Zion Crossroads
Small Area Study

TECH MEMO

EXISTING AND FUTURE NO-BUILD CONDITIONS

JULY 2020

VDOT Planning

CONTENTS

1.0 INTRODUCTION

Kittelson and Associates, Inc. (Kittelson) prepared this report to document the existing and future operational performance and safety for a Small Area Plan in the Zion Crossroads area along US 250 and US 15. This area extends along US 15 from Sommerfield Drive to Starlite Park and along US 250 from Troy Road (Route 631)/Zion Station Court to Poindexter Road (Route 613) spanning both Fluvanna and Louisa Counties, as shown in Figure 1. The Zion Crossroads area continues to experience population growth and changes to land use and as such has experienced increasing safety and operational challenges.

The general topography for the study site can best be described as level to rolling-hill type terrain. Zoning across the corridors includes the following classes:

- Agricultural
- Business
- Commercial
- Industrial
- Industrial, Limited
- Planned Unit Development
- Resort Development (Reference 1,2).

The study intersections, time periods for analysis, and scope of this project were selected through discussions with a stakeholder group comprised of representatives from VDOT, Fluvanna County, Louisa County, and the Thomas Jefferson Planning District Commission (TJPDC) [hereby referred to as the Stakeholder Group].

The following analyses have been conducted:

- Year 2019 existing land use and transportation system conditions along the study corridors,
- Forecast year 2040 no-build traffic conditions during the weekday a.m., weekday p.m. and Saturday peak periods including in-process/approved developments and regional growth,
- Conclusions and recommendations.

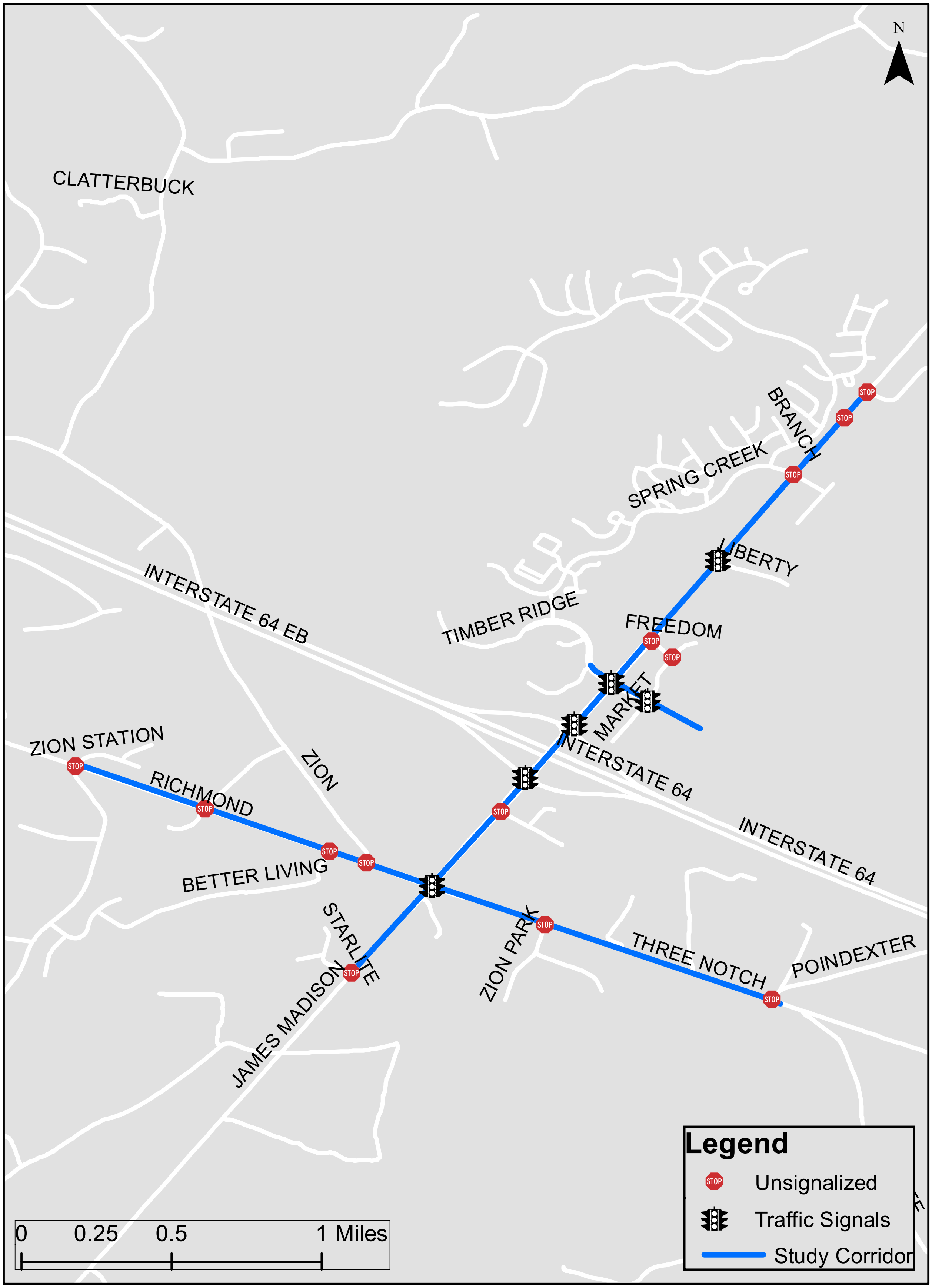


Figure 1: Study Extents - Zion Crossroads Study
(Louisa and Fluvanna County)

2.0 TRAFFIC

This section summarizes the approach and findings for the operational analysis evaluating the existing (2019) and year 2040 no-build traffic conditions. A discussion of the existing transportation infrastructure is also provided.

2.1 Existing Conditions

The existing conditions analysis identifies the site conditions and current operational and geometric characteristics of the roadways within the study area. These conditions will be compared with year 2040 no-build traffic conditions in the following section.

Through coordination with the Stakeholder Group, the following 19 study intersections in the Zions Crossroads area were identified:

1. Sommerfield Business Park/US 15
2. Spring Creek Parkway/US 15
3. Liberty Trail/US 15
4. Freedom Trail/US 15
5. Freedom Drive/US 15
6. Spring Creek Parkway/Camp Creek Parkway/US 15
7. Spring Creek Parkway/Wood Ridge Terrace
8. Camp Creek Parkway/Market Street
9. North DDI Ramp Terminal/US 15
10. South DDI Ramp Terminal/US 15
11. Crossing Pointe Drive/US 15
12. US 250/US 15
13. Starlite Park/US 15
14. Troy Road (Route 631) /Zion Station Ct /US 250
15. Hunters Branch Road (Route 689)/US 250/Edgecomb Road
16. Better Living Drive/US 250
17. Zion Road (Route 615)/US 250
18. Zion Park Road/US 250
19. Poindexter Road (Route 613)/US 250

IN THIS SECTION>>

- Data and approach used for the study corridor analysis
- Key insights into study corridor existing operations

KEY TERMS>>

- **Delay analysis –** Identifying the additional time experienced by drivers at intersections that results from the presence of traffic control and conflicting traffic.
- **Level of service analysis –** Evaluating the quality of traffic service associated with the traffic conditions.
- **Volume-to-capacity ratio analysis –** Assessing the ability of an intersection to accommodate the demand given the roadway conditions.

At that time, Kittelson collected information regarding site conditions, adjacent land uses, existing traffic operations, and transportation facilities in the study area.

2.1.1 Transportation Facilities

Table 1 summarizes the primary transportation facilities in the site vicinity. Figure 2 shows the existing lane configurations and traffic control devices at the study intersections. While no on-street parking was observed on the roadways, parked vehicles were observed within a few feet of the travelled way along business frontages at several locations along the US 15 and US 250 corridors. Current levels of access management are discussed further in Section 2.1.4.

2.1.2 Pedestrian and Bicycle Facilities

Field observations and traffic counts taken in the site vicinity revealed low levels of pedestrian and bicycle activity in this area. Sidewalks are present along the Camp Creek Parkway and Market Street intersection. These sidewalks are used to connect the retail and commercial spaces present along this intersection. Outside of this one location, no pedestrian crossing infrastructure (e.g., crosswalks, pedestrian signals) are present at any of the other study intersections. No protected bicycle infrastructure is present along the corridors.

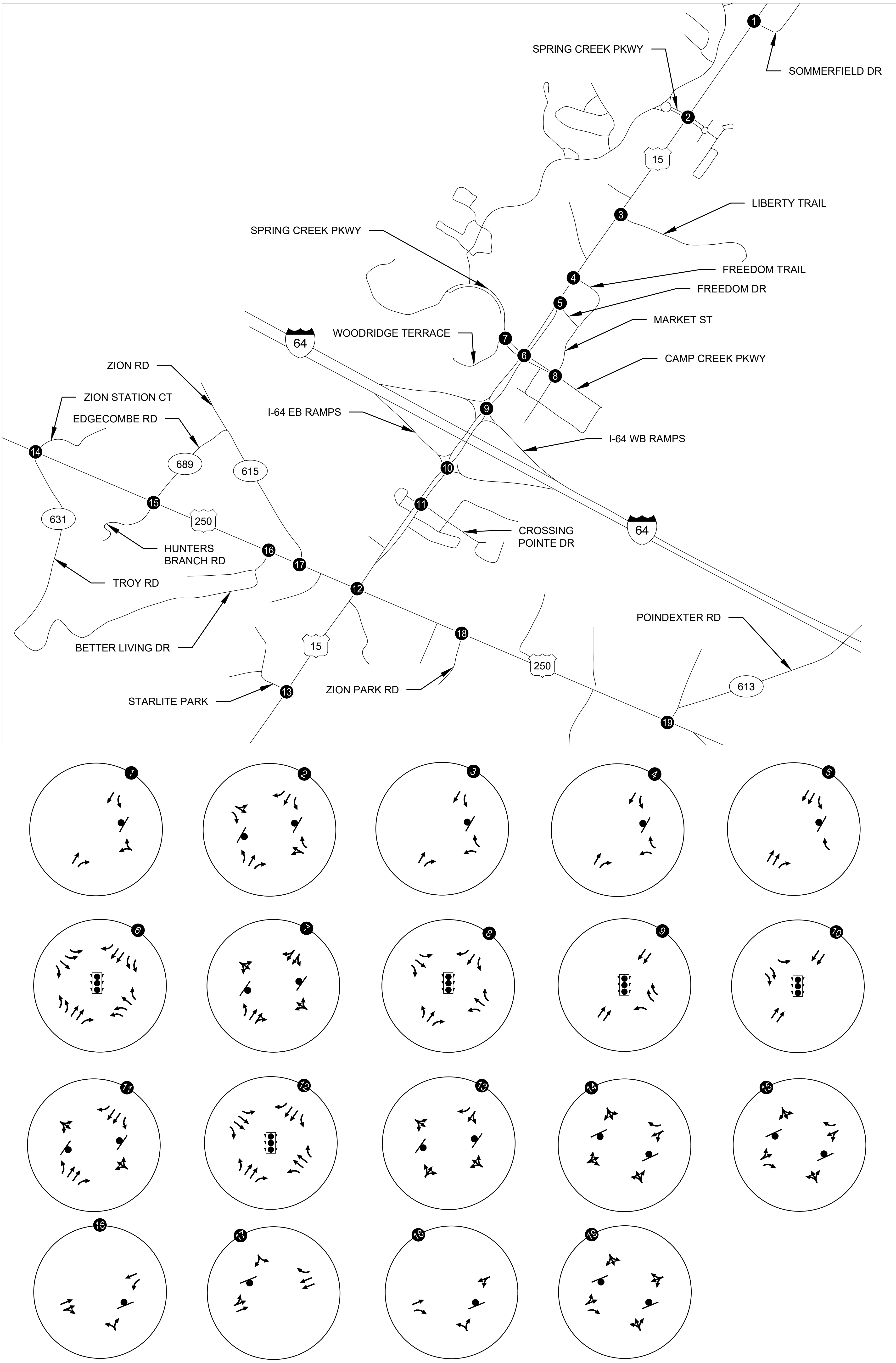
2.1.3 Transit Facilities

Currently, there is one transit facility present in this area at the Zion Crossroads Park and Ride. This location is served by Jaunt Transit.

Table 1 Existing Transportation Facilities and Roadway Designations

Roadway	Classification[1]	Number of Lanes	Speed Limit (MPH)	Median
US 15	Minor Arterial	2-4	30-45-55	Partial
US 250	Major Collector	2-4	45-55	None
Sommerfield Drive	Local	2	25	None
Spring Creek Parkway	Local	2	25-30	Full
Liberty Trail	Local	2	25	None
Freedom Trail	Local	2	25	None
Freedom Drive	Local	2	25	None
Camp Creek Parkway	Local	1-3	25	Full
Woodridge Terrace	Local	2	30	None
Market Street	Local	2	25	None
I-64 Ramps	Interstate	2	30	None
Crossing Pointe Drive	Local	2	25	None
Starlite Park	Local	2	25	None
Zion Station Court/Troy Road	Local	2	25-45	None
Edgecomb Road/Hunters Branch Road	Local	2	25	None
Better Living Drive	Local	2	25	None
Zion Road	Major Collector	2	45	None
Zion Park Road	Local	2	25	None
Poindexter Road	Minor Collector	2	25-45	None

[1]Classifications based on VDOT's 2014 Functional Classification Map (Reference 3).



Existing Lane Configurations
and Traffic Control Devices
Zion Crossroads, VA

Figure
2

2.1.4 Access Management

The character and feel of US 15 and US 250 vary throughout Zion Crossroads area, primarily due to changes in zoning and adjacent land uses within the various sections. The study corridor can generally be divided between the following sections:

- US 15 from Sommerfield Drive to Freedom Trail
- US 15 from Freedom Trail to Camp Creek Parkway
- US 15 from Camp Creek Parkway to Crossing Point Drive
- US 15 from Crossing Pointe Drive to Starlite Park
- Camp Creek Parkway/Spring Creek Parkway from Wood Ridge Terrace to Market Street
- US 250 from Troy Road/Zion Station Court to US 15
- US 250 from US 15 to Poindexter Road

Figure 3 shows each of these sections, which are discussed subsequently.

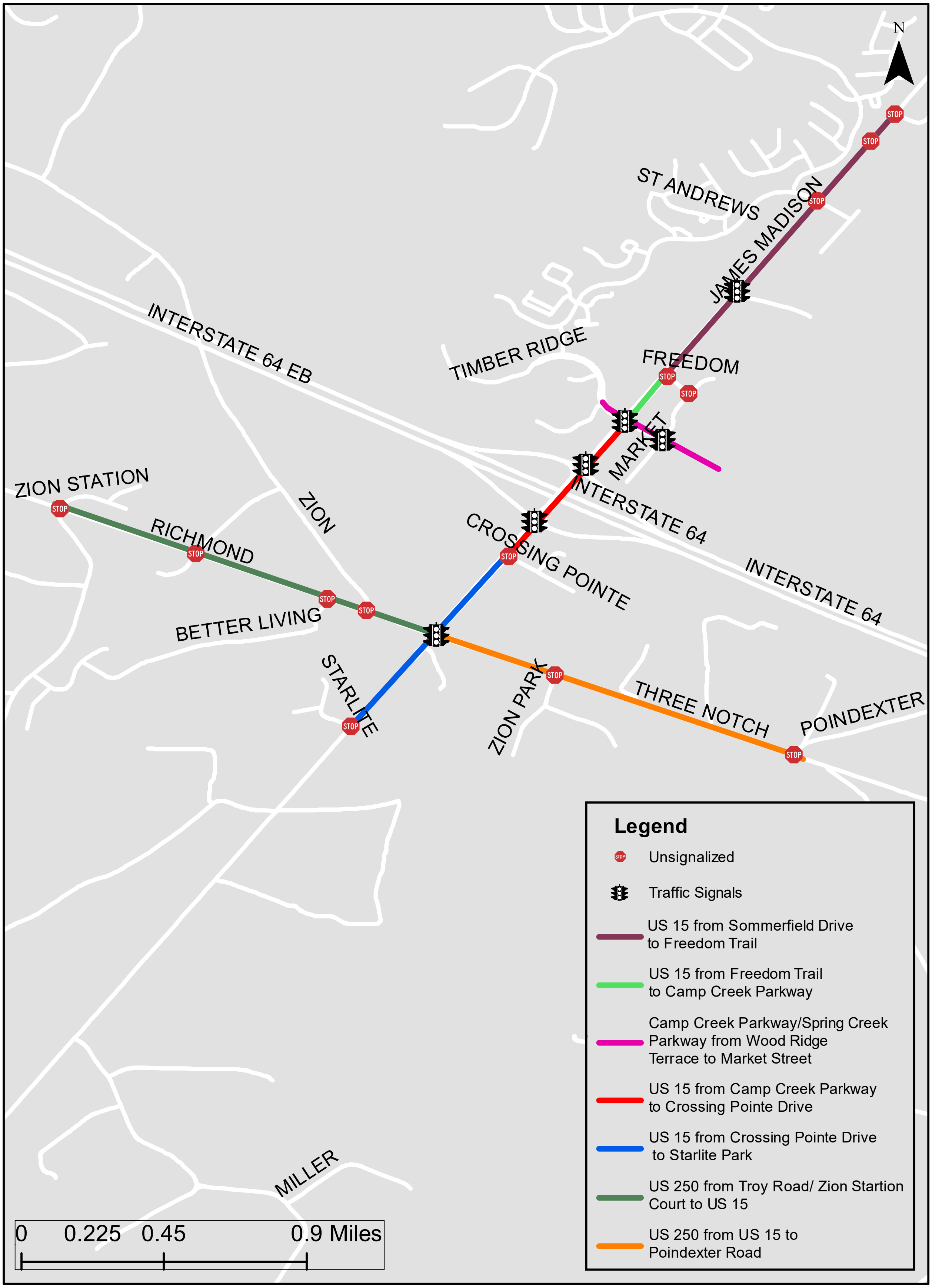


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Figure 3 Sections with Similar Characteristics in the Zion Crossroads Area

2.1.4.1 US 15 from Sommerfield Drive to Freedom Trail

The section of US 15 between Sommerfield Drive to Freedom Drive is home to much of the residential development in this area. These include the Stonegate at the Crossroads (constructed in 2017) and expansions of the Spring Creek community. These existing and future developments result in new and changing driver expectations along this section. The vertical profile of this segment is generally rolling hill terrain – adding to motorists' difficulty to gauge other drivers' behaviors. This is shown in Figure 4 at the intersection of US 15 and Spring Creek Parkway/Stonegate Drive. Trucks from the Walmart Distribution Center tend to enter and exit this area at the intersection of US 15 and Liberty Trail, resulting in a more concentrated area of mixed passenger vehicle and truck traffic.

Figure 4 Westbound Approach on Spring Creek Parkway looking north along US 15 (Intersection #2)

2.1.4.2 US 15 from Freedom Trail to Camp Creek Parkway

The section of US 15 from Freedom Trail to the Camp Creek Parkway features most of the recent and future commercial and retail development. In addition, this portion of US 15 transitions from a two-lane facility to four-lanes with a median. Turn lanes are also present to support access into the new restaurants and businesses. This section also serves much of the heavy vehicles traffic to/from the Walmart Distribution Center and other businesses at the Shoppes at Spring Creek, as shown in Figure 5.

Figure 5 Southbound US 15 at Freedom Drive (Intersection #5)

2.1.4.3 US 15 from Camp Creek Parkway to Crossing Pointe Drive

For the purposes of this study, the DDI and the approaching links were analyzed separately. The DDI connects the high volumes of traffic to/from I-64 and US 15. Two travels lanes in each direction are provided on both I-64 and US 15. Traffic signal control is provided at the DDI crossovers and other major intersections, and within the DDI the speed limit is reduced from 45 MPH to 30 MPH along US 15. However, the Stakeholders have expressed that this reduction in speed is not always obeyed. This facility is shown in Figure 6.

