Final Report

I-95/I-64 Overlap Study

Prepared for:

Virginia Department of Transportation

Prepared by:

Kimley-Horn and Associates, Inc.

March 2013

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KHA Project #: 117306011

EXECUTIVE SUMMARY

Introduction

The I-95/I-64 Overlap Study was conducted over a 12-month period under the direction of Virginia Department of Transportation (VDOT) and in coordination with a Study Work Group (SWG) representing the stakeholders of this study. VDOT identified the I-95/I-64 Overlap area in downtown Richmond to be one of the highest crash, heavily congested corridors in the region. Based on the analysis of the I-95/I-64 corridor, it was determined that deficiencies existed due to significant traffic volumes coupled with numerous closely spaced ramps. Safety and operational concerns persist, especially weaving and merging areas associated with the multiple interstate-to-interstate connections within this study area. The ultimate goal of this study was to determine potential transportation improvement projects that could be incorporated into the VDOT Six-Year Improvement Program (SYIP) to improve safety and operations throughout the corridor.

Study Area

The study corridor was approximately 8 miles long and included 12 interchanges and 15 at-grade intersections as shown in **Figure 1**. The northern limit of the study corridor was in Henrico County at the Hermitage Road interchange at milepost 80 and southern limit was in the City of Richmond at the north end of the James River Bridge at milepost 73. The approximate 1-mile section of I-64 between the Staples Mill Road interchange and the I-95/I-64/I-195 interchange (also known as the Bryan Park Interchange) was also included in the study area due to its proximity to the remainder of the study corridor. Similarly, the approximate 0.1-mile section of I-195 between the Laburnum Avenue interchange and the Bryan Park interchange was included in the study area. The eastern limit of the corridor was the western terminus of the Shockoe Bottom Bridge on I-64 at milepost 191.

Study Process

The study process included data collection, development of concepts, and alternatives analysis. The development of concepts focused on addressing the identified traffic operations and safety challenges in the corridor. The study team conducted a limited amount of engineering using available information, such as data obtained during field reviews and data from geographic information systems (GIS), to develop planning level cost estimates and schedules for project programming purposes. Once these projects are programmed in the SYIP, preliminary engineering, supported by detailed engineering surveys showing vertical constraints and right-of-way impacts, should be conducted to determine more accurate estimated project costs and schedules. The SWG used the results of benefit-cost analyses as one of several factors to prioritize the proposed SYIP projects. A flow chart depicting the study process is provided in **Figure 2**.

Existing Conditions

The consultant team collected existing condition information in the study area by conducting field inventories and by obtaining crash, speed, origin-destination, and traffic count data from VDOT. Traffic and safety analyses were performed using the historical crash data and existing traffic data to determine corridor and intersection safety and network operational efficiency. The results of the existing conditions analyses were used to identify existing operational and safety issues; establish a baseline for comparison of concepts; and confirm the need for this study.

Roadway Deficiencies

This section of I-95/I-64 was initially constructed in the mid-1950s and completed in 1958 resulting in geometric conditions not meeting current design standards. The following key roadway deficiencies, which currently negatively impact operations and safety in the corridor, were documented:

Study Area
I-95 / I-64 Overlap Study
City of Richmond and Henrico County, VA

Figure
1

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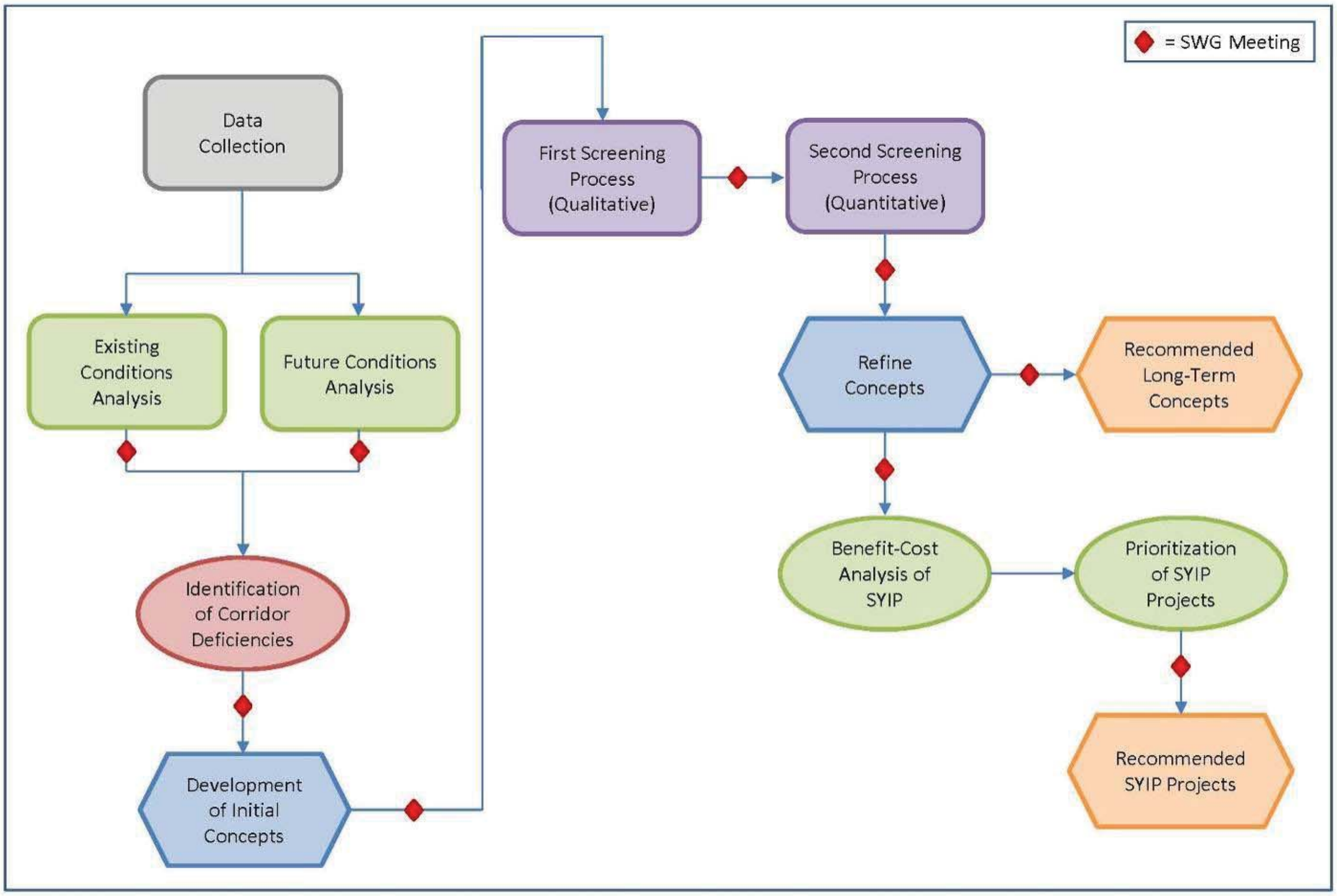
Figure 2: Study Process



- Most roadway shoulders (left and right) are less than 12 feet wide creating a safety hazard for disabled vehicles stopped on the interstate.
- The length of numerous merge, diverge, and weave sections are deficient and do not meet current standards.
- Three interchanges in the northbound direction and three interchanges in the southbound direction do not meet the minimum 1-mile interchange spacing for urban areas.
- Nineteen of the 26 bridges crossing over mainline I-95/I-64 do not meet the 16.5-foot minimum bridge vertical clearance for urban interstates.

<u>Crash Analysis</u>

Crash histograms, developed on a quarter-mile basis, were used by the study team to identify high-crash locations, or crash hot spots, within the study corridor. Crash hot spots were identified using a statistical crash analysis. Most of the crash hot spots were concentrated around the Bryan Park, Belvidere, and I-95/I-64 east interchanges in both directions.

The following crash trends were identified in the study corridor based on an analysis of 3 years of crash data between 2007 and 2009.

- The total number of reported crashes during 3 years was 1,813 with 27% of them resulting in injuries.
- The primary crash type was rear end, which is an expected crash pattern on congested interstates.
- The second highest crash type is fixed-object off-road, which is also a prominent crash type on interstates.
- Over 60% of the crashes occurred during AM and PM peak periods.

- Approximately 30% of the crashes occurred during dark conditions, which is often found in corridors without continuous roadway lighting.
- Due to the east-west alignment of I-64 between Staples Mill and the Bryan Park interchange, sun glare may be a contributing factor to dawn/dusk crashes, which represent 20% of the total crashes.
- The 5 ramps with the highest crash severity are located in system-to-system merges/diverges at the Bryan Park interchange, the I-95/I-64 East interchange, and the northbound on-ramp from Belvidere Street.

Speed Data

AM and PM peak period congestion and related queuing was observed in the field and validated with collected vehicle speed data. Reduced speeds were observed throughout the corridor; specifically, at key junction points through the Bryan Park, Boulevard, and Belvidere interchanges in the AM and PM peak periods. The results of the speed data analysis, which was based on INRIX data provided by VDOT, was consistent with field observations with low speeds in the overlap area during both the AM and PM peak hours.

Traffic Volumes & Origin Destination Data

To determine existing traffic conditions, 2011 traffic data was compiled from a variety of sources for the mainline interstate, 46 ramps, and 15 intersections. VDOT provided data to the study team from permanent traffic count stations, 72-hour directional tube counts, and peak hour intersection turning movement counts. Mainline traffic volumes were used to establish the study analysis peak hours, which were 7:30 and 8:30 AM and 4:30 to 5:30 PM. A seasonal adjustment factor was applied to the collected traffic counts. Heavy vehicle percentages in the peak hours ranged from 5 to 11% on the mainline interstates and between 0% and 31% on the ramps.

Detailed origin-destination (O-D) data was collected throughout the study corridor to assist the study team with determining peak hour traffic volumes for use with the traffic simulation tool used for this study, which was VISSIM. The O-D data was also used to calibrate output results from VISSIM.

Existing 2011 Operational Analyses

Existing 2011 AM and PM peak period traffic operational analyses in the study corridor and at all interchange ramps and weave areas was conducted using VISSIM, while operational analyses at intersections was completed using Synchro. The existing analyses were used to identify operational issues and establish a baseline for comparison of concepts.

Based on the results of the microsimulation analyses, most ramp merges, ramp diverges, weave areas, and mainline interstate operate at level of service (LOS) D or better under existing conditions with the exception of a few points of congestion that operate at LOS E and LOS F. Major bottlenecks in the study area include the eastbound I-64 to northbound I-95 and the northbound I-95 to westbound I-64 movements through the Bryan Park interchange and the eastbound I-64 to southbound I-95 and westbound I-64 to northbound I-95 movements through the I-95/I-64 east interchange. The signalized intersections analyzed within the study area operate with delays equivalent to an overall LOS D or better.

Future Traffic Conditions

VDOT reviewed historical traffic count data, socio-economic data, and traffic volume projections from the following available sources to develop growth rates for 2022 and 2035:

- Statewide Planning System (SPS) data – a database that includes available VDOT Traffic Monitoring System (TMS) traffic counts through 2010
- Richmond/Tri-Cities Travel Demand Model based on the 2031 MPO Constrained Long Range Plan (CLRP)
- Growth rates from the on-going I-64 Environmental Impact Study (EIS) study


Developed growth rates were applied to the 2011 peak hour volumes to project future 2022 No-Build and 2035 No-Build traffic volumes to determine baseline and future traffic demands. The computed growth rates resulted in 2022 and 2035 peak hour traffic volumes that were approximately 20% higher and 30% higher than the existing volumes, respectively.

Future 2022 and 2035 No-Build Capacity Analysis

The results of the 2022 traffic conditions indicated degradation from existing conditions and illustrate the expansion of congestion throughout the study area. Most of the corridor segments are projected to operate at conditions significantly exceeding capacity by 2035. Results indicated that operations throughout the corridor over the next 20 years will continue to deteriorate with the primary congested areas located at the Bryan Park and I-95/I-64 east interchanges.

Concept Development

Initial List of Improvements

Potential corridorwide improvements were developed to address various operational, geometric, maintenance, and safety deficiencies identified during analysis of the 2011 existing, 2022 no-build, and 2035 no-build conditions. An initial list of improvements was developed and screened through a series of meetings and workshops. Based on input discussed at these workshops, the initial list of improvements was categorized and combined into short-term, Six-Year Improvement Program (SYIP), and long-term projects.

First Screening Process

Conceptual figures documenting both SYIP and long-term geometric roadway improvements were developed to a level of detail necessary to determine the feasibility of the proposed improvement(s). The first screening of the initial of list of proposed improvement projects was qualitative in nature and was based on the following factors:

- Safety
- Traffic operations
- Order of magnitude cost
- Environmental
- Impact to adjacent roadways and intersections

Second Screening Process

The second screening process was quantitative and was based on the following criteria:

- Traffic Operations – each SYIP and long-term geometric improvement was modeled in VISSIM to further screen improvements that provided an operational benefit; specially a reduction in travel time.
- Cost – planning level cost estimates and an associated benefit-cost (B/C) analysis were developed for only the SYIP projects and were used to further justify their proposed inclusion in the SYIP.

The final recommended list identified as result of this second screening process consisted of 36 short-term improvements, 11 SYIP projects, and 14 long-term concepts. A full description of each improvement is provided within the report and specific examples are provided below.

Short-Term Improvements

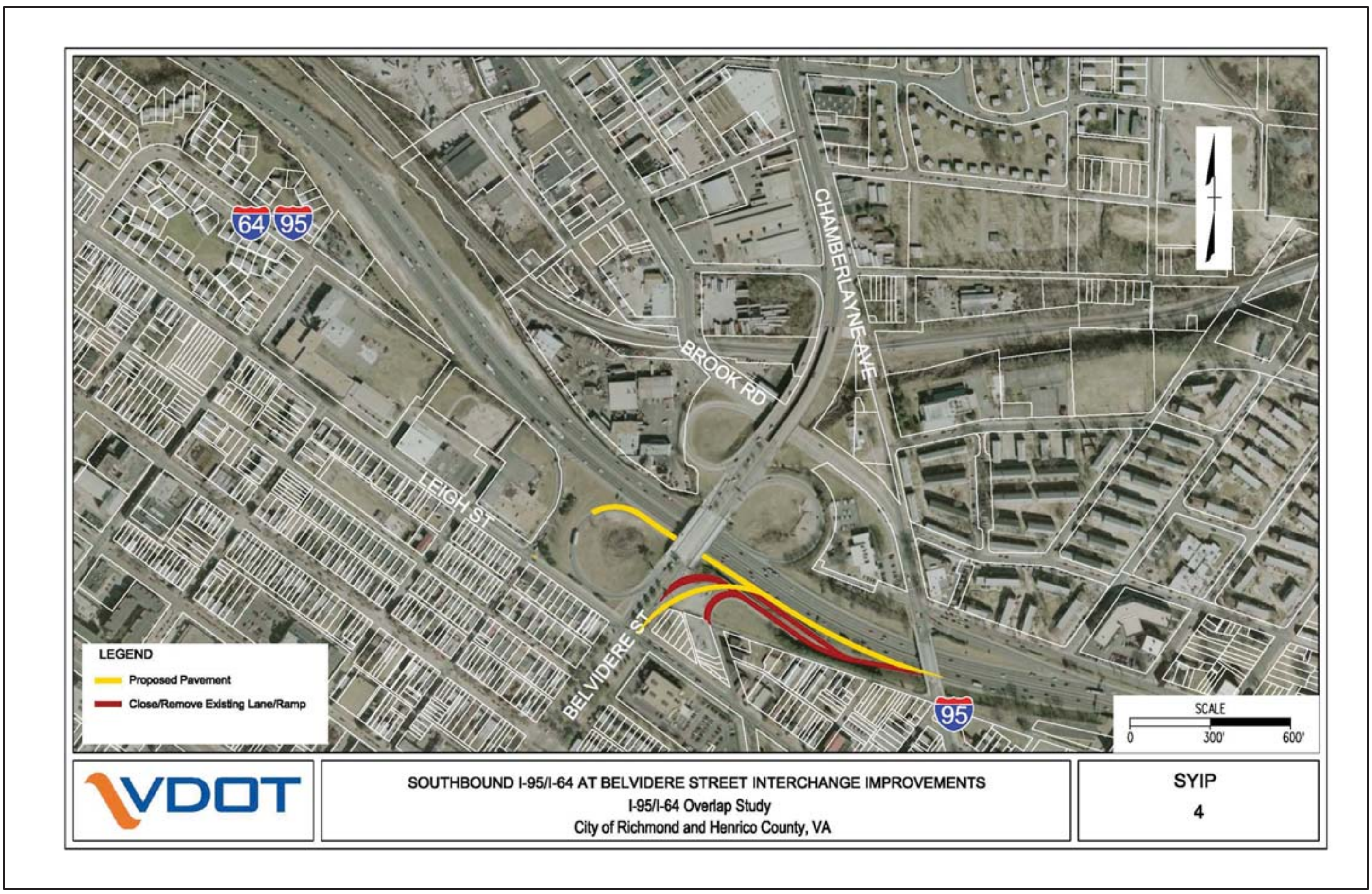
These improvements were either maintenance projects or minor upgrades that may require preliminary engineering with no impact to right-of-way. Short-term improvements typically have the following characteristics: they can be completed in less than three years, they may be completed with VDOT maintenance resources; and they may be programmed in the SYIP. Because short-term improvements, by their nature, did not address major operational issues within the corridor, they were not advanced through the screening process.

Six-Year Improvement Program (SYIP) Projects

One of the primary goals of this study was to develop projects to be considered for inclusion in the upcoming VDOT SYIP (FY14-19). These projects will require detailed preliminary design, and may require right-of-way acquisition depending on the location of the project. SYIP projects were grouped into two categories: geometric and non-geometric improvements.

1. Geometric Roadway Improvements – included projects such as ramp extensions, interchange modifications, intersection modifications, shoulder widening, and/or ramp widening. SYIP 4, as shown in **Figure 3**, is an example of a geometric improvement at the on-ramp from Belvidere Road to southbound I-95/I-64. The proposed project will eliminate the slip ramp from westbound Duval Street, which removes one of the merge points on the eastbound on-ramp. The on-ramps from northbound and southbound Belvidere Street will be realigned to merge together at a lower elevation and west of the existing merge location. This proposed project will remove a conflict point on the ramp and allow vehicles from Belvidere Street and Leigh Street, which is intended to allow vehicles to reach higher speeds and thereby improve merging onto southbound I-95/I-64. Construction of an emergency pull-off area is proposed in conjunction with the realignment of the on-ramps due to the history of crashes on the on-ramp. A pull-off area will provide refuge for disabled vehicles and emergency responders while keeping traffic flowing on the ramp.

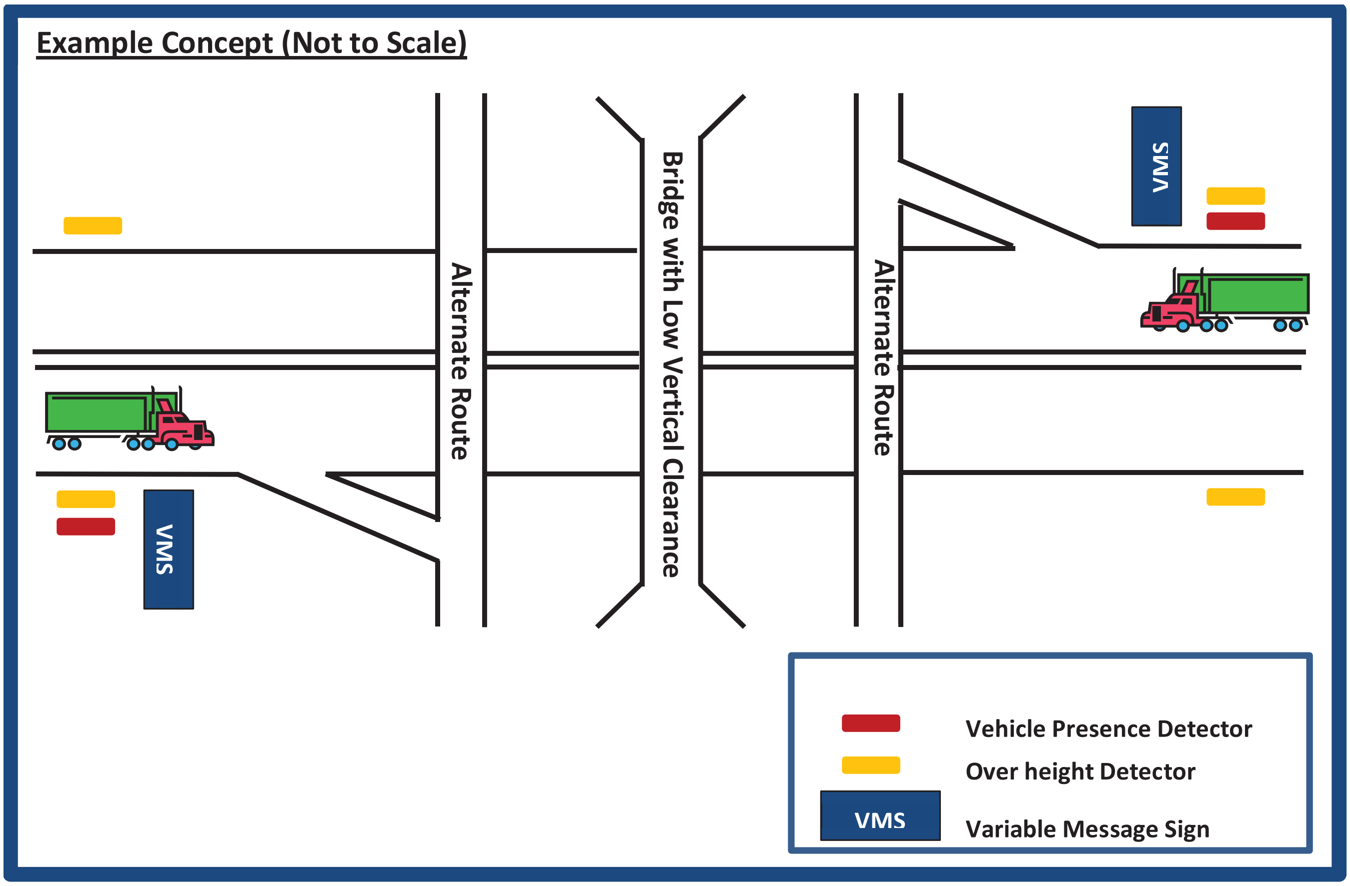
Figure 3: SYIP 4 - Example of Geometric Roadway Improvement



2. Non-Geometric Improvements – included projects such as pavement marking upgrades, retroreflective pavement marker installation, sight distance clearing, roadway lighting construction, median barrier upgrades, intelligent transportation system (ITS) devices construction, shoulder rumble strip construction, and signing improvements. SYIP 1 is an example of a

non-geometric, ITS improvement project that consists of installing a Low Bridge Warning System (**Figure 4**). Many existing bridges throughout the study area do not meet the 16.5-footstandard for vertical clearance on urban interstates. Several proposed locations for these ITS systems were identified on the northbound and southbound I-95 and eastbound and westbound I-64 approaches to the I-95/I-64 overlap. Each system will consists of a pole-mounted vehicle presence detector and an overheight vehicle sensor installed upstream of the low bridge. When an overheight vehicle is detected, a signal is transmitted to a variable message sign (VMS) that displays a message advising the driver to take an alternate route. Operational and safety benefits to the corridor include minimizing the risk of high vehicles striking low bridges and avoiding traffic delays experienced due to a bridge strike.

Figure 4: SYIP 1 - Example of Non-Geometric Improvement

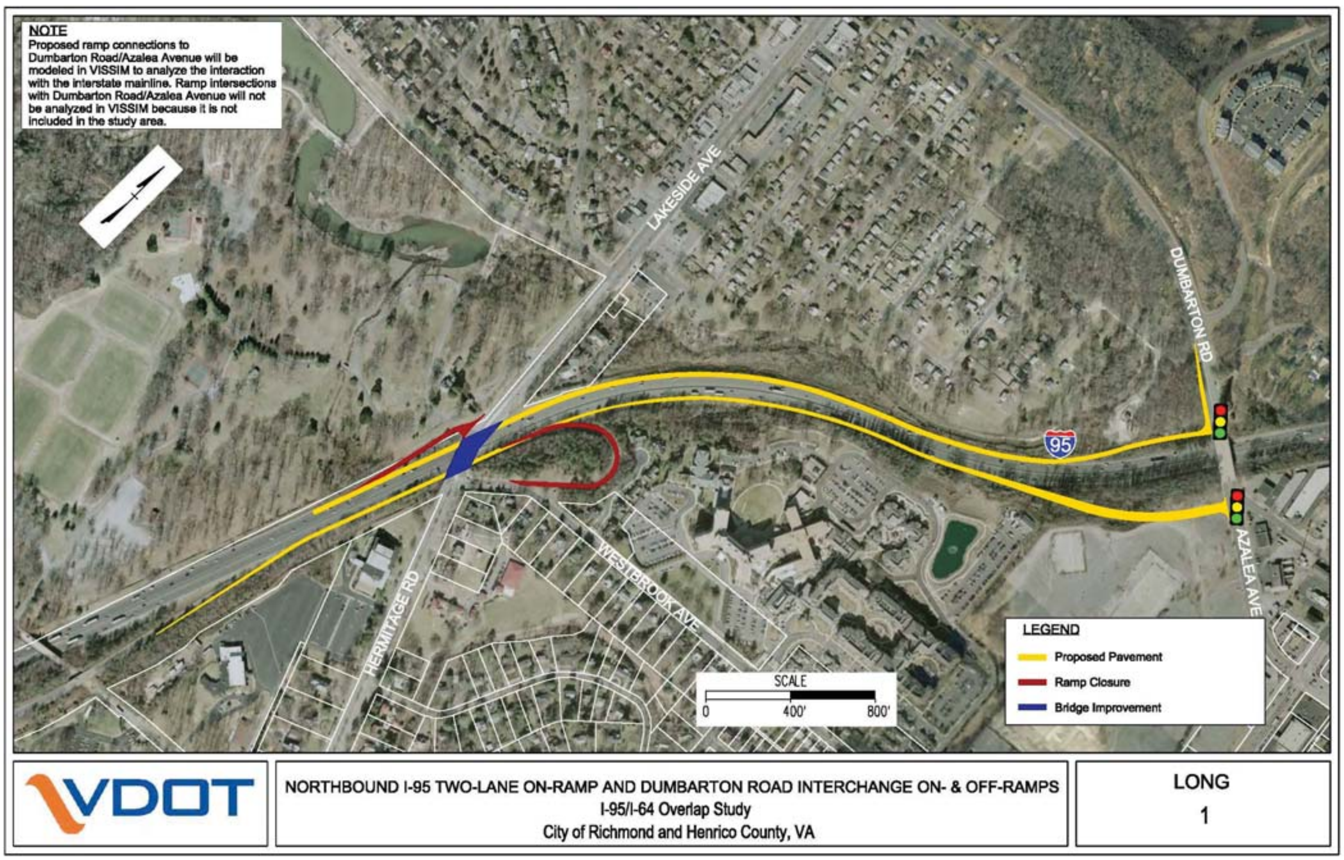


Construction estimated right-of-way costs were developed for the SYIP projects for the purposes of carrying them forward for more evaluation. Planning level cost estimates were developed in context to the level of detail available in this study. For all SYIP projects, costs were broken down into the three categories used for development: PE, ROW, and Construction (CN). Estimated project costs range from $500,000 to $15,560,000 for a grand total of $61,755,000 for all eleven SYIP projects.

Long-Term Concepts

These long-term concepts were the most expensive solutions requiring extensive design, right-of-way acquisition, utility relocation, and construction. Possible projects included new ramp construction, ramp closures, roadway realignments, bridge improvements, new interchange construction, and/or mainline lane additions. Long-term concepts would require further study and refinement and generally fell outside the timeframe of the upcoming SYIP. An example is Long-Term Concept 1 (**Figure 5**) that includes relocating the existing interchange at Hermitage Road to Dumbarton Road by constructing a northbound I-95 off-ramp and a southbound I-95 on-ramp at Dumbarton Road. This concept would involve the removal of the existing northbound I-95 off-ramp and southbound I-95 on-ramp at Brook Road and the construction of two service roads parallel to I-95 connecting Brook Road to Dumbarton Road. Two new traffic signals would be constructed on Dumbarton Road at the proposed ramp termini. The primary objectives of this improvement are to relieve a major bottleneck on northbound I-95 by lengthening the northbound I-95 merge distance; reduce the eastbound I-64/northbound I-195 to northbound I-95 on-ramp PM peak hour queue length; improve the interchange spacing with respect to the Bryan Park interchange; and improve the interchange spacing with respect to the Chamberlayne Road interchange. This concept also would require improvements to the Hermitage Road/Lakeside Road bridge over I-95.

Figure 5: Long-Term Concept 1



Planning level cost estimates were developed to provide an order of magnitude for the significant funding investment required to implement long-term concepts throughout the I-95/I-64 overlap corridor. Cost estimates were developed for one long-term concept at each of the major interchange areas, specifically the Bryan Park interchange to Hermitage Road (Long-Term #1), Bryan Park interchange to Boulevard (Long-Term #2), Belvidere Street/Chamberlayne Parkway interchange (Long-Term #11), and the I-64 East interchange to Broad Street (Long-Term #12). Estimated costs range from $47,800,000 to $602,600,000 with a grand total as high has $948,000,000 for the four long-term concepts. Similar to the SYIP projects, the long-term concepts should be implemented in phases.

<u>Future 2022 and 2035 Build Operational Analyses</u>

VISSIM was used to assess the operational benefits of the proposed geometric SYIP projects and Long-Term concepts. The results of the 2022 and 2035 VISSIM analyses indicated the SYIP projects have negligible operational benefits on the study corridor as a whole,

but they do provide localized benefits at specific locations within the study corridor. Although many of the SYIP projects show minimum impact on operations, many of them will have an immediate improvement on safety. The long-term concepts sufficiently address future traffic conditions throughout the corridor. However, the proposed long-term concepts should be combined to form a comprehensive set of projects that will accommodate future traffic conditions on a corridorwide basis.

Prioritization of Improvements

To compare the cost effectiveness of each project, a benefit-cost (B/C) analysis was conducted for each of the proposed SYIP projects that included geometric improvements that could have an impact on travel time and delay. To quantify the benefit that each project would have on the traveling public, the study team computed the annual delay savings that would result from the proposed improvements. Most of the SYIP projects showed little to no B/C improvement due to the minimal improvement in travel time, with the exception of the realignment of ramps at the Belvidere Street (SYIP 4) interchange and the intersection improvements at the Franklin Street (SYIP 7) interchange.

The benefit-cost analysis for each project was only dependent on travel time savings. For this reason, the 11 proposed SYIP projects were prioritized based on the following three measures of effectiveness (MOEs): operations, safety, and cost. Each prioritization factor was weighted equally (a maximum of 33 points for each factor) to develop a prioritization ranking for each of the 11 SYIP projects. Prioritization results are shown in **Table 1**. Based on this prioritization procedure, the low bridge warning system received a first place ranking, followed by the southbound ramp improvements at the Franklin Street interchange and the northbound deceleration lane at the Hermitage Road interchange.

Table 1: Prioritization Matrix of SYIP Projects

Improvement	Type of Improvement	Prioritization Factors											
		2022 Operational MOE		Safety MOE						Cost		Prioritization Ranking	Overall Ranking
		Travel Time Reduction (AM & PM Peak Hour) Δ	Score (Max. of 33 Points)	Total # Crashes (2007 to 2009)	Crash Reduction Factor	Type of Related Crashes	# of Related Crashes	Reduction in Crashes	Score (Max. of 33 Points)	$	Score (Max. of 33 Points)		
SYIP 1 - ITS - Low Bridge Warning System												66.0	1
- SB I-95 North of Bryan Park Interchange - EB I-64 West of Bryan Park Interchange	Non-Geometric	0.0	33*	^	-	-	-	-	0	500,000	33.0		
SYIP 7 - SB I-95 Exit Ramp/15th Street at Franklin Street (Exit 74B) Improvements												55.8	2
Franklin Street	Geometric	38.8	33	4	0.35	Sideswipe Same Direction Fixed Object - Off Road	4	1	0	1,805,000	22.7		
SYIP 3: NB I-95/WB I-64 at Hermitage Road - Install Deceleration Lane												49.1	3
NB I-95	Geometric	-3.2	0	373	0.75	ALL	373	280	33	2,540,000	16.1		
SYIP 5: NB I-95/EB I-64 at Belvidere Street - Extend Acceleration Lane												45.4	4
NB I-95	Geometric	3.1	3	350	0.75	ALL	350	263	31	3,460,000	11.8		
SYIP 9 - Emergency Pull-Offs												43.5	5
Corridor wide	Non-Geometric	0.0	33*	1724	0.13	Fixed Object - Off Road Sideswipe Same Direction Non-Collision	406	53	6	9,570,000	4.3		
SYIP 8 - Corridor Signing - Replace 5 Option Lane Issue Signs												43.0	6
Corridor wide	Non-Geometric	0.0	11*	^	-	-	-	-	0	1,240,000	32.0		
SYIP 10 - ITS - End of Queue Detection System												41.3	7
Approaches to Overalp - SB I-95 North of Bryan Park Interchange - EB I-64 West of Bryan Park Interchange - NB I-95 South of James River - WB I-64 East of Shockoe Bridge	Non-Geometric	0.0	33*	^	-	-	-	-	0.00	4,940,000	8.3		
SYIP 11 - Corridor Lighting Upgrades												35.0	8
Corridor wide	Non-Geometric	0.0	11*	1538	0.50	Darkness - Not Lighted Darkness - Lighted	362	181	21	15,560,000	2.6		
SYIP 6: SB I-195 Exit Ramp at Laburnum Roundabout & NB I-195 Exit Ramp at Laburnum NB Free-Flow Right Turn												23.5	9
Laburnum Ave	Geometric	5.4	5	4	0.72	ALL	4	3	0	2,210,000	18.5		
SYIP 4: SB I-95/EB I-64 at Belvidere Street - Realignment of On-Ramps												21.7	10
SB I-95	Geometric	-0.5	0	199	0.75	ALL	199	149	18	9,100,000	4.5		
SYIP 2 - Corridor Signing Upgrades												14.8	11
Corridor wide	Non-Geometric	0.0	11*	^	-	-	-	-	0	10,830,000	3.8		

Notes:
^ Unable to determine related crashes
* Operational impacts based on the proposed non-geometric improvements could not be modeled using a traffic simulation tool; however, would have some impact on operations. For purposes of this project operational points for non-geometric improvements were qaulitatively allocated based on the following range 0, 11, 22, or 33.

Next Steps

The I-95/I-64 Overlap Study should be used as a planning tool to achieve the next steps of planning, programming, designing, and constructing the identified safety and operational improvements in the study corridor. Specific steps include:

1. VDOT should implement the recommended short-term improvements once resources become available.
2. VDOT should advance the recommended SYIP improvement projects to the preliminary engineering design stage, so a more refined cost estimate and schedule can be developed. If necessary, supplemental environmental and traffic engineering studies should be conducted to move these projects along the project development process.
3. VDOT should continue to study and refine the operational and environmental impacts of the recommended long-term concepts. This analysis should include investigating the possibility of a phased approach to programming the long-term concepts by developing a subset of smaller projects with independent utility. This process should continue to involve the technical expertise of a study work group to evaluate alternatives while building consensus at the federal, state, and local levels.
4. VDOT should continue to coordinate with the City of Richmond, Henrico County, the Richmond MPO, and within VDOT to aggressively work towards the programming of the SYIP projects and long-term concepts.

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APPENDIX

1.0 Introduction

The Virginia Department of Transportation (VDOT) identified the I-95/I-64 overlap area in downtown Richmond, to be a high crash and high congestion corridor. The ultimate goal of this study was to determine potential transportation improvement projects to be incorporated into the VDOT Six-Year Improvement Program (SYIP) that will improve safety and operations throughout the corridor.

1.1 Study Area

The study corridor was approximately 7 miles long and included 12 interchanges and 15 at-grade intersections as shown in **Figure 1**. The northern limit of the study corridor was in Henrico County at the Hermitage Road interchange at milepost 80 and southern limit was in the City of Richmond at the north end of the James River Bridge at milepost 73. The approximate 1-mile section of I-64 between the Staples Mill Road interchange and the I-95/I-64/I-195 interchange (also known as the Bryan Park Interchange) was also included in the study area due to its proximity to the remainder of the study corridor. Similarly, the approximate 0.1-mile section of I-195 between the Laburnum Avenue interchange and the Bryan Park interchange was included in the study area. The eastern limit of the corridor was the western terminus of the Shockoe Bottom Bridge on I-64 at milepost 191.

The I-95/I-64 overlap is defined as the section of interstate where both I-95 and I-64 exist in the same area from the Bryan Park interchange to the I-95/I-64 interchange to the east (Milepost 79 to Milepost 76). Although the I-95/I-64 overlap has an east-west alignment, for purposes of this study, I-95 is considered to have a north-south alignment and I-64 with an east-west alignment due to their regional alignment through the state.

Table 1 lists the 13 interchanges and 15 at-grade intersections included in the study area.

Table 1: Study Interchanges and At-Grade Intersections

Interchanges	At-Grade Intersection
1. I-64 at Staples Mill Road (Exit 185)	1. Route 161 (Hermitage Rd) at Westbrook Avenue
2. I-64 at I-195 (Exit 186)	2. Northbound I-195 Off-Ramp at E. Laburnum Avenue
3. I-64 at I-95 (Exit 187)	3. Eastbound I-64 Off-Ramp at E. Laburnum Avenue
4. I-95 at Route 161 (Hermitage Road) (Exit 80)	4. Westbound I-64 On-Ramp at E. Laburnum Avenue
5. I-95 at I-64 and I-195 (Exit 79)	5. Hermitage Road at Robin Hood Road
6. I-95 at Route 161 (N. Boulevard) (Exit 78)	6. Southbound I-95 On-Ramp at Robin Hood Road
7. I-95 at Leigh Street (Exit 76B)	7. I-95 Ramps at N. Boulevard
8. I-95 at Chamberlayne Parkway (Exit 76A)	8. W. Leigh Street at Gilmer Street
9. I-95 at I-64 (Exit 75)	9. Northbound I-95 Off-Ramp at Chamberlayne Parkway
10. I-64 at I-95 (Exit 190)	10. E. Jackson Street at N. 3rd Street
11. I-95 at Route 250 (Broad Street) (Exit 74C)	11. E. Jackson Street at N. 4th Street
12. I-95 at E. Franklin Street (Exit 74B)	12. E. Jackson Street at N. 5th Street
13. I-95 at Route 195 (Downtown Expressway) (Exit 74A)	13. E. Broad Street at N. 14th Street
	14. E. Broad Street at College Street
	15. E. Franklin Street at N. 15th Street

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Study Area
I-95 / I-64 Overlap Study
City of Richmond and Henrico County, VA

Figure
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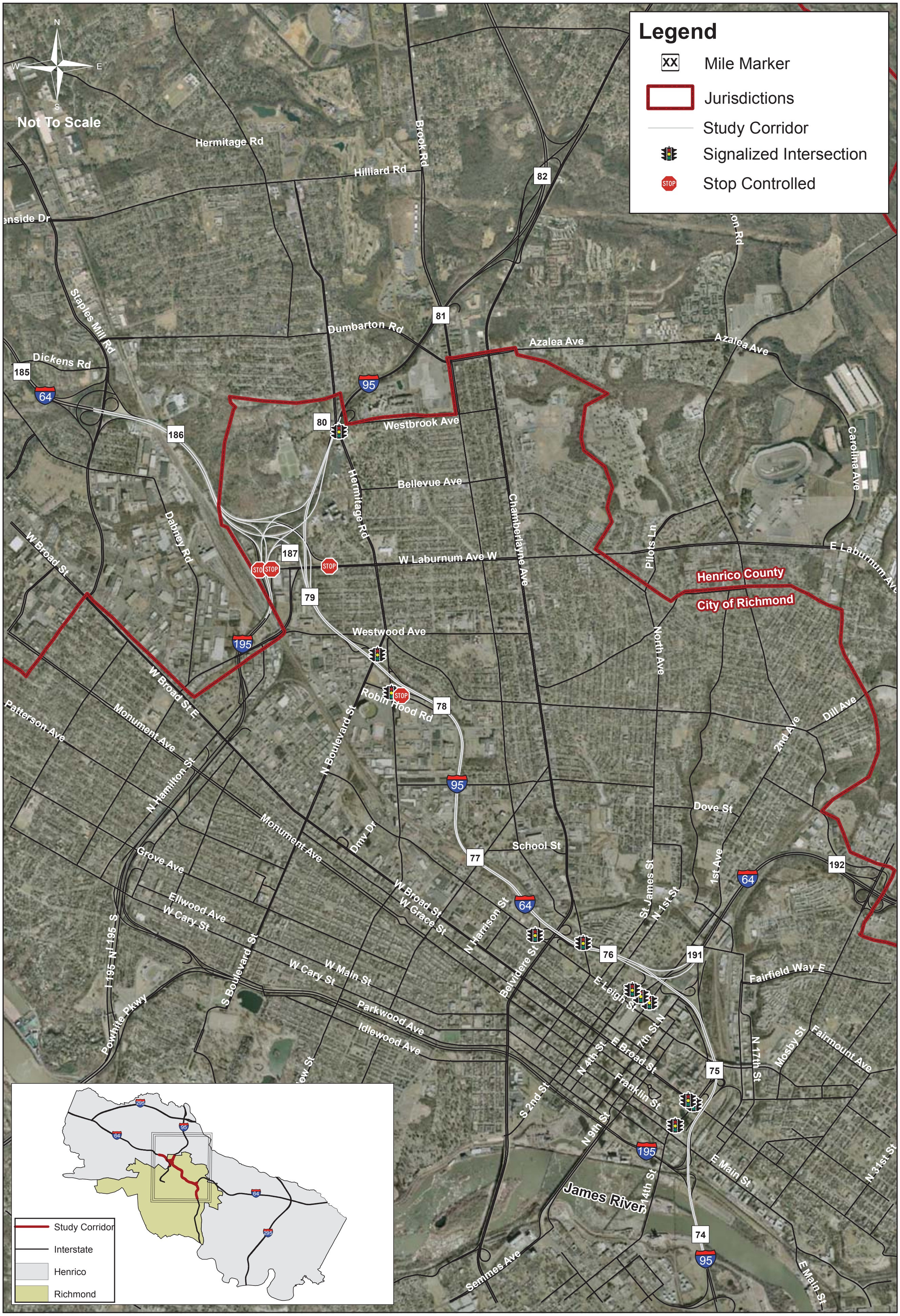

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Corridor Intersections
I-95 / I-64 Overlap Study
City of Richmond and Henrico County, VA

Figure 2

1.2 Study Work Group

Because the I-95/I-64 Overlap corridor is maintained and operated by a number of local and regional entities, a study work group (SWG) was formed to provide institutional knowledge of the corridor, review methodologies, provide input on key assumptions, and review proposed improvements created through the study process. **Table 2** lists members of the SWG representing VDOT, Federal Highway Administration (FHWA), Richmond Regional Planning District Commission (RRPDC), City of Richmond, and Henrico County.

Table 2: Study Work Group (SWG) Members

Agency/Organization	Study Work Group Member
City of Richmond	Mr. Travis Bridewell
FHWA	Mrs. Vanna Lewis
Henrico County	Mr. John Cejka
RRPDC	Ms. Tiffany Tran
VDOT	Mr. Paul Agnello – VDOT Project Manager
VDOT	Mr. Allan Yue
VDOT	Mr. James Cromwell
VDOT	Mr. Mark Riblett
VDOT	Mr. Ronald Svejkovsky
VDOT	Mr. Robert Vilak
VDOT	Mr. Stephen Read
VDOT	Mr. William Guiher
VDOT	Mr. Chad Tucker
VDOT	Mr. Robert Alexander

1.3 Study Process

The study process included data collection, development of concepts, and alternatives analysis. The development of concepts focused on addressing the identified traffic operations and safety challenges in the corridor. The study team conducted a limited amount of engineering using available information, such as data obtained during field reviews and data from geographic information systems (GIS), to develop planning level cost estimates and schedules for project programming purposes. Once these projects are programmed in the SYIP, preliminary engineering, supported by detailed engineering surveys showing vertical constraints and right-of-way impacts, should be conducted to determine more accurate estimated project costs and schedules. The SWG used the results of benefit-cost analyses as one of several factors to prioritize the proposed SYIP projects. A flow chart depicting the study process is provided in **Figure 3**.

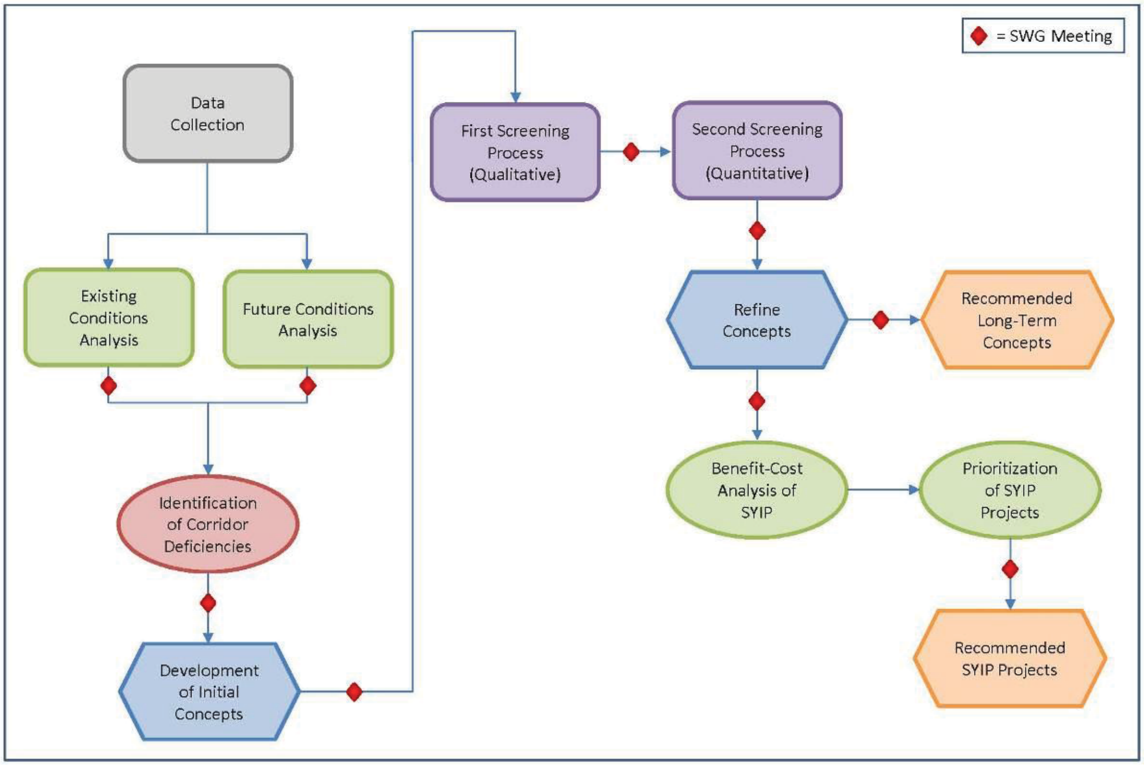
1.4 General Description of the Corridor

Field reconnaissance of existing conditions in the study corridor revealed that the corridor exists primarily within an urban setting with rolling terrain. A majority of the corridor is elevated on bridges or is located adjacent to earthen berms. Three 12-foot lanes are maintained on I-95, I-64, and I-195 throughout the study corridor with a concrete barrier or guardrail separating opposing lanes of travel. The section of I-64 between Staples Mill and the Bryan Park interchange has four lanes in each direction. The posted speed limit throughout the study area is 55 MPH. **Section 2.6** further documents the traffic control and geometric conditions throughout corridor (e.g., pavement markings, lighting, signing, shoulder width, guardrail, etc.). Lane configurations for the overall study corridors and intersections within the study area are shown in **Appendix A**.

2.0 Data Collection and Inventory

Existing origin-destination data, speed data, traffic data, and accident data for the study corridor and intersections was provided by VDOT and City of Richmond.

Figure 3: **Study Process**



2.1 Other Studies and Projects

The study team requested all recent and relevant studies and ongoing construction projects within the study area from the SWG. All studies are provided in **Appendix B** for reference, but the following two projects are described in more detail:

- Bryan Park Interchange Feasibility Study conducted in 1999 by Michael Baker Corporation. The goal of this study was to identify improvements that would improve operations through the Bryan Park interchange. The limits of this study extended north on I-95 to Parham Road, east on I-95/I-64 to Robin Hood Road, west on I-64 to Staples Mill Road and south on I-195 to Broad Street. Proposed concepts in this study were reviewed for consideration.
- Pedestrian Road Safety Audit on Broad Street between College Street and 17th Street, which was conducted in April 2011 by the Louis Berger Group. Pedestrian safety improvements were identified along the north side of Broad Street between College Street and 14th Street.

The following ongoing construction projects located within the study area were identified:

- I-95 Richmond Bridge Restorations - VDOT is currently restoring 13 bridges on I-95/I-64 through the City of Richmond. The project began in 1999 with the replacement of the James River Bridge and Broad Street bridges, which were completed in 2002. Restoration of the remaining 11 bridges is expected to be completed by 2014.

- The only capacity-related improvement to be constructed in conjunction with the bridge restorations projects is the extension of the southbound on-ramp at Robin Hood Road from 640 feet to 1,161 feet. Since the bridge restoration projects are expected to be completed by 2014, the on-ramp extension was included in the 2022 and 2035 no-build roadway network. Nine of the 11 bridge projects are located within the study area. The improvements at the 9 bridge projects are summarized in **Table 3**.

- VDOT is currently installing standard roadway lighting at the Belvidere Street interchange. This improvement project is expected to be completed in the Spring of 2012.

Table 3: I-95 Bridge Restoration Project

Bridge	Improvements
Laburnum Avenue	▪ General restorations to bridge structure
Westwood Avenue	▪ General restorations to bridge structure
I-95 Southbound Ramp to Boulevard	▪ General restorations to bridge structure
Boulevard	▪ General restorations to bridge structure
Hermitage Road	▪ General restorations to bridge structure
Robin Hood Road	▪ General restorations to bridge structure ▪ Widening shoulders from 8 feet to 9 feet in northbound direction ▪ Widening shoulders from 8 feet to 12 feet in southbound direction ▪ Extension of the SB acceleration lane from 640 feet to 1,161 feet
Sherwood Avenue	▪ General restorations to bridge structure ▪ Widening shoulders from 8 feet to 9 feet in northbound direction ▪ Widening shoulders from 8 feet to 12 feet in southbound direction
Overbook Road	▪ General restorations to bridge structure
Lombardy Street	▪ General restorations to bridge structure ▪ Widening shoulders from 2 feet to 12 feet in northbound and southbound directions

2.2 Origin-Destination Data

Origin-Destination (O-D) data was collected to document travel patterns through the study area. This data was also used to develop traffic volumes for the VISSIM models. VDOT used two third-party vendors to obtain the O-D data that is summarized below. Complete O-D data is provided in **Appendix C**.

