BROAD STREET RAPID TRANSIT STUDY

ENVIRONMENTAL ASSESSMENT

APPENDIX A-1: Technology Assessment Report

BROAD STREET RAPID TRANSIT STUDY: TECHNOLOGY ASSESSMENT

The purpose of this technical memorandum is to document the results of an initial screening of mode technologies for the Broad Street Rapid Transit Study based on technical attributes and order-of-magnitude costs. Several studies of the Richmond area over the past decade have analyzed the potential for transit improvements along the Broad Street Corridor. This document will review the findings of those studies with specific regard to the implications each mode would hold for the project, assess each of the technologies previously studied, and provide the basis for the decision to study in detail the implementation of BRT within the Broad Street Corridor.

1.0 BACKGROUND

The Broad Street Corridor runs through the heart of the Richmond, Virginia region. The initial phase of transit investment concerns a 7-mile portion of the corridor, connecting (from west to east) Willow Lawn in Henrico County, the museum district, Virginia Commonwealth University (VCU), the central business district (CBD), the state capitol, Main Street Station (currently intercity rail; potentially a center for high-speed rail) and the Rocketts Landing redevelopment area. The corridor also links the region's highest density residential neighborhoods and its most significant employment centers.

Broad Street itself is of considerable width, generally containing three travel lanes in each direction as well as a median. While the Richmond Area Metropolitan Planning Organization (RAMPO) does not define Broad Street as "impaired" or "congested" (where average speeds are significantly lower than posted speeds), they do use those designations for two adjacent parallel highway facilities (I-64 and I-95). All transit-related studies of the Richmond area over the last decade have identified the corridor as a priority for transit improvement. At present, the Greater Richmond Transit Company (GRTC) offers 39 fixed-route bus services, and most utilize or cross Broad Street at least once in their alignment. During the peak periods, the combined headway can average 75 seconds on some street segments in the CBD.

Though roughly a dozen of GRTC's lines run express with few or no stops between outlying areas and the CBD, the agency currently offers no premium service where transit vehicles operate in dedicated rights-of-way or receive preferential treatment on shared roadway.

2.0 ASSESSMENT OF TRANSIT TECHNOLOGIES

The initial range of alternatives includes four technologies: light rail transit, bus rapid transit, streetcar and enhanced bus service. For the purposes of this document, the term "technology" refers to the type of right-of-way (mixed traffic or exclusive), guidance (steered or guided) and propulsion (electric or internal combustion). Each technology's combination of these attributes has major implications for its time, cost and mobility improvement potential within the Broad Street Corridor.

2.1 Light Rail Transit

Light rail transit (LRT) is the most capital-intensive alternative of those considered to date for the Broad Street Corridor. LRT operates as a single rail vehicle or a short train (two to four cars). Right-of-way can be exclusive, though it often operates with mixed traffic in CBDs. Along roadways and at intersections with high traffic volumes, the right-of-way may be grade-separated to reduce conflicts. Station spacings average ¼ of a mile to one mile depending on surrounding land uses and the desired speed of service.

Propulsion is usually drawn from overhead electric catenary lines; in rare cases onboard diesel engines are used. Overhead electric propulsion has the advantages of low noise and no local air pollution.

Several past studies have considered the implementation of LRT along the Broad Street corridor. The first report entitled Richmond Rail Transit Feasibility Study was completed for the Virginia Department of Transportation (VDOT) and RAMPO in 2003. One of their screened alternatives was a light rail line along Broad Street. (The alignment was slightly different than that currently proposed; it reached only Main Street Station to the east but extended to Short Pump in the west.) This roughly 14-mile line was estimated to cost $791M (2003 dollars). More recently, RAMPO completed the Richmond Regional Mass Transit Study (2008). This report analyzed a slightly longer route, but provided useful cost comparisons. They estimated a 17.6-mile Broad Street light rail line would cost $973M (2006 dollars).

2.2 Bus Rapid Transit

Bus Rapid Transit (BRT) shares right-of-way features with LRT, but not guidance or propulsion. BRT's service characteristics can be nearly identical to LRT. Speedy operation is achieved with dedicated right-of-way; longer stop spacing, traffic signal priority at intersections; and off-board fare collection with multiple points of entry/exit for rapid boarding. Additionally, both stations and vehicles are distinctively branded similar to rail transit services to attract greater ridership.

With respect to guidance and propulsion, BRT is similar to typical bus service. Vehicles are rubber-tired and steered by an operator. This characteristic can allow BRT to repurpose existing roadways for exclusive bus travel and forego much of the costly new infrastructure required by LRT. The lower level infrastructure investment makes BRT faster and less expensive to implement.

BRT propulsion almost always relies on the internal combustion engine. Compressed natural gas (CNG) or hybrid-electric diesel buses are often used in urban areas to help meet regional air quality goals. BRT vehicles are smaller than LRT vehicles and do not have the capability of making a train. However, BRT often uses articulated vehicles to increase line capacity.

BRT has been considered in several of the recent Richmond-area transportation studies. A 2008 Comprehensive Operations Analysis (COA) of the GRTC proposes BRT for the 7.3-mile alignment now being considered in this assessment of alternatives process. Later that same year, the Richmond Area Metropolitan Planning Organization (RAMPO) adopted the findings of the Richmond Regional Mass Transit Study which set forth a transit system plan for the Richmond Metropolitan area. This study, conducted in coordination with GRTC's COA, produced a plan of action for the development and implantation of regional mass transit programs over the mid-range and long-range with consideration given to corridor prioritization.

As a part of this study, multiple technologies were studied for the major transportation corridors in the region, including Broad Street. As shown in the following table, this plan recommends a phased implementation approach for transit improvements in the region and the Broad Street Corridor.

RECOMMENDATIONS OF THE RICHMOND REGIONAL MASS TRANSIT STUDY

TIER	DESCRIPTION	BROAD STREET RECOMMENDATIONS
I	Corridors and modal alternatives that existing development patterns could support	BRT on Broad Street from Rocketts Landing to Willow Lawn
II	Corridors and modal alternatives that projected development patterns for 2031 could support	BRT on Broad Street from Rocketts Landing to Short Pump
III	Corridors and modal alternatives that would require significant changes to projected development patterns by 2031 to be supported	LRT on Broad Street from Rocketts Landing to Short Pump

Implementation of both BRT and LRT were studied relative to the Broad Street Corridor. However, LRT was only considered feasible after 2031 given its substantially higher capital and operating costs. For the 17.6-mile route to Short Pump, LRT was estimated to carry a $973M capital cost and BRT alternative was estimated to cost only $54.4M (2006 dollars). Using those values on a per mile basis, the 7.3-mile route envisioned for Tier I or first phase would run $404M for LRT and $23M for BRT (2006 dollars).

2.3 Streetcar

Streetcars share technical elements of both LRT and regular bus service. Like LRT, streetcars use a steel rail guideway and overhead electric propulsion. This technology can be implemented at a lower cost than LRT; however, it costs substantially more than BRT. Depending on design criteria and local conditions, streetcar tracks can sometimes be placed in existing streets for a much lower capital investment than LRT. Streetcar vehicles tend to be lower profile and lower capacity than LRT vehicles. They are most frequently used for circulation within an urban district, not as a link between multiple urban districts.

Their right-of-way and service characteristics are almost identical to local bus service. Streetcars operate in mixed traffic and make frequent stops (every 2-4 blocks), keeping average travel speeds low.
Stops may consist of a weather-protected shelter, but often do not have the amenities associated with an LRT station.

In 2004, GRTC conducted the Downtown Richmond Streetcar Study to study in more detail specifically what a streetcar network might look like in Richmond. Planners envisioned a 5-phase process, with an initial alignment on Broad Street. This first phase would run only 1.8 miles, however, at a cost of $42M (2004 dollars). Using that per mile figure along the proposed 7.3-mile route would place the full capital cost in the range of $180M (using the CPI to adjust to 2006 dollars, for comparison to LRT and BRT figures above).

3.0 Summary of Previous Studies

The chart on the following page summarizes the previous studies of transit improvements in the Richmond area.

PREVIOUS STUDIES OF TRANSIT IMPROVEMENTS IN THE BROAD STREET CORRIDOR

Study	Date	Modes Considered	Estimated Capital Cost[1, 2]	Estimated Ridership	Comments
Richmond Rail Transit Feasibility Study (VDOT and RAMPO)	June 2003	Light Rail Transit	$451M	33,700 rides/day for 13.5-mile route (Main Street Station to Short Pump)	Forecasts for cost and ridership based on sketch models derived from other light rail systems; ridership estimate exceeds the number of households identified as within ½ mile of the route by 10,400
Downtown Richmond Streetcar Study (GRTC)	Sept. 2004	Streetcar	$180M	1,000 to 3,000 rides/day for 1.8-mile route (Main Street Station to VCU)	Forecasts for cost and ridership based mostly on comparability with other streetcar systems, not on local conditions or travel demand models
Comprehensive Operations Analysis (GRTC)	March 2008	Bus Rapid Transit	No cost estimate	No specific ridership forecast, but points out that route 6 very closely follows the proposed 7.6-mile alignment with 3,600 rides/day	Route 6 ridership is a useful baseline, but given that around 20 other routes currently use some portion of Broad Street and the potential to attract new users, actual ridership would likely be higher
Richmond Regional Mass Transit Study (DRPT and RAMPO)	May 2008	Bus Rapid Transit	$23M	14,000 rides/day for 17.6-mile route (Rocketts Landing to Short Pump)	Ridership estimate is an assumed 1% mode share of total trips projected for the corridor in 2031 by RAMPO
		Light Rail Transit	$404M	Same as above	

Notes: [1] Per mile costs adjusted to fit a 7.3-mile route and given in 2006 dollars; [2] Adjusted to 2006 dollars using the Consumer Price Index (CPI).

All of the studies outlined in the chart on the previous page were performed at the feasibility scale. Each one advised further analysis before moving forward with any sort of project implementation. Ridership estimates have been particularly rough and may have overstated potential in some cases. Analysis using a regional travel demand model is now necessary to gauge the likely benefits of transit investment. More sophisticated cost estimates are also necessary. However, it is already clear that both LRT and streetcar options would involve significantly higher capital costs than BRT.

4.0 SCREENING ANALYSIS

A synthesized evaluation of the technology alternatives is presented below.

BRT would be a cost-effective means of meeting near- and long-term transit needs.

At reasonable capital cost, BRT would provide the region with its first premium transit service. The *Richmond Regional Mass Transit Study* devised a three-tiered implementation approach for improving transit (see table in section 2.2). The study placed a Willow Lawn-Rocketts Landing BRT project on Tier I, defined as a service for which current land development and travel patterns indicate there is sufficient demand. An LRT option was placed on Tier III, indicating significant risk it would not be an effective investment without substantial changes to the growth patterns projected for the region.

These findings would not preclude planners from envisioning alternative higher-density growth patterns. However, until it becomes clear that growth patterns are indeed changing, BRT can provide a practical near-term solution under the Small Starts program while opening the door to various long-term alternatives.

BRT would support plans for expanding and enhancing transit services in the region.

Organizations including the DRPT, RAMPO and GRTC have all expressed interest in introducing premium transit service in Richmond. The most recent studies undertaken by those agencies (*Comprehensive Operations Analysis* and *Richmond Regional Mass Transit Study*) both identified BRT as the appropriate mode technology for initial investment in the Broad Street Corridor. Likewise, preliminary engineering for BRT is included in RAMPO's 2009-2012 Transportation Improvement Program (TIP) and full BRT construction is included in RAMPO's 2031 Long-Range Transportation Plan.

The proposed alignment would support other regional transportation plans. The GRTC *Comprehensive Operations Analysis* calls for five new transit centers, three of which are on the 7.3-mile proposed route. These locations would be the transfer hubs of a rationalized route system for all GRTC buses. A transit center in downtown could serve as a major intermodal connection for the region. The City, GRTC and Amtrak are working to integrate buses, airport shuttles, taxis, intercity trains and, possibly, high-speed trains at this location. BRT on Broad Street and at Main Street Station would provide visitors and travelers with a high quality transit connection to many of Richmond's major destinations.

BRT would comply with regional plans and support local development plans.

The City of Richmond has a future land use agenda that prioritizes transit supportive development. Its draft *Richmond Downtown Plan* calls for a density and mix of land uses compatible with increased transit use. The *Plan* specifically endorses the BRT project recommended in the GRTC *Comprehensive Operations Analysis* with an eye toward possible future conversion to a rail mode.

Henrico County also has transit supportive land use plans. Its Urban Mixed Use zoning designation could provide the right framework for transit-oriented districts at route terminals in Rockett's Landing and Willow Lawn.

Because light rail or streetcar would follow the same alignment as BRT, they would offer very little in terms of cost savings and would introduce additional impacts.

Guided modes of transportation require great infrastructure investment. While all modes would involve the purchase of vehicles, LRT and streetcar would have the added capital expense of track and overhead catenary. A streetcar might provide some cost savings by foregoing the construction of stations and physically separated right-of-way, but those cost savings would not compare to the added costs of track and electrical systems. Given the generous width of Broad Street, exclusive right-of-way would not require much additional land acquisition, making it a negligible cost consideration. Since neither a BRT nor an LRT project proposes significant grade separation, travel times along the corridor between the two would be comparable.

Rail modes have lower noise and no local air pollution impact, but it is important to remember that a BRT trunk line on Broad Street with feeder service to transfer stations would also result in a net decrease in bus traffic, reducing existing inputs to local noise and air pollution.

Current forecasts of population and employment growth indicate that the increased capital and operating costs of light rail and streetcar would not be offset by commensurate increases in ridership benefits.

LRT does provide the opportunity for greater line capacity, and rail modes can prove more effective at attracting choice riders. However, current forecasts for population and employment do not indicate there will be sufficient growth along the Broad Street corridor to produce the kind of immediate demand necessary to justify the additional infrastructure costs. Should future trends shift substantially enough to warrant reconsideration, BRT investment in exclusive right-of-way, stations, traffic signal priority and off-board fare collection can serve as a preliminary investment in higher capacity services.

The additional capital requirements and costs associated with light rail and streetcar would make them uncompetitive candidates for Small Starts funding.

Local officials have expressed interest in applying for a grant through the FTA's Small Starts Program for this project. A stipulation of that program limits FTA grants to $75M and limits total project cost to $250M. Such restrictions would likely make the full 7.3-mile route ineligible for Small Starts funding with LRT as the selected mode. Streetcar might also push the limits of Small Starts funding. With low prospects for significantly higher ridership in the near and medium terms, the almost tenfold higher capital cost for streetcar would make it less competitive in an FTA grant application.

5.0 CONCLUSION

The above evaluation indicates BRT would be the most cost-effective investment for the Broad Street Corridor at the present time. Its technical attributes would allow it to address local transportation needs, support economic development plans and achieve environmental objectives, all within difficult fiscal constraints. Most importantly, the lower capital costs of BRT would make it a more competitive candidate for Small Starts funding, while offering the opportunity to phase in rail alternatives once ridership and land use in the study area warrant further investment.

BROAD STREET RAPID TRANSIT STUDY

ENVIRONMENTAL ASSESSMENT

APPENDIX A-2: Initial Definition of Alternatives Report

Note: At the time this technical memorandum was prepared, the opening year was anticipated to be 2015. At the time this EA was completed, the opening year has been revised to 2017. All references in the main EA document have been updated, but the information in the technical report remains relevant.

BROAD STREET RAPID TRANSIT STUDY: INITIAL DEFINITION OF ALTERNATIVES

The GRTC Transit System and Virginia Department of Rail and Public Transportation (GRTC/DRPT) are conducting an Alternatives Analysis consistent with the requirements of the Federal Transit Administration's (FTA) Small Starts program to evaluate transit improvements along the Broad Street corridor. As required by FTA and documented in the *Broad Street Corridor Rapid Transit Study Evaluation Methodology*, this assessment of alternatives will begin with an initial set of conceptual alternatives which will then be evaluated, screened, and presented to the general public for discussion and feedback. Feedback from the public and the results of the initial screening will then be used to eliminate the least viable alternatives and refine the remaining alternatives further.

In this context, the purpose of this document is to establish an initial set of alternatives that may serve as the basis for preliminary discussions with the study's stakeholders. Each of the alternatives described in this document have been defined in sufficient detail to allow for a qualitative assessment of (a) how well each alternative meets the goals and objectives established for this study; and, (b) how the alternatives compare to one another in terms of costs, benefits, and impacts.

As required by the FTA Small Starts program, there are three general categories of alternatives to be considered as part of this study:

- No-Build Alternative
- Baseline Alternative
- Build Alternatives

Each of these categories and their associated alternatives is summarized in the table on the following page and presented in greater detail in the remaining sections of this technical memorandum.

SUMMARY OF INITIAL ALTERNATIVES

	No-Build*	Baseline	Build Alternatives	
			Build 1	Build 2
Route Length (mi.)	n/a*	7.6		
Miles of Dedicated Bus Lanes	0.75	0.75	3.4	6.7
Number of Stations	Existing local stops	16 stations		
Peak/Off Peak Frequency (min.)	n/a**	10/15		
Hours of Operation	Weekdays: 5:30 AM-11:30 PM Weekends: 6:00 AM-11:30 PM			
Network Changes and Feeder Service	None	Comprehensive Operations Analysis Phase I and Phase II recommendations		
Fare Collection	On-board (cash, Go Cards)		Off-board Proof of purchase (BRT tickets)	
Vehicles	Existing GRTC vehicles		Dedicated BRT vehicles	
Intelligent Transportation Systems	Existing traffic control systems	Signal priority at intersections along bus lanes		
Branding?	No	Stations only	Stations, vehicles, guideway, signage, marketing efforts	

*No service currently operates the entire length of the proposed route. All statistics refer to the three branches of the existing Route 6 service, which serves the majority of the proposed alignment.
**The three branches of the Route 6 currently offer a combined headway of 6-12 minutes during peak hours and 12 minutes during off-peak hours of operation.

1.0 NO-BUILD ALTERNATIVE

The No-Build Alternative is required by NEPA to provide a basis of comparison for the Baseline and Build alternatives, defining what would happen in the study area in the absence of specific facility and operational improvements to the transit system as defined by the other project alternatives.

The No-Build Alternative includes all existing and committed transportation facilities and services that will be operational in the opening year, 2015. In this context, "committed" transportation improvements are those that are programmed in the Richmond Area Metropolitan Transportation Organization's (MPO) financially-constrained Long Range Transportation Plan for implementation by 2015.

1.1 Existing Transit Services and Facilities

The existing GRTC Transit System consists of 39 routes, including 26 local routes and 13 express routes. Service within the City of Richmond operates 20 hours a day, seven days a week. In Henrico County, express services operate during peak hours on weekdays, from 7:00 to 9:30 AM and from 4:00 to 6:00 PM.

As of 2007, the system was operated by a fleet of 169 buses. The majority of the fleet consists of 35'-40' vehicles, all of which are equipped with wheelchair lifts. GRTC is transitioning to a fleet of low-floor buses, which will reduce passenger boarding and alighting times and improve wheelchair and stroller accessibility. All fare collection is done on-board buses. Both cash fares and Go Cards are accepted as payment (exact change is required for cash fares.)

Within the study area, over 20 routes operate along Broad Street for some portion of their alignment, providing a combined frequency of service along the corridor ranging from 19 to 48 buses an hour (see Table 1-1.)

TABLE 1-1: BUSES PER HOUR ON BROAD STREET

Eastbound	20th St	8th St	Belvedere	Robinson	Average
AM Peak	16.8	44.4	24.8	19.6	*26.4*
Midday	12.9	33.4	21.8	15.5	*20.9*
PM Peak	19	48	26	21	*28.5*
Saturday	9.3	24.5	15.7	11.7	*15.3*
Sunday	7.3	17.3	10.8	7.8	*10.8*
Average	*13.1*	*33.5*	*19.8*	*15.1*	

Westbound	20th St	8th St	Belvedere	Robinson	Average
AM	17.6	36	29.2	21.2	*26*
Midday	12.5	26.8	22.9	14.9	*19.3*
PM	19.5	38	31	19.5	*27*
Saturday	9.3	20.5	16.8	11.5	*14.5*
Sunday	7.5	14.5	12.3	8	*10.6*
Average	*13.3*	*27.2*	*22.4*	*15.0*	

Source: GRTC Comprehensive Operations Analysis, 2007, p. 6-2

Existing transit facilities in the corridor consist of the following:

Transit stops. Transit stops within the corridor are spaced approximately one block apart from each other. Under current operating protocols, buses are not permitted to skip stops. All bus stops and transfers within the corridor occur on-street, in the shoulder lane, typically on the near-side corner of an intersection. Transit shelters are present throughout the majority of the downtown area; benches are present at stops in the outlying areas of the corridor.

Peak hour bus lanes. Between 2nd Street and 14th Street, the curbside lanes are limited to bus traffic from 7:00 to 9:00 AM and from 4:00 to 6:00 PM. On-street parking is allowed in these lanes at all other times. As shown in Figure 1-1, the existing bus lanes are narrower than standard transit vehicles operating in the corridor—between 9.5 and 10 feet in width. This is less than the VDOT standard design width of 11 feet, and causes buses operating in the corridor to encroach on adjoining general traffic lanes.

Figure 1-1: Existing Curbside Bus Lanes.

Main Street Station. Main Street Station is the historic downtown train station for Richmond, located on Main Street between I-95 and 17th Street. The station currently operates as a stop along Amtrak's Northeast Regional service, with three northbound and four southbound trains serving the station daily. GRTC routes currently serve the station at curbside transit shelters located along Main Street and shelters located on the western parking lot for the station.

1.2 Programmed Improvements

At this time, there is only one major capital improvement within the study corridor that has been programmed and funded for implementation by 2015: Main Street Station Phase 3. This project represents the final phase of the restoration of Main Street Station, and is intended to maximize opportunities for passenger rail service and enhance the role of this station as a multimodal transfer center. The November 2009 *Regional Transportation Priority Projects Report* published by the Richmond Area MPO lists Main Street Station Phase 3 as the top-ranked priority in the FY 10-FY15 Six Year Improvement Program (SYIP). It should be noted that this project is being completed independently of the Downtown Transfer Center (see Section 1.3).

In addition, the City of Richmond has an ongoing Signal Timing Optimization Program, being implemented as part of its Congestion Mitigation and Air Quality (CMAQ) Improvement Program. The third phase of this project was completed in 2008, resulting in a 48% decrease in travel delay along Broad Street and a 19% decrease in travel delay along Main Street. The City currently has plans for system upgrade to be implemented by the opening year. While the proposed system upgrade does not explicitly provide for transit signal prioritization, such an improvement would not be precluded from inclusion in the system. For the purposes of the No-Build alternative, it is assumed that the signal upgrade would be completed by the opening year, and would not include signal prioritization for transit vehicles.

1.3 Proposed Improvements

In March 2008, GRTC performed a Comprehensive Operational Analysis (COA) of its services in an effort to identify modifications and improvements that would improve the operational efficiency and effectiveness of the system while encouraging transit usage in choice ridership markets. The COA called for three phases of implementation:

- Phase I: Route Recommendations. These recommendations were developed using available demographic data and ridership services to recommend route adjustments. New services included in the Phase I recommendations were developed by modifying existing routes and/or replacing routes recommended for elimination. These route changes are summarized in Table 1-2.
- Phase II: Transfer Centers. These recommendations considered alternative strategies for using off-street transfer centers to improve network connectivity and improve the convenience of transfers while minimizing the operational impacts of transit on downtown roadways.
- Phase III: Bus Rapid Transit (BRT). This recommendation is the basis for the Broad Street Corridor Alternatives Analysis. The COA called for a premium, branded service supported by substantial transit stations, dedicated vehicles, and bus prioritization to build a premium transit ridership market in the Broad Street Corridor.

TABLE 1-2: RECOMMENDED COA PHASE I ROUTE CHANGES

Route		Weekday Ridership	COA Recommendations (Major Changes)	Changes to Service on Broad Street
1/2	Monument / Patterson/ Church Hill	2,239	Separate Routes 1 and 2 in GRTC timetables; reroute Route 1 from Broad St. onto Cary St. between 21st St. and Thompson St.	Removes Route 1 buses between 21st St. and Thompson St.
3/4	Robinson / Fairmount	3,291	Eliminate portion of Routes 3 and 4 west of Belvedere St.	Removes service between Belvedere St. and Robinson St.
6	Broad / Main Street	3,799	Extend those trips currently terminating downtown to Rocketts Landing	Creates branch of Route 6 that serves all but two of the proposed Broad St. stations.
7	Seven Pines	896	No longer use Airport Park-and-Ride, shorten eastern portion of route to use Holly Avenue	None
8	Rosemary/Shepperd/ 9th Street		New route covering areas previously served by western portion of Routes 3, 4, and 11	Replaces previous services on Broad St. west of Belvedere St.
10	Riverview / Jefferson	2,077	Splits route to create 10E and 10W.	Service on Broad St. split in half; 10W serves points west of 9th St.; 10E serves points east of 7th St.
11	Laurel / 17th Street	120	Eliminate portion of Route 11 west of 7th St.	Removes service from Broad St.
13	Main St. / Church Hill	202	Reroute away from Broad; redirect eastern portion of route to serve Rocketts Landing	Removes service from Broad St.; increases service to Rocketts Landing
20	Northside - Willow Lawn	43	Reroute to act as a crosstown route	Removes service from Broad St.

Route		Weekday Ridership	COA Recommendations (Major Changes)	Changes to Service on Broad Street
21	Hull Street / Magnolia Street		New crosstown route to work in conjunction with Route 20	None
22	Hermitage	282	Rerouting of northern portion of route	None
26	Parham Road Park and Ride	216	Eliminate route	Reduces service
27	Glenside Park and Ride	192	Headway adjustments, no routing changes	None
28	Fair Oaks Park and Ride	16	Eliminate route	Reduces service
29	Gaskins Park and Ride	407	Add service to Parham Park-and-Ride	None
34	Highland Park	1,610	Extensions to northern and southern ends	None
37	Chamberlayne	1,794	No recommendations	No recommendations
56	South Laburnum	112	No longer use Fair Oaks Park-and-Ride; terminate service at Richmond International Airport	None
61	Broad Rock		New service	None
62/ 63	Hull Street / Midlothian	2,444	Separate Routes 62 and 63 in GRTC timetables	None
64	Stony Point Express	159	No route changes; increase frequency of service	Increases frequency of service
65	Stony Point Fashion Park	46	No route changes; eliminate every second trip	Reduces frequency by half
66	Beaufont Mall Express	53	Change end terminus to Beaufont Mall	None
67	Chippenham	107	Reconfigure into loop to provide express-type service in peak direction	None
70/ 71	Forest Hill	1,651	Separate Routes 70 and 71 in GRTC timetables	None
96	Richmond - Ashland/Fredericksburg		Add service to Ashland Park-and-Ride	None

Source: GRTC Comprehensive Operations Analysis, 2007, Chapter 6.

Due to the current economic climate, the Phase I and Phase II recommendations of the COA have not been formally adopted for implementation by 2015; therefore, they have not been included as part of the No-Build Alternative. The Phase III recommendation for Bus Rapid Transit is the subject of this Alternatives Analysis.

There are two proposed capital improvements that are currently under study and may have implications for the long-term development of the transit network:

- **Downtown Transfer Center.** Based on the Phase II recommendations of the 2008 COA, GRTC has been studying the potential for developing a Downtown Transfer Center at Main Street Station. An Environmental Assessment for this facility was published in 2008; however, as noted above, plans for implementing this transfer center have been put on hold. The November 2009

Regional Transportation Priority Projects Report reflects this change, listing the Downtown Transfer Center as an unranked priority project.

For the purposes of this study, it is assumed that the Downtown Transfer Center will not be implemented at Main Street Station or any other location by the 2015 opening year.

- **Southeast High Speed Rail (SEHSR).** Main Street Station is located along the Southeast Corridor, one of 11 High Speed Rail corridors designated by the Federal Railroad Administration (FRA). The Southeast Corridor extends from Atlanta, Georgia to Washington, DC, where it then provides a direct connection to Amtrak's Northeast Corridor. DRPT and the North Carolina Department of Transportation have been supporting SEHSR through an incremental program of grade separations and other capital improvements between Richmond and Raleigh. They are currently seeking additional funding under the American Recovery and Reinvestment Act of 2009 (ARRA).

  Two elements of the SEHSR program may have direct implications on passenger rail service to the study area:

  - Washington DC to Petersburg rail improvements. DRPT has applied for funding for track improvements to increase the frequency, speed, and reliability of intercity passenger rail service between Washington DC and the Richmond area. The November 2009 *Regional Transportation Priority Projects Report* lists these improvements are listed as the second-highest priority in the Richmond metropolitan area.
  - Richmond to Hampton Roads passenger rail improvements. The November 2009 *Regional Transportation Priority Projects Report* notes that a future phase of SEHSR implementation would consider improving intercity passenger rail service to the Hampton Roads region. Service improvements to both the Peninsula and Norfolk are currently under study by DRPT.

  As the FRA has yet to make a decision on these applications, these improvements are not included in the No-Build. GRTC/DRPT will monitor the progress of these improvements to determine if changes in rail service to Main Street Station would warrant additional investments in transit services to this intermodal center.

2.0 BASELINE ALTERNATIVE

The Baseline Alternative is a requirement of the Small Starts program. It is intended to provide a basis of comparison for the Build alternatives, defining the best that can be done to meet the goals and objectives of the study in the absence of an investment in a fixed guideway (e.g. rail, bus lane). The Baseline Alternative includes all improvements included in the No-Build Alternative in addition to the service and facility improvements described in this section.

2.1 Route and Alignment

The Baseline Alternative is based on the Phase I and Phase III recommendations of the COA, modifying the Broad Street branch of the existing Route 6 to operate as a limited-stop service. Service along this route would begin at the intersection of Markel Road and Willow Lawn Drive, continuing up one block to the intersection of Willow Lawn Drive and Broad Street. Here, the route would turn east and continue along Broad Street. At 8th Street, the route would depart from the original Broad Street branch of the

Route 6, continuing east along Broad Street, under I-95, and continuing to 18th Street, where it would then turn south and parallel Main Street Station. At Main Street, the route would then turn east along Main Street (State Route 5), continuing until reaching Orleans Street.

At Orleans Street, the route would turn west, looping around to Old Main Street, then returning west along the Main Street to 17th Street, continuing north on 17th Street to Broad Street, then continuing along Broad Street until reaching Willow Lawn Drive. At Willow Lawn Drive, the route would turn south until reaching Markel Road, where it would complete a counterclockwise loop from Markel Road to Byrd Avenue to Fitzhugh Avenue, then terminating at the station at Markel Road and Willow Lawn Road. This route is illustrated in Figure 2-1.

The Baseline Alternative would operate in mixed traffic between Willow Lawn Drive and 2nd Street and between 14th Street and Main Street. Between 2nd Street and 14th Street, the route may use either the existing peak hour bus lanes or the general traffic lanes as is necessary to maintain on-time performance. The Baseline Alternative would operate as a limited-stop service, stopping only at those station areas identified in Figure 2-1 and bypassing all other local stops.

2.2 Stations

The Baseline Alternative envisions no new station stops or facilities, and utilizes the existing transit shelters in place at the stops identified in Figure 2-1. These shelters would be rebranded to identify them with the Baseline Alternative service, and would include additional signage and schedule information to highlight the advantages of the limited-stop service.

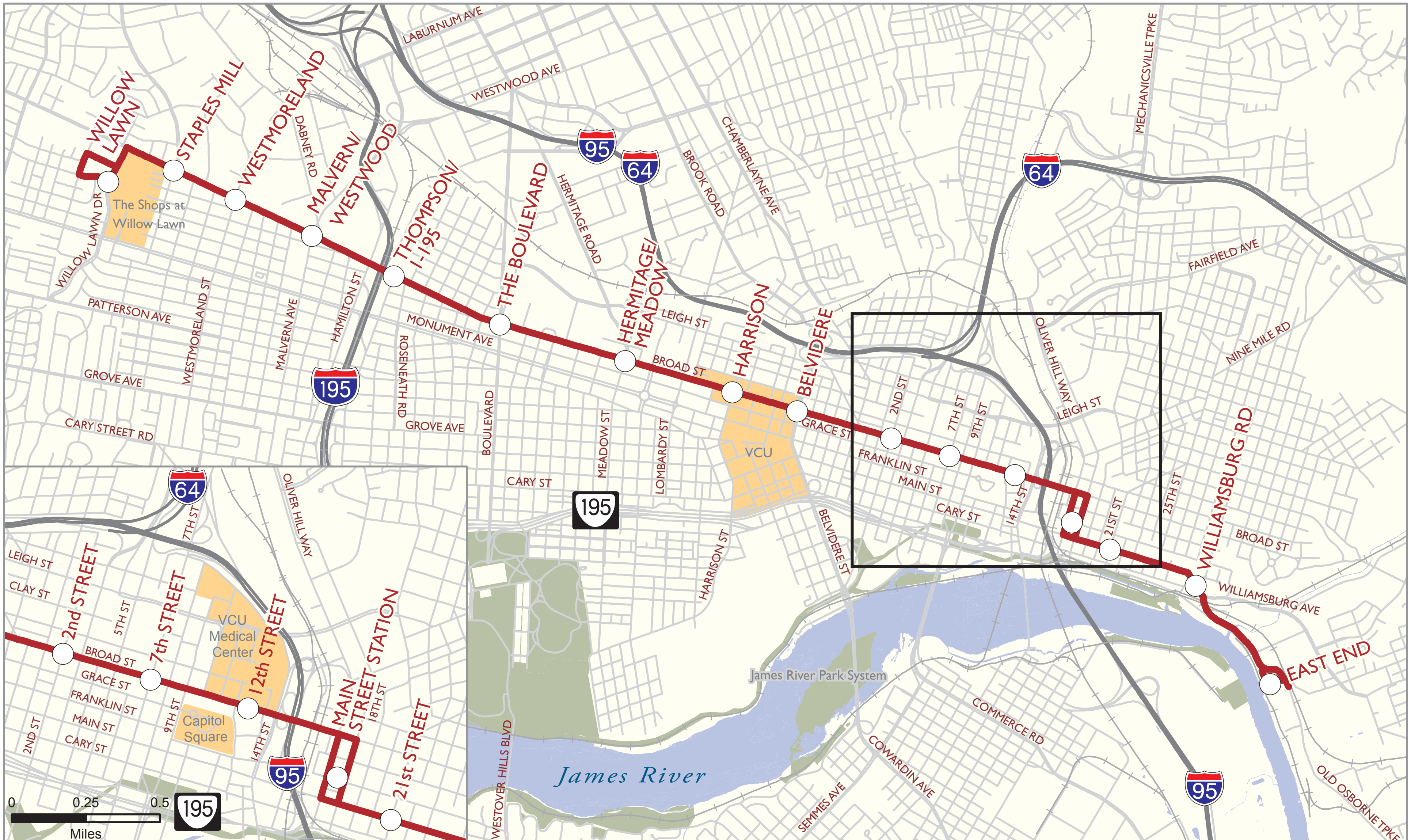
2.3 Schedule

The Baseline Alternative will operate every 10 minutes during peak hours of operation (7:00 to 9:30 AM and from 4:00 to 6:00 PM) and every 15 minutes during off-peak hours (early morning, afternoon, and evening.) It will operate during the same hours as the other branches of the Route 6, from 5:30 AM to 11:30 PM on weekdays and from 6:00 AM to 11:30 PM on weekends.

2.4 Network Changes and Feeder Service

As noted at the beginning of this section, the intent of the Baseline Alternative is to define the best that can be done to meet the study's goals and objectives without making a major capital investment. Consistent with this intent, it is assumed that all of the Phase I recommendations of the 2008 COA will be implemented in conjunction with the Baseline Alternative. Service under the COA would continue to be centered on the CBD (and Broad Street in particular); therefore, no additional feeder services will be introduced as part of the Baseline Alternative. Minor adjustments to route timetables and operating protocols may be considered to ensure the limited stop operation of the Baseline Alternative does not interfere with local route operations along Broad Street.

It is assumed that all transfers between the Baseline Alternative and other local routes will occur at on-street the existing bus stops served by the Baseline Alternative. Timed transfers between the Baseline Alternative and those routes with the highest transfer activity to Route 6 may be considered.



LEGEND

- Proposed BRT Stations
- Proposed BRT Alignment

Figure 2-1

Baseline Alternative

2.5 Fare Collection

It is assumed that the Baseline Alternative will use the same fare structure as other GRTC services under the No-Build. The Baseline Alternative also assumes on-board fare collection, with both exact change and Go Cards being accepted as fare medium.

2.6 Vehicles

The Baseline Alternative will use vehicles from the existing GRTC fleet. As the frequency of service offered by the Baseline Alternative is comparable to that of the existing Broad Street branch of the Route 6, it is assumed that the Baseline Alternative will require no new vehicle acquisitions beyond normal GRTC fleet management practices.

2.7 Intelligent Transportation Systems

It is assumed that the traffic signal system for the corridor will allow for signal priority for Baseline Alternative operations. For the purposes of this initial definition of alternatives, it is assumed that transit signal priority would be implemented at all signalized intersections present along dedicated bus lanes. This offers the potential to improve transit travel speeds and schedule reliability while minimizing potential conflicts with general traffic turns onto and off of Broad Street.

As noted in Section 1.2, the City of Richmond's planned signal upgrade would not preclude signal prioritization; however, this improvement would represent a separate and supplemental upgrade to the traffic signal system. Signal prioritization for Baseline Alternative operations would be coordinated with the three agencies responsible for signals in the corridor (VDOT, the City of Richmond, and Henrico County.)

2.8 Branding

Branding of the Baseline Alternative would be limited to rebranding of existing transit shelters that would be served by the new, limited stop service. Marketing of the new service would be considered as part of the overall marketing strategy for GRTC services in the corridor.

3.0 BUILD ALTERNATIVES

The Build Alternatives represent highest level of capital investment being considered to meet the goals and objectives of this study. As the Small Starts program is limited to projects with a total capital cost of less than $250 million, the number of Build Alternatives and the level of investment considered for the current study is less than what is typical of a rail service. However, the Small Starts program requires that each Build Alternative must meet, at minimum, one of two criteria:

- Provide a peak-period, fixed guideway (e.g. bus lane, rail) for at least 50% of the project length
- Be a corridor-based bus project with the following minimum elements:
    - Substantial Transit Stations
    - Signal Priority/Pre-emption
    - Low Floor / Level Boarding Vehicles

- Special Branding of Service
- Frequent Service - 10 min peak/15 min off peak
- Service offered at least 14 hours per day

Two Build Alternatives are being proposed to meet these criteria.

- Build 1: a BRT service using bus lanes for 50% of its length, thus meeting the minimum requirements for both Small Starts criteria.
- Build 2: a BRT service with bus lanes along its entire alignment. This assumption will also make it possible to make an initial assessment of the potential impacts of other technologies with fully-dedicated guideways, such as LRT and streetcars.

Both alternatives are described in detail in the following sections.

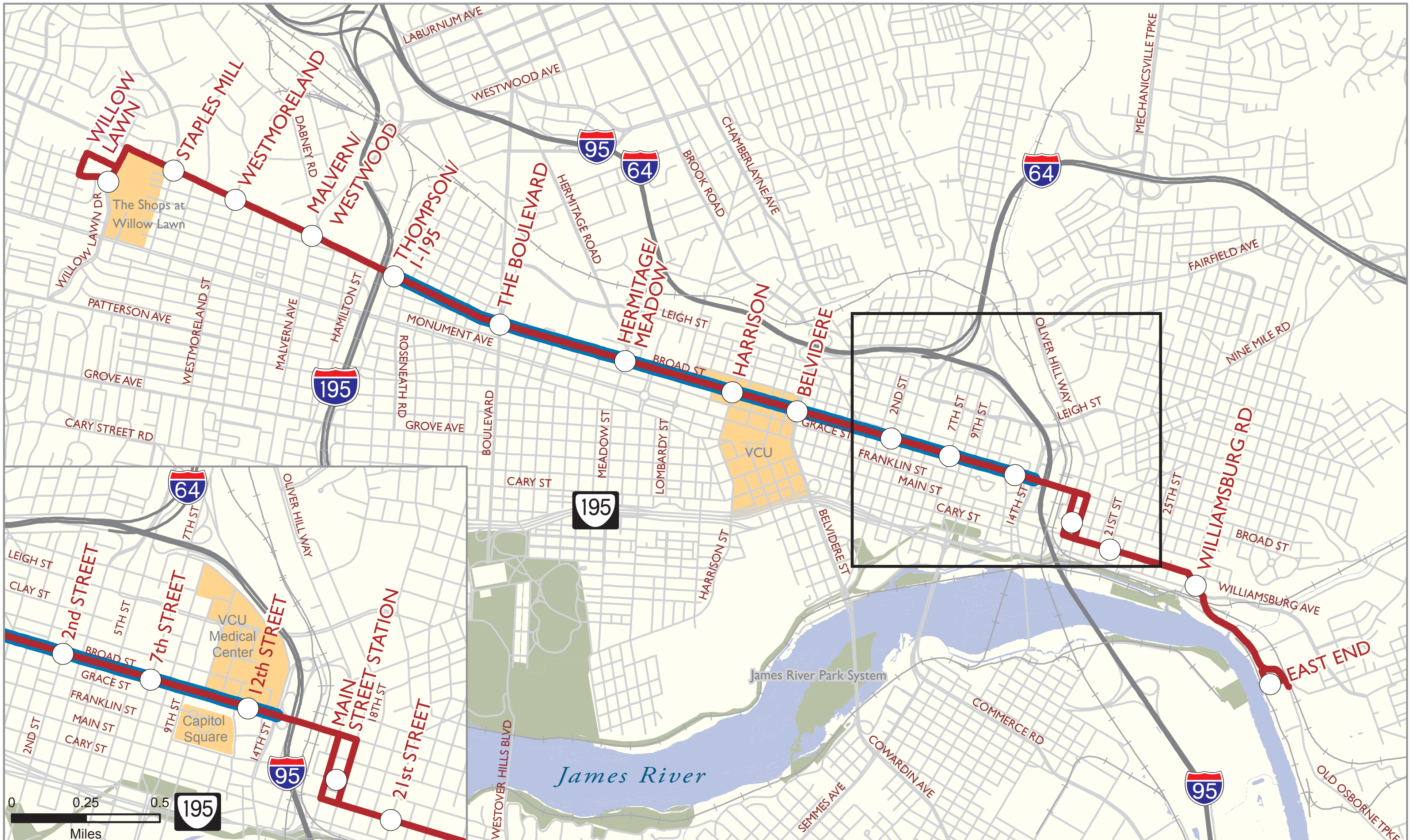
3.1 Build Alternative 1: 50% Guideway (Build 1)

3.1.1 Route and Alignment

Build 1 will follow the same route as the Baseline Alternative (see Figure 3-1). Between Thompson Street and 14th Street (a distance of approximately 3.4 miles), the route would utilize dedicated bus lanes. These bus lanes would replace the existing bus lanes currently in place between 2nd Street and 14th Street, and would differ from the existing bus lanes in the following respects:

- Hours of operation. The dedicated bus lanes would be reserved for transit operations 24 hours a day, as opposed to during peak hours.
- Lane width. The proposed lanes would be wider than the existing bus lanes, minimizing conflicts between BRT operations and adjoining general traffic.
- Operational restrictions. Usage of the dedicated bus lanes would be limited to BRT vehicles and those routes that serve at least 80% of the BRT stations. The exception to this would be where turns from general traffic lanes must cross over the bus lanes—at these points, signal and signage improvements would be necessary to define the interface between BRT and general traffic operations.
- Physical enforcement of the bus lane. General transit and auto traffic would be discouraged from using the bus lane through a combination of improvements that may include: tactile markings, raised lane delineators, lane markings, and/or signage. Examples of potential enforcement strategies are illustrated in Figure 3-2.

As noted in the September 2009 Technical Memorandum, *Definition of BRT Components,* there are four basic configurations that could be considered: median, curbside, outside of parking lane, and contraflow lanes. These options and their tradeoffs are described in Table 3-1. In the interest of providing general traffic with consistent expectations about bus lane operations throughout the corridor, it is assumed that only one bus lane configuration would be used between Thompson Street and 14th Street.



LEGEND

Proposed BRT Stations

Proposed BRT Alignment

Dedicated Bus Lanes

Figure 3-1

Build Alternative 1

TABLE 3-1: OPTIONS FOR DEDICATED LANE IMPLEMENTATION

Option		Advantages	Disadvantages	Examples
	Curbside	• Cost savings for use of existing curb and station facilities. Compatible with existing bus equipment. • Preserves general purpose lanes. • Minimizes conflicts with left-turns.	• Impacts to on-street parking and delivery services for businesses. • Need to allow other bus routes to access lane to provide local stops. • Potential conflicts with right-turns.	• Richmond, VA • Boston Silver Line • San Bernardino, CA
	Outside of Parking Lane	• Preserves on-street parking for businesses fronting BRT line. • Minimizes conflicts with left-turns.	• Rededicates general purpose lanes to exclusive transit use. • Potential conflicts with right turns. • Potential conflicts with parked vehicles. • Potential conflicts with other bus routes serving local stops.	• Boston Silver Line
	Center (Median-Running)	• Potential for single platform to serve both directions of BRT line. • Heightens profile of system. • Minimizes conflicts with right-turns and local bus stops	• Rededicates general purpose lanes. • If center platform used requires special vehicles with left-side doors. (Not compatible with local bus routes.) • If side platforms used, may require additional right-of-way. • Requires signal upgrades and re-sequencing. • Contingent on ROW availability.	• Vancouver, BC • Cleveland, OH • San Bernardino, CA
	Contraflow	• Allows buses with right-side doors to operate in median-running configuration. • Heightens profile of system.	• Rededicates general purpose lanes, requires reconfiguration of roadway. • Contraflow operations may conflict with driver expectations, cause conflicts with left and/or right turns. • Requires signal upgrades and re-sequencing. • Contingent on ROW availability.	• Orlando, FL • Brisbane, Australia

Figure 3-2: Examples of Bus Lane Enforcement, Orlando, FL.

The location of the bus lanes within the cross-section of Broad Street will be determined as part of the next stage of the screening process, using a combination of feedback from stakeholders, historical accident data, and information on existing and projected traffic volumes in the corridor.

3.1.2 Stations

Build 1 will use the same general station locations noted under the Baseline Alternative. Where Build 1 stations are co-located with local bus stops, the stations and loading areas will be physically separate from the local stop, with signage and wayfinding markers so passengers may readily differentiate between the BRT and local services. If a median bus lane is utilized, BRT stations will adjoin the bus lane, using either a central platform or two side platforms. Local bus connections at these stations would be provided at curbside bus stations.

BRT stations will be comparable in scale to the shelters currently in use along Broad Street, but will have a distinct appearance that will differentiate them from local stations. BRT stations will include additional amenities to improve the waiting and boarding experience. At a minimum, BRT stations will include ticket vending machines, system maps, BRT route maps and schedules, canopies, and seating. Additional amenities may include real-time vehicle information, trash receptacles, and physical integration with adjoining buildings and/or land use.

Pedestrian and bicycle connectivity to the stations from adjoining land uses will be considered as part of station area design. Improvements to be considered will include (but are not limited to): pedestrian and bicycle crossings, bicycle storage, pedestrian-level streetlights, and pedestrian and/or bicycle-actuated signals.

The short length of the alignment and the proximity of the termini to the Central Business District may limit the demand for Park-and-Ride facilities at the proposed stations. That being said, drive access to BRT stations will be considered as part of the ridership forecasts developed for the detailed screening of alternatives. If station boardings from drive access trips are forecast to be significant enough to warrant Park-and-Ride and/or Kiss-and-Ride facilities, the costs and impacts of such facilities will be considered as part of the Locally Preferred Alternative.

3.1.3 Schedule

The BRT service provided by Build 1 will utilize the same schedule as the Baseline Alternative, operating every 10 minutes during peak hours of operation (7:00 to 9:30 AM and from 4:00 to 6:00 PM) and every 15 minutes during off-peak hours (early morning, afternoon, and evening.) It will operate during the same hours as the other branches of the Route 6, from 5:30 AM to 11:30 PM on weekdays and from 6:00 AM to 11:30 PM on weekends.

3.1.4 Network Changes and Feeder Service

Consistent with the Baseline Alternative, it is assumed that all of the Phase I recommendations of the 2008 COA will be implemented in conjunction with the Baseline Alternative. Service under the COA would continue to be centered on the CBD (and Broad Street in particular); therefore, no additional feeder services will be introduced as part of the Build Alternative.

As discussed in Section 3.1.1, COA routes that utilize at least 80% of the stations served by dedicated bus lanes will be allowed to use the bus lane. Under Build 1, the only route that would qualify for this would be Route 19, which was recommended by the COA to operate as a limited-stop service east of Willow Lawn. Route 19 would be extended east to serve the proposed BRT station at 12th Street, at which point it would loop through College Avenue, Marshall Street, and North 12th Street to return west.

Where the BRT route uses general traffic lanes, it is assumed that all transfers between the BRT service and other local routes will occur on-street at the existing bus stops served by Build 1. Where dedicated bus lanes are in place, passengers will cross Broad Street to transfer between the BRT station and local bus service. Timed transfers between the BRT service and those routes with the highest transfer activity to the existing Route 6 may be considered.

3.1.5 Fare Collection

It is assumed that Build 1 will use the same fare structure as other GRTC services under the No-Build. Build 1 assumes off-board fare collection using a proof-of-payment system. Passengers would purchase tickets at vending machines located at the BRT stations, allowing them to board any door of a BRT vehicle. Fare inspectors would randomly patrol BRT vehicles to deter fare evasion. Marketing and branding initiatives would be coordinated to reduce confusion of different vehicles and fare collection policies (pre-board vs. on-board) serving the same station.

3.1.6 Vehicles

Build 1 would use a dedicated set of low-floor vehicles to serve the BRT route described in Section 3.1.1. BRT vehicles would use markings (paint scheme, logo, other visual improvements) to differentiate them from local bus routes. BRT vehicle amenities that may be considered during Project Development (i.e. the next stage of the Small Starts process) may include: Automated Vehicle Location (AVL) systems, optical guidance to provide precision level boarding, two or three passenger-side doors, wi-fi services, and other passenger amenities. Should center platform stations be used in conjunction with median dedicated bus lanes, it will be necessary for BRT vehicles (and any other vehicles using the bus lane) to have left-side passenger doors.

3.1.7 Intelligent Transportation Systems

It is assumed that the traffic signal system for the corridor will allow for signal priority for Baseline Alternative operations. For the purposes of this initial definition of alternatives, it is assumed that transit signal priority would be implemented at all signalized intersections present along dedicated bus lanes. This offers the potential to improve transit travel speeds and schedule reliability while minimizing potential conflicts with general traffic turns onto and off of Broad Street.

As noted in Section 1.2, the City of Richmond's planned signal upgrade would not preclude signal prioritization; however, this improvement would represent a separate and supplemental upgrade to the traffic signal system. Signal prioritization for BRT operations would be coordinated with the three agencies responsible for signals in the corridor (VDOT, the City of Richmond, and Henrico County.)

3.1.8 Branding

Build 1 would use distinct vehicles, stations, lane markings, signage, and marketing to create an identity for the new BRT system, ensuring that it is viewed as a premium component of the GRTC route system. Options to consider include rebranding the GRTC system into local and express services, providing a distinction and identity for the two service types.

3.2 Build Alternative 2: 100% Guideway (Build 2)

3.2.1 Route and Alignment

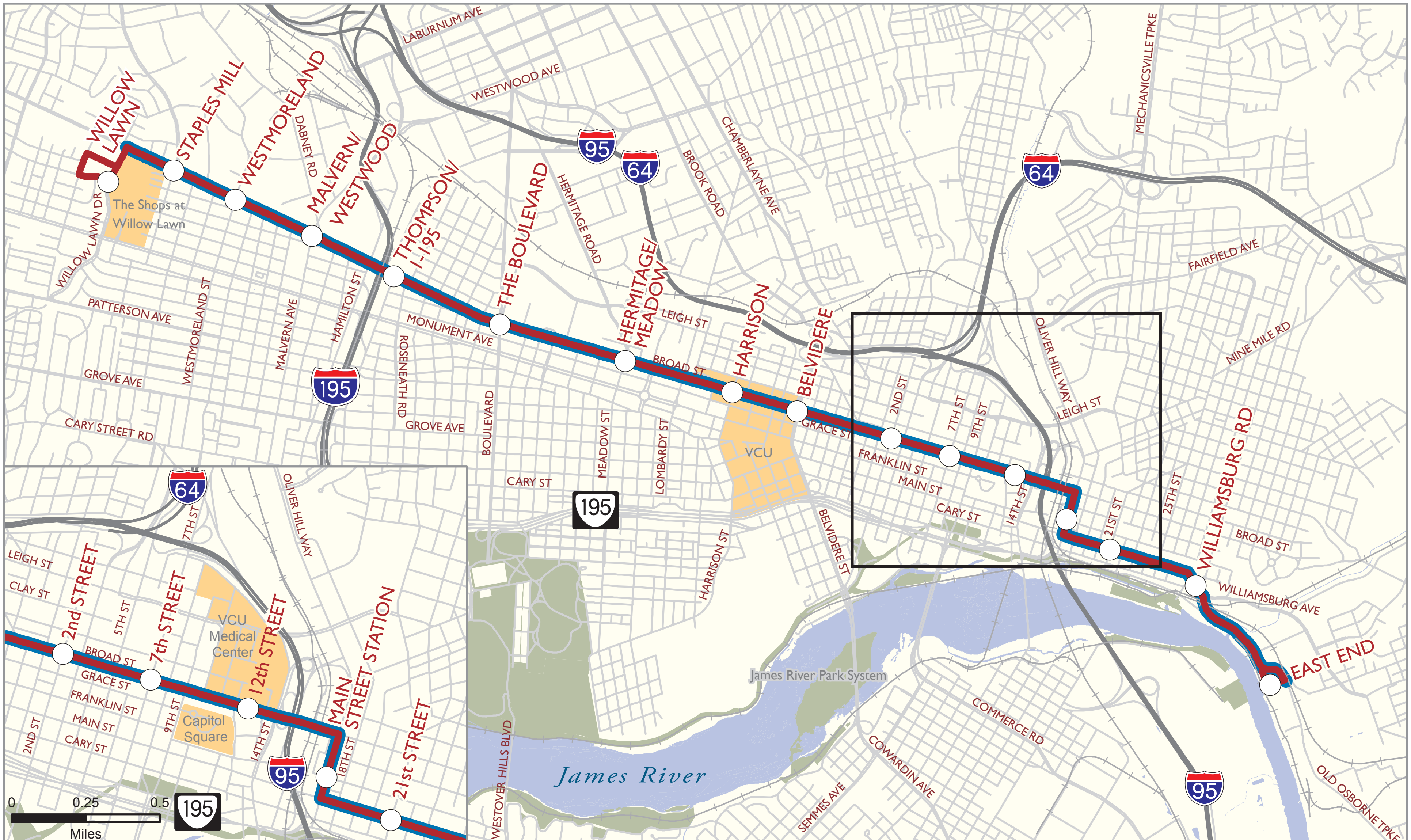
Build 2 will follow the same route as that of the Baseline Alternative (see Figure 3-3), with one exception: both the eastbound and westbound portions of the route will use N. 17th Street to travel between Broad Street and Main Street. Dedicated bus lanes would be put in place for the entire length of Broad Street, Main Street, and 17th Street; buses would operate along general traffic lanes along Willow Lawn Drive, Markel Road, Fitzhugh Road, and Old Main Street. In the interest simplifying driver expectations about BRT operations, it is assumed that the same lane configuration (e.g. median, curbside, contraflow) would be used along the length of Broad Street; an alternate (but consistent) configuration may be applied along the length of Main Street. All assumptions made about bus lane operations for Build 1 would remain applicable for Build 2.

3.2.2 Stations

Build 2 would use the same station areas identified for the Baseline Alternative and Build 1. As noted in the Baseline Alternative, Park-and-Ride facilities will be considered if ridership forecasts completed during the detailed screening of alternatives indicate that there is a market for them. The costs and impacts of Park-and-Ride facilities will be considered as part of the Locally Preferred Alternative.

3.2.3 Schedule

Build 2 would provide the same schedule and frequency of service established for Build 1.



LEGEND

- Proposed BRT Stations
- Proposed BRT Alignment
- Dedicated Bus Lanes

0 0.5 1
Miles

N

Figure 3-3
Build Alternative 2

3.2.4 Network Changes and Feeder Service

Consistent with the Baseline Alternative and Build 1, it is assumed that all of the Phase I recommendations of the 2008 COA will be implemented in conjunction with the Baseline Alternative. Service under the COA would continue to be centered on the CBD (and Broad Street in particular); therefore, no additional feeder services will be introduced as part of the Baseline Alternative.

While the bus lanes would be available to routes that serve at least 80% of the stations along the line, it is recommended that the two branches of Route 6 that have not been designated as BRT services remain in place as local services. This will ensure that all local stops along Broad Street are served, and all passengers using local stops have the opportunity to transfer to BRT services to minimize their travel time.

3.2.5 Fare Collection

It is assumed that Build 1 will use the same fare structure as other GRTC services under the No-Build. Build 1 assumes off-board fare collection using a proof-of-payment system. Passengers would purchase tickets at vending machines located at the BRT stations, allowing them to board any door of a BRT vehicle. Fare inspectors would randomly patrol BRT vehicles to deter fare evasion.

3.2.6 Vehicles

Build 2 would use the same assumptions about BRT vehicles as described in Build 1.

3.2.7 Intelligent Transportation Systems

It is assumed that the traffic signal system for the corridor will allow for signal priority for Baseline Alternative operations. For the purposes of this initial definition of alternatives, it is assumed that transit signal priority would be implemented at all signalized intersections present along dedicated bus lanes. This offers the potential to improve transit travel speeds and schedule reliability while minimizing potential conflicts with general traffic turns onto and off of Broad Street, Main Street, and 17th Street.

As noted in Section 1.2, the City of Richmond's planned signal upgrade would not preclude signal prioritization; however, this improvement would represent a separate and supplemental upgrade to the traffic signal system. Signal prioritization for BRT operations would be coordinated with the three agencies responsible for signals in the corridor (VDOT, the City of Richmond, and Henrico County.)

3.2.8 Branding

Build 2 would use the same assumptions about branding as described in Build 1.

BROAD STREET RAPID TRANSIT STUDY

ENVIRONMENTAL ASSESSMENT

APPENDIX A-3: Evaluation Methodology Report

Note: At the time this technical memorandum was prepared, the opening year was anticipated to be 2015. At the time this EA was completed, the opening year has been revised to 2017. All references in the main EA document have been updated, but the information in the technical report remains relevant.

BROAD STREET RAPID TRANSIT STUDY: EVALUATION METHODOLOGY

This Evaluation Methodology will outline a process for selecting a locally preferred alternative (LPA) for transit improvement along the Broad Street Corridor in Richmond, VA. As part of an Environmental Assessment (EA), this methodology will remain consistent with the requirements of both the Federal Transit Administration's (FTA) Small Starts program and the National Environmental Policy Act (NEPA). Evaluation will involve two tiers of screening to compare alternatives based on concrete measures of effectiveness developed in direct relation to the goals and objectives described in the Problem Statement.

1.0 STUDY PROCESS

The GRTC Transit System and Virginia Department of Rail and Public Transit (GRTC/DRPT) are seeking to implement a premium transit service along what is already the most heavily used transit corridor in Richmond, VA. Both agencies have identified the FTA Small Starts program as an appropriate course through which to help fund this project. As noted in the FTA's *Small Starts Fact Sheet*, the program requires a project to either:

1. Be a fixed guideway for at least 50% of the project length in the peak period, and/or
2. Be a corridor-based bus project with the following minimum elements:
    - Substantial Transit Stations,
    - Signal Priority/Pre-emption (for Bus/LRT),
    - Low Floor/Level Boarding Vehicles,
    - Special Branding of Service,
    - Frequent Service - 10 min peak/15 min off-peak, and
    - Service offered at least 14 hours per day.

As Small Starts are intended to be less capital-intensive than New Starts projects, FTA guidance allows for a simplified approach to the assessment of alternatives. The assessment of the alternatives for the Broad Street Corridor is designed to systematically screen out alternatives least likely to fulfill a Purpose and Need statement for the project by applying an increasingly specific set of criteria to a decreasing number of alternatives. This is done by:

- Establishing a Purpose and Need to document the reason the study is being conducted.
- Developing goals, objectives and measures of effectiveness to evaluate each alternative's ability to meet the Purpose and Need.
- Developing an initial set of conceptual alternatives that could reasonably address the Purpose and Need of the study.
- Evaluating the conceptual alternatives against a set of initial screening criteria and documenting those alternatives considered unsuitable for further study.

- Refining the remaining alternatives to allow for a more detailed assessment of their ability to meet the Purpose and Need of the study.
- Applying detailed screening criteria to the remaining alternatives and comparing their performance against the goals and objectives of the study.
- Using the results of the screening process (in conjunction with input from stakeholders) to recommend an LPA.

To move forward in the project development process, the LPA must be included in the metropolitan planning organization's (MPO) long-range plan and demonstrate that it fulfills all NEPA requirements. The project justification criteria are combined with three local financial commitment criteria to establish an overall project rating.

The following sections of the report provide a more detailed description of the goals, objectives and evaluation criteria to be used as part of this study.

2.0 GOALS, OBJECTIVES AND MEASURES OF EFFECTIVENESS

Table 2-1 lists the goals and objectives established in the Problem Statement for the Broad Street Corridor. These have been established to meet the requirements of Small Starts while reflecting the conditions and priorities of the Richmond region. Gauging the relative ability of each alternative to address these goals and objectives is the aim of the alternatives assessment process. That process is only possible when goals and objectives are matched with measureable indicators. These measures, in turn, need to be tailored to the level of detail available at each stage of the screening process. The following sections will explain which measures will be used at each stage.

TABLE 2-1: GOALS AND OBJECTIVES

Goal	Objectives
Improve local and regional mobility	• Increase transit ridership • Improve access to the regional transit network • Improve transit service in high ridership areas • Decrease travel times in the study area • Increase transit reliability and on time performance • Minimize negative impact on transit and auto operations in the corridor • Increase transportation system productivity (passengers/hour) within the corridor
Support economic development along the corridor	• Improve transit access to existing and future developments • Create connections between transit and centers of employment, education, residence, shopping, culture and entertainment • Provide opportunities for joint development of transit stations and facilities • Provide improved mobility and mode choice to Enterprise Zones planned for redevelopment

Goal	Objectives
Promote livable, transit-oriented development	• Provide high-capacity transit facilities at locations where existing and future land uses make them mutually supportive • Promote improved pedestrian connectivity between transit services and adjoining land uses • Encourage transit usage for different trip types and purposes • Support mixed land use and community design that foster reduced auto use
Create a multi-modal transportation system with attractive travel choices	• Create a premium transit route with service characteristics that make it competitive with the private automobile • Integrate premium transit service with local bus, bicycle, pedestrian, private automobile and intercity travel modes • Provide safe, convenient and attractive transfer facilities • Create opportunities for future upgrades or additional premium transit services
Optimize return on public investment	• Develop cost-effective transit solutions • Capitalize on existing local and regional transit facilities and operations • Support state, regional and local plans • Maximize funding opportunities from state, local, and federal sources
Enhance environmental quality	• Minimize and mitigate negative impacts to the human and natural environment • Contribute to improvements in regional air quality

3.0 INITIAL SCREENING METHODOLOGY

The intention of the initial screening is to generate sufficient information about the conceptual alternatives to screen out those alternatives least likely to meet the established Purpose and Need. At this stage in the analysis, the emphasis is on developing qualitative, order-of-magnitude estimates of the costs, benefits and impacts of each alternative, such that major differences between alternatives are readily apparent. The measures of effectiveness for the initial screening have been developed to reflect the qualitative approach to the initial screening, and are listed in Table 3-1.

TABLE 3-1: INITIAL SCREENING CRITERIA

Goal	Objectives	Measures of Effectiveness
Improve local and regional mobility	• Increase transit ridership • Decrease travel times in the study area • Minimize negative impact on roadway congestion	• Impact on transit ridership • Impact on general traffic • Impact on on-street parking • Impact on vehicle and pedestrian safety within the corridor
Support economic development along the corridor	• Improve transit access to existing and future developments • Create connections between transit and centers of employment, education, residence, shopping, culture and entertainment	• Impact on residential access to transit • Impact on transit access to activity centers • Impact on transit access to redevelopment sites

Goal	Objectives	Measures of Effectiveness
Promote livable, transit-oriented development	• Provide high-capacity transit facilities at locations where existing and future land uses make them mutually supportive	• Ability to support higher density land uses
Create a multi-modal transportation system with attractive travel choices	• Create a premium transit route with service characteristics that make it competitive with the private automobile • Integrate premium transit service with local bus, bicycle, pedestrian, private automobile and intercity travel modes • Create opportunities for future upgrades or additional premium transit services	• Average operating speed • Number of intermodal connections • Level of investment that can support future upgrades • Frequency, schedule, and travel times of transit services in the corridor
Optimize return on public investment	• Develop cost-effective transit solutions	• Order-of-magnitude capital cost • Order-of-magnitude operating cost
Enhance environmental quality	• Minimize and mitigate negative impacts to the human and natural environment	• Impact on natural resources (parklands, wetland, water, habitat) • Impact on historic and cultural resources

In addition to these corridor-wide criteria, each of the proposed station areas for each alternative will be evaluated using a separate station area identification methodology. This methodology will determine which of the initial stations under consideration should be carried forward into the detailed definition of alternatives. The methodology used to evaluate station locations is described in greater detail in the Station Area Assessment Methodology.

Each alternative will be evaluated and ranked according to the fifteen measures of effectiveness listed in Table 3-1. The measures of effectiveness applied to the initial screening will use a five-grade ranking system shown in Table 3-2.

TABLE 3-2: RANKING SYSTEM FOR INITIAL SCREENING CRITERIA

Rank	General Assessment
A	The alternative may provide major benefits and/or significantly minimize negative impacts
B	The alternative may provide some benefits and/or minimize some negative impacts
C	The alternative will have negligible benefits or impacts
D	The alternative may have some negative impacts
F	The alternative may have major negative impacts

The ranking under each criterion will be documented using existing data from local, state, and industry sources. The results of the initial screening will be presented to GRTC/DRPT and local stakeholders to ensure their consensus and so they can recommend which alternatives should be carried forward in the study.

4.0 DETAILED SCREENING METHODOLOGY

Those alternatives recommended from the initial screening will be refined to allow more detailed, quantifiable assessments of their costs, benefits and impacts. Modified alternatives will be defined in sufficient detail to allow the evaluation of variations to the major alternatives retained from the initial screening.

Each alternative and modified alternative will be evaluated using the full set of measures of effectiveness identified in Table 4-1. Many measures have been included to add depth to the evaluation process by differentiating each alternative according to its anticipated impacts and benefits. The measures of effectiveness will be estimated for the proposed opening date in 2015.

TABLE 4-1: GOALS, OBJECTIVES AND MEASURES OF EFFECTIVENESS

Goal	Objectives	Measures of Effectiveness
Improve local and regional mobility	• Increase transit ridership • Improve access to the regional transit network • Improve transit service in high ridership areas • Decrease travel times in the study area • Increase transit reliability and on time performance • Minimize negative impact on transit and auto operations in the corridor • Increase transportation system productivity (passengers/hour) within the corridor	• Number of new transit riders* • Number of low-income households, zero-car households and minority populations with ¼-mile of stations • On-time performance of transit vehicles • Traffic impact at key intersections and on key road segments • Number of on-street parking spaces lost • Person-capacity of corridor's road and transit networks • Impact on vehicle and pedestrian safety within the corridor
Support economic development along the corridor	• Improve transit access to existing and future developments • Create connections between transit and centers of employment, education, residence, shopping, culture and entertainment • Provide opportunities for joint development of transit stations and facilities	• Number of housing units within ½ -mile of transit stations • Square feet of potentially developable land within ¼-mile of transit stations • Square feet of office and retail ½ -mile of transit stations • Square feet of redevelopment within ½ -mile of transit stations
Promote livable, transit-oriented development	• Provide high-capacity transit facilities at locations where existing and future land uses make them mutually supportive • Promote improved pedestrian connectivity between transit services and adjoining land uses • Encourage transit usage for different trip types and purposes	• Total population and employment within ½ -mile of transit stations, current and proposed • Additions to pedestrian infrastructure • Frequency, schedule, and travel times of transit services in the corridor
Create a multi-modal transportation system with attractive travel choices	• Create a premium transit route with service characteristics that make it competitive with the private automobile • Integrate premium transit service with local bus, bicycle, pedestrian, private automobile and intercity travel modes • Provide safe, convenient and attractive transfer facilities • Create opportunities for future upgrades or additional premium transit services	• Average operating speed • Number of intermodal connections • Level of investment that can support future upgrades

Goal	Objectives	Measures of Effectiveness
Optimize return on public investment	• Develop cost-effective transit solutions • Capitalize on existing local and regional transit facilities and operations • Support state, regional and local plans • Maximize funding opportunities from state, local, and federal sources	• Capital cost • Annual operating cost • Increases in tax revenue
Enhance environmental quality	• Minimize and mitigate negative impacts to the human and natural environment • Contribute to improvements in regional air quality	• Impact on natural resources (parklands, wetland, water, habitat) • Impact on historic and cultural resources • Regional vehicle miles traveled • Transit vehicle emissions and idling

The results of the detailed screening will be presented to GRTC/DRPT, affected stakeholders and the general public to receive their input and feedback; where appropriate, alternatives may be further refined to reflect this input.

As with the initial screening, each of the proposed station areas for each alternative will be evaluated using a separate station assessment methodology. This methodology will focus on the localized impacts of stations on land use, transportation and economic development, allowing for a more meaningful dialogue with local stakeholders as to how station plans will affect their communities. The station-specific measures being considered as part of the detailed analysis are detailed in the Station Area Assessment Methodology.

5.0 PROJECT JUSTIFICATION CRITERIA

At the end of the detailed screening, there will be sufficient information to allow GRTC/DRPT to select and recommend an alternative for the region's Long-Range Transportation Plan (LRTP). Some adjustments may be necessary to the proposed alternative's operating assumptions and facility improvements to ensure the alternative meets FTA's cost-effectiveness thresholds.

The majority of the project justification information necessary to complete a Small Starts application for the Build Alternative will have been developed as part of the detailed screening methodology; however, it will be necessary to document the local financial commitment to the project with the following information:

- A financial plan demonstrating how funding will be secured for the local share of capital costs
- Documentation confirming that the increase in operations and maintenance costs associated with the Build Alternative represents less than 5% of the GRTC's total operations budget
- Documentation demonstrating that the operating agency is in "reasonably good financial condition"

All information related to project justification criteria will be entered into the Small Starts templates and submitted to FTA as part of the application for entry into Project Development.

BROAD STREET RAPID TRANSIT STUDY

ENVIRONMENTAL ASSESSMENT

APPENDIX A-4: Initial Screening Report

BROAD STREET RAPID TRANSIT STUDY: INITIAL SCREENING OF ALTERNATIVES

This Initial Screening of Alternatives summarizes the first round analysis performed on the initial set of alternatives identified to meet the Purpose and Need of the Broad Street Rapid Transit Corridor Environmental Assessment (EA). The initial screening utilizes the measures of effectiveness identified in the January 6, 2010 *Evaluation Methodology* in combination with feedback provided by stakeholders (Technical Advisory Committee, Policy Advisory Committee, general public) to make an determination as to which subset of alternatives would be most likely to meet the goals and objectives of the study. This technical memorandum also documents the rationale for removing alternatives from further consideration as part of this study.

1.0 INITIAL ALTERNATIVES

The initial alternatives for this study are summarized in Table 1-1, and are described in greater detail in the January 21, 2010 *Initial Definition of Alternatives*. Each of the alternatives was developed to (a) meet the goals and objectives established for the study; and, (b) ensure that they would meet the minimum requirements of a project under the Federal Transit Administration (FTA) Small Starts program.

TABLE 1-1: SUMMARY OF INITIAL ALTERNATIVES

	No-Build	Baseline	Build Alternatives	
			Build 1	Build 2
Route Length (mi.)	Existing Route 6	7.6		
Miles of Dedicated Bus Lanes	0.75	0.75	3.4	6.7
Number of Stations	Existing local stops	16 stations		
Peak/Off Peak Frequency (min.)	n/a	10/15		
Hours of Operation	Weekdays: 5:30 AM-11:30 PM Weekends: 6:00 AM-11:30 PM			
Network Changes and Feeder Service	None*	Comprehensive Operations Analysis Phase I and Phase II recommendations*		
Fare Collection	On-board (cash, Go Cards)		Off-board Proof of purchase (BRT tickets)	
Vehicles	Existing GRTC vehicles		Dedicated Bus Rapid Transit (BRT) vehicles	
Intelligent Transportation Systems	Existing traffic control systems	Signal priority at intersections along bus lanes		
Branding?	No	Stations only	Stations, vehicles, guideway, signage, marketing efforts	

*Since the initial alternatives were defined, new information from on-board surveys has been made available to the study team. GRTC has indicated that the survey information may warrant the implementation of some COA improvements before the opening year. Refinements in the implementation of the COA will be noted in the No Build and Baseline as part of the Detailed Definition of Alternatives.

2.0 INITIAL SCREENING METHODOLOGY

The intention of the initial screening is to generate sufficient information about the conceptual alternatives to screen out those alternatives least likely to meet the established Purpose and Need. At this stage in the analysis, the emphasis is on developing qualitative, order-of-magnitude estimates of the costs, benefits and impacts of each alternative, such that major differences between alternatives are readily apparent. The measures of effectiveness for the initial screening have been developed to reflect the qualitative approach to the initial screening, and are listed in Table 2-1.

TABLE 2-1: INITIAL SCREENING CRITERIA

Goal	Objectives	Measures of Effectiveness
Improve local and regional mobility	• Increase transit ridership • Decrease travel times in the study area • Minimize negative impact on roadway congestion	• Impact on transit ridership • Impact on general traffic • Impact on on-street parking • Impact on vehicle and pedestrian safety within the corridor
Support economic development along the corridor	• Improve transit access to existing and future developments • Create connections between transit and centers of employment, education, residence, shopping, culture and entertainment	• Impact on residential access to transit • Impact on transit access to activity centers • Impact on transit access to redevelopment sites
Promote livable, transit-oriented development	• Provide high-capacity transit facilities at locations where existing and future land uses make them mutually supportive	• Ability to support higher density land uses
Create a multi-modal transportation system with attractive travel choices	• Create a premium transit route with service characteristics that make it competitive with the private automobile • Integrate premium transit service with local bus, bicycle, pedestrian, private automobile and intercity travel modes • Create opportunities for future upgrades or additional premium transit services	• Average operating speed • Number of intermodal connections • Level of investment that can support future upgrades • Frequency, schedule, and travel times of transit services in the corridor
Optimize return on public investment	• Develop cost-effective transit solutions	• Order-of-magnitude capital cost • Order-of-magnitude operating cost
Enhance environmental quality	• Minimize and mitigate negative impacts to the human and natural environment	• Impact on natural resources (parklands, wetland, water, habitat) • Impact on historic and cultural resources

Each alternative was evaluated against these measures of effectiveness using the five-grade ranking system shown in Table 2-2. A more detailed explanation of the rank assigned to each alternative is provided in Section 3.0.

TABLE 2-2: RANKING SYSTEM FOR INITIAL SCREENING CRITERIA

Rank	General Assessment
A	The alternative may provide major benefits and/or significantly minimize negative impacts
B	The alternative may provide some benefits and/or minimize some negative impacts
C	The alternative will have negligible benefits or impacts
D	The alternative may have some negative impacts
F	The alternative may have major negative impacts

In addition to these corridor-wide criteria, the proposed station areas for each alternative were evaluated using a separate station area identification methodology. This methodology will determine which of the initial stations under consideration should be carried forward into the detailed definition of alternatives. The methodology used to evaluate station locations is described in greater detail in the *Station Area Assessment Methodology*. As each of the alternatives utilizes the same route, it will be possible to feed the results of the station area screening into the results of this initial screening to develop a detailed definition of each of the alternatives that survives this screening.

3.0 INITIAL SCREENING RESULTS

Table 3-1 summarizes the findings of the initial screening. The Baseline and Build Alternatives are anticipated to offer a measurable level of improvement in transit access and mobility over the No Build Alternative, as each of these alternatives will offer a new, limited stop service that will improve transit travel times in the study corridor. In general, the major difference between alternatives is related to the degree to which they use dedicated lanes. While new bus lanes are anticipated to improve transit travel times and reliability of service, these benefits come at the expense of additional capital costs, parking impacts, traffic impacts, and right-of-way requirements.

The following paragraphs provide a more detailed description as to how the alternatives fared against each of the initial screening measures of effectiveness.

TABLE 3-1: SUMMARY OF INITIAL SCREENING RESULTS

Measures of Effectiveness	No Build	Baseline	Build 1	Build 2
Improve local and regional mobility				
▪ Impact on transit ridership	C	B	B	B
▪ Impact on general traffic	C	C	D	F
▪ Impact on on-street parking	C	C	D	F
▪ Impact on vehicle and pedestrian safety	F	F	B	B
Support economic development along the corridor				
▪ Impact on residential access to transit	C	B	B	B
▪ Impact on transit access to activity centers	C	B	A	A
▪ Impact on transit access to redevelopment sites	C	B	A	A
Promote livable, transit-oriented development				
▪ Ability to support higher density land uses	C	C	B	B
Create a multi-modal transportation system with attractive travel choices				
▪ Average operating speed	C	B	B	A
▪ Number of intermodal connections	C	C	B	B
▪ Level of investment that can support future upgrades	C	B	B	B
▪ Frequency, schedule, and travel times of transit services in the corridor	C	B	A	A
Optimize return on public investment				
▪ Order-of-magnitude capital cost	C	C	D	F
▪ Order-of-magnitude operating cost	C	C	D	D
Enhance environmental quality				
▪ Impact on natural resources (parklands, wetland, water, habitat)	C	C	B	B
▪ Impact on historic and cultural resources	C	C	C	C

Notes:
A = The alternative may provide major benefits and/or significantly minimize negative impacts
B = The alternative may provide some benefits and/or minimize some negative impacts
C = The alternative will have negligible benefits or impacts
D = The alternative may have some negative impacts
F = The alternative may have major negative impacts

3.1 Local and Regional Mobility

Impact on Transit Ridership

The Baseline and Build Alternatives were anticipated to provide some benefit to transit ridership. In all cases, the implementation of a new, limited stop transit service was anticipated to encourage new ridership. Under all three alternatives, the local transit network would be optimized to work in conjunction with the new service, which is also anticipated to provide benefits to existing riders and encourage new ridership.

While the dedicated lanes, stations, and other service enhancements of the Build Alternatives are expected to increase transit ridership over the Baseline Alternative, the relative size of the Richmond transit market indicates that these improvements may not be an order-of-magnitude greater than those of the Baseline, hence their "B" ranking. Additional travel demand forecasting will be performed during the detailed screening of alternatives to develop a more accurate assessment of the ridership associated with each alternative.

Impact on General Traffic

As the existing road network would remain unchanged under both the No Build and Baseline Alternatives, both of these alternatives were ranked "C." Build 1 would require the dedication of two lanes for Bus Rapid Transit (BRT) along Broad Street, which could translate to a loss of 25-33% of the roadway capacity between 14th Street and Thompson Street. Build 2 would result in the same losses along Broad Street; in addition, Build 2 would require the removal of two lanes of the existing four along Main Street—an unacceptable potential loss of 50% of the capacity of this roadway.

Impact on On-Street Parking

As the existing road network would remain unchanged under both the No Build and Baseline Alternatives, the parking impacts for both of these alternatives were ranked "C." The impact of Build 1 was ranked as having the same level of impact as under "Impact on General Traffic", as the dedication of bus lanes on Broad Street could require the elimination of some on-street parking if dedicated lanes could not be created from general travel lanes and/or changes to the cross section of Broad Street. Similarly, the impacts of Build 2 on on-street parking were assumed to be significantly negative, as the current cross-section of Main Street would require the elimination of on-street parking in order to accommodate dedicated bus lanes.

Impact on Vehicle and Pedestrian Safety

As the roadway and pedestrian networks would not be altered under either the No Build or the Baseline Alternative, it is anticipated that their impact on vehicle and pedestrian safety would remain the same as today. As the current configuration and width of bus lanes on Broad Street is a contributing factor to the number of bus-related accidents, both the No Build and Baseline were expected to have a continued negative impact on vehicle and pedestrian safety.

Under either Build Alternative, pedestrian and bicycle improvements would be introduced to station areas, improving pedestrian safety along the corridor. Both Build Alternatives would consider reconfiguring the existing bus lanes to minimize conflicts with automobile traffic and local bus traffic; therefore, they received a "B" ranking to reflect these moderate improvements. Additional analysis of traffic and pedestrian impacts will be conducted as part of the detailed screening of alternatives.

3.2 Support for Economic Development

Impact on Residential Access to Transit

As the Baseline and Build Alternatives would offer the first fixed-route transit service available to Rocketts Landing, all three of these alternatives were considered to provide greater residential access to transit than the No Build Alternative. The Build Alternatives would also offer the opportunity to improve pedestrian and bicycle connectivity between the transit stations and local residences. While these new connections would be an improvement over the Baseline Alternative, they may not represent an order-of-magnitude difference; therefore, the Baseline and Build Alternatives all received a "B" ranking. A more detailed assessment of residential access to transit will be considered during the detailed screening of alternatives, in conjunction with station area planning efforts.

Impact on Transit Access to Activity Centers

The Baseline Alternative would provide a more direct service between major activity centers served by the stations, including: downtown Richmond, Rocketts Landing, the Children's Museum, and Willow Lawn. Therefore, the Baseline Alternative was ranked "B." The Build Alternatives would offer the opportunity to introduce improved pedestrian and bicycle access to these and other activity centers; therefore, they were ranked higher than the Baseline Alternative.

Impact on Transit Access to Redevelopment Sites

As noted, the Baseline Alternative would offer a more direct service between redevelopment sites; therefore, it was ranked as having a greater positive impact than the No Build Alternative. The Build Alternatives were ranked as having greater positive impact than the Baseline Alternative, based on their potential to improve pedestrian connectivity. In addition, the stations associated with the Build Alternatives would offer opportunities for joint development with redevelopment sites.

3.3 Livable, Transit-Oriented Development

The Baseline and Build Alternatives would offer a comparative advantage over the No Build in promoting higher density land uses, as each of these alternatives would introduce a new service that is more appealing to choice ridership markets. Both Build Alternatives would have an advantage over the Baseline; since the stations offered under each Build Alternative would offer opportunities for joint development. In addition, the physical improvements associated with the Build Alternatives (stations, guideways) would offer a sense of permanence to the service and help to establish a sense of place, increasing their relative attractiveness to developers and new residents and employers.

3.4 Multi-modal Transportation and Travel Choices

Average Operating Speeds

The Baseline Alternative would be able to achieve higher speeds than the No Build Alternative by limiting the number of bus stops served. Assuming that each bus averages 20 seconds of "dwell time" (the time necessary for buses to stop, allow passengers to board and alight, and depart) at each station, the Baseline Alternative route would spend approximately 5.3 minutes of dwell time on each trip, in comparison to the 21.3 minutes the Route 6 would spend serving the 64 bus stops along the corridor under the No Build Alternative.

The Build Alternatives would also benefit from the same reduced dwell times as the Baseline Alternative. In addition, signal pre-emption and dedicated lanes should improve travel speeds for BRT vehicles by minimizing the impacts of general traffic congestion in the corridor. For the purposes of this initial screening, it is assumed that Build 2 would offer greater travel time improvements than Build 1, as it provides for a dedicated lane throughout the length of the study corridor. The impacts of signal pre-emption and dedicated lanes on travel times will be modeled in greater detail as part of the next stage of the study.

Number of Intermodal Connections

All of the alternatives serve the same intermodal connections (Main Street Station, local bus stops along Broad Street and Main Street); however, the Build Alternatives would offer the opportunity to introduce new park and ride facilities to the corridor. Therefore, the Build Alternatives were ranked as having a greater positive impact on intermodal connections that the No Build and the Baseline Alternative.

Level of Investment to Support Future Upgrades

The Baseline and Build Alternatives all offer the opportunity to develop a new premium transit market in the study corridor. Introducing a new limited-stop service will encourage choice riders to use transit in the corridor which will, in turn, help develop a market for higher levels of investment in transit (advanced BRT applications, streetcar, and light rail transit). While the stations and dedicated lanes associated with the Build Alternatives may offer an opportunity to dedicate rights of way for future investments, this is not a certainty, since the introduction of a new service on the corridor would require the temporary closure of the existing Build Alternative service; furthermore, depending on the technology selected, future investments may have different requirements for stations and rights-of-way that would not allow GRTC to capitalize fully on the investments made in BRT.

Frequency, Schedule, and Travel Times of Transit Services in the Corridor

The operations plan proposed for the Baseline Alternative and the Build Alternatives would offer a higher frequency of service at those stations served by the limited stop service; however, this would come at a reduction of frequency at local stops along the route. The Build Alternatives would offer improved travel times and reliability of service over the No Build and Baseline Alternatives through the use of dedicated lanes and signal pre-emption. The use of off-board fare collection would also improve travel times on the Build Alternatives by reducing the per passenger dwell time associated with purchasing fares on board the vehicle (and forcing other passengers to wait.)

3.5 Return on Public Investment

Order-of-Magnitude Capital Cost

The Baseline Alternative should offer comparable capital costs to the No Build Alternative, as the new limited stop service and improvements recommended by the Comprehensive Operations Analysis would be operated using vehicles from the existing fleet. On the other hand, Build 1 would require the additional costs of 3.5 miles of guideway, new stations, vehicles, and other improvements. As Build 2 would use an additional 3.5 miles of guideway beyond those associated with Build 1, it is reasonable to assume that it would represent at least double the capital cost of Build 1. A more detailed, quantitative assessment of the capital costs will be completed as part of the detailed screening of alternatives, using the approach documented in the *Capital Cost Methodology*.

Order-of-Magnitude Operating Cost

The Baseline Alternative would implement the minor route modifications that are designed to optimize route performance. Therefore, the operating costs of the Baseline should be equal to or less than those of the No Build. The Build Alternatives would introduce new operations and maintenance expenses associated with the upkeep of new stations, guideway, and a dedicated fleet of vehicles. A more detailed, quantitative assessment of the operating costs will be completed as part of the detailed screening of alternatives, using the approach documented in the *Operations and Maintenance Cost Methodology*.

3.6 Environmental Quality

Impact on Natural Resources

The Baseline Alternative should offer a comparable level of impact to the environment as the No Build Alternative, promoting transit ridership while having minimal new impacts to natural resources in the corridor. Similarly, because the Build Alternatives would be constructed entirely within the existing streetscape, they would result in minimal impacts to the natural environment. Further because they offer a net benefit to the natural resources of the region by helping to maintain air quality by encouraging new transit ridership.

Impact on Historic and Cultural resources

No impacts to historic or cultural resources are anticipated as a result of the No Build or Baseline alternatives. The Build Alternatives would add stations and a fixed guideway to the streetscape through downtown Richmond. As a result, historic and cultural resources are being studied to evaluate potential effects to these resources. To date, 54 properties and nine historic districts have been identified near the study corridor that are or potentially are eligible for listing on the historic register. Coordination is on-going with the Virginia Department of Historic Resources to ensure the identification and protection of these resources. In general, because Build 2 has a longer section of guideway than Build 1, it has more potential for effects to historic and cultural resources.

In addition, it was noted in the public meetings of February 2010 that the proposed routing of the Baseline and Build Alternatives would be considered to have a negative effect on the cobblestone street of 17th Street and the nearby Farmer's Market. Based on this feedback, the study team will consider alternative routing between Broad Street and Main Street.

4.0 INPUT RECEIVED AT PUBLIC MEETINGS

Public meetings were held in February 2010 to introduce this project to the general, describe the alternatives under study, and gather public scoping comments on the alternatives and topics to consider in the environmental assessment. Key comments made at these meetings regarding the Initial Alternatives include questions regarding:

- Study of light rail transit,
- Use of 17^{th} Street to access Main Street from Broad Street, and

- Suggestions for station locations.

Previous regional planning efforts and a Technology Assessment conducted as a part of this study have determined that BRT would be the most cost-effective investment for the Broad Street Corridor at the present time. Its technical attributes would allow it to address local transportation needs, support economic development plans and achieve environmental objectives, all within difficult fiscal constraints. Most importantly, the lower capital costs of BRT would make it a more competitive candidate for Small Starts funding, while offering the opportunity to phase in rail alternatives once ridership and land use in the study area warrant further investment.

Given the feedback at the public scoping meetings about the likelihood of impacts of BRT traffic on 17th and 18th Streets, a study was conducted to evaluate options to access Main Street from Broad Street in the vicinity of the Main Street Station. The following options were compared:

- 7th/8th/9thGrace/Bank/Franklin/15th Streets,
- 8th/9th Streets
- 14th Street,
- 17th Street,
- 21st Street, and
- 25th Street.

Based on the analysis documented in the *Broad Street to Main Street Transition Report*, 14th Street represents the best north-south connection between Main and Broad since it minimizes impacts to surrounding businesses and allows for important intermodal connections (at Main Street Station) and regional activity centers (MCV) to be served in the most direct manner. The details regarding the outcome of this technical analysis will be formally presented the Technical Advisory Board and the next public meeting (to be held in the fall of 2010).

Comments were also made regarding potential station locations. These will be considered during the process to select station locations and documented in a separate technical memorandum.

5.0 CONCLUSIONS

Based on the findings of the initial screening and feedback from the general public, the study team made the following conclusions for each of the alternatives:

- **No Build: Retain.** Required by FTA.
- **Baseline Alternative: Retain.** Based on feedback from public meetings held in February 2010, the route will be moved off of 17th Street. Alternative routes will be considered between Broad Street and Main Street as part of the detailed definition of alternatives.
- **Build 1: Retain.** Compared to the Baseline Alternative and the No Build, Build 1 offers advantages in transit travel times, service reliability, and access to activity centers along the study corridor. While Build 1 also has a potentially higher capital cost than the Baseline Alternative, it would be less expense than the anticipated capital costs of Build 2. The exact amount of dedicated lanes necessary to make Build 1 cost-effective will be considered as part of the detailed definition and analysis of alternatives.

- **Build 2: Remove from further study.** Build 2 offers benefits in travel times and service reliability that may exceed those of the other three alternatives; however, the limited right-of-way along Main Street would make it impossible to develop dedicated bus lanes without eliminating on-street parking and/or having major impacts on east-west travel along Main Street. The concerns expressed regarding BRT dedicated lanes near the Farmer's Market, combined with the need to continue studies of Main Street Station, would make it appropriate to postpone the development of a dedicated transitway along Main Street to a later phase of implementation.

5.0 NEXT STEPS

Based on the results of this analysis and feedback from the general public, the Technical Advisory Committee, and the Policy Advisory Committee, the study team will review the remaining alternatives and refine them to make it possible to develop more precise, quantitative assessments of the benefits and impacts of each. These detailed alternatives will then be modeled to forecast their traffic impacts, ridership potential, and costs. The results of the detailed screening will be presented to the public for their feedback before a decision is made on the Locally Preferred Alternative (LPA) to be carried forward into design and implementation.

BROAD STREET RAPID TRANSIT STUDY

ENVIRONMENTAL ASSESSMENT

APPENDIX A-5: Broad Street to Main Street Connection Report

BROAD STREET RAPID TRANSIT STUDY: BROAD STREET TO MAIN STREET TRANSITION

The purpose of this technical memorandum is to document the results of the initial screening of options for transitioning from Broad Street to Main Street in or near the central business district of Richmond. GRTC's Comprehensive Operations Analysis (COA) formed the basis for developing the alignment under study and the COA alignment followed 17th Street between Broad Street and Main Street. Through initial screening and public input it became clear that such a routing would likely have too many negative impacts. Therefore, five new options have been developed and will be evaluated in this memo alongside the original 17th Street option.

1.0 INITIAL OPTIONS

Six routing options have been developed for transitioning from Broad Street to Main Street. These options are shown in Figure 1-1 and described below.

Option 1 **25th Street**: Westbound buses would turn right from Main Street onto 25th Street then left onto Broad Street. Eastbound buses would turn right from Broad Street onto 25th Street then left onto Main Street.

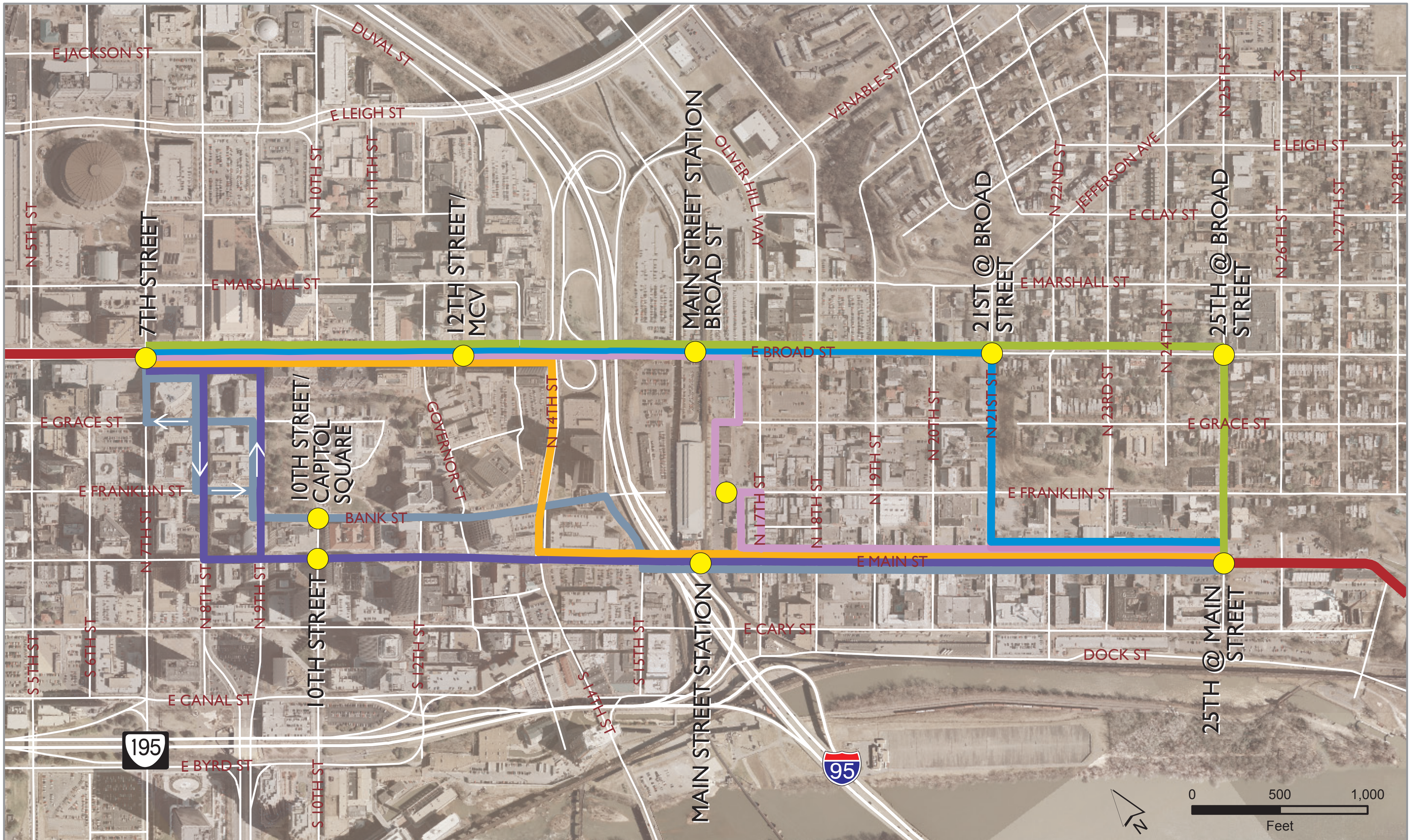
Option 2 **21st Street**: Westbound buses would turn right from Main Street onto 21st Street then left onto Broad Street. Eastbound buses would turn right from Broad Street onto 21st Street then left onto Main Street.

Option 3 **17th Street**: Westbound buses would turn right from Main Street onto 17th Street then left onto Broad Street. Eastbound buses would turn right from Broad Street onto 17th Street then left onto Main Street.

Option 4 **14th Street**: Westbound buses would turn right from Main Street onto 14th Street then left onto Broad Street. Eastbound buses would turn right from Broad Street onto 14th Street then left onto Main Street.