Figure 6 Southbound US 15 at the North DDI Ramp Terminal (Intersection #9)

2.1.4.4 US 15 from Crossing Pointe Drive to Starlite Park

The segment between Crossing Pointe Drive and Starlite Park reflect the US 15/US 250 intersection and its approaching links. This segment has speed limits of 45 MPH north of the US 15/US 250 intersection and 55 MPH south of this intersection. Residential and commercial driveways are located along both sides of the roadway. The combination of driveways and higher speeds with high traffic volumes proves to be a challenge for drivers.

Through field visits and discussions with the Stakeholders, it is evident that drivers have difficulty finding gaps for turns to/from Crossing Pointe Drive and the multiple business driveways. In addition, there is a truck stop at this intersection and an additional truck stop proposed at the intersection of US 15/US 250 which leads to a high level of truck traffic on this segment. These conditions contribute to both operational and safety issues are shown in Figure 7.

Figure 7 Southbound US 15 at Crossing Pointe Drive (Intersection #11)

2.1.4.5 Camp Creek Parkway/Spring Creek Parkway from Wood Ridge Terrace to Market Street

The segment of Camp Creek Parkway/Spring Creek Parkway serves retail and commercial developments as well as provides access to the Spring Creek Community. Future developments are expected along both sides of the roadway, including retail, commercial, hospitality, and residential construction.

The only pedestrian facility in the study area is present along Camp Creek Parkway from the intersection with US 15 to Market Street. This connects the retail and commercial spaces in the four quadrants of the intersection. In addition, there is significant truck traffic along this section predominantly attributable to deliveries serving local businesses. These conditions are shown in Figure 8.

Figure 8 Southbound Approach on Market Street at Camp Creek Parkway (Intersection #8)

Spring Creek Parkway to the west of US 15 provides access to a UVA Hospital and to the Spring Creek Community. There is also a Park and Ride lot, served by Jaunt Transit, on Wood Ridge Terrace.

2.1.4.6 US 250 from Troy Road (Route 631)/Zion Station Court to US 15

The segment of US 250 from Troy Road/Zion Station Road to US 15 is characterized as a two-lane, undivided facility with speeds 55 MPH west of Better Living Drive and 45 MPH east of this intersection. The existing terrain has rolling hills with trees/vegetation adjacent to the roadway. Closely spaced driveways, primarily for industrial and commercial spaces, are located along this segment. This case is demonstrated at the in intersection of Zion Road and US 250, as shown in Figure 9 below.

Figure 9 Zion Road looking west along US 250 towards Better Living Drive

2.1.4.7 US 250 from US 15 to Poindexter Road (Route 613)

The section of US 250 west of US 15 transitions from commercial and industrial to residential and rural land uses. The speed limit transitions from 45 MPH near the US 250/US 15 intersection to 55 MPH at Zion Park Road. This point is also where land use type also transitions, as shown in Figure 10. The terrain tends to flatten out compared to other sections in this study area. These conditions produce an environment where vehicles are able to move quickly throughout this section without stopping.

Figure 10 Eastbound US 250 at Zion Park Road

2.1.5 Existing Traffic Operations and Peak Hour Operations

Turning-movement counts were collected in October 2019 at all study intersections. The counts were conducted on a typical weekday morning (6:00 a.m. – 9:00 a.m.), weekday evening (4:00 p.m. – 7:00 p.m.), and Saturday midday (11 a.m. – 2 p.m.) during peak time periods when school was in session. Appendix A contains all turning movement count data sheets. Using this data, operational analyses were performed at all 19 study intersections.

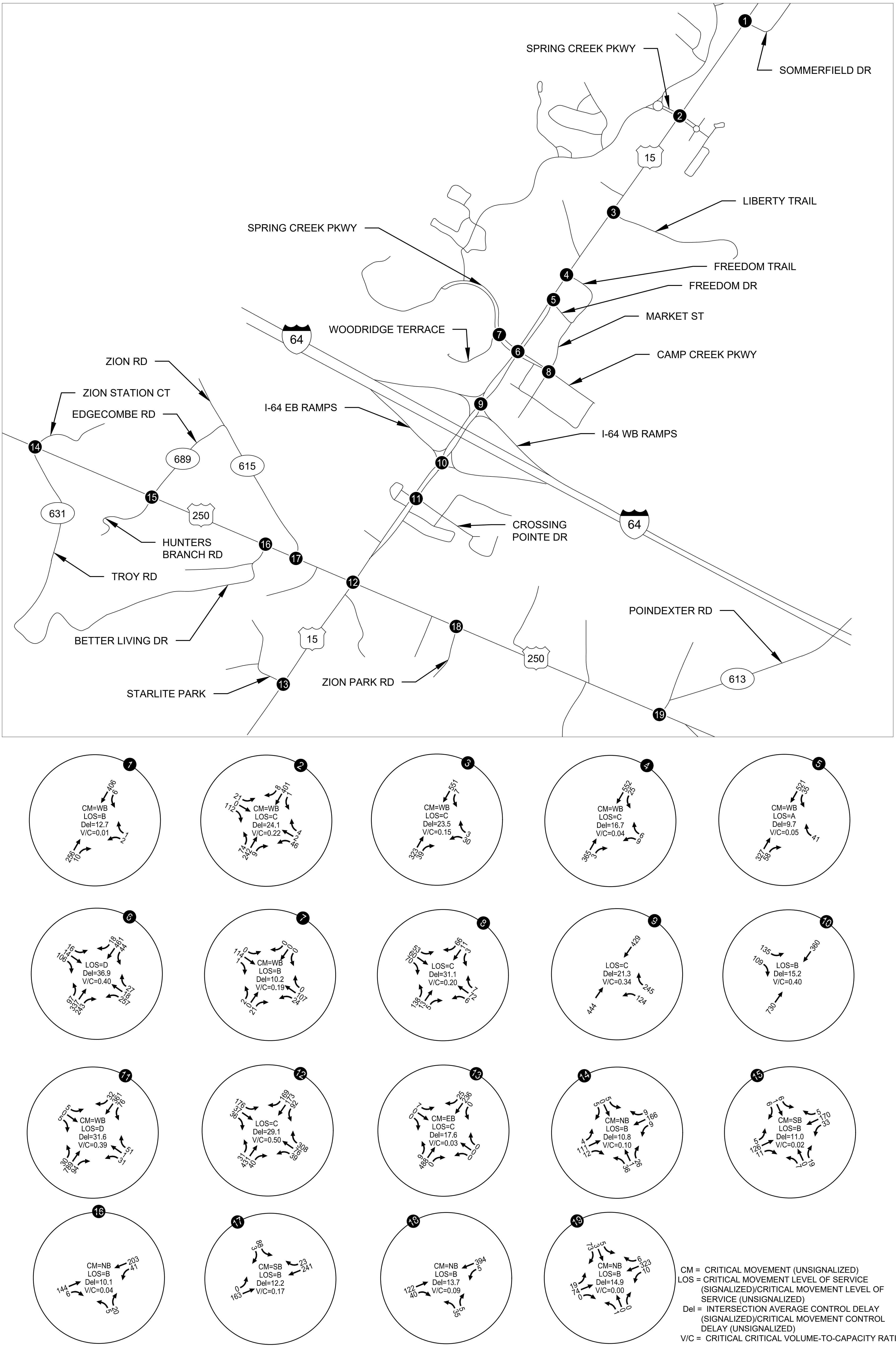
2.1.5.1 Current Levels of Service and Volume-To-Capacity Ratios

All level of service (LOS) analyses described in this report were performed in accordance with the procedures stated in the 2010 Highway Capacity Manual (HCM - Reference 4) and report HCM 2010 outputs. A description of level of service and the criteria by which they are determined is presented in Appendix B.

This analysis is based on the system hourly peak during each of the study periods to evaluate of all intersection levels-of-service. The weekday a.m., weekday p.m. and Saturday midday peak hours were found to occur from 7:00 a.m. to 8:00 a.m., 4:30 p.m. to 5:30 p.m. and 12:00 p.m. and 1:00 p.m., respectively. Traffic operations were evaluated using Synchro 10 in accordance with VDOT's Traffic Operations and Safety Analysis Manual v2.0 (TOSAM – Reference 5).

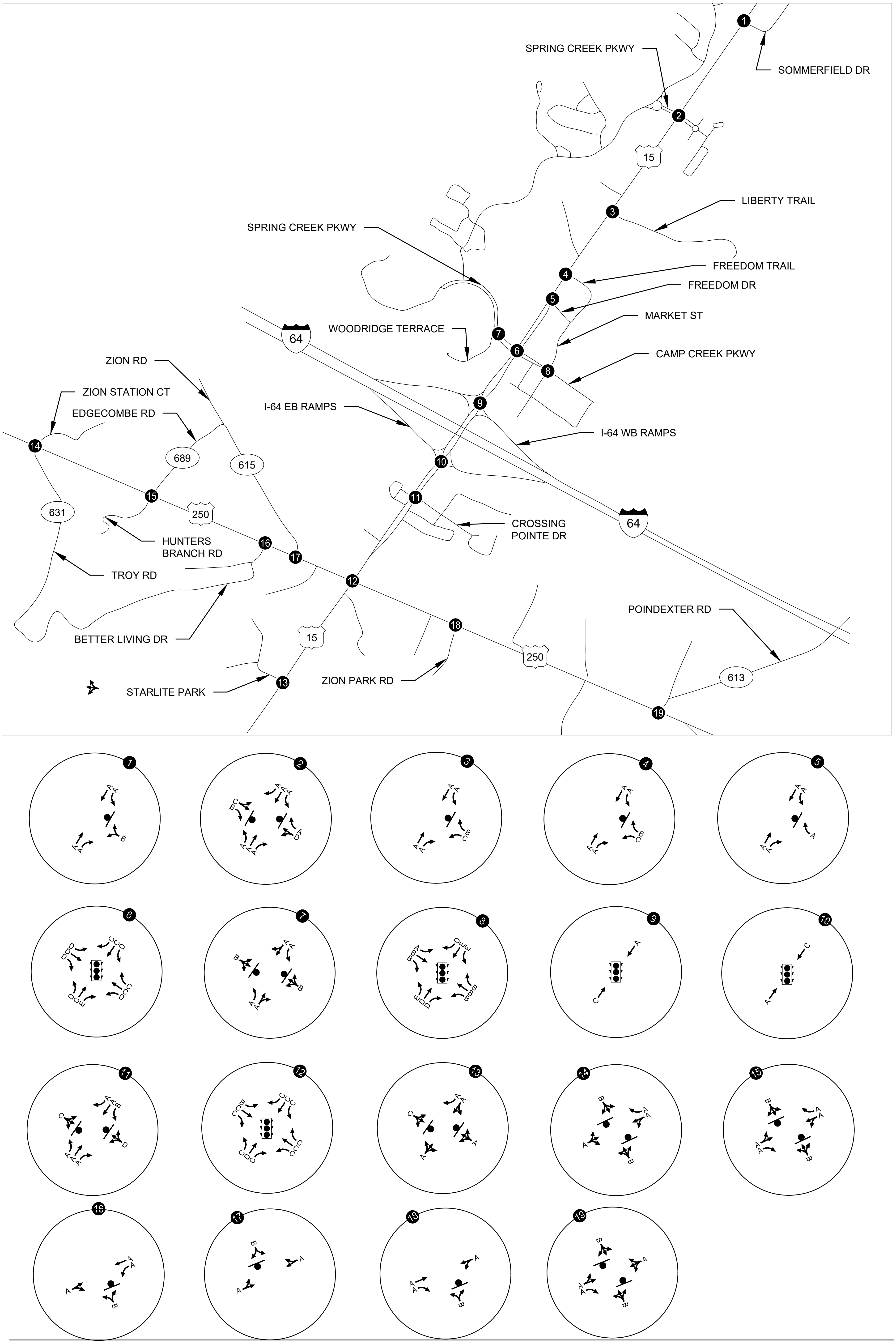
Figure 11 through Figure 16 shows the overall intersection operational results and lane group LOS of the existing traffic operations analysis for the weekday a.m., weekday p.m. and Saturday midday peak hours. Table C.1 in Appendix C summarizes the Synchro 10 peak hour levels of service, 95th percentile back of queue, and delay for each lane group by intersection. Appendix C also contains the existing conditions level of service worksheets.

As shown in the figures and Table C.1, all study intersections currently operate at LOS D or better except for the US 15/Camp Creek Parkway/Spring Creek Parkway intersection (LOS E in the Saturday midday peak hour).



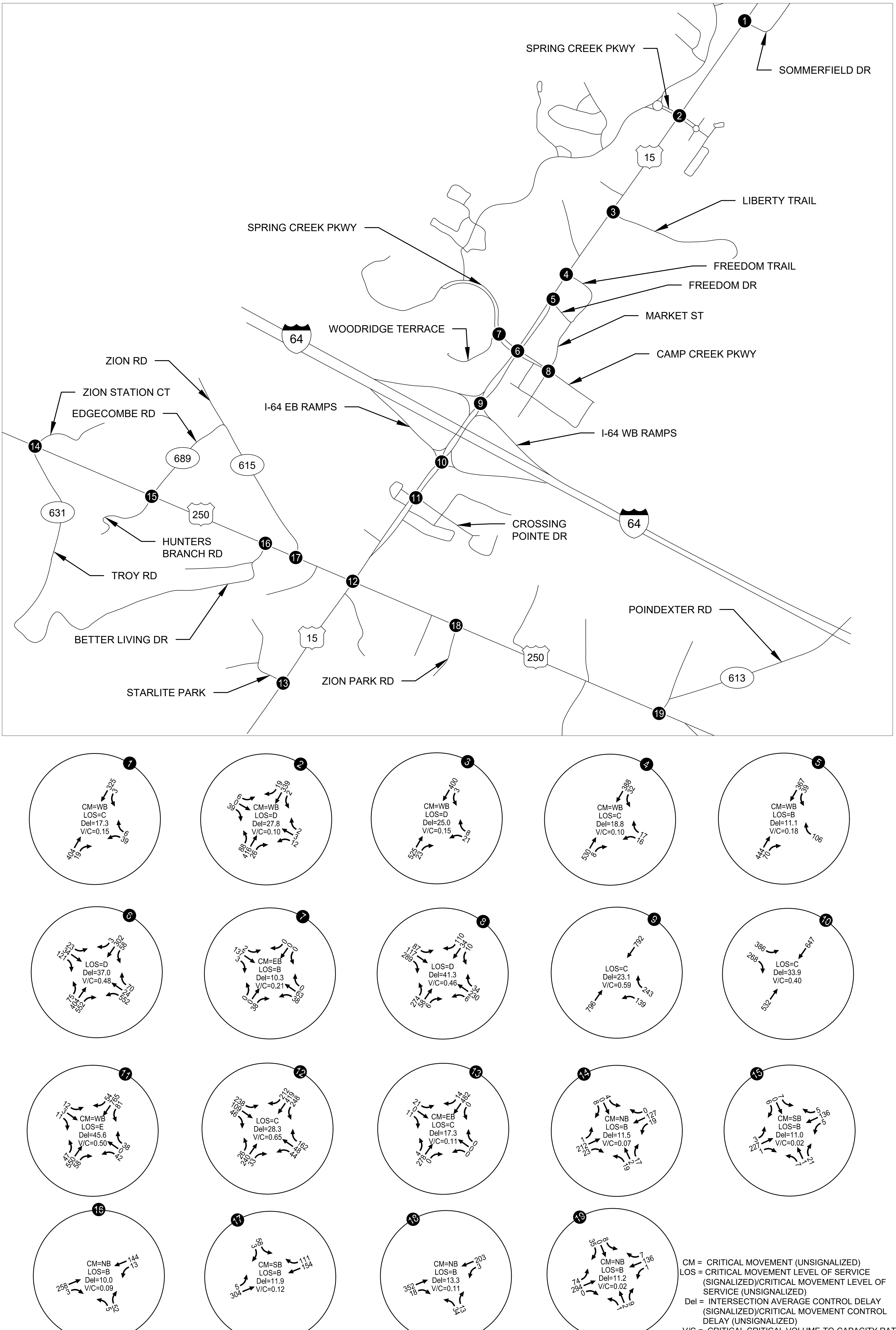
Existing Traffic Conditions
Weekday a.m. Peak Hour
Zion Crossroads, VA

Figure 11



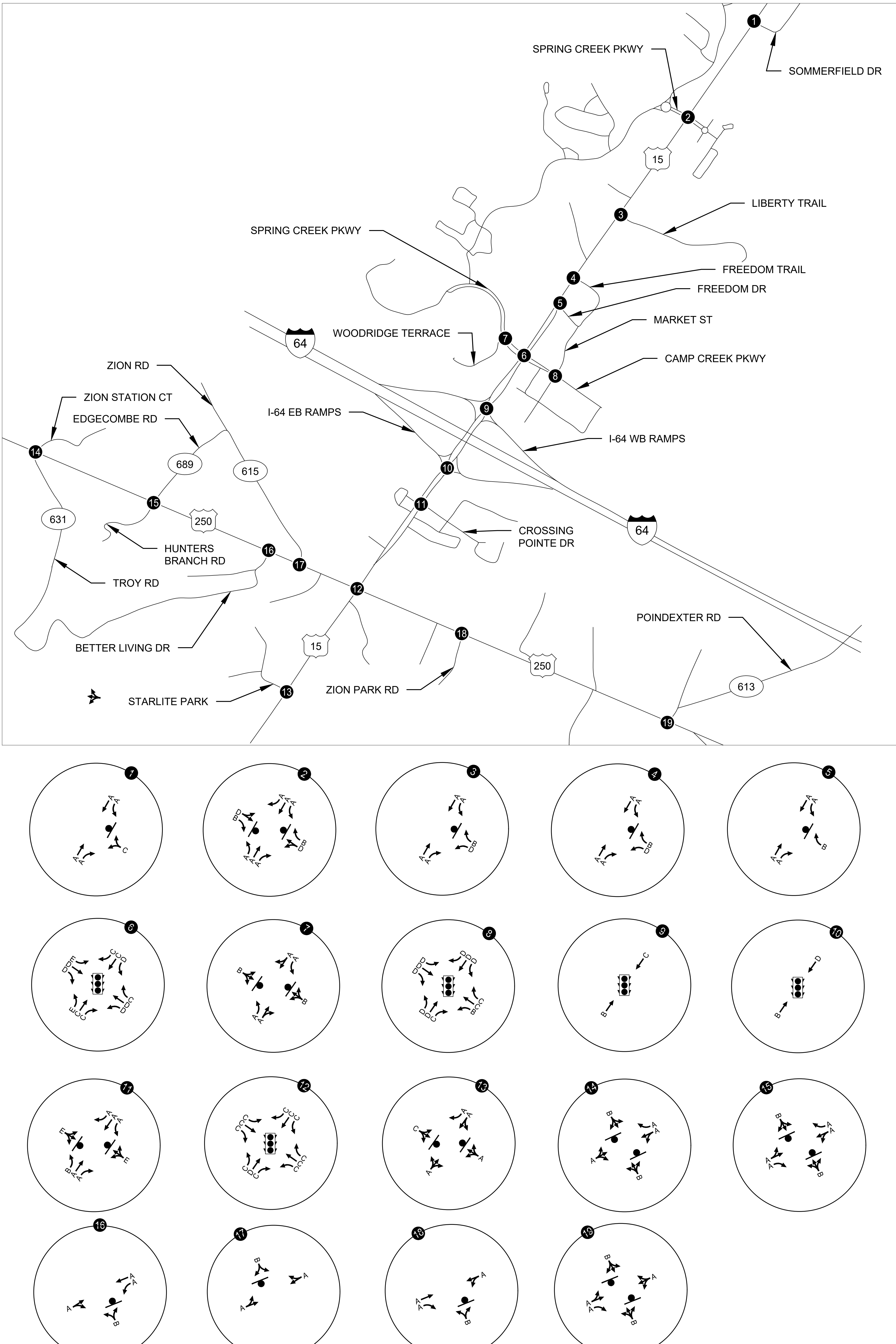
Existing Lane Group Conditions
Weekday a.m. Peak Hour
Zion Crossroads, VA

