### ALTERNATIVE LONG-TERM IMPROVEMENT CONCEPTS

Previously, Albemarle County applied for Smart Scale funding to construct a full roundabout at this location; however, the project did not receive funding. The project's expected benefit/cost ratio of 4.1 ranked 13$^{th}$ out of 35 district applications and 146$^{th}$ out of 404 statewide applications. VHB attempted to develop a lower-cost alternative to increase the benefit to cost ratio, making the project more competitive for future year applications. VHB developed several conceptual designs, presented below, to improve the intersection at a lower cost than a full roundabout; however, VDOT presented a scaled-back version of the original full roundabout design to other funding sources. The revised design received funding through VDOT's High Risk Rural Roads program. VHB's conceptual designs are still presented below as part of this STARS project, but they have been superseded by VDOT's fully funded roundabout.

T-Intersection

**Figure 7.3** presents a traditional T-intersection concept. While this concept does not eliminate any conflict points, it should mitigate the confusion of the eastbound Three Notch'd Road drivers by eliminating the straight approach to Ivy Road. By curving Three Notch'd Road to the apex of the US 250 curve, the eastbound vehicles should no longer perceive the eastbound left-turn movement as the through movement. In addition to a relatively simple change in geometry, this option would not require any right of way acquisition, resulting in a lower total project cost. This concept maintains most movements allowed by the existing intersection; however, access at Route 680 is converted to a right in / right out access point. This does not allow access from northbound Rockfish Gap Turnpike or eastbound Three Notch'd Road to Route 680.


**Figure 7.3 – T-Intersection Long-Term Improvement Concept**

Partial Roundabout

To lower the cost of the previously submitted roundabout concept, VHB considered two partial roundabout options.

**Figure 7.4** presents the first partial roundabout concept. By maintaining the current geometry on US 250 and constructing only the north and west legs of the roundabout, it considerably lowers the cost compared to a full roundabout. This concept does not eliminate the main conflict point between eastbound Three Notch'd Road vehicles and US 250; however, the roundabout does force drivers to lower their speed and alleviates eastbound driver confusion. Operationally, the main movements on US 250 are unaffected and remain in free-flow operation. This concept, however, does eliminate movements. Eastbound Three Notch'd Road vehicles can no longer turn left onto Route 680 and northbound vehicles on Rockfish Gap Turnpike can no longer access Route 680 or westbound Three Notch'd Road.


Figure 7.4 – Partial Roundabout, Stop Controlled Concept

**Figure 7.5** illustrates the second partial roundabout concept. This concept offers similar benefits and disadvantages as the stop-controlled partial roundabout. The main benefit of this concept is that it separates the Three Notch'd Road and Ivy Road / Rockfish Gap Turnpike conflict points. Instead of the eastbound left-turning traffic having to cross both directions of traffic on US 250 at once, eastbound vehicles now must merge with the southbound traffic in the roundabout and then later merge with the northbound traffic on Rockfish Gap Turnpike. Not only does this configuration separate the conflict points, but also mitigates the severity of the conflicts. Under this geometric design, the only conflicts present are merging conflicts rather than the more severe angle conflicts currently encountered.

Operationally, the queues formed within the roundabout (i.e., at the eastbound yield onto US 250) may cause delay to the currently free-flowing southbound US 250 traffic.


Figure 7.5 – Partial Roundabout, Yield Controlled Concept

Crossover

The concept shown in **Figure 7.6** is a crossover design aimed at eliminating the angle conflict between eastbound Three Notch'd Road traffic and US 250 traffic. While this concept does eliminate the existing angle conflict, it creates a new conflict point at each of the stop-controlled crossover locations.

Operationally, westbound/southbound US 250 remains as a free-flow movement; however, the stop-controlled crossover locations included in this concept impede the flow of northbound/eastbound traffic. This concept is the most limiting in the movements allowed. While westbound vehicles on US 250 have access to all three other approaches (i.e., Route 680, Three Notch'd Road, and southbound US 250), the other approaches provide very little access. Southbound Route 680 can only access westbound Three Notch'd Road, eastbound Three Notch'd Road can only access eastbound US 250, and northbound US 250 can only access eastbound US 250.

While this design may require right of way at the crossover locations, it will not require as much additional right of way as the partial roundabout concepts. It will, however, require widening the bridge over Mechums River to accommodate the separated right-turn lane on westbound US 250.


**Figure 7.6 – Long-Term Crossover Concept**

**Figure 7.7** shows a variation of the previously presented crossover concept. This concept offers the same characteristics as the first crossover variation, with the addition of one more access point: a channelized right-turn onto southbound US 250 from eastbound Three Notch'd Road.


**Figure 7.7 – Long-Term Crossover Concept**

**Figure 7.8** presents a hybrid concept combining the crossover design with a partial roundabout. This design gives similar characteristics of the first crossover design, with an increased accessibility from Route 680. With this geometric design, southbound Route 680 traffic can use the partial roundabout to access eastbound US 250. This concept also requires additional widening of the Mechums River Bridge to accommodate the additional separated right-turn lane on westbound US 250.


**Figure 7.8 – Long-Term Crossover Concept**

### Final Improvement Recommendations

Application of a Tier 3 Systemic Template 3 is recommended at this location. Additional, intersection-specific improvements for the intersection of Ivy Road and Three Notch'd Road are presented in this section and summarized in **Table 7.2**. The suggested improvements are *not* listed in any order of significance. No long-term improvements are suggested as the intersection has already been funded for construction of a roundabout.

### Eastbound/Westbound Angle

- Short-term

1. Install a redundant, additional "STOP" (R1-1) sign for the eastbound left-turn movement to make the need to stop more obvious to unfamiliar drivers. (Install double stop signs; angle crashes; all severities; CMF = 0.45)
2. Convert the existing painted island into a raised grass island. (Install raised median; all crash types; all severities; CMF = 0.61)
3. Install "Stop Sign Ahead" (W3-1) sign on the eastbound Three Notch'd Road approach to warn vehicles of the impending need to stop. (Install advance warning signs (positive guidance); angle crashes; all severities; CMF = 0.65)
4. Install series of transverse rumble strips on eastbound Three Notch'd Road to gain driver attention. (Install transverse rumble strips on stop controlled approaches in rural areas; all crash types; fatal and serious injury; CMF = 0.785)

### Fixed Object – Off Road

- Short-term

1. Install chevron alignment (W1-8) signs to delineate the curve. These signs should be either retroreflective or lighted for display during dark. (Install chevron signs on horizontal curves; head on, nighttime, non-intersection, run off road, and sideswipe crashes; all severities; CMF = 0.78)
2. Relocate the additional route direction sign assembly on the westbound Ivy Road approach to the channelization island in breakaway form.
3. Install series of transverse rumble strips on both US 250 approaches to alert drivers of the sharp horizontal curvature and the potential for turning vehicles to be present at the US 250 / Route 240 intersection. (Install transverse rumble strips as a traffic calming device; all crash types; all crash severities; CMF = 0.66)
    - Supplement with the "PennDOT Curve Advance Marking" (see December 2006 FHWA publication, "Low-Cost Treatments for Horizontal Curve Safety") if crashes persist.

### Northbound Left-turn

- Short-term

1. Trim vegetation on inner radius of curve to allow for better sight distance of the southbound traffic on Ivy Road. This will allow northbound left-turning traffic to be able to more accurately judge the gaps present. (Increase triangle sight distance; all crash types; Serious injury, Minor injury; CMF = 0.53)

### Eastbound Rear End

- Short-term

1. Install a redundant, additional "STOP" (R1-1) sign on the eastbound approach to make the need to stop abundantly clear to all cars in the queue. (Install double stop signs; angle crashes; all severities; CMF = 0.45)

**Table 7.2 – Summary of Recommended Improvements at Ivy Road and Three Notch'd Road**

| | Safety Issue | Opportunities for Improvement |
|---|---|---|
| 1 | Eastbound/Westbound Angle | • Install a redundant, additional "STOP" (R1-1) sign for the eastbound left-turn movement.<br>• Convert painted island to raised island.<br>• Install "Stop Sign Ahead" (W3-1) signs.<br>• Install series of transverse rumble strips on eastbound Three Notch'd Road. |
| 2 | Fixed Object – Off Road | • Install chevron alignment (W1-8) signs to delineate the curve.<br>• Install series of transverse rumble strips on both US 250 approaches. Supplement with "PennDOT Curve Advance Marking" if crashes persist. |
| 3 | Northbound Left-turn | • Trim vegetation on inner radius of curve and provide clear line of sight of the westbound Ivy Road vehicles. |
| 4 | Eastbound Rear End | • Install a redundant, additional "STOP" (R1-1) sign on the eastbound approach. |

• Short-term, low-cost
○ Intermediate, medium-cost
❖ Long-term, high-cost

**Figure 7.9** presents the potential safety enhancement suggestions to be considered for the intersection of Ivy Road / Rockfish Gap Turnpike and Three Notch'd Road. The placement of traffic control devices, pavement markings, etc. is not to scale and not according to survey, but is an approximation intended to provide a general idea of location and concept. Designers should consider appropriate standards, policies, and right of way impacts before implementing any potential enhancements.


**Figure 7.9 – Short-Term Concept for Ivy Road / Rockfish Gap Turnpike and Three Notch'd Road**

### *7.1.5.3 Traffic Operations Analysis*

- **Convert to Roundabout Design**
  - A Highway Safety Improvement Program (HSIP) application was submitted in 2016 to construct a single-lane roundabout at this location. As part of the HSIP application effort, McCormick Taylor performed analysis to test the operational impact of converting this intersection to a roundabout. Their analysis indicated acceptable levels of service for all approaches. The lowest level of service was in the PM for the westbound approach (LOS D).
  - VHB performed a high-level analysis to determine if a single-lane roundabout was feasible with the updated count volumes. Further investigation revealed, based on Exhibit 3-14 of NCHRP 672 (**Figure 7.10**), that a single lane roundabout is likely sufficient. The sum of conflicting volumes reaches a maximum of 816 VPH, which is well below the recommended 1,000 VPH threshold.

**Exhibit 3-14**
Volume Thresholds for Determining the Number of Entry Lanes Required

| Volume Range (sum of entering and conflicting volumes) | Number of Lanes Required |
|---|---|
| 0 to 1,000 veh/h | ▪ Single-lane entry likely to be sufficient |
| 1,000 to 1,300 veh/h | ▪ Two-lane entry may be needed<br>▪ Single-lane may be sufficient based upon more detailed analysis. |
| 1,300 to 1,800 veh/h | ▪ Two-lane entry likely to be sufficient |
| Above 1,800 veh/h | ▪ More than two entering lanes may be required<br>▪ A more detailed capacity evaluation should be conducted to verify lane numbers and arrangements. |

Source: New York State Department of Transportation

**Figure 7.10 – NCHRP Report 672 Conflicting Volume Thresholds for Roundabout Designs**

## 7.1.6 Preliminary Cost Estimate

The anticipated cost range for the proposed improvements is presented in **Table 7.3**. VHB developed the costs in Table 7.3 by use of VDOT's Transportation and Mobility Planning Division (TMPD) cost estimation tool.

**Table 7.3 – TMPD Cost Estimate for Improvements at Ivy Road and Three Notch'd Road**

| Alternative | Cost Type | Low | High |
|---|---|---|---|
| Short-term | Preliminary Engineering | $ 2,900 | $ 5,100 |
| | ROW & Utility Relocation | - | - |
| | Construction | $ 16,200 | $ 28,900 |
| | *Short-term Subtotal* | *$ 19,100* | *$ 34,000* |
| **Total** | **Preliminary Engineering** | **$ 2,900** | **$ 5,100** |
| | **ROW & Utility Relocation** | **-** | **-** |
| | **Construction** | **$ 12,200** | **$ 28,900** |
| | ***TOTAL*** | ***$ 19,100*** | ***$ 34,000*** |

VHB further refined these costs using VDOT's Preliminary Cost Estimating Spreadsheet (PCES) and bid item costs. The total projected cost for these alternatives is presented in **Table 7.4**.

**Table 7.4 – Cost Estimate for Improvements at Ivy Road and Three Notch'd Road**

| Alternative | Cost Type | Cost Estimate |
|---|---|---|
| Short-term | Preliminary Engineering | $ 7,800 |
| | ROW & Utility Relocation | - |
| | Construction | $ 33,000 |
| | *TOTAL* | *$ 40,800* |

VHB developed the cost estimate into a 20-year cost estimate accounting for improvement service life and annual maintenance costs. The service lives and annual maintenance costs were derived from the HSIP Safety Improvement Proposal values. **Table 7.5** presents the cost estimate for the alternatives.

**Table 7.5 – 20-Year Cost Estimate for Improvements at Ivy Road and Three Notch'd Road**

| Alternative | Cost Estimate Total | 20-Yr Cost (Based on individual item service life) | Annual Maintenance | Present Value of Maintenance | Total 20-year Cost |
|---|---|---|---|---|---|
| Short-term | $ 40,800 | $ 122,400 | $ 900 | $ 13,400 | **$ 135,800** |

### 7.1.7 Benefit Analysis

**Table 7.6** summarizes the 20-year safety and operational benefits of the short-term suggested improvements. The B/C ratio utilizes the 20-year total cost from Table 7.5**.**

**Table 7.6 - Improvement Benefits at Ivy Road and Three Notch'd Road**

| Improvements | Safety Benefit | Operational Benefit | Total Benefit | B:C Ratio |
|---|---|---|---|---|
| Short-term | $2,234,300 | - | **$2,234,300** | **16.5** |

### 7.1.8 Project Schedule

VHB estimated the project schedule based on the project schedules for similar VDOT projects recently completed. **Figure 7.11** shows the anticipated schedule for this hot spot's improvements.

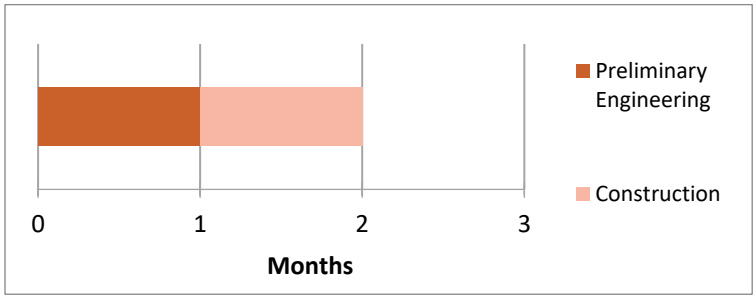



**Figure 7.11 – Short-Term Project Schedule for Ivy Road and Three Notch'd Road**

## 7.2 Ivy Road (US 250) at Gillums Ridge Road

### 7.2.1 Intersection Description and Geometric Conditions

Gillums Ridge Road terminates in a T-intersection with Ivy Road. This intersection is unsignalized. Ivy Road is classified as a minor arterial. Gillums Ridge Road provides access to residences to the south. No pedestrian facilities (i.e., crosswalks or sidewalks) are provided. The intersection lies within the adjacent creek's 100-year floodplain and Albemarle County's Water Protection Ordinance Zone. Steep slopes drop to the creek bed on the southeast corner of the intersection.

Ivy Road is a two-lane undivided roadway. Gillums Ridge Road is also a two-lane undivided roadway. Both Ivy Road approaches are on level terrain. The northbound Gillums Ridge Road approach experiences a downgrade slope as well as a skew in horizontal alignment just before the intersection, but curves to create an almost right-angle with Ivy Road. The lane use at this intersection is as follows:

- Ivy Road eastbound: 1 through lane, 1 right-turn lane
- Ivy Road westbound: 1 shared left-turn/through lane
- Gillums Ridge Road northbound: 1 shared left-turn/right-turn lane

### 7.2.2 Traffic Control Devices

Since this is an unsignalized intersection, there is minimal usage of traffic control devices. Only Gillums Ridge Road northbound is given a stop sign. The Gillums Ridge Road northbound approach does not have a stop bar. The eastbound and westbound approaches are free-flowing.

### 7.2.3 Traffic Conditions

The posted speed limit on Ivy Road is 55 mph. On Gillums Ridge Road, a speed limit of 35 mph is posted. The 2016 VDOT Average Annual Daily Traffic (AADT) is as follows:

- Ivy Road: **12,000 vehicles/day**
- Gillums Ridge Road: **780 vehicles/day** (2012 VDOT AADT)

Four-hour turning movement counts were conducted by Peggy Malone & Associates on May 12, 2016. The peak hour turning movement volumes as well as the intersection performance measures, are shown in **Figure 7.12** below.

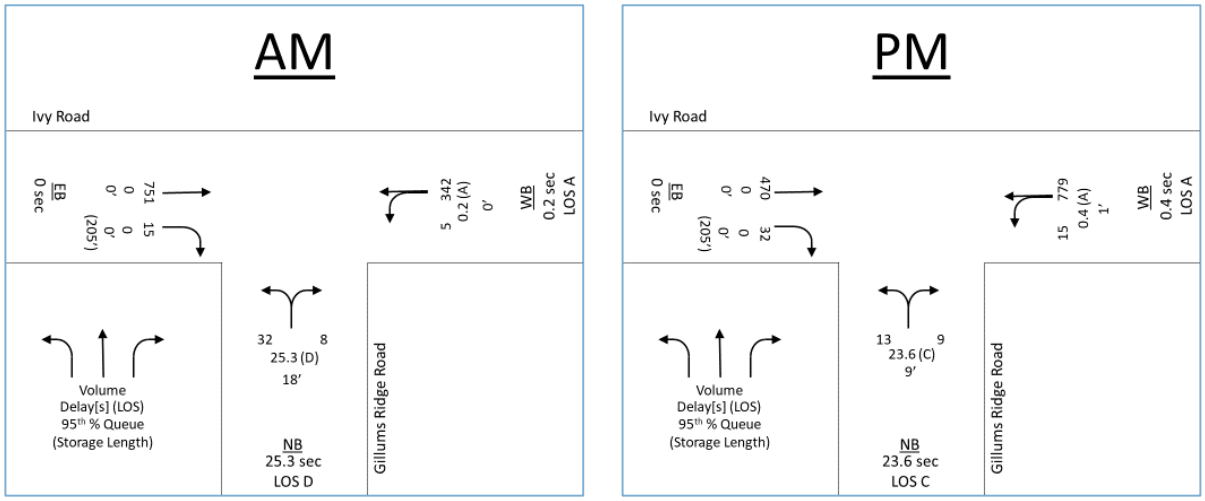



**Figure 7.12 Traffic Conditions at Ivy Road and Gillums Ridge Road**

Minimal delay is experienced at this intersection and it operates under an acceptable level of service (LOS A) during both the AM and PM peak hours. The northbound approach experiences the greatest delay. Though this approach operates at LOS D and C in the AM and PM peak hours, respectively, this delay affects very few vehicles. This approach serves only 40 vehicles in the AM hour and 22 vehicles in the PM hour.

### 7.2.4 Crash Analysis

Crash data for a five-year study period, 2011-2015, was collected for analysis. **Table 7.7** provides a summary of crash data at the subject intersection.

**Table 7.7 – Crash Summary at Ivy Road and Gillums Ridge Road**

| Year | Peak | | Lighting Condition | | | | Pavement | | Type of Collision | | | | | | | | | | Severity | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AM (6-10) | PM (3-7) | Day | Dawn /Dusk | Dark - Road Lighted | Dark - Road Not Lighted | Dry | Wet | RE | A | HO | SS | SO | FI | NC | FO | D | BI | K | A | B | C | PDO | |
| 2011 | 0 | 0 | 1 | 0 | 0 | 1 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | **2** |
| 2012 | 0 | 1 | 2 | 0 | 0 | 1 | 3 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 2 | **3** |
| 2013 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | **1** |
| 2014 | 2 | 2 | 6 | 0 | 0 | 0 | 6 | 0 | 3 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 5 | **6** |
| 2015 | 0 | 0 | 3 | 0 | 0 | 1 | 4 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 4 | **4** |
| **TOT** | **2** | **4** | **13** | **0** | **0** | **4** | **16** | **0** | **8** | **3** | **0** | **1** | **0** | **0** | **0** | **1** | **3** | **0** | **0** | **0** | **2** | **0** | **14** | **16** |
| % | 13% | 25% | 81% | 0% | 0% | 25% | 100% | 0% | 50% | 19% | 0% | 6% | 0% | 0% | 0% | 6% | 19% | 0% | 0% | 0% | 13% | 0% | 87% | |

RE = Rear End; A = Angle; HO = Head On; SS = Sideswipe Same Direction; SO = Sideswipe Opposite Direction; FI = Fixed Object in Road; NC = Non-Collision; FO = Fixed Object Off Road; D = Deer; BI = Backed Into

A summary of crashes by lighting conditions and type of collision can be seen below in **Figure 7.13**.

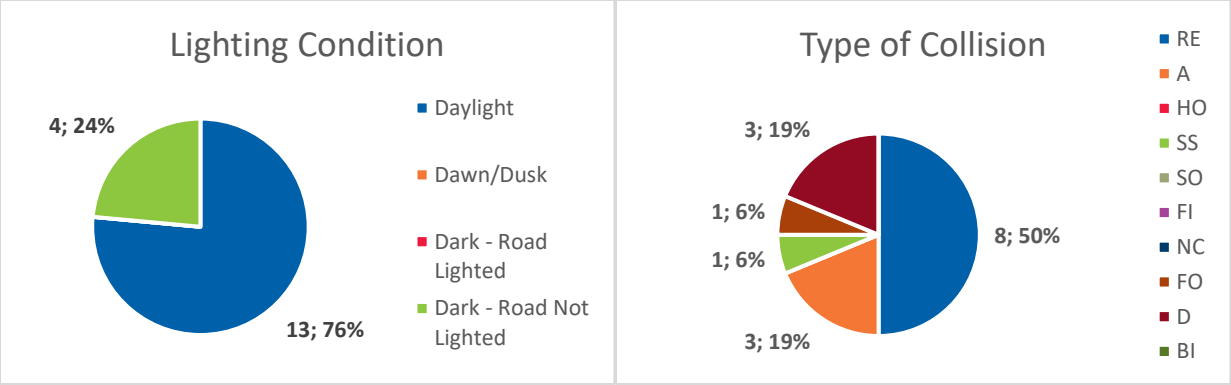



**Figure 7.13 – Lighting Condition and Collision Type at Ivy Road and Gillums Ridge Road**

Rear end collisions account for exactly half of the crashes at Gillums Ridge Road. These rear end crashes were in the westbound direction, suggesting causation from the lack of a westbound left-turn lane. Two of these rear end crashes involved three vehicles. Three crashes with deer occurred within 25 feet of each other at this intersection, where the guardrail opens to an open grass hill. All three deer crashes were at night with no lighting. In addition, three angle crashes occurred at this intersection, one of which caused visible injury.

## 7.2.5 Roadway Safety Assessment

### *7.2.5.1 Safety Issues and Contributing Factors*

#### Westbound Rear End

Possible safety issues and contributing factors for the westbound rear end crashes at Gillums Ridge Road include:

- Vehicles along Ivy Road closely follow the vehicle in front of them and do not allow adequate distance for stopping. Half of the westbound rear end crashes were caused by the driver following too closely and not allowing adequate time to stop in the event of traffic or a turning vehicle.
- Due to the lack of a dedicated left-turn lane in the westbound direction, left-turning vehicles must slow or come to a complete stop from 55 mph in the through lane to wait for a gap in traffic and turn left. The vehicles behind do not anticipate this stop and cannot stop in time to avoid a collision.
- This is the first stretch of roadway that is open, straight, and flat. Roadways with these characteristics are likely to cause distracted drivers, who are not expecting or anticipating any need to stop. These distracted drivers are not aware of the need to stop in the event of a left-turning vehicle and so a crash occurs.

#### Westbound Deer

Three deer crashes occurred at the same location in the study period. Likely contributing factors to these crashes include:

- The deer are likely following the adjacent stream to this location. The opening in the guardrail at this location creates an enticing crossing point for these deer to cross the road to the heavily forested area south of Ivy Road. Though there is a deer warning sign, this may often be ignored by drivers. With no roadway lighting, these deer can be difficult to see in adequate time to stop.

### *7.2.5.2 Suggestions and Opportunities for Improvement*

Application of a Tier 2 Systemic Template 3 is recommended at this location. Additional, intersection-specific improvements for the intersection of Ivy Road and Gillums Ridge Road are presented in this

section and summarized in **Table 7.8**. The suggested improvements are *not* listed in any order of significance.

### WESTBOUND REAR END

- Short-term

    1. Install transverse rumble strips on westbound Ivy Road to alert distracted drivers to the roadway and the possibility of a stopped vehicle ahead. (Install transverse rumble strips as a traffic calming device; all crash types; all crash severities; CMF = 0.66)

- Long-term

    2. Install westbound left-turn lane. (Install left-turn lane; all crash types; all severities; CMF = 0.748)
    3. As an alternative to installing a westbound left-turn lane, direct all westbound left-turning traffic to the to-be-constructed roundabout at Ivy Road and Three Notch'd Road. Vehicles wishing to turn left onto Gillums Ridge Road should be directed to use the roundabout to turn around and then turn right into Gillums Ridge Road, eliminating all westbound left-turn movements at Gillums Ridge Road. A permanent barrier should be placed that allows left-turns from Gillums Ridge Road but prohibits left-turns onto Gillums Ridge Road. Few vehicles (i.e., 5 in the AM and 15 in the PM) would be inconvenienced by using the roundabout as a turnaround. (Prohibit left-turns with "No Left Turn" sign; all crash types; all severities; CMF = 0.32)

### WESTBOUND DEER

- Short-term

    1. Install W11-3 Deer warning signs on both US 250 approaches. (Install advance warning signs (positive guidance); angle crashes; all severities; CMF = 0.65)
    2. Install gate where the existing guardrail openings are to deter deer from crossing at this location.

**Table 7.8– Summary of Recommended Improvements at Ivy Road and Gillums Ridge Road**

| | Safety Issue | Opportunities for Improvement |
|---|---|---|
| 1 | Westbound Rear End | • Install transverse rumble strips on westbound Ivy Road.<br>❖ Install westbound left-turn lane.<br>❖ Prohibit WB left-turns and direct traffic to turnaround at the Three Notch'd Road roundabout. |
| 2 | Westbound Deer | • Install W11-3 Deer warning sign on both approaches.<br>• Install gate where the guardrail openings are. |

• Short-term, low-cost
○ Intermediate, medium-cost
❖ Long-term, high-cost

**Figures 7.14 – 7.16** present the potential safety enhancement suggestions to be considered for the intersection of Ivy Road and Gillums Ridge Road. The placement of traffic control devices, pavement markings, etc. is not to scale and not according to survey, but is an approximation intended to provide a general idea of location and concept. Designers should consider appropriate standards, policies, and right of way impacts before implementing any potential enhancements.

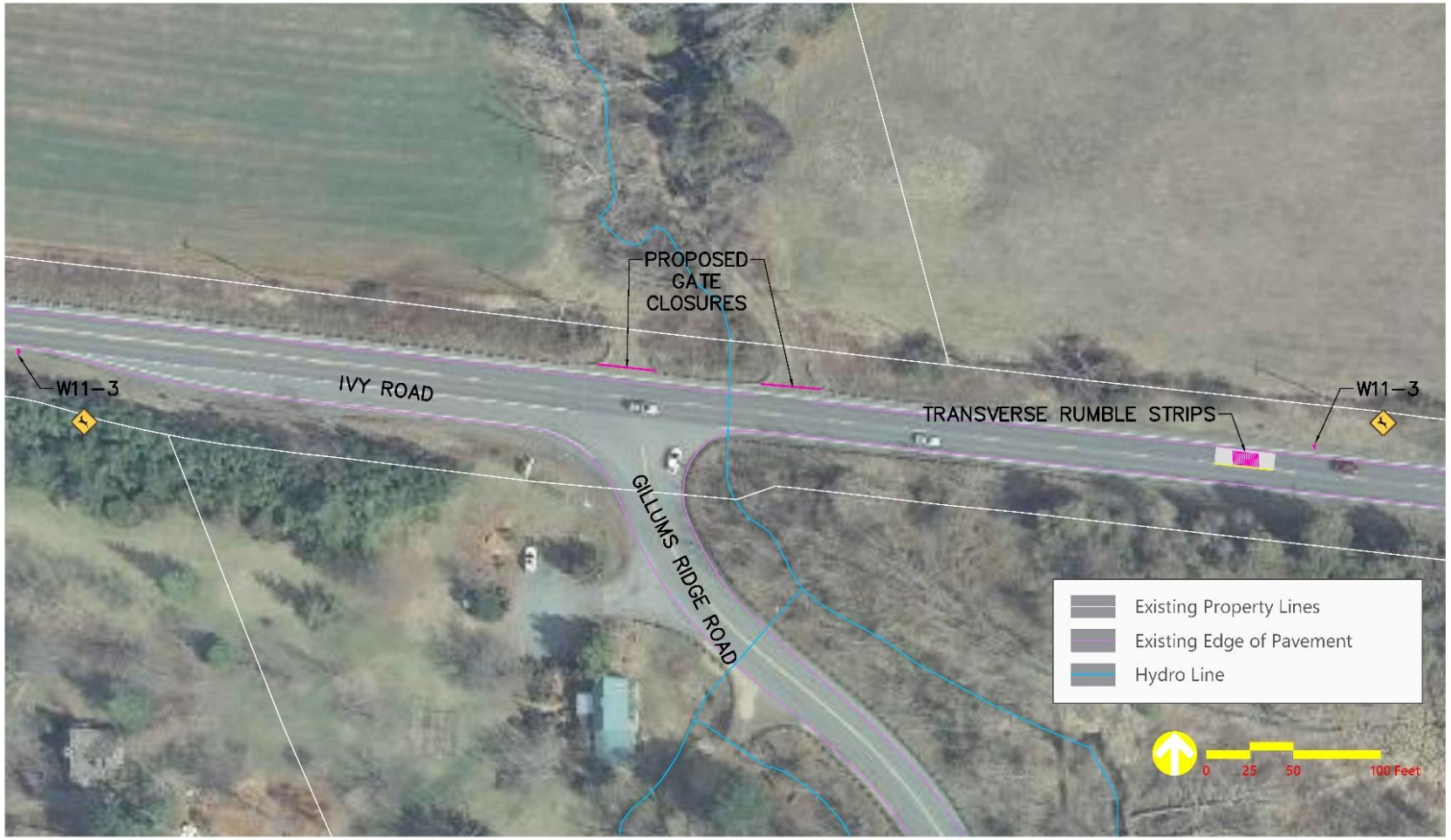



**Figure 7.14 – Short-Term Concept for Ivy Road and Gillums Ridge Road**

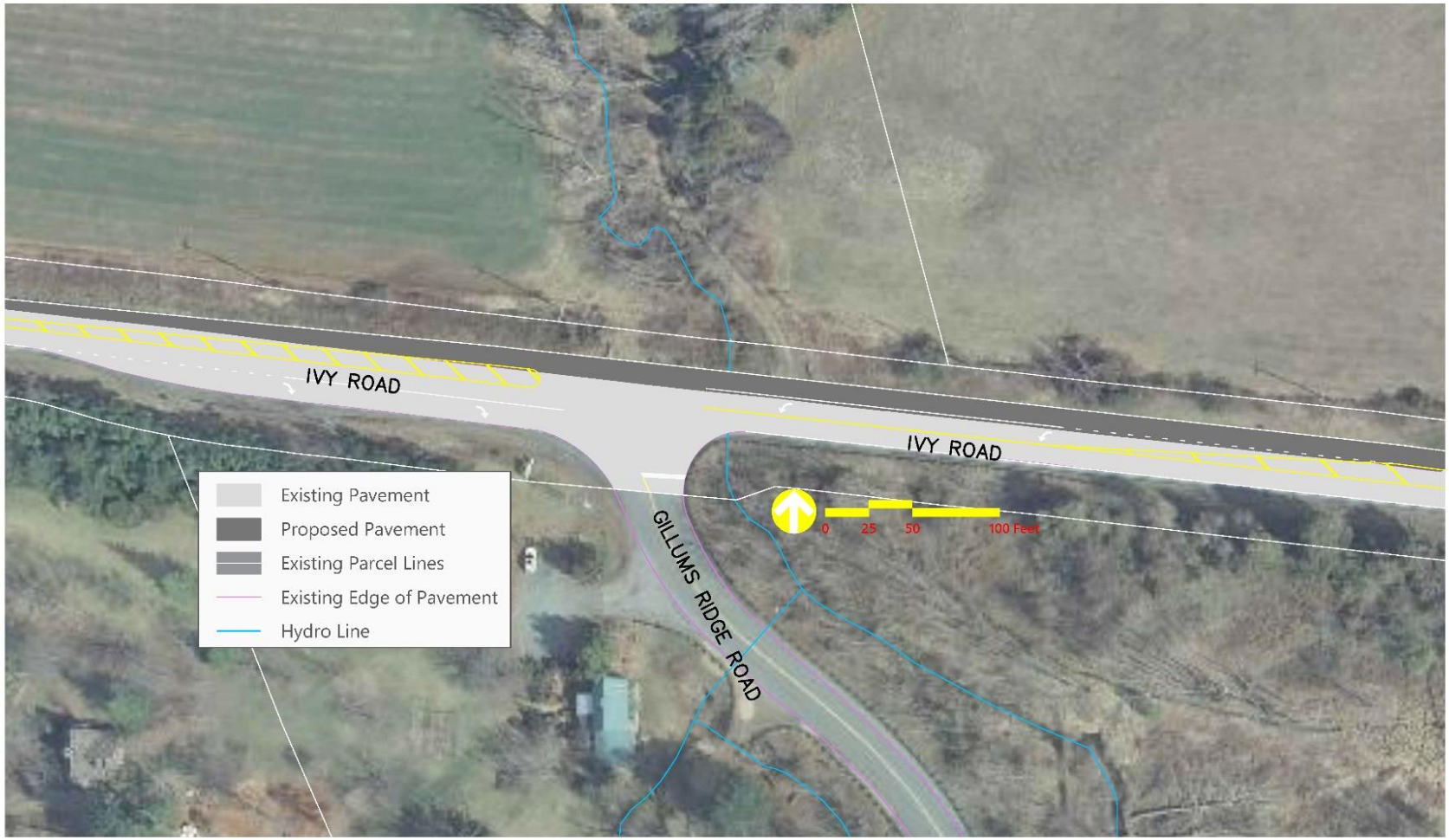



**Figure 7.15 – Long-Term Concept A for Ivy Road and Gillums Ridge Road**

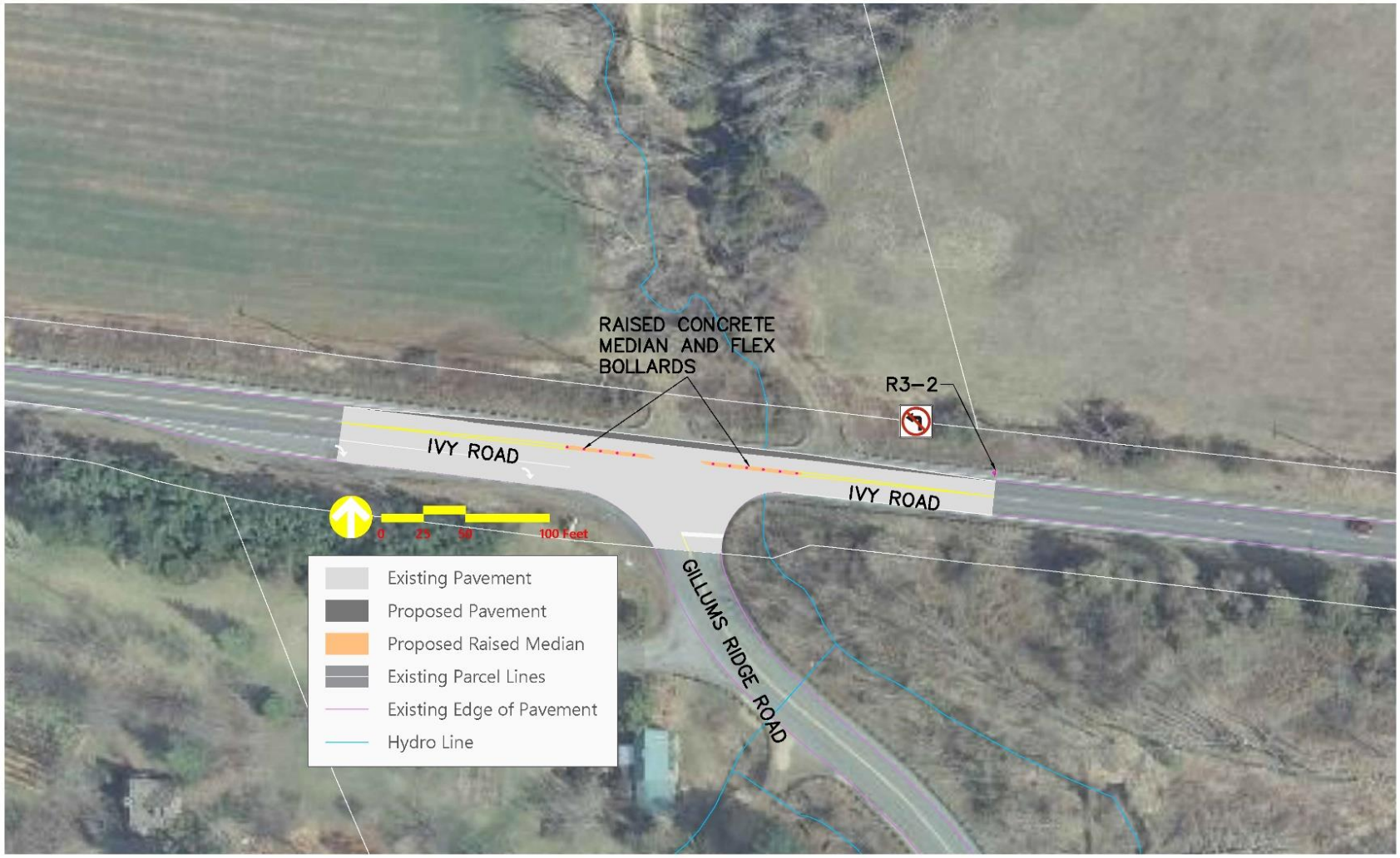



**Figure 7.16 – Long-Term Concept B for Ivy Road and Gillums Ridge Road**

### 7.2.6 Preliminary Cost Estimate

The preliminary estimated cost for the proposed improvements is presented in **Table 7.9**. VHB developed the costs in Table 7.9 by use of VDOT's Transportation and Mobility Planning Division (TMPD) cost estimation tool.

**Table 7.9 – TMPD Cost Estimate for Improvements at Ivy Road and Gillums Ridge Road**

| Alternative | Cost Type | Low | High |
|---|---|---|---|
| Short-term | Preliminary Engineering | $ 1,800 | $ 2,100 |
| | ROW & Utility Relocation | - | - |
| | Construction | $ 10,300 | $ 11,900 |
| | *Short-term Subtotal* | *$ 12,100* | *$ 14,000* |
| Long-term A | Preliminary Engineering | $ 42,000 | $ 52,000 |
| | ROW & Utility Relocation | $ 52,500 | $ 65,000 |
| | Construction | $ 243,600 | $ 288,900 |
| | *Long-Term Subtotal* | *$ 327,900* | *$ 405,900* |
| Long-term B | Preliminary Engineering | $ 1,700 | $ 1,900 |
| | ROW & Utility Relocation | - | - |
| | Construction | $ 10,100 | $ 11,000 |
| | *Long-Term Subtotal* | *$ 11,800* | *$ 12,900* |
| **Total A** | **Preliminary Engineering** | **$ 43,800** | **$ 54,100** |
| | **ROW & Utility Relocation** | **$ 52,500** | **$ 65,000** |
| | **Construction** | **$ 243,600** | **$ 300,100** |
| | ***TOTAL*** | ***$ 340,000*** | ***$ 419,300*** |
| **Total B** | **Preliminary Engineering** | **$ 3,600** | **$ 4,100** |
| | **ROW & Utility Relocation** | **-** | **-** |
| | **Construction** | **$ 19,700** | **$ 22,800** |
| | ***TOTAL*** | ***$ 23,300*** | ***$ 26,900*** |

VHB further refined these costs using VDOT's Preliminary Cost Estimating Spreadsheet (PCES) and district bid item costs. The total projected PCES cost for these alternatives is presented in **Table 7.10**.