- TomTom O-D Data – O-D data was collected from TomTom GPS-enabled devices. This data was one of the two sources traffic data summarized in **Tables 4 - 6** below. A 2-year period from 1/1/2009 to 12/31/2010 was summarized by peak period. The O-D data was for typical weekdays only and did not include Saturdays, Sundays, or major holidays.
- **Figure** 4 illustrates the collection points for the TomTom O-D data entering and exiting the study area.

Figure 4: O-D Locations for TomTom Data

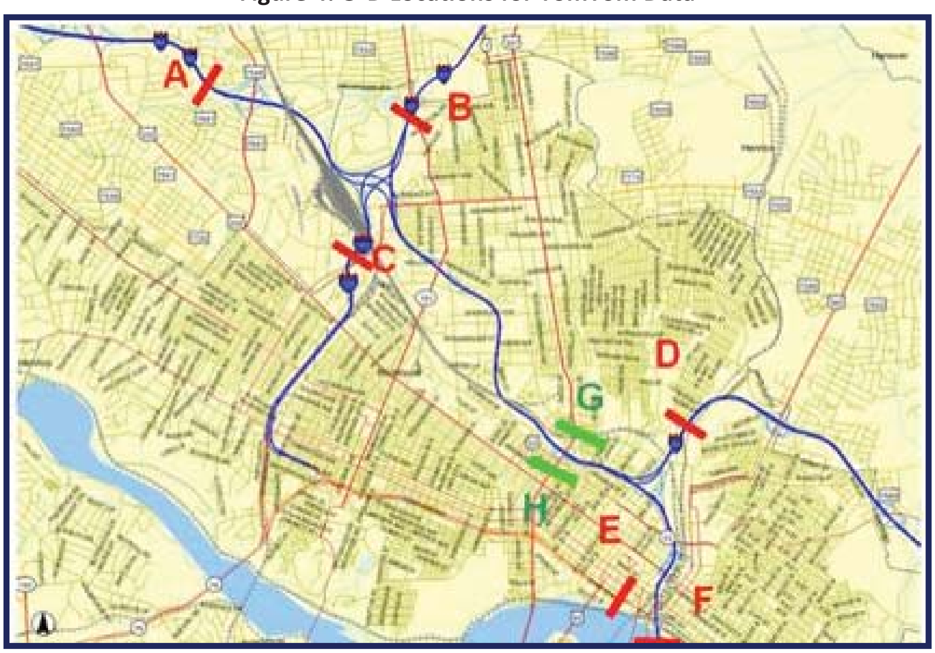


Table 4: TomTom O-D Data – Morning Peak Period (6:00 AM to 9:00 AM)

Destinations	Origins							
	A	B	C	D	E	F	G	H
A – I-64 West of Staples Mill Rd Interchange		9.72%	23.77%	21.48%	1.08%	16.48%	2.54%	15.98%
B – I-95 North of Bryan Park Interchange	12.63%		54.27%	7.59%	2.08%	39.35%	1.41%	17.58%
C – I-195 South of Bryan Park Interchange	15.48%	30.30%		5.41%	0.43%	2.03%	0.00%	0.80%
D – I-64 East of Shockoe Bottom Bridge	25.12%	7.01%	2.62%		65.18%	11.15%	12.39%	23.78%
E – I-195 West of I-95	0.44%	1.72%	0.14%	17.37%		6.88%	1.69%	0.30%
F – I-95 South of I-195 Interchange	10.38%	18.22%	0.75%	11.73%	12.85%		21.13%	4.70%
G – Belvidere St North of I-95/I-64	0.26%	0.19%	0.14%	0.79%	0.57%	0.99%		19.68%
H – Belvidere St South of I-95/I-64	3.41%	4.56%	0.25%	1.09%	0.07%	0.32%	49.01%	
Sample Size	**5,020**	**5,762**	**4,426**	**5,320**	**1,393**	**5,875**	**355**	**1,001**

Table 5: TomTom O-D Data – Midday Peak Period (11:00 AM to 2:00 PM)

Destinations	Origins							
	A	B	C	D	E	F	G	H
A – I-64 West of Staples Mill Rd Interchange		12.20%	25.52%	29.75%	2.78%	18.10%	3.19%	17.29%
B – I-95 North of Bryan Park Interchange	14.66%		52.59%	10.19%	3.57%	37.52%	3.09%	21.19%
C – I-195 South of Bryan Park Interchange	16.93%	29.76%		4.13%	0.56%	2.22%	0.43%	1.17%
D – I-64 East of Shockoe Bottom Bridge	28.32%	6.93%	3.54%		59.84%	14.51%	15.00%	25.59%
E – I-195 West of I-95	0.68%	0.98%	0.25%	13.62%		6.87%	2.34%	0.53%
F – I-95 South of I-195 Interchange	12.02%	22.83%	1.87%	12.06%	16.40%		13.40%	5.43%
G – Belvidere St North of I-95/I-64	0.41%	0.28%	0.09%	1.70%	0.23%	1.52%		17.11%
H – Belvidere St South of I-95/I-64	3.35%	4.80%	0.33%	0.33%	0.32%	0.67%	54.57%	
Sample Size	**9,227**	**9,859**	**6,320**	**9,008**	**2,159**	**7,477**	**940**	**2,817**

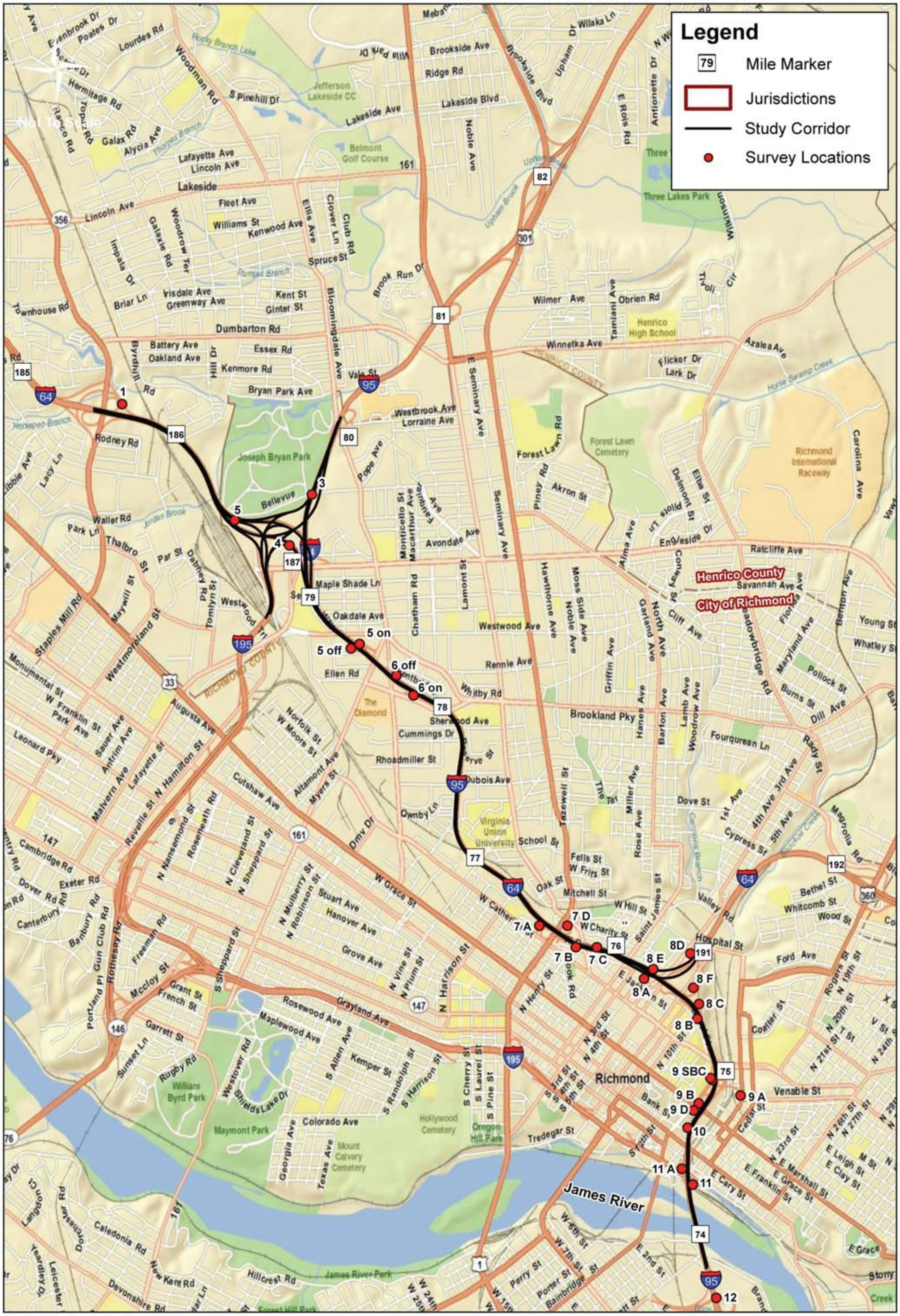
Table 6: TomTom O-D Data – PM Peak Period (4:00 PM to 7:00 PM)

Destinations	Origins							
	A	B	C	D	E	F	G	H
A – I-64 West of Staples Mill Rd Interchange		10.09%	32.87%	29.82%	1.61%	19.61%	2.28%	21.97%
B – I-95 North of Bryan Park Interchange	13.27%		47.67%	8.55%	3.40%	29.91%	1.63%	20.63%
C – I-195 South of Bryan Park Interchange	20.31%	27.82%		2.70%	0.12%	1.66%	0.16%	1.13%
D – I-64 East of Shockoe Bottom Bridge	28.11%	4.75%	2.49%		56.38%	20.57%	15.61%	23.66%
E – I-195 West of I-95	0.49%	0.72%	0.07%	16.68%		7.73%	1.14%	0.46%
F – I-95 South of I-195 Interchange	15.34%	40.25%	1.38%	14.58%	22.17%		15.77%	7.77%
G – Belvidere St North of I-95/I-64	0.15%	0.16%	0.02%	1.56%	0.30%	2.22%		15.23%
H – Belvidere St South of I-95/I-64	3.10%	3.06%	0.29%	1.38%	0.06%	0.69%	55.45%	
Sample Size	**6,479**	**8,847**	**4,135**	**5,520**	**1,678**	**4,463**	**615**	**1,944**

The following major trends were deduced from the O-D data summarized in **Tables 4 - 6**:

- From the east via I-64 (Origin D) most vehicles are traveling through the I-95/I-64 overlap to the west for all peak periods.
- From the west via I-64 (Origin A) most vehicles are traveling through the I-95/I-64 overlap to the east for all peak periods.
- From the north via I-95 (Origin B) most vehicles are utilizing I-195 to head south of the study area during the AM and Midday peak periods. During the PM peak period most motorists travel south of the study area via the I-95/I-64 overlap.
- From the south via I-95 (Origin F) it was assumed most vehicles are traveling through the I-95/I-64 overlap to head north of the study area. It was assumed most motorists chose not to utilize I-195 to bypass the I-95/I-64 overlap due to the tolled section of I-195.

Automatic License Plate Recognition (ALPR) - ALPR (an image processing technology) was used to identify vehicles by their license plates. Cameras were deployed in the field at strategic locations (refer to **Figure 5**) to capture images of license plates. These images were matched automatically with license plate recognition software. Detailed travel patterns were captured between various points within the study area. The license plate survey was conducted on August 10, 2011 during the AM (6:30 to 9:30 AM) and PM (3:30 to 6:30 PM) peak periods. Data was collected in 15-minute increments and was summarized in **Table 7**. Although, the ramp-to-ramp capture rates (percent of vehicles matched from an origin to a destination) were low the data indicated most vehicles originating on a study ramp has an ultimate destination outside of the study area and utilized the interstate system to travel there. Additional data summarized from the license plate survey included minimum, maximum, and average travel times between study locations, which is provided in **Appendix D**.



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License Plate Survey Locations
I-95 / I-64 Overlap Study
City of Richmond and Henrico County, VA

Figure 5

Table 7: License Plate Survey O-D Data

Origins		Destinations																											Total Captures
		1	5	3	4	5 ON	5 Off	6 ON	6 Off	7A	7B	7C	7D	8A	8B	8C	8D	8E	8F	9A	9B	9NBC	9SBC	9D	10	11	11A	12	
1	Westbound I-64 Off-Ramp to Staples Mill Road	100%																											10,129
5	Eastbound I-64 West of Diverge to SB I-195/SB I-95/I-64	19%	81%																										9,653
3	Southbound I-95 North of Off-Ramp to WB I-64			71%			9%			8%				4%											7%				14,369
4	Eastbound I-64 at NB I-195 Merge				62%		13%			9%				6%											9%				14,535
5ON	Northbound I-95/I-64 On-Ramps from Boulevard	10%				90%																							4,709
5OFF	Southbound I-95/I-64 Off-Ramp to Boulevard						100%																						3,831
6ON	Southbound I-95/I-64 On-Ramp from Robin Hood							88%		2%				2%											7%				2,083
6OFF	Northbound I-95/WB I-64 Off-Ramp from Hermitage								100%																				2,137
7A	Southbound I-95/I-64 Off-Ramp to Leigh									100%																			3,209
7B	Southbound I-95/I-64 On-Ramp from Boulevard										92%			1%											6%				4,371
7C	Northbound I-95/I-64 Off-Ramp to Chamberlayne											100%																	3,410
7D	Northbound I-95/I-64 On-Ramp from Belvidere Street	10%							1%				89%																3,342
8A	Southbound I-95/I-64 Off-Ramp to 5th Street													100%															1,804
8B	Southbound I-95 On-Ramp from 5th Street														91%								1%		8%				8,111
8C	Northbound I-95 Off-Ramp to Eastbound I-64															100%													3,215
8D	Westbound I-64 On-Ramp from 7th Street	2%							1%								97%												1,106
8E	Northbound I-95/I-64 On-Ramp from Westbound I-64	13%							8%			12%						67%											9,757
8F	Northbound I-95 to Eastbound I-64 On-Ramp	10%							3%			4%							84%										2,093
9A	Northbound I-95 Off-Ramp to Broad/Oliver Hill Way																			100%									2,512
9B	I-95 On-Ramp from Westbound Broad Street	8%							4%			5%									83%								2,452
9NBC	Northbound I-95 Off-Ramp to Broad Street																					100%							2,094
9SBC	Southbound I-95 Off-Ramp to Broad Street																						100%						223
9D	I-95 On-Ramp from Eastbound Broad Street																							99%					1,477
10	Southbound I-95 Off-Ramp to Franklin/15th																								100%				4,457
11	Southbound I-95 On-Ramp from Eastbound I-195																									100%			2,251
11A	Northbound I-95 Off-Ramp to Westbound I-195	1%										1%				17%				16%		10%					55%		3,764
12	Northbound I-95 On-Ramp from Maury Street	5%							3%			5%				6%				6%		7%				6%		62%	21,669

Notes:
- Blank cells indicate no data was matched between origin-destination points.
- The percent highlighted in orange represents the percentage of the total captured from an origin that was not matched to any destination.

2.3 Speed Data and Travel Time Index

Speed data was utilized from VDOT's recently acquired INRIX data to help identify the peak hour speeds in the study corridor. The speed data was collected to create a complete and consistent average traffic speed data set. **Figures 6** through **9** summarize the average weekday AM (7 – 9 AM) and PM (4 – 6 PM) peak period speeds during 2010 at various locations throughout the study corridor. The ranges in speed shown in **Figures 6** through **9** were determined based on Exhibit 11-15 from the *2010, Highway Capacity Manual.* This figures indicates speeds on facilities with a free flow speed of 55 MPH begin to decline to 50 MPH or less under congested conditions when the volume-to-capacity ratio is greater than 0.80. Based on this, a range of 0 to 45 MPH was determined to represent the slowest condition indicated in red on **Figures 6** through **9**. Further breakdown of speed data into slower ranges was not conducted because the data was provided as an average over the 2-hour peak periods, raw speed data was not provided. Speed data was not available on I-195 within the study area.

The primary locations with reduced speeds (i.e., less the posted speeds limit of 55 MPH) during the peak hours are:

- <u>AM Peak Period</u>
  - Northbound direction: Speeds less than 45 MPH were recorded on the westbound I-64 approach to the Overlap through the Belvidere Street interchange.
  - Southbound direction: Speeds less than 50 MPH were recorded on the southbound I-95 and eastbound I-64 approaches to the Bryan Park interchange, which extended as far west and north as Staples Mills Road and Dumbarton Road, respectively. Recorded speeds at key junction points through the Bryan Park interchange were less than 45 MPH, specifically the eastbound I-64 to northbound I-95 diverge and the eastbound I-64/northbound I-195 to southbound I-95/I-64 merge.

- <u>PM Peak Period</u>
  - Northbound direction: Speeds less than 45 MPH were recorded on the section of I-95 between the Broad Street interchange and the Belvidere interchange during the PM peak period. Reduced speeds were also recorded on the section of northbound I-95 from the Boulevard interchange to the Bryan Park interchange during the PM peak period.
  - Southbound Direction: Speeds less than 50 MPH were recorded on the southbound I-95/I-64 approach from the Belvidere Street interchange to the I-95/I-64 East interchange Speeds less than 45 MPH were recorded on the southbound I-95/I-64 to eastbound I-64 diverge.

Travel Time Index (TTI) was developed by VDOT using INRIX data. TTI is a measure of congestion that focuses on each trip and each mile of travel and is the ratio of travel time during the peak period to travel time during free-flow conditions. For example, a TTI value of 1.30 indicates a 20-minute free-flow trip would take 26 minutes in the peak period. Free-flow speeds were defined as the 85^{th} percentile speeds. The average weekday TTIs for 2010 are summarized by peak period in **Figures 10** and **11**. Study segments with missing TTIs may be missing due one of the following reasons:

1. Data set for the segments is not available
2. Data set for a given segment is too small
3. Segments are too short and do not have enough travel data

The primary locations indicating severe and moderate congestion through the study corridor based on available TTI information are:

- <u>AM Peak Period</u>
  - Southbound direction: A TTI of greater than 2.0 was reported in the eastbound I-64/northbound I-195 to southbound I-95/I-64 merge, which was an indicator of severe congestion. TTIs reflecting moderate congestion were reported on eastbound I-64 through the Staples Mill Road interchange and on the I-95/I-64 Overlap from Robin Hood Road to Belvidere Street.

- <u>PM Peak Period</u>

- Northbound direction: A TTI greater than 2.0 was reported at the I-95/I-64 East interchange. The I-95/I-64 overlap section from Robin Hood Road to Belvidere Street had a TTI indicating moderate congestion.
- Southbound direction: TTIs reflecting moderate congestion were reported on eastbound I-64 through the Bryan Park interchange and the I-95/I-64 overlap from Robin Hood Road to Belvidere Street.

The speed data and TTI information was consistent with field observations. These results provide further confirmation that congestion exists at the system-to-system interchanges (Bryan Park and the I-95/I-64 east interchanges) in the study corridor.

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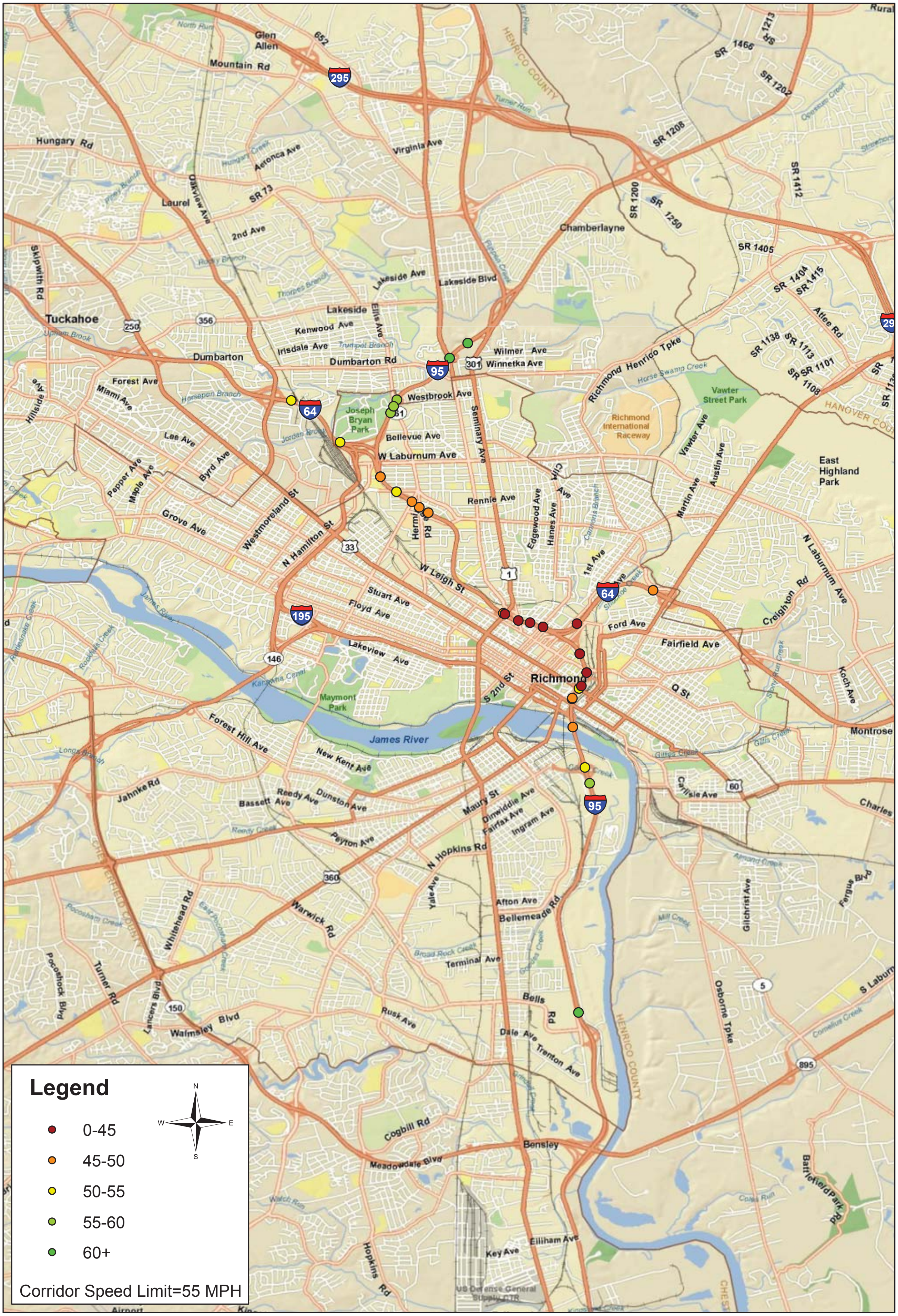
Speed Data - AM Peak Hour (7-9) - I-95 NB and I-64 WB
I-95 / I-64 Overlap Study
City of Richmond and Henrico County, VA

Figure 6



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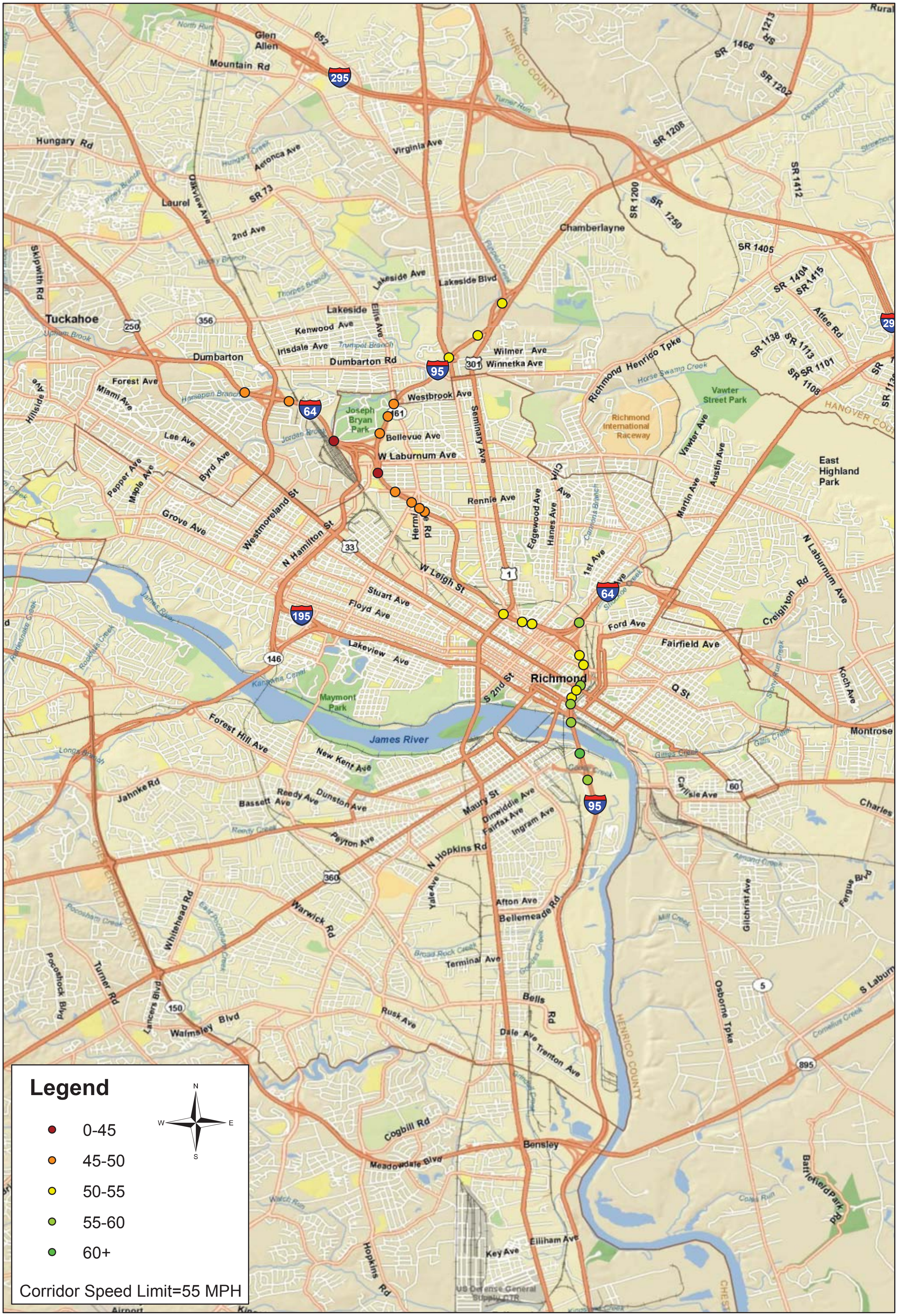
Speed Data - PM Peak Hour (4-6) - I-95 NB and I-64 WB
I-95 / I-64 Overlap Study
City of Richmond and Henrico County, VA

Figure 7



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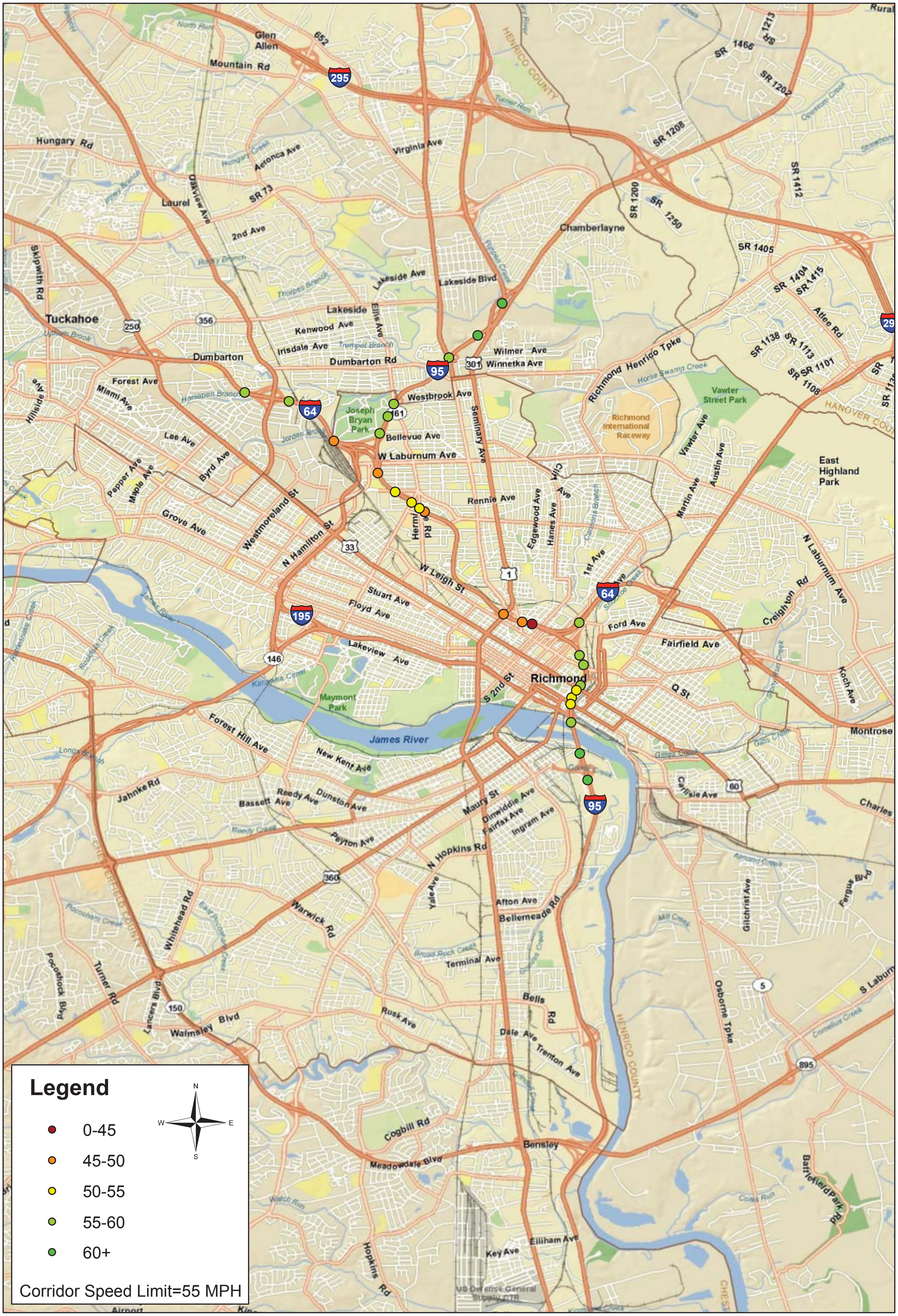
Speed Data - AM Peak Hour (7-9) - I-95 SB and I-64 EB
I-95 / I-64 Overlap Study
City of Richmond and Henrico County, VA

Figure 8



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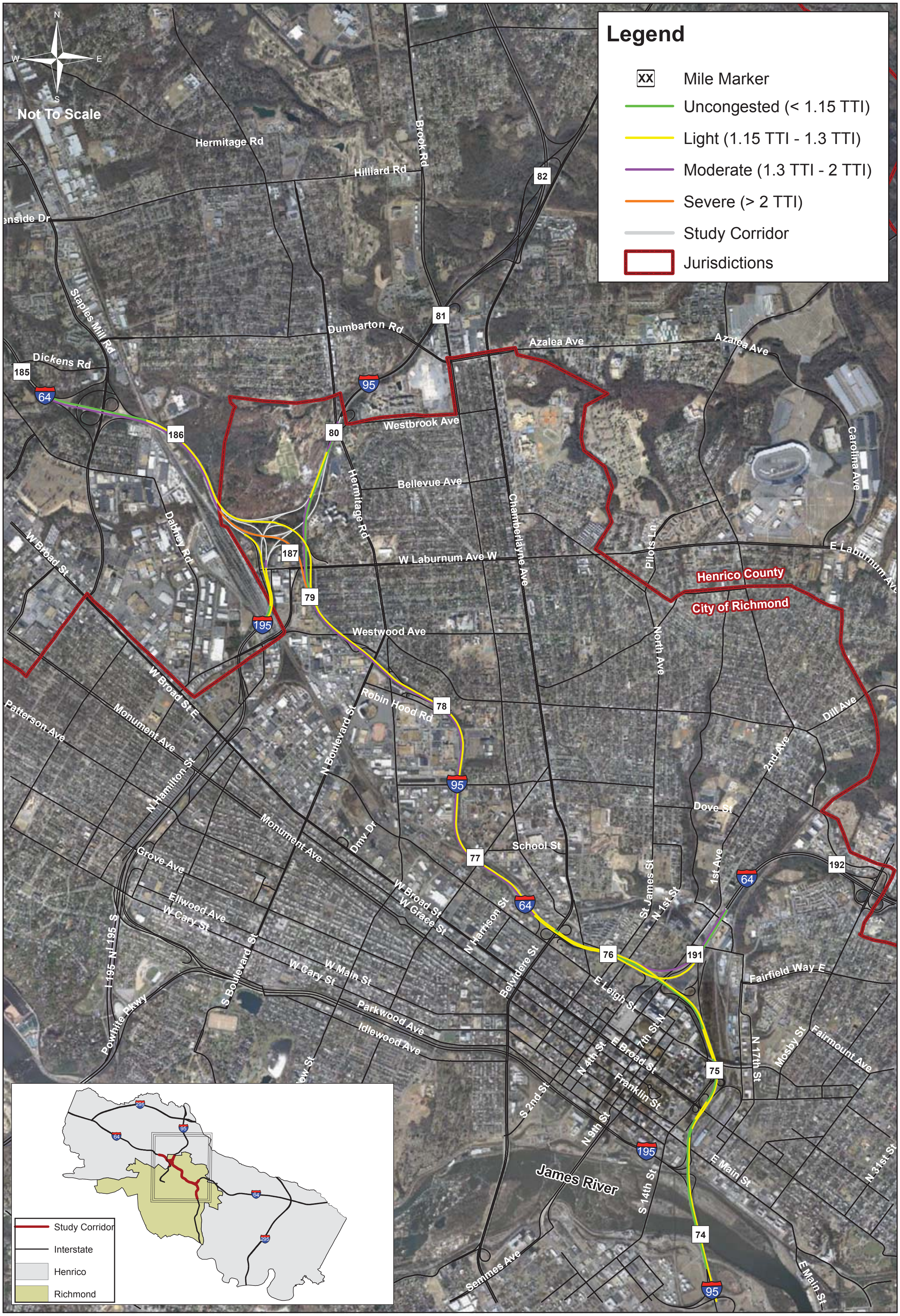
Speed Data - PM Peak Hour (4-6) - I-95 SB and I-64 EB
I-95 / I-64 Overlap Study
City of Richmond and Henrico County, VA

Figure 9



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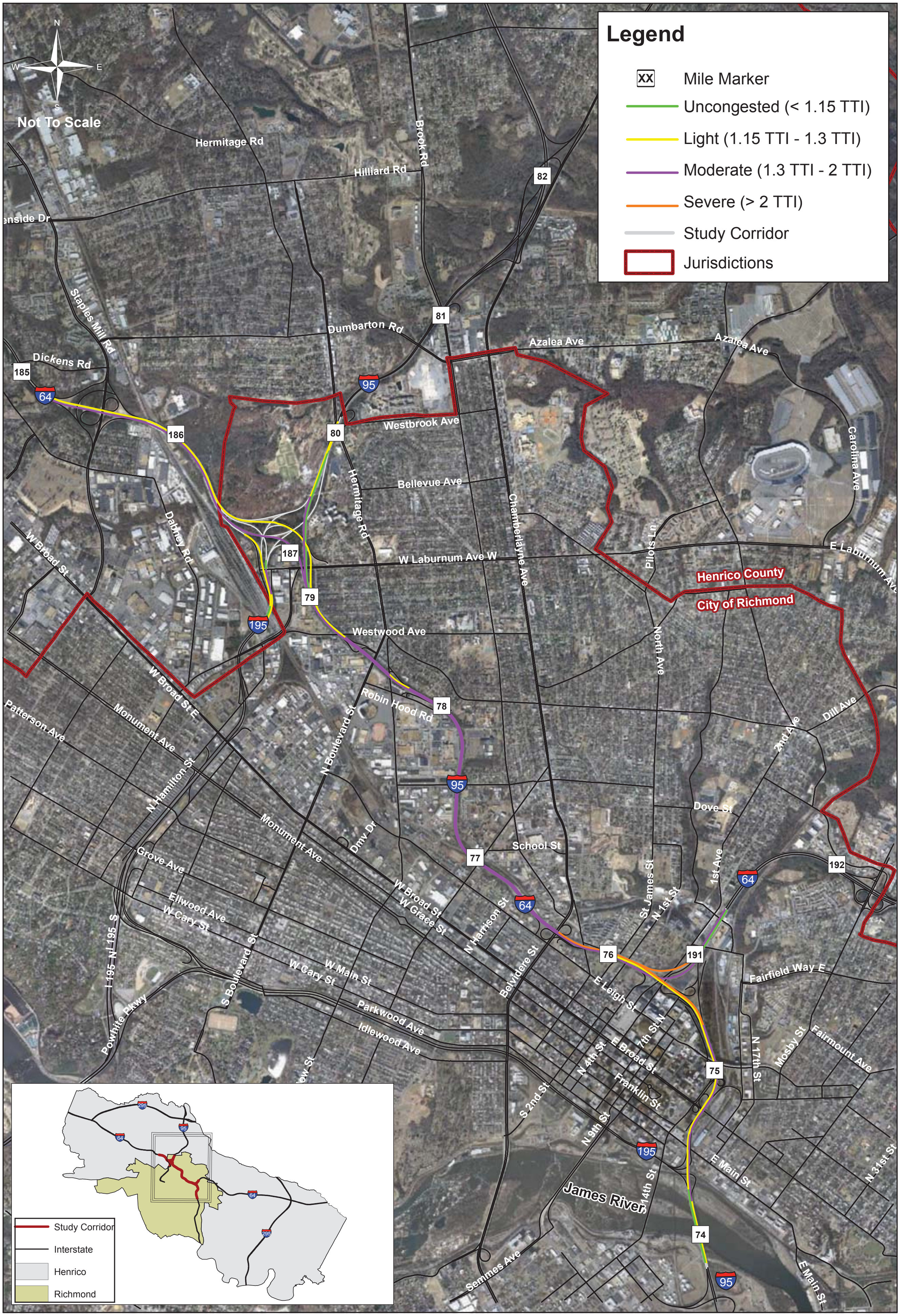
AM (7-9) Travel Time Index
I-95 / I-64 Overlap Study
City of Richmond and Henrico County, VA

Figure 10



PM (4-6) Travel Time Index
I-95 / I-64 Overlap Study
City of Richmond and Henrico County, VA

Figure 11

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2.4 Traffic Volume Data

To determine existing traffic operating conditions in the corridor, 2011 traffic data was compiled from a number of sources for the mainline sections, ramps, and intersections. VDOT supplied data collected from VDOT-maintained permanent count stations and directional tube and turning movement counts conducted by a third party vendor. Inventory of all mainline and ramp traffic counts were provided in **Tables 8** and **9**. Collection of turning movement count (TMC) data, including vehicle classification data, was conducted on Wednesday, August 10, 2011 at the 15 study area intersections. All traffic count data is provided in **Appendix D**, including Average Daily Traffic (ADT) volumes summarized in map format.

2.4.1 Peak Hour Determination

The traffic peak hours were reviewed to determine the common AM and PM peak hours in the study corridors. Column A of **Table 10** indicates that the observed peak hours for multiple mainline sections throughout the study corridor while Column B shows the corresponding volume for that hour. It was determined that 11 of the 19 mainline segments shared a common AM peak hour from 7:30 to 8:30 AM. The remaining 8 mainline segments with differing peak hours had at least 95% of the peak volume occurring between 7:30 and 8:30 AM. Similarly, 12 of the 19 mainline segments share a common PM peak from 4:30 to 5:30 PM. The remaining 7 mainline segments with differing peak hours have at least 92% of the peak volume occurring within the 4:30 to 5:30 PM time period.

Ramp peak hour traffic characteristics are largely dependent on adjacent traffic generators, while mainline traffic volumes provide a more comprehensive approach to peak hour traffic operations through the entire study corridor. Therefore, mainline traffic volumes were used to establish the overall traffic peak hour for the corridor. The same methodology summarized in **Table 11** was reviewed for all ramps in the study corridor and the computations are included in **Appendix E**. Twenty-four of the 57 ramps, or 49%, have a peak hour between 7:30 and 8:30 AM and 22 of the 57 ramps, or 39%, have a peak hour of 4:30 to 5:30 PM. The fact that a majority of mainline segments and ramps shared common peak hours across the study corridor contributed to the level of peak hour congestion.

Peak hour factors (PHFs) were not required because volumes were coded into the microsimulation tool VISSIM (used to conduct the operational analyses for the study) in 15-minute increments; therefore, PHFs were not calculated.

2.4.2 Seasonal Factor Adjustment

A review of available historic traffic data from VDOT's continuous count stations, from July 1, 2010 to July 1, 2011, on I-95 north of Chamberlayne Road and south of Maury Street revealed that the largest traffic volumes occurred during July. All traffic data used for peak hour analysis, including information from mainline segments, ramps, and turning movement counts were collected during the month of August in 2011. Since July traffic volumes were between 2 and 3 percent higher than the August traffic volumes, a seasonal adjustment factor of 1.03 was applied to the traffic counts to factor the August peak hour traffic counts.

2.4.3 Heavy Vehicle Percentages

Heavy vehicle percentages were calculated using available classification counts provided by VDOT from permanent count stations. Only one mainline count station was available within the study area (southbound I-95/I-64 south of Robin Hood Road) that included vehicle classification. Two additional mainline count locations just north and south of the study area on I-95 were available and included vehicle classification data. **Table 12** summarizes peak hour heavy vehicle percentages based on the four available mainline counts. All of the data provided was aggregated into two classes: Class 1 included cars, pickup trucks, and vans (FHWA categories 1 through 3) and Class 2 included all other vehicles (FHWA categories 4 through 13).

Table 8: Inventory of Mainline Traffic Counts

#	Location	Directions	Information		Dated Collected
			Speeds	Classification	
1	I-64 West of Staples Mill Rd	EB	X		Wednesday, August 10, 2011
2	I-64 West of Staples Mill Rd	WB	X		
3	I-95 North of Westbrook	NB	X		
4	I-95 North of Westbrook	SB	X		
5	I-95 North of I-95/I-64/I-195	NB	X		
6	I-95 North of I-95/I-64/I-195	SB	X		
7	Overlap North of North Boulevard	NB	X		
8	Overlap North of North Boulevard	SB	X		
9	Overlap South of Robin Hood Rd	NB	X	X	
10	Overlap under Belvidere Overpass	NB	X		
11	Overlap under Belvidere Overpass	SB	X		
12	Overlap between Chamberlayne & 3rd St	NB	X		
13	Overlap between Chamberlayne & 3rd St	SB	X		
14	I-95 under 7th St Overpass	NB	X		
15	I-95 under 7th St Overpass	SB	X		
16	I-64 East of Overlap	EB	X		
17	I-64 East of Overlap	WB	X		
18	I-95 under Broad St Overpass	NB	X		
19	I-95 under Broad St Overpass	SB	X		

Table 9: Inventory of Ramp Traffic Counts

#	Interchange	Ramp		Source Of Count	Duration Of Count	Information		Dated Collected
		From	To			Speeds	Classification	
1	I-64 at Staples Mill Rd	Eastbound I-64	Staples Mill Rd	Tube	72 hours	X	X	Monday, August 8, 2011 to Thursday, August 11, 2011
2		Westbound I-64	Southbound Staples Mill	Tube	72 hours	X	X	
3		Southbound Staples Mill Rd	Westbound I-64	Tube	72 hours	X	X	
4		Southbound Staples Mill Rd	Eastbound I-64	Tube	72 hours	X	X	
5		Northbound Staples Mill Rd	Westbound I-64	Tube	72 hours	X	X	
6		Northbound Staples Mill Rd	Eastbound I-64	Tube	72 hours	X	X	
7		Westbound I-64	Northbound Staples Mill Rd	Tube	72 hours	X	X	
8	I-95 at Hermitage Rd	Northbound I-95	Westbrook Ave	Tube	72 hours	X	X	
9		Hermitage Road	Southbound I-95	Tube	72 hours	X	X	
10	Bryan Park Interchange	Southbound I-95 a	Westbound I-64	Wavetronix	72 hours	X	X	
11		Southbound I-95 b	Southbound I-195	Wavetronix	72 hours	X	X	
12		Eastbound I-64c	Southbound I-195	Wavetronix	72 hours	X	X	
13		Northbound I-195g	Westbound I-64	Wavetronix	72 hours	X	X	
14		Eastbound I-64h	Northbound I-95	Wavetronix	72 hours	X	X	
15		Westbound I-64 (Overlap)	Southbound I-195	Wavetronix	72 hours	X	X	
16		Westbound I-64 (Overlap)	Westbound I-64	Wavetronix	72 hours	X	X	
17		Laburnum Road k	Westbound I-64	Wavetronix	72 hours	X	X	
18		Northbound I-195 l	Eastbound I-64 (Overlap)	Wavetronix	72 hours	X	X	
19		Northbound I-195 m	Northbound I-95	Wavetronix	72 hours	X	X	
20		Eastbound I-64n	Southbound I-95 (Overlap)	Wavetronix	72 hours	X	X	
21	I-95/I-64 at Boulevard	Northbound I-95 (Overlap)	Hermitage Rd	Tube	72 hours	X	X	
22		Robin Hood Rd	Southbound I-95 (Overlap)	Tube	72 hours	X	X	
23	I-95/I-64 at Belvidere St	Northbound Belvidere	Northbound I-95 (Overlap)	Continuous Loop	24 hours	X	Not Available	
24		Northbound Belvidere	Southbound I-95 (Overlap)	Tube	72 hours	X	X	
25		Southbound Belvidere	Southbound I-95 (Overlap)	Tube	72 hours	X	X	
26		Brook Rd	Southbound I-95 (Overlap)	Tube	72 hours	X	X	
27	I-95/I-64 East Interchange	I-95 SB (Overlap)	3rd St	Tube	72 hours	X	X	
28		I-95 SB (Overlap)	Eastbound I-64	Wavetronix	72 hours	X	X	
29		Westbound I-64	5th St	Wavetronix	72 hours	X	X	
30		Westbound I-64	Northbound I-95 (Overlap)	Wavetronix	72 hours	X	X	
31		Northbound 5th St	Westbound I-64 (Overlap)	Tube	72 hours	X	X	
32		Westbound I-64	Southbound I-95	Tube	72 hours	X	X	
33		7th St	Southbound I-95	Tube	72 hours	X	X	
34		Northbound 7th St	Northbound I-95 (Overlap)	Tube	72 hours	X	X	
35		Northbound 7th St	Eastbound I-64	Tube	72 hours	X	X	
36		Northbound I-95	7th St	Tube	72 hours	X	X	
37		Northbound I-95	7th St/ Eastbound I-64	Continuous Loop	24 hours	X	Not Available	
38	I-95 at Broad St	Southbound I-95	Broad St	Tube	72 hours	X	X	
39		Northbound I-95	Westbound Broad St	Tube	72 hours	X	X	
40		Broad St	Northbound I-95	Tube	72 hours	X	X	
41		Broad St	Southbound I-95	Tube	72 hours	X	X	
42		Northbound I-95	Southbound Oliver Hill Way	Tube	72 hours	X	X	
43	I-95 at I-195	Southbound I-95	Westbound I-195	Tube	72 hours	X	X	
44		Eastbound I-195	Northbound I-95	Tube	72 hours	X	X	
45		Eastbound I-195	Southbound I-95	Tube	72 hours	X	X	
46		Northbound I-95	Westbound I-195	Tube	72 hours	X	X	

Table 10: Study Corridor Peak Hour

Location	AM				PM			
	Column A	Column B	Column C	Column D	Column F	Column G	Column H	Column I
	Observed Peak Hour	Volume Observed in Column A	Volume from 7:30 AM-8:30 AM	% of Column C To Column B	Observed Peak Hour	Volume Observed in Column F	Volume from 4:30 PM-5:30 PM	% of Column H To Column G
Eastbound I-64 West of Staples Mill Rd	7:15-8:15	5,707	5,437	95%	4:45-5:45	7,146	7,053	99%
Westbound I-64 West of Staples Mill Rd	7:30-8:30	7,943	7,943	100%	4:45-5:45	7,069	6,893	98%
Northbound I-95 North of Westbrook Ave	7:30-8:30	3,731	3,731	100%	4:30-5:30	4,868	4,868	100%
Southbound I-95 North of Westbrook Ave	7:30-8:30	5,189	5,189	100%	4:15-5:15	3,801	3,621	95%
Northbound I-95 North of Bryan Park	7:30-8:30	4,000	4,000	100%	4:30-5:30	5,097	5,097	100%
Southbound I-95 North of Bryan Park	7:30-8:30	5,905	5,905	100%	4:15-5:15	4,162	3,839	92%
Northbound I-95/I-64 North of North Boulevard	7:30-8:30	5,590	5,590	100%	4:30-5:30	6,790	6,790	100%
Southbound I-95/I-64 North of North Boulevard	7:15-8:15	6,295	5,969	95%	4:30-5:30	5,600	5,600	100%
Northbound I-95/I-64 South of Robin Hood Rd	7:30-8:30	5,443	5,443	100%	4:30-5:30	5,881	5,881	100%
Northbound I-95/I-64 at Belvidere St Overpass	7:15-8:15	4,963	4,952	100%	4:15-5:15	4,737	4,660	98%
Southbound I-95/I-64 at Belvidere St Overpass	7:30-8:30	5,006	4,847	97%	4:30-5:30	4,978	4,978	100%
Northbound I-95/I-64 btwn Chamberlayne Ave/3rd St	7:30-8:30	5,902	5,902	100%	4:15-5:15	5,453	5,155	95%
Southbound I-95/I-64 btwn Chamberlayne Ave/3rd St	7:30-8:30	5,922	5,922	100%	4:30-5:30	4,808	4,808	100%
Northbound I-95 under 7th St Overpass	7:30-8:30	3,621	3,621	100%	4:45-5:45	3,150	3,137	100%
Southbound I-95 under 7th St Overpass	7:15-8:15	3,370	3,265	97%	5:00-6:00	3,559	3,471	98%
Eastbound I-64 East of I-95/I-64	7:15-8:15	2,566	2,540	99%	4:30-5:30	5,125	5,125	100%
Westbound I-64 WB East of I-95/I-64	7:15-8:15	4,631	4,581	99%	4:30-5:30	3,087	3,087	100%
Northbound I-95 under Broad St Overpass	7:30-8:30	5,083	5,083	100%	4:30-5:30	4,153	4,153	100%
Southbound I-95 under Broad St Overpass	7:15-8:15	4,894	4,821	99%	4:30-5:30	6,051	6,051	100%

Table 11: Seasonal Factor Adjustment

Month	I-95/I-64 North of I-64 at Chamberlayne Road		I-95/I-64 South of I-64 at Maury Street	
	Bi-Directional Monthly Volume	Factor of Highest Month	Bi-Directional Monthly Volume	Factor of Highest Month
Jan	2,509,431	1.29	2,430,281	1.19
Feb	2,466,579	1.31	2,365,391	1.22
Mar	2,852,846	1.13	2,722,991	1.06
Apr	2,913,090	1.11	2,763,488	1.05
May	2,865,639	1.13	2,157,625	1.34
Jun	2,880,962	1.12	2,820,096	1.03
Jul	3,225,857	1.00	2,897,134	1.00
Aug	3,155,371	1.02	2,806,450	1.03
Sep	2,803,938	1.15	2,617,476	1.11
Oct	2,945,648	1.10	2,721,332	1.06
Nov	2,815,697	1.15	2,669,039	1.09
Dec	2,754,946	1.17	2,608,638	1.11
Highest Month	**3,225,857**	**July**	**2,897,134**	**July**

Heavy vehicle percentages on the ramps were calculated from the ramp counts provided by VDOT. Heavy vehicle percentages on the study ramps ranged from 0% up to 31% during the AM peak hour and as high as 51% during the PM peak hour, with the highest being on the system-to-system ramps through the Bryan Park and I-95/I-64 East interchanges. Peak hour ramp heavy vehicle percentages are summarized in **Table 13**. Computations of ramp heavy vehicle percentages are provided in **Appendix F**.