Figure
12



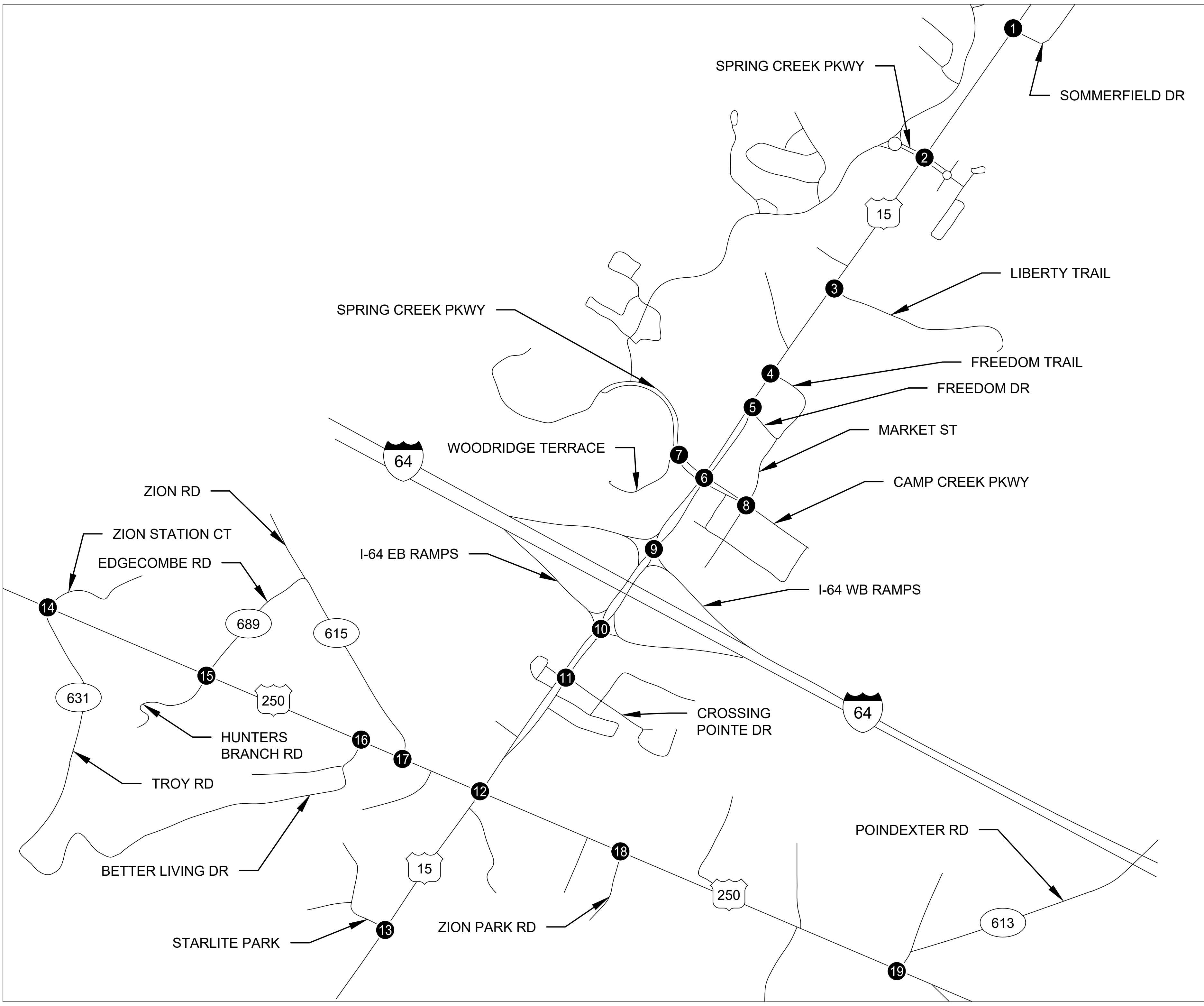
Existing Traffic Conditions
Weekday p.m. Peak Hour
Zion Crossroads, VA

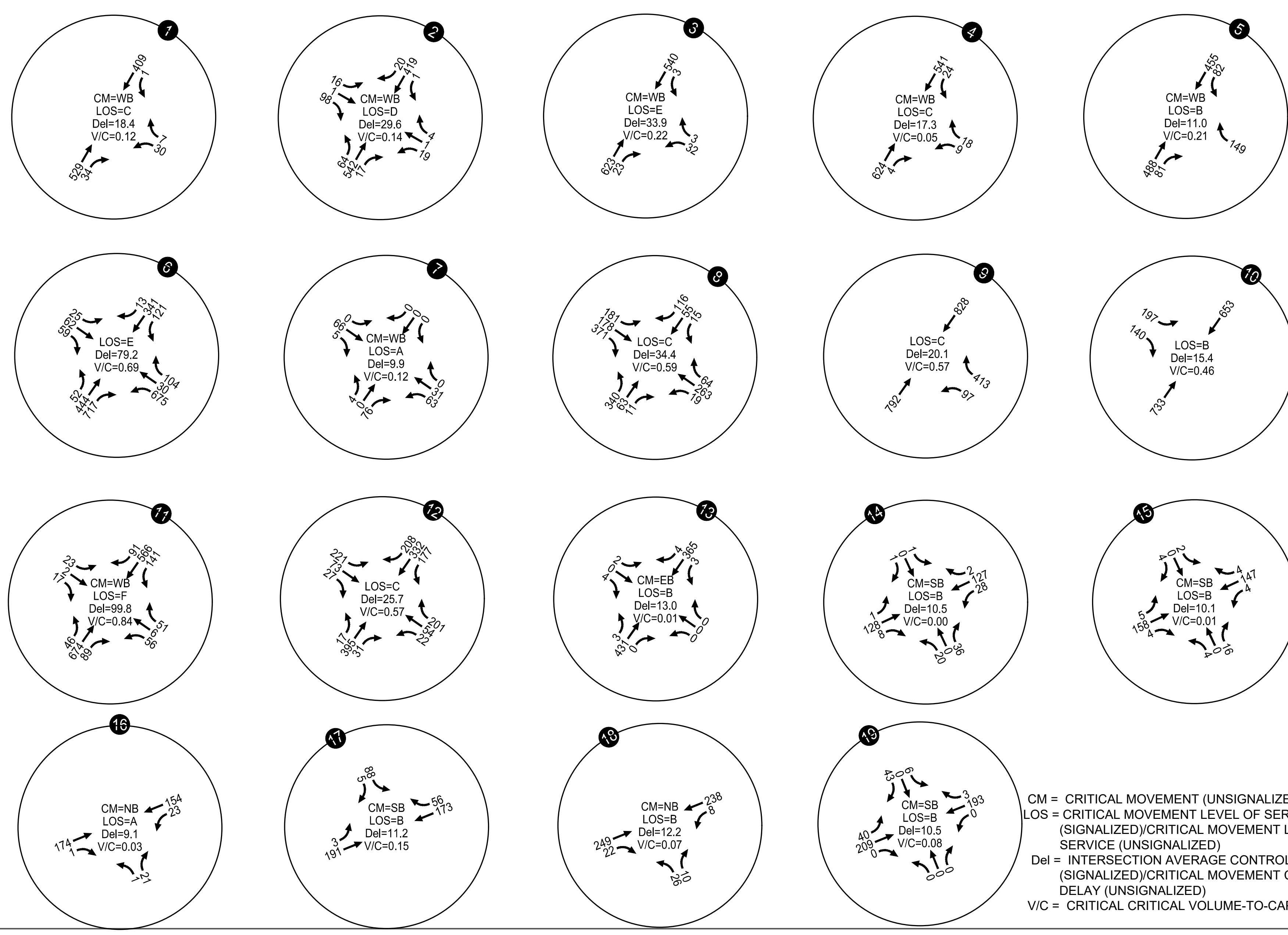
Figure 13



Existing Lane Group Conditions
Weekday p.m. Peak Hour
Zion Crossroads, VA

Figure 14





CM = CRITICAL MOVEMENT (UNSIGNALIZED)
LOS = CRITICAL MOVEMENT LEVEL OF SERVICE (SIGNALIZED)/CRITICAL MOVEMENT LEVEL OF SERVICE (UNSIGNALIZED)
Del = INTERSECTION AVERAGE CONTROL DELAY (SIGNALIZED)/CRITICAL MOVEMENT CONTROL DELAY (UNSIGNALIZED)
V/C = CRITICAL CRITICAL VOLUME-TO-CAPACITY RATIO

Existing Traffic Conditions
Saturday Midday Peak Hour
Zion Crossroads, VA

Figure 15

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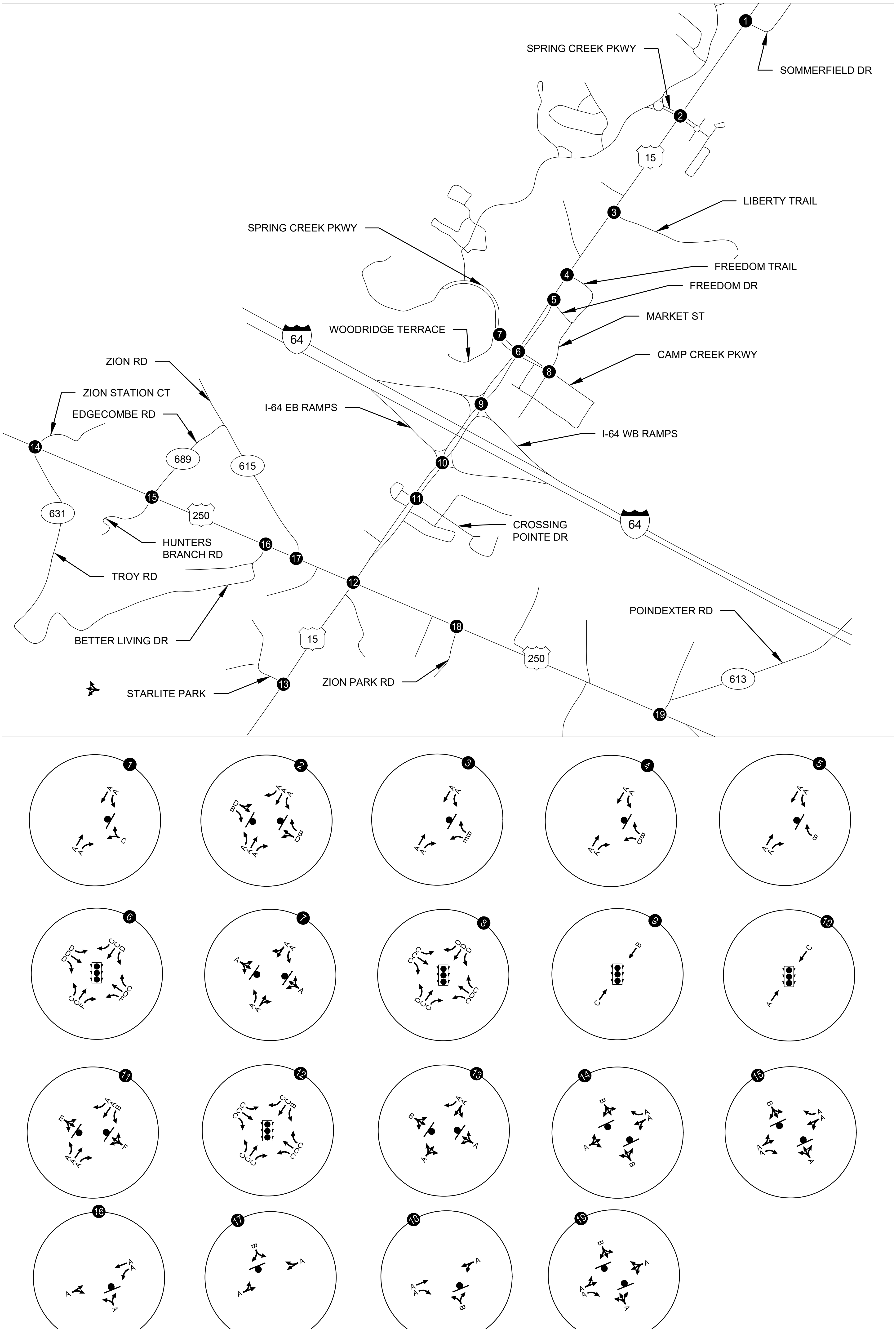


Existing Lane Group Conditions
Saturday Midday Peak Hour
Zion Crossroads, VA

Figure
16

2.2 Year 2040 No-Build Conditions

IN THIS SECTION>>

- Data and approach used for the operational study corridor analysis
- Key insights into study corridor operational patterns and trends
- Study the results of regional growth and in-process developments.

In the future year 2040 no-build analysis, traffic operations with in-process/approved developments are analyzed for the purposes of establishing a baseline against which to measure the impacts of any proposed improvements in the area. The initial background growth in traffic volumes can be attributed to regional growth in the area. In-process/approved developments also contribute to the growth within the study area. These two components of growth are discussed below.

2.2.1 Regional Growth

VDOT staff identified a 1.0% growth rate along US 15 and US 250 to account for near-term regional traffic growth. This growth rate was applied annually to forecast year 2040 no-build traffic volumes.

2.2.2 In-Process Developments

Through coordination with the Stakeholder Group, the total future traffic conditions included the following list of in-process developments:

- Zion Town Center: This mixed-use development consists of 477 residential units, 30,600 square feet of mini-warehouse space, a 120 room hotel, a 5,000 square feet day care, 125,000 square feet of general retail space, 10,000 square feet of high-turnover restaurant space and a 1,200 square feet fast food restaurant with a drive-through window. Camp Creek Parkway will be extended to the east to provide access to this development.
- O'Reilly Auto Parts: This 7,500 square feet automobile parts store will be located in the northwest quadrant of the US 15 and Spring Creek Parkway intersection with driveways on both roadways.
- 7-11: This gas station with a 4,650 square feet convenience market is planned to have 18 fueling positions will be located between the planned O'Reilly Auto Parts and Hampton Inn Hotel in the northwest quadrant of the US 15/Spring Creek Parkway intersection. This development plans to have a right-in/right-out driveway along US 15 and a full access driveway on Spring Creek Parkway to be shared with the O'Reilly Auto Parts.
- Hampton Inn Hotel: This 80-room hotel is planned to be located next to the proposed 7-11 and O'Reilly Auto Parts in the northwest quadrant of the US 15/Spring Creek Parkway intersection. The access to this hotel will be at the driveway, shared with the 7-11, along US 15.
- Crossing Pointe: This development consists of 2 land bays located as an extension of Crossing Pointe Drive. The first land bay consists of a 7,398 square feet restaurant, a 62,500 square feet grocery store/retail, a 5,000 square feet drive-thru coffee shop, and a 115-room hotel. The second land bay is planned to

have 228 multi-family units and 93 townhouses.

- Truck Fueling Facility: This proposed facility will have an 8-dispenser fueling island, 8 truck fueling lanes, and a 10,796 square feet retail space or restaurant. This development is planned to be located in the northeast corner of the US 15/US 250 intersection with driveways on both roadways.
- Boxley Asphalt Plant: This planned development will consist of an asphalt plant located along Midway Lane off of Poindexter Road. This site plans to have a new access road, a material lab, a processing plant, and material stockpiles.

2.2.3 Planned Transportation Improvements

As results of the in-process developments, there is one roadway improvement expected in this area. With the additional traffic produced from the Zion Town Center development, the westbound right turn is proposed to be converted to a right-through lane at the Camp Creek Parkway/Market Street.

2.2.4 Future Traffic Conditions

The future year 2040 no-build analysis forecasts how the transportation system in the study area will operate with the full build out of the proposed developments along the US 15 and US 250 corridors.

Trips generated from approved or in-process developments are shown in Figure 18 (weekday a.m.), Figure 21 (weekday p.m.), and Figure 24 (Saturday midday). These volumes were added to background growth to arrive at the 2040 no-build traffic volumes shown in Figure 19 (weekday a.m.), (weekday p.m.) and Figure 25 (Saturday midday). Figure 20 (weekday a.m.), Figure 23 (weekday p.m.) and Figure 26 (Saturday midday) show the lane group LOS for the weekday a.m. and weekday p.m. peak hours. Table D.1 in Appendix D summarizes the Synchro 10 peak hour levels of service, 95th percentile back of queue, and delay for each lane group by intersection. Appendix D also contains the year 2040 no-build traffic conditions operational worksheets.

The additional traffic on the network is expected to enter the area primarily at US 15/I-64 Interchanges. It is also assumed that a few vehicles will enter/exit the area along US 250, from US 15 south of Starlite Park, and from US 15 north of Sommerfield Drive. As shown in the figures and Table D.1, the following changes in operations occurred at each intersection.

US 15 and Spring Creek Parkway (Intersection #2)

At the intersection of US 15 and Spring Creek Parkway, traffic conditions worsened slightly from LOS A to LOS B in the weekday a.m. and Saturday midday peak hours from traffic generated at the proposed developments in the area. The majority of this traffic is along US 15, resulting in added difficulty for vehicles to exit Spring Creek Parkway, especially for those vehicles on the westbound approach. During the weekday p.m. peak hour, the intersection is expected to continue operating at a LOS A.

US 15 and Freedom Trail (Intersection #4)

The intersection of US 15 and Freedom Trail has traffic conditions that slightly worsen from LOS A to LOS B in the Saturday midday peak. With the additional traffic from the new developments along US 15, vehicles on the westbound approach have added difficulty maneuvering this intersection. Operations are expected to continue at a LOS A in the weekday a.m. and p.m. peak hours.

US 15 and Camp Creek Parkway/Spring Creek Parkway (Intersection #6)

The current operational conditions at US 15 and Camp Creek Parkway/Spring Creek Parkway are expected to get worse between 2019 and 2040. Although this intersection currently operates at LOS D during the weekday a.m. and p.m. and LOS E Saturday midday, it is expected to deteriorate to LOS F in all future time periods. Because this intersection is located at the center of several new and existing developments in this area, it is expected to serve a much higher demand along US 15.

Camp Creek Parkway and Market Street (Intersection #8)

The intersection of Camp Creek Parkway and Market Street will provide access to the new Zion Town Center development. By optimizing the signal timing, this intersection's LOS is expected to improve from a D to C in the weekday p.m. peak. However, the added traffic during the Saturday midday peak will result in the LOS deteriorating from a LOS C to a LOS D.

US 15 and North DDI Ramp Terminal/South DDI Ramp Terminal (Intersections #9 and #10)

The additional traffic in this area is expected to primarily enter/exit at the DDI interchange between I-64 and US 15. As a result of this, the LOS at the North DDI ramp worsens from LOS C to a LOS D in the weekday p.m. peak. The LOS at the South DDI ramp is also expected to change from a LOS B to a C during the Saturday midday peak.

US 15 and Crossing Pointe Drive (Intersection #11)

The Crossing Pointe development is accessed at this intersection just south of the DDI interchange. The additional traffic from the residential units and commercial/retail spaces result in an increased demand in the eastbound and westbound directions. This change is expected to deteriorate the operations from a LOS A in all peak periods to a LOS B in the weekday a.m. and p.m. peak and LOS F in the Saturday midday peak.

US 15 and US 250 (Intersection #12)

The intersection of US 15 and US 250 will likely experience additional traffic from the background growth of the area and the developments north of this intersection. This will likely result in the intersection to operate as a LOS D rather than a LOS C in the p.m. peak.

US 250 and Zion Road (Route 615) (Intersection #17)

Changes at the intersection of US 250 and Zion Road (Route 615) will likely result from the background growth of the area. The change in the distribution of volumes across in the intersection is expected to slightly improve the LOS from B to A in the a.m. peak.