Table 7.10 – Cost Estimate for Improvements at Ivy Road and Gillums Ridge Road

| Alternative | Cost Type | Cost Estimate |
|---|---|---|
| Short-term | Preliminary Engineering | $ 1,500 |
| | ROW & Utility Relocation | - |
| | Construction | $ 6,000 |
| | *Short-term Subtotal* | *$ 7,500* |
| Long-term A | Preliminary Engineering | $ 87,300 |
| | ROW & Utility Relocation | - |
| | Construction | $ 364,000 |
| | *Long-term Subtotal* | *$ 451,300* |
| Long-term B | Preliminary Engineering | $ 34,200 |
| | ROW & Utility Relocation | - |
| | Construction | $ 143,000 |
| | *Long-term Subtotal* | *$ 177,200* |
| **Total A** | **Preliminary Engineering** | **$ 88,800** |
| | **ROW & Utility Relocation** | **-** |
| | **Construction** | **$ 370,000** |
| | ***TOTAL*** | ***$ 458,800*** |
| **Total B** | **Preliminary Engineering** | **$ 35,700** |
| | **ROW & Utility Relocation** | **-** |
| | **Construction** | **$ 149,000** |
| | ***TOTAL*** | ***$ 184,700*** |

VHB developed the cost estimate into a 20-year cost estimate accounting for improvement service life and annual maintenance costs. The service lives and annual maintenance costs were derived from the HSIP Safety Improvement Proposal values. The total projected 20-year cost estimate for the alternatives is presented in **Table 7.11.**

Table 7.11 – 20-Year Cost Estimate for Improvements at Ivy Road and Gillums Ridge Road

| Alternative | Cost Estimate Total | 20-Yr Cost (Based on individual item service life) | Annual Maintenance | Present Value of Maintenance | Total 20-year Cost |
|---|---|---|---|---|---|
| Short-term | $ 7,500 | $ 11,200 | $ 200 | $ 3,000 | **$ 14,200** |
| Long-term A | $ 451,300 | $ 451,300 | $ 200 | $ 3,000 | **$ 454,300** |
| Long-term B | $ 177,200 | $ 210,100 | $ 60 | $ 900 | **$ 211,000** |

### 7.2.7 Benefit Analysis

**Table 7.12** summarizes the 20-year safety and operational benefits of both the short-term and long-term suggested improvements. The B/C ratios utilize the 20-year total cost from Table 7.11.

Table 7.12 – Improvement Benefits at Ivy Road and Gillums Ridge Road

| Improvements | Safety Benefit | Operational Benefit | Total Benefit | B:C Ratio |
|---|---|---|---|---|
| Short-term | $ 368,900 | - | **$ 368,900** | **26.0** |
| Long-term A | $ 273,400 | $ 55,300 | **$ 328,700** | **0.7** |
| Long-term B | $ 737,800 | $ 110,600 | **$ 848,400** | **4.0** |

### 7.2.8 Project Schedule

VHB estimated the project schedule based on the project schedules for similar VDOT projects recently completed. **Figures 7.17-7.19** show the anticipated schedule for this hot spot's improvements.

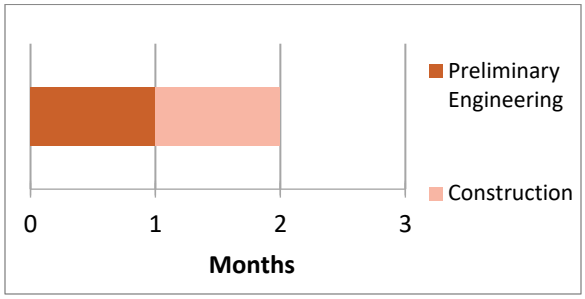
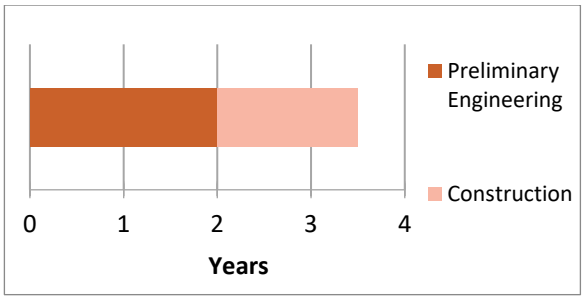
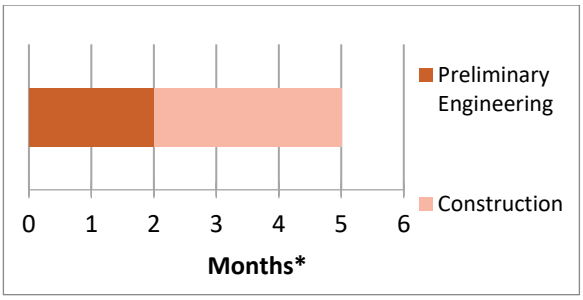



Figure 7.17 – Short-Term Project Schedule for Ivy Road and Gillums Ridge Road




*Must be completed after Three Notch'd roundabout is completed

Figures 7.18 and 7.19 – Long-Term A (left) and Long-Term B (right) Project Schedules for Ivy Road and Gillums Ridge Road

## 7.3 Ivy Road (US 250) at Tilman Road

### 7.3.1 Intersection Description and Geometric Conditions

The intersection of Ivy Road and Tilman Road is a signalized, two-way stop-controlled intersection. Ivy Road is classified as a minor arterial. Tilman Road, south of Ivy Road, is classified as a minor collector. Tilman Road, to the north of Ivy Road, provides access to private residences. A short segment of Tilman Road south of Ivy Road provides access to Morgantown Road. No pedestrian facilities (i.e., crosswalks or sidewalks) are present.

Ivy Road and Tilman Road are both two-way undivided roadways. The Tilman Road intersection is on the crest of a hill on Ivy Road. For this reason, the Ivy Road approaches experience a slight grade in both directions. The Tilman Road approaches also experience a grade. The northbound approach of Tilman Road has a downgrade. This intersection is also in the middle of a horizontal curve in the roadway. The lane use at this intersection is as follows:

- Ivy Road eastbound: 1 shared left-turn/through lane, 1 right-turn lane
- Ivy Road westbound: 1 shared left-turn/through lane, 1 right-turn lane
- Tilman Road northbound: 1 shared left-turn/through/right-turn lane
- Tilman Road southbound: 1 shared left-turn/through/right-turn lane

### 7.3.2 Traffic Control Devices

While this intersection is not under signal-control, intersection control beacons are present. Two two-head intersection control beacons are used on each approach. The eastbound and westbound signals are horizontally mounted and flashing yellow. The signals controlling the northbound and southbound approaches are vertically mounted and flashing red. In addition to these signal heads, the northbound and southbound approaches are given stop signs and stop bars.

A signal warrant analysis was conducted for Ivy Road at Tilman Road in June of 2016 by the Culpeper District Traffic Engineering team of VDOT. The signal warrant analysis concluded that the intersection of Ivy Road and Tilman Road did not meet any warrants studied. Due to the low minor street approach volumes and types of crashes incurred, a signal is not warranted for the intersection of Ivy Road and Tilman Road. The completed signal warrant analysis is attached in **Appendix B** for reference.

### 7.3.3 Traffic Conditions

The posted speed limit on Ivy Road is 55 mph. The southbound approach of Tilman Road has a posted speed limit of 35 mph. No speed limit is posted on the northbound approach of Tilman Road. The 2016 VDOT Average Annual Daily Traffic (AADT) is as follows:

- Ivy Road: **12,000 vehicles/day**
- Tilman Road (South of Ivy Road): **700 vehicles/day**
- Tilman Road (North of Ivy Road): 3**90 vehicles/day**

Eight-hour turning movement counts were conducted by Peggy Malone & Associates on May 12, 2016. The peak hour turning movement volumes as well as the intersection performance measures, are shown in **Figure 7.20** below.

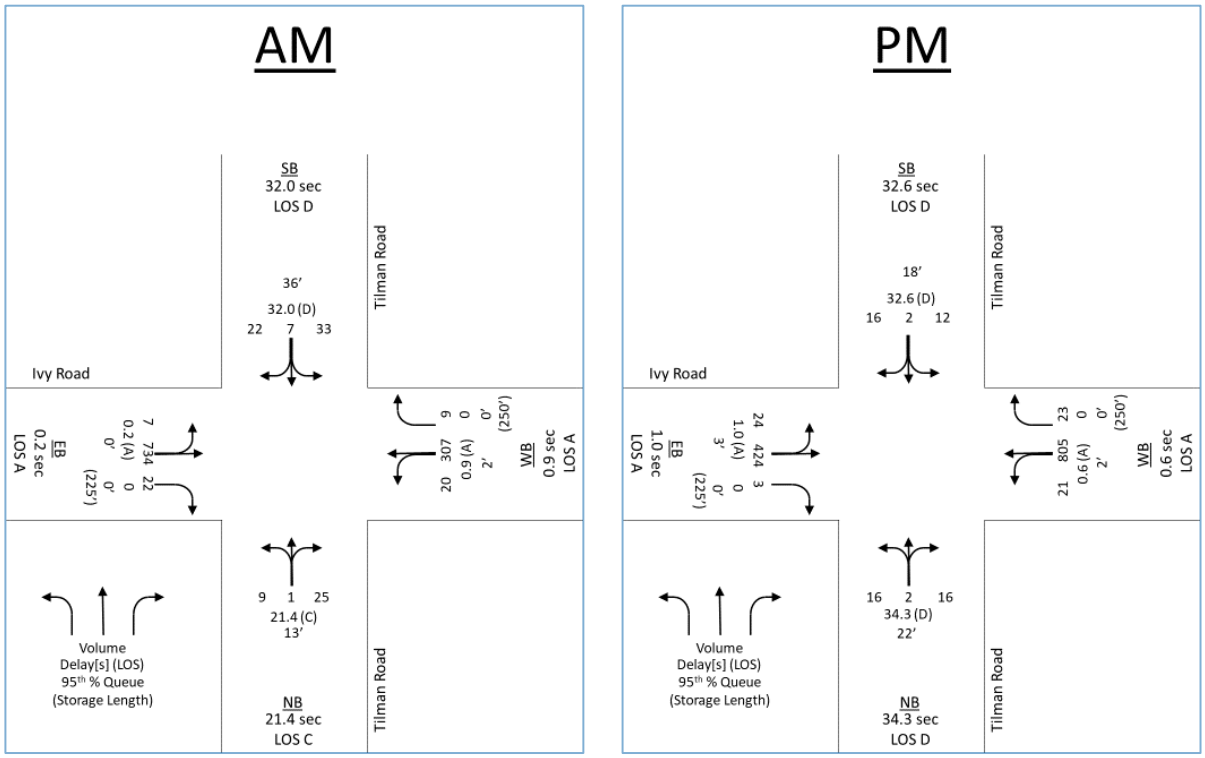



**Figure 7.20 – Traffic Conditions at Ivy Road and Tilman Road**

This intersection experiences little delay and operates at a satisfactory level of service. The greatest delay is seen from the side street (i.e., Tilman Road) approaches. Though these approaches operate on the border of intolerable levels of service, few vehicles are affected by this delay.

### 7.3.4 Crash Analysis

Crash data for a five-year study period, 2011-2015, was collected for analysis. **Table 7.13** provides a summary of crash data at the subject intersection.

**Table 7.13 – Crash Summary at Ivy Road and Tilman Road**

| Year | Peak | | Lighting Condition | | | | Pavement | | Type of Collision | | | | | | | | | | Severity | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AM (6-10) | PM (3-7) | Day | Dawn /Dusk | Dark - Road Lighted | Dark - Road Not Lighted | Dry | Wet | RE | A | HO | SS | SO | FI | NC | FO | D | BI | K | A | B | C | PDO | |
| 2011 | 0 | 0 | 1 | 1 | 0 | 1 | 3 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | **3** |
| 2012 | 1 | 3 | 4 | 0 | 0 | 0 | 4 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 2 | **4** |
| 2013 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | **1** |
| 2014 | 1 | 1 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | **2** |
| 2015 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | **1** |
| **TOT** | **3** | **4** | **8** | **1** | **0** | **2** | **11** | **0** | **4** | **1** | **0** | **0** | **1** | **0** | **0** | **4** | **1** | **0** | **1** | **2** | **1** | **2** | **5** | **11** |
| % | 27% | 36% | 73% | 9% | 0% | 18% | 100% | 0% | 36% | 9% | 0% | 0% | 9% | 0% | 0% | 36% | 9% | 0% | 9% | 18% | 9% | 18% | 45% | |

RE = Rear End; A = Angle; HO = Head On; SS = Sideswipe Same Direction; SO = Sideswipe Opposite Direction; FI = Fixed Object in Road; NC = Non-Collision; FO = Fixed Object Off Road; D = Deer; BI = Backed Into

**Figure 7.21** presents a summary of the crashes by lighting conditions and type of collision.

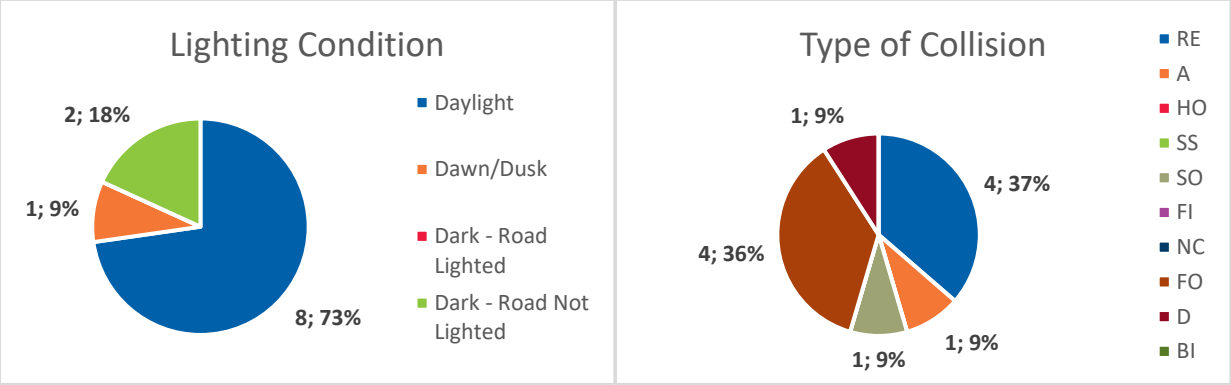



**Figure 7.21 – Lighting Condition and Collision Type at Ivy Road and Tilman Road**

Rear end and fixed object-off road crashes were the most prevalent, with four each in the five-year study period. Three rear end crashes were in the westbound direction. The remaining rear end crash was in the eastbound direction. For one rear end crash, the driver's view was obstructed by sun or headlight glare. All four-fixed object-off road crashes ran off the road on the right side while traveling eastbound (i.e., crashes occurred in the southeast quadrant). Three out of four fixed object-off road crashes cite "Bank or Ledge" as the first harmful crash event.

Crashes occurring at this intersection have high severity. There was one fatality in the five-year study period and it was an angle crash from the side street. Aside from this fatality, half of the remaining crashes were injury-causing.

The fatal crash occurred in 2012. A senior, 79-year-old driver made a left turn onto Ivy Road westbound from Tilman Road northbound and collided, in a right-angle collision, with an eastbound vehicle on Ivy

Road. The senior driver was the fatality. This crash occurred on dry pavement, in the daylight with no adverse weather conditions.

## 7.3.5 Roadway Safety Assessment

### *7.3.5.1 Safety Issues and Contributing Factors*

#### EASTBOUND FIXED OBJECT – OFF ROAD

All the fixed object crashes at Tilman Road occurred in the southeast quadrant. The following safety issues and factors may have contributed to these crashes:

Figure 7.22a – View of "V" Dip

Figure 7.22b – View of EB Right Shoulder (SE Quadrant)

- It was both anecdotally noted and witnessed that when a left-turning vehicle is present (i.e., stopped and waiting to turn left onto Tilman Road), through vehicles that do not wish to wait for this left-turning vehicle to clear the intersection instead use the right-turn only lane as a passing lane. The northbound Tilman Road approach is on a downgrade that extends to the through lanes of Ivy Road. This causes a "V" dip beyond the right-turn only lane, depicted in **Figure 7.22a**. The eastbound through vehicles that are passing in the right-turn lane, generally at very high speeds, must maneuver this dip, which essentially creates an exaggerated super-elevated portion of roadway and forces the vehicle to the left. To further increase the danger, the Southeast quadrant has an unforgiving shoulder, shown in **Figure 7.22b**. The shoulder is very narrow and there is a steep drop-off to the adjacent gravel. This shoulder does not allow the passing drivers to recover if their tires leave the pavement. In two cases, this caused the drivers to overcorrect and cross both lanes of traffic, striking an object in the northeast corner of the intersection.

#### EASTBOUND/WESTBOUND REAR END

Multiple rear end crashes occurred in both the eastbound and westbound direction at this intersection. Safety issues or contributing factors that may be attributed to these crashes include:

- Drivers may perceive the flashing yellow signals to mean a caution to slow down or stop before proceeding. Vehicles following closely behind are not anticipating this stop and do not stop in time.
- The lack of left-turn lanes means that any vehicles wanting to turn left must significantly slow down or come to a complete stop in the through lane. Drivers who are closely following the vehicles do not anticipate this stopping. All rear end crashes at this intersection cite "following too close" as the driver error.

#### NORTHBOUND AND SOUTHBOUND LEFT-TURNS

Residents of this area consistently cite these maneuvers as very dangerous. Residents noted that they avoid this intersection because they do not feel safe making a left-turn onto Ivy Road from Tilman Road. Safety issues or contributing factors that may be attributed to these crashes include:

- The sight distance on Ivy Road from the side street approaches of Tilman Road is not adequate. This intersection is at the apex of both a horizontal and vertical curve, which limits sight distance in both directions. In addition, the surrounding parcels are heavily vegetated, further diminishing the sight distance.
- Due to the sight distance issues, drivers have trouble seeing the oncoming vehicles. This may cause uncertainty and the drivers, being cautious, do not take all the gaps that are given to them. As they wait longer, drivers are willing to accept smaller and smaller gaps in traffic, leading to unsafe maneuvers. **Figure 7.22c** shows the viewpoint of a driver on the northbound Ivy Road approach, looking west. **Figure 7.22d** captures that drivers must pull far in front of the stop bar to see oncoming traffic.

Figure 7.22c – View of NB Approach Sight Distance

Figure 7.22d – Driver Beyond Stop Bar

### *7.3.5.2 Suggestions and Opportunities for Improvement*

Application of a Tier 2 Systemic Template 6 is recommended at this location. Additional, intersection-specific improvements for the intersection of Ivy Road and Tilman Road are presented in this section and summarized in **Table 7.14.** The suggested improvements are *not* listed in any order of significance.

#### EASTBOUND FIXED OBJECT – OFF ROAD

- Short-term

1. Install a raised median between the right-turn lane and through lane to discourage use of the right-turn lane as a passing lane. Install flex bollards on this median. Apply the same treatment to the westbound lanes.
2. Install a "porkchop" island to require vehicles in the right-turn only lane to turn right onto Tilman Road. Apply the same treatment to the westbound right-turn only lane.

- Intermediate

3. Widen the southeast shoulder two feet and install safety edge shoulder so that the pavement drop-off is not as abrupt as existing conditions. This will allow vehicles a greater chance for recovery in the event the vehicle runs off the pavement. (Installation of a safety edge treatment; all types; all severities; CMF = 0.886)

- Long-Term

    4. Install an eastbound and a westbound left-turn lane on Ivy Road so that left-turning vehicles are not obstructing the through lanes. (Install left-turn lane; all crash types; all severities; CMF = 0.748)

### Eastbound/Westbound Rear End

- Long-Term

    1. Install an eastbound and a westbound left-turn lane on Ivy Road so that left-turning vehicles are not obstructing the through lanes. (Install left-turn lane; all crash types; all severities; CMF = 0.748)

### Northbound and Southbound Left-Turns

- Short-term

    1. Remove vegetation in the southeast and southwest quadrant along Ivy Road to improve sight distance for drivers turning onto Ivy Road from northbound Tilman Road. The specific area for tree removal is shown in **Figure 7.22e**. Figure 7.22e is shown from the perspective of a vehicle on the northbound Tilman Road approach looking west. (Increase triangle sight distance; all crash types; Serious injury, Minor injury; CMF = 0.53)

**Figure 7.22e – Vegetation Suggested for Removal**

**Table 7.14 – Summary of Recommended Improvements at Ivy Road and Tilman Road**

| | Safety Issue | Opportunities for Improvement |
|---|---|---|
| 1 | Eastbound Fixed Object – Off Road | • Install raised median and place flex bollards between the right-turn lane and through lane in the eastbound and westbound direction.<br>• Install "porkchop" islands to channelize vehicles in the right-turn lane in the eastbound and westbound direction.<br>○ Widen the southeast shoulder six feet and install safety edge shoulder.<br>❖ Install an eastbound and a westbound left-turn lane on Ivy Road. |
| 2 | Eastbound/Westbound Rear End | ❖ Install an eastbound and a westbound left-turn lane on Ivy Road. |
| 3 | Northbound and Southbound Left-turns | • Remove vegetation in the Southeast and Southwest quadrants. |

• Short-term, low-cost
○ Intermediate, medium-cost
❖ Long-term, high-cost

**Figure 7.23** and **Figure 7.24** present the potential safety enhancement suggestions to be considered for the intersection of Ivy Road and Tilman Road. The placement of traffic control devices, pavement markings, etc. is not to scale and not according to survey, but is an approximation intended to provide a general idea of location and concept. Designers should consider appropriate standards, policies, and right of way impacts before implementing any potential enhancements.

VHB considered a roundabout for this location as a preliminary alternative, but determined the benefit would not exceed the cost, resulting in an undesirable benefit-to-cost ratio. VHB employed VJuST (VDOT's Junction Screening Tool). VJuST is a tool to analyze alternative and unconventional intersection designs. The tool analyzes an intersection configuration's Volume to Capacity ratio (V:C Ratio), but does not analyze the delay or queues. Additionally, the tool does not consider other design attributes such as cost, right of way needs, or specific design requirements. It is meant as a planning level analysis tool. VJuST indicated that the installation of a single-lane roundabout would degrade operations compared to a two-way stop-controlled intersection. The VJuST results are presented below in **Table 7.15**.

**Table 7.15 – Results of VJuST Analysis for Ivy Road and Tilman Road**

| Type of Intersection | Maximum V/C AM | Maximum V/C PM |
|---|---|---|
| Two-Way Stop Control | 0.42 | 0.46 |
| 50' Mini Roundabout | 0.82 | 0.90 |
| 75' Mini Roundabout | 0.81 | 0.88 |
| Roundabout | 0.73 | 0.80 |


**Figure 7.23 – Short-Term Concept for Ivy Road and Tilman Road**

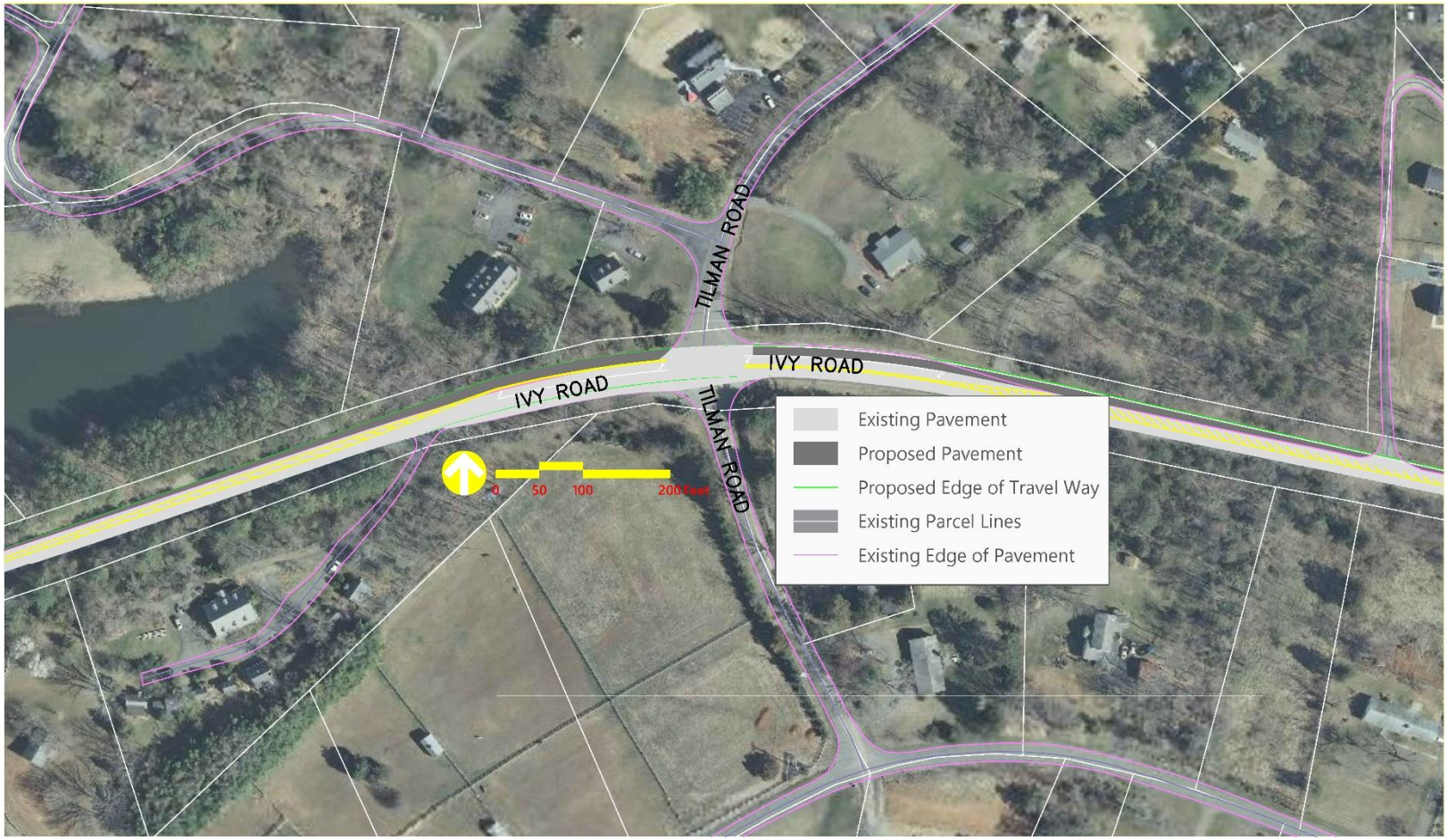



**Figure 7.24 – Long-Term Concept for Ivy Road and Tilman Road**

### 7.3.6 Preliminary Cost Estimate

The preliminary estimated cost for the proposed improvements is presented in **Table 7.16**. VHB developed the costs in Table 7.16 by use of VDOT's Transportation and Mobility Planning Division (TMPD) cost estimation tool.

**Table 7.16 – TMPD Cost Estimate for Improvements at Ivy Road and Tilman Road**

| Alternative | Cost Type | Low | High |
|---|---|---|---|
| Short-term | Preliminary Engineering | $ 600 | $ 2,200 |
| | ROW & Utility Relocation | - | - |
| | Construction | $ 3,400 | $ 12,300 |
| | *Short-term Subtotal* | *$ 4,000* | *$ 14,500* |
| Intermediate | Preliminary Engineering | $ 1,500 | $ 1,900 |
| | ROW & Utility Relocation | - | - |
| | Construction | $ 8,600 | $ 10,600 |
| | *Intermediate Subtotal* | *$ 10,000* | *$ 12,500* |
| Long-term | Preliminary Engineering | $ 84,000 | $ 104,000 |
| | ROW & Utility Relocation | $ 105,000 | $ 182,000 |
| | Construction | $ 462,300 | $ 570,800 |
| | *Long-Term Subtotal* | *$ 651,300* | *$ 856,800* |
| **Total** | **Preliminary Engineering** | **$ 86,000** | **$ 108,000** |
| | **ROW & Utility Relocation** | **$ 105,000** | **$ 182,000** |
| | **Construction** | **$ 473,100** | **$ 592,500** |
| | ***TOTAL*** | ***$ 664,100*** | ***$ 882,500*** |

VHB further refined these costs using VDOT's Preliminary Cost Estimating Spreadsheet (PCES) and district bid averages. The total projected cost for these alternatives is presented in **Table 7.17**.

**Table 7.17 – Cost Estimate for Improvements at Ivy Road and Tilman Road**

| Alternative | Cost Type | Cost Estimate |
|---|---|---|
| Short-term | Preliminary Engineering | $ 90,300 |
| | ROW & Utility Relocation | - |
| | Construction | $ 376,000 |
| | *Short-term Subtotal* | *$ 466,300* |
| Long-term | Preliminary Engineering | $ 241,500 |
| | ROW & Utility Relocation | - |
| | Construction | $ 1,006,000 |
| | *Long-term Subtotal* | *$ 1,247,500* |
| **Total** | **Preliminary Engineering** | **$ 331,800** |
| | **ROW & Utility Relocation** | **-** |
| | **Construction** | **$ 1,382,000** |
| | ***TOTAL*** | ***$ 1,713,800*** |

VHB developed the cost estimate into a 20-year cost estimate accounting for improvement service life and annual maintenance costs. The service lives and annual maintenance costs were derived from the

HSIP Safety Improvement Proposal values. The total projected 20-year cost estimate for the alternatives is presented in **Table 7.18.**

**Table 7.18 – 20-Year Cost Estimate for Improvements at Ivy Road and Tilman Road**

| Alternative | Cost Estimate Total | 20-Yr Cost (Based on individual item service life) | Annual Maintenance | Present Value of Maintenance | Total 20-year Cost |
|---|---|---|---|---|---|
| Short-term | $ 466,300 | $ 500,700 | $ 1,100 | $ 16,400 | **$ 517,100** |
| Long-term | $ 1,247,500 | $ 1,247,500 | $ 400 | $ 6,000 | **$ 1,253,500** |

### 7.3.7 Benefit Analysis

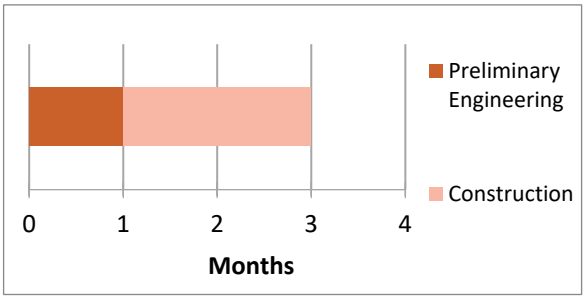
**Table 7.19** summarizes the 20-year safety and operational benefits of both the short-term and long-term suggested improvements. The B/C ratios utilize the 20-year total cost from Table 7.18.

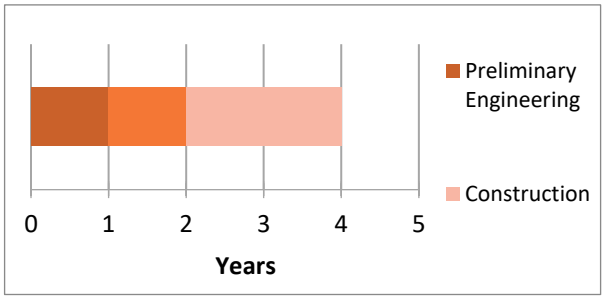
**Table 7.19 - Improvement Benefits at Ivy Road and Tilman Road**

| Improvements | Safety Benefit | Operational Benefit | Total Benefit | B:C Ratio |
|---|---|---|---|---|
| Short-term | $ 7,589,600 | $ - | **$ 7,589,600** | **14.7** |
| Long-term | $ 201,400 | $ 226,700 | **$ 428,100** | **0.3** |

### 7.3.8 Project Schedule

VHB estimated the project schedule based on the project schedules for similar VDOT projects recently completed. **Figures 7.25-7.26** show the anticipated schedule for this hot spot's improvements.




**Figures 7.25 and 7.26 – Short and Long-Term Project Schedules for Ivy Road and Tilman Road**

## 7.4 Ivy Road (US 250) at Owensville Road

### 7.4.1 Intersection Description and Geometric Conditions

The T-intersection of Ivy Road at Owensville Road is unsignalized. Ivy Road is classified as a minor arterial and Owensville Road is classified as a major collector. Owensville Road provides access to residential areas and an elementary school to the north. No pedestrian facilities (i.e., crosswalks or sidewalks) are present.

Ivy Road is an undivided two-lane roadway. Owensville Road is also an undivided two-lane roadway. Approaches are on level terrain. There is no significant variation in horizontal alignment at this intersection. The lane use at this intersection is as follows:

- Ivy Road eastbound: 1 shared left-turn/through lane
- Ivy Road westbound: 1 shared through/right-turn lane
- Owensville Road southbound: 1 left-turn lane, 1 channelized right-turn lane

### 7.4.2 Traffic Control Devices

Both the left-turn and channelized right-turn movements of southbound Owensville Road are controlled by a stop sign. The eastbound and westbound approaches of Ivy Road are free-flowing.

### 7.4.3 Traffic Conditions

Owensville Road has a posted speed limit of 40 mph. Ivy Road has a posted speed limit of 35 mph. The 2016 VDOT Average Annual Daily Traffic (AADT) is as follows:

- Ivy Road: **12,000 vehicles/day**
- Owensville Road: **3,100 vehicles/day**

Four-hour turning movement counts were conducted by Peggy Malone & Associates on May 11, 2016. The peak hour turning movement volumes as well as the intersection performance measures, are shown in **Figure 7.27** below.

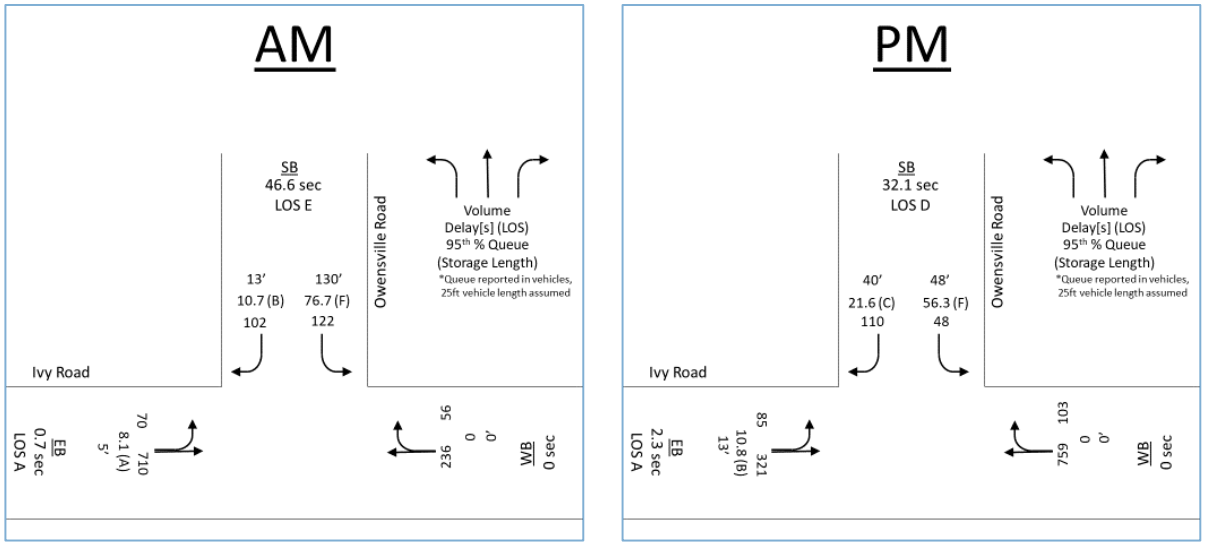



**Figure 7.27 – Traffic Conditions at Ivy Road and Owensville Road**

The southbound left-turn movement experiences considerable delay in the AM and PM peak hours, operating at LOS F during both. This delay commonly causes heavy queueing on the Owensville Road approach, especially in the AM peak hour. Due to the heavy westbound through volume, the eastbound left-turn movement also experiences delay, though not to an alarming level. Overall, the intersection performs at LOS A for both peak hours.

### 7.4.4 Crash Analysis

Crash data for a five-year study period, 2011-2015, was collected for analysis. **Table 7.20** provides a summary of crash data at the subject intersection.

**Table 7.20 – Crash Summary at Ivy Road and Owensville Road**

| Year | Peak | | Lighting Condition | | | | Pavement | | Type of Collision | | | | | | | | | | Severity | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AM (6-10) | PM (3-7) | Day | Dawn /Dusk | Dark - Road Lighted | Dark - Road Not Lighted | Dry | Wet | RE | A | HO | SS | SO | FI | NC | FO | D | BI | K | A | B | C | PDO | |
| 2011 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | **1** |
| 2012 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| 2013 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| 2014 | 1 | 0 | 1 | 0 | 1 | 1 | 3 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | **3** |
| 2015 | 0 | 2 | 1 | 0 | 0 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | **2** |
| **TOT** | **2** | **2** | **3** | **0** | **1** | **2** | **5** | **1** | **5** | **1** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **1** | **1** | **4** | **6** |
| % | 33% | 33% | 50% | 0% | 17% | 33% | 83% | 17% | 83% | 17% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 17% | 17% | 67% | |

RE = Rear End; A = Angle; HO = Head On; SS = Sideswipe Same Direction; SO = Sideswipe Opposite Direction; FI = Fixed Object in Road; NC = Non-Collision; FO = Fixed Object Off Road; D = Deer; BI = Backed Into

**Figure 7.28** presents a summary of the crashes by lighting conditions and type of collision.

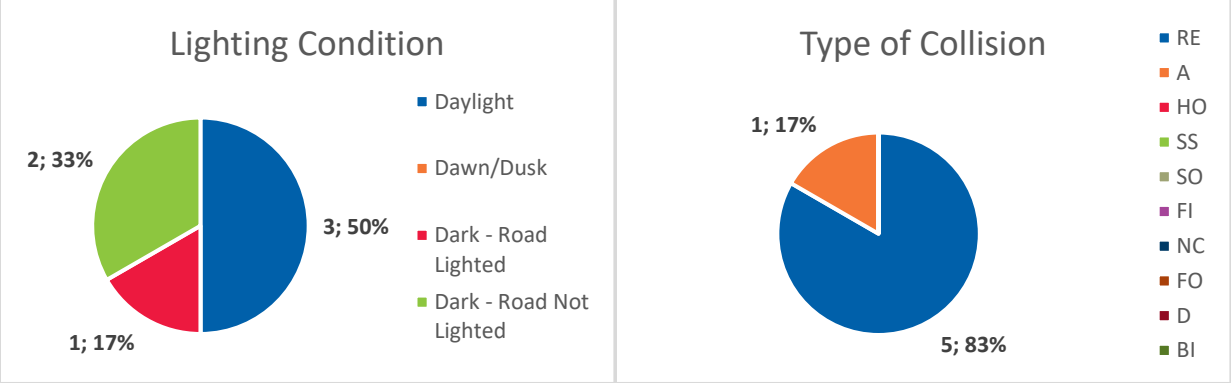



**Figure 7.28 – Lighting Condition and Collision Type at Ivy Road and Owensville Road**

Most crashes at this intersection were rear end crashes. Four of the five rear end crashes were in the eastbound direction. Three of the five rear end crashes involved three vehicles. Half of the crashes, including the one angle crash, occurred at night. The road is lit by only a single street light in the parking lot of a neighboring restaurant.