Table 12: Mainline Heavy Vehicle Percentages

Location	Heavy Vehicle Percentage		
	AM Peak Hour (7:30 to 8:30 AM)	PM Peak Hour (4:30 to 5:30 PM)	Daily
Northbound I-95 – North of Chamberlayne Ave	8%	5%	11%
Southbound I-95 – North of Chamberlayne Ave	7%	6%	11%
Southbound I-95/I-64 – South of Robin Hood Rd	7%	5%	9%
Southbound I-95 – South of Maury St	11%	5%	11%
Data collected Wednesday, August 10, 2011			

2.4.4 Traffic Volume Balancing

Using the available 2011 traffic data compiled by VDOT, balanced traffic volumes were generated for operational analysis of the 2011 existing conditions. AM and PM peak hour traffic volume balancing was required due to the variation between count stations, differences between multiple data sources, and data collected on different dates. Peak hour traffic volumes were balanced using O-D data described in **Section 2.2** and an iterative process of adjusting both the mainline and ramp volumes until they were within a reasonable tolerance. The 2011 peak hour traffic volumes do not balance completely since they were balanced using two different sets of O-D data. The difference between the peak hour ramp and interstate volumes are summarized in **Tables 14** and **15**. The balanced peak hour ramp volumes are within 20% of the unbalanced traffic volumes. The interstate mainline traffic volumes are within 47% of the unbalanced traffic volumes. The resulting peak hour traffic volumes are summarized in **Figures 12 - 17**. This volume balancing process is described further in **Section 3.1** of the report.

Table 13: Peak Hour Ramp Heavy Vehicle Percentages

#	Interchange	Ramp		Heavy Vehicle %	
		From	To	AM Peak Hour (7:30 to 8:30 AM)	PM Peak Hour (4:30 to 5:30 PM)
1	I-64 at Staples Mill Rd	Eastbound I-64	Staples Mill Rd	1%	1%
2		Westbound I-64	Southbound Staples Mill	2%	2%
3		Southbound Staples Mill Rd	Westbound I-64	1%	0%
4		Southbound Staples Mill Rd	Eastbound I-64	2%	2%
5		Northbound Staples Mill Rd	Westbound I-64	7%	0%
6		Northbound Staples Mill Rd	Eastbound I-64	8%	1%
7		Westbound I-64	Northbound Staples Mill Rd	2%	3%
8	I-95 at Hermitage Rd	Northbound I-95	Westbrook Ave	0%	0%
9		Hermitage Road	Southbound I-95	1%	0%
10	Bryan Park Interchange	Southbound I-95	Westbound I-64	5%	6%
11		Southbound I-95	Southbound I-195	18%	14%
12		Eastbound I-64	Southbound I-195	1%	1%
13		Northbound I-195	Westbound I-64	1%	1%
14		Eastbound I-64	Northbound I-95	31%	28%
15		Westbound I-64 (Overlap)	Southbound I-195	23%	19%
16		Westbound I-64 (Overlap)	Westbound I-64	2%	2%
17		Laburnum Road	Westbound I-64	2%	2%
18		Northbound I-195	Eastbound I-64 (Overlap)	9%	10%
19		Northbound I-195	Northbound I-95	1%	2%
20		Eastbound I-64	Southbound I-95 (Overlap)	7%	10%
21	I-95/I-64 at Boulevard	Northbound I-95 (Overlap)	Hermitage Rd	4%	4%
22		Robin Hood Rd	Southbound I-95 (Overlap)	11%	3%
23	I-95/I-64 at Belvidere St	Northbound Belvidere	Northbound I-95 (Overlap)	Not Available	Not Available
24		Northbound Belvidere	Southbound I-95 (Overlap)	1%	2%
25		Southbound Belvidere	Southbound I-95 (Overlap)	4%	2%
26		Brook Rd	Southbound I-95 (Overlap)	3%	0%
27	I-95/I-64 East Interchange	I-95 SB (Overlap)	3rd St	1%	4%
28		I-95 SB (Overlap)	Eastbound I-64	17%	26%
29		Westbound I-64	5th St	8%	38%
30		Westbound I-64	Northbound I-95 (Overlap)	9%	51%
31		Northbound 5th St	Westbound I-64 (Overlap)	12%	4%
32		Westbound I-64	Southbound I-95	4%	4%
33		7th St	Southbound I-95	1%	1%
34		Northbound 7th St	Northbound I-95 (Overlap)	0%	0%
35		Northbound 7th St	Eastbound I-64	2%	0%
36		Northbound I-95	7th St	6%	4%
37		Northbound I-95	7th St/ Eastbound I-64	Not Available	Not Available
38	I-95 at Broad St	Southbound I-95	Broad St	1%	2%
39		Northbound I-95	Westbound Broad St	0%	1%
40		Broad St	Northbound I-95	1%	0%
41		Broad St	Southbound I-95	1%	1%
42		Northbound I-95	Southbound Oliver Hill Way	1%	2%
43	I-95 at I-195	Southbound I-95	Westbound I-195	1%	2%
44		Eastbound I-195	Northbound I-95	1%	1%
45		Eastbound I-195	Southbound I-95	4%	2%
46		Northbound I-95	Westbound I-195	1%	2%
Data collected Wednesday, August 10, 2011					

Table 14: Difference between Unbalanced and Balanced Ramp Traffic Volumes

Location				AM Peak Hour								PM Peak Hour							
				7:30 - 7:45		7:45 - 8:00		8:00 - 8:15		8:15 - 8:30		4:30 - 4:45		4:45 - 5:00		5:00 - 5:15		5:15 - 5:30	
				15-Min Vol	%	15-Min Vol	%	15-Min Vol	%	15-Min Vol	%	15-Min Vol	%	15-Min Vol	%	15-Min Vol	%	15-Min Vol	%
1	I-64 at Staples Mill Rd	Eastbound I-64	Staples Mill Rd	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
2		Westbound I-64	Southbound Staples Mill	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
3		Southbound Staples Mill Rd	Westbound I-64	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
4		Southbound Staples Mill Rd	Eastbound I-64	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
5		Northbound Staples Mill Rd	Westbound I-64	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
6		Northbound Staples Mill Rd	Eastbound I-64	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
7		Westbound I-64	Northbound Staples Mill Rd	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
8	I-95 at Hermitage Rd	Northbound I-95	Westbrook Ave	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
9		Hermitage Road	Southbound I-95	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
10	Bryan Park Interchange	Southbound I-95	Westbound I-64	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
11		Southbound I-95	Southbound I-195	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
12		Eastbound I-64	Southbound I-195	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
13		Northbound I-195	Westbound I-64	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
14		Eastbound I-64	Northbound I-95	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
15		Westbound I-64 (Overlap)	Southbound I-195	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
16		Westbound I-64 (Overlap)	Westbound I-64	0	0%	-44	-4%	-50	-5%	0	0%	81	10%	0	0%	49	5%	0	0%
17		Laburnum Road	Westbound I-64	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
18		Northbound I-195	Eastbound I-64 (Overlap)	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
19		Northbound I-195	Northbound I-95	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
20		Eastbound I-64	Southbound I-95 (Overlap)	107	12%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
21	I-95/I-64 at Boulevard	Northbound I-95 (Overlap)	Hermitage Rd	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
22		Robin Hood Rd	Southbound I-95 (Overlap)	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
23	I-95/I-64 at Belvidere St	Northbound Belvidere	Northbound I-95 (Overlap)	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
24		Northbound Belvidere	Southbound I-95 (Overlap)	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
25		Southbound Belvidere	Southbound I-95 (Overlap)	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
26		Brook Rd	Southbound I-95 (Overlap)	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
27	I-95/I-64 East Interchange	I-95 SB (Overlap)	3rd St	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
28		I-95 SB (Overlap)	Eastbound I-64	0	0%	0	0%	9	3%	-12	-4%	0	0%	0	0%	0	0%	0	0%
29		Westbound I-64	5th St	108	20%	49	8%	-15	-2%	6	1%	28	7%	-36	-8%	50	12%	1	0%
30		Westbound I-64	Northbound I-95 (Overlap)	21	5%	80	16%	-25	-5%	31	7%	-23	-6%	-33	-9%	0	0%	-55	-16%
31		Northbound 5th St	Westbound I-64 (Overlap)	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
32		Westbound I-64	Southbound I-95	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
33		7th St	Southbound I-95	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
34		Northbound 7th St	Northbound I-95 (Overlap)	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
35		Northbound 7th St	Eastbound I-64	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
36		Northbound I-95	7th St	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
37		Northbound I-95	7th St/ Eastbound I-64	0	0%	22	6%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
38	I-95 at Broad St	Southbound I-95	Broad St	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
39		Northbound I-95	Westbound Broad St	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
40		Broad St	Northbound I-95	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
41		Broad St	Southbound I-95	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
42		Northbound I-95	Southbound Oliver Hill Way	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
43	I-95 at I-195	Southbound I-95	Westbound I-195	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
44		Eastbound I-195	Northbound I-95	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
45		Eastbound I-195	Southbound I-95	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
46		Northbound I-95	Westbound I-195	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%

Table 15: Difference between Unbalanced and Balanced Interstate Mainline Traffic Volumes

	Location	AM Peak Hour								PM Peak Hour							
		7:30 - 7:45		7:45 - 8:00		8:00 - 8:15		8:15 - 8:30		4:30 - 4:45		4:45 - 5:00		5:00 - 5:15		5:15 - 5:30	
		15-Min Vol	%	15-Min Vol	%	15-Min Vol	%	15-Min Vol	%	15-Min Vol	%	15-Min Vol	%	15-Min Vol	%	15-Min Vol	%
1	Eastbound I-64 West of Overlap	13	1%	79	5%	44	3%	254	24%	-111	-7%	65	4%	-158	-8%	62	3%
2	Westbound I-64 West of Overlap	-252	-13%	0	0%	0	0%	94	5%	-4	0%	-6	0%	-2	0%	85	5%
3	Northbound I-95 North of Westbrook	197	22%	17	2%	-40	-4%	11	1%	58	5%	-10	-1%	-20	-1%	100	8%
4	Southbound I-95 North of Westbrook	-77	-6%	19	1%	54	4%	22	2%	-202	-22%	-1	0%	-209	-19%	316	47%
5	Northbound I-95 North of I-95/I-64/I-195	205	21%	83	8%	-39	-4%	9	1%	83	7%	54	4%	83	6%	150	12%
6	Southbound I-95 North of I-95/I-64/I-195	-65	-4%	30	2%	25	2%	9	1%	-180	-17%	-25	-2%	-100	-9%	503	81%
7	Northbound Overlap North of North Blvd	34	2%	-7	0%	-77	-5%	5	0%	61	4%	-93	-5%	43	2%	9	1%
8	Southbound Overlap North of North Blvd	13	1%	54	3%	160	11%	76	6%	-146	-11%	-7	0%	-186	-12%	-78	-5%
9	Northbound Overlap South of Robin Hood	-48	-3%	-55	-4%	-71	-5%	27	2%	0	0%	-51	-3%	-3	0%	24	2%
10	Northbound Overlap under Belvidere Overpass	-67	-5%	19	1%	0	0%	61	5%	45	4%	24	2%	9	1%	125	11%
11	Southbound Overlap under Belvidere Overpass	75	6%	18	1%	71	6%	87	8%	-16	-1%	103	8%	-31	-2%	4	0%
12	Northbound Overlap between Chamberlayne & 3rd St	-120	-7%	-4	0%	31	2%	22	2%	28	2%	-1	0%	-33	-2%	251	22%
13	Southbound Overlap between Chamberlayne & 3rd St	-3	0%	-46	-3%	-27	-2%	-230	-15%	237	20%	376	30%	393	31%	348	29%
14	Northbound I-95 under 7th St Overpass	0	0%	0	0%	0	0%	9	1%	0	0%	0	0%	0	0%	0	0%
15	Southbound I-95 under 7th St Overpass	70	8%	-63	-7%	-14	-2%	0	0%	0	0%	34	4%	0	0%	-102	-11%
16	Eastbound I-64 East of Overlap	-16	-2%	1	0%	-11	-2%	0	0%	-121	-10%	-165	-12%	-180	-13%	-129	-10%
17	Westbound I-64 East of Overlap	-188	-15%	4	0%	73	7%	-24	-2%	-26	-3%	42	6%	-13	-2%	-33	-4%
18	Northbound I-95 under Broad St Overpass	43	3%	28	2%	-27	-2%	32	3%	-87	-8%	-87	-8%	-156	-14%	-16	-2%
19	Southbound I-95 under Broad St Overpass	95	7%	-106	-8%	28	2%	-2	0%	-7	0%	75	5%	56	3%	-107	-7%

Figure 12: Existing 2011 Traffic Volumes – AM Peak Hour (1 of 3)

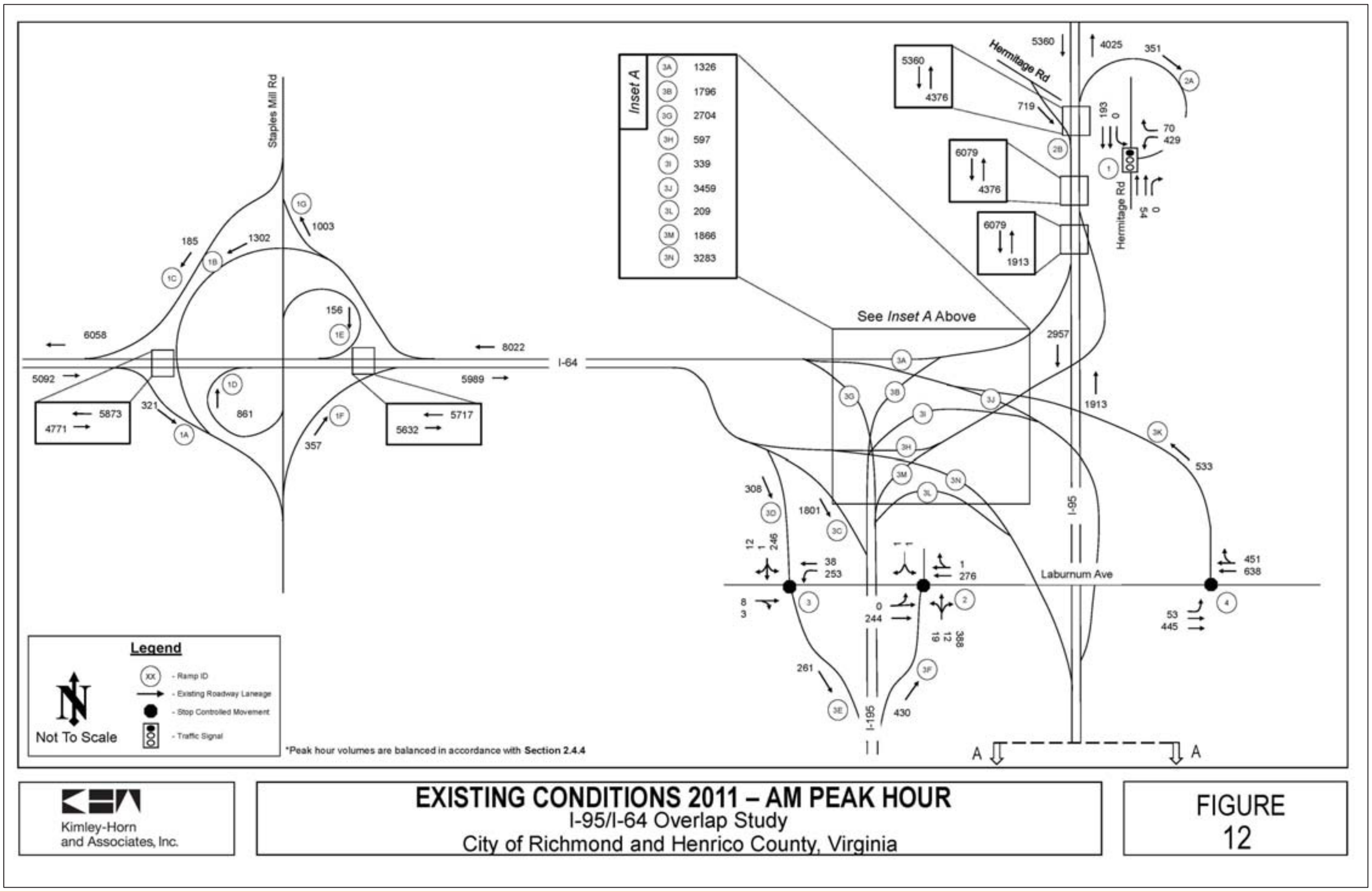

Figure 13: Existing 2011 Traffic Volumes – AM Peak Hour (2 of 3)

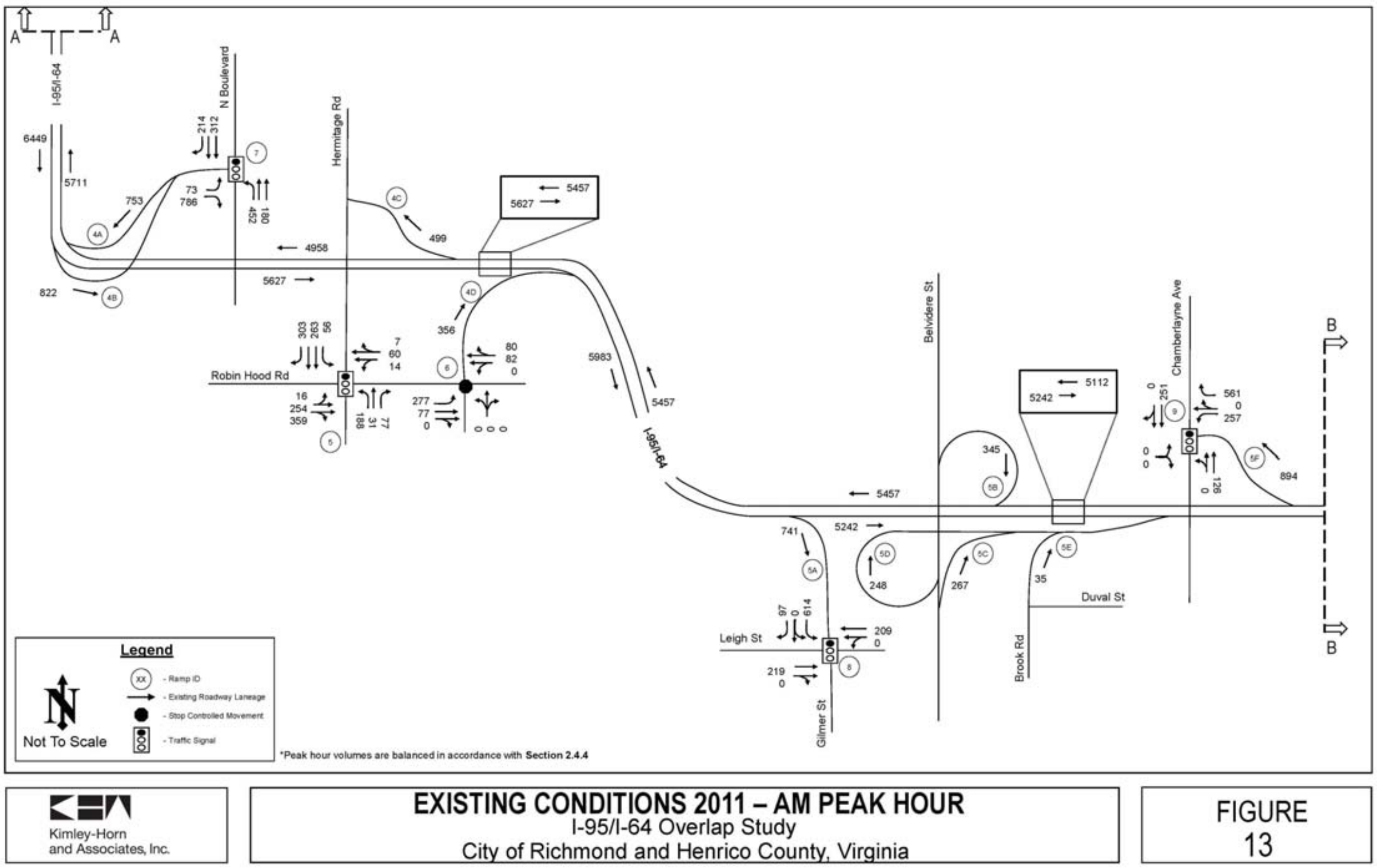

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Figure 14: Existing 2011 Traffic Volumes – AM Peak Hour (3 of 3)

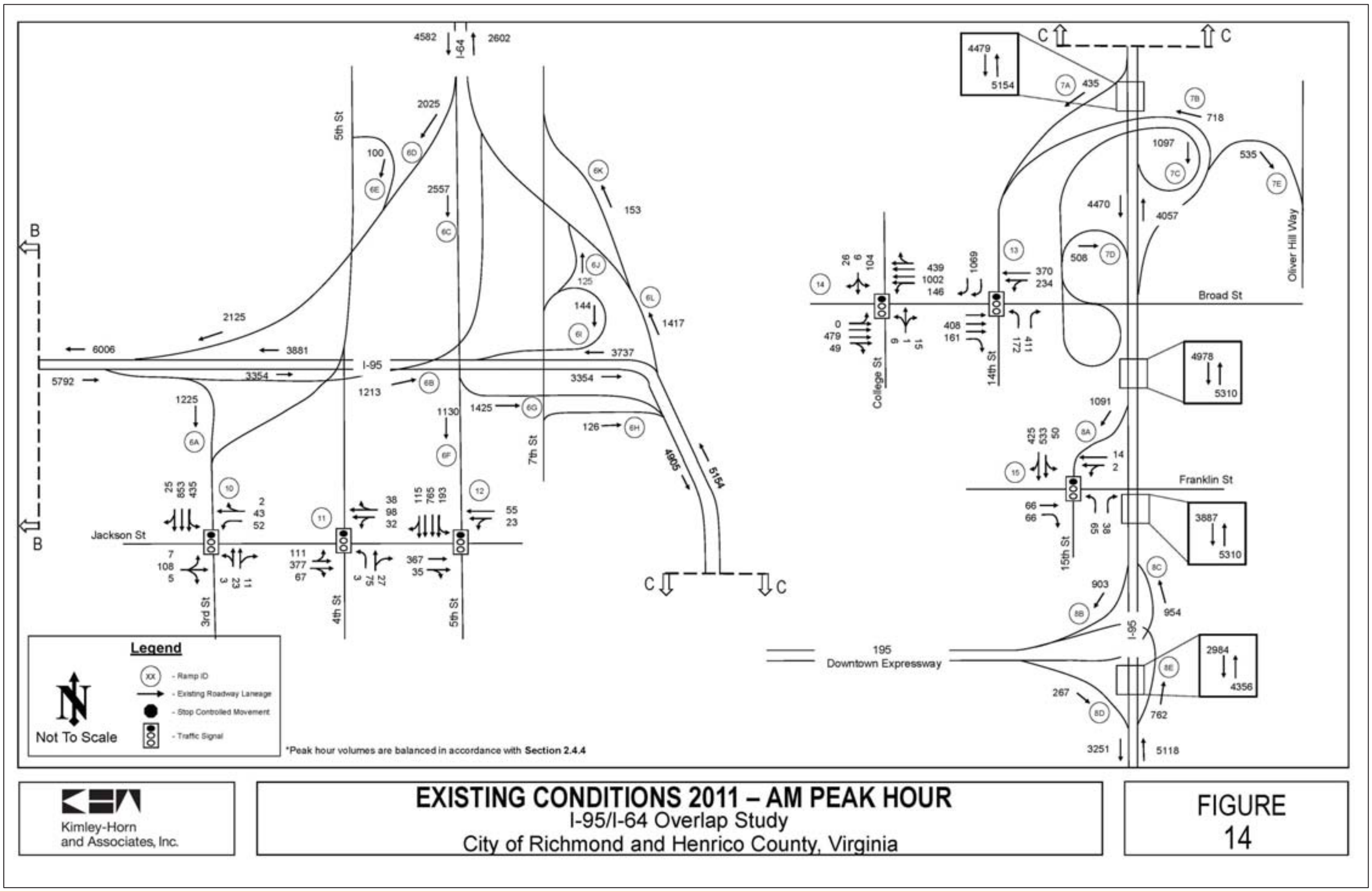


Figure 15: Existing 2011 Traffic Volumes – PM Peak Hour (1 of 3)

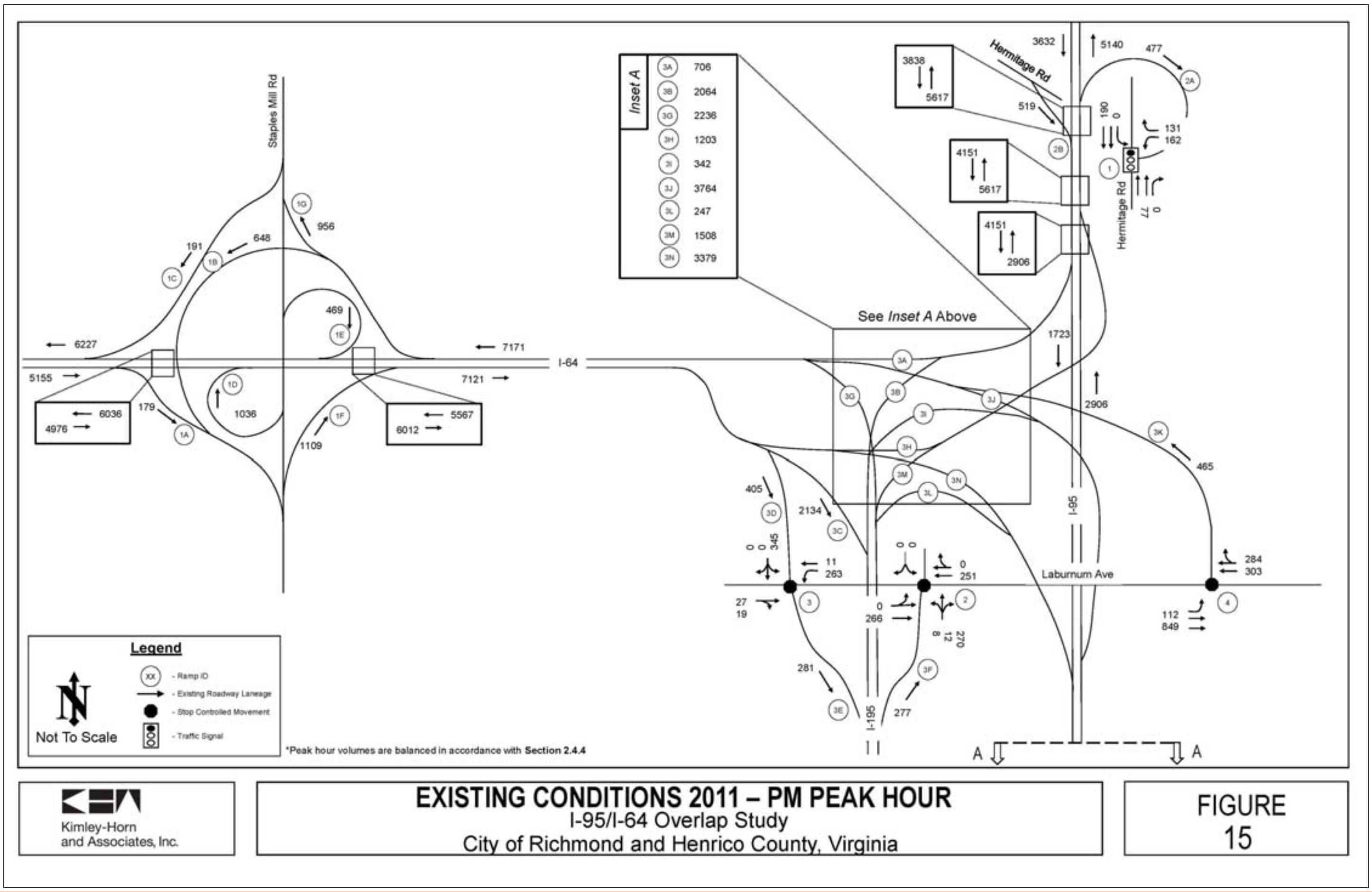


Figure 16: Existing 2011 Traffic Volumes – PM Peak Hour (2 of 3)

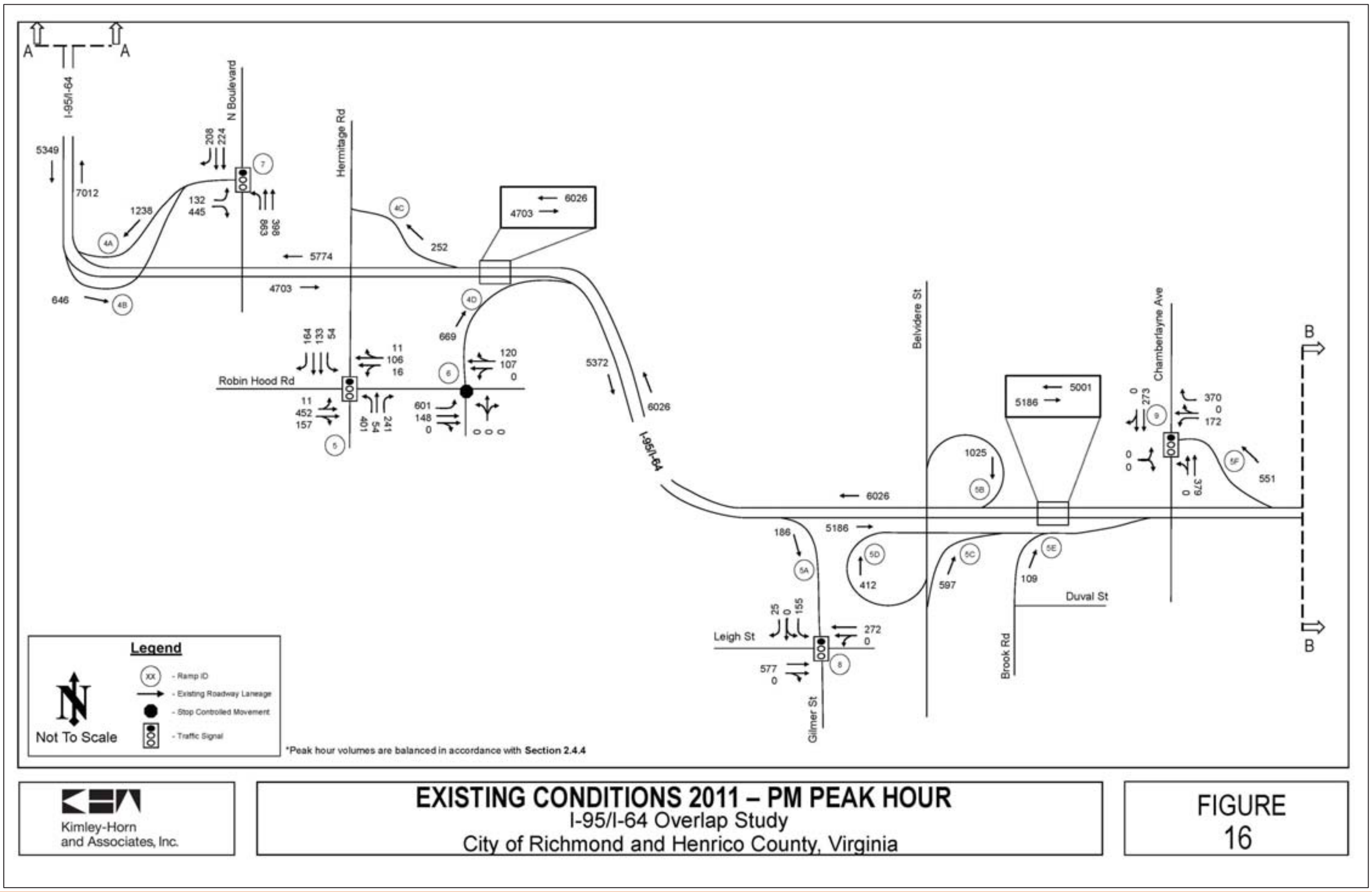
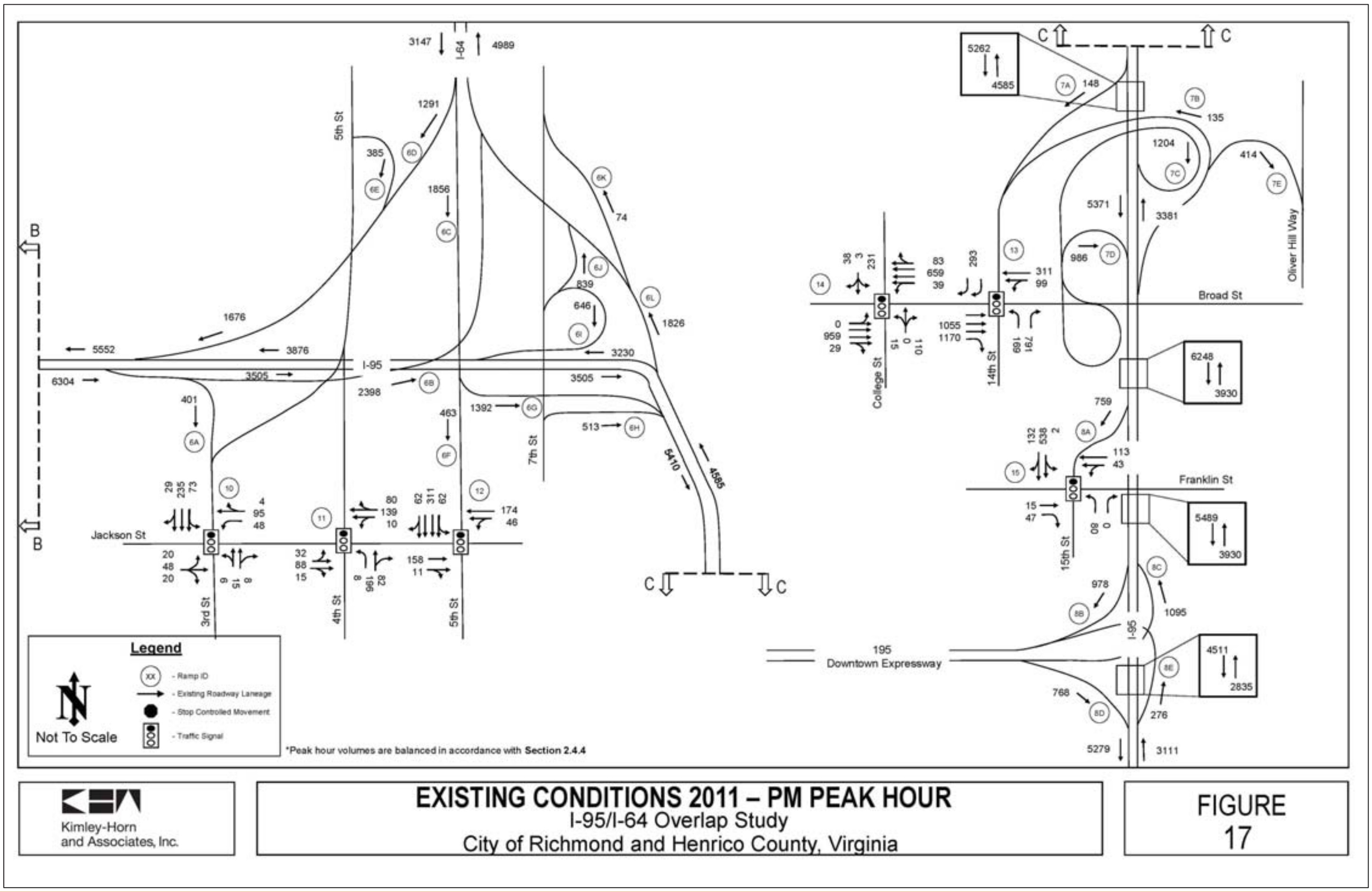


Figure 17: Existing 2011 Traffic Volumes – PM Peak Hour (3 of 3)



2.5 Crash Data & Crash Analysis

An evaluation of corridor safety was conducted based on an analysis of crash summary information and field reconnaissance. Crash data analysis for the study corridors and the associated on- and off-ramps within the study area was conducted using the latest three years of available crash data (January 1, 2007 to December 31, 2009). VDOT sources from which the crash data was obtained included a combination of police reports (FR-300s), the Highway Traffic Records Inventory System (HTRIS), and the Crash Analysis Tool (CAT) and are summarized in the following sections. The primary goal of this study was to identify improvements for the I-95/I-64 study corridors; therefore, for purposes of this study crash analysis was not conducted at the adjacent study intersections.

For purposes of the crash analysis study corridors were defined as having the following beginning and ending milepost (MP):

1. I-64 from Staples Mills Road (MP 185.50) to Bryan Park (MP 187.75)
2. I-95 from Hermitage Road (MP 80.25) to James River Bridge (MP 74.25)
3. I-195 from Bryan Park interchange (MP 2.50) to South of Laburnum Avenue (MP 3.50)

2.5.1 Corridor Crash Summary

The following tables summarize key crash statistics on the study corridors in a 3-year period from 2007 to 2009. Complete crash summary data is provided in **Appendix G**.

<u>Overall Crash Summary</u>

- The total number of reported crashes on all study corridors was 1,813 with 27% resulting in injuries.
- There were 3 fatal crashes in the study corridor. A summary of the circumstances surrounding each fatal crash is described below.
  1. Crash occurred on northbound I-95/I-64 0.2 miles north of the Chamberlayne Road exit at milepost 76.34. The crash involved 1 fatality and 5 injuries and occurred in 2007 on a Wednesday at 2:00 PM. It was a sideswipe in the same direction crash in conditions with dry roadway surface, clear weather, and daylight.
  2. Crash occurred on northbound I-95/I-64 0.2 miles north of the Boulevard at milepost 79.26. The crash involved 1 fatality and 1 injury and occurred in 2007 on a Monday at 2:54 PM. It was a sideswipe in the same direction crash in conditions with dry roadway surface, clear weather, under daylight.
  3. Crash occurred on southbound I-95 at the merge from eastbound I-64/I-195 at milepost 79.05. The crash involved 1 fatality and 1 injury and occurred in 2009 on a Monday at 2:10 AM. It was a fixed-object, off-road crash in conditions with dry roadway surface, clear weather, and darkness.

Table 16: Overall Crash Summary

Segment	Milepost		Direction	Severity			Total
	From	To		PDO	Injuries	Fatalities	
I-64 from Staples Mill Rd to Bryan Park	185.50	187.75	EB	141 (75%)	46 (25%)	0 (0%)	187
			WB	105 (65%)	56 (35%)	0 (0%)	161
I-95 from Hermitage Rd to James River Bridge	80.25	74.25	NB	485 (72%)	189 (28%)	2 (<1%)	676
			SB	502 (73%)	185 (27%)	1 (<1%)	688
I-195 from Bryan Park to S. of Laburnum Ave	2.50	3.50	NB	14 (70%)	6 (30%)	0 (0%)	20
			SB	67 (83%)	14 (17%)	0 (0%)	81
			Corridor Total	**1,314 (72%)**	**496 (27%)**	**3 (<1%)**	**1,813**

Number of Crashes (Percentage of Crashes)
PDO = Property Damage Only

<u>Lighting Conditions</u>

- Most of the corridor crashes occurred during the day with less than 30% occurring under dark conditions. **Appendix H** documents the inventory of existing roadway lighting throughout the study corridors.

- Due to the east-west alignment of I-64, sun glare may be a contributing factor to the 20% of dawn/dusk crashes between Staples Mill Rd and the Bryan Park interchange. Sun glare in the eastbound direction during dawn hours was observed during the various field visits.

Table 17: Crash Summary – Lighting Conditions

Segment	Milepost		Direction	Day	Dawn/Dusk	Dark
	From	To				
I-64 from Staples Mill Rd to Bryan Park	185.50	187.75	EB	124 (66%)	19 (20%)	44 (24%)
			WB	113 (70%)	14 (9%)	34 (21%)
I-95 from Hermitage Rd to James River Bridge	80.25	74.25	NB	485 (72%)	30 (4%)	161 (24%)
			SB	485 (70%)	41 (6%)	162 (24%)
I-195 from Bryan Park to S. of Laburnum Ave	2.50	3.50	NB	14 (70%)	0 (0%)	6 (30%)
			SB	58 (72%)	2 (2%)	21 (26%)
			Corridor Total	**1,279 (70%)**	**106 (6%)**	**428 (24%)**
Number of Crashes (Percentage of Crashes)						

Peak Period

- Sixty-five percent (65%) of the crashes on I-64 and I-95 through the study corridor occurred during AM and PM peak hours.

Table 18: Crash Summary – Peak Periods

Segment	Milepost		Direction	Peak Period		Peak Period	Off Peak
	From	To		AM (6:00 – 10:00)	PM (3:00 – 7:00)		
I-64 from Staples Mill Rd to Bryan Park	185.50	187.75	EB	69 (37%)	71 (38%)	140 (75%)	47 (25%)
			WB	51 (32%)	46 (28%)	97 (60%)	64 (40%)
I-95 from Hermitage Rd to James River Bridge	80.25	74.25	NB	164 (24%)	282 (42%)	446 (66%)	230 (34%)
			SB	151 (22%)	286 (42%)	437 (64%)	251 (36%)
I-195 from Bryan Park to S. of Laburnum Ave	2.50	3.50	NB	1 (5%)	6 (30%)	7 (35%)	13 (65%)
			SB	22 (27%)	24 (30%)	46 (56%)	35 (44%)
					Corridor Total	**1173 (65%)**	**640 (35%)**
Number of Crashes (Percentage of Crashes)							

Figures 18 - 23 summarize crash type percentages throughout the study corridor. The primary crash type on I-95 and I-64 within the study area is rear end. Large percentages of rear-end collisions on free-flow facilities are often an indication of congestion. The second highest crash type through the study area is fixed-object off-road. The largest percentage of crashes on the section of I-195 from Bryan Park to Laburnum Avenue is fixed-object off-road, which is most likely related to a horizontal "s-curve" alignment through the segment.

Figure 18: Crash Type Summary – Eastbound I-64 from Staples Mill Rd to Bryan Park

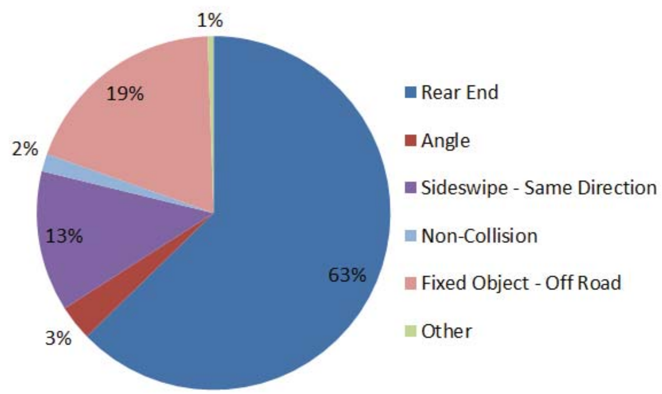


Figure 19: Crash Type Summary – Westbound I-64 from Staples Mill Rd to Bryan Park

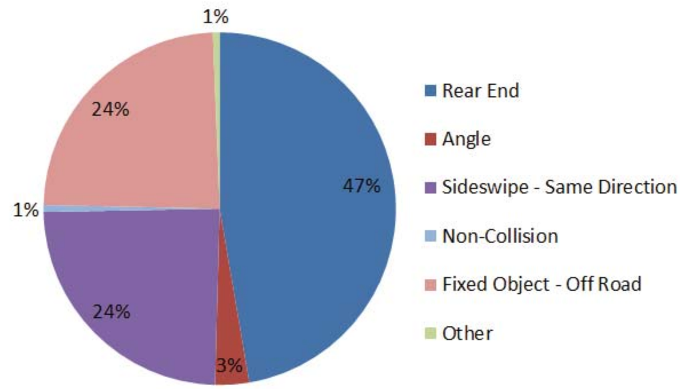


Figure 20: Crash Type Summary – Northbound I-95 from Hermitage Rd to James River Bridge

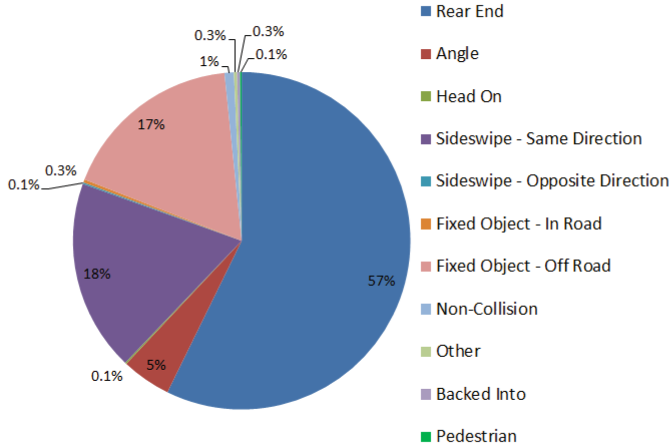


Figure 21: Crash Type Summary – Southbound I-95 from Hermitage Rd to James River Bridge

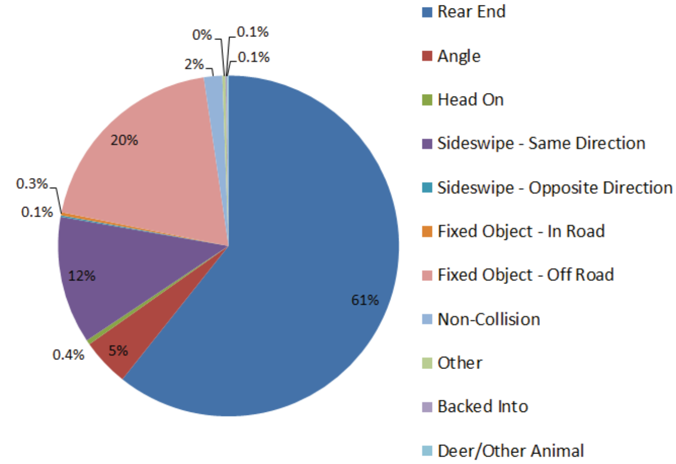


Figure 22: Crash Type Summary – Northbound I-195 from Bryan Park to S. of Laburnum Ave

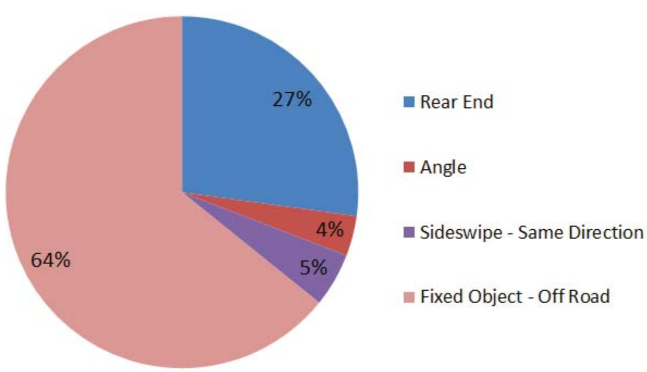
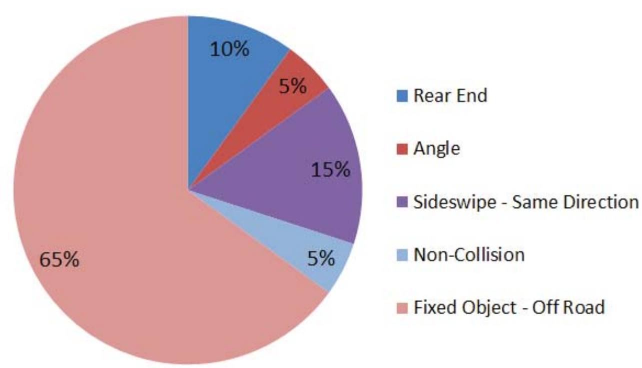


Figure 23: Crash Type Summary – Southbound I-195 from Bryan Park to S. of Laburnum Ave




Crash activities by quarter-mile segments of roadway, or crash density, in each direction along the study corridors between 2007 and 2009 are represented as crash histograms in **Figure 24 - 28**. Crash density by segment was compared to the statistical mean, or average, crash density plus two standard deviations from the average. Quarter-mile segments with more crashes than the average crash density plus two standard deviations (i.e. "critical crash density") for the study corridor are considered to be crash "hot spots". For the I-95 study corridor, VDOT also provided the statewide crash rates per quarter mile for urban sections of I-95 to identify hot spots along the study corridor.