Option 5 **8th/9th Street**: Westbound buses would turn right from Main Street onto 9th Street then left onto Broad Street. Eastbound buses would turn right from Broad Street onto 8th Street then left onto Main Street.

Option 6 **7th/8th/9th/Grace/Bank/Franklin/15th Streets**: Westbound buses would turn right from Main Street onto 15th Street then left onto Franklin Street, continue thru on Bank Street, turn right onto 9th Street, then left onto Grace Street, then right onto 7th Street then left onto Broad Street. Eastbound buses would turn right from Broad Street onto 8th Street then left onto Franklin Street, then right onto 9th Street, then left onto Bank Street, continue thru onto Franklin Street, then turn right onto 15th Street, then left onto Main Street.



Option 1: 25th Street
Option 2: 21st Street
Option 3: 17th Street
Option 4: 14th Street
Option 5: 8th/9th Streets
Option 6: 7th/8th/9th/15th Streets
Possible Stations
BRT Alignment

Figure 1-1:
Broad Street to Main Street Transition Options

BROAD STREET RAPID TRANSIT STUDY

2.0 ASSESSMENT OF TRANSITION OPTIONS

Population, Employment and Special Generators

Based solely on the differences in population and employment within the quarter-mile station areas identified, Options 4 and 5 could provide the most additional riders given their proximity to larger employment bases along Main and Cary Streets in the CBD. Option 1 has the highest population within its station areas, due to its proximity to the center of Church Hill. The actual difference in population is not substantial enough, though, to suggest a large improvement in ridership.

TABLE 2-1: POPULATION AND EMPLOYMENT BY STATION AREA

Station Name	Option(s)	Population	Employment
12th Street/MCV (Broad)	1, 2, 3, 4	131	24,867
10th Street (Main)	5	121	31,326
10th Street/ Capitol Square (Bank)	6	136	31,943
Main Street Station (Broad)	1, 2	355	11,432
Main Street Station (17th)	3	503	7,146
Main Street Station (Main)	4, 5, 6	371	11,230
25th (Broad)	1	1,310	837
21st (Broad)	2	1,269	1,015
25th (Main)	3, 4, 5, 6	770	1,135

Quarter-mile station area assessment of population and employment using 2000 TAZ level data from RRPDC.

TABLE 2-2: POPULATION AND EMPLOYMENT BY OPTION

Option	Total Population	Total Employment
1: 25th Street	1,761	27,525
2: 21st Street	1,485	27,369
3: 17th Street	1,373	28,374
4: 14th Street	1,237	31,406
5: 8th/9th Street	1,253	40,583
6: 7th/8th/9th/Grace/Bank/Franklin/15th Streets	1,269	41,324

Quarter-mile station area assessment of population and employment using 2000 TAZ level data from RRPDC. Totals will not add up between Tables 2-1 and 2-2 due to station area overlap.

These population and employment data rely on traffic analysis zone data from the Richmond Regional Planning District Commission and are based on Census 2000 data. These data do not include population and employment for the many recent warehouse to apartment and office conversions that have occurred in the last 10 years in Shockoe Bottom, which would add to the population and employment served by Main Street Station (Main or 17th) and 25th (Main). For example, over 500 apartments and condominiums have been developed by Forest City in the River Lofts at Tobacco Row development between Main, Cary, 21st and 26th Streets since 2000. Numerous other smaller redevelopment projects have brought additional multi-family housing to Shockoe Bottom. Also, conversion of warehouses to office space has been occurring in Shockoe Bottom, such as the 2006 redevelopment of the Edgeworth Building (East Cary Street between 21^{st} and 22^{nd}) with 166,000 square feet of Class A office space.

Additionally, the population and employment figures for each option do not account for special generators that attract or create many non-work based trips. One major special generator is Virginia Commonwealth University's MCV campus which includes a 779 bed hospital with 30,000 annual admissions and 500,000 annual outpatient visits. Options 1, 2, 3 and 4 would directly serve this major regional destination. According to the most recent GRTC rider survey, between five and ten percent of local and express bus riders have an origin or destination on the MCV Campus.[1] Main Street Station is also an important special generator. While it is currently only served by about 4 trains a day, plans are for the station to become the main hub for intercity train service for the region, including high speed rail service. Option 3 would serve Main Street Station well, but Options 4, 5 and 6 would have the most direct access to the station.

Impacts to Other Modes

Potential impacts to traffic are also critical factors to the assessment of each option. Broad Street between 2nd and 14th Streets has a right of way of approximately 80 feet. Most other east-west routes in the CBD have rights of way less than 50 feet. Thus, any enhanced transit service would likely have the least negative impact to other modes if run along Broad in the CBD. East of 14^{th} Street, Broad Street quickly narrows to a 40 foot right of way, whereas Main Street maintains a 48 foot right of way to 21^{st} Street.

Among the other corridors, 14^{th} Street has a right of way that varies from about 54 feet at its northern end to about 82 feet at its southern end. 7^{th}, 8^{th}, 9^{th}, 21^{st} and 25^{th} all have rights of way less than 44 feet wide. Grace, Franklin, Bank and 15^{th} Streets all have rights of way less than 54 feet wide. 17^{th} Street has the most constrained right of way at 30 feet, plus it is a particularly historic street with cobblestone pavers that would not be conducive to rapid transit service. Thus, any enhanced transit service would likely have the least negative impact to other modes if run along 14^{th} to connect between Broad and Main. Lastly, use of Main Street under Option 5 would require converting Main Street to two-way operation from 8^{th} Street to 12^{th} Street. While the Downtown Master Plan recommends this conversion, the traffic impacts of such a conversion could be considerable.

Congestion

Impacts of traffic congestion on bus operation are also important in that highly congested turn movements could significantly degrade schedule reliability. The existing volumes and LOS for all intersections traversed by these options are shown in Figures 2-1 to 2-14 (at the end of this report). A few intersections have poor levels of service which could detrimentally affect service reliability, but the volume and delay for left turn movements is of particular concern. Options 1 and 2 have congested left turn movements in the PM peak period when turning onto Main Street. These issues are exacerbated by the absence of dedicated left turn lanes on 21^{st} or 25^{th} Streets. Delays would also be exacerbated for Option 1 by the

[1] 216 respondents of 3,929 local and express bus riders surveyed specifically listed VCU Health Systems, MCV Hospitals or other MCV building as their origin or destination building in their answers to Questions 1b or 2b. Only 2,226 and 2,221 respondents, respectively, listed a starting or ending building in their answers to Questions 1b and 2b. Thus, of all respondents, 5.5% listed a starting or ending building at the complex, while a total of 9.7% of those who explicitly provided a building in their answer listed a starting or ending point at the complex.

presence of two all-way stop signs at Broad and 23rd and Broad and 24th. Option 3 would also have issues with left turns onto Main Street from 17th as there is no signal for that portion of the intersection.

Option 4 seems to have the worst intersection LOS issues; however, most of the delays are associated with movements that the proposed routing avoids. Much of the PM congestion is associated with vehicles turning right from northbound 14th to eastbound Broad (to access I-95), whereas transit vehicles would be turning left. There is some delay associated with the southbound left turn onto Main Street from 14th in the PM peak, but this could be easily addressed by providing a dedicated left turn phase at this signal.

Based on existing conditions, Option 5 would not likely encounter substantial delay due to congestion. Yet, the conversion of Main Street to two-way operation, required under this option, could significantly degrade traffic operations at 8th and 9th Streets. Option 6, by virtue of requiring 6 turns, including 3 lefts, is most likely to encounter delay due to congestion. Additionally, the delay associated with the turn movements required by this option at Bank/Franklin and 14th, Franklin and 15th, and Main and 15th are substantial.

3.0 SCREENING ANALYSIS

An evaluation of the transition options is presented below. Plus signs indicate positive attributes of the options while minus signs indicate negative attributes of the option.

Option 1 25th Street

+ Directly serves MCV
+ Slightly higher population served
– Narrow right of way on 25th Street
– Narrow right of way on Broad Street east of 14th Street
– Congested turn movement, southbound left from 25th to Main in PM peak
– Lower employment served
– Fails to served Main Street Station directly

Option 2 21st Street

+ Directly serves MCV
+ Slightly higher population served
– Narrow right of way on 21st Street
– Narrow right of way on Broad Street east of 14th Street
– Congested turn movement, southbound left from 21st to Main in PM peak
– Lower employment served
– Fails to serve Main Street Station directly

Option 3 17th Street

+ Directly serves MCV
+ Slightly higher population served
– Extremely narrow right of way on 17th Street
– Narrow right of way on Broad Street east of 14th Street
– Cobblestone streets and historic farmers market impacts
– Opposition from adjacent business owners

- – Lower employment served
- – Less direct service to Main Street Station than Options 4, 5 and 6

Option 4 14th Street

- \+ Directly serves MCV
- \+ Widest north-south right of way
- \+ Maximizes use of widest east-west rights of way on Broad and Main Streets
- \+ Directly serves Main Street Station
- – Lower employment served
- – Slightly lower population served

Option 5 8th/9th Streets

- \+ Higher employment served
- \+ Directly serves Main Street Station
- – Requires conversion of Main Street to two-way operation east of 8th Street
- – Fails to serve MCV directly
- – Narrow rights of way on 8th and 9th
- – Slightly lower population served

Option 6 7th/8th/9th/Grace/Bank/Franklin/15th Streets

- \+ Higher employment served
- \+ Directly serves Main Street Station
- – Fails to serve MCV directly
- – Narrow rights of way on 7th, 8th, 9th, Grace, Franklin, Bank and 15th Streets.
- – Congested movements at multiple intersections.
- – Confusing operational pattern through CBD
- – Extra turns in CBD add to potential delays
- – Extra turns in CBD add to potential conflicts with pedestrians
- – Slightly lower population served

Option 4 appears to be the best option as it has the most positive attributes and the fewest negative attributes. Furthermore, it is the only option that fulfills the critical elements outlined below.

Virginia Commonwealth University's MCV Campus is a critical regional destination; convenient walking access between transit and the campus should be prioritized.

VCU's MCV campus is a major downtown employer, a critical provider of medical services to the community and, as indicated in survey results, a major destination for current GRTC riders. Options 1, 2, 3 and 4 are the only options that could provide high quality transit service the front door of this critical regional destination.

Main Street Station is a critical intermodal connection; convenient walking access between transit and intercity rail should be prioritized.

Options 4, 5 and 6 are the only options that could provide high quality transit service the front door of this critical regional destination. Option 3 would provide a stop very close to the front door, but it would still be at least 600 feet away. Options 1 and 2 would have a long, circuitous pedestrian route to Main Street Station, requiring a walk of at least a quarter mile.

Significant redevelopment has occurred over the past decade along Main Street in Shockoe Bottom, and future opportunities remain.

Main Street from 15th to 25th Streets is the central artery of Shockoe Bottom. All the recent and planned redevelopment in this area has been largely focused around the Main Street corridor and most of the redevelopment is very transit supportive. Options 3, 4, 5 and 6 provide direct and convenient access to the heart of Shockoe Bottom via Main Street Station and 25th Street stops.

Broad Street west of 14th Street has the widest available east-west right-of-way in the corridor, making it ideal for accommodating rapid transit service with minimal impact on other modes.

Maximizing the use of the wide right of way within the CBD is the most cost effective way of providing high quality transit service through the CBD that also minimizes impacts on other modes. Options 1, 2, 3 and 4 are the only options that maximize the use of Broad Street within downtown.

14th Street has the widest available north-south right-of-way among the options, making it ideal for accommodating rapid transit service with minimal impact on other modes.

Maximizing the use of the wide right of way within the CBD is the most cost effective way of providing high quality transit service through the CBD that also minimizes impacts on other modes. Option 4 is the only option that would make use of this corridor.

4.0 CONCLUSION

The above evaluation indicates that Option 4 is the best option at serving critical destinations, balancing service to population and employment centers in the CBD and avoiding congestion and conflicts with other modes. Option 4, maximizes the use of the widest rights of way on Broad, Main and 14th thus providing the best opportunity for cost effective implementation of rapid transit service while limiting the negative impacts.

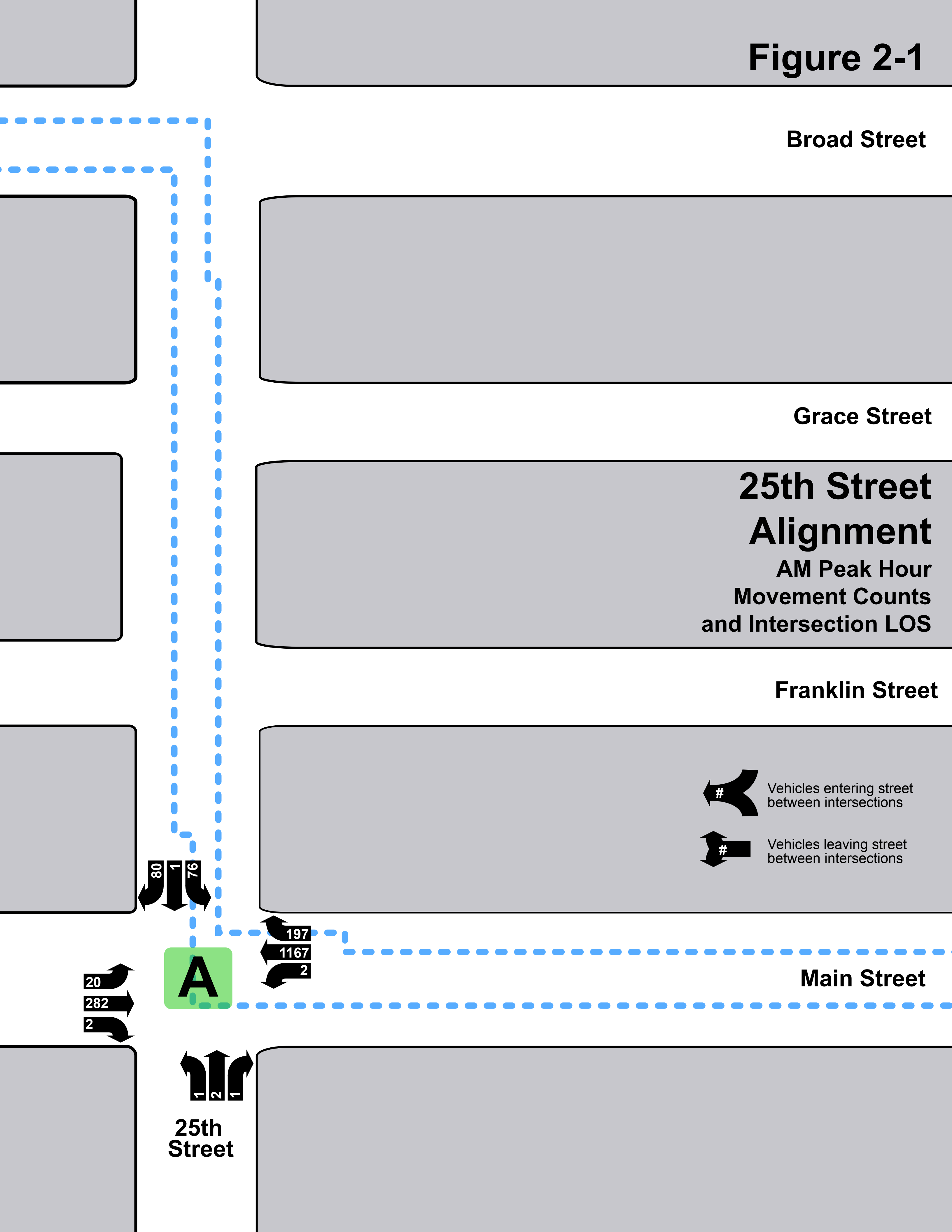


Figure 2-1
Broad Street
Grace Street
25th Street Alignment
AM Peak Hour
Movement Counts
and Intersection LOS
Franklin Street
Vehicles entering street between intersections
Vehicles leaving street between intersections
#
#
80
1
76
197
1167
2
20
282
2
A
Main Street
1
2
1
25th Street

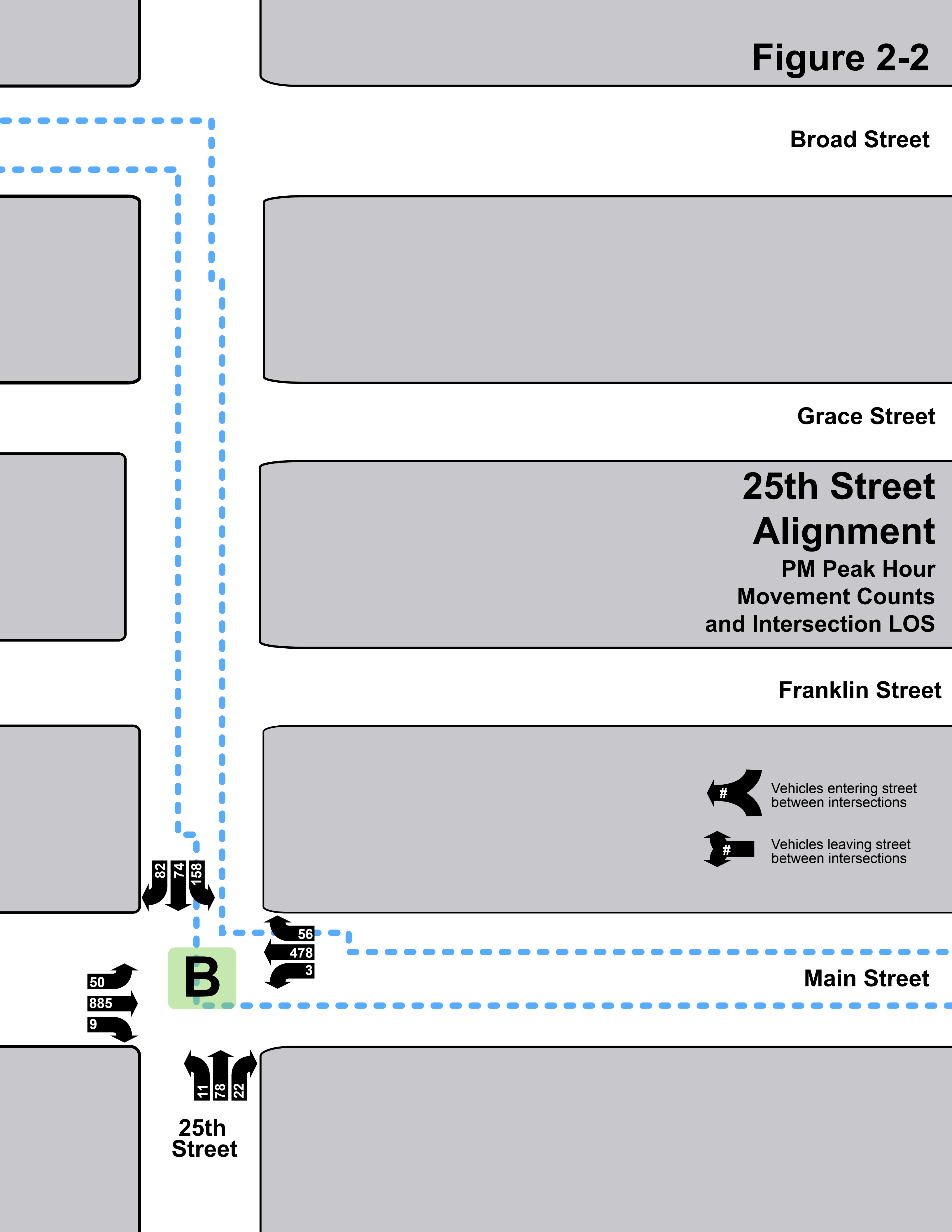


Figure 2-2
Broad Street
Grace Street
25th Street Alignment
PM Peak Hour Movement Counts and Intersection LOS
Franklin Street
Vehicles entering street between intersections
Vehicles leaving street between intersections
#
82
74
158
56
478
3
50
885
9
B
11
78
22
Main Street
25th Street

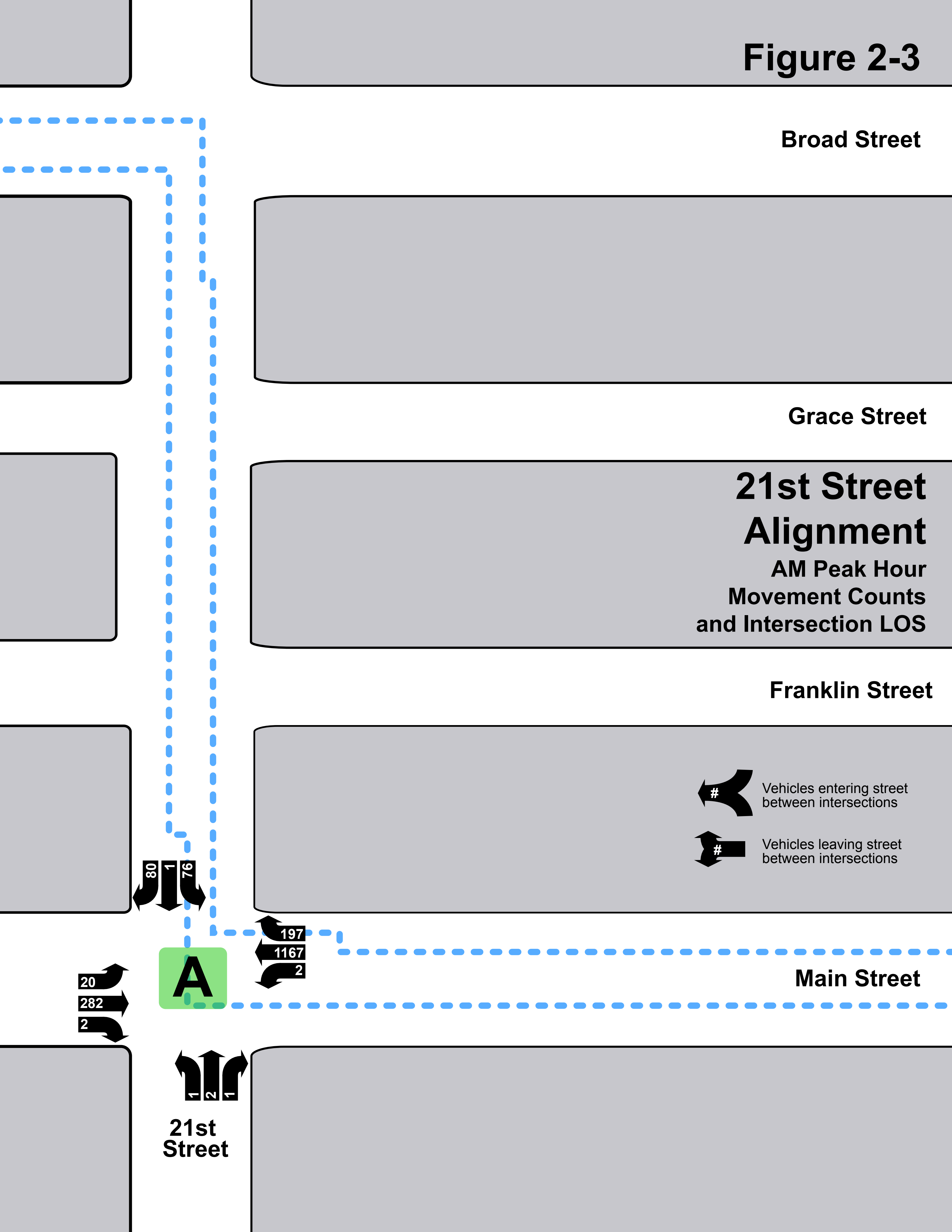


Figure 2-3
Broad Street
Grace Street
21st Street Alignment
AM Peak Hour Movement Counts and Intersection LOS
Franklin Street
Vehicles entering street between intersections
Vehicles leaving street between intersections
80
1
76
197
1167
2
20
282
2
A
1
2
1
Main Street
21st Street

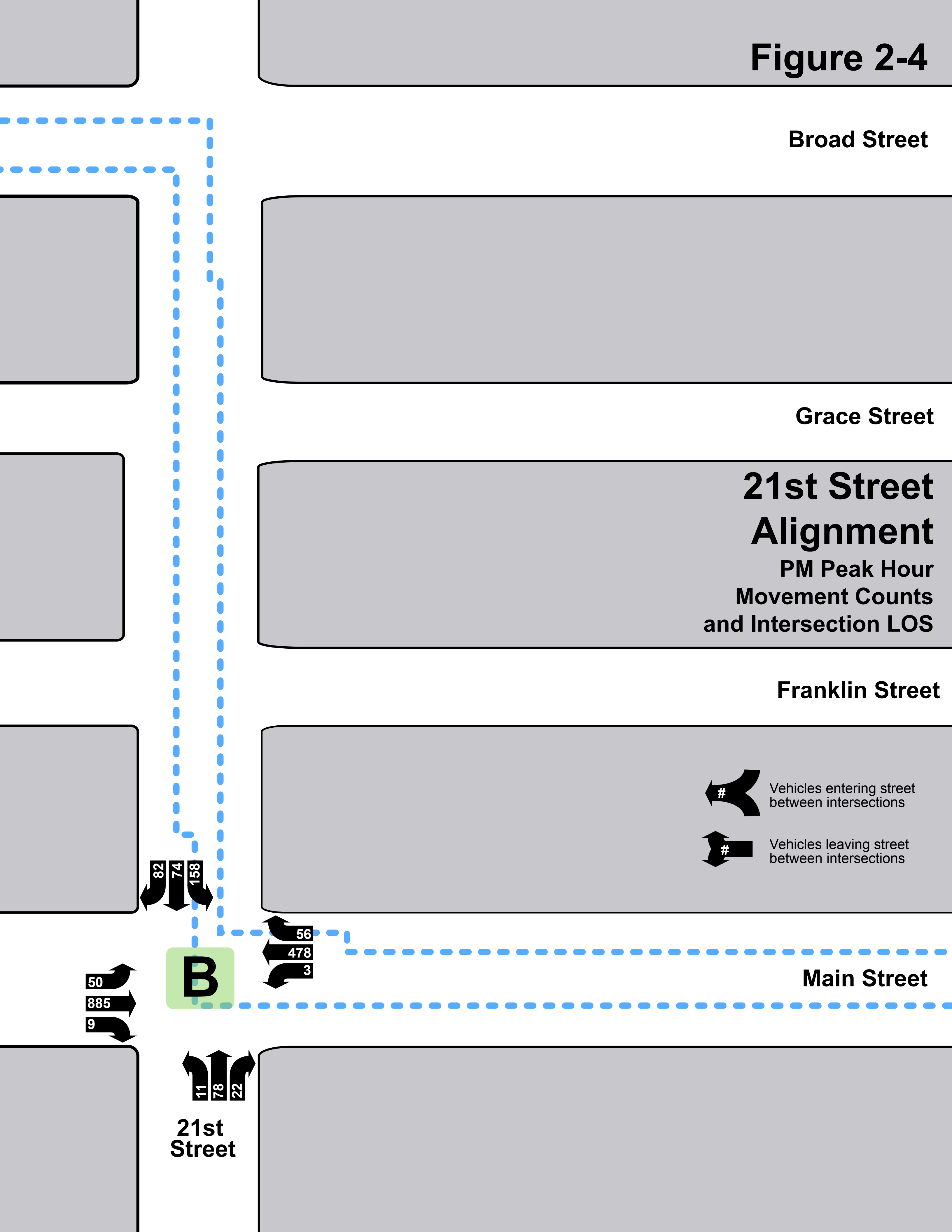
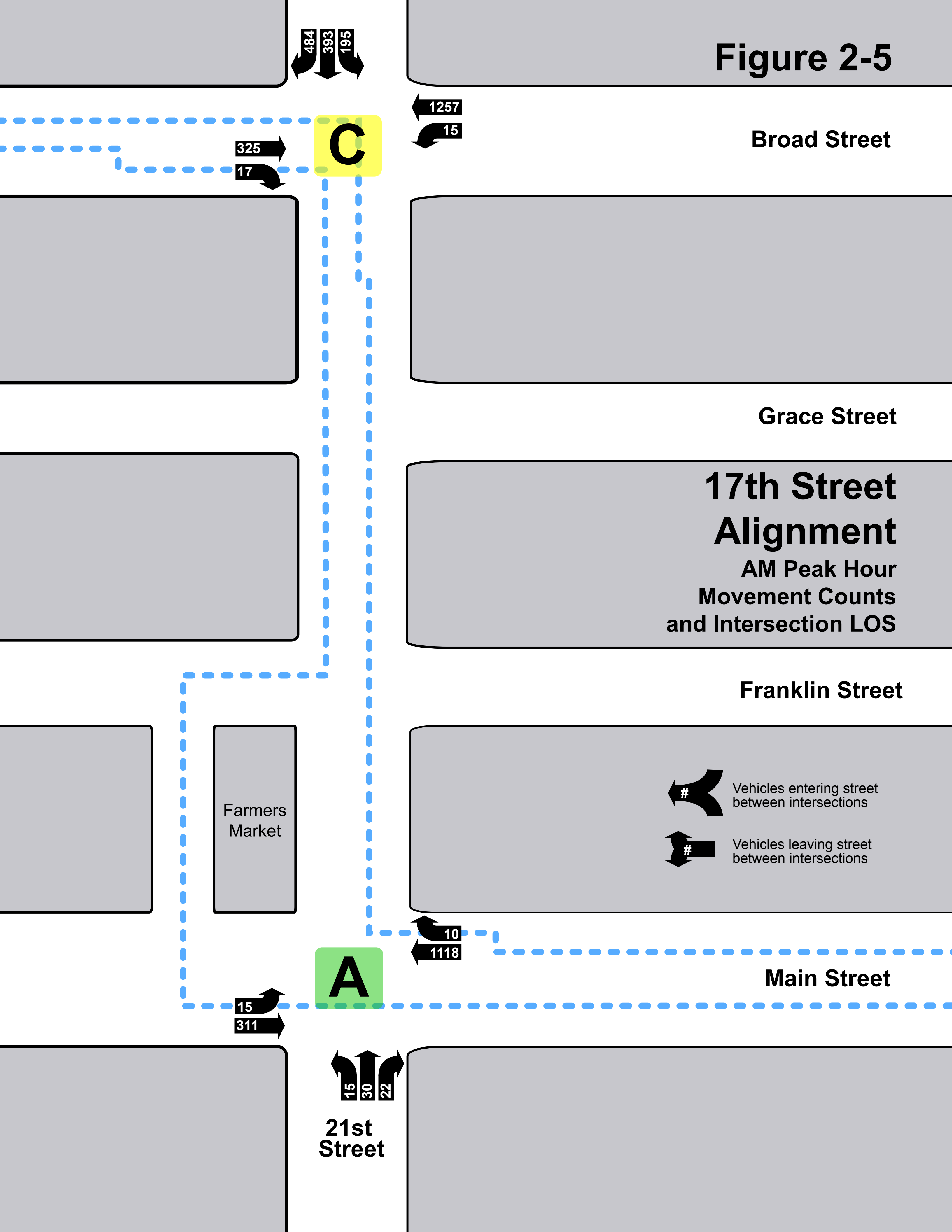


Figure 2-4
21st Street Alignment
PM Peak Hour Movement Counts and Intersection LOS
Broad Street
Grace Street
Franklin Street
Main Street
21st Street
B
82
74
158
56
478
3
50
885
9
11
78
22
#
Vehicles entering street between intersections
#
Vehicles leaving street between intersections

Figure 2-5



484
393
195
1257
15
Broad Street
325
17
C
Grace Street
17th Street Alignment
AM Peak Hour Movement Counts and Intersection LOS
Franklin Street
Farmers Market
#
Vehicles entering street between intersections
#
Vehicles leaving street between intersections
10
1118
A
Main Street
15
311
15
30
22
21st Street

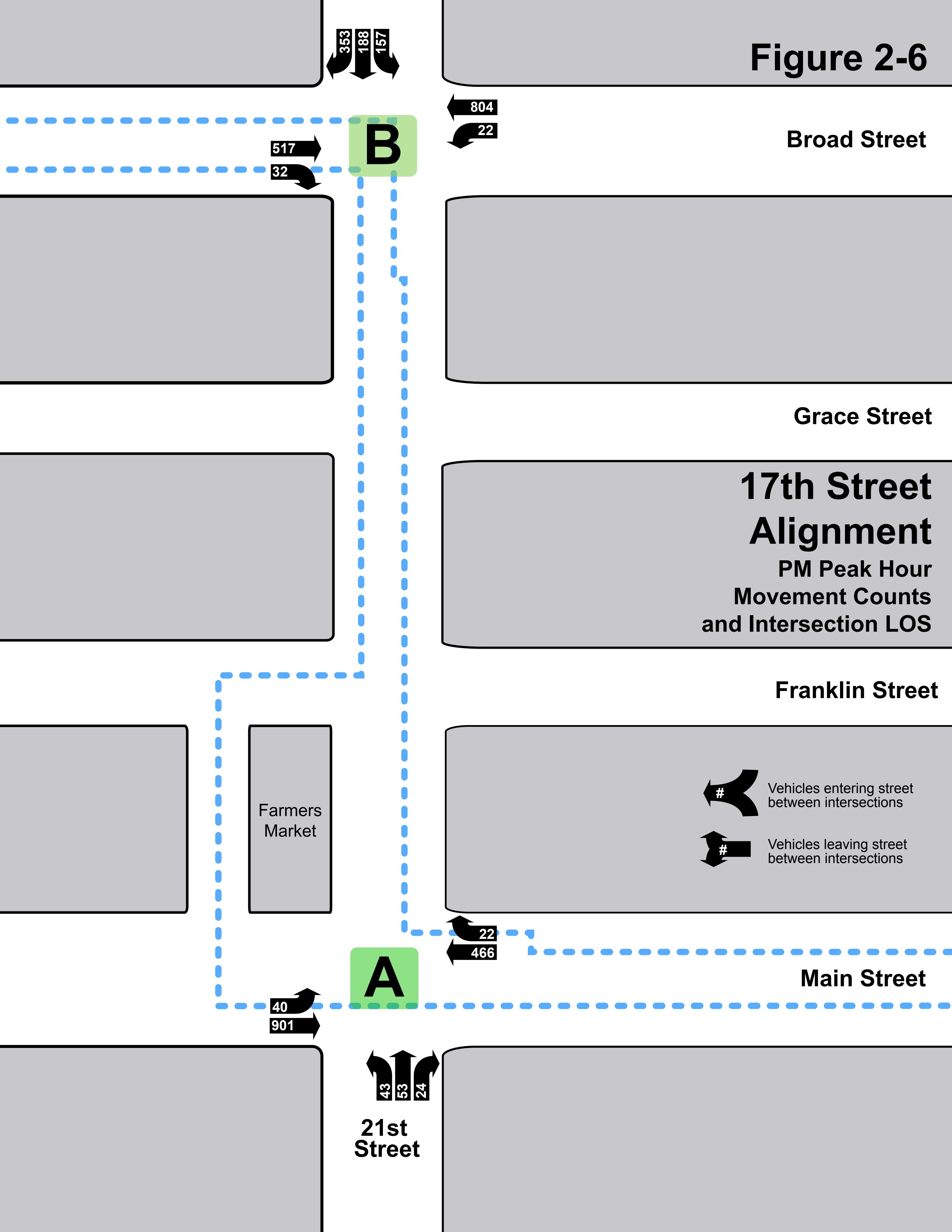


Figure 2-6

17th Street Alignment

PM Peak Hour Movement Counts and Intersection LOS

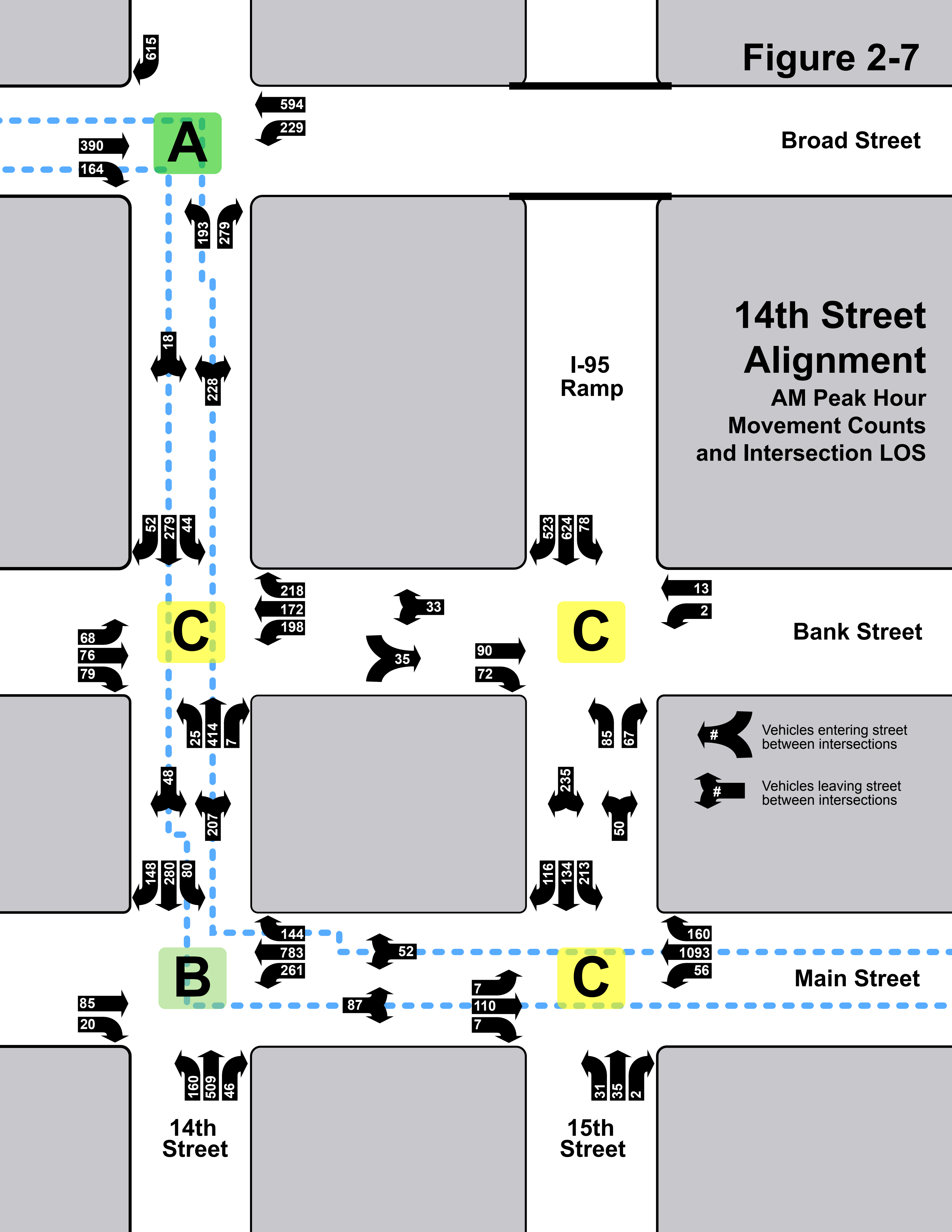


Figure 2-7

14th Street Alignment
AM Peak Hour Movement Counts and Intersection LOS

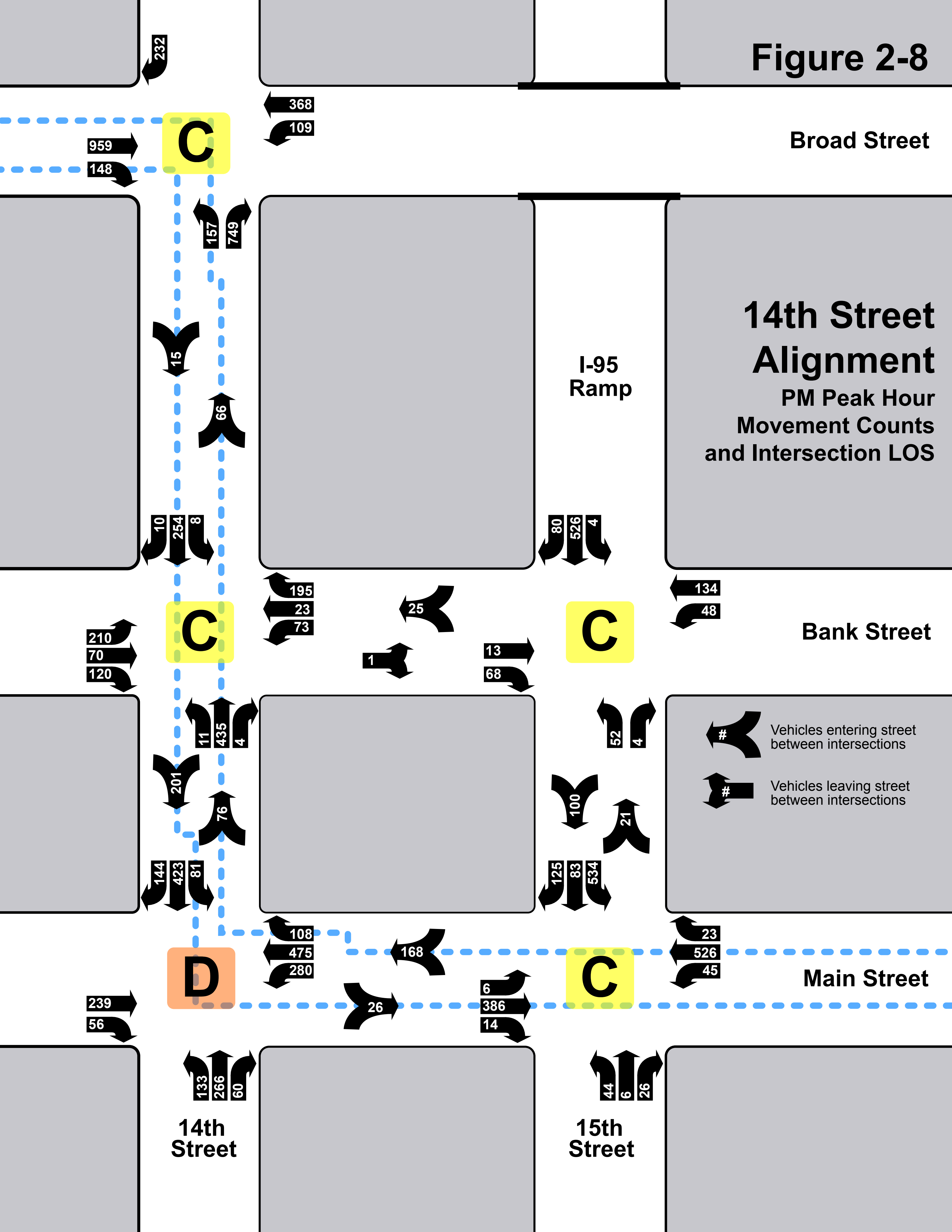


Figure 2-8
14th Street Alignment
PM Peak Hour Movement Counts and Intersection LOS
Broad Street
Bank Street
Main Street
I-95 Ramp
14th Street
15th Street
Vehicles entering street between intersections
Vehicles leaving street between intersections
232
368
109
959
148
157
749
15
99
10
254
8
80
526
4
195
23
73
25
134
48
210
70
120
1
13
68
11
435
4
52
4
201
76
100
21
144
423
81
125
83
534
108
475
280
168
23
526
45
239
56
26
6
386
14
133
266
60
44
6
26
C
C
C
D
C

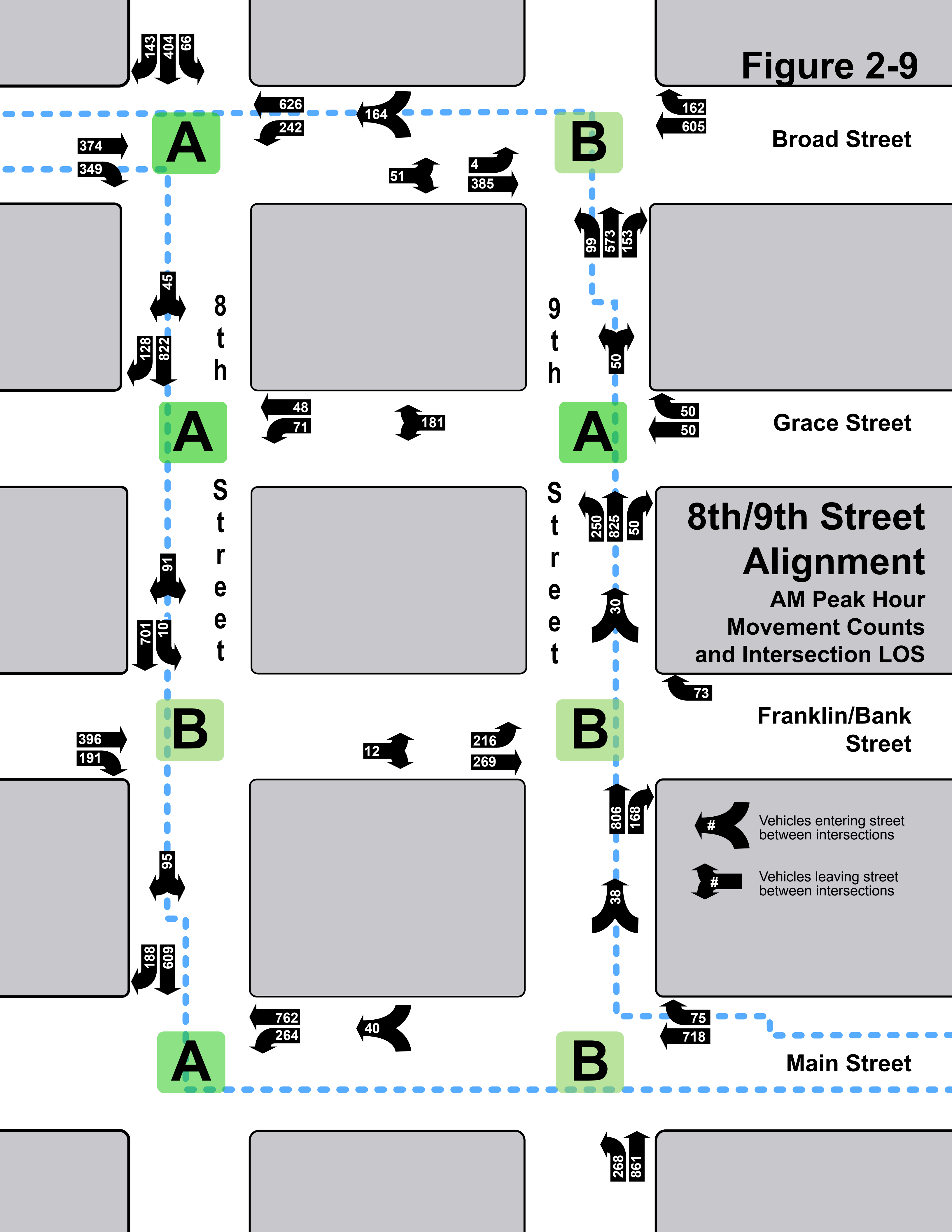
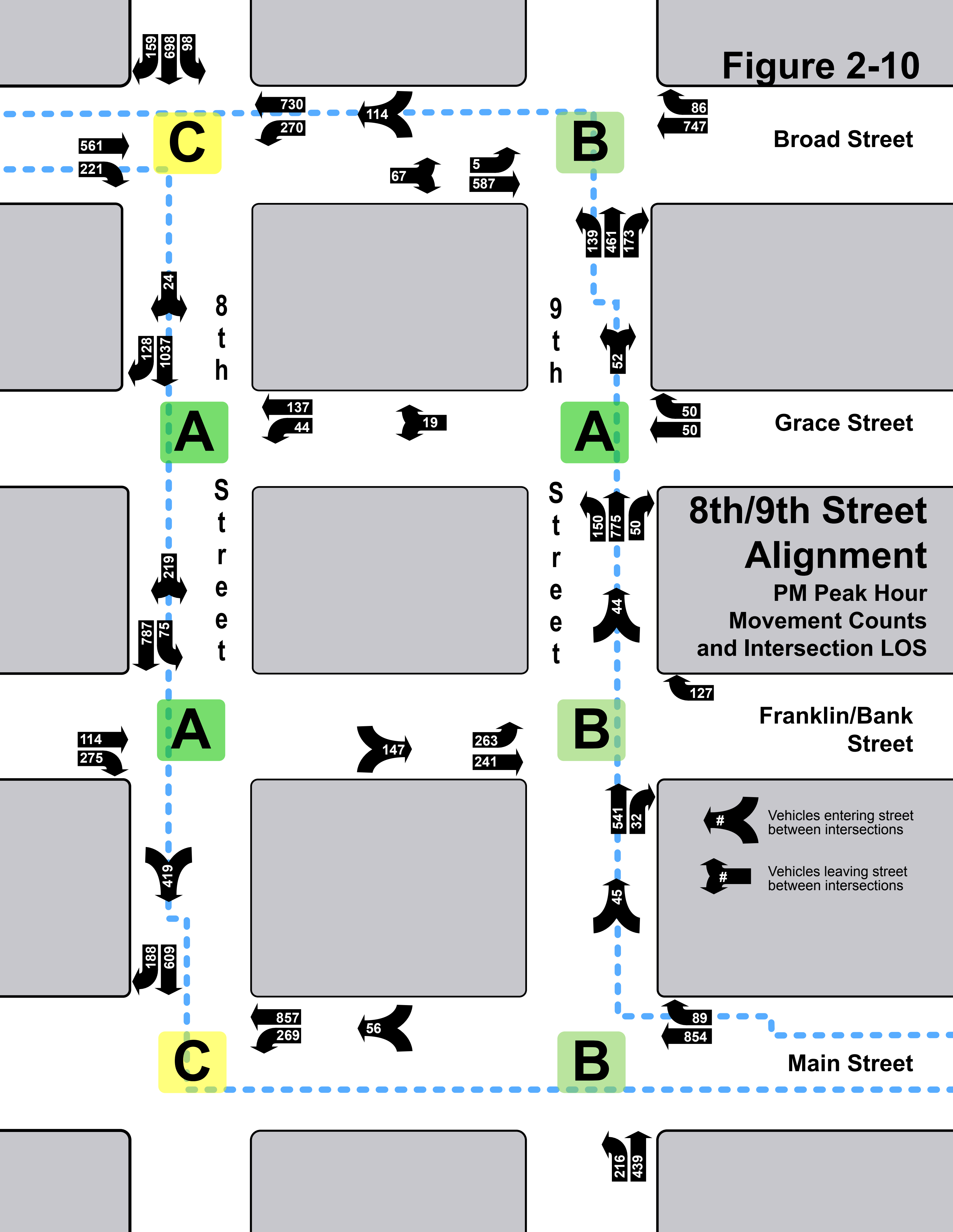


Figure 2-9

8th/9th Street Alignment

AM Peak Hour Movement Counts and Intersection LOS

Figure 2-10



8th/9th Street Alignment
PM Peak Hour Movement Counts and Intersection LOS

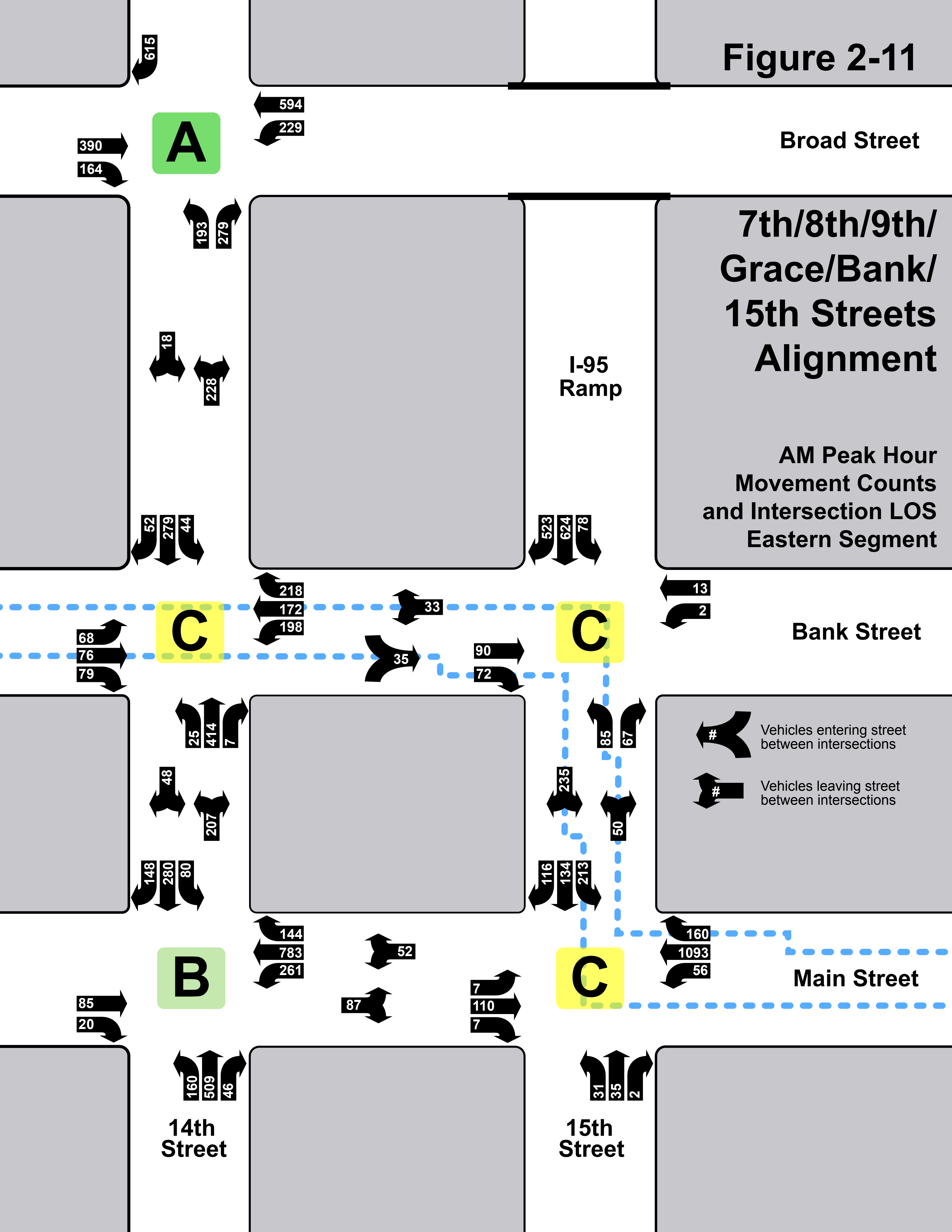


Figure 2-11
7th/8th/9th/Grace/Bank/15th Streets Alignment
AM Peak Hour Movement Counts and Intersection LOS Eastern Segment
Broad Street
Bank Street
Main Street
I-95 Ramp
14th Street
15th Street
A
B
C
C
C
615
594
229
390
164
193
279
18
228
52
279
44
523
624
78
218
172
198
33
13
2
68
76
79
35
90
72
25
414
7
85
67
48
207
235
50
148
280
80
116
134
213
144
783
261
52
160
1093
56
85
20
87
7
110
7
160
509
46
31
35
2
Vehicles entering street between intersections
Vehicles leaving street between intersections
#
#

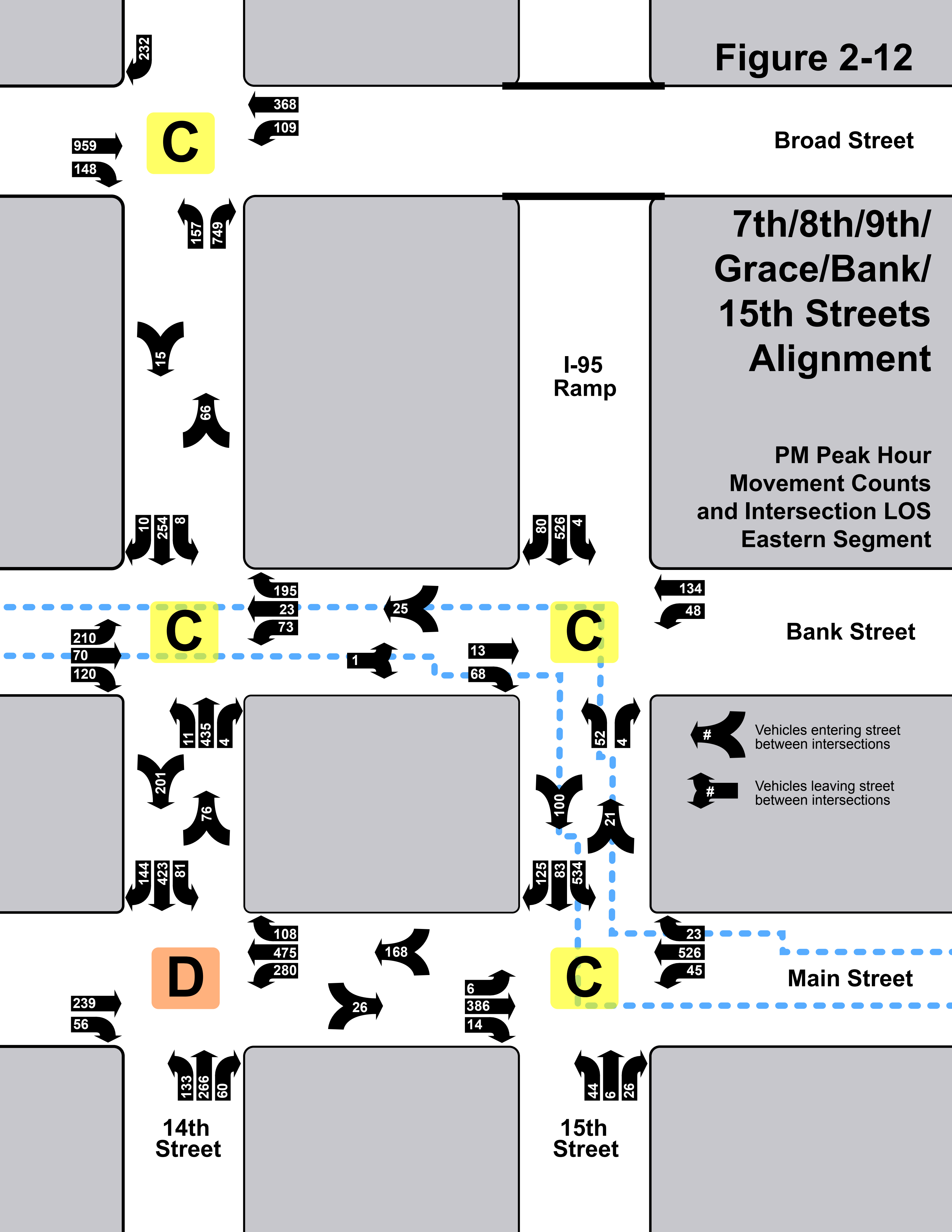
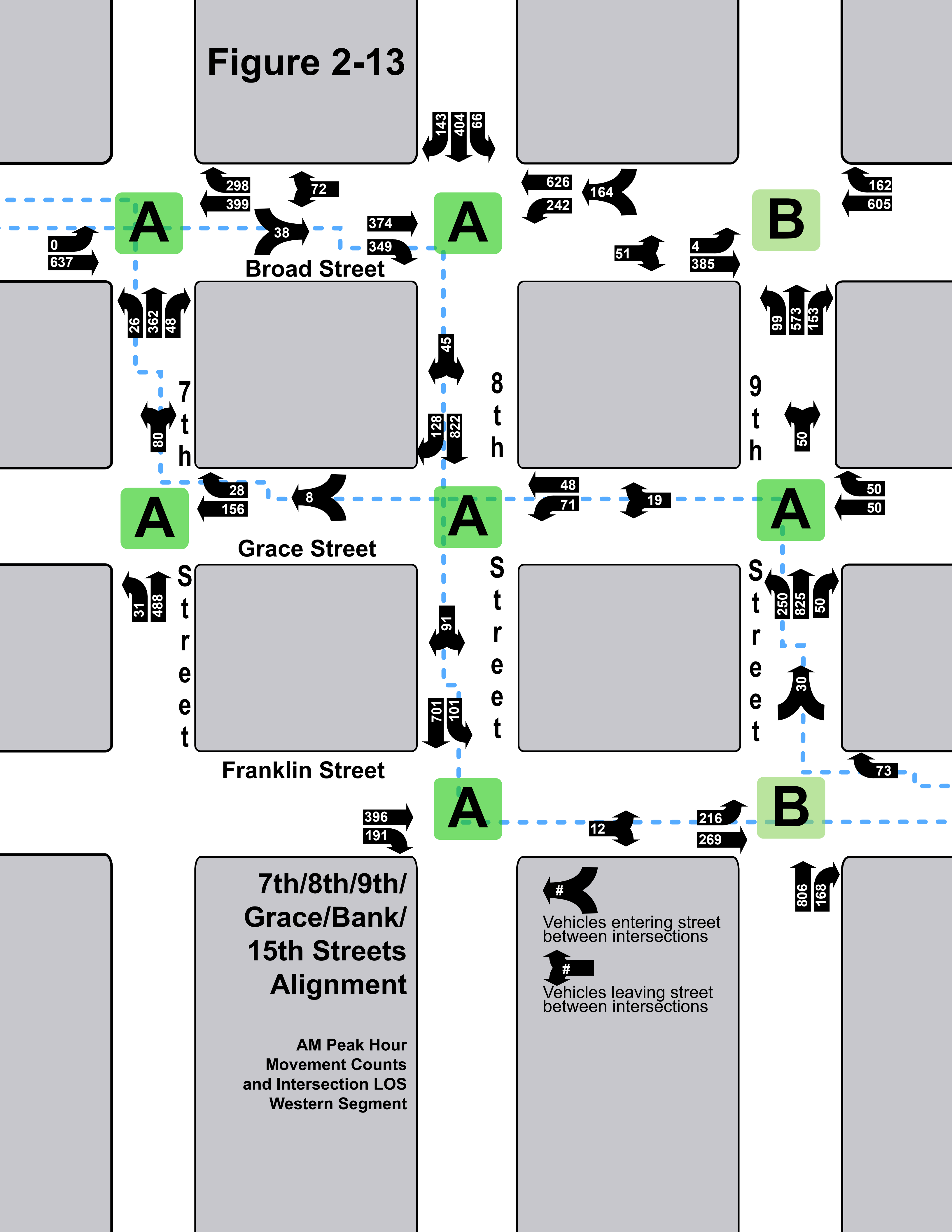


Figure 2-12
7th/8th/9th/ Grace/Bank/ 15th Streets Alignment
PM Peak Hour Movement Counts and Intersection LOS Eastern Segment
Broad Street
Bank Street
Main Street
I-95 Ramp
14th Street
15th Street
Vehicles entering street between intersections
Vehicles leaving street between intersections
#
C
C
C
D
C
232
368
109
959
148
157
749
15
66
10
254
8
80
526
4
195
23
73
25
134
48
210
70
120
1
13
68
11
435
4
52
4
201
76
100
21
144
423
81
125
83
534
108
475
280
168
23
526
45
26
6
386
14
239
56
133
266
60
44
6
26

Figure 2-13



7th/8th/9th/ Grace/Bank/ 15th Streets Alignment

AM Peak Hour
Movement Counts
and Intersection LOS
Western Segment

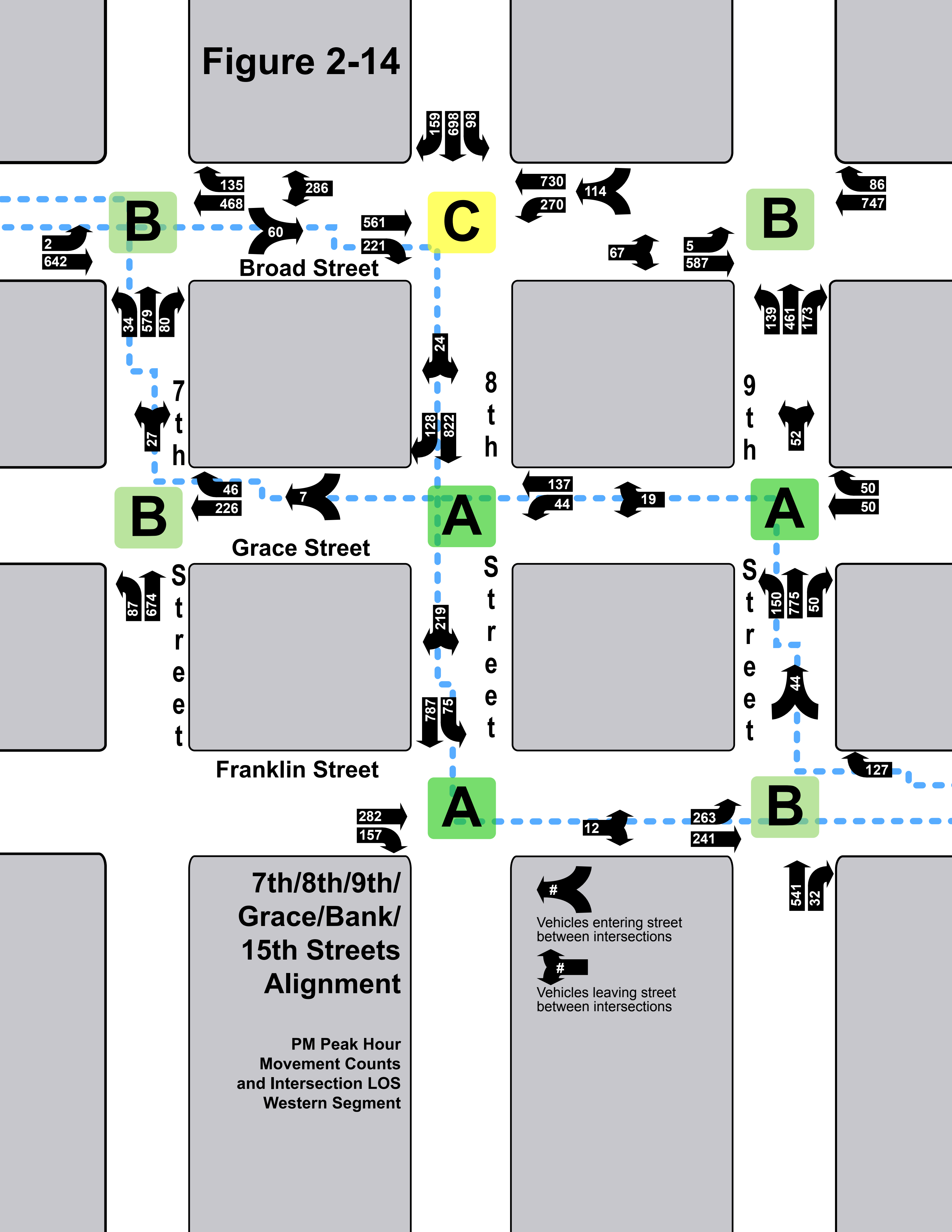


Figure 2-14

7th/8th/9th/Grace/Bank/15th Streets Alignment

PM Peak Hour Movement Counts and Intersection LOS Western Segment

BROAD STREET RAPID TRANSIT STUDY

ENVIRONMENTAL ASSESSMENT

APPENDIX A-6: Station Selection Report

Note: At the time this technical memorandum was prepared, the opening year was anticipated to be 2015. At the time this EA was completed, the opening year has been revised to 2017. All references in the main EA document have been updated, but the information in the technical report remains relevant.

BROAD STREET RAPID TRANSIT STUDY
STATION AREA SCREENING

This Station Selection Methodology will outline the process employed to confirm the station areas to be used in the detailed definition of alternatives of the Broad Street Rapid Transit Study. As part of an assessment of alternatives, this methodology will remain consistent with the requirements of the Federal Transit Administration's (FTA) Small Starts program. The evaluation includes the analysis of Tier I data, as outlined in the technical memorandum, *Station Area Assessment Methodology*. The analysis is based on concrete measures of effectiveness developed in direct relation to the goals and objectives described in the Problem Statement.

1.0 BACKGROUND

The sixteen initial station locations analyzed for this study were chosen based on recommendations presented in GRTC's *Comprehensive Operational Analysis* (COA). The COA identifies Broad Street as having the highest demand for transit in the City. The COA adds that Broad Street already has 19 routes providing service along some length of the corridor with frequencies as high as 48 buses per hour. However, the multiple bus routes and heavy traffic on Broad Street create an inefficient system clogged with congestion and multiple bus stacking. As a result, the COA recommends BRT service from Willow Lawn to Rockett's Landing via Broad and Main Streets. Suggested station locations include:

- Willow Lawn
- Broad & Staples Mill
- Broad & Westmoreland
- Broad & Malvern
- Broad & Thompson
- Broad & Boulevard
- Broad & Hermitage
- Broad & Harrison
- Broad & Belvidere
- Broad & 2nd
- Broad & 7th/8th
- Broad & 13th
- 17th & Grace
- Main & 25th
- Main & Williamsburg
- Rockett's Landing

The COA suggests that this routing was chosen based on Route 6, the highest ridership route in the system. Data was collected regarding boarding and alighting activity and transfer opportunities with Route 6 to pinpoint the recommended station locations.

In addition to the COA, the *Richmond Regional Mass Transit Study* explored options for improved transit service through a screening process that analyzed demographic, land use and travel demand data. The study identified several transit upgrades to improve regional mobility including a recommendation for bus rapid transit service along Broad Street from Willow Lawn to Rockett's Landing.

As a result, the alignment proposed in these studies, also backed by the *2031 Long-Range Transportation Plan* for the Richmond region, was used as a starting point for data collection and analysis. The following report outlines the analysis conducted for each station location and confirms that these general station areas are still appropriate, as well as making an initial recommendation for the location of each station platform.

2.0 ANALYSIS CRITERIA

Data analyzed during the station area identification process correspond with **Table 2-2: Potential Screening Criteria – Initial Station Location Criteria** found in section **2.1 Station Area Identification** in the *Station Area Assessment Methodology*. Specifically, the data analyzed include:

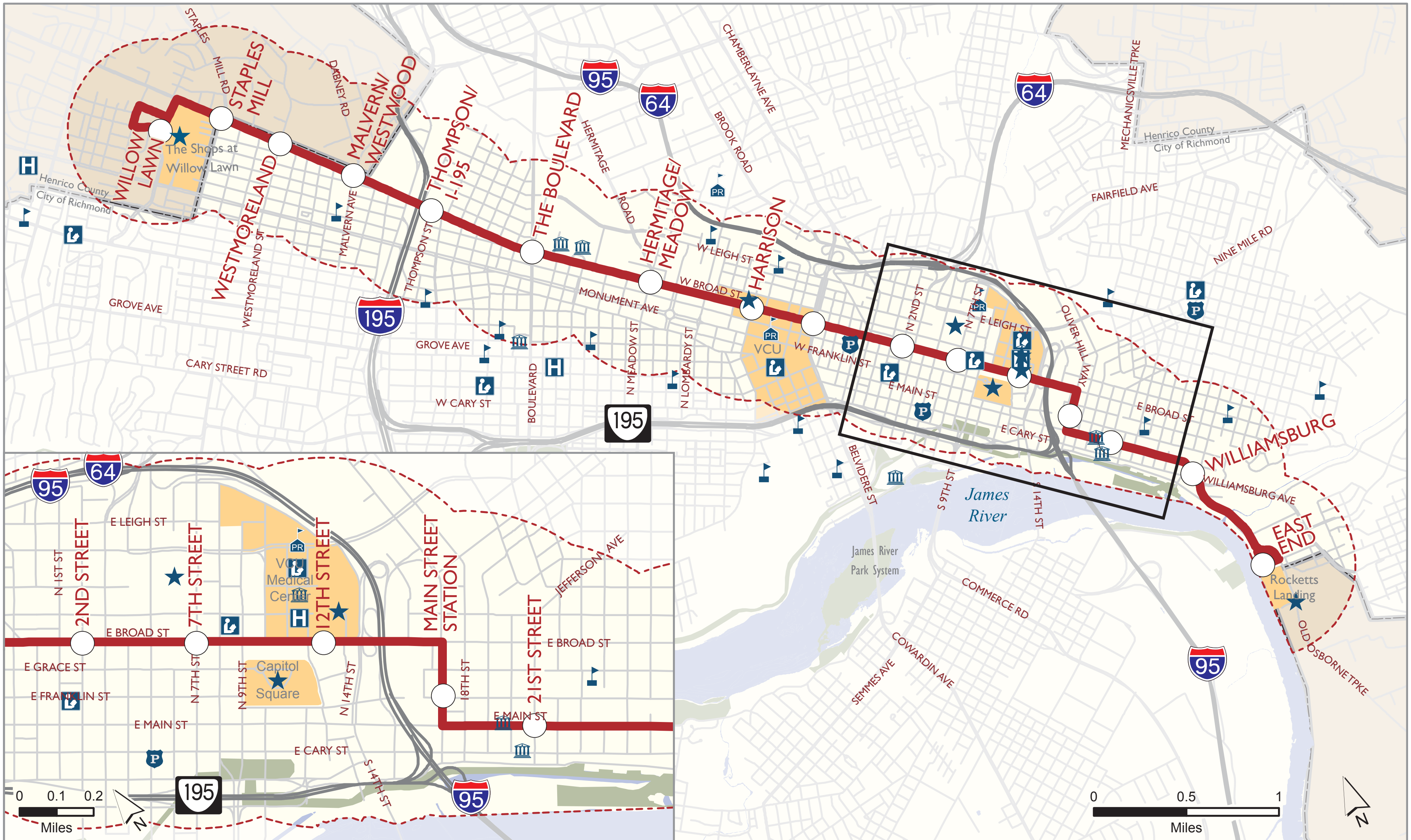
- Community facilities
- Existing and future land use densities for both population and employment
- Distance between stations
- Land use and economic development potential
- Transit supportive plans and policies
- Connections to other modes
- Transit activity
- Traffic impacts

Each criterion was analyzed uniquely and separately. Results of each analysis were combined to determine preliminary station locations. The data source and analysis process for each criterion are enumerated below.

3.0 COMMUNITY FACILITIES

Community facilities were analyzed to ensure that public facilities, cultural sites, and special generators are adequately served by the rapid transit stations. In this case, public facilities include hospitals, police stations, libraries, public schools and universities; cultural sites include state, regional, and local museums; and special generators include shopping centers, sports and entertainment centers, and major developments. These facilities were analyzed spatially using GIS data collected from the City of Richmond and Henrico County and are illustrated in Figure 1. In particular, the special generators include Willow Lawn, the Siegel Center at VCU Monroe Park Campus, VCU Medical Center, Capital Square, the Greater Richmond Convention Center and Rockett's Landing.

Station areas that emerge, based on the location of community facilities, include; the Willow Lawn Station due to its proximity to The Shops at Willow Lawn, which serves as a regional attraction and special generator; the Boulevard Station based on its proximity to major cultural sites of the Virginia Science Museum and the Children's Museum; the Harrison Station based on its proximity to the Siegel Center, a sports arena and a special generator, as well as other facilities associated with VCU's campus; 7th, 12th, 21st and Main Street Stations based on the multiple community facilities, museums and special generators such as the Greater Richmond Convention Center, Coliseum, and Capital Square; and also the East End station due to its proximity to Rockett's Landing, a large mixed use development along the banks of the James River.



Legend

- Proposed BRT Stations
- Proposed BRT Alignment
- Half-Mile Buffer
- Hospital
- Library
- Museum
- Police Station
- Special Generator
- School
- University

Station Selection Memo

Figure 1: Community Facilities

BROAD STREET RAPID TRANSIT STUDY

4.0 EXISTING AND FUTURE DENSITIES

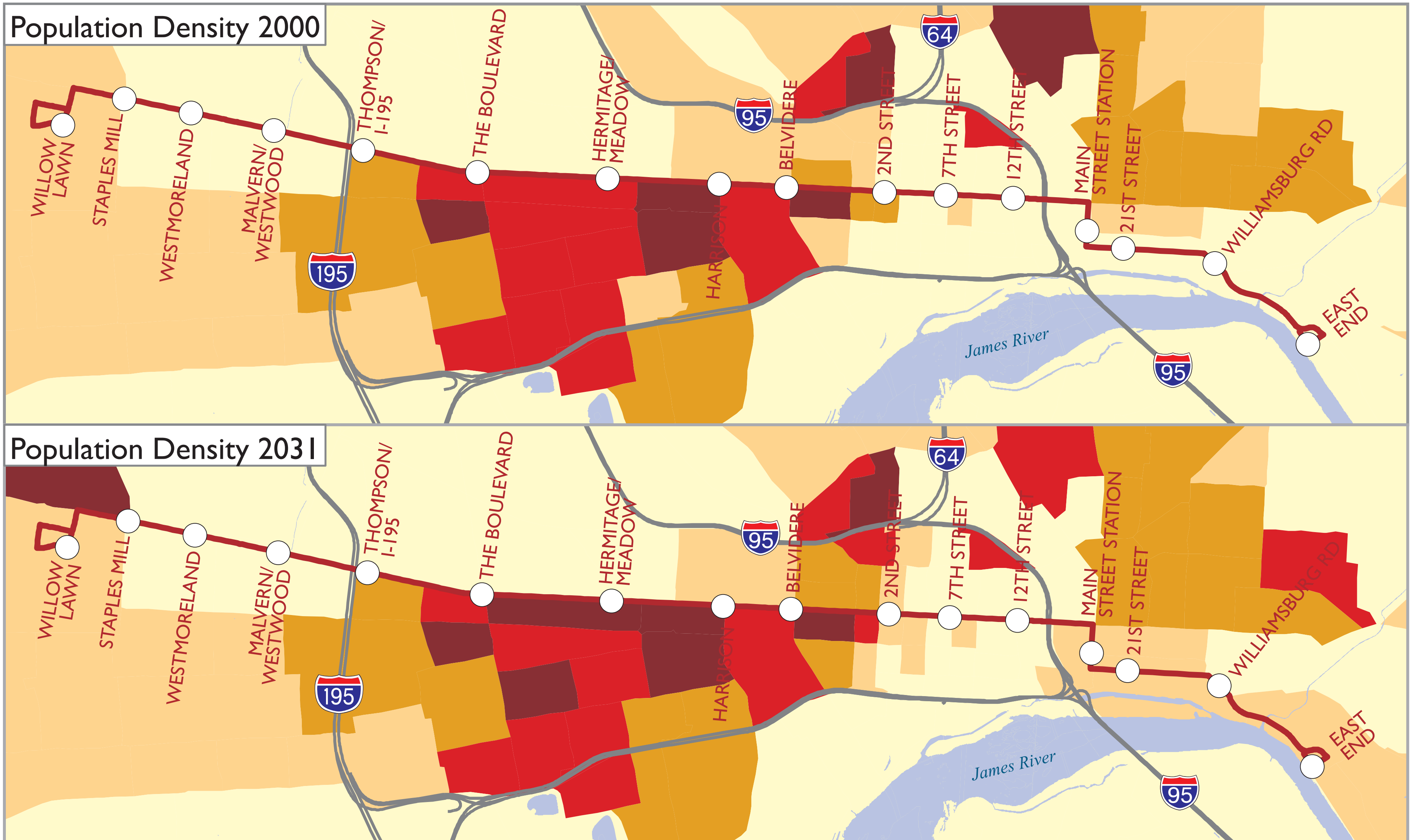
Population and employment densities were analyzed within a quarter mile of each station area for the year 2000 and 2031 (while the opening year of the project is currently planned for 2015, no socioeconomic projections for the corridor exist for this timeframe). The data for this analysis come from the Richmond Regional Planning District Commission (RRPDC) Socioeconomic Data Report developed for transportation planning purposes and is organized by Traffic Analysis Zone (TAZ). Figure 2 and Figure 3 illustrate that, within the study area, the highest concentration of population exists to the south of the corridor between the proposed Boulevard and 2nd Street Stations. The highest concentration of employment exists in the Central Business District of the City of Richmond.

Table 1 summarizes the data presented in the maps. The table sites the average number of persons per square mile and employment per square mile for TAZs that intersect a quarter mile buffer of each proposed station for the year 2000 and 2031. Based on the figures shown in Table 1, the areas located around the Boulevard, Hermitage/Meadow, Harrison, and Belvidere Stations have the highest population densities in the corridor. The areas around the 2nd Street, 7th Street, 12th Street, and Main Street Stations have the highest employment densities. Therefore, these areas are the most appropriate station locations based on population and employment density figures.

Once more, the table can also be used to evaluate growth in the region. Population projections show that the outer edges of the corridor, the east and west ends, will experience the most growth. In particular, the population around East End station is expected to increase by nearly six times. The population around the Willow Lawn station is expected to double. Conversely, employment figures suggest that the most employment growth will occur in the middle of corridor around the Hermitage/Meadow and Harrison stations.

Table 1: Average Population and Employment Density for TAZs a Quarter Mile from Station Areas

	Persons/Sq. Mile		Employment/Sq. Mile	
	2000	2031	2000	2031
Willow Lawn	4,412	9,672	10,270	10,380
Staples Mill	3,070	5,694	11,282	9,701
Westmoreland	2,135	2,147	9,202	7,221
Malvern/Westwood	2,381	2,333	12,409	8,432
Thompson	4,934	4,861	12,046	7,057
The Boulevard	9,889	10,455	8,795	9,041
Hermitage/Meadow	12,343	12,506	7,578	14,337
Harrison	12,500	12,484	14,314	19,427
Belvidere	11,770	13,090	19,192	18,853
2nd Street	4,862	6,943	40,408	39,686
7th Street	1,438	1,563	106,572	105,595
12th Street	1,073	1,542	102,569	94,086
Main Street	2,853	4,045	44,574	33,669
21st Street	5,912	7,196	4,871	4,894
Williamsburg	2,374	3,862	3,640	3,842
East End	399	2,740	496	570



LEGEND

Proposed BRT Stations

Proposed BRT Alignment

Persons Per Square Mile

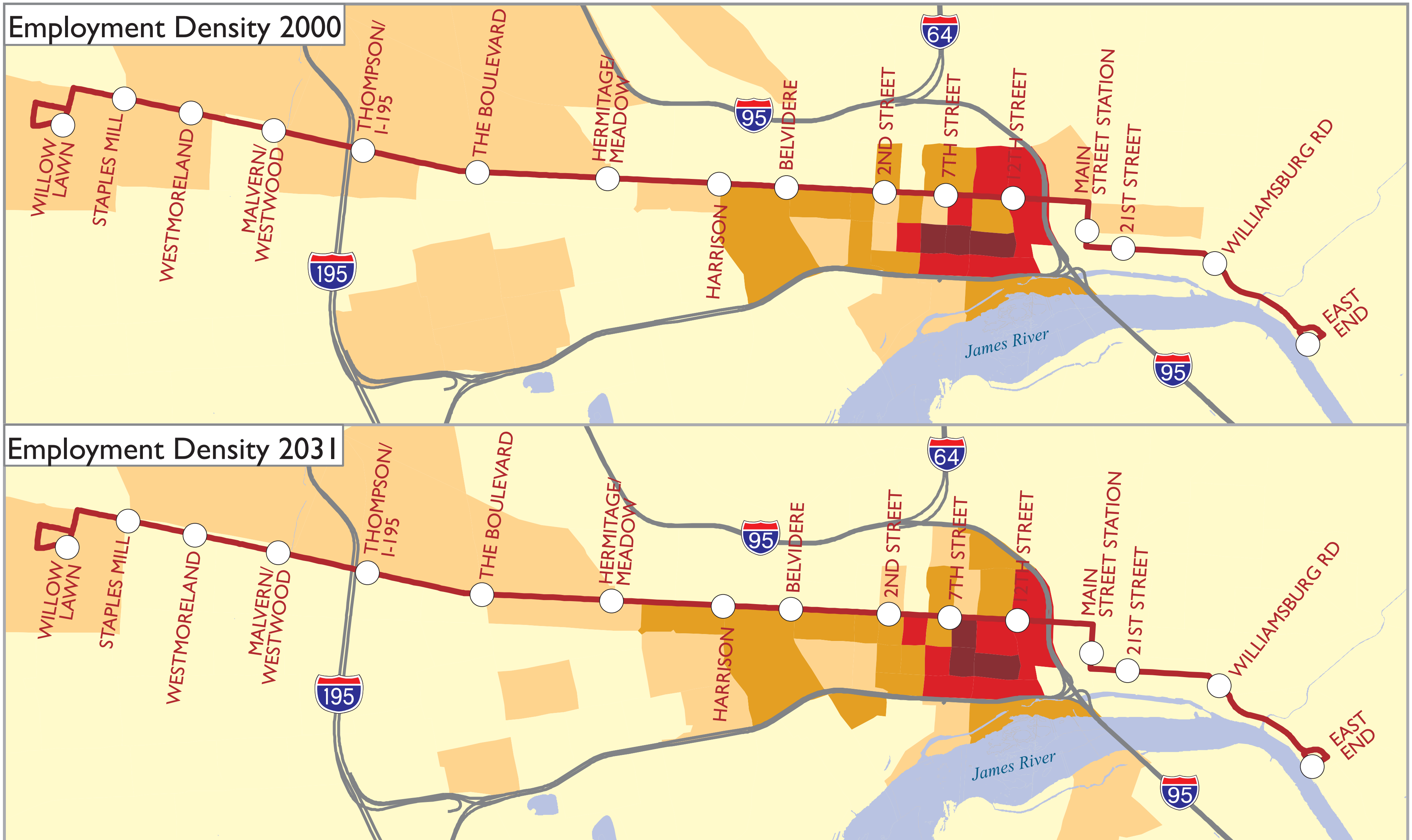
- 3,333 or less
- 3,333 to 6,667
- 6,667 to 10,000
- 10,000 to 15,000
- > 15,000

0 0.5 1 Miles

Station Selection Memo

Figure 2: Population Density

BROAD STREET RAPID TRANSIT STUDY



LEGEND

- Proposed BRT Stations
- Proposed BRT Alignment

Employment Per Square Mile

- 10,000 or less
- 10,000 to 25,000
- 25,000 to 100,000
- 100,000 to 200,000
- 200,000 or above

0 0.5 1
Miles

Station Selection Memo

Figure 3: Employment Density

BROAD STREET RAPID TRANSIT STUDY

5.0 DISTANCE BETWEEN STATIONS

Linear measurements were taken to compare the distance between proposed stations. The appropriate distance between stations must be established to ensure a proper balance of service along the corridor. Locating stations farther apart helps improve the efficiency of service by increasing travel speed and minimizing stops. Yet, stations must be located close enough together so that major gaps in service are avoided and that the appropriate travel markets are served adequately. Regional rapid transit systems typically operate with station spacing of between approximately 0.5 and 1.0 mile. However, stations may be located more closely in dense, urban environments such as Richmond's central business district.

Table 2: Distance Between Stations

Station	Length Feet	Length Miles
Willow Lawn	2,371	0.45
Staples Mill	1,829	0.35
Westmoreland	2,281	0.43
Malvern/Westwood	2,402	0.45
Thompson	3,111	0.59
The Boulevard	3,475	0.66
Hermitage/Meadow	2,984	0.57
Harrison	1,791	0.34
Belvidere	2,616	0.50
2nd Street	1,605	0.30
7th Street	1,814	0.34
12th Street	2,499	0.47
Main Street	1,708	0.32
21st Street	2,543	0.48
Williamsburg	4,945	0.94
East End		

Table 2 identifies the distance between stations in both linear miles and linear feet. There is no specific distance that indicates the proper station distance. However, in the outer edges of the corridor, where the surrounding land use has limited intensity and density and where mode of arrival to stations is likely to be by automobile, stations may need to be consolidated or relocated as a result of their current spacing. Conversely, additional stations and/or closer spacing may be required in the downtown area due to the surrounding intensity of land use and development. As a result, spacing will be considered in determining the final station locations.

6.0 DEVELOPMENT POTENTIAL

The proposed station area locations were evaluated for their development and redevelopment potential to accommodate transit-oriented development (TOD) or as support to the major transit investment. Since an impediment to TOD is often the availability of land surrounding the station area, the development potential analysis consists of a sensitivity analysis to identify the amount of land available within a ¼ mile of each proposed station and its likelihood for redevelopment.

The development potential screening was completed using real estate tax assessment data available from the City of Richmond and Henrico County. Land was classified into four categories of development potential based upon the relationship between assessed land and building/improvement values. The categories were defined as follows: *undevelopable* (land value = 0; includes floodplain, environmental protection areas, etc.), *vacant* (land value > 0, improved value = 0) and, *underutilized* (the ratio of improved value to land value < 2). All parcels not falling into one of these three categories was defined as *utilized*. The analysis excluded all roads, waterways and land not listed in the tax records.

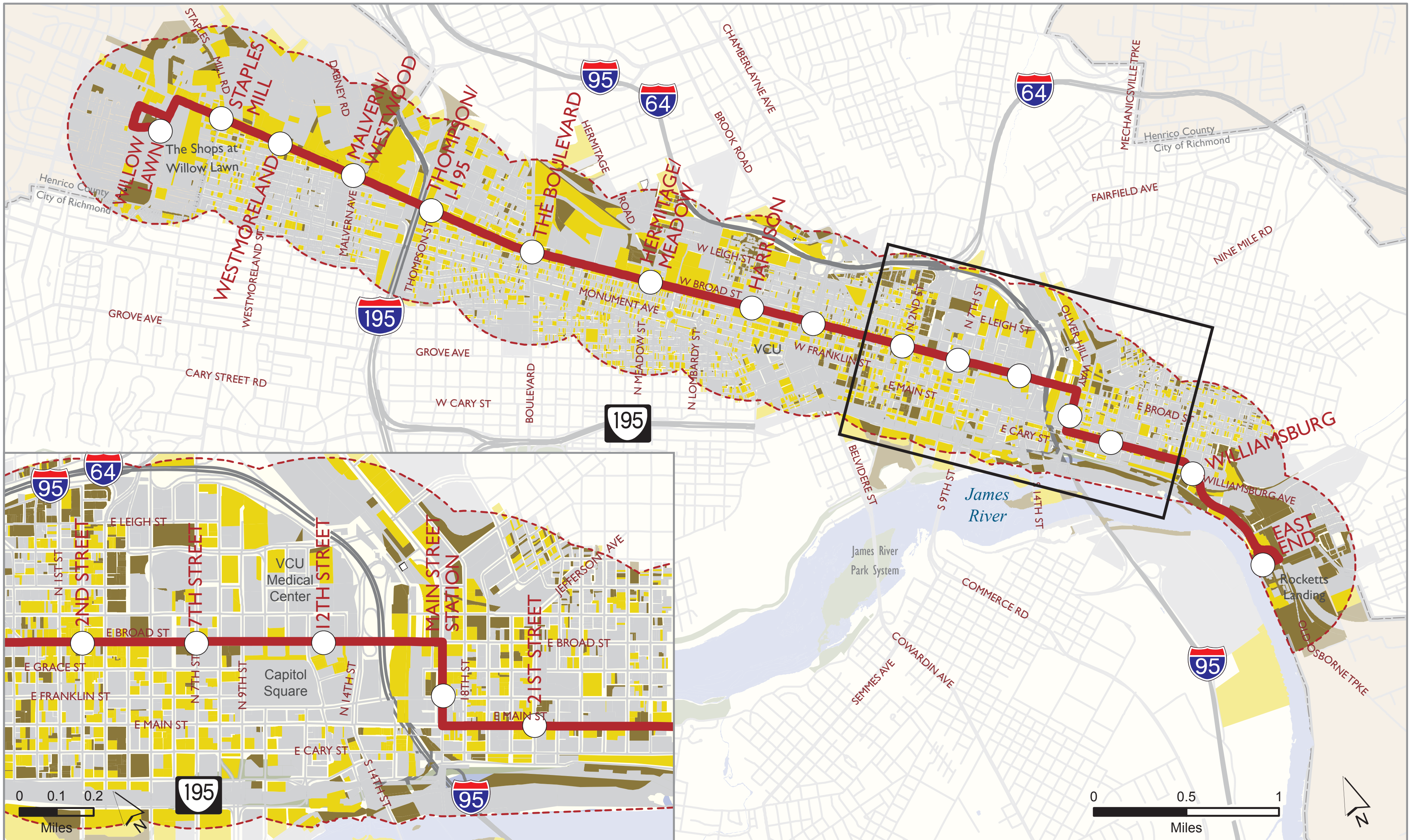
It was assumed for the purposes of this exercise that the low level of investment or improvement value in relationship to land value of *underutilized* properties indicated that they will have the most potential for infill or redevelopment along the corridor in the future. It was also assumed that parcels categorized as *utilized* (i.e., developable land with an assessed improvement value greater than two times the land value) are expected to have less market pressure for near-term redevelopment.

Over 50% of the land within the Broad Street corridor was identified as *utilized* and expected to remain stable in the future. However, as illustrated in Figure 4, portions of the corridor have relatively large percentages of *vacant* and *underutilized* land and indicated a stronger potential for redevelopment. For example, the area west of I-95 and Main Street Station generally consisted of land with less than 15% categorized as *vacant* and approximately 20-50% categorized as *underutilized*, while the area to the east of Main Street Station was categorized as 20-30% *vacant* and 15-40% *underutilized*. The stations with larger contiguous properties categorized as either *vacant* or *underutilized* are located east of the Williamsburg Station and west of the Hermitage/Meadow Station.

Table 3 indicates the percentages of land in each category within a quarter-mile of the proposed station areas. Several stations emerged as having the greatest potential for redevelopment based upon the percentage of *vacant* or *underutilized* land within the station area. In particular, the Thompson/I-195, Hermitage Meadow, 2nd Street, Main Street, Williamsburg and East End stations each have over 50% of the land within a quarter mile designated as either *vacant* or *underutilized*.

Table 3: Land Development Potential within a Quarter Mile of Station

	Land Development Potential			
	Undevelopable	Vacant	Underutilized	Utilized
Willow Lawn	0%	3%	26%	71%
Staples Mill	0%	1%	46%	53%
Westmoreland	0%	7%	40%	53%
Malvern/Westwood	0%	10%	36%	54%
Thompson	0%	5%	46%	49%
Boulevard	0%	6%	37%	57%
Hermitage/Meadow	0%	9%	53%	37%
Harrison	0%	6%	31%	63%
Belvidere	0%	5%	36%	59%
2nd Street	0%	14%	37%	49%
7th Street	0%	7%	23%	70%
12th Street	0%	6%	19%	75%
Main Street	0%	21%	41%	38%
21st Street	0%	22%	27%	51%
Williamsburg	0%	31%	44%	24%
East End	0%	36%	23%	42%



Legend

- Proposed BRT Stations
- Proposed BRT Alignment
- Half-Mile Buffer

Development Potential

- Vacant and Developable
- Underutilized
- Utilized
- Undevelopable

Station Selection Memo

Figure 4: Development Potential

BROAD STREET RAPID TRANSIT STUDY

7.0 TRANSIT SUPPORTIVE PLANS AND POLICIES

The localities/counties within the region have identified rapid transit along the Broad Street corridor as an element of a comprehensive or master plan. These plans tie factors such as land use, urban design and economic development into the existing, planned, and/or recommended transportation infrastructure.

The City of Richmond Master Plan 2000-2020 makes land use recommendations consistent with the implementation of a premium transit service along Broad Street. The plan calls for "Community Commercial" uses along most of Broad Street west of downtown and calls for "Mixed Use" within and east of downtown. The plan states that development in these districts should contain retail on the ground floor with office or residential above, no setback from the street and parking hidden from view. Where auto-oriented uses currently exist, the plan says they should be phased out. The plan argues that investment in a multimodal transportation system would both support and spur this kind of redevelopment.

The Downtown Master Plan (October 2008) affirms the recommendation of the Richmond Regional Mass Transit Study that bus rapid transit is an appropriate first step in rebuilding a multimodal transit system. It proposes a boulevard design for Broad Street, consisting of two travel lanes in each direction, curbside parking and a median BRT facility. The Downtown Master Plan advocates for the eventual conversion of these center lanes into streetcar right-of-way. The Plan integrates recommendations for transit with other key transportation strategies, such as traffic calming, parking management and pedestrian/bicycle facility improvement. Overall, its goal is to transform downtown into a more pedestrian friendly environment, featuring higher densities, mixed uses and infill development. The Plan views high quality transit options as essential in achieving these goals.

The Henrico County 2026 Comprehensive Plan (August 2009) includes mixed-use development recommendations with explicit guidelines to encourage pedestrian-oriented design, reduce automobile use and integrate transit. The plan continues to recommend Urban Mixed-Use Development zoning designations for areas near both terminal locations of the proposed BRT corridor. The plan suggests the consideration of light rail line along Broad Street, as studied in a 2003 RAMPO study.