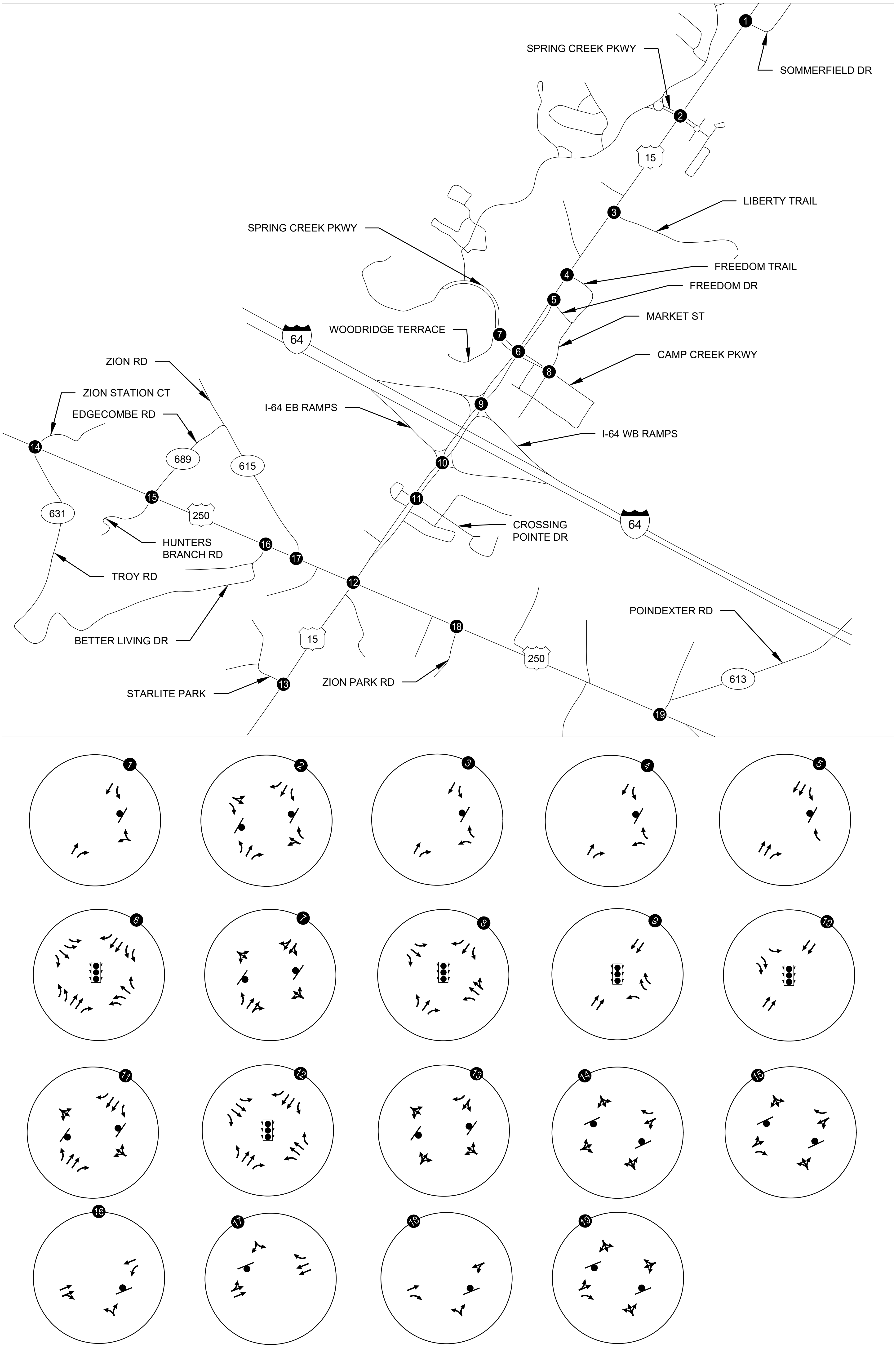
US 250 and Poindexter Road (Route 613) (Intersection #19)

The intersection of US 250 and Poindexter Road (Route 613) will face additional traffic from the background growth of the area and the Boxley Asphalt plant. This is expected to change the LOS from A to B in the p.m. peak.

Summary

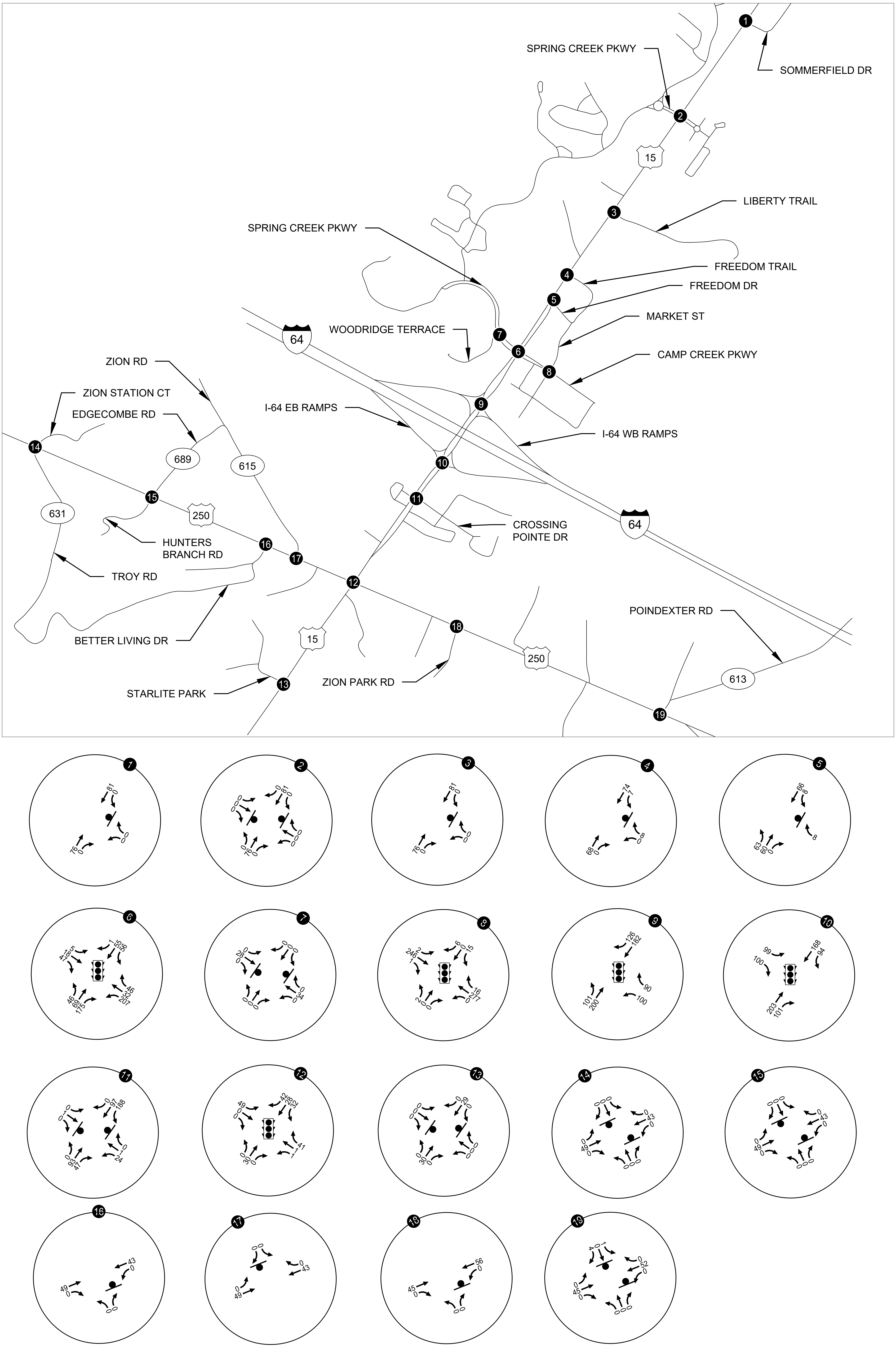
In summary, the study intersections that are expected to experience LOS E or F with the additional traffic demands include:

- US 15/Camp Creek Parkway/Spring Creek Parkway (LOS F in weekday a.m., weekday p.m., and Saturday midday peaks)
- US 15 and Crossing Pointe Drive (LOS F in the Saturday midday peak).



Year 2040 Lane Configurations
and Traffic Control Devices
Zion Crossroads, VA

Figure
17



In-Process Development Generated Trips
Weekday a.m. Peak Hour
Zion Crossroads, VA

Figure
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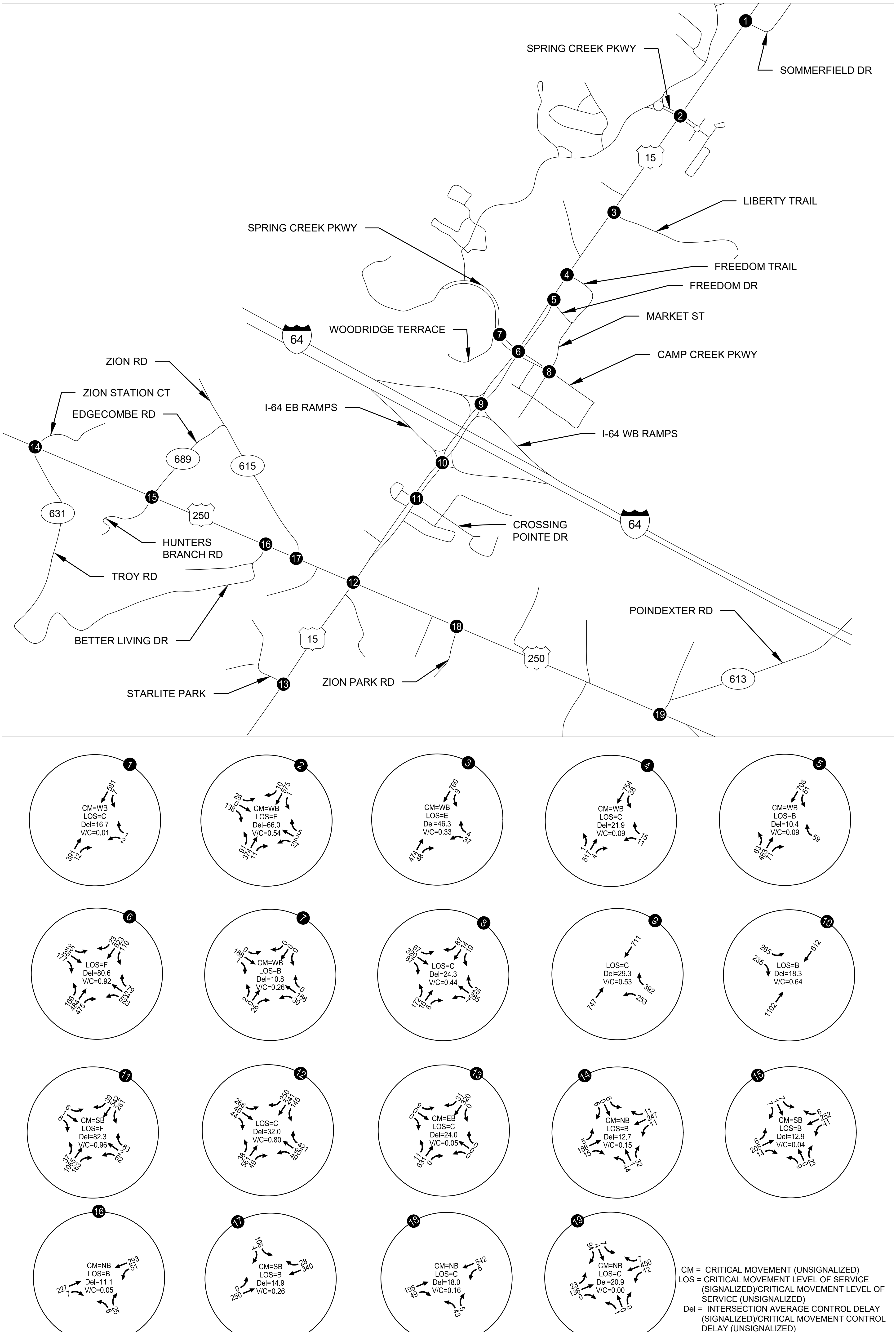

Year 2040 Total Traffic Conditions
Weekday a.m. Peak Hour
Zion Crossroads, VA

Figure
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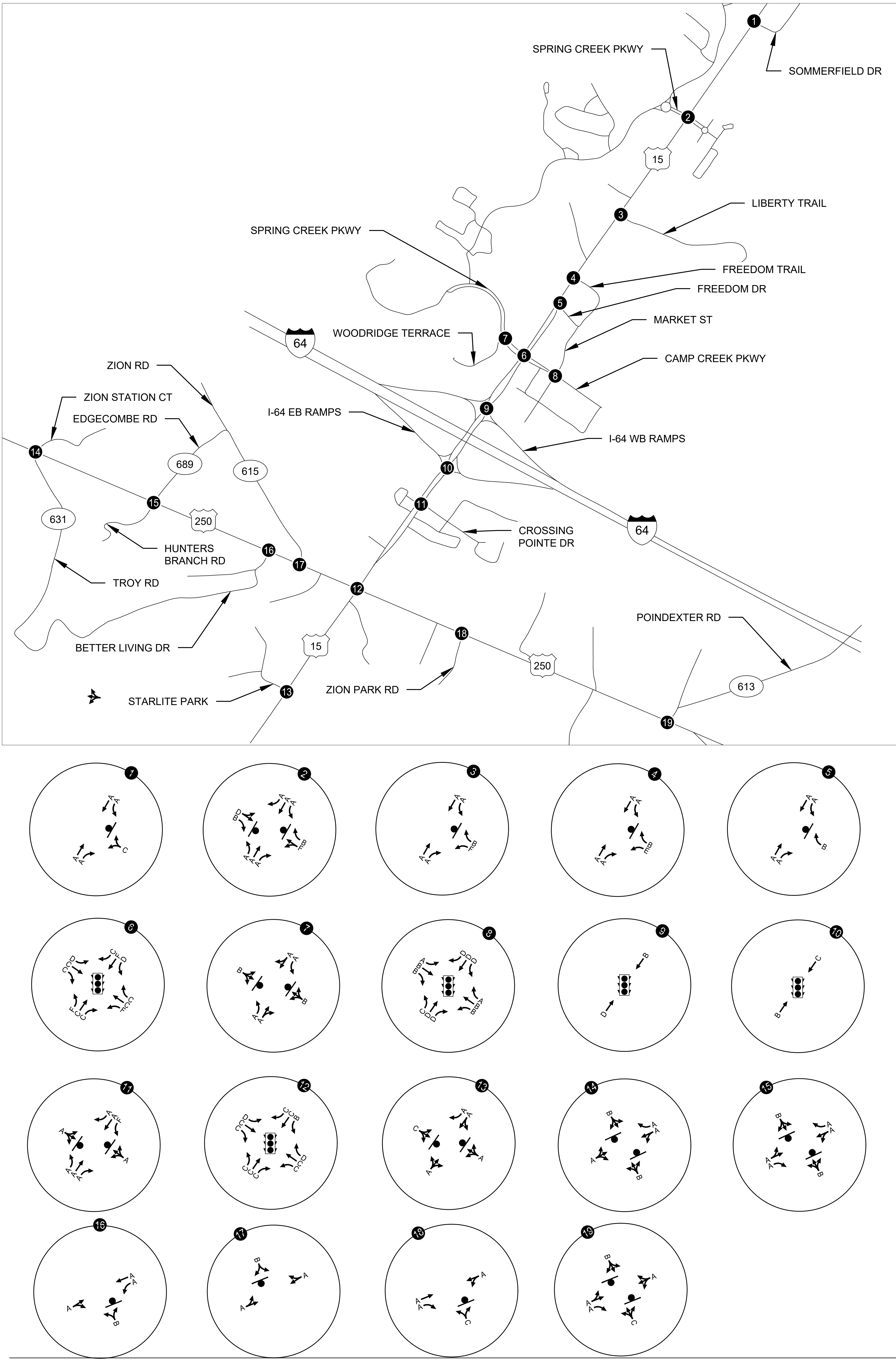
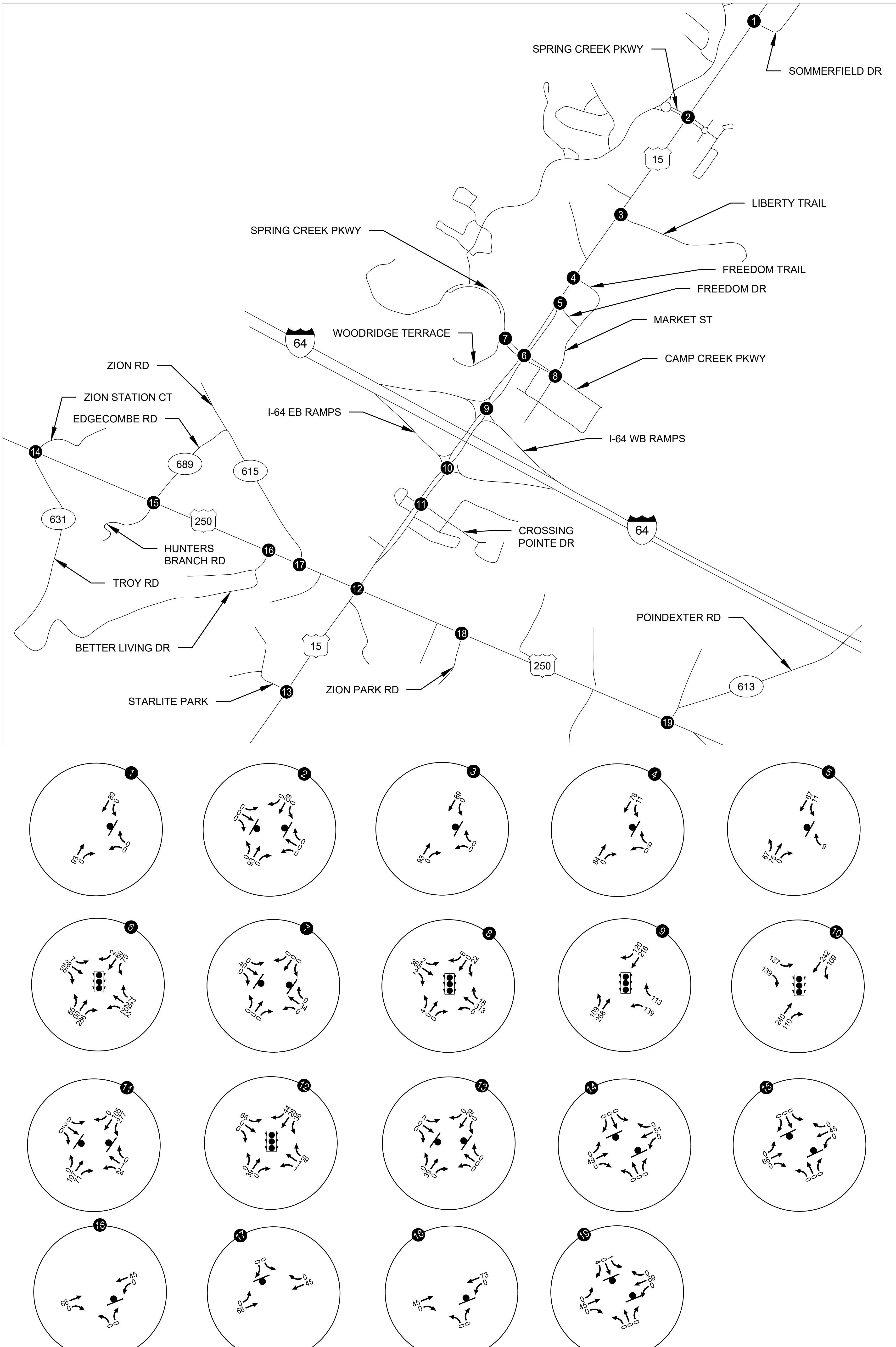