Based on the crash histograms the following crash hot spots were identified:

<u>I-95 from Hermitage Road to James River Bridge</u>

- Northbound
    1. Broad Street – half-mile segment from the loop on-ramp from Broad Street to the northbound I-95 exit to eastbound I-64 (MP 74.75 to MP 75.25)
    2. Belvidere Street – one-mile segment of northbound I-95/I-64 from the exit to Chamberlayne Road to half mile north of Belvidere Street (MP 76.00 to MP 77.00)
    3. Boulevard – one-mile segment of northbound I-95/I-64 from the exit to Hermitage Road to the exit to westbound I-64 at Bryan Park interchange (MP 78.00 to MP 79.00)
- Southbound
    1. Hermitage Road – one-mile segment from the on-ramp from Hermitage Road to the southbound I-95 exit to westbound I-64 (MP 80.25 to MP 79.75)
    2. Bryan Park Interchange – 0.75-mile segment from the eastbound I-64/northbound I-195 to southbound I-95 merger to the exit to Boulevard (MP 79.25 to MP 78.50)
    3. Belvidere Street – 1.25-mile segment from a half-mile north of Belvidere Street through the I-95/I-64 East interchange (MP 76.75 to MP 75.50)
    4. Broad Street – quarter-mile segment from the exit to Broad Street to the loop on-ramp from Broad Street (MP 75.00 to MP 74.75)

<u>I-64 from Staples Mill Rd to Bryan Park</u>

No crash hot spots identified based on the methodology described above.

<u>I-195 from Bryan Park to South of Laburnum Avenue</u>

No crash hot spots identified based on the methodology described above.

In addition to histograms, crash density heat maps were created to summarize crash trends along each study corridor by direction in a map format and are provided in **Appendix G** . These heat maps document crash frequency, crash severity, crash type, lighting condition and time of day.

2.5.2 Ramp Crash Summary

Crash data on study area ramps was summarized to determine the most prevalent crash type and identify the top five ramps based on crash severity. Per the *Highway Safety Manual, 2010,* the Equivalent Property Damage Only (EPDO) Average Crash Frequency performance measure assigns weighting factors to crashes by severity to develop a single, combined frequency and severity score per location. The weighting factors were calculated relative to Property Damage Only (PDO) crashes as shown in **Table 19**. The study ramps with the five highest EPDO scores are summarized in **Table 20**. Complete ramp crash data is provided in **Appendix G**. The top 5 ramps correspond with the identified mainline crash hot spots with 4 of the 5 ramps correlating with system-to-system merges/diverges at the Bryan Park interchange and the I-95/I-64 East interchange. The northbound on-ramp from Belvidere Street also ranks in the top 5 ramps within the corridor.

Figure 24: Crash Density – Eastbound I-64 from Staples Mill Road to Bryan Park

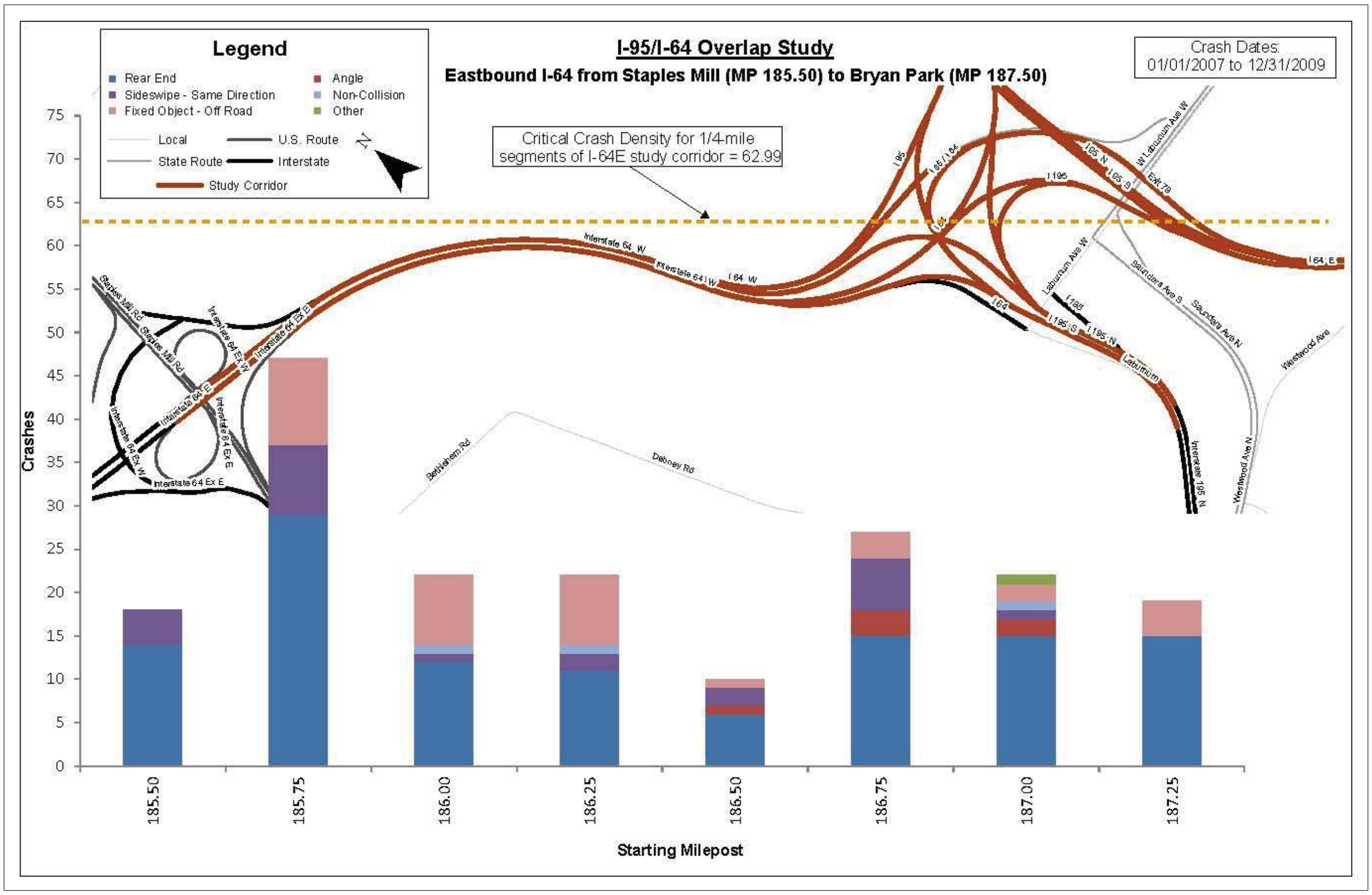


Figure 25: Crash Density – Westbound I-64 from Staples Mill Road to Bryan Park

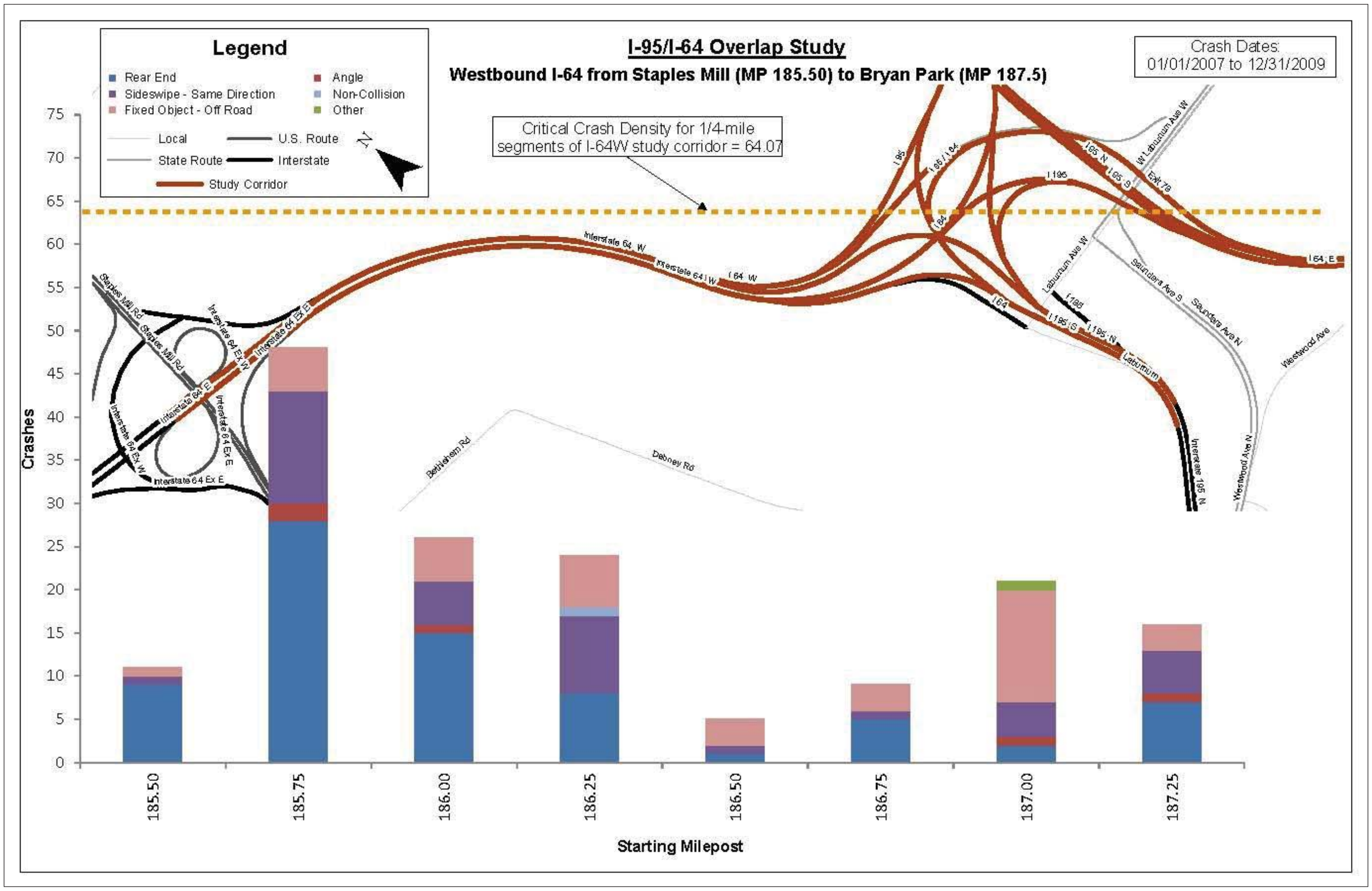


Figure 26: Crash Density – Northbound I-95 from Hermitage Road to James River Bridge

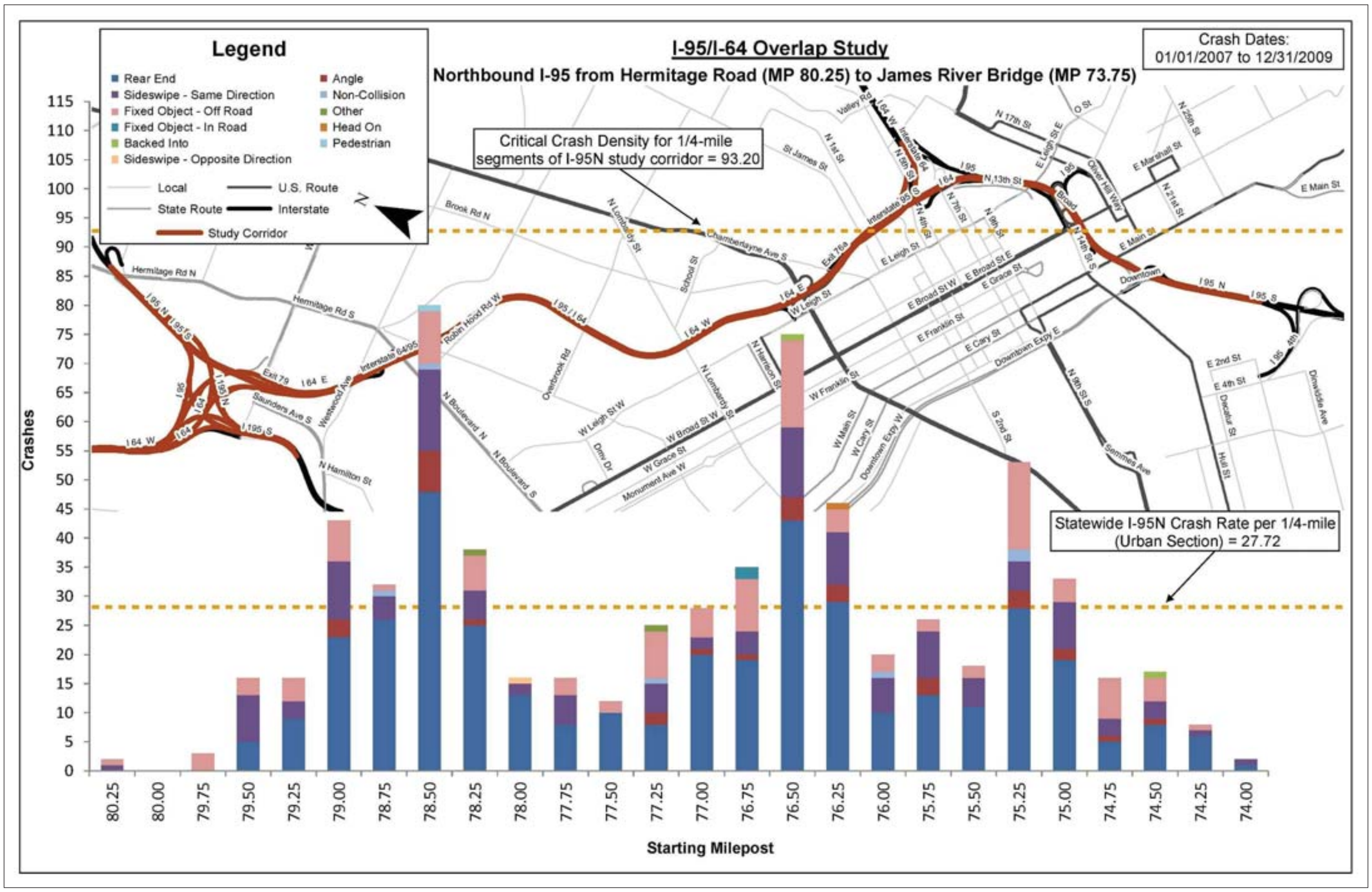


Figure 27: Crash Density – Southbound I-95 from Hermitage Road to James River Bridge

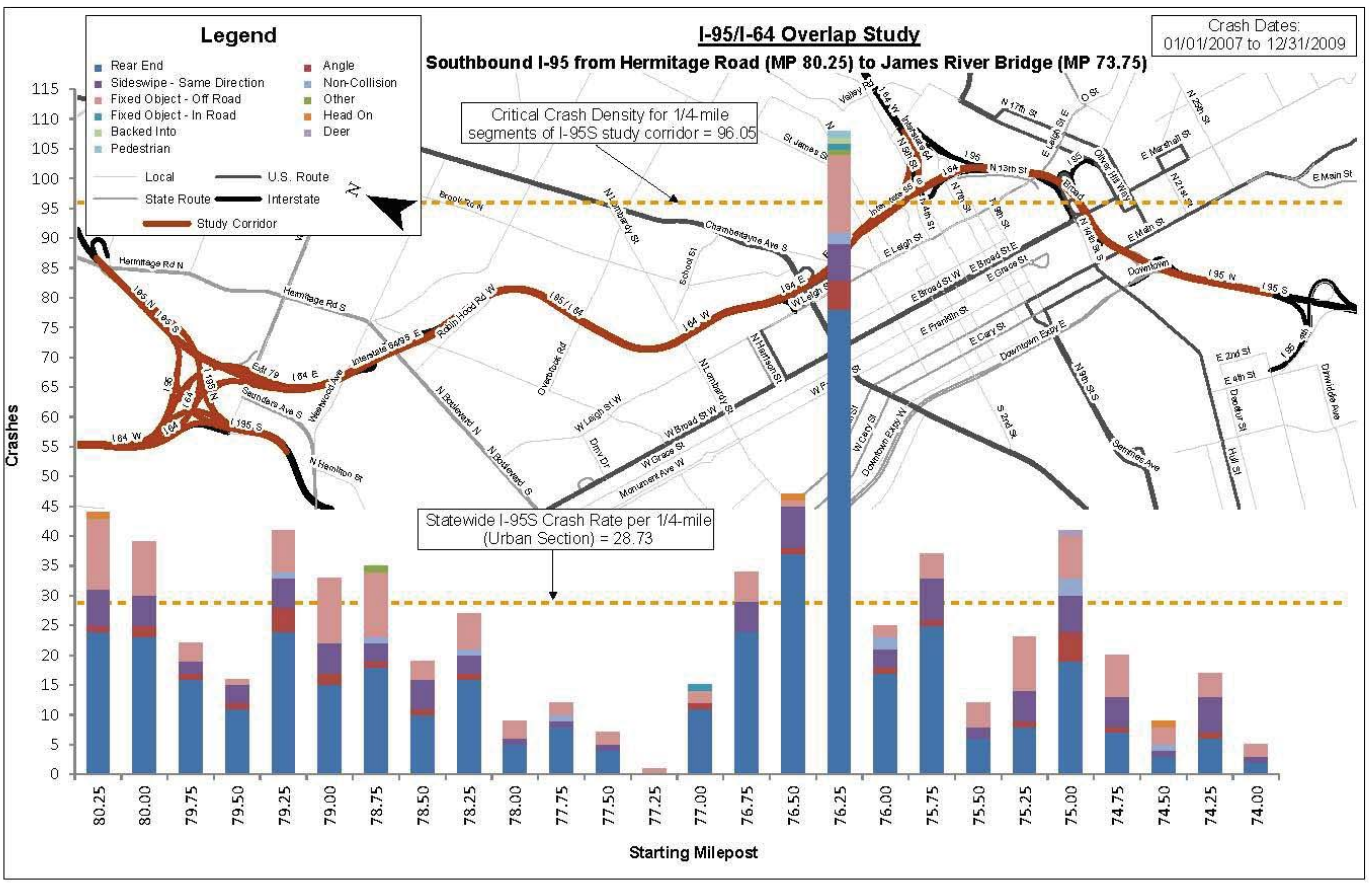


Figure 28: Crash Density – NB and SB I-195 from Bryan Park to S. of Laburnum Avenue

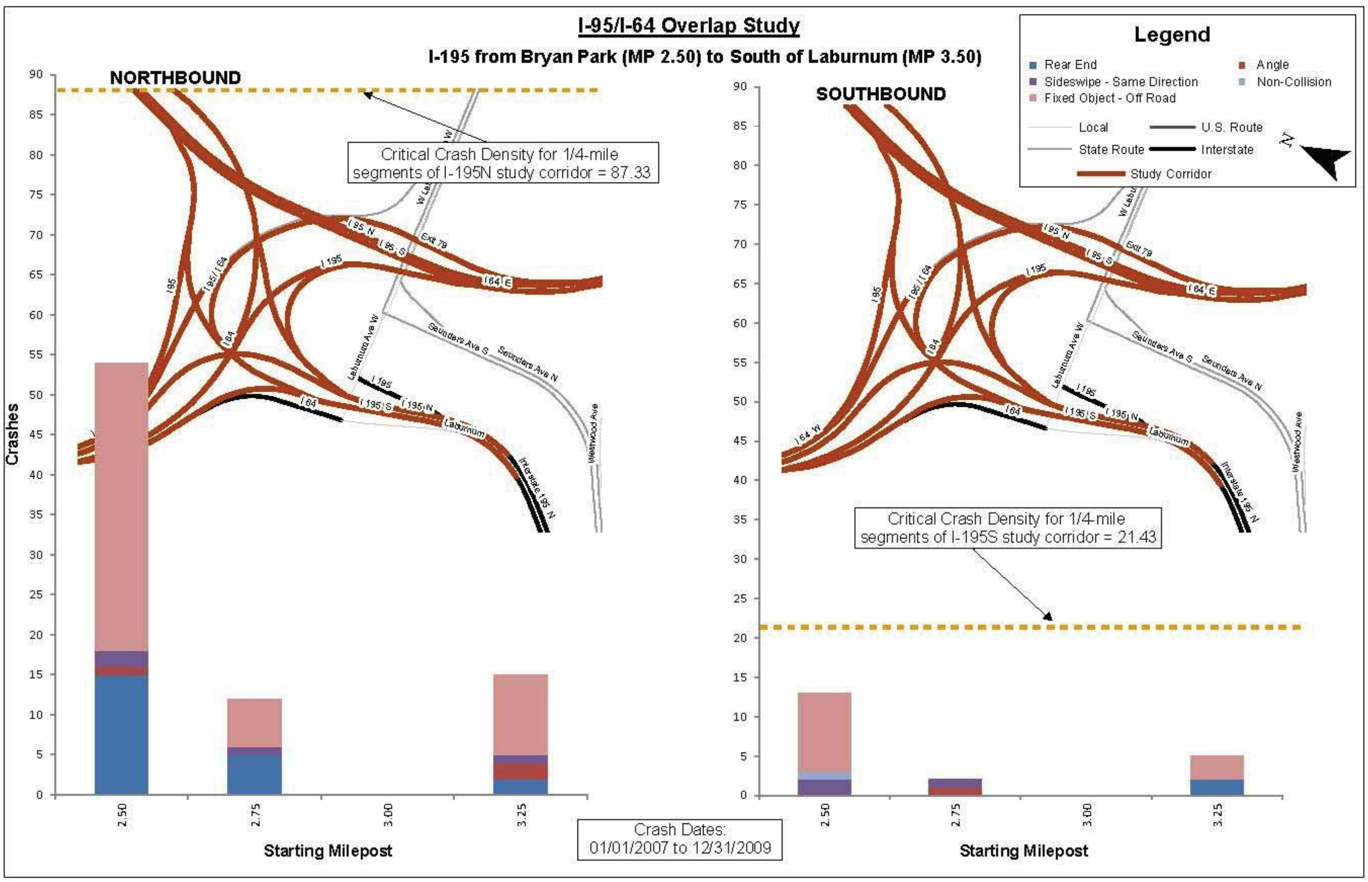


Table 19: EPDO Weighting Factors

Severity	Societal Crash Cost*	Weighting Factor
Fatal	$5,038,456	558
Injury (A/B/C)	$142,925	16
Property Damage Only (PDO)	$9,029	1

Source: Crash cost assumptions obtained from VDOT FY2012-13 Highway Safety Improvement Program (HSIP) application

Table 20: Ramp Crash Summary

Severity	Number of Crashes	Total EPDO		Crash Type					
		Score	Ranking	Angle	Fixed-Object Off-Road	Non-Collision	Rear End	Sideswipe – Same Direction	Other
Ramp: Bryan Park Interchange – Northbound I-95/ I-64 to Westbound I-64									
Fatal	0	412	3	0	0	0	0	0	0
Injury	23			1	11	0	7	4	0
PDO	44			1	14	0	18	8	3
Total	**67**			**22**	**25**	**0**	**25**	**12**	**3**
Ramp: Bryan Park Interchange – Eastbound I-64 to Southbound I-95/I-64									
Fatal	1	764	1	0	1	0	0	0	0
Injury	11			1	3	0	6	1	0
PDO	30			2	3	1	20	3	1
Total	**42**			**3**	**7**	**1**	**26**	**4**	**1**
Ramp: Belvidere Interchange – Northbound Belvidere Street to Southbound I-95/I-64 On-Ramp									
Fatal	0	344	4	0	0	0	0	0	0
Injury	18			1	0	1	15	1	0
PDO	56			0	0	0	54	2	0
Total	**74**			**1**	**0**	**1**	**69**	**3**	**0**
Ramp: I-95/I-64 East Interchange – Southbound I-95/I-64 to Eastbound I-64									
Fatal	0	281	5	0	0	0	0	0	0
Injury	16			1	2	3	9	1	0
PDO	25			1	3	0	18	3	0
Total	**41**			**2**	**5**	**3**	**27**	**4**	**0**
Ramp: I-95/I-64 East Interchange – Westbound I-64 to Northbound I-95/I-64									
Fatal	0	453	2	0	0	0	0	0	0
Injury	24			0	2	0	21	1	0
PDO	69			3	2	1	56	7	0
Total	**93**			**3**	**4**	**1**	**77**	**8**	**0**

2.5.3 Supplemental Field Data Collection

VDOT provided GIS-based asset management information from which mapping was developed. Field verification of various field devices was conducted and summarized in a series of maps provided in **Appendix H**. Additional field observations regarding geometric conditions are summarized below:

- Based on a visual assessment, guardrail is located at areas where protection is required (i.e., bridge structures, sign structures, steep slopes, etc.).
- There are no rumble strips on the right or left shoulders throughout the study area.
- Based on a visual assessment, the pavement is in fair to poor condition throughout the study area.


- Based on a visual assessment, pavement markings (edge lines and lane lines) vary between 4 and 6 inches and the condition varies from good to poor condition.
- No excessive roadway grades or curvature were observed.
- Conventional roadway lighting exists throughout the corridor concentrated primarily at study interchanges. High mast lighting exists at the south end of the corridor from just west of the I-95/I-64 East interchange through the Broad Street interchange area.
- There are four overhead variable message signs (VMS) on I-95 and I-64 approaches to the study corridor at the following locations:
  - On northbound I-95 located approximately 1.8 miles south of Chippenham Parkway
  - On southbound I-95 located approximately 375 feet north of the Brook Road overpass
  - On eastbound I-64 located approximately half a mile east of Parham Road
  - On westbound I-64 at located approximately 4,100 feet east of Nine Mile Road

2.6 Corridor Geometric Deficiencies

An assessment of existing geometric conditions was completed throughout the study area to identify areas that do not meet current geometric standards. The assessments included interchange, merge (acceleration), and weave spacing; shoulder width; and bridge vertical clearance. It is important to identify deficiencies in these areas because they have the potential to negatively impact freeway operations and safety within the study area.

2.6.1 Interchange, Merge, and Weave Spacing

Interchange spacing can have a significant impact on freeway operations especially if they are spaced closely together. According to the American Association of State Highway and Transportation Officials (AASHTO) *A Policy on Geometric Design of Highways and Streets, 2004*, the minimum interchange spacing in urban areas is one mile. Three interchanges in the northbound direction and three interchanges in the southbound direction do not meet the minimum, one-mile interchange spacing for urban areas. Closely spaced interchanges within an urban area create additional friction and turbulence potentially resulting in increased congestion and bottlenecks.

Existing interchange spacing within the study area is summarized in **Table 21**. Three interchanges in the northbound direction and three interchanges in the southbound direction do not meet the minimum interchange spacing of one mile for urban areas. Closely spaced interchanges within an urban area create additional friction and turbulence potentially resulting in increased congestion and bottlenecks.

The merge length is critical to freeway operations as it provides merging vehicles appropriate distance to merge into the mainline through traffic stream. According to the AASHTO *A Policy on Geometric Design of Highways and Streets, 2004*, the minimum merge or acceleration length within the study area is 910 feet based on a 60 mile per hour (MPH) mainline design speed and a 30 MPH entrance curve design speed. **Table 22** shows the existing merge distances within the study area that do not meet the minimum merge length.

Three existing merge lengths within the study area do not meet the minimum merge length of 910 feet. The deficient merge lengths do not allow the merging vehicle to reach the desired speed needed to safely merge into through traffic resulting in greater interference with through traffic, which increases crash potential.

Table 21: Interchange Spacing

	From	To	^Distance (mile)	Deficient Distance (mile)
Northbound I-95/I-64	I-195	Broad Street	0.21	0.79
	Broad Street	Northbound I-95/Eastbound I-64	0.47	0.15
	Northbound I-95/Eastbound I-64	7th Street	0.27	0.73
	7th Street	Westbound I-64	0.27	0.73
	Westbound I-64	Chamberlayne Parkway	0.21	0.79
	Chamberlayne Parkway	Belvidere Street	0.27	0.73
	Belvidere Street	Hermitage Road	1.90	-
	Hermitage Road	Boulevard	0.44	0.56
	Boulevard	Bryan Park	0.32	0.68
	Bryan Park	Staples Mill Road	1.65	-
Southbound I-95/I-64	Staples Mill Road	Bryan Park	0.88	0.12
	Bryan Park	Boulevard	1.04	-
	Boulevard	Leigh Street	2.19	-
	Leigh Street	Eastbound I-64/3rd Street	0.55	0.45
	Eastbound I-64/3rd Street	Broad Street	0.85	0.15
	Broad Street	Franklin Street	0.40	0.60

^Distance between interchanges was measured ramp gore to ramp gore.

Table 22: Merge Deficiencies

Location	Merge Length (feet)	Deficient Distance (feet)
Northbound I-95/I-64 On-Ramp from 7th Street	250	660
Northbound I-95/I-64 On-Ramp from Belvidere Street/Chamberlayne Avenue	200	710
Southbound I-95/I-64 On-Ramp from Robin Hood Road^	640	270

^The Robin Hood Road on-ramp is currently be extended 521 feet to 1,161 feet, estimated to be completed by Fall of 2014

Weaving occurs when merge segments are closely followed by diverge segments requiring drivers to cross two (or more) traffic streams. According to the AASHTO *A Policy on Geometric Design of Highways and Streets, 2004*, sufficient weaving length should be provided between successive ramp terminals. Sufficient weaving length for a merge followed by a diverge is 2,000 feet for a system-to-service interchange and 1,600 feet for a service-to-service interchange. An example of the system-to-service interchange is between the Bryan Park interchange and the Boulevard interchange. An example of a service-to-service interchange is between the Boulevard interchange and the Belvidere interchange. **Table 23** shows the existing weave distances within the study area. The seven identified weave segments within the study area, shown in **Table 23**, do not meet the sufficient weaving length as recommended by AASHTO. The deficient weave length does not provide a safe distance for vehicles to cross two (or more) traffic streams, which could result in an unsafe condition with an increased crash potential.

Table 23: Weave Distances

Merge	Diverge	Distance (feet)	Deficient Distance (feet)
Northbound I-95/I-64			
Eastbound I-195 to Northbound I-95	Northbound I-95 to Broad Street	800	1,200
Broad Street to Northbound I-95	Northbound I-95 to Eastbound I-64	1,600	400
Westbound I-64 to Northbound I-95/I-64	Northbound I-95/I-64 to Chamberlayne Ave	1,050	950
Boulevard to Northbound I-95/I-64	Northbound I-95/I-64 to Westbound I-64/Southbound I-195	1,500	500
Southbound I-95/I-64			
Belvidere Street to Southbound I-95/I-64	Southbound I-95/I-64 to Eastbound I-64/3rd Street	800	800
Westbound I-64 to Southbound I-95	Southbound I-95 to Broad Street	1,000	1,000
Broad Street to Southbound I-95	Southbound I-95 to Franklin Street	800	800

2.6.2 Shoulder Width

Adequate shoulder width through the study area allows stopped vehicles to be accommodated outside of the travel-way provides an area for emergency use and structural support for the roadway. According to Appendix A of the VDOT *Road Design Manual*, the left and right paved shoulder width should be a minimum of 12 feet based on a 6-lane (3-lanes in each direction) urban interstate. Much of the corridor includes concrete barrier and a high number of heavy vehicles effectively reducing the amount of usable shoulder; therefore, an additional 1 to 2 feet, for a total of 14 feet of physical shoulder is desirable to account for the impacts of barriers and heavy vehicles throughout the corridor. Figures provided in **Appendix I** identify the existing shoulder width within the study area. As shown in the provided figures, the majority of the left and right shoulders are less than 12 feet wide creating a safety hazard for vehicles that stop on the interstate.

2.6.3 Bridge Vertical Clearance

According to the VDOT *Manual of the Structure and Bridge Division – Volume V – Part 2 Design Aids* (Chapter 6 Geometrics), the minimum bridge vertical clearance is 16.5 feet for urban interstates. Figures provided in **Appendix I** identify each bridge crossing over the mainline corridor through the study area and whether 16.5 feet or more of vertical clearance is provided. As shown in the figures in **Appendix I**, 19 of the 26 bridge crossings over the mainline are deficient, thereby creating potential hazards to vehicles that require 16.5 feet of vertical clearance.

Historical bridge strike information was provided by VDOT for a 10-year period from 2001 to 2011 and is summarized in. There were a total of 26 reported bridge strikes located within and adjacent to the study corridor in the 10-year period. Six strikes occurred at bridges outside of the study corridor, but they are documented due to their close proximity to the study corridor and their potential impact to corridor operations and safety. The highest number of bridge strikes was recorded at the Belvidere Street/Chamberlayne Avenue bridge over I-95 with 7 strikes, followed by the Scott Road bridge over I-95 with 5 strikes. VDOT noted the actual number of bridge strikes may be higher as many of the impacts do not stop the vehicle and the damage is not discovered until the next bridge inspection is conducted.

Table 24: Historical Bridge Strike Information from 2001 to 2011

Location	Number of Bridge Strikes	^Bridge Height < 16.5 feet
Belvidere Street/Chamberlayne Avenue over I-95/I-64	7	✓
*Scott Road over Southbound I-95/I-64	5	✓
4th/5th Street over Southbound I-95	4	✓
1st Street over Northbound I-95/I-64	3	✓
7th Street over Southbound I-95	3	✓
*Chamberlayne Avenue over I-95/I-64	1	✓
I-95 over Robin Hood Road	1	
Southbound I-95 over Broad Street Ramp to Northbound I-95	1	✓
Hermitage Road over Northbound I-95	1	
Total =	26	
Total (within study corridor) =	20	
Total (adjacent to study corridor) =	6	

^ Minimum bridge vertical clearance is 16.5 feet for urban interstates (Source: VDOT *Manual of the Structure and Bridge Division – Volume V – Part 2 Design Aids* (Chapter 6 Geometrics)
*Bridge not located in study area; however, included due to close proximity to the study corridor

3.0 Analysis of Existing Conditions

Detailed field observations were completed in the early stages of the project so the study team could obtain a thorough understanding of the 2011 existing conditions within the study corridor. Existing conditions were analyzed using a combination of the collected data and visual observations of the operational characteristics of the corridor. The existing condition analyses provided the study team with a general understanding of baseline traffic conditions. This analysis was broken into two categories: quantitative analyses using operational and safety analysis tools and qualitative assessments using visual assessments and GIS-based tools. The intent of the quantitative and qualitative analyses was to provide a starting point to be used for comparison purposes to the future conditions analysis and associated mitigation strategies.

3.1 Existing Conditions VISSIM Model

Due to congested peak hour conditions of the study area, VISSIM was selected as the microsimulation analysis tool because of its capability to model traffic conditions when volume-to-capacity ratios exceed 1.0. Coding of the base VISSIM model included all network geometry, speed data, and AM and PM peak hour traffic signal timing. The base model was then modified to accommodate data input and output requirements and to calibrate the network to observed traffic conditions. The AM and PM peak hours were identified as 7:30 to 8:30 and 4:30 to 5:30, respectively. However, in order to ensure the entire peak hour was modeled, the VISSIM analysis was conducted over a 2-hour period for both the AM and PM peak periods. This methodology ensured the analysis would capture free-flow conditions prior to and after each peak hour. Below are the 2 hour analysis periods for the AM and PM peak periods respectively:

- AM peak period
  - 7:15 – 8:15 AM
  - 8:15 – 9:15 AM
- PM peak period
  - 4:00 – 5:00 PM
  - 5:00 – 6:00 PM

Calibration targets were established and based on two measures of effectiveness (MOEs) – traffic volume throughput and vehicle speeds. Because the model is microscopic in nature, an unrealistically modeled bottleneck at one point in the model would affect operations downstream because too much or too little traffic would pass through that point. The model bottlenecks were adjusted until traffic volumes that passed through the simulation network reached the levels measured during field data collection. The traffic flows were calibrated based on the target thresholds regarding volumes and link speeds. The resulting 2-hour traffic volumes used in the traffic simulation models are provided in **Appendix J**.

The unique geometry, traffic patterns, and congested conditions in the study area posed some challenges for microsimulation modeling. The short merge/weave sections and numerous lane drops required several modifications to the default parameters in VISSIM supplemented by an add-on custom logic script developed by the study team to more accurately replicate the congested traffic conditions in the corridor. Saturation flow rates on some segments of the corridor approached the limits of the simulation software. A memorandum documenting specific measures taken to calibrate VISSIM is provided in **Appendix J**. The purpose of this memorandum was to document the model development and calibration process used to match the model results to the data collected in the field. The resulting existing conditions VISSIM models met or nearly met every calibration target for volumes and link speeds. Detailed outputs of these results can be found in Attachment A of the memorandum **Appendix J**.

The goal of calibrating the models to existing conditions is to replicate a "typical" weekday, but the likelihood of collecting data throughout an entire peak period in this area without an incident or other non-typical slowdown is very low. Because traffic incidents occurred during the days when data was collected for this project, it was not be feasible to meet every calibration target. However, the vast majority of the targets were met. The calibrated model is a valid representation of the study area traffic


conditions currently and was used to create future 2022 and 2035 VISSIM models to compare the relative impacts of proposed improvement alternatives.

3.2 2011 Levels of Service

To develop levels of service (LOS) within the study area, results were recorded from VISSIM for one peak hour during both the AM (7:30 – 8:30 AM) and PM (4:30 – 5:30 PM) peak hours. The LOS results were recorded for mainline sections, ramp merge/diverge points, weaving segments, and intersections.

3.2.1 Intersection Results

Intersection capacity analysis was performed for 25 intersections within the study area, 20 of which were signalized, using VISSIM. Intersection capacity is defined by the *Highway Capacity Manual* (*HCM), 2010 Edition* as the maximum number of vehicles that can pass through a particular intersection within fixed time duration. The operating conditions are described by LOS, which is an indicator of the degree of congestion and ranges from LOS A (free flowing) to LOS F (a congested, forced flow condition). Level of service D or worse was used to identify locations with the greatest need for improvement for which study efforts were focused. **Table 25** shows level of service and ranges of delay per vehicle for signalized and unsignalized intersections.

Table 25: HCM Intersection Level of Service Delay Thresholds

Level of Service (LOS)	Delay (seconds per vehicle)	
	Signalized Intersections	Unsignalized Intersections
A	≤ 10	0-10
B	> 10 – 20	> 10 – 15
C	> 20 – 35	> 15 – 25
D	> 35 – 55	> 25 – 35
E	> 55 – 80	> 35 – 50
F	> 80	> 50

Source: *Highway Capacity Manual* (*HCM), 2010 Edition*

Average vehicle delay results were collected from VISSIM using the Node Evaluation method. These delay results were then assigned a LOS letter grade based on the HCM thresholds in the above table. It should be noted that the HCM-defined levels of service thresholds were applied to the delay values reported by VISSIM for ease of review, but were not calculated by directly applying HCM methodology. VISSIM simulates individual vehicles traveling through the network and measures the delay (seconds/vehicle) of each vehicle passing through an intersection. While the results are very similar, this differs from the deterministic methodology described in the HCM which applies equations to estimate delay. The results for ten separate iterations of the VISSIM model were averaged to account for randomness in the model for the AM and PM peak hours.

The results of the existing conditions capacity analyses show that all of the signalized intersections analyzed within the study area operate with delays equivalent to an overall intersection LOS D or better during the AM and PM peak hours. The approach with the most potential for delay at all of the unsignalized intersections analyzed within the study area operate at LOS C or better under existing conditions during the AM and PM peak hours. Existing 2011 VISSIM capacity analysis results summarized for each movement and for the overall intersection are provided in **Appendix K** for both signalized and unsignalized intersections.

3.2.2 Mainline and Ramp/Weaving Segment Results

The VISSIM model developed for this study included all existing mainline, ramp, and weave sections within the study area. All mainline segments were classified as "Freeway (free lane section)" segments. Based on the *HCM 2010* requirements, the MOE used to define LOS for freeway segments is vehicle density (vehicles per lane per mile (vplpm)). This value was collected on a link-by-link

basis from VISSIM using the Link Evaluation tool. The results of the ten iterations of the model with unique random number seeds were averaged to calculate a single value for vehicle density. LOS was assigned for each link depending on its classification as either a basic freeway segment or weave segment. For the purpose of this analysis, a weave segment was defined as any link that contained an auxiliary acceleration/deceleration lane upstream or downstream of a ramp. Using the density value reported for the link from VISSIM, basic freeway and weave segments were assigned a LOS based on the thresholds as defined in the *HCM 2010* (Exhibit 10-7: LOS Criteria for Freeway Facilities and Exhibit 12-10: LOS for Weaving Segments). **Table 26** shows LOS and density ranges for freeway and weave segments.

Table 26: HCM Freeway and Weave Segment Level of Service Delay Thresholds

Level of Service (LOS)	Density (pc/mi/ln)	
	Freeway Facility	Freeway Weaving Segments
A	≤ 11	0-10
B	> 11 – 18	> 10 – 20
C	> 18 – 26	> 20 – 28
D	> 26 – 35	> 28 – 35
E	> 35 – 45	> 35 – 43
F	> 45	> 43

Source: *Highway Capacity Manual* (*HCM), 2010 Edition*

For each analysis scenario, the existing AM and PM peak hour LOS for each mainline section, ramp merge/diverge point, and weaving segment within the study corridor, as determined by the VISSIM analysis, is presented graphically in **Appendix K**. Across the top of each figure is a graphical representation of the number of lanes and classification (freeway or ramp/weave) of each link from VISSIM. A comparison of peak hour link traffic volumes that were input into the model and the resulting throughput is also included in the graphic as a verification of the model calibration. The average speed and density results extracted from VISSIM are reported for each link along with the corresponding LOS based on the density output. The results are presented for both the overall segment as well as individual lanes. LOS threshold criteria from *HCM 2010* for both basic freeway and ramp/weave segments are included in the legend. Locations exhibiting LOS D, LOS E, or LOS F have been highlighted in yellow, orange, and red, respectively.

Based on the vehicle densities reported by VISSIM, a majority of the segments along I-95, I-64, and I-195 operate at LOS D or better with the exception of a few congestion points in the network, which operate at LOS E and LOS F. Sections projected to operate at LOS E or LOS F during the peak hours are summarized in **Table 27**.

Overall, the following congested areas are encountered throughout the study area:

<u>AM Peak Hour</u>

- Northbound I-95/I-64 between the on-ramp from Belvidere Street to the on-ramp from N. Boulevard
- Southbound I-95/I-64 between the off-ramp to N. Boulevard to the off-ramp to Leigh Street
- Westbound I-64 between the on-ramp from southbound I-95 and the on-ramp from northbound I-195

<u>PM Peak Hour</u>

- Northbound I-95 between the off-ramp to Hermitage Road to the off-ramp to I-64
- Southbound I-95/I-64 between the off-ramp to Leigh Street and the off-ramp to eastbound d I-64 /3rd Street

Overall, the results from VISSIM show that all segments are operate at speeds above 35 MPH with the exception of the following segments:

<u>AM Peak Hour</u>

- Southbound I-95/I-64 at the on-ramp from Robin Hood Road
- Westbound I-64 at the on-ramp from 5th Street

PM Peak Hour

- Southbound I-95/I-64 at the on-ramp from Robin Hood Road
- Westbound I-64 at the on-ramp from 5th Street
- Northbound I-195 north of the off-ramp to southbound I-95/I-64

Table 27: Existing 2011 Mainline and Ramp/Weave Segment Analysis Results – AM and PM Peak Hour

Location	Segment Type	Segment^ Number	Density (pc/ln/mi)	Overall LOS	Speed (MPH)
AM Peak Hour					
Northbound I-95 – South of I-195	Freeway	302	35.3	E	48.3
Northbound I-95 – between I-64 and Chamberlayne Avenue	Ramp/Weave	337	36.1	E	42.3
Northbound I-95 – between Belvidere Street and Boulevard	Freeway Ramp/Weave Freeway	311 312 315	35.5 46.8 42.7	E F E	52.7 41.0 42.2
Southbound I-95 – North of Hermitage Road	Freeway	354	35.7	E	51.2
Southbound I-95 – between Boulevard and Leigh Street	Freeway Ramp/Weave Freeway	387 441 386	43.1 55.5 37.5	E F E	45.5 26.7 55.5
Southbound I-95 – between Broad Street and Franklin Street	Ramp/Weave	289	36.0	E	36.8
Westbound I-64 – West of 5th Street on-ramp	Freeway	584	46.3	F	47.0
Westbound I-64 – between southbound I-95 and Route 33	Freeway Freeway	322 324	36.3 36.4	E E	47.5 53.9
PM Peak Hour					
Northbound I-95 – between Hermitage Road and I-64	Freeway Freeway Ramp/Weave	312 315 317	36.6 37.9 36.7	E E E	53.0 50.5 47.5
Southbound I-95 – On-ramp from Robin Hood Road	Ramp/Weave	441	43.2	E	31.4
Southbound I-95 – between Leigh Street and eastbound I-64/3rd Street	Freeway Ramp/Weave	394 397	38.4 36.1	E E	48.6 44.9
Southbound I-95 – between Broad Street and Franklin Street	Ramp/Weave	289	41.4	E	37.1
Westbound I-64 – West of on-ramp from 5th Street	Freeway	584	39.8	E	46.5
Westbound I-64 – Off-ramp to Southbound I-195	Freeway	418	35.7	E	54.5

^ Segment numbers are provided for reference and correspond to the VISSIM graphical output sheets provided in **Appendix K**

4.0 Modeling and Forecasting

4.1 Analysis Scenarios

A future conditions analysis was required to evaluate how a proposed improvement (e.g., roadway widening, interchange modification, construction of an acceleration/deceleration lane, etc.) would operate under future traffic conditions. Two future analysis years of 2022 and 2035 were identified by VDOT to be consistent with region long-range vision, goals, and objectives. Future traffic volume projections were developed to analyze weekday AM and PM peak periods under future (2022 and 2035) traffic conditions for the following scenarios:

- **2022 No Build** – evaluation of 2022 future traffic demand on the existing roadway network
- **2035 No-Build** – evaluation of 2035 future traffic demand on the existing roadway network
- **2022 Future Build –** evaluation of 2022 future traffic demand on the existing roadway network in addition to the proposed improvements

- **2035 Future Build –** evaluation of 2035 future traffic demand on the existing roadway network in addition to the proposed improvements

4.2 Growth Rate Methodology

For the purpose of developing 2022 and 2035 traffic volumes, VDOT staff reviewed available travel demand models, Statewide Planning System (SPS) data for the interstates and select cross streets within the study area, and information from the ongoing Interstate 64 Peninsula Study Environmental Impact Statement (EIS). Travel demand modeling results were obtained from the existing Richmond/Tri-Cities Travel Demand Model based on the 2031 MPO Constrained Long Range Plan (CLRP). SPS is an Oracle database tool that VDOT uses to develop planning level traffic forecasts based on historical trend line analysis for roadways throughout Virginia. SPS results for this effort included available VDOT Traffic Monitoring System (TMS) traffic counts through 2010.

For the six principal inflow/outflow locations in the VISSIM model, an extensive review of historical traffic count data was performed to verify if results were being skewed by major highway changes in the region (e.g., opening of major new roadways such as Route 288, construction on I-64 near Staples Mill Rd., etc.). These six locations were I-64 West, I-64 East, I-95 North, I-95 South, I-195 North, and I-195 South.

After reviewing existing travel demand modeling results for reasonableness, VDOT staff concluded these results were not adequate for use in developing growth rates for this study. As a result, the draft proposed growth rates were developing based on SPS data and growth rates used in the I-64 Peninsula Study. For this project, 2010 was considered the base forecast year and 2035 was the horizon forecast year. The 2022 forecast was an interpolation between the 2010 base counts and 2035 forecast using the proposed growth rate. The resulting SPS growth rates were determined to be aggressive when compared to the growth rates used in the I-64 Peninsula Study. Therefore, the chosen growth rates summarized in **Table 25** are more in line with the I-64 Peninsula Study traffic growth rates, generally between the SPS results and the travel demand model projections. These traffic growth rates were applied to the 2011 balanced peak hour volumes identified in **Section 2.4.4** to project future 2022 and 2035 traffic volumes. Ramp and intersection growth rate determination methodology is documented in **Tables 29** and **30**.