8.0 MULTIMODAL CONNECTIONS

Multimodal connections are an important element when choosing an effective station location and coordinating it with other transportation services and facilities. For the Broad Street corridor, each of the proposed station locations was analyzed for access to parking, sidewalks, bike routes and transit. The data for this analysis were gathered from the Richmond and Henrico GIS layers and is summarized in Table 4. The table provides the square footage of off-street surface parking and sidewalks within a quarter mile of each station. In addition, Table 4 summarizes the presence or absence of bicycle routes in the station area, as well as the transit routes that serve each station area. Sidewalk information was not available within Henrico County. Bicycle access refers to roadways that have been identified as appropriate shared roadways for bicycles, even though no dedicated bike facilities exist.

The elements analyzed provide information regarding the different infrastructure types that allow access to each station and can illustrate the general landscape of the surrounding area. For example, the proposed 2nd Street station area has one of the highest square feet of sidewalk, has access to transit and the bicycle network, and has less parking lot space than over half of the other proposed stations. This suggests that this station will frequently be accessed via non-motorized and alternative transportation methods. On the other hand, the Staples Mill Station has a limited amount of sidewalk space, no bicycle access, and the highest square footage of parking of any proposed station. This suggests that additional pedestrian and bicycle improvements may be necessary to enhance access to this station area.

Table 4: Multimodal Connections

Multimodal Connections

	Parking (sq ft)	Sidewalk (sq ft)	Access to Bike Routes	Accessible Transit Routes
Willow Lawn	4,284,569	29,781	No	6, 18, 20, 91
Staples Mill	6,307,621	126,034	No	6, 18, 19, 20, 91
Westmoreland	4,759,570	167,352	No	6, 19, 20, 91
Malvern/Westwood	3,176,219	242,162	No	6, 19, 20, 91
Thompson	1,721,810	340,679	No	6, 19, 20
The Boulevard	1,407,608	440,706	Yes	1, 2, 6, 19, 20, 24
Hermitage/Meadow	1,850,011	509,980	Yes	1, 2, 3, 4, 6, 19, 20, 24
Harrison	778,535	576,914	No	1, 2, 3, 4, 6, 10, 19, 22, 24
Belvidere	971,740	598,576	Yes	1, 2, 3, 4, 6, 10, 11, 19, 22, 24, 74
2nd Street	950,288	978,803	Yes	1, 2, 3, 4, 6, 10, 11, 19, 22, 24, 32, 37, 74
7th Street	391,914	1,095,933	No	1, 2, 3, 4, 6, 7, 10, 11, 13, 19, 22, 24, 32, 37, 56, 62, 63, 67, 70, 71, 74
12th Street	833,570	675,774	No	1, 2, 3, 4, 6, 7, 10, 22, 24, 37, 56, 67, 74
Main Street	1,426,379	431,343	Yes	11
21st Street	45,793	450,817	Yes	6, 13
Williamsburg	204,997	263,699	No	6
East End	1,506,955	42,450	Yes	--

Results of this analysis, presented in Table 4, suggest an auto-oriented landscape in the west and east ends and a more pedestrian-oriented landscape in the urban areas of Richmond. Specifically, the stations from Willow Lawn to Thompson and the East End Station have significantly more land dedicated to parking than sidewalks, intermittent access to bicycle routes and fewer accessible transit routes. On the other hand, the stations from Harrison to 12th Street have a more even ratio of land dedicated to sidewalks and parking lots, more consistent access to bicycle routes and numerous transit opportunities. In this regard the stations between Harrison and 12th Street are the most appropriate station locations based on multimodal connectivity.

9.0 TRAFFIC IMPACTS

A traffic impact analysis was conducted to identify major intersections with Broad Street that may prohibit station location due to high traffic volumes and/or roadway design. For the purposes of this analysis, roadway traffic volumes were taken from VDOT's internal database known as the Statewide Planning System (SPS).

Figure 5 highlights the major roads and their current Average Annual Daily Traffic (AADT) volumes. The map shows three at-grade intersections that may cause considerable traffic impacts due to high crossing volumes and/or intersection design. Namely, these intersections include Staples Mill, The Boulevard, and Belvidere. Staples Mill experiences approximately 19,000 vehicles daily, most of which are making turning movements onto Broad Street as Staples Mill transitions from six lanes north of Broad to four lanes south of Broad. The Boulevard experiences approximately 20,000 vehicles daily and is a major local connector to Interstate 95/64. Belvidere experiences nearly 30,000 daily vehicles, handling both local and regional traffic as it serves as US Route 1 through Richmond.

10.0 TRANSIT ACTIVITY

Two levels of analysis were performed to assess transit activity along the Broad Street corridor. These analyses include the calculation of boardings and alightings across the entire GRTC system and the number of daily transfers to Route 6, which closely mirrors the proposed rapid transit corridor. The calculated results of these analyses were also spatially analyzed using GIS.

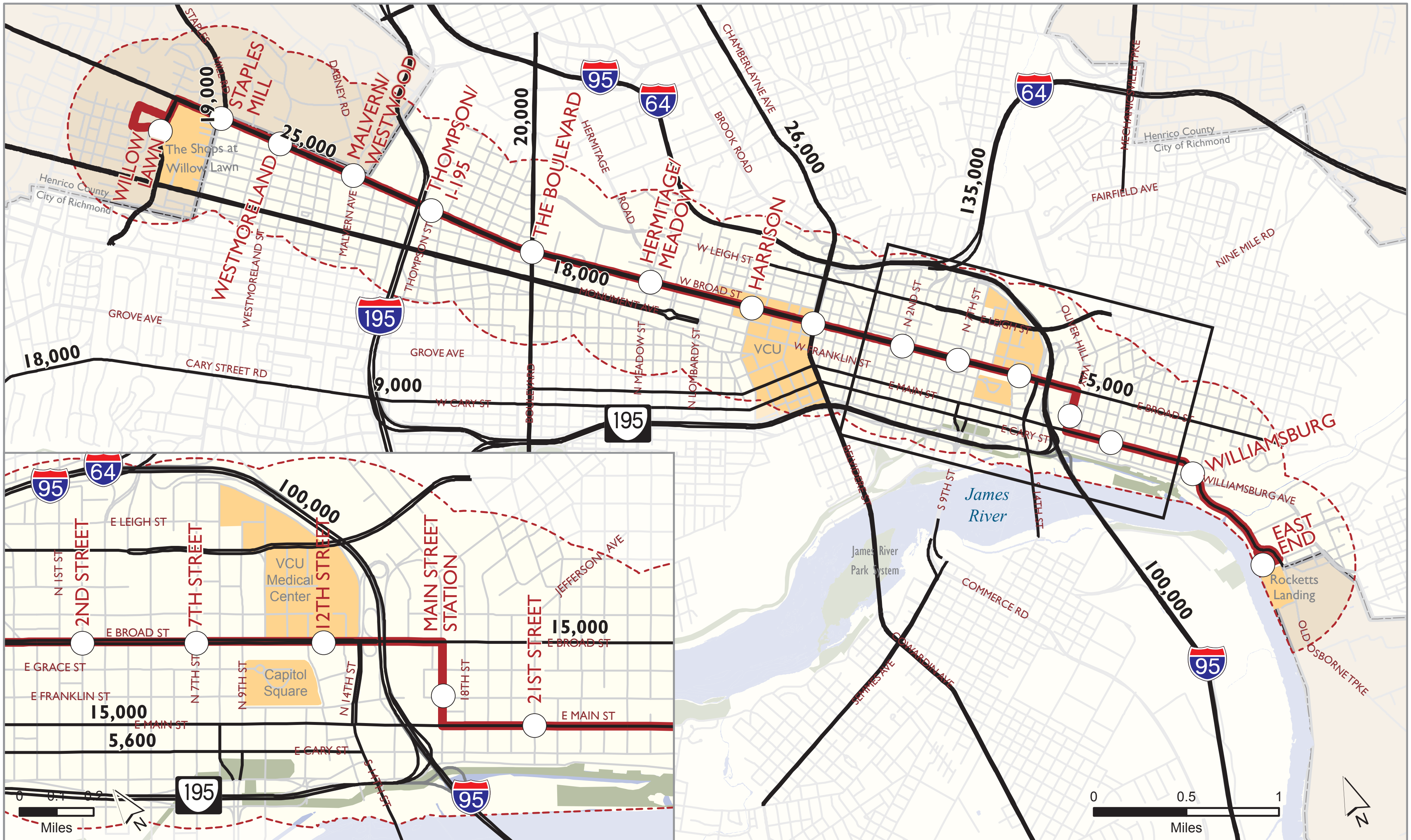
Table 5 and Figure 6 illustrate the daily boardings and alightings throughout the GRTC system. The map shows that relative to the overall GRTC system higher levels of boardings and alightings occur along most of the Broad Street corridor. More specifically, the table indicates that the highest activity levels along the corridor occur in the downtown area around the proposed 2nd Street, 7th Street, and 12th Street Stations.

Table 5: Daily Transit Activity by Station

Daily Stop Activity within Quarter Mile of Station

	Boardings	Alightings	Total
Willow Lawn	639	429	1,068
Staples Mill	298	270	568
Westmoreland	182	111	293
Malvern/Westwood	192	166	358
Thompson	173	179	352
The Boulevard	645	608	1,253
Hermitage/Meadow	290	313	603
Harrison	951	977	1,928
Belvidere	729	641	1,370
2nd Street	4,363	3,856	8,219
7th Street	4,817	5,599	10,416
12th Street	2,508	3,156	5,664
Main Street	485	345	830
21st Street	166	132	298
Williamsburg	33	39	72
East End	--	--	--

Currently, GRTC Route 6 operates more closely to the proposed rapid transit route than any other route in the GRTC system. Route 6 includes service along Main Street from Williamsburg Road to 7th Street and along Broad Street from 7th Street to Willow Lawn. As a result, the current number of daily transfers to and from Route 6 was calculated to represent potential transfer levels for the proposed rapid transit alignment. Figure 7 illustrates the results of this analysis, showing that the five routes with the highest transfer rates to and from Route 6 converge in the downtown area. Together, Routes 10, 32, 34, 37 and 62 account for over 800 daily transfers. The route with the sixth highest transfer rate, Route 18, accounts for 93 daily transfers and meets Route 6 at Willow Lawn.



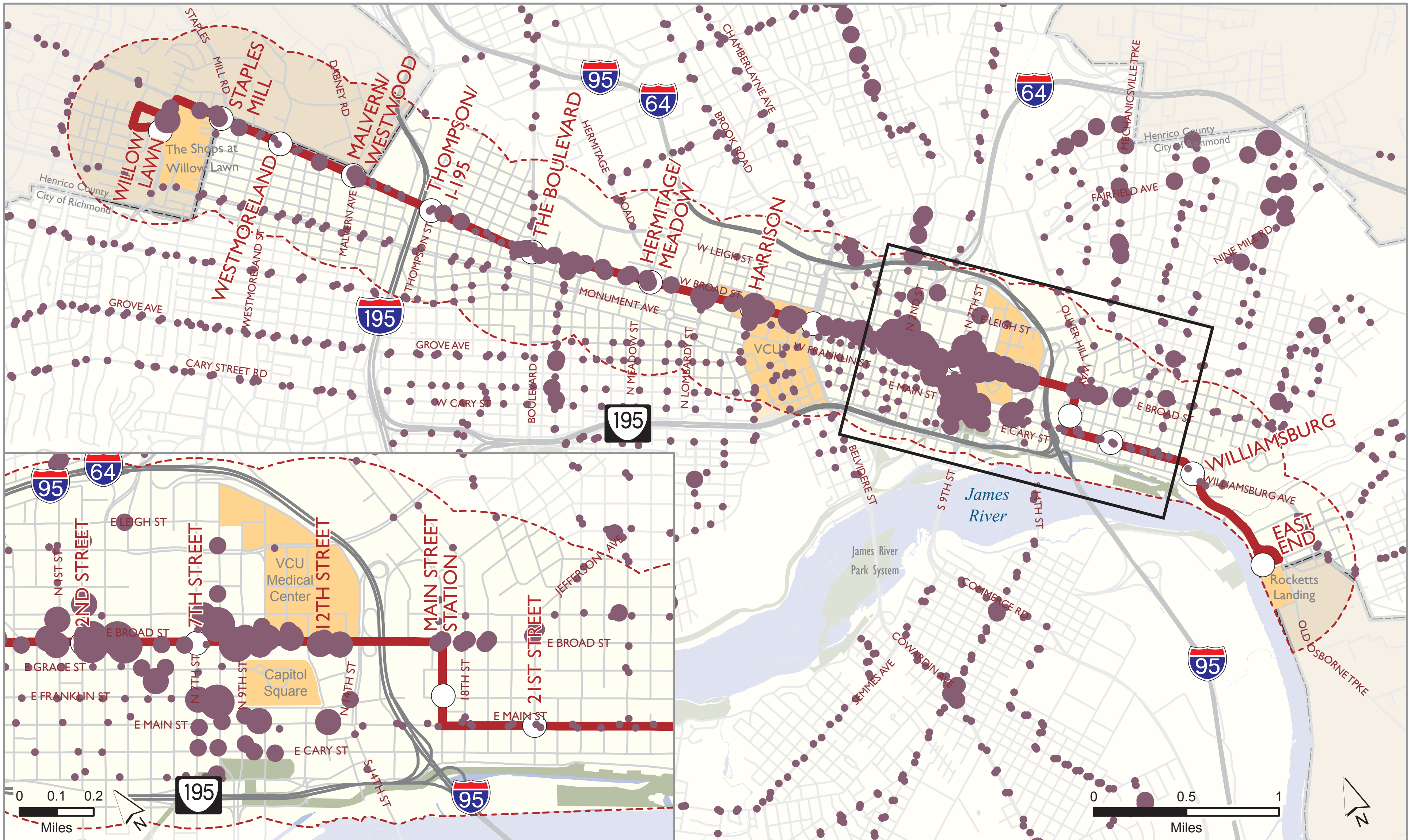
Legend

- Proposed BRT Stations
- Proposed BRT Alignment
- Half-Mile Buffer
- Major Roadways

Station Selection Memo

Figure 5: Major Roadways and Traffic Volumes

BROAD STREET RAPID TRANSIT STUDY



Legend

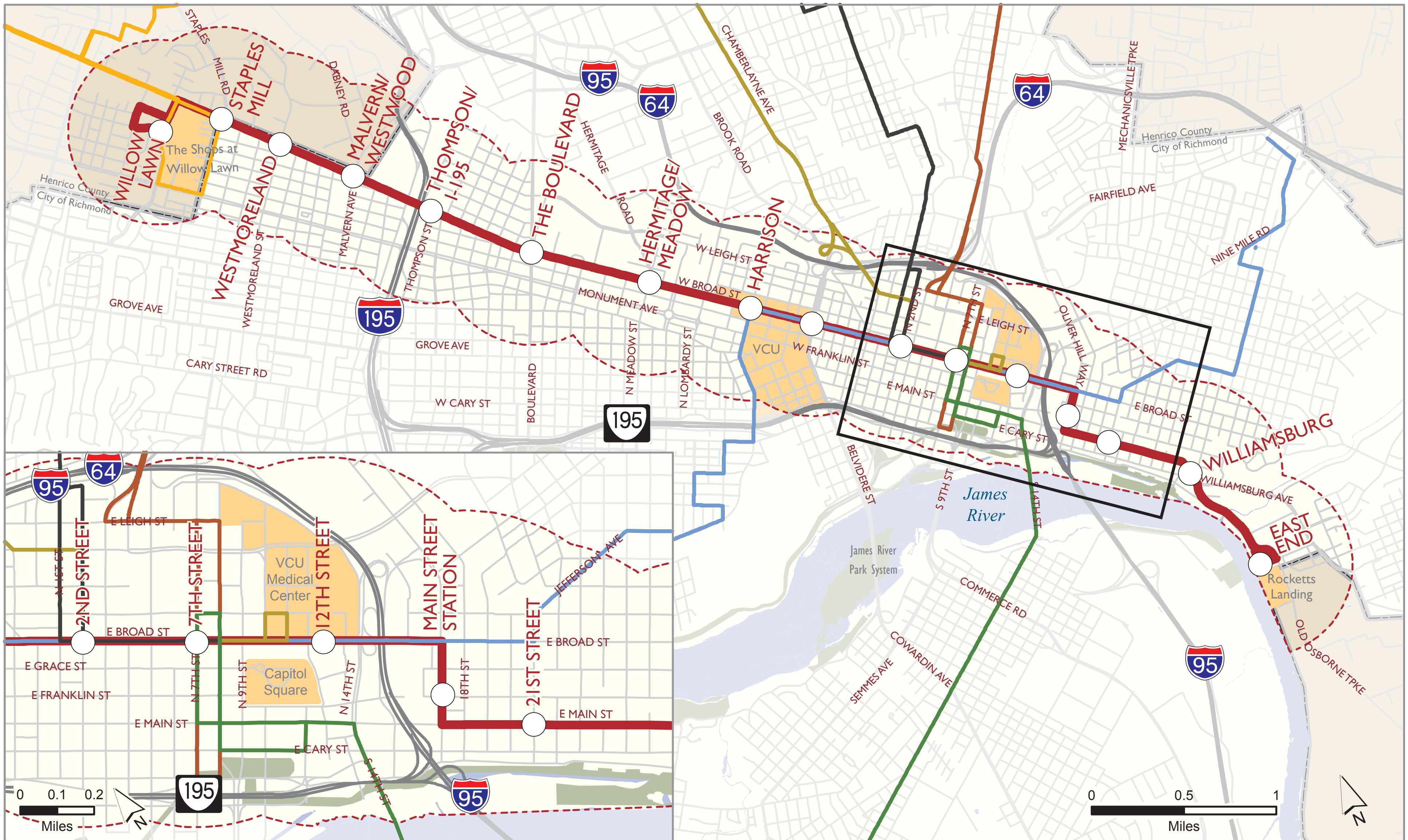
- Proposed BRT Stations
- Proposed BRT Alignment
- Half-Mile Buffer

Daily Boardings and Alightings

- 0 - 50
- 51 - 250
- 251 - 750
- 751 - 1957

Station Selection Memo
Figure 6: GRTC Daily Boardings and Alightings

BROAD STREET RAPID TRANSIT STUDY



Legend

- Proposed BRT Stations
- Proposed BRT Alignment
- Half-Mile Buffer

Route Number	Total Daily Transfers	Route Visualization
Route 32	234	
Route 10	165	
Route 37	154	
Route 34	147	
Route 62	138	
Route 18	93	

Station Selection Memo

Figure 7: Daily Transfers

BROAD STREET RAPID TRANSIT STUDY

11.0 STATION LOCATION RECOMMENDATIONS

Based on the data analysis, several station locations emerge as appropriate and several station locations reveal deficiencies. The following section outlines the attributes of each proposed station location and provides input on recommended changes. In so doing, the corridor has been divided into four geographic locations to assist with an in depth examination of station placement. Each section includes detailed maps, with one map that designates the originally proposed station locations as green, yellow, or red, and the second map that shows the new recommended station locations. In the first map, Green stations are recommended to stay in their currently proposed location, yellow stations should be moved and red stations are recommended to be removed from the alternatives. In addition, each station has a brief narrative explaining the reasoning for each recommendation.

West End

For the purposes of this discussion, the west end of the corridor includes the proposed Willow Lawn, Staples Mill, Westmoreland, Malvern/Westwood, and Thompson/I-95 Stations. This section of the corridor generally has a less dense pattern of development, fewer community facilities and activity centers, as well as a more auto-oriented landscape, including fewer multimodal connections and larger land areas dedicated to surface parking lots. As a result, it is recommended that fewer stations serve this area. Specifically, Westmoreland and Malvern/Westwood Stations should be removed and the Staples Mill and Thompson/I-195 Stations be shifted to achieve the appropriate spacing and target areas of potential ridership. In-fill stations between Staples Mill and Thompson Street may be considered as part of a later stage in the corridor's development, should new development in this area warrant additional service.

Willow Lawn: The station at Willow Lawn should remain at its proposed location. This station creates a destination point at the terminus of the rapid transit corridor. The retail and commercial facilities at Willow Lawn Shopping Center is identified as a special generator in the region and currently serves as a major transfer center for existing GRTC routes.

Staples Mill: It is recommended that the Staples Mill Station be moved further east of its currently proposed location. Data analysis shows that the high traffic volumes and complicated roadway geometry on Staples Mill hinders station development. Yet, with convenient access to I-64 and multiple large parking lots in the vicinity, there is a potential for park and ride coordination near this intersection.

Westmoreland: It is recommended that the Westmoreland Station be removed from the corridor. Westmoreland has relatively low population and employment density, lower transit and multimodal connectivity, and is in very close proximity to the Staples Mill Station.

Malvern/Westwood: Like the Westmoreland Station, the proposed Malvern/Westwood Station has relatively low employment and population density and is expecting a decline in both densities as well. As a result the Malvern/Westwood Station is recommended for removal.

Thompson/I-195: Due to the recommended removal of the Westmoreland and Malvern/Westwood Stations the Thompson/I-95 Station is recommended to be moved west of I-195 in order to maintain appropriate spacing. In addition, the area to the west of I-195 has the potential to accommodate park and ride users due to its proximity to multiple parking lots and the interstate. With several underutilized parcels, this area also has a high redevelopment potential.

Figure 8: West End Station Adjustments

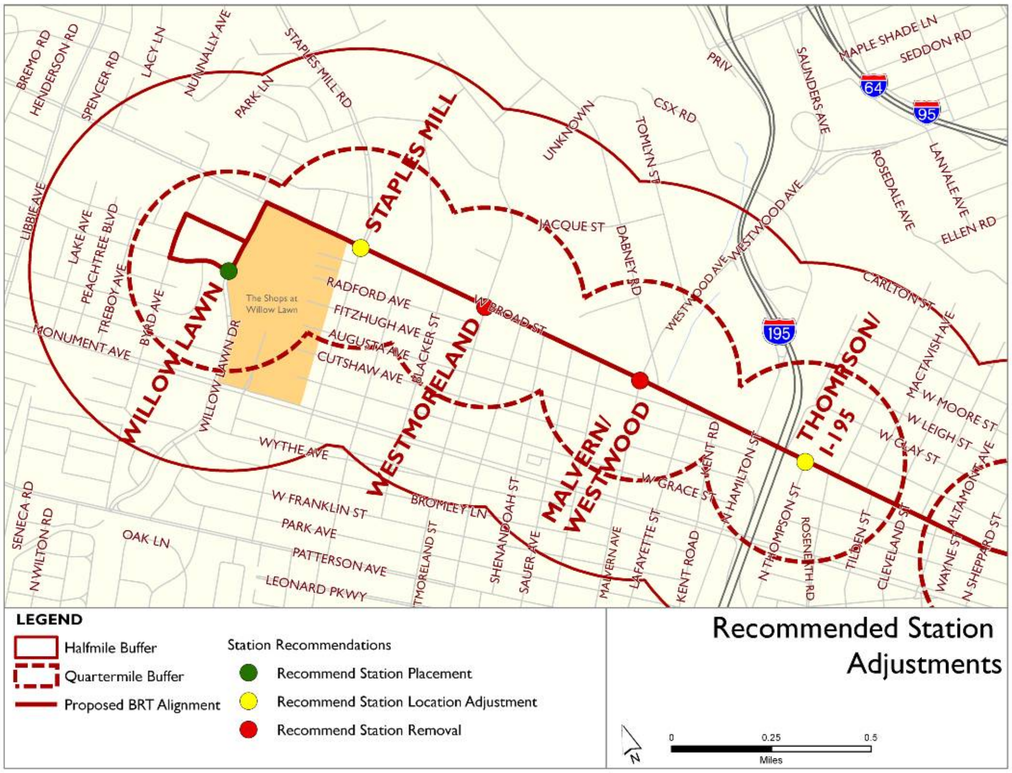
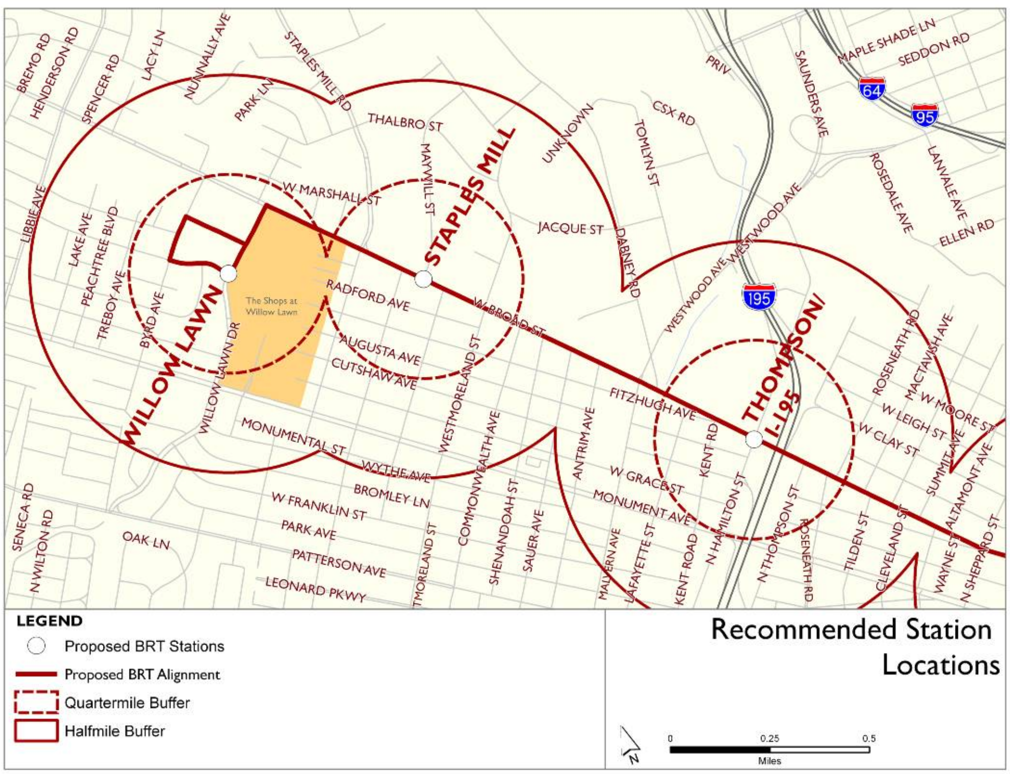


Figure 9: West End Recommended Station Locations



Museum District/VCU

The Museum District/VCU, referring to the proposed station locations of The Boulevard, Hermitage/Meadow, Harrison, and Belvidere, is an urban, multimodal environment with relatively high residential density on the south side of Broad Street and redevelopment potential within the industrial parcels to the north of Broad Street. This area includes several major attractions including the Science Museum of Virginia, the Children's Museum of Richmond, the Siegel Center, and Virginia Commonwealth University Monroe Park Campus. Several factors including spacing issues and providing better access to transit and activity centers influenced the recommended changes to station locations along this section of the corridor.

The Boulevard: High traffic volumes and turning movements create problems for station development at the intersection of Broad Street and the Boulevard. It is recommended that this station be moved east to place it in front of the Children's Museum and Science Museum. This will allow the station to provide direct service to two major cultural facilities, capture the higher density residential neighborhoods south of Broad and improve connections to routes serving both Broad Street and Robinson Street.

Hermitage/Meadow: It is recommended that this station location remain at Hermitage Road and Broad Street. This will preserve the spacing between this station and its adjoining stations while allowing for service to the residential areas south of Broad Street and the commercial and retail locations at this intersection.

Harrison and Belvidere: Analysis showed that the Harrison and Belvidere Stations were in close proximity to one another. In addition, high traffic volumes on Belvidere create complications for station location at this intersection. As a result, it is recommended that these stations be consolidated to one station between the Harrison Station and Belvidere Station. This recommendation keeps service at the major activity center of VCU, but reduces the number of stops to improve route efficiency.

Figure 10: Museum District/VCU Station Adjustments

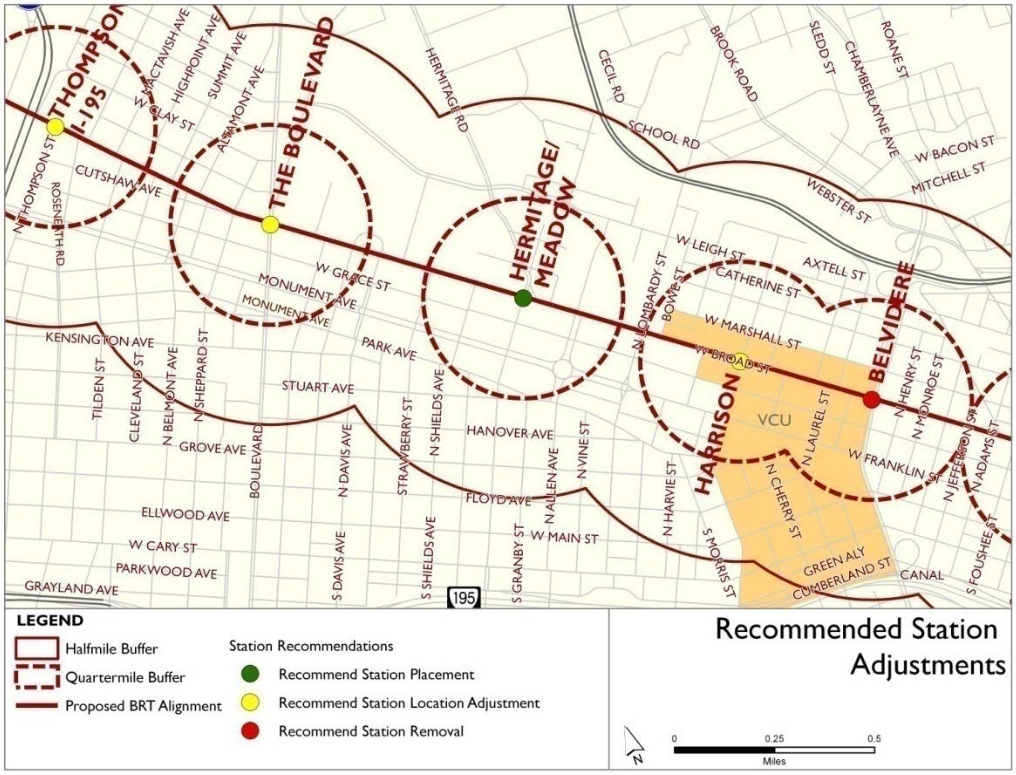
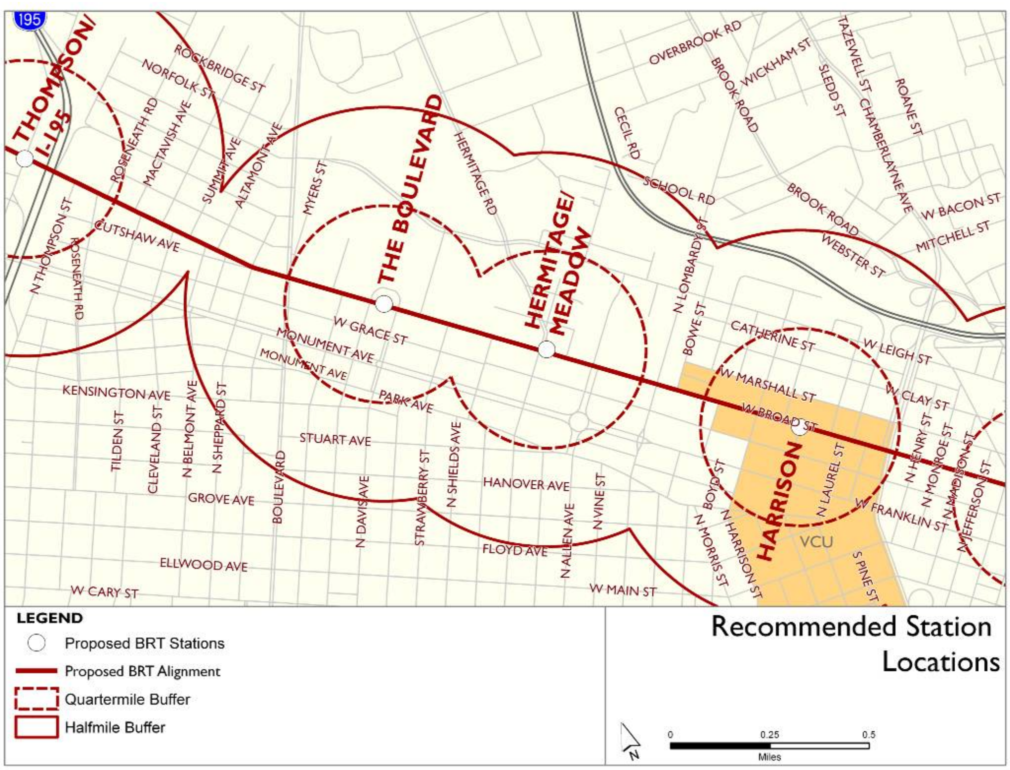


Figure 11: Museum District/VCU Recommended Station Locations



Downtown

The Downtown portion of the corridor is the central business district of the region, including the proposed stations at 2nd Street, 7th Street, 12th Street, and Main Street Stations. This highly urban environment has the highest transit usage and transfer rates in the region; several major employment centers, including the state capital complex; and multiple attractions and activity centers. Station spacing in this section of the corridor must be closer than elsewhere in the study area to maximize the interface between the stations and local bus routes; the closer station spacing will also help to distribute ridership across multiple stations, rather than causing crowding at a smaller number of downtown stations.

> **2nd Street/7th Street/12th Street:** It is recommended that two additional stations be provided in this service area. These stations serve several major attractions including City Hall, the Coliseum, the Convention Center, Capital Square, and VCU Medical Center. The areas around these stations also include the highest boardings, alightings, and transfers in the region. As a result, it is recommended that 2nd Street station move one block west to 1st Street and new stations be inserted at 4th and 10th Streets. These recommended adjustments allows for three block spacing between stations in the downtown core service district.
>
> **Main Street Station:** Although exact routing will be determined in concurrent route alternatives analysis, routing should allow the proposed Main Street Rapid Transit Station to move to the front of the Main Street Amtrak Station. This direct multimodal connection is vital to regional mobility.

Figure 12: Downtown Station Adjustments

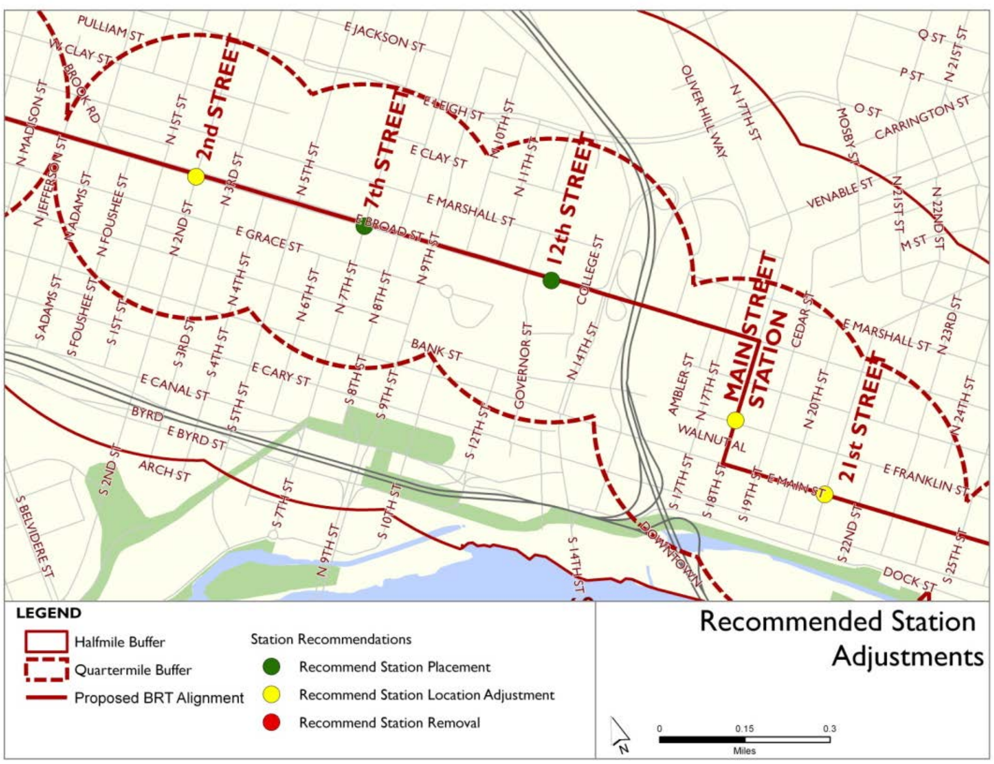
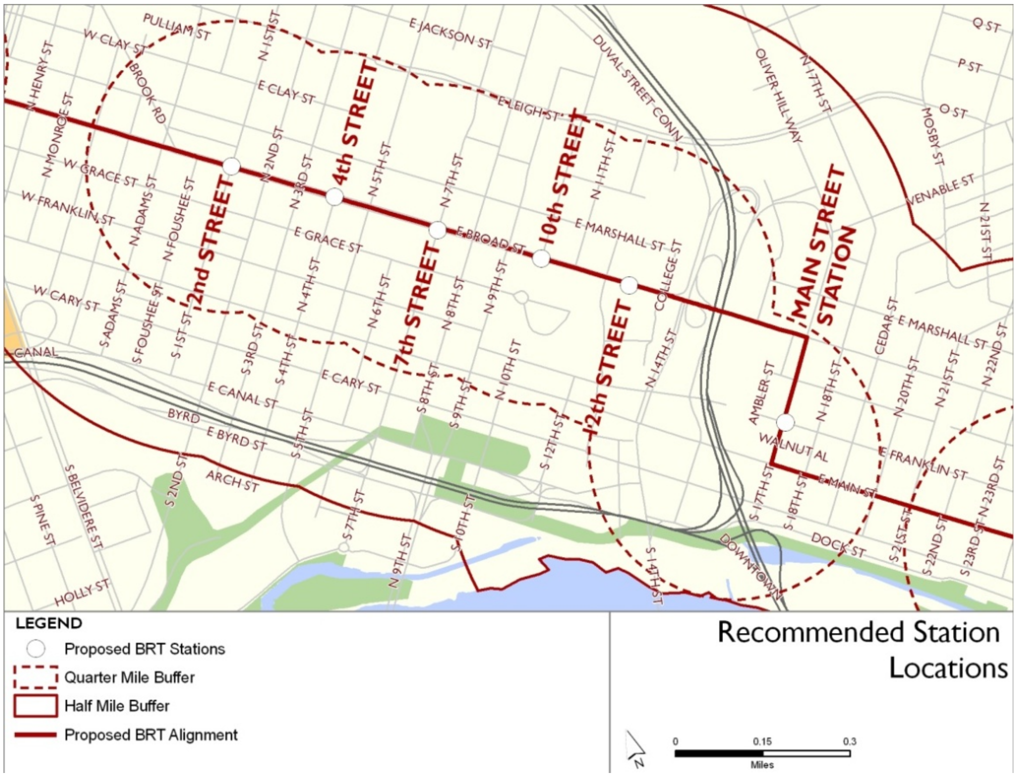


Figure 13: Downtown Recommended Station Locations



East End

The East End of the proposed corridor includes the 21st Street Station, Williamsburg Road Station and East End Transit Center. Relative to the rest of the corridor, this section has very low transit activity, few activity centers, and low population and employment densities. Yet, the major redevelopment occurring at Rockett's Landing establishes another destination point at the terminus of the corridor and could serve as an intermodal connection to future transit operations serving points east of Rockett's Landing.

21st Street: It is recommended that the proposed 21st Street Station be moved to the intersection of 25th and Main Streets. This adjustment provides direct access to the shopping center at this location.

Williamsburg Road: Since the 21st Street Station is recommended to move east to 25th Street, spacing issues as well as the low transit use, population and employment requires that the Williamsburg Road Station be removed.

East End Transit Center: The redevelopment at Rockett's Landing includes multiple land uses consisting of 1,500 residences, multiple restaurants and offices, a hotel and outdoor recreational activities. With the completion of the development set for the opening year of 2015, Rockett's Landing will be an appropriate terminus of the rapid transit corridor. As a result, it is recommended that the station remain in its proposed location.

Figure 14: East End Station Adjustments

Figure 15: East End Recommended Station Locations

Full Corridor

Table 6 and Figure 16 provide an overview of the corridor wide analysis and recommendations. Table 6 summarizes the results of each element of analysis in a matrix format. Within the table, a "√" denotes a station that was considered particularly strong in a category of analysis. For example, the Willow Lawn Station shows a "√" under community facilities because the shopping center at Willow Lawn is considered a special generator. Conversely, an "X" denotes a possible hindrance to a station location. One example includes Staples Mill Station, which received an "X" under traffic impacts due to the high traffic volumes and roadway geometry, as discussed in more detail above. The placement of each station is also marked as "Confirm", "Shift", or "Remove". This column summarizes the recommendations as discussed above.

Table 6: Station Evaluation Matrix

Station Evaluation Matrix

	Community Facilities	Development Potential	Distance Between Station	Population Density	Employment Density	Multimodal Connections	Transit Activity	Traffic Impacts	Placement
Willow Lawn	√						√		Confirm
Staples Mill			X					X	Shift
Westmoreland			X						Remove
Malvern/Westwood									Remove
Thompson		√							Shift
The Boulevard	√			√				X	Shift
Hermitage/ Meadow		√		√					Confirm
Harrison	√		X	√		√	√		Shift
Belvidere			X	√		√	√	X	Remove
2nd Street		√	X		√	√	√		Confirm
7th Street	√		X		√	√	√		Confirm
12th Street	√		X		√	√	√		Confirm
Main Street	√	√	X		√	√			Shift
21st Street	√		X			√			Shift
Williamsburg		√							Remove
East End	√	√							Confirm

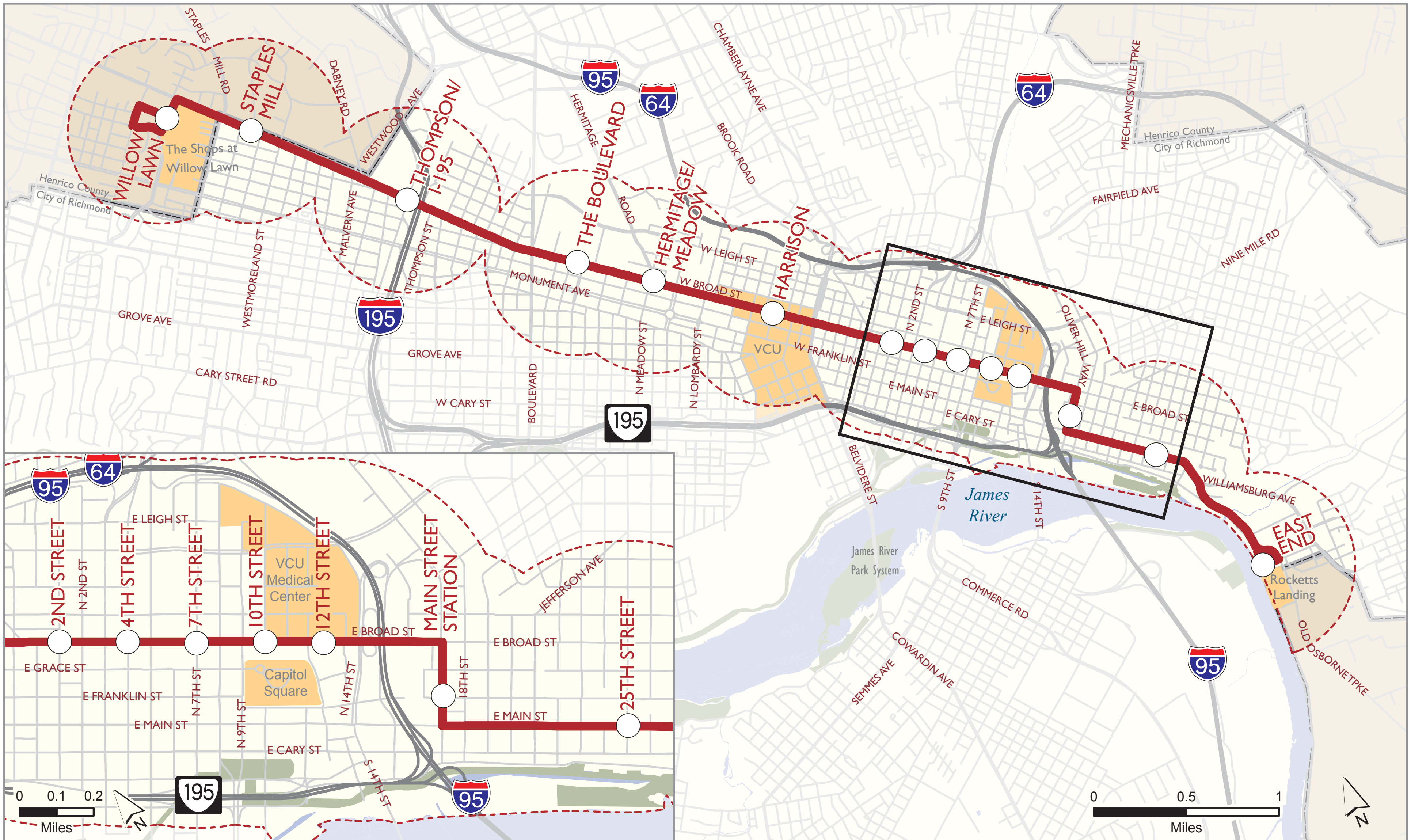
Comparatively, Table 7 is a similar matrix depicting which elements of analysis were improved based on the recommended station adjustment. This table shows only the seven stations that were recommended to be moved and indicates which of the analyzed elements were improved based on the station's recommended new location. The new Staples Mill station location improved the multimodal connectivity by capturing a better ratio of sidewalk to off-street surface parking lots, eliminated the spacing issue due to the removal of Westmoreland, and eliminated the traffic impacts by moving away from the intersection of Staples Mill and Broad. The Thompson/I-95 station location improved multimodal connectivity by increasing the potential for park and ride. The employment density also increased within a quarter mile of the new Thompson/I-95 station location. Adjustment of the Boulevard station more directly serves the adjacent community facilities, increases the employment density within a quarter mile of the station, and eliminates the traffic impacts by moving away from the Boulevard and Broad Street intersection. The adjustment to the Harrison station experiences greater employment and population density and multimodal connectivity. In addition, spacing issues are corrected due to the elimination of the Belvidere station. The shift of the 2nd Street station along with the additional two stations recommended in the downtown area will more adequately serve the multiple community facilities, high employment density, and high transit activity in Richmond's CBD. The recommended Main Street Station location more directly serves the Amtrak station, experiences an increase in employment density within a quarter mile of the station, and improves connection with transit routes. The recommended 21st Street station location eliminates the spacing issues with the Main Street Station location.

Table 7: Characteristics Improvement from Station Location Adjustment

Adjusted Station Location: Improved Characteristics

	Community Facilities	Developmen t Potential	Distance Between Station	Population Density	Employment Density	Multimodal Connections	Transit Activity	Traffic Impacts
Staples Mill			√			√		√
Thompson		√			√	√		
The Boulevard	√				√			√
Harrison			√	√	√	√		
2nd Street	√		√		√	√	√	
Main Street	√				√	√	√	
21st Street		√	√					

Figure 16 provides an approximate visualization of the changes to station location recommended above. The locations depicted reflect appropriate changes based on the data analyzed. The stations are labeled with their original names. These names do not necessarily indicate their current location, but should be used as a reference to the originally proposed station location and represent how that station location has been altered.



Legend

- Proposed BRT Stations
- Proposed BRT Alignment
- Half-Mile Buffer

Station Selection Memo

Figure 16: Recommended Station Locations

BROAD STREET RAPID TRANSIT STUDY

12.0 NEXT STEPS

The station locations shown reflect the approximate site of station platforms and facilities. These locations will be used for the purposes of modeling bus operations, identifying transfers between services, and forecasting ridership. These locations will be analyzed as part of the Detailed Screening of Alternatives, and will be presented to the public in order to benefit from their feedback. The results of the detailed screening and public comment will then be used to refine these locations further. Final decisions regarding precise station location, configuration, and appearance will be determined as part of the design work, to be completed if the FTA permits this study to move into Project Development.

BROAD STREET RAPID TRANSIT STUDY

ENVIRONMENTAL ASSESSMENT

APPENDIX A-7: Detailed Screening Report

BROAD STREET RAPID TRANSIT STUDY
DETAILED SCREENING OF ALTERNATIVES

This Detailed Screening of Alternatives summarizes the second round analysis performed on the detailed set of alternatives identified to meet the Purpose and Need of the Broad Street Rapid Transit Study Environmental Assessment (EA). This screening proceeds with an initial screening and utilizes the measures of effectiveness identified in the January 6, 2010 *Evaluation Methodology* in combination with feedback provided by stakeholders (Technical Advisory Committee, Policy Advisory Committee, general public) to make a determination as to which alternative would be most likely to meet the goals and objectives of the study.

1.0 INITIAL ALTERNATIVES AND INITIAL SCREENING

The initial alternatives for this study are summarized in Table 1-1, and are described in greater detail in the January 21, 2010 *Initial Definition of Alternatives*. Each of the alternatives was developed to (a) meet the goals and objectives established for the study; and, (b) ensure that they would meet the minimum requirements of a project under the Federal Transit Administration (FTA) Small Starts program.

TABLE 1-1: SUMMARY OF INITIAL ALTERNATIVES

	No Build	Baseline	Build Alternatives	
			Build 1	Build 2
Route Length (mi.)	Existing Route 6	7.6		
Miles of Dedicated Bus Lanes	0.75	0.75	3.4	6.7
Number of Stations	Existing local stops	16 stations		
Peak/Off Peak Frequency (min.)	n/a	10/15		
Hours of Operation	Weekdays: 5:30 AM-11:30 PM Weekends: 6:00 AM-11:30 PM			
Network Changes and Feeder Service	None*	Comprehensive Operations Analysis Phase I and Phase II recommendations*		
Fare Collection	On-board (cash, Go Cards)		Off-board Proof of purchase (BRT tickets)	
Vehicles	Existing GRTC vehicles		Dedicated Bus Rapid Transit (BRT) vehicles	
Intelligent Transportation Systems	Existing traffic control systems	Signal priority at intersections along bus lanes		
Branding?	No	Stations only	Stations, vehicles, guideway, signage, marketing efforts	

*Since the initial alternatives were defined, new information from on-board surveys has been made available to the study team. GRTC has indicated that the survey information may warrant the implementation of some COA improvements before the opening year. Refinements in the implementation of the COA will be noted in the No Build and Baseline as part of the Detailed Definition of Alternatives.

These alternatives underwent an initial screening process summarized in Table 1-2. The results of this analysis, in conjunction with feedback provided by stakeholders (Technical Advisory Committee, Policy Advisory Committee, general public) resulted in the advancement of three alternatives (No Build, Baseline and Build 1) and the removal of one alternative from further consideration (Build 2). Details on this screening are available in the *Initial Screening of Alternatives Report*.

TABLE 1-2: SUMMARY OF INITIAL SCREENING RESULTS

Measures of Effectiveness	No Build	Baseline	Build 1	Build 2
Improve local and regional mobility				
▪ Impact on transit ridership	C	B	B	B
▪ Impact on general traffic	C	C	D	F
▪ Impact on on-street parking	C	C	D	F
▪ Impact on vehicle and pedestrian safety	F	F	B	B
Support economic development along the corridor				
▪ Impact on residential access to transit	C	B	B	B
▪ Impact on transit access to activity centers	C	B	A	A
▪ Impact on transit access to redevelopment sites	C	B	A	A
Promote livable, transit-oriented development				
▪ Ability to support higher density land uses	C	C	B	B
Create a multi-modal transportation system with attractive travel choices				
▪ Average operating speed	C	B	B	A
▪ Number of intermodal connections	C	C	B	B
▪ Level of investment that can support future upgrades	C	B	B	B
▪ Frequency, schedule, and travel times of transit services in the corridor	C	B	A	A
Optimize return on public investment				
▪ Order-of-magnitude capital cost	C	C	D	F
▪ Order-of-magnitude operating cost	C	C	D	D
Enhance environmental quality				
▪ Impact on natural resources (parklands, wetland, water, habitat)	C	C	B	B
▪ Impact on historic and cultural resources	C	C	C	C

2.0 DETAILED ALTERNATIVES

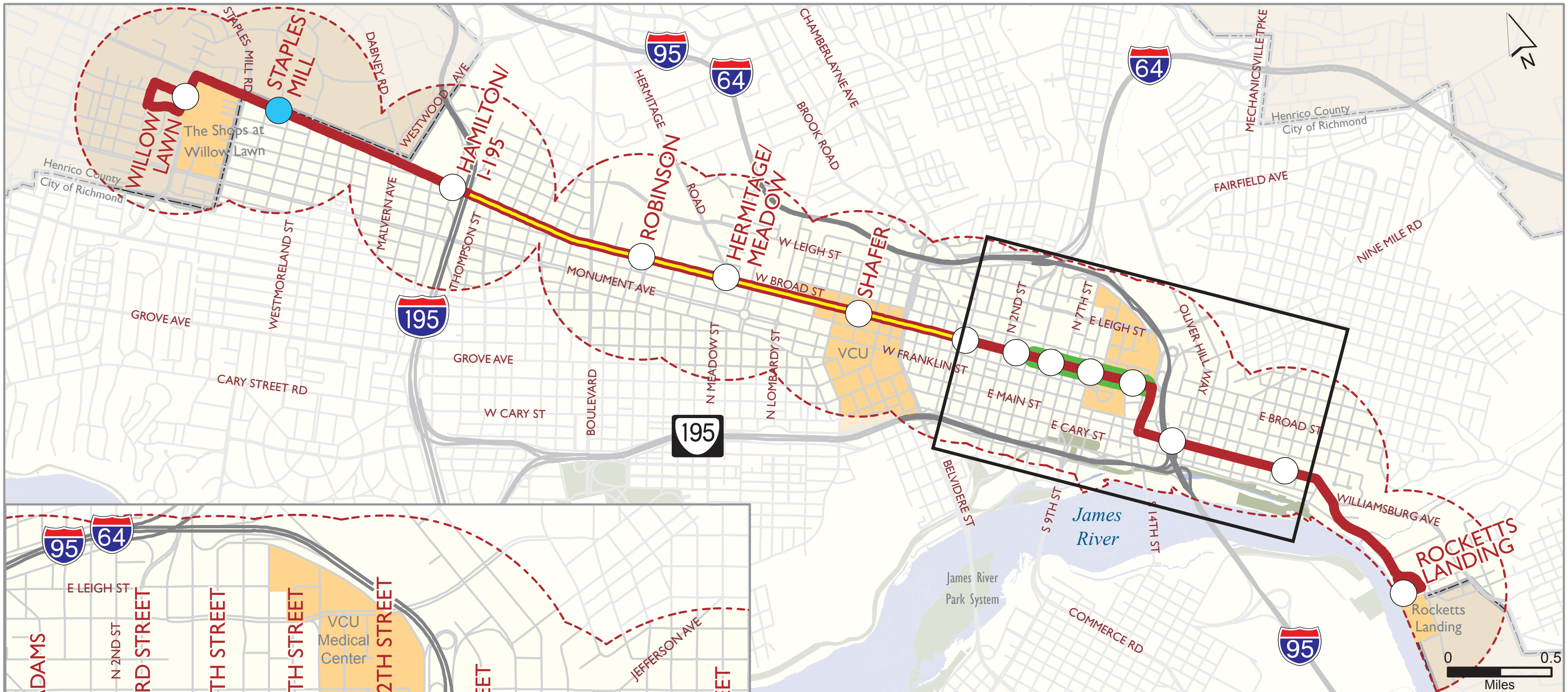
Following the initial screening of alternatives, the retained alternatives were refined and defined in sufficient detail such that this second screening could evaluate (a) how well each alternative meets the goals and objectives established for the study; and, (b) how the alternatives compare to one another in terms of costs, benefits, and impacts. Refinements included discrete analyses of north/south routing options between the Broad Street and Main Street portions of the corridor, and of the most appropriate number and locations of stations. Detail was established such that assessments could take on a more quantitative nature than during the initial screening. Furthermore, during the time between the initial screening completion and the detailed screening analysis, FTA regulations changed so that a Baseline alternative is no longer required. Since the Baseline Alternative did not meet economic development goals of the project, it has therefore been eliminated from further consideration. A summary of details for the two remaining alternatives is included in Table 2-1. Figure 2-1 shows the alignments and key features of the Build Alternative. Full descriptions of all alternatives are available in the *Detailed Definition of Alternatives Report*.

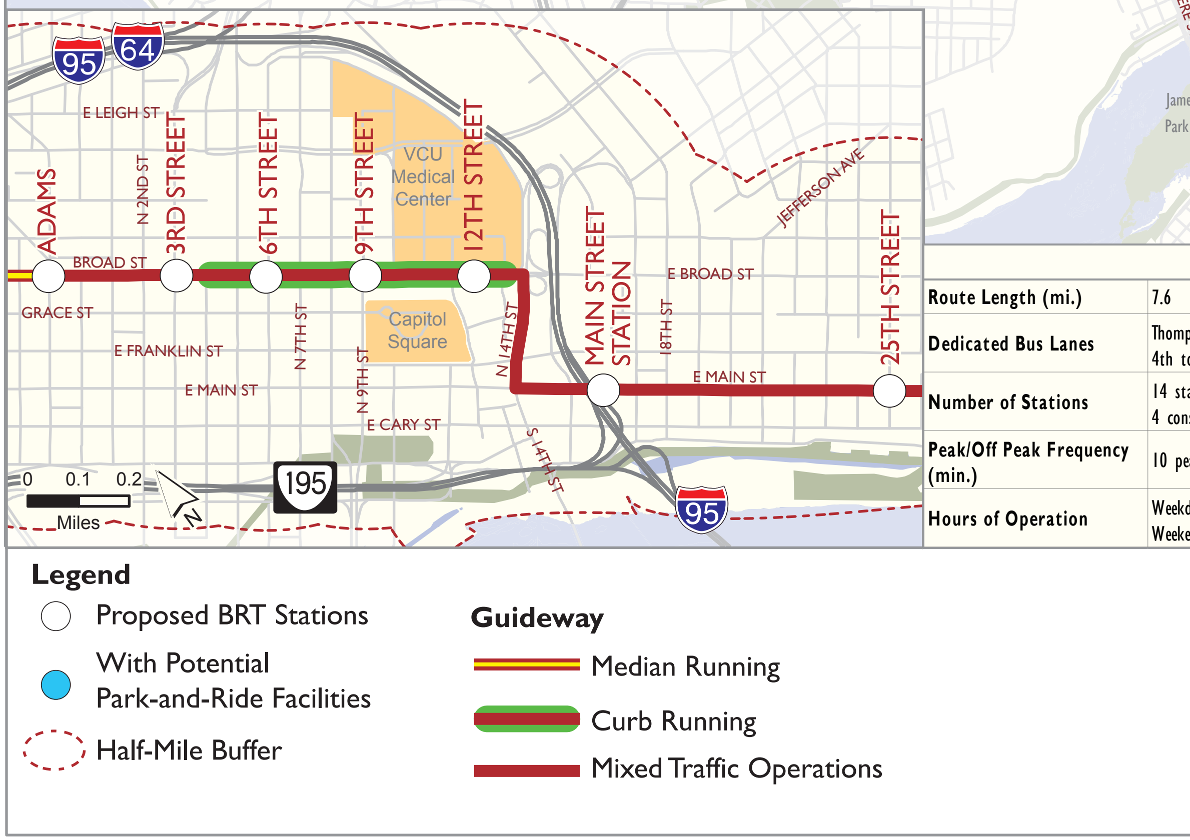
TABLE 2-1: SUMMARY OF DETAILED ALTERNATIVES

	No Build*	**Build Alternative**
Route Length (mi.)	n/a*	7.6
Dedicated Bus Lanes?	Existing 2nd to 14th Street lanes	Thompson to Adams: median lanes 4th to 14th: widened shoulder lanes
Number of Stations	Existing local stops	14 stations (4 center, 4 consolidated, 6 curbside)
Station Amenities	Basic shelters, signage, and benches	Enhanced shelters with branding, real-time schedule information, bicycle racks
Peak/Off Peak Frequency (min.)	n/a**	10 peak/15 off-peak
Hours of Operation	Weekdays: 5:30 AM-11:30 PM	
Route Changes	Refined adjustments to routes using Broad Street based on Transit Development Plan (TDP)	No-Build + BRT service + consolidated bus stops between 2nd and 14th Street. Reductions in frequency for local Route 6 Service.
Fare Collection	On-board (cash, Go Cards)	Go Cards only at stations served by bus lanes, Off-board fare collection for BRT services
Vehicles	Existing GRTC vehicles	Dedicated BRT vehicles
Intelligent Transportation Systems	Existing traffic control systems	Signal priority at intersections along bus lanes
Park and Ride	n/a	One Park-and-Ride possible lot at Staples Mill Road Station
Branding?	No	Stations, vehicles, guideway, signage, marketing efforts

*No service currently operates the entire length of the proposed route.

**The three branches of the Route 6 currently offer a combined headway of 6-12 minutes during peak hours and 12 minutes during off-peak hours of operation.





Build Alternative: Key Features

Route Length (mi.)	7.6	**Vehicles**	Dedicated BRT vehicles
Dedicated Bus Lanes	Thompson to Adams: median lanes 4th to 14th: widened shoulder lanes	**Fare Collection**	Go Cards only at stations. Off-board fare collection for BRT.
Number of Stations	14 stations (4 center, 4 consolidated, 6 curbside)	**Route Changes**	No Build + BRT service + consolidated bus stops between 2nd and 14th Streets + reduction in Route 6 local frequency
Peak/Off Peak Frequency (min.)	10 peak / 15 off-peak	**Branding**	Stations, vehicles, guideway, signage, marketing efforts
Hours of Operation	Weekdays: 5:30 AM-11:30 PM Weekends: 6:00 AM-11:30 PM	**Intelligent Transportation Systems**	Signal priority at intersections along bus lanes

Figure 2-1: Build Alternative

BROAD STREET RAPID TRANSIT STUDY

3.0 DETAILED SCREENING METHODOLOGY

The intention of the detailed screening is to generate sufficient information about the remaining alternatives to screen out those alternatives least likely to meet the established Purpose and Need. At this stage in the analysis, the emphasis is on developing quantitative estimates of the costs, benefits and impacts of each alternative, such that differences between alternatives are readily apparent. Many measures have been included to add depth to the evaluation process by differentiating each alternative according to its anticipated impacts and benefits. The measures of effectiveness are estimated for the base year, 2015.

TABLE 3-1: GOALS, OBJECTIVES AND MEASURES OF EFFECTIVENESS

Goal	Objectives	Measures of Effectiveness
Improve local and regional mobility	• Increase transit ridership • Improve access to the regional transit network • Improve transit service in high ridership areas • Decrease travel times in the study area • Increase transit reliability and on time performance • Minimize negative impact on transit and auto operations in the corridor • Increase transportation system productivity (passengers/hour) within the corridor	• Number of new transit riders • Number of low-income households, zero-car households and minority populations with ½ -mile of stations • On-time performance of transit vehicles • Traffic impact at key intersections and on key road segments • Number of on-street parking spaces lost • Person-capacity of corridor's road and transit networks • Impact on vehicle and pedestrian safety within the corridor
Support economic development along the corridor	• Improve transit access to existing and future developments • Create connections between transit and centers of employment, education, residence, shopping, culture and entertainment • Provide opportunities for joint development of transit stations and facilities	• Number of housing units within ½ -mile of transit stations • Number of retail/office jobs within ½-mile of transit stations • Acres of potentially developable (vacant) land within ¼-mile of transit stations • Acres of potential redevelopment within ¼ -mile of transit stations
Promote livable, transit-oriented development	• Provide high-capacity transit facilities at locations where existing and future land uses make them mutually supportive • Promote improved pedestrian connectivity between transit services and adjoining land uses • Encourage transit usage for different trip types and purposes	• Total population and employment within ½ -mile of transit stations, current and proposed • Additions to pedestrian infrastructure • Frequency, schedule, and travel times of transit services in the corridor
Create a multi-modal transportation system with attractive travel choices	• Create a premium transit route with service characteristics that make it competitive with the private automobile • Integrate premium transit service with local bus, bicycle, pedestrian, private automobile and intercity travel modes • Provide safe, convenient and attractive	• Average operating speed • Number of intermodal connections • Level of investment that can support future upgrades

Goal	Objectives	Measures of Effectiveness
	transfer facilities • Create opportunities for future upgrades or additional premium transit services	
Optimize return on public investment	• Develop cost-effective transit solutions • Capitalize on existing local and regional transit facilities and operations • Support state, regional and local plans • Maximize funding opportunities from state, local, and federal sources	• Capital cost • Annual operating cost • Cost-effectiveness index • Increases in tax revenue
Enhance environmental quality	• Minimize and mitigate negative impacts to the human and natural environment	• Impact on natural resources (parklands, wetland, water, habitat) • Impact on historic and cultural resources

4.0 DETAILED SCREENING RESULTS

Table 4-1 summarizes the findings of the detailed screening. Performance for each measure is categorized as generally positive (+), generally negative or adverse (-) or having negligible effects on the study area (O). A double positive sign (++) indicates a situation where two alternatives have positive effects, but one alternative has a greater positive effect.

In general, the major differences between alternatives are related to the number of stops made along Broad Street and the degree to which buses use dedicated lanes. While new bus lanes are anticipated to improve transit travel times and reliability of service, these benefits come at the expense of additional capital costs, parking impacts, and traffic impacts. While the conditions for livability and economic revitalization are the same throughout the corridor for 2015, the text that follows describes how the interaction of these characteristics with the alternatives may produce more positive results and achieve local land use objectives. In this regard, the Build Alternative is anticipated to provide the most positive effects.

The following paragraphs provide a more detailed description as to how the alternatives fare under each of the detailed screening measures of effectiveness.

TABLE 4-1: SUMMARY OF DETAILED SCREENING RESULTS

Measures of Effectiveness	No-Build Alternative	Build Alternative
Improve local and regional mobility		
Number of new transit riders	+	+
Number of low-income households, zero-car households and minority populations within ½-mile of stations (rating represents number/benefits)	+/O	+/+
On-time performance of transit vehicles	O	+
Traffic impact at key intersections and on key road segments	O	–

Measures of Effectiveness	No-Build Alternative	Build Alternative
Number of on-street parking spaces lost	O	–
Person-capacity of corridor's road and transit networks (Peak Hour)	O	–
Impact on vehicle and pedestrian safety within the corridor	O	+
Support economic development along the corridor		
Number of housing units within ½-mile of transit stations	O	+
Jobs within ½-mile of transit stations	O	+
Acres of potentially developable land within ¼-mile of transit stations	O	+
Acres of redevelopment within ¼ -mile of transit stations	O	+
Promote livable, transit-oriented development		
Total population and employment within ½-mile of transit stations, current and proposed	O	+
Additions to pedestrian infrastructure	O	+
Frequency, schedule, and travel times of transit services in the corridor	O	+
Create a multi-modal transportation system with attractive travel choices		
Average operating speed	O	+
Number of intermodal connections	O	+
Level of investment that can support future upgrades	O	+
Optimize return on public investment		
Capital cost	O	–
Annual operating cost	O	–
Increases in tax revenue	O	+

4.1 Local and Regional Mobility

A key reason to invest in transit infrastructure is to improve mobility for the population served. The measures described below assess how well each alternative improves mobility in the corridor through expanding ridership, expanding population served or improving transit or traffic operations.

4.1.1 Number of New Transit Riders

Ridership is expected to increase under all alternatives, based on the ridership modeling completed for the project. Based on the 2009 rider survey, existing ridership on all routes is 27,650. In the No Build Alternative, this would increase to 29,670 by 2015. Under the Build Alternative, ridership is forecast to reach 29,700. Therefore, the No Build would lead to 2,020 new riders and the Build 2,050. These represent a 7.3% and 7.4% increase over existing ridership, respectively.

4.1.2 Number of Low-Income Households, Zero-Car Households and Minority Populations within ½-mile of Stations

Low income households are defined as those households earning less than 30% of the median income for each jurisdiction. As such, in Henrico County, households earning less than $14,755 annually are considered to be low-income. For the City of Richmond, households earning less than $9,336 are considered to be low-income. Low income households are predominately located in the City of Richmond between the Hermitage/Meadow and 12th Street stations.

Minority populations also must be considered and minority populations are concentrated in many of the same areas as low-income households.

Lastly, zero-car households were calculated as those without access to personal automobiles are dependent on public transportation to meet their transportation needs. Similar to patterns of minority populations and low-income households, zero-car households are also concentrated in Richmond between the Adams and 12th Street stations.

While the number of low income households, zero-car households and minority persons is not expected to be any different under any alternative, the service improvements under the Build Alternative would benefit theses populations within the study area. These populations will experience increased frequency of service, travel time savings and increased regional accessibility as a result of the Build Alternative. Table 4.1-1 shows the breakdown of low income and minority populations by station area. Table 4.4-2 shows the breakdown of zero car households by station area.

TABLE 4.1-1: MINORITY AND LOW INCOME POPULATIONS IN STUDY CORRIDOR

Census Tract	Jurisdiction	Total Population (2010)	Total Minorities (% Minority)	Total Low-Income (% Low-Income)	Primary Station Area(s)	Secondary Station Area(s)
Total for City of Richmond		204,214	120,926 (59.2%)	40,434 (19.8%)	n/a	n/a
Total for Henrico County		306,935	125,216 (40.8%)	22,099 (7.2%)	n/a	n/a
2003.01	Henrico County	1,250	143 (11.4%)	0 (0.0%)	Willow Lawn	
504	City of Richmond	2,907	263 (9.0%)	1,134 (3.9%)	Willow Lawn	
2005.01	Henrico County	2,154	956 (44.4%)	69 (3.2%)	Willow Lawn	Staples Mill
502	City of Richmond	3,006	182 (6.1%)	93 (3.1%)	Staples Mill	Willow Lawn
2005.02	Henrico County	2,061	391 (19.0%)	115 (5.6%)	Staples Mill	Hamilton/I-195
501	City of Richmond	2,577	292 (11.3%)	126 (4.9%)	Hamilton/I-195	Staples Mill
407	City of Richmond	2,373	315 (13.3%)	0 (0.0%)	Hamilton/I-195	
402	City of Richmond	3,900	2,273 (58.3%)	234 (6.0%)	Hamilton/I-195	Robinson, Hermitage/ Meadow, Shafer
406	City of Richmond	1,810	231 (12.8%)	0 (0.0%)	Robinson	Hamilton/I-195
409	City of Richmond	2,544	402 (15.8%)	201 (7.9%)	Robinson	
405	City of Richmond	3,152	403 (12.8%)	120 (3.8%)	Robinson	Hermitage/ Meadow

TABLE 4.1-1: MINORITY AND LOW INCOME POPULATIONS IN STUDY CORRIDOR

Census Tract	Jurisdiction	Total Population (2010)	Total Minorities (% Minority)	Total Low-Income (% Low-Income)	Primary Station Area(s)	Secondary Station Area(s)
410	City of Richmond	2,625	202 (7.7%)	0 (0.0%)	Robinson	Hermitage/ Meadow
404	City of Richmond	4,032	879 (21.8%)	637 (15.8%)	Hermitage/ Meadow	Shafer
111	City of Richmond	2,932	2,661 (90.8%)	337 (11.5%)	Hermitage/ Meadow	Shafer
411	City of Richmond	3,724	907 (24.4%)	454 (12.2%)	Shafer	
403	City of Richmond	4,101	1,745 (42.6%)	1,107 (27.0%)	Shafer	Adams Street
412	City of Richmond	1,179	152 (12.9%)	98 (8.3%)	Adams	
301	City of Richmond	2,895	2,843 (98.2%)	1,980 (68.4%)	Adams	3rd Street
302	City of Richmond	2,055	1,084 (52.7%)	388 (18.9%)	Adams, 3rd, 6th, 9th, 12th	
305	City of Richmond	4,029	2,136 (53.0%)	1,056 (26.2%)	Adams, 3rd, 6th, 9th, 12th, Main Street Station	
204	City of Richmond	5,115	5,052 (98.8%)	2,517 (49.2%)	12th Street	
205	City of Richmond	3,851	1,550 (40.2%)	597 (15.5%)	Main Street Station	12th Street, 25th Street
206	City of Richmond	1,544	639 (41.4%)	174 (11.3%)	25th Street	
208	City of Richmond	1,410	530 (37.6%)	124 (8.8%)	25th Street	Rocketts Landing
211	City of Richmond	1,432	1,212 (84.6%)	115 (8.0%)	Rocketts Landing	25th Street
212	City of Richmond	1,575	1,352 (85.8%)	468 (29.7%)	Rocketts Landing	
2015.01	Henrico County	9,872	8,105 (82.1%)	1,204 (12.2%)	Rocketts Landing	
2016.02	Henrico County	4,916	2,155 (43.8%)	0 (0.0%)	Rocketts Landing	

Source: US Census Data, 2010
Shaded cells indicate census tracts where the percentage of the population of concern is greater than 50% OR greater than the percentage in the corresponding locality.

TABLE 4.1-2: ZERO CAR HOUSEHOLDS IN STUDY CORRIDOR

Census Tract	Jurisdiction	Zero Car Households	% Zero Car Households	Primary Station Area(s)	Secondary Station Area(s)
Total for City of Richmond		14,973	17.9%	n/a	n/a
Total for Henrico County		7,594	6.1%	n/a	n/a
2003.01	Henrico County	38	6.9%	Willow Lawn	
504	City of Richmond	54	7.3%	Willow Lawn	
2005.01	Henrico County	21	2.5%	Willow Lawn	Staples Mill
502	City of Richmond	251	6.6%	Staples Mill	Willow Lawn
2005.02	Henrico County	52	2.6%	Staples Mill	Hamilton/I-195
501	City of Richmond	188	18.8%	Hamilton/ I-195	Staples Mill
407	City of Richmond	848	61.2%	Hamilton/ I-195	
402	City of Richmond	299	13.6%	Hamilton/ I-195	Robinson, Hermitage/ Meadow, Shafer
406	City of Richmond	64	7.7%	Robinson	Hamilton/I-195
409	City of Richmond	45	8.0%	Robinson	
405	City of Richmond	63	12.6%	Robinson	Hermitage/ Meadow
410	City of Richmond	89	17.0%	Robinson	Hermitage/ Meadow
404	City of Richmond	771	69.9%	Hermitage/ Meadow	Shafer
111	City of Richmond	156	20.6%	Hermitage/ Meadow	Shafer
411	City of Richmond	494	27.6%	Shafer	
403	City of Richmond	198	17.0%	Shafer	Adams Street
412	City of Richmond	115	35.1%	Adams	
301	City of Richmond	488	27.7%	Adams	3rd Street
302	City of Richmond	217	12.2%	Adams, 3rd, 6th, 9th, 12th	
305	City of Richmond	96	9.6%	Adams, 3rd, 6th, 9th, 12th, Main Street Station	
204	City of Richmond	110	8.6%	12th Street	
205	City of Richmond	122	9.1%	Main Street Station	12th Street, 25th Street
206	City of Richmond	95	6.9%	25th Street	
208	City of Richmond	180	10.5%	25th Street	Rocketts Landing
211	City of Richmond	59	11.3%	Rocketts Landing	25th Street
212	City of Richmond	110	7.7%	Rocketts Landing	
2015.01	Henrico County	33	2.3%	Rocketts Landing	
2016.02	Henrico County	10	0.9%	Rocketts Landing	

Source: US Census Data, 2010
Shaded cells indicate census tracts where the percentage of the population of concern is greater than 50% OR greater than the percentage in the corresponding locality.

4.1.3 On-Time Performance of Transit Vehicles

While the bus operations modeling did not specifically address on-time performance, improvements in on-time performance can be inferred from the modeling of bus speeds and travel times. This is particularly plausible in light of the fact that current bus operations have been shown to experience issues with on-time performance in this corridor (discussed in detail in Chapter 3 of the Environmental Assessment). Faster bus speeds and shorter travel times would suggest fewer congestion-related delays in bus operations and therefore a higher likelihood of on-time performance. Based on the VISSIM modeling completed for the project, Build Alternative is projected to positively affect travel times and speeds along the corridor. Table 4.1-3 shows the VISSIM model travel times and speeds for the two alternatives in both the peak and reverse peak directions. The comparison of travel time and speed to the local bus service is limited to the Willow Lawn to 12th Street section since the proposed Route 6 service in the future would not serve the east end. In the peak direction of the No Build Alternative, the local bus travel time is 36.04 minutes with an average travel speed of 7.99 miles per hour. The reverse peak direction is forecasted to have a travel time of 36.78 minutes and an average bus travel speed of 7.83 mph.

Compared to the No Build Alternative, the Build alternative substantially reduces travel times and increases the travel speed of buses. The VISSIM simulation of the Build Alternative shows a reduction in the travel time of 14 minutes compared to No Build Alternative in both the peak and reverse peak directions. Additionally, of the two alternatives, the Build Alternative is expected to have the highest bus travel speeds, with an average travel speed of 13.24 mph in the peak direction and 12.62 mph in the reverse peak direction. Furthermore, the Build Alternative is the only alternative where the proposed improvements would improve operations on other routes as well. The Build Alternative would include consolidated platforms for stations between 2nd and 14th Street in downtown. These consolidated platforms would speed the boarding and alighting process at downtown stations for all routes that stop at those stations, thereby reducing dwell times and improving on-time performance for all routes that operate over that segment of Broad Street.

TABLE 4.1-3: BUS RUNNING TIMES AND SPEEDS

Direction	Alternative	Local Bus Travel Time(mins)	Local Bus Speed (mph)	Limited Stop or BRT Travel Time (mins)	Limited Stop or BRT Speed (mph)
Peak	No Build	36.04	7.99	-	-
	Build Alternative	32.69	8.87	21.88	13.24
Reverse Peak	No Build	36.78	7.83	-	-
	Build Alternative	35.77	8.10	22.96	12.62

Source: VHB, 2010.

4.1.4 Traffic Impact at Key Intersections and on Key Road Segments

Based on the Synchro analysis of the 2015 conditions, the majority of intersections in the corridor are forecast to operate with an overall LOS C or better under all alternatives. Under the No Build Alternative, three intersections are forecast to operate at LOS D in either the AM peak, PM peak or both:

AM Peak:

- Broad Street at Malvern Avenue/Westwood Avenue (LOS D)

PM Peak:

- Broad Street at Staples Mill Road (LOS D)
- Broad Street at Malvern Avenue/Westwood Avenue (LOS D)
- Broad Street at Belvidere Street (LOS D).

Under the Build Alternative, two additional intersections would operate at LOS D in the PM Peak:

- Broad Street at Boulevard (LOS D)
- Broad Street at Bowe Street (LOS D)

Given that LOS D is considered to be acceptable in an urban environment such as the Project Corridor, and given that the reduction of only two intersections from LOS C to LOS D is not likely to cause diversion of traffic from the corridor, the Build Alternative's negative impact is minimal.

4.1.5 Number of On-Street Parking Spaces Lost

With the limited changes expected under the No Build Alternative, few, if any, on-street parking spaces are expected to be removed within the corridor. The space necessary to accommodate stations and exclusive bus lanes under the Build Alternative would require the removal of on-street parking in some sections of the corridor. Specifically, where median running guideway is recommended, between Thompson Street and Adams Street, the existing right-of-way is only wide enough to preserve on-street parking on one side of the street. This will result in approximately a 50% reduction in the remaining on-street parking. On-street parking space losses in this section of the corridor are expected to total 453 spaces. Where curb running guideway is recommended, between 4th and 14th Streets, on-street parking will be restricted 24 hours per day. Currently, parking is allowed in many sections of the existing curb lane in off-peak periods. The on-street parking restrictions, therefore, will be expanded in this area, resulting in a loss of parking availability in the off-peak periods. On-street parking space losses during the off-peak periods in this section of the corridor are expected to total 161 spaces. Currently, however, the existing restricted bus lane exists between 2nd and 14th Streets. Therefore, under the Build Alternative, about 20 on-street parking spaces within the two blocks between 2nd and 4th Streets will be reclaimed during the peak periods. Table 4.1-4 details the on-street parking impacts

TABLE 4.1-4: ON-STREET PARKING IMPACTS

Corridor Section	Curb Length (ft)		Estimated Existing On-Street Spaces	Estimated Build On-Street Spaces	Difference
	Existing Available for Parking	Build Available for Parking			
I-195 to Hermitage/Meadow	6,974	2,764	387	154	234
Hermitage/Meadow to Adams	7,068	3,127	393	174	219
2nd Street to 14th Street[1]	2,905	312	161	17	144
Total	16,947	6,203	942	345	597

Source: City of Richmond GIS, 2009.

Table Notes: 1. Existing bus lanes from 2nd to 14th are only enforced in the peak periods. The Build Alternative would reduce the dedicated lanes to the section from 4th to 14th but would expand the hours of enforcement to 24 hours. The result is a loss of 144 spaces in the off-peak periods, but an increase of 17 spaces in the peak periods.

4.1.6 Person-Capacity of Corridor's Road and Transit Networks

Four sections of the corridor were analyzed under all alternatives to estimate effects of the different guideway types. Person-capacity of the corridor was calculated in two steps, one for roadway capacity and one for transit capacity. Roadway capacity was calculated by reducing the saturation free flow volume of the roadway by the average green time for signals and then multiplying the resulting vehicle capacity by the average typical occupancy of 1.2 persons per vehicle. Transit capacity was calculated by counting the number of buses traveling along each segment and multiplying each by the maximum capacity of the typical GRTC bus, about 47 persons.

TABLE 4.1-5: PERSON CAPACITY OF CORRIDOR BY SECTION

Segment	Section	Total Capacity		Difference to No Build
		No Build	Build	
Broad Street	Willow Lawn to I-195	7,659	8,033	375
Broad Street	I-195 to Adams Street	8,130	6,091	-2,039
Broad Street	Adams Street to 14th Street	9,746	10,082	336
Main Street	14th Street to Williamsburg Rd	5,343	5,905	562

For the I-195 to Adams Street segment, person-capacity would be lower under the Build compared to the No Build as the increased bus service provided by the BRT does not fully replace the person-capacity of one general travel lane in each direction removed to accommodate the median bus lanes. That being said, as noted in previous sections, this loss of lane capacity would be result in only a marginal impact on LOS at key intersections in the corridor suggesting that congestion would be minimally affected.

4.1.8 Impact on Vehicle and Pedestrian Safety within the Corridor

In the No Build Alternative there will be no physical changes to the Broad Street corridor that would alter vehicle or pedestrian safety compared to existing conditions. The Build Alternative, however, includes improvements to the cross-section of Broad Street throughout the fixed guideway portion of the project from Thompson Street to Adams Street and from 4th Street to 14th Street. Some of these improvements will modestly narrow the travel lanes for general traffic, but in no case will the resulting lane-widths compromise safety.

The existing curb running bus lanes will be rebuilt and widened from their existing width of 9 to 10 feet. This will help transit vehicles avoid infringement on the general traffic in the adjacent travel lane, which will improve the safety of both transit and general traffic operations.

In the median-running portion of the Build Alternative, very few dedicated left-turn lanes exist today, with the effect that left-turning traffic stops through-traffic in the left lane while waiting to turn, although left turns are prohibited at many intersections either all day or during peak periods. Where left turns are allowed along Broad Street, the Build Alternative will allow these vehicles to turn from the bus lane, which reduces the likelihood of rear-end collisions from stopping in the through-lane. With the Build Alternative, potential improvements for pedestrian safety include increased shelter and lighting at BRT bus stops and updated pedestrian crossing signalization at intersections where traffic signals will be reconstructed or updated. Furthermore, where median BRT stations are provided, the mid-street islands would also serve as pedestrian refuge medians where pedestrians could stop should the signals turn red while they cross.

4.2 Support for Economic Development

Support of economic development goals of the region is another key goal of many transportation projects. The measures below assess how well each alternative encourages increases in housing, employment, development or redevelopment within the corridor. In general, the economic development characteristics described in the following sections will be the same at base year for the No-Build and Build Alternatives. However, the Build Alternative would foster economic growth more so than the No Build Alternative by offering higher levels of transit service and peak period headways that would strongly support transit access throughout the corridor. Furthermore, given that the Build Alternative provides travel times that are even more competitive with the automobile and provides the enhanced service features of branded, low-floor BRT buses and the median-running and improved curb-running fixed-guideway portions of the corridor, the Build Alternative would be expected to be more supportive of economic development in the corridor. This is supported by the research and case studies noted in the *Economic Impacts Analysis*.

4.2.1 Number of Housing Units within ½-Mile of Transit Stations

The corridor is surrounded by some of the more densely populated neighborhoods within the City of Richmond. Based on the Richmond Area MPO's (RAMPO) most recent socioeconomic data estimates at the traffic analysis zone (TAZ) level, in 2008 there were a total of 16,381 housing units within a ½-mile of the transit stations. This is expected to increase to 17,859 by 2015, an increase of 9 percent under all alternatives.

4.2.2 Number of Jobs within ½-Mile of Transit Stations

The RAMPO TAZ employment forecasts only provide data for retail employment and non-retail employment. Therefore the total employment is being used as the best estimate of employment activity in the corridor, even though it may include some industrial employment that may not be conducive to transit use. According to RAMPO data, there were a total of 77,124 jobs in the corridor in 2008. This is expected to increase to 87,398 jobs by 2035, an increase of about 13%.

4.2.3 Acres of Potentially Developable Land within ¼-Mile of Transit Stations

There is little vacant land within the corridor with most vacant land in the vicinity of Rocketts Landing. In total there is 94.9 acres of vacant land available in the corridor and this is expected to decline somewhat by 2015 as new development occurs. Table 4.2-1 shows the breakdown of vacant and redevelopable land by station. The acres of potentially developable land within ¼-mile of transit stations is expected to be the same in 2015, though the Build Alternative is expected to encourage redevelopment more so than the No Build Alternative beyond 2015.

The Build Alternative foster economic growth more so than the No Build Alternative by offering higher levels of transit service and peak period headways that would strongly support transit access throughout the corridor. The Build Alternative is the only one that provides transit service the Rocketts Landing area, where much of the existing vacant land is found.

TABLE 4.2-1: VACANT AND REDEVELOPABLE LAND BY STATION

Station	Acres of Vacant Land	Acres of Redevelopable Land	Total Acres with Development Potential
Willow Lawn	3.0	26.6	29.6
Staples Mill	3.6	39.8	43.4
Hamilton/I-195	4.7	47.1	51.9
Robinson	3.5	29.6	33.1
Hermitage/Meadow	8.5	50.0	58.5
Shafer	3.9	27.7	31.6
Adams	8.5	20.4	28.9
3rd	8.3	18.9	27.3
6th	2.9	9.0	12.0
9th	1.2	9.2	10.4
12th	4.3	9.3	13.6
Main Street Station	11.8	22.8	34.7
25th	7.7	19.1	26.8
Rocketts Landing	22.7	12.1	34.9
Total	94.9	341.7	436.5

4.2.4 Acres of Redevelopable Land within ¼ -Mile of Transit Stations

The corridor has significant amounts of redevelopable land capable of accommodating the expected increase in infill development triggered by the BRT system. Every proposed station of the BRT system has more than 10% of land available for redevelopment potential. In total there is 341.7 acres of redevelopable land within ¼-mile of the corridor. Table 4.2-1 shows the acres of redevelopable land by station area.

The acres of redevelopable land within ¼-mile of transit stations is expected to be the same in 2015, though the Build Alternative is expected to encourage redevelopment more so than the No Build Alternative beyond 2015. This alternative provides significant transit service enhancement to the Shockoe Bottom area along Main Street where substantial redevelopment has already occurred and further redevelopment is expected. In particular, the enhanced sense of place and identity of the transit stations and fixed guideway portions with the Build Alternative would likely encourage further redevelopment of the industrial areas north of Broad Street in the Shafer, Hermitage/Meadow and Robinson station areas as these station areas would have faster transit access to downtown via the median guideway.

4.3 Livable, Transit-Oriented Development

Encouraging the development of a more transit oriented built environment is a key goal of major transit investment. Based on the analysis *Land Use and Multimodal Connectivity Report*, the downtown and VCU sections of the corridor are already highly transit supportive in their land use mix and density. While other sections of the corridor are currently less supportive, such as Rocketts Landing, land use plans and zoning for the corridor is highly supportive of transit oriented development. The report provides recommendations to improve the livability and multimodal accessibility throughout the corridor in concert with the development of rapid transit. The measures below quantify the existing and future measures of livability and transit-oriented development.

4.3.1 Total Population and Employment within ½-Mile of Transit Stations, Current and Proposed

The proposed corridor traverses the City of Richmond's densely populated neighborhoods and central business district, which includes major government centers, a state university and medical college, as well as multiple retail and commercial businesses. RAMPO TAZ data indicates a total of 35,032 persons within a ½-mile of proposed stations in 2008. The same data source indicates 78,040 jobs within the same area; more than double the number of persons in the study area. By 2015 the population and employment are expected to increase to 37,033 and 81,987, respectively.

While the population and employment in 2015 are expected to be the same under all alternative as no induced land use changes are anticipated prior to 2015, the Build Alternative is expected to encourage higher population and employment growth within the corridor beyond 2015. The Build Alternative would foster economic growth more so than the No Build Alternative by offering higher levels of transit service and peak period headways that would strongly support transit access throughout the corridor. In particular, the mode specific effects of the Build Alternative would likely encourage further redevelopment of the industrial areas north of Broad Street in the Shafer, Hermitage/Meadow and Robinson station areas, as these station areas would have faster transit access to downtown via the median guideway.

4.3.2 Additions to Pedestrian Infrastructure

With the limited infrastructure changes anticipated under the No Build Alternative, no change is expected in any pedestrian infrastructure. Under the Build Alternative, some improvements are expected in the pedestrian infrastructure along the corridor. Specifically, pedestrian infrastructure improvements are expected to be incorporated into station design and in particular station areas along the median and curb guideways. Such improvements may include new pedestrian signals, new curb ramps, wider medians for pedestrian refuge at median stations and other streetscape improvements.

4.3.3 Frequency, Schedule, and Travel Times of Transit Services in the Corridor

Under the No Build Alternative, the Route 6 would offer service frequencies of 10 to 12 minutes in the peak periods and 15 minutes in the off-peak periods. Under the Build Alternative, the BRT service would offer service frequencies of every 10 minutes in the peak period and every 15 minutes in the off-peak periods. Under the Build Alternative the local Route 6 service offered would be reduced to 20 minutes during the peak periods and 30 minutes in the off-peak periods. In all alternatives, these services are expected to be offered weekdays from 5:30 a.m. to 11:30 p.m. and weekends from 6:00 a.m. to 11:30 p.m.

As previously described in section 4.1, Build Alternative reduces travel times for transit service in the corridor. The Build Alternative provides a reduction in the travel time of 14 minutes compared to No Build alternative in both the peak and reverse peak directions. The combination of auto-competitive travel times, high frequencies and span of service provided under the Build would be particularly supportive of more transit-oriented development by providing a transit service that allows residents and workers in the corridor to access transit without regard to a specific timetable thereby encouraging a much less auto-centric development pattern.

4.4 Multi-modal Transportation and Travel Choices

A major goal of any transportation investment is to increase travel options and encourage more multi-modal travel connections. The measures below enumerate how the alternatives perform in expanding and improving the multi-modal transportation system.

4.4.1 Average Operating Speed

The Build Alternative is also projected to positively affect travel times and speeds along the corridor. Table 4.1-2 shows the VISSIM model travel times and speeds for the alternatives in both the peak and reverse peak directions. The improvements in bus running times and speeds are discussed in Section 4.1.3.

Compared to the No Build Alternative, the Build Alternative would significantly reduce travel times and increase the travel speed of buses. The Build Alternative is anticipated to improve conditions for passengers on existing local routes: travel speeds are forecast to increase up to 11% for local buses operating between Willow Lawn and 25th Street under the Build, while travel times for these routes are expected to decrease up to 9%. This may be directly attributed to the positive effects of introducing wider shoulder bus lanes and consolidated stations in downtown Richmond.

4.4.2 Number of Intermodal Connections

While all alternatives provide serve at Main Street Station, the Build Alternative would greatly enhance the number of buses serving Main Street Station. Furthermore, as the Build Alternative would provide for wider, rebuilt shoulder bus lanes with multiple platforms at each stop, it should provide for more efficient intermodal connections between the BRT and local bus services. The Build Alternative includes a park and ride facility at Broad Street and Staples Mill Road, providing an intermodal connection for auto trips.

4.4.3 Level of Investment That Can Support Future Upgrades

The Build Alternative would provide a higher level of transit service in the region than has been provided anytime in the last few decades. As such this alternative would test the market for premium transit service in Richmond and determine the appropriate level of future upgrades within the study corridor and other corridors. As the Build Alternative represents a higher level of investment and a stronger branding of the higher quality transit service, it would create a stronger case for extending or upgrading dedicated guideways in the corridor and in other corridors.

4.5 Return on Public Investment

As with any public investment, the return on investment is a critical factor in determining the value provided by a proposed project. The factors below enumerate the costs, capital, operating and maintenance, any tax benefits and the cost-effectiveness of the alternatives.

4.5.1 Capital Cost

The *Capital Costs Estimate Report* describes the methodology for estimating capital costs for all alternatives. As the No Build will not require any changes other than those already programmed, there are no capital costs associated with it. The Build Alternative incurs additional capital cost for the dedicated guideway construction, larger station structures a potential right-of-way costs for small property impacts. Total estimated capital cost in 2015 dollars is $53,751,800.

4.5.2 Annual Operating Cost

The *Operations and Maintenance Costs Estimate Report* describes the methodology for estimating operations and maintenance (O&M) costs for all alternatives. The No Build costs include the costs associated with the existing system and total cost in 2015 dollars is $46,535,000, or 1.6% more than existing costs. The Build Alternative costs total $46,899,000, or 2.4% more than existing costs.

4.5.3 Increases in Tax Revenue

Based on comparisons to other similar corridors, as documented in the *Economic Impacts Analysis* report, the Build Alternative could increase property tax revenues in the corridor due to inducement of development and redevelopment. The average annual increase in property tax revenue over 20 years is estimated to be approximately $4,250,000 and $330,000 for the City of Richmond and Henrico County, respectively.

4.6 Environmental Quality

The potential environmental effects are vital factors to consider in screening alternatives. The measures below enumerate the major categories of environmental effects, both positive and negative, associated with the alternatives. Additional detail on environmental effects is included in the draft Environmental Assessment.

4.6.1 Impact on Natural Resources (Parklands, Wetland, Water, Habitat)

None of the alternatives will have any adverse impact on parklands, wetlands or water habitats within the corridor.

4.6.2 Impact on Historic and Cultural Resources

As the No Build would have few changes and none outside existing right-of-way, it would have no impact on historic and cultural resources. The Build Alternative, while it would include new or expanded station platforms and other infrastructure changes in the vicinity of historic and cultural resources, it would have no adverse impact on any historic or cultural resource in the corridor.

5.0 INPUT RECEIVED AT PUBLIC MEETINGS

Input from the public was received via the study website, mail and in person at public meetings. Overall, much of the public input was supportive of the proposed Build Alternative with some concerns regarding the specific details of implementation. There was some desire to study light rail as an alternative and some concern about too many stations downtown and possible shifting of other stations. Many comments indicated a desire to see the BRT system expanded to serve other activity centers. There was strong support for the median guideway from the comments, including a desire to see the median guideway extended to 14th Street. Furthermore, some comments noted the importance of transit investment as a means to encourage transit oriented development.

6.0 CONCLUSIONS

The Build Alternative best meets the purpose and need of the study as it rates as the best on the most measures of effectiveness. It rates the best in the quantitative measures on

- Number of new transit riders,
- Frequency, schedule and travel times of transit services in the corridor and
- Average operating speed.

While the quantitative measures for all alternatives are the same for seven of the measures of effectiveness, the qualitative measures indicate that the Build Alternative rates best on:

- On-time performance of transit vehicles,
- Impact of vehicle and pedestrian safety,
- Additions to pedestrian infrastructure,
- Number of intermodal connections and
- Level of investment that can support future upgrades.

The Build Alternative rates lowest on:

- Traffic impact at key intersections and on key road segments,
- Number of on-street parking spaces lost, and
- Capital cost.

The traffic and parking impacts, however, are fairly small relative to the overall level of traffic congestion and the overall availability of parking in the corridor. While the capital cost is substantial, the overall benefits to ridership, improved transit service frequency and reliability indicates that the return on investment would be worthwhile.

While the No Build rates best on traffic impacts, on-street parking spaces lost, capital cost and operations and maintenance cost, it rates worst on most other measures meaning that overall, it does not best meet the purpose and need of this study.