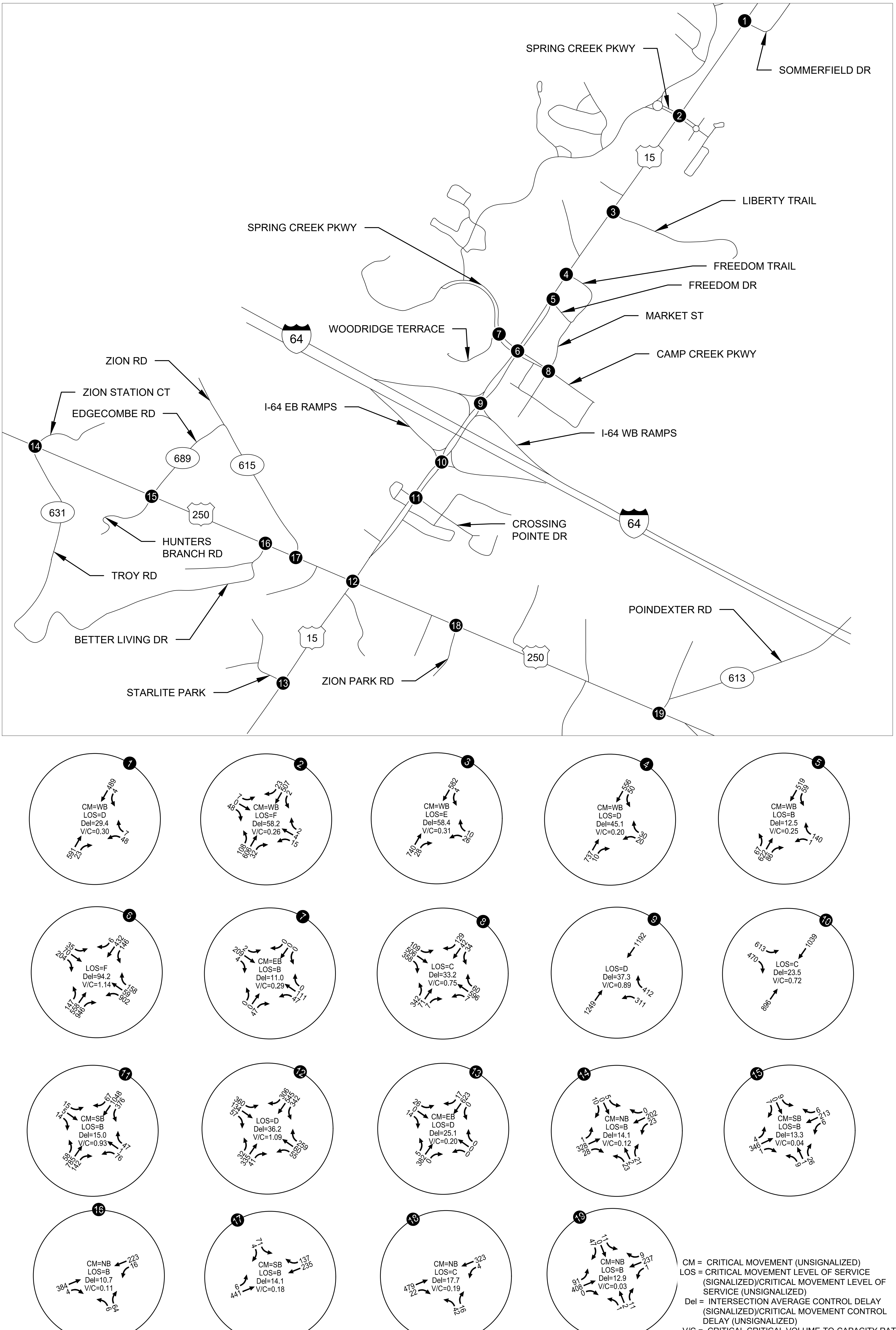
Year 2040 Total Traffic Conditions Lane Group Conditions
Weekday a.m. Peak Hour
Zion Crossroads, VA

Figure 20



In-Process Development Generated Trips
Weekday p.m. Peak Hour
Zion Crossroads, VA

Figure 21



Year 2040 Total Traffic Conditions
Weekday p.m. Peak Hour
Zion Crossroads, VA

Figure
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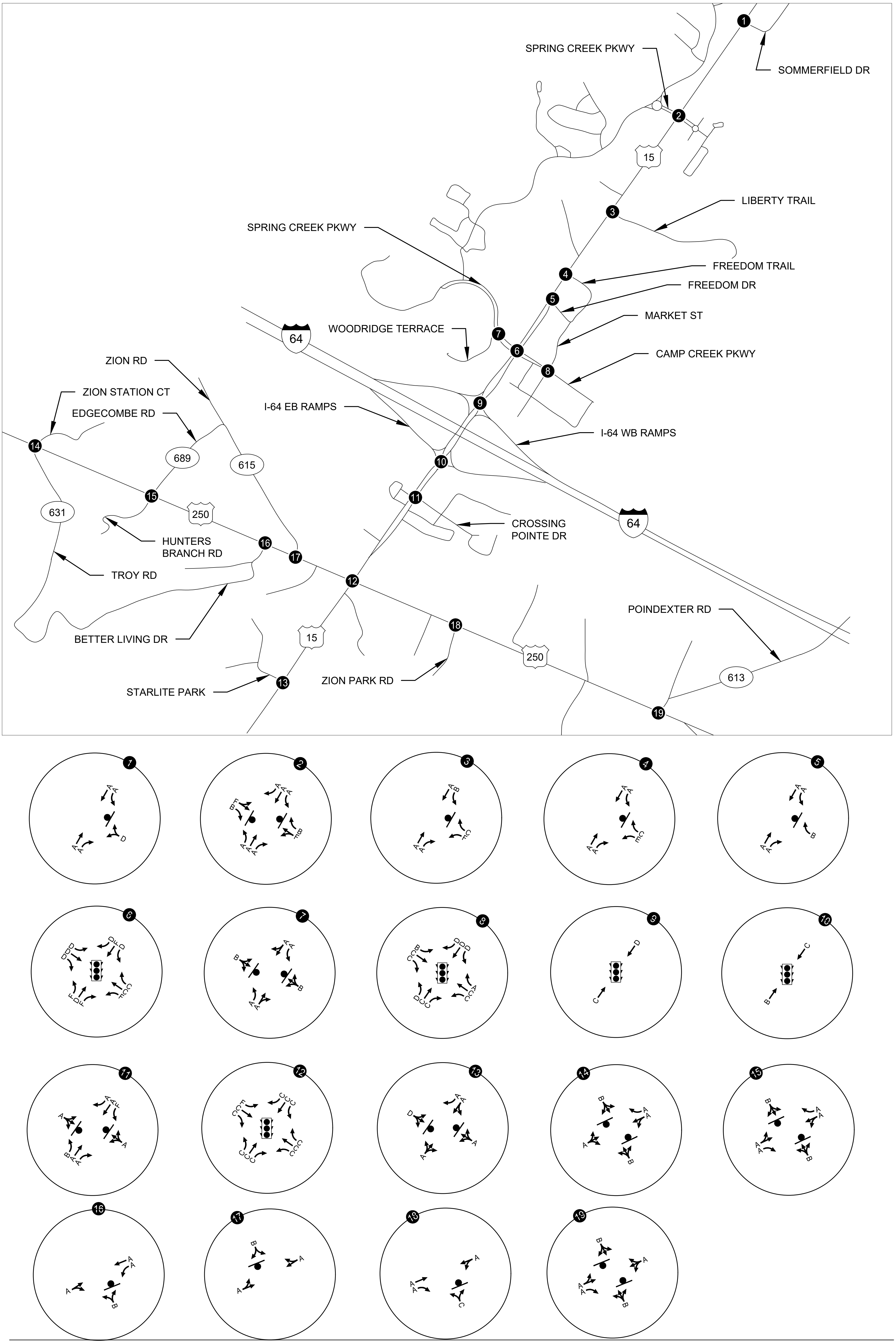

Year 2040 Total Traffic Conditions Lane Group Conditions
Weekday p.m. Peak Hour
Zion Crossroads, VA

Figure
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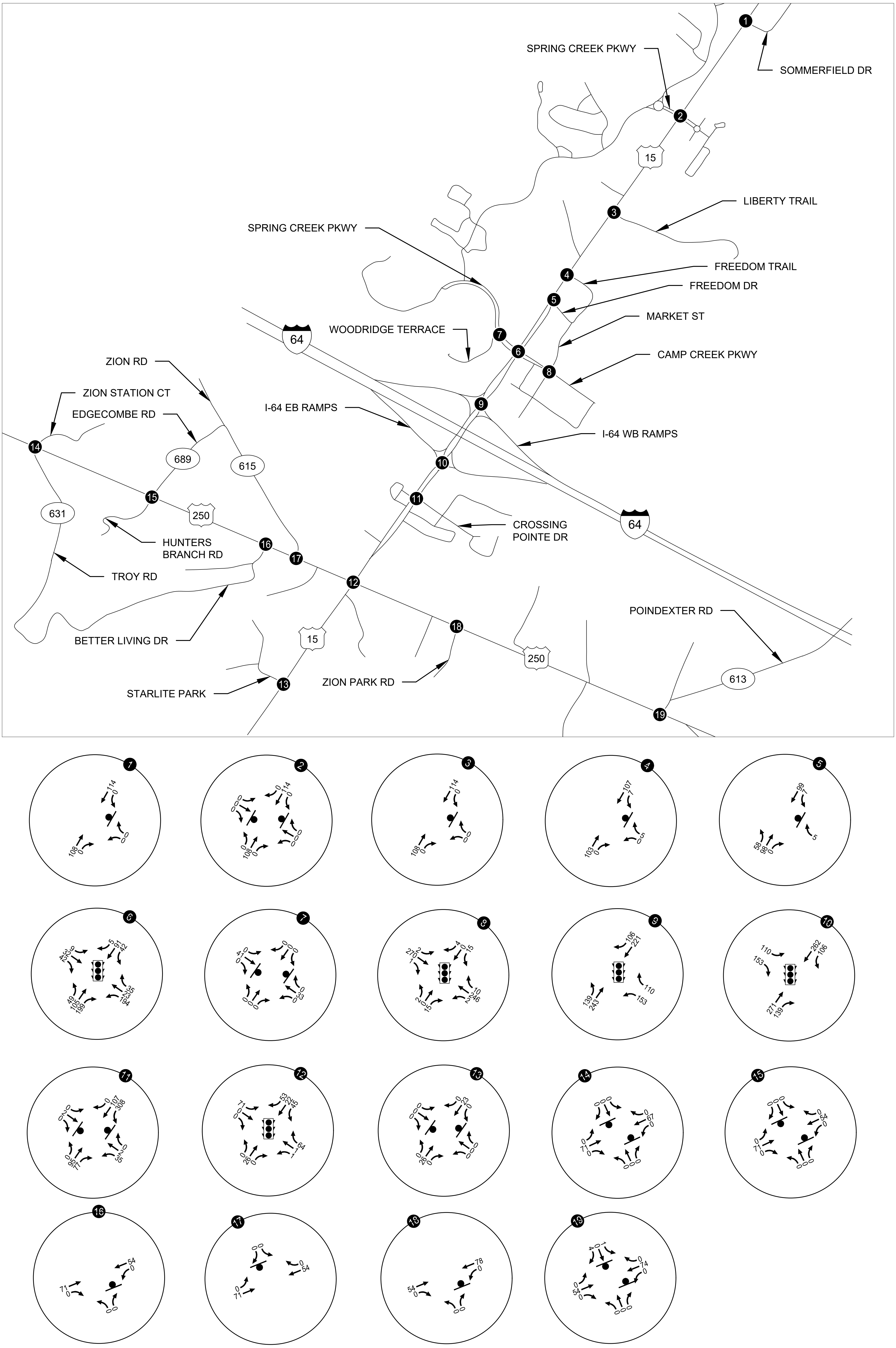
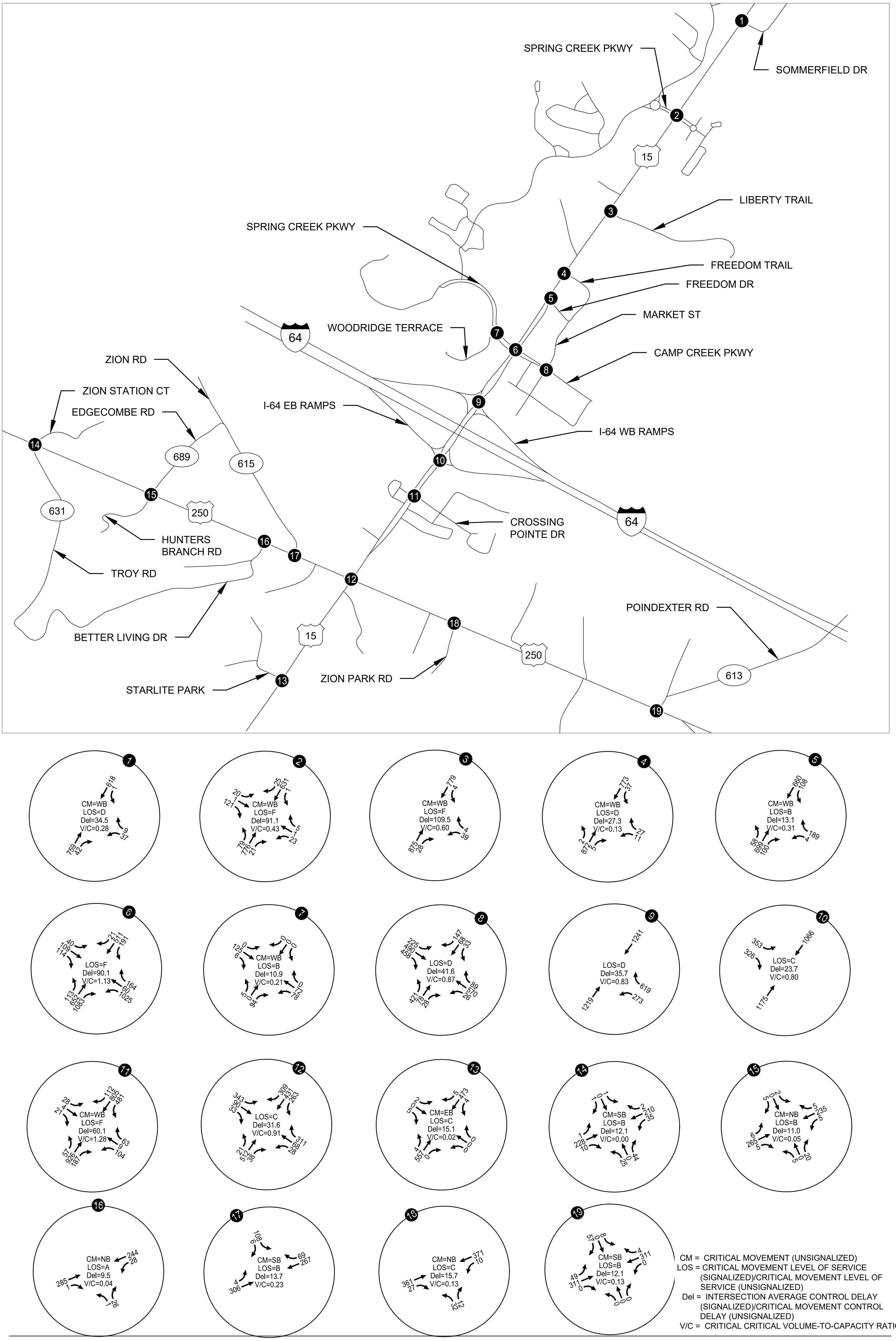


In-Process Development Generated Trips
Saturday Midday Peak Hour
Zion Crossroads, VA

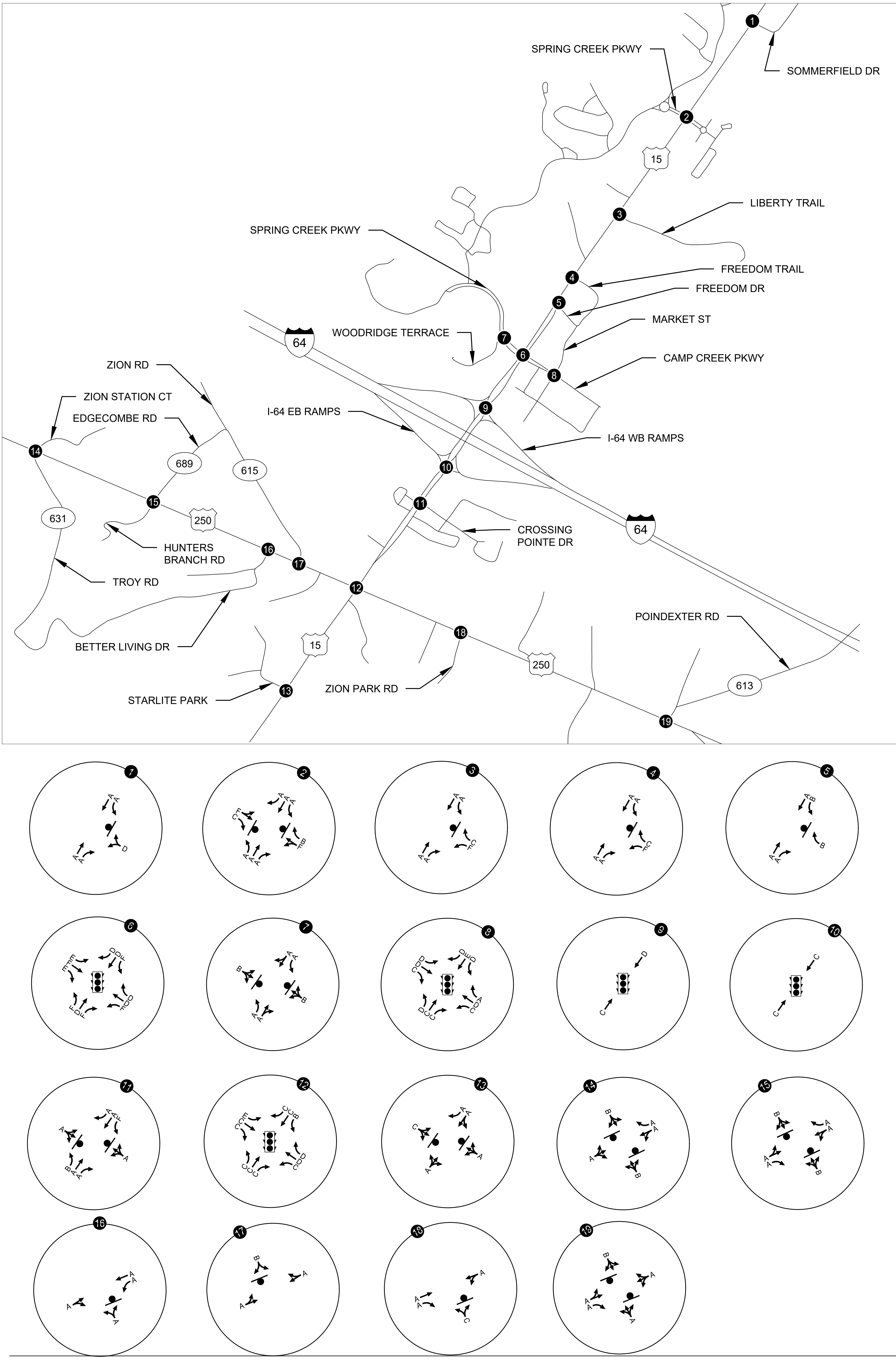
Figure 24



Year 2040 Total Traffic Conditions
Saturday Midday Peak Hour
Zion Crossroads, VA

Figure 25

KITTELSON & ASSOCIATES



Year 2040 Total Traffic Conditions Lane Group Conditions
Saturday Midday Peak Hour
Zion Crossroads, VA

Figure 26

3.0 SAFETY

This section summarizes the approach and findings for crash analysis. The material below discusses study area crash patterns and trends; network screening; and systemic safety evaluation. The analysis focuses on the study area only (US 15 from Sommerfield Drive to Starlite Park and along US 250 from Troy Road (Route 631)/Zion Station Court to Poindexter Road (Route 613). Maps that detail the location, type and severity of the crashes that occurred along the US 15 and US 250 corridors between 2014 and 2018 can be found in Appendix E.