## 7.4.5 Roadway Safety Assessment

### *7.4.5.1 Safety Issues and Contributing Factors*

#### EASTBOUND REAR END

Most crashes at this intersection were eastbound rear end crashes and were likely caused by the following contribution(s):

- The lack of an eastbound left-turn lane forces all eastbound vehicles turning left to either significantly slow down or come to a complete stop in the through lane while waiting to turn left. Vehicles following closely behind may not anticipate this stop and collide with the vehicle in front.
- The speed limit abruptly drops from 55 mph to 35 mph in the eastbound direction just before this intersection. Drivers may not observe the new 35 mph speed limit and maintain a faster speed through this area. Their faster speeds make it more difficult to stop in the event of a left-turning vehicle ahead.

### *7.4.5.2 Suggestions and Opportunities for Improvement*

Application of a Tier 1 Systemic Template 3 is recommended at this location. Additional, intersection-specific improvements for the intersection of Ivy Road and Owensville Road are presented in this section and summarized in **Table 7.21**. The suggested improvements are *not* listed in any order of significance.

#### EASTBOUND REAR END

- Short-term

1. Introduce speed control measures to alert drivers of the 35-mph speed limit. These may include transverse rumble strips, transverse speed bars, colored speed-zone entrance pavement markings, or police enforcement. (Install transverse rumble strips as a traffic calming device; all crash types; all crash severities; CMF = 0.66)

- Long-term

2. Install an eastbound left-turn lane so that the eastbound left-turning vehicles do not impede the through traffic while waiting to turn left. (Install left-turn lane; all crash types; all severities; CMF = 0.748)
3. Realign this intersection and the intersection at Morgantown Road into a single roundabout configuration. To meet the maximum grade restrictions and tie in quickly to minimize the impact to the surrounding parcels, the roundabout will be raised to 4-feet above the existing intersection elevation. (Conversion of intersection into single-lane roundabout; all crash types; all severities; CMF = 0.64)

**Table 7.21 – Summary of Recommended Improvements at Ivy Road and Owensville Road**

| | Safety Issue | Opportunities for Improvement |
|---|---|---|
| 1 | Eastbound Rear End | • Introduce speed control measures to alert drivers to the 35-mph speed limit. These may include transverse rumble strips, transverse speed bars, colored speed-zone entrance pavement markings, or police enforcement.<br>❖ Install an eastbound left-turn lane.<br>❖ Realign this intersection and the intersection at Morgantown Road into a single roundabout configuration. |

• Short-term, low-cost
○ Intermediate, medium-cost
❖ Long-term, high-cost

**Figures 7.29** - 7**.31** present the potential safety enhancement suggestions to be considered for the intersection of Ivy Road and Owensville Road. The placement of traffic control devices, pavement markings, etc. is not to scale and not according to survey, but is an approximation intended to provide a general idea of location and concept. Designers should consider appropriate standards, policies, and right of way impacts before implementing any potential enhancements.

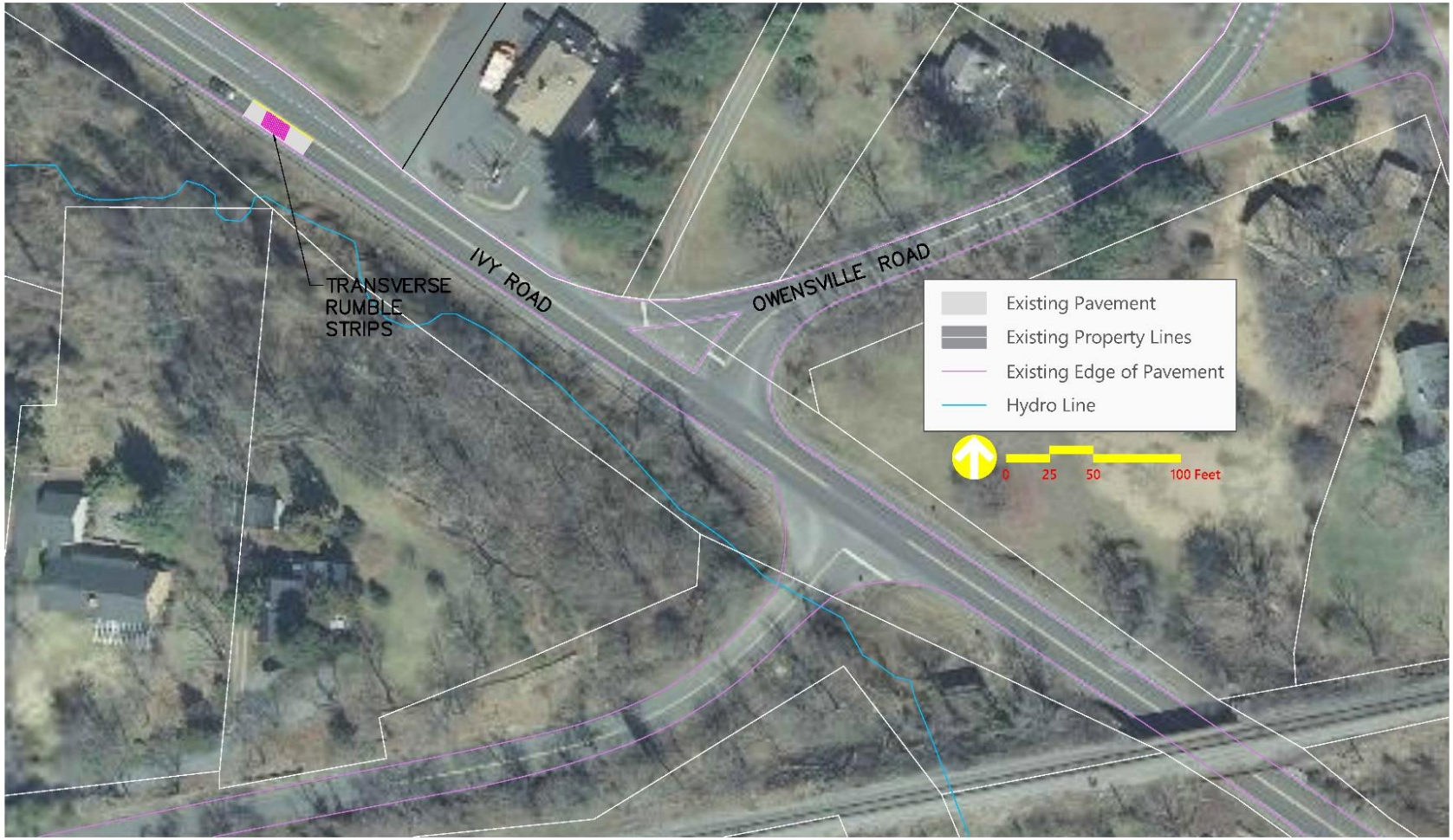



**Figure 7.29 – Short-Term Concept for Ivy Road and Owensville Road**

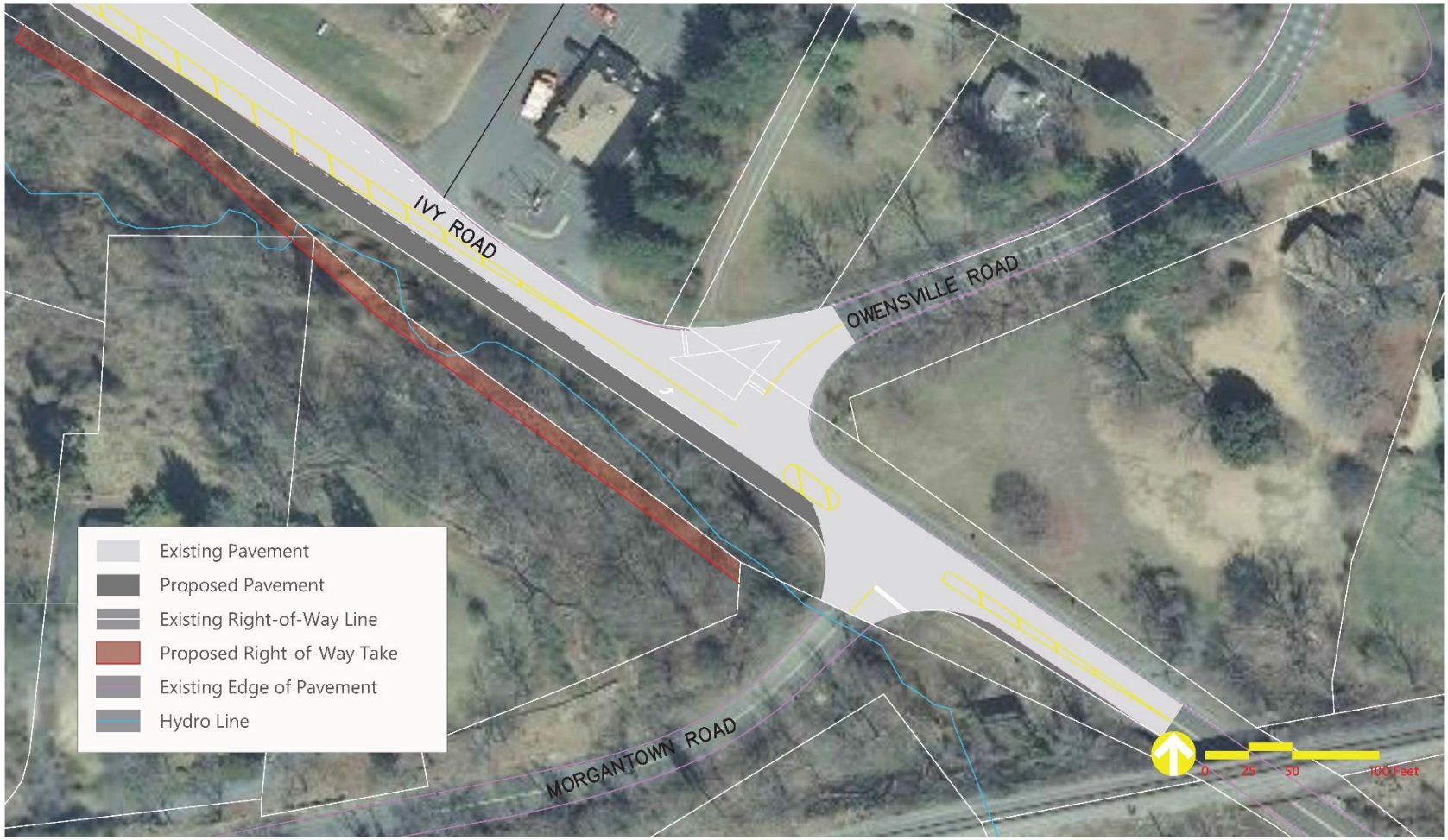



**Figure 7.30 – Long-Term Concept A for Ivy Road and Owensville Road**


**Figure 7.31 – Long-Term Concept B for Ivy Road and Owensville Road**

### *7.4.5.3 Traffic Operations Analysis*

- **Long-Term Alternative B**
  - Under this effort, an initial high-level planning analysis was performed with the recent 2016 turning movement counts. The investigation revealed, based on Exhibit 3-14 of NCHRP 672 (included below as **Figure 7.32**), that a single lane roundabout should suffice, but may need additional analysis. The highest sum of conflicting volumes was 1,099 veh/h, occurring during the PM. This volume is just above the recommended 1,000 veh/h threshold, but well below the 1,300 veh/h threshold that indicates the need for a two-lane roundabout.

| Volume Range (sum of entering and conflicting volumes) | Number of Lanes Required |
|---|---|
| 0 to 1,000 veh/h | ▪ Single-lane entry likely to be sufficient |
| 1,000 to 1,300 veh/h | ▪ Two-lane entry may be needed<br>▪ Single-lane may be sufficient based upon more detailed analysis. |
| 1,300 to 1,800 veh/h | ▪ Two-lane entry likely to be sufficient |
| Above 1,800 veh/h | ▪ More than two entering lanes may be required<br>▪ A more detailed capacity evaluation should be conducted to verify lane numbers and arrangements. |

Source: New York State Department of Transportation

**Exhibit 3-14**
Volume Thresholds for Determining the Number of Entry Lanes Required

**Figure 7.32 – NCHRP Report 672 Conflicting Volume Thresholds for Roundabout Designs**

  - VHB also employed VJuST (VDOT's Junction Screening Tool). VJuST is a tool to analyze alternative and innovative intersection designs. The tool analyzes an intersection configuration's Volume to Capacity ratio (V:C Ratio), but does not analyze the delay or queues. Additionally, the tool does not consider other design attributes such as cost, right of way needs, or specific design requirements. It is meant as a planning level analysis tool. VJuST reinforces the results of the NCHRP analysis: a single-lane roundabout will suffice, but may experience mild congestion. The volume to capacity ratio of a single-lane roundabout is 0.80 in the AM and 0.85 in the PM.
  - VHB also performed additional analysis using Synchro and SIDRA. For the purposes of this analysis, the existing condition at Owensville Road and Morgantown Road was considered as a single intersection through the Highway Capacity Manual's methodology for evaluating a distributed intersection. Note that the existing conditions and 2025 No-Build conditions perform the same as there is no growth in volume anticipated.
  - The 2025 Build Conditions perform better in both the AM and PM peak hour. The 2025 Build conditions experience a 5.6 second reduction in delay in the AM and a 3.8 second reduction in delay in the PM, when compared to 2025 No-Build conditions. Moreover, the Build conditions improve the intersection to LOS A in both peak hours, from LOS B in the No-Build conditions. The full comparison between Existing/No-Build and Build conditions is presented in **Table 7.22** below.

Table 7.22 - Delay and LOS Comparison for Long-Term Alternative B at Ivy Road and Owensville Road

| | | 2025 No-Build Conditions for Owensville Road and Morgantown Road Intersections as a Distributed Intersection System | | | | | | 2025 Build Conditions (Single Roundabout) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Delay (s/veh) | LOS | Delay (s/veh) | LOS | Int. Delay (s) | Int. LOS | Delay (s/veh) | LOS | Delay (s/veh) | LOS | Int. Delay (s) | Int. LOS |
| **Ivy Road at US 29 Northbound Interchange** | | | | | | | | | | | | | |
| Ivy Road EB | Left | 8.1/10.8 | A/B | 3.4/ 3.6 | A/A | **11.8/ 10.1** | **B/B** | 9.6/8.7 | A/A | 6.0/4.2 | A/A | **6.2/ 6.3** | **A/A** |
| | Through | 3.0/3.0 | A/A | | | | | 4.2/3.1 | A/A | | | | |
| | Right | 0/0 | A/A | | | | | 4.2/3.3 | A/A | | | | |
| Ivy Road WB | Left | 10.8/8.4 | B/A | 3.8/ 3.4 | A/A | | | 11.2/12.2 | B/B | 4.1/6.8 | A/A | | |
| | Through | 3.0/3.0 | A/A | | | | | 4.0/6.6 | A/A | | | | |
| | Right | 0/0 | A/A | | | | | 4.2/7.0 | A/A | | | | |
| Owensville Road SB | Left | 79.7/59.3 | F/F | 48.3/ 42.1 | E/E | | | 12.5/19.8 | B/C | 10.0/14.1 | B/B | | |
| | Through | 0/0 | A/A | | | | | 6.6/12.7 | A/B | | | | |
| | Right | 10.7/21.6 | B/C | | | | | 7.1/13.0 | A/B | | | | |
| Morgantown Road NB | Left | 32.2/19.9 | D/C | 29.4/ 17.1 | D/C | | | 11.6/11.3 | B/B | 6.1/6.5 | A/A | | |
| | Through | 0/0 | A/A | | | | | 5.2/5.6 | A/A | | | | |
| | Right | 29.2/16.9 | D/C | | | | | 5.7/5.8 | A/A | | | | |

## 7.4.6 Preliminary Cost Estimate

The preliminary estimated cost for the proposed improvements is presented in **Table 7.23**. VHB developed the costs in Table 7.23 by use of VDOT's Transportation and Mobility Planning Division (TMPD) cost estimation tool. For Concept B, the TMPD cost estimation tool was not applied; VHB developed a separate cost estimate using bid item costs, presented in **Table 7.24**.

Table 7.23 – TMPD Cost Estimate for Improvements at Ivy Road and Owensville Road

| Alternative | Cost Type | Low | High |
|---|---|---|---|
| Short-term | Preliminary Engineering | $ 100 | $ 100 |
| | ROW & Utility Relocation | - | - |
| | Construction | $ 600 | $ 700 |
| | *Short-term Subtotal* | *$ 700* | *$ 800* |
| Long-term A | Preliminary Engineering | $ 27,500 | $ 57,500 |
| | ROW & Utility Relocation | $ 34,400 | $ 100,600 |
| | Construction | $ 152,600 | $ 318,500 |
| | *Long-term A Subtotal* | *$ 214,500* | *$ 476,600* |
| **Total Long-Term A** | **Preliminary Engineering** | **$ 27,600** | **$ 57,600** |
| | **ROW & Utility Relocation** | **$ 34,400** | **$ 100,600** |
| | **Construction** | **$ 153,200** | **$ 319,200** |
| | ***TOTAL*** | ***$ 215,200*** | ***$ 477,400*** |

Table 7.24 – VHB Cost Opinion for Long-Term Alternative B

| Alternative | Cost Type | Low | High |
|---|---|---|---|
| Long-term B | Preliminary Engineering | $ 367,000 | $ 367,000 |
| | ROW & Utility Relocation | $ 458,800 | $ 642,300 |
| | Construction | $ 1,982,700 | $ 1,982,700 |
| | *Long-term B Subtotal* | *$ 2,808,500* | *$ 2,992,000* |
| **Total Long-Term B** | **Preliminary Engineering** | **$ 367,100** | **$ 367,100** |
| | **ROW & Utility Relocation** | **$ 458,800** | **$ 642,300** |
| | **Construction** | **$ 1,983,400** | **$ 1,983,400** |
| | ***TOTAL*** | ***$ 2,809,300*** | ***$ 2,992,800*** |

VHB further refined the TMPD costs using VDOT's Preliminary Cost Estimating Spreadsheet (PCES) and district bid averages. The total projected cost for these alternatives is presented in **Table 7.25**. A PCES cost was not estimated for Concept B; the PCES worksheet does not provide an accurate cost estimation for the construction of a roundabout, especially since the Owensville roundabout is assumed to be 4-feet above existing elevation. Instead, a cost item take-off was developed for Concept B.

Table 7.25 – Cost Estimate for Improvements at Ivy Road and Owensville Road

| Alternative | Cost Type | Cost Estimate |
|---|---|---|
| Short-term | Preliminary Engineering | $ 300 |
| | ROW & Utility Relocation | - |
| | Construction | $ 1,000 |
| | *Short-term Subtotal* | *$ 1,300* |
| Long-term A | Preliminary Engineering | $ 52,500 |
| | ROW & Utility Relocation | $ 12,000 |
| | Construction | $ 219,000 |
| | *Long-term A Subtotal* | *$ 283,500* |
| Long-term B | Preliminary Engineering | $ 467,100 |
| | ROW & Utility Relocation | $ 24,000 |
| | Construction | $ 1,946,000 |
| | *Long-term A Subtotal* | *$ 2,437,100* |
| **Total A** | **Preliminary Engineering** | **$ 52,800** |
| | **ROW & Utility Relocation** | **$ 12,000** |
| | **Construction** | **$ 220,000** |
| | ***TOTAL*** | ***$ 284,800*** |
| **Total B** | **Preliminary Engineering** | **$ 467,400** |
| | **ROW & Utility Relocation** | **$ 24,000** |
| | **Construction** | **$ 1,947,300** |
| | ***TOTAL*** | ***$ 2,438,400*** |

VHB developed the cost estimate into a 20-year cost estimate accounting for improvement service life and annual maintenance costs. The service lives and annual maintenance costs were derived from the HSIP Safety Improvement Proposal values. The total projected 20-year cost estimate for the alternatives is presented in **Table 7.26.**

Table 7.26 – 20-Year Cost Estimate for Improvements at Ivy Road and Owensville Road

| Alternative | Cost Estimate Total | 20-Yr Cost (Based on individual item service life) | Annual Maintenance | Present Value of Maintenance | Total 20-year Cost |
|---|---|---|---|---|---|
| Short-term | $ 1,300 | $ 2,600 | - | - | **$ 2,600** |
| Long-term A | $ 283,500 | $ 283,500 | $ 200 | $ 3,000 | **$ 286,500** |
| Long-term B | $ 2,437,100 | $ 2,437,100 | $ 500 | $ 7,400 | **$ 2,444,500** |

### 7.4.7 Benefit Analysis

**Table 7.27** summarizes the 20-year safety and operational benefits of both the short-term and long-term suggested improvements. The B/C ratios utilize the 20-year total cost from Table 7.26.

Table 7.27 - Improvement Benefits at Ivy Road and Owensville Road

| Improvements | Safety Benefit | Operational Benefit | Total Benefit | B:C Ratio |
|---|---|---|---|---|
| Short-term | $ 138,300 | - | **$138,300** | **53.2** |
| Long-term A | $ 102,500 | $326,800 | **$ 429,300** | **1.5** |
| Long-term B | $ 146,500 | $3,072,100 | **$3,218,600** | **1.3** |

### 7.4.8 Project Schedule

VHB estimated the project schedule based on the project schedules for similar VDOT projects recently completed. **Figures 7.33-7.35** show the anticipated schedule for this hot spot's improvements.

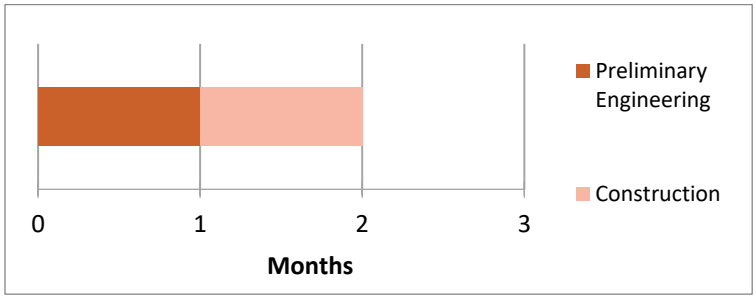
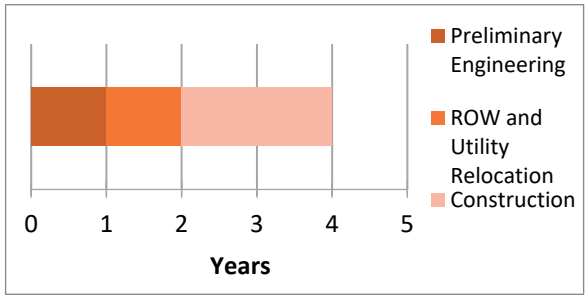
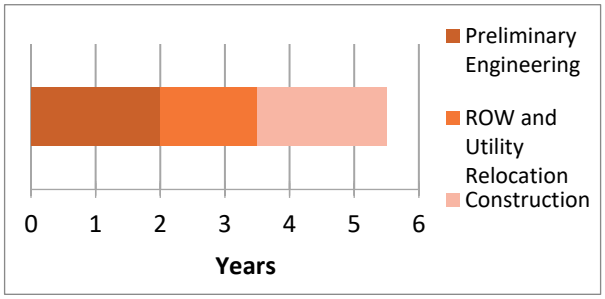



Figure 7.33 – Short-Term Project Schedule for Ivy Road and Owensville Road




Figures 7.34 and 7.35 – Long-Term A (left) and B (right) Project Schedules for Ivy Road and Owensville Road

## 7.5 Ivy Road (US 250) at Broomley Road

### 7.5.1 Intersection Description and Geometric Conditions

The intersection of Ivy Road and Broomley Road is signalized. Broomley Road is classified as a minor collector. Ivy Road is classified as a minor arterial. To the north, Broomley Road provides access to private residences. The northbound approach of this intersection provides access to/from a private residence. No pedestrian facilities (i.e., crosswalks or sidewalks) are present.

Both Ivy Road and Broomley Road are two-way undivided roadways. This intersection is on a slope of a crest vertical curve with its apex east of Broomley Road. For this reason, the eastbound approach is on a positive grade and the westbound approach experiences a negative grade at this intersection. No skew in horizontal alignment is present; Broomley Road intersects with Ivy Road at a 90-degree angle. The lane use at this intersection is as follows:

- Ivy Road eastbound: 1 left-turn lane, 1 shared through/right-turn lane
- Ivy Road westbound: 1 left-turn lane, 1 through lane, 1 right-turn lane
- Broomley Road southbound: 1 left-turn lane, 1 right-turn lane

### 7.5.2 Traffic Control Devices

This intersection is signal controlled. All signal heads are mounted on mast arms. One additional near side signal is provided for the northbound approach. Signal heads are 12" with incandescent bulbs and non-retroreflective back plates. Right turn on red is permitted for all approaches. No pedestrian signal heads are present.

**Signal Type: Actuated Coordinated**

**Signal Operations and Phasing Observations**

- The eastbound left-turn movement operates under protected/permissive phasing.
- Northbound and southbound approaches operate with split phasing.

### 7.5.3 Traffic Conditions

Broomley Road has no posted speed limit. Given the residential nature of Broomley Road, a speed limit of 25 mph is assumed. 45 mph is the posted speed limit for Ivy Road at this intersection. The 2016 VDOT Average Annual Daily Traffic (AADT) is as follows:

- Ivy Road: **13,000 vehicles/day**
- Broomley Road: **NOT REPORTED**

Four-hour turning movement counts were conducted by Peggy Malone & Associates on May 11, 2016. The peak hour turning movement volumes as well as the intersection performance measures, are shown in **Figure 7.36** below.

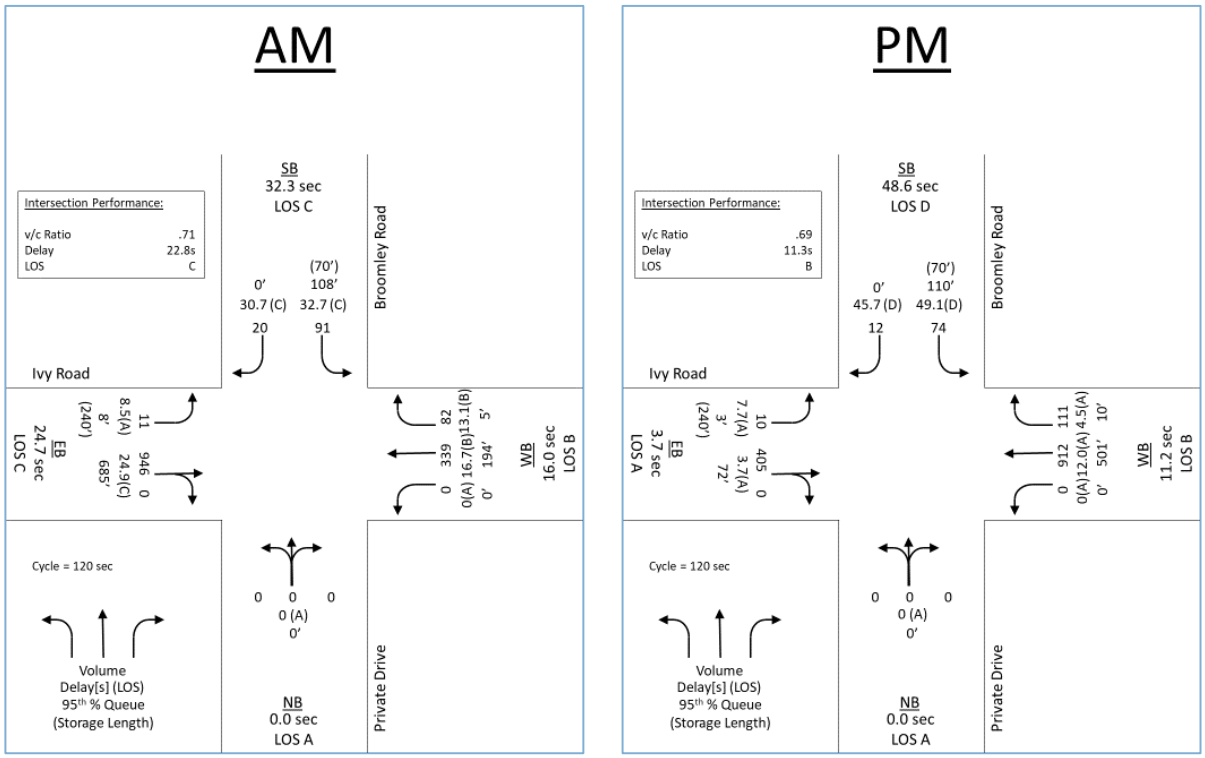



**Figure 7.36 – Traffic Conditions at Ivy Road and Broomley Road**

This intersection experiences heavy through volumes on the eastbound and westbound approaches. This results in both extensive queuing and delays in the AM peak hour. While the delay is lessened in the PM peak hour, similar queues remain. Since most of the green time must be given to the main street through movements, the side street movements deteriorate. The southbound approach operates at LOS C and D in the AM and PM peak hours, respectively. This delay is largely from the southbound left-turn movement.

### 7.5.4 Crash Analysis

Crash data for a five-year study period, 2011-2015, was collected for analysis. **Table 7.28** provides a summary of crash data at the subject intersection.

**Table 7.28 – Crash Summary at Ivy Road and Broomley Road**

| Year | Peak | | Lighting Condition | | | | Pavement | | Type of Collision | | | | | | | | | | Severity | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AM (6-10) | PM (3-7) | Day | Dawn /Dusk | Dark - Road Lighted | Dark - Road Not Lighted | Dry | Wet | RE | A | HO | SS | SO | FI | NC | FO | D | BI | K | A | B | C | PDO | |
| 2011 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | **1** |
| 2012 | 2 | 0 | 3 | 0 | 0 | 0 | 3 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | **3** |
| 2013 | 2 | 0 | 3 | 0 | 0 | 1 | 4 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 3 | **4** |
| 2014 | 1 | 2 | 2 | 0 | 0 | 2 | 4 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | **4** |
| 2015 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| **TOT** | **5** | **2** | **8** | **0** | **0** | **4** | **12** | **0** | **7** | **2** | **0** | **0** | **0** | **0** | **0** | **2** | **0** | **1** | **0** | **1** | **0** | **0** | **11** | **12** |
| % | 42% | 17% | 67% | 0% | 0% | 33% | 100% | 0% | 58% | 17% | 0% | 0% | 0% | 0% | 0% | 17% | 0% | 8% | 0% | 8% | 0% | 0% | 92% | |

RE = Rear End; A = Angle; HO = Head On; SS = Sideswipe Same Direction; SO = Sideswipe Opposite Direction; FI = Fixed Object in Road; NC = Non-Collision; FO = Fixed Object Off Road; D = Deer; BI = Backed Into

**Figure 7.37** presents a summary of the crashes by lighting conditions and type of collision.

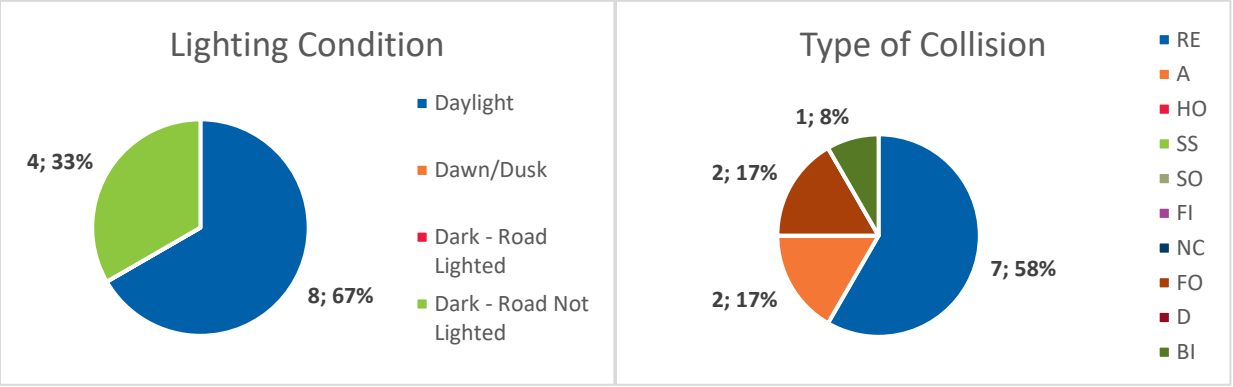



**Figure 7.37 – Lighting Condition and Collision Type at Ivy Road and Broomley Road**

Rear end collisions account for over half of the documented crashes and occurred predominately in the eastbound direction. Most of these crashes caused property damage only, except for one four-vehicle rear-end collision resulting in an ambulatory injury. 33% of total crashes occurred in the dark with no lighting on the roadway. The remaining 67% occurred during the daylight.

### 7.5.5 Roadway Safety Assessment

#### *7.5.5.1 Safety Issues and Contributing Factors*

EASTBOUND REAR END

Eastbound rear end crashes were predominant at this intersection. These crashes may be attributed to the following safety issues and contributing factors:

- It is common for eastbound Ivy Road to experience congestion at this intersection. The vehicles that are following too closely do not have adequate spacing to stop in time in the event of a stopped vehicle or congestion ahead.
- This is the first signalized intersection in the corridor in the eastbound direction. Vehicles traveling eastbound are used to free-flowing traffic and may not expect a signalized intersection or congestion.
- It was observed in the field that this intersection experiences a slow start-up in the eastbound direction when the signal turns green. This is likely attributed to both congestion and the positive grade of the approach.
- This signal has long yellow times (4.9 seconds) and very short all-red times (1.3 seconds) for the eastbound and westbound approaches. The long yellow signal timing encourages drivers to speed up, while the very short all-red interval timing does not allow enough time for these vehicles to safely clear the intersection before the next movement is given a green signal indication.
- Additionally, the speed limit drops, in the eastbound direction, from 55 mph to 45 mph just before this intersection. Vehicles may not slow down and maintain speeds higher than 45 mph. The high speed intensifies the risks posed by the previous contributing factors.

#### *7.5.5.2 Suggestions and Opportunities for Improvement*

Application of a Tier 2 Systemic Template 8 is recommended at this location. Additional, intersection-specific improvements for the intersection of Ivy Road and Broomley Road are presented in this section and summarized in **Table 7.29**. The suggested improvements are *not* listed in any order of significance.

##### EASTBOUND REAR END

- Short-term

1. Reconfigure traffic signal timings to allow for better progression of eastbound and westbound through vehicles at this signal. This will help to mitigate the congestion experienced.
2. Extend all-red time to at least 2 seconds for the eastbound and westbound movements to allow all vehicles to clear the intersection. (Increase all red clearance interval; all crash types; all severities; CMF = 0.798)
3. Replace and relocate existing eastbound and westbound "Watch for Stopped Vehicles" signs with W3-4 "Be Prepared to Stop" warning signs farther upstream of intersection.
4. Convert the existing left-turn lanes (i.e., the westbound left-turn lane onto the private drive and the eastbound left-turn lane into the Regents School of Charlottesville) into a two-way left-turn lane that terminates on either end in a dedicated turn lane for the respective driveway.

**Table 7.29 – Summary of Recommended Improvements at Ivy Road and Broomley Road**

| | Safety Issue | Opportunities for Improvement |
|---|---|---|
| 1 | Eastbound Rear End | • Reconfigure traffic signal timings to allow for better progression of eastbound and westbound through vehicles at this signal.<br>• Extend all-red time to at least 2 seconds.<br>• Replace and relocate existing eastbound and westbound "Watch for Stopped Vehicles" signs with W3-4 "Be Prepared to Stop" warning signs farther upstream.<br>• Convert the existing left-turn lanes (i.e., the westbound left-turn lane onto the private drive and the eastbound left-turn lane into the Regents School of Charlottesville) into a two-way left-turn lane that terminates on either end in a dedicated turn lane for the respective driveway. |

- • Short-term, low-cost
- ○ Intermediate, medium-cost
- ❖ Long-term, high-cost

**Figure 7.38** presents the potential safety enhancement suggestions to be considered for the intersection of Ivy Road and Broomley Road. The placement of traffic control devices, pavement markings, etc. is not to scale and not according to survey, but is an approximation intended to provide a general idea of location and concept. Designers should consider appropriate standards, policies, and right of way impacts before implementing any potential enhancements.


**Figure 7.38 – Short-Term Concept for Ivy Road and Broomley Road**

#### *7.5.5.3 Traffic Operations Analysis*

- **Reconfigure signal timings**
  - Reconfigure traffic signal timings to allow for better progression of eastbound and westbound through vehicles at this signal. This improvement has the following impact on the intersection's operations:
    - In the AM peak hour, overall intersection delay decreases from 22.8 seconds to 20.0 seconds.
    - In the PM peak hour, overall intersection delay decreases from 11.3 seconds to 8.5 seconds.
- **Extend all-red time to at least 2 seconds to allow all vehicles to clear the intersection**
  - Extending the all-red time from 1.3 seconds to 2.0 seconds for all eastbound and westbound movements has minimal impact on operations of the intersection. It will, however, improve the safety of the intersection.

### 7.5.6 Preliminary Cost Estimate

The preliminary estimated cost for the proposed improvements is presented in **Table 7.30**. VHB developed the costs in Table 7.30 by use of VDOT's Transportation and Mobility Planning Division (TMPD) cost estimation tool.

**Table 7.30 – TMPD Cost Estimate for Improvements at Ivy Road and Broomley Road**

| Alternative | Cost Type | Low | High |
|---|---|---|---|
| Short-term | Preliminary Engineering | $ 4,500 | $ 6,000 |
| | ROW & Utility Relocation | - | - |
| | Construction | $ 25,500 | $ 33,400 |
| | *Short-term Subtotal* | *$ 30,000* | *$ 39,400* |
| **Total** | **Preliminary Engineering** | **$ 4,500** | **$ 6,000** |
| | **ROW & Utility Relocation** | **-** | **-** |
| | **Construction** | **$ 25,500** | **$ 33,400** |
| | ***TOTAL*** | ***$ 30,000*** | ***$ 39,400*** |

VHB further refined these costs using VDOT's Preliminary Cost Estimating Spreadsheet (PCES) and district bid averages. The total projected cost for these alternatives is presented in **Table 7.31.**

**Table 7.31 – Cost Estimate for Improvements at Ivy Road and Broomley Road**

| Alternative | Cost Type | Cost Estimate |
|---|---|---|
| **Total** | **Preliminary Engineering** | **$ 8,700** |
| | **ROW & Utility Relocation** | **-** |
| | **Construction** | **$ 36,000** |
| | ***TOTAL*** | ***$ 44,700*** |

VHB developed the cost estimate into a 20-year cost estimate accounting for improvement service life and annual maintenance costs. The service lives and annual maintenance costs were derived from the HSIP Safety Improvement Proposal values. The total projected 20-year cost estimate for the alternatives is presented in **Table 7.32.**

Table 7.32 – 20-Year Cost Estimate for Improvements at Ivy Road and Broomley Road

| Alternative | Cost Estimate Total | 20-Yr Cost (Based on individual item service life) | Annual Maintenance | Present Value of Maintenance | Total 20-year Cost |
|---|---|---|---|---|---|
| Short-term | $ 44,700 | $ 137,700 | - | - | **$ 137,700** |

### 7.5.7 Benefit Analysis

**Table 7.33** summarizes the 20-year safety and operational benefits of both the short-term and long-term suggested improvements. The B/C ratio utilizes the 20-year total cost from Table 7.31**.**

Table 7.33 - Improvement Benefits at Ivy Road and Broomley Road

| Improvements | Safety Benefit | Operational Benefit | Total Benefit | B:C Ratio |
|---|---|---|---|---|
| Short-term | $ 164,400 | $1,757,500 | **$ 1,921,000** | **14.0** |

### 7.5.8 Project Schedule

VHB estimated the project schedule based on the project schedules for similar VDOT projects recently completed. **Figure 7.39** shows the anticipated schedule for this hot spot's improvements.