Table 28: Traffic Growth Rates

Location	Growth Rates
Mainline	
I-64 West of Overlap	1.0%
I-64 East of Overlap	0.9%
I-95 North of Overlap	0.5%
I-95 South of Overlap	0.5%
I-195 South of Overlap	1.0%
Intersections	
Staples Mill	1.0
Others	0.5

Table 29: Growth Rate Development – Mainline Segments

Roadway	From	To	Source: Statewide Planning System (SPS)					Source: Richmond/Tri-Cities Model				Proposed Growth Rate for I-95/I-64 Overlap Study	Resulting AADTs Based on Proposed Growth Rates		Overlap Between I-95/64 Study and I-64 EIS?
			Annual Average Daily Traffic (AADT)			Growth Rates: 2010 to 2035		Annual Average Daily Traffic (AADT)		Growth Rate: 2011 to 2035					
			1998	2010	2035	Linear	Exponential	2011	2035	Linear	Exponential		2022	2035	
I-64 (West)	Broad Street	Staples Mill Road	98,202	107,433	160,000	1.96%	1.61%	2011	2035	0.28%	0.27%	1.00%	121,100	137,800	No
I-64 (West)	Staples Mill Road	Bryan Park	128,885	134,436	171,000	1.09%	0.97%	90,164	96,238	0.28%	0.27%	1.00%	151,500	172,500	No
I-195 (North)	Broad Street	Laburnum Ave	74,123	84,557	120,000	1.68%	1.41%	101,571	108,475	0.42%	0.40%	1.00%	95,300	108,500	No
I-95 (North)	Brook Road	Hermitage Road	92,418	108,576	163,000	2.01%	1.64%	75,897	83,499	0.30%	0.29%	0.50%	115,300	123,000	No
I-95 (North)	Hermitage Road	Bryan Park	92,418	114,656	163,000	1.69%	1.42%	88,246	94,583	0.04%	0.04%	0.50%	121,800	129,900	No
I-95/64 Overlap	Bryan Park	Boulevard	130,876	150,333	201,300	1.36%	1.17%	86,837	87,585	-0.12%	-0.12%	0.50%	159,700	170,300	No
I-95/64 Overlap	Boulevard	Belvidere Street	130,515	142,483	183,600	1.15%	1.02%	98,555	95,750	0.12%	0.12%	0.50%	151,300	161,500	No
I-95/64 Overlap	Belvidere Street	I-64 (East)	--	141,609	--	--	--	96,555	99,277	0.50%	0.48%	0.50%	150,400	160,500	**Yes**
I-95 (South)	I-64 (East)	Broad Street	111,000	124,440	161,000	1.18%	1.04%	103,157	115,631	0.61%	0.57%	0.50%	132,200	141,000	**Yes**
I-95 (South)	Broad Street	I-195 (South)	108,602	124,059	166,000	1.35%	1.17%	84,114	96,463	0.35%	0.33%	0.50%	131,800	140,600	No
I-95 (South)	I-195 (South)	James River	53,042	100,531	134,000	1.33%	1.16%	102,180	110,682	0.22%	0.21%	0.50%	106,800	113,900	No
I-195 (South)	Canal Street	I-95 (South)	21,935	28,881	34,000	0.71%	0.63%	107,400	112,981	0.60%	0.57%	0.70%	31,700	34,700	No
I-64 (East)	I-95/64 Overlap	US 360	95,289	95,338	137,000	1.75%	1.46%	36,621	41,929	1.49%	1.28%	0.90%	106,200	119,300	**Yes**

I-64 EIS Peninsula Study – Growth Rate Results

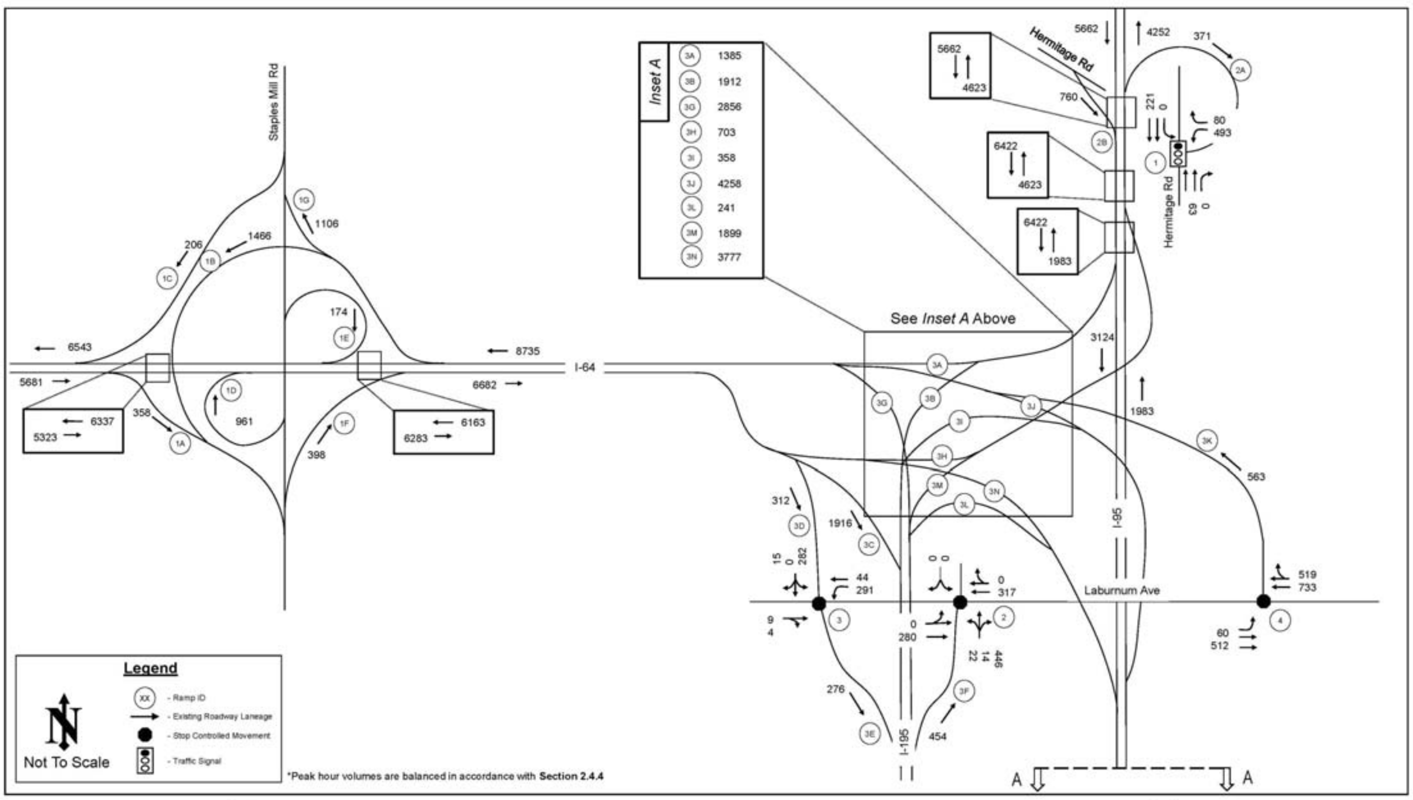
Roadway	From	To	Historic AADT			Growth Rates: 1976 to 2010		Source: Tidewater Super Regional Model				Proposed Growth Rate From I-64 EIS Study	Resulting AADTs Based on Proposed Growth rates		Overlap Between I-95/64 Study and I-64 EIS?
								Annual Average Daily Traffic (AADT)		Growth Rate: 2000 to 2034					
			1976	2000	2010	Linear	Exponential	2000	2034	Linear	Exponential		2022	2035	
I-64 (East): (I-64 EIS)	I-95/64 Overlap	US 360	58,730	97,000	95,000	1.82%	1.42%	70,720	96,212	1.06%	0.91%	EB = 1.0% WB = 0.8%	105,800	118,900	**Yes**
I-95/64 (I-64 EIS)	Belvidere Street	I-64 (East)	--	--	141,609	NA	NA	101,563	114,809	0.38%	0.36%	0.40%	148,600	156,500	**Yes**
I-95 (I-64 EIS)	I-64 (East)	Broad Street	--	--	124,440	NA	NA	83,853	95,588	0.41%	0.39%	0.40%	130,600	137,600	**Yes**

Green = Key inflows to the study corridor

Table 30: Proposed Growth Rates - Intersections

Roadway	From	To	Source: Statewide Planning System (SPS)					Proposed Growth Rate for I-95/I-64 Overlap Study	Resulting AADTs Based on Proposed Growth Rates	
			Annual Average Daily Traffic (AADT)			Growth Rates: 2010 to 2035				
			1998	2010	2035	Linear	Exp.		2022	2035
Staples Mill Rd	Dickens Rd	I-64 (West)	31,244	17,844	29,247	2.56%	2.00%	1.00%	20,200	22,900
Staples Mill Rd	I-64 (West)	Bethlehem Rd	31,250	17,844	28,697	2.43%	1.92%	1.00%	20,200	22,900
Boulevard	Robin Hood Rd	I-95	20,846	22,844	25,700	0.50%	0.47%	0.50%	24,300	25,900
Boulevard	I-95	Westwood Ave	15,393	12,544	14,112	0.50%	0.47%	0.50%	13,400	14,300
Hermitage Rd	Robin Hood Rd	I-95 Off ramps	9,396	7,196	8,096	0.50%	0.47%	0.50%	7,700	8,200
Hermitage Rd	I-95 Off ramps	Brookland Park	4,079	2,194	2,468	0.50%	0.47%	0.50%	2,400	2,500
Belvidere St	Broad	Chamberlayne	29,637	29,790	33,514	0.50%	0.47%	0.50%	31,700	33,800
Chamberlayne Ave	Leigh St	Brook Rd	7,481	6,735	7,577	0.50%	0.47%	0.50%	7,200	7,700
Broad St	12th St	14th St	26,013	17,822	20,050	0.50%	0.47%	0.50%	19,000	20,200
Broad ST	RR Bridges	17th St	26,676	21,719	24,434	0.50%	0.47%	0.50%	23,100	24,700
Broad ST	17th St	18th St	26,676	21,719	24,434	0.50%	0.47%	0.50%	23,100	24,700
17th St (SB)	Balding St	Venable St	4,910	4,983	5,605	0.50%	0.47%	0.50%	5,300	5,700
17th St (SB)	Venable St	Broad St	NA	12,690	15,741	0.96%	0.87%	0.90%	14,200	15,900
17th St	Broad St	Grace St	3,405	3,146	3,539	0.50%	0.47%	0.50%	3,400	3,600
18th St (NB)	Broad St	Balding St	4,266	4,037	4,542	0.50%	0.47%	0.50%	4,300	4,600
14th St	Franklin St	Broad St	7,257	13,275	14,208	0.28%	0.27%	0.30%	13,800	14,400

Figure 29: Future 2022 No-Build Traffic Volumes – AM Peak Hour (1 of 3)



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NO-BUILD CONDITIONS 2022 – AM PEAK HOUR
I-95/I-64 Overlap Study
City of Richmond and Henrico County, Virginia

FIGURE 29

Figure 30: Future 2022 No-Build Traffic Volumes – AM Peak Hour (2 of 3)

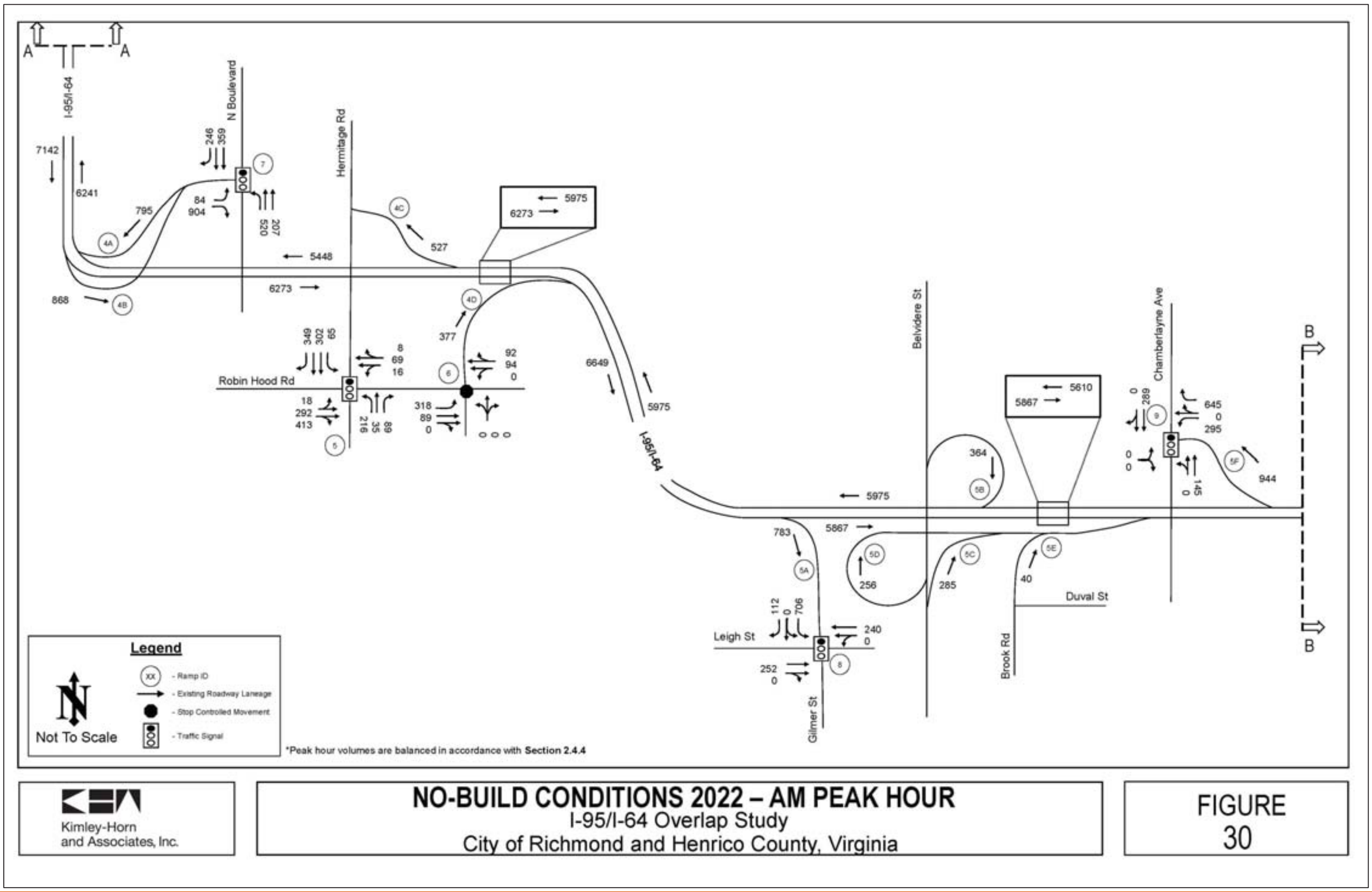


Figure 31: Future 2022 No-Build Traffic Volumes – AM Peak Hour (3 of 3)

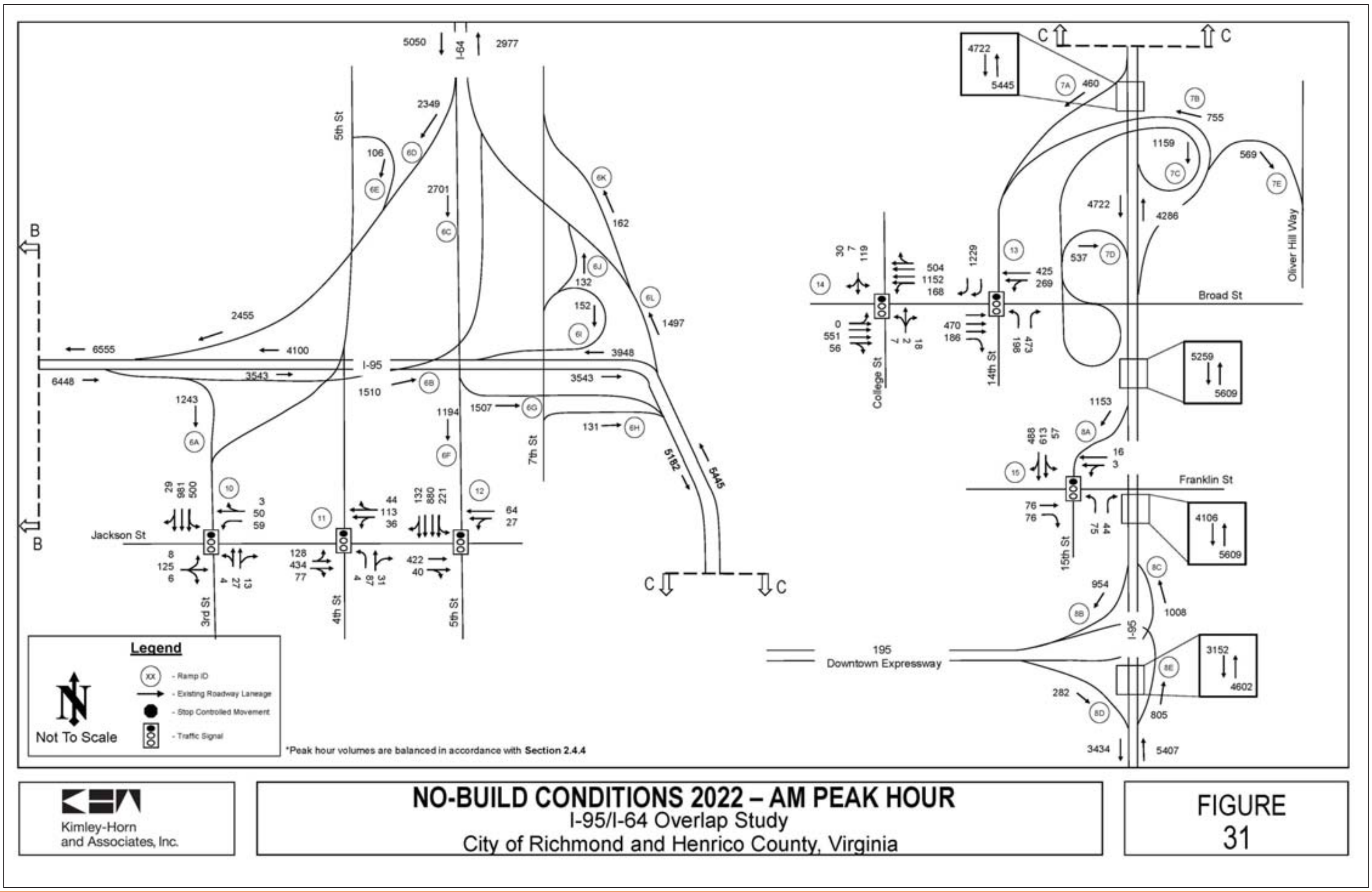


Figure 32: Future 2022 No-Build Traffic Volumes – PM Peak Hour (1 of 3)

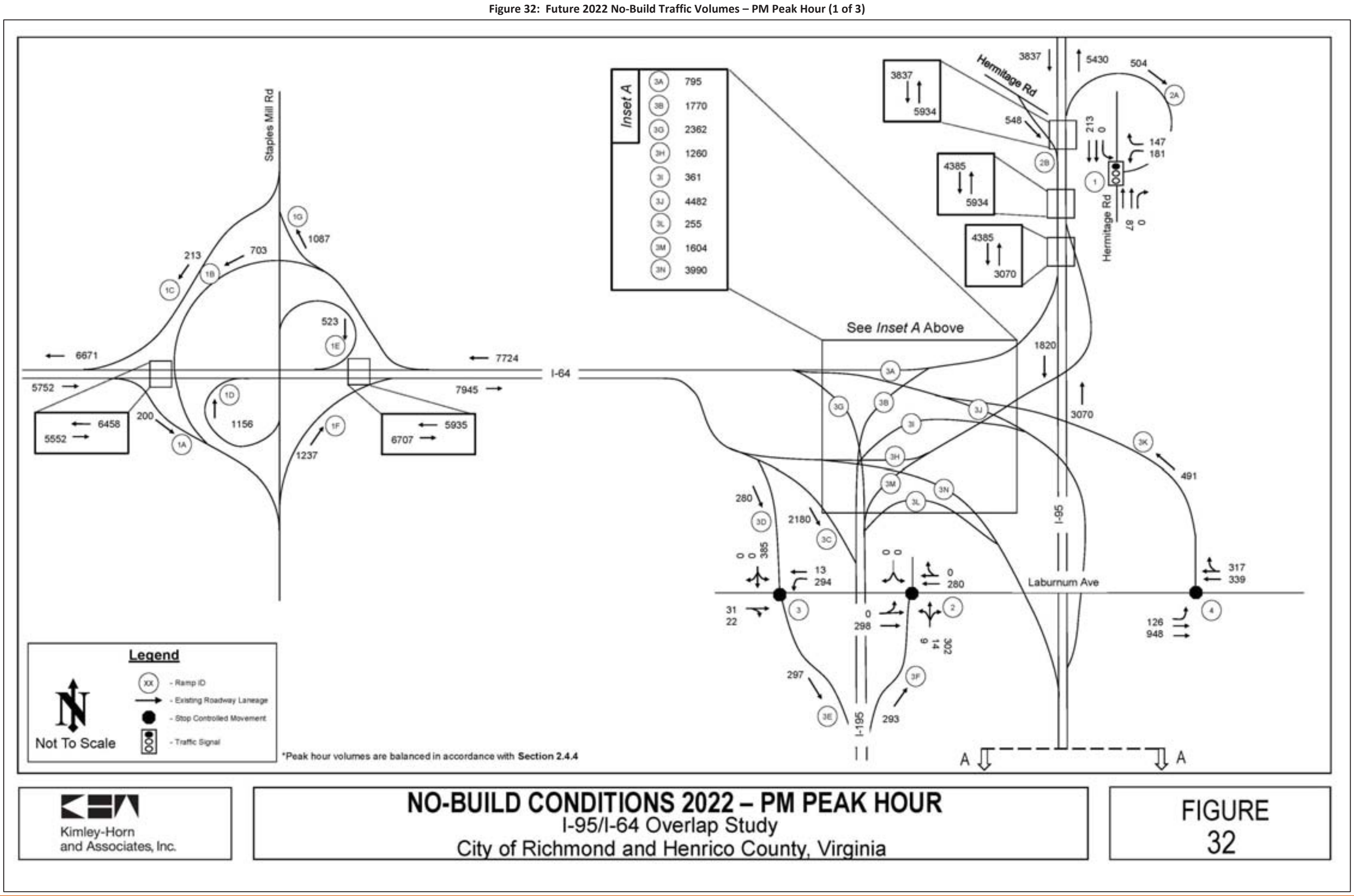
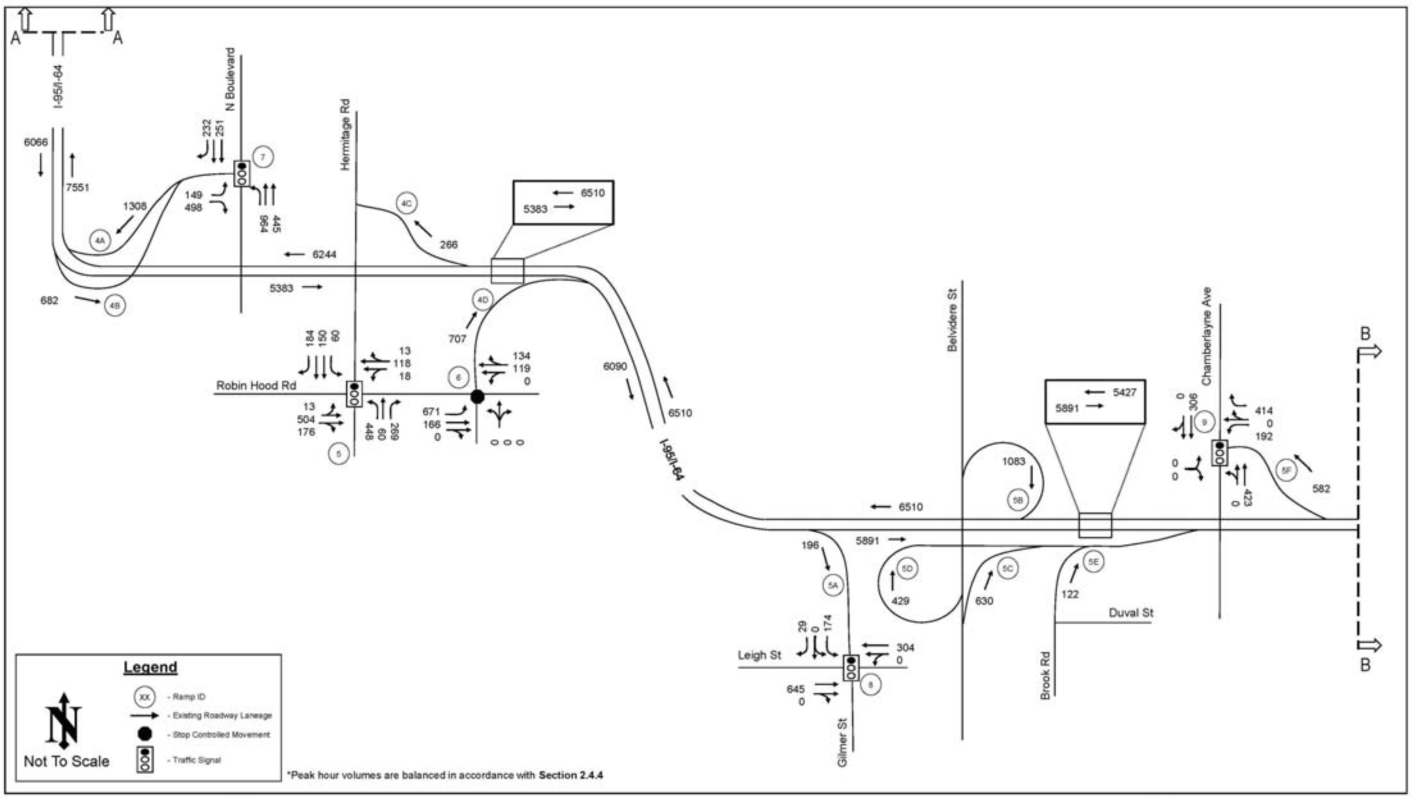


Figure 33: Future 2022 No-Build Traffic Volumes – PM Peak Hour (2 of 3)



NO-BUILD CONDITIONS 2022 – PM PEAK HOUR

I-95/I-64 Overlap Study

City of Richmond and Henrico County, Virginia

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FIGURE 33

Figure 34: Future 2022 No-Build Traffic Volumes – PM Peak Hour (3 of 3)

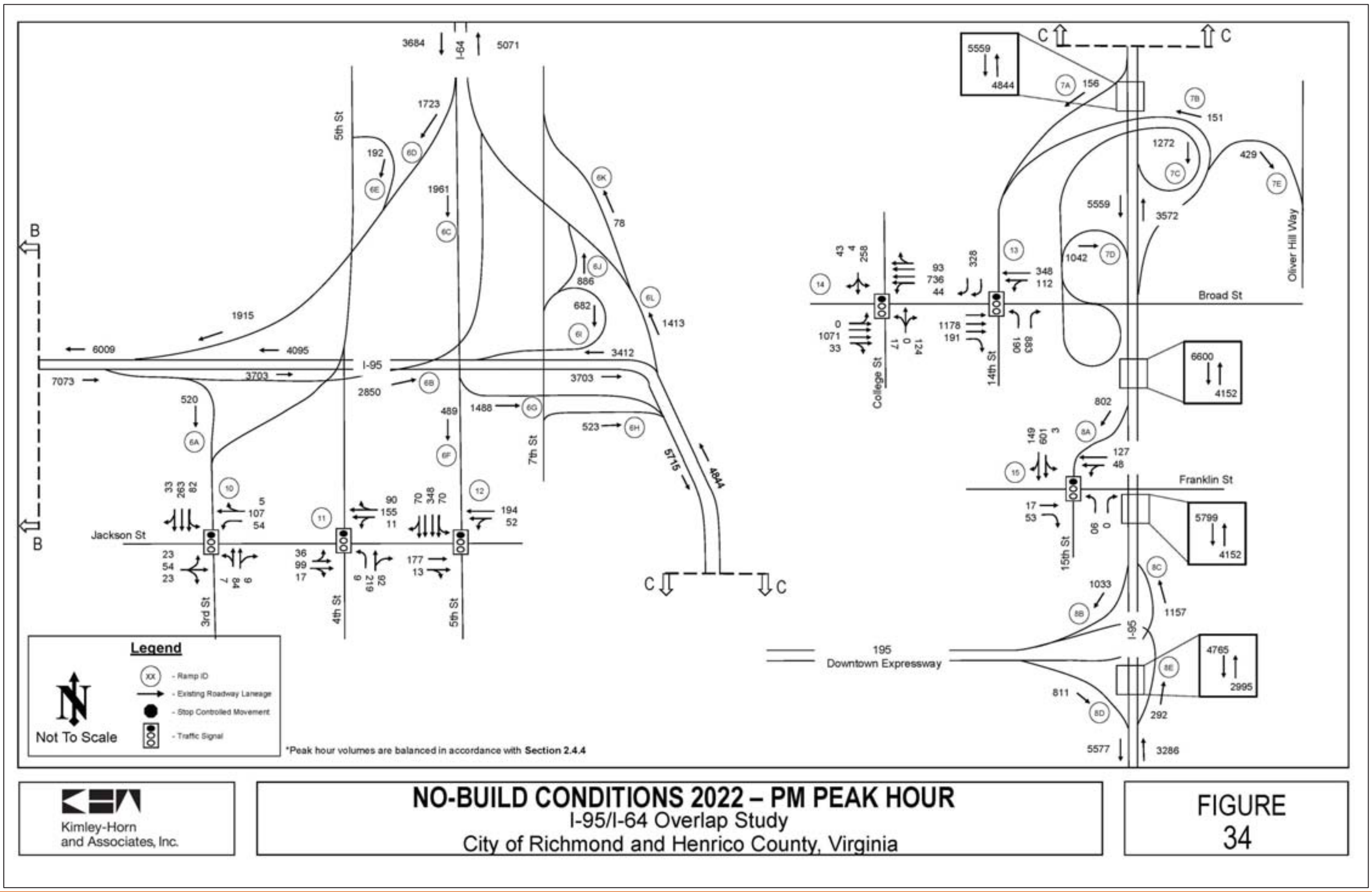


Figure 35: Future 2035 No-Build Traffic Volumes – AM Peak Hour (1 of 3)

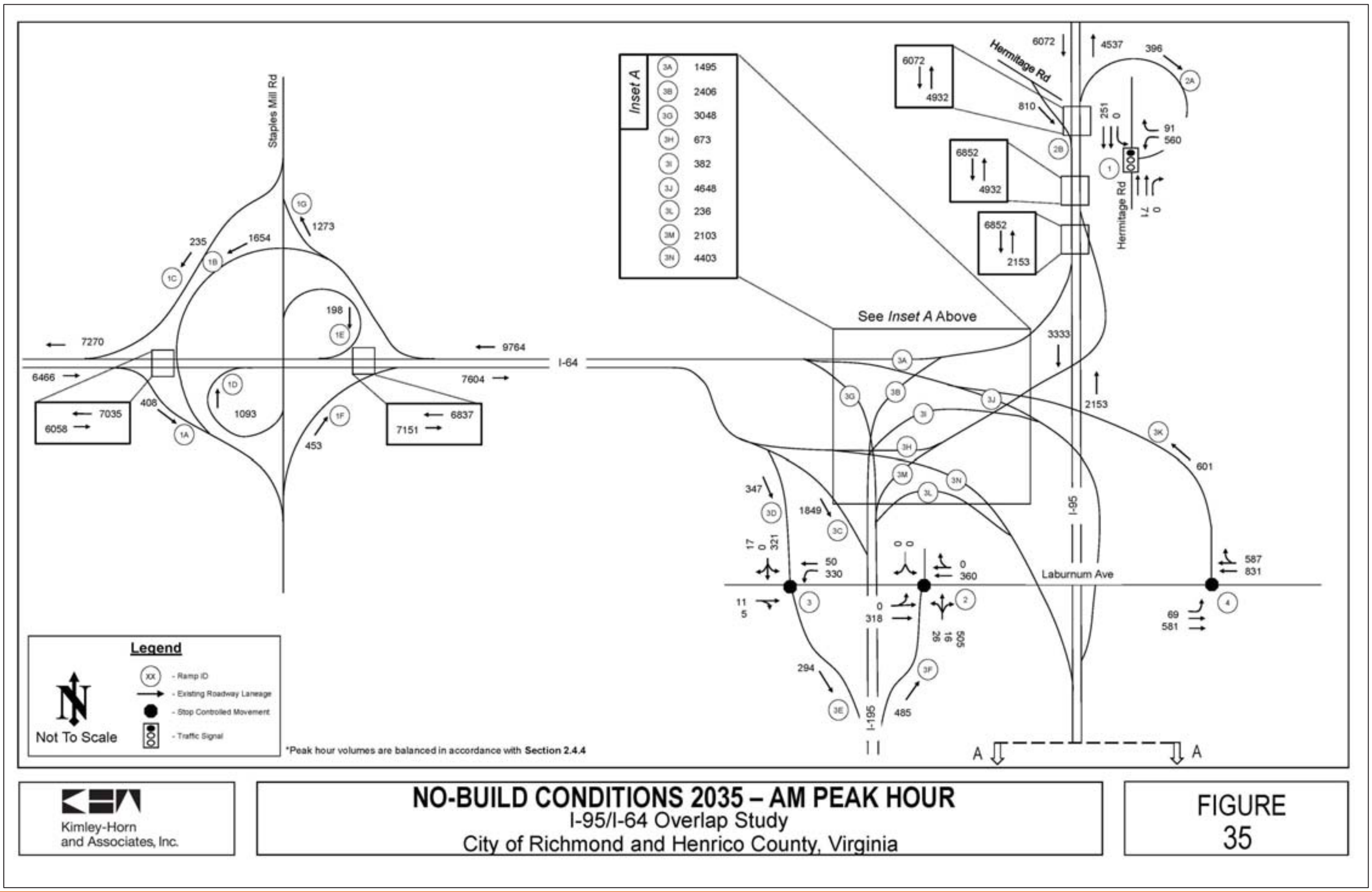
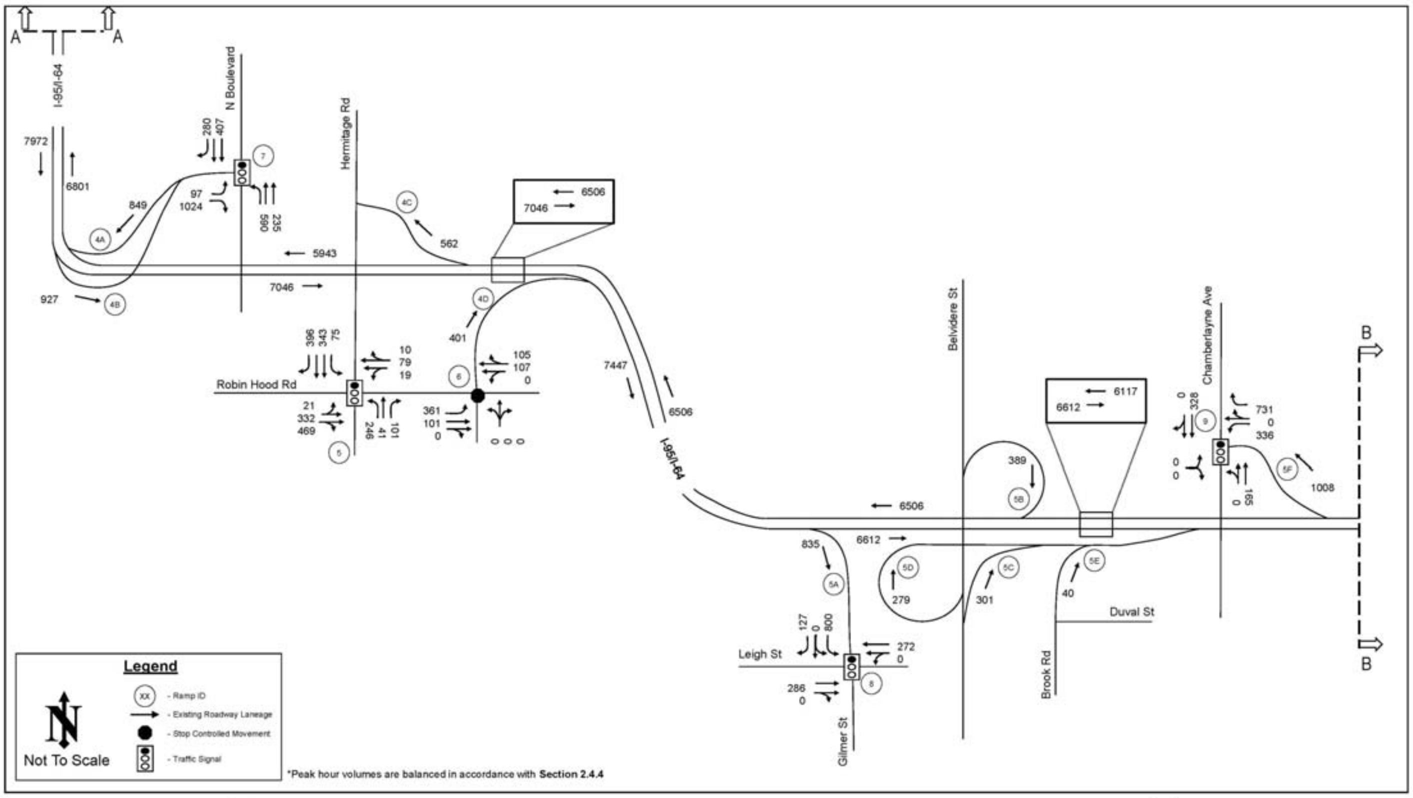


Figure 36: Future 2035 No-Build Traffic Volumes – AM Peak Hour (2 of 3)



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NO-BUILD CONDITIONS 2035 – AM PEAK HOUR

I-95/I-64 Overlap Study

City of Richmond and Henrico County, Virginia

FIGURE 36

Figure 37: Future 2035 No-Build Traffic Volumes – AM Peak Hour (3 of 3)

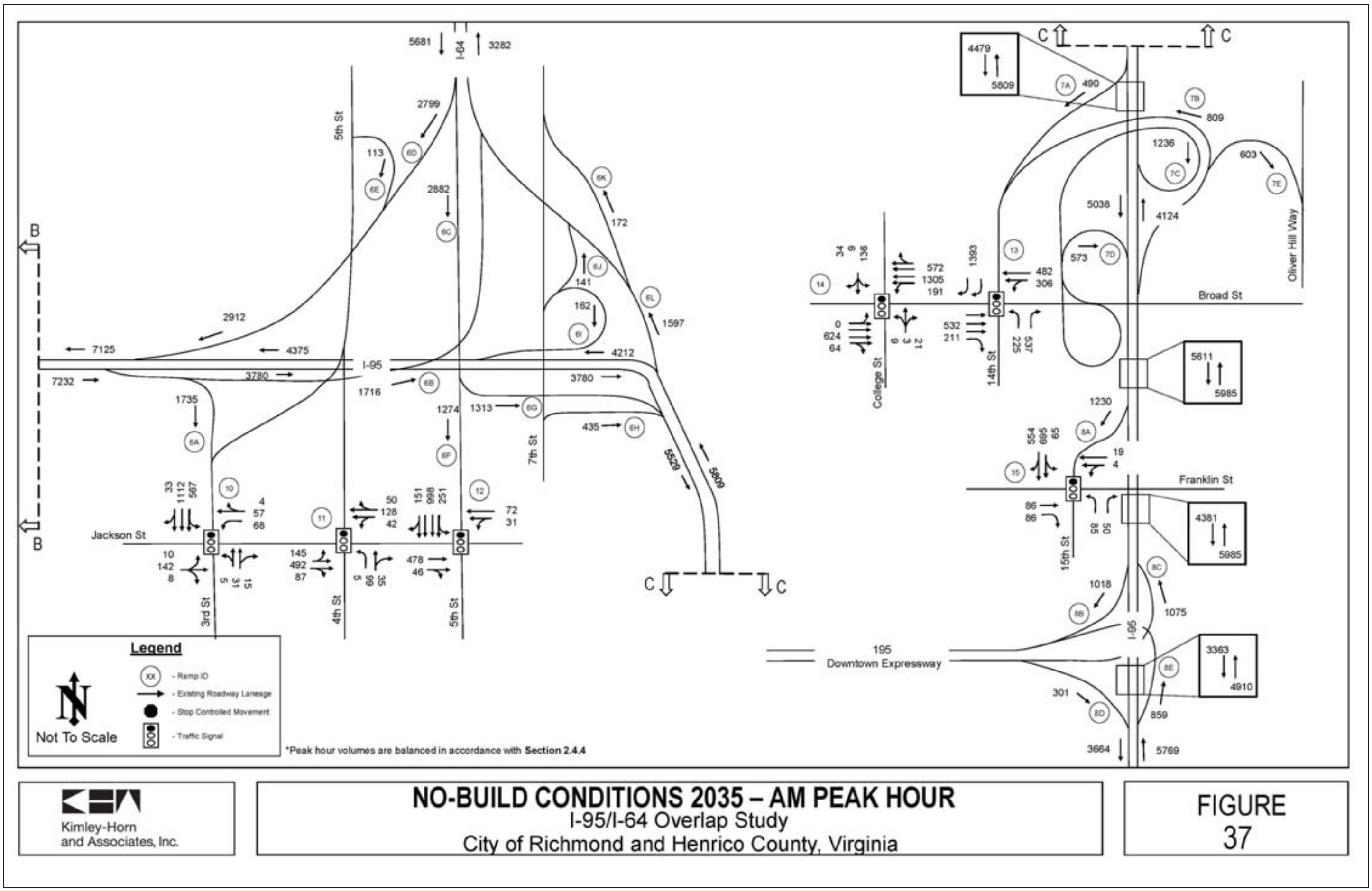


Figure 38: Future 2035 No-Build Traffic Volumes – PM Peak Hour (1 of 3)

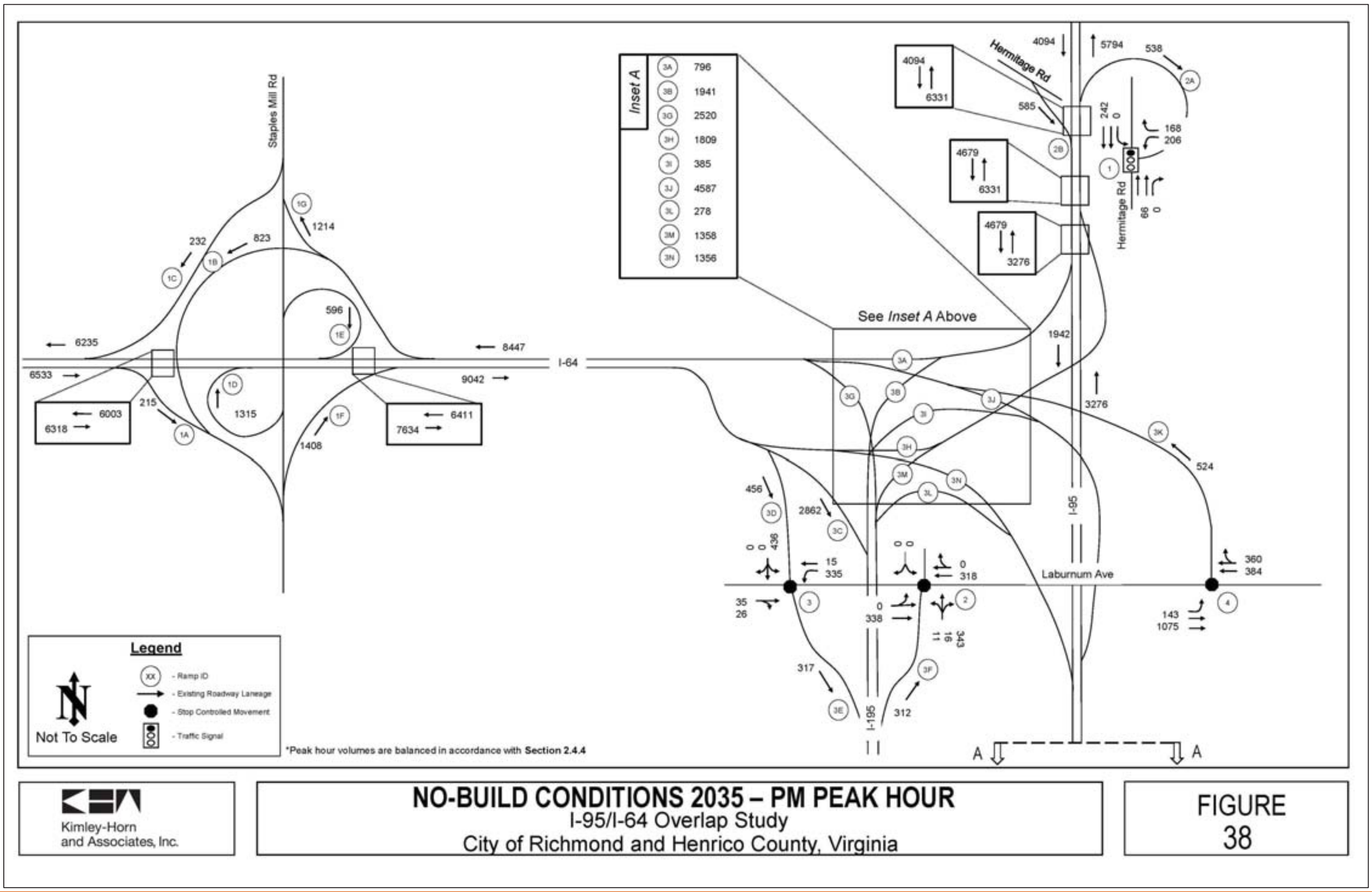
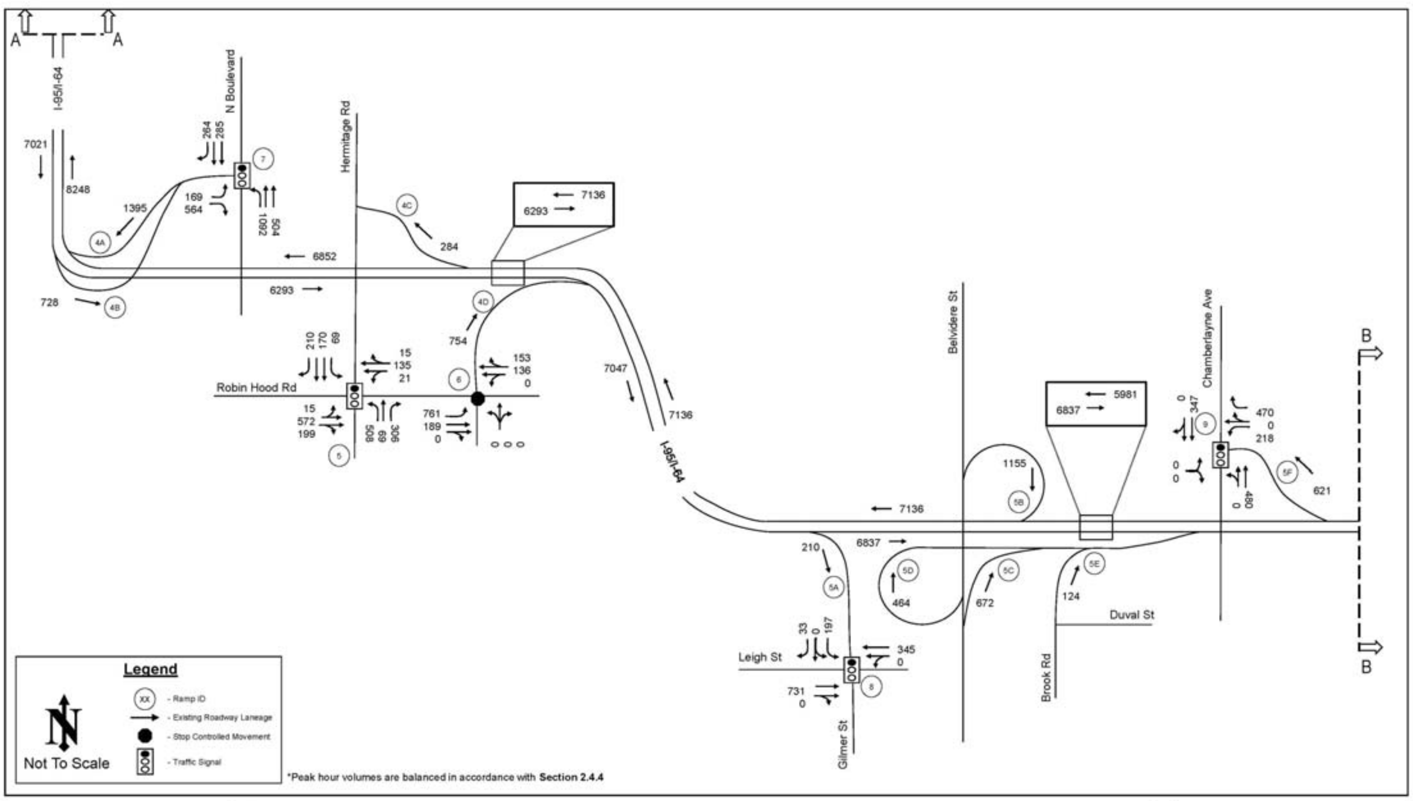


Figure 39: Future 2035 No-Build Traffic Volumes – PM Peak Hour (2 of 3)



Kimley-Horn and Associates, Inc.

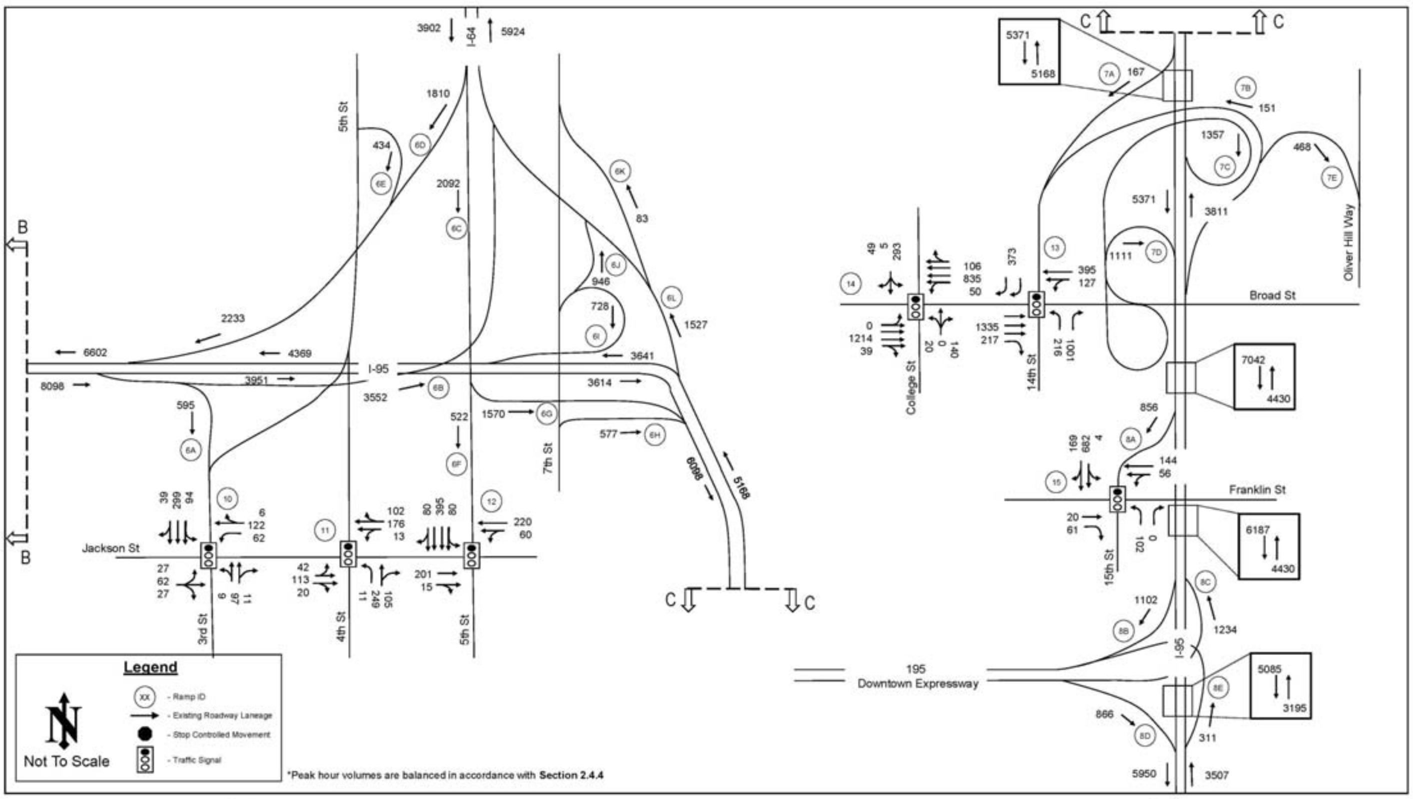
NO-BUILD CONDITIONS 2035 – PM PEAK HOUR

I-95/I-64 Overlap Study

City of Richmond and Henrico County, Virginia

FIGURE 39

Figure 40: Future 2035 No-Build Traffic Volumes – PM Peak Hour (3 of 3)



NO-BUILD CONDITIONS 2035 – PM PEAK HOUR
I-95/I-64 Overlap Study
City of Richmond and Henrico County, Virginia

Kimley-Horn and Associates, Inc.

FIGURE 40

5.0 No-Build Analysis – 2022 and 2035

5.1 Intersection Results

The results of the 2022 and 2035 No-Build intersection capacity analyses show that a majority of the signalized intersections analyzed within the study area operate with delays equivalent to a LOS D or better during the AM and PM peak hours. The three intersections that exceed LOS D under 2035 No-Build conditions are identified in **Table 31**. The critical approaches at all of the unsignalized intersections analyzed within the study area operate at LOS C or better under 2022 No-Build and 2035 No-Build conditions during the AM and PM peak hours. The 2022 and 2035 No-Build VISSIM capacity analysis results summarized for each movement and for the overall intersection are provided in **Appendices L** and **M** for both signalized and unsignalized study area intersections for 2022 and 2035, respectively.