KEY TERMS>>

- **Network Screening –**Evaluating the entire street network to identify high-crash locations based on number of crashes, severity of crashes, and traffic volume.
- **Systemic analysis –** Identifying risk factors associated with high-crash locations and prioritizing locations based on risk factors and crash history.

3.1 Key Findings

- The following key crash patterns and trends were found:
  - Over 38% of the reported crashes were rear-end collisions. Approximately 67% of these collisions were property-damage-only.
  - 1% of the reported crashes resulted in a fatality.
  - Injuries accounted for 25% of reported crashes.
- The following crash types exhibited higher proportions of fatal and/or injuries than other reported crash types:
  - The only pedestrian crash resulted in a severe injury.
  - Rear-end crashes (33% resulting in fatality or injury)
  - Two fatal crashes occurred along the US 15 and US 250 corridors as the result of an angle collision and a non-collision crash.
- Network Screening and Systemic Findings
  - Kittelson screened the roadway network using: (1) the Equivalent Property Damage Only (EPDO) safety performance measure; and (2) a risk-based analysis to determine roadway characteristics potentially associated with higher crash risk.
  - The EPDO performance measure identifies locations that have exhibited a combined greater severity and frequency of crashes than other locations. It gives more weight to locations at which more severe crashes have occurred.
- Kittelson identified the following priority locations:
  - Liberty Trail/US 15
  - Spring Creek Parkway/Wood Ridge Terrace
  - North DDI Ramp Terminal/US 15
  - US 15/US 250
  - Troy Road (Route 631)/US 250/Zion Station Court

3.2 Study Area Crash Patterns and Trends

The following presents study area crash trends and patterns. Findings from this section will be used to determine countermeasures and multimodal transportation solutions that could be effective along the study corridor.

IN THIS SECTION>>

- Data and approach used for the study area analysis
- Key insights into study area crash patterns and trends
- Study corridor crash patterns compared to VDOT's Culpeper District

Data and Approach

The study team obtained and analyzed the most recent five (5) years of complete crash data available for the Zion Crossroads area from VDOT's database. The crash data used was from January 1, 2014 to December 31, 2018; there were 134 reported crashes in this period. The location data allowed the study team to geocode the crashes and map them in GIS software.

Findings

The study team considered crash patterns and trends in the corridor data by evaluating the following:

- Crash severity,
- Crash type,
- Lighting,
- Speed,
- Weather and roadway condition, and
- Year.

In the five years of data analyzed, one crash involved pedestrians and there were no crashes that involved bicyclists. The rest of the reported crashes involved motor vehicles or motor vehicles and other objects (see Figure 27). Rear-end and angle were the top two crash types. The study team will use these findings to help identify and prioritize safety treatments.

Severity

Table 2 summarizes the reported crashes by severity. Injury crashes are organized by severe injuries, other visible injuries, and injuries involving a complaint of pain but no visible injury.

- 99 of the 134 crashes recorded resulted in property damage only. This accounted for 74% of the total crashes.
- Two crashes (1% of total crashes) resulted in a fatality, and four crashes (3% of total crashes) resulted in severe injury.

Table 2 Crash Severity, January 2014 – December 2018.

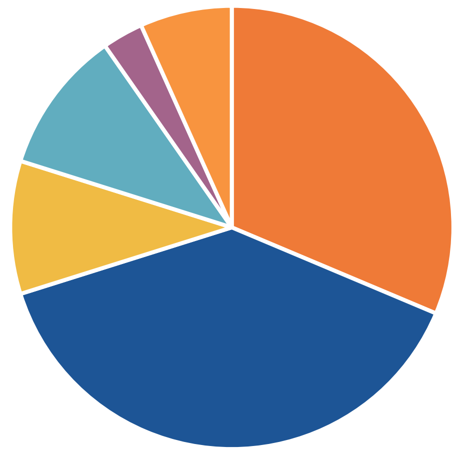
CRASH SEVERITY	CRASH COUNT
Fatal	2 (1%)
Injury (Severe)	4 (3%)
Injury (Other Visible)	25 (19%)
Injury (Complaint of Pain)	4 (3%)
Property Damage Only (PDO)	99 (74%)

Source: Virginia Department of Transportation, Kittelson 2020.

Crash Type

Figure 27 identifies the crash types of the reported crashes.

Figure 27 Vehicle Crash Types, January 2014 – December 2018.

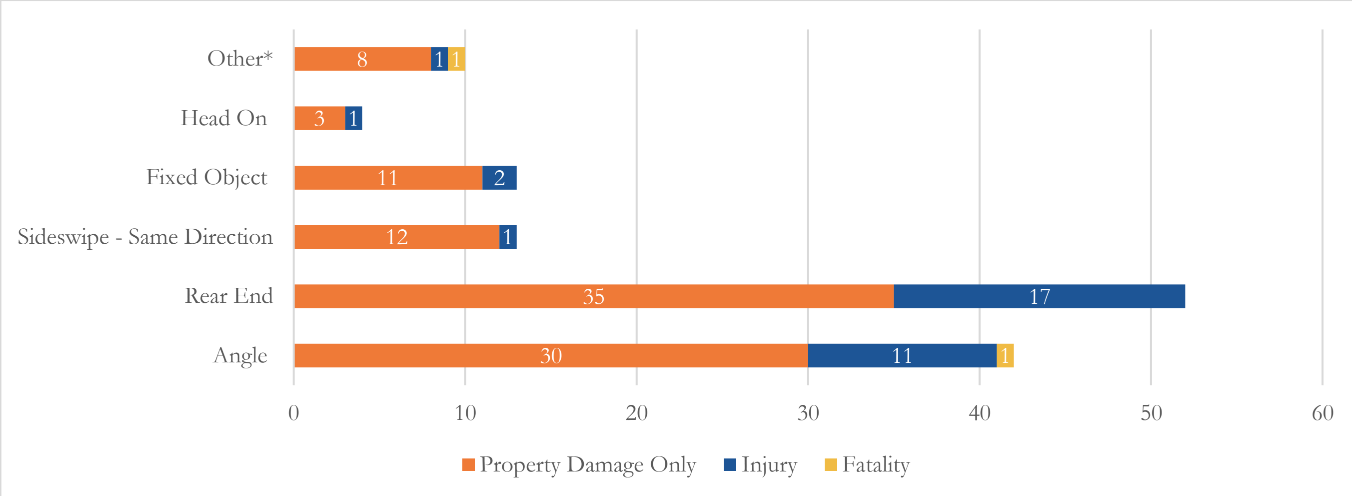


* The "Other" category includes Deer (6), Pedestrian (1), Non-Collision (1), and crash types that were categorized as "Other" (1) in the data.
Source: Virginia Department of Transportation, Kittelson 2020.

- Rear end (39%) and angle (31%) crashes represent the largest proportions of crash types.
- Rear end (52 total crashes) and angle (42 total crashes) make up over 70% of all crashes.
- The two fatalities that occurred on this corridor had crash types of angle and "other."

Figure 28 summarizes reported crashes by crash type and severity.

Figure 28 Reported Crashes by Crash Type and Severity, January 2014-December 2018.



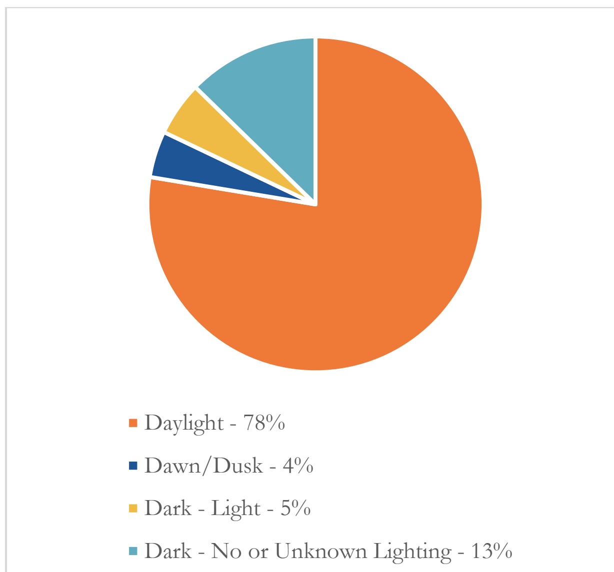
* The "Other" category includes Deer (6), Pedestrian (1), Non-Collision (1), and crash types that were categorized as "Other" (1) in the data.
Source: Virginia Department of Transportation, Kittelson 2020.

- Of the 52 rear-end crashes, 33% resulted in injury and the other 67% resulted in property-damage only.
- 26% of the total angle crashes resulted in injury. 2% of the angle crashes resulted in a fatality and approximately 72% resulted in property-damage only.
- No other crash types exhibited a higher proportion of injuries than in the total reported crashes for the study corridor (26% of study corridor crashes resulted in injury or fatality).

Lighting

Figure 29 displays the study corridor crash count by reported lighting condition.

Figure 29 Percent of Reported Crashes by Lighting, January 2014 – December 2018.



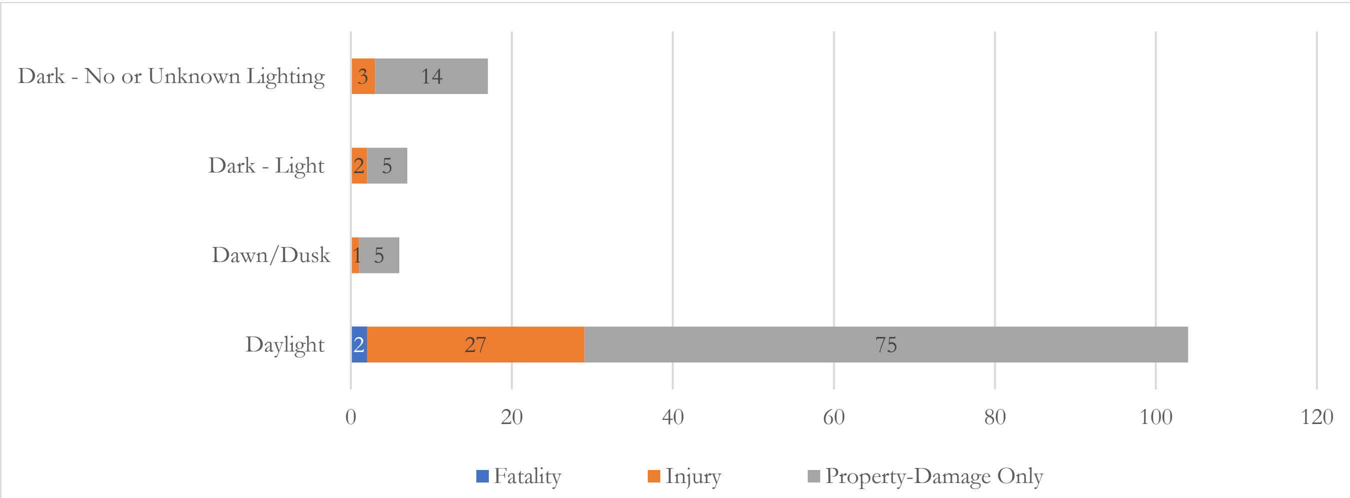
Source: Virginia Department of Transportation, Kittelson 2020.

- The majority of crashes (78%) occurred under daylight conditions.
- Of the 24 crashes that occurred in dark conditions, 71% of those occurred in unlit or unknown lighting conditions.

Figure 30 summarizes reported crashes by lighting condition and severity.

- Injury crashes that occurred under daylight (26%) and dark with lighting (29%) were slightly overrepresented compared to all crashes (25%).
- The two fatalities that occurred on this corridor had lighting conditions of daylight.

Figure 30 Reported Crashes by Lighting Condition and Severity, January 2014-December 2018.



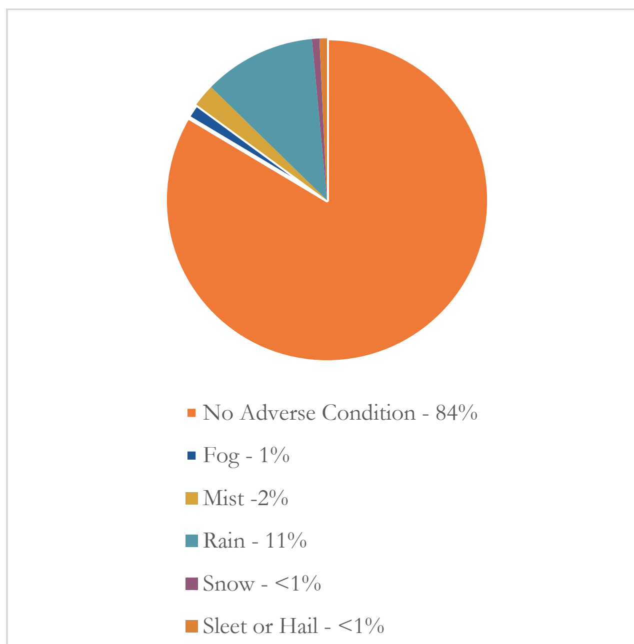
Source: Virginia Department of Transportation, Kittelson 2020.

Weather and Roadway Conditions

Figure 31 displays the study corridor crash count by reported weather condition.

- The majority of crashes (84%) occurred under no adverse or dry conditions.
- Rain accounted for 15 of the total crashes (11%).

Figure 31 Crashes by Reported Weather Condition, January 2014 – December 2019.

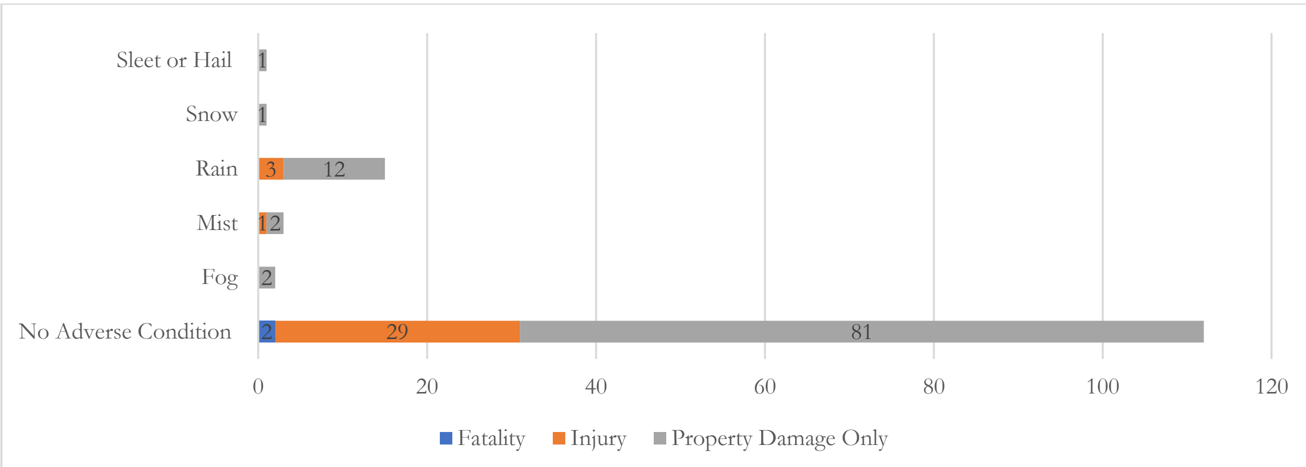


Source: Virginia Department of Transportation, Kittelson 2020.

Figure 32 summarizes reported crashes by lighting condition and severity.

- Injury crashes that occurred under misty conditions (33%) and no adverse conditions (26%) were slightly underrepresented compared to all crashes (25%).
- Of the 3 crashes that occurred in misty conditions, 33% (1 crash) resulted in an injury.
- Both fatal crashes occurred under no adverse weather condition.

Figure 32 Reported Crashes by Weather Condition and Severity, January 2014-December 2018.

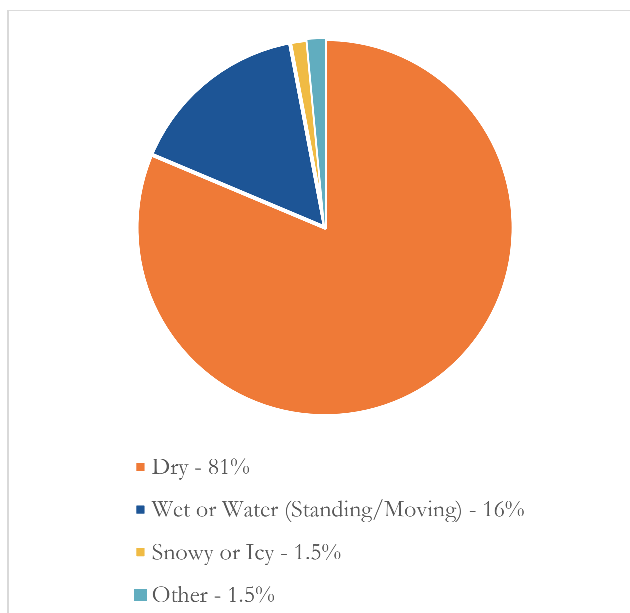


Source: Virginia Department of Transportation, Kittelson 2020.

Figure 33 displays the study corridor crash count by the reported roadway condition as an alternative way to describe the weather condition present at the time of the crash.

- The majority of crashes (81%) occurred while the roadway condition was reported to be dry.
- Snowy, icy, or wet roadway conditions accounted for 17.5% of the total crashes on this corridor.

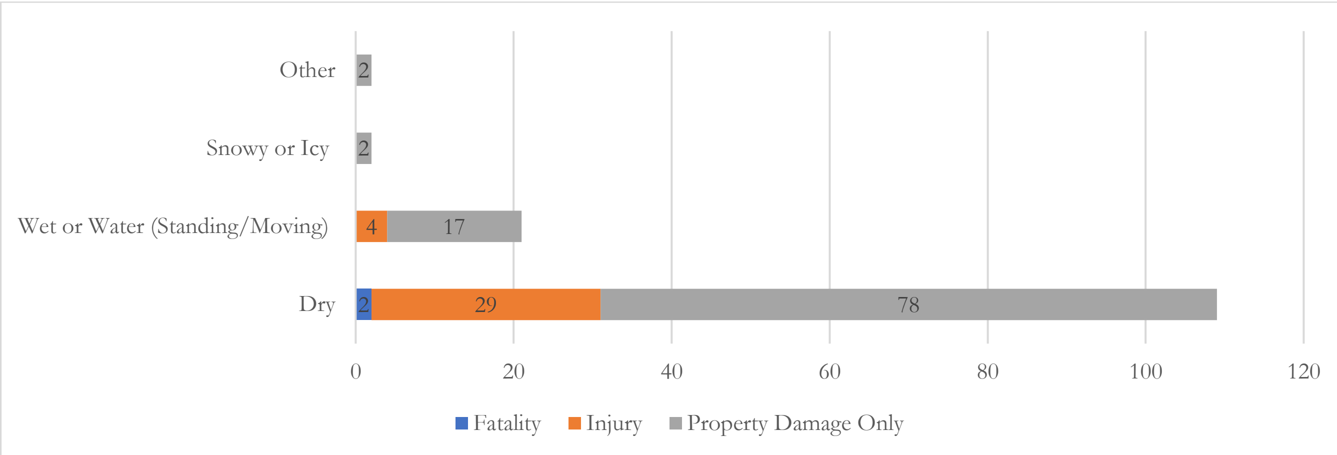
Figure 33 Crashes by Roadway Condition, January 2014 - December 2018



Source: Virginia Department of Transportation, Kittelson 2020.

Figure 34 summarizes the roadway condition and severity of crashes.

Figure 34 Reported Crashes by Roadway Condition and Severity, January 2014-December 2018.



Source: Virginia Department of Transportation, Kittelson 2020.