7.0 NEXT STEPS

The results of this analysis will need to be presented to the public. Based on the results of this analysis and feedback from the general public, the Technical Advisory Committee and the Policy Advisory Committee will select a Locally Preferred Alternative (LPA) to be carried forward into design and implementation.

BROAD STREET RAPID TRANSIT STUDY

ENVIRONMENTAL ASSESSMENT

APPENDIX A-8: BRT Fare Collection Report

BROAD STREET CORRIDOR RAPID TRANSIT STUDY
BRT FARE COLLECTION STRATEGIES

As requested by the Federal Transit Administration on December 7, 2010, the study team for the Broad Street Rapid Transit Corridor has considered the benefits and potential impacts of including off-board fare collection as part of the study's Build Alternative. Table 1 summarizes the pros and cons of both on-board and off-board fare collection.

TABLE 1: COMPARISON OF BRT FARE COLLECTION STRATEGIES

Factor/Issue	Pay On-Board Driver Assisted	Pay Off-Board Self-Service Fare Collection
Equipment needed	Fareboxes, ticket processing units	TVMs, validators, hand-held readers
Station or platform characteristics	NA	Space, shelters and utilities required for equipment
Handling large passenger volumes	Slows boarding	Reduces platform boarding and station dwell times.
Fare evasion	Caused by using invalid pass. Also caused by crowding at boarding point.	Depends on inspection pattern, fine structure, level of crowding
How customers use automated fare collection system	Uses on-board units/card readers to validate pass.	Use to buy pass, or validate pass—or have pass inspected (inspectors needs hand- held readers)
Security and customer service	Driver responsible for security and customer assistance on bus.	Inspectors provide additional presence on vehicles and platforms. Added security needed during TVM servicing.
Customer convenience	Requires exact change or prepayment (pass or multi- ride option); may be queues at boarding.	Provides validation of multi-ride passes; eliminates queues to buy or validate passes at boarding. Potential for Credit/Debit card acceptance.
Station dwell time	Involvement of the BRT vehicle driver in on-boarding fare collection transactions can increase dwell time. May require the purchase of more vehicles to maintain the 10 minute headway. Use of passes can reduce transaction time.	Allows multiple door boardings which can significantly reduce BRT vehicle dwell time at station. Increases the ability to maintain headways (i.e., better service without adding vehicles)
Capital costs	Lowest costs: fareboxes, but no TVMs	Higher costs. Requires additional station equipment. .
Operating costs	Lowest labor cost	Higher labor cost

Overall, it is estimated that off-board fare collection could result in a travel time savings of 1.5 seconds per Bus Rapid Transit (BRT) boarding while adding $2.7 million to the capital costs of the Build Alternative and $626,000 to GRTC's annual operations and maintenance costs. As decreased boarding times on BRT services could have a positive effect on reducing dwell times for all services using the dedicated lanes proposed along Broad Street, it is anticipated that the benefits of off-board fare collection may outweigh the additional costs of implementing such improvements. The following sections discuss the recommended approach to off-board fare collection and its implications for BRT operations under the Build Alternative.

OVERVIEW OF OFF-BOARD FARE COLLECTION

On-board and off-board fare collection strategies present different advantages and disadvantages to the BRT operation. As noted in Table 1, paying off-board has two major advantages: reduced station dwell times and the elimination of the vehicle operator from fare collection tasks. These advantages may reduce travel times and improve the schedule reliability of services that allow off-board fare collection. However, these advantages come with increased capital and operating costs, including: fare inspectors, station provisions for TVM installation, and the purchase of TVMs.

ASSESSMENT OF BRT FARE COLLECTION BENEFITS

To consider the benefits and impacts of off-board fare collection, the study team assumed that off-board fare collection would allow an average boarding time of 2.5 seconds per passenger boarding a BRT vehicle under the Build Alternative, while boarding times on local buses under all scenarios would remain at 4.0 seconds per passenger. The boarding times for local buses is consistent with observed boarding times on existing GRTC services; the assumed boarding times for off-board fare collection are consistent with the ranges documented in the *Transit Capacity and Quality of Service Manual*. These boarding times were coded into VISSIM models of the No Build, Baseline, and Build Alternatives.

As the dedicated route under the Baseline Alternative was forecast to carry approximately 4,200 daily boardings, it would be anticipated that, at a boarding time savings of 1.5 seconds per passenger, the BRT route under the Build Alternative would experience at least 105 minutes (4,200 boardings x 1.5 seconds savings/60 minutes) in travel time savings in the course of the day. The results of the VISSIM model bears this out: the model indicated that the BRT route under the Build Alternative would have a roundtrip travel time of approximately 64 minutes, while the same route under the Baseline would have a roundtrip travel time of 72 minutes. While the impact of dedicated bus lanes and consolidated stations are likely to have contributed to the travel time savings under the Build Alternative, it is reasonable to assume that off board fare collection also plays a role and should be considered as part of the strategy for implementing the Build Alternative.

OFF-BOARD FARE COLLECTION RECOMMENDATIONS

To maximize the travel time savings forecast by the VISSIM model, the study team recommends an off-board fare collection system to be implemented as part of the Build Alternative. The recommended approach would allow passengers with validated tickets to board through all doors of BRT vehicles. The off-board/proof-of-payment system would provide ticket vending machines installed at stations for customers needing to purchase Go Cards. The TVMs will also provide ticket validation of Go Cards prior to boarding the BRT buses.

Because of the configuration of the CBD stations, which will have large stations platforms with the inclusion of non-BRT vehicles, it is recommended that Stand Alone Validators (SAV) be installed at these stations to provided additional devices for Go Card validation. These will only be used to validate the Go Cards and two SAVs are recommended for each of the four CBD stations.

Table 2 summarizes the recommended equipment, the estimated capital costs, and first year operating and maintenance costs for the proposed BRT fare collection system. All told, it is anticipated that off-board fare collection would add $2.7 million to the capital costs of the Build Alternative and $626,000 to the operating costs. Key features that would contribute to these costs include:

- Purchase and installation of TVMs and SAVs
- Additional space and systems required to integrate off-board fare collection into current GRTC fare collection practices
- Additional manpower associated with fare inspectors and maintenance staffing

As the total capital cost for the Build Alternative is estimated to be approximately $54.2 million in 2010 dollars, it is anticipated that the additional costs of off board fare collection may be accommodated without major negative impacts to the cost effectiveness of the Build Alternative.

TABLE 2: BROAD STREET BRT FARE COLLECTION SYSTEM ESTIMATE

Fare Collection System Estimate, Off-Board Equipment

Note	Capital Cost	Cost (2010 $)
	1. BRT Stations - Includes 28 TVMs and 8 SAVs installed at 14 stations, 4 hand held devices and network equipment. TVMs costs estimated at $40k each for commercially available units accepting cash and credit/debit cards,	1,274,000
	2. Cash Room	164,400
	3. Central Computer and System Support	335,00
	Subtotal-Capital Cost by Dept.	**1,773,400**
A	Percent add-ons	939,800
	SUBTOTAL CAPITAL	**2,713,200**

Note	Operating Costs (Year 1)	Qty	Unit	Total
B	1. Fare Inspectors (1 inspector per 3,000 riders)	2	65,250	130,500
B	2. Revenue, TVM Servicing	2	65,250	130,500
	3. Fare Media, TVM Stock	1	Lot	68,400
	4. Communications Services	1	Lot	30,200
	5. Credit/Debit Services	1	Lot	68,600
	SUBTOTAL OPERATING			**428,200**

Note	Maintenance Costs (Year 1)	Qty	Unit	Total
B	1. Maintenance Staffing	2	87,000	174,000
C	2. Maintenance Materials	1	Lot	23,900
	SUBTOTAL MAINTENANCE			**197,900**
	SUBTOTAL O&M			**626,100**

Notes:

A Add-on includes Engineering (10%), Installation (5%), Support (5%), Non-recurring Parts & Services (13.5%), and Contingency (15%).

B Staffing fringe benefits are estimated at 45%.

C Alternatives based on 10% of Non-recurring Parts & Services cost

D Estimate based on projected daily ridership of 4,685 for year 1.

BROAD STREET RAPID TRANSIT STUDY

ENVIRONMENTAL ASSESSMENT

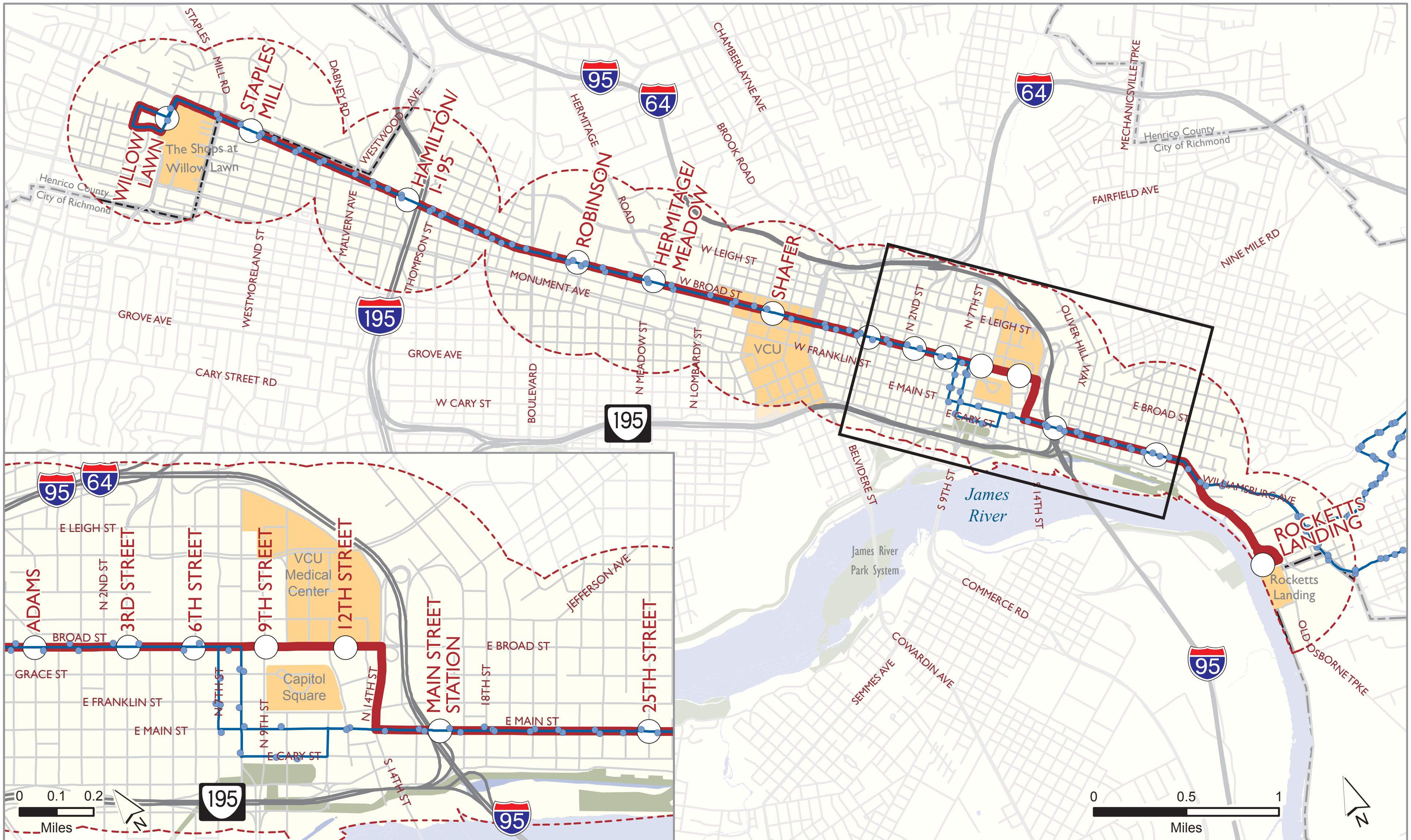
APPENDIX A-9: Transportation System Technical Report

BROAD STREET RAPID TRANSIT STUDY TRANSPORTATION SYSTEMS TECHNICAL REPORT

The Virginia Department of Rail and Public Transportation (DRPT), in partnership with GRTC Transit System, is conducting a detailed study of transit investment along a seven-mile corridor that spans the City of Richmond and portions of Henrico County. The corridor (Broad Street Corridor) follows Broad Street for five miles from Willow Lawn Drive in Henrico County, east through downtown Richmond, to 14th Street, where it then turns south to Main Street to connect to the Amtrak Station. From there, the corridor heads east along Main Street through historic Shockoe Bottom to the new Rocketts Landing development in eastern Henrico County. Figure 1 shows the project corridor in relation to the City of Richmond and Henrico County and the existing GRTC Route 6. The study is following Federal Transit Administration (FTA) Small Starts program guidance and will result in the completion of an Environmental Assessment (EA) document. The EA is evaluating the enhancement of existing transit service along the Broad Street Corridor with Bus Rapid Transit (BRT) service.

The proposed Broad Street BRT system is expected to provide transit passengers with an enhanced and efficient bus service along the existing GRTC routes on Broad Street, 14th Street, and Main Street. The proposed alternatives are expected to affect traffic operations in those corridors. This report is intended to provide information for completing the EA documents. For purposes of the analyzing alternatives, traffic analysis and VISSIM microsimulation modeling was used to develop and evaluate the various alternatives for the BRT service. Detailed results from the analysis are presented in a separate document *Traffic and Transit Operations Analysis: Proposed GRTC Bus Rapid Transit System* by Vanasse Hangen Brustlin, Inc. (VHB). For purposes of the EA, traffic forecasting to 2035 was completed and traffic operations analyzed to determine impacts to operations.

This Transportation Systems Technical Report is intended to provide a detailed review of existing and planned transportation system elements and the results and conclusions of the existing, base year and forecast year traffic conditions analyses. This will set the basis for documenting, in the EA, the traffic and changes associated with the No-Build and Build Alternatives.



Legend

- Proposed BRT Stations
- Proposed BRT Alignment
- Half-Mile Buffer
- Route 6 Bus Stops
- Route 6 Broad/Main Street

Sources: GRTC (Route and Stops), VGIN RCL (Roads)

Traffic Operations Report

Figure 1: Broad Street Corridor

BROAD STREET RAPID TRANSIT STUDY

1.0 EXISTING CONDITIONS

1.1 EXISTING BUS SERVICE AND RIDERSHIP

Route 6 is the primary route that extends along most of the corridor. The existing services in the corridor generally provide stops every 1-2 blocks, minimizing walk distance for patrons and maximizing accessibility to transit within each route's service area. This service pattern results in slow bus speeds and long travel times for bus riders in the corridor.

Table 1 provides the recent history of transit ridership trends in the corridor. Annual ridership on Route 6 has been declining in recent years, due mostly to two major factors. First, in the fall of 2006, GRTC discontinued its discount ticket program with the effect that the loss of the associated 25¢ per ride discount depressed ridership. Second, the recent economic recession has similarly depressed ridership.

TABLE 1: ROUTE 6 ANNUAL RIDERSHIP FISCAL YEARS 2006-2010

Fiscal Year	Annual Riders on Route 6	Year over Year Percent Change
FY 2005-2006	1,208,947	
FY 2006-2007	1,158,544	-4.2%
FY 2007-2008	1,113,732	-3.9%
FY 2008-2009	1,056,438	-5.1%
FY 2009-2010	1,032,105	-2.3%

Source: GRTC, 2010.

Table Notes: 1. GRTC Fiscal Years are from July 1 to June 30.

Table 2 shows the schedules and actual running times for Route 6 in the AM peak and midday periods along the Broad Street section of the corridor. Overall, the average actual run time is less than the scheduled run time which provides a small cushion in the schedules. Yet, the 85th percentile running time is substantially higher, between 15 and 22 percent higher, than the average indicating that mixed traffic operations introduce considerable variation into typical bus running times. Furthermore, the 85th percentile run time in the AM peak is actually higher than the scheduled run time, indicating that at least 15 percent of AM peak bus runs are unable to keep their scheduled running times.

1.2 EXISTING STREETS AND INTERSECTIONS

The project corridor consists of two major road segments, Broad Street and Main Street, connected by 14th Street downtown and loops along local streets at each end. The corridor has easy freeway access to I-95, I-195 and I-64. I-95 and I-195 are north-south freeways that cross the corridor, connecting Richmond to northern Henrico and Hanover counties, in the north and the south sections of the city, and to Chesterfield County in the south. I-64 roughly parallels Broad Street north of the corridor, connecting downtown Richmond to the eastern and western sections of Henrico County.

TABLE 2: ROUTE 6 (BROAD STREET) ON-TIME PERFORMANCE

Direction	Segment	Scheduled Running Time	Average of Actual Run Time	85th Percentile Actual Running Time
AM Peak				
East	1st & Broad to 14th & Bank	10.82	7.71	8.70
	Robinson & Broad to 1st & Broad	9.86	9.66	10.60
	Willow Lawn & Markel to Robinson & Broad	11.77	11.00	13.80
	Total	***32.44***	***28.37***	***33.10***
West	14th & Bank to Main & 13th	0.75	1.55	2.37
	Main & 13th to 1st & Broad	9.48	9.75	11.16
	1st & Broad to Robinson & Broad	9.52	8.87	10.32
	Robinson & Broad to Willow Lawn & Markel	23.56	16.34	18.31
	Total	***43.31***	***36.52***	***42.16***
Midday				
East	1st & Broad to 14th & Bank	11.00	8.20	9.91
	Robinson & Broad to 1st & Broad	10.00	11.19	13.07
	Willow Lawn & Markel to Robinson & Broad	11.97	12.58	14.69
	Total	32.97	31.98	37.67
West	14th & Bank to Main & 13th	1.00	1.54	2.82
	Main & 13th to 1st & Broad	9.37	10.10	11.87
	1st & Broad to Robinson & Broad	9.96	10.57	12.04
	Robinson & Broad to Willow Lawn & Markel	28.30	16.95	20.97
	Total	***48.63***	***39.16***	***47.70***

Source: GRTC, 2010.

In addition to the Interstates, numerous state and local routes intersect the corridor including: US 33 at Staples Mill Road, and VA 197 at Westwood and Malvern Avenues in the West End; US 1/301 at Belvidere Street in the Virginia Commonwealth University (VCU) District; and, US 360 downtown. For its entire length in the project corridor, Broad Street carries the designation of US 250. At the eastern end of the corridor, the proposed alignment travels along segments of VA 5 and US 60 on Main Street.

Overall, the street network around the corridor is comprised of a standard, east-west oriented grid system structured around a few key arterials and local streets that are sporadically traversed by a network of freeways. The street network is well connected downtown and in the VCU and Museum District areas. The western portions of the corridor retain a grid system, but that system is slightly less connected due to larger industrial uses. In the east end, topography and older industrial uses lead to a breakdown in the typical street grid.

Broad Street (Willow Lawn Drive to 14th Street)

Broad Street is classified as an Urban Principal Arterial through the study area and is a six-lane roadway, divided by a raised median, which is too narrow for dedicated turn lanes except in the section between Willow Lawn Drive and Staples Mill Rd. Left turns from Broad Street are prohibited or limited during peak hours at many intersections. Right turns and permitted left turns operate mostly from shared lanes with the through movement, as only 5 of 44 total signalized intersections in this segment have exclusive turn lanes.

Between 2nd Street and 14th Street, the outside lane in each direction of Broad Street is restricted to buses and turning vehicles only during the AM peak period of 7-9 a.m. and the PM peak period of 4-6 p.m., but the lack of delineation and enforcement result in general traffic for through movements using the lanes. In off-peak periods, these lanes are available for on-street parking. Along the Broad Street corridor, on-street parking is generally available east of I-195 in the Museum/VCU, and downtown areas. Two-hour parking is prevalent throughout the corridor. Pockets of no-parking segments are located around Belvidere Street, and certain downtown buildings, at bus stops and various loading zones.

14th Street (Broad Street to Main Street)

This section of 14th Street is classified as an Urban Principal Arterial and is a four-lane divided roadway. This portion of 14th Street has both exclusive and shared turn lanes at the intersections of Broad Street and Main Street. On-street parking is permitted and utilized on both sides of 14th Street.

Main Street (14th Street to Rocketts Landing)

Between 14th Street and 18th Street, Main Street is classified as an Urban Principal Arterial. Main Street is classified as an Urban Minor Arterial between 18th Street and Williamsburg Avenue. There are 8 signalized intersections along Main Street in the study area, plus one additional pedestrian signal directly in front of Main Street Station, between 15th Street and 17th Street.

Between 14th Street and 20th Street, Main Street is a five-lane undivided roadway, with two lanes eastbound and three lanes westbound. The outside eastbound and westbound lanes serve a dual purpose as both a right turn lane west of 17th Street and two hour on-street parking between the I-95 overpass and 20th Street. Between 15th Street and 17th Street, travel lane widths range from 9 to 10½ feet. Between 20th Street and Williamsburg Avenue, Main Street is a typical four-lane, undivided, roadway with two lanes in each travel direction. On-street parking is generally permitted in off-peak hours but specific restrictions vary by block along this segment. Travel lanes are generally 10 feet and wider in this section of Main Street. East of Williamsburg Avenue, Main Street becomes a two lane, undivided roadway with wide shoulders.

Study Area Intersections

In total, there are 53 signalized intersections along the corridor, with 44 of those along Broad Street. The existing intersection geometry graphics showing intersection lane configurations, prohibited and limited left turns, one-way streets, and bus-only lanes for the study area roadways are provided in Figures 2A through 2D.

1.3 2008 EXISTING TRAFFIC VOLUMES

Historic traffic counts for the study area roadway segments were obtained from the Virginia Department of Transportation (VDOT) traffic count database. Table 3 documents Average Annual Daily Traffic (AADT) volumes from 2008-2012. The majority of the roadway segments have experienced little to no change since 2008. As the economy has slowly recovered in recent years, traffic volumes have held steady or increased somewhat along the corridor. One segment had a decline in traffic from 2008 to 2012, while four segments saw no change over the same period. Three segments saw an increase of 1,000 vehicles per day (vpd) or less. Six segments saw an increase of between 2,000 and 4,000 vpd.

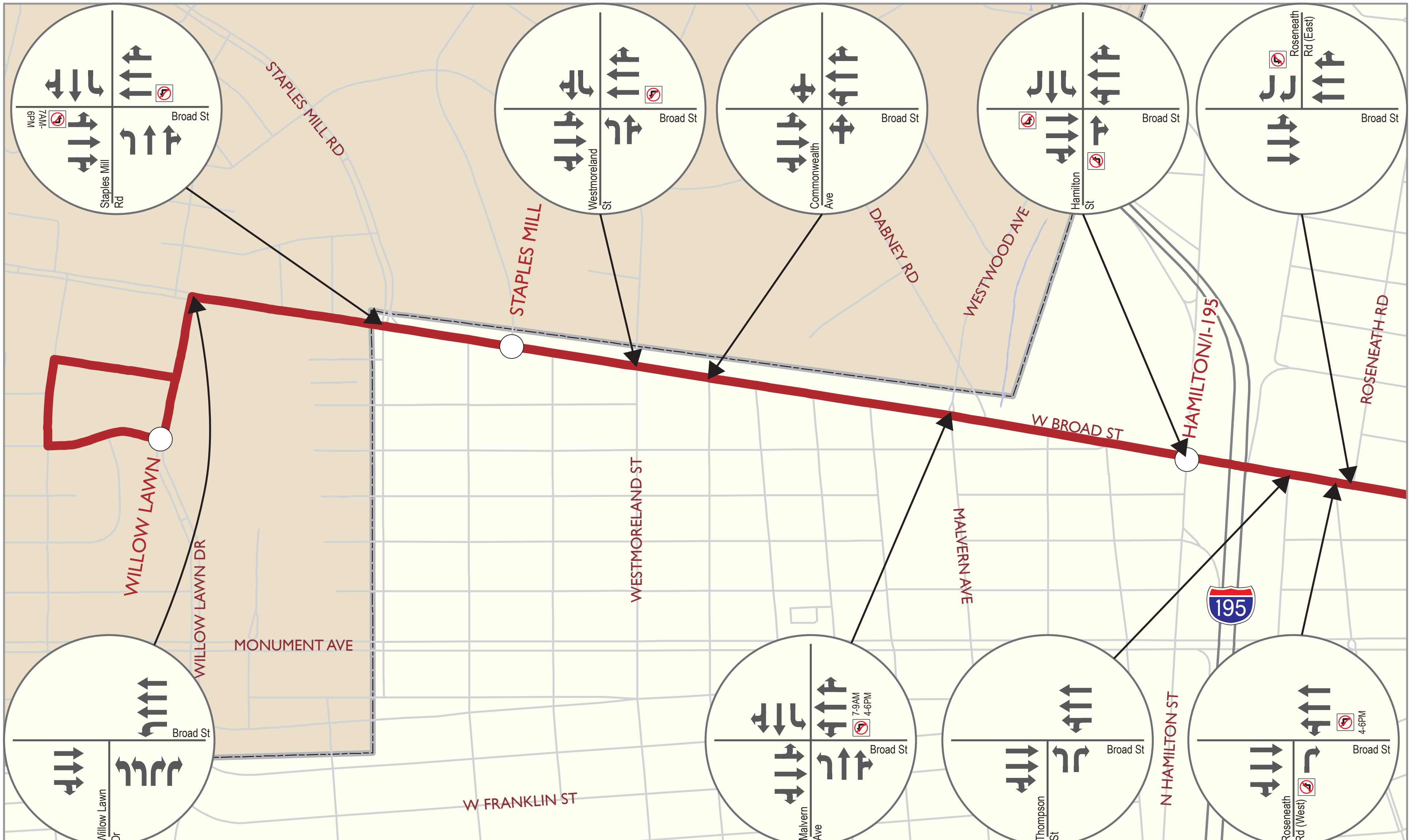
Table 3 shows the trends from 2008 to 2012 for all segments for which data is available from the Virginia Department of Transportation.

TABLE 3: AVERAGE ANNUAL DAILY TRAFFIC (AADT) ESTIMATES

Street	From	To	2008	2009	2010	2011	2012	Change 2008-2012
Broad St	Horsepen Road	Richmond City Line	27,000	27,000	27,000	27,000	27,000	-
Broad St	Richmond City Line	Staples Mill Road	27,000	27,000	28,000	27,000	29,000	2,000
Broad St	Staples Mill Road	Malvern Avenue	25,000	25,000	24,000	24,000	25,000	-
Broad St	Malvern Avenue	Sheppard Street	23,000	23,000	24,000	23,000	23,000	-
Broad St	Sheppard Street	Terminal Place	22,000	22,000	23,000	22,000	24,000	2,000
Broad St	Terminal Place	Harrison Street	20,000	20,000	22,000	20,000	24,000	4,000
Broad St	Harrison Street	Hancock Street	23,000	23,000	24,000	23,000	26,000	3,000
Broad St	Hancock Street	2nd Street	15,000	15,000	14,000	15,000	15,000	-
Broad St	2nd Street	8th Street	14,000	14,000	15,000	15,000	16,000	2,000
Broad St	8th Street	14th Street	17,000	17,000	18,000	17,000	21,000	4,000
Main St	25th Street	Williamsburg Avenue	15,000	15,000	16,000	16,000	16,000	1,000
Main St	Williamsburg Avenue	Nicholson Street	6,500	6,500	6,900	6,800	6,800	300
Main St	Nicholson Street	Richmond City Line	12,000	12,000	11,000	11,000	11,000	-1,000

Source: VDOT Daily Traffic Volume Estimates Special Locality Reports, 2008-2012.

AM and PM peak hour intersection traffic volumes were obtained from the City of Richmond from years 2008-2009. The Broad Street at Willow Lawn Drive and Main Street at Williamsburg Avenue (near the eastern study area boundary) intersections were also counted in the AM and PM peak periods as part of this study. AM and PM peak hour intersection traffic volumes are further discussed and presented in the Section 1.4.



Intersection Geometry

- Right Turn Lane
- Shared Thru/Right
- Thru Lane
- Shared Thru/Left
- Left Turn Lane
- Turn Restrictions
- 7-9AM and 4-6PM: Buses and Turning Vehicles Only; Other Times: Parking Lane

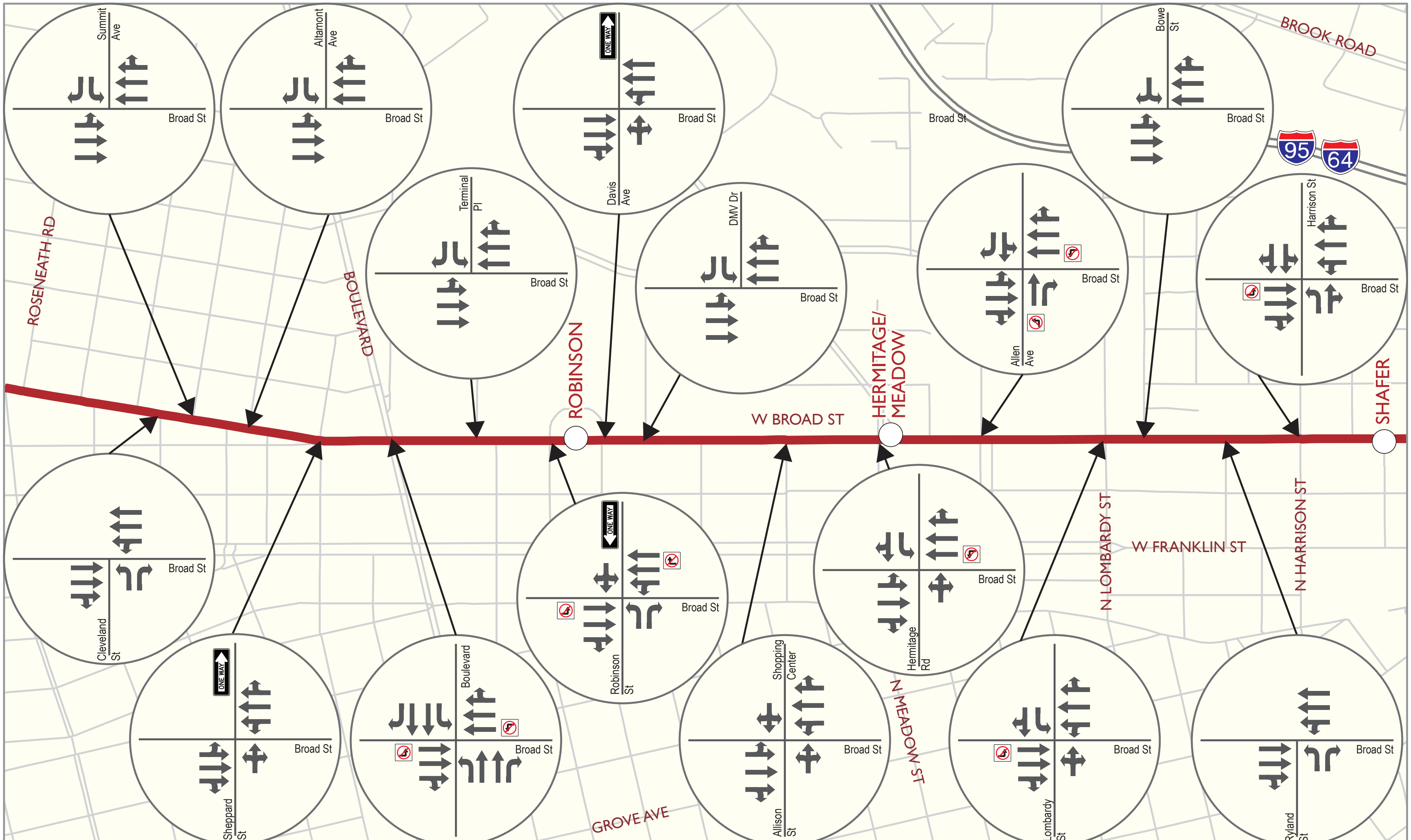
BRT Alignment

- Proposed BRT Stations
- Proposed BRT Alignment

0 0.125 0.25
Miles

Traffic Operations Report
Figure 2A: Existing Intersection Geometry

BROAD STREET RAPID TRANSIT STUDY



Intersection Geometry

- Right Turn Lane
- Shared Thru/Right
- Thru Lane
- Shared Thru/Left
- Left Turn Lane

Turn Restrictions

7-9AM and 4-6PM: Buses and Turning Vehicles Only

Other Times: Parking Lane

BRT Alignment

- Proposed BRT Stations
- Proposed BRT Alignment

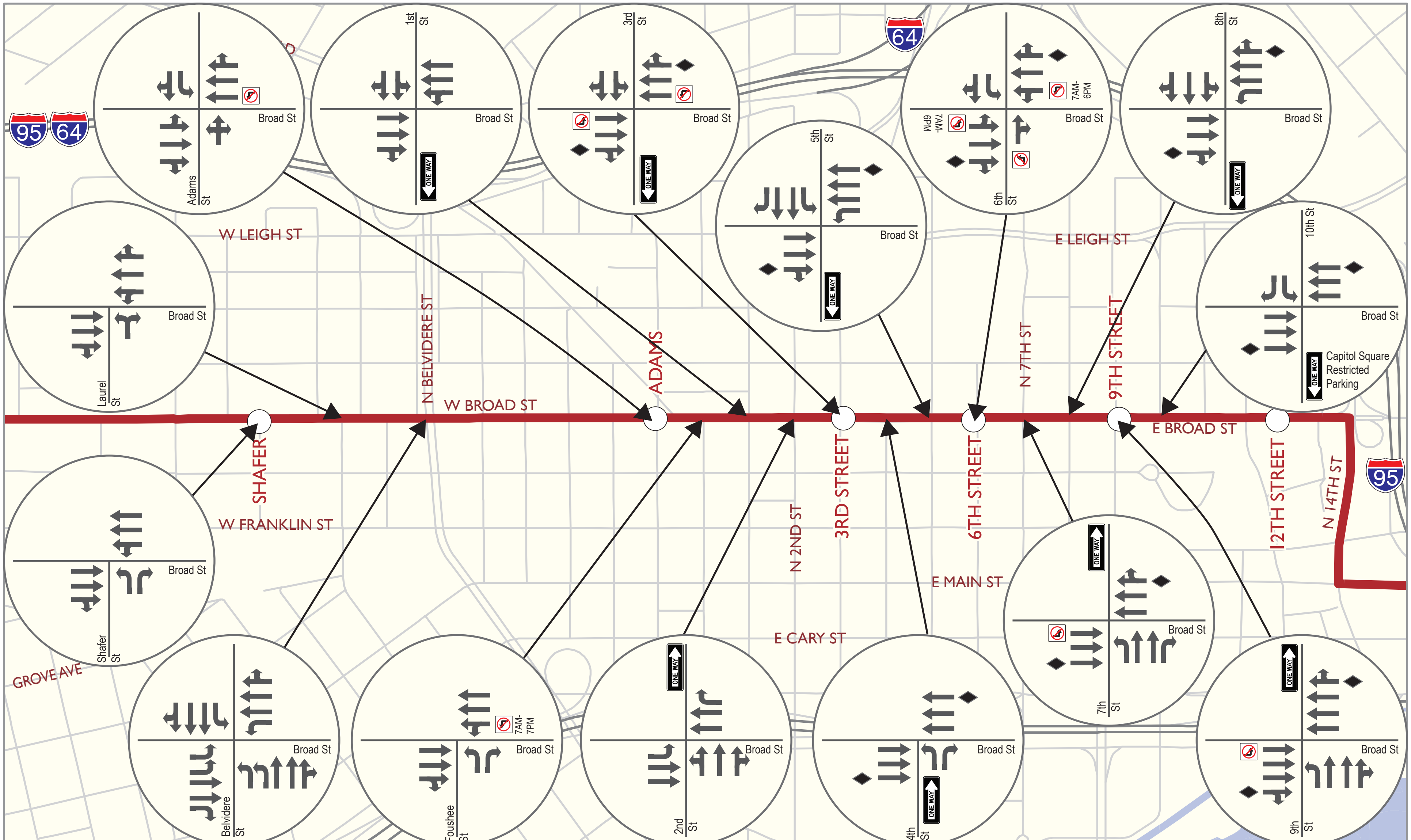
0 0.125 0.25

Miles

Traffic Operations Report

Figure 2B: Existing Intersection Geometry

BROAD STREET RAPID TRANSIT STUDY



Intersection Geometry

- Right Turn Lane
- Shared Thru/Right
- Thru Lane
- Shared Thru/Left
- Left Turn Lane

Turn Restrictions

7-9AM and 4-6PM: Buses and Turning Vehicles Only

Other Times: Parking Lane

BRT Alignment

Proposed BRT Stations

Proposed BRT Alignment

0 0.125 0.25

Miles

Traffic Operations Report

Figure 2C: Existing Intersection Geometry

BROAD STREET RAPID TRANSIT STUDY

Intersection Geometry

- Right Turn Lane
- Shared Thru/Right
- Thru Lane
- Shared Thru/Left
- Left Turn Lane

Turn Restrictions

7-9AM and 4-6PM: Buses and Turning Vehicles Only
Other Times: Parking Lane

BRT Alignment

- Proposed BRT Stations
- Proposed BRT Alignment

0 0.125 0.25
Miles

Traffic Operations Report
Figure 2D: Existing Intersection Geometry

BROAD STREET RAPID TRANSIT STUDY

1.4 2008 EXISTING CONDITIONS CAPACITY ANALYSIS

Capacity analyses were conducted for the existing conditions at 53 intersections along the GRTC study area corridors using Synchro 7.0 software. As mentioned in the previous sections, the AM and PM peak hour existing conditions Synchro models were obtained from the City of Richmond, containing intersection count data from the 2008-2009 period and up-to-date traffic signal timing and phasing information. The Main Street at Williamsburg Avenue intersection was added to the model. The Synchro model was updated to balance intersection volumes, where necessary. Since the Broad Street at Willow Lawn Drive intersection was not within the City, the capacity results from the VISSIM modeling were used.

The key output from the capacity analyses is level of service for each intersection. The Level of Service (LOS) is used by transportation professionals to "grade" intersections by traffic delay, expressed in terms of average stopped delay per vehicle. At signalized intersections, levels of service range from LOS 'A' (indicating average delays of 10 seconds or less) to LOS 'F' (indicating average delays of greater than 80 seconds). LOS 'D' is generally considered as the desirable upper limit of delay for most drivers (55 seconds), while LOS 'E' and 'F' are considered undesirable. It should be noted, however, that longer traffic delays are generally considered more acceptable in traditional downtown business areas. In urban areas, such as this BRT corridor, it is often not cost effective to make necessary enhancements to improve from LOS D.

Intersection delay and LOS results using Highway Capacity Manual methodologies were extracted from the Synchro software analysis and are shown in Table 4. Figures 3A through 3D show the existing intersection volumes and levels of service. Note that GRTC's consultant VHB also analyzed existing conditions along the corridor using VISSIM microsimulation software. Detailed results from the analysis are documented in a separate document *Traffic and Transit Operations Analysis: Proposed GRTC Bus Rapid Transit System*. It is important to note that the methodologies for calculating delay in Synchro and in VISSIM are different. Delay calculations within Synchro models rely on static calculations based on methodologies listed in the Highway Capacity Manual (HCM). Delay calculations within the VISSIM model are calculated directly from the delay experienced by each individual vehicle within the network, which yields variation between the results. Synchro was used for traffic impact analysis because it enables a comparable assessment between existing and future conditions for the Environmental Assessment's traffic, noise, and air quality analyses, whereas the VISSIM analysis was only prepared for existing (2008) and base (2015) years for the analysis of alternatives. Also, the method by which LOS is calculated in Synchro is consistent with City and VDOT planning practices.

A comparison between the Synchro and VISSIM analysis results shows slight differences in level of service for the 2008 Existing Conditions. The majority of the analyzed intersections show no difference in level of service in either the AM or PM peak hours, while some intersections show a one level of service difference between the software outputs, for example showing an LOS A in VISSIM versus an LOS B in Synchro. The results from the intersection of Broad Street and 14th Street in the PM peak hour shows a two level of service difference. Synchro output shows this intersection operating at LOS C, whereas the VISSIM simulation results indicate a LOS A. Actual observed intersection conditions suggest that LOS C is a more realistic estimate of actual delay occurring under the existing traffic volumes.

As shown in the table and figures, the majority of the intersections are currently operating with an overall LOS C or better. Four intersections, identified in the following list, are operating at LOS D in either the AM or PM peak hour.

AM Peak:

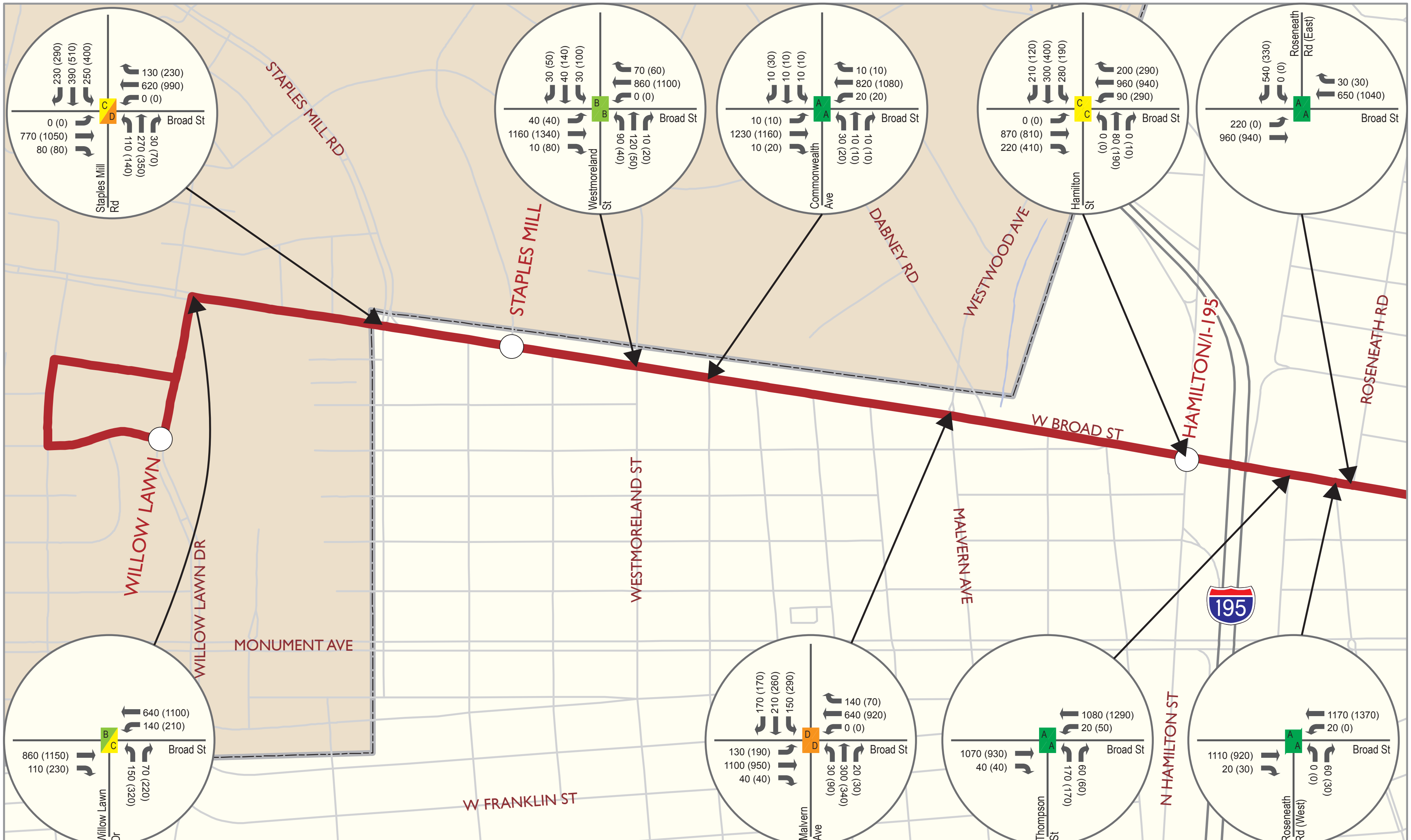
- Broad Street at Malvern Avenue/Westwood Avenue (LOS D)

PM Peak:

- Broad Street at Staples Mill Road (LOS D)
- Broad Street at Malvern Avenue/Westwood Avenue (LOS D)
- Broad Street at Belvidere Street (LOS D)

TABLE 4: 2008 EXISTING CONDITIONS – INTERSECTION ANALYSIS SUMMARY

Intersection Analysis	Existing AM		Existing PM	
	Avg. Int. Delay (sec/veh)	Synchro LOS	Avg. Int. Delay (sec/veh)	Synchro LOS
Broad Street at Willow Lawn Drive	18.1	B	25.3	C
Broad Street at Staples Mill Road	27.5	C	39.9	D
Broad Street at Westmoreland Street	17.7	B	14.9	B
Broad Street at Commonwealth Avenue	3.1	A	3.6	A
Broad Street at Malvern Avenue	43.5	D	44.5	D
Broad Street at Hamilton Street	22.3	C	29.1	C
Broad Street at Thompson Street	9.6	A	8.6	A
Broad Street at Roseneath Road (West)	7.2	A	3.5	A
Broad Street at Roseneath Road (East)	6.6	A	6.7	A
Broad Street at Cleveland Street	1.0	A	1.2	A
Broad Street at Summit Avenue	1.9	A	3.7	A
Broad Street at Altamont Avenue	0.9	A	1.7	A
Broad Street at Sheppard Street	12.8	B	10.6	B
Broad Street at Boulevard	27.6	C	25.9	C
Broad Street at Terminal Place	6.4	A	6.0	A
Broad Street at Robinson Street	5.9	A	5.8	A
Broad Street at Davis Avenue	2.0	A	4.7	A
Broad Street at DMV Drive	11.1	B	7.7	A
Broad Street at Allison Street	2.4	A	3.0	A
Broad Street at Hermitage Road	9.4	A	16.9	B
Broad Street at Allen Avenue	10.3	B	11.0	B
Broad Street at Lombardy Street	16.3	B	27.3	C
Broad Street at Bowe Street	21.0	C	27.5	C
Broad Street at Ryland Street	5.2	A	5.6	A
Broad Street at Harrison Street	6.5	A	7.5	A
Broad Street at Shafer Street	12.5	B	14.3	B
Broad Street at Laurel Street	7.5	A	10.1	B
Broad Street at Belvidere Street	33.0	C	37.8	D
Broad Street at Adams Street	7.5	A	8.3	A
Broad Street at Foushee Street	8.0	A	5.2	A
Broad Street at 1st Street	3.9	A	6.6	A
Broad Street at 2nd Street	7.8	A	17.7	B
Broad Street at 3rd Street	8.3	A	11.8	B
Broad Street at 4th Street	5.9	A	8.6	A
Broad Street at 5th Street	14.4	B	15.7	B
Broad Street at 6th Street	8.1	A	4.0	A
Broad Street at 7th Street	8.8	A	13.2	B
Broad Street at 8th Street	8.1	A	22.6	C
Broad Street at 9th Street	12.4	B	17.0	B
Broad Street at 10th Street	10.1	B	11.7	B
Broad Street at 11th Street	12.4	B	7.7	A
Broad Street at 12th Street	5.3	A	3.5	A
Broad Street at Old 14th Street	5.7	A	13.0	B
Broad Street at 14th Street	10.1	B	26.7	C
Franklin Street at 14th Street	26.9	C	34.3	C
Main Street at 14th Street	12.9	B	18.2	B
Main Street at 15th Street	24.8	C	25.2	C
Main Street at 17th Street	2.7	A	4.7	A
Main Street at 18th Street	17.5	B	21.8	C
Main Street at 19th Street	3.6	A	8.4	A
Main Street at 21st Street	6.9	A	13.3	B
Main Street at 25th Street	17.3	B	22.9	C
Main Street at Williamsburg Avenue	26.2	C	11.8	B



Intersection Volumes and LOS

Right
Thru
Left

(#) AM (PM) Volumes

AM PM Overall Intersection LOS

A B C D E F

BRT Alignment

Proposed BRT Stations

Proposed BRT Alignment

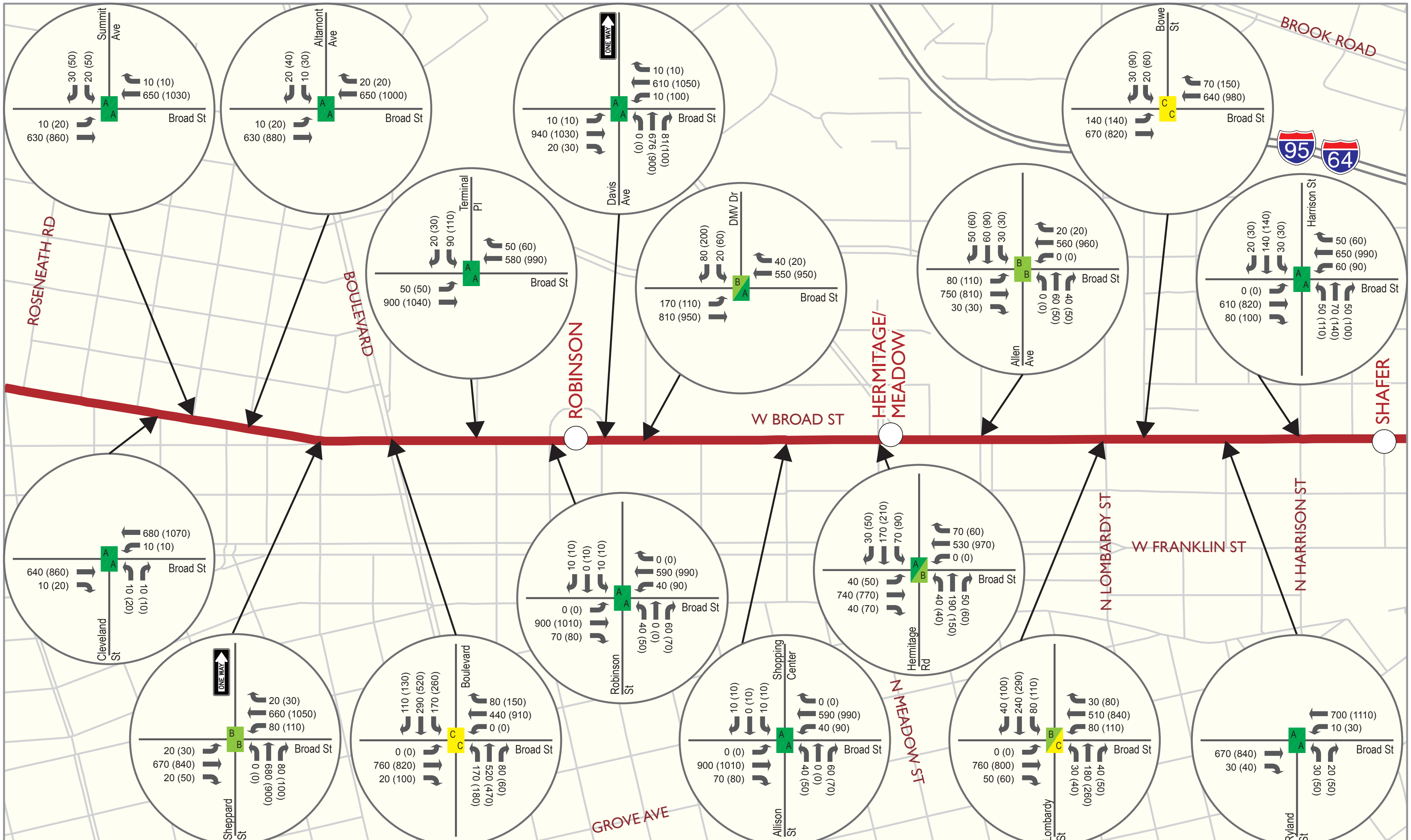
N

0 0.125 0.25
Miles

Traffic Operations Report

Figure 3A: Existing, 2015 No-Build Intersection Volumes and LOS

BROAD STREET RAPID TRANSIT STUDY



Intersection Volumes and LOS

- Right
- Thru
- Left

(#) AM (PM) Volumes

AM PM Overall Intersection LOS

A B C D E F

BRT Alignment

Proposed BRT Stations

Proposed BRT Alignment

N

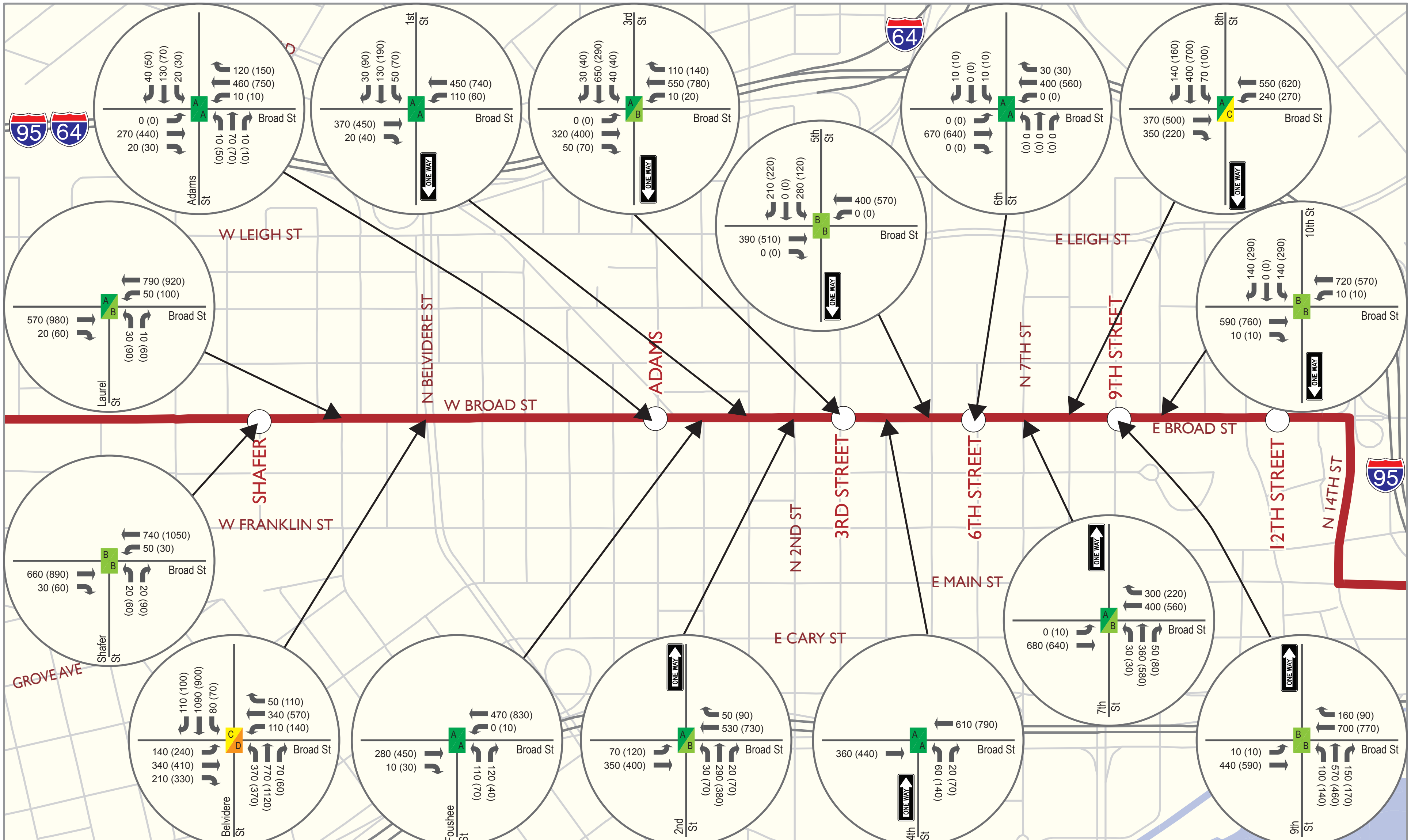
0 0.125 0.25

Miles

Traffic Operations Report

Figure 3B: Existing, 2015 No-Build Intersection Volumes and LOS

BROAD STREET RAPID TRANSIT STUDY



Intersection Volumes and LOS

Right
Thru
Left

(#) AM (PM) Volumes

AM PM Overall Intersection LOS

A B C D E F

BRT Alignment

Proposed BRT Stations

Proposed BRT Alignment

N

0 0.125 0.25
Miles

Traffic Operations Report

Figure 3C: Existing, 2015 No-Build Intersection Volumes and LOS

BROAD STREET RAPID TRANSIT STUDY

Intersection Volumes and LOS

Right
Thru
Left

\# (#) AM (PM) Volumes

AM
PM
Overall Intersection LOS

A B C D E F

BRT Alignment

Proposed BRT Stations

Proposed BRT Alignment

N

0 0.125 0.25
Miles

Traffic Operations Report

Figure 3D: Existing, 2015 No-Build Intersection Volumes and LOS

BROAD STREET RAPID TRANSIT STUDY

1.5 NON-MOTORIZED TRANSPORTATION

While there are pedestrian facilities along the majority of the Broad Street corridor, some sections are more conducive to pedestrian travel than others. In the West End (from Willow Lawn Drive to I-195), Broad Street has sidewalks on both sides of the street, but pedestrian travel is hindered by numerous curb cuts, utility pole obstructions, high traffic volumes and speeds, as well as the narrow width of sidewalks that lack a buffer between the curb and vehicle travel lanes. Further east along the corridor, conditions for pedestrians improve in the Museum/VCU and Downtown Districts (I-195 to Adams Street and Adams to 14th Streets, respectively –the *Land Use and Multimodal Connectivity Report* discusses these districts further) as minimal building setbacks, wider sidewalks, slower traffic speeds and pedestrian signals and crosswalks provide for a more pedestrian friendly streetscape. Adequate pedestrian conditions are also found in the East End of the corridor between Main Street Station and the Main Street at Williamsburg Avenue intersection. East of this intersection, the corridor lacks curb, gutter, sidewalks and/or paths, and there are no pedestrian amenities incorporated into the streetscape.

While there are no bicycle lanes within the corridor, one of the few existing bicycle lanes that exists on City streets is located along Lombardy Street and connects to Broad Street in the VCU district. Parallel to, but south of the corridor, in Shockoe Bottom is the Virginia Capital Trail, which currently runs adjacent to Dock Street from near 14th Street to Great Ship Lock Park at Pear Street. Plans exist for this off-street bicycle and pedestrian trail to be extended to Rocketts Landing and, eventually, to Williamsburg. There are no other on-street bicycle facilities within the corridor, but VCU, government institutions and some shopping centers and offices provide bicycle racks and other bicycle amenities.

1.6 PARKING

Substantial amounts of public and private parking are currently available throughout most of the corridor. In the West End, ample surface lots associated with the suburban pattern of development provide abundant parking along the corridor. While surface parking lots are less prominent in the Museum/VCU, downtown, and Shockoe Bottom areas, parking garages and on-street parking generally provide an adequate parking supply along the corridor. In these areas, two hour on-street parking is provided on weekdays from 9 a.m. to 4 p.m., with the majority of the downtown and VCU sections being metered parking. In downtown Richmond, parking garages and a few surface parking lots exist adjacent to the corridor and provide parking based on hourly or daily parking fees. VCU is a major generator of parking demand and the university provides numerous surface lots and parking garages available through subscription, while certain garages provide daily parking for students, faculty, staff, and visitors for a fee. Two neighborhoods adjacent to the corridor, the Fan and Carver, have residential on-street parking permit programs largely due to their proximity to VCU. These parking permit programs allow for unlimited on-street parking for permit holders in otherwise time-limited parking zones. None of these permit zones, however, includes Broad Street.

1.7 PASSENGER AND FREIGHT RAIL

Passenger and freight rail lines are present within the vicinity of the corridor. Both CSX and Norfolk Southern operate freight rail lines that go through the City of Richmond. The CSX North End Subdivision crosses Broad Street at I-195 as the double tracked line is located in the median of the highway. This line is CSX's main east coast freight line and it connects to the CSX owned Acca Rail Yard, one of its busiest, located north of the corridor near Westwood Avenue. CSX also maintains the

Bellwood Subdivision rail line that roughly parallels I-95 from Acca Yard through Main Street Station to south Richmond. Just north of Main Street Station is the interconnection between the CSX Bellwood, Piedmont and Peninsula Subdivisions. At the east end of the corridor, across from Rocketts Landing, is CSX's Fulton Yard. The Norfolk Southern Richmond District line bisects the city from west to east, crossing the corridor under Main Street, just east of Williamsburg Avenue.

In addition to freight rail, passenger rail service is also provided in the corridor. Amtrak provides passenger rail service at Main Street Station in downtown Richmond as well as at the Staples Mill Station, about two miles north of the western terminus of the corridor, in Henrico County. All Amtrak service in the Richmond area uses CSX owned rail lines. Sixty-eight Amtrak trains serve the Staples Mill station weekly, while 29 of those also serve Main Street Station. Only trains that provide service to or from Newport News serve Main Street Station, while all trains that travel through the Richmond region along Amtrak's Northeast Regional, Palmetto, Carolinian, Silver Meteor and Silver Star routes serve the Staples Mill Station.

2.0 PLANNED IMPROVEMENTS AND TRAFFIC GROWTH

2.1 PLANNED TRANSIT IMPROVEMENTS

While there are no immediate planned transit improvements along the Broad Street corridor within the six year Transportation Improvement Plan (TIP), GRTC plans a number of route changes for its system that will affect service on Broad Street based on recommendations from its 2008 *Comprehensive Operations Analysis* (COA). In addition, substantial intercity rail transportation improvements are planned that affect the corridor. The Southeast High Speed Rail Corridor is planned to extend from Washington, DC to Charlotte, NC via Main Street Station in Richmond. Also, the Virginia Department of Rail and Public Transportation (DRPT) and City of Richmond have plans that, while unfunded, recommend changing the current passenger rail service pattern to add service to Main Street Station.

2.2 PLANNED ROADWAY IMPROVEMENTS

According to the Richmond Area Metropolitan Planning Area (RAMPO) Transportation Improvement Plan (TIP) For Fiscal Years 2009-2012, planned roadway improvements are scheduled along the corridor. Based on the TIP, the Broad Street corridor is scheduled to receive a series of signal modifications and enhanced pavement markings within the VCU and Downtown districts, as well as a series of pedestrian improvements that include landscaping and sidewalk construction with crosswalk and lighting improvements along the East Broad Street corridor. There are no current plans to add additional travel lanes within the corridor.

2.3 FORECAST METHODOLOGY

This section documents the process taken to grow the 2008 Existing Conditions traffic volumes to Future Year 2035 traffic volumes. Year 2035 was chosen as the forecast year because it is at least 20 years out from the 2008 Existing Conditions and the local Metropolitan Planning Organization (MPO) recently developed 2035 socioeconomic data for use in updating the regional travel demand model and the next regional Long Range Transportation Plan. Furthermore, these forecasts have been used as a basis for the Alternatives Analysis (AA) and EA analysis.

2.4 SOCIOECONOMIC DATA FROM TRAVEL DEMAND MODEL

The regional Travel Demand Model (TDM), developed by the Richmond Regional Planning District Commission (RRPDC), was used to assess employment and population characteristics and growth rates at the Traffic Analysis Zone (TAZ) level. Household and employment data for 2008 and 2035 was assessed within a half mile of each proposed GRTC station. For TAZs that partially fall within the half mile radius, socioeconomic statistics were estimated proportionally. In situations where TAZs overlapped, the TAZs were divided equally between station areas. The proportion of the TAZ area within each station area was used to calculate existing 2008 and future 2035 total population and employment within each station area. The results are show in Table 5.

TABLE 5: POPULATION AND EMPLOYMENT STATISTICS

Station Area	Population 2008	Population 2035	Employment 2008	Employment 2035
Willow Lawn	1,927	4,690	3,766	5,646
Staples Mill	1,097	1,605	3,409	4,730
Hamilton/I-195	2,861	3,352	5,133	5,867
Robinson	4,403	4,649	3,819	4,191
Hermitage/Meadow	4,686	4,952	1,993	2,187
Shafer	7,373	7,667	10,370	11,375
Adams	4,703	4,927	4,892	5,365
3rd Street	515	629	3,379	3,709
6th Street	77	674	6,828	7,501
9th Street	433	475	8,746	9,594
12th Street	429	894	15,835	17,372
Main Street Station	1,006	1,710	7,394	8,109
25th Street	3,237	3,753	1,368	1,501
Rocketts Landing	651	884	192	251
Total	33,398	40,861	77,124	87,398

Source: RRPDC, 2012.

2.5 RESULTING GROWTH RATES

Traffic growth rates were based on forecasted population and employment socioeconomic growth trends. Population and employment data were weighted evenly and the total combined growth was used as the anticipated traffic growth. The average annual growth rates for the study area corridors range from 0.5% to 3.0%. The eastern and western termini of the study area are expected to experience higher growth than the rest of the study area. The areas of Staples Mill Road and Rocketts Landing are expected to grow at 1.5% per year, while the Willow Lawn area is expected to grow at 3.0% per year due to growth further west in Henrico County. Between years 2008 and 2035, the majority of the study area is expected to experience low to moderate growth between 0.5 - 0.7% per year (13 – 18%, total). A growth rate of 0.6% (non-compounded) was used in these areas. Table 6 shows the sum of the 2008 and 2035 population and employment totals and the resulting growth rates.

The 2008 existing peak hour traffic volumes at the study area intersections were grown to Year 2035 projected volumes by applying the non-compounded growth rates shown in Table 6.

2.6 TRANSIT AND TRAFFIC INTERACTION

As the approved Travel Demand Model (TDM) developed by the Richmond Regional Planning District Commission (RRPDC) does not currently allow for accurate forecasts of the impacts of transit investments on traffic conditions, it was not possible to provide a quantitative assessment of how transit ridership may be affected by increases in development and traffic volumes in the corridor in 2035 under the No-Build and Build Alternatives. That being said, it is assumed that the operating plans developed under both alternatives would remain in effect in 2035; therefore, the transit network would contribute no additional vehicles to the network in 2035 beyond those already in place in the opening year. Furthermore, as transit alternatives become more attractive to riders as traffic congestion increases, it is reasonable to assume that the limited stop services offered under the Build Alternative would see an increase in ridership in response to future increases in development and land use density in the study area. Such increases in ridership may offset the increase in traffic trips generated by additional development in the study area. It is conceivable that the Build Alternative might reduce traffic impacts even further because the MPO land use forecasts indicate an improved jobs-housing balance and increased land use densities in the corridor (see the *Land Use and Multimodal Accessibility Report*, Appendix A-10, for additional details).

TABLE 6: 2008 EXISTING AND 2035 RESULTING GROWTH RATES

Station	2008 Population + Employment	2035 Population + Employment	Calculated Growth Rate	Applied Growth Rate
Willow Lawn	5,693	10,336	3.0%	3.0%
Staples Mill	4,506	6,335	1.5%	1.5%
Hamilton	7,994	9,219	0.6%	0.6%
Robinson	8,222	8,840	0.3%	
Hermitage	6,679	7,139	0.3%	
Shafer	17,743	19,042	0.3%	
Adams	9,595	10,292	0.3%	
3rd	3,894	4,338	0.4%	
6th	6,905	8,175	0.7%	
9th	9,179	10,069	0.4%	
12th	16,264	18,266	0.5%	
Main Street	8,400	9,819	0.6%	
25th	4,605	5,254	0.5%	
Rocketts	843	1,135	1.3%	1.5%
Total	110,522	128,259	0.6%	-

The 2008 peak hour traffic volumes at the study area intersections were grown to Year 2035 projected volumes by applying the above non-compounded growth rates. Table 7 shows the 2008 and 2035 average annual daily traffic (AADT) for the corridor. The 2035 forecast turning movement volumes at the intersections are shown in Figures 6A through 6D in Section 3.7.

TABLE 7: FORECAST AVERAGE ANNUAL DAILY TRAFFIC (AADT) ESTIMATES

Road Name	From	To	2008 Existing AADT	Average Annual Growth Rate	2035 No-Build Forecast AADT
Broad St	Horsepen Rd	Richmond City Line	27,000	3.0%	48,900
Broad St	Richmond City Line	Staples Mill Rd	27,000	1.5%	37,900
Broad St	Staples Mill Rd	Malvern Ave	25,000	1.5%	35,100
Broad St	Malvern Ave	Sheppard St	23,000	0.6%	26,700
Broad St	Sheppard St	Terminal Place	22,000	0.6%	25,600
Broad St	Terminal Place	Harrison St	20,000	0.6%	23,200
Broad St	Harrison St	Hancock St	23,000	0.6%	26,700
Broad St	Hancock St	2nd St	15,000	0.6%	17,400
Broad St	2nd St	8th St	14,000	0.6%	16,300
Broad St	8th St	14th St	17,000	0.6%	19,800
Main St	25th St	Williamsburg Ave	15,000	0.6%	17,400
Main St	Williamsburg Ave	Nicholson St	6,500	1.5%	9,100
Main St	Nicholson St	Richmond City Line	12,000	1.5%	16,900

Source: VDOT Traffic Engineering Division 2008 AADT Volume Estimates Report (Existing AADT)

3.0 TRANSPORTATION EFFECTS

This section documents the forecast year conditions for the transportation system. The alternatives include the No-Build Alternative and the Build Alternative. Descriptions of the alternatives, transit service and ridership, roadway lane configuration changes associated with the alternatives, and resulting intersection capacity analysis for 2035 conditions are discussed. Capacity analysis results of the alternatives are presented in this section with problem intersections identified and discussed. Impacts are reviewed and potential mitigation measures are recommended.

3.1 NO-BUILD ALTERNATIVE OVERVIEW

The No-Build Alternative is required by the National Environmental Policy Act (NEPA) to provide a basis of comparison for the Build Alternative, defining what would happen in the study area in the absence of specific facility and operational improvements to the transit system as defined by the other project alternatives. The No-Build Alternative includes all existing and committed transportation facilities and services operational in the base year (2015) and 2035. There are no differences between the 2015 and 2035 No-Build scenarios concerning signal timing or geometric improvements. The No-Build Alternative is described in detail in the *Detailed Screening of Alternatives* report (Appendix A-7).

Additionally, the City of Richmond has an ongoing Signal Timing Optimization Program being implemented as part of its Congestion Mitigation and Air Quality (CMAQ) Improvement Program. The City currently has plans for a system upgrade to be implemented by the opening year. While the proposed system upgrade does not explicitly provide for transit signal prioritization, such an improvement would not be precluded from inclusion in the system. For the purposes of the No-Build Alternative, it is assumed the signal upgrade would be completed by the opening year and would not include signal prioritization for transit vehicles.

In November 2011, GRTC completed its Transit Development Plan (TDP) in an effort to identify modifications and improvements that would increase system efficiency, better serve existing riders, and encourage transit usage in choice ridership markets. The TDP included goals and objectives for the transit system as well as a service and system evaluation. Several route modifications were recommended. However, consultation with GRTC indicated that these modifications are not expected to occur in the near future and therefore these modifications have not been incorporated in the No-Build assumptions. The No-Build assumes that the system in 2015 will operate as it does today.

As discussed earlier, the majority of the roadway segments have experienced stable or small increases in traffic volumes since 2008; therefore, it was assumed there would be no growth in traffic between 2008 and 2015 along the Broad Street Corridor. Since volumes and roadway geometry are not changing from existing conditions, the capacity analysis at the intersections and roadway links for the No-Build Alternative in 2015 would produce the same results as those shown in earlier sections. As a result, section 3.1 does not review the 2015 No-Build lane configurations, volumes and capacity.

3.2 BUILD ALTERNATIVE OVERVIEW

The Build Alternative represents the highest level of capital investment being considered to meet the goals and objectives of this study. The Build Alternative would include a guideway (dedicated bus lanes) for portions of the seven-mile route between Willow Lawn and Rocketts Landing. From Willow Lawn to Thompson Street, the Build Alternative would operate in mixed traffic. From Thompson Street to Adams Street the Build Alternative would use a center running dedicated guideway. Between 4th Street and North Adams Street, the center guideway would open to traffic as buses transition to the curb where they would travel in mixed traffic until the 3rd Street Station. From 4th Street to 14th Streets the Build Alternative would use the existing dedicated curb lane but that lane would be widened.

These bus lanes would replace the existing bus lanes between 4th Street and 14th Street, and would differ from the existing bus lanes in the following respects:

- **Median bus lanes between Thompson Street and Adams Street.** This approach (a) allows vehicles to take advantage of signal progression without interference from local bus routes; and, (b) contributes a more substantial physical presence to the system.
- **Hours of operation.** The dedicated bus lanes would be reserved for transit operations 24 hours a day, as opposed to during peak hours.
- **Lane width.** The proposed lanes would be wider than the existing bus lanes (from 9 ft. to 11 ft.), minimizing conflicts between BRT operations and adjacent general traffic.
- **Operational restrictions.** Usage of the dedicated bus lanes would be limited to BRT vehicles between Thompson Street and Adams Street. The exception to this would be where left turns must cross over the bus lanes—at these points, signal and signage improvements would be necessary to define the interface between BRT and general traffic operations.

In addition to the new dedicated lane, up to 14 new BRT stations (sheltered bus stops) would be installed. Typical stations would consist of one-story, glass-enclosed shelters with metal frames, each approximately 10 to 20 feet wide. Existing stations would be removed and replaced, as necessary, and stations would be clustered as much as possible to minimize visual intrusions on the streetscape. Low-light signage would be installed on the stations denoting route information.

Where the Build Alternative stops are located curbside, two approaches would be used. Outside the Central Business District (CBD), local buses would simply share the new distinctive stations and loading areas with BRT. The branding of vehicles would help customers distinguish between local and BRT services. Within the CBD (between 4th Street and 14th Street), the Build Alternative would include a consolidated set of multi-platform stations where BRT and local bus loading areas would be adjacent but physically separate with signage and wayfinding markers allowing passengers to differentiate between services. To increase system speed and efficiency, all buses (local and BRT) would only make stops at the proposed multiple platform station locations. Local buses would be allowed to let passengers board and alight at any of the local platforms at these stations.

In order to encourage use of the BRT system as an alternative to driving into downtown Richmond, park-and-ride facilities were considered in developing the Build Alternative. Based on availability of land, likelihood of capturing riders and the cost to develop stand-alone lots, park-and-ride facilities are only being considered at the Staples Mill Station.

Pedestrian and bicycle connectivity to the stations from adjoining land uses would be considered as part of station area design. Improvements to be considered would include (but would not be limited to): pedestrian and bicycle crossings, bicycle storage, pedestrian-level streetlights, and pedestrian and/or bicycle-actuated signals.

The BRT service provided by the Build Alternative would operating every 10 minutes during peak hours of operation (7:00 to 9:30 AM and from 4:00 to 6:00 PM) and every 15 minutes during off-peak hours (early morning, afternoon, and evening.) It would operate during the same hours as modified Routes 6 and 53, from 5:30 AM to 11:30 PM on weekdays and from 6:00 AM to 11:30 PM on weekends.

Under the Build Alternative only Go Cards would be accepted for the BRT service. Additionally, local buses would only accept Go Cards as payment when using stations along the dedicated right-of-way. Such a policy should improve the flow of passengers and the user benefits across all routes using the Broad Street bus lanes.

The Build Alternative would use a dedicated set of low-floor vehicles to serve the BRT route. BRT vehicles would use markings (paint scheme, logo, and other visual improvements) to differentiate them from local bus routes.

The Build Alternative assumes the traffic signal system for the corridor will allow for signal priority for BRT operations at all signalized intersections present along dedicated bus lanes. For the Build Alternative, these operational improvements would be made for the entire length of Broad Street from Thompson Street to 14th Street. These modifications offer the potential to improve transit travel speeds and schedule reliability while minimizing potential conflicts with general traffic turns onto and off of Broad Street.

Detailed information on the Build Alternative is contained in the *Detailed Screening of Alternatives* report (Appendix A-7).

3.3 2015 BUILD ALTERNATIVE TRAFFIC CONDITIONS

2015 Build Alternative Lane Configurations

The Base Year (2015) Build Alternative represents a future year 2015 condition that assumes that the transit service along Broad Street would use median-running dedicated bus lanes between Thompson Street and Adams Street. Providing these dedicated bus lanes would require using one of the three general purpose thru-lanes in each direction along Broad Street. This would result in reducing the passenger vehicle capacity of Broad Street. It was assumed passenger vehicle left turns from Broad Street, where permitted, would be made from the center median dedicated bus lanes. The only exception is at Belvidere where left turns are made from exclusive left turn lanes adjacent to the median bus lanes. Figures 4A through 4D show the base year build condition lane configurations. It should be noted that the intersection lane configurations of intersections without median-running dedicated bus lanes do not change from existing conditions.

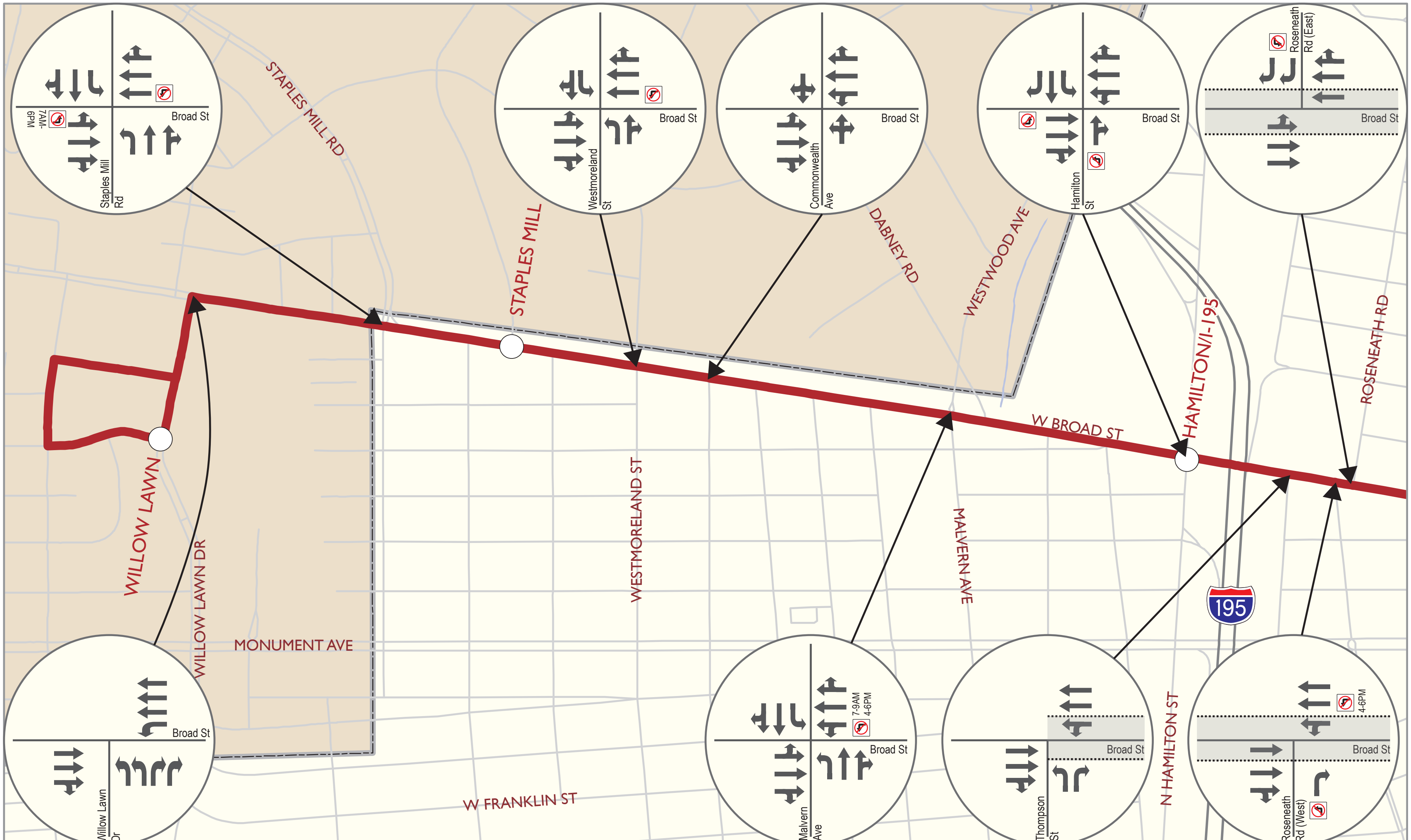
2015 Build Alternative Volumes

The changes proposed under the Build Alternative do not change the non-bus traffic volumes used under the No-Build Alternative. Therefore, the traffic volumes used in the Synchro capacity analysis at the intersections and roadway links for the Build Alternative in 2015 are the same as those used in the No-Build Alternative.

2015 Build Alternative Capacity Analysis

Capacity analyses were again conducted for the study area intersections. The 2015 traffic volumes, discussed in the previous section, were analyzed with the Build Alternative in place between Thompson Street and Adams Street. Analysis was performed using Synchro, with delay and LOS being determined using Highway Capacity Methodology. Traffic signal timings, phasing, and offsets for the intersections between Thompson Street and Adams Street were optimized using VISSIM and exported to Synchro for the analysis.

Table 9 shows the 2015 Base Year conditions results between Thompson Street and Adams Street. The intersections outside of this segment are expected to operate as they do in the 2008 Existing Conditions scenario and 2015 No-Build Scenario. Intersection traffic volumes and resulting LOS are shown in Figures 5A through Figure 5D.



Intersection Geometry

- Right Turn Lane
- Shared Thru/Right
- Thru Lane
- Shared Thru/Left
- Left Turn Lane
- BRT Bus Lane
- Turn Restrictions
- Lane Restricted to Buses and Turning Vehicles Only

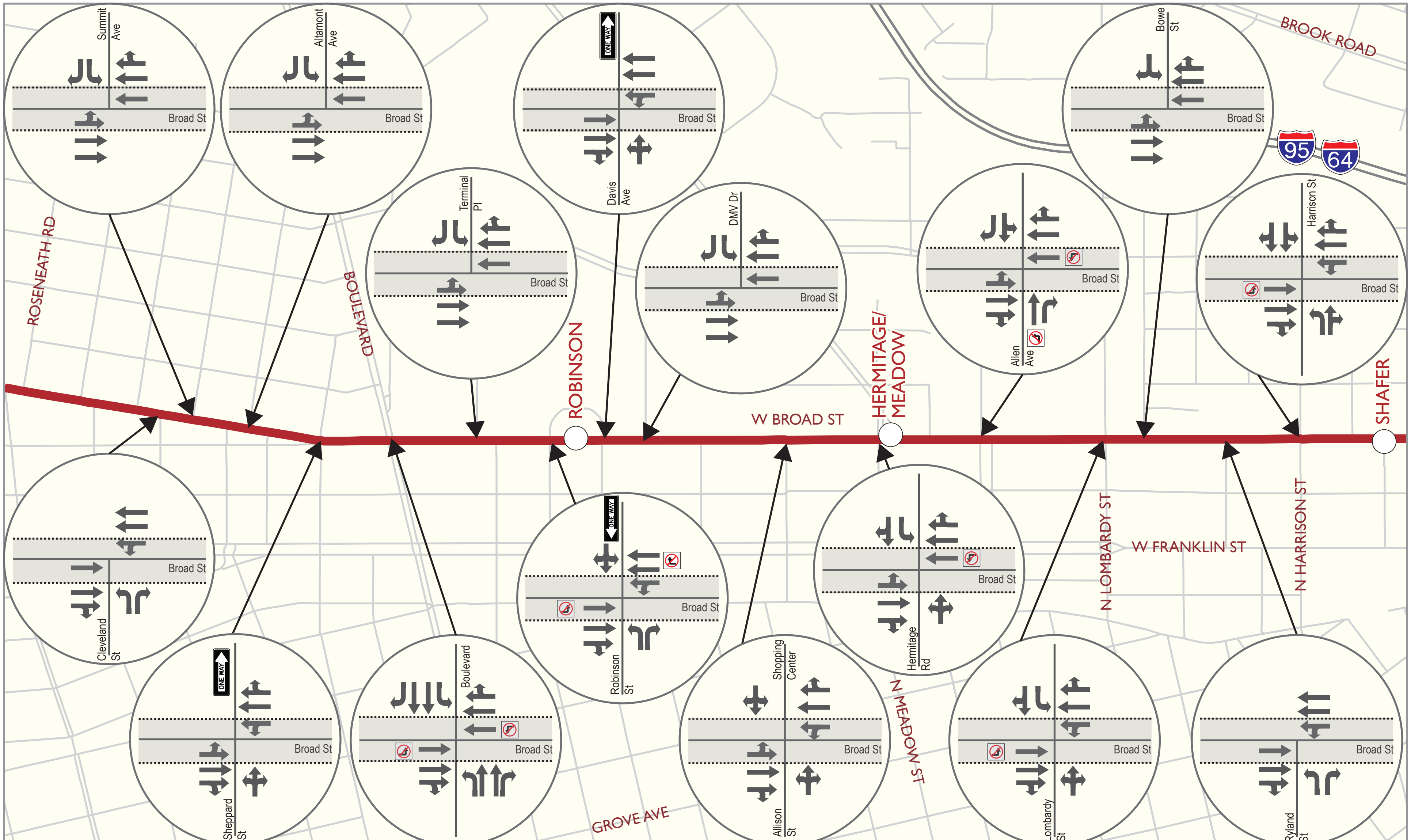
BRT Alignment

- Proposed BRT Stations
- Proposed BRT Alignment

0 0.125 0.25
Miles

Traffic Operations Report
Figure 4A: 2015 Base Year Build Alternative Intersection Geometry

BROAD STREET RAPID TRANSIT STUDY



Intersection Geometry

- Right Turn Lane
- Shared Thru/Right
- Thru Lane
- Shared Thru/Left
- Left Turn Lane
- BRT Bus Lane
- Turn Restrictions
- Lane Restricted to Buses and Turning Vehicles Only

BRT Alignment

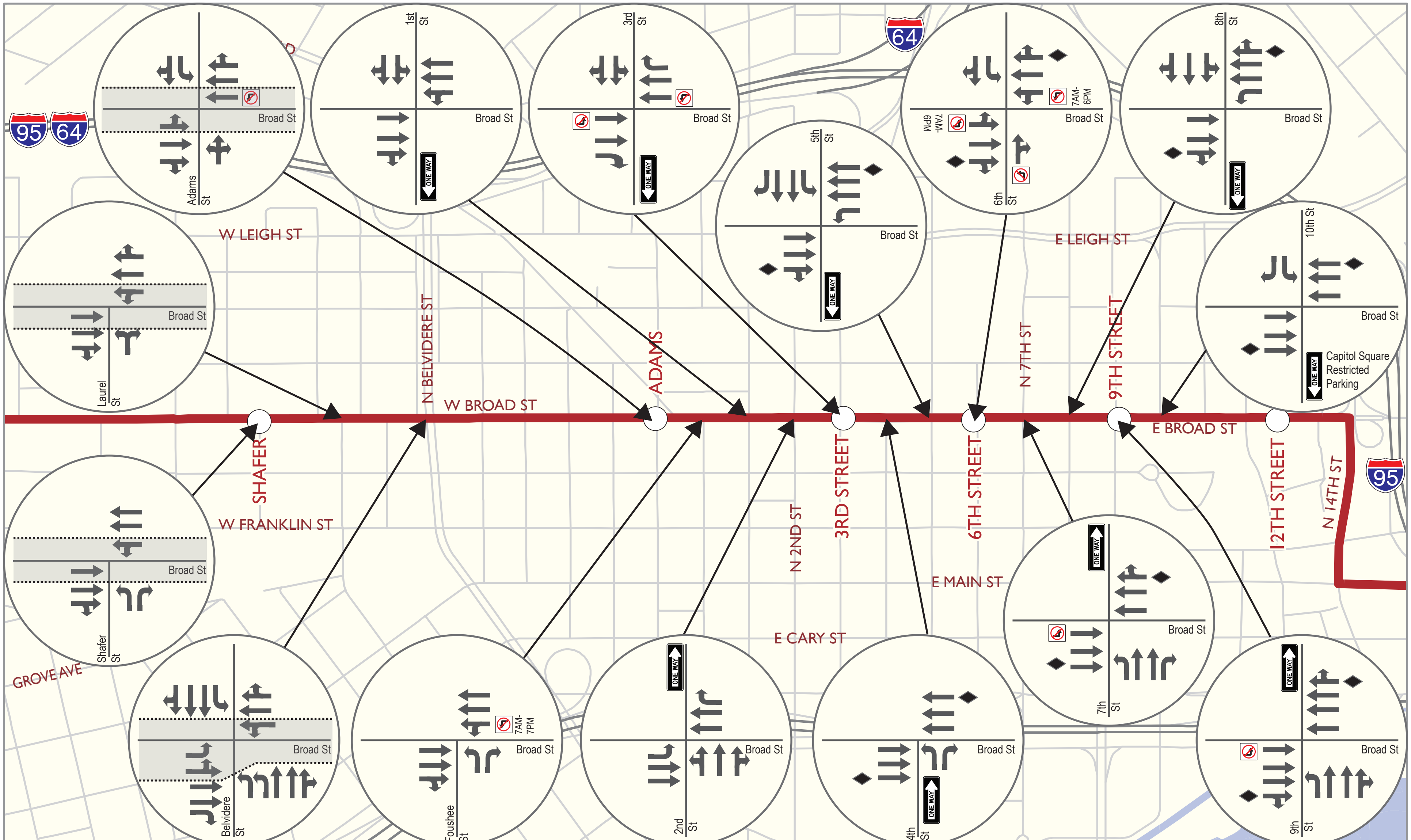
- Proposed BRT Stations
- Proposed BRT Alignment

0 0.125 0.25
Miles

N

Traffic Operations Report
Figure 4B: 2015 Base Year Build Alternative Intersection Geometry

BROAD STREET RAPID TRANSIT STUDY



Intersection Geometry

- Right Turn Lane
- Shared Thru/Right
- Thru Lane
- Shared Thru/Left
- Left Turn Lane
- BRT Bus Lane
- Turn Restrictions
- Lane Restricted to Buses and Turning Vehicles Only

BRT Alignment

- Proposed BRT Stations
- Proposed BRT Alignment

0 0.125 0.25
Miles

Traffic Operations Report
Figure 4C: 2015 Base Year Build Alternative Intersection Geometry

BROAD STREET RAPID TRANSIT STUDY

Intersection Geometry

- Right Turn Lane
- Shared Thru/Right
- Thru Lane
- Shared Thru/Left
- Left Turn Lane
- BRT Bus Lane
- Turn Restrictions
- Lane Restricted to Buses and Turning Vehicles Only

BRT Alignment

- Proposed BRT Stations
- Proposed BRT Alignment

N

0 0.125 0.25
Miles

Traffic Operations Report
Figure 4D: 2015 Base Year Build Alternative Intersection Geometry

BROAD STREET RAPID TRANSIT STUDY

A comparison between the Synchro and VISSIM analysis results showed moderate differences in level of service for the 2015 Base Year Build Alternative Conditions. Twenty-three of the 53 analyzed intersections show no difference in level of service in either the AM or PM peak hours, while the majority of the intersections show a one or two level of service difference between the software outputs. For example, VISSIM shows a LOS A, while Synchro shows a LOS B. During the PM peak hour, the intersection of Broad Street and 14th Street again shows a two level of service difference, operating at LOS C in Synchro and LOS A in VISSIM. Actual observed intersection conditions suggest that LOS C is a more realistic estimate of delay under the 2015 Build Alternative traffic conditions. The intersection of Broad Street at Bowe Street also shows a two level of service difference between the software results. Synchro shows a projected LOS D, whereas the VISSIM simulation output shows LOS B. This intersection is the only intersection where one software output shows an LOS of D or worse and the other shows LOS C or better, and in this instance the Synchro output shows the worst LOS. In general, the use of the Synchro output provides a more conservative estimate of future traffic conditions and related impacts in the corridor. At the same time, both models confirm travel conditions in the corridor are anticipated to be largely acceptable (LOS D or better) in the base year (2015) under the Build Alternative.

The majority of the intersections between Thompson Street and Adams Street are still expected to operate at LOS C or better in the AM and PM peak hours of the Build scenario. Due to the reduced capacity of Broad Street, some intersections are expected to worsen to LOS D. The intersections along the corridor expected to operate with LOS D during the AM or PM peak hours are shown below. Intersections in bold text are intersections expected to deteriorate in operating conditions under the Build Alternative compared to the No-Build Alternative.

AM Peak:

- Broad Street at Malvern Avenue/Westwood Avenue (LOS D)

PM Peak:

- Broad Street at Staples Mill Road (LOS D)
- Broad Street at Malvern Avenue/Westwood Avenue (LOS D)
- **Broad Street at Boulevard (LOS D)**
- **Broad Street at Bowe Street (LOS D)**
- Broad Street at Belvidere Street (LOS D)

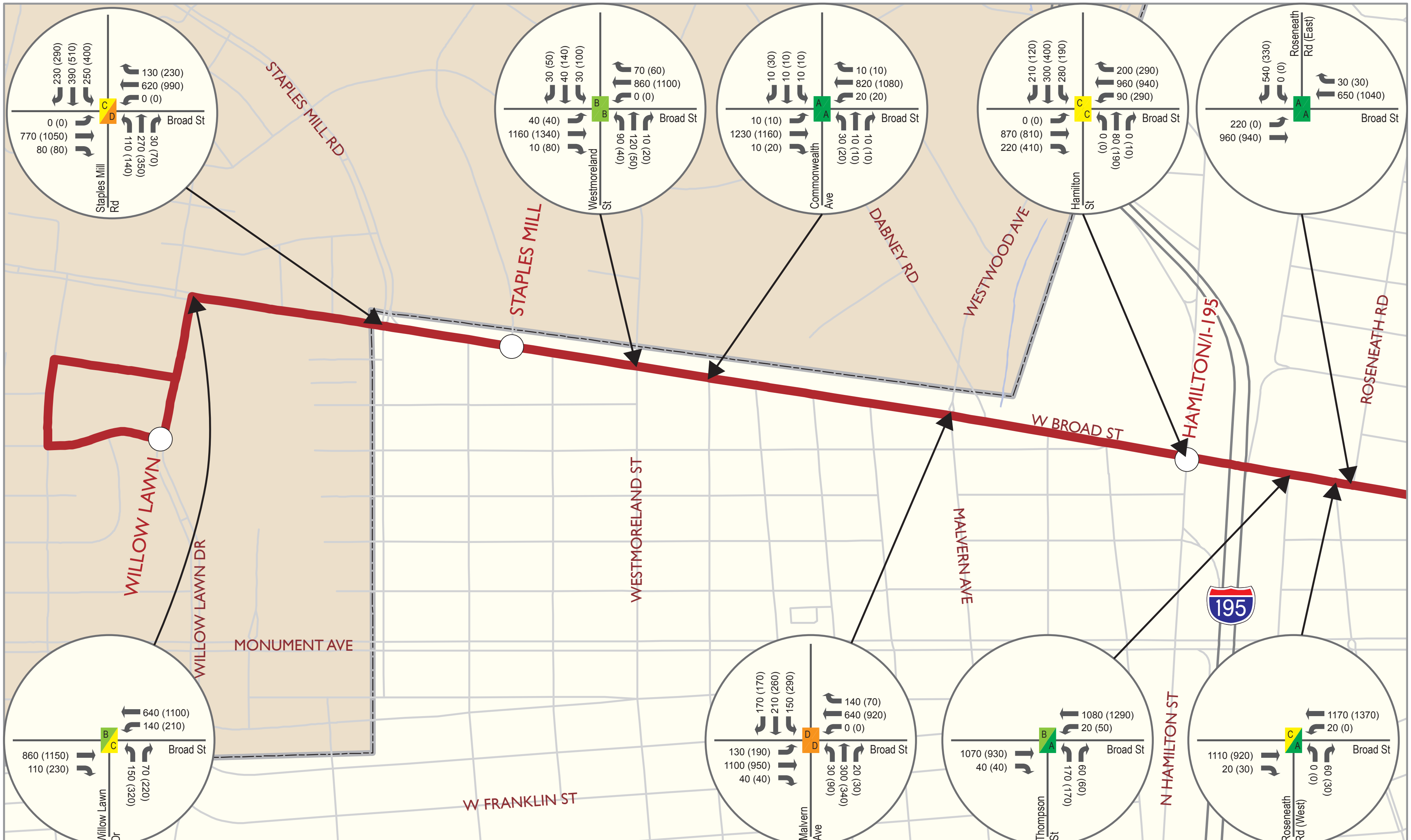
A total of two intersections that operate acceptably under the No-Build Alternatives are expected to have a LOS D or worse under the Build Alternative in 2015; therefore, very little to no traffic is expected to divert from the Broad Street Corridor to parallel facilities. Possible mitigation measures for these two intersections are discussed in Section 6.0. The highest cross-street volumes in the corridor occur at Broad Street and Belvidere Street. The analysis shows an acceptable LOS on the basis of assuming the BRT lanes can be combined with left turn lanes. The feasibility of this configuration will be determined during Preliminary Engineering.