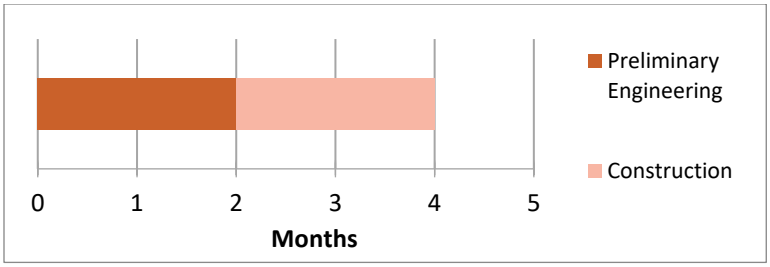



Figure 7.39 – Short-Term Project Schedule for Ivy Road and Broomley Road

## 7.6 Ivy Road (US 250) at UVA Northridge Medical Park

### 7.6.1 Intersection Description and Geometric Conditions

The access to UVA Northridge Medical Park intersects Ivy Road at a right angle, creating a T-intersection. At this intersection, Ivy Road is classified as a minor arterial. No pedestrian facilities (i.e., crosswalks or sidewalks) are present.

On either side of this intersection, Ivy Road is a two-lane roadway divided by a two-way left-turn lane. Approaches of Ivy Road are on a slight grade. Significant variation in horizontal alignment is not present. The lane use at this intersection is as follows:

- Ivy Road eastbound: 1 left-turn lane, 1 through lane
- Ivy Road westbound: 1 through lane, 1 right-turn lane
- UVA Northridge Medical Park southbound: 1 left-turn lane, 1 right-turn lane

### 7.6.2 Traffic Control Devices

This intersection is signalized. Mast arms are used for all signal heads. The eastbound approach operates under protected/permissive mode, using a 5-section dog house signal. All other approaches operate under permissive mode. Signal heads are 12" with incandescent bulbs and non-retroreflective back plates. Right turn on red is permitted for all movements.

**Signal Type: Actuated Coordinated**

**Signal Operations and Phasing Observations**

- The eastbound left-turn movement operates under protected/permissive phasing.

### 7.6.3 Traffic Conditions

The posted speed limit on Ivy Road at this intersection is 45 mph. The 2016 VDOT Average Annual Daily Traffic (AADT) is as follows:

- Ivy Road: **13,000 vehicles/day**
- UVA Northridge Medical Park: **NOT REPORTED**

Four-hour turning movement counts were conducted by Peggy Malone & Associates on May 10, 2016. The peak hour turning movement volumes as well as the intersection performance measures, are shown in **Figure 7.40** below.

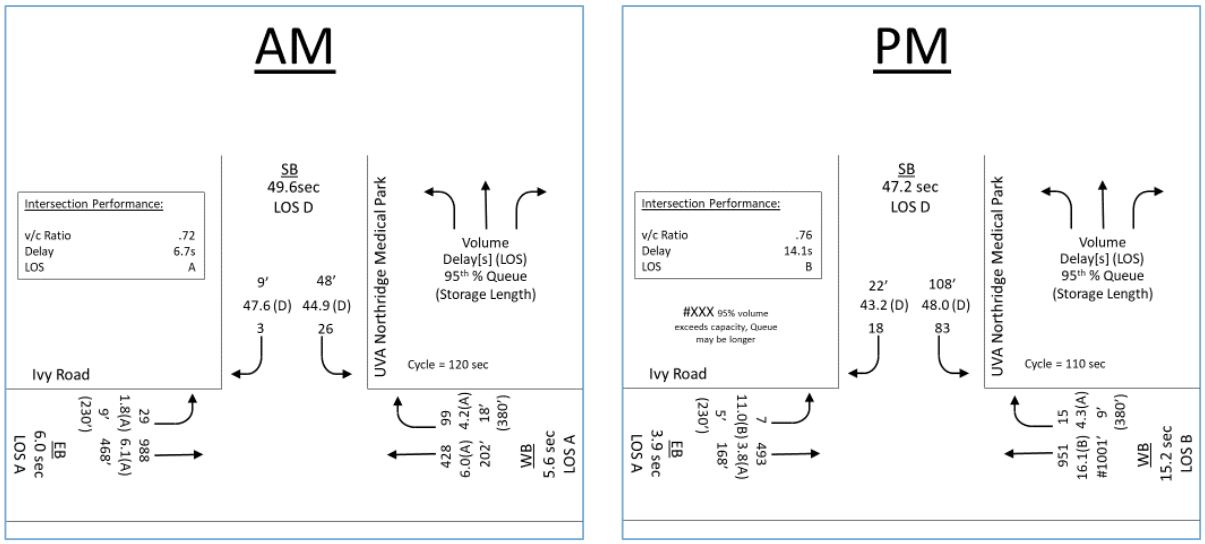



**Figure 7.40 – Traffic Conditions at Ivy Road and UVA Northridge Medical Park Entrance**

The side street approach of the UVA Northridge Medical Park endures the most delay at this intersection. This approach operates at LOS E in the AM peak hours and LOS D in the PM peak hour. While the intersection experiences little delay, the substantial volume of westbound through vehicles causes lengthy queues, especially in the PM peak hour.

### 7.6.4 Crash Analysis

Crash data for a five-year study period, 2011-2015, was collected for analysis. **Table 7.34** provides a summary of crash data at the subject intersection.

**Table 7.34 – Crash Summary at Ivy Road and Northridge Medical Park Entrance**

| Year | Peak | | Lighting Condition | | | | Pavement | | Type of Collision | | | | | | | | | | Severity | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AM (6-10) | PM (3-7) | Day | Dawn /Dusk | Dark - Road Lighted | Dark - Road Not Lighted | Dry | Wet | RE | A | HO | SS | SO | FI | NC | FO | D | BI | K | A | B | C | PDO | |
| 2011 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| 2012 | 0 | 2 | 2 | 1 | 0 | 0 | 3 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | **3** |
| 2013 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | **1** |
| 2014 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | **1** |
| 2015 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | **1** |
| **TOT** | **2** | **3** | **4** | **2** | **0** | **0** | **6** | **0** | **6** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **6** | **6** |
| % | 33% | 50% | 67% | 33% | 0% | 0% | 100% | 0% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | |

RE = Rear End; A = Angle; HO = Head On; SS = Sideswipe Same Direction; SO = Sideswipe Opposite Direction; FI = Fixed Object in Road; NC = Non-Collision; FO = Fixed Object Off Road; D = Deer; BI = Backed Into

**Figure 7.41** presents a summary of the crashes by lighting conditions and type of collision.

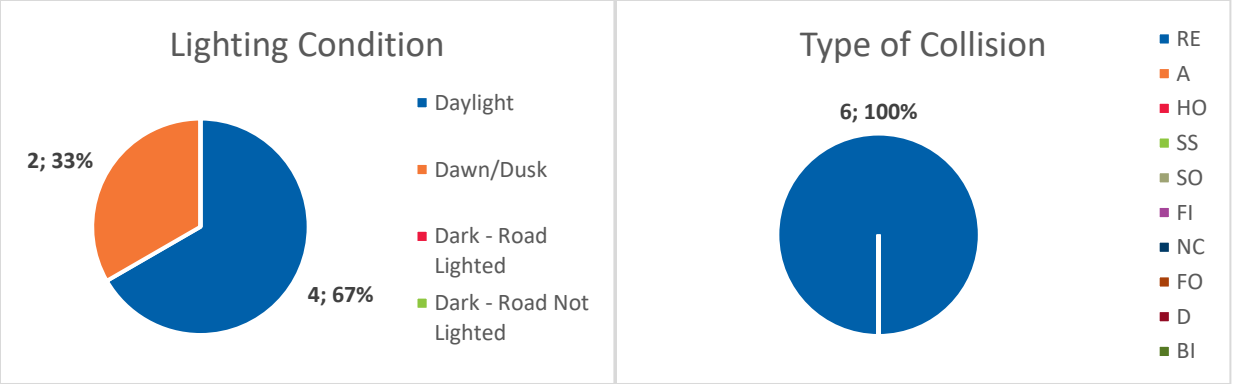



**Figure 7.41 – Lighting Condition and Collision Type at Ivy Road and UVA Northridge Medical Park Entrance**

All the crashes that occurred at the UVA Northridge Medical Park entrance within the five-year study period were rear end crashes resulting in property damage only. Four out of the six rear end crashes occurred in the eastbound direction. Most crashes took place during daylight, apart from two crashes that happened during dawn or dusk.

### 7.6.5 Roadway Safety Assessment

#### *7.6.5.1 Safety Issues and Contributing Factors*

Upon further investigation of this intersection, there are no observed issues in the field. The rear end crashes experienced at this intersection are characteristic of a signalized intersection. Though four eastbound rear end crashes occurred from 2011-2015, this is not an alarming amount for a signalized intersection of this volume. No improvements are recommended for this intersection at this time.

## 7.7 Ivy Road (US 250) at Canterbury Road / Old Garth Road

### 7.7.1 Intersection Description and Geometric Conditions

The intersection of Ivy Road and Canterbury Road / Old Garth Road is signalized. Ivy Road is classified as a minor arterial. North of Ivy Road, Old Garth Road is classified as a freeway or expressway ramp and provides access to US 29 North and access from US 29 South. Old Garth Road also provides access to two residential communities and a couple of businesses to the north of Ivy Road. To the south of Ivy Road, Canterbury Road provides residential access. One crosswalk is placed across the eastbound Ivy Road approach. This crosswalk is accompanied by two pedestrian signal heads attached to the traffic signal poles.

West of Canterbury Road / Old Garth Road, Ivy Road is a two-lane roadway divided by a two-way left-turn lane. Eastbound Ivy Road, to the east of Canterbury Road / Old Garth Road, becomes two lanes. The two eastbound lanes and one westbound lane are divided by use of a median. Approaches are on level terrain, except for the Old Garth Road approach and receiving lanes. The lane use at this intersection is as follows:

- Ivy Road eastbound: 1 left-turn lane, 1 through lane, 1 right-turn lane
- Ivy Road westbound: 1 left-turn lane, 1 shared through/right-turn lane
- Canterbury Road northbound: 1 shared left-turn/through lane, 1 right-turn lane
- Old Garth Road southbound: 1 shared left-turn/through lane, 1 right-turn lane

### 7.7.2 Traffic Control Devices

This intersection is signalized. The eastbound and westbound approaches operate under protected/permissive conditions. The northbound and southbound approaches operate under split phasing. One mast arm is used per approach. Signal heads are 12" with incandescent bulbs and non-retroreflective back plates. On the eastbound and westbound approaches, a 5-section doghouse signal is used to allow for protected/permissive left-turns. Right turn on red is permitted for all approaches.

**Signal Type: Actuated Coordinated**

**Signal Operations and Phasing Observations**

- The eastbound left-turn movement operates under protected/permissive phasing.
- The westbound left-turn movement operates under protected/permissive phasing.
- Northbound and southbound approaches operate with split phasing.
- The southbound right-turn movement is also served with an overlap during the eastbound left-turn protected phase.

### 7.7.3 Traffic Conditions

Along Ivy Road, the posted speed limit is 35 mph. Canterbury Road has a posted speed limit of 25 mph. The 2016 VDOT Average Annual Daily Traffic (AADT) is as follows:

- Ivy Road: **13,000 vehicles/day**
- Canterbury Road: **1,300 vehicles/day**
- Old Garth Road: **NOT REPORTED**

Four-hour turning movement counts were conducted by Peggy Malone & Associates on May 10, 2016. The peak hour turning movement volumes as well as the intersection performance measures, are shown in **Figure 7.42** below.

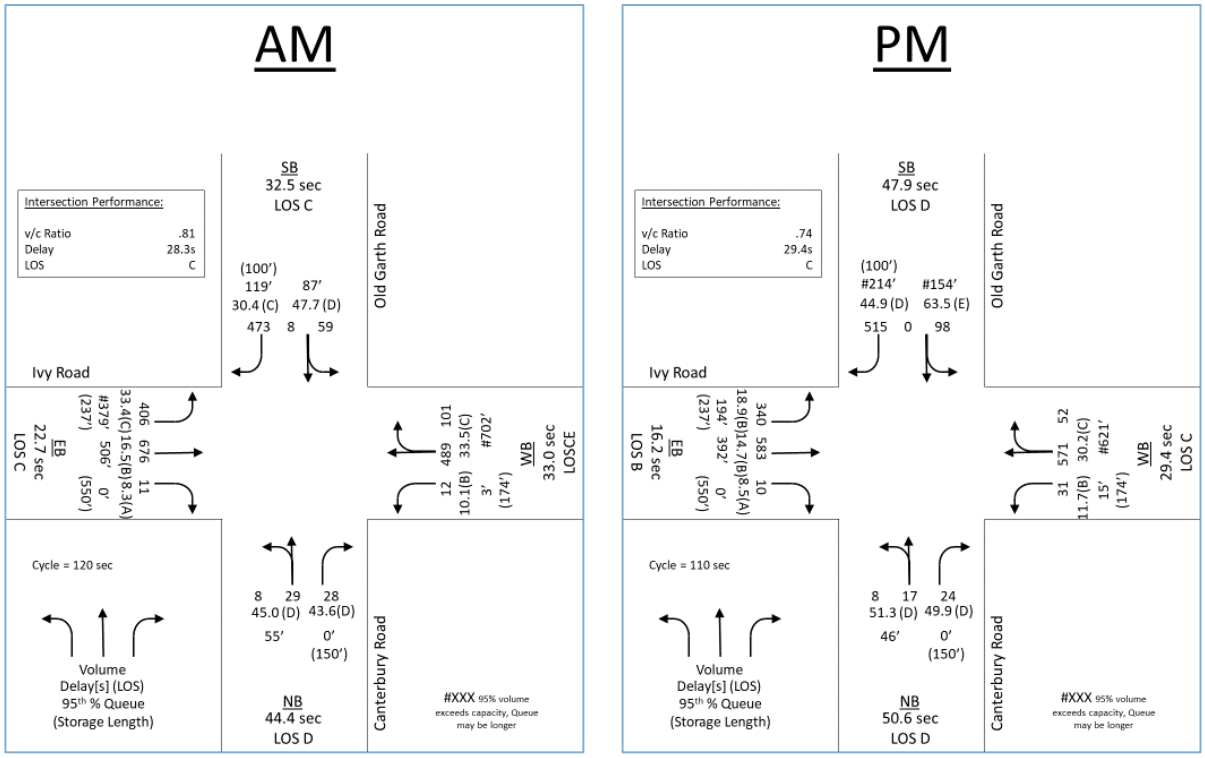



**Figure 7.42 – Traffic Conditions at Ivy Road and Canterbury Road / Old Garth Road**

This intersection experiences high delay and lengthy queues at each approach. In the AM peak hour, this intersection operates at LOS D. The PM peak hour operates at LOS C. Particularly, the westbound through movement operates at LOS E and C in the AM and PM peak hours, respectively. The left-turning

movements also experience high delays. In the AM peak hour, the left-turn movements operate at LOS D or E, save the westbound left-turn movement that operates at LOS B and serves few vehicles. In the PM peak hour, the eastbound, southbound, and northbound left-turns operate at LOS B, D, and D, respectively.

### 7.7.4 Crash Analysis

Crash data for a five-year study period, 2011-2015, was collected for analysis. **Table 7.35** provides a summary of crash data at the subject intersection.

**Table 7.35 – Crash Summary at Ivy Road and Canterbury Road / Old Garth Road**

| Year | Peak | | Lighting Condition | | | | Pavement | | Type of Collision | | | | | | | | | | Severity | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AM (6-10) | PM (3-7) | Day | Dawn /Dusk | Dark - Road Lighted | Dark - Road Not Lighted | Dry | Wet | RE | A | HO | SS | SO | FI | NC | FO | D | BI | K | A | B | C | PDO | |
| 2011 | 1 | 2 | 4 | 1 | 0 | 0 | 5 | 0 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 | **5** |
| 2012 | 1 | 4 | 5 | 0 | 1 | 1 | 6 | 1 | 4 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 6 | **7** |
| 2013 | 1 | 3 | 9 | 0 | 0 | 0 | 7 | 2 | 6 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 7 | **9** |
| 2014 | 0 | 1 | 2 | 0 | 0 | 0 | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | **2** |
| 2015 | 1 | 3 | 6 | 0 | 0 | 1 | 7 | 0 | 2 | 4 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 5 | **7** |
| **TOT** | **4** | **13** | **26** | **1** | **1** | **2** | **27** | **3** | **15** | **11** | **1** | **1** | **1** | **0** | **1** | **0** | **0** | **0** | **0** | **0** | **7** | **1** | **22** | **30** |
| % | 13% | 43% | 87% | 3% | 3% | 7% | 90% | 10% | 50% | 37% | 3% | 3% | 3% | 0% | 3% | 0% | 0% | 0% | 0% | 0% | 23% | 3% | 74% | |

RE = Rear End; A = Angle; HO = Head On; SS = Sideswipe Same Direction; SO = Sideswipe Opposite Direction; FI = Fixed Object in Road; NC = Non-Collision; FO = Fixed Object Off Road; D = Deer; BI = Backed Into

**Figure 7.43** presents a summary of the crashes by lighting conditions and type of collision.

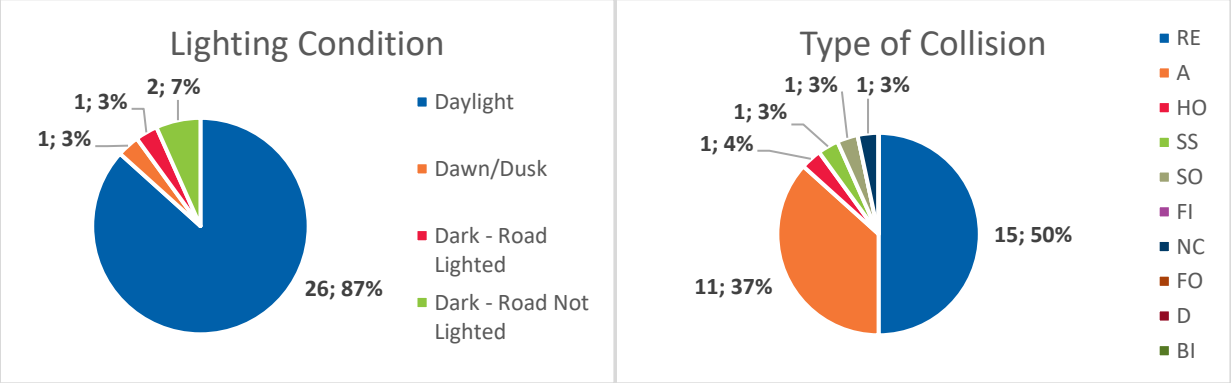



**Figure 7.43 – Lighting Condition and Collision Type at Ivy Road and Canterbury Road / Old Garth Road**

30 total crashes occurred at the intersection of Ivy Road and Canterbury Road / Old Garth Road within the five-year study period. 50% of the crashes were rear end crashes. This is followed closely by angle crashes, at 37%. All other collision types documented occurred only once within the study period. While most of the crashes caused only property damage, 8 crashes caused injuries, seven visible and one non-visible. Predominately, the crashes occurred in ideal conditions (i.e., in daylight and on dry pavement). Most rear end crashes were caused by following too closely. Over half of the rear end crashes were in the eastbound direction, one-third were in the westbound direction, and the remaining crashes were in the southbound direction. One eastbound rear end crash involved four vehicles and occurred on wet pavement, causing

visible injury. Angle crashes consistently occurred between an eastbound left-turning vehicle, who did not have the right of way, and a westbound through vehicle, who did have the right of way.

## 7.7.5 Roadway Safety Assessment

### *7.7.5.1 Safety Issues and Contributing Factors*

#### EASTBOUND LEFT TURN/ANGLE

This intersection had numerous crashes caused by an eastbound left-turning vehicle colliding with a westbound through vehicle. These crashes may be attributed to the following safety issues and contributing factors:

Figure 7.44a – View of Old Garth Receiving Lane


Figure 7.44b– View of Eastbound Left Turning Vehicles

- The left-turn lanes on Ivy Road are negatively offset of each other. For this reason, the westbound left-turning vehicle queue may block the sight distance of the eastbound left-turning vehicles.
- This intersection experiences heavy traffic volume and congestion. This signal is currently operating under protected/permissive phasing, meaning that there is a portion of time where the left-turning vehicles must confront the opposing through vehicles to find an adequate gap in traffic to turn left. The high eastbound left-turning volume paired with the heavy opposing, westbound through volume results in few adequate gaps for left-turners to turn.
- The geometry of the roadway encourages the eastbound left-turning vehicles to turn left at high speeds. The left-turning vehicles are on a slight downgrade, encouraging high speeds. In addition, the angle of the receiving lane on Old Garth Road encourages speed as the drivers do not have to make a complete 90-degree turn.
- The receiving lane of Old Garth Road is not properly delineated. It is difficult to see the roadway until the driver is in the path of the westbound through vehicles. Drivers may slow down to better see the roadway as they are turning. However, slowing down was not accounted for in their gap selection and so the gap they selected was not large enough. A view of the receiving lane of Old Garth Road from the eastbound left-turn lane is pictured in **Figure 7.44a**.
- During the yellow phase of the permissive left-turn movement, drivers were observed to closely follow the left-turning vehicle in front of them, without giving much attention to the through traffic. This is portrayed in **Figure 7.44b**.

#### EASTBOUND REAR END

Eastbound rear end crashes occurred frequently at this intersection. These rear end crashes may likely be caused by the following factors:

- Three eastbound rear end crashes occurred specifically in the eastbound left-turn lane. These may be attributed to a misperception of the following vehicle that the leading vehicle was going to turn left. Instead, the leading vehicle stops to wait for an adequate gap.
- As this is a signalized intersection, rear end crashes are expected. Drivers tend to closely follow the vehicles in front of them and do not have adequate distance to stop in the event of a signal phase change. Five out of the six eastbound rear end crashes at this intersection cite the driver's action as "following too close."
- It was observed that the adjacent signal at Ivy Road and the US 29 southbound interchange was not coordinated with this signal. This causes excess congestion and queuing and does not promote progression of traffic. The congestion experienced may attribute to these rear end crashes.

#### WESTBOUND REAR END

Similarly, westbound rear end crashes commonly occurred. Contributing factors to these crashes may include:

- For vehicles to turn right onto Old Garth Road from westbound Ivy Road, they must slow down significantly due to the U-turn like geometry of the southbound approach. The following vehicles may not be expecting this slow down and are following too closely.
- Rear end crashes are to be expected since this is a signalized intersection. Four out of the five westbound rear end crashes cite "following too close" as the driver action. This may not give the driver adequate time to respond and stop in the event of a phase change.
- It was observed that the adjacent signal at Ivy Road and the US 29 southbound interchange was not coordinated with this signal. This causes excess congestion and queuing and prohibits full progression of traffic. The congestion experienced may attribute to these rear end crashes.

#### SOUTHBOUND REAR END

Southbound rear end crashes, though less so than eastbound or westbound rear end crashes, were common at this intersection. Likely contributing factors include:

- By nature of a signalized intersection, rear end crashes are probable, especially at an intersection that experiences so much congestion. All three of the southbound rear end crashes cite "following too close" as the driver action. This may not give the driver adequate time to respond and stop in the event of a phase change.
- The curve of this approach may also present a challenge for vehicles. The long queues of this approach generally extend to the curve. The curve of this approach makes it difficult for vehicles to see beyond the curve to see the signal or any vehicles in the queue, creating the potential for rear end collisions.

### *7.7.5.2 Suggestions and Opportunities for Improvement*

Application of a Tier 2 Systemic Template 8 is recommended at this location. Additional, intersection-specific improvements for the intersection of Ivy Road and Canterbury Road / Old Garth Road are presented in this section and summarized in **Table 7.36**. The suggested improvements are *not* listed in any order of significance.

#### EASTBOUND LEFT TURN/ANGLE

- Short-term

1. Replace the existing 5-section "Doghouse" signal head with a 4-section Flashing Yellow Arrow signal head for the left-turn movement. (Change from 5-section "Doghouse" protected/permissive left turn to FYA – protected/permissive left turn; Left-turn crashes; all severities; CMF = 0.838)

2. Modify eastbound left-turning movement to protected only phasing during the off-peak hours. This is only suggested for the off-peak hours because it is expected to have a negative effect on operations in the peak hours. Additionally, the eastbound left-turn / angle crashes more commonly occurred during the off-peak hours. (Change from permitted-protected to protected on major approach; angle crashes; all severities; CMF = 0.01)
3. Install "puppy track" markings to better delineate the left-turn movement to Old Garth Road.
4. Install delineators (i.e., flex bollards) on the receiving lane of Old Garth Road to better delineate the receiving lane and direct vehicles accordingly.

### Eastbound Rear End

- Short-term

1. Change eastbound left-turning movement to protected only phasing during off-peak hours. This will mitigate the confusion during the peak hours, when all left-turning rear end collisions occurred. (Change from permitted-protected to protected on major approach; angle crashes; all severities; CMF = 0.01)
2. Coordinate this signal with adjacent signals (i.e., signals at the Ivy Road and US 29 interchange) to promote progression of traffic through this intersection and mitigate congestion and queues.

- Long--term

3. In conjunction with recommended widening of the westbound approach, restripe the existing eastbound exclusive right-turn lane to become a shared through / right-turn lane.

### Westbound Rear End

- Short-term

1. Coordinate this signal with adjacent signals (i.e., signals at the Ivy Road and US 29 interchange) to promote progression of traffic through this intersection and mitigate congestion and queues.

- Long-term

2. Widen the westbound approach to the south to provide an additional approach lane. The final lane configuration will consist of one left-turn lane, one through lane, and one shared through / right-turn lane. This will eliminate congestion at this approach and increase throughput capacity. (Install an additional lane; all crash types; fatal and injury severity; CMF = 0.76)
3. Widen the north side of Ivy Road west of the intersection to ensure proper utilization of the second westbound through lane. This lane currently exists as a series of right-turn only lanes and can be extended approximately 1,700 feet to Colridge Drive with minimal widening. (Install an additional lane; all crash types; fatal and injury severity; CMF = 0.76)

**Table 7.36 – Summary of Recommended Improvements at Ivy Road and Canterbury Road / Old Garth Road**

| | Safety Issue | Opportunities for Improvement |
|---|---|---|
| 1 | Eastbound Left-turn/Angle | • Replace the existing 5-section "Doghouse" signal head with a 4-section Flashing Yellow Arrow signal head for the left-turn movement.<br>• Modify eastbound left-turning movement to protected only phasing during the off-peak hours.<br>• Install "puppy track" markings to better delineate the left-turn movement to Old Garth Road.<br>• Install delineators (i.e., flex bollards) on the receiving lane of Old Garth Road. |
| 2 | Eastbound Rear End | • Modify eastbound left-turning movement to protected only phasing during off-peak hours.<br>• Optimize signal timings and coordinate this signal with adjacent signals (i.e., signals at the Ivy Road/US 29 interchange).<br>❖ Restripe the eastbound exclusive right-turn lane to become a shared through / right-turn lane. |
| 3 | Westbound Rear End | • Optimize signal timings and coordinate this signal with adjacent signals (i.e., signals at the Ivy Road/US 29 interchange).<br>❖ Widen the westbound approach to the south to provide an additional approach through lane.<br>❖ Widen the north side of Ivy Road west of the intersection to ensure proper utilization of the second westbound through lane. |

• Short-term, low-cost
○ Intermediate, medium-cost
❖ Long-term, high-cost

**Figure 7.45** and **Figure** 7**.46** present the potential safety enhancement suggestions to be considered for the intersection of Ivy Road and Canterbury Road / Old Garth Road. The placement of traffic control devices, pavement markings, etc. is not to scale and not according to survey, but is an approximation intended to provide a general idea of location and concept. Designers should consider appropriate standards, policies, and right of way impacts before implementing any potential enhancements.


**Figure 7.45 – Short-Term Concept for Ivy Road and Canterbury Road / Old Garth Road**

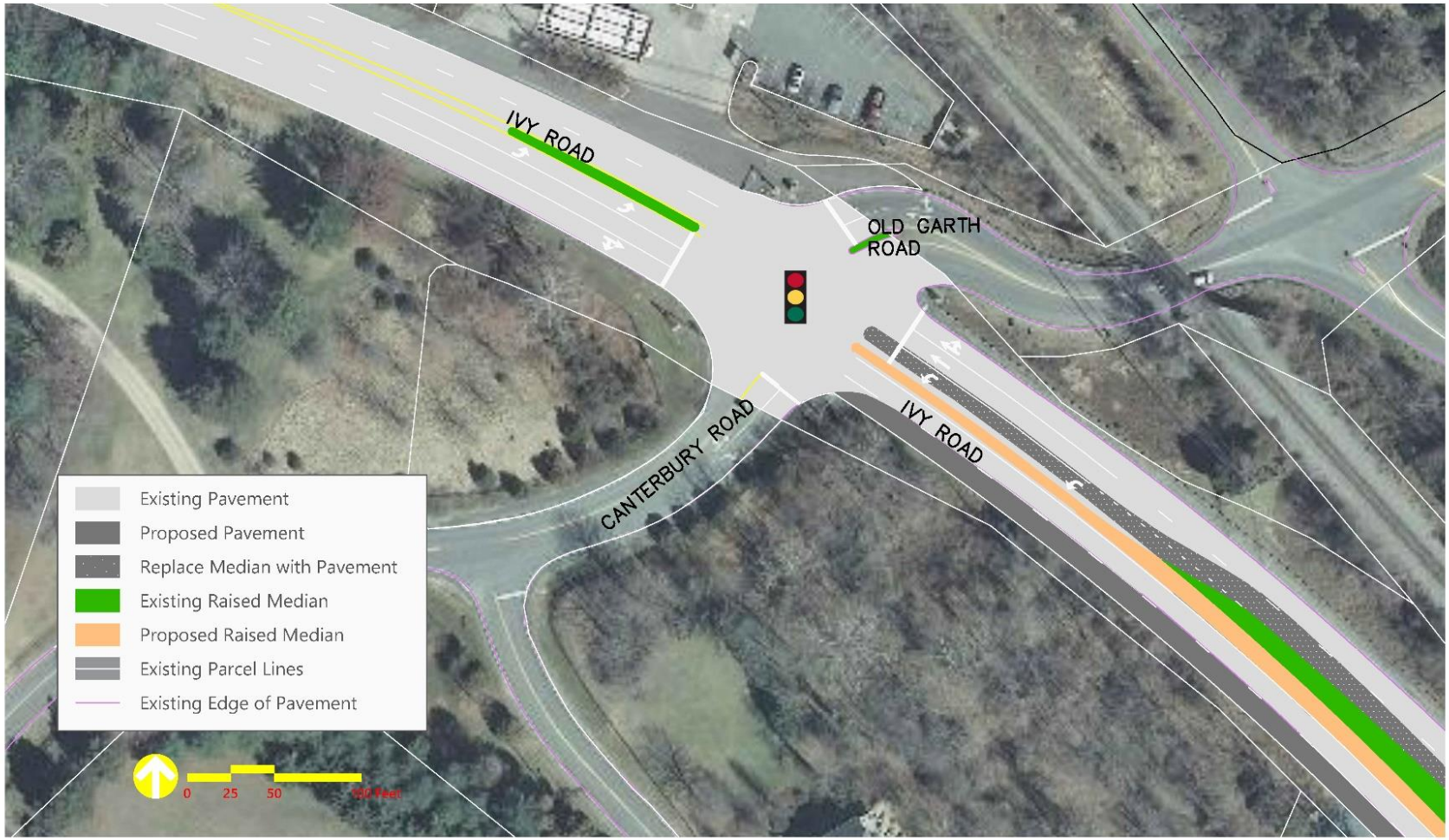



**Figure 7.46 – Long-Term Concept for Ivy Road and Canterbury Road / Old Garth Road**

### *7.7.5.3 Traffic Operations Analysis*

- **Modify east-bound left-turning movement to protected-only**
  - Since this improvement affects only the non-peak hour, this improvement was not modeled or analyzed for the effect on operations. However, it is not anticipated to have a large impact on the operations at this intersection. The off-peak hour signal timings should be optimized to accommodate this phasing scheme.
- **Other Improvements (i.e., widen the westbound direction, restripe exclusive right-turn lane as shared through/right-turn lane, and optimize signal timings)**
  - Under Existing Conditions, this intersection operates at LOS C in the AM and PM peak hours. With the 1% growth factor applied, this intersection is expected to degrade to LOS D in the AM and PM in 2025, under No-Build conditions. However, with all the above improvements in place, this intersection is anticipated to operate at LOS C for both peak hours. As shown in **Figure 7.47**, the delay experienced in the 2025 Build scenario is less than or comparable to the delay in Existing conditions. The suggested improvements help to mitigate the increase in delay due to the anticipated growth. The complete LOS and delay comparison between Existing, 2025 No-Build, and 2025 Build conditions is provided in **Table 7.37**.

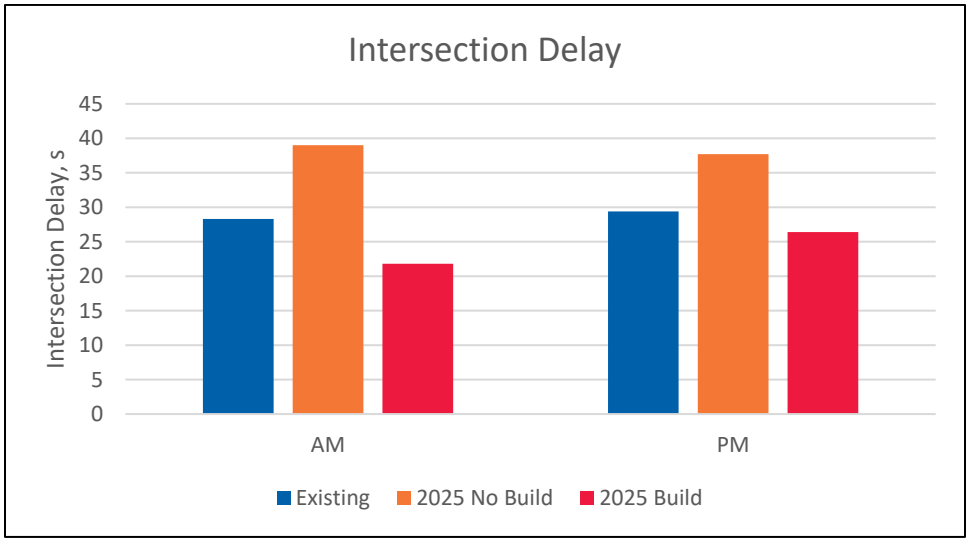



**Figure 7.47 – Intersection Delay at Ivy Road and Canterbury Road / Old Garth Road**

Table 7.37 – Operational Performance of Improvements to Ivy Road and Canterbury Road / Old Garth Road

| | | Existing Conditions | | | | | | 2025 No-Build Conditions | | | | | | 2025 Build Conditions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Delay (s/veh) | LOS | Delay (s/veh) | LOS | Int. Delay (s) | Int. LOS | Delay (s/veh) | LOS | Delay (s/veh) | LOS | Int. Delay (s) | Int. LOS | Delay (s/veh) | LOS | Delay (s/veh) | LOS | Int. Delay (s) | Int. LOS |
| **Ivy Road at Canterbury Road / Old Garth Road** | | | | | | | | | | | | | | | | | | | |
| Ivy Road EB | Left | 33.4/18.9 | C/B | 22.7/ 16.2 | C/B | **28.3/ 29.4** | **C/C** | 56.4/39.3 | E/D | 32.4/ 24.8 | C/C | **39.0/ 37.7** | **D/D** | 9.6/10.5 | A/B | 5.6/ 11.0 | A/B | **21.8/ 26.4** | **C/C** |
| | Through | 16.5/14.7 | B/B | | | | | 18.4/16.6 | B/B | | | | | 3.2/11.3 | A/B | | | | |
| | Right | 8.3/8.5 | A/A | | | | | 8.4/9.0 | A/A | | | | | - | - | | | | |
| Old Garth Road SB | L/T | 47.7/63.5 | D/E | 32.5/ 47.9 | C/C | | | 49.6/72.3 | D/E | 32.4/ 49.6 | C/D | | | 58.0/54.0 | E/D | 50.4/ 45.7 | D/D | | |
| | Right | 30.4/44.9 | C/D | | | | | 29.9/45.2 | C/D | | | | | 49.3/44.1 | D/D | | | | |
| Ivy Road WB | Left | 10.1/11.7 | B/B | 33.0/ 29.4 | C/C | | | 10.2/14.8 | B/B | 56.3/ 44.1 | F/D | | | 12.2/20.0 | B/B | 22.0/ 28.5 | C/C | | |
| | T/R | 33.5/30.2 | C/C | | | | | 57.2/45.5 | E/D | | | | | 22.2/28.9 | C/C | | | | |
| Canterbury Road NB | L/T | 45.0/51.3 | D/D | 44.4/ 50.6 | D/D | | | 44.9/50.1 | D/D | 44.3/ 49.5 | D/D | | | 55.8/51.7 | E/D | 54.8/ 50.9 | D/D | | |
| | Right | 43.6/49.9 | D/D | | | | | 43.4/48.9 | D/D | | | | | 53.6/50.1 | D/D | | | | |

### 7.7.6 Preliminary Cost Estimate

The preliminary estimated cost for the proposed improvements is presented in **Table 7.38**. VHB developed the costs in Table 7.38 by use of VDOT's Transportation and Mobility Planning Division (TMPD) cost estimation tool.

**Table 7.38 – TMPD Cost Estimate for Improvements at Ivy Road and Canterbury Road / Old Garth Road**

| Alternative | Cost Type | Low | High |
|---|---|---|---|
| Short-term | Preliminary Engineering | $ 3,800 | $ 4,900 |
| | ROW & Utility Relocation | - | - |
| | Construction | $ 21,000 | $ 26,700 |
| | *Short-term Subtotal* | *$ 24,800* | *$ 31,600* |
| Long-term | Preliminary Engineering | $ 138,900 | $ 204,500 |
| | ROW & Utility Relocation | $ 344,000 | $ 660,100 |
| | Construction | $ 760,300 | $ 1,115,600 |
| | *Long-Term Subtotal* | *$ 1,243,200* | *$ 1,980,200* |
| **Total** | **Preliminary Engineering** | **$ 142,800** | **$ 209,300** |
| | **ROW & Utility Relocation** | **$ 344,000** | **$ 660,100** |
| | **Construction** | **$ 780,700** | **$ 1,141,800** |
| | ***TOTAL*** | ***$ 1,267,500*** | ***$ 2,011,200*** |

VHB further refined these costs using VDOT's Preliminary Cost Estimating Spreadsheet (PCES) and district bid averages. The total projected cost for these alternatives is presented in **Table 7.39**.