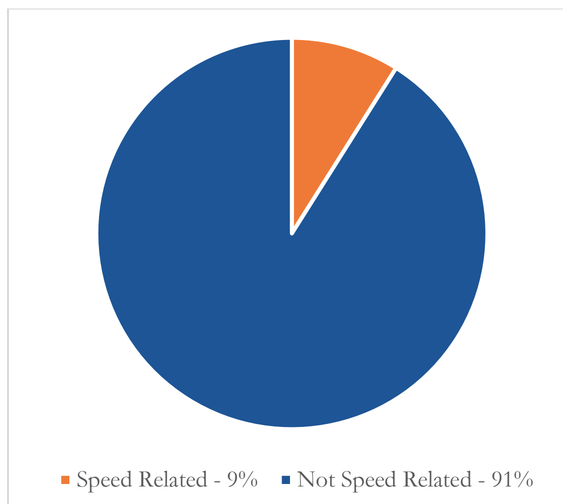
- Of the 21 crashes that occurred with wet roadway conditions, 19% (4 crashes) resulted in an injury.
- Both fatal crashes occurred while the roadway was considered to be dry.

Speed

Figure 35 summarizes the crashes by speeding condition and Figure 36 displays the speeding condition by severity of crashes.

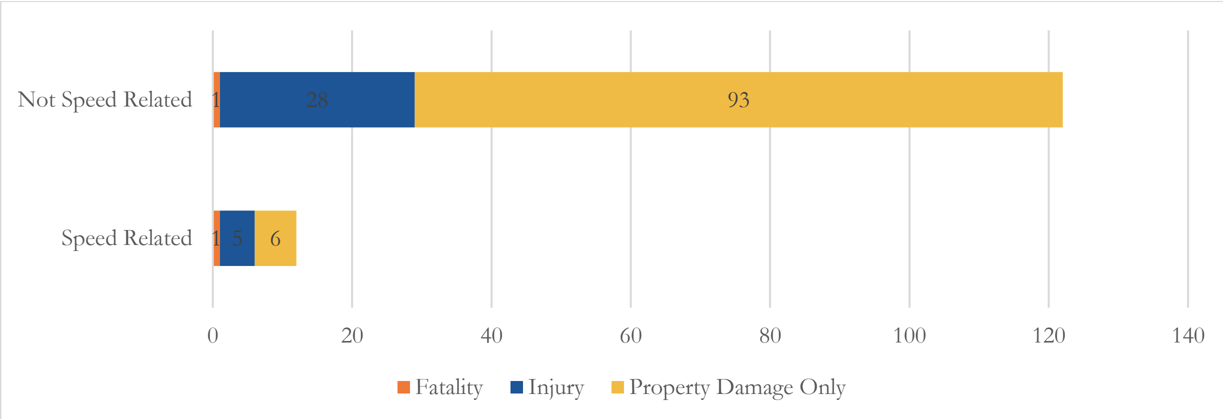
- The majority of crashes (91%) occurred when speed was not a factor (122 total crashes).
- Of the 12 crashes with speeding, 41% (5 crashes) resulted in an injury. This is a higher proportion of injuries than exhibited in the total reported crashes for the study corridor (25% of study corridor crashes resulted in injury).
- One fatal crash occurred with speeding and the other fatal crash occurred without speeding.

Figure 35 Crashes by Speed Condition, January 2014 - December 2018



Source: Virginia Department of Transportation, Kittelson 2020.

Figure 36 Reported Crashes by Speed Condition and Severity, January 2014-December 2018.



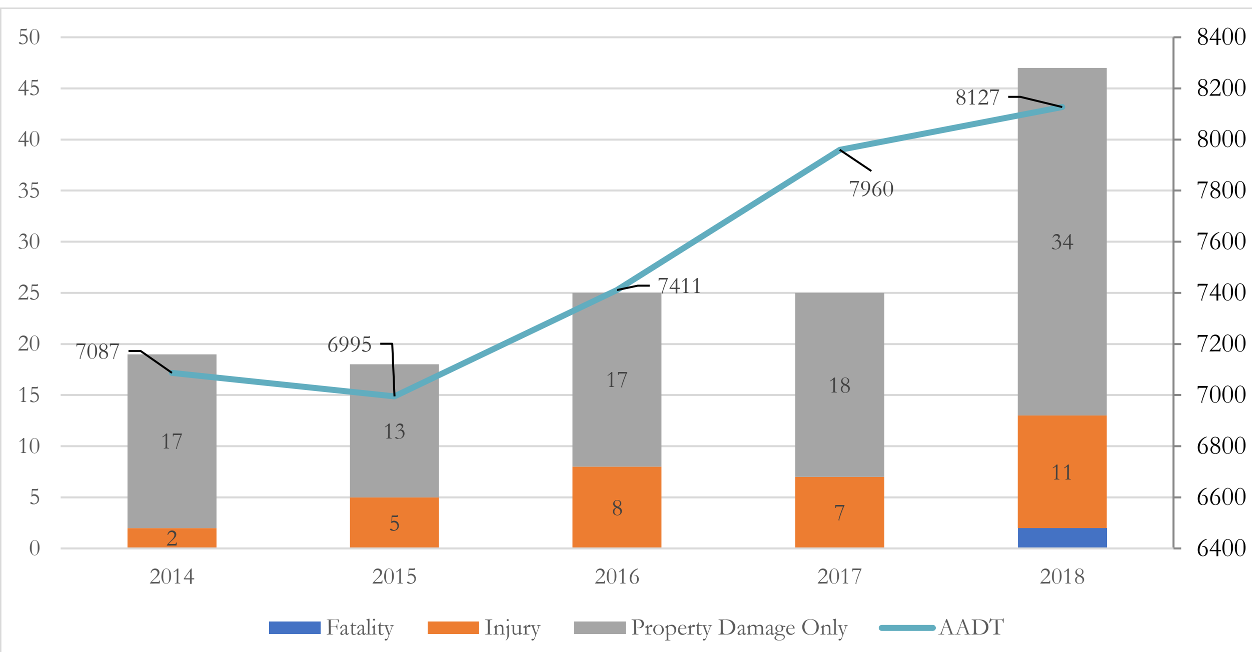
Source: Virginia Department of Transportation, Kittelson 2020.

Crash Year

Figure 37 summarizes the crash count and severity of crashes by year.

- 2018 had the highest count of crashes (47 total crashes).
- The number of annual crashes has increased by 147% since 2014 whereas the observed growth in average annual daily traffic (AADT) increased by 15%.
- The fatal crashes occurred in 2018.

Figure 37 Crashes by Year, January 2014 – December 2018



Source: Virginia Department of Transportation, Kittelson 2020.

Districtwide Ranking

Using the latest *Highway Safety Manual* (HSM) methods, VDOT conducts a roadway network screening process to identify intersections and segments with Potential for Safety Improvement (PSI) or Target Safety Needs (TSN). The comparison allows cities and counties to identify local "hot-spots" relative to peers. A number 1 in ranking is the worst performer relative to other peers in the group. All locations with a PSI greater than zero have a potential for safety improvement and a TSN indicates that a location has been considered a PSI for 3 to 5 years. This section presents relevant PSI and TSN rankings for VDOT's Culpeper District between 2014 and 2018.

Two study intersections are highlighted as intersections with Potential for Safety Improvement (PSI). The first is the intersection of US 15 and Camp Creek Parkway/Spring Creek Parkway (District Rank: 106). This location does not meet the requirements of a Target Safety Needs (TSN) location. The second is the intersection of US 15 and US 250 (District Rank: 28). This location also does not meet the requirements of a Target Safety Needs (TSN) location.

There are no segments within the limits of this study considered for Potential for Safety Improvements (PSI) and Target Safety Needs (TSN)

3.3 Network Screening and Systemic Findings

This section describes the network screening and systemic evaluation of the study corridor roadway network. First, the data and approach used to screen the study corridor roadway network and identify potential systemic risk factors are described.

Data and Approach

Kittelson identified the high-priority safety intersections using the EPDO network screening performance measure from the HSM. We performed the EPDO screening calculation for all intersections along the study corridor. The EPDO performance measure is described below.

Equivalent Property Damage Only

The EPDO performance measure assigns weighting factors to crashes by severity relative to property damage only (PDO) crashes. The weighting factors used for the network screening are based on the crash costs by severity used for Caltrans' Highway Safety Improvement Program Benefit Calculator Tool. The crash costs vary based on the location type: signalized intersection, unsignalized intersection, or roadway. The weights for each crash severity by location type are shown in Table 3.

Table 3 Crash Weights by Severity and Location Type

	LOCATION TYPE	SIGNALIZED INTERSECTION	UNSIGNALIZED INTERSECTION
CRASH WEIGHTS BY SEVERITY	**Fatal**	126	200
	Injury (Severe)	126	200
	Injury (Other Visible)	10.86	10.86
	Injury (Complaint of Pain)	6.13	6.13
	Property Damage Only (PDO)	1	1

Source: Caltrans, Highway Safety Improvement Program Benefit Calculator Tool, 2016.

The weights generally reflect an order of magnitude difference between the societal costs of fatal and severe injury collisions versus non-severe injury collisions. The weighting factors intentionally weigh fatal and severe injuries equally to recognize that the difference between a severe injury crash versus a fatal crash is often more of a function of the individuals involved – therefore, both represent locations where VDOT may want to prioritize improvements. The crash weights vary by location type due to the relative costs associated with the crash severity at those location types. Hence, fatal or severe crashes at an unsignalized intersection location result in more persons injured or more severely injured in a fatal or severe injury crash and as a result have a higher average cost than at a signalized intersection.

We first coded reported crashes by severity. Crashes within 250 feet of an intersection were then spatially joined and summarized in ArcGIS to develop the total number of crashes by severity at each intersection. Where intersections were less than 500 feet from each other, crashes were assigned to the nearest intersection. Crashes occurring more than 250 feet from an intersection were excluded from the intersection analysis.

The EPDO score for intersections was calculated by multiplying each crash severity total by its associated weight (by intersection type) and summing the results, using the following formula:

*EPDO Score = Fatal weight * # of fatal crashes + severe injury weight * # of severe injury crashes + other visible injury weight * # of other visible injury crashes + complaint of pain injury weight * # of complaint of pain injury weight crashes + PDO crashes*

The EPDO score was then annualized by dividing the score by the number of years (five) of crash data used in the analysis.

Findings

Following the calculation of the network screening performance measures, Kittelson identified priority intersections using the annualized EPDO scores. As shown in Table 4, the EPDO scores ranged from zero (no crashes occurring during the five-year time frame analyzed) to 80.80 for intersections.

Table 4 Intersections by EPDO and Annualized EPDO, January 2014 – December 2018

Intersection	EPDO	EPDO - Annualized
Sommerfield Business Park/US 15	0	0
Spring Creek Parkway/US 15	0	0
Liberty Trail/US 15	41.71	8.34
Freedom Trail/US 15	0	0
Freedom Drive/US 15	11.86	2.37
Spring Creek Parkway/Camp Creek Parkway/ US 15	73.16	14.63
Spring Creek Parkway/Wood Ridge Terrace	2	0.4
Camp Creek Parkway/Market Street	6	1.2
North DDI Ramp Terminal/US 15	164.72	32.94

South DDI Ramp Terminal/US 15	20.26	4.05
Crossing Pointe Drive/US 15	21.86	4.37
US 15/US 250	215.02	43.00
Starlite Park/US 15	13.86	2.77
Troy Road (Route 631)/US 250/Zion Station Court	404.0	80.80
Hunters Branch Road (Route 689)/US 250/Edgecombe Road	0	0
Better Living Drive/US 250	0	0
Zion Road (Route 615)/US 250	3	0.60
Zion Park Road/US 250	2	0.40
Poindexter Road (Route 613)/US 250	12.86	2.572

3.4 Priority Locations

Priority Locations

Candidate priority locations were drawn from the Phase I locations identified in the network screening and finalized based on discussions with the County. The following five intersections were selected as the top five priority locations because they experienced the majority of crashes along the study corridor and had the highest Annualized EPDO scores, shown in Table 5.

Table 5 Draft Priority Intersections

PRIORITY INTERSECTION	TOTAL CRASH COUNT
Liberty Trail/US 15	7
Spring Creek Parkway/Camp Creek Parkway/US 15	14
North DDI Ramp Terminal/US 15	20
US 15/US 250	21
Troy Road (Route 631)/US 250/Zion Station Court	6

Location-Specific Analysis Approach

To help inform the selection of the focus sites, Kittelson refined the corridor wide crash pattern and trends analysis to focus on the individual priority intersections. This approach allows for a more nuanced understanding of how each priority intersection's safety performance varies across the study area. This refined understanding of the individual crash patterns and trends for each location will assist in developing a crash profile for the site that can be used to select appropriate safety treatments to improve safety performance.

This extraction process resulted in a focused crash data set of 68 priority intersection-related crashes. These 68 crashes account for 51% of all reported crashes in the study area. Of these 68 crashes, 4 were fatal or severe injury crashes, accounting for 100% of the reported fatal and severe injury crashes in the study area. More detailed summaries of key crash characteristics are discussed below.

Location-Specific Findings

This section discusses crash trends along the priority intersections, highlighting notable differences between patterns in a specific intersection and the countywide patterns previously discussed. The analysis includes the following considerations:

- Crash severity
- Crash type
- Crash contributing factor

Crash Severity by Intersection

Table 6 summarizes reported crashes by draft priority intersection and severity. PDO crashes were the most common crash type by all five priority intersections followed by moderate injury and then minor injury crashes. The intersection of Liberty Trail had few crashes (7 total crashes), over half of these were a moderate or minor injury. The intersection of US 250/US 15 had the highest EPDO score with 38% of its 21 crashes resulting in severe or moderate injury.

Table 6 Crashes by Priority Intersection and Severity, January 2014 to December 2018

PRIORITY CORRIDOR	FATALITY	SEVERE INJURY	MODERATE INJURY	MINOR INJURY	PDO
Liberty Trail/US 15	0	0	3	1	3
Spring Creek Parkway/Camp Creek Parkway/ US 15	0	0	6	0	8
North DDI Ramp Terminal/US 15	1	0	2	0	17
US 15/US 250	0	1	7	0	13
Troy Road (Route 631)/US 250/Zion Station Court	1	1	0	0	4

Source: Kittelson, 2020

- Liberty Trail/US 15: Above corridor average for moderate and minor injuries.
- Spring Creek Parkway/Camp Creek Parkway/US 15: Above corridor average for moderate injuries.
- North DDI Ramp Terminal/US 15: Above corridor average for fatal, moderate injury and property damage only crashes.
- US 15/US 250: Above corridor average for severe injuries and moderate injuries.
- Troy Road (Route 631)/US 250/Zion Station Court: Above corridor average for fatal and severe injury crashes.

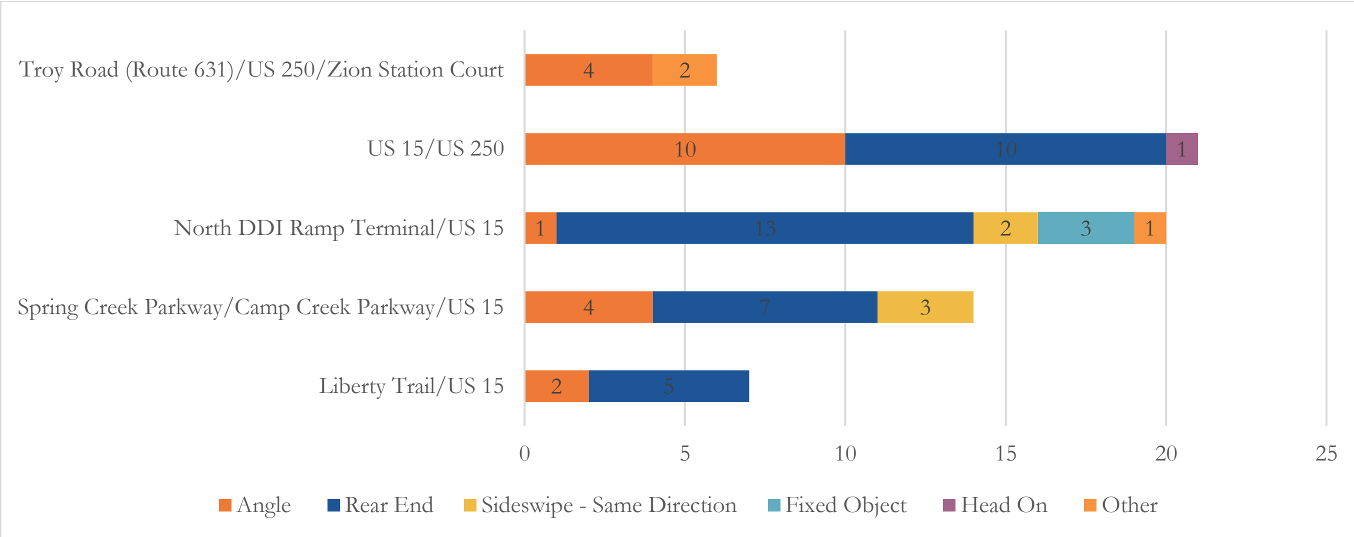
Crash Type by Intersection

As already discussed, the most common crash types study areawide are the following:

- PDO: 74% of total and
- Moderate Injury (Visible): 19% of total

Figure 38 summarizes crash types on each of the priority intersections. Rear end crashes are the most common crash types for each intersection except for the Troy Road (Route 631)/US 250/Zion Station Court where angle crashes were more. The intersection of US 250/US 15 had an equal number of both rear end and angle crashes.

Figure 38 Crash Type by Intersection, January 2014 to December 2018



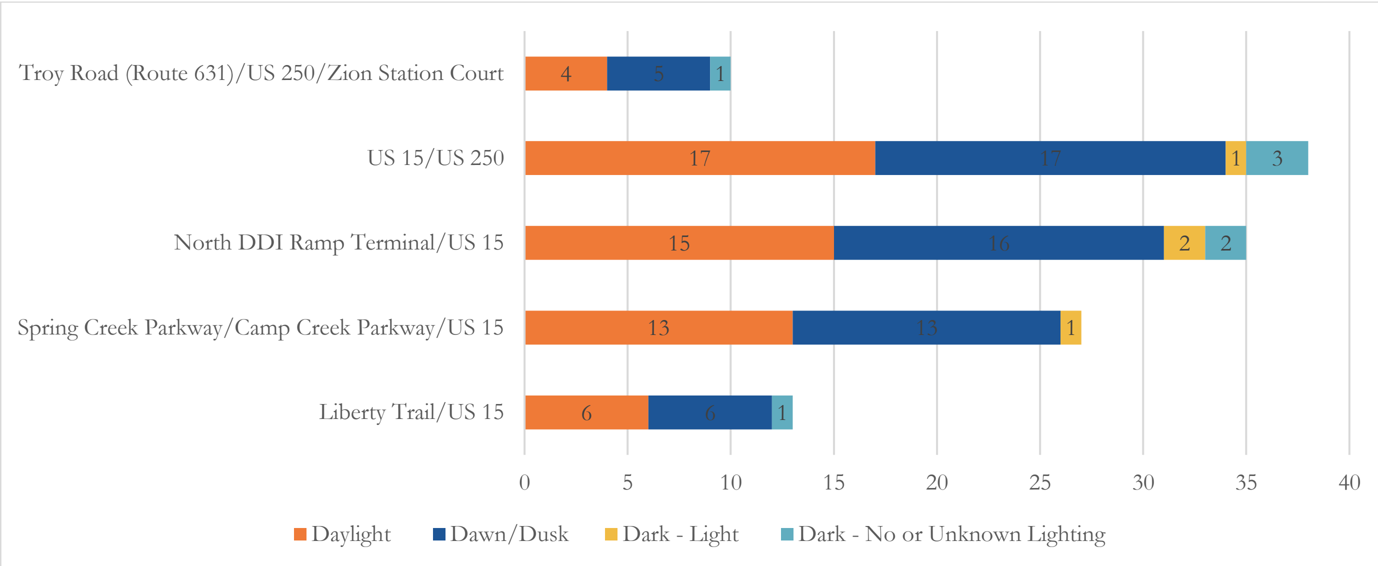
Source: Kittelson, 2020

- Liberty Trail/US 15: Above corridor average for rear end crashes.
- Spring Creek Parkway/Camp Creek Parkway/US 15: Above corridor average for rear-end and sideswipe-same direction crashes.
- North DDI Ramp Terminal/US 15: Above corridor average for rear end, sideswipe-same direction, fixed object crashes.
- US 15/US 250: Above corridor average for angle, rear end, and head on crashes.
- Troy Road (Route 631)/US 250/Zion Station Court: Above corridor average for angle and other crashes.