Table 31: Summary of 2035 No-Build Intersection Capacity Analysis Results – Signalized Intersections

Signalized Intersection	AM Peak Hour		PM Peak Hour	
	Delay (sec/veh)	Overall LOS	Delay (sec/veh)	Overall LOS
Broad Street / 14th Street	9.1	A	64.8	E
Broad Street / 17th Street	31.3	C	139.2	F
Belvidere Street / Leigh Street	29.9	C	65.5	E

5.2 Mainline and Ramp/Weaving Segment Results

The 2022 and 2035 No-Build AM peak hour LOS for each mainline section, ramp merge/diverge point, and weaving segment within the study corridor, as determined by the VISSIM analysis, is presented graphically in **Appendices L** and **M**.

Table 32 summarizes the 2022 No-Build study segments with LOS E or LOS F during the peak hours. When compared to Existing 2011 AM peak hour conditions, the same congested areas along with new areas are identified within the study area. The highlighted cells in the table indicate degradation from existing conditions compared to 2022 No-Build conditions, which illustrates the expansion of congestion throughout the study area.

Under 2035 No-Build AM peak hour conditions, a majority of the network is projected to operate at LOS E and LOS F. The congested areas as identified under Existing 2011 and 2022 No-Build conditions, show a further degradation of LOS. In addition, congestion is projected to increase with operating speeds projected as low as 18 MPH and 8 MPH during the AM and PM peak hours, respectively. These capacity deficiencies indicate that operations throughout the corridor over the next 20 years will continue to deteriorate. Overall, the primary congested areas are centered around the Bryan Park interchange and the I-95/I-64 East interchanges areas. Congested sections in the study area include:

<u>AM Peak Hour</u>

- Northbound I-95 from I-195 to eastbound I-64
- Northbound I-95/I-64 between the on-ramp from Belvidere Street to the off-ramp to westbound I-64/southbound I-195
- Southbound I-95/I-64 from north of Hermitage Road to the on-ramp from Robin Hood Road
- Eastbound I-64 from west of Staples Mill Road to east of Bryan Park interchange
- Westbound I-64 from the off-ramp to southbound I-95/5th Street to west of 5th Street
- Westbound I-64 from east of southbound I-195 to the on-ramp from northbound I-195
- Northbound I-195 from south of Laburnum Avenue to the off-ramp to southbound I-95/I-64

<u>PM Peak Hour</u>

- Northbound I-95 between the off-ramp to I-195 and the off-ramp to eastbound I-64

- Northbound I-95 between the on-ramp from westbound I-64 to the off-ramp to westbound I-64/southbound I-95
- Southbound I-95 between the on-ramp from eastbound I-64/northbound I-195 to the off-ramp to eastbound I-64/3rd Street
- Eastbound I-64 from west of Staples Mill Rd to east of the Bryan Park interchange
- Westbound I-64 east of I-95/I-64

A majority of the study segments are projected to operate at LOS E or LOS F during the AM and PM peak hour under 2035 No-Build conditions. The summary of mainline, ramp, and weave sections is in **Appendix M** for reference.

Table 32: 2022 No-Build Mainline and Ramp/Weave Segment Analysis Results – AM and PM Peak Hours

Location	Segment Type	Segment Number	Density (pc/ln/mi)	Overall LOS	Speed (MPH)
AM Peak Hour					
Northbound I-95 – south of I-195	Freeway	302	36.8	E	47.8
Northbound I-95 – between I-195 and Broad Street	Ramp/Weave	304	43.6	E	32.0
Northbound I-95 – between westbound I-64 and Chamberlayne Avenue	Ramp/Weave	337	43.2	E	37.0
Northbound I-95 – between northbound Belvidere and I-64	Freeway	311	41.8	E	46.3
	Freeway	312	56.6	F	33.6
	Freeway	315	51.7	F	35.0
	Ramp/Weave	317	37.7	E	41.3
Southbound I-95 – between north of Hermitage Road and I-64/I-195	Freeway	354	40.9	E	44.2
	Ramp/Weave	356	42.4	E	36.1
Southbound I-95 – between I-64/I-195 to Belvidere Street	Ramp/Weave	384	35.1	E	51.6
	Freeway	387	44.9	E	47.8
	Ramp/Weave	441	43.1	E	38.0
	Freeway	386	44.0	E	51.2
	Ramp/Weave	390	35.8	E	48.4
	Freeway	394	42.5	E	48.5
Southbound I-95 – between Broad Street and Franklin Street	Ramp/Weave	289	38.4	E	35.4
Eastbound I-64 – between Staples Mill Road and I-195	Freeway	375	39.2	E	44.4
Eastbound I-64 – between northbound I-95 and northbound I-195	Freeway	462	45.5	F	43.0
	Freeway	480	35.1	E	36.2
Westbound I-64 – between east of southbound I-95/5th Street and 5th Street	Freeway	332	49.6	F	34.4
	Freeway	526	46.6	F	26.7
Westbound I-64 – west of on-ramp from 5th Street	Freeway	584	55.2	F	41.4
Westbound I-64 – between southbound I-195 and Staples Mill Rd	Freeway	418	47.2	F	40.7
	Freeway	425	48.9	F	35.7
	Freeway	320	52.7	F	25.4
	Ramp/Weave	321	59.9	F	21.8
	Freeway	322	43.6	E	39.2
	Freeway	324	38.1	E	52.0
Northbound I-195 – south of Laburnum Avenue	Freeway	385	40.2	E	45.7
Northbound I-195 – between Laburnum Avenue and westbound I-64	Freeway	383	45.7	F	38.2
PM Peak Hour					
Northbound I-95 – between Broad Street and eastbound I-64	Freeway	403	37.6	E	41.2
	Ramp/Weave	306	69.8	F	20.5
Northbound I-95 – between Chamberlayne Avenue and I-64	Freeway	339	36.2	E	47.9
	Ramp/Weave	341	41.3	E	35.7
	Freeway	311	41.8	E	49.4
	Freeway	312	52.4	F	39.9
	Freeway	315	54.2	F	37.7
	Ramp/Weave	317	41.3	E	44.2
Northbound I-95 – between I-64 and Westbrook Avenue	Freeway	350	35.4	E	51.7
Southbound I-95 – between Boulevard and eastbound I-64/3rd Street	Freeway	387	48.6	F	37.3
	Ramp/Weave	441	49.8	F	29.0
	Freeway	386	55.4	F	35.6
	Ramp/Weave	390	49.5	F	35.6
	Freeway	394	57.3	F	35.6
	Ramp/Weave	397	44.0	E	39.2
Southbound I-95 – between Broad Street and Franklin Street	Ramp/Weave	289	42.6	E	36.7
Eastbound I-64 – west of Staples Mill Road to northbound I-195 Northbound	Freeway	376	38.6	E	46.1
	Freeway	372	42.7	E	38.6
	Ramp/Weave	374	46.6	F	32.8
	Freeway	375	40.5	E	46.5
	Freeway	377	36.7	E	46.2
	Freeway	462	40.6	E	47.9
Westbound I-64 – west of on-ramp from 5th Street	Freeway	584	47.7	F	43.8
Westbound I-64 – off-ramp to southbound I-195	Freeway	418	37.2	E	54.9
Northbound I-195 – between Laburnum Avenue and southbound I-95	Freeway	383	37.3	E	40.6
	Freeway	473	36.2	E	28.0
Northbound I-195 – north of southbound I-95	Freeway	575	40.1	E	18.3

6.0 Alternative Concepts

Initial List of Improvements

Potential corridorwide improvements were developed to address various operational, geometric, maintenance, and safety deficiencies identified from the 2011 existing, 2022 no-build, and 2035 no-build conditions analyses. An initial list of improvements was developed and screened through a series of meetings and workshops.

Based on input discussed at these workshops, the initial list of improvements was categorized into short-term improvements, Six-Year Improvement Program projects, and long-term concepts using the general guidelines below:

- **Short-Term Improvements** – These improvements are either maintenance projects or minor upgrades that may require preliminary engineering with no impact to right-of-way. Short-term improvements typically have the following characteristics: they can be completed in less than three years, they may be completed with VDOT state forces, and they may be programmed in the SYIP. Because short-term improvements by nature do not address major operational issues within the corridor, they were not advanced through the screening process. These improvements are documented in **Section 6.1** for VDOT to implement as resources allow.

- **Six-Year Improvement Program (SYIP) Projects** – One of the primary goals of this study was to develop projects to be considered for inclusion in the upcoming VDOT SYIP (FY14-19). These projects will require detailed preliminary design, and may require right-of-way acquisition depending on the location of the project. SYIP projects were grouped into two categories:
    1. Geometric Roadway Improvements – Projects in this category could include items such as ramp extensions, interchange modifications, intersection modifications, shoulder widening, constructing additional lanes to ramps, etc.
    2. Non-Geometric Improvements – Projects in this category could include items such as pavement markings, retroreflective pavement markers, sight distance clearing, roadway lighting, median barrier upgrades, shoulder rumble strips, intelligent transportation systems (ITS), signing improvements, etc.

- **Long-Term Concepts** – These concepts are the most expensive solutions, requiring extensive design, right-of-way acquisition, utility relocation, and construction. Possible projects include new ramp construction, ramp closures, roadway realignments, bridge improvements, new interchange construction, and/or mainline lane additions. Long-term concepts would require further study and refinement and fell outside the timeframe of the upcoming SYIP.

First Screening Process

Conceptual figures documenting both SYIP and long-term geometric roadway improvements were developed to a level of detail necessary to determine the feasibility of the proposed improvement(s). The first screening of the initial of list of proposed improvement projects was qualitative in nature and was based on the following factors:

- Safety
- Traffic operations
- Order of magnitude cost
- Environmental
- Impact to adjacent roadways and intersections

VISSIM results were used to assess the operational benefits of geometric improvements that progressed beyond the first screening process. Because only one VISSIM model was used to analyze the proposed alternatives, only a single preferred alternative in each direction could be analyzed at each of the interchanges. The geometric improvements at each interchange were screened to one preferred alternative in each direction that was then considered during the second screening process.

Second Screening Process

The second screening process was quantitative and based on the following criteria:

- Traffic Operations – Each geometric improvement was modeled in VISSIM to further screen improvements that provided an operational benefit. **Section 7.0** summarizes the projected reduction in travel times for each SYIP and long-term improvement.
- Cost – Planning-level cost estimates and a benefit-cost (B/C) analysis (described in **Sections 8.0** and **9.1**) were developed for the SYIP projects only and were used to further justify their proposed inclusion in the SYIP.

Subsequent sections provide descriptions of the final list of proposed short-term improvements, SYIP projects, and long-term concepts identified as result of this screening process.

6.1 Short-Term Improvements

These minor improvements are primarily related to maintenance and/or minor upgrades that may require preliminary engineering. They can be completed in less than three years with minimal expense and no right-of-way impacts, and may be identified in the SYIP. These improvements were not modeled, but are documented in **Table 33** for VDOT to prioritize and address as the Department deems necessary.

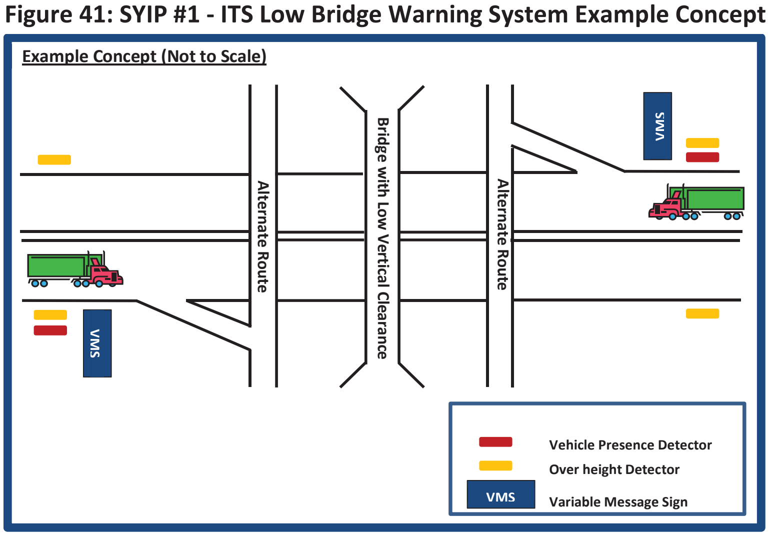
6.2 Six-Year Improvement Program (SYIP) Projects

The 11 SYIP projects developed during this study process are described in more detail in this section of the report. As study work group consensus was reached on these projects, they were recommended for inclusion in the FY14-19 SYIP. Although one of the goals of this study was to identify SYIP Interstate projects specifically, additional funding sources such as Highway Safety Improvement Program (HSIP), Congestion Mitigation and Air Quality Program (CMAQ), and Regional Surface Transportation Program (RSTP) should also be considered to implement the following projects.

SYIP #1 - ITS Low Bridge Warning System – North of the Bryan Park Interchange and South of the James River

Many existing bridges throughout the I-95/I-64 study area do not meet the minimum geometric standard of 16.5 feet for vertical clearance on an urban interstate as shown on the maps in **Appendix I**. Therefore, an ITS Low Bridge Warning System project was proposed.

Figure 41: SYIP #1 - ITS Low Bridge Warning System Example Concept



The ITS Low Bridge Warning System project includes the installation of a low bridge warning system on the northbound and southbound I-95 and eastbound and westbound I-64 approaches to the I-95/I-64 overlap section. Each system will consist of a pole-mounted vehicle presence detector and an overheight vehicle sensor installed upstream of the low bridge structure. When an overheight vehicle is detected, a signal is transmitted to a variable message sign (VMS), which then displays a message advising the driver to take an alternate route. Potential locations on I-95 may include prior to I-195 in the northbound direction and prior to I-295 in the southbound direction, as both could serve as alternate routes around the I-95/I-64 overlap area that contains a number of low bridge structures. Potential locations on I-64 may include prior to the Bryan Park interchange in the eastbound direction and I-295 in the westbound direction. An example concept of an ITS Low Bridge Warning System is shown in **Figure 41**.

Table 33: Short-Term Improvements

Improvement Number	Location Description	Improvement Description
Corridor Wide		
1	Corridor wide	Install object markers
2	Corridor wide	Pavement upgrades
3	Corridor wide	Pavement marking upgrades from 4" to 6"
4	Corridor wide	ITS - Use existing changeable message signs on NB and SB I-95, prior to the overlap section, to provide travel time information so that motorists can make an informed decision to consider an alternate route (similar to the I-66 travel time pilot project)
Interchange		
5	I-95/I-64/I-195 (Bryan Park Interchange) (Exit 79)	Install Lane Ends (W4-2) warning sign and supplemental pavement marking arrows indicating the SB I-95 to WB I-64 lane is ending and to merge left
6	I-95 at Route 161 (N. Boulevard) (Exit 78)	Restripe SB I-95 approach to the Boulevard off ramp
Intersection		
7	NB I-195 Off-Ramp at Laburnum Avenue	Construct sidewalk along north side of Laburnum
8		Install stop bar on northbound off-ramp approach
9		Separate left and right-turn movement, install yield sign for right-turn movement
10		Upgrade ADA ramps at the intersection
11	EB I-64 Off-Ramp at Laburnum Avenue	Upgrade ADA ramps at the intersection
12		Trim trees on the NE quadrant to improve sight distance
13		Install dual indicated stop signs
14		Relocate stop bar forward on eastbound off-ramp approach to improve sight distance
15	WB I-64 On-Ramp at Laburnum Avenue	Upgrade sidewalks in the vicinity of the intersection
16		Upgrade ADA ramps at the intersection
17		Install shoulder striping along north side of Laburnum
18		Extend eastbound left-turn lane
19		Widen eastbound left-turn lane, 9' wide (take width from median, 11' wide median)
20		Adjust "Through Traffic Keep Right Signs"
21	Hermitage Road at Robin Hood Road	Upgrade faded pavement markings (stop bars) at the intersection
22	SB I-95/EB I-64 On-Ramp at Robin Hood Road	Upgrade faded pavement markings (arrows) at the EB left-turn lane from Hermitage Road
23	I-95/I-64 Ramps at N. Boulevard	Improve turning radius from NB Boulevard to NB I-95/WB I-64 on-ramp by cutting back curb on NW quadrant of intersection; existing curb shows evidence of damage
24	W. Leigh Street at SB I-96/EB I-64 Off-Ramp/Gilmer Street	Offset SB right-turn stop bar to improve sight distance for SB right-turn movement onto Leigh Street
25	E. Jackson Street at N. 3rd Street	Improve signing to I-95/I-64
26		Upgrade to ADA ramps at intersection
27	E. Jackson Street at N. 4th Street	Improve signing to I-95/I-64
28	E. Jackson Street at N. 5th Street	Upgrading intersection striping on the eastbound approach
29		Improve signing to I-95/I-64
30	E. Broad Street at N. 14th Street	Improvements to pedestrian accommodations documented in the "Pedestrian Road Safety Audit on Broad Street between College Street and 17th Street Study" referenced in the I-95/I-64 Overlap Study
31		Improve drainage on south leg/SE quadrant of the intersection to prevent ponding
32	E. Broad Street at College Street	Improvements to pedestrian accommodations documented in the "Pedestrian Road Safety Audit on Broad Street between College Street and 17th Street Study" referenced in the I-95/I-64 Overlap Study
33	E. Franklin Street at N. 15th Street	Upgrade pavement markings at the intersection
34		Upgrade ADA ramp in the northeast corner
35		Repair pedestrian push button
36		Repair damaged sidewalk in the southeast corner

The benefits of installing a low bridge warning system include, but are not limited to, improvements to safety and operations throughout the corridor, such as minimizing the risk of high vehicles striking low bridges and avoiding traffic delays due to a bridge strike.

SYIP #2 - Corridorwide Signing Upgrades

Thirty-five guide signs (ground mounted and overhead) are located within the study corridor with varying degrees of condition and compliance to existing retroreflectivity standards. This proposed project aims to improve safety in the corridor by reducing nighttime crashes.

The project recommends a corridorwide condition assessment of the 35 existing guide signs (ground mounted and overhead) and an upgrade of non-standard guide signs to meet current retroreflective sheeting and lighting standards. The location of the 35 guide signs in the study area is shown in **Appendix R**. This project would not include overhead guide signs mounted on bridges, since they will be replaced as part of a statewide directive to remove all signing from bridge structures or the five guide signs with option lane issues that are being proposed for replacement as a separate project (SYIP #8). The *Manual on Uniform Traffic Control Devices* (MUTCD) does not define a compliance date for guide sign retroreflectivity. However, the MUTCD does state guide signs should be added to an assessment or management method designed to maintain retroreflectivity at or above the established minimum level as resources allow.

SYIP #3 - Northbound I-95/I-64 at Hermitage Road – Install Deceleration Lane to Hermitage Road

Currently, no existing deceleration lane exists from northbound I-95/I-64 to Hermitage Road (Exit 78), even though this ramp is located in a high-crash location of the corridor.

The northbound I-95/I-64 Hermitage Road improvement project includes the construction of a northbound I-95/I-64 deceleration lane to Hermitage Road and the construction of an emergency pull-off area in conjunction with the construction of the deceleration lane. The construction of a deceleration lane will allow vehicles to exit the interstate with minimal effect on the through traffic stream and reduce the risk of rear-end crashes at this location. The proposed deceleration lane is shown in **Figure 42**.

Photograph 1: Northbound I-95/I-64 Approach to Hermitage Road Off-Ramp

SYIP #4 - Southbound I-95/I-64 at Belvidere Street Interchange Improvements

This project includes the following improvements (as shown in **Figure 43**):

- Eliminate the slip ramp from Leigh Street, which removes one of the existing merge points. Realign the on-ramps from northbound and southbound Belvidere Street to merge together at a lower elevation and west of the existing merge location.
- Create an emergency pull-off area in conjunction with the realignment of the on-ramps.

This improvement removes a conflict point on the ramps and allows vehicles from Belvidere Street and Leigh Street to reach higher speeds on the on-ramps. Higher speeds will allow for improved merging onto southbound I-95/I-64.

Photograph 2: Looking East from Collector-Distributor Road from Belvidere Street Loop On-Ramp

Photograph 3: Looking East from Slip Ramp from Leigh Street

Photograph 4: Looking East from Merge Point of Upstream On-Ramps from Belvidere Street

Figure 42: SYIP #3 - Northbound I-95/I-64 at Hermitage Road (Exit 78) – Install Deceleration Lane

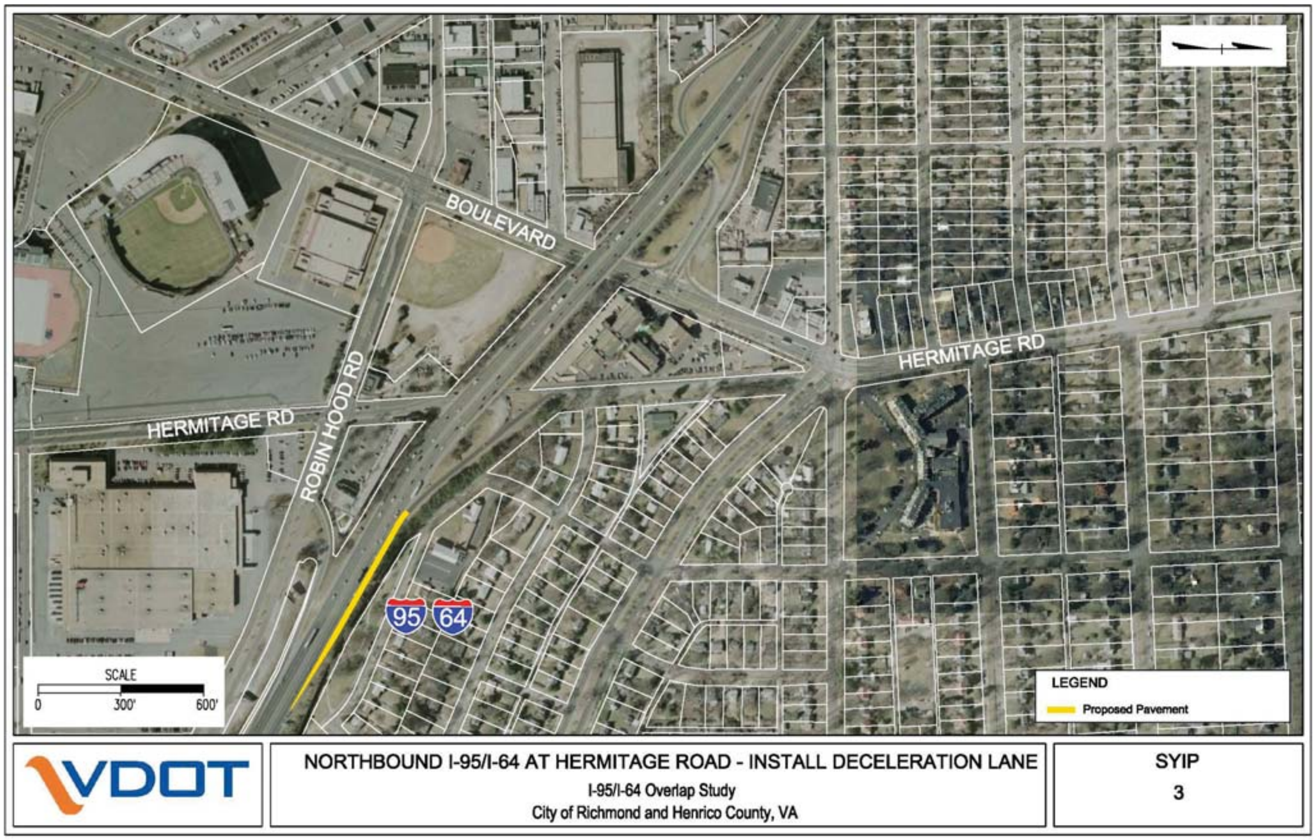
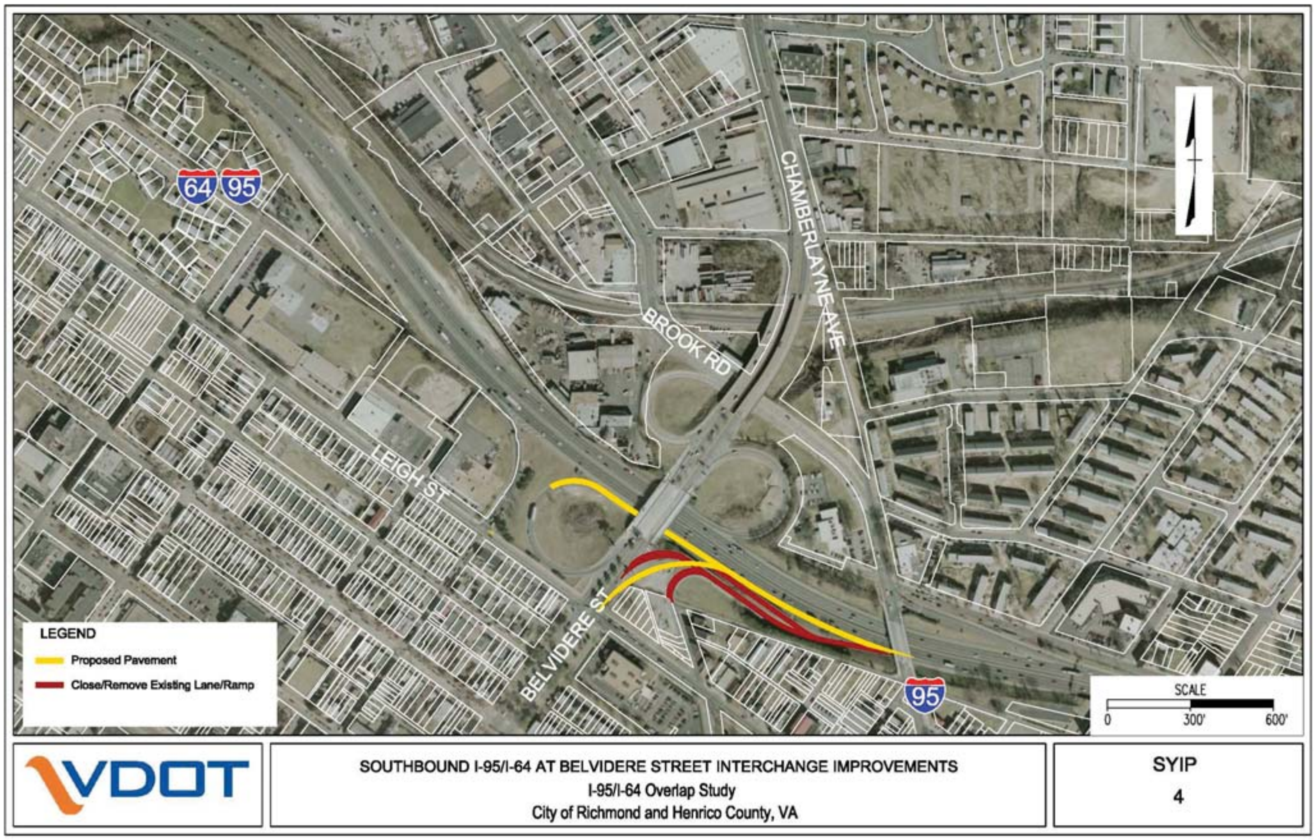


Figure 43: SYIP #4 - Belvidere Street Interchange Improvements



SYIP #5 - Extend Northbound Belvidere Street Acceleration Lane

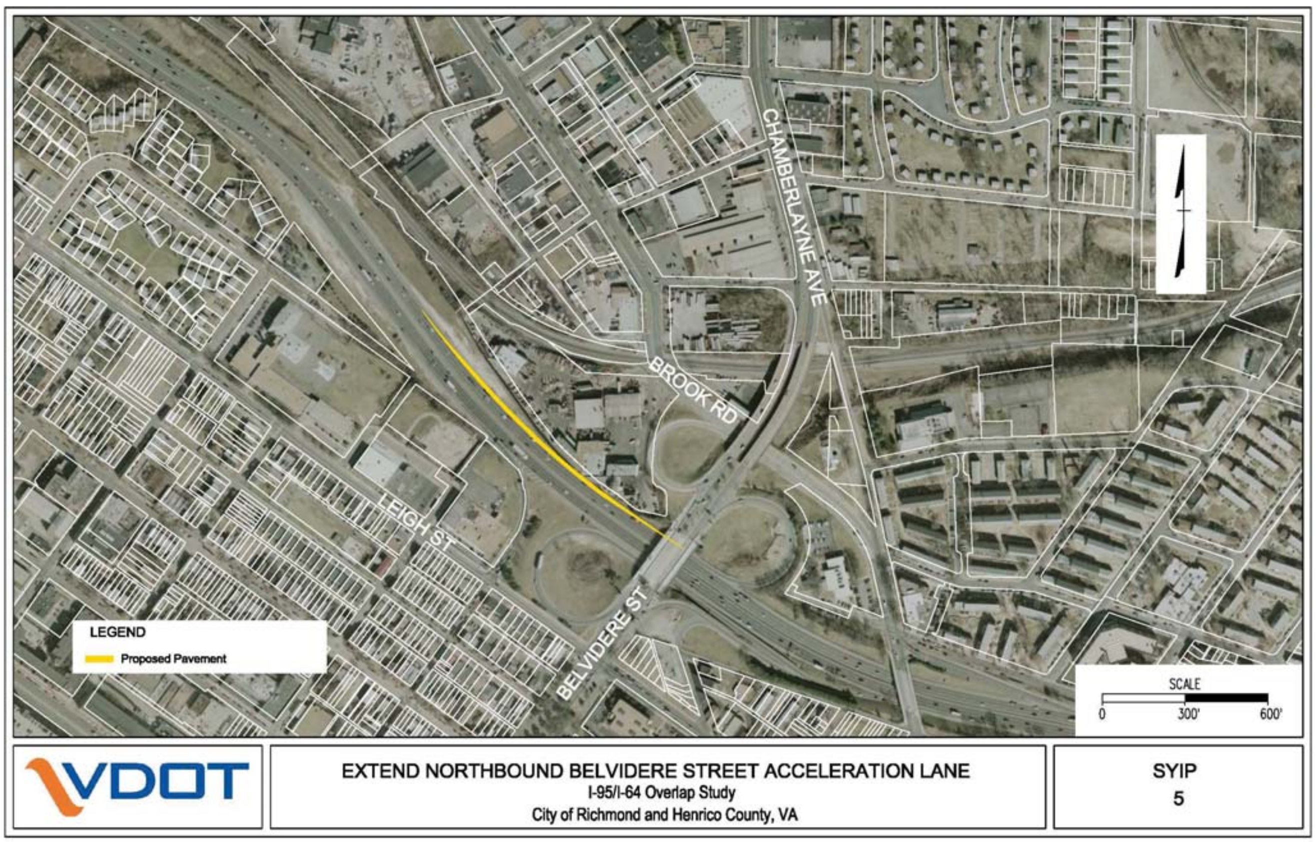
The existing northbound acceleration lane from the Belvidere Street on-ramp is approximately 400 feet long and does not meet the current design standards of 1,020 feet for a ramp speed of 25 MPH.

The existing acceleration lane is approximately 620 feet deficient, conveys approximately 350 vehicles per hour in the AM peak, and carries approximately 1,030 vehicles per hour in the PM peak.

This project is projected to improve traffic operations on mainline I-95/I-64 and on the northbound on-ramp from Belvidere Street by extending the northbound acceleration lane to the recommended length of 1,020 feet. Extending the acceleration lane will provide safer access to northbound I-95/I-64 from the Belvidere Street on-ramp by providing a longer acceleration length. Vehicles merging onto northbound I-95/I-64 will also have an additional 620 feet of full-width lane to accelerate up to the mainline design speed of 60 MPH. The construction of the acceleration lane extension would impact right-of-way and would require land acquisition from the property on the northwest quadrant of the Belvidere Street interchange. Ample right-of-way is available adjacent to this property where the I-95/I-64 toll booths once existed and can be used to maximize the length of the acceleration lane. The proposed acceleration lane is shown in **Figure 44**.

Photograph 5: Northbound I-95/I-64 Approaching the Belvidere Street On-Ramp

Figure 44: SYIP #5 - Northbound I-95/I-64 at Belvidere Street – Extend Acceleration Lane



SYIP #6 - I-195 Interchange Improvements at Laburnum Avenue

Queuing currently occurs during the peak hours on the I-195 off-ramps to Laburnum Avenue. This project proposes to reduce queuing on the northbound and southbound I-195 off-ramps during the peak hours as well as improve the overall safety of the intersections at the end of the ramps on Laburnum Avenue.

Photograph 6: Southbound I-195 Off-Ramp to Laburnum Avenue, Proposed Roundabout Location

The I-195 Interchange Improvements at Laburnum Avenue project includes the following improvements as shown in **Figure 45**

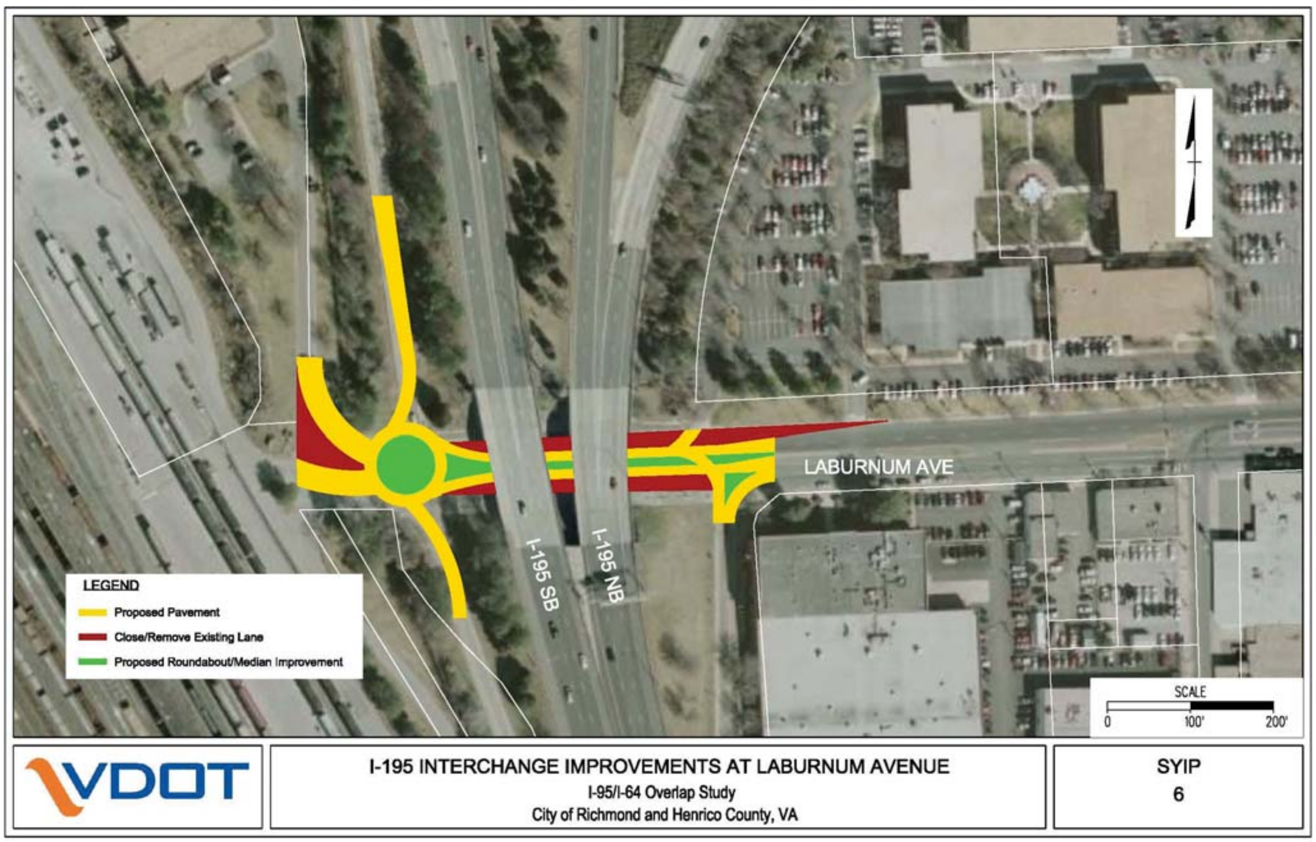
- Southbound I-195 Off-Ramp at Laburnum Avenue – This improvement recommends constructing a single lane roundabout to accommodate the heavy conflicting southbound left turns (AM = 309, PM = 398) and westbound left turns (AM = 281, PM = 323). This improvement will require a lane drop of the rightmost westbound through lane on Laburnum Avenue prior to the roundabout, which can be accomplished by installing signing and pavement markings.

- Northbound I-195 Off-Ramp at Laburnum Avenue – This improvement suggests dropping the rightmost eastbound through lane just west of the off-ramp, using signing and pavement markings. The northbound right-turn movement would be converted to free flow by using the rightmost eastbound through lane. This improvement can be accomplished using existing pavement since there are minimal northbound left turns (AM = 24, PM = 4) and northbound throughs (AM = 19, PM = 0) requiring minimal storage. A short left turn lane, approximately 50 to 100 feet in length, and an exclusive right-turn lane can be striped out using the existing pavement. This option will require the restriction of eastbound left turns and southbound left turns to and from the office park on the north side of Laburnum Avenue, which could be reinforced with some minor median improvements to restrict certain movements.

Photograph 7: Looking East from I-195 Off-Ramp Sight Distance Impacted by Vegetation

Photograph 8: Northbound I-195 Northbound Off-Ramp to Laburnum Proposed Free-Flow Right-Turn Lane

Figure 45: SYIP #6 - Interchange Improvements at Laburnum Avenue and I-195



SYIP #7 - Franklin Street Off-Ramp Area Improvements

The existing southbound I-95 off-ramp to Franklin Street often experiences queuing during the peak hours, particularly during the AM peak hour (**Photograph 9**). The existing ramp length is approximately 380 feet, which is an insufficient length to store queues during the AM peak hour. Vehicles queuing onto mainline I-95 create a safety issue due to the speed differential between the exiting and mainline traffic. Geometric conditions on the off-ramp, which include the change in grade, provide poor intersection visibility to exiting drivers approaching the signalized intersection at the base of the intersection (**Photograph 10**). The pedestrian crossing on the west leg of the intersection in combination with the existing signal timing, also contributes to the queuing issue on the ramp.

Photograph 9: AM Peak Hour Queue at the Southbound I-95 Exit Ramp to Franklin Street/15th Street

In addition, vehicles on Franklin Street were observed during the AM peak hour stopping to drop off passengers at the Monroe Building located in the northwest quadrant of the intersection. This operation negatively impacted westbound through traffic on Franklin Street contributing to the queuing issue on the ramp.

Photograph 10: Southbound I-95 Off-Ramp to Franklin Street/15th Street Limited Sight Distance to Downstream Traffic Signal

Photograph 11: Looking North at Southbound I-95 Off-Ramp to Franklin Street/15th Street

The Franklin Street off-ramp geometric roadway improvements are shown in **Figure 46** and include the following improvements:

<u>Southbound I-95 Off-Ramp at Franklin Street:</u>

1. Widen the southbound off-ramp approach from two lanes to three lanes (**Photograph 11**). The additional lane will allow for more efficient signal timing operations and provide more storage for queued vehicles.
2. Install ramp pre-emption at the intersection. Once the southbound queue reaches a specific point (e.g. 250 feet from the stop bar), then the intersection controller can prioritize demand from the ramp and clear the queue before it spills back onto I-95.
3. Install actuated pedestrian push buttons on each signal pole on each quadrant of the intersection to provide more efficient signal timing.

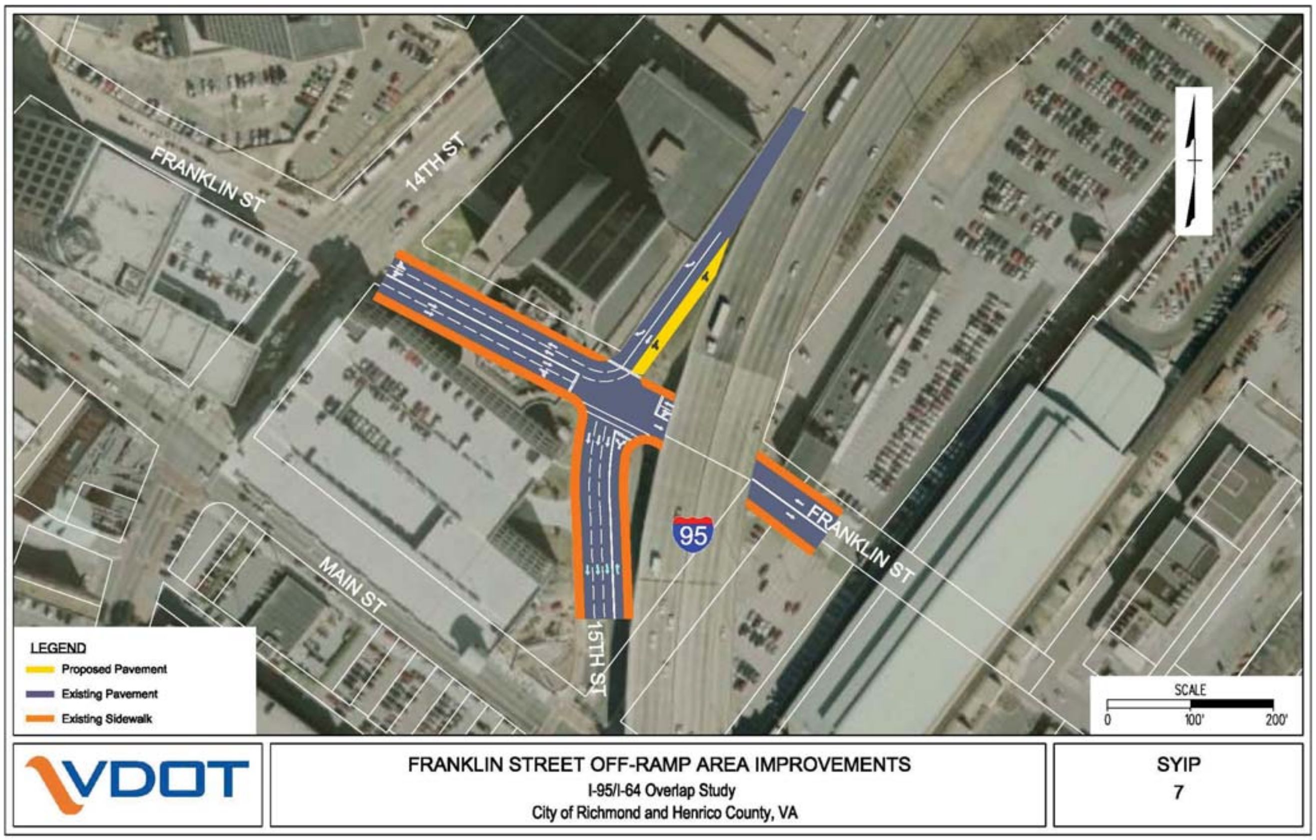
Under a separate City of Richmond improvement project, the northbound approach of 15th Street will be restriped from its current configuration of two northbound lanes and two southbound lanes to three southbound lanes and 1 northbound lane as shown in **Figure 46**.

<u>Franklin Street:</u>

1. Coordinate with Monroe building management to restrict loading/unloading during the peak hours to reduce the impact on traffic flow and prevent queuing on the southbound off-ramp during the AM peak hour.

Overall, the Franklin Street Off-Ramp Area Improvements would likely reduce peak hour queuing on the southbound I-95 off-ramp, improve traffic flow on Franklin Street, and ultimately improve safety and operation for vehicles and pedestrians.

Figure 46: SYIP #7 - Franklin Street Off-Ramp Area Improvements



SYIP #8 - Sign Improvements to Clarify Guide Signs with Option Lane Issues

Five guide signs with option lanes are located within the study corridor. An option lane is defined as a lane from which both the exit destination and the mainline destination can be reached. All five option lanes are identified in **Photographs 12 - 16**. Existing signing creates expectancy problems for drivers who are unfamiliar with the area.

Photograph 12: Southbound I-95 to Eastbound I-64

The existing guide signs with option lanes issue do not meet current standards and should be upgraded to meet the Manual on Uniform Traffic Control Devices (MUTCD) Overhead Arrow-per-Lane standard.

This project includes upgrading the five non-standard guide signs with option lane issues to meet the MUTCD Overhead Arrow-Per-Lane standard. In addition to new guide signs, new sign assemblies are recommended including overhead sign bridges, foundations, and sign lighting. The guide signs with lane use arrows shown for each lane will provide a clearer message to motorists as to downstream geometry; thereby, improving safety at these critical diverge points throughout the study area.

Photograph 13: Northbound I-95/I-64 to Westbound I-64/Southbound I-195

Photograph 14: Westbound I-64 to Northbound I-95/I-64

Photograph 15: Eastbound I-64 to Northbound I-95/Southbound I-195

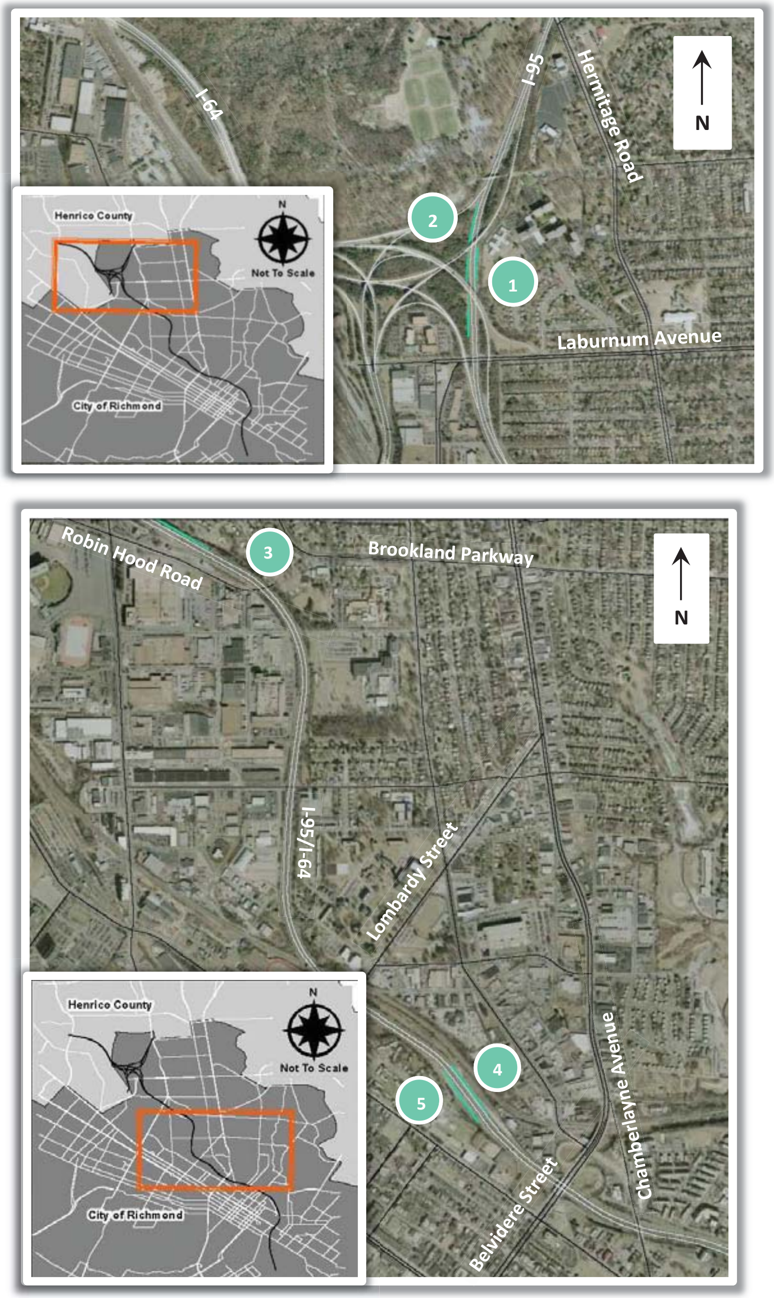
Photograph 16: Southbound I-95 to Westbound I-64/Southbound I-195

SYIP #9 - Create Five New Emergency Pull-Offs

Frequently-spaced pull-off areas increase the likelihood that they will be used; however, throughout much of the I-95/I-64 study area, left and right shoulder widths are either nonexistent or are so narrow there is no room for disabled vehicles. Designated emergency pull-off areas are not located within the study corridor.

This project recommends creating five new emergency pull-off areas within the corridor. Proposed locations for new pull-off areas were considered throughout the study corridor. Locations were primarily selected based on available right-of-way and constructability, and are shown in **Figure 47**. Additional figures provided in **Appendix R** show approximate dimensions of each proposed pull-off developed using aerial mapping.

Figure 47: Proposed Emergency Pull-off Locations



These proposed pull-offs include the following improvements to incident management and safety:

- Motorists experiencing problems will be allowed to exit the roadway without blocking through traffic. This reduces the duration of traffic congestion and the potential for secondary incidents that occur due to impacts of a disabled vehicle.
- Designated areas will be provided for crash clearing and/or investigation. When crashes occur, vehicles need to be cleared to the shoulder quickly to minimize the amount of upstream traffic congestion. Additionally, a pull-off area may provide emergency response vehicles with adequate space to aid victims after a crash without taking up a traffic lane.
- Additional acceleration and deceleration space will be provided for disabled and emergency response vehicles when arriving and departing a crash.
- Areas for law enforcement officers to apprehend non-compliant motorists without impacting traffic will be provided.
- Designated areas for law enforcement officers and incident management personnel to respond to a crash that has been moved out of the travel lanes will be provided.

SYIP #10 - ITS End-of-Queue Detection System for I-95/I-64 Overlap Approaches

The corridor currently experiences queues during the peak hours particularly at the interstate-to-interstate junctions; specifically, I-95/I-64/I-195 interchange to the northwest and I-95/I-64 interchange to the southeast. Queuing often leads to rear-end crashes; in fact, the predominant crash type from 2007 to 2009 within the study corridor was rear end, which accounted for 58% of total crashes. Sixty-five percent (65%) of the corridor crashes from 2007 to 2009 occurred during the AM and PM peak hours, when the area experiences the most queuing.

This project includes the installation of end-of-queue detection systems on the I-95 and I-64 approaches to the overlap section. Each end-of-queue detection system will consist of detectors at various locations on an approach to act as "trigger points" that activate roadside variable message signs (VMS) once queues reach each point. VMS will alert drivers to the upcoming traffic congestion. Locations of the proposed ITS end-of-queue detection systems are shown in **Figure 48**. An example conceptual layout of an ITS end-of-queue detection system is shown in **Figure 49**.