**Table 7.39 – Cost Estimate for Improvements at Ivy Road and Canterbury Road / Old Garth Road**

| Alternative | Cost Type | Cost Estimate |
|---|---|---|
| Short-term | Preliminary Engineering | $ 6,300 |
| | ROW & Utility Relocation | - |
| | Construction | $ 26,000 |
| | *Short-term subtotal* | *$ 32,300* |
| Long-term | Preliminary Engineering | $ 169,200 |
| | ROW & Utility Relocation | - |
| | Construction | $ 705,000 |
| | *Long-term subtotal* | *$ 874,200* |
| **Total** | **Preliminary Engineering** | **$ 175,500** |
| | **ROW & Utility Relocation** | **-** |
| | **Construction** | **$ 731,000** |
| | ***TOTAL*** | ***$ 906,500*** |

VHB developed the cost estimate into a 20-year cost estimate accounting for improvement service life and annual maintenance costs. The service lives and annual maintenance costs were derived from the HSIP Safety Improvement Proposal spreadsheet values. The total projected 20-year cost estimate for the alternatives is presented in **Table 7.40.**

Table 7.40 – 20-Year Cost Estimate for Improvements at Ivy Road and Canterbury Road / Old Garth Road

| Alternative | Cost Estimate Total | 20-Yr Cost (Based on individual item service life) | Annual Maintenance | Present Value of Maintenance | Total 20-year Cost |
|---|---|---|---|---|---|
| Short-term | $ 32,300 | $ 102,600 | $ 50 | $ 700 | **$ 103,300** |
| Long-term | $ 874,200 | $ 877,800 | $ 500 | $ 7,400 | **$ 885,200** |

### 7.7.7 Benefit Analysis

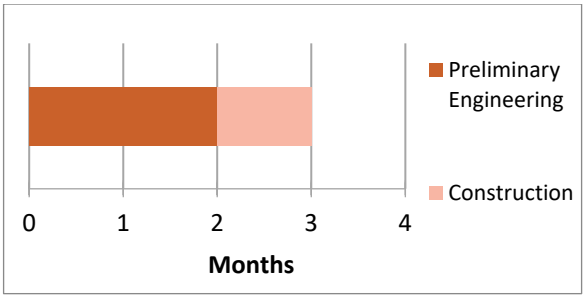
**Table 7.41** summarizes the 20-year safety and operational benefits of both the short-term and long-term suggested improvements. The B/C ratios utilize the 20-year total cost from Table 7.40.

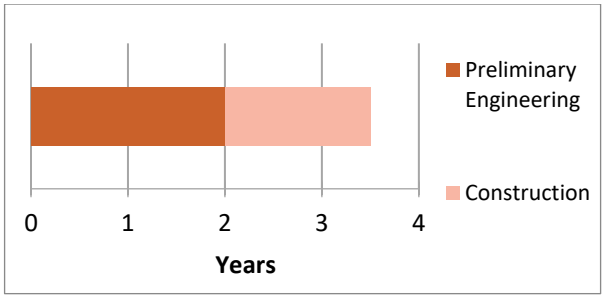
Table 7.41 - Improvement Benefits at Ivy Road and Canterbury Road / Old Garth Road

| Improvements | Safety Benefit | Operational Benefit | Total Benefit | B:C Ratio |
|---|---|---|---|---|
| Short-term | $ 1,237,900 | $714,200 | **$ 1,952,100** | **18.9** |
| Long-term | $ 903,700 | $9,252,600 | **$ 10,156,300** | **11.5** |

### 7.7.8 Project Schedule

VHB estimated the project schedule based on the project schedules for similar VDOT projects recently completed. **Figures 7.48** and **7.49** show the anticipated schedule for this hot spot's improvements.




Figures 7.48 and 7.49 – Short and Long-Term Project Schedules for Ivy Road and Canterbury Road / Old Garth Road

## 7.8 Ivy Road (US 250) at US 29 Southbound Interchange

### 7.8.1 Intersection Description and Geometric Conditions

The intersection of Ivy Road and the US 29 southbound interchange is signalized. To the west of this intersection, Ivy Road is classified as a minor arterial. To the east of this intersection, Ivy Road is classified as a principal arterial. US 29 is classified as a freeway or expressway. US 29 southbound provides access to Interstate 64 to the south. No pedestrian facilities (i.e., crosswalks or sidewalks) are present. Ivy Road is a four-lane divided highway. Approaches are on level terrain. Variation in horizontal alignment is minimal. The lane use at this intersection is as follows:

- Ivy Road eastbound: 2 through lanes, 1 channelized right-turn lane
- Ivy Road westbound: 1 left-turn lane, 1 through lane
- US 29 southbound ramp northbound: 1 left-turn lane, 1 channelized right-turn lane

### 7.8.2 Traffic Control Devices

This intersection is signalized. The westbound left-turn operates under protected-only phasing. All other movements are controlled by permissive operation. Both channelized right-turns are given yield signs. All signal heads are anchored on to mast arms. Signal heads are 12-inch with incandescent bulbs and non-retroreflective back plates.

**Signal Type: Actuated Coordinated**

**Signal Operations and Phasing Observations**

- The westbound left-turn movement operates under a protected-only phase.

### 7.8.3 Traffic Conditions

At this intersection, Ivy Road has a posted speed limit of 35 mph. US 29 has a posted speed limit of 55 mph, with a posted advisory speed of 20 mph for the off ramp. The 2016 VDOT Average Annual Daily Traffic (AADT) is as follows:

- Ivy Road: **13,000 vehicles/day**
- US 29 southbound ramp: **NOT REPORTED**

Four-hour turning movement counts were conducted by Peggy Malone & Associates on May 10, 2016. The peak hour turning movement volumes as well as the intersection performance measures, are shown in **Figure 7.50** below.

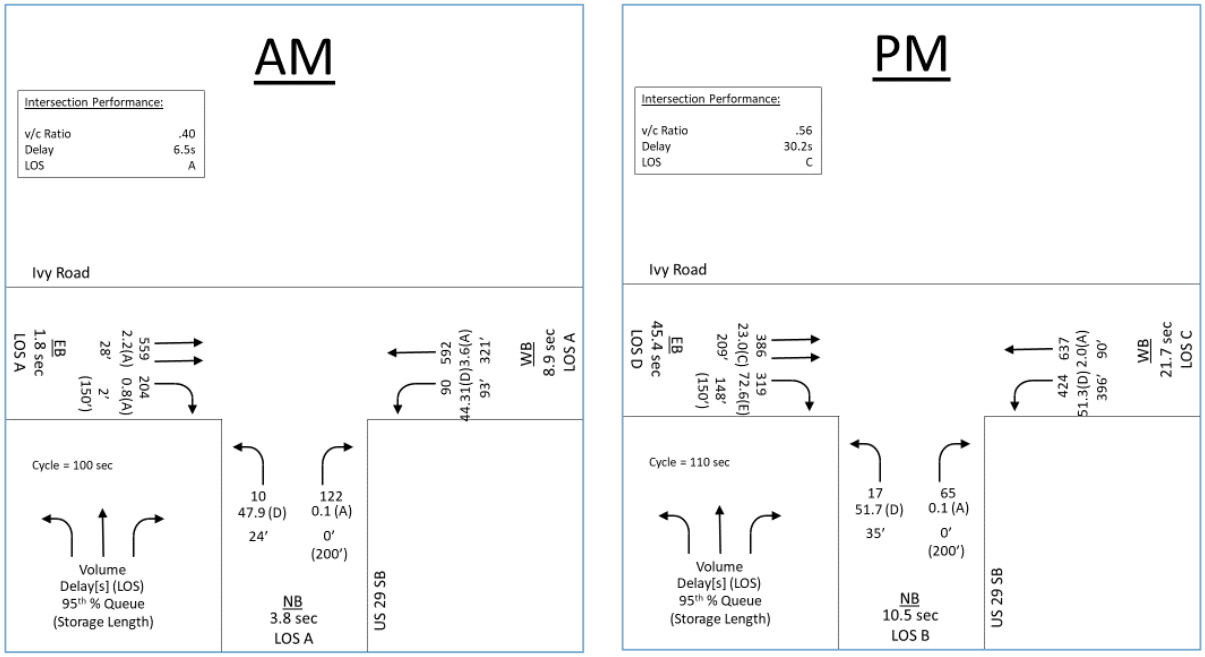



**Figure 7.50 – Traffic Conditions at Ivy Road and US 29 Southbound Interchange**

The left-turning movements of this intersection operate at LOS D for both peak hours. The eastbound through movement performs satisfactorily in the AM peak hour, but deteriorates to LOS C in the PM peak hour. This deterioration is likely due to the significant increase in westbound left-turning volumes.

### 7.8.4 Crash Analysis

Crash data for a five-year study period, 2011-2015, was collected for analysis. **Table 7.42** provides a summary of crash data at the subject intersection.

Table 7.42 – Crash Summary at Ivy Road and US 29 Southbound Interchange

| Year | Peak | | Lighting Condition | | | | Pavement | | Type of Collision | | | | | | | | | | Severity | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AM (6-10) | PM (3-7) | Day | Dawn /Dusk | Dark - Road Lighted | Dark - Road Not Lighted | Dry | Wet | RE | A | HO | SS | SO | FI | NC | FO | D | BI | K | A | B | C | PDO | |
| 2011 | 0 | 1 | 3 | 0 | 0 | 0 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | **3** |
| 2012 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | **1** |
| 2013 | 3 | 2 | 5 | 0 | 0 | 0 | 5 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 3 | **5** |
| 2014 | 1 | 2 | 3 | 0 | 1 | 0 | 2 | 2 | 1 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | **4** |
| 2015 | 1 | 1 | 3 | 0 | 0 | 0 | 3 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | **3** |
| **TOT** | **5** | **7** | **15** | **0** | **1** | **0** | **13** | **3** | **10** | **5** | **0** | **1** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **3** | **1** | **12** | **16** |
| % | 31% | 44% | 94% | 0% | 6% | 0% | 81% | 19% | 63% | 31% | 0% | 6% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 19% | 6% | 75% | |

RE = Rear End; A = Angle; HO = Head On; SS = Sideswipe Same Direction; SO = Sideswipe Opposite Direction; FI = Fixed Object in Road; NC = Non-Collision; FO = Fixed Object Off Road; D = Deer; BI = Backed Into

**Figure 7.51** presents a summary of the crashes by lighting conditions and type of collision.

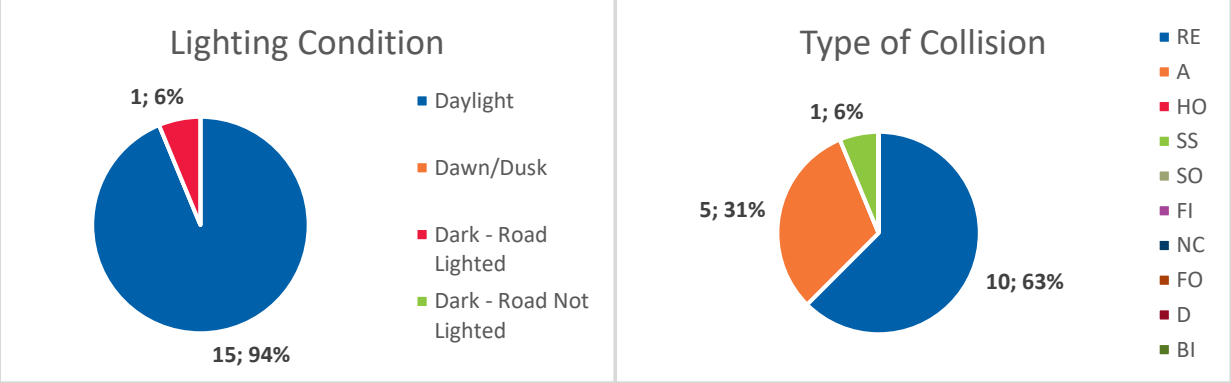



Figure 7.51 – Lighting Condition and Collision Type at Ivy Road and US 29 Southbound Interchange

Rear end crashes were predominant at this intersection. Of the 10 rear end crashes, seven were in the eastbound direction. All rear end crashes were on dry pavement in the daylight. Angle crashes were the second most prevalent collision type. All five angle crashes, located very close to each other, were caused by the eastbound through driver disregarding the traffic signal. Four of the five angle crashes were westbound left-turning vehicles making proper left-turns and colliding with red-light-running eastbound through vehicles. The remaining angle crash involved a northbound left-turning vehicle making a legal left turn, and an eastbound through vehicle that disregarded the traffic signal. One-fourth of the crashes during the five-year study period were injury causing.

## 7.8.5 Roadway Safety Assessment

### *7.8.5.1 Safety Issues and Contributing Factors*

#### EASTBOUND REAR END

Eastbound rear end crashes frequently occurred at this intersection and may be attributed to the following factors:

- As this is a signalized intersection, rear end crashes are likely to occur. All rear end crashes cited "following too close" as the driver action which may not give the driver adequate time to respond and stop in the event of a phase change.
- This intersection experiences heavy congestion. Drivers want to make it through the yellow phase, so they closely follow the vehicle in front, hoping to make it through the intersection. If the vehicle in front suddenly stops for the red signal, the following driver must quickly stop.

#### EASTBOUND ANGLE

Four of the five angle crashes were between a westbound left-turning vehicle and an eastbound through vehicle. The remaining angle crash was between a northbound left-turning vehicle and an eastbound through vehicle. The eastbound through vehicles were always at fault by disregarding the traffic signal (i.e., running the red light). The reasons and contributing factors for these crashes may include:

- Rain and wet pavement can be attributed to two of these crashes. Rain, creating wet, slippery pavement, increases the distance needed for a vehicle to stop. If the drivers are maintaining their regular following distance (i.e., following distance under clear conditions), then there is not adequate time to stop if necessary.
- This intersection experiences heavy congestion. Drivers may have to wait additional cycles before they make it through the intersection. Drivers wish to avoid extra delay, so they push the limits of the yellow signal, causing red-light running. If there is not an adequate all-red time that allows these red-light running vehicles to clear the intersection, conflict may occur with the next movement. The yellow and red signal timings for the eastbound through movement are 4.1 seconds and 3.2 seconds, respectively.
- The drivers may be unaware of the traffic signal. This may infer a visibility issue of the traffic signal.
- The clear line of sight to the downstream traffic signal at the US 250 and US 29 NB intersection may cause driver confusion. Drivers may confuse those signal heads as their own for the US 250 and US 29 SB intersection, causing them to follow a green indication at the downstream signal, even though the immediate signal indication is red.

### *7.8.5.2 Suggestions and Opportunities for Improvement*

Application of a Tier 2 Systemic Template 7 is recommended at this location. Additional, intersection-specific improvements for the intersection of Ivy Road and the US 29 southbound interchange are presented in this section and summarized in **Table 7.43**. The suggested improvements are *not* listed in any order of significance.

#### EASTBOUND REAR END

- Short-term

1. Adjust signal timings to improve progression of traffic through the intersection.

#### EASTBOUND ANGLE

- Short-term

1. Re-configure signal timings to include additional all-red timing. (Increase all red clearance interval; all crash types; all severities; CMF = 0.798)
2. Redirect all westbound US 250 traffic exiting from southbound US 29 to the Old Ivy Ramp.
    - At a minimum, this should occur during the peak hours. Install remote operated gates in the northbound US 29 off-ramp left-turn lane to deny access during the peak hours. For the peak hours, adjust the signal phasing to remove the northbound left-turn phase and optimize the signal timings. Install appropriate guidance signage.

- Alternatively, the northbound left turn could be closed permanently. Remove the left-turn lane or stripe as closed. Adjust the signal phasing to remove the northbound left-turn phase and optimize the signal timings.

3. Install angled visors on the eastbound signal heads at the US 250 / US 29 NB intersection to avoid driver confusion due to the clear line of sight to those signal heads.
4. Implement red-light running enforcement strategies at this location. (Install red-light cameras; angle crashes; all severities; CMF = 0.75)
5. Install elongated route shield pavement marking for US 29 in the westbound left-turn lane to reinforce that it is a left-turn only lane.

OTHER

- Long-term

1. Widen the westbound approach to two through lanes and one designated left-turn lane. The intent of this widening is to match the cross-section of the westbound approach at the adjacent signals, allowing for better progression of traffic. (Install an additional lane; all crash types; fatal and injury severity; CMF = 0.76)
2. In addition to widening the westbound approach, permanently close the northbound left-turn lane by joining the existing raised islands. The westbound left-turn movement should operate in permissive mode during the peak hours. This allows the mainline through traffic to travel uninterrupted, promoting the mobility enhancement segment priority.

**Table 7.43 – Summary of Recommended Improvements at Ivy Road and the US 29 Southbound Interchange**

| | Safety Issue | Opportunities for Improvement |
|---|---|---|
| 1 | Eastbound Rear End | • Adjust signal timings to improve progression of traffic through the intersection. |
| 2 | Eastbound Angle | • Re-configure signal timings to include additional all-red timing.<br>• Redirect northbound left-turning traffic and optimize signal phasing.<br>• Install angled visors on the eastbound signal heads at the US 250 / US 29 NB intersection.<br>• Implement red-light running enforcement strategies at this location. |
| 3 | Other | • Install elongated route shield pavement marking for US 29 in the westbound left-turn lane.<br>❖ Widen westbound approach to two through lanes.<br>❖ Permanently close the NB left-turn lane by a raised median. |

• Short-term, low-cost
○ Intermediate, medium-cost
❖ Long-term, high-cost

**Figures 7.52** - **7.54** present the potential safety enhancement suggestions to be considered for the intersection of Ivy Road and US 29 southbound. "Long-term Alternative Concept A" includes only the widening of the westbound direction. "Long-term Alternative Concept B" includes the permanent closure of the northbound left-turn lane in addition to the widening of the westbound approach. The placement of traffic control devices, pavement markings, etc. is not to scale and not according to survey, but is an approximation intended to provide a general idea of location and concept. Designers should consider appropriate standards, policies, and right of way impacts before implementing any potential enhancements.

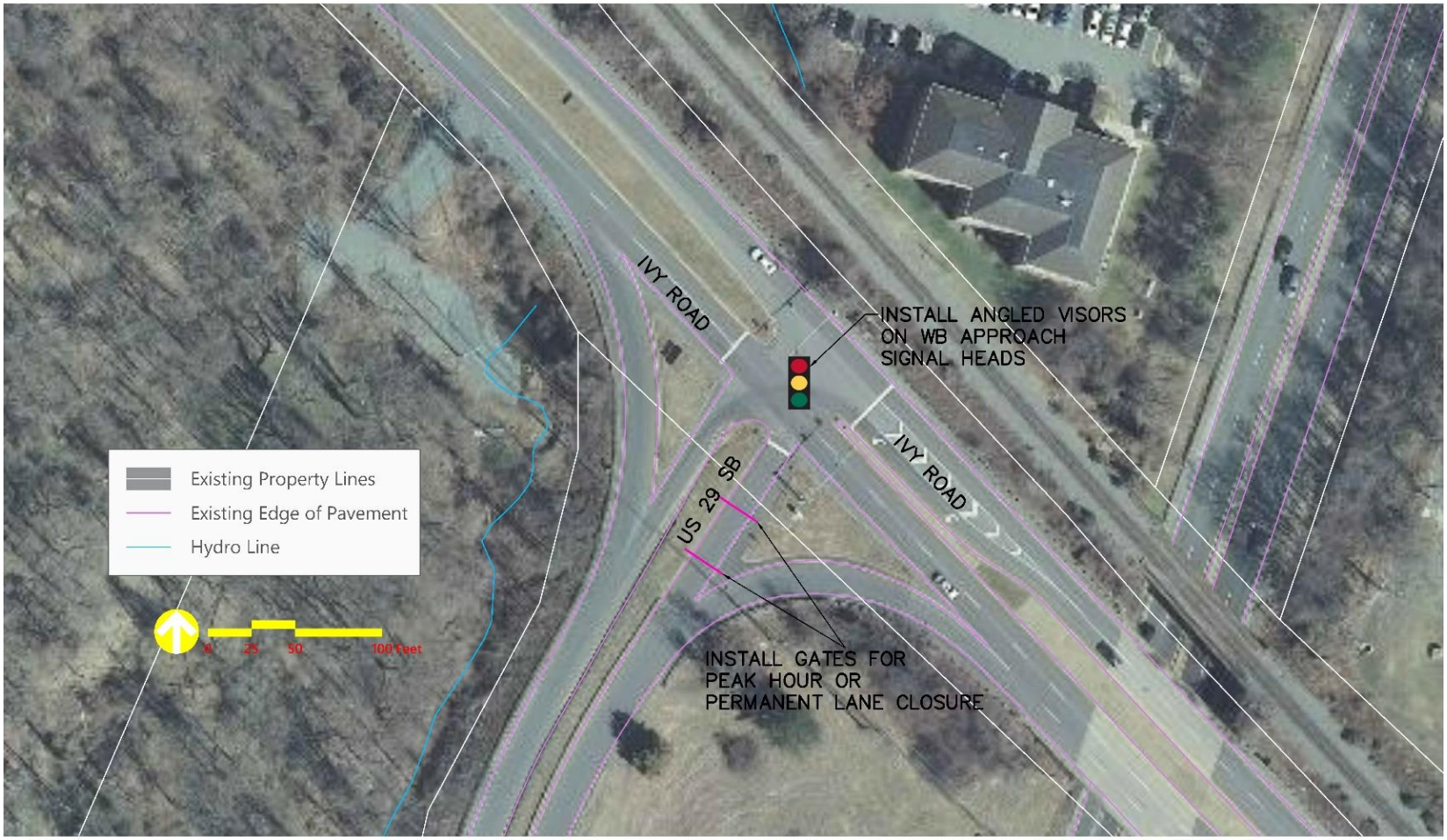



**Figure 7.52 – Short-Term Concept for Ivy Road and Southbound US 29**


**Figure 7.53 – Long-Term Concept A for Ivy Road and Southbound US 29**


**Figure 7.54 – Long-Term Concept B for Ivy Road and Southbound US 29**

### *7.8.5.3 Traffic Operations Analysis*

- **Short-Term Alternative**
  - For the analysis of the short-term alternative, only the peak hours were considered. Therefore, this analysis reflects the closure of the westbound left-turn movement, regardless of if it is operational in the non-peak hours or not.
  - In the short-term alternative (with existing traffic volumes), 10 vehicles in the AM peak and 17 vehicles in the PM peak are rerouted to the Old Ivy Road Ramp at Old Garth Road. In 2025, 11 AM and 18 PM vehicles are rerouted. The addition of this small traffic volume to the roughly 500 existing right-turning vehicles from Old Garth Road to Ivy Road will not significantly degrade traffic conditions. The short-term recommendation improves the intersection LOS to A in both peak hours and reduces delay by 1.9 seconds in the AM and 23.3 in the PM. The complete LOS and delay comparison between existing conditions and the short-term alternative conditions is provided in the first row of **Table 7.44.**
- **Long-Term Alternative A**
  - Under Long-Term Alternative A conditions, the level of service remains the same (LOS A in the AM) and improves to LOS B, from LOS C, in the PM. The 2025 Build conditions sees a 0.9 second increase in delay in the AM and a 20.4 second reduction in delay in the PM when compared to the 2025 No-Build scenario. The complete LOS and delay comparison between existing, 2025 No-Build, and 2025 Build conditions is provided in the second row of Table 7.44.
- **Long-Term Alternative B**
  - Under Long-Term Alternative B conditions, the level of service remains at A in the AM and improves to LOS A in the PM (from LOS C in 2025 No-Build conditions). The 2025 Build scenario experiences a 5.3 second reduction in delay in the AM and a 31.1 second reduction in delay in the PM. The complete LOS and delay comparison between existing, 2025 No-Build, and 2025 Build conditions is provided in the third row of Table 7.44.

Table 7.44 – Operational Performance of Improvements to Ivy Road and US 29 Southbound

| Short-Term | | Existing Conditions | | | | | | Short-Term Improvements | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Delay (s/veh) | LOS | Delay (s/veh) | LOS | Int. Delay (s) | Int. LOS | Delay (s/veh) | LOS | Delay (s/veh) | LOS | Int. Delay (s) | Int. LOS |
| **Ivy Road at US 29 Southbound Interchange** | | | | | | | | | | | | | |
| Ivy Road EB | Through | 2.2/23.0 | A/C | 1.8/ 45.4 | A/D | **5.1/ 30.2** | **A/C** | 2.7/6.2 | A/A | 3.4/ 6.6 | A/A | **3.2/ 6.9** | **A/A** |
| | Right | 0.8/72.6 | A/E | | | | | 5.2/7.1 | A/A | | | | |
| US 29 NB Ramp | Left | 47.9/51.7 | D/D | 8.9/ 10.5 | A/B | | | - | - | 0.1/0.1 | A/A | | |
| | Right | 0.1/0.1 | A/A | | | | | 0.1/0.1 | A/A | | | | |
| Ivy Road WB | Left | 44.3/51.3 | D/D | 3.8/ 21.7 | A/C | | | 24.3/17.9 | B/B | 3.6/ 7.5 | A/A | | |
| | Through | 3.6/2.0 | A/A | | | | | 0.5/0.5 | A/A | | | | |

| Long-Term A | | Existing Conditions | | | | | | 2025 No-Build Conditions | | | | | | 2025 Build Conditions Long-Term Improvement A | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Delay (s/veh) | LOS | Delay (s/veh) | LOS | Int. Delay (s) | Int. LOS | Delay (s/veh) | LOS | Delay (s/veh) | LOS | Int. Delay (s) | Int. LOS | Delay (s/veh) | LOS | Delay (s/veh) | LOS | Int. Delay (s) | Int. LOS |
| **Ivy Road at US 29 Southbound Interchange** | | | | | | | | | | | | | | | | | | | |
| Ivy Road EB | Through | 2.2/23.0 | A/C | 4.9/ 18.8 | A/B | **5.1/ 30.2** | **A/C** | 2.3/25.8 | A/C | 1.9/ 50.4 | A/D | **5.4/31.7** | **A/C** | 7.4/13.8 | A/B | 9.2/ 13.5 | A/B | **6.3/ 11.3** | **A/B** |
| | Right | 0.8/72.6 | A/E | | | | | 0.7/80.2 | A/F | | | | | 13.6/13.1 | B/B | | | | |
| US 29 NB Ramp | Left | 47.9/51.7 | D/D | 3.8/ 10.5 | A/A | | | 48.1/51.7 | D/D | 3.8/ 10.8 | A/B | | | 27.8/28.4 | C/C | 2.3/ 6.0 | A/A | | |
| | Right | 0.1/0.1 | A/A | | | | | 0.1/0.1 | A/A | | | | | 0.1/0.1 | A/A | | | | |
| Ivy Road WB | Left | 44.3/51.3 | D/D | 8.8/ 21.7 | A/C | | | 45.8/49.1 | D/D | 9.6/ 20.9 | A/C | | | 27.5/23.0 | C/C | 4.1/ 10.3 | A/B | | |
| | Through | 3.6/2.0 | A/A | | | | | 4.1/2.1 | A/A | | | | | 0.6/1.8 | A/A | | | | |

| Long-Term B | | Existing Conditions | | | | | | 2025 No-Build Conditions | | | | | | 2025 Build Conditions Long-Term Improvement B | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Delay (s/veh) | LOS | Delay (s/veh) | LOS | Int. Delay (s) | Int. LOS | Delay (s/veh) | LOS | Delay (s/veh) | LOS | Int. Delay (s) | Int. LOS | Delay (s/veh) | LOS | Delay (s/veh) | LOS | Int. Delay (s) | Int. LOS |
| **Ivy Road at US 29 Southbound Interchange** | | | | | | | | | | | | | | | | | | | |
| Ivy Road EB | Through | 2.2/23.0 | A/C | 1.8/ 45.4 | A/D | **5.1/ 30.2** | **A/C** | 2.3/25.8 | A/C | 1.9/ 50.4 | A/D | **5.4/31.7** | **A/C** | 0.1/0.1 | A/A | 0.1/ 0.2 | A/A | **0.1/ 0.6** | **A/A** |
| | Right | 0.8/72.6 | A/E | | | | | 0.7/80.2 | A/F | | | | | 0.2/0.3 | A/A | | | | |
| US 29 NB Ramp | Left | 47.9/51.7 | D/D | 8.9/ 10.5 | A/B | | | 48.1/51.7 | D/D | 3.8/ 10.8 | A/B | | | - | - | 0.1/ 0.1 | A/A | | |
| | Right | 0.1/0.1 | A/A | | | | | 0.1/0.1 | A/A | | | | | 0.1/0.1 | A/A | | | | |
| Ivy Road WB | Left | 44.3/51.3 | D/D | 3.8/ 21.7 | A/C | | | 45.8/49.1 | D/D | 9.6/ 20.9 | A/C | | | 0.1/2.0 | A/A | 0.0/ 0.9 | A/A | | |
| | Through | 3.6/2.0 | A/A | | | | | 4.1/2.1 | A/A | | | | | 0.0/0.1 | A/A | | | | |

### 7.8.6 Preliminary Cost Estimate

The preliminary estimated cost for the proposed improvements is presented in **Table 7.45**. VHB developed the costs in Table 7.45 by use of VDOT's Transportation and Mobility Planning Division (TMPD) cost estimation tool.

**Table 7.45 -– TMPD Cost Estimate for Improvements at Ivy Road and US 29 Southbound**

| Alternative | Cost Type | Low | High |
|---|---|---|---|
| Short-term | Preliminary Engineering | $ 7,000 | $ 9,600 |
| | ROW & Utility Relocation | - | - |
| | Construction | $ 37,900 | $ 50,700 |
| | *Short-term Subtotal* | *$ 44,900* | *$ 60,300* |
| Long-term A | Preliminary Engineering | $ 13,000 | $ 13,100 |
| | ROW & Utility Relocation | $ 32,600 | $ 42,400 |
| | Construction | $ 72,800 | $ 72,800 |
| | *Long-Term Subtotal* | *$ 118,400* | *$ 128,300* |
| Long-term B | Preliminary Engineering | $ 16,900 | $ 18,200 |
| | ROW & Utility Relocation | $ 32,600 | $ 42,400 |
| | Construction | $ 94,300 | $ 101,200 |
| | *Long-Term Subtotal* | *$ 143,800* | *$ 161,800* |
| **Total A** | **Preliminary Engineering** | **$ 20,100** | **$ 22,600** |
| | **ROW & Utility Relocation** | **$ 32,600** | **$ 42,400** |
| | **Construction** | **$ 112,100** | **$ 126,200** |
| | ***TOTAL*** | ***$ 164,800*** | ***$ 191,200*** |
| **Total B** | **Preliminary Engineering** | **$ 24,000** | **$ 27,800** |
| | **ROW & Utility Relocation** | **$ 32,600** | **$ 42,400** |
| | **Construction** | **$ 133,600** | **$ 154,700** |
| | ***TOTAL*** | ***$ 190,200*** | ***$ 224,900*** |

VHB further refined these costs using VDOT's Preliminary Cost Estimating Spreadsheet (PCES) and district bid averages. The total projected cost for these alternatives is presented in **Table 7.46**.

**Table 7.46 – Cost Estimate for Improvements at Ivy Road and US 29 Southbound**

| Alternative | Cost Type | Cost Estimate |
|---|---|---|
| Short-term | Preliminary Engineering | $ 9,600 |
| | ROW & Utility Relocation | - |
| | Construction | $ 40,000 |
| | *Short-term Subtotal* | *$ 49,600* |
| Long-term A | Preliminary Engineering | $ 47,100 |
| | ROW & Utility Relocation | - |
| | Construction | $ 196,000 |
| | *Long-term Subtotal* | *$ 243,100* |
| Long-term B | Preliminary Engineering | $ 56,100 |
| | ROW & Utility Relocation | - |
| | Construction | $ 234,000 |
| | *Long-term Subtotal* | *$ 290,100* |
| **Total A** | **Preliminary Engineering** | **$ 56,700** |
| | **ROW & Utility Relocation** | **-** |
| | **Construction** | **$ 236,000** |
| | ***TOTAL*** | ***$ 292,700*** |
| **Total B*** | **Preliminary Engineering** | **$ 65,700** |
| | **ROW & Utility Relocation** | **-** |
| | **Construction** | **$ 274,000** |
| | ***TOTAL*** | ***$ 339,700*** |

*Overlapping project costs between Short-term and Long-term B alternatives were removed.

VHB developed the cost estimate into a 20-year cost estimate accounting for improvement service life and annual maintenance costs. The service lives and annual maintenance costs were derived from the HSIP Safety Improvement Proposal values. The total projected 20-year cost estimate for the alternatives is presented in **Table 7.47.**

**Table 7.47 – 20-Year Cost Estimate for Improvements at Ivy Road and US 29 Southbound**

| Alternative | Total Cost Estimate | 20-Yr Cost (Based on individual item service life) | Annual Maintenance | Present Value of Maintenance | Total 20-year Cost |
|---|---|---|---|---|---|
| Short-term | $ 49,600 | $ 78,700 | - | - | **$ 78,700** |
| Long-term A | $ 243,100 | $ 243,100 | $ 150 | $ 2,200 | **$ 245,300** |
| Long-term B | $ 290,100 | $ 348,000 | $ 200 | $ 3,000 | **$ 351,000** |

### 7.8.7 Benefit Analysis

**Table 7.48** summarizes the 20-year safety and operational benefits of both the short-term and long-term suggested improvements. The B/C ratios utilize the 20-year total cost from Table 7.47.

Table 7.48 - Improvement Benefits at Ivy Road and US 29 Southbound

| Improvements | Safety Benefit | Operational Benefit | Total Benefit | B:C Ratio |
|---|---|---|---|---|
| Short-term | $359,300 | $8,635,700 | **$ 8,995,000** | **114.3** |
| Long-term A | $ 113,000 | $ 6,752,800 | **$ 6,865,800** | **28.0** |
| Long-term B | $ 113,000 | $ 12,239,400 | **$ 12,352,400** | **35.2** |

### 7.8.8 Project Schedule

VHB estimated the project schedule based on the project schedules for similar VDOT projects recently completed. **Figures 7.55-7.57** show the anticipated schedule for this hot spot's improvements.

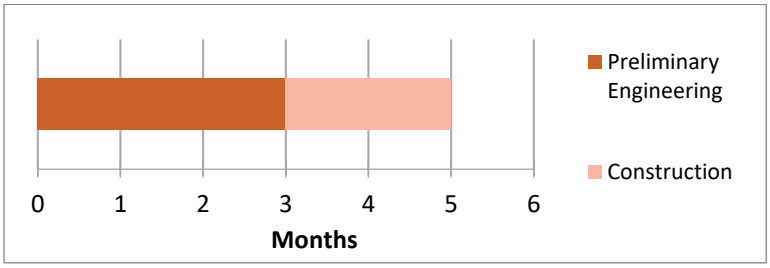
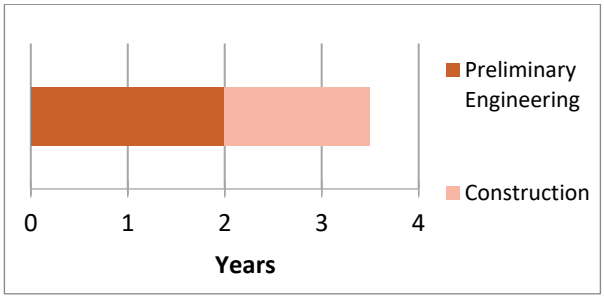
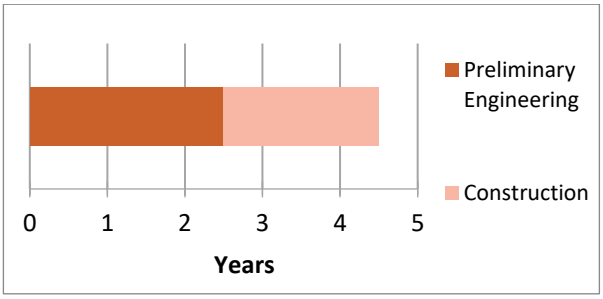



Figure 7.55 – Short -Term Project Schedules for Ivy Road and US 29 Southbound




Figures 7.56 and 7.57 – Long-Term A (left) and Long-Term B (Right) Long-Term Project Schedules for Ivy Road and US 29 Southbound

## 7.9 Ivy Road (US 250) at US 29 Northbound Interchange

### 7.9.1 Intersection Description and Geometric Conditions

The intersection of Ivy Road and the US 29 northbound interchange is signalized. Ivy Road is classified as a principal arterial. US 29 is classified as a freeway or expressway. US 29 northbound provides access to northern Charlottesville. No pedestrian facilities (i.e., crosswalks or sidewalks) are present. Ivy Road is a four-lane divided highway. Approaches are on level terrain. Significant variation in horizontal alignment does occur on the off-ramp of northbound US 29 leading to Ivy Road. The lane use at this intersection is as follows:

- Ivy Road eastbound: 2 through lanes, 1 channelized right-turn lane
- Ivy Road westbound: 1 left-turn lane, 2 through lanes
- US 29 northbound ramp northbound: 1 left-turn lane, 1 channelized right-turn lane

### 7.9.2 Traffic Control Devices

This intersection is signalized. The westbound left-turn operates under protected/permissive phasing. All other movements are controlled by permissive operation. Both channelized right-turns are given yield signs. Mast arms are used for all signal heads. Signal heads are 12-inch with incandescent bulbs and non-retroreflective back plates.

**Signal Type: Actuated Coordinated**

**Signal Operations and Phasing Observations**

- The westbound left-turn movement operates under protected/permissive phasing.

### 7.9.3 Traffic Conditions

Ivy Road has a posted speed limit of 35 mph. US 29 has a posted speed limit of 55 mph, with a posted advisory speed of 15 mph for the US 29 on ramp. The 2016 VDOT Average Annual Daily Traffic (AADT) is as follows:

- Ivy Road: **13,000 vehicles/day**
- US 29 northbound ramp: **NOT REPORTED**

Four-hour turning movement counts were conducted by Peggy Malone & Associates on May 10, 2016. The peak hour turning movement volumes as well as the intersection performance measures, are shown in **Figure 7.58** below.

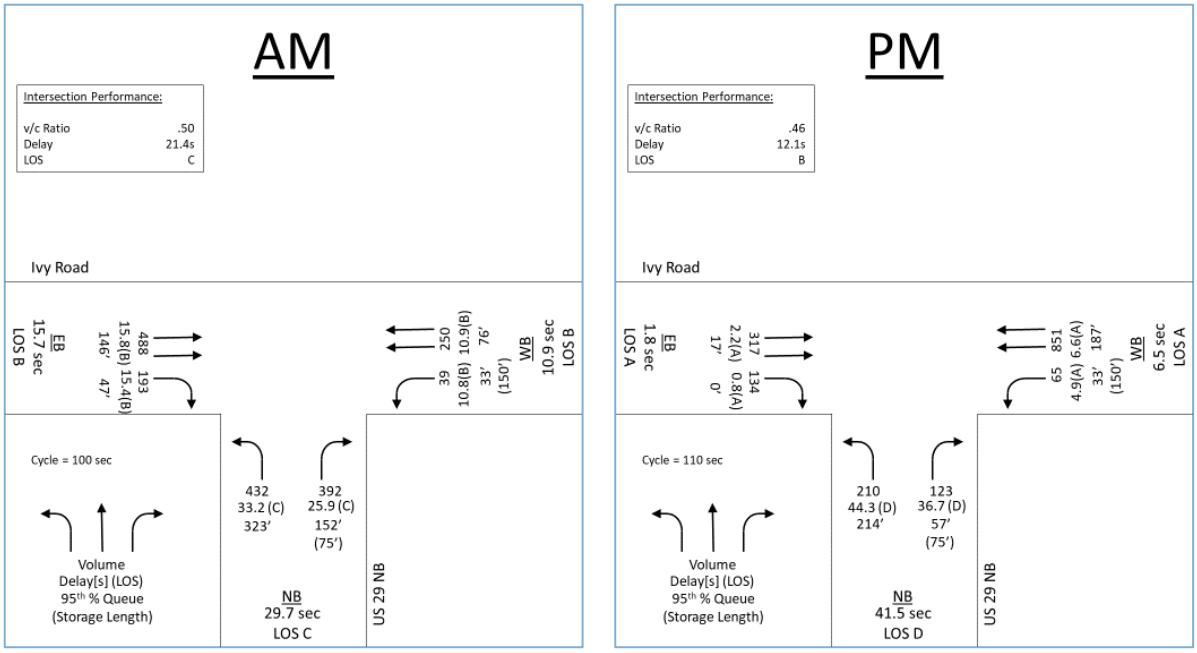



**Figure 7.58 – Traffic Conditions at Ivy Road and US 29 Northbound Interchange**

This intersection operates at LOS C during the AM peak hour and LOS B during the PM peak hour. The only movements to perform worse than LOS B are the northbound movements, which perform at LOS C in the AM peak hour and LOS D in the PM peak hour. This is likely due to the large volume of northbound left-turning vehicles present.