VHB modeled the Build Alternative in VISSIM to get travel times for the various bus services along Broad Street. The results are documented in the report *Traffic and Transit Operations Analysis:*

Proposed GRTC Bus Rapid Transit System and shown in Table 12, in Section 3.6. Travel times for the BRT under the Build Alternative were significantly quicker than for the local bus service under the No-Build Alternative. Reductions of 7 to 16 minutes in the AM peak hour and 11 to 20 minutes in the PM peak hour are expected.

TABLE 9: 2015 BASE YEAR BUILD ALTERNATIVE CONDITIONS – INTERSECTION ANALYSIS SUMMARY

Intersection	Existing (2008) Year No-Build AM		Existing (2008) Year No-Build PM		2015 Base Year Build Alternative AM Peak Hour		2015 Base Year Build Alternative PM Peak Hour	
	Avg. Int. Delay (sec/veh)	Synchro LOS	Avg. Int. Delay (sec/veh)	Synchro LOS	Avg. Int. Delay (sec/veh)	Synchro LOS	Avg. Int. Delay (sec/veh)	Synchro LOS
Broad Street at Thompson Street	9.6	A	8.6	A	10.8	B	8.8	A
Broad Street at Roseneath Road (W)	7.2	A	3.5	A	12.0	B	4.3	A
Broad Street at Roseneath Road (East)	6.6	A	6.7	A	7.6	A	7.8	A
Broad Street at Cleveland Street	1.0	A	1.2	A	6.3	A	2.8	A
Broad Street at Summit Avenue	1.9	A	3.7	A	7.1	A	7.1	A
Broad Street at Altamont Avenue	0.9	A	1.7	A	3.9	A	2.1	A
Broad Street at Sheppard Street	12.8	B	10.6	B	17.2	B	13.6	B
Broad Street at Boulevard	27.6	C	25.9	C	27.7	C	37.3	D
Broad Street at Terminal Place	6.4	A	6.0	A	7.7	A	12.0	B
Broad Street at Robinson Street	5.9	A	5.8	A	5.9	A	7.4	A
Broad Street at Davis Avenue	2.0	A	4.7	A	11.8	B	13.0	B
Broad Street at DMV Drive	11.1	B	7.7	A	12.6	B	12.1	A
Broad Street at Allison Street	2.4	A	3.0	A	13.0	B	4.9	A
Broad Street at Hermitage Road	9.4	A	16.9	B	10.0	B	18.9	B
Broad Street at Allen Avenue	10.3	B	11.0	B	13.1	B	16.6	B
Broad Street at Lombardy Street	16.3	B	27.3	C	18.0	B	29.6	C
Broad Street at Bowe Street	21.0	C	27.5	C	23.3	C	41.6	D
Broad Street at Ryland Street	5.2	A	5.6	A	14.3	B	7.5	A
Broad Street at Harrison Street	6.5	A	7.5	A	16.9	B	14.9	B
Broad Street at Shafer Street	12.5	B	14.3	B	11.4	B	16.6	B
Broad Street at Laurel Street	7.5	A	10.1	B	25.0	C	15.0	B
Broad Street at Belvidere Street	33.0	C	37.8	D	33.5	C	40.5	D
Broad Street at Adams Street	7.5	A	8.3	A	8.2	A	9.3	A



Intersection Volumes and LOS

- Right
- Thru
- Left

(#) AM (PM) Volumes

AM / PM — Overall Intersection LOS (A B C D E F)

BRT Alignment

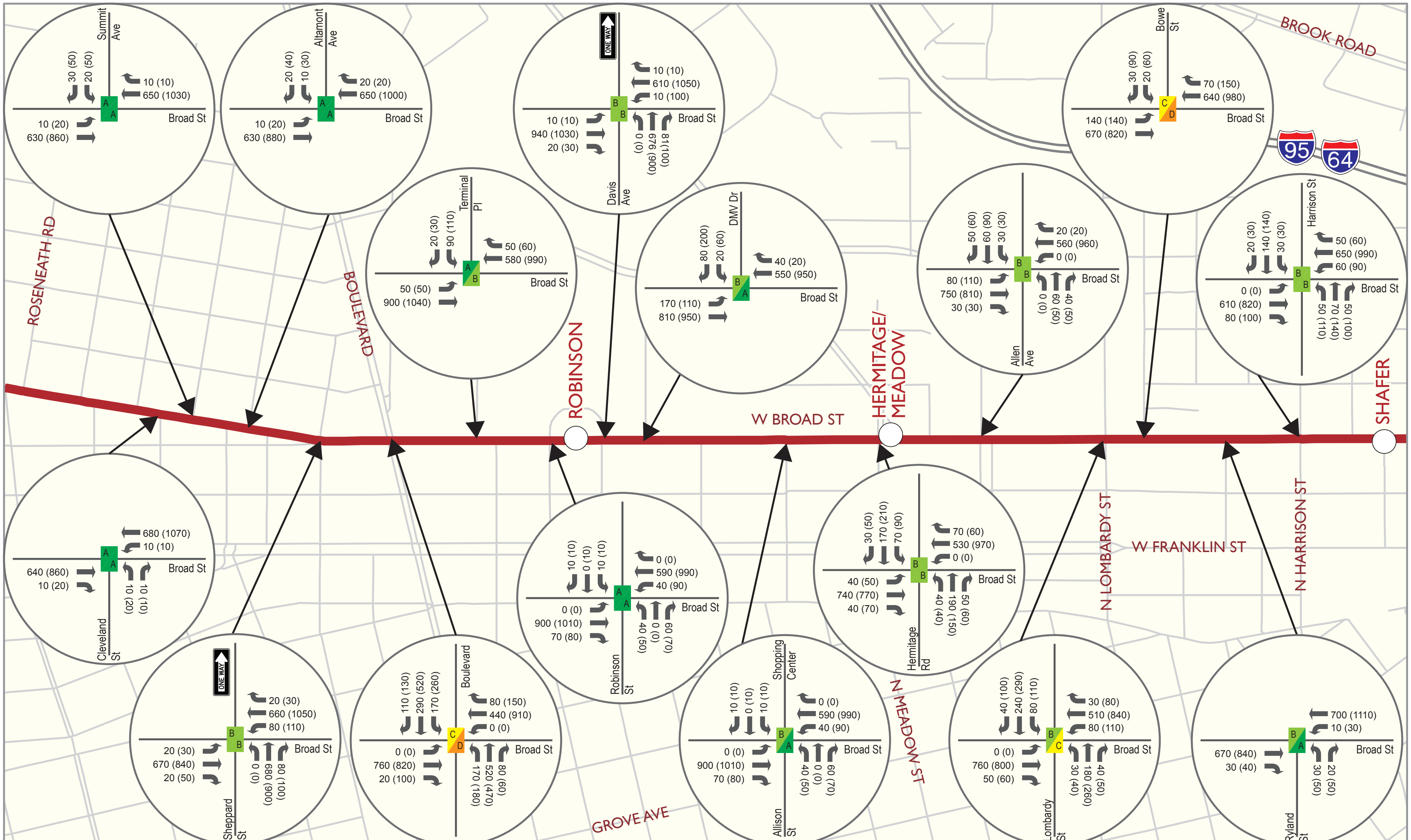
- Proposed BRT Stations
- Proposed BRT Alignment

N

0 — 0.125 — 0.25 Miles

Traffic Operations Report
Figure 5A: 2015 Build Alternative Intersection Volumes and Levels of Service

BROAD STREET RAPID TRANSIT STUDY



Intersection Volumes and LOS

- Right
- Thru
- Left

(#) AM (PM) Volumes

AM PM Overall Intersection LOS

A B C D E F

BRT Alignment

Proposed BRT Stations

Proposed BRT Alignment

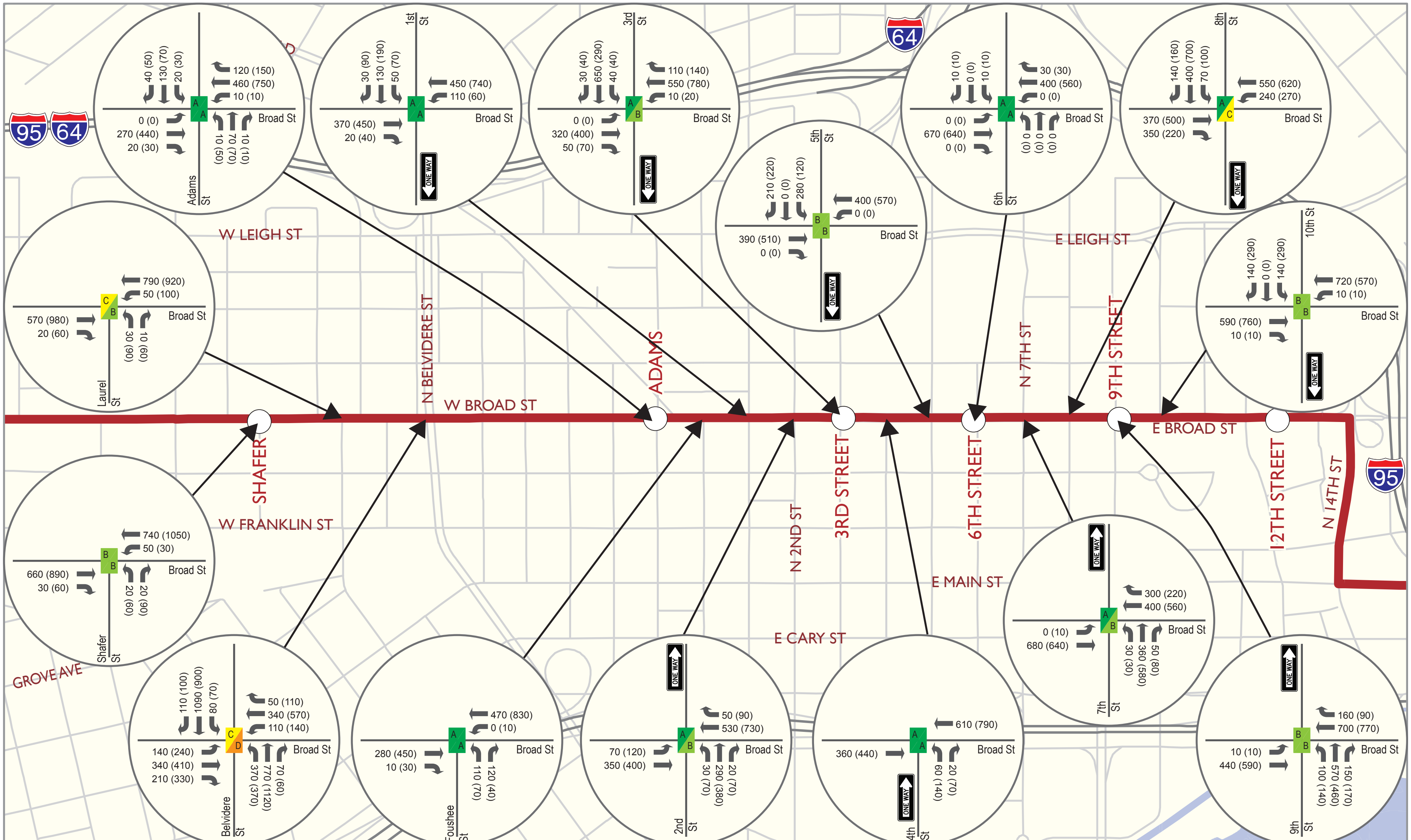
N

0 0.125 0.25

Miles

Traffic Operations Report
Figure 5B: 2015 Build Alternative Intersection Volumes and Levels of Service

BROAD STREET RAPID TRANSIT STUDY



Intersection Volumes and LOS

- Right
- Thru
- Left

(#) AM (PM) Volumes

AM / PM Overall Intersection LOS

A B C D E F

BRT Alignment

Proposed BRT Stations

Proposed BRT Alignment

N

0 0.125 0.25

Miles

Traffic Operations Report

Figure 5C: 2015 Build Alternative Intersection Volumes and Levels of Service

BROAD STREET RAPID TRANSIT STUDY

Intersection Volumes and LOS

Right
Thru
Left

(#) AM (PM) Volumes

AM PM Overall Intersection LOS

A B C D E F

BRT Alignment

Proposed BRT Stations

Proposed BRT Alignment

N

0 0.125 0.25
Miles

Traffic Operations Report
Figure 5D: Build Alternative Intersection Volumes and Levels of Service

BROAD STREET RAPID TRANSIT STUDY

3.4 2015 RIDERSHIP

Because the Build Alternative is a proposed Small Starts project within existing right of way and the regional travel demand model is inadequate to develop long range forecasts of transit ridership, the forecasting for the Broad Street Rapid Transit Study is limited to the 2015 Base Year results provided by the data-driven model developed for this project. Ridership growth from 2015 to 2035 is expected to grow in tandem with the surrounding land use, and mode split is expected to increase as transit-oriented redevelopment occurs in the station areas. Table 10 shows the passenger boarding results from the 2009 on-board survey as well as the forecasted weekday passenger boarding estimates for the 2015 No-Build and Build Alternatives, grouped by the type of GRTC route.

No-Build Alternative

According to the results from the on-board survey, there were approximately 27,000 weekday passenger boardings of GRTC local and express routes (VCU routes excluded). Forecasts project that overall passenger boardings will increase to just over 30,000 under the No-Build. Route 6, which operates most closely to the proposed BRT alignment, had 3,600 passenger boardings in 2008. The 2015 ridership forecast predicts that daily boardings would increase to 3,900 on Route 6 under the No-Build Alternative.

Build Alternative

Under the Build Alternative, and accounting for the alternative-specific effects of a branded high-quality service, boardings for both Route 6 and the BRT services would be even higher with over 6,700 weekday boardings, 5,500 on the BRT service and 1,200 on the local Route 6 service. This forecast indicates that with the implementation of a BRT system, overall ridership would increase system-wide, with the greatest increase under the Build Alternative.

TABLE 10: EXISTING AND FORECAST WEEKDAY BOARDINGS BY ROUTE

Group	Route Number	2008 Surveyed Boardings	2015 No-Build Boardings	2015 Build Alternative Boardings
Local Routes	1 / 2	2,340	2,770	2,720
	3 / 4	1,660	2,900	2,970
	5	-	-	-
	6	3,630	3,000	440
	7	1,010	1,840	1,860
	8	-	-	-
	10	1,860	590	650
	11	160	190	140
	13	310	0	0
	16	630	340	310
	18	250	170	200
	19	290	610	410
	20	30	0	0
	22	330	40	40
	24	430	540	580
	32	2,180	2,470	2,480
	34	1,650	1,890	1,790
	53	-	940	660
	37	1,900	1,880	1,850
	45	-	260	260
	61	-	-	-
	62/63	3,300	2,570	2,540
	67	-	400	410

TABLE 10: EXISTING AND FORECAST WEEKDAY BOARDINGS BY ROUTE

Group	Route Number	2008 Surveyed Boardings	2015 No-Build Boardings	2015 Build Alternative Boardings
	68	20	0	0
	70/71	1,410	1,510	1,360
	72/73	1,460	1,330	1,350
	74	900	560	560
	91	220	370	360
	92	20	0	0
	93	60	30	30
	95	-	30	30
	100	-	-	-
	101		60	20
	999-Express/BRT	-	-	3,280
*Subtotal**		*26,035*	*27,330*	*27,360*
Express Routes	26	200	450	430
	27	230	230	220
	28	30	10	10
	29	460	510	510
	64	210	310	310
	65	-	-	-
	66	-	360	390
	81	180	40	40
	82	310	430	430
*Subtotal**		*1,610*	*2,340*	*2,340*
Total*		***27,650***	***29,670***	***29,700***

Source: AECOM, 2010. *Totals may not be exact due to rounding.

3.5 STATION BOARDINGS

While the Small Starts travel demand model does not specifically address future station boarding and alighting activity, current stop activity within a quarter-mile of the corridor, combined with projected ridership data, provides statistical data regarding station level boarding activity. Table 11 shows the boardings and alightings at existing bus stops along the corridor within a quarter-mile of proposed stations. These boarding and alighting counts are for all routes that serve the corridor, not just Route 6. As shown in the table, the majority of boarding and alighting activity takes place in the downtown area along Broad Street, with 3rd Street and 9th Street showing the highest activity levels. Four other stations areas, Robinson, Shafer, Adams and 12th Street, have over 1,000 daily boarding and alightings occurring within a quarter-mile. Future boarding and alighting activity for the proposed BRT service is expected to have a similar pattern. Given that the proposed BRT platforms would substantially increase boarding space at the downtown stations and that projected ridership is not an order of magnitude higher than existing ridership, the proposed BRT station platforms should easily accommodate the forecasted daily boarding and alighting activity.

TABLE 11: EXISTING BOARDINGS AND ALIGHTINGS BY STATION AREA

Station	2009 Boardings and Alightings	Percent of Corridor Boardings and Alightings
Willow Lawn	894	6%
Staples Mill	385	2%
Hamilton/I-195	316	2%
Robinson	1,162	7%
Hermitage/Meadow	484	3%
Shafer	1,509	9%
Adams	1,613	10%
3rd Street	4,635	29%
6th Street	132	1%
9th Street	3,364	21%
12th Street	1,367	9%
Main Street Station	94	1%
25th Street	118	1%
Rocketts Landing	-	-
Total	16,073	100%

Source: GRTC, 2009.

3.6 TRANSIT OPERATIONS

In addition to forecasted increases in ridership, the Build Alternative is projected to positively affect travel times and speeds along the corridor. Table 12 shows the VISSIM model travel times and speeds for both alternatives in the peak and reverse peak directions. The comparison of travel time and speed to the local bus service is limited to the Willow Lawn to 12th Street section, because the proposed Route 6 service in the future would not serve the East End.

No-Build Alternative

In the peak direction of the No-Build Alternative, the local bus travel time is 36.04 minutes with an average travel speed of 7.99 miles per hour (MPH). The reverse peak direction is forecasted to have a travel time of 36.78 minutes and an average bus travel speed of 7.83 MPH.

Build Alternative

The Build Alternative is forecast to have an even greater impact on the travel times and speeds of limited stop BRT services. The VISSIM simulation of the Build Alternative shows BRT services have travel times 14 minutes shorter than bus operations under the No-Build alternative, in both the peak and reverse peak directions. Additionally, the Build Alternative is expected to have the highest BRT travel speeds, with average BRT travel speed of 13.24 MPH in the peak direction and 12.62 MPH in the reverse peak direction.

The Build Alternative is anticipated to improve conditions for passengers on existing local routes: travel speeds are forecast to increase up to 11% for local buses operating between Willow Lawn and 25th Street, while travel times for these routes are expected to decrease up to 9%. This may be directly attributed to the positive effects of introducing wider shoulder bus lanes and consolidated stations in downtown Richmond.

TABLE 12: BUS RUNNING TIMES AND SPEEDS (2015 BASE YEAR)

Direction	Alternative	Local Bus Travel Time(mins)	Local Bus Speed (mph)	BRT Travel Time (mins)	BRT Speed (mph)
Peak	No-Build	36.04	7.99	-	-
	Build Alternative	32.69	8.87	21.88	13.24
Reverse Peak	No-Build	36.78	7.83	-	-
	Build Alternative	35.77	8.10	22.96	12.62

Source: AECOM, 2010.

3.7 2035 ROADWAY EFFECTS

2035 No-Build Alternative

The No-Build Alternative defines what would happen in the study area in the absence of specific facility and operational improvements to the transit system, as defined by the other project alternatives. The No-Build Alternative includes all existing and committed transportation facilities and services that will be operational in 2035. The No-Build Alternative is described in detail in Section 3.1.

Capacity analyses were conducted for the study area intersections under the No-Build Alternative. The forecasted 2035 traffic volumes were analyzed using Synchro, with delay and LOS being determined using Highway Capacity Methodology. Table 13 shows the 2035 No-Build Alternative operations results.

The majority of the study area intersections are still expected to operate at a LOS C or better in the AM and PM peak hours. Due to the expected traffic volume increase, some intersections are expected to deteriorate to LOS D or worse. The intersections operating with LOS D or worse during the AM or PM peak hours are shown below. Intersection volumes and level of service are shown in Figures 6A to 6D.

AM Peak:

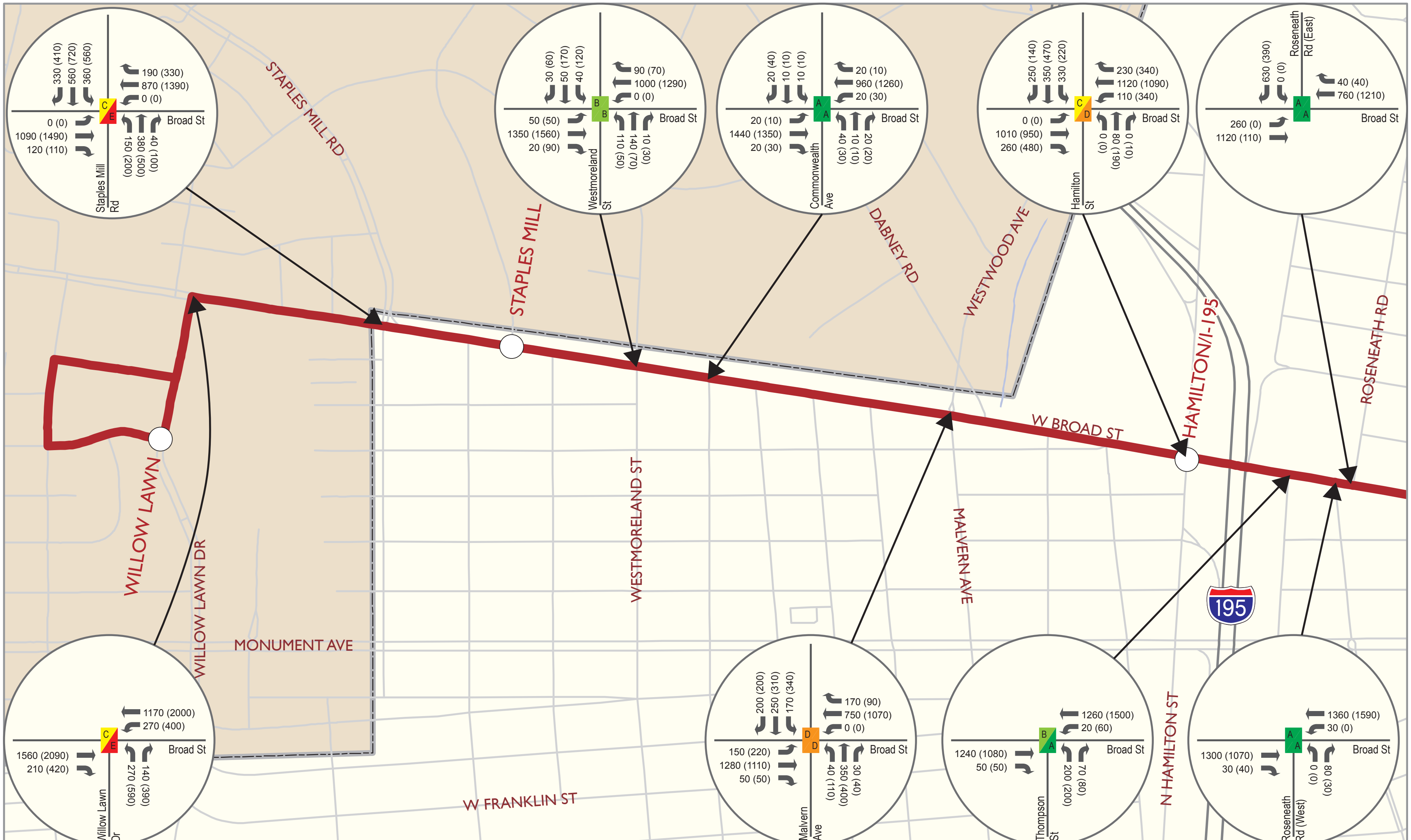
- Broad Street at Malvern Avenue/Westwood Avenue (LOS D)
- Broad Street at Belvidere Street (LOS D)
- 14th Street at Franklin Street (LOS E)
- Main Street at 15th Street (LOS E)
- Main Street at Williamsburg Avenue (LOS F)

PM Peak:

- Broad Street at Willow Lawn Drive (LOS E)
- Broad Street at Staples Mill Rd (LOS E)
- Broad Street at Malvern Avenue/Westwood Avenue (LOS D)
- Broad Street at Hamilton Street (LOS D)
- Broad Street at Lombardy Street (LOS F)
- Broad Street at Belvidere Street (LOS D)
- Broad Street at 14th Street (LOS D)
- 14th Street at Franklin Street (LOS E)
- Main Street at 18th Street (LOS D)
- Main Street at 25th Street (LOS D)

TABLE 13: 2035 NO-BUILD CONDITIONS – INTERSECTION ANALYSIS SUMMARY

Intersection	2035 No-Build AM		2035 No-Build PM	
	Avg. Int. Delay (sec/veh)	Synchro LOS	Avg. Int. Delay (sec/veh)	Synchro LOS
Broad Street at Willow Lawn Dr	25.8	C	61.3	E
Broad Street at Staples Mill Road	34.1	C	76.6	E
Broad Street at Westmoreland Street	18.8	B	16.6	B
Broad Street at Commonwealth Avenue	3.9	A	4.6	A
Broad Street at Malvern Avenue	46.9	D	54.9	D
Broad Street at Hamilton Street	29.4	C	36.9	D
Broad Street at Thompson Street	10.3	B	9.5	A
Broad Street at Roseneath Road (West)	8.0	A	3.7	A
Broad Street at Roseneath Road (East)	7.0	A	7.1	A
Broad Street at Cleveland Street	1.3	A	1.7	A
Broad Street at Summit Avenue	2.2	A	4.2	A
Broad Street at Altamont Avenue	1.2	A	1.9	A
Broad Street at Sheppard Street	15.0	B	13.3	B
Broad Street at Boulevard	29.8	C	28.8	C
Broad Street at Terminal Place	7.1	A	8.5	A
Broad Street at Robinson Street	6.4	A	5.9	A
Broad Street at Davis Avenue	2.5	A	7.3	A
Broad Street at DMV Drive	13.3	B	8.8	A
Broad Street at Allison Street	3.0	A	4.2	A
Broad Street at Hermitage Road	12.1	B	27.8	C
Broad Street at Allen Avenue	12.5	B	13.3	B
Broad Street at Lombardy Street	20.1	C	82.2	F
Broad Street at Bowe Street	23.5	C	29.3	C
Broad Street at Ryland Street	6.2	A	6.2	A
Broad Street at Harrison Street	7.2	A	10.4	B
Broad Street at Shafer Street	12.8	B	14.9	B
Broad Street at Laurel Street	8.3	A	11.7	B
Broad Street at Belvidere Street	38.3	D	43.0	D
Broad Street at Adams Street	8.2	A	9.0	A
Broad Street at Foushee Street	8.9	A	5.7	A
Broad Street at 1st Street	3.9	A	7.6	A
Broad Street at 2nd Street	8.8	A	18.5	B
Broad Street at 3rd Street	9.9	A	12.2	B
Broad Street at 4th Street	6.3	A	9.3	A
Broad Street at 5th Street	15.1	B	12.8	B
Broad Street at 6th Street	8.2	A	4.3	A
Broad Street at 7th Street	10.2	B	14.5	B
Broad Street at 8th Street	11.4	B	25.7	C
Broad Street at 9th Street	13.5	B	17.5	B
Broad Street at 10th Street	10.0	A	13.7	B
Broad Street at 11th Street	18.9	B	8.8	A
Broad Street at 12th Street	5.8	A	4.0	A
Broad Street at Old 14th Street	6.9	A	15.7	B
Broad Street at 14th Street	12.2	B	49.6	D
Franklin Street at 14th Street	62.3	E	63.0	E
Main Street at 14th Street	15.3	B	22.9	C
Main Street at 15th Street	60.4	E	33.3	C
Main Street at 17th Street	3.3	A	9.6	A
Main Street at 18th Street	28.6	C	44.3	D
Main Street at 19th Street	4.6	A	9.6	A
Main Street at 21st Street	9.1	A	19.5	B
Main Street at 25th Street	26.0	C	47.5	D
Main Street at Williamsburg Ave	103.5	F	22.2	C



Intersection Volumes and LOS

Right
Thru
Left

(#) AM (PM) Volumes

AM PM Overall Intersection LOS

A B C D E F

BRT Alignment

Proposed BRT Stations

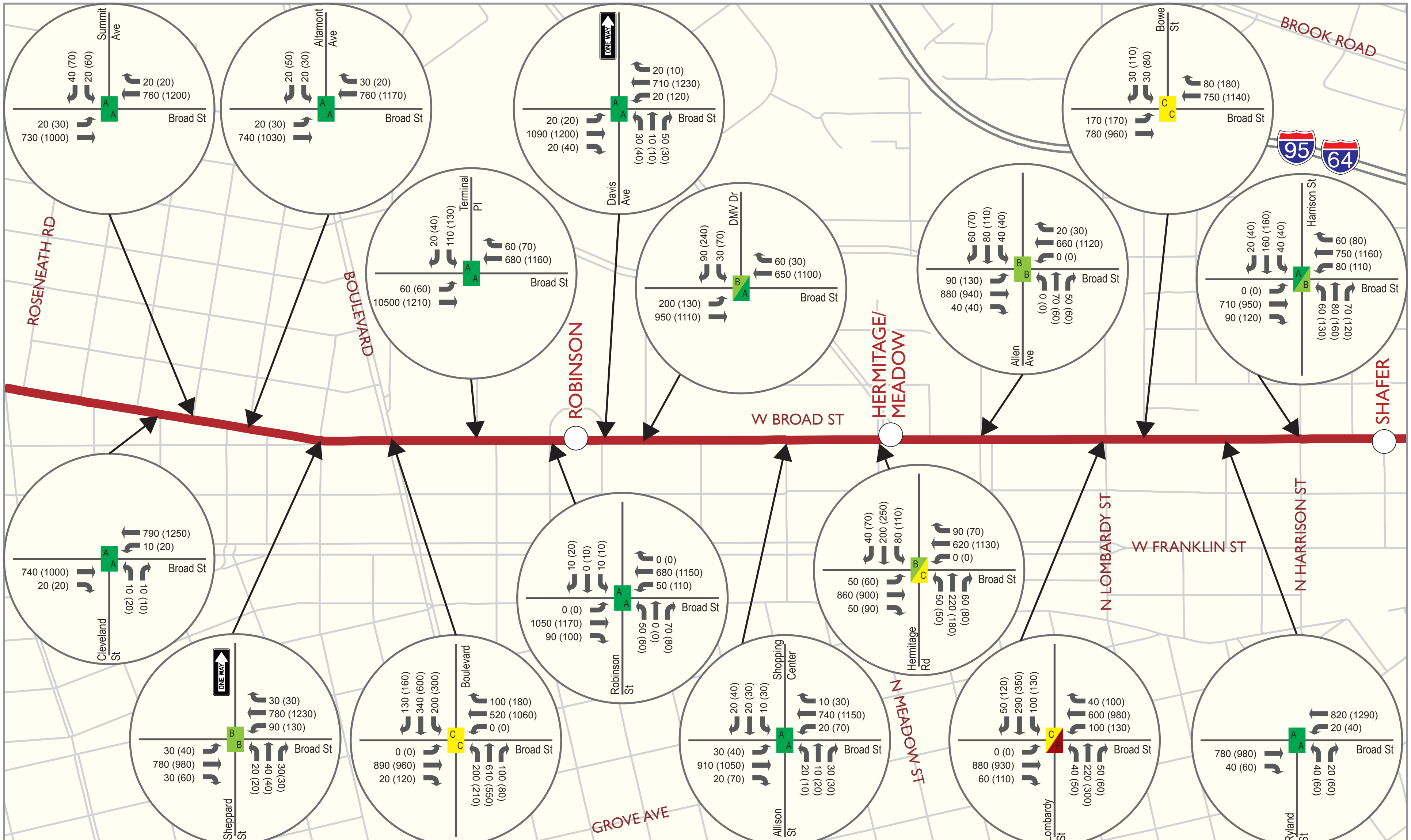
Proposed BRT Alignment

N

0 0.125 0.25
Miles

Traffic Operations Report
Figure 6A: 2035 No-Build
Intersection Volumes
and Levels of Service

BROAD STREET RAPID TRANSIT STUDY



Intersection Volumes and LOS

Right
Thru
Left
(#) AM (PM) Volumes

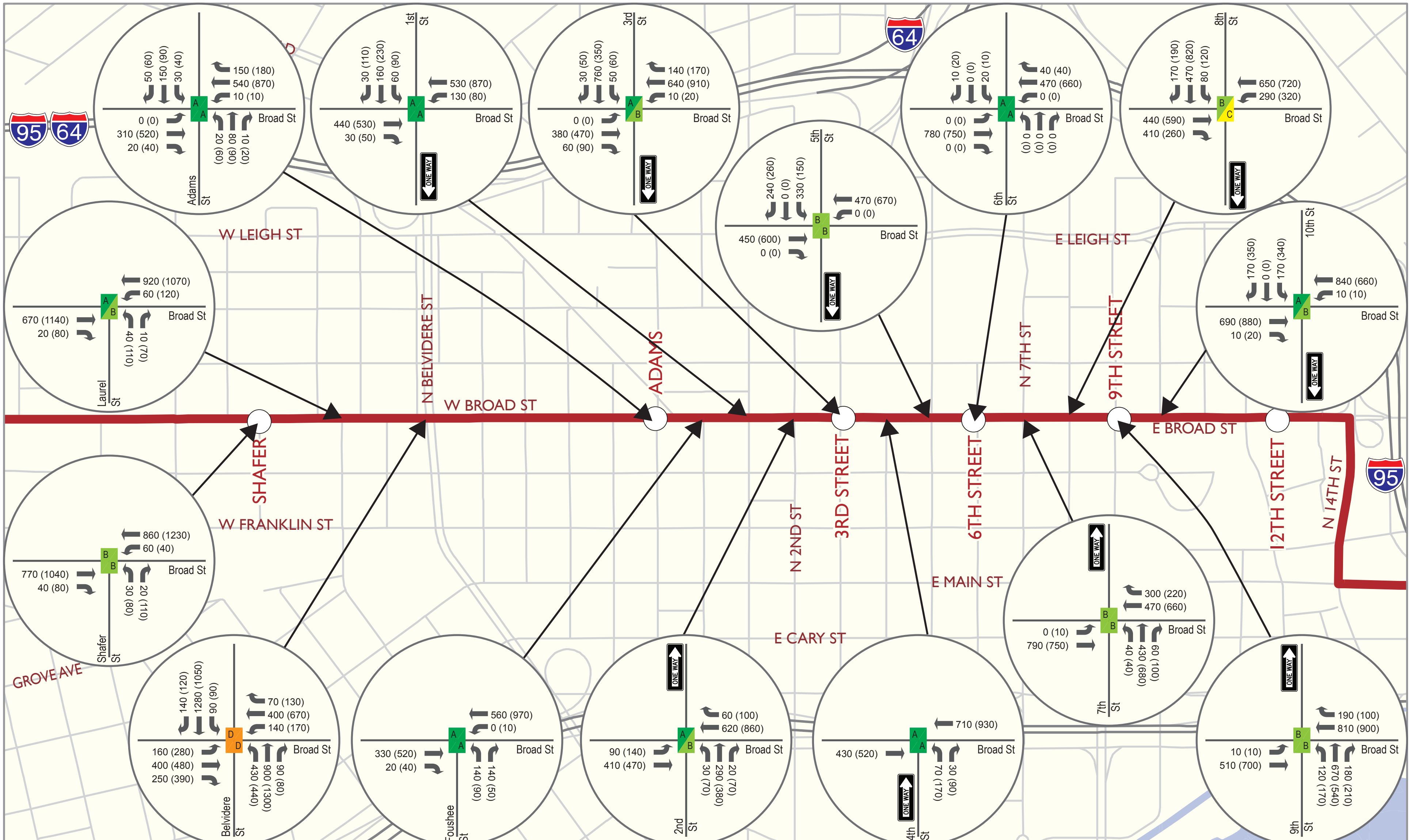
AM PM Overall Intersection LOS
A B C D E F

BRT Alignment

Proposed BRT Stations
Proposed BRT Alignment

N
0 0.125 0.25
Miles

Traffic Operations Report
Figure 6B: 2035 No-Build Intersection Volumes and Levels of Service



Intersection Volumes and LOS

Right
Thru
Left

(#) AM (PM) Volumes

AM PM Overall Intersection LOS

A B C D E F

BRT Alignment

Proposed BRT Stations

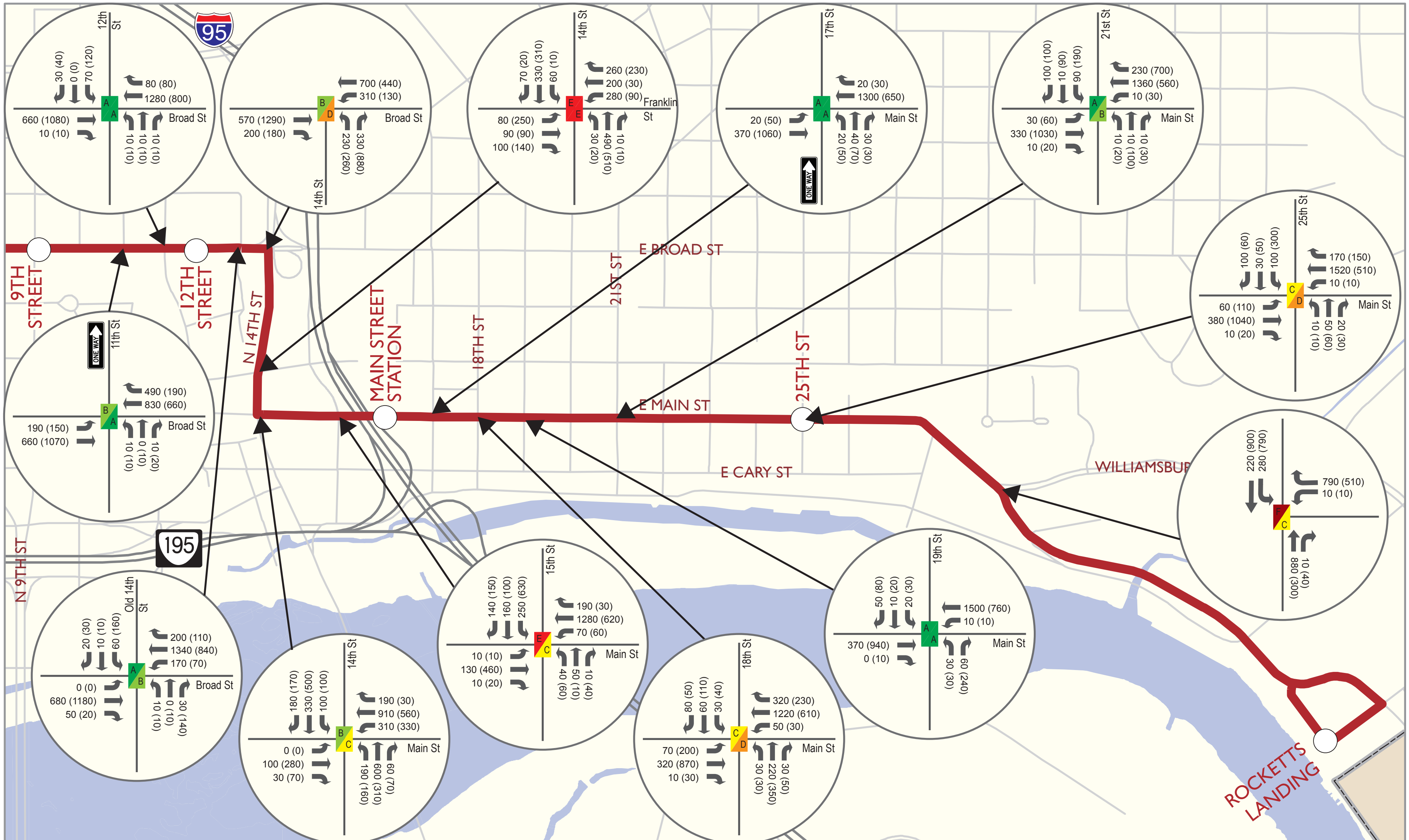
Proposed BRT Alignment

N

0 0.125 0.25
Miles

Traffic Operations Report
Figure 6C: 2035 No-Build Intersection Volumes and Levels of Service

BROAD STREET RAPID TRANSIT STUDY



Intersection Volumes and LOS

- Right
- Thru
- Left

(#) AM (PM) Volumes

AM PM Overall Intersection LOS

A B C D E F

BRT Alignment

- Proposed BRT Stations
- Proposed BRT Alignment

N

0 0.125 0.25
Miles

Traffic Operations Report
Figure 6D: 2035 No-Build Intersection Volumes and Levels of Service

BROAD STREET RAPID TRANSIT STUDY

2035 Build Alternative

This section documents the 2035 Build Alternative lane configuration changes and resulting intersection capacity analysis. Results of the Build Alternative are presented in this section and problem intersections are identified and discussed.

Intersection Geometry

The 2035 Build Alternative represents a future condition that assumes the median-running transit service along Broad Street that was described in Section 3.2. No other improvements are expected to be in place in this alternative. Figures 4A through 4D in Section 3.3 show the Build Alternative intersection geometry. The lane configurations for intersections without the median-running dedicated bus lanes do not change from the No-Build.

Build Alternative Volumes

The changes proposed under the Build Alternative do not change the non-bus traffic volumes used under the No-Build Alternative. Volumes are shown in Figures 7A through 7D.

Capacity Analysis

Capacity analyses were again conducted for the study area intersections. Only the intersections between Thompson Street and Adams Street are affected, resulting from the median-running bus lanes. All other intersections in the study area are expected to operate with the same delay and level of service as the No-Build.

The majority of the intersections between Thompson Street and Adams Street are still expected to operate at a LOS C or better in the AM and PM peak hours of the Build Alternative. Due to the expected traffic volume increase and reduced capacity of Broad Street, some intersections' LOS are expected to deteriorate to LOS D or worse. The intersections along the corridor that are expected to operate with LOS D or worse during the AM or PM peak hours are shown below. Intersections in bold type are intersections that are expected to deteriorate in operating conditions under the Build Alternative only, and not under the No-Build Alternative.

AM Peak:

- Broad Street at Malvern Avenue/Westwood Avenue (LOS D)
- Broad Street at Belvidere Street (LOS D)
- 14th Street at Franklin Street (LOS E)
- Main Street at 15th Street (LOS E)
- Main Street at Williamsburg Avenue (LOS F)

PM Peak:

- Broad Street at Willow Lawn Drive (LOS E)
- Broad Street at Staples Mill (LOS E)
- Broad Street at Malvern Avenue (LOS D)
- **Broad Street at Boulevard (LOS E)**
- Broad Street at Lombardy Street (LOS F)

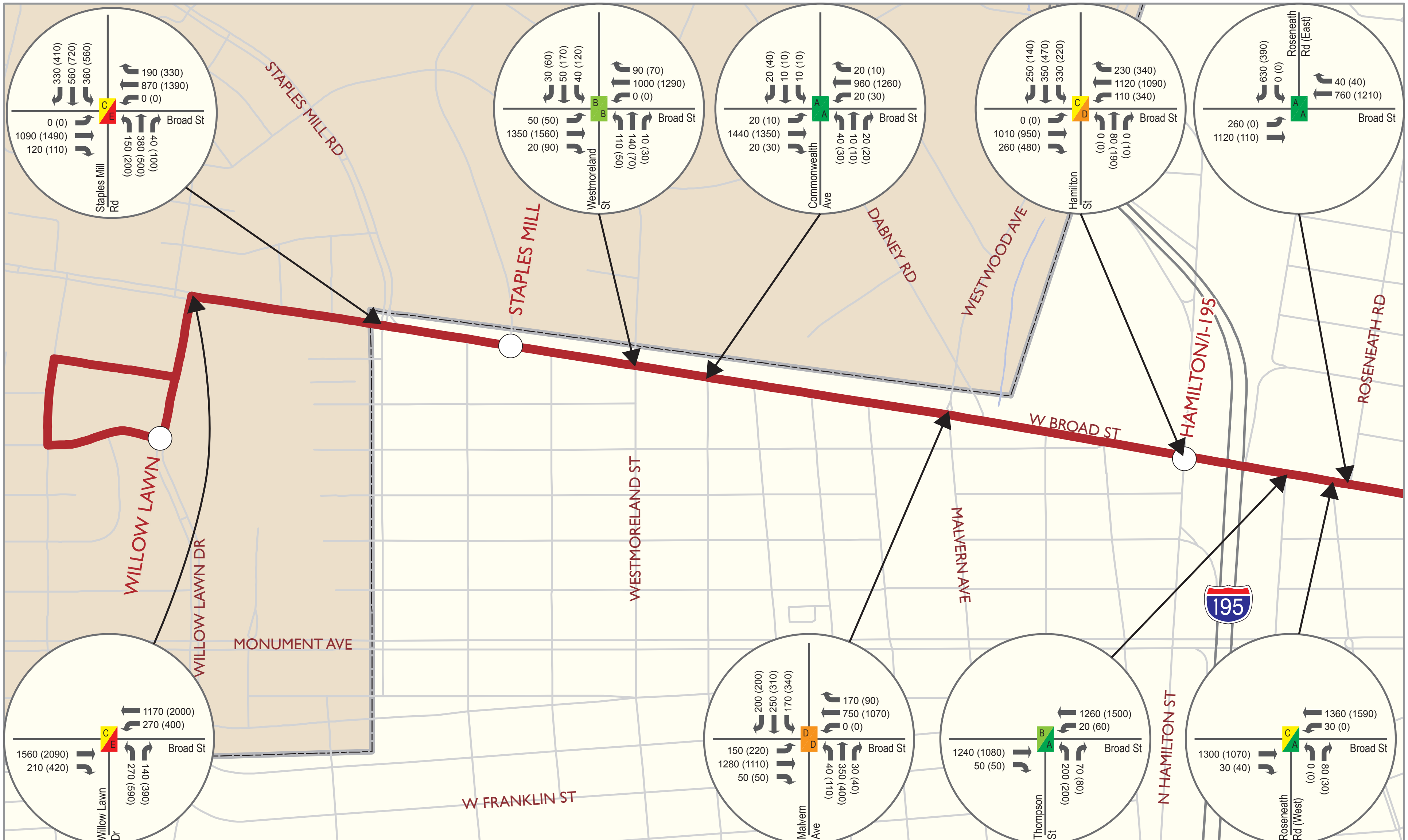
- **Broad Street at Bowe Street (LOS E)**
- Broad Street at Belvidere Street (LOS D)
- Broad Street at 14th Street (LOS D)
- 14th Street at Franklin Street (LOS E)
- Main Street at 18th Street (LOS D)
- Main Street at 25th Street (LOS D)

Table 14shows the 2035 Build Alternative operations results compared with the 2035 No-Build results. Intersection volumes and level of service are shown in Figures 7A through 7D.

A total of two intersections along Broad Street, that operate acceptably under the No-Build Alternative, are expected to have a LOS D or worse under the Build Alternative; therefore, very little to no traffic is expected to divert from the Broad Street Corridor to parallel facilities as a result of the Build Alternative. The highest cross-street volumes in the corridor occur at Broad and Belvidere, where intersection delay would increase with the Build Alternative. The analysis shows an acceptable LOS on the basis of assuming the BRT lanes can be combined with left-turn lanes. The feasibility of this configuration will be determined during final design. Possible mitigation measures to bring the two LOS E or F intersections back to LOS D or better, and to address the potential operational issues at Belvidere, are discussed in Section 3.11.

TABLE 14: 2035 BUILD ALTERNATIVE CONDITIONS – INTERSECTION ANALYSIS

Intersection	2035 Build AM		2035 Build PM	
	Avg. Int. Delay (sec/veh)	Synchro LOS	Avg. Int. Delay (sec/veh)	Synchro LOS
Broad Street at Willow Lawn Dr	25.8	C	61.3	E
Broad Street at Staples Mill Road	34.1	C	76.6	E
Broad Street at Westmoreland Street	18.8	B	16.6	B
Broad Street at Commonwealth Avenue	3.9	A	4.6	A
Broad Street at Malvern Avenue	46.9	D	54.9	D
Broad Street at Hamilton Street	29.4	C	36.9	D
Broad Street at Thompson Street	11.9	B	10.0	A
Broad Street at Roseneath Road (West)	26.1	C	4.8	A
Broad Street at Roseneath Road (East)	8.4	A	8.8	A
Broad Street at Cleveland Street	6.7	A	3.1	A
Broad Street at Summit Avenue	7.7	A	9.0	A
Broad Street at Altamont Avenue	4.3	A	2.3	A
Broad Street at Sheppard Street	17.8	B	18.9	B
Broad Street at Boulevard	31.4	C	57.6	E
Broad Street at Terminal Place	8.6	A	15.7	B
Broad Street at Robinson Street	7.3	A	9.5	A
Broad Street at Davis Avenue	12.3	B	15.8	B
Broad Street at DMV Drive	15.1	B	14.6	B
Broad Street at Allison Street	13.7	B	6.7	A
Broad Street at Hermitage Road	13.3	B	35.0	C
Broad Street at Allen Avenue	15.3	B	27.8	C
Broad Street at Lombardy Street	24.2	C	83.1	F
Broad Street at Bowe Street	26.3	C	67.4	E
Broad Street at Ryland Street	15.1	B	8.8	A
Broad Street at Harrison Street	18.1	B	17.2	B
Broad Street at Shafer Street	11.4	B	18.2	B
Broad Street at Laurel Street	26.2	C	22.6	C
Broad Street at Belvidere Street	39.1	D	51.4	D
Broad Street at Adams Street	9.0	A	10.3	B
Broad Street at Foushee Street	8.8	A	5.7	A
Broad Street at 1st Street	3.9	A	7.6	A
Broad Street at 2nd Street	8.7	A	18.4	B
Broad Street at 3rd Street	9.9	A	12.2	B
Broad Street at 4th Street	6.3	A	9.3	A
Broad Street at 5th Street	15.1	B	12.8	B
Broad Street at 6th Street	8.2	A	4.3	A
Broad Street at 7th Street	10.2	B	14.4	B
Broad Street at 8th Street	11.4	B	25.7	C
Broad Street at 9th Street	13.5	B	17.5	B
Broad Street at 10th Street	10.0	A	13.7	B
Broad Street at 11th Street	18.9	B	8.8	A
Broad Street at 12th Street	5.8	A	4.0	A
Broad Street at Old 14th Street	6.9	A	15.7	B
Broad Street at 14th Street	12.2	B	49.6	D
Franklin Street at 14th Street	62.3	E	62.9	E
Main Street at 14th Street	15.3	B	22.9	C
Main Street at 15th Street	60.4	E	33.3	C
Main Street at 17th Street	3.3	A	9.6	A
Main Street at 18th Street	28.6	C	44.6	D
Main Street at 19th Street	4.6	A	9.3	A
Main Street at 21st Street	9.1	A	19.5	B
Main Street at 25th Street	26.0	C	47.5	D
Main Street at Williamsburg Ave	103.5	F	22.2	C



Intersection Volumes and LOS

- Right
- Thru
- Left

(#) AM (PM) Volumes

AM / PM Overall Intersection LOS

A B C D E F

BRT Alignment

- Proposed BRT Stations
- Proposed BRT Alignment

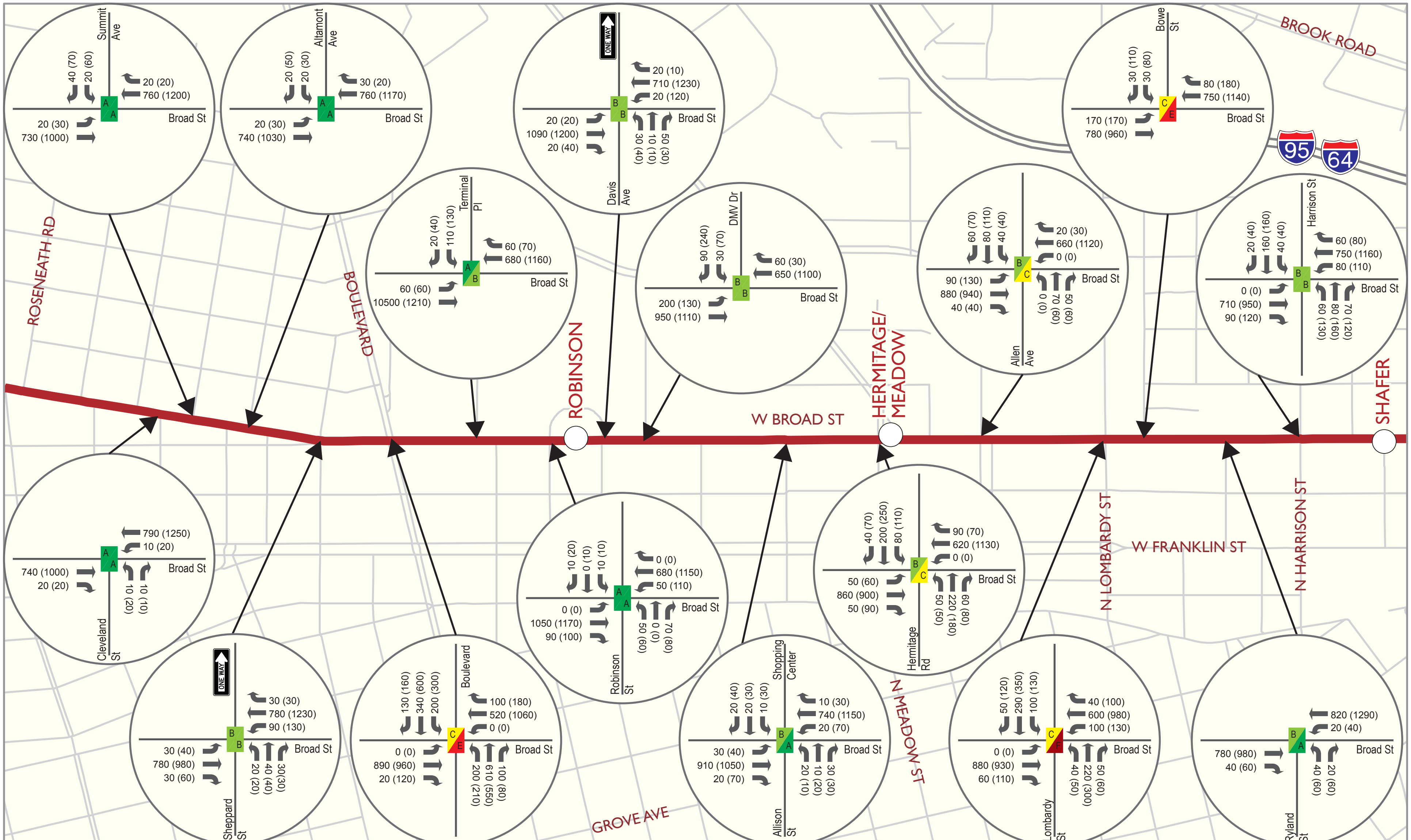
0 0.125 0.25

Miles

Traffic Operations Report

Figure 7A: 2035 Build Alternative Intersection Volumes and LOS

BROAD STREET RAPID TRANSIT STUDY



Intersection Volumes and LOS

Right
Thru
Left

(#) AM (PM) Volumes

AM PM Overall Intersection LOS

A B C D E F

BRT Alignment

Proposed BRT Stations

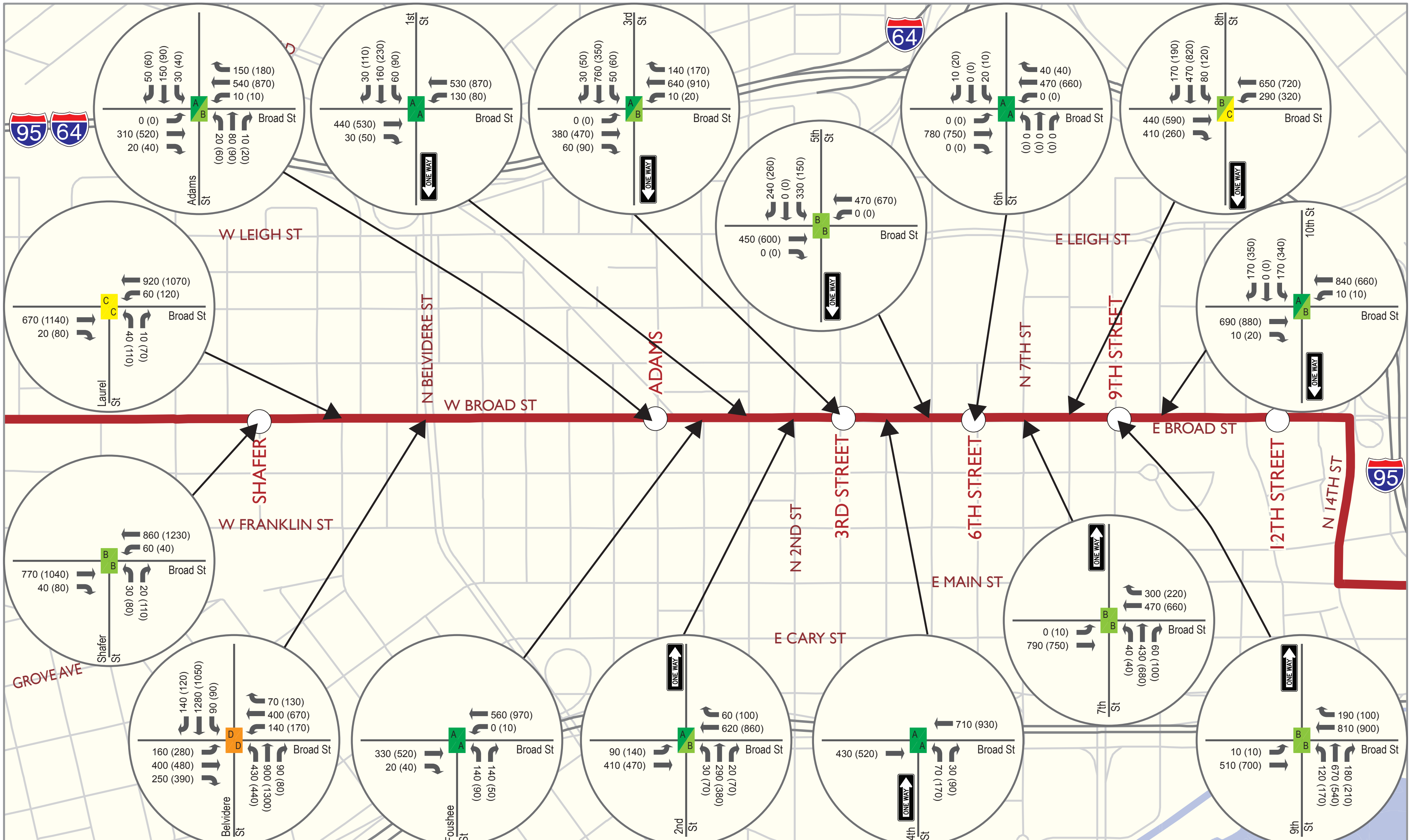
Proposed BRT Alignment

N

0 0.125 0.25
Miles

Traffic Operations Report

Figure 7B: 2035 Build Alternative Intersection Volumes and LOS



Intersection Volumes and LOS

- Right
- Thru
- Left

(#) AM (PM) Volumes

AM PM Overall Intersection LOS

A B C D E F

BRT Alignment

Proposed BRT Stations

Proposed BRT Alignment

N

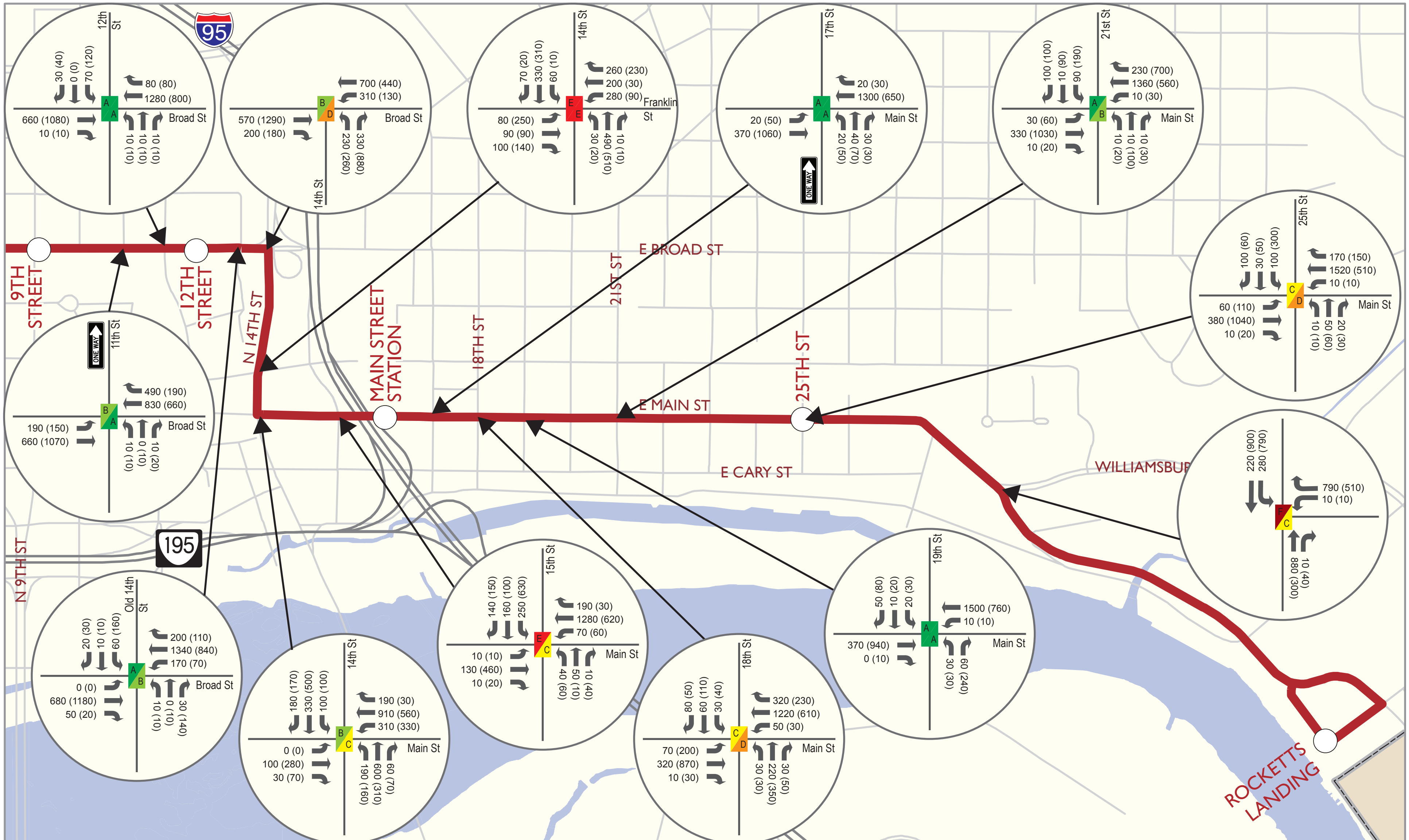
0 0.125 0.25

Miles

Traffic Operations Report

Figure 7C: 2035 Build Alternative Intersection Volumes and LOS

BROAD STREET RAPID TRANSIT STUDY



Intersection Volumes and LOS

Right
Thru
Left

(#) AM (PM) Volumes

AM
PM
Overall Intersection LOS

A B C D E F

BRT Alignment

Proposed BRT Stations

Proposed BRT Alignment

0 0.125 0.25
Miles

N

Traffic Operations Report

Figure 7D: 2035 Build Alternative Intersection Volumes and LOS

BROAD STREET RAPID TRANSIT STUDY

3.8 NON MOTORIZED TRANSPORTATION EFFECTS

No-Build Alternative

Implementation of the No-Build Alternative will not significantly affect pedestrian travel in the study corridor. Likewise, implementation of the No-Build Alternative will not appreciably affect bicycle travel in the study corridor.

Build Alternative

Construction for the Build Alternative is expected to occur within the existing right of way and will not require substantial reconstruction of the curb and sidewalk facilities. The sole potential exception is in the eastbound direction of Broad Street at Belvidere Street. To maintain acceptable vehicular levels of service, it may be necessary to widen the eastbound approach to the Belvidere intersection to maintain the existing lane configuration of two left, two thru and one right turn lanes. This widening could require some narrowing of the sidewalk on the east side of the intersection from 18 feet to as narrow as 6 feet. Final determination of the need for roadway widening, and of sidewalk width narrowing, in this area will be determined during Preliminary Engineering, as discussed in Section 3.3 Additionally, all stations outside the median guideway section may require additional use of sidewalk space to provide shelters, ticketing machines and other amenities for the BRT service. Overall, the effect of the Build Alternative on pedestrian infrastructure will be minimal. Also, implementing the Build Alternative will encourage increased densities and mixed use development, which will encourage walking along the corridor.

Currently, there is only one bicycle lane in the vicinity of the corridor and it will remain unaffected by any of the alternatives under study. Furthermore, the existence of numerous, lower traffic alternative roadways parallel to Broad Street means that few cyclists currently use Broad Street and few are likely to use it in the future. Implementation of the Build Alternative will not subtract from any existing bicycle infrastructure, nor will it contribute to bicycle infrastructure appreciably. The proposed rapid transit vehicles for use under all alternatives will have the ability to carry bicycles to assist with multimodal connections. Therefore, those alternatives that provide higher levels of service, including the Build Alternative, will provide cyclists with greater regional accessibility as a result. The *Land Use and Multimodal Connectivity Report* provides insight on ways that bicycle connectivity to the BRT project could be improved.

3.9 PARKING EFFECTS

No-Build Alternative

On-street parking restriction at station areas is commensurate with GRTC's current practice of excluding on-street parking at bus stops. Implementation of the No-Build Alternative would have very little effect on parking. No off-street parking facilities would be affected under the No-Build.

Build Alternative

The Build Alternative would have a number of impacts to on-street parking and some minor impacts to off-street parking. Commensurate with GRTC's current practice of excluding on-street parking at bus stops, on-street parking would be prohibited at all station areas, though most station areas are already GRTC stops. Outside of the station areas, on-street parking will be further reduced under the Build Alternative in areas with dedicated guideway, specifically, between Thompson Street and Adams Street and between 4th Street and 14th Street. Where median running guideway is recommended, between Thompson Street and Adams Street, the existing right-of-way is only wide enough to preserve on-street parking on one side of the street. This will result in approximately a 50% reduction in the remaining on-street parking. Where curb running guideway is recommended, between 4th and 14th Streets, on-street parking will be restricted 24 hours per day. Currently, parking is allowed in many sections of the existing curb lane in off-peak periods. The on-street parking restrictions, therefore, will be expanded in this area resulting in a loss of parking availability in the off-peak periods. However, the existing restricted bus lane exists between 2nd and 14th Streets, therefore, under the Build Alternative some on-street parking within the two blocks between 2nd and 4th Streets will be reclaimed during the peak periods.

Table 15 shows the estimated impact to on-street parking from these changes. The corridor was analyzed in three segments: two within the median guideway section (I-195 to Hermitage/Meadow and Hermitage/Meadow to Adams) and one within the curb running guideway section (2nd to 14th). Existing on-street parking was estimated from the City's GIS data on curb lengths. Curb sections within 50 feet of a bus stop, 20 feet of a fire hydrant or 5 feet of a curb cut were subtracted from the total curb length. In addition, loading zones were mapped based on a field survey and were also removed from the curb length available for on-street parking. The estimated curb lengths were then divided by 18 feet to estimate the number of spaces available. For the Build Alternative, all curb areas along the 4th to 14th Street section were removed, and all curb sections on the westbound side of Broad Street were removed, to estimate the effect of removing on-street parking from one direction of travel. Additionally, curb lengths within 50 feet of station areas were also removed. The results indicate that a total of 597 on-street spaces would be lost under the Build Alternative, but nearly 40 percent of these spaces would be lost in the section between I-195 and Meadow Street where on-street parking is largely underused.

For comparison, the total available off-street parking within 600 feet of the corridor is summarized in Table 16. Surface parking was estimated based on the total square footage of off-street parking surfaces from the City's GIS. Availability of structured parking was calculated from data provided by VCU for its parking facilities and from the Ridefinders Downtown Commuter Guide. As shown, the available off-street parking is much greater than the potential loss of on-street parking. In addition, VCU recently built three additional parking decks within two blocks of the corridor with a combined capacity of nearly 1,000 vehicles. Therefore, the overall impact from the loss of fewer than 600 on-street parking spaces is mitigated by the substantial amount of off-street parking available throughout the corridor. The development of a park-and-ride facility in the Recommended Locally Preferred Alternative also would help mitigate the on-street parking impacts, as explained later in this section.

TABLE 15: ON-STREET PARKING IMPACTS

Corridor Section	Curb Length (ft)		Estimated Existing On-Street Spaces	Estimated Build Alternative On-Street Spaces	Difference
	Existing Available for Parking	Build Alternative Available for Parking			
I-195 to Hermitage/Meadow	6,974	2,764	387	154	234
Hermitage/Meadow to Adams	7,068	3,127	393	174	219
2nd Street to 14th Street[1]	2,905	312	161	17	144
Total	16,947	6,203	942	345	597

Source: City of Richmond GIS, 2009.

Table Notes: 1. Existing bus lanes from 2nd to 14th are only enforced in the peak periods. The Build Alternative would reduce the dedicated lanes to the section from 4th to 14th but would expand the hours of enforcement to 24 hours. The result is a loss of 144 spaces in the off-peak periods, but an increase of 17 spaces in the peak periods.

Loading zone impacts were analyzed for the corridor to estimate impacts to business from possible loss of loading zones. A field survey of the corridor from I-195 to 14th Street found 34 loading zones: 8 between I-195 and Meadow Street; 18 between Meadow Street and Adams Street; and, 8 between 2nd and 14th Street. Table 17 shows the results of that survey and the analysis of impacts to loading zones. Under the Build Alternative, 19 loading zones would be lost: 8 in the downtown area, 9 within the Meadow Street to Adams Street section and 2 within the I-195 to Meadow Street section. Loss of these loading zones could be mitigated by increasing use of alleys for deliveries and shifting some loading zones to side streets where feasible. Furthermore, shifting some remaining loading zones to side streets under the Build Alternative could reduce some of the impact of on-street parking losses. While this shift would not necessarily increase the overall parking availability, it could reduce the impact of losing on-street parking in front of some businesses.

TABLE 16: OFF-STREET PARKING AVAILABILITY WITHIN 600 FEET OF CORRIDOR

Corridor Section	Estimated Number of Spaces		
	Surface Parking	Structured Parking	Total
I-195 to Hermitage/Meadow	7,418	0	7,418
Hermitage/Meadow to Adams[1]	5,086	1,416	6,502
2nd Street to 14th Street[2]	1,482	1,886	3,368
Total	13,986	3,316	17,302

Source: City of Richmond GIS, 2009, Ridefinders Downtown Commuter Guide, 2009, Virginia Commonwealth University Parking and Transportation Office, 2010.

Table Notes: 1. VCU has two parking decks with a total of 1,416 spaces in this section of the corridor. Both decks allow visitor parking but not all spaces are available for visitors. Two new parking decks have recently opened, with a total capacity of nearly 1,000 vehicles, but none of that capacity is available for visitors. 2. Only includes publicly available structured parking listed in the Ridefinders Downtown Commuter Guide.

TABLE 17: NUMBER OF LOADING ZONES

Corridor Section	Existing	Build Alternative	Difference
I-195 to Hermitage/Meadow	8	6	2
Hermitage/Meadow to Adams[1]	18	9	9
2nd Street to 14th Street[2]	8	0	8
Total	34	15	19

Source: Michael Baker Jr, Inc., 2011.

The Build Alternative would use a portion of the existing Anthem Headquarters surface parking lot as a park-and-ride facility. Preliminary discussions with Anthem on shared usage were incorporated as part of stakeholder outreach and the prospect for success appears feasible. The existing surface lot has substantial excess capacity and the portion expected to be used is mostly underutilized. The Build Alternative includes 95 parking spaces at this location, but with a total acreage (2.5 acres) planned that could accommodate future expansion.

3.10 FREIGHT AND PASSENGER RAIL

Since none of the alternatives cross, at-grade, any railroad corridor or impede on any railroad rights of way, there are no anticipated physical impacts to railroad operations or activities. The Build Alternative includes increased service to Main Street Station in the City of Richmond. The enhancement of local transit service to this multimodal transportation hub will further augment the transportation options available to passengers using the station.

3.11 SUMMARY OF IMPACTS AND MITIGATION

Overall, the impacts to transit service are positive under the Build Alternative. More frequent service and enhanced on-time performance from the dedicated bus lanes would encourage higher ridership and improve services for existing riders. Consolidated stations and improved bus lanes downtown would enhance operations for all routes on Broad Street between 3rd and 14th Streets. Off-board fare collection and consolidated stations would also decrease boarding times, reducing dwell times for buses, and decreasing the overall travel times of buses operating along Broad Street.

Traffic impacts for the project alternatives are minimal, as the Broad Street Corridor has few existing traffic operational problems. The majority of the intersections within the study area are currently operating at acceptable levels of service (LOS C or better) and no intersections operate at worse than LOS D. Over the last five years, traffic volumes on the Broad Street Corridor have remained consistent or increased slightly.

For the forecast year of 2035, traffic volumes along the Broad Street Corridor are expected to increase approximately 16% from existing volumes for the majority of the corridor, with higher growth at both the west and east ends of the corridor. Under the 2035 No-Build Alternative, 11 of the 53 intersections along the corridor are expected to operate at LOS D or worse. Generally, the operating conditions along the corridor are not significantly affected under the 2035 Build Alternative. Only two intersections that operate acceptably under the No-Build Alternative operate with LOS D or worse in one or both peak hours in the Build Alternative in 2035. Despite the anticipated acceptable operation of the Broad and Belvidere intersection, there are potential traffic issues at that location. The following sections describe possible mitigation measures that could be evaluated during the design phase for the three intersections.

Broad Street / Boulevard

The operational issue at this intersection is the heavy eastbound and westbound through and right turn movements sharing two lanes in each direction. A possible mitigation strategy that should be explored during design includes striping the wide outside lane as a right turn lane in both directions. This may require a slight widening of the roadway. Both directions have ample sidewalk area, so no property takings are expected, only possible curb replacement and utilities relocation.

Broad Street / Bowe Street

As with the Boulevard intersection, the operational issue at this intersection is the heavy westbound through and right turn movements sharing two lanes. A possible mitigation strategy that should be explored during design includes striping the wide outside lane as a right turn lane. This may require a minor widening of the roadway. There is ample sidewalk area, so no property takings are expected, only possible curb replacement and utilities relocation.

Broad Street / Belvidere Street

As the highest cross-street volumes in the corridor occur at Broad and Belvidere, the options for maintaining acceptable traffic congestion levels involve tradeoffs between the elements of a dedicated bus lane, dedicated turn lanes for traffic, and the number of through lanes. The primary issue is in the east-bound direction, as currently there are two left turn lanes from eastbound Broad Street to northbound

Belvidere Street. Further review of the intersection design will be required during the Preliminary Engineering phase to determine if it can operate successfully with the bus lane sharing the right-hand left turn lane. If so, the intersection is anticipated to operate at an acceptable level of service for traffic. If that design is not feasible, then there are three options with clear tradeoffs: 1) loss of the current exclusive right turn lane, which would cause the right and through movements to function at an unacceptable congestion level; 2) a reconfiguration of the roadway so that an additional lane is accommodated maintaining the current number of left, through and right lanes as existing plus the eastbound exclusive bus lane; or 3) discontinue the bus lane through the intersection, with the bus using the general travel lane in the eastbound direction in the immediate area of the intersection. The second option would be considered if lane width reductions and sidewalk width reductions along Broad Street both east and west of Belvidere Street would accommodate the alternative; property impacts on the East Side of Belvidere are assumed to be avoided. If this type of design alternative is not feasible, the third option offers a scenario where bus operations would be potentially less efficient in favor of avoiding property impacts and associated costs.

Parking

On-street parking will be reduced under the Build Alternative, but limited to areas with dedicated guideway, specifically between Thompson Street and Adams Street and between 4th Street and 14th Street. In total, an estimated 597 on-street parking spaces would be lost under the Build Alternative, but approximately 20 on-street spaces would be reclaimed during the peak period. Of the estimated 597 spaces lost, 144 are currently unavailable for on-street parking in the peak period as they are within the existing bus lane.

Overall, the impact to on and off-street parking does not appear to constitute a critical loss of capacity. While the removal of 597 on-street parking spaces seems substantial, the use of on-street parking in the section from Thompson Street to Meadow Street is far below capacity. From Meadow Street to Adams Street, where on-street parking usage is much higher, ample off-street parking options are available and numerous adjacent streets have on-street parking availability. Similarly, in the section from 4th to 14th Streets, where the current bus lane allows on-street parking in off-peak periods, numerous off-street parking facilities are available in close proximity to the corridor. Also the Build Alternative includes a 95 space park-and-ride lot at Broad Street and Staples Mill Road using a portion of the existing surface lot for Anthem headquarters.

Lastly, the Build Alternative should reduce overall parking demand as the proposed alternative would encourage an increase in transit use over vehicular use in accessing destinations along the corridor. Thus, the reduction in available on-street parking on Broad Street would be partially offset by the reduction in parking demand.

BROAD STREET RAPID TRANSIT STUDY

ENVIRONMENTAL ASSESSMENT

APPENDIX A-10: Land Use and Multimodal Connectivity Report

Note: This report represents a comprehensive review of land use and redevelopment characteristics of the proposed transit corridor. Some data in the EA have been updated, but the statistics in this technical report remain per the original analysis for internal consistency. The updated census and MPO socioeconomic data do not change any of the conclusions presented herein.

BROAD STREET RAPID TRANSIT STUDY
LAND USE AND MULTIMODAL CONNECTIVITY REPORT

The GRTC Transit System and Virginia Department of Rail and Public Transportation (GRTC/DRPT) are conducting an Alternatives Analysis consistent with the requirements of the Federal Transit Administration's (FTA) Small Starts program to evaluate transit improvements along the Broad Street Corridor located in the City of Richmond and Henrico County, Virginia. An assessment of the transit supportiveness of the Corridor is an important component of the FTA New Starts program evaluation. In particular, the project evaluation emphasizes land use and economic development factors that support transit. The new FTA guidelines call for clearly demonstrating that a potential project is built upon a solid foundation of transit supportive land uses, physical conditions and policies as important factors in receiving federal project funding support. The following technical assessment summarizes the existing land use and multimodal connectivity conditions and outlines the transit supportive features for the station areas that have been identified in the Broad Street Corridor.

TRANSIT SUPPORTIVE ELEMENTS

The FTA applies specific criteria to evaluate candidate transit improvement projects seeking federal funding assistance under the Small Starts and New Starts programs. Funding is an extremely competitive process with numerous projects across the nation seeking funds. Therefore, the extent to which a project can demonstrate community commitment to transit supportive land uses and policies can be critical in the project evaluation process.

The FTA evaluation explicitly considers the following transit supportive land use categories and factors:

1. Existing land use
2. Transit Supportive Plans and Policies, including the following factors
    a. Growth management
    b. Transit supportive corridor policies
    c. Supportive zoning regulations near transit stations
    d. Tools to implement land use policies
3. Performance and Impacts of Policies, including the following factors
    a. Performance of land use policies
    b. Potential impact of transit projects on regional land use

The evaluation of transit supportive existing land use and future patterns is similar for Small Starts project evaluation, but eliminates the growth management and some optional land use considerations.

REPORT ORGANIZATION

The report is organized in three main sections:

Section 1: Methodology

This includes an overview of the methodology used for the Corridor rating of the transit supportive land uses and multimodal mobility and a brief discussion of the importance of the measures used.

Section 2: Corridor-wide Analysis of Transit Supportive Land Use and Multimodal Mobility

This section presents a corridor-wide analysis of the existing land use and development patterns, multimodal connectivity and station access, as well as current plans and policies.

Section 3: Corridor Districts and Station Areas

This section includes a detailed explanation of existing conditions and policies for each district station, providing a qualitative discussion that further supports the rankings in Section 2. The existing conditions analysis is followed by recommendations for each district that could potentially improve the current rating of the stations under the New Starts program.

1.0 METHODOLOGY

FTA REQUIREMENTS

The Broad Street Bus Rapid Transit Corridor project represents a significant opportunity to coordinate transportation investments that can ultimately improve regional mobility, reduce congestion, and foster economic development. In order to understand and plan for these opportunities, it is important to have a clear picture of both existing conditions and future development potential along the Corridor.

The area's existing land use and development patterns provide a solid platform to support increased transit ridership if coupled with an enhanced transit system in the Broad Street Corridor. With proper planning, this major transit investment can provide an impetus for new construction and redevelopment opportunities. Conversely, future residential and employment concentrations in the Corridor help support a potential increase in transit ridership.

National research has demonstrated that stronger transit ridership occurs where large concentrations of population and employment are located within walking distance to a transit station. Station area multimodal connectivity, convenience and direct access to transit facilities are important contributing factors to supporting transit ridership, Enhancing the effectiveness and convenience of the rider's experience also helps to make transit a desirable transportation mode choice, and can provide overall improved mobility along the Corridor.

The following assessment looks at key transit supportive factors and characteristics within each of the proposed station areas along the Broad Street Corridor. This report contains a series of analytic summaries that document the physical, economic, land use and demographic characteristics of the Corridor, followed by a narrative description of each segment and finally a series of recommendations to enhance each section to improve the overall transit supportive character of the Corridor.

The land use and multimodal connectivity assessment report was prepared based on a review of current plans and policies, interviews with the local jurisdictions, and a comprehensive technical analysis using best available data from the City of Richmond and Henrico County. For the purpose of this analysis, the station area is defined as the area generally encompassing one-quarter mile radius around a proposed station. The one-quarter mile radius was applied since it represents a typical five minute walking distance from the station, and is a valuable representation of the typical ridership base for BRT. In consideration that adjacent station areas may overlap, station area boundaries were adjusted to avoid double counting population and employment data and provide clearer assessment results (see Figure 1).

Figure 1. Station areas with refined quarter-mile buffers

The following elements were analyzed during the preparation of this assessment summary:

1. Existing land use and development patterns
2. Multimodal connectivity and station access
3. Current plans and policies

1.1 Land Use and Development Patterns

The land use analysis was designed and executed to be consistent with the FTA New Starts Criteria. Population and employment densities, the ratio of jobs to households, and land development potential within a station area were evaluated (see Table 1). Population and employment densities were calculated using regional socioeconomic data for station areas based on traffic analysis zones (TAZ). Gross density indicators and jobs-to-housing ratio targets were used to comparatively evaluate transit station areas. Though ridership modeling is not the primary reason for the assessment, potential boardings were derived from the socioeconomic analysis and provide a good indication of the current and future land use balance and mix. For the purposes of evaluating station areas of varying sizes, densities are used as a common measure to reflect overall transit supportiveness for each station. Table 1 summarizes the methodology and assumptions for each measurement.

Table 1. Definitions and Assumptions of Transit Supportive Land Use Measures

Household Density	Household density is measured as households per acre. It is derived from a proportion of the population within the TAZ and assumes an average household size of 2.33 persons per dwelling unit for the City of Richmond.
Employment Density	Employment density is measured as employees per acre. It is derived from a proportion of the number of employees within the station area based on TAZ data.
Jobs-to-Housing Ratio	The jobs-to-housing ratio is an indicator of the proportion of employees and dwelling units within station areas. It is computed using household and employment densities. Jobs-to-housing ratios help to estimate the number of trips that can be produced or attracted to each station area. More jobs rich station areas represent greater trip attractions, whereas more housing rich stations represent greater trip productions.
Development Potential	Land development potential provides a measure for the availability of land along the transit corridors and in station areas. The development potential screening was completed using real estate tax assessment data available from the City of Richmond and Henrico County. Land was classified into four categories of development potential based upon the relationship between assessed land and building/improvement values. The categories were defined as follows: undevelopable (land value = 0; includes floodplain, environmental protection areas, etc.), vacant (land value > 0, improved value = 0) and, underutilized (the ratio of improved value to land value < 2). All parcels not falling into one of these three categories were defined as utilized. The analysis excluded all roads, waterways, canals and land not listed in the tax records.
Potential Boardings	Gross density indicators and jobs-to-housing ratio targets (which support desired mix of uses) were used to estimate potential boardings. The estimate assumed 6 trips per household and 2 per employee. Based on the current modeling analysis being completed under a separate analysis and socioeconomic data above, the approximate mode split can be assumed as 2.5%.

1.2 Multimodal Connectivity and Station Access

Multimodal connectivity and station access are important factors in determining the ability of a station area to support transit. A highly connected street network with adequate sidewalks, pathways, and roadway crossings helps increase pedestrian and bicyclist safety and supports transit use. In addition, providing opportunities to quickly transfer between routes or modes also facilitates transit use. Table 2 summarizes the measures used to evaluate station area walkability and accessibility.

Table 2. Definitions and Assumptions for Multimodal Mobility and Station Access Measures

Intersection Density	Intersection density is a measure of the number of intersections (nodes) per square mile. Intersection density is a proxy measure for street connectivity or grid density, walkability and accessibility.
Link to Node Ratio	Link to node ratio is a standard connectivity measure. The ratio is derived by the number of links divided by the number of nodes within a station area. Links are defined as roadway or alley segments between two nodes or a stub-out. A node is defined as a point that connects a minimum of two roadway segments.
Sidewalk to Roadway Ratio	Sidewalk to roadway ratio is a measure of walkability comparing the length of sidewalk miles to roadway miles. A low ratio is indicative of missing sidewalk facilities.
Bicycle Path to Roadway Ratio	Bicycle path to roadway ratio is a measure of available bicycle facilities. The ratio is calculated as designated bicycle path miles to roadway miles.
Bus Stop Density	Bus stop density is a measure of the intensity of bus facilities available. The density value is calculated as bus stop per square mile.
Bus Activity Score	Bus activity score is a measure that accounts for the frequency and distance of transit service. The score is an effective measure of the degree of accessibility to subarea/regional destinations and was calculated as the weighted length of bus routes.

1.3 Current Plans and Policies

Both the City of Richmond and Henrico County identified rapid transit along the Broad Street Corridor as an element of their comprehensive or master plans. These plans tie factors such as land use, urban design and economic development into the existing, planned, and/or recommended transportation infrastructure.

The following plans and policies were evaluated to indicate whether each local government was actively promoting high density transit supportive land uses. Transit supportive policies include those that promote pedestrian movements, promote mixed uses adjacent to transit, limit parking, and provide high, transit supportive by-right residential and commercial densities in station areas.

- City of Richmond Master Plan 2000-2020
- City of Richmond Downtown Master Plan
- Henrico County Vision 2026 Comprehensive Plan

2.0 CORRIDOR ANALYSIS

2.1 Land Use and Development Patterns

Land use and development patterns that support strong walking environments and access to multiple destinations within close proximity to one another help maximize transit ridership. For the purposes of this study, existing and future population and employment densities, the ratio of jobs to households, and land development potential within a station area were evaluated based on the FTA criteria for assessing land use and economic development. Stations were assigned a rating of high, medium, or low based on transit supportive development criteria and thresholds (see Table 3). Proposed transit projects that exhibit land use characteristics within the high range below would likely receive a favorable land use rating.

Table 3. Benchmarks for Land Use and Development Potential

Household Density (HH/Acre)	High	> 10
	Medium	5-10
	Low	< 5
Employment Density (Employee/Acre)	High	> 23
	Medium	5.2-23
	Low	<5.2
Jobs-to-Housing Ratio	High	< 1
	Medium	1 -5
	Low	> 5
Percent of Land That is Vacant and Developable	High	>20%
	Medium	10-20%
	Low	<10%
Percent of Land That is Underutilized	High	>20%
	Medium	10-20%
	Low	<10%
Percent of Land That is Vacant/Developable or Underutilized	High	>40%
	Medium	20-40%
	Low	<20%

Source: Federal Transit Administration, Office of Planning and Environment, *Discussion Paper on the Evaluation of Economic Development*, October 2008 and Renaissance Planning Group, 2010.

2.1.1 Population and Employment Density

Over the past several years, researchers have identified specific characteristics of land use and development patterns that strongly influence travel demand, mode choices and traffic impacts. Density, the number of households, jobs and activities within a station area, and the mix of land uses directly influence the number of person-trips generated. In particular, when larger concentrations of residents and/or employees are located within close proximity, typically one-quarter to one-half mile from the transit station, higher levels of transit ridership are often present.

While the Small Starts application considers the opening year of the project, currently planned for 2015, no socioeconomic projections for the Corridor exist for this timeframe. Therefore, the following analysis of population and employment densities used data for 2008 and 2035 from the Richmond Regional Planning District Commission (RRPDC) Socioeconomic Data Report; the RRPDC socioeconomic data replaced 2000 and 2030 projections and was received in December 2010. Household and employment densities were calculated for the Traffic Analysis Zones (TAZ) within a quarter-mile radius of each station.

Table 4 summarizes the household and employment densities for each station area. The highest residential densities for both 2008 and 2035 are located between the Robinson and Adams Stations and the highest residential densities located at Adams. Employment densities are highest in the Downtown District between the 6th and 12th Street Stations.

Table 4. Household and Employment Densities

Station	2008 Household Density (HH/Ac)	2008 Household Density Rating	2035 Household Density (HH/Ac)	2035 Household Density Rating	2008 Jobs Density (Jobs/Ac)	2008 Jobs Density Rating	2035 Jobs Density (Jobs/Ac)	2035 Jobs Density Rating
Willow Lawn	2.12	Low	3.96	Low	10.86	Med	16.23	Med
Staples Mill	1.36	Low	1.93	Low	9.30	Med	12.72	Med
Hamilton/I-195	2.27	Low	2.61	Low	13.96	Med	16.26	Med
Robinson	5.03	Med	5.78	Med	10.33	Med	12.03	Med
Hermitage/Meadow	5.99	Med	6.89	Med	7.76	Med	9.04	Med
Shafer	11.25	High	12.35	High	36.06	High	42.00	High
Adams	10.63	High	12.14	High	21.41	Med	24.94	High
3rd Street	2.52	Low	2.93	Low	27.24	High	31.73	High
6th Street	0.81	Low	2.66	Low	61.77	High	72.13	High
9th Street	1.43	Low	1.69	Low	101.91	High	118.72	High
12th Street	0.55	Low	0.66	Low	136.24	High	158.70	High
Main Street Station	2.04	Low	2.44	Low	48.10	High	56.04	High
25th Street	3.79	Low	4.54	Low	5.56	Med	6.48	Med
Rocketts Landing	0.23	Low	0.80	Low	0.91	Low	1.31	Low

Source: RRPDC and Renaissance Planning Group, 2010.

2.1.2 Land Development Potential

Land development potential measures the availability of land in station areas along the Corridor. The percent of vacant or underutilized land provides an indication of the existing conditions, the potential to support future transit-oriented development and ultimately, potential transit ridership. Vacant land is assumed to have full infill or redevelopment potential within station areas, and underutilized lands are considered to contain only a partial redevelopment potential. The land development potential was used to project additional population and housing potential and then analyzed for its support to maximize potential transit ridership. With the lack of precise zoning intensities and densities specified for City and County zoning, the added household and jobs density was calculated by extrapolating the existing zoning conditions and based on land development assumptions.

Over 50% of the land within the Broad Street Corridor was considered utilized and expected to remain stable in the future. In addition, analysis shows there is relatively little vacant land within each station area. However, significant opportunities for redevelopment exist. With the exception of the 9th and 12th Street Stations, all station areas have land that is categorized with 20% or greater development potential (vacant and underutilized). The highest development potential exists at Rocketts Landing, Hermitage/Meadow, Hamilton/I-195, and 3rd Street Stations, respectively. As properties redevelop over time, significant opportunity exists to provide a more transit supportive form of new development.

Table 5. Development Potential

Station	Development Potential	Development Potential Rating	Vacant	Vacant Rating	Redevelopable	Redevelopable Rating
Willow Lawn	23.6%	Low	2.4%	Low	21.2%	High
Staples Mill	34.6%	Med	2.9%	Low	31.7%	High
Hamilton/I-195	41.3%	High	3.8%	Low	37.5%	High
Robinson	27.3%	Med	2.9%	Low	24.4%	High
Hermitage/Meadow	48.2%	High	7.0%	Low	41.2%	High
Shafer	25.2%	Med	3.1%	Low	22.1%	High
Adams	28.5%	Med	8.4%	Low	20.1%	High
3rd Street	41.1%	High	12.6%	Med	28.5%	High
6th Street	20.6%	Med	5.0%	Low	15.6%	Med
9th Street	16.4%	Low	2.0%	Low	14.4%	Med
12th Street	16.3%	Low	5.2%	Low	11.2%	Med
Main Street Station	35.5%	Med	12.1%	Med	23.4%	High
25th Street	29.7%	Med	8.6%	Low	21.1%	High
Rocketts Landing	49.4%	High	32.2%	High	17.2%	Med

Source: City of Richmond, Henrico County and Renaissance Planning Group, 2010.

Table 6 compares the growth forecast by RRPDC for the period from 2008 to 2035 to the total potential growth based on the existing land development potential. RRPDC growth projections indicate an approximate increase of 1,000 households and 7,500 jobs for the Corridor over the next 27 years.

Under current zoning and by maximizing the land development potential, the Corridor has the potential to capture an additional 3,000 households and nearly 40,000 jobs. Since this Corridor is already rich in jobs, zoning changes that allow more households to support a mixture of uses will greatly enhance the potential for increased transit ridership.

Table 6. Comparison of Projected Growth to Capacity Under Existing Zoning

Station	Growth Forecast (RRPDC data)		Total Potential Growth (based on Land Development Potential)		Growth Forecast (RRPDC data)		Total Potential Growth (based on Land Development Potential)	
	Household	Jobs	Household	Jobs	Household	Jobs	Household	Jobs
Willow Lawn	231	673	310	1,163	High	High	High	High
Staples Mill	73	429	494	1,399	High	High	High	High
Hamilton/I-195	43	289	687	1,871	Med	Med	High	High
Robinson	91	207	150	3,471	Med	Med	High	High
Hermitage/Meadow	109	155	182	2,611	Med	Med	High	High
Shafer	138	747	206	5,234	Low	Med	Med	High
Adams	153	359	246	4,205	Med	Med	High	High
3rd Street	27	298	111	5,484	Med	Med	High	High
6th Street	108	603	32	2,623	High	Med	High	High
9th Street	17	1,071	35	2,291	Med	Med	High	High
12th Street	9	1,864	37	2,550	Med	Med	High	High
Main Street Station	40	774	115	3,106	Med	Med	High	High
25th Street	67	83	148	1,431	Med	Med	High	High
Rocketts Landing	40	28	312	1,852	High	High	High	High
Corridor	1,145	7,579	3,064	39,289				

Source: RRPDC and Renaissance Planning Group, 2010.

2.1.3 Jobs and Housing Balance

The jobs and housing balance indicates the ratio of available housing to available jobs within a geographic area. It also can serve as a measure of the presence of multiple land uses and the degree to which their locations are balanced across the area. Few trips are made between similar land uses (i.e., few trips are between two homes). Rather, trips are usually made between different uses (i.e., a trip from home to work or from work to lunch). Jobs rich station areas serve as trip attractions, whereas more housing rich stations serve as trip productions.

A jobs-to-housing ratio of 2:1 is typically promoted as an ideal balance that provides jobs and retail opportunities for all of the population within a corridor or area. It also reflects a better balance of internal trip distribution and reduction of longer distance commuting trips. Bearing a ratio of nearly 16:1, the Corridor is jobs rich with nearly 68,000 jobs and 4,300 houses. A similar imbalance is reflected at the station level. Only the Adams, Robinson, 25th Street, and Hermitage/Meadow Stations show a slightly better balance, albeit one that is lower than the target. The high concentration of jobs along the Corridor demonstrates a strong pattern of in-commuting to the Corridor.

Employment and household projections for 2035 show little change when compared to 2008 in the overall balance of jobs and houses both at the Corridor and station area levels. The jobs/housing balance does show a stable trend with a ratio of approximately 7.5:1. With significant land available for redevelopment, there are opportunities to improve this balance in the future.