The proposed system will provide real-time information to drivers about upcoming traffic conditions from which they can make a decision to choose an alternate route, if available, or be aware of downstream queues and/or slow speeds; thereby, improving safety and flow through congested portions of the corridor.

Figure 48: Proposed ITS End-of-Queue Detection System Locations

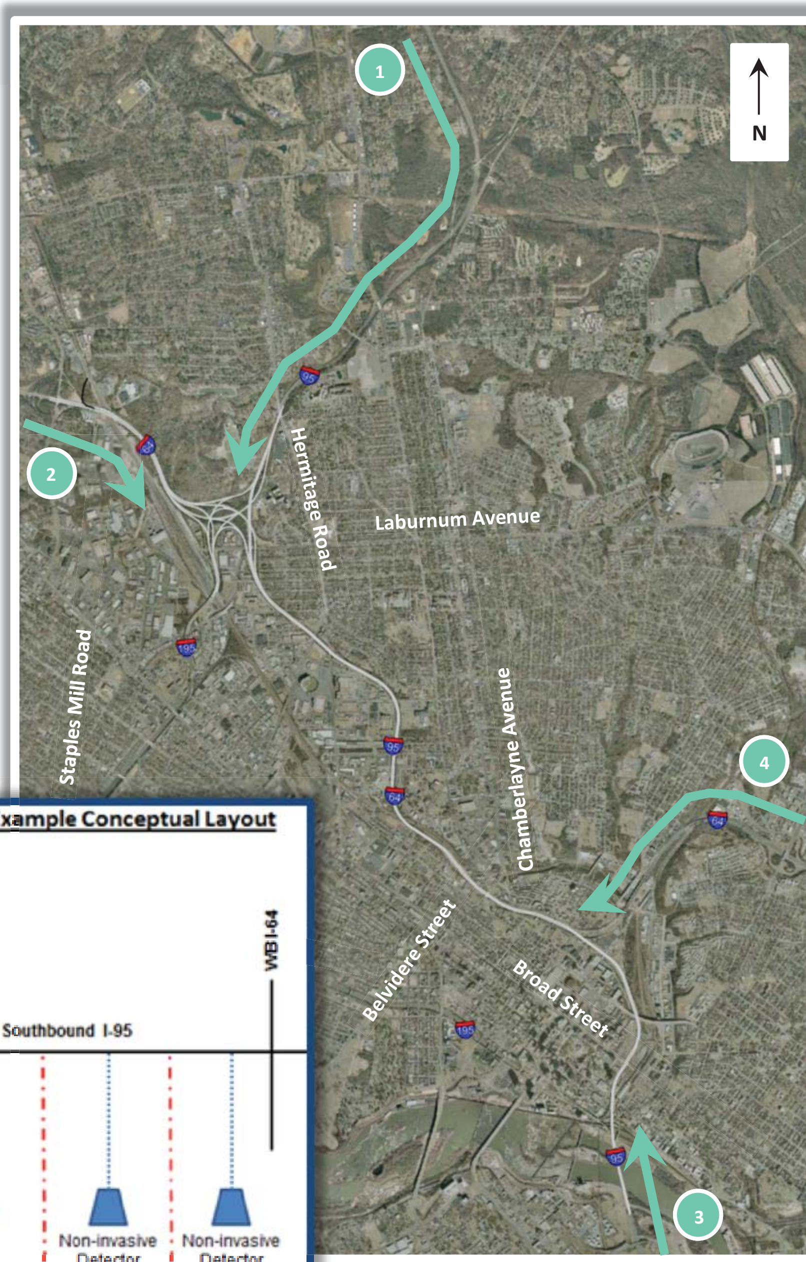
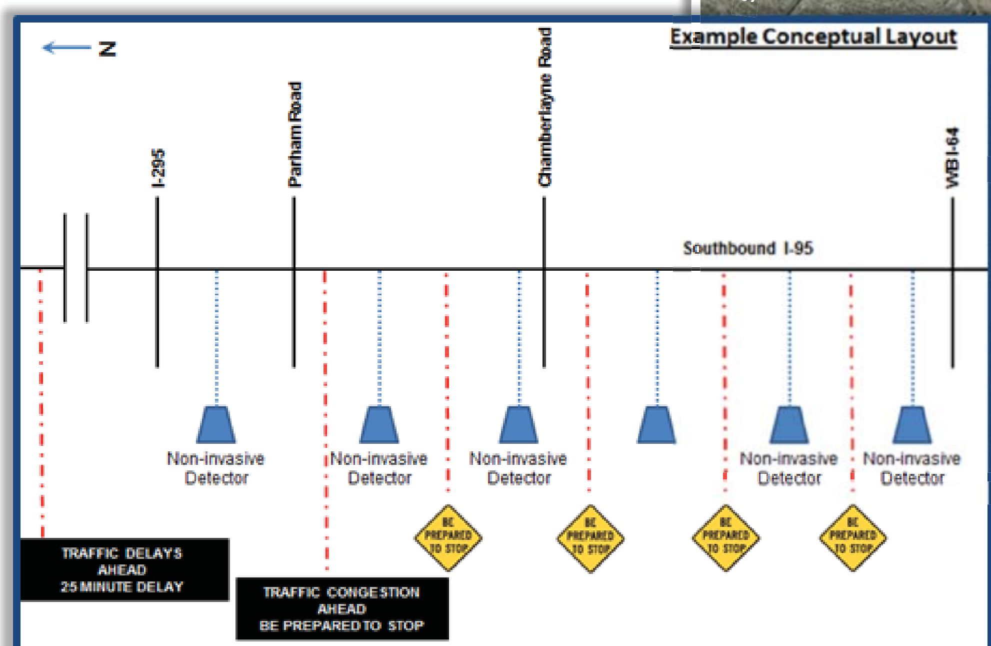


Figure 49: Conceptual Layout of End-of-Queue Detection System




SYIP #11 - Corridorwide Lighting Upgrades

Both high-mast and conventional roadway lighting currently exist in the I-95/I-64 study area; however, existing lighting is primarily concentrated around interchanges. This project recommends the removal of existing roadway lighting followed by the upgrade to continuous corridorwide high-mast lighting. This project is anticipated to improve the safety throughout the corridor by reducing nighttime crashes. The location of proposed high mast lighting is shown in **Appendix R**.

6.3 Long-Term Concepts

The most expensive recommended improvements (greater than approximately $50 million), requiring extensive right-of-way acquisition, utility relocation, and construction cost, were categorized as long-term concepts. Long-term concepts included both geometric and non-geometric improvements developed through a cooperative work group process. These long-term concepts also typically fell outside the limits of the current SYIP, which is more than 10 years to start of construction. These improvements are considered concepts because further study and refinement is necessary before they can be implemented. Long-term concepts are intended to illustrate the order of magnitude required to make corridorwide operational and safety improvements throughout the I-95/I-64 overlap corridor. Phasing of improvements included in a particular concept should be considered, which may allow portions of these concepts to be implemented over a shorter period of time. This section of the report includes a brief description and a graphical representation of the 12 long-term improvement concepts developed within the study area. Long-term concepts #1 – #9 were finalized as the priority concepts by the study team and were carried forward through the operational analysis portion of this study where their feasibility was investigated based on the results of the 2022 and 2035 traffic analyses. The results of these analyses are included in **Section 7.2**.

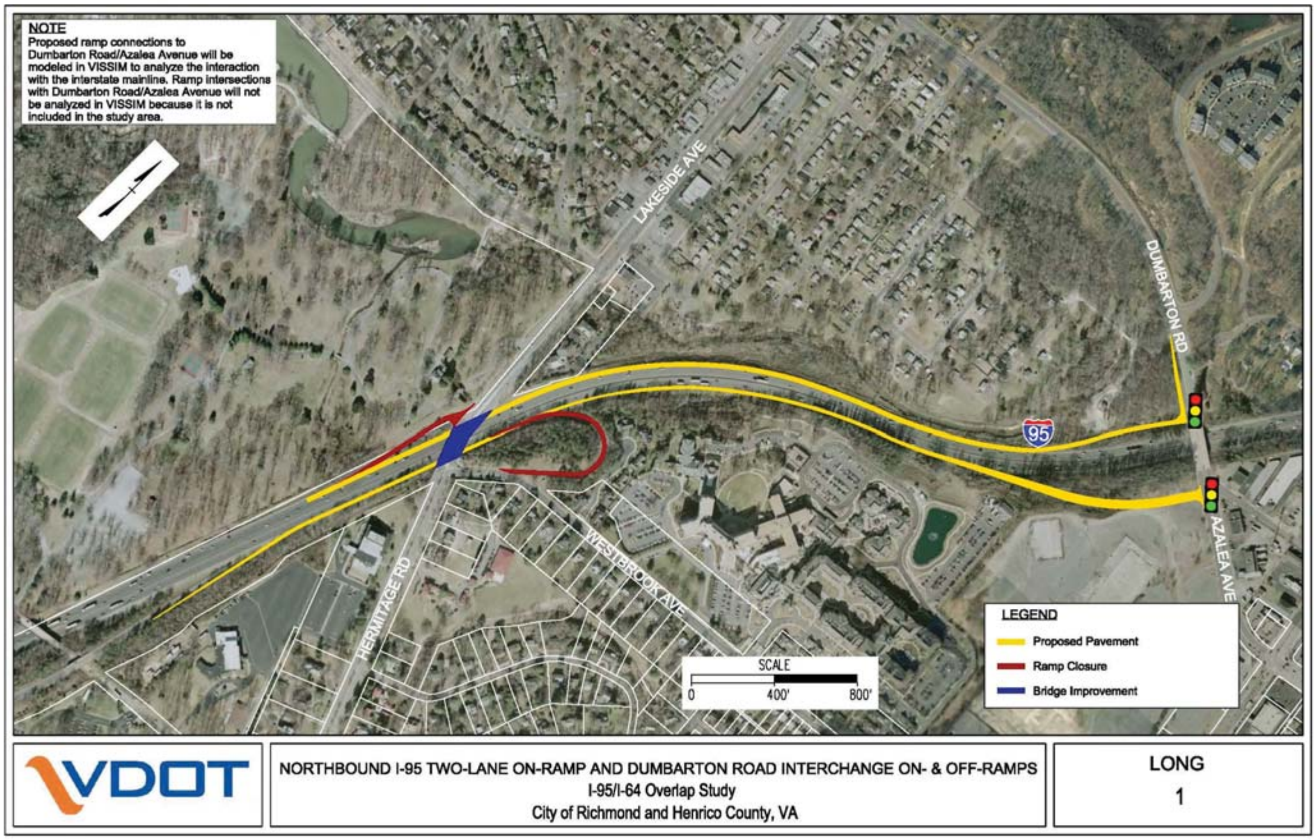
Three additional long-term concepts, #10 – #12, were developed for consideration at the end of the planning process. While these concepts were discussed with the study work group, not all stakeholders agreed with the details of each concept but agreed the concepts merited further consideration. These three additional concepts represent modifications to the previously described long-term concepts. Operational impacts of these three concepts were not included in subsequent traffic simulation section of this report. However, these concepts were considered worthy of documentation and were recommended for further study and refinement. A general description and graphical representation of these three concepts are provided below.

Additional concepts that progressed beyond the first screening process but were not carried forward are documented in **Appendix S**. Included are general descriptions, graphical figures, and documentation of reasons each concept was eliminated from consideration. These concepts are provided to serve as reference in support of possible future planning efforts throughout the corridor.

Long-Term #1 - Northbound I-95 Two-Lane On-Ramp and Dumbarton Road Interchange On- & Off-Ramps

This concept, shown in **Figure 50**, consists of relocating the existing interchange at Hermitage Road to Dumbarton Road by constructing a northbound I-95 off-ramp and a southbound I-95 on-ramp at Dumbarton Road. This concept would involve the removal of the existing northbound I-95 off-ramp and southbound I-95 on-ramp at Brook Road and the construction of two service roads parallel to I-95 connecting Brook Road to Dumbarton Road. Two new traffic signals would be constructed on Dumbarton Road at the proposed ramp termini. The primary objectives of this improvement are to relieve a major bottleneck on northbound I-95 by lengthening the northbound I-95 merge distance; reduce the eastbound I-64/northbound I-195 to northbound I-95 on-ramp PM peak hour queue length; improve the interchange spacing with respect to the Bryan Park interchange; and improve the interchange spacing with respect to the Chamberlayne Road interchange. This concept also would require improvements to the Hermitage Road/Lakeside Road bridge over I-95. The northern limit of the I-95/I-64 Overlap Study was the Hermitage Road interchange; therefore, impacts of this concept on operations at interchanges north of Hermitage Road were not further investigated in this study. Future studies conducted to refine this concept should consider expanding the study limits northward to include the Parham Road and Chamberlayne Road interchanges.

Figure 50: Long-Term Concept #1 – Northbound I-95 Two-Lane On-Ramp and Dumbarton Road Interchange On- & Off-Ramps



This concept also includes the Bryan Park interchange (Exit 79) northbound I-95 on-ramp improvement concept which consists of the construction of an additional lane on the eastbound I-64/northbound I-195 on-ramp to provide a total of two lanes entering onto northbound I-95 and extending the merge length onto northbound I-95. The primary objective of this improvement was to improve traffic flow on the on-ramp as a result of increasing the capacity, extend the merge area onto northbound I-95, reduce/eliminate the existing queue, and eliminate the existing weave by improving the interchange spacing.

Long-Term #2 - I-95/I-64 Boulevard Interchange (Exit 78) – Braided Ramps

This concept (**Figure 51**) includes the following improvements:

- <u>Northbound Direction</u>
  - Construct braided ramps to separate movements from northbound I-95/I-64 to westbound I-64 and the on-ramp from Boulevard to northbound I-95/I-64

This improvement reduces the number of lanes on northbound I-95 from three to two lanes to the south of the Boulevard interchange to provide a dedicated lane for the downstream on-ramp from eastbound I-64 to northbound I-95 to merge into.

- <u>Southbound Direction</u>
  - Construct braided ramps to separate movements from the southbound I-95/I-64 off-ramp to Boulevard and the on-ramp from northbound I-195
  - Reduce southbound I-95 from three to two lanes west of Boulevard to provide a dedicated lane for the on-ramp from northbound I-195 to southbound I-95/I-64 to merge into

The primary objective of this concept is to remove the weaving sections between the Bryan Park interchange and the Boulevard interchange. This concept would result in impacts to residential and business land uses located along I-95/I-64 in both the northbound and southbound directions. This concept would include numerous elevated structures, improvements to existing bridges, and improvements to adjacent arterials.

Long-Term #3 - I-95/I-64 Belvidere Street Interchange (Exit 76A) – On- & Off-Ramps

This concept, shown in **Figure 52**, includes eliminating the northbound off-ramp to Chamberlayne Avenue, eliminating the existing loop ramp from northbound Belvidere Street to northbound I-95/I-64, and constructing new on- and off-ramps to and from Belvidere Street. The primary objective of this improvement includes eliminating the existing, deficient acceleration lane from northbound Belvidere Street to northbound I-95/I-64 loop ramp and increasing the length of the weave section between the westbound I-64 to northbound I-95/I-64 on-ramp and the off-ramp to Chamberlayne Avenue.

Long-Term #4 - I-95/I-64 East Interchange

This concept includes a complete redesign of the I-95/I-64 East interchange consisting of the following improvements (**Figure 53**):

- A flyover ramp from westbound I-64 to southbound I-95
- Increase capacity of southbound I-95/I-64 to eastbound I-64 from one lane to two lanes by restriping and using the existing pavement
- Widen the Shockoe Bottom Bridge in the eastbound direction from four lanes to five lanes
- Eliminate on-ramps from 7th Street to northbound I-95/I-64 and eastbound I-64 and construct new on-ramps from 5th Street, which would require 5th Street to be converted to a two-way facility.

The primary objective of this concept is to provide dedicated lanes for heavy freeway-to-freeway movements surrounding the I-95/I-64 East interchange. This concept would have impacts on the 7th Street bridge over I-95/I-64.

Figure 51: Long-Term Concept #2 – I-95/I-64 Boulevard Interchange (Exit 78) – Braided Ramps

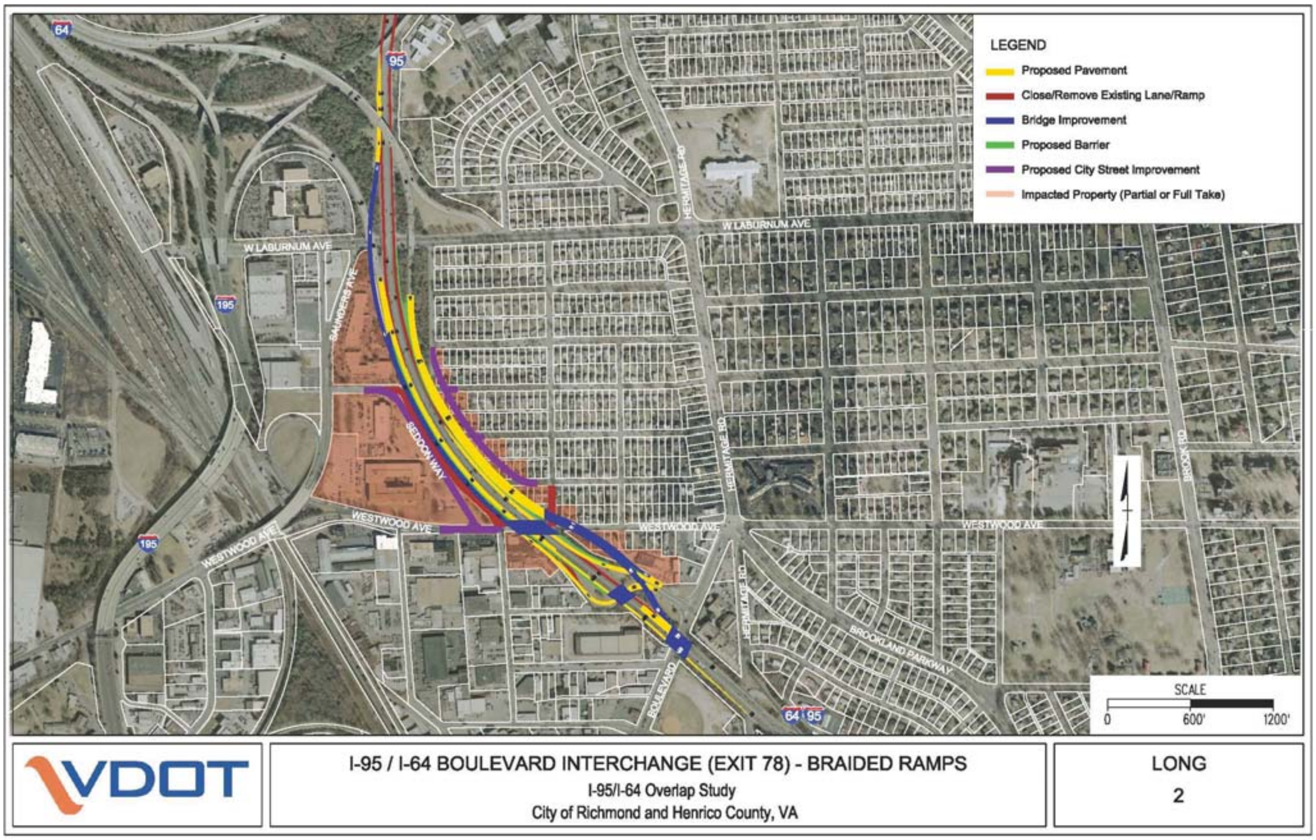


Figure 52: Long-Term Concept #3 – I-95/I-94 Belvidere Street Interchange (Exit 76A) – On- & Off-Ramps

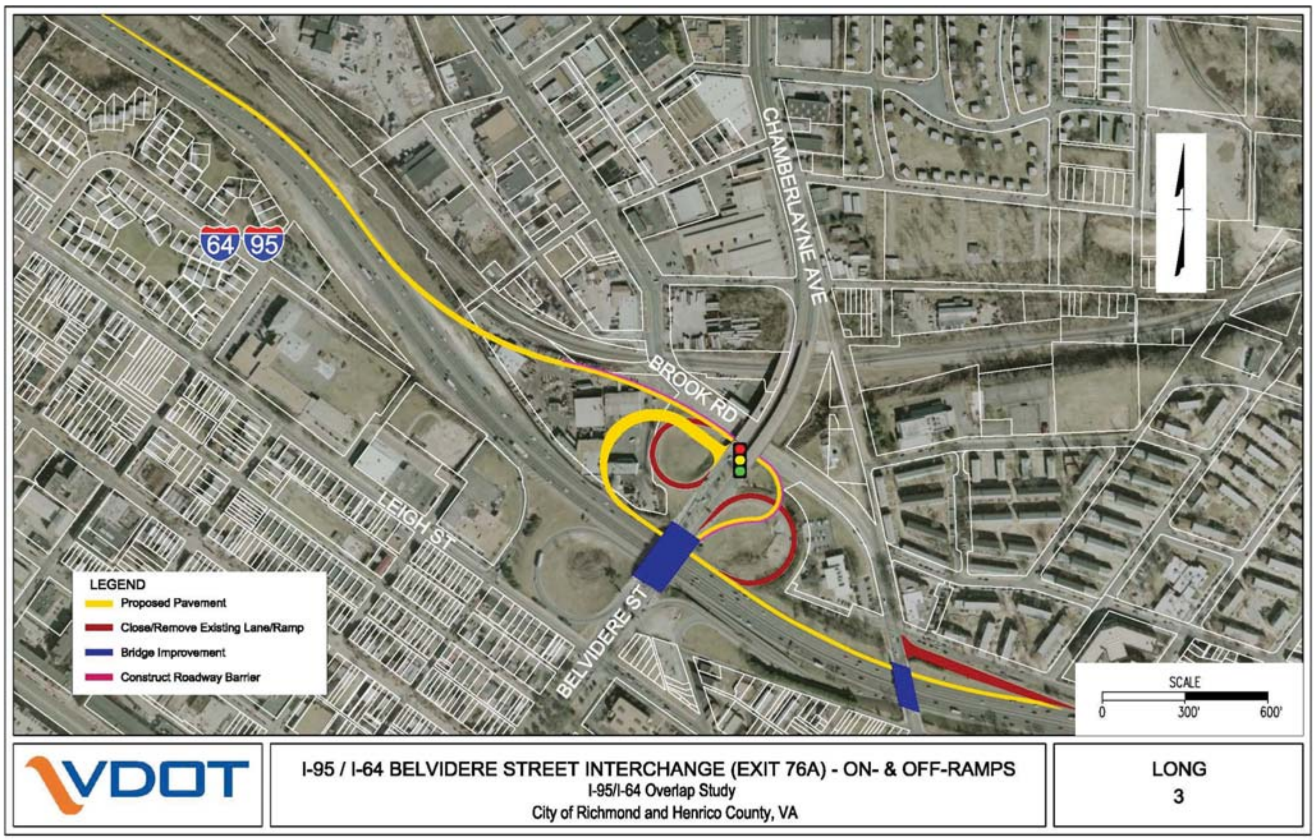
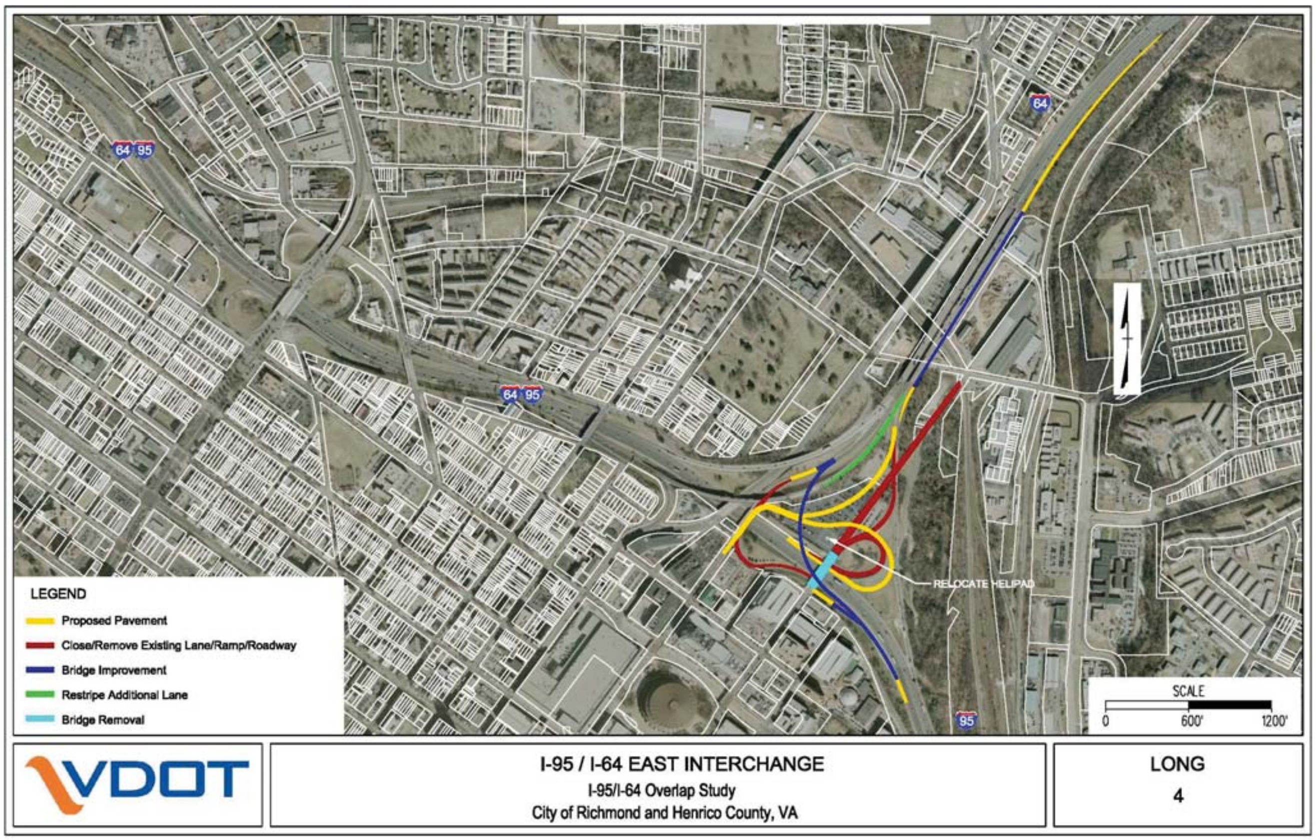


Figure 53: Long-Term Concept #4 – I-95/I-64 East Interchange



Long-Term #5 - I-95 at Broad Street Interchange (Exit 74) – Braided Ramps

This concept (**Figure 54**) includes constructing of a pair of braided ramps for the northbound I-95 on-ramp from the Broad Street interchange and the off-ramp to eastbound I-64. Northbound I-95 traffic would be redirected to west Broad Street from the existing off-ramp to Oliver Hill Way. Another aspect of this concept is to construct dual right-turn lanes from Oliver Hill Way to Broad Street to improve operations on adjacent surface streets as a result of this traffic pattern change and increase in traffic volumes. The primary objective of this concept was to remove the weave section between the northbound I-95 on-ramp from Broad Street and the off-ramp to eastbound I-64.

Long-Term #6 - I-95 at Broad Street Interchange (Exits 74 & 75) – Slip Ramp from N. 14th Street

This concept includes constructing a northbound slip ramp on 14th street under the existing at-grade intersection with Broad Street (**Figure 55**). The northbound traffic on 14th destined for northbound I-95/I-64 would use the proposed slip ramp. Northbound vehicles on 14th Street destined for southbound I-95 will continue making the right turn at Broad Street and using the existing loop ramp. The proposed slip ramp is for northbound I-95/I-64 only and will require a barrier between the leftmost lane and the two rightmost lanes at the weaving section prior to the loop ramp. The primary objective of this concept is to remove the heavy northbound right-turn movement from the intersection of 14th Street at Broad Street; thereby, improving operations on Broad Street. Traffic volume on the existing loop ramp from eastbound Broad Street would also be reduced as a result of this concept. The proposed barrier would eliminate the existing weave movement between the two loop ramps from eastbound Broad Street to southbound I-95. This concept shows also shows an alternate configuration of the braided ramp shown in Long-Term concept #5.

Long-Term #7 - Corridorwide Shoulder Upgrades

As summarized in **Section 2.6.2**, most of the existing shoulders are less than the recommended standard of 12 feet. Corridorwide shoulder upgrades are recommended (**Figures 56** - **58**) to improve the overall safety of the corridor, provide additional capacity and allow for easier maintenance activities in the corridor. Specific benefits of corridorwide paved shoulders include:

- Safety
  - Provide space to make evasive maneuvers
  - Accommodate driver error
  - Add a recovery area to regain control of a vehicle
  - Provide space for disabled vehicles to stop or drive slowly
- Capacity
  - Highways with paved shoulders can carry more traffic
  - Provide space for off-tracking of heavy vehicle's rear wheels in curved sections
  - Provide space for disabled vehicles, mail delivery and bus stops
- Maintenance
  - Highways with paved shoulders are easier to maintain
  - Provide structural support to the pavement
  - Discharge water further from the travel lanes, reducing the undermining of the base and subgrade
  - Provide space for maintenance operations

Mapping provided in **Appendix I** documents each section of the corridor where minor (level terrain), major (requires major earthwork to build up shoulder), and bridge improvements are required to upgrade shoulders throughout the study corridor.

Long-Term #8 - Guardrail Upgrades

The non-geometric long-term improvements recommended for the I-95/I-64 overlap include upgrading non-standard guardrail, repairing damaged guardrail, and conducting a corridorwide guardrail assessment. The primary objective of this improvement is to provide safer roadside barriers in an attempt to reduce crash severity. Mapping provided in **Appendix H** documents existing guardrail through the corridor.

Figure 54: Long-Term Concept #5 – I-95 at Broad Street Interchange (Exit 74) – Braided Ramps

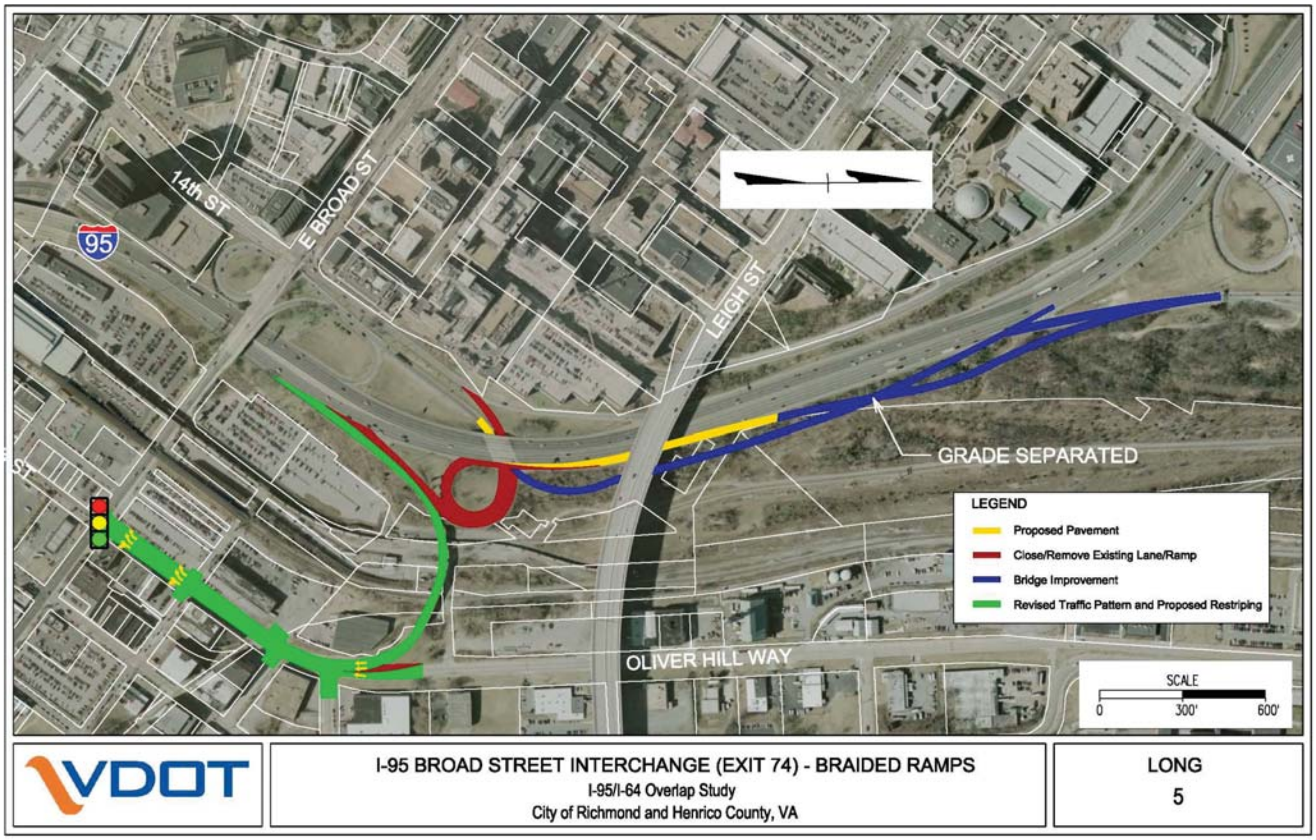
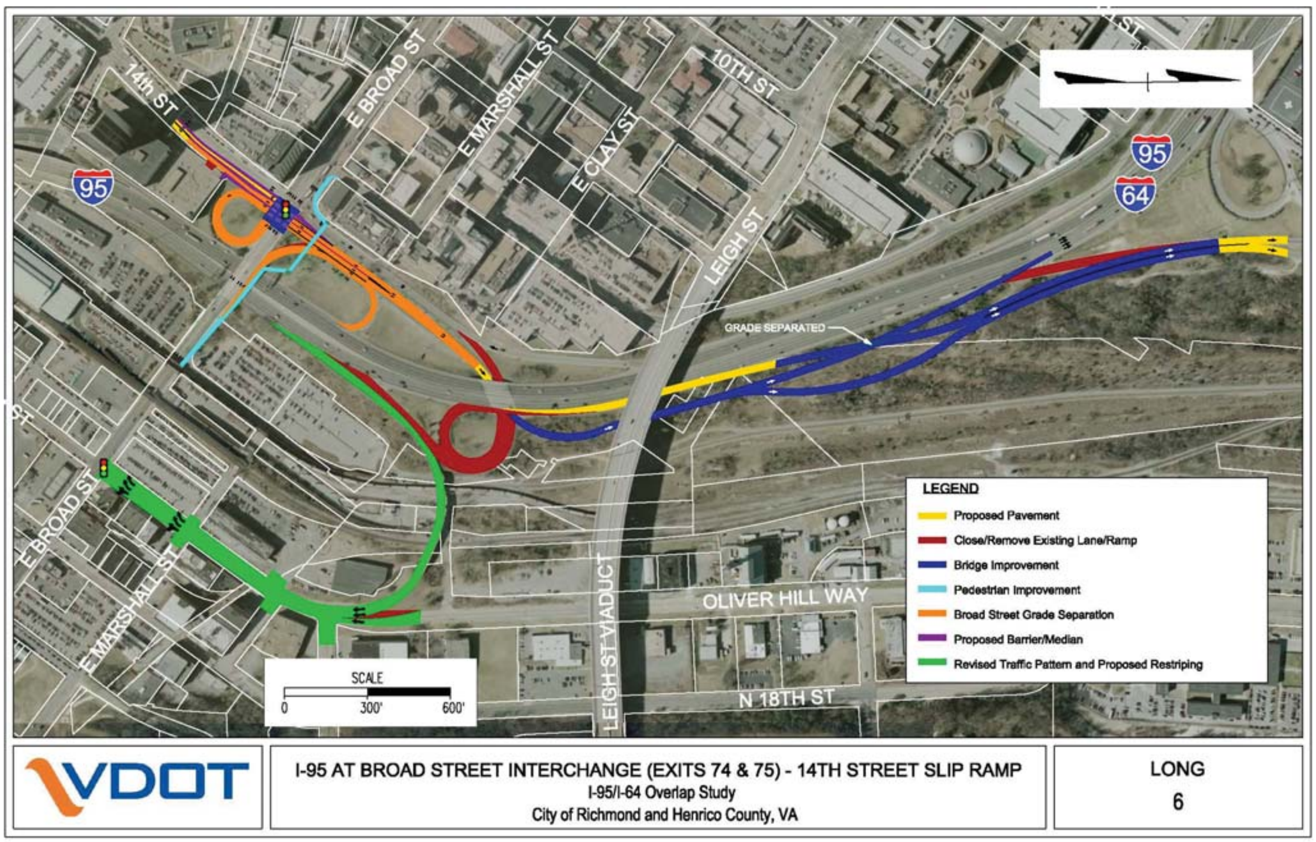


Figure 55: Long-Term Concept #6 – I-95 at Broad Street Interchange (Exits 74 & 75) – 14th Street Slip Ramp



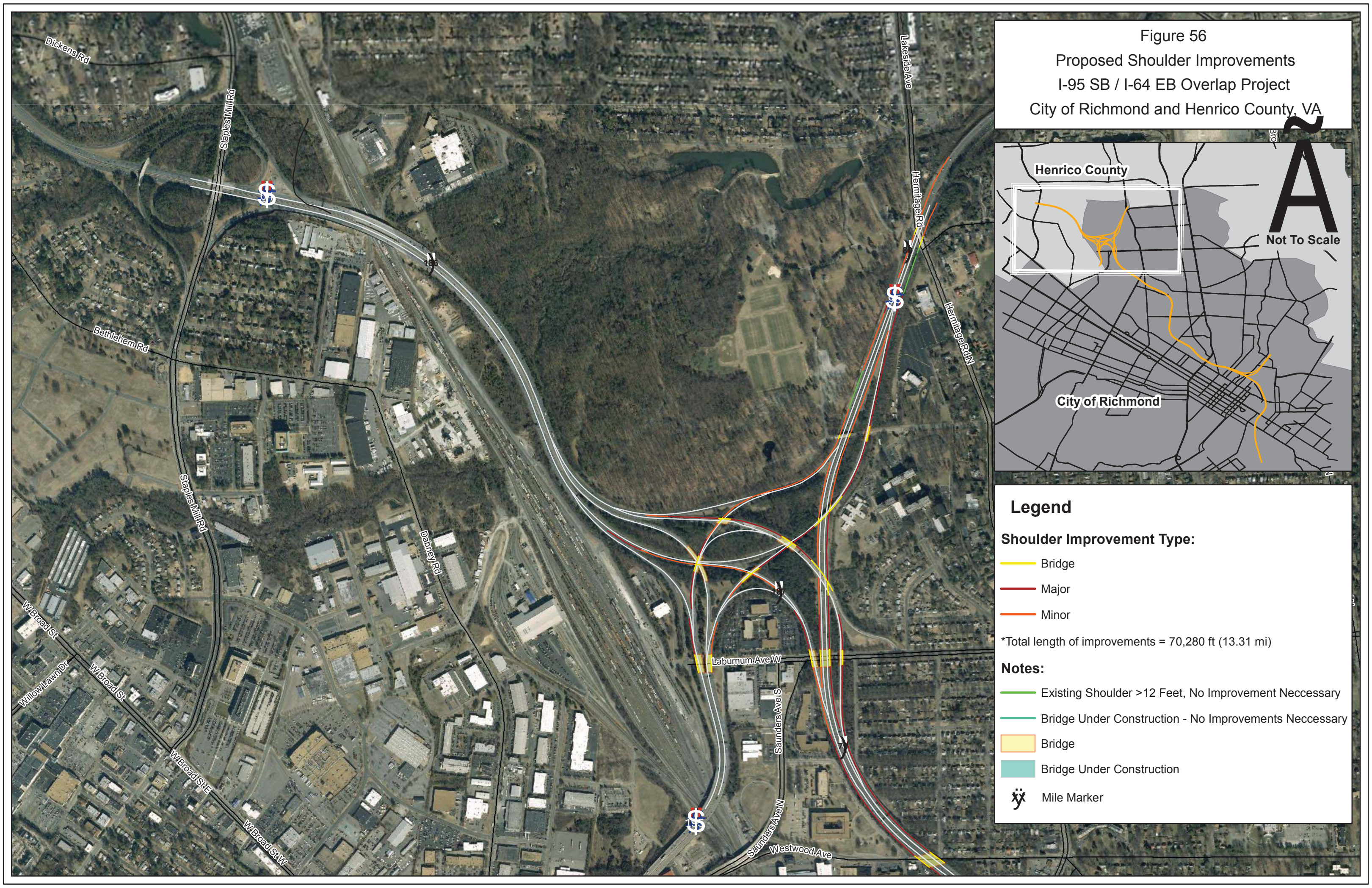


Figure 56
Proposed Shoulder Improvements
I-95 SB / I-64 EB Overlap Project
City of Richmond and Henrico County, VA
Henrico County
City of Richmond
Not To Scale
Legend
Shoulder Improvement Type:
Bridge
Major
Minor
*Total length of improvements = 70,280 ft (13.31 mi)
Notes:
Existing Shoulder >12 Feet, No Improvement Neccessary
Bridge Under Construction - No Improvements Neccessary
Bridge
Bridge Under Construction
Mile Marker
Dickens Rd
Staples Mill Rd
Bethlehem Rd
Dabney Rd
W Broad St
Willow Lawn Dr
W Broad St E
W Broad St W
Lakeside Ave
Hermitage Rd
Laburnum Ave W
Saunders Ave S
Saunders Ave N
Westwood Ave

Figure 57
Proposed Shoulder Improvements
I-95 SB / I-64 EB Overlap Project
City of Richmond and Henrico County, VA

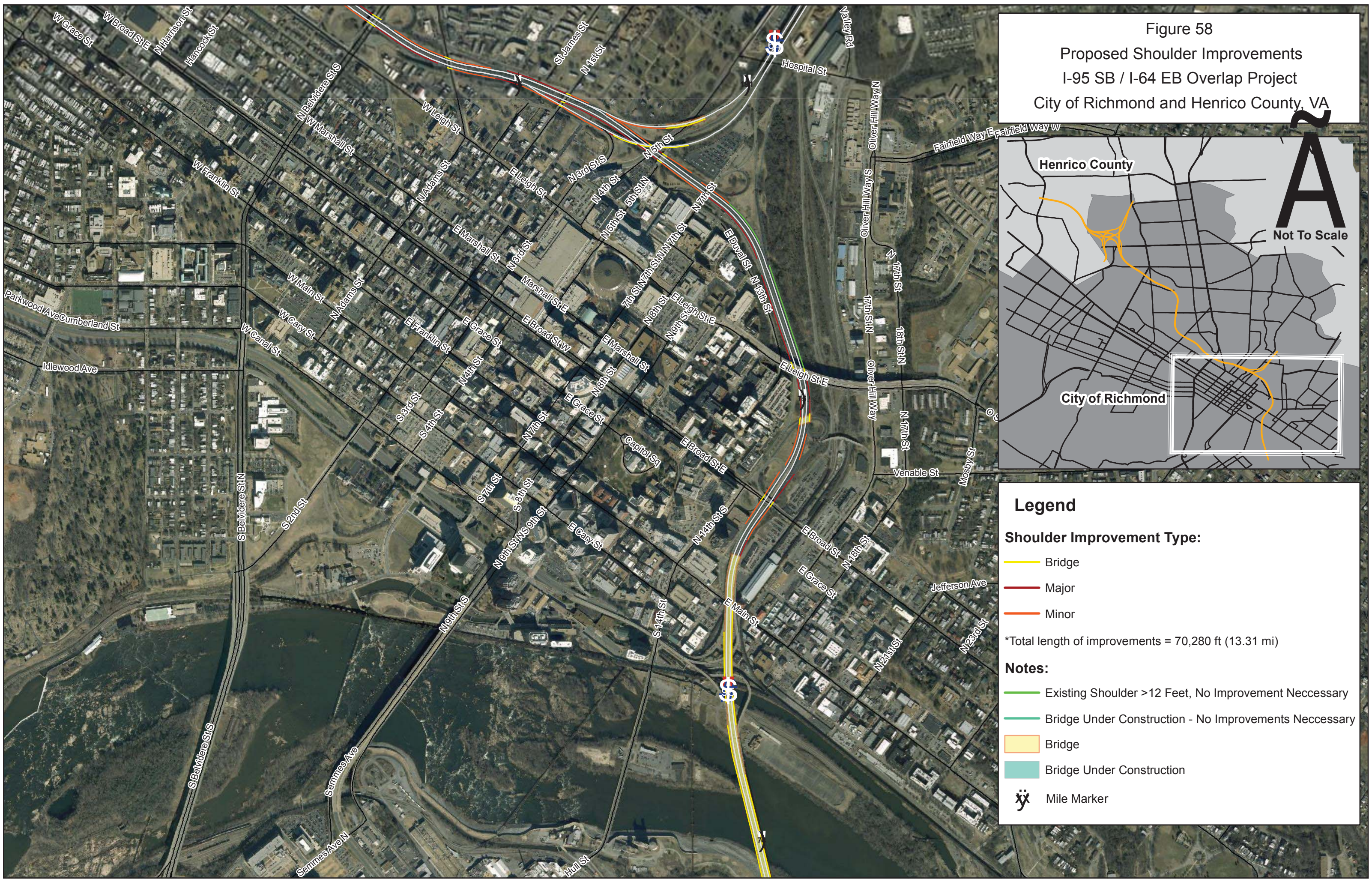


Figure 58
Proposed Shoulder Improvements
I-95 SB / I-64 EB Overlap Project
City of Richmond and Henrico County, VA
Henrico County
City of Richmond
Not To Scale
Legend
Shoulder Improvement Type:
Bridge
Major
Minor
*Total length of improvements = 70,280 ft (13.31 mi)
Notes:
Existing Shoulder >12 Feet, No Improvement Neccessary
Bridge Under Construction - No Improvements Neccessary
Bridge
Bridge Under Construction
Mile Marker

Long-Term #9 - Corridorwide Drainage System Upgrades

Based on input received during this planning process, the existing drainage system is undersized which results in ponding during intense rain events. Specific problem locations within the study area are on I-95 just north of the Broad Street interchange and on I-95 just north of the Bryan Park interchange to the Hermitage Road overpass. Significant upgrades to the stormwater drainage system appear to be needed. A comprehensive drainage study is recommended to determine the extent of improvements required.

Long-Term #10 - I-95/I-64 Boulevard Interchange (Exit 78) – Roundabout

This concept is a modification of Long-Term #2 to include a roundabout at the intersection of Boulevard and the on-ramp to the I-95/I-64 overlap (**Figure 60**). A roundabout configuration was considered as an alternative intersection concept compared to the traditional at-grade intersection shown in Long-Term #2 since it could accommodate heavy peak hour traffic movements to and from the interstate. A two-lane roundabout was warranted based on the 2022 and 2035 projected turning movement volumes at this intersection.

Long-Term #11 - I-95/I-64 Belvidere Street Interchange (Exit 76A) – On- & Off-Ramps

This concept is similar to Long-Term #3 since it involves eliminating the existing northbound off-ramp to Chamberlayne Avenue, eliminating the existing loop ramp from northbound Belvidere Street to northbound I-95/I-64, and constructing new on- and off-ramps to and from Belvidere Street (**Figure 61**). The primary objective of this improvement was to eliminate the existing deficient acceleration lane from northbound Belvidere Street to the northbound I-95/I-64 loop ramp and increase the length of the weave section between the westbound I-64 to northbound I-95/I-64 on-ramp and the off-ramp to Chamberlayne Avenue.

Long-Term #12 - I-95 & Broad Street Interchange (Exits 74 & 75) – Long-Range Vision

This proposed concept includes Long-Term concepts #5 - #6 and is a combination of interstate and surface street improvements that would provide a comprehensive set of improvements to the Broad Street interchange area. **Figures 61** - **63** show the overall and enlarged vision of the concept. Specific improvements are summarized in **Table 34** along with a summary of the key benefits and design considerations associated with this concept.

Table 34: Long-Term #12 – I-95 & Broad Street Interchange (Exits 74 & 75) – Long-Range Vision

Improvement	Benefits and Design Considerations/Challenges
<u>Interstate Improvements</u> Southbound I-95: ▪ Construct westbound I-64 to southbound I-95 flyover ramp ▪ Construct collector-distributor (CD) road between eastbound I-64 to southbound I-95 and Broad Street ▪ Construct on-ramp from CD road to Broad Street ▪ Close Franklin Street exit Northbound I-95: ▪ Construct braided ramps ▪ Close existing loop ramp from Broad Street to northbound I-95/I-64	<u>Benefits:</u> ▪ In the northbound direction, weaving movement between loop ramp from Broad Street and ramp to eastbound I-64 are removed ▪ Will allow for the closure of the Franklin Street ramp on southbound I-95 <u>Design Consideration/Challenges:</u> ▪ Retaining wall required to construct CD road ▪ Challenge to get under the 7th Street bridge
<u>Intersection Improvements</u> ▪ Grade separate the intersection of Broad Street & N. 14th Street ▪ Provide slip ramp from northbound 14th Street to provide connection to loop on-ramp to southbound I-95	<u>Benefits:</u> ▪ Increases capacity at the intersection of Broad Street & 14th Street <u>Design Consideration/Challenges:</u> ▪ Minimal right-of-way available along 14th Street south of Broad Street ▪ Significant retaining walls required along east and west sides of 14th Street ▪ Westbound left-turn from Broad Street to 14th requires improvements to bridge over I-95 ▪ Impacts 1 of 3 access points to the parking garage on the east side of 14th Street
<u>Pedestrian Improvement</u> ▪ Construct pedestrian overpass along the north side of Broad Street from N. 14th Street to east of the westbound on-ramp from Broad Street to southbound I-95	<u>Benefits</u>: ▪ Removes pedestrian conflicts at the intersection of Broad Street & 14th Street ▪ Removes pedestrian conflicts at the westbound Broad Street on-ramp to southbound I-95

<u>Other Surface Street Improvements</u>
▪ Construct a cul-de-sac on Oliver Hill Way to the north of Venable Street
▪ Construct roundabouts at the intersections of:
  ○ Broad Street & 17th Street
  ○ Oliver Hill Way & Venable Street
  ○ 18th Street & Venable Street
  ○ Mechanicsville Turnpike & Venable Street
  ○ Mechanicsville Turnpike & Leigh Street Viaduct
▪ Convert 17th Street and 18th Street from one-way to two-way roadways
▪ Convert outer lanes on Leigh Street Viaduct to bike lanes
	<u>Benefits</u>:
	▪ Long-term #5 would redirect northbound I-95 traffic to west Broad Street from the existing off-ramp to Oliver Hill Way. These improvements are intended to improve traffic operations on adjacent surface streets as a result of this traffic pattern change and increase in traffic volumes.