### 7.9.4 Crash Analysis

Crash data for a five-year study period, 2011-2015, was collected for analysis. **Table 7.49** provides a summary of crash data at the subject intersection.

Table 7.49 – Crash Summary at Ivy Road and US 29 Northbound Interchange

| Year | Peak | | Lighting Condition | | | | Pavement | | Type of Collision | | | | | | | | | | Severity | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AM (6-10) | PM (3-7) | Day | Dawn /Dusk | Dark - Road Lighted | Dark - Road Not Lighted | Dry | Wet | RE | A | HO | SS | SO | FI | NC | FO | D | BI | K | A | B | C | PDO | |
| 2011 | 1 | 1 | 2 | 0 | 1 | 1 | 2 | 2 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | **4** |
| 2012 | 0 | 1 | 2 | 0 | 0 | 0 | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | **2** |
| 2013 | 1 | 2 | 2 | 0 | 0 | 1 | 3 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | **3** |
| 2014 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | **1** |
| 2015 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | **2** |
| **TOT** | **2** | **5** | **9** | **0** | **1** | **2** | **10** | **2** | **8** | **3** | **0** | **0** | **0** | **0** | **0** | **1** | **0** | **0** | **0** | **0** | **1** | **1** | **10** | **12** |
| % | 17% | 42% | 75% | 0% | 8% | 17% | 83% | 17% | 67% | 25% | 0% | 0% | 0% | 0% | 0% | 8% | 0% | 0% | 0% | 0% | 8% | 8% | 83% | |

RE = Rear End; A = Angle; HO = Head On; SS = Sideswipe Same Direction; SO = Sideswipe Opposite Direction; FI = Fixed Object in Road; NC = Non-Collision; FO = Fixed Object Off Road; D = Deer; BI = Backed Into

**Figure 7.59** presents a summary of the crashes by lighting conditions and type of collision.

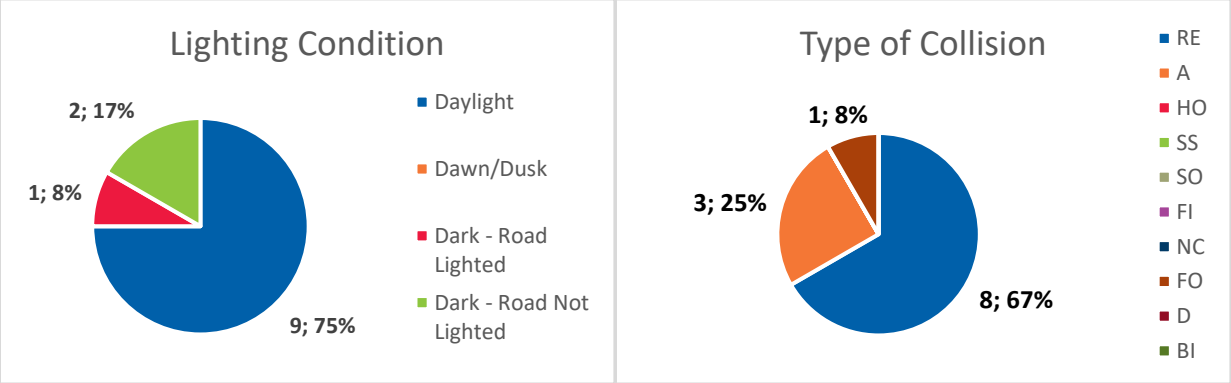



Figure 7.59– Lighting Condition and Collision Type at Ivy Road and US 29 Northbound Interchange

At the intersection of Ivy Road and the US 29 northbound ramp, mostly rear end crashes occurred within the study period. Of the seven rear end crashes, four occurred on the US 29 northbound off-ramp. The angle crashes were all collisions with eastbound traffic. Two of the three angle crashes were caused by the westbound vehicles making improper left-turns. The third angle crash was caused by an eastbound through vehicle disregarding the traffic signal and colliding with a northbound left-turning vehicle.

## 7.9.5 Roadway Safety Assessment

### *7.9.5.1 Safety Issues and Contributing Factors*

#### Northbound Rear End

Northbound rear end crashes were common at this intersection, likely due to the following contributing factors:

- The geometry of the off-ramp (i.e., the northbound approach) does not provide adequate sight distance of the traffic signal. The vegetation on the inside of the ramp further blocks view of the traffic signal. This intersection often experiences long queues, the view of which is often shrouded by the limited sight distance on the ramp.

- To clearly identify gaps in the oncoming traffic, right-turning vehicles must look towards Ivy Road for an extended period. This takes their focus away from the vehicles in front of them and they may not be aware of stopping.
- As is consistent with signalized intersections, rear end crashes were common. All the northbound rear end crashes cite "following too close" as the driver action. This may not give the driver adequate time to respond and stop in the event of a phase change or congestion.

#### WESTBOUND/EASTBOUND ANGLE

Westbound left-turn vehicles commonly made improper left turns and, thus, collided with eastbound through vehicles. The following factors may contribute to these crashes:

- The westbound left-turn movement currently operates under protected/permissive phasing. The high volume of opposing traffic results in a lack of adequate gaps for the left-turning vehicles to take during the permissive portion.

### *7.9.5.2 Suggestions and Opportunities for Improvement*

Application of a Tier 2 Systemic Template 8 is recommended at this location. Additional, intersection-specific improvements for the intersection of Ivy Road and US 29 northbound ramp are presented in this section and summarized in **Table 7.50**. The suggested improvements are *not* listed in any order of significance.

#### NORTHBOUND REAR END

- Short-term

1. Trim vegetation on inside radius of the ramp and provide clear line of sight to the traffic signal. (Increase triangle sight distance; all crash types; Serious injury, Minor injury; CMF = 0.53)

#### WESTBOUND/EASTBOUND ANGLE

- Short-term

1. Re-configure signal timings to include additional all-red timing. (Increase all red clearance interval; all crash types; all severities; CMF = 0.798)
2. Redirect all northbound US 29 traffic entering from westbound US 250 to the Old Ivy Road on-ramp.
   - At a minimum, this should occur during the peak hours. Install remote operated gates in the westbound US 250 left-turn lane to deny access during the peak hours. For the peak hours, adjust the signal phasing to remove the northbound left-turn phase and optimize the signal timings. Install appropriate guidance signage.
   - Alternatively, the westbound left-turn movement could be prohibited permanently by removing the left-turn lane or striping the lane as closed. Adjust the signal phasing to remove the westbound left-turn phase and optimize the signal timings. (Prohibit left-turns with "No Left Turn" sign; all crash types; all severities; CMF = 0.32)
   - This ramp modification also eliminates the existing short merge safety issue at the gore of the current on-ramp on US 29.
3. Install angled visors on the westbound signal heads at the US 250 / US 29 SB intersection to avoid driver confusion due to the clear line of sight to those signal heads.
4. Install elongated route shield pavement marking for US 29 in the left-most westbound through lane to reinforce that the lane becomes a left-turn only onto US 29 at the next intersection.

- Long-term
    5. As a long-term solution, convert this intersection into a modified continuous green-T concept, described below. (Prohibit left-turns with "No Left Turn" sign; all crash types; all severities; CMF = 0.32).

**Table 7.50 – Summary of Recommended Improvements at Ivy Road and the US 29 Northbound Interchange**

| | Safety Issue | Opportunities for Improvement |
|---|---|---|
| 1 | Northbound Rear End | • Trim vegetation on inside radius of the ramp and provide a clear line of sight to the traffic signal. |
| 2 | Westbound/Eastbound Angle | • Re-configure signal timings to include additional all-red timing.<br>• Redirect westbound left-turning traffic and optimize signal phasing.<br>• Install angled visors on the eastbound signal heads at the US 250 / US 29 SB intersection.<br>• Install elongated route shield pavement marking for US 29 in the left-most westbound through lane.<br>❖ Convert intersection into a modified continuous green-T. |
| • Short-term, low-cost<br>○ Intermediate, medium-cost<br>❖ Long-term, high-cost | | |

**Figure 7.60** presents the potential safety enhancement suggestions to be considered for the intersection of Ivy Road and US 29 northbound. The placement of traffic control devices, pavement markings, etc. is not to scale and not according to survey, but is an approximation intended to provide a general idea of location and concept. Designers should consider appropriate standards, policies, and right of way impacts before implementing any potential enhancements.


**Figure 7.60 – Short-Term Concept for Ivy Road and Northbound US 29**

### CONTINUOUS GREEN-T CONCEPT

The proposed long-term improvement for this intersection is a continuous green-T, shown in **Figure 7.61**. The continuous green-T intersection is a variant of a T-intersection that minimizes the delay to through traffic. In this concept, the westbound through traffic does not have to stop at the traffic signal; it becomes a free-flow movement. The northbound left-turning traffic will first complete the turn and then merge with the through traffic downstream of this intersection. To avoid excess weaving movements, the vehicles that wish to turn left onto southbound US 29 will be funneled into the left lane prior to the intersection with northbound US 29. These vehicles will be under signal control, unlike the through traffic. This concept requires permanently closing the westbound left-turn lane. This project upholds the priorities of the Mobility Enhancement Segment by prioritizing the through traffic over the side street traffic.

As a preliminary analysis of this concept, VHB employed VJuST (VDOT's Junction Screening Tool). VJuST is a tool to analyze alternative and unconventional intersection designs. The tool analyzes an intersection configuration's Volume to Capacity ratio (V:C Ratio), but does not analyze the delay or queues. Additionally, the tool does not consider other design attributes such as cost, right of way needs, or specific design requirements. It is meant as a planning level analysis tool. The expected volume to capacity is 0.77 in the AM peak hour and 0.38 in the PM peak hour. This intersection configuration performs very well in the PM peak hour due to the heavy westbound through traffic that incurs no delay under this configuration.

Note that it is important that this long-term concept be done in conjunction with the long-term widening concept proposed at the intersection of Ivy Road and southbound US 29. This concept relies on the 2$^{nd}$ westbound through lane to give the through vehicles their own lane while accommodating the northbound and westbound left-turning vehicles.


**Figure 7.61 – Long-Term Concept for Ivy Road and Northbound US 29**

#### *7.9.5.3 Traffic Operations Analysis*

- **Short-Term Improvements**
  - For the analysis of the short-term alternative, only the peak hours were analyzed. Therefore, this analysis reflects the closure of the westbound left-turn movement, regardless of if it is operational in the non-peak hours or not.
  - With the short-term improvements, 39 vehicles in the AM peak and 65 vehicles in the PM peak are rerouted to the Old Ivy Road on-ramp. This traffic volume will be rerouted onto Old Ivy Road approximately 0.6 miles east of this intersection. VHB does not have traffic volumes for the Ivy Road / Old Ivy Road intersection, but facilities should have the capacity to absorb this rerouted traffic. The exception is the 5 AM peak hour trucks and 1 PM peak hour truck that will not be able to route along Old Ivy Road due to the low railroad bridge clearance. This small truck volume must reroute onto northbound US 29 utilizing one of the several other on-ramps in the vicinity. As shown in the first row of **Table 7.51**, the recommended short-term improvements result in an 8.7 second reduction in the AM and a 4.2 second reduction in the PM. With the short-term improvements in place, this intersection is anticipated to operate at LOS B in the AM peak hour and LOS A in the PM peak hour.
- **Long-Term Improvements**
  - With the modified continuous green-T in place, the intersection operates at a LOS B in the AM and A in the PM, an improvement from the 2025 No-Build scenario of LOS C in the AM and B in the PM. The 2025 Build condition offers an 8.3 second reduction in delay in the AM and a 5.7 second reduction in delay in the PM over the 2025 No-Build conditions. The full Existing, 2025 No-Build, and 2025 Build conditions are presented in the second row of Table 7.51.

Table 7.51 – Operational Performance of Improvements to Ivy Road and US 29 Northbound

| Short-Term Improvement | | Existing Conditions | | | | | | Short-Term Improvement Scenario | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Delay (s/veh) | LOS | Delay (s/veh) | LOS | Int. Delay (s) | Int. LOS | Delay (s/veh) | LOS | Delay (s/veh) | LOS | Int. Delay (s) | Int. LOS |
| **Ivy Road at US 29 Northbound Interchange** | | | | | | | | | | | | | |
| Ivy Road EB | Through | 15.8/2.2 | B/A | 15.7/ 1.8 | B/A | **21.4/ 12.1** | **C/B** | 11.2/3.6 | B/A | 12.5/ 3.0 | B/A | **12.2/ 8.6** | **B/A** |
| | Right | 15.4/0.8 | B/A | | | | | 15.6/1.7 | B/A | | | | |
| US 29 NB Ramp | Left | 33.2/44.3 | C/D | 29.7/ 41.5 | C/D | | | 13.5/18.4 | B/B | 12.6/ 17.4 | B/B | | |
| | Right | 25.9/36.7 | C/D | | | | | 11.7/15.8 | B/B | | | | |
| Ivy Road WB | Left | 10.8/4.9 | B/A | 10.9/ 6.5 | B/A | | | - | - | 10.4/8.0 | B/A | | |
| | Through | 10.9/6.6 | B/A | | | | | 10.4/8.0 | B/A | | | | |

| Long-Term Improvement | | Existing Conditions | | | | | | 2025 No-Build Conditions | | | | | | 2025 Build Conditions Long-Term Improvement Scenario | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Delay (s/veh) | LOS | Delay (s/veh) | LOS | Int. Delay (s) | Int. LOS | Delay (s/veh) | LOS | Delay (s/veh) | LOS | Int. Delay (s) | Int. LOS | Delay (s/veh) | LOS | Delay (s/veh) | LOS | Int. Delay (s) | Int. LOS |
| **Ivy Road at US 29 Northbound Interchange** | | | | | | | | | | | | | | | | | | | |
| Ivy Road EB | Through | 15.8/2.2 | B/A | 15.7/ 1.8 | B/A | **21.4/ 12.1** | **C/B** | 17.3/2.7 | B/A | 16.8/ 2.1 | B/A | **21.5/ 12.5** | **C/B** | 11.9/6.1 | B/A | 14.7/ 6.0 | B/A | **13.2/ 6.8** | **B/A** |
| | Right | 15.4/0.8 | B/A | | | | | 15.6/0.8 | B/A | | | | | 21.7/5.6 | C/A | | | | |
| US 29 NB Ramp | Left | 33.2/44.3 | C/D | 29.7/ 41.5 | C/D | | | 32.2/43.8 | C/D | 28.7/ 40.9 | C/D | | | 16.2/13.8 | B/B | 15.2/ 12.9 | B/C | | |
| | Right | 25.9/36.7 | C/D | | | | | 24.9/36.0 | C/D | | | | | 14.1/11.4 | B/B | | | | |
| Ivy Road WB | Left | 10.8/4.9 | B/A | 10.9/ 6.5 | B/A | | | 12.1/5.3 | B/A | 12.1/ 7.3 | B/A | | | - | - | 3.6/4.9 | A/A | | |
| | Through | 10.9/6.6 | B/A | | | | | 12.1/7.4 | B/A | | | | | 11.2/9.8 | B/A | | | | |

### 7.9.6 Preliminary Cost Estimate

The preliminary estimated cost for the proposed improvements is presented in **Table 7.52**. VHB developed the costs in Table 7.52 by use of VDOT's Transportation and Mobility Planning Division (TMPD) cost estimation tool.

**Table 7.52 – TMPD Cost Estimate for Improvements at Ivy Road and US 29 Northbound**

| Alternative | Cost Type | Low | High |
|---|---|---|---|
| Short-term | Preliminary Engineering | $ 5,200 | $ 9,000 |
| | ROW & Utility Relocation | - | - |
| | Construction | $ 27,800 | $ 48,500 |
| | *Short-term Subtotal* | *$ 32,900* | *$ 57,500* |
| Long-term | Preliminary Engineering | $ 4,100 | $ 5,300 |
| | ROW & Utility Relocation | - | - |
| | Construction | $ 23,100 | $ 29,700 |
| | *Short-term Subtotal* | *$ 27,200* | *$ 35,000* |
| **Total** | **Preliminary Engineering** | **$ 9,300** | **$ 14,300** |
| | **ROW & Utility Relocation** | **-** | **-** |
| | **Construction** | **$ 50,900** | **$ 78,200** |
| | ***TOTAL*** | ***$ 60,200*** | ***$ 92,500*** |

VHB further refined these costs using VDOT's Preliminary Cost Estimating Spreadsheet (PCES) and district bid averages. The total projected cost for these alternatives is presented in **Table 7.53**.

**Table 7.53 – Cost Estimate for Improvements at Ivy Road and US 29 Northbound**

| Alternative | Cost Type | Cost Estimate |
|---|---|---|
| Short-term | Preliminary Engineering | $12,300 |
| | ROW & Utility Relocation | - |
| | Construction | $ 51,000 |
| | *Short-term Subtotal* | *$ 63,300* |
| Long-term | Preliminary Engineering | $ 100,200 |
| | ROW & Utility Relocation | - |
| | Construction | $ 418,000 |
| | *Short-term Subtotal* | *$ 518,200* |
| **Total** | **Preliminary Engineering** | **$112,500** |
| | **ROW & Utility Relocation** | **-** |
| | **Construction** | **$ 469,000** |
| | ***TOTAL*** | ***$ 581,500*** |

*Overlapping project costs between Short-term and Long-term alternatives were removed.

VHB developed the cost estimate into a 20-year cost estimate accounting for improvement service life and annual maintenance costs, which were derived from the HSIP Safety Improvement Proposal values. The total projected 20-year cost estimate for the alternatives is presented in **Table 7.54.**

Table 7.54 – 20-Year Cost Estimate for Improvements at Ivy Road and US 29 Northbound

| Alternative | Cost Estimate Total | 20-Yr Cost (Based on individual item service life) | Annual Maintenance | Present Value of Maintenance | Total 20-year Cost |
|---|---|---|---|---|---|
| Short-term | $ 63,300 | $ 95,200 | $ 100 | $ 1,500 | **$ 96,700** |
| Long-term | $ 518,200 | $ 518,200 | $ 74 | $ 1,100 | **$ 519,300** |

### 7.9.7 Benefit Analysis

**Table 7.55** summarizes the 20-year safety and operational benefits of both the short-term and long-term suggested improvements. The B/C ratios utilize the 20-year total cost from Table 7.54.

Table 7.55 - Improvement Benefits at Ivy Road and US 29 Northbound

| Improvements | Safety Benefit | Operational Benefit | Total Benefit | B:C Ratio |
|---|---|---|---|---|
| Short-term | $ 350,700 | $ 5,772,300 | **$ 6,123,000** | **63.3** |
| Long-term | $ 242,100 | $ 6,363,200 | **$ 6,605,300** | **12.7** |

### 7.9.8 Project Schedule

VHB estimated the project schedule based on the project schedules for similar VDOT projects recently completed. **Figures 7.62** and **7.63** show the anticipated schedule for this hot spot's improvements.

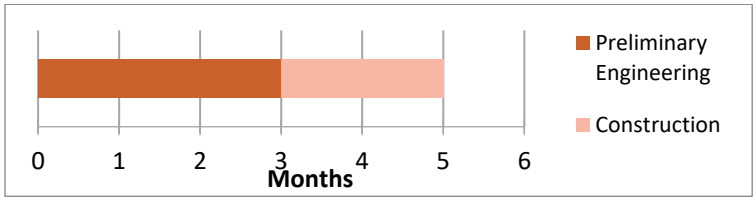



Figure 7.62 – Short-Term Project Schedule for Ivy Road and US 29 Northbound

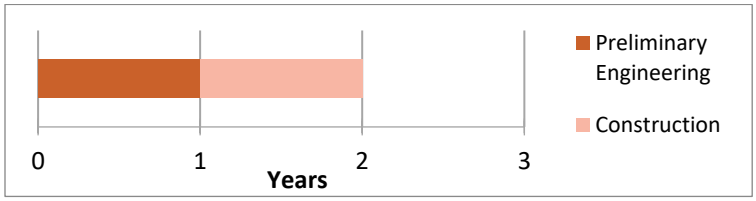



Figure 7.63 – Long-Term Project Schedule for Ivy Road and US 29 Northbound

## 7.10 Ivy Road between Farmington Drive and Canterbury Road / Old Garth Road

### 7.10.1 Intersection Description and Geometric Conditions

This segment is a two-lane road divided by a two-way left-turn lane. Most entrances along this segment are given an exclusive right-turn lane. This segment is approximately 0.73 miles in length and is an unsignalized segment adjoined by two signalized intersections. Ivy Road is classified as an urban minor arterial. This segment provides access to commercial, residential, and recreational land uses. This segment does experience a slight downgrade in the eastbound direction.

### 7.10.2 Traffic Control Devices

This segment is unsignalized. All entrances are assumed stop-controlled and Ivy Road is free-flowing. The only stop sign is placed on the driveway of the White Gables Condo Community.

### 7.10.3 Traffic Conditions

Ivy Road has a posted speed limit of 35 mph. The 2016 VDOT Average Annual Daily Traffic (AADT) is as follows:

- Ivy Road: **13,000 vehicles/day**

VHB conducted an analysis of the volume to capacity ratio along the corridor. In the eastbound direction, this segment experiences a volume to capacity ratio of 0.94 in the AM and 0.46 in the PM. In the westbound direction, this segment experiences a volume to capacity ratio of 0.81 in the AM and 1.05 in the PM. This segment becomes very congested from the commuter traffic experienced.

### 7.10.4 Crash Analysis

Crash data for a five-year study period, 2011-2015, was collected for analysis. **Table 7.56** provides a summary of crash data at the segment between Farmington Drive and the west entrance of Bellair Exxon.

Table 7.56 – Crash Summary on Ivy Road between Farmington Drive and Canterbury Road / Old Garth Road

| Year | Peak | | Lighting Condition | | | | Pavement | | Type of Collision | | | | | | | | | | Severity | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AM (6-10) | PM (3-7) | Day | Dawn /Dusk | Dark - Road Lighted | Dark - Road Not Lighted | Dry | Wet | RE | A | HO | SS | SO | FI | NC | FO | D | BI | K | A | B | C | PDO | |
| 2011 | 4 | 0 | 3 | 1 | 0 | 2 | 6 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 1 | 1 | 4 | **6** |
| 2012 | 0 | 1 | 1 | 2 | 0 | 0 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | **3** |
| 2013 | 1 | 1 | 4 | 1 | 0 | 0 | 5 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 3 | 0 | 2 | **5** |
| 2014 | 1 | 0 | 2 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | **2** |
| 2015 | 4 | 4 | 9 | 1 | 0 | 0 | 8 | 2 | 4 | 4 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 9 | **10** |
| **TOT** | **10** | **6** | **19** | **5** | **0** | **2** | **22** | **4** | **10** | **7** | **1** | **1** | **0** | **0** | **0** | **6** | **1** | **0** | **0** | **0** | **6** | **1** | **19** | **26** |
| % | 38% | 23% | 73% | 19% | 0% | 8% | 85% | 15% | 38% | 27% | 4% | 4% | 0% | 0% | 0% | 23% | 4% | 0% | 0% | 0% | 23% | 4% | 73% | |

RE = Rear End; A = Angle; HO = Head On; SS = Sideswipe Same Direction; SO = Sideswipe Opposite Direction; FI = Fixed Object in Road; NC = Non-Collision; FO = Fixed Object Off Road; D = Deer; BI = Backed Into

**Figure 7.64** presents a summary of the crashes by lighting conditions and type of collision.

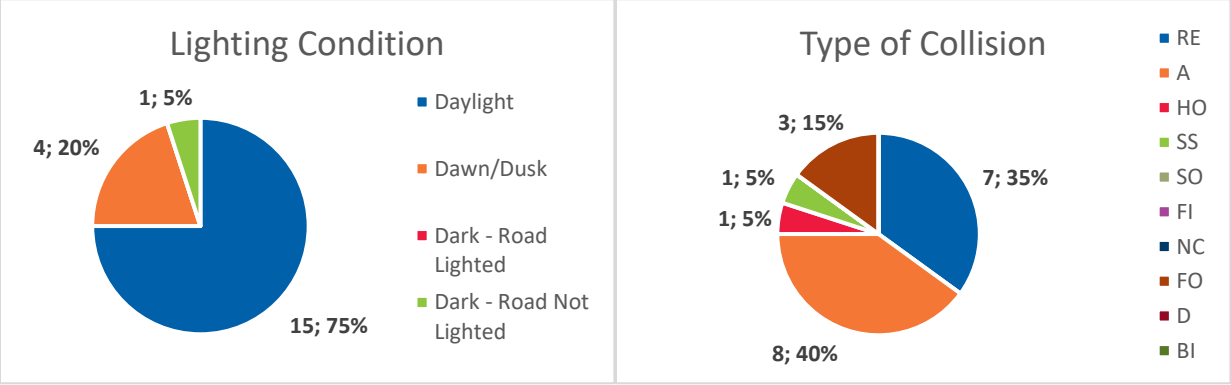



Figure 7.64 – Lighting Condition and Collision Type on Ivy Road between Farmington Drive and Canterbury Road / Old Garth Road

Angle crashes were common in this segment, likely due to the multitude of entrances and exits combined with the heavy traffic experienced. Four angle crashes were caused by a vehicle turning left onto the mainline from a side street or a parking lot entrance. This segment experienced ten rear end crashes: six in the eastbound direction and four in the westbound direction. Most of the crashes caused only property damage. Two rear end crashes involved three vehicles.

## 7.10.5 Roadway Safety Assessment

### *7.10.5.1 Safety Issues and Contributing Factors*

#### EASTBOUND REAR END

Eastbound rear end crashes were common at the Ivy Road and Canterbury Road / Old Garth Road intersection, likely due to the following contributing factors:

- This segment experiences heavy congestion and queuing. All eastbound rear end crashes cite the driver at fault as "following too close." This may not allow drivers enough time to stop in the event of congestion or an upstream signal change.

- This segment also experiences a slight curve. It is possible that the vegetation on the inner radius of this curve may limit the sight distance. If the vegetation becomes too overgrown, the visibility of the traffic signal may be jeopardized.

#### ANGLE

Angle crashes were very common at the entrance to the retail space west of Bellair Exxon. The following factors may contribute to these angle crashes in this segment:

- Several access points are along this segment. Though a two-way left-turn lane is provided for most of the segment, no dedicated left-turn lanes are provided for these entrances.
- Heavy traffic volumes on Ivy Road create very few acceptable gaps for left-turning vehicles.

### *7.10.5.2 Suggestions and Opportunities for Improvement*

Application of a Tier 2 Systemic Template 9 is recommended at this location. Additional, segment specific improvements for the segment of Ivy Road between Farmington Drive and Canterbury Road / Old Garth Road are presented in this section and summarized in **Table 7.57**. The suggested improvements are *not* listed in any order of significance.

#### EASTBOUND REAR END

- Short-term

    1. Trim vegetation along Ivy Road and provide clear line of sight to the traffic signal. (Increase triangle sight distance; all crash types; Serious injury, Minor injury; CMF = 0.53)
    2. Reconfigure signal timings at Canterbury Road / Old Garth Road to allow for better progression of the eastbound traffic in this segment.

- Long-term

    3. Widen eastbound direction to two lanes from Farmington Drive to the intersection of Canterbury Road / Old Garth Road and convert the exclusive right-turn lane to a shared right-turn / through lane. This will help with the congestion in the eastbound direction, which is the direction of most rear end crashes. (Concept A) (Install an additional lane; all crash types; fatal and injury severity; CMF = 0.76)
    4. Install one of the two reversible lane concepts discussed below.
        i. Three-lane cross section replacing two-way left-turn lane. (Concept B)
        ii. Four-lane cross section maintaining two-way left-turn lane and adding reversible lane (Concept C)
            - Widening the eastbound direction (Concept A) to two through lanes could be a precursor to implementing the four-lane cross section in the future. Once the road is widened to four lanes, it is only a matter of converting the pavement markings and adding changeable lane use signs for the reversible lane concept.

#### ANGLE

- Intermediate

    1. Use the existing left-turn lane and open median to delineate a designated left-turn lane for each of the following: the entrance to the New Virginia Tractor Shopping Center, the west entrance to the Bellair Exxon, and Old Garth Road.

**Table 7.57 – Summary of Recommended Improvements on Ivy Road between Farmington Drive and Canterbury Road / Old Garth Road**

| | Safety Issue | Opportunities for Improvement |
|---|---|---|
| 1 | Eastbound Rear End | • Trim vegetation along Ivy Road and provide clear line of sight to the traffic signal.<br>• Reconfigure signal timings at Canterbury Road / Old Garth Road to allow for better progression of the eastbound traffic in this segment.<br>❖ Install a reversible center lane.<br>❖ Widen eastbound direction to two lanes from Ednam Center to the intersection of Canterbury Road / Old Garth Road. |
| 2 | Angle | ○ Use the existing left-turn lane and open median to delineate a designated left-turn lane for each of the following: the entrance to the New Virginia Tractor Shopping Center, the west entrance to the Bellair Exxon, and Old Garth Road. |

• Short-term, low-cost
○ Intermediate, medium-cost
❖ Long-term, high-cost

## 7.10.6 Alternate Intersection Control

As part of a different study adjacent to this segment of the US 250 corridor, VHB examined alternate intersection control for the intersections of Ednam Drive and Colridge Drive / Golf Course Drive. Signal warrant analysis revealed the existing intersection control – signal at Ednam and two-way stop-control at Colridge / Golf Course – is the preferred condition, and a signal at Colridge / Golf Course was not warranted. A preliminary analysis of a US 250 coordinated signal system indicated that a coordinated system from Broomley Road through the US 29 interchange would decrease peak hour travel time in the peak direction of travel by 1.2% (AM-eastbound) and by 0.6% (PM-westbound).

**Figures 7.65-7.66** present the potential enhancement suggestions to be considered for Long Term Concept A. The placement of traffic control devices, pavement markings, etc. is not to scale and not according to survey, but is an approximation intended to provide a general idea of location and concept. Designers should consider appropriate standards, policies, and right of way impacts before implementing any potential enhancements.

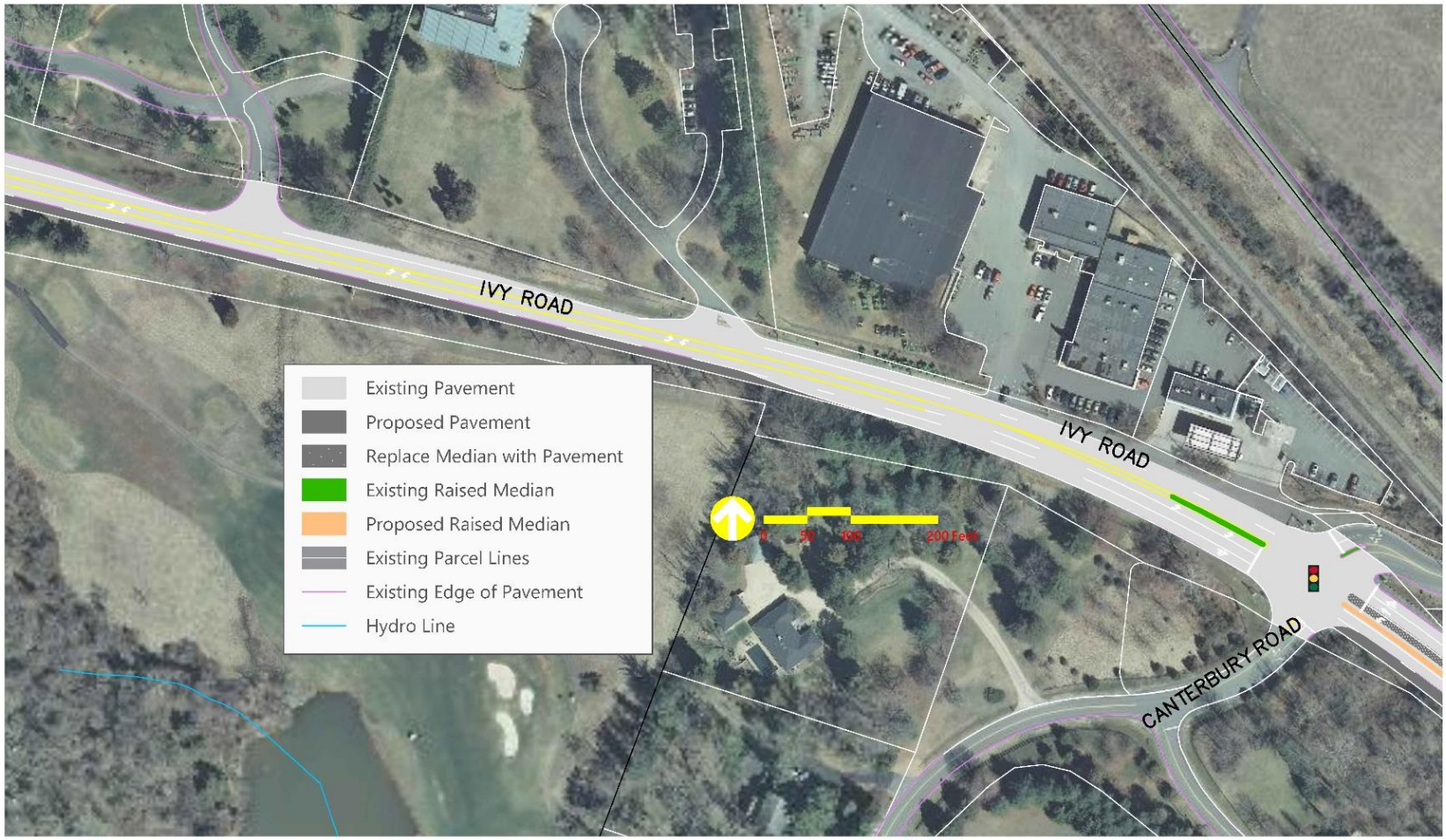



**Figure 7.65 – Four-Lane Widening Concept (A) for Ivy Road**

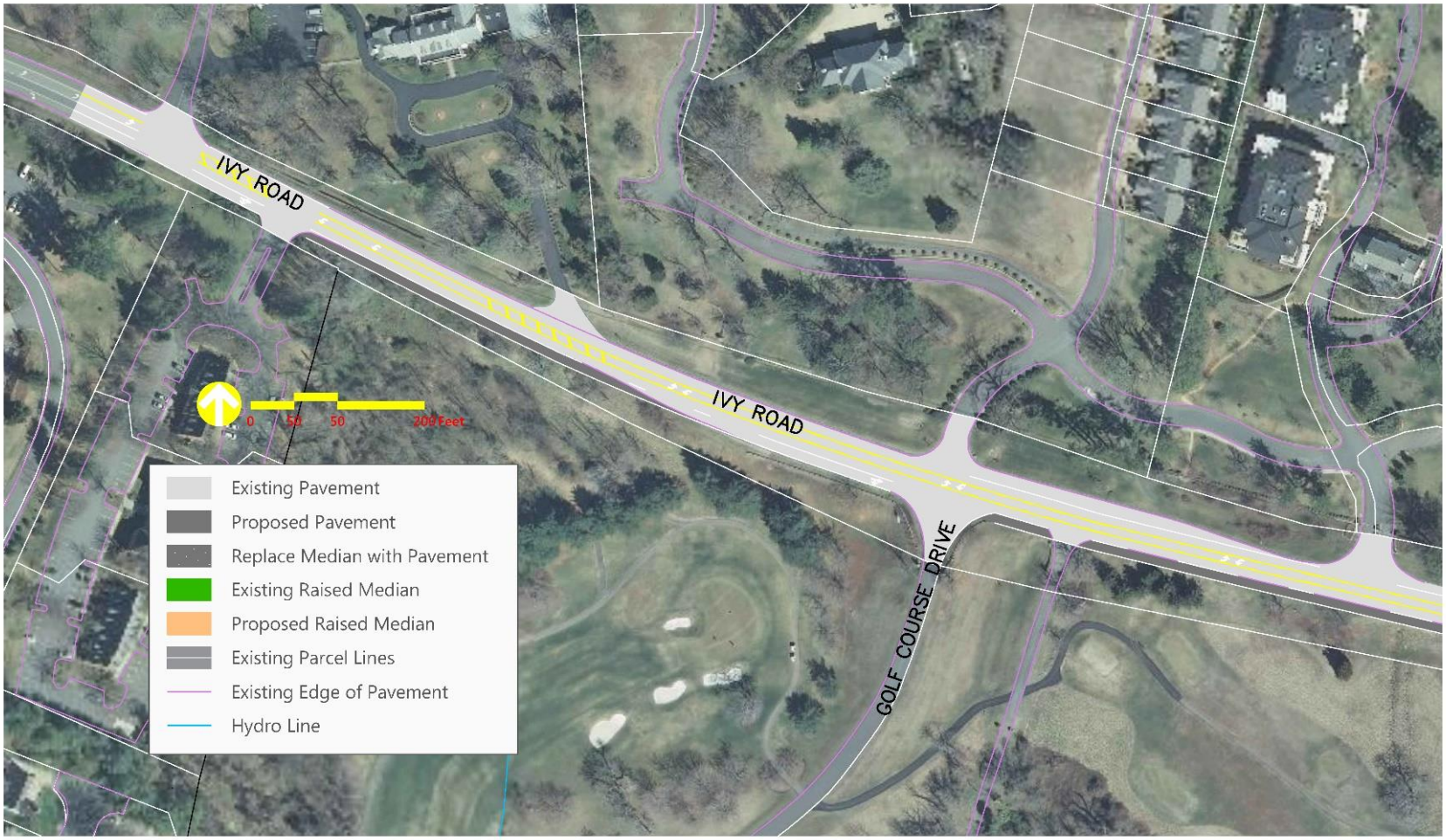



**Figure 7.66 – Four-Lane Widening Concept (A) for Ivy Road**

### Reversible Lane Alternatives

To mitigate the congestion experienced in this segment, VHB developed two reversible lane alternatives. In the reversible lane, the direction of vehicular traffic switches based on the demand of the network. This corridor is a prime candidate for a reversible lane due to the heavy commuter traffic experienced. The commuter traffic produces an average directional split of 3:1 in the eastbound and westbound directions during the AM and PM peak periods, respectively.

The reversible lane concept is often used on interstates (e.g., High Occupancy Toll lanes on I-95 in Virginia and High Occupancy Vehicle lanes on I-64 in Virginia) to increase the capacity in the peak travel direction. On interstates, the reversible lanes are divided from the through lanes; however, reversible lanes on arterials are generally undivided. Though arterial reversible lanes are still relatively uncommon, they are gaining momentum in Virginia and surrounding areas. Virginia has long operated an undivided reversible lane in Newport News and is constructing a second in Hampton. Washington D.C. and Maryland each have also operated multiple locations of a reversible lane on an arterial. Georgia's reversible lane (Vineville Avenue in Macon) has been in service for decades and has a high density of access points along the road. Texas operates a 6-lane reversible lane concept in Arlington. This concept also includes a two-way left-turn lane that shifts lanes depending on the direction of the reversible lane.

The reversible lane is proposed along Ivy Road between Canterbury Road / Old Garth Road and Farmington Drive. VHB developed two reversible lane alternatives, described below.

Reversible Lane – 3-Lane Alternative

Concept B consists of a three-lane cross section through this segment, as it currently exists. The current lane configuration is one lane in each direction divided by a two-way left-turn lane. Concept B converts the two-way left-turn lane into a reversible lane. This alternative is shown in **Figures 7.67-7.69**.

In the AM peak hour, the lane configuration would be as follows:

- Ivy Road eastbound: 1 shared through / right-turn lane, 1 shared through / left-turn lane (reversible lane)
- Ivy Road westbound: 1 shared left-turn / through / right-turn lane

In the PM peak hour, the movements would be opposite:

- Ivy Road eastbound: 1 shared left-turn / through / right-turn lane
- Ivy Road westbound: 1 shared through / right-turn lane, 1 shared through / left-turn lane (reversible lane)

In the off-peak hour, the reversible lane will be utilized as a two-way left-turn lane, as it currently is.