Table 7. Existing Jobs-to-Housing Ratio (2008)

Station	Households (2008)	Employment (2008)	Jobs/Housing Ratio (2008)	Jobs/Housing Rating (2008)
Willow Lawn	266	1,363	5.1	Low
Staples Mill	170	1,167	6.9	Low
Hamilton/I-195	285	1,754	6.2	Low
Robinson	610	1,253	2.1	Med
Hermitage/Meadow	727	942	1.3	Med
Shafer	1,413	4,530	3.2	Med
Adams	1,080	2,175	2.0	Med
3rd Street	167	1,805	10.8	Low
6th Street	47	3,592	76.2	Low
9th Street	91	6,496	71.4	Low
12th Street	46	11,305	247.7	Low
Main Street Station	199	4,696	23.6	Low
25th Street	342	502	1.5	Med
Rocketts Landing	17	64	3.9	Med
Corridor	5,460	41,642	7.6	Low

Source: RRPDC and Renaissance Planning Group, 2010.

Table 8. Future Jobs/Housing Ratio (2035)

Station	Households	Employment (2035)	Jobs/Housing Ratio (2035)	Jobs/Housing Rating (2035)
Willow Lawn	496	2,036	4.1	Med
Staples Mill	243	1,596	6.6	Low
Hamilton/I-195	328	2,043	6.2	Low
Robinson	702	1,460	2.1	Med
Hermitage/Meadow	836	1,097	1.3	Med
Shafer	1,552	5,276	3.4	Med
Adams	1,234	2,533	2.1	Med
3rd Street	194	2,102	10.8	Low
6th Street	155	4,195	27.1	Low
9th Street	108	7,567	70.4	Low
12th Street	55	13,169	241.0	Low
Main Street Station	239	5,470	22.9	Low
25th Street	410	585	1.4	Med
Rocketts Landing	56	92	1.6	Med
Corridor	6,605	49,221	7.5	Low

Source: RRPDC and Renaissance Planning Group, 2010.

2.1.4 Potential Boardings

While a separate transit ridership modeling effort is being completed for the study, the following potential boardings assessment was prepared using RRPDC socioeconomic data to illustrate how land use conditions support transit ridership and travel mode choices. The estimated person trip and boardings were calculated using assumption for households (six trips per dwelling unit) and jobs (two trips per employee).

The potential boardings assessment results provide a good indication of the current and future land use balance and mix. More jobs rich station areas serve as trip attractions, whereas more housing rich stations serve as trip productions. The high concentration of jobs (i.e, attractions) along the Corridor demonstrates a strong pattern of in-commuting to the Corridor. Currently most of these commute trips are by car.

Based on the socioeconomic data summarized at the TAZ level, the estimated ridership for the Broad Street Corridor can be assumed to be approximately a 2.5% mode split for total productions and attractions based on socioeconomic data for 2008. Under existing conditions, the highest concentration is located at the 9th Street, 12th Street, and Shafer Stations (see Table 9). Using 2035 projections (see Table 10), boardings increase most significantly at Shafer, 6th Street, 9th Street, 12th Street and Main Street Stations.

Table 9. Land Use Derived Estimate of Existing Boardings (2008)

Station	Households	Jobs	Estimated Person Trips Prod	Estimated Person Trips Attrs	Estimated Boardings	Boardings Rankings
Willow Lawn	266	1,363	1,594	2,725	108	Low
Staples Mill	170	1,167	1,020	2,333	84	Low
Hamilton/I-195	285	1,754	1,710	3,507	130	Low
Robinson	610	1,253	3,663	2,506	154	Low
Hermitage/Meadow	727	942	4,360	1,884	156	Low
Shafer	1,413	4,530	8,480	9,059	438	Low
Adams	1,080	2,175	6,480	4,349	271	Low
3rd Street	167	1,805	1,001	3,609	115	Low
6th Street	47	3,592	283	7,184	187	Low
9th Street	91	6,496	546	12,991	338	Low
12th Street	46	11,305	274	22,610	572	Med
Main Street Station	199	4,696	1,194	9,392	265	Low
25th Street	342	502	2,054	1,005	76	Low
Rocketts Landing	17	64	99	129	6	Low

Source: RRPDC and Renaissance Planning Group, 2010.
Note: The results are for evaluation purposes and do not reflect travel demand model calculations.

Table 10. Land Use Derived Estimate of Future Boardings (2035)

Station	Households	Jobs	Estimated Person Trips Prods	Estimated Person Trips Attrs	Estimated Boardings	Boardings Rankings
Willow Lawn	496	2,036	2,978	6,107	227	Low
Staples Mill	243	1,596	1,456	4,787	156	Low
Hamilton/I-195	328	2,043	1,966	6,129	202	Low
Robinson	702	1,460	4,211	4,379	215	Low
Hermitage/Meadow	836	1,097	5,013	3,292	208	Low
Shafer	1,552	5,276	9,310	15,829	628	Med
Adams	1,234	2,533	7,401	7,600	375	Low
3rd Street	194	2,102	1,165	6,307	187	Low
6thStreet	155	4,195	929	12,584	338	Low
9th Street	108	7,567	645	22,700	584	Med
12th Street	55	13,169	328	39,506	996	Med
Main Street Station	239	5,470	1,432	16,411	446	Low
25th Street	410	585	2,458	1,756	105	Low
Rocketts Landing	56	92	337	277	15	Low

Source: RRPDC and Renaissance Planning Group, 2010.
Note: The results are for evaluation purposes and do not reflect travel demand model calculations.

By improving the jobs-to-housing ratio with increased residential densities and improving the quality of the urban environment, the proposed transit system has greater potential to capture transit users and better serve the employment uses along the Corridor.

2.2 Multimodal Connectivity and Station Access

Multimodal connectivity and station access are important factors in determining the ability of a station area to support transit. A highly connected street network with adequate sidewalks, pathways, and roadway crossings helps increase pedestrian and bicyclist safety and supports transit use. In addition, providing opportunities to quickly transfer between routes or modes facilitates transit use. To evaluate station area walkability and accessibility, the measures shown in Table 11 were applied.

Table 11. Measures for Station Area Walkability and Accessibility

Intersection Density (per sq. mile)	High	> 465
	Medium	465 – 155
	Low	< 155
Link-to-Node Ratio	High	> 4
	Medium	1 – 4
	Low	<1
Sidewalk to Roadway Ratio	High	>0.75
	Medium	0.75 – 0.25
	Low	< .25
Bicycle Path to Roadway Ratio	High	> 0.75
	Medium	0.75 – 0.25
	Low	< .25
Bus Stop Density (per sq. mile)	High	> 1000
	Medium	1000 – 500
	Low	< 500
Bus Activity Score High / Medium / Low	High	> 10
	Medium	10 – 1
	Low	< 1

Source: Renaissance Planning Group, 2010.

2.2.1 *Station Area Connectivity*

The surrounding street network is an important consideration when evaluating access to a station area. The walking range of the typical person is a one-quarter to one-half mile radius or about a five to ten minute walk from a transit station. Therefore, a complete grid street network with shorter block lengths provides improved access to many more destinations than a street network with long block lengths and/or cul-de-sacs.

Link-to-node ratios and intersection density were used to quantify how well a roadway network serves station areas. Link-to-node ratios evaluate the number of segments between intersections (links) compared to intersections (nodes). A higher index means that travelers have an increased route choice that allows more direct connections between any two locations. Intersection density measures the number of intersections within the station area. The measurement corresponds closely to block size with greater intersection density reflecting smaller blocks, and smaller blocks are indicative of greater walkablity in the station area. Intersection density has received relatively little attention in research and in public policy, but recent studies suggests that it is the most important factor for walking and one of the most important factors for increasing transit use and reducing miles driven.

Intersection density is highest at Adams Street and within the Downtown District Station areas and decreases for station areas both east and west of downtown. The block lengths currently range from 300 feet in the central business district to 1000 feet in the east and west ends of the Corridor reflecting that the station areas in the downtown are more walkable and accessible.

Table 12. Station Area Connectivity

Station	Station Area (miles^2)	Roadway (links)	Intersections (nodes)	Link - Node Ratio		Intersection Density (per mile^2)	
Willow Lawn	0.20	39.00	13.00	3.00	Med	65	Low
Staples Mill	0.20	50.00	17.00	2.94	Med	85	Low
Hamilton/I-195	0.20	59.00	22.00	2.68	Med	110	Low
Robinson	0.19	56.00	23.00	2.43	Med	121	Low
Hermitage/Meadow	0.19	75.00	23.00	3.26	Med	121	Low
Shafer	0.20	100.00	41.00	2.44	Med	205	Med
Adams	0.16	92.00	46.00	2.00	Med	288	Med
3rd Street	0.10	53.00	18.00	2.94	Med	180	Med
6th Street	0.09	58.00	14.00	4.14	High	156	Med
9th Street	0.10	79.00	22.00	3.59	Med	220	Med
12th Street	0.13	54.00	21.00	2.57	Med	162	Med
Main Street Station	0.15	107.00	35.00	3.06	Med	233	Med
25th Street	0.14	77.00	28.00	2.75	Med	200	Med
Rocketts Landing	0.11	16.00	10.00	1.60	Med	91	Low

Source: City of Richmond, Henrico County and Renaissance Planning Group, 2010.

Policies that limit block lengths or establish connectivity standards to encourage a grid of vehicular connections and small blocks to be traversed by pedestrians could further support station area development. Maximum block length requirements ranging from 200 to 600 feet are appropriate.

2.2.2 *Multimodal Infrastructure*

Providing safe and comfortable places for pedestrians and cyclists to navigate along roadways can support access and use of a transit system. Walking and cycling conditions are affected by the quantity and quality of sidewalks, crosswalks and paths; path system connectivity; and the security and attractiveness of pedestrian facilities and features, such as bike racks and changing facilities.

Overall, the Corridor has ample sidewalk coverage as indicated by the sidewalk to roadway ratio analysis (see Table 13), and widths in the 10 to 20 feet range are the norm. Sidewalks are less prevalent at the Willow Lawn and Rocketts Landing Stations, where sidewalks may not be provided or connect to one another. Though sidewalk coverage is adequate overall, surfaces are inconsistent and generally not well maintained. There are also opportunities to improve crossings with high visibility striping, accessible curb ramps, and pedestrian countdown signals to better support pedestrian use.

Bicycle infrastructure, on the other hand, is generally lacking throughout the Corridor. No bicycle facilities currently exist on Broad Street. A few parallel routes exist within one-half mile of the Corridor, but only in a few cases (Hermitage/Meadow, 3rd Street, and Main Street Station) do routes connect a proposed station. The longest single bicycle route exists within the Rocketts Landing Station area along the Orleans/Old Osborne Turnpike, but it does not connect to the station area. Supporting bicycle facilities, such as bike racks, were also lacking.

Table 13. Sidewalk and Bicycle Connectivity

Station	Roadway (miles)	Sidewalk (miles)	Bicycle Path (miles)	Sidewalk-Roadway Ratio	Sidewalk-Roadway Rating	Bicycle Path - Roadway Ratio	Bicycle Path - Roadway Rating
Willow Lawn	2.61	1.43	0.00	0.27	Med	0.00	Low
Staples Mill	3.26	3.92	0.00	0.60	Med	0.00	Low
Hamilton/I-195	3.65	4.64	0.00	0.64	Med	0.00	Low
Robinson	3.23	5.04	0.59	0.78	High	0.18	Low
Hermitage/Meadow	3.37	5.22	0.90	0.77	High	0.27	Med
Shafer	4.99	7.92	0.59	0.79	High	0.12	Low
Adams	5.02	7.88	0.58	0.78	High	0.12	Low
3rd Street	2.60	4.66	0.99	0.90	High	0.38	Med
6th Street	2.14	3.66	0.38	0.86	High	0.18	Low
9th Street	2.56	3.97	0.43	0.78	High	0.17	Low
12th Street	2.55	3.43	0.33	0.67	Med	0.13	Low
Main Street Station	4.38	5.64	0.74	0.64	Med	0.17	Low
25th Street	3.61	5.60	0.70	0.78	High	0.19	Low
Rocketts Landing	1.25	0.37	0.46	0.15	Low	0.37	Med

Source: City of Richmond, Henrico County and Renaissance Planning Group, 2010.

Updating plans to include detailed standards for pedestrian and bicycle facilities, detailed plans for specific high-priority improvements, and funding/implementation strategies for each station area could help support future transit.

2.2.3 *Transit Stop Density and Activity*

Locating BRT stops at key locations and connecting them to regular buses help maximize the effectiveness of overall transit service. Improving connections between BRT and local bus schedules allows for easier transfers and shorter waiting time. Shortening the duration of a transit trip supports improving service and attracting more riders.

To assess the ease with which potential riders could transfer between modes, bus stop density and activity was measured for the approximate one-quarter mile around each station. Bus stop density is highest between 3rd and 9th Street Stations.

The bus activity score is a measure that accounts for the frequency and distance of transit service. The score is an effective measure of the degree of accessibility to subarea/regional destinations, and was calculated as the weighted length of bus routes. A higher bus activity score reflects a proportionately greater number of longer trip distance bus routes as well as an overall higher frequency of service. Based on this analysis, existing transit service moderately supports access to regional destinations.

Table 14. Transit Stop Density and Activity

Station	Station Area (miles^2)	Bus Route (miles)	Bus Stops	Bus Stop Density (Station Area)	Bus Stop Density (per sq. mile)		Bus Activity Score	
Willow Lawn	0.20	2.52	3	15	75	Low	2.75	Med
Staples Mill	0.20	1.78	9	45	225	Low	1.50	Med
Hamilton/I-195	0.20	1.07	10	50	250	Low	1.30	Med
Robinson	0.19	3.28	13	68	360	Low	4.46	Med
Hermitage/Meadow	0.19	3.22	10	53	277	Low	4.36	Med
Shafer	0.20	5.10	20	100	500	Med	6.89	Med
Adams	0.16	4.84	24	150	938	Med	6.50	Med
3rd Street	0.10	4.48	17	170	1700	High	5.42	Med
6th Street	0.09	7.69	20	222	2469	High	7.63	Med
9th Street	0.10	9.34	15	150	1500	High	8.51	Med
12th Street	0.13	5.26	9	69	533	Med	4.46	Med
Main Street Station	0.15	2.90	14	93	622	Med	3.02	Med
25th Street	0.14	0.52	14	100	714	Med	1.19	Med
Rocketts Landing	0.11	0.00	0	0	0	Low	0.00	Low

Source: GRTC and Renaissance Planning Group, 2010.

2.3 Current Land Use Plans and Policies

Both the City of Richmond and Henrico County have identified rapid transit along the Broad Street Corridor as an element of their primary comprehensive or master plans governing land use. These plans tie factors such as land use, urban design and economic development into the existing, planned, and/or recommended transportation infrastructure.

2.3.1 Downtown Master Plan – City of Richmond

The City of Richmond Downtown Master Plan, as amended, was adopted by City Council in July 2009 after a two-year city-wide effort. The majority of the Broad Street Corridor is addressed in the Downtown Plan. The Downtown study area boundary encompasses the Broad Street Corridor from 21st Street to the east and to Harrison Street to the west. The area between Harrison Street west to the city line at Staples Mill Road is not covered by the Downtown Plan.

As the first comprehensive planning effort undertaken by the City in almost a decade, the Downtown Plan is based upon urban form and design rather than land use and sets the tone for future planning in Richmond. Overall, the vision of the Downtown Plan is to transform Downtown into a more pedestrian friendly environment featuring higher densities, mixed uses and infill development. The Plan views high quality transit options as essential to achieving these goals and uses the following transit-oriented themes to provide a foundation:

- Diversifying land uses
- Providing a full range of transportation options - encouraging alternative transportation modes by re-introducing a trolley system
- Providing connectivity between land uses-between the James River and Broad Street
- Improving streetscapes and the pedestrian experience
- Reinforcing the scale and character of existing architecture through infill and redevelopment
- Promoting of ground-floor, street fronting uses
- Increasing the mix of uses vertically as well as horizontally, and
- Introducing a range of housing types and a mix of commerce as well as office uses

2.3.2 City Master Plan 2000-2020 – City of Richmond

The City Master Plan was adopted by City Council in 2000 and is a traditional comprehensive planning document that summarizes the City's visions and goals, key strategies and directions, transportation, natural resources and the environment, public facilities and services, neighborhoods and housing, community character, and land use.

The Plan's land use recommendations are consistent with supporting implementation of a premium transit service along Broad Street, and includes two key strategies directly supportive of the Broad Street Corridor, as follows:

- Development of a regional multi-modal public transportation system consisting of light rail transit along Broad Street, commuter rail, express bus service and improved taxi service
- Recognition of Downtown as the primary business and employment center for Richmond and the metropolitan area in need of continuous support as an employment center, an entertainment and visitation destination, and as a residential neighborhood

The Plan calls for community commercial uses along most of the Corridor west of Downtown and mixed use within and east of Downtown. The Plan calls for residential and office uses above ground floor commercial uses with zero setbacks, and parking that is hidden from view. The Plan recommends phasing out auto-oriented uses and emphasizes that investment in a multimodal transportation system would both support and spur this kind of redevelopment over time.

2.3.3 Vision 2026 Comprehensive Plan - Henrico County

Henrico County's Vision 2026 Comprehensive Plan was adopted in August 2009 as the result of a multi-year effort with citizen input at strategic points during the process. The Plan includes mixed use development recommendations with explicit guidelines for encouraging pedestrian-oriented design, reducing automobile dependency and integrating transit. The Plan recommends urban mixed use zoning designations for areas near both terminal locations of the Corridor and suggests consideration of light rail along Broad Street, as recommended in the 2003 Richmond Area Metropolitan Planning Organization study.

In addition, the Plan recommends:

- Intensifying land uses through infill and redevelopment taking advantage of existing infrastructure, services and utilities
- Promoting diverse land use patterns including mixed use town centers and traditional neighborhood development
- Increasing the quantity and variety of housing types near employment centers
- Encouraging economic development nodes (mixed use large tract development that provides retail services and employment opportunities near residential concentrations); promoting new and expanding growth where various transportation modes converge
- Promoting development and implementation of multimodal transportation facilities and intermodal connectivity
- Encouraging development that includes facilities to accommodate the pedestrian and bicyclist as well as transit

2.4 Land Development Policies

The above plans and policies were evaluated to indicate whether each local government was actively promoting high density transit supportive land uses. Transit supportive policies include those that promote pedestrian movements, promote mixed uses adjacent to transit, limit parking, and provide high, transit supportive by-right residential and commercial densities in station areas.

2.4.1 Density, Intensity and Mix of Uses

The City Master Plan 2000-2020 identifies additional density and intensity and bicycle and pedestrian facilities as necessary to improve access to and demand for transit systems, such as the light rail recommended for Broad Street. Specific recommendations for West Broad Street between Belvidere Street and the Boulevard include encouraging vacant buildings to develop first floor commercial uses with office and/or residential uses on the upper floors. The Plan recognizes that Broad Street ideally should be a dense urban development area with an emphasis on pedestrians and ensuring compatibility with adjacent residential development. The Plan embraces form-based principles with recommendations for new development along West Broad Street to be oriented to the street without setbacks, and promotes using a strong urban form that complements the prevailing urban storefront character. Additional off-street parking is planned to be provided with minimal visual impact on the Corridor. Table 15 summarizes the City's future land use categories for the West Broad Street area located west of Harrison Street to the Henrico County line.

Table 15. City of Richmond Master Plan

Land Use Category	Typical Land Uses	Typical Density	Recommended Zoning Categories
Single Family Residential (low density)	SF detached dwellings, schools, places of worship, neighborhood parks, recreation facilities, limited public and semi-public uses	Up to 7 DU/Acre	R-1, R-2, R-3, R-4, R-5
Single Family Residential (medium density)	One and two family dwellings (attached and detached), schools, places of worship, neighborhood parks and recreation facilities, limited public and semi-public uses	Between 8 to 20 DU/Acre	R-5A, R-6, R-7
Multi-Family (medium density)	Multi-family dwellings; day nurseries, adult care and residential support uses such as schools, places of worship, neighborhood parks and recreation facilities, limited public and semi-public uses	Up to 20 DU/Acre	R-43, R-48
Community Commercial	Office, retail, personal service and other commercial and service uses; intended to provide the shopping and service needs of residents of a number of nearby neighborhoods or a section of the City. As compared to Neighborhood Commercial, this category includes a broader range of uses of greater scale and intensity, with greater vehicular access and orientation, but that are also compatible with nearby residential areas.		B-2, UB
General Commercial	A broad range of office, retail, general commercial, wholesale and service uses, typically located along major transportation corridors and serving large portions of the City, the region, or the travelling public.	Typically of larger scale and intensity than Community Commercial uses; may not always be highly compatible with residential uses.	B-3
Transitional Office	Professional, business and administrative offices, medical and dental clinics that are compatible with adjacent residential uses and serve as a transition between residential areas and nearby commercial or other higher intensity uses or features.	Low to medium intensity	RO-1, RO-2
Mixed Use	Combinations of office, retail, personal service, general commercial and service uses and, in some cases, multi-family residential and dwelling units above ground floor commercial. Generally such areas consist of a mix of several types of uses designed and arranged to be compatible with one another. Each use can function independently, but all benefit from proximity to one another.		B-5, UB
Institutional	Institutional uses such as places of worship, private schools, universities, museums, hospitals and other care facilities.	Typically this category includes larger scale uses, while small scale uses of this type are incorporated within the surrounding land use categories.	Institutional
Industrial	Manufacturing, processing, research and development, warehousing, distribution, office-warehouse and service uses. Office, retail and other uses that complement industrial areas are often secondary uses. The mix and character of such areas may vary depending on the location and available highway access.		OS, M-1, M-2

Source: City of Richmond Master Plan, 2000.

These recommended land use categories reflect a range of uses with residential densities up to 20 dwelling units per acre served by neighborhood commercial uses and buffered from heavier intensity general commercial and industrial uses by community commercial and transitional office. The mixed use category begins to introduce a more transit supportive combination of office, retail and residential uses coupled with complementary zoning that permits a mix of uses within buildings as well as within blocks and neighborhoods.

The City of Richmond Downtown Master Plan recommends that future development comply with established "Character Areas" based upon an evaluation of existing conditions. Each Character Area has a unique set of urban design qualities including building orientation and height, sidewalk configuration and streetscape standards. They reflect the existing built environment and focus future development on infill and redevelopment strategies.

Along the Broad Street Corridor, the Character Areas are mixed use, of medium to high density, and encourage ground floor retail with residential and office uses above. The Plan recommends a variety of restaurants, convenience stores, high-end specialty shops, national retailers and everyday services to support the thousands of workers in Downtown as well as residents. There is an emerging trend of downtown apartments and condominiums, where older buildings not originally intended for residential uses are adaptively reused and provide opportunities to improve the balance between office, retail and residential uses. Recommended incentives include micro loans and grants, a reduction in permit fees, tax relief, a decrease in parking requirements, increased density, and public infrastructure improvements. Table 16 summarizes the City of Richmond Downtown Plan future land use categories. These categories emphasize mixed use, highly pedestrian-oriented, and transit supportive density and intensity recommendations.

Table 16. City of Richmond Downtown Plan

	Typical Land Uses	Typical Density
General Urban Area	Mixed use development distributed along medium sized blocks with a connected network of blocks, streets and buildings shaping the public space. The mix of buildings ranges from single-family homes to rowhouses to mixed use main street buildings.	Medium density
Urban Center Area	Mixed use development with a fine-grained street network, wide sidewalks, regular street tree plantings and minimal setbacks. Parking is either on-street or at the rear of the lots. Buildings are 4-6 stories with a dense mix of office and residential above first floor commercial uses.	Higher density
Urban Core Area	An intense mix of uses distributed along urban blocks with wide sidewalks, regular street tree planting with 5+ story buildings containing a range of office, residential and retail space. Buildings are typically located on larger lots with an active street frontage with doors and windows fronting directly on the sidewalk; one building may cover a significant portion of the block. Uses are minimally restricted and commercial uses are permitted on the ground floor in all cases. Parking is located on-street or mid-block in lined parking garages. If rear alleys exist parking is accessed from the alley.	High density

Source: City of Richmond Downtown Plan, 2009.

In the past three years, the City of Richmond has sought to introduce form-based principles of new urbanism into the Zoning Ordinance by increasing the mix of uses permitted within most zoning classifications, narrowing setbacks, decreasing parking requirements and adjusting lot area, coverage and density requirements. Most of the City of Richmond zoning classifications found within one-quarter mile of the transit stations emphasize transit supportive mix of uses, permitted densities, and parking exemptions (see Appendix for additional details).
The Henrico County's Vision 2026 Comprehensive Plan reflects the County's more generalist approach to comprehensive planning, revealing the intention to build full flexibility into the planning and zoning process; project approvals are a result of individually negotiated development proffers. The Henrico County Vision 2026 promotes development at densities that can be supported by site conditions, availability of public facilities and the transportation network. Mixed use developments are promoted as infill or redevelopment of sites, where public facilities are available to handle an intensification of land uses. Vertical mixed uses are strongly encouraged in the Urban Mixed Use (UMU) and traditional neighborhood development areas; with commercial uses recommended for the lower stories of high rise structures, offices on secondary stories and residential uses on upper stories.

Henrico County land use categories for the Broad Street Corridor include Suburban Residential 2, Multi-Family Residential, Commercial Arterial, Commercial Concentration, Office, Light Industrial, Heavy Industrial and Urban Mixed Use. The UMU category is the only land use classification that promotes a mix of residential and non-residential land uses, and yet the development community has been extremely receptive of the UMU category and its matching zoning classification. The County has approved several promising UMU development projects in recent years, one of which is located beyond the study area in the Short Pump area and is approaching buildout. Table 17 summarizes Henrico County's Vision 2026 Comprehensive Plan future land use categories.

In addition to the UMU land use category, Vision 2026 includes several land use categories that permit a range of densities and a mix of land uses: Urban Residential, Suburban Mixed use and Traditional Neighborhood Development. These categories permit a density from 3.4 to 12 dwelling units per acre and a full mix of uses. These categories are designated further west along the Broad Street Corridor from the interchange with I-64, just west of the proposed Willow Lawn Station to the Goochland County line (see Table 18).

Henrico County's Zoning Ordinance is also supportive of transit in a few zoning classifications that permit limited mixing of multifamily development with commercial uses and services (R-5 and R-6, B-1, B-2 and B-3) and strongly mixed with urban densities in the UMU zone. All other zoning classifications are primarily single use and perpetuate the separation of uses typical of suburban localities. Certain zoning classifications permit buildings up to 200 feet with increased density and shared parking following a provisional use permit approval. Though the Henrico Zoning Ordinance does not have the variety of zoning classifications and form-based provisions similar to the City of Richmond, there is some flexibility is built into their codes and policies.

Table 17. Henrico County Vision 2026

	Typical Land Uses	Typical Density
Suburban Residential 2 (SR2)	Detached, single-family residential uses.	Maximum of 3.4 units per acre.
Multi-Family Residential (MFR)	Multi-family dwellings such as apartments, townhouses and condominium complexes.	Maximum of 19.8 units per acre.
Urban Mixed Use (UMU)	A range of residential, commercial, public and semi-public uses that emphasize pedestrian-oriented activity centers which may contain a mix of retail, office, multi-family residential, cultural, educational, open space and other public and private uses, with a balance among the various uses. a mix of uses can occur within a single structure, in a group of structures on a parcel, or on a group of parcels. Multi-story buildings with a vertical mix of uses are encouraged.	40 DU/acre on approximately 60% of the land area of the master-planned site. A minimum of 20% of land area must be dedicated open space and natural resource protection. Commercial and office/service uses should be developed in a quantity that can balance the residential development.
Office (OF)	Development of offices on individual properties rather than an "office park." Uses include professional and administrative offices, medical offices, artist studios, child care centers, banks, employment agencies, funeral homes, etc.	Varying intensities
Light Industry (LI)	Manufacturing, fabricating and warehousing establishments with the least potential for adverse impacts on adjacent development. Uses and provisions will mitigate noise, heavy truck traffic, fumes, vibration or other forms of pollution.	
Heavy Industry (HI)	Manufacturing and fabricating establishments which generally produce noise, vibration, heavy truck traffic, fumes and other impacts which may be objectionable to adjacent users.	
Commercial Arterial (CA)	Wholesale and retail sales and service establishments that may function independently of adjoining development and require individual access to a roadway.	
Commercial Concentration (CC)	Retail and/or wholesale sales and service establishments with coordinated design for shared parking areas and shared points of access to a roadway.	

Source: Henrico County Vision 2026

Table 18. Henrico County Vision 2026 Land Uses

	Typical Land Uses	Typical Density
Urban Residential 2 (UR)	Although limited to residential uses, this category permits a variety of housing types and higher densities in neighborhoods exhibiting many characteristics of Traditional Neighborhood Development.	3.4 to 6.8 units per acre.
Suburban Mixed Use (SMX)	A variety of housing types as the primary use, with a minimum of 5% of the area dedicated to nonresidential uses including open space/recreation, office/service and commercial uses. a minimum of 15% open/recreation space and/or preservation of natural resources.	Maximum of 4 units per acre.
Traditional Neighborhood Development (TND)	Mix of housing types and small, local-scale retail and service uses that serve the local population. Encourage vertically-mixed structures. Multi-story buildings with a vertical mix of uses are encouraged. A minimum of 20% of land area to be dedicated to open/recreation space.	Maximum 12 units per acre on 60% of the land area. A minimum of 20% of the land area should be dedicated to nonresidential uses and should include both office and commercial uses.

Source: Henrico County Vision 2026

Henrico County's overlay district approach to planning allows developers to propose higher-intensity uses such as UMU, if they can negotiate the required urban services with the County. The County is anticipating additional use of the UMU zoning category in future, and has recently completed a study of the Innsbrook area that doubles its density and intensity and creates a more pedestrian-oriented urban environment.

2.4.2 Parking

Henrico County's parking requirements reflect typical suburban standards with the exception of the shared parking available in R-5, R-6, and the slightly reduced parking requirement available in UMU, or by request from the Planning Commission if adequate evidence is provided that the sharing of certain uses causes a reduction in the parking demand. In contrast, the City has eliminated parking requirements in several zoning classifications and has created parking overlay zones for the exemption of requirements for underlying areas and the credit of others toward shared parking.

The City of Richmond Master Plan and the Downtown Plan both recommend development of an integrated system of clearly marked, affordable and conveniently located parking garages either as part of the capital improvements program, as part of a public-private entity, or through a special authority. The plans recommend that garages be placed at the interior of the block and lined with habitable space for shops, offices and apartments and be sensitive to the scale and design of surrounding structures. Shared parking standards are recommended to maximize the use of both structured and surface parking. Retention of on-street parking is recommended in the Downtown Plan to serve the retailers, particularly along Broad Street.

2.4.3 *Walkability*

The Downtown Plan recommends streetscape improvements such as street tree replacement and addition, street furniture, historic markers, signage and wayfinding, unique lighting and distinct paving and the creation of memorable intersections, gateways and places with the creation of a series of small parks or plazas in vacant spaces to improve the pedestrian experience in Downtown. Proposed street sections for Broad Street in the Downtown area include wide sidewalks with a canopy of shade trees and/or a system of arcades and awnings for pedestrian comfort, street furniture such as benches and planters, and frequently placed and maintained trash cans to help keep the street clean. An active street is encouraged through recommendations for human-scaled public façade respecting the height and fenestration of historic buildings, responding to their level of architectural detail, in particular their pattern of window and door openings.

Henrico's Vision 2026 encourages sidewalks and other pedestrian facilities in new developments as well as connections to other neighborhoods and key destinations such as schools, libraries and parks. In addition, the Plan encourages the inclusion of residential units in vertical, mixed use developments to promote housing opportunities near existing and future employment centers, insisting upon pedestrian orientation as the emphasis of mixed use developments, discouraging the accommodation of the automobile as primary transportation mode.

Vision 2026 introduced the Mixed Use Land Use Group that encourages significantly higher intensity and density, pedestrian-friendly and walkable site design while accommodating bicycle traffic safety. Other land use groups also support the provision of access and circulation systems for pedestrians and bicyclists. The Residential Land Use Group recommends the use of alleys for rear lot access in the Urban Residential category. The Office/Service/Industrial Land Use Group recommends that multi-building and multi-phase developments be designed to include an interconnected, interior street network, providing pedestrian circulation through a series of sidewalks and trails connected with existing and planned off-site paths. The Retail/Commercial Land Use Group recommends that pedestrian circulation be provided through on-site walkways connected to adjacent public sidewalks and uses. In addition, the transportation chapter of the Plan states that "the zoning and subdivision ordinances will be amended to promote high-quality, diverse land use patterns including mixed use town centers, traditional neighborhood developments and villages, all of which are pedestrian-friendly."

2.4.4 Transit

The City Master Plan recommends development of light rail along West Broad Street as a critical component of an envisioned "regional multi-modal transportation system consisting of commuter and light rail, local and express buses, BRT transitways, ridesharing, improved taxi service and bikeways to support the safe, efficient movement of people and goods." The Master Plan recommends establishment of a light rail transit system connecting key stops within the City and metropolitan area along major transportation corridors, including Broad Street from the Main Street Station to the west.

This concept is further refined in the Downtown Plan and recommends reintroducing the streetcar along Broad Street with the establishment of a rapid transit system as a first step. Both the City Master Plan and Downtown Plan acknowledge the long term need for improved connectivity between the Virginia Commonwealth University Monroe Park and Medical Center of Virginia (MCV) campuses, western Downtown to City Center, Manchester to Shockoe, the Capitol District, the Convention Center, and Jackson Ward to serve residents, visitors and workers alike. The Downtown Plan recommends a street section that includes on-street parking to provide a buffer between pedestrian and automobiles, two traffic lanes and dedicated transit lanes in the center of the roadway. The Plan integrates recommendations for transit with other key transportation strategies, such as traffic calming, parking management and pedestrian / bicycle facility improvement.

Up to this time transit has been provided within Henrico County on a limited basis. The County indicates that there is interest on the part of existing employers and the County staff for the extension of premium transit service beyond the current planned Willow Lawn Station terminus west to Short Pump. The County's Vision Plan anticipates that mixed use developments will accommodate future transit services. In addition, there have been a number of developments completed between the City line at Staples Mill Road west to the Short Pump area in the past few years at densities, intensities and with a mix of uses not previously experienced in the County.

The transportation chapter of the County's Vision Plan introduces the concept of light rail service between Short Pump and downtown Richmond's Main Street Station, envisioned as an opportunity to serve growth in Short Pump and to the west, while serving the Broad Street Corridor into the City of Richmond. The Plan anticipates that the route would support redevelopment and mixed use projects, and recommends that potential station locations be considered in the design of mixed use developments.

3.0 DISTRICTS AND STATION AREAS

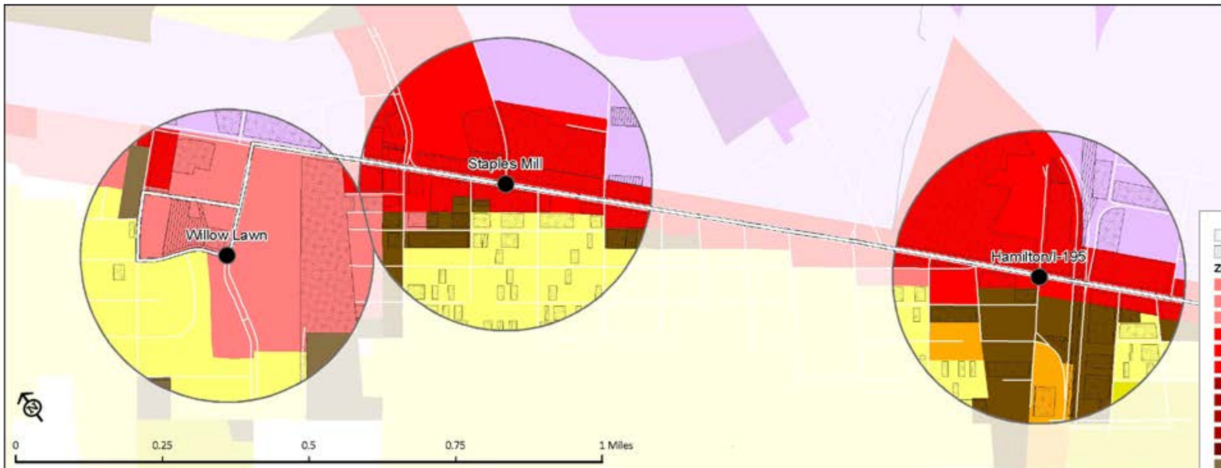
The analysis was completed for the entirety of the study area. Though considered as a continuous corridor, the Broad Street Rapid Transit Study Corridor can be characterized as a series of distinct districts reflecting the corresponding types of land use and development character. The analysis of land use, urban form, and multimodal connectivity reveals that there are four distinct districts, each with their own unique attributes and special characteristics. For the purposes of this analysis, they have been identified the West End, Museum/VCU, Downtown and East End Districts.

3.1 West End District

The west end of the Corridor includes the proposed Willow Lawn, Staples Mill, and Thompson/I-195 Stations. West End is generally characterized as an auto-oriented, suburban commercial landscape with few multimodal connections and large land areas dedicated to surface parking lots. Numerous driveways and curb-cuts provide access to Corridor businesses. Located behind the Corridor-oriented development, there is a significant amount of industrial development on the northern side of Broad Street and primarily residential uses on the southern side. The existing pattern of development is represented by residential uses separated from employment uses, large surface parking lots, buildings set back from the road, and numerous driveways and curb cuts. The current conditions do not serve as optimal conditions to safe and convenient access to transit.

3.1.1 West End District – Current Policies

The predominant zoning classifications for the three stations located within the West End District are R-3, R-5, B-2, B-3, RO-2 and M-1 (see Table 19 and Figure 2). Richmond's RO-2 and B-3 zones and Henrico's B-2 and B-3 zones can be considered the most transit supportive based upon the mix of uses permitted and the relative zoning capacity. There is a need for additional incentives, however, due to the suburban nature of the western station areas in the County and the lack of true policies within these zoning classifications that encourage an increase in density. Currently the County does not offer any overlay zones in the area that help reduce parking requirements or permit a mix of uses and densities. In addition, the residential zoning abutting the transit alignment does not allow any mixing of uses and has a relatively low density of up to four units per acre. However, the B-2 zones surrounding Willow Lawn Shopping Center and the B-3 zones that dominate the intersection of Staples Mill and Broad Street both permit multi-family development. These zoning classifications offer some potential, given the large expanse of surface parking within both station areas, for redevelopment with structured parking, office and residential above. The station at Hamilton and I-195 offers potential with the B-3 and RO-2 zones in the City.



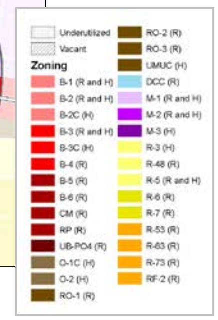


Figure 2. West End District Stations – Zoning and Land Development Potential

Table 19. West End District Zoning

	Henrico				Richmond			
Zoning	R-3	B-2	B-3	M-1	R-5	RO-2	B-3	M-1
Land Uses	SFD	MF, mixed	MF, mixed	Industrial	SFD, civic uses	Mixed	Mixed	Light Industrial
Density/FAR	4 DU/Ac	N/A	N/A	N/A	7.3 DU/Ac	12.1-19.8 DU/Ac	2.0 FAR	N/A
Height	45’	45’-110’	45’-110’	45’-200’	35’	35’-60’	35’	45’
Parking						Reduced	Reduced	

Source: City of Richmond and Henrico County

3.1.2 West End District – Development Potential

Development potential within this District ranges from 24% at Willow Lawn to over 40% at Hamilton/I-195. Pipeline development projects include Faison Residences, a roughly 7 acre development consisting of 45 dwelling units and approximately 4,500 SF of commercial space.

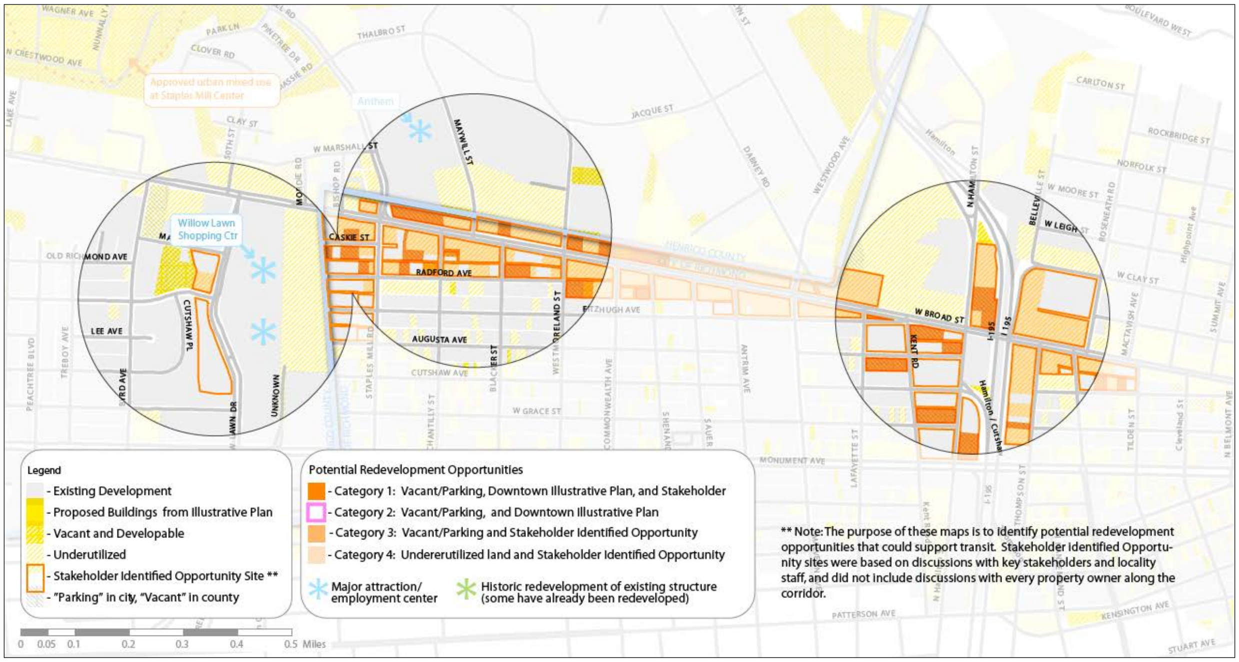


Figure 3. West End District Stations – Potential Development Opportunities

3.1.3 West End District – Multimodal Connectivity

Multimodal connectivity is generally low in this area. The wide sidewalks directly adjacent to the station are supported on the south by a connected network of streets and sidewalks, though the block lengths are slightly larger (approximately 600 feet) than the pedestrian-scale block lengths of Downtown Richmond. The grid on the north, however, is more typical of suburban conditions with larger block sizes (approximately 900 feet) intersecting with higher speed arterial roads and limited sidewalk connectivity. There are no bicycle facilities in the immediate station area, but a shared bicycle route exists along Monument Avenue within one-half mile of the station and runs generally parallel to Broad Street.

Figure 4. West End District Stations – Multimodal Connectivity

3.1.4 West End Station Areas

Willow Lawn: The area immediately surrounding the transit station is primarily characterized by large retail and commercial uses of Willow Lawn Shopping Center and Willow Lawn Plaza. Together with retail outparcels and personal service and office facilities, the area acts as a special ridership generator in the region. Residential uses exist to the south of the station, including a few higher density residential developments and 5100 Monument Avenue, a high rise 50+ condominium building. The existing pattern of development with residential uses separated from employment uses, large surface parking lots, buildings set back from the road, and numerous driveways and curb cuts currently may serve as a barrier to safe and convenient access to transit. Approximately 24% of the station area is considered vacant or redevelopable.

While the Willow Lawn Shopping Center serves as an important transfer center for existing GRTC routes, multimodal facilities within the area are very limited. The existing platform is narrow and is not connected to the public sidewalk or the Willow Lawn Shopping Area. There is virtually no block network within the shopping center, and the network that exists west of Willow Lawn Drive is not pedestrian-scale (block lengths range from 600 to 1,000 feet). Sidewalks exist on the west side of Willow Lawn Drive, but do not connect to the transit station. A short segment of sidewalk along the east side of Willow Lawn connects Monument to the southern end of the shopping area, but ends in the parking lot with no direct access to the front doors of the shopping area. There is a bicycle route that runs along Monument Avenue within one-half mile of the station, but does not connect to the station.

Staples Mill: Immediately surrounding this station are numerous auto-oriented employment, commercial, and retail uses with ample surface parking and multiple access points. Uses include fast food restaurants (some vacant, some occupied), convenience store/gas stations, and a few large employers (i.e. Anthem). The station area includes portions of the Dabney Center Industrial Park, a large employment generator. The westbound station location is directly in front of the Anthem parking lot that has a deep setback from Broad Street and is nicely landscaped and screened from the station area. The southern portion of the station area has significant residential uses. The northern portion is zoned industrial and business uses. The existing pattern of development, with residential uses separated from employment uses, large surface parking lots, buildings set back from the road, and numerous driveways and curb cuts, currently may serve as a barrier to safe and convenient access to transit. Approximately 35% of the station area is considered vacant or redevelopable.

The sidewalk network surrounding this station is adequate, but multimodal connectivity is low overall. The wide sidewalks directly adjacent to the station are supported on the south by a connected network of streets and sidewalks, and block lengths are slightly larger than average (approximately 600 feet) compared to the rest of the Corridor. Street infrastructure to the north, however, is more typical of suburban conditions with larger block sizes (approximately 900 feet) and is intersected with higher speed arterial roads and has limited sidewalk connectivity. There are no bicycle facilities in immediate station area, but a shared bicycle route exists along Monument Avenue within one-half mile of the station area.

Hamilton/I-195: The area surrounding this station is characterized primarily by office/light industrial uses, with a mix of large and small building footprints, and large amounts of surface parking. United Methodist Family Services has a large campus-like facility at the northwest corner of Hamilton and Broad Streets with buildings set back from the road and surrounded by grass and landscaping. Some higher density residential uses exist to the south. This area is zoned for a mixture of uses (commercial, industrial, office, and multi-family residential) but the layout of development may not be currently transit supportive. This station contains one of the highest development capacities with nearly 41% of land considered vacant or redevelopable. There are several underutilized and vacant parcels ripe for infill development. Sidewalks are present and generally wide, but are not well maintained. A crosswalk exists at Hamilton Street, but it is not very visible. There are very few trees and little to buffer pedestrians from the high speed arterial.

Multimodal connectivity at this station is generally low. While sidewalks are wide in the immediate station area and well-connected to the residential areas to the south, they suffer from maintenance issues in certain locations. Street connectivity is limited because of the large apartment complex in the northwest portion of the station area and I-195, which runs underneath Broad Street near the station area. There is virtually no block network in the northern part of the station area and the pedestrian-scale block network that exists in the southern part is disconnected because of I-195. The presence of the interstate creates traffic patterns that pose safety concerns for pedestrians and cyclists. Crosswalks exist at Hamilton and Thompson Streets, although they currently require repainting. There are few street trees and little buffer between pedestrians and the roadway. There are no bicycle facilities in immediate station area, but a shared bicycle route exists along Monument Avenue, one-quarter mile from the station.

3.1.5 West End District Recommendations to Improve Transit Supportive Land Uses

Planning Initiatives

- Consider permitting mixed use development within one-quarter mile radius of proposed transit stations to achieve the goals of improving connectivity, increasing multimodal transportation opportunities and encouraging pedestrian-oriented development
- Consider creating Transit Overlay Zones for each station area to facilitate higher density, mixed use development in selected locations to ensure implementation of planning goals and create incentives for increased density and multimodal improvements
- Consider amending Vision 2026 to reflect the desire for transit-oriented development at identified station locations along Broad Street, specifically targeting the Willow Lawn and Staples Mill station areas for an increase in density, intensity and a mix of land uses
- In Henrico County, consider designating redevelopment properties as UMU or TND on the Future Land Use Map, and rezoning to UMU
- Consider developing a TOD future land use category, or amending the UMU and Mixed use land use categories to reflect more transit supportive land use policies
- Consider amending the Henrico County Zoning Ordinance to create TND and Mixed use zoning classifications to permit a range of density, intensity and a mix of uses, and promoting a variety of housing types with a transit supportive character or urban design
- Identify redevelopment properties within the station areas as potentially appropriate for rezoning to more transit supportive zoning classifications
- Consider amendments to local comprehensive plans that reflect the transit supportive land use policies present in the City of Richmond Downtown Plan along Broad Street and other potential transit corridors
- Consider converting the large surface lot at the Anthem Building to a parking structure lined with a mix of uses (office/retail) to take advantage of the convenient access to I-64 via Staples Mill Road, as market conditions permit, to potentially serve as a park and ride lot and capture commuters from western Henrico, Goochland and Hanover Counties
- Consider accommodating park and ride users within the area to the west of I-195
- Consider working with developers and applicants to improve the mix of uses, street connectivity and building form within the District through redevelopment opportunities

Policy Recommendations

- Consider financial and policy incentives to stimulate new development and retain existing employers and residents
- Consider assisting developers with parcel assembly to mitigate one of the development obstacles associated with infill development
- Consider reduced parking requirements and streamlined development review processes
- Consider working with business owners to ensure their mobility needs are being addressed
- Consider improving pedestrian comfort and safety, as redevelopment occurs over time, by developing buildings closer to the street edge, providing parking and access to businesses from the rear of properties, while still safely accommodating pedestrians and bicyclists through the implementation of bike lanes, sidewalks, landscaping, street furniture, lighting and signalized crossings

Improvement Projects

- Install a larger station platform at the Willow Lawn Station to provide adequate access for boardings
- Improve the crossing at Markel with high visibility crossings to ensure safe connections and transfers between routes
- Install sidewalks on the east side of Willow Lawn to provide a seamless connection between Monument and Broad
- Provide direct pedestrian access between the Willow Lawn Station and the front doors of the shopping center
- Consider reconfiguring/restriping along Willow Lawn Drive to provide designated bicycle lanes and extend the current bicycle network on Monument and Patterson to the new transit station.
- Improve sidewalk and bicycle connections between the eastbound Staples Mill Station and the neighborhoods located south of Broad Street
- Provide signage and/or pavement markings, such as sharrows (shared lane markings), along Chantilly, Kent Road and North Hamilton Streets to connect the bicycle route on Monument to the Station
- Prioritize sidewalk maintenance and improve crosswalks with high visibility markings, ADA curbs, and pedestrian countdown signals
- Designate a park and ride lot to offer opportunities to easily access the new transit service

3.2 Museum/VCU District

The Museum District/VCU includes the proposed Robinson, Hermitage/Meadow and Shafer Street Stations. This area includes several major attractions including the Science Museum of Virginia, the Children's Museum of Richmond, the Siegel Center, and the Virginia Commonwealth University Monroe Park Campus. It is generally an urban, multimodal environment with relatively high residential density on the south side of Broad Street and redevelopment potential within the commercial/industrial parcels to the north of Broad Street. Around North Lombardy Street, the character of the buildings changes from primarily auto-oriented strip development to a mix of older urban commercial development and newly redeveloped buildings fronting the street and wide sidewalks. Throughout this District, the roadway has a small median (approximately five feet) and wide sidewalks. Almost all signalized intersections have marked crosswalks and older pedestrian signals. There are numerous bicycle routes that intersect with Broad Street in this District.

3.2.1 Museum/VCU District – Current Policies

The predominant zoning classifications for the three stations located within the Museum/VCU District are R-6, R-7, R-48, R-73, B-4, and M-1(see Table 20 and Figure 5). With the exception of the M-1 zoning, all of the predominant zoning classifications within the Museum/VCU District permit transit supportive densities. The R-73 and B-4 zones permit mixed uses.

Table 20. Museum/VCU District Zoning

RICHMOND						
Zoning	R-6	R-7	R-48	R-73	B-4	M-1
Land Uses	Residential, civic	Residential, civic	Residential, civic	Mixed	Mixed	Light industrial
Density/FAR	8.7-10 DU/Ac	12.7-19.8 DU/Ac	12-20 DU/Ac	12.1-19.8 DU/Ac 2.0 FAR	6.0 FAR	N/A
Height	35'	35'	35'	150'		45'
Parking					Reduced	

Source: City of Richmond

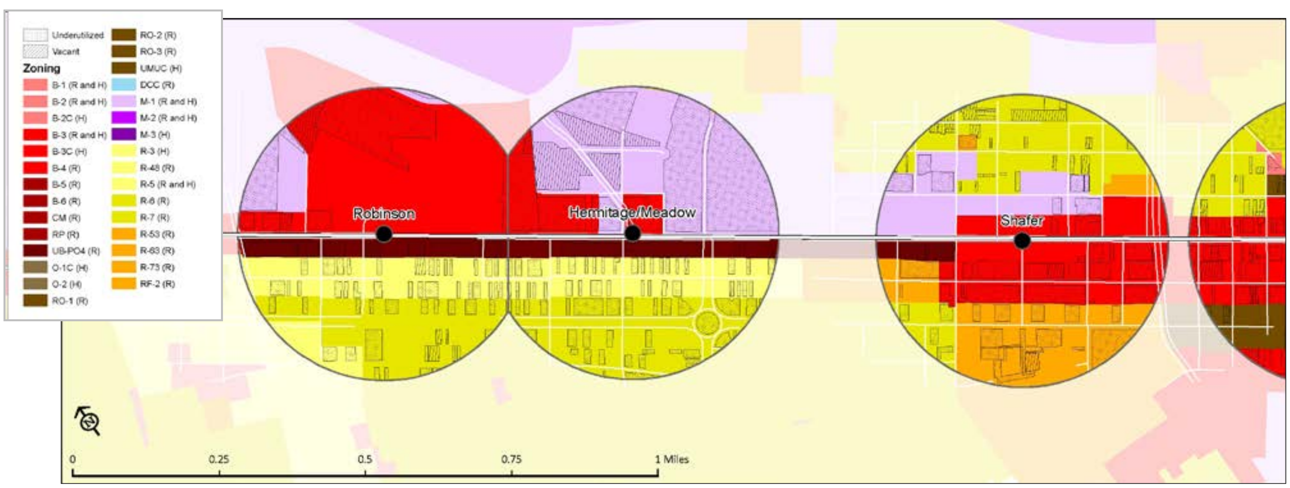


Figure 5. Museum/VCU District Stations – Zoning and Land Development Potential

3.2.2 *Museum/VCU District – Potential Development Opportunities*

Redevelopment opportunities in the Museum/VCU District are located in the northern parts of the Robinson and Hermitage Stations, and around the Shafer Station that builds upon the momentum of existing redevelopment generated by Virginia Commonwealth University (VCU). While the amount of vacant land is more limited compared to potential redevelopment, the existing zoning has the potential to support additional employment and residential uses.

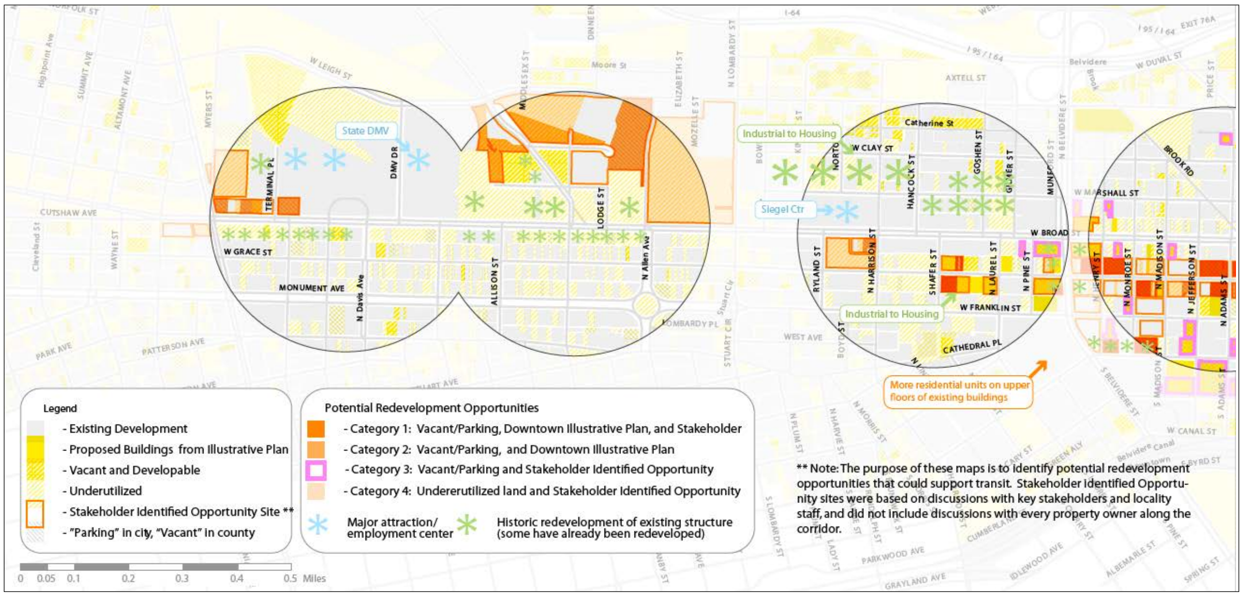


Figure 6. Museum/VCU District Stations – Potential Development Opportunities

3.2.3 *Museum/VCU District – Multimodal Connectivity*

Multimodal connectivity is generally adequate in this District. Wide sidewalks (approximately 15 to 17 feet) are well-connected to the residential areas to the south. The gridded street network maintains adequate density throughout the District, except in the northern areas surrounding the museum, where old passenger rail lines create limited vehicular and pedestrian access to any uses to the north. Crosswalks and older pedestrian signals exist at many of the intersections surrounding the station areas and a five-foot median is present along the length of Broad Street. A number of bicycle routes exist in this District, including Bicycle Route 1 that runs along Hermitage Road.

Figure 7. Museum/VCU District Stations – Multimodal Connectivity

3.2.4 *Museum/VCU District – Station Areas*

Robinson: This station is defined primarily by its location directly in front of the Science Museum and Children's Museum, which is set back a great distance from the road and fronted with landscaping and surface parking. The Boulevard skirts the western edge of the station area and provides a strong linkage to the Virginia Historical Society and the Virginia Museum of Fine Arts that are located about one-half mile from the station. The Department of Motor Vehicles operates its large car pooling and maintenance facility on the north edge of the station area. The south side of Broad Street is fronted with underutilized urban commercial uses, and flanked by a mix of medium density residential uses (one- and two-family units) that contribute to the high household density in this area. This station has the potential to capture the higher density residential neighborhoods and improve connections to transit routes serving Broad and Robinson Streets, as well as a number of bicycle routes. Approximately 27% of the land in the station area is considered vacant or redevelopable.

Multimodal connectivity in this station area is generally adequate. There are wide sidewalks (approximately 15 to 17 feet) in the immediate station area, and they are well-connected to the residential areas to the south. The gridded street network maintains adequate density in the southern portion of the station area, although the northern portion is characterized by larger parcels that abut old passenger rail lines, creating limited vehicular and pedestrian access to any uses to the north. Crosswalks and pedestrian signals exist at the intersections surrounding the station area and a five-foot median is present along the length of Broad Street in this station area. Three bicycle routes exist within one-quarter mile of the station area – Boulevard, Monument Street, and N. Mulberry Street - but none connect to the station. Three other bicycle routes exist on N. Sheppard Street, Hermitage Road, and Grove Avenue within one-half mile of the station.

Hermitage/Meadow: This station will provide service to residential areas south of Broad Street and the commercial and retail locations at this intersection. The immediate station area is characterized by a mix of established and underutilized, urban-scaled retail, commercial and industrial uses, including the historic Sauer's Spice factory, as well as numerous auto-oriented uses and parking lots. The Virginia Department of Taxation and the Department of Motor Vehicles office buildings are located within this station area. The development pattern within this station area varies. In some areas, small-scale, multi-story buildings are pulled close to the street with street trees and on-street parking. Other areas contain large buildings with blank facades, large surface parking lots, and multiple driveways. The urban scale transitions to a mixture of suburban-style retail and auto-oriented uses at Lombardy and Main Streets with a Lowe's set back from the road and surrounded by surface parking lots. Gas stations operate in the outparcels fronting on Broad Street. Medium density residential uses surround the older commercial uses along the southern portion of the Corridor. This contributes to the high household density in the area. Approximately 50% of the land in this station area is considered vacant or redevelopable.

Multimodal connectivity in this station area is adequate overall. There are wide sidewalks (approximately 15 to 17 feet) in the immediate station area, and they are well-connected to the residential areas to the south. There are high visibility crosswalks and ADA curb ramps at the Hermitage Road/Meadow Street intersection. The gridded street network maintains adequate density in the southern portion of the station area, although block lengths are longer than average (ranging from 600 to 900 feet) compared to the rest of the Corridor. Limited landscaping, varying sidewalk condition, frequent curb cuts, and surface parking lots abutting the street further preclude an ideal pedestrian environment to the north. Within one-quarter mile of the station area, two bicycle routes exist: Hermitage Road and Monument Ave. The Hermitage route (Bike Route 1) passes almost directly by the station area. Additional routes are located within one-half mile: Lombardy, Grove, and N. Mulberry Streets.

Shafer: The area surrounding this station can be characterized as a mixed use shopping/retail/ residential district that supports at the needs generated by VCU students and employees. A number of large, multi-story residential buildings and university buildings contribute to the high residential density in this station area. VCU is the primary activity center in this station area. Although the VCU population is quickly becoming dominated by a full-time student population, it still maintains a very strong part-time commuter student population. In addition to VCU, the Landmark Center, located on Belvidere at Main Street, is a significant entertainment venue in the area. The area immediately surrounding the station has a very urban character with buildings fronting the street and a consistently transparent street frontage that supports pedestrian use. However, the character transitions to a more automobile centric form around the Belvidere intersection with gas stations and large surface parking lots fronting the street. Approximately 25% of the station area is considered vacant or redevelopable.

The proposed Shafer Station has one of the highest levels of street connectivity. Sidewalks are wide and generally well-connected throughout the station area. Broad Street has on-street, metered parking on both sides of the road, which creates an adequate buffer for pedestrians. Crossings exist at nearly every intersection south of Broad Street and Shafer Street specifically has high visibility crosswalks and pedestrian countdown signals. The width of Belvidere Street can make it challenging to cross. Bike routes exist along Belvidere and Franklin Streets, but neither connects to the station area. Bicycle parking exists at the bookstore and at the dormitories.

3.2.5 *Museum/VCU District Recommendations to Improve Transit Supportive Land Uses*

Planning Initiatives

- Consider permitting mixed use development within one-quarter mile radius of proposed transit stations to achieve the goals of improving connectivity, increasing multimodal transportation opportunities and encouraging pedestrian-oriented development
- Consider creating Transit Overlay Zones for each station area to facilitate higher density, mixed use development in selected locations to ensure implementation of planning goals and create incentives for increased density and multimodal improvements

Policy Recommendations

- Consider financial and policy incentives to stimulate new development and retain existing employers and residents
- Consider assisting developers with parcel assembly to mitigate one of the development obstacles associated with infill development
- Consider reduced parking requirements and streamlined development review processes
- Consider working with business owners to ensure their mobility needs are being addressed

Improvement Projects

- Target streetscape improvements along Broad Street and at proposed station locations to create an improved environment for both motorists and pedestrians
- Install high visibility crosswalks and newer pedestrian activated countdown signals with push buttons
- Provide pedestrians refuge in medians along Broad Street for improved crossing safety and pedestrian comfort.
- Install ADA curb ramps at all intersections and in the median
- Provide signage and/or pavement markings, such as sharrows (shared lane markings), along N. Robinson or N. Davis Ave to connect the bicycle route on Monument to the station
- Provide ADA crossings and signage/sharrow markings along N. Harrison, Shaffer or N. Laurel Streets to connect the bicycle route along W. Franklin Street to the Shafer Street Station

3.3 Downtown District

The Downtown District includes the proposed stations at Adams Street, 3rd Street, 6th Street, 9th Street, and 12th Street. As this area comprises the City's core business and state government employment areas, the highly urbanized environment represents the highest transit usage and transfer rates in the region. The major employment centers include City Hall, the Coliseum, the Convention Center, various state and City office buildings, the state capital complex and VCU Medical Center, as well as numerous other attractions and activity centers. The character of the area transitions from a primarily commercial corridor with a fine grain of uses around Adams Street Station towards the larger scale institutional uses associated with the state government and hospital buildings around the 12th Street Station. A raised median is present in the area around 6th Street to prevent mid-block pedestrian crossings. High visibility crosswalks (painted and brick textured) are present at the intersections around these stations. Several intersections located between 7th and 9th Streets have auditory pedestrian countdown signals, though curb ramps are not always available. The urban environment changes in proximity to 14th Street where I-95 intersects the Corridor and creates an automobile-dominated streetscape with the associated Interstate access ramps. The City is currently replacing sidewalks from 4th Street to Adams Street and is anticipated to include improvements, such as six to ten feet sidewalks with tree wells and new brick.

3.3.1 *Downtown District – Current Policies*

The predominant zoning classifications for the five stations located within the Downtown District are R-6, RO-3, B-4, CM, DCC and M-1 (see Table 21 and Figure 8). With the exception of M-1, these zones are transit supportive with their permitted mix of uses and the defined density and intensity of use.

Table 21. Downtown District Zoning

RICHMOND						
Zoning	R-6	RO-3	B-4	CM	DCC	M-1
Land Uses	Residential, civic	Mixed	Mixed	Mixed (no res.)	Mixed (no res.)	Light industrial
Density/FAR	8.7-10 DU/Ac	12.7-19.8 DU/Ac	6.0 FAR	N/A	N/A	N/A
Height	35'	35'-50'	N/A	80'	95'	45'
Parking		Reduced	Reduced	Exempt	Exempt	

Source: City of Richmond

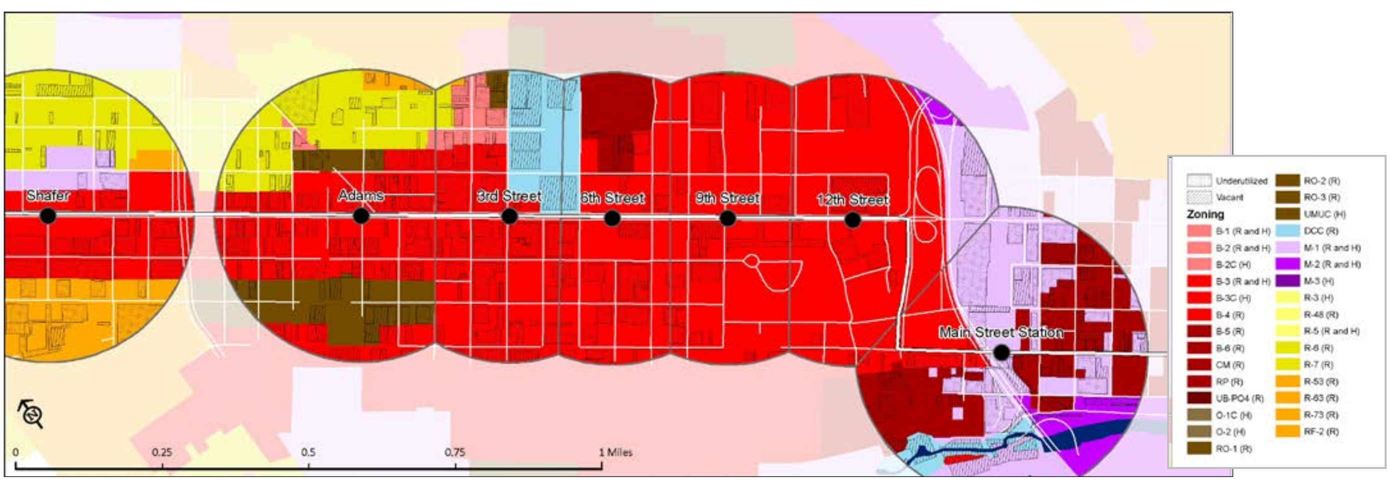


Figure 8. Downtown District Stations – Zoning and Land Development Potential

3.3.2 Downtown District – Potential Development Opportunities

While the amount of vacant land is limited compared to potential redevelopment, the existing zoning provides the potential to support a significant amount of additional employment and residential uses.

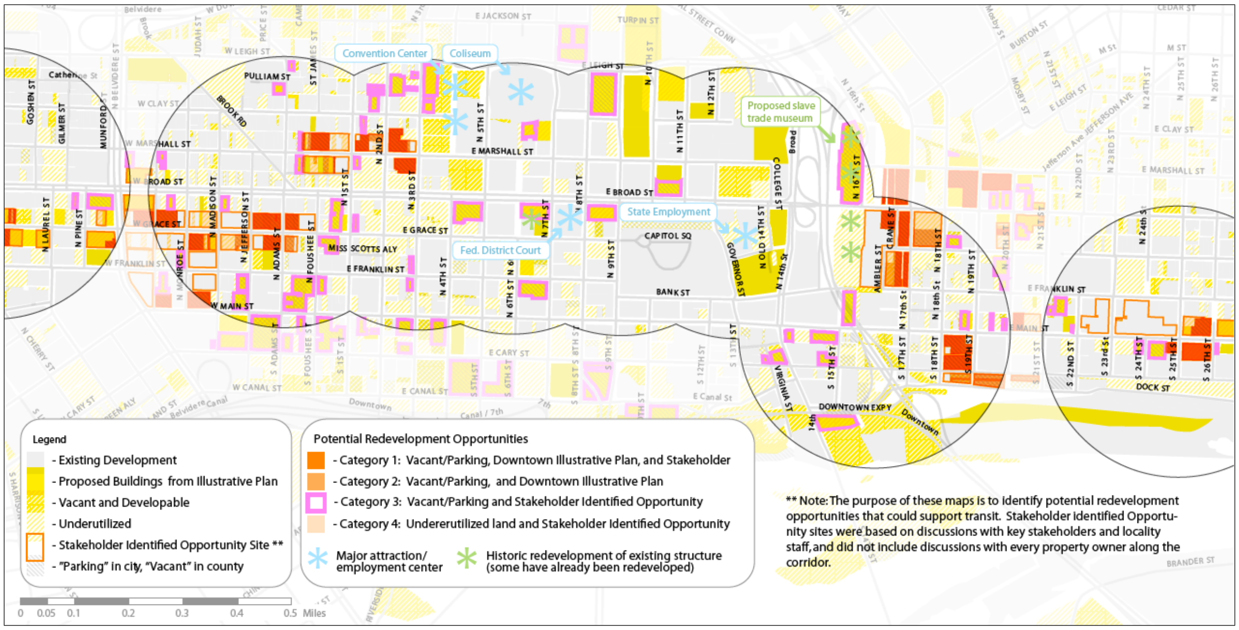


Figure 9. Downtown District Stations – Potential Development Opportunities

3.3.3 Downtown District – Multimodal Connectivity and Accessibility

The Downtown District has the potential to be a highly multimodal, urban environment. Numerous local buses currently operate within this District and provide opportunities to easily transfer between routes. There are wide sidewalks on both sides of Broad Street with some street trees, on-street parking, and pedestrian-oriented street lights. Block lengths throughout the station areas are pedestrian-oriented (approximately 300 feet). The street and sidewalk network connects the office and residential uses in the station areas and is maintained overall. Many large scale buildings and surface parking lots, however, detract from the pedestrian environment. A number of bicycle routes exist.

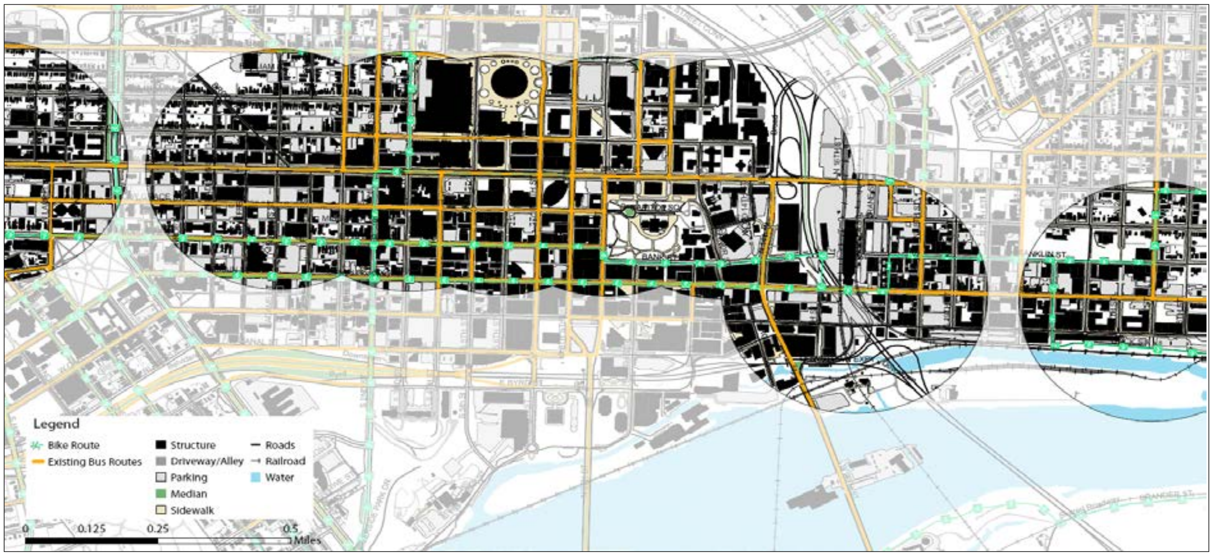


Figure 10. Downtown District Stations – Multimodal Connectivity

3.3.4 Downtown District – Station Area Characteristics

Adams: Adams Street serves as a western boundary of the downtown area. The portion of Broad Street surrounding the proposed Adams Street Station was historically the commercial center of the City. The character of the area has not changed much since that time, despite many changes in the uses. The area is primarily commercial with buildings fronting the street with many retaining their original street facades. The area serves as the location of the successful First Friday's Art Walk and a concentration of art galleries, music studios, graphic design and architecture offices, boutiques, cafés and restaurants. The area includes larger buildings such as the newly renovated Richmond Doubletree Hotel, the Jefferson Hotel, the Richmond Main Library and the YMCA. The strong mix of station area uses include residential and are located behind the Broad Street commercial frontages. While the historic structures along Broad Street meet high architectural and design standards, they suffer from vacancy issues. Parking is located in alleys, in the rear of the buildings that front Broad Street, and in small parking lots tucked to the side. Approximately 29% of station area is considered vacant or redevelopable.

The proposed Adams Street Station has the potential to be a highly multimodal, urban environment. There are wide sidewalks on both sides of Broad Street with street trees buffering the road, on-street parking, and pedestrian-oriented street lights. Block lengths throughout the station area are pedestrian-oriented (approximately 300 feet). However, Brook Road disrupts the block pattern on the north side of the station area with a diagonal road, and creates a triangular block known locally as Lonesome Pine Park. A narrow median exists along this stretch of roadway and high visibility crosswalks are currently located on the Broad Street approaches. The street and sidewalk network connects the office and residential uses surrounding the station and is generally well maintained, though many large, surface parking lots within the station area detract from the pedestrian environment. Bicycle routes exist along Franklin Street and West Leigh Street, but do not connect to the station.

3rd Street: This immediate station area can be characterized as having comparatively higher-density cultural and entertainment uses, interspersed with surface parking lots and parking garages. A major generator located within this station area is the Richmond Convention Center. While the street and pedestrian networks are wide and highly connected, and buildings are pulled close to the street (albeit farther away than those on Adams Street), the building footprints are generally larger and tree canopy coverage varies, making the pedestrian environment less desirable. Nearly all of the 21 blocks show some potential for redevelopment.

The 3rd Street Station has a high degree of intersection density and one of the most intact grid networks of any of the downtown station areas. This density facilitates dispersed vehicular movement, while creating an environment of consistent block lengths that allows pedestrians to efficiently walk between destinations. The exception to this pattern occurs at 4th Street, where the grid network is disrupted, creating some confusing traffic patterns and limiting north-south access. The City is currently in the process of replacing sidewalks from 4th Street to Adams Street to provide high-quality sidewalks, landscaping, lighting, and well-marked pedestrian crossings, all of which encourage pedestrian usage. In addition to white, ladder crosswalk pavement markings, some key intersections use brick pavement to visually reinforce the presence of the pedestrian crosswalk. There is a shared bicycle route that runs along N. 2nd Street, and turns east on Broad Street to connect north on 3rd Street. This is the only bicycle facility that connects directly with a downtown station.

6th Street: The immediate station area is characterized by numerous cultural, entertainment, and tourist destinations that are interspersed with supporting surface parking lots and parking garages. The Richmond Coliseum, National Theater and Theater Row, Federal District Court Building, Richmond Marriot, Hilton Garden Inn located in the old Miller & Rhodes building, and Center Stage are some of the major attractions within this station area. These uses contribute to the high employment densities in the station area. While the street and pedestrian networks are wide and highly connected, and buildings are pulled close to the street (albeit farther away than those on Adams Street), building footprints are generally larger, tree canopy varies, and large surface parking lots make the pedestrian environment less desirable. Currently 20% of the station area is considered vacant or redevelopable.

The 6th Street Station has a highly connected network of streets south of E. Marshall Street. In this area, block lengths are pedestrian-oriented (approximately 330 feet), allowing pedestrians to efficiently walk between destinations. While the Coliseum occupies the equivalent of four city blocks north of Marshall Street, ample pedestrian facilities and public open space facilitate a seamless pedestrian network. The station area is characterized by high-quality sidewalks, landscaping, lighting, and well-marked pedestrian crossings, all of which encourage pedestrian usage. In addition to white ladder crosswalk pavement markings, some key intersections use brick pavement to visually reinforce the presence of the pedestrian crosswalk. There is a shared bicycle route that runs east-west along North Franklin Street, but it does not connect to the station.

9th Street: The immediate station area is characterized by civic and institutional uses which support significant employment densities. Major buildings and facilities include the Internal Revenue Service, Social Security Administration, Richmond General District Court, Library of Virginia, City Hall and City of Richmond School Board and Social Services, the Virginia General Assembly and VCU's Medical College of Virginia campus. The historic architectural quality of these buildings is unique and visually appealing. However, the buildings are set back from the sidewalk and often occupy an entire city block.

In addition, a few large surface parking lots exist in this station area and detract from the pedestrian environment. Currently16% of the station area is considered vacant or redevelopable.

Multimodal connectivity within the 9th Street Station is limited because of the large institutional uses that occupy multiple blocks. Along Broad and E. Marshall Street, block lengths are pedestrian-oriented (approximately 330 feet), but the large institutional uses north and south of these roads disrupt efficient walking routes. The station area is characterized by high-quality sidewalks, landscaping, lighting, and well-marked pedestrian crossings, all of which encourage pedestrian usage. In addition to white, ladder crosswalk pavement markings, some key intersections use brick pavement to visually reinforce the presence of the pedestrian crosswalk. There is a shared bicycle route that runs east-west along Bank Street/North Franklin Street, but it does not connect to the station.

12th Street/VCU Medical: This area is characterized by large institutional uses (primarily medical and government) and some supportive office uses, which contribute to extremely high employment densities. Wide sidewalks are present on both sides of Broad St. (approximately 15 to 20 feet) and buildings generally front the sidewalk. The urban design condition of the immediate station area is heavily influenced by the I-95 Interchange, Virginia Medical College, large state government uses, and large structured parking lots. The numerous parking garages detract from an otherwise pedestrian-friendly scale. There is limited streetscaping and the ground floors of adjacent office buildings do not feature active features. Very little land is available for redevelopment.

Multimodal connectivity within the 12th Street Station is limited because of the large institutional uses that occupy multiple blocks, as well as the interstate and railroad trestles that create a barrier on the eastern edge of the station area. The limited block network is significantly larger than the scale of blocks within downtown (approximately 800 feet). On Broad Street, there are high-quality, wide sidewalks, but limited landscaping and enhanced crosswalks could improve the pedestrian environment. There is a shared bicycle route that runs east-west along Bank Street/North Franklin Street that does not connect to the proposed station location.

14th Street: Although a station is not proposed for 14th Street, the proposed rapid transit route continues south on 14th Street from Broad before turning eastward onto Main Street. The area along 14th Street is generally characterized by large parking lots and garages surrounded by large government office buildings. The sidewalks are wide (10 to 20 feet) with on-street parking and lack of streetscaping. The large building setbacks, single-uses (offices, parking), six-lane roadway with a raised median, and grade separation between north and southbound travel lanes are not pedestrian-friendly. A pedestrian overpass, located mid-block between Broad and Bank Streets, connects a 25 story state office building on the east side of 14th Street to several other state office buildings on the west side. Steeps slopes are present along the eastern portion of the station area. Sidewalks in this area are not continuous. Marked crosswalks exist at the major intersections, but could benefit from improved visibility. No crosswalks are available at the intersection of Broad Street and overpass to 1-95, although pedestrian activity was present.

3.3.5 Downtown District Recommendations to Improve Transit Supportive Land Uses

Planning Initiatives

- Consider creating Transit Overlay Zones for each station area to facilitate higher density, mixed use development in selected locations to ensure implementation of planning goals and create incentives for increased density and multimodal improvements

Policy Recommendations

- Consider financial and policy incentives to stimulate new development and retain existing employers and residents
- Consider assisting developers with parcel assembly to mitigate one of the development obstacles associated with infill development
- Consider reduced parking requirements and streamlined development review processes
- Consider working with business owners to ensure their mobility needs are being addressed

Improvement Projects

- Target streetscape improvements along Broad Street and at proposed station locations to create an improved environment for both motorists and pedestrians
- Maintain a consistent tree canopy and curb ramps on all corners to improve accessibility
- Provide sidewalk improvements, landscaping, street furniture, crosswalks and signalized crossings
- Provide pedestrians refuge in medians along Broad Street for improved crossing safety and pedestrian comfort
- Revise pedestrian signal timing to provide a longer crossing time, and in particular, around the medical center and government buildings to serve persons with limited mobility
- Focus on providing improved median accessibility, pedestrian countdowns, appropriate signal timing and the provision of bike parking

3.4 East End District

The East End District includes Main Street Station, 25th Street and Rocketts Landing Stations, where each station area has a different character and context. Relative to the other station areas, East End currently has a lower level of existing transit activity, fewer activity centers, and lower population and employment densities. It is anticipated that these areas will undergo substantial change with continued infill, redevelopment and adaptive reuse of buildings in Shockoe Bottom, as well as the buildout development of Rocketts Landing. Rocketts Landing is a mixed use redevelopment project, located at the eastern terminus of the Corridor, and is planned to include 2,000 residences, 200,000 SF of retail and entertainment space, 500,000 SF of office space, a hotel and outdoor recreational activities. Rocketts Landing is planned to provide intermodal connection serving points further east in Henrico County, where the Tree Hill development has been approved for 2,770 residences, 300,000 SF of office space and 860,000 SF of commercial space.

3.4.1 *East End District – Current Policies*

The predominant zoning classifications for the three stations located within the East End District are R-6, B-4, B-5, M-1, M-2 (R and H), and UMU (H) (see Table 22 and Figure 11). With the exception of the industrial zoning classifications for both jurisdictions, all of the predominant zoning classifications can be considered transit supportive based upon the permitted mix of uses and densities.

Table 22. East End District Zoning

	HENRICO			RICHMOND			
Zoning	M-1	UMU	R-6	B-4	B-5	M-1	M-2
Land Uses	Light Industrial	Mixed	Mixed	Mixed	Mixed	Light Industrial	Heavy Industrial
Density/FAR	N/A	12-40	8.7-10	6.0	N/A	N/A	N/A
Height	45'-200'	60'	35'	None	60'	45'	45'
Parking		Reduced		Exempt	Exempt		

Source: City of Richmond and Henrico County

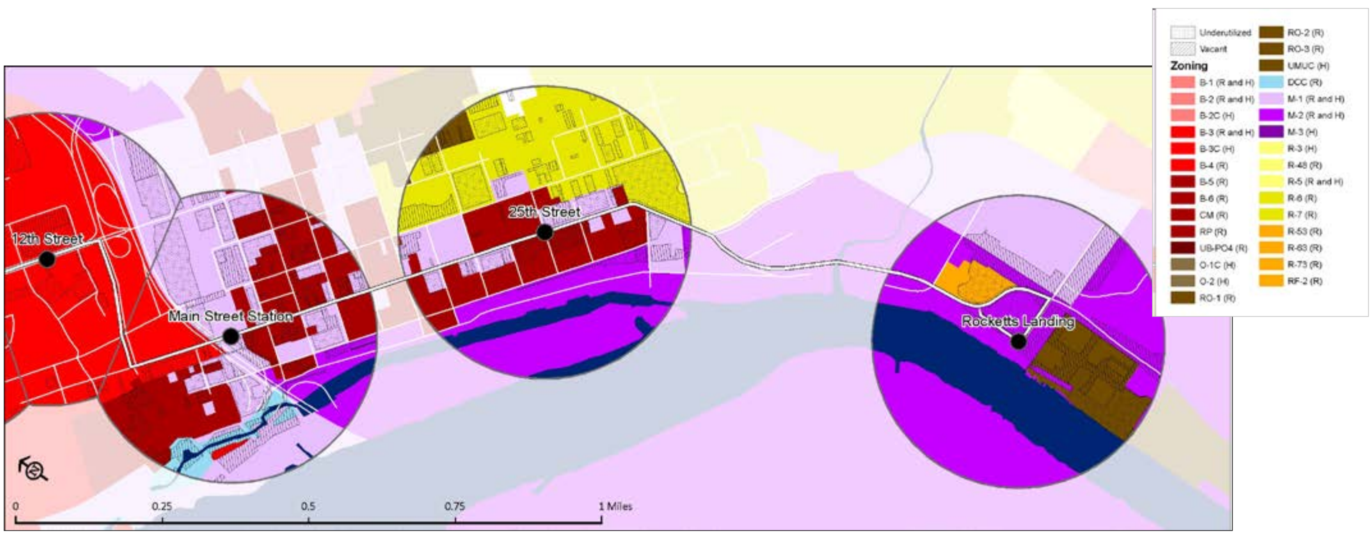


Figure 11. East End District Stations – Zoning and Land Development Potential

3.4.2 *East End District – Potential Development Opportunities*

Development potential in this District is generally high. A number of adaptive reuse projects with several hundred residences and additional commercial square feet have been approved in the past year and are anticipated for completion in the near future.

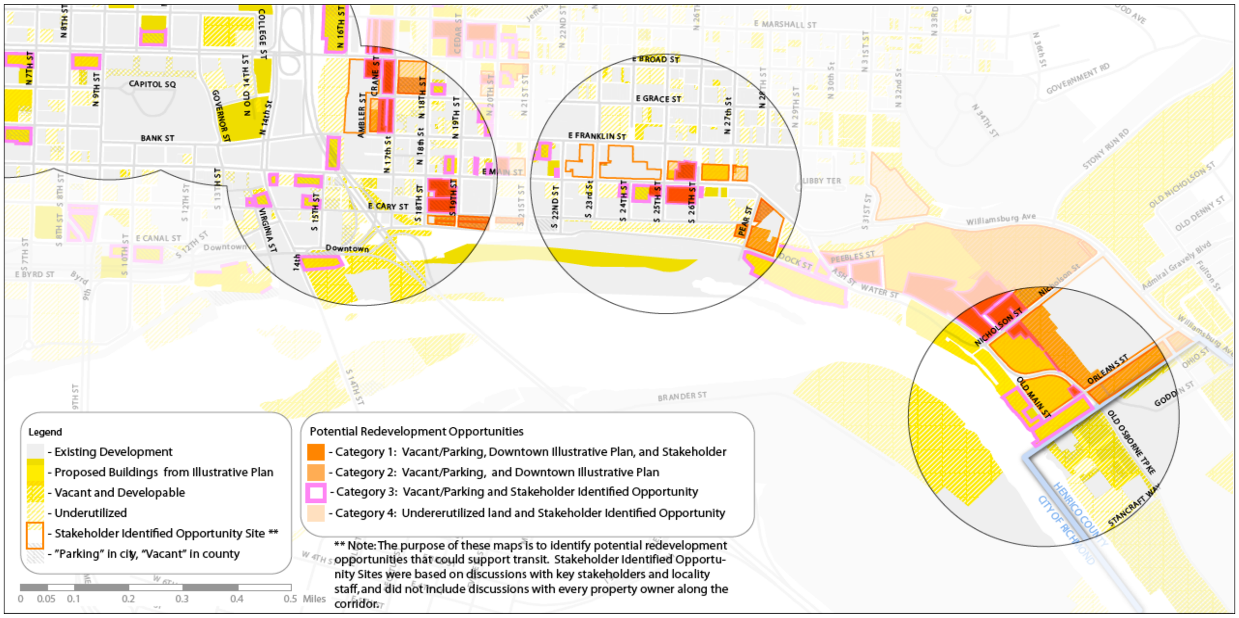


Figure 12. East End District Stations – Potential Development Opportunities

3.4.3 East End District – Multimodal Connectivity and Accessibility

Multimodal connectivity is limited within this District due to the presence of I-95 and multiple railroad trusses, as well the limited street network that connects Rocketts Landing. East Main Street is a truck route and the main artery connecting Downtown to eastern Henrico County. Peak commuter traffic operates at lower effective speed due to regular congestion. While there are numerous sidewalks throughout the District, sidewalk quality, lighting and other street amenities often do not exist. There lacks a consistent type and level of lighting, sidewalk paving, crosswalk markings, or curb ramps throughout the area. A shared bicycle route exists along E. Franklin Street and E. Main Street.

Figure 13. East End District Stations – Multimodal Connectivity

3.4.4 East End District – Station Area Characteristics

Main Street Station: Main Street Station is located in Shockoe Bottom area of the City and is a historic, urban neighborhood with industrial beginnings. It is one of the largest areas reflecting the architectural character of "Old Richmond." This character has played an important role in the renovation and rehabilitation of many properties in recent years. In addition to the large industrial buildings, the area contains a mix of older, small scale commercial/retail/restaurant uses that are generally oriented to the street and have active storefronts and outdoor dining. The Farmer's Market is located adjacent to the train station entrance and a park and ride lot on Main Street. Together, these uses contribute to the high employment densities in the area and generate significant pedestrian trips. A number of adaptive use projects with several hundred residences have been approved in the past year. These include 204 units approved for a mixed use building located at 305 N. 18th Street and 74 units for a mixed use building at 227 ½ N. 20th Street. In addition, the adaptive reuse of the historic Reynolds Metals building has been approved, at the western edge of the station area, with approximately 225 dwelling units and 38,000 square feet of non-residential uses. Approximately 36% of the land in the station area is considered vacant or redevelopable.

Multimodal connectivity is limited due to the presence of I-95 and multiple railroad trusses that bisect the station area. While both are elevated and pedestrian facilities exist along Main Street and Broad Street to connect uses on the east and west sides of the station area, the physical presence of these large auto- and rail-oriented structures creates an environment less attractive for pedestrians. East Main Street is a designated truck route and arterial roadway connecting Downtown to eastern Henrico County. In addition, the Main Street Station and its parking areas occupy the equivalent of three city blocks, further limiting east-west connectivity in the station area. To the east of the station area, the pedestrian environment is inviting and comfortable with outdoor dining, active storefronts, wide sidewalks, street trees, and small block sizes. However, sidewalk quality, lighting and other street amenities are sometimes lacking. High visibility crosswalks are present in the immediate station area. A shared bicycle route exists along E. Franklin Street and crosses in front of the station along E. Main Street. The facility is not well-marked.

25th Street: The area between 19th Street and Pear Street is known as "Tobacco Row," reflecting Richmond's historic role in the tobacco industry. Tobacco Row has a mix of residential uses and small scale, older commercial as well as newer commercial uses. East of 19th Street, the small-scale buildings on the south side of Main Street start to transition to the larger tobacco warehouse/factory buildings constructed in the late 19th and early 20th centuries. The north side of East Main Street consists primarily of automobile-oriented commercial uses set back from the road with parking located directly along the street, though some smaller-scale, older commercial uses are present. Building use and form is varied, including manufacturing or warehousing uses, offices, retail and restaurant uses, and a number of former factory/warehouse buildings that have been converted to multi-family residential. Most of the structures in this area are two and three-stories in height. East of the station area lies Echo Harbor, a pending zoning application proposing 102 dwelling units, a 158 room hotel and 120,000 square feet of commercial and office uses. In addition, a number of redevelopment projects have been approved in the past year, including 96 units approved within a mixed use building located at 2005 East Franklin Street and a rezoning from M-1 to B-5 with ground floor commercial and upper floor residential uses at 2026 East Main Street. Approximately 30% of the station area is considered vacant or redevelopable.

Multimodal connectivity is generally balanced, with opportunities to drive, bicycle, and walk within the station area. The traditional street grid remains largely intact, though north-south connectivity is limited on 22nd and 24th Streets due to topography and development patterns. Wide, brick sidewalks (10 to 15 feet) and street trees generally line Main Street in this station area. However, sidewalk quality, lighting and other street amenities are sometimes lacking. Marked crosswalks with pedestrian signals exist only at 21st and 25th Streets and curb ramp conditions vary throughout. Connecting streets are narrow with on-street parking, sidewalks and street trees. There are some obstructions within the pedestrian traveled way. Bicycle routes exist along Dock Street, Broad Street and Franklin Street, providing both north-south and east-west bicycle connections within the station area. None of the routes connects directly with the station.

Rocketts Landing: The area surrounding the Rocketts Landing Station is in transition from an industrial brownfield to a new, mixed use village along the James River. Currently there is limited mix of uses with some multi-family residential uses and office/retail space on the ground floor. However, construction, sale and leasing of the Rocketts Landing Village is on-going and existing household and employment densities reflect the transitional nature of this station area. There is a restaurant along the waterfront, a small public open space, and some industrial uses to the northwest of the developing Village. Site plans for a private marina have been approved and the City is reviewing an application for a multi-use condominium high rise with 93 dwelling units, parking and 120,000 square feet of office and commercial uses. Approximately 50% of the station is considered vacant or redevelopable.

In the Rocketts Landing Station area, multimodal connectivity is generally limited. Where sidewalks exist along Old Osborne Turnpike, they are only on one side of the street and vary in condition. Near the station along Orleans Street, wide (6 to 8 feet) sidewalks have been added as properties have developed, but the sidewalk network overall is incomplete and no sidewalk currently exists in the proposed station area. In addition, those sidewalks are generally fronted with large, surface parking lots, creating a less desirable pedestrian environment. There are ADA ramps on Old Main Street, but no marked crosswalks. Brick sidewalks (five to eight feet) are present along Old Main Street within the apartment area and on-street parking and street trees are present to buffer pedestrians within the development. There is a bicycle route along Orleans Street that connects the residential and industrial uses on the north side of the station area to Old Osborne Turnpike and points east and west, but there is no direct connection to the proposed station.

3.4.5 East End District Recommendations to Improve Transit Supportive Land Uses

Planning Initiatives

- Consider permitting mixed use development within one-quarter mile radius of proposed transit stations to achieve the goals of improving connectivity, increasing multimodal transportation opportunities and encouraging pedestrian-oriented development
- Consider creating Transit Overlay Zones for each station area to facilitate higher density, mixed use development in selected locations to ensure implementation of planning goals and create incentives for increased density and multimodal improvements

Policy Recommendations

- Consider financial and policy incentives to stimulate new development and retain existing employers and residents
- Consider assisting developers with parcel assembly to mitigate one of the development obstacles associated with infill development
- Consider reduced parking requirements and streamlined development review processes
- Consider working with business owners to ensure their mobility needs are being addressed

Improvement Projects

- Target streetscape improvements along Broad Street and at proposed station locations to create an improved environment for both motorists and pedestrians
- Provide sidewalk improvements, landscaping, street furniture, crosswalks and signalized crossings
- Provide a high visibility crosswalk at the Main/North 14th Street intersection
- Provide bicycle parking facilities throughout the District
- Improve crosswalk and sidewalk conditions and streetscaping
- Provide an adequate platform and station waiting area within the Rocketts Landing Station with shelter, bench and trash receptacle, at a minimum
- Expand the sidewalk network within Rocketts Landing to connect the station area to surrounding uses
- Provide "complete streets" with bicycle lanes and sidewalks along Old Osborne Turnpike/East Main Street

4.0 SUMMARY

Future transit investments in the Broad Street corridor will need to be complemented by supportive land use and multimodal improvements in order to maximize the ridership potential for Bus Rapid Transit in the corridor.

Making transit more safe, convenient, and desirable along Broad Street can be accomplished not only by providing the appropriate mix of land uses and supporting multimodal infrastructure, but also by enhancing the quality of the built environment. Recommended strategies should include supporting new mixed use development, improving connectivity of streets and land uses, providing transit-friendly design features, and enhancing accessibility to alternative modes of transportation. For station areas to be truly pedestrian and transit friendly, attention must also be paid to design features such as parking location, building setbacks, streetscaping, and the provision of public/civic space.