Lighting Conditions at Intersection Crash

Figure 39 summarizes crash types on each of the priority intersections regarding lighting conditions. Crashes during the dawn/dusk are the most common crash type for all five priority intersections with the intersections of Liberty Trail/US 15, Spring Creek Parkway/Camp Creek Parkway/US 15 and US 15/US250 having equal number of daylight and dawn/dusk crashes.

Figure 39 Reported Crashes by Lighting Condition, January 2014 to December 2018



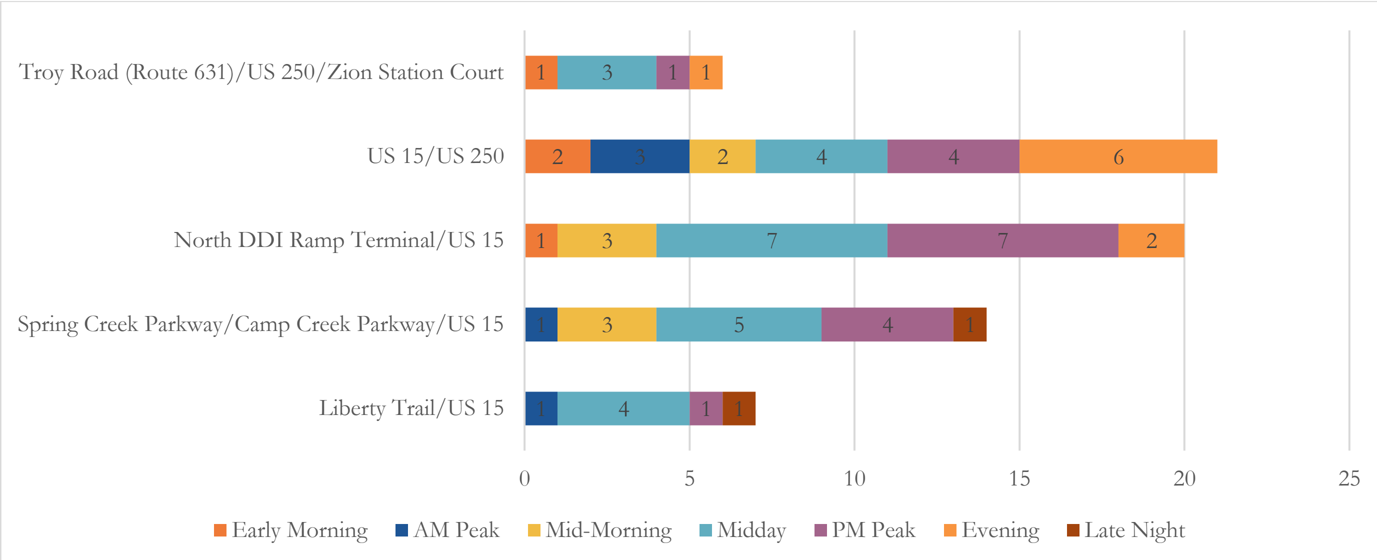
Source: Kittelson, 2020

- Liberty Trail/US 15: Above corridor average for dawn/dusk crashes.
- Spring Creek Parkway/Camp Creek Parkway/US 15: Above corridor average for dawn/dusk crashes.
- North DDI Ramp Terminal/US 15: Above corridor average for dawn/dusk and dark-lighted roadway crashes.
- US 15/US 250: Above corridor average for dawn/dusk crashes.
- Troy Road (Route 631)/US 250/Zion Station Court: Above corridor average for dawn/dusk crashes.

Time of Day at Intersection Crash

Figure 40 summarizes crash types on each of the priority intersections regarding time of day. Crashes during the midday peak are the most common crash type for all priority intersections except for US 15/US 250. This intersection had the most crashes during the p.m. peak. In addition, there was an equal number of crashes during the midday and p.m. peaks at the North DDI Ramp Terminal/US 15.

Figure 40 Reported Crashes by Time of Day, January 2014 to December 2018



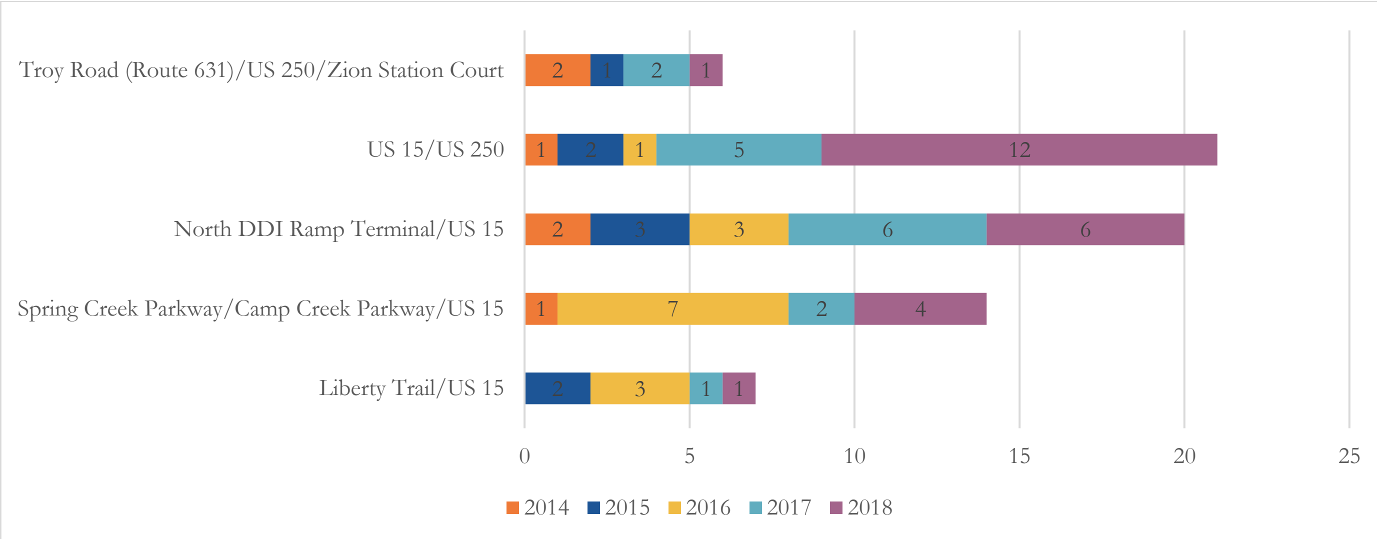
Source: Kittelson, 2020

- Liberty Trail/US 15: Above corridor average for a.m. peak, midday, and late-night crashes.
- Spring Creek Parkway/Camp Creek Parkway/US 15: Above corridor average for mid-morning, midday, p.m. peak and late-night crashes.
- North DDI Ramp Terminal/US 15: Above corridor average for early morning, mid-morning, midday, and p.m. peak crashes.
- US 15/US 250: Above corridor average for early morning, a.m. peak and evening crashes.
- Troy Road (Route 631)/US 250/Zion Station Court: Above corridor average for early morning, midday, and evening crashes.

Year at Intersection Crash

Figure 41 summarizes crash types on each of the priority intersections regarding reported year.

Figure 41 Reported Crashes by Year, January 2014 to December 2018



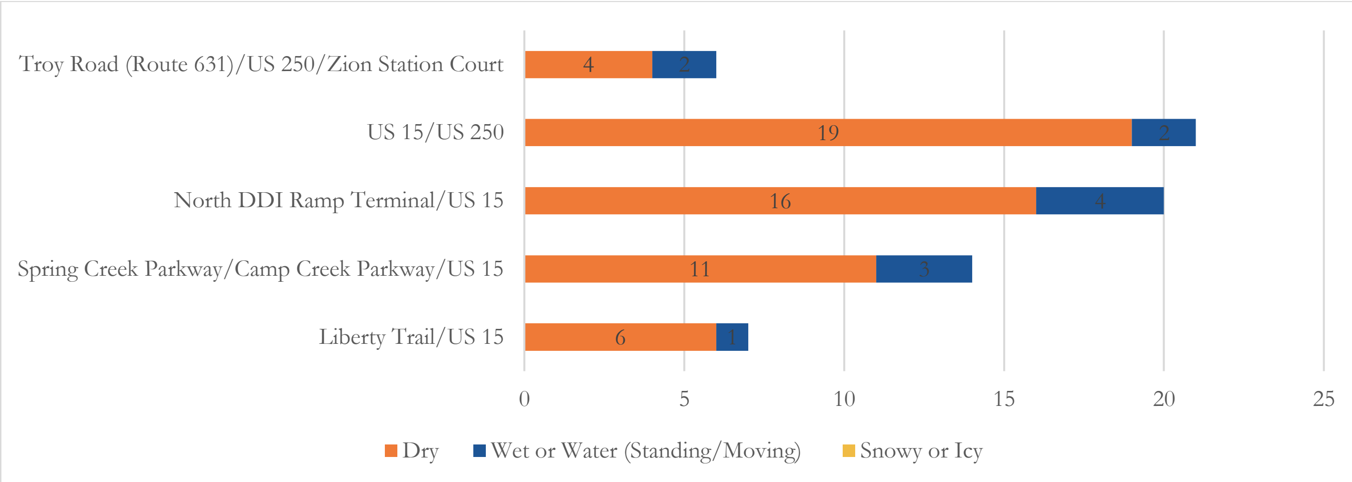
Source: Kittelson, 2020

- Liberty Trail/US 15: Above corridor average for crashes in 2015 and 2016.
- Spring Creek Parkway/Camp Creek Parkway/US 15: Above corridor average for crashes in 2016.
- North DDI Ramp Terminal/US 15: Above corridor average for crashes in 2015 and 2017.
- US 15/US 250: Above corridor average for crashes in 2017 and 2018.
- Troy Road (Route 631)/US 250/Zion Station Court: Above corridor average for crashes in 2014, 2015 and 2017.

Roadway Surface Condition at Intersection Crash

Figure 42 summarizes crash types on each of the priority intersections regarding roadway surface conditions. Most of the priority intersection crashes occurred on dry roadway surfaces.

Figure 42 Reported Crashes by Roadway Surface Condition, January 2014 to December 2018



Source: Kittelson, 2020

- Liberty Trail/US 15: Above corridor average for dry roadway crashes.
- Spring Creek Parkway/Camp Creek Parkway/US 15: Above corridor average for wet roadway crashes.
- North DDI Ramp Terminal/US 15: Above corridor average for wet roadway crashes.
- US 15/US 250: Above corridor average for dry roadway crashes.
- Troy Road (Route 631)/US 250/Zion Station Court: Above corridor average for wet roadway crashes.

Summary

- The five priority intersections were selected as the top five priority locations because they experienced this highest annualized EPDO score across the 19 intersections evaluated along this corridor.
- PDO crashes tended to be the most common crash type by all five priority intersections followed by moderate injury and then severe injury and fatal crashes.
- Rear end crashes are the most common crash types for each intersection except for the Troy Road (Route 631)/US 250/Zion Station Court where angle crashes were more. At the intersection of US 250/US 15, there was an equal number of both rear end and angle crashes.
- Crashes during the daytime are the most common crash type for all five priority intersections, but all priority intersections had above corridor average for dawn/dusk crashes.
- Crashes during the midday peak are the most common crash type for all priority intersections except for US 15/US 250. This intersection had the most crashes during the PM peak. In addition, there was an equal number of crashes during the midday and p.m. peaks at the North DDI Ramp Terminal/US 15.
- Most of the priority intersection crashes occurred on dry roadway surfaces.

4.0 CONCLUSION AND NEXT STEPS

Based on the analysis of existing and background operations and existing safety, strategies and alternatives will be identified to address operational, safety, and access management deficiencies. All study intersections will be evaluated for potential improvements, including innovative intersection control strategies. After an initial screening of potential alternatives, up to two (2) improvements will be evaluated further for each intersection through development of conceptual designs and more detailed operational analysis.

An access management plan, including a typical cross-section(s), will be developed for the entire study corridor to plan for future growth. Specific emphasis will be placed on the following segments with existing or planned higher density land uses:

- Camp Creek Parkway/Spring Creek Parkway from Wood Ridge Terrace to Market Street
- US 15 from the first commercial entrance north of Camp Creek Parkway to US 250.

Preliminary recommendations will be developed in annotated graphical format and circulated to the stakeholder group for subsequent discussions. Where feasible, improvements/strategies will be broken into smaller, phase-able improvements with individual summary pages.

5.0 REFERENCES

1. Fluvanna County Interactive Web Based GIS. https://www.webgis.net/va/fluvanna/
2. Louisa County Interactive Web Based GIS. https://louisagis.timmons.com/#/mwl?location=-78.218976_37.970933&zoom=16
3. VDOT 2014 Approved Functional Classifications. https://www.arcgis.com/home/webmap/viewer.html?webmap=3eca6c9adb6649c988d98734f85baddb
4. Transportation Research Board. Highway Capacity Manual 6. 2016.
5. Virginia Department of Transportation. Traffic Operations and Safety Analysis Manual, v 2.0. February 2020.

6.0 APPENDICES

Appendix A: Traffic Counts

Appendix B: Level-of-Service Concept

Level of service (LOS) is a concept developed to quantify the degree of comfort (including such elements as travel time, number of stops, total amount of stopped delay, and impediments caused by other vehicles) afforded to drivers as they travel through an intersection or roadway segment. Six grades are used to denote the various level of service from "A" to "F".[1]

Signalized Intersections

The six level-of-service grades are described qualitatively for signalized intersections in Table C1. Additionally, Table C2 identifies the relationship between level of service and average control delay per vehicle. Control delay is defined to include initial deceleration delay, queue move-up time, stopped delay, and final acceleration delay. Using this definition, Level of Service "D" is generally considered to represent the minimum acceptable design standard.

Table C1: Level-of-Service Definitions (Signalized Intersections)

Level of Service	Average Delay per Vehicle
A	Very low average control delay, less than 10 seconds per vehicle. This occurs when progression is extremely favorable, and most vehicles arrive during the green phase. Most vehicles do not stop at all. Short cycle lengths may also contribute to low delay.
B	Average control delay is greater than 10 seconds per vehicle and less than or equal to 20 seconds per vehicle. This generally occurs with good progression and/or short cycle lengths. More vehicles stop than for a level of service A, causing higher levels of average delay.
C	Average control delay is greater than 20 seconds per vehicle and less than or equal to 35 seconds per vehicle. These higher delays may result from fair progression and/or longer cycle lengths. Individual cycle failures may begin to appear at this level. The number of vehicles stopping is significant at this level, although many still pass through the intersection without stopping.
D	Average control delay is greater than 35 seconds per vehicle and less than or equal to 55 seconds per vehicle. The influence of congestion becomes more noticeable. Longer delays may result from some combination of unfavorable progression, long cycle length, or high volume/capacity ratios. Many vehicles stop, and the proportion of vehicles not stopping declines. Individual cycle failures are noticeable.
E	Average control delay is greater than 55 seconds per vehicle and less than or equal to 80 seconds per vehicle. This is usually considered to be the limit of acceptable delay. These high delay values generally (but not always) indicate poor progression, long cycle lengths, and high volume/capacity ratios. Individual cycle failures are frequent occurrences.

[1] Most of the material in this Appendix is adapted from the Transportation Research Board, Highway Capacity Manual, (2010).

F	Average control delay is in excess of 80 seconds per vehicle. This is considered to be unacceptable to most drivers. This condition often occurs with oversaturation. It may also occur at high volume/capacity ratios below 1.0 with many individual cycle failures. Poor progression and long cycle lengths may also contribute to such high delay values.

Most of the material in this Appendix is adapted from the Transportation Research Board, Highway Capacity Manual, (2000).

Table C2: Level-of-Service Criteria for Signalized Intersections

Level of Service	Average Control Delay per Vehicle (Seconds)
A	<10.0
B	>10 and (20
C	>20 and (35
D	>35 and (55
E	>55 and (80
F	>80

Unsignalized Intersections

Unsignalized intersections include two-way stop-controlled (TWSC) and all-way stop-controlled (AWSC) intersections. The 2010 Highway Capacity Manual (HCM) provides models for estimating control delay at both TWSC and AWSC intersections. A qualitative description of the various service levels associated with an unsignalized intersection is presented in Table C3. A quantitative definition of level of service for unsignalized intersections is presented in Table C4. Using this definition, Level of Service "E" is generally considered to represent the minimum acceptable design standard.

Table C3: Level-of-Service Criteria for Unsignalized Intersections

Level of Service	Average Delay per Vehicle to Minor Street
A	• Nearly all drivers find freedom of operation. • Very seldom is there more than one vehicle in queue.
B	• Some drivers begin to consider the delay an inconvenience. • Occasionally there is more than one vehicle in queue.
C	• Many times, there is more than one vehicle in queue. • Most drivers feel restricted, but not objectionably so.
D	• Often there is more than one vehicle in queue. • Drivers feel quite restricted.
E	• Represents a condition in which the demand is near or equal to the probable maximum number of vehicles that can be accommodated by the movement. • There is almost always more than one vehicle in queue.

	• Drivers find the delays approaching intolerable levels.
F	• Forced flow. • Represents an intersection failure condition that is caused by geometric and/or operational constraints external to the intersection.

Table C4: Level-of-Service Criteria for Unsignalized Intersections

Level of Service	Average Control Delay per Vehicle (Seconds)
A	<10.0
B	>10.0 and <15.0
C	>15.0 and <25.0
D	>25.0 and <35.0
E	>35.0 and <50.0
F	>50.0

It should be noted that the level-of-service criteria for unsignalized intersections are somewhat different than the criteria used for signalized intersections. The primary reason for this difference is that drivers expect different levels of performance from different kinds of transportation facilities. The expectation is that a signalized intersection is designed to carry higher traffic volumes than an unsignalized intersection. Additionally, there are a number of driver behavior considerations that combine to make delays at signalized intersections less galling than at unsignalized intersections. For example, drivers at signalized intersections are able to relax during the red interval, while drivers on the minor street approaches to TWSC intersections must remain attentive to the task of identifying acceptable gaps and vehicle conflicts. Also, there is often much more variability in the amount of delay experienced by individual drivers at unsignalized intersections than signalized intersections. For these reasons, it is considered that the control delay threshold for any given level of service is less for an unsignalized intersection than for a signalized intersection. While overall intersection level of service is calculated for AWSC intersections, level of service is only calculated for the minor approaches and the major street left turn movements at TWSC intersections. No delay is assumed to the major street through movements. For TWSC intersections, the overall intersection level of service remains undefined: level of service is only calculated for each minor street lane.

In the performance evaluation of TWSC intersections, it is important to consider other measures of effectiveness (MOEs) in addition to delay, such as v/c ratios for individual movements, average queue lengths, and 95th-percentile queue lengths. By focusing on a single MOE for the worst movement only, such as delay for the minor-street left turn, users may make inappropriate traffic control decisions. The potential for making such inappropriate decisions is likely to be particularly pronounced when the HCM level-of-service thresholds are adopted as legal standards, as is the case in many public agencies.

Appendix C: Existing Conditions Level-of-Service

Table C.1. Existing Conditions – Summary of Peak Hour Levels of Service, 95th Percentile Back of Queue, and Delay for Each Lane Group by Intersection

Appendix D: Future Traffic Conditions Level-of-Service

Table D.1 Future Conditions – Summary of Peak Hour Levels of Service, 95th Percentile Back of Queue, and Delay for Each Lane Group by Intersection

Appendix E: Safety Maps

VDOT

Planning