This alternative utilizes the existing pavement cross section and, therefore, needs no widening through the corridor. The existing two-way left-turn lane must be restriped to a reversible lane for this alternative. Public outreach and education are vital efforts in successful implementation of a reversible lane.

During the peak hours, the left turns currently in the two-way left-turn lane will be displaced to the shared lanes, presenting operational and safety implications. There are no published crash modification factors (CMFs) associated with removing a two-way left-turn lane; however, *installing* a two-way left-turn lane on a two-lane road has a CMF of 0.797 for all crashes and 0.739 for all fatal and injury crashes. As installing a two-way left-turn lane is expected to reduce the crashes experienced, it can be inferred that removing the two-way left-turn lane may increase crashes, though the magnitude is uncertain. Other safety

implications are also unclear due to a lack of published research. The reversible lane strategy will reduce congestion which general traffic engineering knowledge states will reduce the risk of rear end crashes; however, there is no published science (CMF) that quantifies this reduction. Additionally, there is no published safety research on the implementation of a reversible lane strategy; this expected crash reduction related to congestion relief may be offset by an increase in head-on collision risk. Operationally, the corridor is anticipated to improve with the increased capacity provided by the reversible lane in the peak hours. VHB does not have the turning movement counts for each entrance in this segment; therefore, VHB could not estimate the operational effect of the left-turning vehicles in the through lanes. A more detailed safety and operational analysis may be required before implementing this alternative.

Reversible Lane – 4-Lane Alternative

Reversible Lane Concept C comprises a four-lane cross section through this segment. This additional lane allows for the retention of the two-way left-turn lane. This alternative largely maintains the existing lane configuration while adding a reversible lane. This alternative is shown in **Figures 7.70-7.72.**

In the AM peak hour, the lane configuration would be as follows:

- Ivy Road eastbound: 1 shared through / right-turn lane, 1 through lane (reversible lane)
- Ivy Road westbound: 1 shared through / right-turn lane
- Ivy Road eastbound/westbound: 1 two-way left-turn lane

In the PM peak hours, the movements would be opposite:

- Ivy Road eastbound: 1 shared through / right-turn lane
- Ivy Road westbound: 1 shared through / right-turn lane, 1 through lane (reversible lane)
- Ivy Road eastbound/westbound: 1 two-way left-turn lane

**Figure 7.74** presents the anticipated lane use for the peak hours.

In the off-peak hour, the reversible lane could continue to operate in the peak direction. Multiple 24-hour counts would be necessary to determine which direction the reversible lane should operate in. Alternatively, the reversible lane could be closed for the off-peak hours. Due to the existing right-turn lanes along the segment, minimal widening is required to achieve a four-lane cross section for the entirety of this segment. The existing right-turn only lanes would be absorbed into the additional through lane.

Operationally, Concept C is expected to perform better than Concept B as the left turns will maintain their dedicated two-way left-turn lane and will not impede traffic flow in the through lanes. The additional through lane in the eastbound in the AM decreases the V:C ratio from 0.94 to only 0.50. Likewise, the westbound PM V:C ratio is decreased from 1.05 to only 0.52.

There is a trade-off from the safety perspective. While this alternative does keep the left-turns separate from the through traffic (compared to Concept B), the right-turns that once had a dedicated right-turn lane will now share a lane with the through vehicles, and the risk of rear-end crashes may rise.

As a reversible lane is still a unique concept, public outreach and education are vital components of successfully implementing this alternative.

This concept is a more intensive construction alternative than Concept B; however, it will provide increased operational benefits in the corridor by maintaining separated left turns.

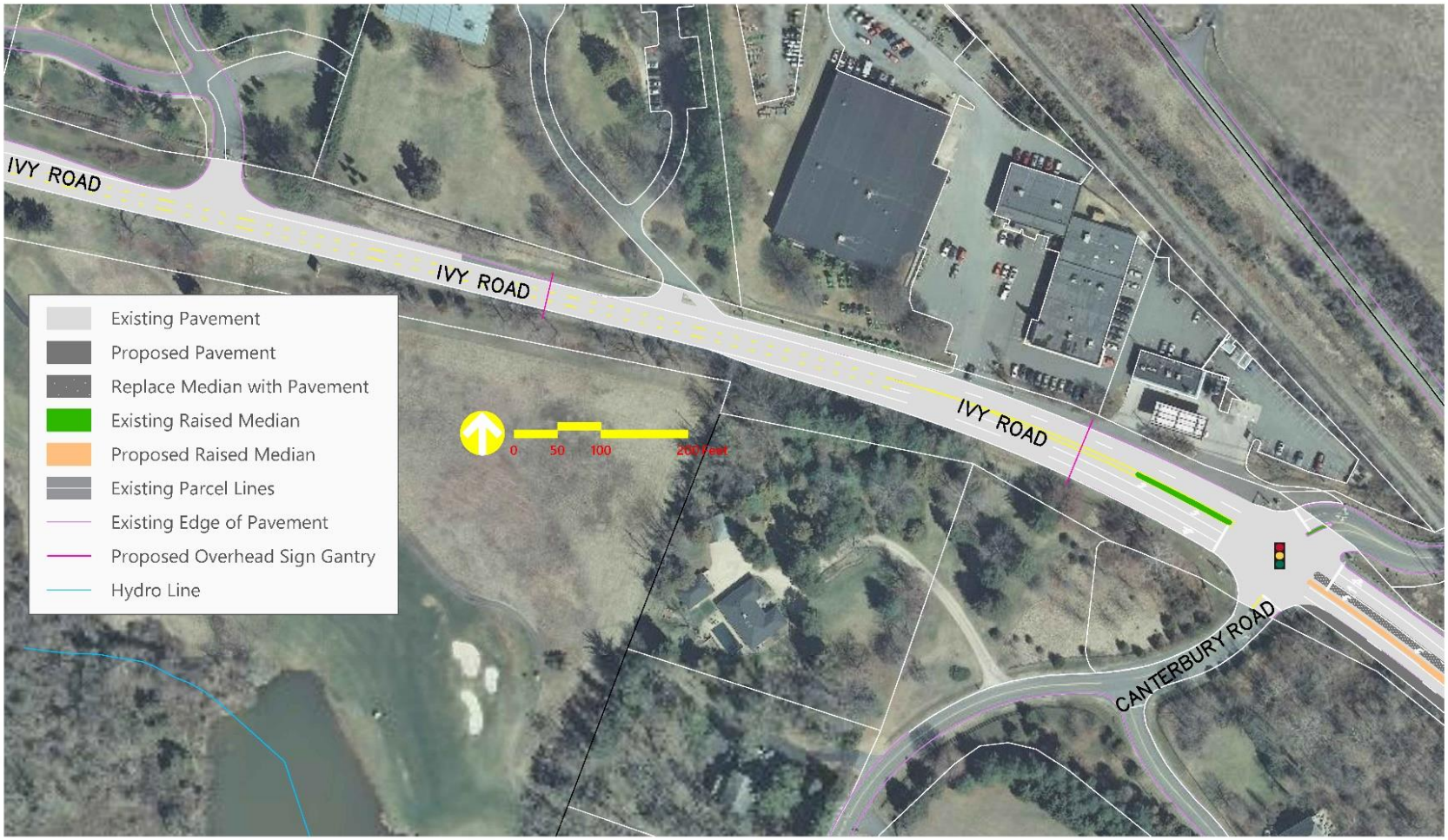



**Figure 7.67 – Three-Lane Reversible Concept (B) for Ivy Road**


**Figure 7.68 – Three-Lane Reversible Concept (B) for Ivy Road**


**Figure 7.69 – Three-Lane Reversible Concept (B) for Ivy Road**

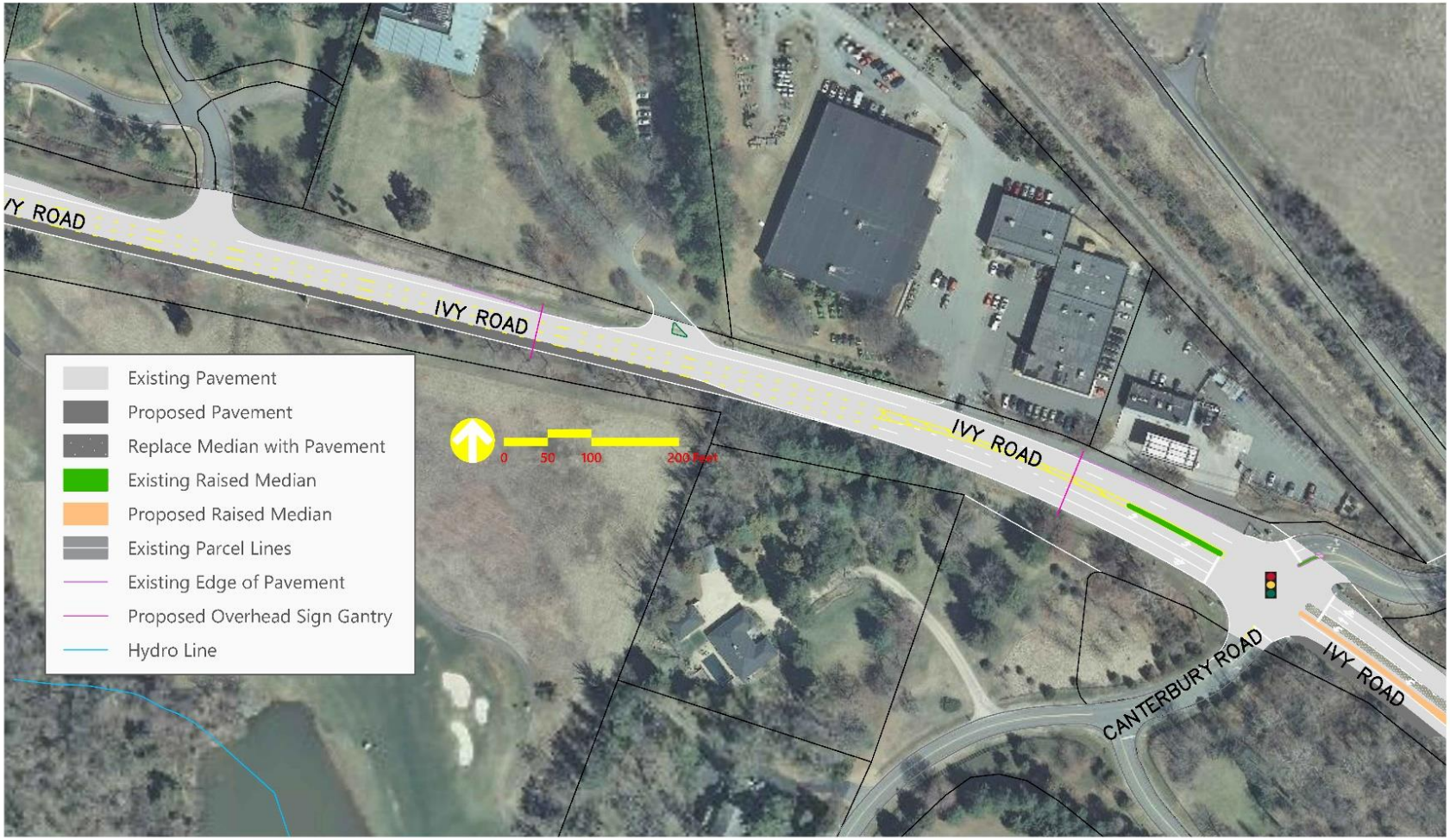



**Figure 7.70 – Four-Lane Reversible Concept (C) for Ivy Road**

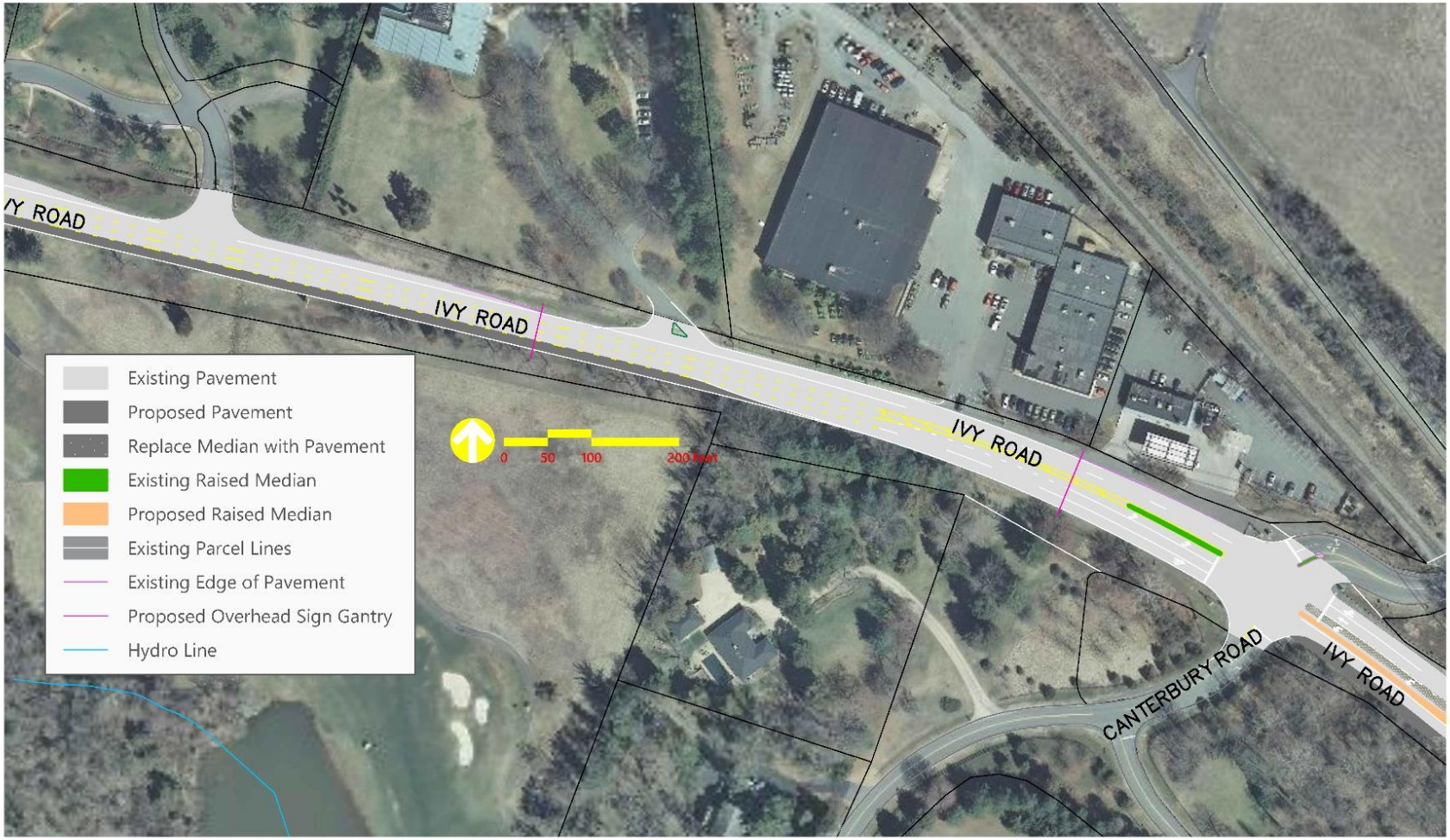
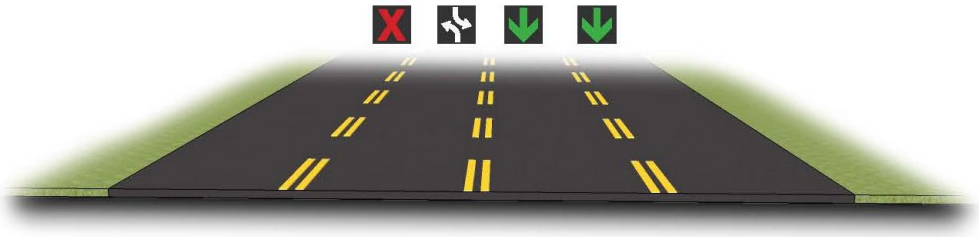
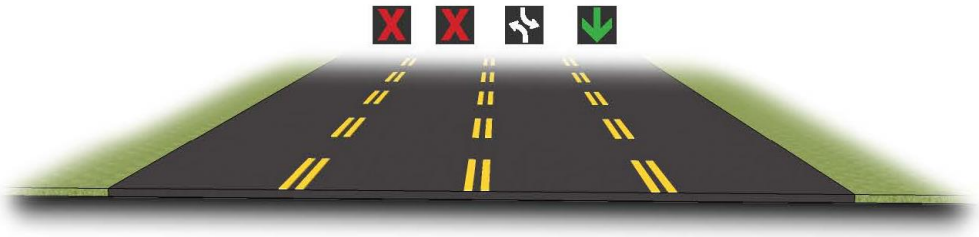



**Figure 7.71 – Four-Lane Reversible Concept (C) for Ivy Road**

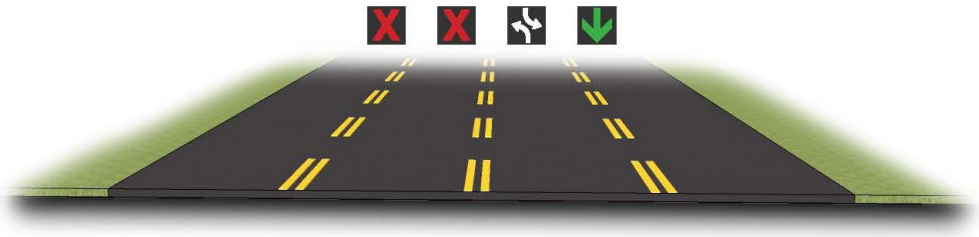

**Figure 7.72 – Four-Lane Reversible Concept (C) for Ivy Road**



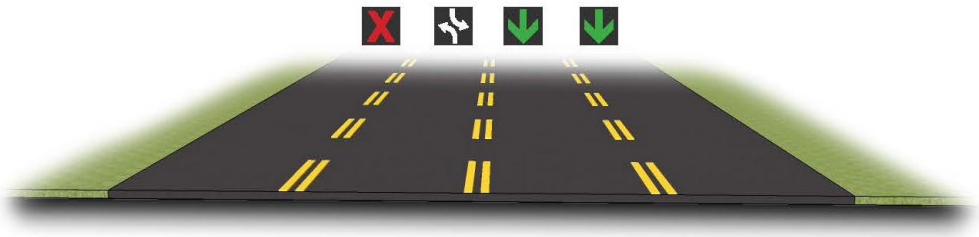
Eastbound AM Peak Hour Operations



Eastbound PM Peak Hour Operations



Westbound AM Peak Hour Operations



Westbound PM Peak Hour Operations

Figure 7.73 – Peak Hour Lane Use for Four-Lane Reversible Concept (C)

### 7.10.7 Preliminary Cost Estimate

The preliminary estimated cost for the proposed improvements is presented in **Table 7.58.** VHB developed the costs in Table 7.58 by use of VDOT's Transportation and Mobility Planning Division (TMPD) cost estimation tool.

**Table 7.58 – TMPD Cost Estimate for Improvements on Ivy Road between Farmington Drive and Canterbury Road / Old Garth Road**

| Alternative | Cost Type | Low | High |
|---|---|---|---|
| Short-term | Preliminary Engineering | $ 2,300 | $ 5,000 |
| | ROW & Utility Relocation | - | - |
| | Construction | $ 13,000 | $ 27,500 |
| | *Short-term Subtotal* | *$ 15,300* | *$ 32,500* |
| Long-term A | Preliminary Engineering | $ 78,300 | $ 78,300 |
| | ROW & Utility Relocation | $ 195,800 | $ 254,500 |
| | Construction | $ 431,000 | $ 431,000 |
| | *Long-Term A Subtotal* | *$ 705,100* | *$ 763,800* |
| Long-term B | Preliminary Engineering | $ 86,100 | $ 101,800 |
| | ROW & Utility Relocation | - | - |
| | Construction | $ 473,300 | $ 559,100 |
| | *Long-Term B Subtotal* | *$ 559,400* | *$ 660,900* |
| Long-term C | Preliminary Engineering | $ 168,900 | $ 188,200 |
| | ROW & Utility Relocation | $ 195,800 | $ 254,500 |
| | Construction | $ 923,200 | $ 940,900 |
| | *Long-Term C Subtotal* | *$ 1,287,900* | *$ 1,383,600* |
| **Total A** | **Preliminary Engineering** | **$ 81,500** | **$ 84,100** |
| | **ROW & Utility Relocation** | **$ 195,800** | **$ 254,500** |
| | **Construction** | **$ 448,200** | **$ 462,800** |
| | ***TOTAL A*** | ***$ 725,500*** | ***$ 801,400*** |
| **Total B** | **Preliminary Engineering** | **$ 89,200** | **$ 107,600** |
| | **ROW & Utility Relocation** | **-** | **-** |
| | **Construction** | **$ 490,500** | **$ 590,200** |
| | ***TOTAL B*** | ***$ 579,700*** | ***$ 697,800*** |
| **Total C** | **Preliminary Engineering** | **$ 172,100** | **$ 194,000** |
| | **ROW & Utility Relocation** | **$ 195,800** | **$ 254,500** |
| | **Construction** | **$ 940,400** | **$ 1,059,000** |
| | ***TOTAL C*** | ***$ 1,308,300*** | ***$ 1,507,500*** |

VHB further refined these costs using VDOT's Preliminary Cost Estimating Spreadsheet (PCES) and district bid averages. The total projected cost for these alternatives is presented in **Table 7.59**.

**Table 7.59 – Cost Estimate for Improvements on Ivy Road between Farmington Drive and Canterbury Road / Old Garth Road**

| Alternative | Cost Type | Cost Estimate |
|---|---|---|
| Short-term | Preliminary Engineering | $ 6,500 |
| | ROW & Utility Relocation | - |
| | Construction | $ 22,800 |
| | *Short-term Subtotal* | *$ 29,300* |
| Long-term A | Preliminary Engineering | $ 168,900 |
| | ROW & Utility Relocation | - |
| | Construction | $ 704,000 |
| | *Long-term A Subtotal* | *$ 872,900* |
| Long-term B | Preliminary Engineering | $ 278,700 |
| | ROW & Utility Relocation | $ 200,000 |
| | Construction | $ 1,161,000 |
| | *Long-term B Subtotal* | *$ 1,639,700* |
| Long-term C | Preliminary Engineering | $ 466,200 |
| | ROW & Utility Relocation | $ 200,000 |
| | Construction | $ 1,943,000 |
| | *Long-term C Subtotal* | *$ 2,609,200* |
| **Total A** | **Preliminary Engineering** | **$ 175,400** |
| | **ROW & Utility Relocation** | **-** |
| | **Construction** | **$ 710,500** |
| | ***TOTAL*** | ***$ 879,400*** |
| **Total B** | **Preliminary Engineering** | **$ 345,200** |
| | **ROW & Utility Relocation** | **$ 200,000** |
| | **Construction** | **$ 1,183,800** |
| | ***TOTAL*** | ***$ 1,669,000*** |
| **Total C** | **Preliminary Engineering** | **$ 472,700** |
| | **ROW & Utility Relocation** | **$ 200,000** |
| | **Construction** | **$ 1,965,800** |
| | ***TOTAL*** | ***$ 2,638,500*** |

VHB developed the cost estimate into a 20-year cost estimate accounting for improvement service life and annual maintenance costs, which were derived from the HSIP Safety Improvement Proposal values. The total projected 20-year cost estimate for the alternatives is presented in **Table 7.60.**

**Table 7.60 – 20-Year Cost Estimate for Improvements on Ivy Road between Farmington Drive and Canterbury Road / Old Garth Road**

| Alternative | Cost Estimate Total | 20-Yr Cost (Based on individual item service life) | Annual Maintenance | Present Value of Maintenance | Total 20-year Cost |
|---|---|---|---|---|---|
| Short-term | $ 29,300 | $ 106,800 | $ 100 | $ 1,500 | **$ 108,300** |
| Long-term A | $ 872,900 | $ 872,900 | $ 1,500 | $ 22,300 | **$ 895,200** |
| Long-term B | $ 1,639,700 | $ 1,660,000 | $ 5,250 | $ 78,100 | **$ 1,738,200** |
| Long-term C | $ 2,609,200 | $ 2,629,300 | $ 7,450 | $ 110,800 | **$ 2,740,100** |

## 7.10.8 Benefit Analysis

**Table 7.61** summarizes the 20-year safety and operational benefits of both the long-term suggested improvements. The B/C ratios utilize the 20-year total cost from Table 7.60.

**Table 7.61 - Improvement Benefits at Ivy Road and US 29 Northbound**

| Improvements | Safety Benefit | Operational Benefit | Total Benefit | B:C Ratio |
|---|---|---|---|---|
| Short-Term* | - | - | - | - |
| Long-Term A | $ 0 | $ 658,400 | **$ 658,400** | **0.7** |
| Long-Term B | $ 0 | $ 1,113,900 | **$ 1,113,900** | **0.6** |
| Long-Term C | $ 0 | $ 1,113,900 | **$ 1,113,900** | **0.4** |

* Requisite data collection and level of analysis for a Coordinated Signal System exceeded scope of this study.

Qualitatively, the reversible lanes will increase corridor capacity in the peak direction, thus reducing corridor delay. The presence and performance of a TWLTL will also dictate impact as this lane will separate left-turns from the through lanes. The operational impact of all three long-term alternatives was evaluated in HCS as the improvement in all three alternatives is additional lane capacity between intersections. While HCS reported a 50% reduction in peak direction V/C for all alternatives, HCS only reported a minor reduction in travel time along the 3700-foot analysis segment – 4% (AM) and 3% (PM) in Alternative A, and 3% (AM) and 3% (PM) in Alternatives B and C.

As discussed above, the quantitative safety benefit of these alternatives is unclear due to the novel design nature of a reversible lane segment – there are no CMFs for example. Industry common knowledge says that rear end crashes occur at higher frequency in congested conditions, so a reduction of congestion should decrease frequency of rear end crashes. There will be more gaps in traffic for right turns off minor streets due to the additional travel lane. Conversely, there is potential for the risk of head-on collisions to increase due to the reversible lane scheme, and Alternative B includes the removal of the two-way left-turn lane during the peak hours. For these qualitative reasons, neutral safety impacts were assumed – neither a decrease or increase in expected crash frequency; however, the three alternatives can be qualitatively ranked from most to least safety benefit: Alternative A, Alternative C, and last, Alternative B.

## 7.10.9 Project Schedule

VHB estimated the project schedule based on the project schedules for similar VDOT projects recently completed. **Figures 7.74-7.77** show the anticipated schedule for this hot spot's improvements.

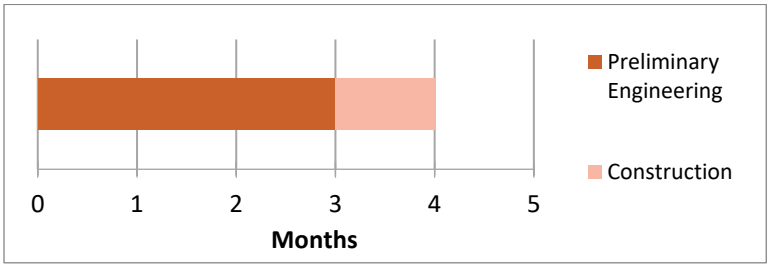



**Figure 7.74 – Short-Term Project Schedule for Ivy Road between Farmington Drive and Canterbury Road / Old Garth Road**

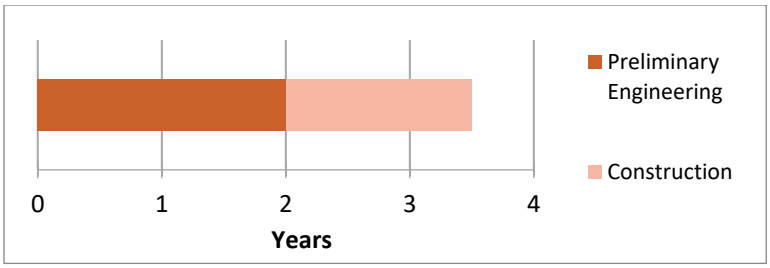



**Figure 7.75 – Long-Term A Project Schedule for Ivy Road between Farmington Drive and Canterbury Road / Old Garth Road**

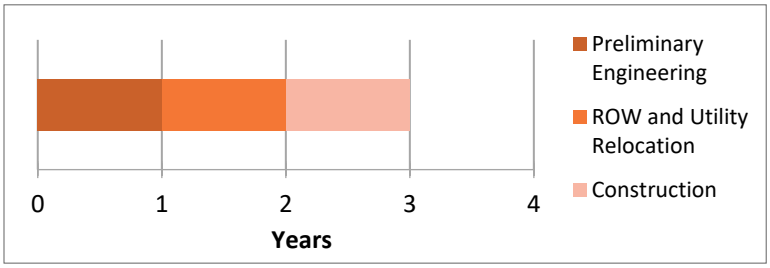



**Figure 7.76 – Long-Term B Project Schedule for Ivy Road between Farmington Drive and Canterbury Road / Old Garth Road**

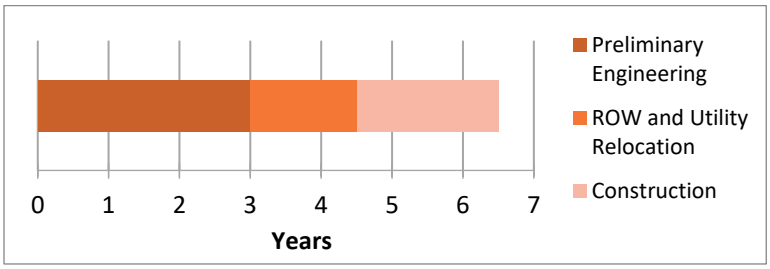



**Figure 7.77 – Long-Term C Project Schedule for Ivy Road between Farmington Drive and Canterbury Road / Old Garth Road**

## 7.11 The East Entrance of UVA Northridge Medical Park to Broomley Road

### 7.11.1 Intersection Description and Geometric Conditions

This segment is a two-lane road, divided by either a two-way left-turn lane or an exclusive left-turn lane. All entrances along this segment are given an exclusive right-turn lane and a left-turn lane. This segment is approximately 0.49 miles in length and includes two signalized intersections: one at UVA Northridge Medical Park and one at Broomley Road. This segment also includes an emergency signal to accommodate

the fire station. Ivy Road is classified as an urban minor arterial. This segment provides access to medical facilities, a fire station, religious facilities, a car dealership, and a school. This segment does not experience any significant variation in horizontal alignment; however, the segment does contain a vertical crest curve and a constant slope of 6%.

### 7.11.2 Traffic Control Devices

This segment contains two signalized intersections: Ivy Road at UVA Northridge Medical Park and Ivy Road at Broomley Road. All other entrances within this segment are assumed stop-controlled, though no stop signs are present. Ivy Road is free-flowing at all unsignalized access points.

### 7.11.3 Traffic Conditions

Ivy Road has a posted speed limit of 45 mph. The 2016 VDOT Average Annual Daily Traffic (AADT) is as follows:

- Ivy Road: **13,000 vehicles/day**

VHB conducted an analysis of the volume to capacity ratio along the corridor. In the eastbound direction, this segment experiences a volume to capacity ratio of 0.60-0.80 in the AM and 0.33-0.47 in the PM. In the westbound direction, this segment experiences a volume to capacity ratio of 0.42-0.46 in the AM and 0.87-0.91 in the PM. As shown in the volume to capacity ratios, this segment becomes congested from the commuter traffic experienced.

### 7.11.4 Crash Analysis

Crash data for a five-year study period, 2011-2015, was collected for analysis. **Table 7.61** provides a summary of crash data at the segment between the east entrance of UVA Northridge Medical Park and Broomley Road. The data *excludes* any crashes already accounted for in the intersection analyses at the main entrance for UVA Northridge Medical Park and Broomley Road.

**Table 7.62 – Crash Summary on Ivy Road between the East Entrance of UVA Northridge Medical Park and Broomley Road**

| Year | Peak | | Lighting Condition | | | | Pavement | | Type of Collision | | | | | | | | | | Severity | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AM (6-10) | PM (3-7) | Day | Dawn /Dusk | Dark - Road Lighted | Dark - Road Not Lighted | Dry | Wet | RE | A | HO | SS | SO | FI | NC | FO | D | PED | K | A | B | C | PDO | |
| 2011 | 2 | 2 | 4 | 0 | 0 | 1 | 5 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 5 | **5** |
| 2012 | 2 | 1 | 3 | 0 | 0 | 2 | 4 | 1 | 3 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 4 | **5** |
| 2013 | 1 | 2 | 3 | 0 | 0 | 0 | 1 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | **3** |
| 2014 | 1 | 1 | 1 | 0 | 0 | 2 | 3 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | **3** |
| 2015 | 1 | 2 | 3 | 1 | 0 | 1 | 3 | 2 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 3 | **5** |
| **TOT** | **7** | **8** | **14** | **1** | **0** | **6** | **16** | **5** | **15** | **2** | **0** | **0** | **1** | **0** | **1** | **0** | **1** | **1** | **1** | **0** | **3** | **0** | **17** | **21** |
| % | 33% | 38% | 67% | 5% | 0% | 29% | 76% | 24% | 71% | 10% | 0% | 0% | 5% | 0% | 5% | 0% | 5% | 5% | 5% | 0% | 14% | 0% | 81% | |

RE = Rear End; A = Angle; HO = Head On; SS = Sideswipe Same Direction; SO = Sideswipe Opposite Direction; FI = Fixed Object in Road; NC = Non-Collision; FO = Fixed Object Off Road; D = Deer; PED=Pedestrian

**Figure 7.78** presents a summary of the crashes by lighting conditions and type of collision.

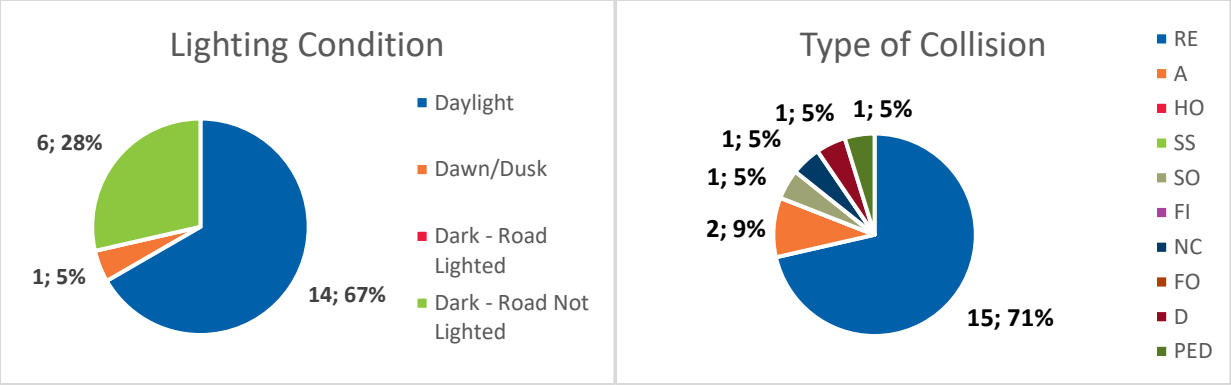



**Figure 7.78– Lighting Condition and Collision Type on Ivy Road between the East Entrance of UVA Northridge Medical Park and Broomley Road**

In the five-year study period analyzed, 15 rear end crashes occurred. Rear end crashes were by far the most common crash type. 11 of these rear end crashes were in the eastbound direction. Three of these eastbound rear end crashes involved four cars and three of them involved three cars. All but one rear end crash caused property damage only. There was one fatality in this segment, involving a pedestrian.

Both angle crashes were caused by a vehicle turning left from an entrance onto eastbound Ivy Road and colliding with a westbound vehicle on Ivy Road.

## 7.11.5 Roadway Safety Assessment

### *7.11.5.1 Safety Issues and Contributing Factors*

#### Eastbound Rear End

Eastbound rear end crashes were common at this segment, likely due to the following contributing factors:

- This segment experiences congestion. Seven of the 11 eastbound rear end crashes cite "following too close" as the driver action. This may not give the driver adequate time to respond and stop in the event of congestion or a phase change at an upstream traffic signal.
- The speed limit in the eastbound direction is reduced from 55 mph to 45 mph just west of Broomley Road. Vehicles are likely still driving 55 mph through this segment, making it even more difficult for vehicles to stop suddenly, especially when factoring in the downgrade that this segment experiences in the eastbound direction. Not only does this make speeding more likely, it also decreases the ability to stop quickly.
- This segment contains a vertical crest curve. This vertical crest curve may limit sight distance, making it more difficult to know that upstream vehicles are slowing or coming to a stop.
- Drivers may have difficulty finding the UVA Northridge Medical Park and are confused where to turn. They may significantly slow down to find their way or turn too suddenly, impeding traffic flow.

#### Westbound Rear End

Westbound rear end crashes were common at this segment, likely due to the following contributing factors:

- This segment experiences congestion. All four westbound rear end crashes cite "following too close" as the driver action. This may not give the driver adequate time to respond and stop in the event of congestion or a phase change at an upstream traffic signal.

- This segment contains a vertical crest curve. This vertical crest curve may limit sight distance, making it more difficult to know that upstream vehicles are slowing or coming to a stop.
- Drivers may have difficulty finding the UVA Northridge Medical Park and are confused where to turn. They may significantly slow down to find their way or turn too suddenly, impeding traffic flow.

#### *7.11.5.2 Suggestions and Opportunities for Improvement*

Application of a Tier 2 Systemic Template 9 is recommended at this location. Additional, segment specific improvements for the segment of Ivy Road between the East Entrance of UVA Northridge Medical Park and Broomley Road are presented in this section and summarized in **Table 7.62**. The suggested improvements are *not* listed in any order of significance. The same countermeasures will address both the eastbound and westbound rear end crashes.

EASTBOUND AND WESTBOUND REAR END

- Short-term

1. Reconfigure signal timings at Broomley Road, the UVA Northridge Medical Park entrance, Ednam Drive, and Farmington Drive to allow for better progression between these intersections.
2. Improve wayfinding signing for UVA Northridge Medical Park. Improved signing may mitigate confusion among the drivers turning into the UVA Northridge Medical Park.

**Table 7.63 – Summary of Recommended Improvements on Ivy Road between the East Entrance of UVA Northridge Medical Park and Broomley Road**

| | Safety Issue | Opportunities for Improvement |
|---|---|---|
| 1 | Eastbound and Westbound Rear End | • Reconfigure signal timings at Broomley Road, the UVA Northridge Medical Park entrance, Ednam Drive, and Farmington Drive to allow for better progression between these intersections.<br>• Improve wayfinding signing for UVA Northridge Medical Park. |

• Short-term, low-cost
○ Intermediate, medium-cost
❖ Long-term, high-cost

## 7.11.6 Preliminary Cost Estimate

The preliminary estimated cost for the proposed improvements is presented in **Table 7.63**. VHB developed the costs in Table 7.63 by use of VDOT's Transportation and Mobility Planning Division (TMPD) cost estimation tool.

**Table 7.64 – TMPD Cost Estimate for Improvements on Ivy Road between the East Entrance of UVA Northridge Medical Park and Broomley Road**

| Alternative | Cost Type | Low | High |
|---|---|---|---|
| Short-term | Preliminary Engineering | $ 9,600 | $ 14,000 |
| | ROW & Utility Relocation | - | - |
| | Construction | $ 53,500 | $ 78,300 |
| | *Short-term Subtotal* | *$ 63,100* | *$ 92,300* |
| **Total** | **Preliminary Engineering** | **$ 9,600** | **$ 14,000** |
| | **ROW & Utility Relocation** | **-** | **-** |
| | **Construction** | **$ 53,500** | **$ 78,300** |
| | ***TOTAL*** | ***$ 63,100*** | ***$ 92,300*** |

VHB further refined these costs using VDOT's Preliminary Cost Estimating Spreadsheet (PCES) and district bid averages. The total projected cost for these alternatives is presented in **Table 7.64**.