Current population and employment densities and locations in the Corridor are transit supportive overall. Despite vacancies and underutilized properties in certain blocks along the corridor, and auto-oriented suburban development on the east and west ends, the majority of Broad Street retains the walkable, pedestrian-friendly urban fabric that has historically supported commerce and development. The historic urban areas consist of smaller blocks, a grid of streets, variety of uses and street activity and correspond to greater multimodal facilities and improved mobility for transit users.

The Corridor street network is highly connected, offering transit users a variety of options for walking to their destination. Sidewalks are generously wide along much of the corridor's length with street trees, lighting, and other appropriate streetscape amenities that create a safe and comfortable environment. The majority of the historic storefronts, office and apartment buildings remain intact, which provides visual interest, generates pedestrian activity and creates a defined edge providing "spatial enclosure," - all important qualities for a pedestrian and transit-friendly streetscape. There are a number of opportunities, however, to build upon and to make each district more transit-supportive through potential policies and improvements.

As the West End District transitions over time from a suburban to an urban context, the City and County land development policies and plans should be modified to support a stronger urban form, improve accessibility and mobility, and target urban infill redevelopment. In particular, transit overlay zones, transit supportive densities and intensities, complete sidewalks, multimodal facilities, and park and ride lots are recommended, Additionally, Henrico County should consider planning for mixed use redevelopment in the area surrounding the Willow Lawn Station to support future transit usage.

The Museum/VCU District provides a logical area for continued redevelopment along the Broad Street corridor despite projected slow growth in the district. The current densities and ridership potentials in this district are already supportive of a transit investment. The Fan Historic District has redeveloped extensively in recent years, and mixed use development opportunities continue to emerge with available parcels around VCU and in station areas. Shared parking areas should be developed to support increased development, and Broad Street frontages will need to be sensitively developed over time using strategies to promote strong urban design, connectivity, intensity and diversity of uses.

The Downtown District is a major activity center with the Corridor's largest concentration of jobs and serves as the primary destination for current transit riders. In order to improve the job-to-housing ratio, considerations during implementation of the Downtown Master Plan include targeting approvals for development with transit-supportive intensity and density, and urban design features, as well as adopting transit overlays zoning districts or other policies that facilitate transit-oriented development. Compact, mixed use development will need to be supported by adequate but not excessive parking, and preferably by district parking solutions. Transit service improvements will need to be an integral part of the downtown mobility strategy.

The East End District has a historic development pattern that has supportive densities overall, and with the recent residential development, is providing an improved jobs-to-housing balance. Although multimodal facilities are available, there are some existing constraints (i.e., limited sidewalk widths and connectivity issues) that should be improved. The City and County should work cooperatively to provide a complete and continuous street network with bicycle and pedestrian facilities along Old Osborne Turnpike/Water Street, and the Rocketts Landing area will need to continue extending sidewalks, multimodal access, and a transit-supportive urban form.

In summary, the existing conditions along the Broad Street Corridor provide a solid foundation to support new transit investments. The Corridor has a strong employment base as well as available land for redevelopment. Additional residential and transit-oriented mixed use development can be targeted to help foster more vitality along the Corridor and to improve the overall jobs-to-housing balance. The Corridor's multimodal connectivity elements are recommended to be enhanced. In particular, the adoption of more effective transit-supportive land use policies will help achieve a higher rating as part of the FTA New Starts program evaluation, and support transit-oriented development implementation. Continued discussions with City and County stakeholders will be needed to further evaluate any specific policy modifications and improvements. Finally, the results of this analysis will require coordination with other ongoing project technical analyses to ultimately define the recommended project alternative.

A. APPENDIX

CITY OF RICHMOND		
Topic		Description
R-5 Single-Family	Permitted uses	SF Detached; libraries, museums, schools, parks, churches, agriculture, recreational facilities, etc.
	Lot area and width	6,000 SF; 50 feet wide
	Yards	Front: 25'
	Lot coverage	35%
	Height	35'
R-6 Single-Family Attached	Permitted uses	Same as R-5 plus SF attached, two-family detached and two-family attached dwellings; one dwelling unit located in an accessory building
	Lot area and width	2,200 – 5,000 SF; 50 feet wide; maximum average density w/i development of 10 DU per acre
	Yards	Front: 15'
	Lot coverage	55%
	Height	35'
XR-7 Single-Family Attached	Intent of district	To preserve and enhance the established character of older urban residential neighborhoods in the inner areas of the city.
	Permitted uses	Same as R-5 plus SF attached provided no more than 4 DUs shall be attached laterally in a series; two-family detached and two-family attached lawfully existing prior to effective date of ordinance.
	Lot area and width	2,200 – 4,400 SF; 21'-42' in width
	Yards	Front: 15'
	Lot coverage	55%
	Height	35'
R-48 Multi-Family	Permitted uses	Same as R-5 plus multi-family dwellings, day nurseries and adult day care facilities.
	Lot area and width	Single-family and two-family dwellings same as R-7; multi-family dwellings 2,200 SF minimum lot area.
	Yards	Front: 15' minimum for single- and two-family; 25' minimum all other uses.
	Usable open space	50% minimum.
	Lot coverage	50% maximum.
	Height	35' maximum.

R-53 Multi-family	Permitted uses	Same as R-48 plus tourist homes and parking areas serving permitted uses in district.
	Lot area and width	Single-family and two-family dwellings same as R-7; multi-family dwellings 1,250 SF minimum lot area
	Yards	Front: 15’ minimum.
	Usable open space	40% minimum
	Lot coverage	60% maximum
	Height	35’ to 60 feet
R-63 Multi-family Urban	Intent of district	To encourage development of medium density neighborhoods comprised of a mix of residential uses and to promote a pedestrian-oriented urban environmental that is primarily residential in character, but that includes limited non-residential uses that serve many of the day-to-day convenience needs of neighborhood residents and provide opportunities for residents to live and work within the neighborhood.
	Permitted uses	Same as R-48 plus live/work units. Uses permitted on corner lots include art galleries, barber shops and beauty salons, grocery stores, convenience stores, restaurants and cafes, video rental stores, and the like. Such uses are limited to the ground floor of buildings devoted to other permitted uses; maximum FAR of such uses is 2,500 SF. Accessory uses include parking decks.
	Lot area and width	SFD: 3,000 SF lot area, 25’ width SFA: 2,200 SF lot area, 16’ width Two-family detached: 3,200 SF lot area, 27’ width Two-family attached: 2,600 SF lot area, 20 feet to 23’ width MF: 4,000 SF lot area; 1,000 SF minimum for each unit.
	Yards	Front: none
	Usable open space	30% minimum
	Lot coverage	65% maximum.
	Height	24’ minimum; 35’ to 40 feet maximum generally if a portion of street level story is devoted to parking; corner buildings may not exceed a total height of 48’.
	Transparency	Building facades have fenestration requirements: corner uses must have a minimum of 60% transparency; dwelling uses must have a minimum of 30% transparency.
R-73	Permitted uses	Same as R-53 plus nursing homes, parking decks serving permitted uses in the district, offices and hospitals. Incidental uses scaled for the convenience of the occupants of multi-family developments, nursing homes and offices may be permitted. Such uses include convenience stores, restaurants and personal service establishments.
	Lot area and width	Single-family and two-family dwellings same as R-7.
	Yards	Front: 15’ minimum.
	Floor area and usable open space	FAR for uses other than single- and two family dwellings: 2.0 maximum provided that the FAR of buildings or portions thereof devoted to non-dwelling uses shall not exceed 1.4. Usable open space ratio: .25% minimum shall be provided for dwelling uses.
	Height	150 feet maximum.

RO-1 Residential Office	Permitted uses	Same as for R-73 plus private schools and funeral homes.
	Lot area and width; density; unit width	SFA and two-family dwellings same as for R-6; multi-family dwelling minimum 3,000 SF per DU.
	Yards	Front: 15’ minimum for SFA; 25’ minimum all others.
	Usable open space	60% minimum for MF.
	Lot coverage	40% maximum for uses other than MF.
	Height	25’ maximum.
RO-2 Residential Office	Permitted uses	Same as for RO-1 plus banks, radio broadcasting studios and offices and communications centers. Permitted accessory uses include restaurant facilities and shops for the sale of gifts and convenience items within hospitals.
	Lot area and width	SFA and two-family dwellings same as for R-7; multi-family minimum lot size is 5,000 SF and not less than 1,250 SF in area for each dwelling unit.
	Yards	Front: 15’ minimum for SFA; 25’ minimum all others.
	Usable open space	40% minimum for MF dwellings, nursing homes, adult care residences, group homes and lodging houses.
	Lot coverage	60% maximum for uses other than MF dwellings, nursing homes and lodging houses.
	Height	35’ to 60 feet maximum.
RO-3 Residential Office	Permitted uses	Same as for RO-2 plus lodges and similar meeting places and hotels/motels. Incidental uses scaled for the convenience of the occupants of multi-family developments, hotels and motels, nursing homes and offices may be permitted. Such uses include convenience stores, restaurants and personal service establishments.
	Lot area and width	SFA and two-family dwellings same as for R-7.
	Yards	Front: 15’ minimum.
	Floor area and usable open space	FAR for uses other than single- and two family dwellings: 4.6 maximum provided that the FAR of buildings or portions thereof devoted to non-dwelling uses shall not exceed 1.4. Usable open space ratio: .25” minimum shall be provided for dwelling uses.
	Lot coverage	35% maximum for buildings, or portions of buildings, over 35’ in height.
	Height	35’to 50 feet
RF-2 Riverfront	Permitted uses	Mixed
	Yards	Front: 0
	Land area coverage	35% maximum for portions of buildings over 4 stories
	Building dimensions	300 feet maximum along lot line, street or public space
	Usable open space	Minimum of 10%
	Height	13 stories maximum, 2 stories minimum
B-1 Neighborhood Business	Permitted uses	Mixed
	Yards	Front: 0
	Height	25’ maximum.
B-2 Community Business	Permitted uses	Mixed
	Yards	Front: 25’ minimum.
	Height	35’ maximum.

B-3 General Business	Permitted uses	Mixed
	Yards	Front: 0
	Floor area and usable open space	FAR: 2.0 maximum OS: 25% minimum
	Height	35' maximum
B-4 Central Business District	Permitted uses	Mixed
	Yards	Front: 0
	Floor area and usable open space	FAR: 6.0 maximum OS: 8% minimum
	Height	No maximum height limit.
B-5 Central Business District	Permitted uses	Mixed
	Yards	Front: 0
	Height	60 feet maximum.
M-1	Yards	Front: 0
	Height	45' maximum.
M-2	Yards	Front: 0
	Height	45' maximum.
CM Coliseum Mall	Permitted uses	Mixed with the exception of residential uses.
	Height	80 feet maximum.
DCC Downtown Civic & Cultural	Permitted uses	Mixed with the exception of residential uses.
	Height	95' maximum.
RP Research Park	Permitted uses	Mixed with the exception of residential uses.
	Yards	Front: 0
	Height	85' maximum; no portion of any building located within 300 feet of any residential, RO-1, RO-2, or B-2 district shall exceed a height of 60 feet.
UB Urban Business	Intent of district	*"To encourage business areas with a densely developed pedestrian-oriented urban shopping character, compatible with adjacent residential neighborhoods, and with minimal disruption from vehicle-oriented land uses and features that would detract from a safe, convenient and economically viable pedestrian environment"*
	Permitted uses	Same as
	Yard	Front: 0
	Height	28' maximum.
Supplemental Regulations	Permitted Bonuses	Floor area bonuses are permitted for the following features in the RO-3 and B-4 districts: • Pedestrian Plaza: 10 SF per SF of plaza area. • Building setback: 5 SF per SF of qualifying area. • Arcade or open walkway: 5 SF per SF of qualifying area. • Improved roof area: 2 SF per SF of qualifying area. • Reduction in lot coverage (B-4 only): 10% basic floor area for first 20% reduction in each building dimension. • Enclosed parking (B-4 only): 100 SF for each parking space. Dwelling use (B-4 only): 1 SF per SF of dwelling floor area.

HENRICO COUNTY ZONING ORDINANCE		
Henrico County	Topic	Description
R-3 One-Family Residence	Permitted uses	SF Detached; child-care centers, schools, parks, churches, agriculture, recreational facilities and the like.
	Lot area and width	11,000 SF minimum lot area; 80 feet width
	Yards	Front: 40 feet
	Height	45' maximum
R-5 General Residence	Permitted uses	Multifamily development, group care facilities, rooming houses, child care centers, townhouses
	Provisional uses	B-1 principal uses on 1st or 2nd story of a structure exceeding 2 stories w/ provisional use permit.
	Density and Floor area	TH: maximum 12 units per acre B-1 uses: maximum 35% of floor area of structure
	Frontage	TH: 18' minimum lot frontage; at least 3 but no more than 12 units continuously connected.
	Parking	B-1 uses: parking for B-1 uses may be reduced up to 50% if shared by residential uses.
	Height	45' maximum for 3 or more family dwellings; up to 200 feet with provisional use permit.
UMU Urban Mixed Use	Purpose of District	To allow development of mixed use, pedestrian-oriented, activity centers containing a variety of uses including business, retail, residential, cultural, educational and other public and private uses. Permits a compatible mix of uses in a single structure or a group of structures on a parcel or group of parcels. The zone should be limited to areas with adequate infrastructure and served by necessary transportation facilities such as available public transit, close proximity to an I-interchange, etc.
	Permitted uses	Mixed; no principal use other that an office building, parking garage, hotel or motel may exceed 10,000 SF in floor area. Includes MF and SFA residential uses.
	Provisional uses	With a PUP additional uses, height and density may be permitted: buildings may exceed 60 feet in height, MF density may exceed 50 DUs/acre and TH density may exceed 12 DU/ac.
	Mix of Uses	25% minimum of bldg SF shall be for commercial or office uses 20% minimum open space requirement
	Area and density	20 Acre minimum for project area MF: maximum 40 DUs/acre SFA: townhouses maximum of 12 DUs/acre
	Height	60 feet maximum
	Parking	On-street permitted but cannot be counted toward required minimum parking standards. Restaurant: 1 space/150 SF GFA Retail: 1//250 SF GFA Office: 1/300 SF GFA Hotel/Motel: 1/room Residential: 1/ 1 bedroom studio unit; 1 ½ spaces/2+ bedroom unit.

B-1 Business	Purpose of zone	Primarily for low-intensity retail and personal service uses developed to serve the needs of nearby residential neighborhoods.
	Permitted uses	Multifamily developments, child care centers, shops, banks, bakeries, veterinarians, office buildings, neighborhood shopping centers, restaurants, churches, group care facilities, rooming houses, nursing homes, etc.
	Provisional uses	Grocery stores in excess of 30,000 SF of floor area, office buildings in excess of 15,000 SF of floor area, up to 4 accessory dwelling units located on floors above retail or office uses, hospitals, hotel or motel on 50 acres or more.
	Height	80 feet maximum for 3 or more family dwellings; 35' other permitted uses.
B-2 Business	Purpose of zone	To provide commercial and community shopping, recreational and service activities generally serving a community of several neighborhoods and appropriately located on major collector or arterial roadways.
	Permitted uses	Multifamily developments; uses permitted in B-1 and subject to B-2 development standards; gas stations, department stores, flea markets, garden centers, hotels/motels, offices and office buildings, printing establishments less than 5,000 SF, recreation facilities, shopping centers, restaurants, specialty stores, etc.
	Provisional uses	Self-service storage facilities, accessory dwellings up to 4 units located on floors above a retail or office use, buildings up to 200 feet in height; auto parts sales, billiard parlors, recycling facilities.
	Height	80 feet maximum for 3 or more family dwellings; 45' other permitted uses. Buildings in excess of 45' but not exceeding 110 feet in height permitted as conditional use.
B-3 Business	Purpose of zone	To provide locations for a variety of commercial automotive, recreational and service activities, serving a wide area of the County and located along arterial thoroughfares.
	Permitted uses	Uses permitted in B-1 and B-2 subject to B-3 development standards; animal hospital or kennel, auto repair, service or sales; building materials store; boat and RV sales, service and storage; gas stations; regional shopping centers; department stores, flea markets, garden centers, hotels/motels, offices and office buildings, printing establishments less than 5,000 SF, recreation facilities, shopping centers, restaurants, specialty stores, etc.
	Provisional uses	Amusement park, auditorium, bus and railroad passenger station, drive-in theater, heliport, commercial recreational facilities, self-service storage facilities, auto parts sales, billiard parlors, recycling facilities, accessory dwellings up to 4 units located on floors above a retail or office use, buildings up to 200 feet in height.
	Conditional uses	Retail businesses requiring outside display of merchandise, any retail business including any kind of manufacturing.
	Height	80 feet maximum for 3 or more family dwellings; 45' other permitted uses. Buildings in excess of 45' but not exceeding 110 feet in height permitted as conditional use.
O-1 Office	Purpose of zone	To provide for nonresidential buildings on sites that may not be considered appropriate for residential use but generally compatible with low density residential development.

	Permitted uses	Offices and office buildings; medical offices, artist or musician studios, child care centers.
	Provisional uses	Accessory dwellings up to 4 units located on floors above an office use.
	Height	30 feet maximum
O-2 Office	Purpose of zone	To provide for office buildings in attractive surroundings compatible with medium density residential surroundings.
	Permitted uses	Offices and office buildings; medical offices; banks, employment agency, funeral homes, artist or musician studios, child care centers.
	Provisional uses	Accessory dwellings up to 4 units located on floors above an office use.
	Conditional uses	Hospitals, retail and service facilities in an office building of at least 50,000 SF, provided such facilities do not occupy more than 10% of the floor area.
	Height	45' maximum; buildings in excess of 45' but not exceeding 8 stories or 110 feet in height permitted w/ PUP.
M-1 Light Industrial	Permitted uses	Any use permitted in B-3 except dwellings, schools, hospitals and other institutions for human care; manufacturing and assembling, distribution or storage of products made from previously prepared basic materials; manufacturing, processing, packaging of cosmetics, pharmaceuticals and food products; manufacture of pottery or ceramic products; laboratories; warehouses; on-site recycling collection facilities.
	Provisional uses	Buildings up to 200 feet in height.
	Conditional uses	Sand or gravel pits; airports; mixing of cement concrete.
	Height	45' maximum; buildings up to 110 feet permitted as a conditional use.
M-2 General Industrial	Permitted uses	Any use permitted in M-1 plus generally accepted heavy industrial uses involving manufacturing and assembly. Buildings up to 200 feet in height.
	Provisional uses	Sewage disposal plants; recycling collection facility.
	Conditional uses	Any conditional use permitted in M-1 and any other lawful use that would otherwise be prohibited because it is especially obnoxious or dangerous.
	Height	50 feet maximum; buildings up to 200 feet permitted with PUP.

BROAD STREET RAPID TRANSIT STUDY

ENVIRONMENTAL ASSESSMENT

APPENDIX A-11: Calculation of Linked Trips on Project Report

AECOM
2101 Wilson Blvd, Suite 800
Arlington, VA 22201
www.aecom.com

703 340 3100 tel
703 340 3001 fax

Memorandum

To	Amy Inman – DRPT, Lorna Parkins – Michael Baker	Page	1
CC	Jeffrey Roux		
Subject	Richmond Broad Street BRT Calculation of Linked Trips on Project, Methodology and Results		
From	Daniel Evans		
Date	December 12, 2013		

This technical memorandum describes the methodology used to compute the "linked trips on project" statistic for the Richmond Broad Street Bus Rapid Transit (BRT) project. The linked trips on project statistic will be used to support the Federal Transit Administration (FTA) Small Starts project justification evaluation metrics including mobility benefits and cost-effectiveness.

Average Weekday Linked Trips on Project Statistic

FTA's migration to using the linked trips on project statistic created a challenge for the forecasting team to extract the evaluation statistics. This challenge was due to the different categories of riders who will benefit from the Broad Street BRT project as well as the complexity of the accounting required to assemble the statistics consistent with FTA expectations. The Broad Street project is intended to benefit Greater Richmond Transit Company (GRTC) customers in the following fashion:

1. Improve mobility for longer-haul Broad Street transit customers by introducing dedicated BRT service on Broad Street. The BRT will utilize dedicated bus lanes (curb running in Downtown along with a median approaching downtown from the west), will use differentiated BRT branding, and will provide formal stations with:
    a. Passenger information systems
    b. Off-board fare collection
    c. Enhanced shelters

2. Improve the customer experience for local GRTC bus customers riding into downtown Richmond. Many GRTC routes perform downtown distribution on Broad Street. The project will introduce a dedicated bus lane through downtown Richmond, which will 1) offer improved travel times, 2) consolidate station stops (BRT route and all locals at three stops in the bus lane), 3) reduce bus bunching, and 4) improve operational reliability.

After consulting with the FTA, AECOM and FTA defined a "project boarding" as any boarding that meets one of the following criteria:

- All customers boarding the BRT trunk line.
- A boarding in which the customer boards or alights from a local bus at a BRT station outside the dedicated bus lane.
- A boarding by a local bus customer who either is on-board as the bus enters the dedicated bus lane or boards the local bus which operates within the dedicated bus lane.

Based on the criteria above, project boardings could be classified in two ways: boardings by customers who either (1) board or alight at a BRT station, or (2) completely "run through" the downtown dedicated bus lane.

Linked Trips on Project Boarding or Alighting at a BRT Station

A customer who boarded or alighted at a BRT station was counted as a project boarding, regardless of whether the customer used BRT, local bus, or express bus. For each transit mode (local bus, express bus, and BRT), skims were generated to indicate the beginning node and ending node of linked transit trips between zones. If either the first or last node of a linked trip was one of the 14 BRT stations, the transit trips in the input trip table for a given zonal pair were counted as project boardings for a particular mode.

Linked Trips on Project "Running Through" Downtown Dedicated Bus Lane

AECOM estimated the number of local bus linked trips that "run through" the dedicated bus lane along Broad Street in downtown Richmond (from 3rd St. to 12th St.). These linked trips are local bus linked trips that run through the downtown bus lane, but do not use a BRT station. To estimate the number of these linked trips, AECOM used the 2009 GRTC on-board origin-destination survey to compute the number of linked trips that began to the east/west of the bus lane, passed through the downtown bus lane, and ended to the west/east of the bus lane. Three steps were taken to extract relevant records from the survey.

- Survey records without a transfer were selected.
- Local bus routes were selected which traversed the dedicated bus lane. These routes include the #1 & 2, 3 & 4, 6, 10, 19, 22, 24, 37, and 74.
- The trip origin had to be east/west of the downtown bus lane, and the trip destination had to be beyond the opposite limits of the bus lane. Survey data included longitudinal coordinates for origins and destinations, so the team was able to isolate trips that began east/west of the bus lane and ended west/east of the bus lane.

Together, the three criteria essentially would require a trip to run through the downtown bus lane using a route that traverses the bus lane. The zonal pairs of the survey records that met the three criteria were used to create a "dummy" trip table. The dummy trip table simply indicated with a "1" every zonal pair meeting the three criteria (all other zonal pairs had a value of 0 in the dummy trip table). The 2015 and 2035 Build 3 scenario trip tables were then multiplied by the dummy trip table to estimate the number of linked trips "running through" the downtown dedicated bus lane on Broad Street. In order to avoid double-counting "run-through" trips that began or ended at a BRT station (these trips would have been counted already because of a stop at a BRT station), "run-through" trips were not counted for any zonal pair interchange in which a BRT station was a beginning or ending node in the transit skims (local bus, express bus, and BRT skims).

Linked Trips on Project Results

Table 1 below shows the forecasted average weekday linked trips on project by transit mode for both the current and horizon years. Also, the table includes the number of linked trips on the project made by households with a vehicle and by zero-car households, a proxy for transit-dependent customers. A few observations can be made based on the results:

- The overall total project boardings increase approximately 20 percent between today and 2035.
- Transit-dependent custumers account for roughly half of total average weekday linked trips on project.

Table 1 – Average Weekday Linked Trips on Project

	Current (2015)			Horizon (2035)		
Linked Trips	**All**	**0-Car**	**1+ Car**	**All**	**0-Car**	**1+ Car**
BRT	3,300	1,800	1,500	4,000	2,100	1,900
Local Bus	7,600	4,000	3,600	9,200	4,800	4,400
Express Bus	700	100	600	900	100	800
Local Run-Through	300	200	100	300	200	100
Total	11,900	6,100	5,800	14,400	7,200	7,200

Table 2 below shows the annual linked trips on project and is based on the data in Table 1. An annualization factor was derived using GRTC's reported average weekday and annual unlinked trips in the 2011 National Transtit Database (NTD). The resulting factor was 289, which was used to convert the average weekday figures in Table 1 to annual figures in Table 2. The FTA evaluation measure for mobility benefits is calculated as:

FTA Evaluation Measure = 1.0 * Annual Trips Made by Non-Dependents (1+ car HHs) + 2.0 * Annual Trips Made by Transit-Dependents (0 car HHs)

Table 2 shows that the FTA evaluation measure for linked trips on the project is calculated as 5.2M in the current year and 6.2M in the horizon year (2035). FTA allows project sponsors to submit either the current year forecasts or the average of the current year forecast and the 20-year horizon forecast. In either case, our forecasts show that the Broad Street BRT project would earn a "medium" rating on mobility benefits (annual boardings of between 5 and 15 million).

Table 2 – Annual Linked Trips on Project

	Current (2015)			Horizon (2035)		
Linked Trips	**All**	**0-Car**	**1+ Car**	**All**	**0-Car**	**1+ Car**
BRT	953,700	520,200	433,500	1,156,000	606,900	549,100
Local Bus	2,196,400	1,156,000	1,040,400	2,658,800	1,387,200	1,271,600
Express Bus	202,300	28,900	173,400	260,100	28,900	231,200
Local Run-Through	86,700	57,800	28,900	86,700	57,800	28,900
Total	3,439,100	1,762,900	1,676,200	4,161,600	2,080,800	2,080,800
FTA Evaluation Measure		**5,202,000**			**6,242,400**	

BROAD STREET RAPID TRANSIT STUDY

ENVIRONMENTAL ASSESSMENT

APPENDIX A-12: Operating and Maintenance Cost Estimate Report

BROAD STREET RAPID TRANSIT STUDY
OPERATIONS AND MAINTENANCE COST ESTIMATES

The GRTC Transit System and Virginia Department of Rail and Public Transportation (GRTC/DRPT) are conducting a study consistent with the requirements of the Federal Transit Administration's (FTA) Small Starts program to evaluate transit improvements along the Broad Street corridor. This memo provides a summary of the Operations and Maintenance (O&M) costs estimated for the No Build, and Build Alternatives. Based on the results of the O&M cost model, the study team reached the following conclusions:

- **In 2015 dollars, the O&M costs for the Build Alternative are 2.4% higher than the 2012 O&M costs for the existing system.** Small Starts projects can receive a "Medium" rating for Local Financial Commitment if their costs are less than 5% of existing O&M costs. Even taking into account inflation between 2012 and 2015, the Build Alternative is anticipated to be only slightly more expensive to operate than the existing system due to:
    - The conversion of the existing fleet to compressed natural gas (CNG) vehicles, which is expected to lower unit fuel costs by 16% for the total fleet by 2015;
    - The use of CNG vehicles on the BRT service, which is expected to result in fuel costs 56% lower than if the BRT service were operated using diesel vehicles;
    - The reduction of headways on the Route 6 to account for the transfer of ridership to the BRT service on the Broad Street corridor.

- **In 2015 dollars, the total O&M costs for the Build Alternative are 1% higher than operations under the No Build Alternative.** The No Build Alternative anticipates that GRTC will have 47 CNG vehicles available for fixed-route service by 2015; therefore, it is more comparable to the Build Alternative than the existing, all-diesel service provided by GRTC. The difference in costs between the Build and No Build can be largely attributed to the costs of providing off-board fare collection as part of the BRT service. The additional costs of providing 10 minute peak and 15 minute off-peak BRT service have been offset by reductions in service on Route 6.

1.0 OVERVIEW OF METHODOLOGY AND ASSUMPTIONS

As described in the October 2013 update of the *O&M Cost Methodology Report*, these cost estimates were developed in a manner consistent with FTA guidance published in two documents:

- Part II (Conduct of the Analysis), Chapter 4 (Operating and Maintenance Costs) of *Procedures and Technical Methods for Transit Project Planning*; and,

- *Final Guidance on New Starts/Small Starts Policies and Procedures*.

O&M costs were developed using a fully allocated cost model, where costs were estimated based on changes in three, key driving supply variables:

- Revenue hours of service
- Revenue miles of service
- Peak vehicle requirements

Each category of operations and maintenance expense associated with non-specialized service was assigned to one of these variables. The incremental cost associated with each key driving supply variable was then calculated by summing the line item costs associated with the variable by the total for the year 2012 (e.g. dividing total costs associated with revenue hours by the total revenue hours in 2012).

Where the introduction of BRT services was anticipated to change the costs of specific cost categories, the study team introduced an adjustment factor that would be applied to incremental costs of BRT operations. A similar approach was used to account for GRTC's planned transition from diesel buses to CNG buses, of which 47 will be available for fixed-route service by 2015. The categorization of line item costs and adjustments for BRT service and CNG vehicles may be found in the *O&M Cost Methodology Report*. Table 1 summarizes the incremental costs of the key driving supply variables used in the fully allocated cost model. Appendix A provides a detailed accounting of the line item costs used to develop the incremental costs.

Table 1: Incremental Costs of Key Driving Supply Vehicles

	2012$			2015$		
	Existing	No Build/ Non-BRT Build*	BRT	Existing	No Build/ Non-BRT Build*	BRT
Incremental cost per revenue hour	$43.82	$43.82	$43.82	$46.58	$46.58	$46.58
Incremental cost per revenue mile	$1.74	$1.59	$1.30	$1.85	$1.69	$1.38
Incremental cost per vehicle	$86,500	$86,500	$92,600	$92,000	$92,000	$98,400
Incremental cost, off-board fare collection			$626,100			$665,600

*Refers to the fixed-route services operated under the No Build Alternative and the non-BRT, fixed-route services operated under the Build Alternative.

Source: GRTC's *Statement of Operating Expenses and Taxes for the Year Ending June 30, 2012. Vehicle and off-board fare collection costs rounded to nearest $100. 2015 costs assume 2% annual inflation.*

The total O&M cost of non-specialized services under each alternative was then calculated using the formula:

$$C(h,m,v) = h \times C_h + m \times C_m + v \times C_v \ + l \times C_l$$

Where:

- *C(h,m,v)* is the estimated annual operations and maintenance cost of an alternative that includes *h* hours of service, *m* revenue miles of service, and *v* peak vehicles.
- C_h is incremental operating cost of adding an additional revenue hour of service
- C_m is incremental operating cost of adding an additional revenue mile of service
- C_v is incremental operating cost of adding an additional peak hour vehicle to the transit system

- C_l is incremental operating cost of adding an additional route-mile of bus lane to the transit system

Per the request of the Federal Transit Administration, the Build Alternative was modified to consider the impacts of off-board fare collection. As this cost is anticipated not to vary by hours or frequency of operation, it was considered a fixed cost to be added to the O&M costs of the Build Alternative.

For purposes of this study, it is assumed that specialized services (including paratransit, chartered buses, and long-distance service to Petersburg) would remain constant across all alternatives. Therefore, the O&M cost of specialized services was added to the estimated O&M cost of each alternative to arrive at the total operating expense for each alternative. The revenue hours, revenue miles, and vehicle requirements for specialized services were not calculated as part of each alternative.

2.0 ESTIMATION OF KEY DRIVING SUPPLY VARIABLES

As the travel demand model being used as part of this study does not provide estimates of revenue hours, revenue miles, or vehicle requirements for each alternative, these variables were estimated using the route lengths, two-way travel times, and frequencies of service input into the travel demand model for local and express bus services. To ensure the validity of this approach, the study team first tested it on the existing system, comparing calculated values for the key driving supply variables against the real data available from the GRTC *Statement of Operating Expenses and Taxes for the Year Ending June 30, 2012*. The results of this test are summarized in Table 2; the route-by-route calculation of these variables is provided in Appendix B.

Table 2: Summary of O&M Costs and Statistics, Local and Express Services

Unit	Existing Service		
	Actual*	Modeled	Model vs. Actual
Annual Revenue Hours Operated	397,288	386,427	-3%
Annual Revenue Miles Operated	4,766,011	4,242,864	-11%
Fleet Size	136	131	-4%

*Sources: GRTC's *Statement of Operating Expenses and Taxes for the Year Ending June 30, 2012.* Fleet size represents maximum vehicles in service, as reporting in the *2009 National Transit Database*.

The estimated values for revenue hours were 3% lower than actual values and the estimated values for revenue miles were 11% lower than actual. Estimated fleet requirements were 4% lower than actual due to the need to round vehicle requirements on a route-by-route basis. These variations may be attributed to two issues:

1. The travel times used to estimate revenue miles and hours were derived from the travel times used in the travel demand forecast, and may vary from actual operating conditions in 2012.

2. The method used to estimate revenue miles and revenue hours may not completely reflect actual revenue miles and hours associated with pull-ins and pull-outs of vehicles in revenue service.

That being said, this level of accuracy still makes it possible to make meaningful comparisons between the No Build and the Build Alternatives. These estimates will be refined and revised as the project moves forward and more detailed information is available to the study team.

The key driving supply variables for each alternative were calculated using the information input into the travel demand forecast for each alternative. The inputs to the travel demand forecasts, in turn, were derived from VISSIM microsimulations of each alternative, which were able to quantify the impacts of the service and facility improvements on travel times in the corridor. Both the travel demand forecasts and VISSIM microsimulations were developed from the description of alternatives provided in the November 17, 2010 *Detailed Definition of Alternatives* technical memorandum. Appendix C provides a route-by-route account of the inputs and calculations of each key supply variable.

3.0 MODEL RESULTS

Table 3 summarizes the key driving supply variables and estimated O&M costs for each alternative. The key findings from these estimates are as follows:

No Build Alternative: In 2015 dollars, No Build Alternative is estimated to cost 1.6% more to operate than the existing system. This reflects the impacts of inflation on operating the system, which are countered by both the increased use of CNG vehicles and potential of the model to underestimate revenue miles and hours. The No Build is anticipated to generate O&M costs 5% higher than the modeled existing service, due to estimated increases in miles and hours generated by the splitting of Route 6 into Routes 6 and 53.

Build Alternative: The Build Alternative is estimated to cost 2.4% more in 2015 dollars than the 2012 O&M costs for the existing system. The Build Alternative is also estimated to cost less than one percent more than the No Build Alternative to operate. In both cases, the addition of BRT service is offset by the decrease of service on Route 6 and the increased use of CNG vehicles, both on the BRT service and across the GRTC system.

Small Starts projects can receive a "Medium" rating for Local Financial Commitment if their costs are less than 5% of existing O&M costs. That being said, the model used to estimate O&M costs slightly underestimates revenue miles and revenue hours. Therefore, it is more appropriate to compare the Build Alternative with the No Build Alternative, as the costs for both alternatives were derived from the same model. Comparing the Build Alternative versus the No Build, it is likely that the Build Alternative will meet the 5% threshold that would allow for a "Medium" rating.

Table 3: Summary of O&M Costs and Statistics

		Existing Service (June 2012)	Modeled Service (June 2013)	No Build (2015)	Build (2015)			Build (2015$) vs. Existing (2012$)
					BRT Route	All Other Services	Total	
Operating Statistics	Peak Vehicle Requirement	136	131	133	7	127	134	-1.5%
	Annual Vehicle Hours	397,300	386,400	391,700	28,000	359,000	$387,000	-2.6%
	Annual Vehicle Miles	4,766,000	4,242,900	4,288,900	79,700	4,113,800	$4,193,500	-12.0%
Cost Breakdown by Category	Operating Costs (2012$)			Operating Costs (2015$)				
	Hourly Costs	$17,409,000	$16,933,000	$18,246,000	$1,308,000	$16,724,000	$18,032,000	3.6%
	Mileage Costs	$8,305,000	$7,393,000	$7,245,000	$110,000	$6,949,000	$7,059,000	-15.0%
	Vehicle Costs	$11,769,000	$11,336,000	$12,235,000	$689,000	$11,683,000	$12,372,000	5.1%
	Fixed Costs*				$626,000		$626,000	
	Subtotal: Non-specialized services	$37,483,000	$35,663,000	$37,726,000	$2,733,000	$35,356,000	$38,089,000	1.6%
	Specialized Services**	$8,301,000	$8,301,000	$8,809,000			$8,809,000	
	Total: all O&M costs	$45,784,000	$43,964,000	$46,535,000			$46,899,000	2.4%
	% of total 2012GRTC expenses	100.0%	96.0%	101.6%			102.4%	

All vehicle hours and vehicle miles rounded to the nearest 100. All costs rounded to the nearest $1,000
*Includes costs associated with off-board fare collection. **Specialized services for 2015 inflated by 2% annually, assume same level of service.

While the model used to estimate O&M costs is of sufficient accuracy to compare the No Build versus the Build Alternative, it should be noted that there may be additional costs associated with operating both scenarios. Furthermore, should the costs of specialized services decrease, relative cost of the Build Alternative versus the No Build would increase. Therefore, it will be critical to refine these estimates as the project moves forward.

4.0 NEXT STEPS

The travel demand forecasts for the study are being finalized, pending final input from FTA. Once these forecasts have been finalized, they will be used in conjunction with the annualized costs for the project to estimate the Cost-Effectiveness Index (CEI) for the project. The operating costs will also be utilized by the cost model for the project so that an appropriate financial plan for the project may be developed.

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APPENDIX A:
O&M UNIT COSTS

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APPENDIX A

O&M Unit Costs

Source: GRTC, for 12 months ending June 30, 2012

				Unit Costs (2012$)				Unit Costs (2015$)			
Category	Actual	Budget	Unit	Base Unit Cost	No Build, non-BRT Build	Adjustment Factor: BRT	Adjusted Unit Costs, BRT only	Inflation Factor	Base Unit Cost	No Build, non-BRT Build	Adjusted Unit Costs, BRT only
Operations											
Operators Wages	$11,058,718	$11,590,386	Hours	$27.84	$27.84		$27.84	2%	$29.59	$29.59	$29.59
Transportation Supervisors	$1,362,911	$1,345,156	Hours	$3.43	$3.43		$3.43	2%	$3.65	$3.65	$3.65
Fuel and Lubricants (Ops)	$4,605,738	$4,848,971	Miles	$0.97	$0.81	-56%	$0.43	2%	$1.03	$0.86	$0.46
Tires and Tubes	$327,946	$332,734	Miles	$0.07	$0.07		$0.07	2%	$0.07	$0.07	$0.07
Other Materials and Supplies (Ops)	$458,841	$436,101	Peak Vehicles	$3,373.83	$3,373.83	20%	$4,048.60	2%	$3,586.66	$3,586.66	$4,303.99
Off-Board Fare Collection Operating Costs			Fixed	$167,192.00	$167,192.00		$167,192.00	2%	$177,738.78	$177,738.78	$177,738.78
Maintenance											
Mechanics Wages	$1,776,927	$1,620,111	Miles	$0.37	$0.37	20%	$0.45	2%	$0.40	$0.40	$0.48
Mechanics Supervisors	$423,569	$426,533	Miles	$0.09	$0.09	20%	$0.11	2%	$0.09	$0.09	$0.11
Contractor Support (Maint)	$111,091	$114,501	Miles	$0.02	$0.02		$0.02	2%	$0.02	$0.02	$0.02
Fuel and Lubricants (Maint)	$71,222	$53,400	Peak Vehicles	$523.69	$523.69		$523.69	2%	$556.73	$556.73	$556.73
Vehicle Parts	$2,139,936	$1,981,000	Peak Vehicles	$15,734.82	$15,734.82	20%	$18,881.79	2%	$16,727.40	$16,727.40	$20,072.89
Other Materials and Supplies (Maint)	$225,225	$198,090	Peak Vehicles	$1,656.07	$1,656.07	5%	$1,738.87	2%	$1,760.53	$1,760.53	$1,848.56
Utilities Cost (Maint)	$254,689	$350,796	Peak Vehicles	$1,872.71	$1,872.71	20%	$2,247.26	2%	$1,990.85	$1,990.85	$2,389.02
Off-Board Fare Collection Maintenance Costs			Fixed	$458,940.90	$458,940.90		$458,940.90	2%	$487,891.73	$487,891.73	$487,891.73
Buildings, Grounds, Facilities											
Maintenance Worker Wages	$856,190	$952,549	Peak Vehicles	$6,295.51	$6,295.51	20%	$7,554.62	2%	$6,692.65	$6,692.65	$8,031.18
Contractor Support (Bldg)	$0	$500	Peak Vehicles	$0.00	$0.00		$0.00	2%	$0.00	$0.00	$0.00
Administrative Building Materials	$323,845	$200,000	Peak Vehicles	$2,381.21	$2,381.21	20%	$2,857.46	2%	$2,531.42	$2,531.42	$3,037.71
Administration											
Administrative Wages/Salaries	$2,687,052	$2,622,002	Peak Vehicles	$19,757.74	$19,757.74		$19,757.74	2%	$21,004.09	$21,004.09	$21,004.09
Contractor Support (Admin)	$583,422	$279,000	Peak Vehicles	$4,289.87	$4,289.87		$4,289.87	2%	$4,560.48	$4,560.48	$4,560.48
Fuel and Lubricants (Admin)	$3,961	$4,750	Peak Vehicles	$29.13	$29.13		$29.13	2%	$30.96	$30.96	$30.96
Office Supplies (Admin)	$1,728,078	$1,755,544	Peak Vehicles	$12,706.46	$12,706.46		$12,706.46	2%	$13,508.00	$13,508.00	$13,508.00
Utilities Cost (Admin)	$97,898	$108,000	Peak Vehicles	$719.84	$719.84		$719.84	2%	$765.25	$765.25	$765.25
Pension	$1,883,463	$2,043,185	Hours	$4.74	$4.74		$4.74	2%	$5.04	$5.04	$5.04
Health Insurance	$3,104,019	$3,501,175	Hours	$7.81	$7.81		$7.81	2%	$8.31	$8.31	$8.31
Vehicle Liability Insurance	$1,059,838	$1,035,000	Miles	$0.22	$0.22		$0.22	2%	$0.24	$0.24	$0.24
Comprehensive Insurance	$394,018	$500,000	Peak Vehicles	$2,897.19	$2,897.19		$2,897.19	2%	$3,079.95	$3,079.95	$3,079.95
Other Insurance	$1,944,608	$1,931,008	Peak Vehicles	$14,298.59	$14,298.59		$14,298.59	2%	$15,200.57	$15,200.57	$15,200.57

Subtotal: Non-specialized Services	**$37,483,205**
Gross cost per revenue hour	$94.35
Gross cost per revenue mile	$7.86
Gross cost per vehicle	$275,611.80

	2012			**2015**		
	Existing	**No Build**	**BRT**	**Existing**	**No Build**	**BRT**
Incremental cost per revenue hour	$43.82	$43.82	$43.82	$46.58	$46.58	$46.58
Incremental cost per revenue mile	$1.74	$1.59	$1.30	$1.85	$1.69	$1.38
Incremental cost per vehicle	$86,536.65	$86,536.65	$92,551.08	$91,995.54	$91,995.54	$98,389.37
Incremental cost, off-board fare collection			$626,132.90			$665,630.50

APPENDIX B:
ESTIMATES OF KEY DRIVING SUPPLY VARIABLES FOR THE EXISTING SYSTEM

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				Off-Peak Hours of Operation				Existing															
Name	Group	Direction	Type	Distance	Weekday	Saturday	Sunday	PK Headway	Pk Vehicles/Hr	Combined Headway	OP Headway	End-to-End Travel PK Travel time	End-to-End Travel OP Travel time	Number of Round Trips (Express Bus only)	Fleet Requirement	Peak Vehicles Required	Off Peak Vehicles Required	Peak Vehicle Revenue Hours	Off Peak Vehicle Revenue Hours	Total Revenue Hours	Peak Vehicle Revenue Miles	Off Peak Vehicle Revenue Miles	Total Revenue Miles
1	1	Inbound		8.48	8.57	17.22	17.22	30	2	30	30	53.05	50.81		4	4	3	4,160	12,054	16,214	39,831	120,785	160,616
1-	1	Outbound		8.48	13.27	17.22	17.22	30	2		30	53.23	50.74										
2	2	Inbound		13.64	13.83	6.85	6.85	60	1	20	34	73.13	70.68		3	2	4	2,080	17,236	19,316	23,222	199,677	222,898
2-	2	Outbound		13.64	14.93	18.28	18.28	60	1		34	73.48	70.61										
2.CITY	2	Inbound		8.9	15.77	0.00	0.00	30	2		NA	54.55	NA		4	4	0	4,160	0	4,160	40,652	0	40,652
2.CITY-	2	Outbound		8.9	9.37	0.00	0.00	30	2		NA	54.74	NA										
3	3	Outbound		7.42	15.50	19.83	18.33	30	2	20	NA	50.03	NA		4	3	0	3,120	0	3,120	27,803	0	27,803
3PP	3	Inbound		7.42	15.50	19.83	18.33	24	3		NA	49.89	NA										
3.OP	3	Inbound		7.42	15.50	19.83	18.33	NA			27	NA	47.82		0	0	4	0	24,059	24,059	0	223,820	223,820
3.OP-	3	Outbound		7.42	15.50	19.83	18.33	NA			27	NA	47.89										
4	4	Outbound		6.06	15.77	19.97	19.38	24	3	20	NA	45.36	NA		4	4	0	4,160	0	4,160	34,427	0	34,427
4P	4	Inbound		6.65	15.77	19.97	19.38	24	3		NA	46.79	NA										
4.OP	4	Outbound		6.98	15.77	19.97	19.38	NA			27	NA	47.92		0	0	3	0	18,437	18,437	0	163,725	163,725
4.OP-	4	Inbound		6.98	15.77	19.97	19.38	NA			27	NA	46.4										
5.SOUTH				NA	15.77	19.97	19.38	NA			NA	NA	NA		0	0	0	0	0	0	0	0	0
5.NORTH				NA	15.77	19.97	19.38	NA			NA	NA	NA										
6	6	Inbound		4.96	12.22	15.02	15.38			10													
6	6	Outbound		4.96	13.72	17.29	15.42																
6.DNTN	6	Inbound		5.29	12.82	1.05	2.28	30	2		17	40.4	40.13		3	3	5	3,120	17,528	20,648	24,251	137,319	161,570
6.DNTN-	6	Outbound		5.29	13.42	0.58	0.57	30	2		17	41.27	40.9										
6.EAST	6	Inbound		9.01	12.40	14.82	15.50	40	2		60	63.67	59.37		3	3	2	3,120	9,601	12,721	27,574	85,223	112,797
6.WEST	6	Outbound		8.24	13.03	16.00	15.55	40	2		60	53.44	50.28										
6.EAST#2	6	Inbound		7.78	11.43	15.22	15.25	30	2		80	57.24	54.12		4	3	1	3,120	4,557	7,677	27,334	49,052	76,385
6.WEST#2	6	Outbound		8.87	14.70	18.58	15.28	30	2		80	56.79	53.17										
7.EAST	7	Outbound		9.1	10.53	0.00	0.00	40	2	15	40	43.43	39.97		3	2	2	2,080	5,477	7,557	25,743	73,647	99,390
7.EAST#2	7	Outbound		9.37	10.53	0.00	0.00	40	2		40	46.11	42.45										
7.WEST	7	Inbound		8.95	10.53	0.00	0.00	40	2		40	43.78	40.81		3	2	2	2,080	5,477	7,557	25,799	72,582	98,380
7.WEST#2	7	Inbound		10.43	10.53	0.00	0.00	40	2		40	49.97	46.94										
8.EB					0.00	0.00	0.00																
8.WB					0.00	0.00	0.00																
10.EB	10	Inbound		3.83	15.68	18.70	18.70	30	2	30	30	29.95	28.66		2	2	2	2,080	12,045	14,125	15,757	94,893	110,650
10.WB	10	Outbound		3.72	15.68	18.70	18.70	30	2		30	29.85	28.84										
11.EAST	11	Outbound		3.15	7.00	6.32	0.00	30	2	30	30	20.47	18.39		2	1	1	1,040	2,148	3,188	9,014	20,676	29,690
11.WEST	11	Inbound		2.26	7.00	6.32	0.00	30	2		34	16.98	15.34										
16.EAST_PK	16	Inbound		6.97	9.92	0.00	0.00	17	4	15	NA	38.52	NA		5	4	0	4,160	0	4,160	47,323	0	47,323
16.WEST_PK	16	Outbound		6.26	9.92	0.00	0.00	20	3		NA	31.26	NA										
16.EAST_OP	16	Inbound		4.13	9.92	0.00	0.00	NA			60	NA	24.51		0	0	1	0	2,578	2,578	0	27,081	27,081
16.WEST_OP	16	Outbound		3.42	9.92	0.00	0.00	NA			60	NA	18.62										
18.1	18	Inbound		3.63	8.33	0.00	0.00	60	1	60	60	15.31	14.78		1	1	1	1,040	2,167	3,207	15,830	33,854	49,683
18.2	18	Outbound		7.06	8.33	0.00	0.00	60	1		60	26.83	26.27										
-18.2					8.33	0.00	0.00																
-18.1					8.33	0.00	0.00																
19.EB	19	Inbound		10.77	8.22	0.00	0.00	60	1	60	240	61.75	60.62		3	2	1	2,080	2,136	4,216	22,015	22,967	44,982
19.WB	19	Outbound		10.4	8.53	0.00	0.00	60	1		240	58.26	57.53										
22	22	Inbound		6.26	9.57	11.92	11.92	120	1	60	NA	38.76	NA		1	1	0	1,040	0	1,040	10,090	0	10,090
22-	22	Outbound		6.26	9.57	11.92	11.92	120	1		NA	38.67	NA										
24.EAST	24	Inbound		5.4	13.48	15.20	15.20	30	2	30	80	36.62	36.19		2	1	1	1,040	5,086	6,126	9,202	47,082	56,283
24.EAST#2	24	Inbound		6.88	13.48	15.20	15.20	NA			80	NA	43.41										
24.WEST#1	24	Outbound		5.46	13.48	15.20	15.20	40	2		120	36.48	36.05		3	2	1	2,080	5,086	7,166	19,082	47,710	66,791
24.WEST#2	24	Outbound		6.94	13.48	15.20	15.20	120	1		60	44.62	43.27										
26.EB	26	Inbound	Express	11.37	0.00	0.00	0.00	20	3	20	NA	33.54	NA	7	4	4	0	2,153	0	2,153	42,934	0	42,934
26.WB	26	Outbound	Express	12.22	0.00	0.00	0.00	30	2		NA	37.43	NA										
27.EB	27	Inbound	Express	9	0.00	0.00	0.00	20	3	20	NA	34.48	NA	9	4	4	0	2,756	0	2,756	42,916	0	42,916
27.WB	27	Outbound	Express	9.34	0.00	0.00	0.00	20	3		NA	36.18	NA										
28	28	Inbound	Express	7.68	0.00	0.00	0.00	60	1	60	NA	28.85	NA	2	1	1	0	495	0	495	7,987	0	7,987
28-	28	Outbound	Express	7.68	0.00	0.00	0.00	60	1		NA	28.24	NA										
29.EB	29	Inbound	Express	12.94	0.00	0.00	0.00	11	5	12	NA	36.7	NA	11	7	7	0	3,513	0	3,513	74,789	0	74,789
29.WB	29	Outbound	Express	13.21	0.00	0.00	0.00	15	4		NA	36.99	NA										
32.EAST	32	Inbound		4.16	15.32	19.62	19.50	10	6	10	20	24.73	24.08		5	5	2	5,200	12,033	17,233	55,564	131,998	187,562
32.WEST	32	Outbound		4.7	15.32	19.62	19.50	10	6		20	25.02	24.38										
34.NORTH	34	Outbound		3.91	15.33	18.80	18.87	17	4	20	19	24.01	22.11		3	3	2	3,120	11,891	15,011	28,675	119,818	148,493
34.SOUTH	34	Inbound		3.32	15.33	18.80	18.87	20	3		20	23.19	20.94										
37.NORTH	37	Outbound		5.61	15.07	18.72	18.90	13	5	12	20	29.84	29.14		5	5	3	5,200	17,620	22,820	55,234	191,316	246,550
37.SOUTH	37	Inbound		5.55	15.07	18.72	18.90	13	5		22	33.2	32.53										
45	45	Outbound		3.17	15.55	0.00	18.40	24	3	20	30	26.36	24.58		3	2	2	2,080	10,000	12,080	14,929	77,157	92,086
45-	45	Inbound		3.17	15.55	0.00	18.40	24	3		30	26.64	24.72										
53	53	Outbound		3.83	13.72	17.29	15.42																
53	53	Inbound		3.97	12.22	15.02	15.38																
56.EAST	56	Outbound		9.74	11.37	0.00	0.00	120	1	60	NA	46.28	NA		1	1	0	1,040	0	1,040	13,488	0	13,488
56.WEST	56	Inbound		11.46	11.37	0.00	0.00	60	1		NA	51.8	NA										
61					0.00	0.00	0.00																
-61					0.00	0.00	0.00																
62.BD	62	Outbound		8.17	14.75	19.35	18.83	40	2	15	60	41.02	37.18		3	2	1	2,080	5,821	7,901	24,957	76,741	101,698
62.BD-	62	Inbound		8.17	14.75	19.35	18.83	40	2		60	40.69	37.18										

				Off-Peak Hours of Operation				Existing															
Name	Group	Direction	Type	Distance	Weekday	Saturday	Sunday	PK Headway	Pk Vehicles/Hr	Combined Headway	OP Headway	End-to-End Travel PK Travel time	End-to-End Travel OP Travel time	Number of Round Trips (Express Bus only)	Fleet Requirement	Peak Vehicles Required	Off Peak Vehicles Required	Peak Vehicle Revenue Hours	Off Peak Vehicle Revenue Hours	Total Revenue Hours	Peak Vehicle Revenue Miles	Off Peak Vehicle Revenue Miles	Total Revenue Miles
62.CS	62	Outbound		6.81	14.75	19.35	18.83	NA			80	NA	34.53		0	0	1	0	5,821	5,821	0	68,875	68,875
62.CS-	62	Inbound		6.81	14.75	19.35	18.83	NA			80	NA	34.53										
63.CSQ	63	Outbound		7.97	14.75	19.35	18.83	40	2	12	48	42.38	39.05		3	2	2	2,080	11,641	13,721	23,464	142,555	166,019
63.CSQ-	63	Inbound		7.97	14.75	19.35	18.83333333	40	2		48	42.4	39.05										
63.CWB	63	Outbound		5.1	15.53	18.55	18.60	24	3		60	29.41	26.5		3	2	1	2,080	5,970	8,050	21,605	68,942	90,547
63.CWB-	63	Inbound		5.1	15.53	18.55	18.60	24	3		60	29.51	26.5										
62.HSNORTH	62	Inbound		5.33	15.53	18.55	18.60	40	2	15	80	28.87	26.12		1	1	1	1,040	5,970	7,010	11,520	70,551	82,072
62.HSSOUTH	62	Outbound		5.5	15.53	18.55	18.60	NA			240	NA	28.87										
64.NORTH	64	Inbound	Express	10.27	0.00	0.00	0.00	24	3	20	NA	33.83	NA	12	4	3	0	4,035	0	4,035	65,863	0	65,863
64.SOUTH	64	Outbound	Express	10.84	0.00	0.00	0.00	40	2		NA	43.77	NA										
66.EB	66	Inbound	Express	9.37	0.00	0.00	0.00	40	2	30	NA	38.56	NA	4.5	2	2	0	1,361	0	1,361	21,657	0	21,657
66.WB	66	Outbound	Express	9.14	0.00	0.00	0.00	60	1		NA	31.21	NA										
67	67	Inbound	Express	7.9	11.57	0.00	0.00	40	2	30	NA	43.38	NA	4	3	2	0	1,503	0	1,503	16,432	0	16,432
67-	67	Outbound		7.9	11.57	0.00	0.00	40	2		NA	43.36	NA										
70.NORTH	70	Inbound		9.44	13.82	17.43	16.92	60	1	60	40	42.18	40.66		2	2	2	2,080	10,757	12,837	26,169	140,573	166,742
70.SOUTH	70	Outbound		10.04	13.82	17.43	16.92	30	2		34	50.72	48.78										
70FHSPW					13.82	17.43	16.92																
70FHSPN					13.82	17.43	16.92																
71	71	Inbound		7.62	10.50	13.62	1.53	40	2	30	34	33.38	32.02		2	2	2	2,080	7,036	9,116	28,554	100,458	129,012
71-	71	Outbound		7.62	10.50	13.62	1.53	40	2		34	33.23	32.02										
72	72	Inbound		6.56	13.67	0.00	0.00	40	2	30	NA	32.39	NA		2	2	0	2,080	0	2,080	25,319	0	25,319
72-	72	Outbound		6.56	13.67	0.00	0.00	40	2		NA	32.28	NA										
73	73	Inbound		7.26	16.10	19.12	19.12	40	2	30	30	34.06	32.04		2	2	2	2,080	12,348	14,428	26,582	167,881	194,463
73-	73	Outbound		7.26	16.10	19.12	19.12	40	2		30	34.11	32.04										
74.NORTH	74	Inbound		5.54	15.48	18.57	18.57	24	3	20	40	31.71	30.85		4	3	2	3,120	11,913	15,033	30,844	121,263	152,107
74.SOUTH	74	Outbound		7.17	15.48	18.57	18.57	24	3		40	45.43	44.07										
81.EB	81	Inbound	Express	12.53	0.00	0.00	0.00	60	1	60	NA	44.93	NA	2.5	2	1	0	928	0	928	16,192	0	16,192
81.WB	81	Outbound	Express	12.38	0.00	0.00	0.00	120	1		NA	40.7	NA										
82	82	Inbound	Express	22.06	0.00	0.00	0.00	40	2	30	NA	62.2	NA	3	4	3	0	1,598	0	1,598	34,414	0	34,414
82-	82	Outbound	Express	22.06	0.00	0.00	0.00	40	2		NA	60.72	NA										
84	84	Inbound	VCU	3.93	6.25	11.00	11.00		#DIV/0!														
86	86	Outbound	VCU	0.99	15.00	0.00	0.00		#DIV/0!														
86.S	86	Inbound	VCU	1.33	15.00	0.00	0.00		#DIV/0!														
87	87	Outbound	VCU	1.33	15.13	0.00	0.00		#DIV/0!														
87-	87	Inbound	VCU	1.33	15.13	0.00	0.00		#DIV/0!														
91	91	Outbound		12.21	7.92	0.00	0.00	60	1	60	48	51.04	49.05		2	2	2	2,080	4,117	6,197	29,964	61,392	91,356
91-	91	Inbound		12.21	7.92	0.00	0.00	60	1		48	50.67	49.2										
93	93	Outbound		2.44	8.50	0.00	0.00	30	2	30	NA	10.64	NA		1	1	0	1,040	0	1,040	14,350	0	14,350
93-	93	Inbound		2.44	8.50	0.00	0.00	30	2		NA	10.58	NA										
95.NORTH	95	Inbound	Express	25.18	0.00	0.00	0.00	60	1	60	NA	56.06	NA	4	2	2	0	1,821	0	1,821	50,918	0	50,918
95.SOUTH	95	Outbound	Express	23.78	0.00	0.00	0.00	120	1		NA	48.99	NA										
99	99	Outbound		0.84	0.00	0.00	0.00	10	6	10	10	8.11	7.52		2	2	1	2,080	0	2,080	12,753	0	12,753
99-	99	Inbound		0.84	0.00	0.00	0.00	10	6		10	8.33	7.4										
101	101	Inbound		2.84	5.13	0.00	0.00	NA			30	NA	11.24		0	0	1	0	1,335	1,335	0	20,234	20,234
101-	101	Outbound		2.84	5.13	0	0	NA			30	NA	11.24										
999.BRT	999	Inbound		6.85	0	0	0	NA			NA	NA	NA		0	0	0	0	0	0	0	0	0
999.BRT-	999	Outbound		6.76	0	0	0	NA			NA	NA	NA										
Total										**30**					**131**	**112**	**61**	**106,482**	**279,945**	**386,427**	**1,263,018**	**2,979,846**	**4,242,864**

APPENDIX C:
ESTIMATES OF KEY DRIVING SUPPLY VARIABLES FOR THE NO BUILD AND BUILD ALTERNATIVES

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				Off-Peak Hours of Operation				No Build (Split Route 6 and 53)															
Name	Group	Direction	Type	Distance	Weekday	Saturday	Sunday	PK Headway	Pk Vehicles/Hr	Combined Headway	OP Headway	End-to-End Travel PK Travel time	End-to-End Travel OP Travel time	Number of Round Trips (Express Bus only)	Fleet Requirement	Peak Vehicles Required	Off Peak Vehicles Required	Peak Vehicle Revenue Hours	Off Peak Vehicle Revenue Hours	Total Revenue Hours	Peak Vehicle Revenue Miles	Off Peak Vehicle Revenue Miles	Total Revenue Miles
1	1	Inbound		8.48	8.57	17.22	17.22	30	2	30	30	53.05	50.81		4	4	3	4,160	12,054	16,214	39,831	120,785	160,616
1-	1	Outbound		8.48	13.27	17.22	17.22	30	2		30	53.23	50.74										
2	2	Inbound		13.64	13.83	6.85	6.85	60	1	20	34	73.13	70.68		3	2	4	2,080	17,236	19,316	23,222	199,677	222,898
2-	2	Outbound		13.64	14.93	18.28	18.28	60	1		34	73.48	70.61										
2.CITY	2	Inbound		8.9	15.77	0.00	0.00	30	2		NA	54.55	NA		4	4	0	4,160	0	4,160	40,652	0	40,652
2.CITY-	2	Outbound		8.9	9.37	0.00	0.00	30	2		NA	54.74	NA										
3	3	Outbound		7.42	15.50	19.83	18.33	30	2	20	NA	50.03	NA		4	3	0	3,120	0	3,120	27,803	0	27,803
3PP	3	Inbound		7.42	15.50	19.83	18.33	24	3		NA	49.89	NA										
3.OP	3	Inbound		7.42	15.50	19.83	18.33	NA			27	NA	47.82		0	0	4	0	24,059	24,059	0	223,820	223,820
3.OP-	3	Outbound		7.42	15.50	19.83	18.33	NA			27	NA	47.89										
4	4	Outbound		6.06	15.77	19.97	19.38	24	3	20	NA	45.36	NA		4	4	0	4,160	0	4,160	34,427	0	34,427
4P	4	Inbound		6.65	15.77	19.97	19.38	24	3		NA	46.79	NA										
4.OP	4	Outbound		6.98	15.77	19.97	19.38	NA			27	NA	47.92		0	0	3	0	18,437	18,437	0	163,725	163,725
4.OP-	4	Inbound		6.98	15.77	19.97	19.38	NA			27	NA	46.4										
5.SOUTH				NA	15.77	19.97	19.38	NA			NA	NA	NA		0	0	0	0	0	0	0	0	0
5.NORTH				NA	15.77	19.97	19.38	NA			NA	NA	NA										
6	6	Inbound		4.96	12.22	15.02	15.38	10	6	10	12	36.97	36.97		8	7	6	7,280	28,540	35,820	57,998	227,374	285,373
6	6	Outbound		4.96	13.72	17.29	15.42	10	6		12	37.74	37.74										
6.DNTN	6	Inbound		5.29	12.82	1.05	2.28	NA			NA	NA	NA		0	0	0	0	0	0	0	0	0
6.DNTN-	6	Outbound		5.29	13.42	0.58	0.57	NA			NA	NA	NA										
6.EAST	6	Inbound		9.01	12.40	14.82	15.50	NA			NA	NA	NA		0	0	0	0	0	0	0	0	0
6.WEST	6	Outbound		8.24	13.03	16.00	15.55	NA			NA	NA	NA										
6.EAST#2	6	Inbound		7.78	11.43	15.22	15.25	NA			NA	NA	NA		0	0	0	0	0	0	0	0	0
6.WEST#2	6	Outbound		8.87	14.70	18.58	15.28	NA			NA	NA	NA										
7.EAST	7	Outbound		9.1	10.53	0.00	0.00	40	2	15	40	43.43	39.97		3	2	2	2,080	5,477	7,557	25,743	73,647	99,390
7.EAST#2	7	Outbound		9.37	10.53	0.00	0.00	40	2		40	46.11	42.45										
7.WEST	7	Inbound		8.95	10.53	0.00	0.00	40	2		40	43.78	40.81		3	2	2	2,080	5,477	7,557	25,799	72,582	98,380
7.WEST#2	7	Inbound		10.43	10.53	0.00	0.00	40	2		40	49.97	46.94										
8.EB					0.00	0.00	0.00	NA			NA	NA	NA										
8.WB					0.00	0.00	0.00	NA			NA	NA	NA										
10.EB	10	Inbound		3.83	15.68	18.70	18.70	30	2	30	30	29.95	28.66		2	2	2	2,080	12,045	14,125	15,757	94,893	110,650
10.WB	10	Outbound		3.72	15.68	18.70	18.70	30	2		30	29.85	28.84										
11.EAST	11	Outbound		3.15	7.00	6.32	0.00	30	2	30	30	20.47	18.39		2	1	1	1,040	2,148	3,188	9,014	20,676	29,690
11.WEST	11	Inbound		2.26	7.00	6.32	0.00	30	2		34	16.98	15.34										
16.EAST_PK	16	Inbound		6.97	9.92	0.00	0.00	17	4	15	NA	38.52	NA		5	4	0	4,160	0	4,160	47,323	0	47,323
16.WEST_PK	16	Outbound		6.26	9.92	0.00	0.00	20	3		NA	31.26	NA										
16.EAST_OP	16	Inbound		4.13	9.92	0.00	0.00	NA			60	NA	24.51		0	0	1	0	2,578	2,578	0	27,081	27,081
16.WEST_OP	16	Outbound		3.42	9.92	0.00	0.00	NA			60	NA	18.62										
18.1	18	Inbound		3.63	8.33	0.00	0.00	60	1	60	60	15.31	14.78		1	1	1	1,040	2,167	3,207	15,830	33,854	49,683
18.2	18	Outbound		7.06	8.33	0.00	0.00	60	1		60	26.83	26.27										
-18.2					8.33	0.00	0.00																
-18.1					8.33	0.00	0.00																
19.EB	19	Inbound		10.77	8.22	0.00	0.00	60	1	60	240	61.75	60.62		3	2	1	2,080	2,136	4,216	22,015	22,967	44,982
19.WB	19	Outbound		10.4	8.53	0.00	0.00	60	1		240	58.26	57.53										
22	22	Inbound		6.26	9.57	11.92	11.92	120	1	60	NA	38.76	NA		1	1	0	1,040	0	1,040	10,090	0	10,090
22-	22	Outbound		6.26	9.57	11.92	11.92	120	1		NA	38.67	NA										
24.EAST	24	Inbound		5.4	13.48	15.20	15.20	30	2	30	80	36.62	36.19		2	1	1	1,040	5,086	6,126	9,202	47,082	56,283
24.EAST#2	24	Inbound		6.88	13.48	15.20	15.20	NA			80	NA	43.41										
24.WEST#1	24	Outbound		5.46	13.48	15.20	15.20	40	2		120	36.48	36.05		3	2	1	2,080	5,086	7,166	19,082	47,710	66,791
24.WEST#2	24	Outbound		6.94	13.48	15.20	15.20	120	1		60	44.62	43.27										
26.EB	26	Inbound	Express	11.37	0.00	0.00	0.00	20	3	20	NA	33.54	NA	7	4	4	0	2,153	0	2,153	42,934	0	42,934
26.WB	26	Outbound	Express	12.22	0.00	0.00	0.00	30	2		NA	37.43	NA										
27.EB	27	Inbound	Express	9	0.00	0.00	0.00	20	3	20	NA	34.48	NA	9	4	4	0	2,756	0	2,756	42,916	0	42,916
27.WB	27	Outbound	Express	9.34	0.00	0.00	0.00	20	3		NA	36.18	NA										
28	28	Inbound	Express	7.68	0.00	0.00	0.00	60	1	60	NA	28.85	NA	2	1	1	0	495	0	495	7,987	0	7,987
28-	28	Outbound	Express	7.68	0.00	0.00	0.00	60	1		NA	28.24	NA										
29.EB	29	Inbound	Express	12.94	0.00	0.00	0.00	11	5	12	NA	36.7	NA	11	7	7	0	3,513	0	3,513	74,789	0	74,789
29.WB	29	Outbound	Express	13.21	0.00	0.00	0.00	15	4		NA	36.99	NA										
32.EAST	32	Inbound		4.16	15.32	19.62	19.50	10	6	10	20	24.73	24.08		5	5	2	5,200	12,033	17,233	55,564	131,998	187,562
32.WEST	32	Outbound		4.7	15.32	19.62	19.50	10	6		20	25.02	24.38										
34.NORTH	34	Outbound		3.91	15.33	18.80	18.87	17	4	20	19	24.01	22.11		3	3	2	3,120	11,891	15,011	28,675	119,818	148,493
34.SOUTH	34	Inbound		3.32	15.33	18.80	18.87	20	3		20	23.19	20.94										
37.NORTH	37	Outbound		5.61	15.07	18.72	18.90	13	5	12	20	29.84	29.14		5	5	3	5,200	17,620	22,820	55,234	191,316	246,550
37.SOUTH	37	Inbound		5.55	15.07	18.72	18.90	13	5		22	33.2	32.53										
45	45	Outbound		3.17	15.55	0.00	18.40	24	3	20	30	26.36	24.58		3	2	2	2,080	10,000	12,080	14,929	77,157	92,086
45-	45	Inbound		3.17	15.55	0.00	18.40	24	3		30	26.64	24.72										
53	53	Outbound		3.83	13.72	17.29	15.42	15	4		30	25.21	20.92		4	5	1	5,200	5,267	10,467	50,333	61,106	111,439
53	53	Inbound		3.97	12.22	15.02	15.38	15	4		30	23.14	19.42										
56.EAST	56	Outbound		9.74	11.37	0.00	0.00	120	1	60	NA	46.28	NA		1	1	0	1,040	0	1,040	13,488	0	13,488
56.WEST	56	Inbound		11.46	11.37	0.00	0.00	60	1		NA	51.8	NA										
61					0.00	0.00	0.00																
-61					0.00	0.00	0.00																
62.BD	62	Outbound		8.17	14.75	19.35	18.83	40	2	15	60	41.02	37.18		3	2	1	2,080	5,821	7,901	24,957	76,741	101,698
62.BD-	62	Inbound		8.17	14.75	19.35	18.83	40	2		60	40.69	37.18										

Name	Group	Direction	Type	Distance	Off-Peak Hours of Operation			No Build (Split Route 6 and 53)															
					Weekday	Saturday	Sunday	PK Headway	Pk Vehicles/Hr	Combined Headway	OP Headway	End-to-End Travel PK Travel time	End-to-End Travel OP Travel time	Number of Round Trips (Express Bus only)	Fleet Requirement	Peak Vehicles Required	Off Peak Vehicles Required	Peak Vehicle Revenue Hours	Off Peak Vehicle Revenue Hours	Total Revenue Hours	Peak Vehicle Revenue Miles	Off Peak Vehicle Revenue Miles	Total Revenue Miles
62.CS	62	Outbound		6.81	14.75	19.35	18.83	NA			80	NA	34.53		0	0	1	0	5,821	5,821	0	68,875	68,875
62.CS-	62	Inbound		6.81	14.75	19.35	18.83	NA			80	NA	34.53										
63.CSQ	63	Outbound		7.97	14.75	19.35	18.83	40	2	12	48	42.38	39.05		3	2	2	2,080	11,641	13,721	23,464	142,555	166,019
63.CSQ-	63	Inbound		7.97	14.75	19.35	18.83333333	40	2		48	42.4	39.05										
63.CWB	63	Outbound		5.1	15.53	18.55	18.60	24	3		60	29.41	26.5		3	2	1	2,080	5,970	8,050	21,605	68,942	90,547
63.CWB-	63	Inbound		5.1	15.53	18.55	18.60	24	3		60	29.51	26.5										
62.HSNORTH	62	Inbound		5.33	15.53	18.55	18.60	40	2	15	80	28.87	26.12		1	1	1	1,040	5,970	7,010	11,520	70,551	82,072
62.HSSOUTH	62	Outbound		5.5	15.53	18.55	18.60	NA			240	NA	28.87										
64.NORTH	64	Inbound	Express	10.27	0.00	0.00	0.00	24	3	20	NA	33.83	NA	12	4	3	0	4,035	0	4,035	65,863	0	65,863
64.SOUTH	64	Outbound	Express	10.84	0.00	0.00	0.00	40	2		NA	43.77	NA										
66.EB	66	Inbound	Express	9.37	0.00	0.00	0.00	40	2	30	NA	38.56	NA	4.5	2	2	0	1,361	0	1,361	21,657	0	21,657
66.WB	66	Outbound	Express	9.14	0.00	0.00	0.00	60	1		NA	31.21	NA										
67	67	Inbound	Express	7.9	11.57	0.00	0.00	40	2	30	NA	43.38	NA	4	3	2	0	1,503	0	1,503	16,432	0	16,432
67-	67	Outbound		7.9	11.57	0.00	0.00	40	2		NA	43.36	NA										
70.NORTH	70	Inbound		9.44	13.82	17.43	16.92	60	1	60	40	42.18	40.66		2	2	2	2,080	10,757	12,837	26,169	140,573	166,742
70.SOUTH	70	Outbound		10.04	13.82	17.43	16.92	30	2		34	50.72	48.78										
70FHSPW					13.82	17.43	16.92																
70FHSPN					13.82	17.43	16.92																
71	71	Inbound		7.62	10.50	13.62	1.53	40	2	30	34	33.38	32.02		2	2	2	2,080	7,036	9,116	28,554	100,458	129,012
71-	71	Outbound		7.62	10.50	13.62	1.53	40	2		34	33.23	32.02										
72	72	Inbound		6.56	13.67	0.00	0.00	40	2	30	NA	32.39	NA		2	2	0	2,080	0	2,080	25,319	0	25,319
72-	72	Outbound		6.56	13.67	0.00	0.00	40	2		NA	32.28	NA										
73	73	Inbound		7.26	16.10	19.12	19.12	40	2	30	30	34.06	32.04		2	2	2	2,080	12,348	14,428	26,582	167,881	194,463
73-	73	Outbound		7.26	16.10	19.12	19.12	40	2		30	34.11	32.04										
74.NORTH	74	Inbound		5.54	15.48	18.57	18.57	24	3	20	40	31.71	30.85		4	3	2	3,120	11,913	15,033	30,844	121,263	152,107
74.SOUTH	74	Outbound		7.17	15.48	18.57	18.57	24	3		40	45.43	44.07										
81.EB	81	Inbound	Express	12.53	0.00	0.00	0.00	60	1	60	NA	44.93	NA	2.5	2	1	0	928	0	928	16,192	0	16,192
81.WB	81	Outbound	Express	12.38	0.00	0.00	0.00	120	1		NA	40.7	NA										
82	82	Inbound	Express	22.06	0.00	0.00	0.00	40	2	30	NA	62.2	NA	3	4	3	0	1,598	0	1,598	34,414	0	34,414
82-	82	Outbound	Express	22.06	0.00	0.00	0.00	40	2		NA	60.72	NA										
84	84	Inbound	VCU	3.93	6.25	11.00	11.00		#DIV/0!	60													
86	86	Outbound	VCU	0.99	15.00	0.00	0.00		#DIV/0!														
86.S	86	Inbound	VCU	1.33	15.00	0.00	0.00		#DIV/0!	30													
87	87	Outbound	VCU	1.33	15.13	0.00	0.00		#DIV/0!														
87-	87	Inbound	VCU	1.33	15.13	0.00	0.00		#DIV/0!	60													
91	91	Outbound		12.21	7.92	0.00	0.00	60	1		48	51.04	49.05		2	2	2	2,080	4,117	6,197	29,964	61,392	91,356
91-	91	Inbound		12.21	7.92	0.00	0.00	60	1	10	48	50.67	49.2										
93	93	Outbound		2.44	8.50	0.00	0.00	30	2		NA	10.64	NA		1	1	0	1,040	0	1,040	14,350	0	14,350
93-	93	Inbound		2.44	8.50	0.00	0.00	30	2		NA	10.58	NA										
95.NORTH	95	Inbound	Express	25.18	0.00	0.00	0.00	60	1		NA	56.06	NA	4	2	2	0	1,821	0	1,821	50,918	0	50,918
95.SOUTH	95	Outbound	Express	23.78	0.00	0.00	0.00	120	1		NA	48.99	NA										
99	99	Outbound		0.84	0.00	0.00	0.00	10	6		10	8.11	7.52		2	2	1	2,080	0	2,080	12,753	0	12,753
99-	99	Inbound		0.84	0.00	0.00	0.00	10	6		10	8.33	7.4										
101	101	Inbound		2.84	5.13	0.00	0.00	NA			30	NA	11.24		0	0	1	0	1,335	1,335	0	20,234	20,234
101-	101	Outbound		2.84	5.13	0	0	NA			30	NA	11.24										
999.BRT	999	Inbound		6.85	0	0	0	NA			NA	NA	NA		0	0	0	0	0	0	0	0	0
999.BRT-	999	Outbound		6.76	0	0	0	NA			NA	NA	NA										
Total										**30**					**133**	**115**	**60**	**109,602**	**282,067**	**391,668**	**1,292,191**	**2,996,733**	**4,288,923**

				Off-Peak Hours of Operation				Build (Split Route 6 and 53)															
Name	Group	Direction	Type	Distance	Weekday	Saturday	Sunday	PK Headway	Pk Vehicles/Hr	Combined Headway	OP Headway	End-to-End Travel PK Travel time	End-to-End Travel OP Travel time	Number of Round Trips (Express Bus only)	Fleet Requirement	Peak Vehicles Required	Off Peak Vehicles Required	Peak Vehicle Revenue Hours	Off Peak Vehicle Revenue Hours	Total Revenue Hours	Peak Vehicle Revenue Miles	Off Peak Vehicle Revenue Miles	Total Revenue Miles
1	1	Inbound		8.48	8.57	17.22	17.22	30	2	30	30	50.21	47.97		4	3	3	3,120	12,054	15,174	31,157	126,230	157,387
1-	1	Outbound		8.48	13.27	17.22	17.22	30	2		30	51.69	49.2										
2	2	Inbound		13.64	13.83	6.85	6.85	60	1	20	34	70.29	67.84		3	2	4	2,080	17,236	19,316	23,937	206,065	230,002
2-	2	Outbound		13.64	14.93	18.28	18.28	60	1		34	71.94	69.07										
2.CITY	2	Inbound		8.9	15.77	0.00	0.00	30	2		NA	51.71	NA		4	3	0	3,120	0	3,120	31,762	0	31,762
2.CITY-	2	Outbound		8.9	9.37	0.00	0.00	30	2		NA	53.2	NA										
3	3	Outbound		7.42	15.50	19.83	18.33	30	2	20	NA	48.49	NA		4	3	0	3,120	0	3,120	29,077	0	29,077
3PP	3	Inbound		7.42	15.50	19.83	18.33	24	3		NA	47.05	NA										
3.OP	3	Inbound		7.42	15.50	19.83	18.33	NA			27	NA	46.28		0	0	3	0	18,044	18,044	0	175,916	175,916
3.OP-	3	Outbound		7.42	15.50	19.83	18.33	NA			27	NA	45.05										
4	4	Outbound		6.06	15.77	19.97	19.38	24	3	20	NA	43.82	NA		4	4	0	4,160	0	4,160	36,145	0	36,145
4P	4	Inbound		6.65	15.77	19.97	19.38	24	3		NA	43.95	NA										
4.OP	4	Outbound		6.98	15.77	19.97	19.38	NA			27	NA	46.38		0	0	3	0	18,437	18,437	0	171,698	171,698
4.OP-	4	Inbound		6.98	15.77	19.97	19.38	NA			27	NA	43.56										
5.SOUTH				NA	15.77	19.97	19.38	NA			NA	NA	NA		0	0	0	0	0	0	0	0	0
5.NORTH				NA	15.77	19.97	19.38	NA			NA	NA	NA										
6	6	Inbound		4.96	12.22	15.02	15.38	20	3	20	30	33.6	33.6		4	4	2	4,160	9,513	13,673	35,241	80,592	115,833
6	6	Outbound		4.96	13.72	17.29	15.42	20	3		30	36.66	36.66										
6.DNTN	6	Inbound		5.29	12.82	1.05	2.28	NA			NA	NA	NA		0	0	0	0	0	0	0	0	0
6.DNTN-	6	Outbound		5.29	13.42	0.58	0.57	NA			NA	NA	NA										
6.EAST	6	Inbound		9.01	12.40	14.82	15.50	NA			NA	NA	NA		0	0	0	0	0	0	0	0	0
6.WEST	6	Outbound		8.24	13.03	16.00	15.55	NA			NA	NA	NA										
6.EAST#2	6	Inbound		7.78	11.43	15.22	15.25	NA			NA	NA	NA		0	0	0	0	0	0	0	0	0
6.WEST#2	6	Outbound		8.87	14.70	18.58	15.28	NA			NA	NA	NA										
7.EAST	7	Outbound		9.1	10.53	0.00	0.00	40	2	15	40	43.15	39.69		3	2	2	2,080	5,477	7,557	25,905	74,151	100,056
7.EAST#2	7	Outbound		9.37	10.53	0.00	0.00	40	2		40	45.83	42.17										
7.WEST	7	Inbound		8.95	10.53	0.00	0.00	40	2		40	43.38	40.41		3	2	2	2,080	5,477	7,557	26,021	73,249	99,270
7.WEST#2	7	Inbound		10.43	10.53	0.00	0.00	40	2		40	49.57	46.54										
8.EB					0.00	0.00	0.00	NA			NA	NA	NA										
8.WB					0.00	0.00	0.00	NA			NA	NA	NA										
10.EB	10	Inbound		3.83	15.68	18.70	18.70	30	2	30	30	27.59	26.3		2	2	2	2,080	12,045	14,125	16,889	102,007	118,896
10.WB	10	Outbound		3.72	15.68	18.70	18.70	30	2		30	28.2	27.19										
11.EAST	11	Outbound		3.15	7.00	6.32	0.00	30	2	30	30	20.47	18.39		2	1	1	1,040	2,148	3,188	9,014	20,676	29,690
11.WEST	11	Inbound		2.26	7.00	6.32	0.00	30	2		34	16.98	15.34										
16.EAST_PK	16	Inbound		6.97	9.92	0.00	0.00	17	4	15	NA	38.52	NA		5	4	0	4,160	0	4,160	47,323	0	47,323
16.WEST_PK	16	Outbound		6.26	9.92	0.00	0.00	20	3		NA	31.26	NA										
16.EAST_OP	16	Inbound		4.13	9.92	0.00	0.00	NA			60	NA	24.51		0	0	1	0	2,578	2,578	0	27,081	27,081
16.WEST_OP	16	Outbound		3.42	9.92	0.00	0.00	NA			60	NA	18.62										
18.1	18	Inbound		3.63	8.33	0.00	0.00	60	1	60	60	15.31	14.78		1	1	1	1,040	2,167	3,207	15,830	33,854	49,683
18.2	18	Outbound		7.06	8.33	0.00	0.00	60	1		60	26.83	26.27										
-18.2					8.33	0.00	0.00																
-18.1					8.33	0.00	0.00																
19.EB	19	Inbound		10.77	8.22	0.00	0.00	60	1	60	240	58.38	57.25		2	2	1	2,080	2,136	4,216	22,879	23,883	46,761
19.WB	19	Outbound		10.4	8.53	0.00	0.00	60	1		240	57.1	56.37										
22	22	Inbound		6.26	9.57	11.92	11.92	120	1	60	NA	36.3	NA		1	1	0	1,040	0	1,040	10,666	0	10,666
22-	22	Outbound		6.26	9.57	11.92	11.92	120	1		NA	36.95	NA										
24.EAST	24	Inbound		5.4	13.48	15.20	15.20	30	2	30	80	33.78	33.35		2	1	1	1,040	5,086	6,126	9,975	50,700	60,675
24.EAST#2	24	Inbound		6.88	13.48	15.20	15.20	NA			80	NA	40.57										
24.WEST#1	24	Outbound		5.46	13.48	15.20	15.20	40	2		120	34.82	34.39		2	2	1	2,080	5,086	7,166	19,896	49,794	69,690
24.WEST#2	24	Outbound		6.94	13.48	15.20	15.20	120	1		60	42.96	41.61										
26.EB	26	Inbound	Express	11.37	0.00	0.00	0.00	20	3	20	NA	32.69	NA	7	4	3	0	2,118	0	2,118	42,934	0	42,934
26.WB	26	Outbound	Express	12.22	0.00	0.00	0.00	30	2		NA	37.15	NA										
27.EB	27	Inbound	Express	9	0.00	0.00	0.00	20	3	20	NA	33.63	NA	9	4	3	0	2,712	0	2,712	42,916	0	42,916
27.WB	27	Outbound	Express	9.34	0.00	0.00	0.00	20	3		NA	35.9	NA										
28	28	Inbound	Express	7.68	0.00	0.00	0.00	60	1	60	NA	28	NA	2	1	1	0	486	0	486	7,987	0	7,987
28-	28	Outbound	Express	7.68	0.00	0.00	0.00	60	1		NA	28.1	NA										
29.EB	29	Inbound	Express	12.94	0.00	0.00	0.00	11	5	12	NA	35.85	NA	11	7	7	0	3,459	0	3,459	74,789	0	74,789
29.WB	29	Outbound	Express	13.21	0.00	0.00	0.00	15	4		NA	36.71	NA										
32.EAST	32	Inbound		4.16	15.32	19.62	19.50	10	6	10	20	23.27	22.62		5	5	2	5,200	12,033	17,233	57,602	136,973	194,575
32.WEST	32	Outbound		4.7	15.32	19.62	19.50	10	6		20	24.72	24.08										
34.NORTH	34	Outbound		3.91	15.33	18.80	18.87	17	4	20	19	24.01	22.11		3	3	2	3,120	11,891	15,011	28,675	119,818	148,493
34.SOUTH	34	Inbound		3.32	15.33	18.80	18.87	20	3		20	23.19	20.94										
37.NORTH	37	Outbound		5.61	15.07	18.72	18.90	13	5	12	20	29.54	28.84		5	5	3	5,200	17,620	22,820	57,619	199,771	257,390
37.SOUTH	37	Inbound		5.55	15.07	18.72	18.90	13	5		22	30.89	30.22										
45	45	Outbound		3.17	15.55	0.00	18.40	24	3	20	30	24.05	22.27		3	2	2	2,080	10,000	12,080	16,085	83,619	99,705
45-	45	Inbound		3.17	15.55	0.00	18.40	24	3		30	25.14	23.22										
53	53	Outbound		3.83	13.72	17.29	15.42	15	4		30	24.78	20.49		4	3	1	3,120	5,267	8,387	30,471	61,765	92,236
53	53	Inbound		3.97	12.22	15.02	15.38	15	4		30	23.14	19.42										
56.EAST	56	Outbound		9.74	11.37	0.00	0.00	120	1	60	NA	45.86	NA		1	1	0	1,040	0	1,040	13,546	0	13,546
56.WEST	56	Inbound		11.46	11.37	0.00	0.00	60	1		NA	51.8	NA										
61					0.00	0.00	0.00																
-61					0.00	0.00	0.00																
62.BD	62	Outbound		8.17	14.75	19.35	18.83	40	2	15	60	41.02	37.18		3	2	1	2,080	5,821	7,901	24,957	76,741	101,698
62.BD-	62	Inbound		8.17	14.75	19.35	18.83	40	2		60	40.69	37.18										

				Off-Peak Hours of Operation				Build (Split Route 6 and 53)															
Name	Group	Direction	Type	Distance	Weekday	Saturday	Sunday	PK Headway	Pk Vehicles/Hr	Combined Headway	OP Headway	End-to-End Travel PK Travel time	End-to-End Travel OP Travel time	Number of Round Trips (Express Bus only)	Fleet Requirement	Peak Vehicles Required	Off Peak Vehicles Required	Peak Vehicle Revenue Hours	Off Peak Vehicle Revenue Hours	Total Revenue Hours	Peak Vehicle Revenue Miles	Off Peak Vehicle Revenue Miles	Total Revenue Miles
62.CS	62	Outbound		6.81	14.75	19.35	18.83	NA			80	NA	34.53		0	0	1	0	5,821	5,821	0	68,875	68,875
62.CS-	62	Inbound		6.81	14.75	19.35	18.83	NA			80	NA	34.53										
63.CSQ	63	Outbound		7.97	14.75	19.35	18.83	40	2	12	48	42.38	39.05		3	2	2	2,080	11,641	13,721	23,464	142,555	166,019
63.CSQ-	63	Inbound		7.97	14.75	19.35	18.83333333	40	2		48	42.4	39.05										
63.CWB	63	Outbound		5.1	15.53	18.55	18.60	24	3		60	29.41	26.5		3	2	1	2,080	5,970	8,050	21,605	68,942	90,547
63.CWB-	63	Inbound		5.1	15.53	18.55	18.60	24	3		60	29.51	26.5										
62.HSNORTH	62	Inbound		5.33	15.53	18.55	18.60	40	2	15	80	28.87	26.12		1	1	1	1,040	5,970	7,010	11,520	70,551	82,072
62.HSSOUTH	62	Outbound		5.5	15.53	18.55	18.60	NA			240	NA	28.87										
64.NORTH	64	Inbound	Express	10.27	0.00	0.00	0.00	24	3	20	NA	33.83	NA	12	4	3	0	3,969	0	3,969	65,863	0	65,863
64.SOUTH	64	Outbound	Express	10.84	0.00	0.00	0.00	40	2		NA	42.49	NA										
66.EB	66	Inbound	Express	9.37	0.00	0.00	0.00	40	2	30	NA	37.28	NA	4.5	2	2	0	1,336	0	1,336	21,657	0	21,657
66.WB	66	Outbound	Express	9.14	0.00	0.00	0.00	60	1		NA	31.21	NA										
67	67	Inbound	Express	7.9	11.57	0.00	0.00	40	2	30	NA	42.1	NA	4	3	2	0	1,474	0	1,474	16,432	0	16,432
67-	67	Outbound		7.9	11.57	0.00	0.00	40	2		NA	42.96	NA										
70.NORTH	70	Inbound		9.44	13.82	17.43	16.92	60	1	60	40	42.18	40.66		2	2	2	2,080	10,757	12,837	26,408	141,906	168,314
70.SOUTH	70	Outbound		10.04	13.82	17.43	16.92	30	2		34	49.88	47.94										
70FHSPW					13.82	17.43	16.92																
70FHSPN					13.82	17.43	16.92																
71	71	Inbound		7.62	10.50	13.62	1.53	40	2	30	34	33.38	32.02		2	2	2	2,080	7,036	9,116	28,554	100,458	129,012
71-	71	Outbound		7.62	10.50	13.62	1.53	40	2		34	33.23	32.02										
72	72	Inbound		6.56	13.67	0.00	0.00	40	2	30	NA	32.39	NA		2	2	0	2,080	0	2,080	25,319	0	25,319
72-	72	Outbound		6.56	13.67	0.00	0.00	40	2		NA	32.28	NA										
73	73	Inbound		7.26	16.10	19.12	19.12	40	2	30	30	34.06	32.04		2	2	2	2,080	12,348	14,428	26,582	167,881	194,463
73-	73	Outbound		7.26	16.10	19.12	19.12	40	2		30	34.11	32.04										
74.NORTH	74	Inbound		5.54	15.48	18.57	18.57	24	3	20	40	30.09	29.23		4	3	2	3,120	11,913	15,033	32,500	127,976	160,476
74.SOUTH	74	Outbound		7.17	15.48	18.57	18.57	24	3		40	43.12	41.76										
81.EB	81	Inbound	Express	12.53	0.00	0.00	0.00	60	1	60	NA	43.65	NA	2.5	2	1	0	900	0	900	16,192	0	16,192
81.WB	81	Outbound	Express	12.38	0.00	0.00	0.00	120	1		NA	39.42	NA										
82	82	Inbound	Express	22.06	0.00	0.00	0.00	40	2	30	NA	60.92	NA	3	4	3	0	1,576	0	1,576	34,414	0	34,414
82-	82	Outbound	Express	22.06	0.00	0.00	0.00	40	2		NA	60.32	NA										
84	84	Inbound	VCU	3.93	6.25	11.00	11.00		#DIV/0!	60													
86	86	Outbound	VCU	0.99	15.00	0.00	0.00		#DIV/0!														
86.S	86	Inbound	VCU	1.33	15.00	0.00	0.00		#DIV/0!	30													
87	87	Outbound	VCU	1.33	15.13	0.00	0.00		#DIV/0!														
87-	87	Inbound	VCU	1.33	15.13	0.00	0.00		#DIV/0!	60													
91	91	Outbound		12.21	7.92	0.00	0.00	60	1		48	50.55	48.56		2	2	2	2,080	4,117	6,197	30,136	61,756	91,892
91-	91	Inbound		12.21	7.92	0.00	0.00	60	1	10	48	50.58	49.11										
93	93	Outbound		2.44	8.50	0.00	0.00	30	2		NA	10.64	NA		1	1	0	1,040	0	1,040	14,350	0	14,350
93-	93	Inbound		2.44	8.50	0.00	0.00	30	2		NA	10.58	NA										
95.NORTH	95	Inbound	Express	25.18	0.00	0.00	0.00	60	1		NA	55.63	NA	4	2	2	0	1,799	0	1,799	50,918	0	50,918
95.SOUTH	95	Outbound	Express	23.78	0.00	0.00	0.00	120	1		NA	48.14	NA										
99	99	Outbound		0.84	0.00	0.00	0.00	10	6		10	7.83	7.24		2	2	1	2,080	0	2,080	12,910	0	12,910
99-	99	Inbound		0.84	0.00	0.00	0.00	10	6		10	8.41	7.48										
101	101	Inbound		2.84	5.13	0.00	0.00	NA			30	NA	11.24		0	0	1	0	1,335	1,335	0	20,234	20,234
101-	101	Outbound		2.84	5.13	0	0	NA			30	NA	11.24										
999.BRT	999	Inbound		6.85	0	0	0	10	6		15	31.69	31.69		7	6	4	6,240	21,840	28,080	79,693	0	79,693
999.BRT-	999	Outbound		6.76	0	0	0	10	6		15	32.25	32.25										
Total										**30**					**134**	**112**	**59**	**108,228**	**278,865**	**387,094**	**1,327,813**	**2,865,715**	**4,193,528**

BROAD STREET RAPID TRANSIT STUDY

ENVIRONMENTAL ASSESSMENT

APPENDIX A-13: Capital Cost Estimate Report

BROAD STREET RAPID TRANSIT STUDY
CAPITAL COST ESTIMATES

The GRTC Transit System and Virginia Department of Rail and Public Transportation (GRTC/DRPT) are conducting a study consistent with the requirements of the Federal Transit Administration's (FTA) Small Starts program to evaluate transit improvements along the Broad Street corridor. This memo provides a summary of the capital costs estimated for the Build Alternative as defined in the November 17, 2010 *Detailed Definition of Alternatives*. As shown in Table 1, the total capital cost for the Build Alternative is estimated at $51.7 million in 2013 dollars ($53.8 million in 2015 dollars). These numbers reflect the operating plans and travel times modeled by VHB and AECOM and discussed with GRTC and DRPT. They also reflect adjustments made based on discussions with stakeholders and the Federal Transit Administration (FTA), including:

- Reduction of BRT headways from 5 minutes peak to 10 minutes peak (thereby reducing BRT rolling stock requirements from 16 vehicles to nine);
- Increase in professional services from 30 to 35%, consistent with the guidelines of the Virginia Department of Transportation (VDOT);
- Removal of Park and Ride lot at Rocketts Landing;
- Allowance for right-of-way (if necessary) to accommodate an eastbound bus lane at Belvidere and Broad Street; and,
- Addition of off-board fare collection to the Build Alternative.

These estimates are well within the capital cost limits of the Small Starts program.