Figure 59: Long-Term Concept #10 – I-95/I-64 Boulevard Interchange (Exit 78) – Roundabout

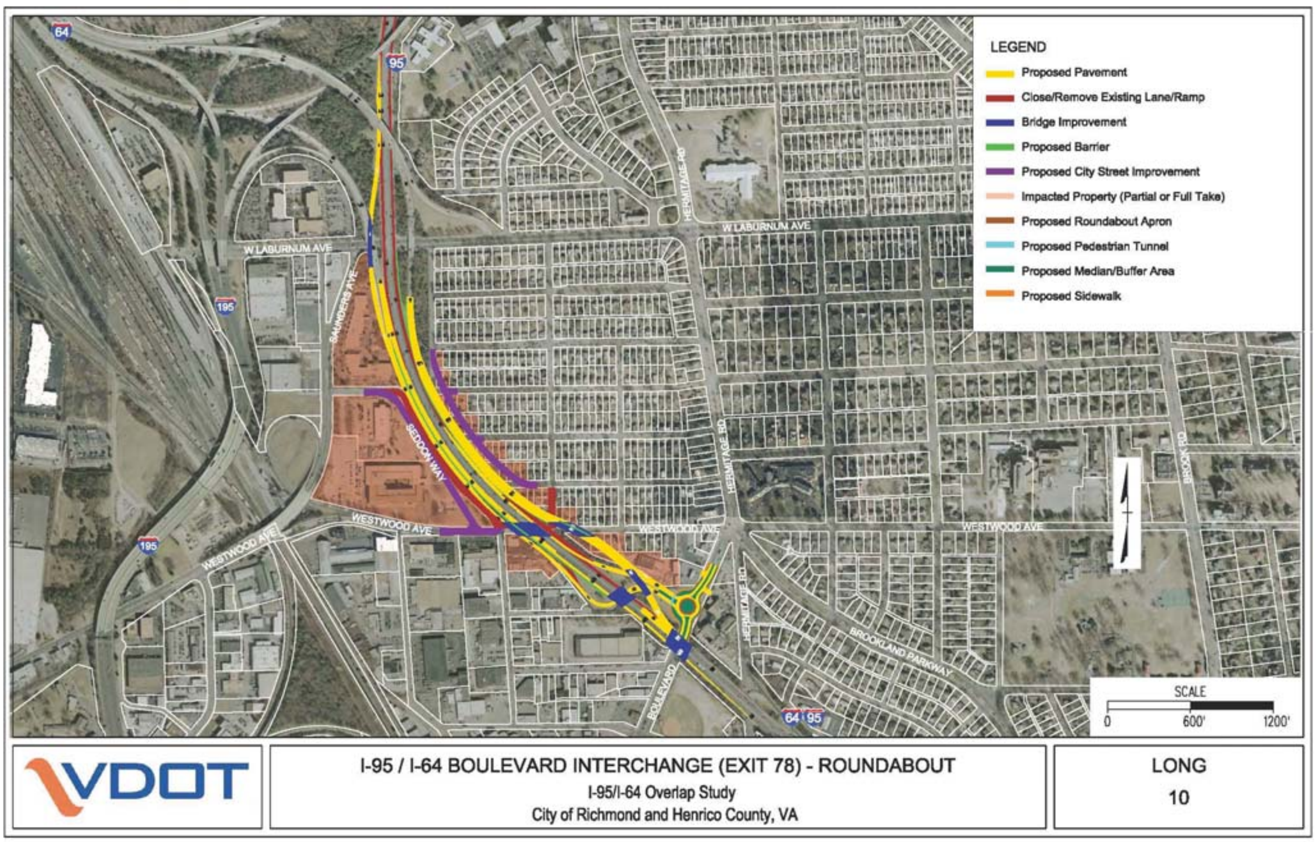


Figure 60: Long-Term #11 - I-95/I-64 Belvidere Street Interchange (Exit 76A) – On- & Off-Ramps

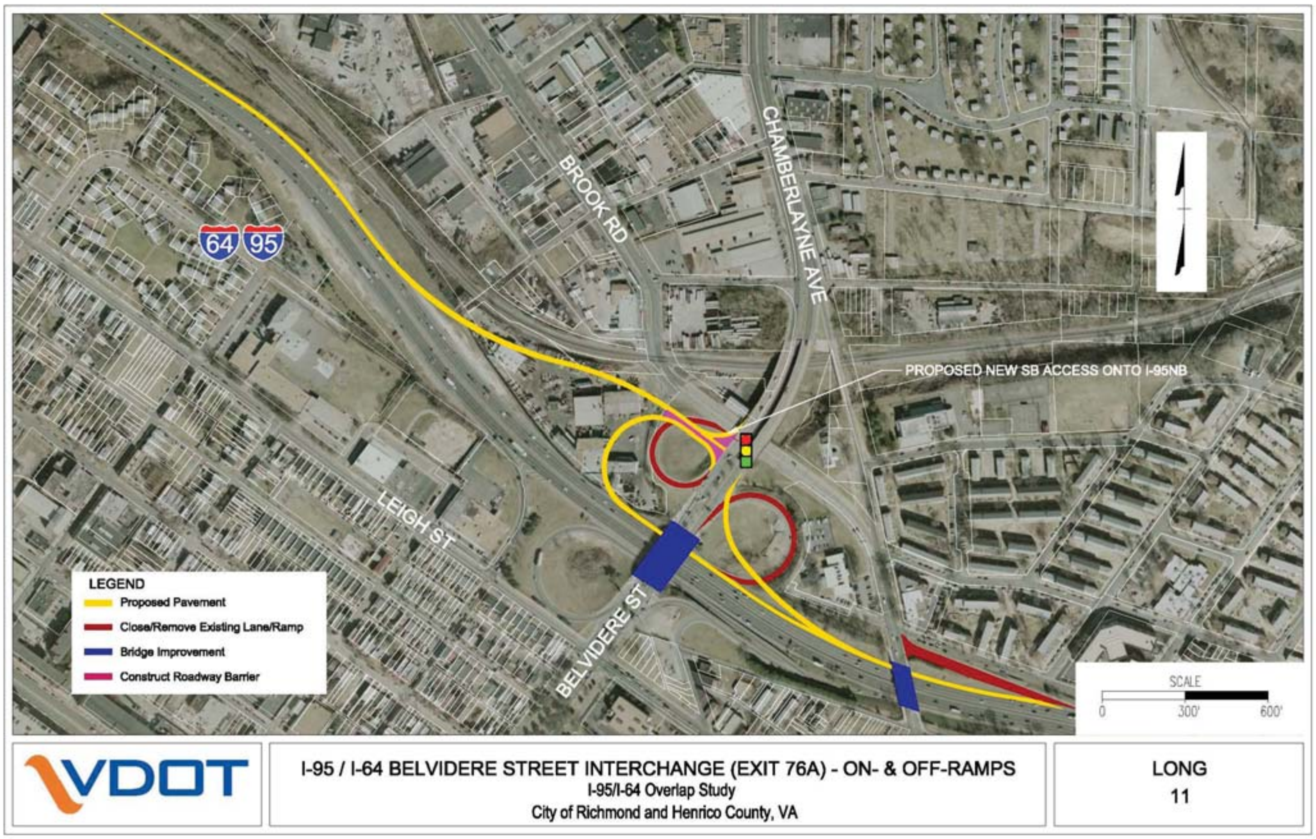


Figure 61: Long-Term #12 - I-95 & Broad Street Interchange (Exits 74 & 75) – Long-Range Vision

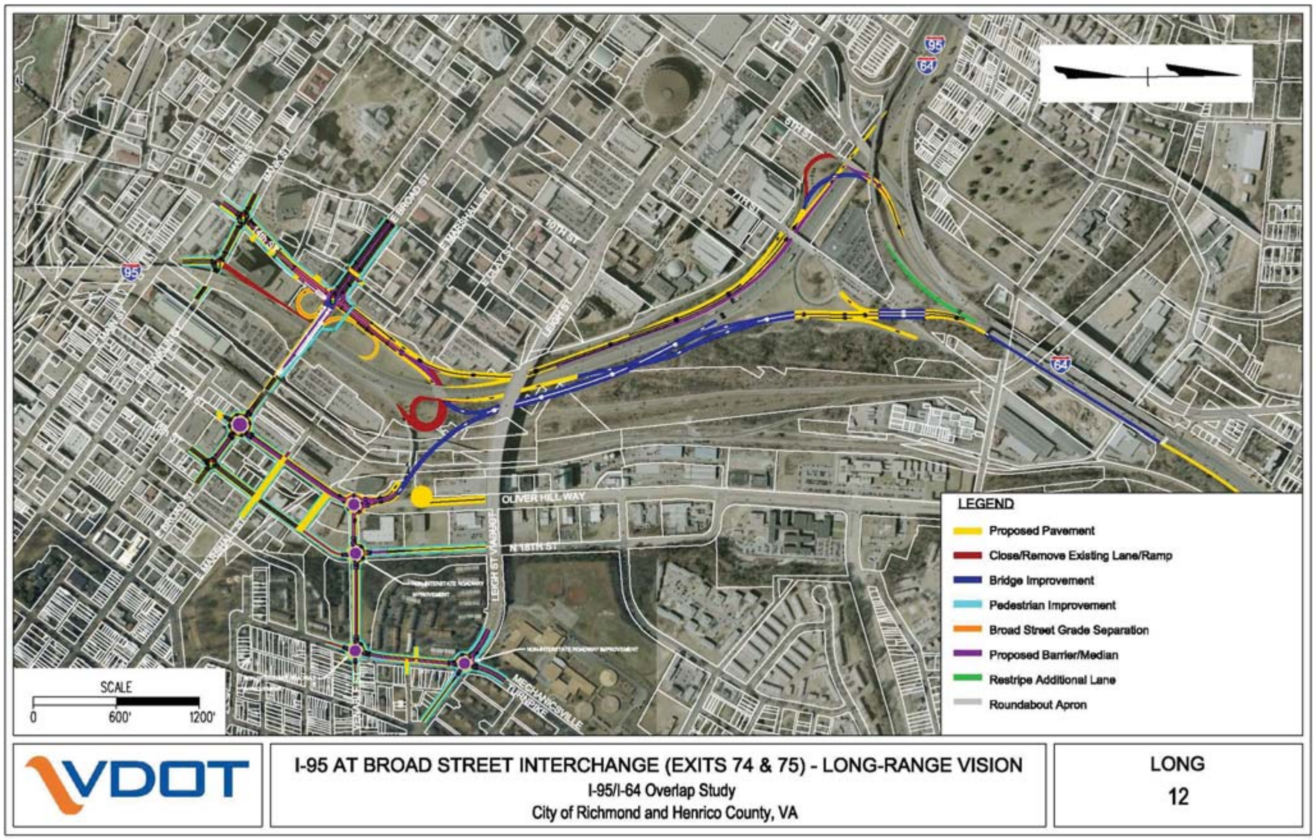


Figure 62: Long-Term #12A - I-95 & Broad Street Interchange (Exits 74 & 75) – Long-Range Vision - North

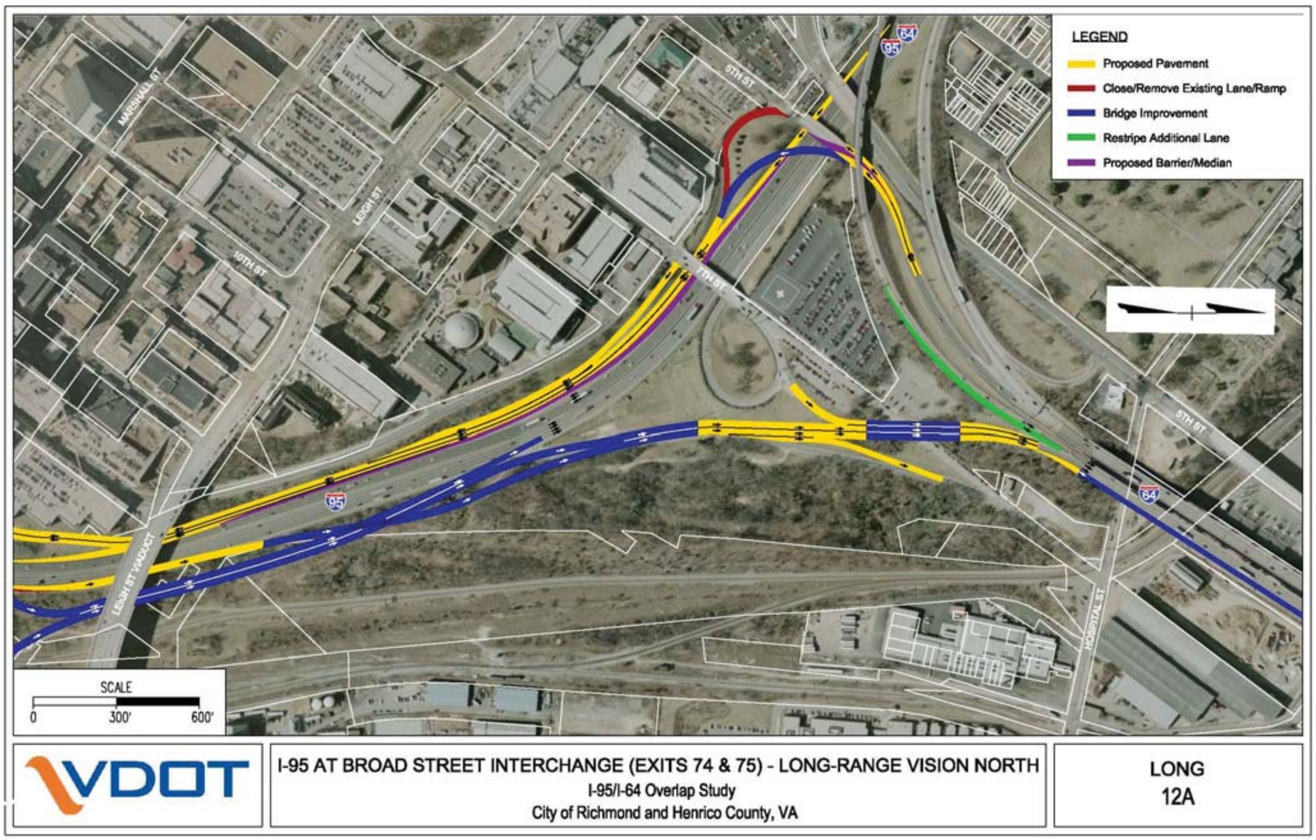
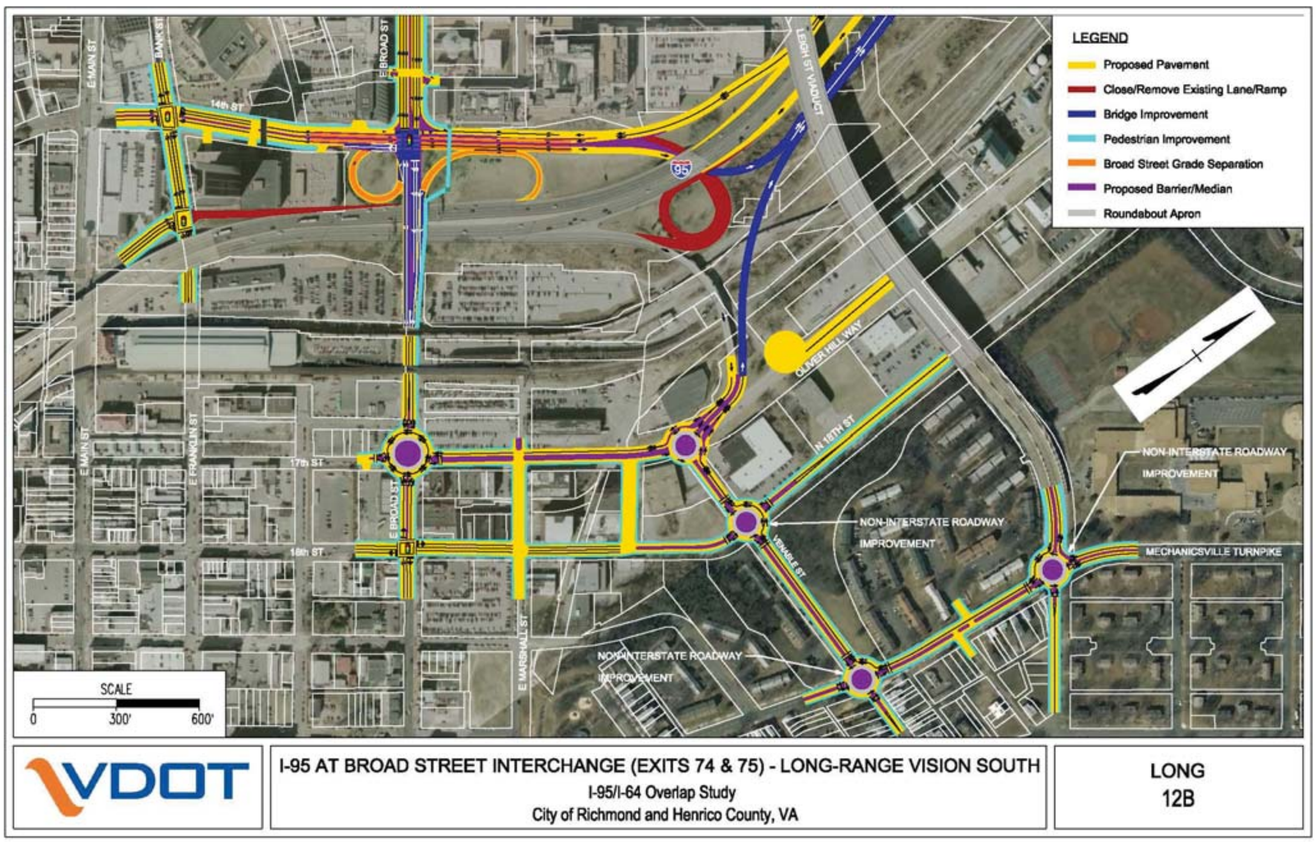


Figure 63: Long-Term #12B - I-95 & Broad Street Interchange (Exits 74 & 75) – Long-Range Vision - South



7.0 2022 and 2035 Build Conditions

A 2022 and 2035 VISSIM operational analysis of the proposed geometric SYIP projects and long-term concepts was conducted to determine the operational benefits. A description of the analyses performed and their corresponding results are summarized in the following sections. The 2022 and 2035 Build VISSIM capacity analysis results for the SYIP improvements and long-term concepts are provided in **Appendices N** - **Q**.

7.1 VISSIM Analysis – Six-Year Improvement Projects

To compare the operational impacts of each of the proposed geometric SYIP improvements, a travel time evaluation was conducted using VISSIM. While traffic volume throughput is a good measure of the validity of the traffic operations, it does not take into account the overall traffic flow through the corridor. As travel times are measured through the microsimulation model, a bottleneck can significantly impact the results. Since microsimulation models have an element of randomness to account for variability from one day to the next, the travel time evaluation results are the average of 10 simulation runs with unique random number seeds. In each run, the volumes are generated into the network with a slight variation. For this reason, a bottleneck can be present in one simulation run and not the next. Therefore, an acceptable tolerance interval was applied to the results since it was not reasonable to require that all travel time runs be exactly the same. For the purposes of this report, if the travel time runs were within 10% of each other, then the travel time runs were considered to have no change.

As shown in **Table 35**, when comparing 2022 No-Build and Build conditions and 2035 No-Build and Build conditions, all travel time runs were within 10% for SYIP #3, #4, and #5 with the exception of SYIP #4 during the AM peak hour, which shows a 65% improvement. Therefore, it was determined that SYIP #3, #4, and #5 do not significantly impact travel times through their respective segments of the study corridor. The SYIP projects were focused on spot improvements and did not have a significant impact on the corridor as a whole.

Intersection delay was used to evaluate the intersection improvements identified in SYIP # 6 and #7 as opposed to travel time runs. As shown in **Table 35**, both SYIP #6 and #7 showed an improvement in intersection delay between 2022 No-Build and Build conditions and 2035 No-Build and Build conditions. Delay improvements ranged from 1% to 56% during AM and PM peak hour conditions.

7.2 VISSIM Analysis – Long-Term Concepts

A travel time evaluation was conducted for each of the geometric long-term concepts using the same methodology as described for the SYIP projects. With the long-term concepts focused on improving the study corridor as a whole, it can be expected that travel time runs were a useful measure of effectiveness, unlike the SYIP projects which were more localized improvements. As shown in **Table 36**, when comparing 2022 No-Build and Build conditions, all long-term concepts showed an improvement greater than 10% during the AM and/or PM peak hour. The proposed southbound I-95 on-ramp from Dumbarton Road, included in Long-Term concept #1, showed a reduction of less than 10% during both AM and PM peak hours. Overall, based on the travel time results, all long-term concepts showed a projected reduction in travel time through the corridor.

Table 35: 2022 and 2035 Build VISSIM Travel Time Results – SYIP Projects

Proposed SYIP Improvements			Start of Segment	End of Segment	Peak Hour	Travel Times (Seconds)							
						2022				2035			
Figure	Location	Description				No-Build	Build	Δ	%Δ	No-Build	Build	Δ	%Δ
SYIP 3	Northbound I-95/I-64 at Hermitage Road Interchange (Exit 78)	Install Deceleration Lane	Northbound Belvidere On-Ramp	I-64 Off-Ramp	AM	225.7	212.3	13.4	5.9%	323.3	337.5	-14.2	-4.4%
					PM	209.3	225.9	-16.7	-8.0%	290.9	285.7	5.3	1.8%
SYIP 4	Southbound I-95/I-64 at Belvidere Road Interchange (Exit 76)	Realignment of On-Ramps	Leigh St Off-Ramp	I-64/7th St On-Ramp	AM	81.3	82.2	-0.9	-1.1%	81.6	28.5	53.0	65.0%
					PM	96.7	96.2	0.4	0.5%	36.2	36.8	-0.6	-1.8%
SYIP 5	Northbound I-95/I-64 at Belvidere Street Interchange (Exit 76)	Extend Acceleration Lane	Chamberlayne Ave Off-Ramp	Boulevard On-Ramp	AM	221.4	206.0	15.4	7.0%	318.2	334.7	-16.5	-5.2%
					PM	207.1	219.4	-12.3	-5.9%	301.0	294.7	6.3	2.1%
Proposed SYIP Improvements					Peak Hour	Intersection Delay (Seconds)							
						2022				2035			
Figure	Location	Description				No-Build	Build	Δ	%Δ	No-Build	Build	Δ	%Δ
SYIP 6	Southbound I-195 at Laburnum Avenue Interchange	Roundabout			AM	8.6	6.1	2.5	29.1%	8.4	7.5	0.9	10.7%
					PM	11.2	9.3	1.9	17.0%	7.9	7.7	0.2	2.5%
SYIP 6	Northbound I-195 at Laburnum Avenue Interchange	Northbound Free-Flow Right-Turn Lane			AM	1.5	1.0	0.5	33.3%	1.6	1.1	0.5	31.3%
					PM	1.0	0.5	0.5	50.0%	1.0	0.5	0.5	50.0%
SYIP 7	Franklin Street at Southbound I-95 Exit Ramp/15th Street	Additional Southbound Lane			AM	59.0	26.0	33.0	55.9%	29.5	18.5	11.0	37.3%
					PM	30.3	24.5	5.8	19.0%	35.8	35.5	0.3	0.8%

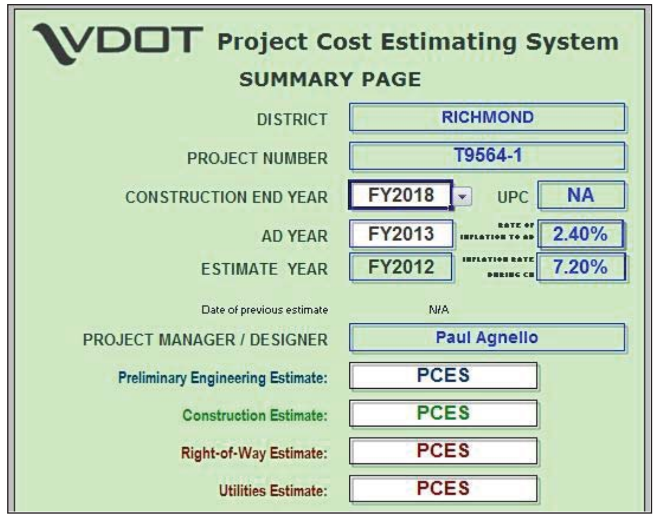

Table 36: 2022 and 2035 VISSIM Travel Time Results – Long-Term Concepts

Long-Term Concepts				Peak Hour	Travel Times (Seconds)							
Concept #	Project Description	Limits of Travel Time Results			2022				2035			
		From	To		No-Build	Build	Δ	%Δ	No-Build	Build	Δ	%Δ
LONG 1	Northbound I-95 Off-Ramp to Dumbarton Road^	NB I-95 Off-Ramp to WB I-64/SB I-195	Dumbarton Road^	AM	107.6	50.9	56.7	52.7%	107.7	50.9	56.7	52.7%
				PM	110.6	51.8	58.8	53.1%	109.8	51.7	58.1	52.9%
	Southbound I-95 On-Ramp from Dumbarton Road^	Dumbarton Road^	SB I-95 Off-Ramp to WB I-64/SB I-195	AM	145.2	138.6	6.6	4.5%	162.8	151.6	11.2	6.9%
				PM	109.1	107.3	1.8	1.6%	113.0	110.8	2.2	1.9%
	Eastbound I-64/Northbound I-195 to Northbound I-95 - 2 Lane On-Ramp	EB I-64 west of Staples Mill Road	Dumbarton Road^	AM	386.2	352.9	33.3	8.6%	476.1	419.2	56.9	11.9%
		NB I-195 from Broad Street	Dumbarton Road^	PM	441.9	336.2	105.8	23.9%	532.6	413.7	118.8	22.3%
LONG 2	Northbound I-95/I-64 Braided Ramps	NB I-95 On-Ramp from Belvidere	NB I-95 Off-Ramp to WB I-64/SB I-195	AM	258.6	220.7	37.9	14.7%	350.2	172.4	177.7	50.8%
				PM	243.1	205.4	37.7	15.5%	322.7	158.9	163.8	50.8%
	Southbound I-95/I-64 Braided Ramps	SB I-95 Off-Ramp to WB I-64/SB I-195	SB I-95 On-Ramp from Robin Hood Road	AM	109.3	112.5	-3.1	-2.8%	165.0	138.7	26.4	16.0%
				PM	128.5	122.8	5.7	4.4%	284.4	227.4	57.0	20.0%
LONG 3	Northbound I-95/I-64 On- & Off-Ramps to/from Belvidere Street	NB I-95/I-64 On-Ramp from 7th Street	NB I-95/I-64 Off-Ramp to Hermitage Road	AM	210.2	191.4	18.7	8.9%	291.4	193.0	98.4	33.8%
				PM	194.2	171.3	22.9	11.8%	295.7	191.7	104.0	35.2%
LONG 4	Westbound I-64 to Southbound I-95 Directional Ramp	WB I-64 east of I-95/I-64 Overlap	SB I-95 On-Ramp from WB I-64	AM	73.4	70.9	2.5	3.5%	108.6	70.3	38.3	35.3%
				PM	73.8	73.3	0.4	0.6%	124.8	75.5	49.4	39.5%
LONG 5	Northbound I-95 Braided Ramps	NB I-95 On-Ramp from Route 195	NB I-95 Off-Ramp to EB I-64	AM	55.4	42.0	13.4	24.2%	75.9	46.0	29.9	39.4%
				PM	96.8	37.1	59.7	61.7%	189.3	40.6	148.7	78.6%
LONG 6	Northbound Slip Ramp from N. 14th Street, Broad Street & 14th - At-Grade Intersection (Includes Long-Term Concept 5)	NB I-95 On-Ramp from Route 195	NB I-95 On-Ramp from WB I-64	AM					87.4	61.9	25.6	29.3%
				PM					160.1	53.1	107.0	66.8%

^ Dumbarton Road is not included in the study area; however, proposed ramp connections to Dumbarton Road as part of Long-Term Concept 1 were modeled in VISSIM to analyze the interaction with the interstate mainline and for comparison purposes.

8.0 Planning Level Cost Estimates

Construction estimated right-of-way costs were developed for the SYIP projects for the purposes of carrying them forward for more evaluation. Planning level cost estimates were also developed for the long-term concepts to understand the order of magnitude required to fund the larger scaled projects. VDOT staff used the Project Cost Estimating System (PCES) as the primary tool for estimating project costs for SYIP candidate projects. PCES is the project cost estimation tool used in Virginia for SYIP project cost development and accounts for the full range of potential project costs including preliminary engineering (PE), right of way (ROW), construction, utilities, signing, bridge, and other miscellaneous project costs. Planning level cost estimates were developed in context to the level of detail available in this study.



Photograph 17: Screenshot of PCES Summary Page

Table 37 showing the key assumptions used in PCES for project cost estimation for this study. The only candidate project which used a different cost estimation tool was the I-195/Laburnum Avenue Interchange project which used a planning estimate developed from the VDOT Transportation & Mobility Planning Division (TMPD) Statewide Planning Level Cost Estimates spreadsheet. This approach was used because the study team felt that it was a better tool for estimating potential roundabout costs. The same key assumptions used in PCES were used for this approach (e.g., construction year, inflation rate, etc.) A screenshot of this spreadsheet is shown in **Photograph 17**.

Table 37: PCES Assumptions

Key Assumption	Value
VDOT District	Richmond
Ad Year	2013
Construction Year	2018
Inflation Rate	2.40%

For all SYIP projects, costs were broken down into the three categories used for development: PE, ROW, and Construction (CN). Lastly, costs for these three categories were rounded to the nearest $10,000 and summed to determine the total project cost as summarized in **Table 38**. Estimated project costs range from $500,000 to $15,560,000 for a grand total of $61,755,000 for all eleven SYIP projects. Some of the SYIP projects can be implemented in phases, such as the constructing corridorwide emergency pull-offs, in which case sub-cost by phase are provided.

Planning level cost estimates were developed to provide an order of magnitude for the significant funding investment required to implement long-term concepts throughout the I-95/I-64 overlap corridor. Cost estimates were developed for one long-term concept at each of the major interchange areas, specifically the Bryan Park interchange to Hermitage Road (Long-Term #1), Bryan Park interchange to Boulevard (Long-Term #2), Belvidere Street/Chamberlayne Parkway interchange (Long-Term #11), and the I-64 East interchange to Broad Street (Long-Term #12). Because the scale of the long-term concepts was greater than the SYIP projects with many unknowns (e.g., impacts to utilities, environmental permitting and mitigation requirements, etc.) a more conservative approach was used to develop planning level cost estimates for the long-term concepts. Planning level costs for major construction items such as roadway improvements, drainage, and bridge improvements were developed in context to the level of detail available in this study and are documented in **Appendix T**. A range of costs rounded to the nearest $100,000 is summarized in **Table 39** along with key assumptions regarding the development of PE, ROW, and construction costs. Estimated costs range from $47,800,000 to $602,600,000 with a total as high has $948,000,000 for the four long-term concepts. Similar to the SYIP projects, the long-term concepts should be implemented in phases.

Table 38: SYIP Planning Level Cost Estimate

No.	Location	Improvement Description	Planning Level Cost Estimate PE	ROW	Construction	Total
SYIP 1	Southbound I-95 North of Bryan Park Interchange	ITS - Low Bridge Warning System	$ 25,000	$ -	$ 100,000	$ 125,000
	Northbound I-95 South of the James River	ITS - Low Bridge Warning System	$ 25,000	$ -	$ 100,000	$ 125,000
	Eastbound I-64 West of Bryan Park Interchange	ITS - Low Bridge Warning System	$ 25,000	$ -	$ 100,000	$ 125,000
	Westbound I-64 East of the Shockoe Valley Bridge	ITS - Low Bridge Warning System	$ 25,000	$ -	$ 100,000	$ 125,000
		SYIP 1 Subtotal	**$ 100,000**	**$ -**	**$ 400,000**	**$ 500,000**
SYIP 2	Corridor Wide	Signing Upgrades	**$ 1,800,000**	**$ -**	**$ 9,030,000**	**$ 10,830,000**
SYIP 3	I-95/I-64 Hermitage Road Interchange	Install Deceleration Lane to Hermitage Road	**$ 330,000**	**$ 190,000**	**$ 2,020,000**	**$ 2,540,000**
SYIP 4	I-95/I-64 Belvidere Road Interchange	Interchange Safety Improvements	**$ 820,000**	**$ 240,000**	**$ 8,040,000**	**$ 9,100,000**
SYIP 5	I-95/I64 Belvidere Street Interchange	Extend Acceleration Lane	**$ 400,000**	**$ 530,000**	**$ 2,530,000**	**$ 3,460,000**
SYIP 6	I-195/Laburnum Avenue Interchange	Roundabout & Northbound Free-Flow Right-Turn Lane	**$ 440,000**	**$ -**	**$ 1,770,000**	**$ 2,210,000**
SYIP 7	Franklin Street at Southbound I-95 Off-Ramp/15th Street	Interchange Modification to Off-Ramp	$ 220,000	$ 290,000	$ 1,260,000	$ 1,770,000
	Franklin Street at Southbound I-95 Off-Ramp/15th Street	Ramp Pre-Emption	$ 20,000	$ -	$ 15,000	$ 35,000
		SYIP 7 Subtotal	**$ 240,000**	**$ 290,000**	**$ 1,275,000**	**$ 1,805,000**
SYIP 8	Northbound I-95 to Westbound I-64/Southbound I-195	Replace Guide Sign w/Option Lane Issue	$ 52,000	$ -	$ 258,000	$ 310,000
	Southbound I-95 to Westbound I-64	Replace Guide Sign w/Option Lane Issue	$ -	$ -	$ -	$ -
	Southbound I-95 to Eastbound I-64	Replace Guide Sign w/Option Lane Issue	$ 52,000	$ -	$ 258,000	$ 310,000
	Eastbound I-64 to Northbound I-95/Southbound I-195	Replace Guide Sign w/Option Lane Issue	$ 52,000	$ -	$ 258,000	$ 310,000
	Westbound I-64 to Northbound I-95/Southbound I-195	Replace Guide Sign w/Option Lane Issue	$ 52,000	$ -	$ 258,000	$ 310,000
		SYIP 8 Subtotal	**$ 208,000**	**$ -**	**$ 1,032,000**	**$ 1,240,000**
SYIP 9	Bryan Park Interchange - Northbound & Southbound	Emergency Pull-Off	$ 780,000	$ 190,000	$ 3,120,000	$ 4,090,000
	Just south of Boulevard - Northbound	Emergency Pull-Off	$ 390,000	$ 100,000	$ 1,560,000	$ 2,050,000
	Just north of Belvidere - Northbound & Southbound	Emergency Pull-Off	$ 310,000	$ -	$ 3,120,000	$ 3,430,000
		SYIP 9 Subtotal	**$ 1,480,000**	**$ 290,000**	**$ 7,800,000**	**$ 9,570,000**
SYIP 10	Southbound I-95 North of Bryan Park Interchange	ITS - End of Queue Detection System	$ 250,000	$ -	$ 985,000	$ 1,235,000
	Eastbound I-64 West of Bryan Park Interchange	ITS - End of Queue Detection System	$ 250,000	$ -	$ 985,000	$ 1,235,000
	Northbound I-95 South of James River	ITS - End of Queue Detection System	$ 250,000	$ -	$ 985,000	$ 1,235,000
	Westbound I-64 East of Shockoe Bridge	ITS - End of Queue Detection System	$ 250,000	$ -	$ 985,000	$ 1,235,000
		SYIP 10 Subtotal	$ 1,000,000	$ -	$ 3,940,000	**$ 4,940,000**
SYIP 11	Corridor Lighting	High Mast for Mainline & Interchanges	**$ 3,110,000**	**$ -**	**$ 12,450,000**	**$ 15,560,000**
					Grand Total	**$ 61,755,000**

Table 39: Long-Term Concepts - Planning Level Cost Estimates

Long-Term Concept	Concept Description	Planning Level Cost Estimate Range (Rounded to the Nearest $100,000)	
		Minimum	Maxmimum
LONG 1	Northbound I-95 Two-Lane On-Ramp and Dumbarton Road Interchange On- & Off-Ramps	$ 57,200,000	$ 77,400,000
LONG 2	I-95/I-64 Boulevard Interchange (Exit 78) – Braided Ramps	$ 150,500,000	$ 203,700,000
LONG 11	I-95/I-64 Belvidere Street Interchange (Exit 76A) – On- & Off-Ramps	$ 47,800,000	$ 64,700,000
LONG 12	I-95 & Broad Street Interchange (Exits 74 & 75) – Long-Range Vision	$ 445,400,000	$ 602,600,000
	Grand Total =	**$ 700,900,000**	**$ 948,400,000**

Assumptions:
- Preliminary Engineering = 14% of major construction items (roadway, drainage, and bridge costs)
- Right of Way (ROW) = 125% of major construction items (roadway, drainage, and bridge costs)
- Construction costs includes Construction Engineering & Inspection (CEI) = 12.5% of major construction items (roadway, drainage, and bridge cos
- Contingency = 20% of (PE + ROW + Construction)

8.1 Project Summaries

At the request of VDOT, one-page project summaries were developed for each of the 11 SYIP projects to serve as a quick reference when needed. One-page project summaries were also developed for one long-term concept at each of the major interchange areas, specifically the Bryan Park interchange to Hermitage Road (Long-Term #1), Bryan Park interchange to Boulevard (Long-Term #2), Belvidere Street/Chamberlayne Parkway interchange (Long-Term #11), and the I-64 East interchange to Broad Street (Long-Term #12). These concepts are representative of the scale of improvements required to mitigate long-term operational and safety issues throughout the I-95/I-64 overlap corridor. Project summaries include a description of the project, the estimated project cost, and anticipated project schedule (provided for SYIP projects only). The one-page project summary sheets are included in **Appendix R**.

9.0 Prioritization of SYIP Projects

9.1 Benefit-Cost Analysis

A benefit-cost (B/C) analysis was conducted for each of the proposed SYIP projects to compare the cost effectiveness of each project. To quantify the benefit that each of the proposed projects would have on the driving public, the annual delay savings resulting from the proposed improvements was calculated.

To determine annual peak hour delay savings, the calculated delay reduction per vehicle in each respective peak hour was multiplied by the peak hour traffic volume, assuming an average vehicle occupancy of 1.25 and 250 work days per year. The annual peak hour delay savings for each project in 2022 and 2035 dollars is shown in **Table 40**.

According to the Virginia Transportation Research Council (VTRC) *A Return on Investment Study of the Hampton Roads Safety Service Patrol Program study, 2000*, the travel time values for each occupant in a vehicle in Virginia is $15.04/hour and the travel time value for commercial vehicles is $73.32/hour. Using the Consumer Price Index (CPI), the travel time values were grown from 2011. Using the annual peak hour delay savings (based on speed (MPH) and distance traveled) and identified travel time values, the annual cost benefits for each alternative in 2022 and 2035 was determined. The annual cost benefit of reducing delay (benefit) was divided by the annual cost estimate based on service life (cost) to determine the B/C of each alternative shown in **Table 40**.

Most of the SYIP projects show minimal to no B/C improvement due to the minimal travel time savings with the exception of the realignment of ramps at Belvidere Street (SYIP #4) and the intersection improvements at Franklin Street (SYIP #7).

Table 40: Benefit-Cost Analysis of SYIP Projects

Peak Hour	Year: 2022							Year: 2035						
	No-Build Travel Time (sec)	Build Travel Time (sec)	Mainline Travel Time Reduction (sec)	Annual Peak Hour Delay Savings (Hr)	Annual Benefits ($)	Annual Cost Based on Service Life	B/C	No-Build Travel Time (sec)	Build Travel Time (sec)	Mainline Travel Time Reduction (sec)	Annual Peak Hour Delay Savings (Hr)	Annual Benefits ($)	Annual Cost Based on Service Life	B/C
SYIP 3: NB I-95/WB I-64 at Hermitage Road - Install Deceleration Lane														
AM	225.7	212.3	13.4	6,990	$134,211	-	-	323.3	337.5	-14.2	-7,911	-$151,906	-	-
PM	209.3	225.9	-16.7	-9,395	-$169,440	-	-	290.9	285.7	5.3	3,202	$57,756	-	-
Total	**435.0**	**438.2**	**-3.2**	**-2,405**	**($35,229)**	**$254,000**	**-0.14**	**614.2**	**623.2**	**-9.0**	**-4,709**	**($94,150)**	**$254,000**	**-0.37**
SYIP 4: SB I-95/EB I-64 at Belvidere Street - Realignment of On-Ramps														
AM	81.3	82.2	-0.9	-471	-$9,047	-	-	81.6	28.5	53.0	34,056	$653,927	-	-
PM	96.7	96.2	0.4	225	$4,064	-	-	36.2	36.8	-0.6	-433	-$15,030	-	-
Total	**178.0**	**178.4**	**-0.5**	**-246**	**($4,983)**	**$910,000**	**-0.01**	**117.7**	**65.3**	**52.4**	**33,623**	**$638,897**	**$910,000**	**0.70**
SYIP 5: NB I-95/EB I-64 at Belvidere Street - Extend Acceleration Lane														
AM	221.4	206.0	15.4	8,021	$154,013	-	-	318.2	334.7	-16.5	-9,156	-$175,801	-	-
PM	207.1	219.4	-12.3	-6,934	-$125,070	-	-	301.0	294.7	6.3	3,798	$68,496	-	-
Total	**428.5**	**425.4**	**3.1**	**1,086**	**$28,943**	**$346,000**	**0.08**	**619.2**	**629.4**	**-10.2**	**-5,358**	**($107,305)**	**$346,000**	**-0.31**
Peak Hour	**Year: 2022**							**Year: 2035**						
	No-Build Intersection Delay (sec)	**Build Intersection Delay (sec)**	**Intersection Delay (sec)**	**Annual Peak Hour Delay Savings (Hr)**	**Annual Benefits ($)**	**Annual Cost Based on Service Life**	**B/C**	**No-Build Intersection Delay (sec)**	**Build Intersection Delay (sec)**	**Intersection Delay (sec)**	**Annual Peak Hour Delay Savings (Hr)**	**Annual Benefits ($)**	**Annual Cost Based on Service Life**	**B/C**
SYIP 6: SB I-195 Exit Ramp at Laburnum Roundabout & NB I-195 Exit Ramp at Laburnum NB Free-Flow Right Turn														
AM	10.1	7.1	3.0	449	$7,522	-	-	10.0	8.6	1.4	238	$6,575	-	-
PM	12.2	9.8	2.4	458	$7,198	-	-	8.9	8.2	0.7	152	$2,827	-	-
Total	**22.3**	**16.9**	**5.4**	**907**	**$14,720**	**$221,000**	**0.07**	**18.9**	**16.8**	**2.1**	**390**	**$9,402**	**$221,000**	**0.04**
SYIP 7: Franklin Street at SB I-95 Exit Ramp/15th Street														
AM	59.0	26.0	33.0	4,148	$89,316	-	-	29.5	18.5	11.0	238	$136,774	-	-
PM	30.3	24.5	5.8	590	$10,641	-	-	35.8	35.5	0.3	152	$633	-	-
Total	**89.3**	**50.5**	**38.8**	**4,738**	**$99,957**	**$180,500**	**0.55**	**65.3**	**54.0**	**11.3**	**390**	**$137,407**	**$180,500**	**0.76**

9.2 Prioritization Matrix

The benefit-cost analysis was only dependent on travel time savings and did not include a more comprehensive evaluation of the specific benefits from each project. For this reason, the 11 proposed SYIP projects were prioritized based on the following three measures of effectiveness (MOEs): operations, safety, and cost. Each prioritization factor was weighted equally (a maximum of 33 points for each factor) to develop a prioritization ranking for the 11 SYIP projects.

<u>Operations MOE</u>

To determine the impact of the operations MOE, a maximum score of 33 points was assigned to project with the largest travel time reduction in 2022. A score was assigned to the remaining projects proportionately compared to the project with the largest travel time reduction. Operations impacts based on the proposed non-geometric improvements could not be modeled using a traffic simulation tool; however, many of them would have a positive impact on operations. Therefore, proportional points for non-geometric improvements were qualitatively allocated based on the following ranges: 0, 11, 22, or 33.

<u>Safety MOE</u>

To determine the impact of the safety MOE, a maximum score of 33 points was assigned to the project with the largest reduction in crashes. A score was assigned to the remaining projects proportionately compared to the project with the largest reduction in crashes. A score of zero was assigned to those projects with no related crashes.

<u>Planning Level Cost Estimate MOE</u>

To determine the impact of the cost MOE, a maximum score of 33 points was assigned to the project with the lowest cost. Since the cost of SYIP #1 was significantly lower than the other ten projects, a score of 33 was also assigned to the project with the second lowest cost. A score was assigned to the remaining projects proportionately compared to the assigned cost of each project.

The prioritization ranking was the sum of the three prioritization factor scores for each project, which allowed the study team to rank the 11 SYIP projects for comparison purposes. The prioritization factors, prioritization ranking, and overall rankings are shown in **Table 41**. SYIP #1 – Low Bridge Warning System ranked first among the 11 SYIP projects while SYIP #2 – Corridor Signing Upgrades ranked last among the 11 SYIP projects.

10.0 Next Steps

The I-95/I-64 Overlap Study should be used as a planning tool to achieve the next steps of planning, programming, designing, and constructing the identified safety and operational improvements in the study corridor. Specific steps include:

1. VDOT should implement the recommended short-term improvements once resources become available.
2. VDOT should advance the recommended SYIP improvement projects to the preliminary engineering design stage, so a more refined cost estimate and schedule can be developed. If necessary, supplemental environmental and traffic engineering studies should be conducted to move these projects along the project development process.
3. VDOT should continue to study and refine the operational and environmental impacts of the recommended long-term concepts. This analysis should include investigating the possibility of a phased approach to programming the long-term concepts by developing a subset of smaller projects with independent utility. This process should continue to involve the technical expertise of a study work group to evaluate alternatives while building consensus at the federal, state, and local levels.
4. VDOT should continue to coordinate with the City of Richmond, Henrico County, the Richmond MPO, and within VDOT to aggressively work towards the programming of the SYIP projects and long-term concepts.

Table 41: Prioritization Matrix of SYIP Projects

Improvement	Type of Improvement	Prioritization Factors										Prioritization Ranking	Overall Ranking
		2022 Operational MOE		Safety MOE						Cost			
		Travel Time Reduction (AM & PM Peak Hour) Δ	Score (Max. of 33 Points)	Total # Crashes (2007 to 2009)	Crash Reduction Factor	Type of Related Crashes	# of Related Crashes	Reduction in Crashes	Score (Max. of 33 Points)	$	Score (Max. of 33 Points)		
SYIP 1 - ITS - Low Bridge Warning System													
- Southbound I-95 North of Bryan Park Interchange - Eastbound I-64 West of Bryan Park Interchange	Non-Geometric	0.0	33*	^	-	-	-	-	0	500,000	33.0	66.0	1
SYIP 7 - Southbound I-95 Off-Ramp/15th Street at Franklin Street (Exit 74B) Improvements													
Franklin Street	Geometric	38.8	33	4	0.35	Sideswipe Same Direction Fixed Object - Off Road	4	1	0	1,805,000	22.7	55.8	2
SYIP 3: Northbound I-95/I-64 at Hermitage Road - Install Deceleration Lane													
Northbound I-95/I-64	Geometric	-3.2	0	373	0.75	ALL	373	280	33	2,540,000	16.1	49.1	3
SYIP 5: Northbound I-95/I-64 at Belvidere Street - Extend Acceleration Lane													
Northbound I-95/I-64	Geometric	3.1	3	350	0.75	ALL	350	263	31	3,460,000	11.8	45.4	4
SYIP 9 - Emergency Pull-Offs													
Corridor wide	Non-Geometric	0.0	33*	1724	0.13	Fixed Object - Off Road Sideswipe Same Direction Non-Collision	406	53	6	9,570,000	4.3	43.5	5
SYIP 8 - Corridor Signing - Replace 5 Option Lane Issue Signs													
Corridor wide	Non-Geometric	0.0	11*	^	-	-	-	-	0	1,240,000	32.0	43.0	6
SYIP 10 - ITS - End of Queue Detection System													
Approaches to I-95/I-64 Overalp - Southbound I-95 North of Bryan Park Interchange - Eastbound I-64 West of Bryan Park Interchange - Northbound I-95 South of James River - Westbound I-64 East of Shockoe Bridge	Non-Geometric	0.0	33*	^	-	-	-	-	0.00	4,940,000	8.3	41.3	7
SYIP 11 - Corridor Lighting Upgrades													
Corridor wide	Non-Geometric	0.0	11*	1538	0.50	Darkness - Not Lighted Darkness - Lighted	362	181	21	15,560,000	2.6	35.0	8
SYIP 6: Southbound I-195 Exit Ramp at Laburnum Roundabout & Northbound I-195 Off-Ramp at Laburnum Northbound Free-Flow Right Turn													
Laburnum Ave	Geometric	5.4	5	4	0.72	ALL	4	3	0	2,210,000	18.5	23.5	9
SYIP 4: Southbound I-95/I-64 at Belvidere Street - Realignment of On-Ramps													
Southbound I-95	Geometric	-0.5	0	199	0.75	ALL	199	149	18	9,100,000	4.5	21.7	10
SYIP 2 - Corridor Signing Upgrades													
Corridor wide	Non-Geometric	0.0	11*	^	-	-	-	-	0	10,830,000	3.8	14.8	11

Notes:

^ Unable to determine related crashes

* Operational impacts based on the proposed non-geometric improvements could not be modeled using a traffic simulation tool; however, would have some impact on operations. For purposes of this project operational points for non-geometric improvements were qaulitatively allocated based on the following range 0, 11, 22, or 33.

Appendix A: Lane Configuration Figures


Appendix B: Past Studies

Appendix C: Origin-Destination Data

Appendix D: Traffic Counts


Appendix E: Peak Hour Calculations

Appendix F: Heavy Vehicle Percentages


Appendix G: Crash Data & Analysis

Appendix H: Interstate Assest Management Inventory

Appendix I: Corridor Geometric Deficiencies

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Appendix J: VISSIM Model – Existing Conditions Calibration Report

Appendix K: VISSIM Results - Existing 2011

Appendix L: VISSIM Results - Future No-Build 2022

Appendix M: VISSIM Results - Future No-Build 2035

Appendix N: VISSIM Results - Future Build 2022 SYIP Projects

Appendix O: VISSIM Results - Future Build 2022 Long-Term Concepts

Appendix P: VISSIM Results - Future Build 2035 SYIP Projects

Appendix Q: VISSIM Results - Future Build 2035 Long-Term Concepts

Appendix R: Project Summaries

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Appendix S: Other Concepts Considered

Appendix T: Planning Level Cost Estimates – Long-Term Concepts