**Table 7.65 –Cost Estimate for Improvements at Ivy Road between the East Entrance of UVA Northridge Medical Park and Broomley Road**

| Alternative | Cost Type | Cost |
|---|---|---|
| **Total** | **Preliminary Engineering** | **$ 16,900** |
| | **ROW & Utility Relocation** | **-** |
| | **Construction** | **$ 59,000** |
| | ***TOTAL*** | ***$ 75,900*** |

VHB developed the cost estimate into a 20-year cost estimate accounting for improvement service life and annual maintenance costs. The service lives and annual maintenance costs were derived from the HSIP Safety Improvement Proposal values. The total projected 20-year cost estimate for the alternatives is presented in **Table 7.65.**

**Table 7.66 – 20-Year Cost Estimate for Improvements on Ivy Road between the East Entrance of UVA Northridge Medical Park and Broomley Road**

| Alternative | Cost Estimate Total | 20-Yr Cost (Based on individual item service life) | Annual Maintenance | Present Value of Maintenance | Total 20-year Cost |
|---|---|---|---|---|---|
| Short-term | $ 75,900 | $ 247,400 | - | - | **$ 247,400** |

## 7.11.7 Benefit Analysis

The requisite data collection and analysis to develop and evaluate a coordinated signal plan exceeded the scope of this STARS project; however, VHB conducted a preliminary analysis of a US 250 coordinated signal system as part of a different project in this corridor. This analysis indicated that a coordinated system from Broomley Road through the US 29 interchange would decrease peak hour travel time in the peak direction of travel by 1.2% (AM-eastbound) and by 0.6% (PM-westbound). From a safety perspective, a coordinated signal plan reduces the frequency of vehicle stops due to red lights, thus reducing the risk for rear end crashes.

### 7.11.8 Project Schedule

VHB estimated the project schedule based on the project schedules for similar VDOT projects recently completed. **Figure 7.79** shows the anticipated schedule for this hot spot's improvements.

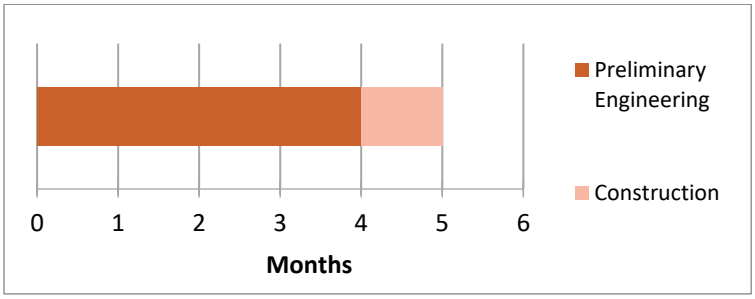



**Figure 7.79 – Short-Term Project Schedule for Ivy Road between East Entrance of UVA Northridge Medical Park and Broomley Road**

## 7.12 The C&O Railroad Overpass to Private Driveway

### 7.12.1 Intersection Description and Geometric Conditions

This segment is a two-lane, undivided road. This segment is approximately 0.17 miles in length. Ivy Road is classified as an urban minor arterial. This segment provides access to various retail businesses. This segment does not experience any significant variation in horizontal alignment. The vertical alignment is mostly level until a grade begins east of Scott's Ivy Exxon.

### 7.12.2 Traffic Control Devices

This segment is unsignalized. Access points along the segment are assumed stop-controlled, though no stop signs are placed. Ivy Road is free-flowing traffic.

### 7.12.3 Traffic Conditions

Ivy Road has a posted speed limit of 35 mph. The 2016 VDOT Average Annual Daily Traffic (AADT) is as follows:

- Ivy Road: **12,000 vehicles/day**

VHB conducted an analysis of the volume to capacity ratio along the corridor. In the eastbound direction, this segment experiences a volume to capacity ratio of 0.55 in the AM and 0.23 in the PM. In the

westbound direction, this segment experiences a volume to capacity ratio of 0.27 in the AM and 0.49 in the PM. As shown in the volume to capacity ratios, this segment does not experience heavy congestion.

### 7.12.4 Crash Analysis

Crash data for a five-year study period, 2011-2015, was collected for analysis. Located near the intersection of Ivy Depot Road, the limits of this dataset extend from the railroad overpass to the private driveway just to the east of Scott's Ivy Exxon. **Table 7.66** provides a summary of crash data at the segment between the C&O Railroad Overpass and the Private Driveway. The data excludes any crashes already accounted for at the intersection of US 250 and Ivy Depot Road.

**Table 7.67 – Crash Summary on Ivy Road between the C&O Railroad Overpass and Private Driveway**

| Year | Peak | | Lighting Condition | | | | Pavement | | Type of Collision | | | | | | | | | | Severity | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AM (6-10) | PM (3-7) | Day | Dawn /Dusk | Dark - Road Lighted | Dark - Road Not Lighted | Dry | Wet | RE | A | HO | SS | SO | FI | NC | FO | D | BI | K | A | B | C | PDO | |
| 2011 | 0 | 1 | 3 | 0 | 0 | 0 | 3 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | **3** |
| 2012 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | **3** |
| 2013 | 1 | 0 | 3 | 0 | 0 | 0 | 1 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | **3** |
| 2014 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| 2015 | 0 | 0 | 3 | 0 | 0 | 0 | 3 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | **3** |
| **TOT** | **1** | **2** | **10** | **1** | **0** | **1** | **8** | **4** | **10** | **2** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **3** | **0** | **9** | **12** |
| % | 8% | 17% | 83% | 8% | 0% | 8% | 67% | 33% | 83% | 17% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 25% | 0% | 75% | |

RE = Rear End; A = Angle; HO = Head On; SS = Sideswipe Same Direction; SO = Sideswipe Opposite Direction; FI = Fixed Object in Road; NC = Non-Collision; FO = Fixed Object Off Road; D = Deer; BI = Backed Into

**Figure 7.80** presents a summary of the crashes by lighting conditions and type of collision.

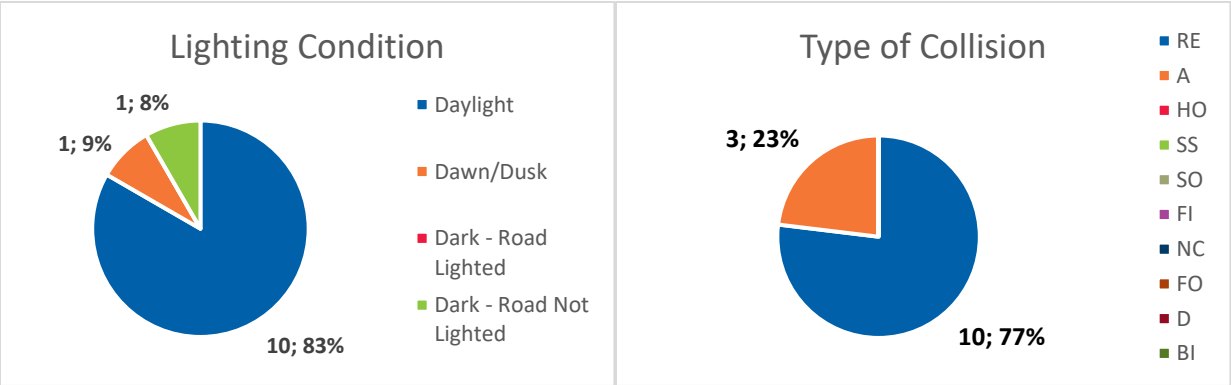



**Figure 7.80 – Lighting Condition and Collision Type on Ivy Road between the C&O Railroad Overpass and Private Driveway**

Rear end crashes were the predominant crash type, with 10 total in the five-year study period. Eight of the 10 rear end crashes were in the eastbound direction. 75% of the total crashes only caused property damage. The remaining 25% caused visible injury.

Of concern in this segment is a point located in front of Toddsbury of Ivy Convenience store, just east of the intersection of Ivy Road and Ivy Depot Road. Half of the rear end crashes occurred at this location,

including all three visible injury crashes and both westbound rear end crashes. Two of the eastbound rear end crashes at this location involved three vehicles.

## 7.12.5 Roadway Safety Assessment

### *7.12.5.1 Safety Issues and Contributing Factors*

#### EASTBOUND REAR END

Eastbound rear end crashes were common at this intersection, likely due to the following contributing factors:

- The numerous access points along this segment are very open and not well defined. This may cause drivers to stop suddenly to turn into the parking lots at a random location. Many crashes cited that the front vehicle was stopped waiting to turn left into Scott's Ivy Exxon.
- Vehicles are following too closely, not allowing enough time to stop in case of congestion or the vehicle in front of them making a sudden turn. Seven of the eight eastbound rear end crashes cite "following too close" as the driver action.
- The speed limit abruptly drops from 55 mph to 35 mph in the eastbound direction just before this segment. Drivers may not observe the new 35-mph speed limit and speed through this area. The faster speeds make it more difficult to stop in the event of congestion or a turning vehicle ahead.

#### WESTBOUND REAR END

Westbound rear end crashes were common at this intersection. The following factors may contribute to these crashes:

- The numerous access points along this segment are very open and not well defined. This may cause drivers to stop suddenly to turn into the parking lots at a random location.
- Vehicles are following too closely, not allowing enough time to stop in case of congestion or the vehicle in front of them making a sudden turn.

### *7.12.5.2 Suggestions and Opportunities for Improvement*

Application of a Tier 2 Systemic Template 11 is recommended for the curve in this segment. A Tier 2 Systemic Template 9 should be applied at all other locations in this segment. Additional, segment specific improvements for the segment of Ivy Road between the C&O Railroad Overpass and Private Driveway are presented in this section and summarized in **Table 7.67**. The suggested improvements are *not* listed in any order of significance.

#### EASTBOUND REAR END

- Short-term

1. Implementation of a 45-mph speed limit zone, as opposed to dropping directly to 35 mph from 55 mph, is in process.
2. Introduce speed control measures throughout this segment. This could include police enforcement to deter speeding, transverse rumble strips to alert drivers of the speed reduction, transverse speed bars, or a colored speed-zone entrance at the location where the speed limit becomes 35mph. (Install transverse rumble strips as a traffic calming device; all crash types; all crash severities; CMF = 0.66)

- Intermediate

    3. Install curb and gutter within right of way to designate single entry/exit points for each parking lot. (Absence of access points; all crash types; all severities; CMF = 0.56)

WESTBOUND REAR END

- Intermediate
    1. Install curb and gutter within right of way to designate single entry/exit points for each parking lot. (Absence of access points; all crash types; all severities; CMF = 0.56)

**Table 7.68 – Summary of Recommended Improvements on Ivy Road between the C&O Railroad Overpass and Private Driveway**

| Safety Issue | | Opportunities for Improvement |
|---|---|---|
| 1 | Eastbound Rear End | • Implementation of a 45-mph speed limit zone, as opposed to dropping directly to 35 mph from 55 mph, is in process.<br>• Introduce speed control measures throughout this segment. This could include police enforcement to deter speeding, transverse rumble strips to alert drivers of the speed reduction, transverse speed bars, or a colored speed-zone entrance at the location where the speed limit becomes 35mph.<br>○ Install curb and gutter within right of way to designate single entry/exit points for each parking lot. |
| 2 | Westbound Rear End | ○ Install curb and gutter within right of way to designate single entry/exit points for each parking lot. |

• Short-term, low-cost
○ Intermediate, medium-cost
❖ Long-term, high-cost

**Figure 7.81** presents the potential safety enhancement suggestions to be considered for the intersection of Ivy Road and US 29 southbound. The placement of traffic control devices, pavement markings, etc. is not to scale and not according to survey, but is an approximation intended to provide a general idea of location and concept. Designers should consider appropriate standards, policies, and right of way impacts before implementing any potential enhancements.


**Figure 7.81– Short-Term Concept on Ivy Road between the C&O Railroad Overpass and Private Driveway**

### 7.12.6 Preliminary Cost Estimate

The preliminary estimated cost for the proposed improvements is presented in **Table 7.68.** VHB developed the costs in Table 7.68 by use of VDOT's Transportation and Mobility Planning Division (TMPD) cost estimation tool.

**Table 7.69 – TMPD Cost Estimate for Improvements on Ivy Road between the C&O Railroad Overpass and Private Driveway**

| Alternative | Cost Type | Low | High |
|---|---|---|---|
| Short-term | Preliminary Engineering | $ 100 | $ 100 |
| | ROW & Utility Relocation | - | - |
| | Construction | $ 600 | $ 700 |
| | *Short-term Subtotal* | *$ 700* | *$ 800* |
| Intermediate | Preliminary Engineering | $ 3,300 | $ 3,900 |
| | ROW & Utility Relocation | - | - |
| | Construction | $ 18,400 | $ 22,400 |
| | *Short-term Subtotal* | *$ 21,700* | *$ 26,300* |
| **Total** | **Preliminary Engineering** | **$ 3,400** | **$ 4,000** |
| | **ROW & Utility Relocation** | - | - |
| | **Construction** | **$ 19,000** | **$ 23,100** |
| | ***TOTAL*** | ***$ 22,400*** | ***$ 27,100*** |

VHB further refined these costs using VDOT's Preliminary Cost Estimating Spreadsheet (PCES) and district bid averages. The total projected cost for these alternatives is presented in **Table 7.69.**

**Table 7.70 – Cost Estimate for Improvements on Ivy Road between the C&O Railroad Overpass and Private Driveway**

| Alternative | Cost Type | Cost Estimate |
|---|---|---|
| **Total** | **Preliminary Engineering** | **$ 6,900** |
| | **ROW & Utility Relocation** | - |
| | **Construction** | **$ 29,000** |
| | ***TOTAL*** | ***$ 35,900*** |

VHB developed the cost estimate into a 20-year cost estimate accounting for improvement service life and annual maintenance costs. The service lives and annual maintenance costs were derived from the HSIP Safety Improvement Proposal values. The total projected 20-year cost estimate for the alternatives is presented in **Table 7.70.**

**Table 7.71 – 20-Year Cost Estimate for Improvements on Ivy Road between the C&O Railroad Overpass and Private Driveway**

| Alternative | Cost Estimate Total | 20-Yr Cost (Based on individual item service life) | Annual Maintenance | Present Value of Maintenance | Total 20-year Cost |
|---|---|---|---|---|---|
| Short-term | $ 36,000 | $ 36,000 | - | - | **$ 36,000** |

### 7.12.7 Benefit Analysis

**Table 7.71** summarizes the 20-year safety and operational benefits of both the short-term and long-term suggested improvements. The B/C ratio utilizes the 20-year total cost from Table 7.70.

**Table 7.72 - Improvement Benefits on Ivy Road between the C&O Railroad Overpass and Private Driveway**

| Improvements | Safety Benefit | Operational Benefit | Total Benefit | B:C Ratio |
|---|---|---|---|---|
| Short-term | $ 358,000 | - | **$ 358,000** | **9.9** |

### 7.12.8 Project Schedule

VHB estimated the project schedule based on the project schedules for similar VDOT projects recently completed. **Figure 7.82** shows the anticipated schedule for this hot spot's improvements.

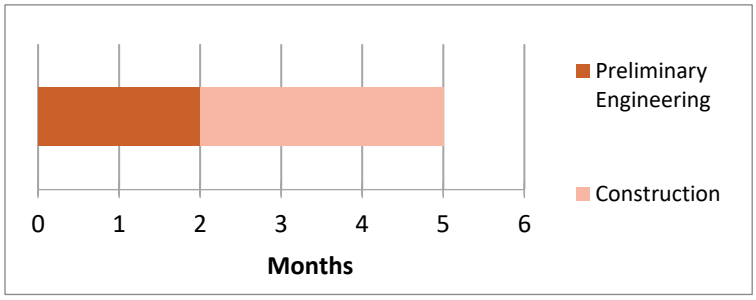



**Figure 7.82 – Short-Term Project Schedule for Ivy Road between the C&O Railroad Overpass and Private Driveway**

# 8 ADDITIONAL CORRIDOR PROJECTS

Ivy Road is both a Corridor of Statewide Significance (CoSS) and a Mobility Enhancement Segment (MES). VDOT's goal on these corridors is to preserve and enhance the capacity of the Arterial Preservation Network while ensuring:

- Mainline through traffic is served with priority
- Access points and traffic control do not degrade travel speed and safety
- Safety is improved

These goals are not limited to the hot spots on the corridor. Therefore, to realize these goals to the fullest, some improvements are recommended beyond the hot spot intersection improvements that promote the flow of traffic along the mainline (Ivy Road).

## 8.1 Ivy Road and Ednam Drive Continuous Green-T

### 8.1.1 Existing Conditions Assessment

#### *8.1.1.1 Safety Issues and Contributing Factors*

Though the intersection of Ivy Road and Ednam Drive was not identified as one of the 12 hot spot locations, it is within the segment that qualifies as a Mobility Enhancement Segment. This intersection experiences mild delay. Additionally, the close spacing of this intersection with the Farmington Drive intersection (approximately 525' east) presents operational deficiencies for the Ivy Road traffic.

#### *8.1.1.2 Suggestions and Opportunities for Improvement*

The recommended long-term improvement is a continuous green-T intersection. The continuous green-T concept at this location will maintain all existing movements; however, the Ivy Road westbound through traffic will no longer operate under signal control. A barrier will be placed between the westbound through movement and the rest of the intersection, effectively creating a bypass lane separated from the control of the traffic signal. The remaining movements will operate as they do under existing conditions, apart from the northbound left-turn from Ednam Drive. The Ednam Drive northbound left-turning vehicles will proceed through the signalized intersection as normal but will then merge into the Ivy Road westbound through traffic downstream of the intersection.

This improvement has both safety and operational benefits. In addition to eliminating the angle conflict point between the westbound through vehicles and the northbound left vehicles, this improvement reduces the traffic signal operation to only two-phases. The two-phase operation allows the traffic signal to progress traffic more efficiently than the existing three-phase operation.

**Figure 8.1** presents the potential safety enhancement suggestions to be considered for the intersection of Ivy Road and Ednam Drive. The placement of traffic control devices, pavement markings, etc. is not to scale and not according to survey, but is an approximation intended to provide a general idea of location and concept. Designers should consider appropriate standards, policies, and right of way impacts before implementing any potential enhancements.


**Figure 8.1 – Long-Term Alternative for Ivy Road and Ednam Drive**

#### *8.1.1.3 Traffic Operations Analysis*

- **Long-Term Improvements**
  - With the continuous green-T concept, all approaches experience a reduction in delay, and Ednam drive is expected to operate at LOS A in both the AM and PM peak hours.
  - The 2025 Build condition offers a 15.4 second delay in reduction during the AM peak hour and a 4.8 second reduction in delay in the PM peak hour. The mainline through traffic on Ivy Road experiences little to no delay in the continuous green-T concept and operates at LOS A for both peaks. The 2025 No-Build and 2025 Build comparison is presented in **Table 8.1**. Since there is no growth anticipated in this segment of the corridor, the Existing conditions mimic the 2025 No-Build conditions, so there is not a separate comparison to the existing conditions.

**Table 8.1 - Operational Performance of Improvements to Ivy Road and Ednam Drive**

| | | 2025 No-Build Conditions | | | | | | 2025 Build Conditions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Delay (s/veh) | LOS | Delay (s/veh) | LOS | Int. Delay (s) | Int. LOS | Delay (s/veh) | LOS | Delay (s/veh) | LOS | Int. Delay (s) | Int. LOS |
| **Ivy Road at Ednam Drive** | | | | | | | | | | | | | |
| Ivy Road EB | Through | 21.0/15.0 | C/B | 22.4/14.7 | C/B | **21.7/13.0** | **C/B** | 4.1/6.1 | A/A | 3.9/6.0 | A/A | **6.3/8.2** | **A/A** |
| | Right | 6.4/8.8 | A/A | | | | | 0.7/2.7 | A/A | | | | |
| Ivy Road WB | Left | 71.4/1.5 | E/A | 18.5/4.3 | B/A | | | 8.9/5.3 | A/A | 2.2/2.5 | A/A | | |
| | Through | 1.4/4.7 | A/A | | | | | 0.1/2.1 | A/A | | | | |
| Ednam Drive NB | Left | 50.4/48.5 | D/D | 50.3/47.5 | D/D | | | 50.4/40.9 | D/D | 50.3/40.0 | D/D | | |
| | Right | 50.3/47.2 | D/D | | | | | 50.3/39.8 | D/D | | | | |

### 8.1.2 Preliminary Cost Estimate

The preliminary estimated cost for the proposed improvements is presented in **Table 8.2**. VHB developed the costs in Table 8.2 by use of VDOT's Preliminary Cost Estimating Spreadsheet (PCES) and district bid averages.

**Table 8.2 – Cost Estimate for Improvements at Ivy Road and Ednam Drive**

| Alternative | Cost Type | Cost Estimate |
|---|---|---|
| **Total** | **Preliminary Engineering** | **$ 50,400** |
| | **ROW & Utility Relocation** | **-** |
| | **Construction** | **$ 210,000** |
| | ***TOTAL*** | ***$ 260,400*** |

VHB developed the cost estimate into a 20-year cost estimate accounting for improvement service life and annual maintenance costs, which were derived from the HSIP Safety Improvement Proposal values. The total projected 20-year cost estimate for the alternatives is presented in **Table 8.3.**

Table 8.3 – 20-Year Cost Estimate for Improvements at Ivy Road and Ednam Drive

| Alternative | Cost Estimate Total | 20-Yr Cost (Based on individual item service life) | Annual Maintenance | Present Value of Maintenance | Total 20-year Cost |
|---|---|---|---|---|---|
| Long-term | $ 260,400 | $ 260,400 | $ 20 | $ 300 | **$ 260,700** |

### 8.1.3 Benefit Analysis

**Table 8.4** summarizes the 20-year safety and operational benefits of the continuous green-T. The B/C ratio utilizes the 20-year total cost from Table 8.3.

Table 8.4 - Improvement Benefits at Ivy Road and Ednam Drive

| Improvements | Safety Benefit | Operational Benefit | Total Benefit | B:C Ratio |
|---|---|---|---|---|
| Continuous Green-T | $ 8,500 | $ 7,397,400 | **$ 7,405,900** | **28.4** |

### 8.1.4 Project Schedule

VHB estimated the project schedule based on the project schedules for similar VDOT projects recently completed. **Figure 8.2** shows the anticipated schedule for this hot spot's improvements.

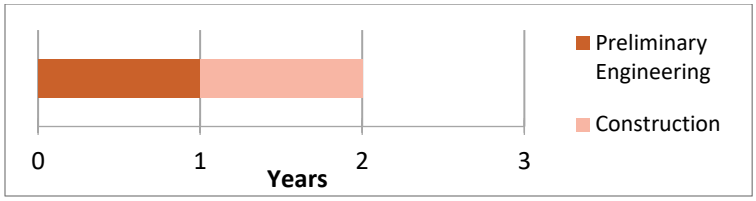



Figure 8.2 – Long-Term Project Schedule for Ivy Road and Ednam Drive

# 9 PROJECT PRIORITIZATION RECOMMENDATION

**Table 9.1** summarizes the recommended project prioritization for each individual improvement project. VHB evaluated each proposed project for its total 20-year safety and operational benefit, total 20-year cost, and Benefit to Cost (B/C) Ratio. Additionally, each project impact was categorized as green, yellow, or red based on their anticipated right of way, safety, and operational impacts. For the safety and operational impacts, the projects categorized as green present a high benefit, and the projects categorized as red show minimal benefit, but not necessarily a negative benefit.

**Table 9.1 – Improvement Prioritization Summary**

| Improvement | 20-year Benefit | 20-year Cost | B/C Ratio | ROW Impacts* | Safety Impacts** | Operational Impacts** |
|---|---|---|---|---|---|---|
| Three Notch'd Road | $ 2,234,300 | $ 135,800 | 16.5 | | | |
| Gillums Ridge Road (Short-term) | $ 368,900 | $ 14,200 | 26.0 | | | |
| Gillums Ridge Road (Long-term A) | $ 328,700 | $ 454,300 | 0.7 | | | |
| Gillums Ridge Road (Long-term B) | $ 848,400 | $ 211,000 | 4.0 | | | |
| Tilman Road (Short-term) | $ 7,589,600 | $ 517,100 | 14.7 | | | |
| Tilman Road (Long-term) | $ 428,100 | $ 1,253,500 | 0.3 | | | |
| Owensville Road (Short-term) | $ 138,300 | $ 2,600 | 53.2 | | | |
| Owensville Road (Long-term A) | $ 429,300 | $ 286,500 | 1.5 | | | |
| Owensville Road (Long-term B) | $ 3,218,600 | $ 2,444,500 | 1.3 | | | |
| Broomley Road | $ 1,921,000 | $ 137,700 | 14.0 | | | |
| Canterbury Road / Old Garth Road (Short-term) | $ 1,952,100 | $ 103,300 | 18.9 | | | |
| Canterbury Road / Old Garth Road (Long-term) | $ 10,156,300 | $ 885,200 | 11.5 | | | |
| US 29 SB (Short-term) | $ 8,995,000 | $ 78,700 | 114.3 | | | |
| US 29 SB (Long-term A) | $ 6,865,800 | $ 245,300 | 28.0 | | | |
| US 29 SB (Long-term B) | $ 12,352,400 | $ 351,000 | 35.2 | | | |
| US 29 NB (Short-term) | $ 6,123,000 | $ 96,700 | 63.3 | | | |
| US 29 NB (Long-term) | $ 6,605,300 | $ 519,300 | 12.7 | | | |
| Farmington/Canterbury Segment (Short-term) | TBD*** | $ 108,300 | TBD*** | | TBD | TBD |
| Farmington/Canterbury Segment (Long-term A) | $ 1,162,200 | $ 895,200 | 1.3 | | | |
| Farmington/Canterbury Segment (Long-term B) | $ 1,113,900 | $ 1,738,200 | 0.6 | | | |
| Farmington/Canterbury Segment (Long-term C) | $ 1,113,900 | $ 2,740,100 | 0.4 | | | |
| UVA Northridge Segment | TBD*** | $ 247,400 | TBD*** | | TBD | TBD |
| Ivy Depot Segment | $ 358,000 | $ 36,000 | 9.9 | | | |
| Ednam Drive Green-T | $ 7,405,900 | $ 260,700 | 28.4 | | | |

*Green in the ROW impact category represents minimal to no additional ROW needed. Red in the ROW impact category represents a large amount of additional ROW needed.
**Red in the Safety/Operational impact categories represents less than $200,000 20-year benefit. Yellow represents between $200,000 and $500,000 20-year benefit. Green represents greater than $500,000 20-year benefit.
*** TBD: Requisite data collection and level of analysis for a Coordinated Signal System exceeded scope of this study. See narrative in report regarding US 250 coordinated signal system quantitative benefit calculated in previous study.

## 9.1 Project Funding Sources

To realize the full benefits of these various improvement strategies, a variety of funding sources will need to be identified. Many of the improvement strategies could be funded through several different mechanisms, and are listed accordingly in the following sections. In multiple cases, there are improvement strategies described above which should be grouped as a single project. These improvements are very similar in nature, and it would be cost-effective to perform multiple improvements at different locations as part of a single project.

### 9.1.1 Maintenance Funds

VDOT maintenance funds can be utilized to handle low-cost, easy to implement improvements such as additional signing, transverse rumble strips, installing delineators, raised island work, and trimming vegetation. The short-term improvements at the following locations could be partially or fully completed using maintenance funds. Some of these improvements can also be rolled into existing maintenance work such as the next paving cycle.

- Three Notch'd Road (temporary before construction of funded roundabout)
- Gillums Ridge Road Short-Term
- Owensville Road Short-Term
- Ivy Depot Segment
- Broomley Road
- Canterbury Road / Old Garth Road Short-Term
- US 29 Southbound Short-Term
- US 29 Northbound Short-Term
- Systemic templates application throughout corridor

### 9.1.2 HSIP (Highway Safety Improvement Program) Funds

#### *9.1.2.1 General HSIP Funds*

HSIP funds can be utilized to fund improvements that have a safety benefit/cost ratio greater than 1.0. Improvements eligible for HSIP funds include all the improvements eligible for maintenance funds plus the following improvement concepts:

- Gillums Ridge Road Long-Term B (Note: Long-Term A and B are exclusive improvements)
- Tilman Road Short-Term
- Canterbury Road / Old Garth Road Long-Term

While these discrete intersection improvements are all individually eligible for HSIP funds, there are two natural groupings of improvements that will likely reduce overall cost due to savings in mobilization and equipment. Through the rural portion of the corridor, the improvements are largely similar in design and implementation. For this reason, the improvements could be grouped together as one HSIP project. Specifically, this group of improvements includes:

- Gillums Ridge Road Short-Term
- Tilman Road Short-Term
- Owensville Road Short-Term
- Ivy Depot Segment

Through the suburban portion of the corridor, the improvements are also similar in nature. The improvements largely consist of additional signing for rerouting traffic, traffic signal optimization and modification, signal head modifications, and movement delineation. For this reason, the improvements could be grouped together as a second HSIP project. Specifically, these short-term improvements include:

- Broomley Road
- Canterbury Road / Old Garth Road Short-Term
- US 29 SB Short-Term
- US 29 NB Short-Term

**Table 9.2** presents the anticipated 20-year safety benefit, 20-year cost, and safety benefit / cost ratio of the two HSIP Projects.

**Table 9.2 - Estimated Benefit and Cost for HSIP Projects**

| HSIP Project | Total 20-year Safety Benefit | Total 20-year Cost | Total Safety B/C Ratio |
|---|---|---|---|
| HSIP Project A | $ 8,454,800 | $ 569,900 | 14.8 |
| HSIP Project B | $ 2,112,300 | $ 416,400 | 5.1 |

#### *9.1.2.2 High Risk Rural Roads HSIP Funds*

High Risk Rural Roads funds are a subset of HSIP funds, and can be utilized in rural areas of the state where a proposed improvement has a safety benefit/cost ratio exceeding 1.0. All the improvements west of Owensville Road (except Gillums Ridge Road Long-Term A) are eligible for this funding source.

#### *9.1.2.3 Systemic Treatment HSIP Funds*

This special pool of HSIP funds can only be applied to systemic treatment projects. The systemic templates applied to the corridor are eligible for this funding source.

### 9.1.3 CMAQ (Congestion Mitigation and Air Quality) Funds

Improvements with an operational benefit/cost ratio greater than 1.0 are eligible for CMAQ funds. The list of CMAQ eligible improvement concepts includes:

- Broomley Road
- Canterbury Road / Old Garth Road Short-Term
- US 29 Southbound Short-Term
- US 29 Northbound Short-Term
- Owensville Road Long-Term B (Note: Long-Term A and B are exclusive improvements)
- Ednam Drive Green-T
- Canterbury Road / Old Garth Road Long-Term
- US 29 Southbound Long-Term
- US 29 Northbound Long-Term

### 9.1.4 Smart Scale Funds

Smart Scale applications are scored on a series of weighted measures that vary based on the application's location within the state; the Ivy Road study corridor is located within the Charlottesville-Albemarle Metropolitan Planning Organization – an MPO located in scoring measure Category B. The scoring factors and associated weights for a Category B application are as follows: Congestion Mitigation (15%), Economic Development (20%), Accessibility (25%), Safety (20%), Environmental Quality (10%), and Land Use (10%). **Table 9.4** qualitatively indicates how each of the proposed Smart Scale projects score in the six measures.

#### *9.1.4.1 Corridor-Long Safety Improvement Project – Smart Scale Project A*

The first set of improvements proposed to be grouped as a Smart Scale project is the combination of HSIP Projects A and B. This grouping represents an alternative funding source than HSIP, and Smart Scale funding always the operational benefits of the improvements to be considered in the funding scoring process. **Table 9.3** presents the anticipated 20-year benefit, 20-year cost, and benefit/cost ratio of Smart Scale Project A.

#### *9.1.4.2 Rural Neighborhoods Access Project – Smart Scale Project B*

The second proposed Smart Scale project includes Gillums Ridge Road Long-Term A and Tilman Road Short-Term. Both improvements are in the rural, western portion of the Ivy Road study corridor, and both will improve safety and operations for residents accessing the neighborhoods on these two side streets. Gillums Ridge Road Long Term A alleviates the westbound rear end crash issue by providing a left turn lane while not adding significant delay to the westbound left movement (which Long Term B concept does). Tilman Road Short-Term addresses the existing safety and citizen concerns by improving sight distance, reducing intersection crossing distance, and preventing through vehicles from using the right-turn lane; Tilman Road Long-Term addresses the safety concern but does not address citizen issue of turning left from Tilman onto Ivy. **Table 9.3** presents the anticipated 20-year benefit, 20-year cost, and benefit/cost ratio of Smart Scale Project B.

#### *9.1.4.3 US 29 Bypass Access Project – Smart Scale Project C*

This project includes all the long-term improvement strategies that influence traffic flow at the US 29 Bypass interchange; the western limits of this project were identified as Farmington Drive where the eastbound cross-section widens to two lanes. Farmington/Canterbury Segment Long-Term C, Canterbury Road / Old Garth Road Long-Term, US 29 SB Long-Term B, and US 29 NB Long-Term are thus grouped into this single project to reduce congestion approaching the interchange. Concept C was included for the Farmington/Canterbury Segment as the most conservative cost estimate – Concepts A or B could be substituted for less cost but also less improvement benefit. **Table 9.3** presents the anticipated 20-year benefit, 20-year cost, and benefit/cost ratio of Smart Scale Project C.

#### *9.1.4.4 Ivy Road Progression Project – Smart Scale Project D*

The fourth set of improvements grouped for Smart Scale application improve traffic conditions in the center third of the Ivy Road study corridor. These improvements include Owensville Road Long-Term B, Ednam Drive Green-T, and signal coordination from Broomley Road through Farmington Drive. Owensville Long-Term B (roundabout) was included due to its much greater benefit than Long-Term A (eastbound left-turn lane); however, Long-Term A could be substituted due its fewer construction impacts. **Table 9.3** presents the anticipated 20-year benefit, 20-year cost, and benefit/cost ratio of Smart Scale Project D.

Table 9.3 - Estimated Benefit and Cost for Smart Scale Projects

| Smart Scale Project | Total 20-year Benefit | Total 20-year Cost | Total B/C Ratio |
|---|---|---|---|
| Smart Scale Project A | $ 27,466,800 | $ 986,300 | 27.8 |
| Smart Scale Project B | $ 7,918,300 | $ 971,400 | 8.2 |
| Smart Scale Project C | $ 30,227,900 | $ 4,495,600 | 6.7 |
| Smart Scale Project D | $ 15,888,500 | $ 2,805,200 | 5.7 |

Table 9.4 – Qualitative Smart Scale Project Scoring

| | Congestion Mitigation | Economic Development | Accessibility | Safety | Environmental Quality | Land Use |
|---|---|---|---|---|---|---|
| Smart Scale Project A | High | Medium | Medium | High | Medium | Medium |
| Smart Scale Project B | Low | Medium | Low | High | Low | Medium |
| Smart Scale Project C | High | High | Medium | Low | Medium | High |
| Smart Scale Project D | High | High | Low | Low | Low | Medium |

## 9.2 Project Prioritization

VHB considered each project and their benefits, costs, benefit/cost ratios, and relative schedules to prioritize the projects. VHB recommends the following prioritization of projects:

1. Smart Scale Project A
2. HSIP Project A (subset of Smart Scale Project A if completed separately)
3. Smart Scale Project B
4. Smart Scale Project C
5. Smart Scale Project D
6. HSIP Project B (subset of Smart Scale Project A if completed separately)

# 10 Conclusion

VHB conducted a safety and operational analysis of Ivy Road between Three Notch'd Road and the US 29 interchange. This analysis included crash analysis, an RSA-like field visit, and operational analyses via Synchro and HCS 2010. This corridor experiences moderate safety and operational deficiencies. After performing the analyses, VHB identified nine hot spot intersections and three hot spot segments. VHB presented short-term and long-term improvements for each of these hot spots. These improvements focus on both safety and operations. In addition to the spot-specific treatments, VHB also recommended the implementation of systemic templates for improvements.

The intersection geometry at Ivy Road / Rockfish Gap Turnpike and Three Notch'd Road leads to driver confusion and conflicts. Through the High Risk Rural Roads program, VDOT has received funding to construct a roundabout at this location. The roundabout will improve both safety and operations for this intersection by eliminating conflict points and lowering speeds.

Gillums Ridge Road experienced numerous westbound rear end crashes. These crashes were likely due to left-turning vehicles slowing or stopping in the through lanes and vehicles following too closely. The

proposed short-term improvements (i.e., transverse rumble strips and signs) aim to alert drivers of the possible turning vehicles. In the long-term, a westbound left-turn lane is proposed to separate the left-turning traffic from the through traffic. This intersection also experienced deer crashes due to deer entering the roadway at the opening in the guardrail. To deter deer from crossing at this location, gates are proposed to effectively close the guardrail openings.

Tilman Road presents unique safety issues when drivers use the right-turn only lane as a through lane to avoid cars queued in the shared left-turn/through lane waiting to turn left. These vehicles, approaching at high speeds, hit a longitudinal "V" dip in the roadway caused by the tie-in of the northbound Tilman Road approach. The eastbound right shoulder is unforgiving and does not allow the vehicles to properly recover. Vehicles then overcorrect, cross the roadway, and run off the road. To mitigate this in the short-term, improvements are proposed to discourage the use of the right-turn lane as a through/passing lane. VHB also proposed widening of the shoulder to aid the errant vehicles in recovery. A long-term solution is to install dedicated left-turn lanes to separate the left-turning traffic from the through traffic.

Owensville Road experiences multiple rear end crashes, likely due to the speeding through this segment and the lack of an eastbound left-turn lane. Speed control measures (i.e., transverse rumble strips) are proposed for this intersection. Two long-term solutions are presented. The first is the installation of an eastbound left-turn lane; the second aligns Owensville Road and Morgantown Road into a single roundabout intersection. Both alternatives are expected to positively impact safety and operations at this intersection.

Speeding remains an issue to the east of Owensville road as well. When combined with the numerous open access points in this segment, conflicts arise. While the transverse rumble strips placed at Owensville Road should mitigate the speeding, it is also proposed to install curb within right of way on Ivy Road to designate one entry point for each parking lot.

The area of Broomley Road and the UVA Northridge Medical Park experienced multiple rear end crashes. Some of these crashes may be attributed to the presence of a signal and others to lack of wayfinding for the UVA Northridge Medical Park. The improvements for this section are intended to provide more warning/guidance for the drivers as well as optimize the traffic signal timings to promote the progression of traffic.

The eastern portion of the corridor (i.e., east of Farmington Drive) experiences the highest operational deficiencies. VHB has proposed a few different alternatives for this segment. Short-term improvements include various phasing and timing changes. There are several long-term alternatives to increase capacity, including widening of the roadway and installation of a reversible lane. Due to the lengths and proximity of the existing turn bays, minimal widening would be needed to provide an additional through lane in each direction. The reversible lane would allow for additional capacity in the eastbound direction in the morning and westbound direction in the afternoon. Increasing the capacity of this segment, thus improving the operations, is expected to also increase the safety of this intersection as many conflicts likely occurred due to the congestion.

The interchange with Ivy Road and US 29 experiences moderate delay. In addition to other short-term improvements, a proposed alternative at this location is to reroute left-turning traffic away from this interchange to the existing on/off ramp on Old Ivy Road / Old Garth Road. By redirecting various left-turn

movements, the signal phasing and timing can be streamlined to better serve Ivy Road. This will also mitigate the number and severity of angle crashes experienced at these intersections.

The improvements proposed are intended to increase both operations and safety of this corridor.