TABLE 1: SUMMARY OF CAPITAL COSTS

Category/Element	Capital Cost (x1,000) 2013 $	2015 $
10 GUIDEWAY & TRACK ELEMENTS	$3,955.4	$4,115.2
20 STATIONS, STOPS, TERMINALS, INTERMODAL	$3,859.7	$4,015.6
30 SUPPORT FACILITIES	n/a	n/a
40 SITEWORK & SPECIAL CONDITIONS	$11,009.3	$11,454.0
50 SYSTEMS	$9,393.7	$9,773.2
60 ROW, LAND, EXISTING IMPROVEMENTS	$1,776.00	$1,847.8
70 VEHICLES	$9,450.00	$9,831.8
80 PROFESSIONAL SERVICES	$9,761.6	$10,156.0
90 UNALLOCATED CONTINGENCY	$2,459.0	$2,558.3
Total Project Cost (10-90)	**$51,664.7**	**$53,751.8**

1.0 OVERVIEW OF METHODOLOGY AND ASSUMPTIONS

As described in the January 5, 2010 *Capital Cost Methodology Report*, these cost estimates were developed in a manner consistent with FTA guidance published in two documents:

- Part II (Conduct of the Analysis), Chapter 3 (Estimation of Capital Costs) of *Procedures and Technical Methods for Transit Project Planning*; and,
- *Final Guidance on New Starts/Small Starts Policies and Procedures*.

All costs were based on the description of the Build Alternative provided in the November 17, 2010 *Detailed Definition of Alternatives* technical memorandum. The Build Alternative assumes that the dedicated service would operate at a peak headway of 10 minutes and off-peak headway of 15 minutes using a dedicated fleet of compressed natural gas (CNG) vehicles.

Capital costs were developed based on unit costs from three, primary sources:

- Transport, a Virginia Department of Transportation (VDOT) tool for establishing unit costs. These costs were rounded up to the next whole dollar to reflect the conceptual nature of the estimate.
- Transit vehicle, system, and facility costs provided by GRTC in a September 27, 2010 e-mail from Larry Hagin.
- Federal Transit Administration. *Reporting Instructions for the Section 5309 Small Starts Criteria*. July 2010. p. 14, Table 1: Small Starts Baseline Prototypical Costs for Specific Elements.

All costs were organized according to FTA cost categories, with unit costs being multiplied versus quantities estimated for each category. Allocated contingencies were then applied to each category based on the degree of uncertainty anticipated for each type of cost. An unallocated contingency of 5% was applied to the subtotal of all unit costs; this is consistent with current FTA practice for projects in the Alternatives Analysis stage of the Small Starts program. Appendix A provides detailed explanations of the unit costs and quantities used to develop the capital costs for the Build Alternative.

Current FTA guidance requires that all capital costs for Small Starts be presented in current year dollars. Year of expenditure (YOE) have also been listed to provide a better representation of likely capital costs associated with the Build Alternative. To provide a conservative estimate of total capital costs, it was assumed that the opening year of 2015 was the year of expenditure for all cost categories. Actual years of expenditure will be refined during Project Development as a design and construction schedule is established for the project.

Table 2 compares the capital costs of the Build Alternative to prototypical costs established by the FTA in 2010, as well as the costs submitted for other Small Starts projects that have been approved by FTA to continue into Project Development. On a cost per-mile basis, the guideway costs of the Build Alternative fall well within the range of costs seen on other, competitive Small Starts projects. Costs per station for the Build Alternative average approximately $275,000 per station—almost ten times greater than the

$25,000 shelters currently used by GRTC, but relatively less expensive than the stations being designed for the other Small Starts in this table.

Table 3 provides a detailed breakdown of the costs associated with the Build Alternative. The quantities and unit costs used to develop these estimates are provided in Appendix A.

2.0 NEXT STEPS

The travel demand forecasts for the study are being finalized, pending final input from FTA. Once these forecasts have been finalized, they will be used in conjunction with the annualized costs for the project to estimate the Cost-Effectiveness Index (CEI) for the project. The capital costs will also be utilized by the cost model for the project so that an appropriate financial plan for the project may be developed.

BROAD STREET RAPID TRANSIT STUDY

TABLE 2: COMPARISON OF BUILD ALTERNATIVE COSTS TO OTHER SMALL START PROJECTS

Category/Element		Unit	Broad Street Build 1 Unit Costs (2013$ x 1,000)	FTA Prototypical Unit Costs* (2010$ x 1,000)	Unit Costs of BRT Projects in Project Development (2010$)			
					E Street (San Bernardino, CA)	East Bay (AC Transit)	El Camino (San Jose, CA)	Division Avenue (Grand Rapids, MI)
10 GUIDEWAY & TRACK ELEMENTS								
10.02	Guideway: At-grade semi-exclusive (allows cross-traffic)	per route mile	$1,273	$1,200	$1,746	$643	$2,427	$171
20 STATIONS, STOPS, TERMINALS, INTERMODAL								
20.01	At-grade station, stop, shelter, mall, terminal, platform	per station	$276	$225	$713	$615	$3,061	$404
40 SITEWORK & SPECIAL CONDITIONS								
40.07	Automobile, bus, van accessways including roads, parking lots	per on-grade space	$6.2	$5.6				
50 SYSTEMS								
50.02	Traffic signals and crossing protection	per intersection	$104	$28				
50.05	Communications	per vehicle	$64	$20				
50.06	Fare collection system and equipment	per vehicle	$181	$11				
50.07	Central Control	per vehicle	$0	$17-28				
60 ROW, LAND, EXISTING IMPROVEMENTS								
60.01	Purchase or lease of real estate	lump sum	$1,776					
70 VEHICLES								
70.04	Bus (Standard GRTC)	per vehicle	$390	$500				
70.04	Bus (BRT)	per vehicle	$1,050	$1,000	$1,117	$0	$1,100	$654
80 PROFESSIONAL SERVICES		25 - 35% of Construction Subtotal (10-50)	35%	25-35%	40%	46%	40%	24%
90 UNALLOCATED CONTINGENCY		5% of Subtotal (10-80)	5%	5%	7%	4%	2%	9%
Allocated Contingency as % of Base Yr. Dollars			10%		10%	56%	18%	12%
TOTAL PROJECT COST (YOE)			$53,751.83		$191,706	$216,121	$239,584	$36,688
YOE Total Project Cost per Mile w/o Vehicles			$5,779		$11,193	$15,029	$19,926	$3,000
Total Length			7.6		14.38	15.7	11.16	9.87
Semi-exclusive ROW			3.1		14.38	5.4	11.16	9.87

TABLE 3: BUILD ALTERNATIVE CAPITAL COST BY STANDARD COST CATEGORY CODE (SCC)

Category/Element		Unit	Quantity	Base Cost 2013$ (x$1,000)	Contingency	Total Cost 2013$ (x$1,000)	Base Year Unit Cost 2013$ ($1,000)	YOE 2015 (x$1,000)
10 GUIDEWAY & TRACK ELEMENTS						$3,955.42		$4,115.22
10.02	Guideway: At-grade semi-exclusive (allows cross-traffic)	route mile	3.1	$3,588.82	10%	$3,947.70	$1,273.5	
10.03	Guideway: At-grade in mixed traffic	route mile	4.5	$7.02	10%	$7.72	$1.7	
20 STATIONS, STOPS, TERMINALS, INTERMODAL								
20.01	At-grade station, stop, shelter, mall, terminal, platform	station	14	$3,356.24	15%	$3,859.67	$275.7	$4,015.60
40 SITEWORK & SPECIAL CONDITIONS						$11,009.26		$11,454.03
40.01	Demolition, clearing, Earthwork	route mile	7.6	$157.68	10%	$173.44	$22.8	
40.02	Site utilities, Utility Relocation	route mile	7.6	$369.97	10%	$406.96	$53.5	
40.06	Pedestrian/Bike Access and Accommodation	route mile	7.6	$193.98	10%	$213.38	$28.1	
40.07	Automobile, bus, van accessways including roads, parking lots	on-grade space	95	$532.00	10%	$585.20	$6.2	
40.08	Temporary Facilities and other indirect cost during construction	route mile	7.6	$8,754.79	10%	$9,630.27	$1,267.1	
50 SYSTEMS						$9,393.66		$9,773.16
50.02	Traffic signals and crossing protection	intersection	55	$5,195.00	10%	$5,714.50	$103.9	
50.05	Communications	vehicle	9	$840.00	15%	$966.00	$107.3	
50.06	Fare collection system and equipment	vehicle	9	$2,359.27	15%	$2,713.16	$301.5	
50.07	Central Control	vehicle	9	$0.00	10%			
60 ROW, LAND, EXISTING IMPROVEMENTS								
60.01	Purchase or lease of real estate	lump sum	1	$1,480.00	20%	$1,776.00	$1,776.0	$1,847.75
60.02	Relocation of existing households and businesses			$0.00	20%			
70 VEHICLES								
70.04	Bus	vehicle	9	$9,000.00	5%	$9,450.00	$1,050.0	$9,831.78
80 PROFESSIONAL SERVICES		25 - 35% of Construction Subtotal (10-50)		$8,874.16	10%	$9,761.58	35%	$10,155.95
90 UNALLOCATED CONTINGENCY		5% of Subtotal (10-80)		$2,235.45	10%	$2,458.99	5%	$2,558.33
TOTAL				**$46,944.36**		**$51,664.58**		**$53,751.83**

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APPENDIX A:
BUILD ALTERNATIVE
CAPITAL COST ASSUMPTIONS

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BUILD ALTERNATIVE: COST ESTIMATE SUMMARY BY SECTION (2013$, without contingency)

				SYSTEMWIDE ELEMENTS		MEDIAN RUNNING SEGMENTS		CURB RUNNING SEGMENTS		MIXED TRAFFIC SEGMENTS		TOTAL
	COST CATEGORY	UNIT	UNIT COST	QUANTITY	COST	QUANTITY	COST	QUANTITY	COST	QUANTITY	COST	
10	**GUIDEWAY AND TRACK ELEMENTS**											
	10.02 Guideway: At-grade semi-exclusive(allows cross traffic)											
	Aggregate Base Material Type I, Size 21B	TON	$20.00			2,929	$58,580	1,811	$36,220			
	Asphalt Concrete Base CR TY BM-25.0A	TON	$59.00			2,424	$143,016	1,499	$88,441			
	Asphalt Concrete Ty SM-9.5A	TON	$84.00			12,266	$1,030,344	4,944	$415,296			
	Asphalt Concrete Ty SM-19.0	TON	$65.00			741	$48,165	458	$29,770			
	Flexible Pavement Planing	SY	$3.00			194,332	$582,996	76,151	$228,453			
	Median (MS-1)	SY	$75.00			8,096	$607,200		$0			
	Sign Panels	SF	$26.00			740	$19,240	70	$1,820			
	Sign Post Steel 4"	LF	$61.00			144	$8,784	72	$4,392			
	Ty. B Cl I Pavement Line Marking 4"	LF	$1.00			57,684	$57,684	19,272	$19,272			
	Ty. B Cl I Pavement Line Marking 6"	LF	$1.00			46,656	$46,656	19,008	$19,008			
	Ty. B Cl I Pavement Line Marking 12"	LF	$3.00			12,144	$36,432	7,392	$22,176			
	Ty. B Cl I Pavement Line Marking 24"	LF	$5.00			2,382	$11,910		$0			
	Rumble Strip, Asphalt (RS-5)	LF	$2.00			23,328	$46,656	9,504	$19,008			
	Liquid Asphalt Coating (Rumble Strips)	SY	$2.00			2,592	$5,184	1,056	$2,112			
	SUB-TOTAL						$2,702,847		$885,968			$3,588,815
	10.03 Guideway: At-grade in mixed traffic											
	Sign Panels	SF	$26.00							101	$2,626.00	
	Sign Post Steel 4"	LF	$61.00							72	$4,392.00	
	SUB-TOTAL										$7,018.00	$7,018
	SUB-TOTAL						$2,702,847		$885,968		$7,018.00	**$3,595,833**
20	**STATIONS, STOPS, TERMINALS,INTERMODAL**											
	20.01 At-grade station, stop, shelter, mall,terminal,platform.											
	Concrete Bus Pad	CY	$744.00			98	$72,912	293	$217,992	147	$109,368.00	
	Concrete Platform	SY	$75.00			480	$36,000	1,760	$132,000	880	$66,000.00	
	Station Furniture(Lighting, Benches and Bike Racks)	LS				1	$87,200	1	$261,600	1	$130,800.00	
	Sign Panels	SF	$26.00			60	$1,560	60	$1,560	53	$1,365.00	
	Sign Post Steel 4"	LF	$61.00			216	$13,176	216	$13,176	189	$11,529.00	
	Enhanced Shelters	Per Platform	$50,000.00			8	$400,000	24	$1,200,000	12	$600,000.00	
	SUB-TOTAL						$610,848		$1,826,328		$919,062.00	**$3,356,238**
40	**SITEWORK & SPECIAL CONDITIONS**											
	40.01 Demolition, Clearing, Earthwork											
	Removal of existing trees	LS				1	$0	1	$10,000			
	Removal of Median	SY	$8.00			6,733	$53,864	4,164	$33,312		$0.00	
	Removal of Sidewalk	SY	$8.00			533	$4,264	1,280	$10,240	687	$5,496.00	
	Removal of curb and gutter	LF	$5.00			960	$4,800	1,440	$7,200	720	$3,600.00	
	Demolition of Pavement(Flexible)	SY	$4.00			480	$1,920	1,760	$7,040	880	$3,520.00	
	Remove Ty I Signs	EA	$230.00			20	$4,600	8	$1,840	26	$5,980.00	
	SUB-TOTAL						$69,448		$69,632		$18,596.00	$157,676
	40.02 Site Utilities, Utility Relocation											
	Drainage (20% of the pavement cost)	LS					$256,021		$113,945		$0.00	
	SUB-TOTAL						$256,021		$113,945		$0.00	$369,966
	40.06 Pedestrian/Bike access and Accommodation											
	Hydr. Cement Concrete Sidewalk 4"	SY	$36.00			533	$19,188	800	$28,800	400	$14,400.00	

BUILD ALTERNATIVE: COST ESTIMATE SUMMARY BY SECTION (2013$, without contingency)

				SYSTEMWIDE ELEMENTS		MEDIAN RUNNING SEGMENTS		CURB RUNNING SEGMENTS		MIXED TRAFFIC SEGMENTS		TOTAL
	COST CATEGORY	UNIT	UNIT COST	QUANTITY	COST	QUANTITY	COST	QUANTITY	COST	QUANTITY	COST	
	St'd Combination Curb and Gutter CG-6	LF	$20.00			960	$19,200	1,440	$28,800	720	$14,400.00	
	CG-12 Curb Ramp	SY	$186.00			288	$53,568	48	$8,928	36	$6,696.00	
	SUB-TOTAL						$91,956		$66,528		$35,496.00	$193,980
	40.07 Automobile, bus, van, accessways including roads,parking lots											
	Parking spaces	per space	$5,600.00	95.00	$532,000							
	SUB-TOTAL	LS			$532,000		$0		$0		$0.00	$532,000
	40.08 Temporary Facilities and other indirect costs during construction											
	Landscaping (1% of 10-50)	LS			$30,713		$75,911		$41,024		$18,351.72	
	Maintenance of Traffic (10% of 10-50)	LS			$256,998		$766,703		$414,343		$185,352	
	Construction Survey (1% of 10-50)	LS			$33,897		$85,096		$45,988		$20,572.28	
	Mobilization (5%(10-50)	LS			$169,644		$425,942		$230,188		$102,972	
	Contingency (30% of 10-50)	LS			$1,068,756		$2,683,432		$1,450,183		$648,726.24	
	SUB-TOTAL				$1,560,008		$4,037,084		$2,181,725		$975,975.03	$8,754,792
	SUB-TOTAL			1	**$2,092,008**		**$4,454,509**		**$2,431,831**		**$1,030,067.03**	**$10,008,415**
50	**SYSTEMS**											
	50.02 Traffic signals and crossing protection	LS				1	$3,740,000	1	$780,000	1	$675,000.00	$5,195,000
	50.05 Communications											$840,000
	Variable Message Signs	LS					$120,000		$360,000		$180,000.00	
	Vehicle Communication	per vehicle	$20,000.00	9	$180,000							
	50.06 Fare Collection	LS	$2,359,269.00	1	$2,359,269							$2,359,269
	SUB-TOTAL				**$2,539,269**		**$3,860,000**		**$1,140,000**		**$855,000.00**	**$8,394,269**
60	**ROW, LAND, EXISTING IMPROVEMENTS**											
	60.01 Purchase or lease of real estate	LS					$1,480,000					$1,480,000
	60.02 Relocation of existing households and bussinesses											
	SUB-TOTAL				**$0**		**$1,480,000**		**$0**		**$0.00**	**$1,480,000**
70	**VEHICLES**											
	70.04 Bus	BRT Vehicle	$1,000,000.00	9	$9,000,000							**$9,000,000**
		GRTC Vehicle	$390,000.00									
80	**PROFESSIONAL SERVICES**											
	35% of Construction (10-50)				**$1,620,947**		**$4,069,871**		**$2,199,444**		**$983,901.46**	**$8,874,164**
90	**UNALLOCATED CONTINGENCY**											
	5% of Sub-total (10-80)				**$762,611**		**$858,904**		**$424,179**		**$189,752.42**	**$2,235,446**
	TOTAL COST				**$16,014,835**		**$18,036,979**		**$8,907,750**		**$3,984,800.91**	**$46,944,365**

Median Running - *2.2 mi from Thompson St. to Adams St.*

10 GUIDEWAY AND TRACK ELEMENTS

10.02 Guideway: At-grade semi-esclusive (allows cross traffic)

Aggregate Base Material Type I, Size 21B			60,596	SF
Assumes 8" thickness			40,397	CF
@ 145 LBS/CF			5,857,613	LBS
			2,929	TONS
Asphalt Concrete Base CR TY BM-25.0A			60,596	SF
@ 120 LBS/SY/IN			6,733	SY
Assumes 6" thickness			807,947	LBS/IN
			4,847,680	LBS
			2,424	TONS
Ashpalt Concrete Ty. SM-9.5A			60,596	SF
@ 120 LBS/SY/IN			6,733	SY
Assumes 1.5" thickness			807,947	LBS/IN
			1,211,920	LBS
			606	TONS
Ashpalt Concrete Ty. SM-9.5A (Overlay)	2.3 mi		12,144	SF
@ 120 LBS/SY/IN	77		97,166	SY
Assumes 2.0" thickness			11,659,893	LBS/IN
			23,319,787	LBS
			11,660	TONS
		Sub-total	**12,266**	TONS
Asphalt Concrete Ty. SM-19.0			60,596	SF
@ 110 LBS/SY/IN			6,733	SY
Assumes 2" thickness			740,618	LBS/IN
			1,481,235	LBS
			741	TONS
Flexible Pavement Planing	2.3 MI		12,144	LF
Assume milling the entire cross section (77ft)	77 FT Cross Section			
	12144*77-60596		**194,332**	SY
Median Strip MS-1				
Between Bus Lane and Travel Lanes	2.3*5280*3*2		72,864	SF
W=3' Assume 2.3 mi on both direction			**8,096**	SY
Sign Panels				
Assumes 1 sign per 0.25 mile				
Preferential Only Lane Operation for 2.3 mi - overhead	72 IN X 60 IN		600	SF
Additional Sign near Station (4 Each station)	30 IN X 42 IN		140	SF
		Sub-total	**740**	SF
Sign Post Steel 4"	9*4*4		**144**	LF
Additional Sign near Station (4 Each station)				
Rumble Strip, Asphalt				
Assumes application between Bus Lane and Car Travel Lane	2.3*5280 minus platforms		11,664	LF
RS-5 12" Rumble Strips in east and west direction			**23,328**	LF

Median Running - *2.2 mi from Thompson St. to Adams St.*

Liquid Asphalt Coating	2.3*5280 minus platforms	11,664	LF
RS-5 12" Rumble Strips		11,664	SF
In east and west direction		23,328	SF
		2,592	SY
Ty. B Cl I Pavement Line Marking 4"	2.3 *5280/40*10*3	9,108	LF
Assumes 3 Broken and 4 Solid markings. See Typical	2.3*5280*4	48,576	LF
		57,684	LF
Ty. B Cl I Pavement Line Marking 6"	2.3*5280 minus platforms	11,664	LF
Assumes striping on each side of rumble strip		23,328	LF
In east and west direction along Broad Street		**46,656**	LF
Ty. B Cl I Pavement Line Marking 12"	2.3*5280	**12,144**	LF
Ty. B Cl I Pavement Line Marking 24"	13*15*10	**1,950**	LF
Assumes 13 locations w/crosswalk			
Assumes 1 solid and 15 stop bars	33*8+24*7	432	
	Sub-total	**2,382**	

20 STATIONS, STOPS, TERMINALS,INTERMODAL

Concrete Bus Pad			
at Station Location L=60' W=11' T=6"	4*2*60*11*6/12	**98**	CY
Concrete Platform Slabs	Area of Platform (9' X 60') =	540	SF
2 platform per station, 4 Stations	540*2*4	4320	SF
		480	SY
Station Furnitures			
Lighting at Station			
2 platform per station, 4 Stations	$7,500/pole *2*4	$60,000.00	LS
Bench			
2 platform per station, 4 Stations	$1,500/bench*2*2*4	$24,000.00	LS
2 per platform			
Bicycle Rack			
2 platform per station, 4 Stations	$400/rack*2*4	$3,200.00	LS
Station Furnitures Sub-Total		**$87,200**	LS
Enhanced Shelters			
2 platform per station, 4 Stations	$50,000/platform *2*4	8	Platforms
Sign Panel at station location			
No Parking (with transit logo)	12 IN X 30 IN	2.5	SF
Assumed 6 signs per station (1 for bus stop, 2 for no parking on each side of the street)		**60**	SF
Sign Post Steel 4"			
At station location	9*3*2*4	**216**	LF
pole length of 9 FT			

Median Running - *2.2 mi from Thompson St. to Adams St.*

40 SITEWORK & SPECIAL CONDITIONS

40.01 Demolition , Clearing, Earthwork

Removal of Median		60,596	SF
Measured from GIS layer		**6,733**	SY
Removal of sidewalk			
2 platform per station, 4 Stations	2*4*2*60*5	4,800	SF
L=60', W=5' replace both sides of the platform		**533**	SY
Removal of Curb and gutter			
2 platform per station, 4 Stations	2*4*2*60	**960**	LF
L=60', replace both sides of the platform			
Demolition of Pavement	9*60*8	**480**	SY
at Station Location 4 Station			
Remove Ty. I Signs	2.3 MI / 0.25 MI	**20**	EA
Assumes 1 sign per 0.25 mile			

40.06 Pedestrian/Bike Access Accomodation

Hydr. Cement Concrete Sidewalk 4"			
2 platform per station, 4 Stations	2*4*2*60*5	4,800	SF
L=60', W=5' replace both sides of the platform		**533**	SY
St'd Combination Curb and Gutter CG-6			
2 platform per station, 4 Stations	2*4*2*60	**960**	LF
L=60', replace both sides of the platform			
CG-12 Curb Ramp			
12 curb ramp per station, 4 station, 54 sf per ramp	12*4*54	**288**	SY

50 SYSTEMS

50.02 Traffic signal and crossing Protection

There are 28 signals between Thompson and Adams	Pre-emption ($5,000 per signal)	$140,000	LS
Where structures are located in the median and must be relocated, costs will be assumed for entire intersection; includes costs for moving loops and pavement markings 15 signals will be impacted	$120,000 per T-Intersection $220,000 per 4-Leg Intersection	$1,320,000 $880,000	LS LS
		$2,340,000	LS
There are 28 signalized intersection between Thompson and Adams	$50,000 per box per intersection	$1,400,000	LS
	Sub-Total	**$3,740,000**	

50.05 Communications

Variable Message Signs			
2 platform per station, 4 Stations	$15,000/platform	$120,000	LS

Median Running - *2.2 mi from Thompson St. to Adams St.*

60 ROW, LAND, EXISTING IMPROVEMENTS

60.01 Purchase or Lease of Real Estate

Belvidere and Broad Street: assume total value of parcel and improvements of parking lot in SE corner of the intersection (ROW needed to fit bus lane in without losing a dedicated turn lane)	$1,480,000	LS

10 GUIDEWAY AND TRACK ELEMENTS

10.02 Guideway: At-grade semi-esclusive (allows cross traffic)

Aggregate Base Material Type I, Size 21B			37,479	SF
Assumes 8" thickness			24,986	CF
@ 145 LBS/CF			3,622,970	LBS
			1,811	TONS
Asphalt Concrete Base CR TY BM-25.0A			37,479	SF
			4,164	SY
@ 120 LBS/SY/IN			499,720	LBS/IN
Assumes 6" thickness			2,998,320	LBS
			1,499	TONS
Ashpalt Concrete Ty. SM-9.5A			37,479	SF
			4,164	SY
@ 120 LBS/SY/IN			499,720	LBS/IN
Assumes 1.5" thickness			749,580	LBS
			375	TONS
Ashpalt Concrete Ty. SM-9.5A(Overlay)	0.9 mi		342,681	SF
	80		38,076	SY
@ 120 LBS/SY/IN			4,569,080	LBS/IN
Assumes 2" thickness			9,138,160	LBS
			4,569	TONS
		Sub-total	**4,944**	TONS
Asphalt Concrete Ty. SM-19.0			37,479	SF
			4,164	SY
@ 110 LBS/SY/IN			458,077	LBS/IN
Assumes 2" thickness			916,153	LBS
			458	TONS
Flexible Pavement Planing				
Assume milling the entire cross section	0.9 MI		4,752	SF
	80 FT Cross Section		342,681	SF
			76,151	SY
Sign Panels				
Assumes 1 sign per 0.25 mile	30 IN X 42 IN		**70**	SF
Preferential Only Lane Operation for 0.9 mi - ground				
Sign Post Steel 4"	9*8		**72**	LF
Assumes 1 sign per 0.25 mile for 0.9mi				
pole length of 9 FT				
Rumble Strip, Asphalt				
Assumes application between Bus Lane and Car Travel Lane	0.9*5280		4,752	LF
RS-5 12" Rumble Strips in east and west direction			**9,504**	LF

Curb Running - ***0.9 mi Adams St. to 14th St.***

Liquid Asphalt Coating	0.9*5280	4,752	LF
RS-5 12" Rumble Strips		4,752	SF
In east and west direction		9,504	SF
		1,056	SY
Ty. B Cl I Pavement Line Marking 4"	0.2*5280*5+02*5280/40*10*4	6,336	LF
	0.7*5280*3+.7*5280/40*10*2	12,936	LF
		19,272	LF
Ty. B Cl I Pavement Line Marking 6"	0.9*5280	4,752	LF
Assumes striping on each side of rumble strip		9,504	LF
In east and west direction along Broad Street		**19,008**	LF
Ty. B Cl I Pavement Line Marking 12"	0.7*5280*2	**7,392**	LF

20 STATIONS, STOPS, TERMINALS,INTERMODAL

Concrete Bus Pad	6*4*60*11*6/12	**293**	CY
at Station Location L=60' W=11' T=6"			
Concrete Platform	Area of Platform (11' X 60') =	660	SF
6 platforms per station, 4 Stations	660*6*4	15,840	SF
		1,760	SY
Station Furnitures			
Lighting at Station	$7,500/pole *6*4	$180,000	LS
6 platforms per station, 4 Stations			
Bench	$1,500/bench*6*2*4	$72,000	LS
6 platforms per station, 4 Stations			
2 benches per platform			
Bicycle Rack	$400/rack*6*4	$9,600	LS
6 platforms per station, 4 Stations			
Station Furniture Sub-Total		**$261,600**	LS
Enhanced Shelters	$50,000/platform *6*4	24	Platforms
6 platforms per station, 4 Stations			
Sign Panels at station location	12 IN X 30 IN		
No Parking (with transit logo)		**60**	SF
Assumed 6 signs per station (1 for bus stop, 2 for no parking on each side of the street)			
	9*3*2*4	**216**	LF
Sign Post Steel 4" at station Location			
pole length of 9 FT			

40 SITEWORK & SPECIAL CONDITIONS

40.01 Demolition , Clearing, Earthwork

Removal of Existing trees along median		**$10,000**	LS
Removal of Median		37,479	SF

Curb Running - ***0.9 mi Adams St. to 14th St.***

Measured from GIS layer		**4,164** SY
Removal of Median/Sidewalk	4*6*60*8	11,520 SF
at Station location, sidewalk width from aerial		**1,280** SY
Removal of Curb and gutter	6*4*60	**1,440** LF
6 per station, 4 Stations		
L=60'		
Demolition of Pavement	60*11*6*4	**1,760** SY
at Station Location 4 Station		
Remove Ty. I Signs	0.9 MI / 0.25 MI	**8** EA
Assumes 1 sign per 0.25 mile		
40.06 Pedestrian/Bike Access Accomodation		
Hydr. Cement Concrete Sidewalk 4"	6*4*60*5	7,200 SF
6 per station, 4 Stations		**800** SY
L=60', W=5'		
St'd Combination Curb and Gutter CG-6	6*4*60	**1,440** LF
6 per station, 4 Stations		
L=60'		
CG-12 Curb Ramp	2*4*54	**48** SY
2 curb ramp per station, 4 station, 54 sf per ramp		

50 SYSTEMS

50.02 Traffic Signal and Crossing Protection

There are 12 signals between N. 3rd St and N. 14th St	Pre-emption ($5,000 per signal)	$60,000 LS
Where structures are located in the median and must be relocated, costs will be assumed for entire intersection; includes costs for moving loops and pavement markings	$120,000 per T-Intersection	$120,000 LS
	$220,000 per 4-Leg Intersection	$0 LS
1 signal will be impacted		
	Sub-total	$180,000 LS
There are 12 signalized intersections between N. 3rd St and N. 14th St	$50,000 per box per intersection	$600,000 LS
	Sub-Total	**$780,000** LS

50.05 Communications

Variable Message Signs	$15,000/sign*6*4	$360,000 LS
6 platform per station, 4 Stations		

Mixed Traffic Operations - *4.5 miles*

10 GUIDEWAY AND TRACK ELEMENTS

10.03 Guideway: At-grade in mixed traffic

Sign Panels			
Assumes 1 sign per 0.25 mile	66 IN X 36 IN	66	SF
Preferential Only Lane Ahead for 1 mi approaching Thompson St	30 IN X 42 IN	35	SF
Preferential Only Lane Ahead for 1 mi approaching 12th St - ground	`	**101**	SF
Sign Post Steel 4"	8*9	**72**	LF
Assumes 1 sign per 0.25 mile and			
pole length of 9 FT			

20 STATIONS, STOPS, TERMINALS,INTERMODAL

ConcreteBus Pad	12*60*11*6/12	**147**	CY
12 platform, 6 stations			
L=60' W=11' T=6"			
Concrete Platform)	Area of Platform (11' X 60') =	660	SF
12 platform, 6 stations	660*12	7,920	SF
		880	SY
Station Furnitures			
Lighting at Station	$7,500/pole *6*2	$90,000	LS
2 platforms per station, 6 stations			
Bench	$1,500/bench*6*2*2	$36,000	LS
2 platforms per station, 6 stations			
2 per platform			
Bicycle Rack	400/rack*6*2	$4,800	LS
2 platforms per station, 6 stations			
		$130,800	LS
Station Furnitures Sub-Total			
Enhanced Shelters	$50,000/platform *6*2	12	Platforms
2 platforms per station, 6 stations			
Sign Panels	12 IN X 30 IN	**53**	SF
No Parking (with transit logo)			
Assumed 6 signs per station (1 for bus stop, 2 for no parking on each side of the street)			
Sign Post Steel 4"		**189**	LF
pole length of 9 FT			

Mixed Traffic Operations - *4.5 miles*

40 SITEWORK & SPECIAL CONDITIONS			
40.01 Demolition , Clearing, Earthwork			
Removal of Sidewalk	3*5*60+12*4*60+5*8*60	6,180	SF
at Station location, sidewalk width from aerial		**687**	SY
Removal of curb and gutter 12 platform, 6 Stations L=60'	12*60	**720**	LF
Demolition of Pavement at Station Location 12 platform, 6 stations	11*60*12	**880**	SY
Remove Ty. I Signs	1.42 MI / 0.25 MI	12	EA
Assumes 1 sign per 0.25 mile	1.75 MI / 0.25 MI	14	EA
		26	EA
40.06 Pedestrian/Bike Access Accomodation			
Hydr. Cement Concrete Sidewalk 4"	12*60*5	3,600	SF
12 platform, 6 Stations		**400**	SY
L=60', W=5' replace the sidewalk on the other side of the platform			
St'd Combination Curb and Gutter CG-6 12 platform, 6 Stations L=60'	12*60	**720**	LF
CG-12 Curb Ramp 6 station, 54 sf per ramp	6*54	**36**	SY
50 SYSTEMS			
50.02 Traffic signal and crossing Protection			
There are 15 signals	Pre-emption ($5,000 per signal)	$75,000	LS
There are 6 signalized intersection between Willow Lawn and N. Hamilton and 9 between Bank St. and Orleans St.	$50,000 per box per intersection	$600,000	LS
	Sub-Total	**$675,000**	
50.05 Communications			
Variable Message Signs 12 platform, 6 stations	15000/sign*12	$180,000	LS

Systemwide Elements

40 SITEWORK & SPECIAL CONDITIONS			
40.07 Automobile, bus, van, accessways including roads,parking lots			
Parking spaces	Assume 95 spaces at $5,600/space	300	parking spaces
50 SYSTEMS			
50.05 Communications			
Vehicle Communications Costs are assumed per vehicle *The Build Alternative will require 15 vehicles (12 peak, 3 spare)*	$20,000 per vehicle	$300,000	LS
50.06 Fare Collection *Includes TVMs, stand-alone validators, cash room modifications, and control systems. See table "Broad Street BRT Fare Collection System" for details*		$2,359,269	LS
60 ROW, LAND, EXISTING IMPROVEMENTS			
60.01 Purchase or Lease of Real Estate *2103 Staples Mill Rd: assume agreement in place with Anthem to use a portion of their lot. Costs to restripe or dedicate this section to Park and Ride included under 40.07*			LS
70 VEHICLES			
70.04 Bus			
BRT Vehicles Costs are assumed per vehicle	7 peak vehicles, 2 spares $1,000,000 per vehicle	9	vehicles

Exhibit 2
Broad Street BRT Fare Collection System

Mode	Note	Equipment/Modification Type	Quantity	Unit Cost	Year 1	Year 2	Year 3	Year 4	Year 5	TOTAL
BRT Stations		TVMs (2 per station)	28	40,000	1,120,000					1,120,000
		Stand Alone Validators, SAVs (2 each at 4 CBD Stations)	8	8,000	64,000					
		Hand Held Devices (2 per Inspector)	4	5,000	20,000					20,000
		Network Equipment at Stations (1 set per station)	14	5,000	70,000					70,000
		subtotal (equipment)			1,274,000	0	0	0	0	1,274,000
	A	Engineering (10%)			127,400	0	0	0	0	127,400
	A	Installation and Testing (5%)			63,700	0	0	0	0	63,700
	A	Support, Training and Manuals (5%)			63,700	0	0	0	0	63,700
	A	Non-recurring Parts & Services (13.5%)			171,990	0	0	0	0	171,990
	A	Contingency (15%)			255,119	0	0	0	0	255,119
		subtotal (add-ons)			681,909	0	0	0	0	681,909
		Total Future Cost for Equip./Mod.			1,955,909	0	0	0	0	1,955,909
	B	Maintenance materials (10% of Non-recurring Parts & Services)			17,199	18,059	18,962	19,910	20,905	95,035
		Total future cost of equip./mod. and materials			1,973,108	18,059	18,962	19,910	20,905	2,050,944
Cash Room		Additional Change Hoppers (2 per TVM)	56	500	28,000					28,000
		Additional Coin Vaults (1 per TVM)	28	300	8,400					8,400
		Additional Bill Vaults (1 per TVM)	28	1,000	28,000					28,000
		Revenue Carts	2	50,000	100,000					100,000
		subtotal (equipment)			164,400	0	0	0	0	164,400
	A	Engineering (10%)			16,440	0	0	0	0	16,440
	A	Support (5%)			8,220	0	0	0	0	8,220
	A	Non-recurring Parts & Services (13.5%)			22,194	0	0	0	0	22,194
	A	Contingency (15%)			31,688	0	0	0	0	31,688
		subtotal (add-ons)			78,542	0	0	0	0	78,542
		Total Future Cost for Equip./Mod.			242,942	0	0	0	0	242,942
	B	Maintenance materials (10% of Non-recurring Parts & Services)			2,219	2,330	2,447	2,569	2,698	12,264
		Total future cost of equip./mod. and materials			245,162	2,330	2,447	2,569	2,698	255,206

Exhibit 2
Broad Street BRT Fare Collection System

Mode	Note	Equipment/Modification Type	Quantity	Unit Cost	Year 1	Year 2	Year 3	Year 4	Year 5	TOTAL
Central and System Support		Central Computer System	1	325,000	325,000					325,000
		Workstations	2	5,000	10,000					10,000
		subtotal (equipment)			335,000	0	0	0	0	335,000
	A	Engineering (10%)			33,500	0	0	0	0	33,500
	A	Installation (5%)			16,750	0	0	0	0	16,750
	A	Support (5%)			16,750	0	0	0	0	16,750
	A	Non-recurring Parts & Services (13.5%)			45,225	0	0	0	0	45,225
	A	Contingency (15%)			67,084	0	0	0	0	67,084
		subtotal (add-ons)			179,309	0	0	0	0	179,309
		Total Future Cost for Equip./Mod.			514,309	0	0	0	0	514,309
	B	Maintenance materials (10% of Non-recurring Parts & Services)			4,523	4,749	4,986	5,235	5,497	24,990
		Total future cost of equip./mod. and materials			518,831	4,749	4,986	5,235	5,497	539,298
Grand Total Future Cost					2,737,100	25,138	26,395	27,715	29,100	2,845,448

Notes:

A. Percentage of equipment subtotal
B. Escalation rate of 5% for years 2 to 10

Estimate of ROW Costs at Belvidere and Broad Street

ParcelID	Property_1	LandUse	ACREAGE	SqFt	OwnerName	Assessment	LandValue	DwellingVa	TotalValue
9169	B Drug Stores/Pharmacy	Commercial	0.69	30,205	Rite-va1 Administrator Inc C/o Rite Aid Corporation	1/1/2009	$698,000.00	$873,600.00	$1,571,600.00
38183	B Vehicle Srvc Station w/pumps	Commercial	0.60	26,330	Hess Realty Corp	1/1/2009	$515,000.00	$119,000.00	$634,000.00
51968	B College/University Facility	Institutional	2.24	97,426	Vcuref	1/1/2009	$3,066,000.00	$24,039,000.00	$27,105,000.00
80531	B Paved Surface Parking	Commercial	0.71	30,981	Universal Ford Acquisition Corp	1/1/2009	$1,396,000.00	$84,000.00	$1,480,000.00
80533	B Commercial Vacant Land	Vacant	0.01	608	City Of Richmond Public Works	1/1/2009	$45,000.00	$0.00	$45,000.00

BROAD STREET RAPID TRANSIT STUDY

ENVIRONMENTAL ASSESSMENT

APPENDIX A-14: Report on Visual and Aesthetic Findings

BROAD STREET CORRIDOR EA
REPORT ON VISUAL AND AESTHETIC FINDINGS

1 VISUAL AND AESTHETIC RESOURCES

This section describes the basic terminologies of visual resources used in this report. This information will provide background for the assessment procedures described in the later sections.

Visual resources are those physical features that make up the visual landscape, including land, water, vegetation, and man-made elements. These elements are the stimuli upon which one's visual experience is based. Substantial visual and aesthetic resources within the project area would include historic structures, parklands, and undeveloped open space/natural areas. Potential sensitive visual receptors would include areas or users affected by changes in the visual and aesthetic character of the study area.

NEPA and CEQ regulations address visual impacts under the heading of aesthetics. These regulations identify aesthetics as one of the elements or factors in the human environment that must be considered in determining the effects of a project. Further, 23 USC 109(h) cites "aesthetic values" as a matter that must be fully considered in developing a project.

The *Master Plan for the City of Richmond* (2000) identifies Broad Street as a Principal Arterial Image Corridor with a Minor Gateway located on Broad Street at the western city limit. The Master Plan defines image corridors as key transportation corridors that have the ability to form an impression on travelers passing through the city without actually visiting. They provide an opportunity to convey a positive image of the city and city life. Gateways are defined as locations where transportation routes intersect with entrances to the city. They help create a "sense of place" and provide an opportunity to establish an image of the city for both residents and visitors.

The *Henrico County Vision 2026 Comprehensive Plan* (2009) defines community character based on land use. Visual and aesthetic character is one of the factors which comprise community character. The majority of the land uses adjacent to the corridor within Henrico County are commercial and industrial. The Comprehensive Plan states "the general character of these areas should reflect and respect the surrounding context and use appropriate transitions to buffer the impacts of higher activity uses on surrounding residences."

The visual effects of changes in the viewshed as a result of the proposed project are based on site visits, reviews of local planning documents, photographs of the study area, and photographs and illustrations of typical BRT vehicles and facilities. Because the corridor is within a developed urban and suburban area, the viewshed for this visual and aesthetic resource assessment is confined in most areas by the buildings and properties immediately adjacent to the proposed alignment. Within the open areas near the eastern terminus of the corridor, the viewshed was determined to extend ¼-mile from the proposed alignment.

This visual assessment was prepared consistent with the methodologies established by the U.S. Department of Transportation, Federal Highway Administration's *Visual Impact Assessment for Highway Projects* (1981). This methodology was selected since it is customarily used for transportation projects along linear corridors, including transit projects.

Typical views, called key viewpoints, were selected for the study area to represent the views to/from the project. Existing visual quality from the viewpoints is judged by three criteria: vividness, intactness, and unity, as follows:

- Vividness: the memorability of the landscape components as they combine to form striking or distinctive patterns.
- Intactness: the integrity of visual order in the view and its freedom from visual encroachment.
- Unity: the visual coherence and composition of the landscape viewed to form a harmonious visual pattern.

These criteria provide a method for describing the form, line, color, and texture of the components found within a view. As in all things aesthetic, any visual analysis is somewhat subjective; however, as outlined in the FHWA methods, the use of these descriptors provides a basis for understanding the evaluator's rationale behind a visual quality determination. It is important to note that visual character terms are descriptive and non-evaluative, meaning that they are based on defined attributes which are neither good nor bad by themselves. Changes in visual character cannot be described as having good or bad attributes until compared with viewer responses to the change.

Visual sensitivity is based on the number and types of users, viewers, or sensitive receptors typically found in the study area. Generally, viewers in parks and residential areas are assumed to be the most sensitive to visual and aesthetic impacts, and viewers in industrial areas would be the least sensitive. The level of sensitivity for viewers from an adjacent roadway or transit corridor varies depending on the number of viewers and the corridor's landscape context.

Visual quality is evaluated based on consideration of landscape qualities related to natural and/or man-made features, specifically:

- Natural features, including topography, water courses, rock outcrops, and natural vegetation;
- The positive and negative effects of man-made alterations to the environment and built structures on visual quality; and
- Visual composition, including an assessment of the complexity and vividness of patterns that exist in the landscape.

The Broad Street corridor was evaluated for the visual quality of existing conditions as well as for the viewers' visual sensitivity.

4.5.1 Affected Environment

The seven-mile Broad Street corridor encompasses a range of land uses and development patterns, from auto-oriented suburban development in the western portion of the corridor to the urban central business district to active and redeveloped industrial properties at the eastern terminus. For visual analysis purposes, the corridor can be divided into seven distinct regions, referred to as visual assessment units (Figure 1):

- Visual Assessment Unit 1: Western Terminus to Boulevard
- Visual Assessment Unit 2: Boulevard to Hermitage
- Visual Assessment Unit 3: Hermitage to Belvidere
- Visual Assessment Unit 4: Belvidere to 3rd Street
- Visual Assessment Unit 5: 3rd Street to I-95/Main Street Station
- Visual Assessment Unit 6: I-95/Main Street Station to 24th Street

- Visual Assessment Unit 7: 24th Street to Eastern Terminus

The existing visual conditions in each of these areas are discussed below, and representative photographs are shown in Figures 2 through 8. Within each visual assessment unit are several distinct viewer groups with varying degrees of sensitivity to visual and aesthetic changes to the environment. These include:

- **Community Residents:** Residents can be expected to have the highest sensitivity and be the most aware of any groups, since the project is located within their immediate environment or surroundings.
- **Business Owners, Employees, and Customers:** This user group would be associated with the existing offices and business within the study area. These viewers are anticipated to have a low level of concern regarding the changes to the visual environment; their principal concern is likely to be the effect of any construction on business access for employees or customers.
- **Regular Motorists and Pedestrians:** Included in this user group are commuters and local residents/workers who frequently travel within the study area. These viewers would be aware of any changes to the visual environment because of their repeated exposure. They would be moderately sensitive to the change in the visual environment.
- **Occasional Motorists and Pedestrians:** These viewers include tourists and regional residents from outside the immediate area who infrequently travel the area. These viewers generally have a low exposure and awareness of changes to the visual environment.

4.5.1.1 Visual Assessment Unit 1: Western Terminus to Boulevard

Visual Assessment Unit 1 begins at the westernmost point of the proposed BRT line at Byrd Avenue and continues east for approximately two miles to Boulevard. Much of this segment of the corridor features typical suburban, auto-dependent, arterial development, with big box retail, car dealerships, strip malls, drive-thru establishments, and large surface parking lots. East of Staples Mill Road, there is also some suburban office development at various locations along the corridor, set well back from Broad Street by associated surface parking. At the eastern end of this portion of the corridor are smaller service-oriented businesses such as gas stations, banks, and small restaurants; a Virginia Department of Game and Inland Fisheries building; a United Methodist Family Services complex set back from Broad Street by a large, walled lawn; several mid-size office buildings; and a Comfort Inn hotel. Viewers in this visual assessment unit will mainly include business owners, employees, customers, and both regular and occasional motorists, all of whom are already accustomed to observing bus service along Broad Street.

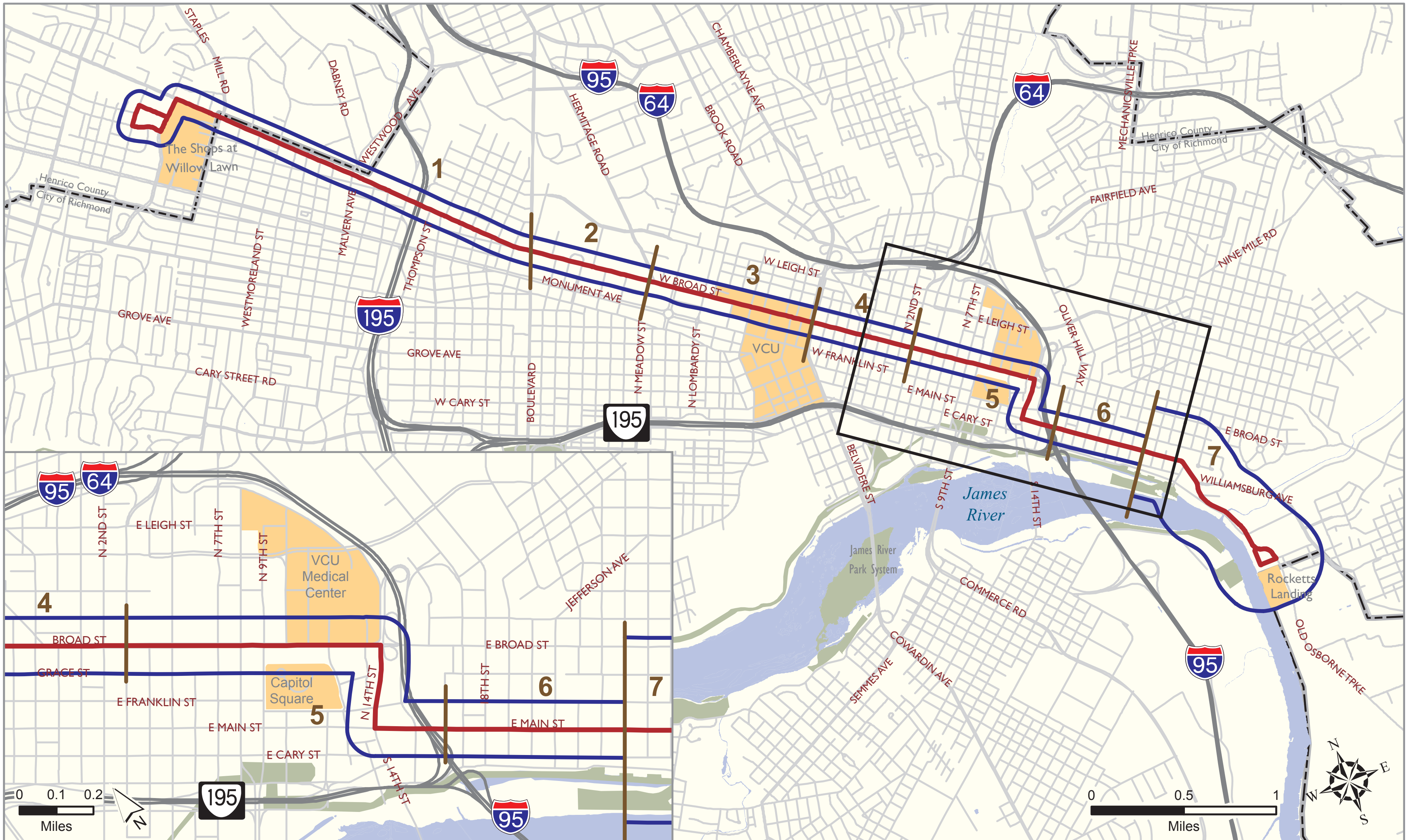
An exception to this general development pattern and viewer group composition occurs at the western end of the proposed alignment, where BRT vehicles would make the loop from Willow Lawn Drive to Fitzhugh Avenue, Byrd Avenue, and Markel Road before returning to northbound Willow Lawn Drive heading back towards Broad Street. Fitzhugh Avenue and Byrd Avenue are residential streets, with single family detached homes and the Gateway Homes-Greater Richmond, a transitional residential treatment facility for adults with mental illness. Also along the proposed route on Byrd Avenue is the Faison School for Autism, a private day school for students ages 18 months through 22 years. Neighborhood residents, as well as students and faculty at the school, would have high sensitivity to visual changes along this portion of the alignment.

4.5.1.2 Visual Assessment Unit 2: Boulevard to Hermitage

Visual Assessment Unit 2 stretches approximately 0.6 miles from Boulevard to Hermitage Road. It is characterized by large buildings. It is slightly less auto-dependent than Visual Assessment Unit 1, though still characterized by large areas of surface parking, especially on the north side. Residents of the William Byrd Apartments near Boulevard Station will be the most sensitive to visual changes in this segment of the corridor. Viewers in this visual assessment unit will mainly include business owners, employees, customers, regular motorists, and occasional motorists such as those visiting the museums.

4.5.1.3 Visual Assessment Unit 3: Hermitage to Belvidere

Visual Assessment Unit 3 is primarily a revitalized university area, incorporating a portion of the VCU MCV campus and health care center. It is considerably more pedestrian-oriented than units 2 and 3, although there is a Lowe's home improvement store fronted by a large surface parking lot at the western end of the unit. In addition to business owners, employees, and customers and regular and occasional motorists and pedestrians through the area, viewers will include students traveling between buildings and shops, as well as student residents of the VCU Ackell Residence Center and the VCU Broad and Belvidere Apartments.



Legend

Proposed BRT Alignment

Viewshed Area

1 | 2 Visual Assessment Unit Breakpoint

Source: VGIN RCL (Roads)

Environmental Assessment Figure 1: Visual Assessment Units

BROAD STREET RAPID TRANSIT STUDY

Environmental Assessment

Figure 2: Representative Photographs of Visual Assessment Unit 1

BROAD STREET RAPID TRANSIT STUDY

Environmental Assessment

Figure 3: Representative Photographs of Visual Assessment Unit 2

BROAD STREET RAPID TRANSIT STUDY

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Environmental Assessment

Figure 4: Representative Photographs of Visual Assessment Unit 3

BROAD STREET RAPID TRANSIT STUDY

Environmental Assessment

Figure 5: Representative Photographs of Visual Assessment Unit 4

BROAD STREET RAPID TRANSIT STUDY

Environmental Assessment

Figure 6: Representative Photographs of Visual Assessment Unit 5

BROAD STREET RAPID TRANSIT STUDY

Environmental Assessment

Figure 7: Representative Photographs of Visual Assessment Unit 6

BROAD STREET RAPID TRANSIT STUDY

Environmental Assessment

Figure 8: Representative Photographs of Visual Assessment Unit 7

BROAD STREET RAPID TRANSIT STUDY

4.5.1.4 Visual Assessment Unit 4: Belvidere to 3rd Street

Visual Assessment Unit 4 includes approximately 0.5 miles of the Broad Street corridor, from N. Belvidere Street to N. 3rd Street, though an older section of the city. Like unit 3, this is a more pedestrian oriented area, with street-front retail and food businesses and predominantly on-street parking. Viewers in this visual assessment unit will mainly include business owners, employees, customers, regular and occasional motorists and pedestrians, although there are some residential apartments above store front businesses, as well as the mid-rise Richmond Dairy Apartments one block north of Broad Street, the upper floors of which may have views of the proposed alignment.

4.5.1.5 Visual Assessment Unit 5: 3rd Street to I-95/Main Street Station

Visual Assessment Unit 5 comprises Richmond's urban downtown and many of its cultural institutions and government buildings, including City Hall, the State Capitol, Federal Courthouse, the Virginia Department of Transportation, the Library of Virginia, and the Theater Row Building. It also includes the Greater Richmond Convention Center and several hotels, as well as campus buildings and hospitals associated with the VCU Medical College and Medical College of Virginia. Parking is a mix of on-street, surface, and structured. Many of the buildings in this unit are eligible or potentially eligible for listing on the National Register of Historic Places.

Viewers in this area will include government and hospital employees, as well as occasional visitors to government buildings, hospitals, and cultural/historic sites.

4.5.1.6 Visual Assessment Unit 6: I-95/Main Street Station to 24th Street

Stretching east of I-95 and Main Street Station along E. Main Street for approximately 0.5 miles, Visual Assessment Unit 6 is an urban, pedestrian-oriented area with bars, restaurants, and small retail shops located in older buildings. The 17th Street Farmers Market, Edgar Allen Poe Museum, and the Virginia Holocaust Museum are also located in this area.

In addition to apartments above the storefront shops and restaurants, there are several mid-rise apartment buildings along the segment of the corridor. Residents of these apartments will be the most sensitive viewers in this unit, which will also include business owners, employees, customers, and other occasional motorists and pedestrians.

4.5.1.7 Visual Assessment Unit 7: 24th Street to Eastern Terminus

Visual Assessment Unit 7 includes approximately 1 mile along E. Main Street and the James River waterfront, from 24th Street to the Rocketts Landing development at the eastern terminus of the proposed alignment. This area includes a mix of active industrial sites and large-scale residential redevelopment projects in former industrial space. There is also parkland and recreation facilities, including Libbie Hill Park and Cannonball Triangle Park on the north side of Main Street, and a sand volleyball court and boat launch near the Rocketts Landing apartments. Viewers in this visual assessment unit include apartment residents along the length of this segment, as well as employees of the active industrial properties.

4.5.2 Environmental Consequences

The visual impact of project alternatives is determined by assessing the visual resource change due to the project and predicting viewer response to that change. Visual resource change is the total change in visual character and visual quality. The first step in determining visual resource change is to assess the compatibility of the proposed project with the existing visual character of the landscape. The second step is to compare the visual quality of the existing resources with the projected visual quality after the project is constructed. Viewer response to the changes is the sum of viewer exposure and viewer sensitivity to the project. The resulting level of visual impact is determined by combining the severity of resource change with the degree to which people are likely to oppose the change.

No-Build Alternative

The No-Build Alternative would maintain existing bus service and facilities along the Broad Street corridor. This alternative would not result in any direct, indirect, or temporary construction impacts to visual and aesthetic resources.

Build Alternative

The Build Alternative would implement BRT service along the Broad Street from Willow Lawn to 14th Street, via 14th Street from Broad Street to Main Street and via Main Street from 14th Street to Rocketts Landing. The Build Alternative would stop at the 14 station locations along this route. BRT vehicles would operate both in mixed traffic and dedicated right-of-way, as described for each visual assessment unit below.

The existing transit shelters at the 14 Build Alternative station locations would be replaced with BRT stations, each with one to three platforms. BRT stations would be comparable in scale to the shelters currently in use along Broad Street, but would have a distinct appearance that would differentiate them from local-only stops. BRT stations would include additional amenities to improve the waiting and boarding experience, including ticket vending machines, system maps, BRT route maps and schedules, canopies, and seating. At multiple platform stations, real-time kiosks would be present at each platform to identify which buses would stop at which platform. Additional amenities may include trash receptacles and physical integration with adjoining buildings and/or land uses.

The visual and aesthetic impacts of the Build Alternative within each visual assessment unit are detailed below. The proposed changes in all seven units are consistent with the visual and aesthetic components of both the City of Richmond's Master Plan and Henrico County's Comprehensive Plan.

Visual Assessment Unit 1: Western Terminus to Boulevard

BRT service would run in mixed traffic for most of this segment of the corridor, with median-running dedicated BRT lanes east of I-195. Three stations would be constructed within Visual Assessment Unit 1:

- **Willow Lawn Transit Center Station:** A consolidated station with three platforms – one for BRT and two for local buses – would be added on eastbound Willow Lawn Drive in the same location as the existing bus stop.
- **Staples Mill Road Station:** Eastbound and westbound curbside side platforms, both west of Chantilly Street, would be co-located with the existing eastbound and westbound bus stops. In addition, park-and-ride facilities are proposed to be added within the existing surface parking lot at the Anthem Headquarters property adjacent to the westbound station platform.
- **Hamilton/I-95 Station:** Eastbound and westbound curbside side platforms would be added, both on the near side of Hamilton Street with respect to the direction of travel. The westbound station platform would be co-located with the existing westbound bus stop.

The implementation of BRT service would not change the existing aesthetic character of Visual Assessment Unit 1. Viewers here are predominantly business owners, employees, customers, and other motorists, all of whom are already accustomed to bus service along Broad Street and a busy commercial environment. The replacement of existing curbside transit shelters with curbside BRT stations at the Staples Mill Road and Hamilton/I-95 stations would have only a minor effect on these viewers.

From Thompson Street to the Boulevard, motorists and pedestrians in the corridor will experience the visual impact of the median-running guideway. The implementation of the guideway would not change the existing aesthetic character of Visual Assessment Unit 1 but would introduce a new element to the streetscape. Viewers in this visual assessment unit will mainly include business owners, employees, customers, regular motorists, and occasional motorists such as those visiting the shops and institutional properties. Of these groups, regular motorists are most likely to perceive the change, as viewers from the properties flanking Broad Street will be separated from the new BRT facilities by two lanes of traffic plus curbside parking in one direction. Overall, visual impacts to these groups would be minor.

Sensitive viewer groups, including residents along Fitzhugh Avenue and Byrd Avenue, students, staff, and parents at the Faison School for Autism, and patients and staff at the Gateway Homes, exist in the vicinity of the proposed Willow Lawn Transit Center Station. Buses already travel this route, and the Build Alternative would not change the overall character of the neighborhood. While the new station would not be in direct view of the school or neighborhood homes, the addition of a platform station in this area would be perceived as a moderate change by these viewers as they travel to and from their homes or the school. Some of these viewers may consider this change to be positive, however, as it will replace an existing bus shelter along a block lined with surface parking with an attractive, branded station facility.

Temporary visual impacts would occur during construction of the three BRT stations. These temporary impacts are expected to be minor for business owners, employees, customers, and other motorists, and moderate for residents, students, and patients near the Willow Lawn Transit Center Station.

Visual Assessment Unit 2: Boulevard to Hermitage

BRT service in Visual Assessment Unit 2 would be median-running in dedicated BRT lanes, with one new station. Boulevard Station would be a split-platform, median station, with right-side platforms on the far side of N. Robinson Street with respect to the direction of travel. Local bus connections would continue to be provided at curbside bus stations.

The implementation of BRT service would not change the existing aesthetic character of Visual Assessment Unit 2 but would introduce a new element to the streetscape, adding dedicated BRT lanes and station platforms in the median of the roadway, where only local curbside bus service exists today.

Viewers in this visual assessment unit will mainly include business owners, employees, customers, regular motorists, and occasional motorists such as those visiting the museums. Of these groups, regular motorists are most likely to perceive the change, as viewers from the properties flanking Broad Street will be separated from the new BRT facilities by two lanes of traffic plus curbside parking in one direction. Overall, visual impacts to these groups would be minor.

Sensitive viewers in this visual assessment unit include residents of the William Byrd Apartments near Boulevard Station, some of whom would have an aerial view of the new BRT lanes and the new station from their apartments, and all of whom would have views of these facilities as they travel to and from home. Because the overall character of corridor will not change despite the addition of these new facilities, visual impacts to these residents would be moderate.

Temporary visual impacts would occur during construction of Boulevard Station. These temporary impacts are expected to be minor for business owners, employees, customers, and other motorists, and moderate for residents near the station.

Visual Assessment Unit 3: Hermitage to Belvidere

As in Visual Assessment Unit 2, BRT service in this portion of the corridor would be median-running in dedicated BRT lanes, with two new stations: the Hermitage/Meadow Station straddling visual assessment units 2 and 3, and Shafer Station at N. Shafer Street. Like Boulevard Station, these would be split-platform, median stations, with right-side platforms on the far side of each station's cross street with respect to the direction of travel. Local bus connections would continue to be provided at curbside bus stations.

Similar to Visual Assessment Unit 2, the implementation of BRT service would not change the existing aesthetic character of this area but would introduce a new element to the streetscape, adding dedicated BRT lanes and station platforms in the median of the roadway, where only local curbside bus service exists today. At the eastern end of this visual assessment unit, an existing landscaped median between Pine Street and Henry Street would be removed and replaced with BRT lanes.

In addition to business owners, employees, and customers and regular and occasional motorists and pedestrians through the area, viewers will include students traveling between buildings and shops. Of these groups, regular motorists and pedestrians are most likely to perceive the change, as viewers from inside the commercial properties flanking Broad Street would be separated from the new BRT facilities by two lanes of traffic plus curbside parking in each direction. Overall, visual impacts to these groups would be minor.

Sensitive viewers in this visual assessment unit include student residents of the VCU Ackell Residence Center and the VCU Broad and Belvidere Apartments, some of whom would have an aerial view of the new BRT lanes and the new stations from their residences. These students also make up the most frequent travelers in this corridor, typically traveling to and from their residences on foot. Because the overall character of the corridor will not change despite the addition of these new facilities, visual impacts to these residents would be moderate.

Temporary visual impacts would occur during construction of the new stations. These temporary impacts are expected to be minor for business owners, employees, customers, and other motorists, and moderate for residents near the stations.

Visual Assessment Unit 4: Belvidere to 3rd Street

BRT service in Visual Assessment Unit 4 would be primarily median-running in dedicated BRT lanes, with BRT vehicles transitioning through mixed traffic to curbside lanes at 2nd Street. There would be one new station at N. Adams Street. Like the BRT stations in Visual Assessment Units 2 and 3, Adams Station would be a median, split platform station adjoining the bus lane with right-side platforms on the far side of N. Adams Street with respect to the direction of travel. Local bus connections would continue to be provided at curbside bus stations.

Similar to Visual Assessment Units 2 and 3, the implementation of BRT service would not change the existing aesthetic character of this area but would introduce a new element to the streetscape, adding dedicated BRT lanes and station platforms in the median of the roadway, where only local curbside bus service exists today. At the western end of this visual assessment unit, an existing landscaped median between Pine Street and Henry Street would be removed and replaced with BRT lanes. A landscaped median that straddles visual assessment units 4 and 5, from 2nd Street to 8th Street, would also be removed to make room for new curbside BRT lanes. . Also straddling these two visual assessment units, from 4th Street to 2nd Street, the existing curbside bus lane would be removed, and at 4th Street, the existing bus stop and shelter would be removed.

As described earlier in this section, Visual Assessment Unit 4 is a more pedestrian-oriented area, with street-front retail and food businesses throughout this segment of the corridor. Viewers in this visual assessment unit mainly include business owners, employees, customers, and regular and occasional motorists, as well as a large number of regular and occasional pedestrians traveling to and from businesses and restaurants on foot. Of these groups, regular motorists and pedestrians are most likely to perceive the change, although the overall visual impact to these groups would still be minor.

Sensitive viewers in this visual assessment unit include residents of apartments over storefront businesses along both sides of Broad Street, as well as residents of the upper floors of the mid-rise Richmond Dairy Apartments one block north of Broad Street. These residents may have an aerial view of the new BRT lanes and the new station from their residences and also make up the most frequent travels in this corridor. Visual impacts to these residents include removal of the landscaped median; impacts to them are considered moderate.

Temporary visual impacts would occur during construction of the new stations. These temporary impacts are expected to be minor for business owners, employees, customers, and other motorists and pedestrians, and moderate for residents near the station.

Visual Assessment Unit 5: 3rd Street to I-95/Main Street Station

Through most of Visual Assessment 5, BRT vehicles would travel in dedicated curbside lanes created by widening the existing roadway shoulders from 4th Street to 14th Street. From 14th Street to Main Street Transit Center, BRT vehicles would travel in mixed traffic.

Four new stations would be constructed in this portion of the corridor: 3rd Street Station, 6th Street Station, 9th Street Station, and 12th Street Station. All would be consolidated stations with three side platforms, one for BRT and two for local buses. Both the eastbound and westbound platforms would be east of each station's cross street.

Between the consolidated stations, existing bus stations markers and shelters would be removed from Broad Street. Some of these flank historic buildings that will, in some sense, be enhanced by the removal of modern street architecture. Further details on the potential for impacts to historic architecture are included in Section 4.4.

The implementation of BRT service would not change the existing aesthetic character of Visual Assessment Unit 5, which already features bus service in mixed traffic with curbside stops. While the landscaped median from 2nd Street to 8th Street would be removed to make room for new curbside BRT lanes, most sidewalk landscaping and street trees will remain. The replacement of existing curbside transit shelters with curbside BRT stations at 3rd Street, 6th Street, 9th Street, and 12th Street would have only a minor effect on viewers in this corridor, who mainly include government and hospital employees, as well as occasional visitors to government buildings, hospitals, and cultural/historic sites. The operational improvements afforded by the bus lanes and consolidated stations are anticipated to reduce "bus bunching" in the corridor, which creates a visual barrier for both pedestrians and motorists in the area. This improvement and the removal of stations at 2nd, 4th, 5th, 7th, 8th, 10th and 11th streets in part offsets the visual impacts of the consolidated stations. Consequently, visual impacts to these groups would be minor, as would the temporary visual impacts that would occur during construction of the new stations and improved bus lane.

Visual Assessment Unit 6: I-95/Main Street Station to 24th Street

Like the No-Build Alternative, BRT vehicles will travel in mixed traffic throughout Visual Assessment Unit 6. One new station would be added adjacent to the existing Main Street Amtrak station. Main Street Station would have eastbound and westbound curbside side platforms, both directly in front of/directly across the street from the train station entrance. However, an existing bus stop and shelter exist in each direction in this location, and the BRT station could involve minimal improvements to the existing bus stop in order to avoid visual impacts to historic Main Street Station.

The implementation of BRT service would not change the existing aesthetic character of Visual Assessment Unit 6, which already features bus service in mixed traffic with curbside stops. The addition of a BRT station adjacent to the existing rail station would have only a minor effect on viewers in this corridor, who include a mix of residents, business owners, employees, customers, and other occasional motorists and pedestrians. While this portion of the corridor includes both apartments above the storefront shops and restaurants and several mid-rise apartment buildings, the long-term visual changes in this portion of the corridor would be minor, even for sensitive viewers.

Temporary visual impacts would occur during construction of the new station. These temporary impacts are expected to be minor for business owners, employees, customers, and other motorists and pedestrians, and moderate for residents near the station.

Visual Assessment Unit 7: 24th Street to Eastern Terminus

Like the No-Build Alternative, BRT vehicles will travel in mixed traffic throughout Visual Assessment Unit 7. Two new stations would be constructed in this portion of the corridor:

- **25th Street Station:** Eastbound and westbound curbside side platforms, both east of 25th Street, would be co-located with the existing eastbound and westbound bus stops.
- **Rocketts Landing Station:** One side platform would be constructed at Orleans Street, with direct pedestrian access to the Rocketts Landing development.

The implementation of BRT service would not change the existing aesthetic character of Visual Assessment Unit 7, which already features bus service in mixed traffic with curbside stops. The replacement of existing curbside transit shelters with curbside BRT stations at the 25th Street Station and would have a minor effect viewers in this portion of the corridor, who mainly include apartment residents at Rocketts Landing and along E. Main Street west of Libbie Hill Park, and employees of the active industrial properties in the area.

The addition of Rocketts Landing Station would have a moderate effect on residents at Rocketts Landing, some of whom may have an aerial view of the new BRT station from their residences.

Temporary visual impacts would occur during construction of the new stations. These temporary impacts are expected to be minor for employees and apartment residents at the western end of the visual assessment unit, and moderate for Rocketts Landing residents.

Environmental Justice

The potential for visual effects to environmental justice communities would be the same as the effects to those of the general population and there would be no disproportionately high or adverse impacts.

4.5.3 Minimization Measures and Recommended Mitigation

Because none of the proposed improvements would result in a substantial visual impact for viewers along the corridor, no mitigation measures are recommended for any of the alternatives under consideration.

BROAD STREET RAPID TRANSIT STUDY

ENVIRONMENTAL ASSESSMENT

APPENDIX A-15: Report on Natural Resource Findings

BROAD STREET CORRIDOR EA
REPORT ON NATRUAL RESOURCE FINDINGS

1 INTRODUCTION

The Virginia Department of Rail and Public Transportation (DRPT), in partnership with GRTC Transit System, is conducting a detailed study of transit investment along a seven-mile corridor that spans the City of Richmond and portions of Henrico County. The corridor (Broad Street Corridor) follows Broad Street for five miles from Willow Lawn Drive in Henrico County, east through downtown Richmond, to 14th Street, where it then turns south to Main Street to connect to the Amtrak Station. From there, the corridor heads east along Main Street through historic Shockoe Bottom to the new Rocketts Landing development in eastern Henrico County. The study is following Federal Transit Administration (FTA) Small Starts Program guidance and will result in the completion of an Environmental Assessment (EA) document. The EA is evaluating the enhancement of existing transit service along the Broad Street Corridor with Bus Rapid Transit (BRT) service.

The proposed Broad Street Corridor BRT system is expected to provide passengers with an enhanced and efficient bus service along the existing GRTC transit system routes on Broad Street, 14th Street, and Main Street. The proposed alternatives may affect natural resources in the area. This report is intended to provide information for completing the EA by reviewing the affected environment, environmental consequences, minimization measures and recommended mitigation for the following natural resources:

- Rare, Threatened and Endangered Species
- Surface Waters
- Floodplains
- Water Quality
- Coastal Zone

2 RARE, THREATENED, AND ENDANGERED SPECIES

Under the Endangered Species Act (ESA) of 1973, any federal action that would likely result in a negative impact to federally protected plants or animals is subject to review by the US Fish and Wildlife Service (USFWS). Even in the absence of federal actions, the USFWS has the power, through the provisions of Section 9 of the ESA, to exercise jurisdiction on behalf of a protected plant or animal. The USFWS and other wildlife resource agencies also exercise jurisdiction in accordance with the Fish and Wildlife Coordination Act (48 Statute 401, as amended: 16 U.S.C. 661 et seq.). The Commonwealth of Virginia also designates plant and animal species deemed threatened and endangered within the state.

2.1 AFFECTED ENVIRONMENT

The Virginia Department of Conservation and Recreation (VDCR), Virginia Division of Game and Inland Fisheries (VDGIF), and USFWS were contacted requesting information on potential impacts related to the proposed project. VDCR searched their Biotics Data System for threatened and endangered species and other natural heritage resources in the project study area. Under a Memorandum of Agreement between VDCR and Virginia Department of Agriculture and Consumer Services (VDACS), VDCR represents VDACS in identifying state-listed threatened and endangered plant and insect species. No State Natural Area Preserves are located in the study area.

The VDGIF, Fish and Wildlife Information Service were consulted for information on endangered and threatened species, trout waters, and anadromous fish waters. The results of this search are included in Appendix D. In the vicinity of the project, the James River is confirmed anadromous fish water. Areas designated as “Anadromous Fish Use Areas” are migration pathways, spawning grounds, or nursery areas identified by VDGIF as having been used, or having the potential to be used, by anadromous fish. Confirmed Anadromous Fish Use Areas are those waters where anadromous fish species have been observed. Anadromous fish species in Virginia include: alewife (Alosa pseudoharengus), blueback herring (A. aestivalis), American shad (A. sapidissima), shad (A. mediocris), striped bass (Morone americana), and some populations of yellow perch (Perca flavescens). Anadromous fish stocks have declined in recent decades and many efforts are underway to conserve, and to restore, these species.
The USFWS did not note any federally listed species or critical habitats with the potential to be impacted in the study area.

2.2 ENVIRONMENTAL CONSEQUENCES

The potential effects of the Broad Street Rapid Transit Study alternatives on wildlife, vegetation, and rare, threatened or endangered species are discussed in this section.

No-Build Alternative

The No-Build Alternative would not require any land disturbances, and therefore would not have any impacts to rare, threatened and endangered species, critical habitats, State Natural Area Preserves, trout waters, or anadromous fish waters.

Build Alternative

This study alternative involves use of existing roads and previously developed parcels of land. An existing parking lot near Staples Mill Road is proposed for utilization as a park-and-ride facility. After searching the Biotics database, VDCR stated that no adverse impacts to natural heritage resources, including endangered and threatened species, are anticipated based on the scope of the proposed alternative and the distance to resources. Additionally, VDCR concludes that the proposed alternative will not affect any state-listed plants or insects. The USFWS states that no impacts to federally listed species or designated critical habitat will occur, and that the proposed alternative will not impact endangered or threatened species, critical habitats, State Natural Area Preserves or trout waters. Correspondence from VDCR and USFWS is included in Appendix B.

Because the project is located within 0.5 mile of confirmed anadromous fish water, DRPT and GRTC will need to further coordinate with the VDGIF, prior to any construction, to determine if additional protection measures are necessary (e.g., time of year restrictions).

2.3 MINIMIZATION MEASURES AND RECOMMENDED MITIGATION

To avoid the establishment of invasive terrestrial or aquatic animal or plant species during construction of the proposed project, special provisions will be added to the construction specifications to require prompt seeding of disturbed areas with seeds that are tested in accordance with the Virginia Seed Law to ensure that seed mixes are free of noxious species. While disturbed areas are vulnerable to the colonization of invasive plant species from adjacent properties, implementation of the stated provisions will reduce the potential for the establishment and proliferation of invasive species.

Because the project is located within 0.5 mile of confirmed anadromous fish water, GRTC and DRPT will need to further coordinate with the VDGIF prior to any construction to determine if additional protection measures are necessary, such as time of year restrictions or specific BMPs, to provide additional protections to water quality. Time of year restrictions depend on the type of work planned and its' location relative to the water body in question. Exact restrictions vary depending on the species, type of work, and location. The Build Alternative would not involve any instream work, and construction within the 0.5 mile of the anadromous fish water (the James River) is minimal.

Further, Best Management Practices would be used to minimize the potential for impacts to surface waters. Stormwater Management (SWM) and Erosion and Sediment Control (ESC) plans will be prepared as required.

In accordance with Executive Order 13112, Invasive Species, the potential for the establishment of invasive terrestrial or aquatic animal or plant species during construction of the proposed project will be minimized through adhering to special provisions.

3 HYDROLOGY/WATER QUALITY

This section discusses wetlands, surface waters, floodplains, and water quality, as well as consistency with coastal zone and Chesapeake Bay Preservation Act regulations. The study area is defined as within 300 feet of the project centerline for these provisions.

3.1 AFFECTED ENVIRONMENT

This section discusses the existing surface waters, floodplains, and Chesapeake Bay Preservation Areas within the defined study area. Coastal zone regulations and consistency are also discussed. The project would not impact wetland areas. No sole source aquifers, or wild and scenic rivers, are located in the vicinity of the study area.

3.1.1 Surface Waters

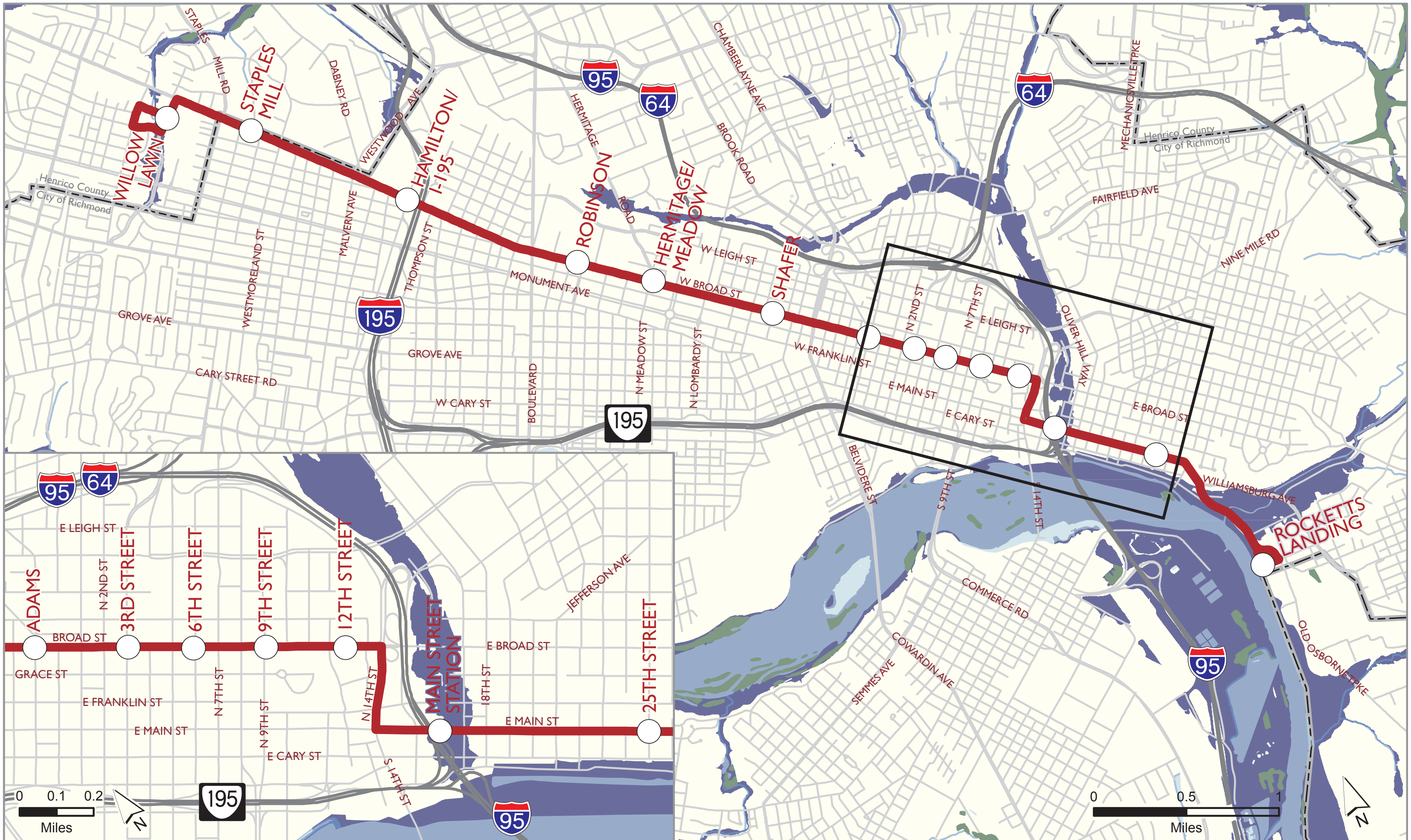
Figure 3-1 depicts nearby surface waters. One surface water body, Gillies Creek which is a tributary of the James River, is crossed by the proposed project. At this crossing, the proposed route is located within 200 feet of the river on E. Main Street within the existing right-of-way with no construction or additional pavement required. Gillies Creek currently travels underground for over 200 feet under E. Main t and Wharf Streets. The James River is considered a navigable river by the US Coast Guard.

No wetlands are located within the defined study area for this resource consisting of 300 feet to each side of the project centerline.

3.1.2 Floodplains

Executive Order 11988, “Floodplain Management,” and U.S. DOT Order 5650.2, “Floodplain Management and Protection” prescribe policies and procedures for the avoidance and mitigation of floodplain impacts. According to the Federal Emergency Management Agency (FEMA), the 100-year floodplain refers to the areas along or adjacent to a stream or body of water that are capable of storing or conveying floodwaters during a 100-year frequency storm.

The limits of the 100-year floodplains within the study area are shown in Figure 3-1. Three areas of the 100-year floodplain are traversed by the proposed project. The first area is located in the vicinity of Willow Lawn Station. The second is near Main Street Station, and the third is associated with Gillies Creek and the James River located just west of Rocketts Landing.



Legend

- Proposed BRT Stations
- Proposed BRT Alignment
- Wetland
- Surface Waters
- 100 Year Floodplain

Sources: City of Richmond GIS and FEMA 2009 (Floodplains), NWI 2010 (Wetlands), NHD 2010 (Surface Waters), VGIN RCL (Roads)

Environmental Assessment

Figure 3-1: Water Resources

BROAD STREET RAPID TRANSIT STUDY

3.1.3 Water Quality

The Virginia Department of Environmental Quality (DEQ) regulates surface water quality under Section 401 of the Clean Water Act and wetlands under State Water Control Law (Section 62.1-44.15:5) and Virginia Administrative Code (9 VAC 25-210-10 et seq.). The Commonwealth of Virginia, State Water Control Board reviews plans for pollution discharge and elimination (VPDES) permit requirements. DEQ administers the federal Clean Water Act and enforces state laws to improve the quality of Virginia's streams, rivers, bays and ground water for aquatic life, human health and other water uses. The DEQ issues permits to businesses, industries, local governments and individuals that take into account physical, chemical and biological standards for water quality.

The James River Basin, Virginia's largest river basin, occupies the central portion of Virginia covering 10,265 square miles. In the area of Richmond, the James River Basin extends to the fall line gradually turning into gently rolling slopes with lower elevation in the eastern portion of the province. The fall zone separates the Coastal Plain Province from the Piedmont. The fall zone is a three-mile stretch of river running through Richmond, where the river descends 84 feet as it flows from the resistant rocks of the Piedmont to the softer sediments of the Coastal Plain.

The DEQ's Assessment Survey for Reporting Year 2008 notes that the James River water quality is "impaired," and the Draft 2010 305(b)/303(d) Water Quality Assessment Integrated Report released August 2010 listed the James River as Category 5A, designating a waterway that requires Total Maximum Daily Load (TMDL) studies. The James River is the primary drinking water source for the metropolitan Richmond area, including the surrounding counties.

The City of Richmond Department of Public Utilities (DPU) is the water provider for the City of Richmond. The DPU conducts tests and prepares an annual report. The 2009 DPU report noted that the City's water is safe and 100 percent compliant with the Environmental Protection Agency's (EPA) Lead and Copper Rule. In addition, the report indicates that Richmond water quality meets EPA standards for microbial contaminants, regulated substances, disinfectants, and turbidity.

The City of Richmond maintains a Combined Sewer Overflow (CSO) system in which a discharge of untreated storm and wastewater, from a combined sewer, flow into the environment. CSOs typically occur when combined sewers fill up with too much water for the system to handle, most often during heavy rains, and the excess water is released into a stream or river. Based on monthly reports from September 2009 to August 2010, these discharges occurred at an average of 3 times per month with an average duration of 9.5 hours.

3.1.4 Coastal Zone

The coastal zone in the Commonwealth of Virginia encompasses 29 counties, 17 cities, and 42 incorporated towns all located in what is considered "Tidewater Virginia." Both the City of Richmond and Henrico County are included in this area.

The Virginia Coastal Zone Management (CZM) Program is part of a national coastal zone management program, a voluntary partnership between the National Oceanic and Atmospheric Administration (NOAA) National Ocean Service Office of Ocean and Coastal Resource Management (OCRM) and U.S. coastal states and territories authorized by the Federal 1972 Coastal Zone Management Act (16 U.S.C.

1451). The Virginia CZM Program was established in 1986 by Executive Order to protect and manage Virginia's coastal resources (Virginia Executive Order 18, 2010).

The Virginia Department of Environmental Quality (DEQ) serves as the lead agency for the coastal zone management program and helps agencies and localities develop and implement coordinated coastal policies and resolve coastal management problems. All Federal actions within Virginia's coastal zone must be consistent with the Commonwealth's CZM Program.

3.1.5 Chesapeake Bay Preservation Act

Virginia's Chesapeake Bay Preservation Act (CBPA), Code of Virginia §10.1 et seq., requires local governments in Tidewater Virginia to implement ordinances designed to protect and restore the quality of perennial streams and their associated non-tidal wetlands, as the conditions in these environments have been determined to directly affect the condition of the Chesapeake Bay. The CBPA and its related program regulations (Title 9, Virginia Administrative Code, §10-2-10 et seq.) call for the establishment of Chesapeake Bay Preservation Areas in local jurisdictions subject to the Act, including the City of Richmond and Henrico County. Both the City and County regulate these environments through development restrictions in these sensitive areas (Henrico County Code of Ordinances §24-106.3 and Richmond Code of Ordinances §50-300 et seq.). For this study, the Department of Conservation and Recreation (DCR) is the reviewing agency authorized to implement CBPA regulations through the Chesapeake Bay Local Assistance Program.

Chesapeake Bay Preservation Areas include Resource Protection Areas (RPAs) and Resource Management Areas (RMAs). RPAs include lands adjacent to water bodies with perennial flow that have an intrinsic water quality value due to the ecological and biological processes they perform, or are sensitive to impacts that may cause significant degradation to the quality of state waters. In both Henrico County and the City of Richmond, RPAs include: tidal wetlands, non-tidal wetlands connected by surface flow, and contiguous to tidal wetlands or water bodies with perennial flow, tidal shores, and a 100-foot vegetated buffer around each such feature, as well as all water bodies with perennial flow.

RMAs include land contiguous to the inland boundary of RPAs, as well as any other land that, if improperly used or developed, has the potential for causing significant water quality degradation or for diminishing the functional value of the RPA. In both study area jurisdictions, these include 100-year floodplains; highly erodible soils, including steep slopes; highly permeable soils; and non-tidal wetlands not included within RPAs. In Henrico County, the 100-foot area inland of, and contiguous to, the RPA is also included in the RMA, regardless of whether this land would otherwise qualify for inclusion in the RMA.

The City of Richmond also designates Intensely Developed Areas, areas within Chesapeake Bay Preservation Areas where little of the natural environment remains. Intensely Developed Areas can be designated in areas with more than 50 percent impervious surface, existing public sewer and water systems and/or a stormwater drainage system, and a housing density of at least four dwelling units per acre.

The proposed BRT alignment traverses the RMA associated with the James River and Gillies Creek from I-95 through Rocketts Landing. A small area of the RPA surrounding Gillies Creek and bordering the James River near Rocketts Landing is also crossed. Figure 3-2 shows the RMA and RPA boundaries.

3.2 ENVIRONMENTAL CONSEQUENCES

This section describes effects to hydrology, water quality and water resources.

3.3.1 Surface Waters

The potential for effects to surface waters is described below.

No-Build Alternative

The No-Build Alternative would not require any land disturbances and would not have any impacts to surface waters as a result of this project.

Build Alternative

The proposed alternative involves use of existing roads and previously developed parcels of land. New stations will be constructed within existing rights of way, on adjacent sidewalks, and adjacent to Broad Street; all surfaces that are primarily impervious today. No surface waters will be impacted. An existing parking lot near Staples Mill Road is proposed for utilization as a park-and-ride.

The alignment will cross over Gillies Creek on the existing lanes of E. Main Street. Gullies Creek is currently piped under Main Street at this location. There will be no disturbance or construction in the vicinity of Gillies Creek, as the existing lanes will be utilized.

3.2.2 Floodplains

The potential for effects to floodplains is described below.

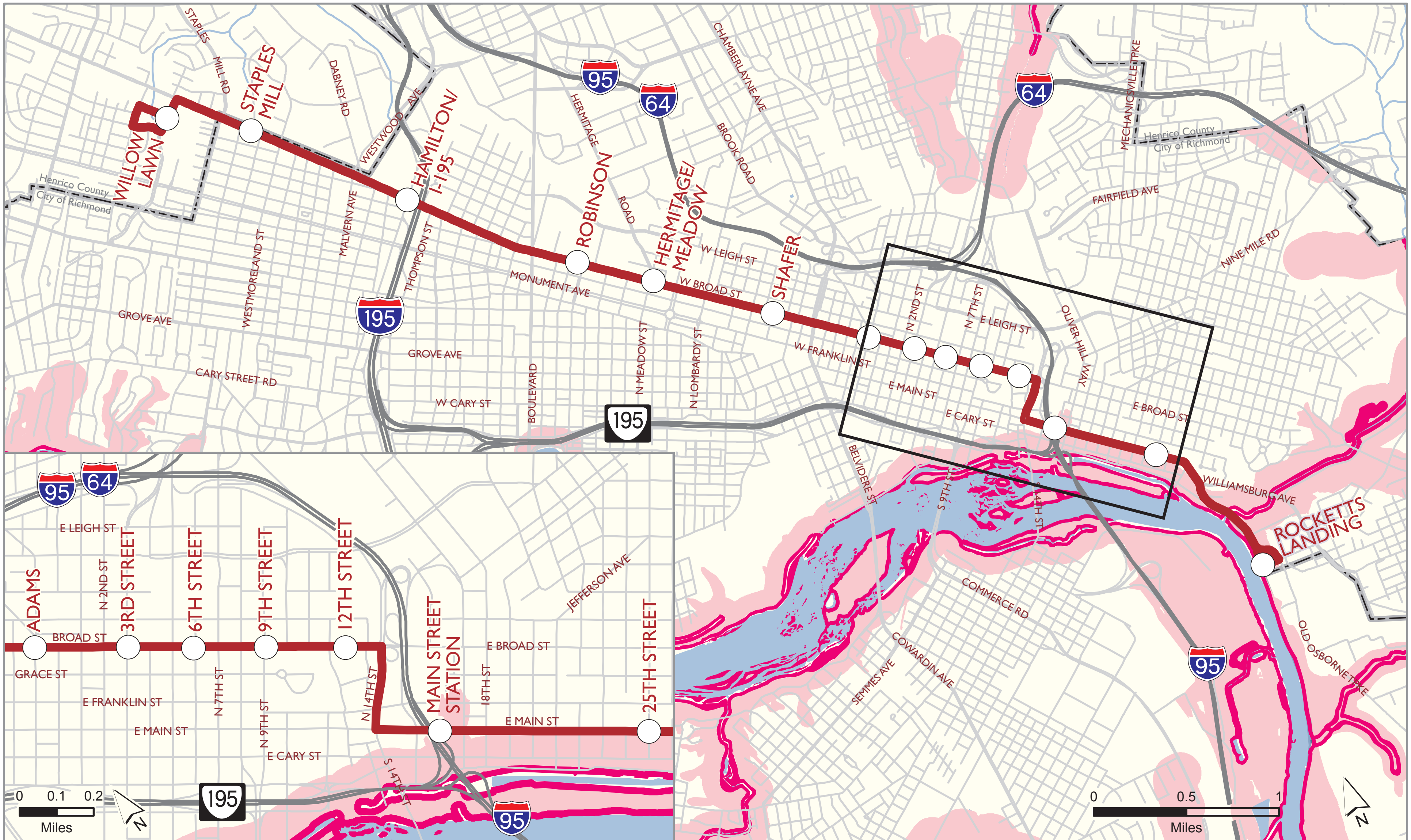
No-Build Alternative

The No-Build Alternative would not require any land disturbances and would not have any impacts to 100-year floodplains from the Broad Street Rapid Transit Project.

Build Alternative

Three areas of the 100-year floodplain will be traversed; near Willow Lawn Station, in the vicinity of Main Street Station, and west of Rocketts Landing. Existing roadway lanes will be utilized in all of the floodplain crossing areas.

Construction within the 100-year floodplain will consist only of the new Bus Rapid Transit stations at Main Street Station and Rocketts Landing. No other station areas are located within the 100-year floodplain. The construction of the Main Street and Rocketts Landing Stations will have minimal impacts to the floodplain with less than 2,310 square feet of construction within the floodplain. No substantial effects on natural or beneficial floodplain values are expected to result from the proposed project. No changes in surface elevations are anticipated. Impacts to the floodplain were minimized to the extent possible through utilizing existing Broad Street/Markel Road and Willow Lawn Drive at the western terminus, and E. Main Street throughout the easternmost section of the project.



Legend

- Proposed BRT Stations
- Proposed BRT Alignment
- Resource Protection Area (RPA)
- Resource Management Area (RMA)
- Surface Waters

Sources: City of Richmond GIS (RPAs and RMAs), VGIN RCL (Roads)

Environmental Assessment

Figure 3-2: Chesapeake Bay Preservation Areas

BROAD STREET RAPID TRANSIT STUDY

3.2.3 Water Quality

Water quality can be affected by increased run-off and increased loads of pollutants. The nature of these impacts depends on the uses and flow rate or volume of the receiving water body, rainfall characteristics and roadway characteristics. Heavy metals associated with vehicle tire and brake wear, oil and grease and, exhaust emissions are the primary pollutants associated with transportation corridors. Generally, roadway storm water run-off has the following pollutants: Total Suspended Solids (TSS), nitrate nitrogen, Total Kjeldahl Nitrogen (TKN), phosphorous, Ortho-phosphate, Copper, Lead and Zinc. Some sources of these pollutants are natural erosion, phosphorus from tree leaves, combustion products from fossil fuels and the wearing of brake pads. Construction activities, particularly if excavation is involved, can result in soil erosion reaching receiving waters.

No-Build Alternative

Under the No-Build Alternative, there would be no impact to water quality related to the Broad Street Rapid Transit Project.

Build Alternative

Implementation of the Build Alternative would be accomplished within the existing roadway rights-of-way. An existing parking lot near Staples Mill Road is proposed for utilization as a park-and-ride. It will involve minimal construction for station platforms. The new stations will be installed primarily on existing impervious surfaces, such as sidewalks, and on existing rights-of-way.

The Build Alternative would require running 136 additional buses along the Broad/Main Street corridor. This could result in negligible increases of pollutants generated from vehicle and brake wear and tear, grease or exhaust emissions with limited potential to create further degradation of water quality. The total difference in the number of vehicles miles traveled in 2035, between the No-Build Alternative and the Build Alternative, is anticipated to be negligible. The potential for additional pollution from more buses will likely be offset by the removal of single occupancy vehicles from the roadway, as people may opt to use the new higher quality transit system.

The intake for the drinking water treatment plant is located on the James River, south of the corridor, nearly three miles away. During construction, BMPs would be used to protect water quality in Gillies Creek and the James River by controlling stormwater, sedimentation and erosion.

3.2.4 Coastal Zone

The following section evaluates the extent to which the alternatives under consideration would result in reasonably foreseeable effects on coastal resources or coastal uses.

No-Build Alternative

Under the No-Build Alternative no impacts to coastal resources or uses would occur as a result of the Broad Street Rapid Transit Project.

Build Alternative

The Build Alternative would operate within the existing roadway right-of-way. Construction of station platforms and signage would occur in areas that are already developed and involve minimal excavation, therefore would not increase impervious surfaces. These facilities would not increase nonpoint source water pollution and would have no effect on coastal resources such as wetlands, fisheries, subaqueous lands, dunes, beaches, or coastal lands. This alternative would not contribute to point source air or water pollution or affect shoreline sanitation, and no coastal uses would be affected.

The Build Alternative will also include a new park-and-ride facility near the Staples Mill Road Station. This facility is proposed to be located within an existing paved surface parking lot at the adjacent Anthem Headquarters property and would not affect coastal resources or uses. If the Build Alternative is selected, a negative determination will be provided to DEQ for review and approval prior to any ground-disturbing activity.

During station construction, BMPs would be used to minimize temporary impacts to soils and water quality, and an erosion and sediment control plan will be prepared to satisfy Virginia Stormwater Management Regulations. No long-term impacts to coastal resources or uses are anticipated; therefore, no additional mitigation measures are proposed.

3.2.5 Chesapeake Bay Preservation Act

This section evaluates the project's potential impacts in the RPA and RMA in the study area.

No-Build Alternative

Under the No-Build Alternative no impacts to Chesapeake Bay Preservation areas would occur as a result of the Broad Street Rapid Transit Project.

Build Alternative

As shown in Figure 3-2, the easternmost segment of the Build Alternative alignment would pass through the RMA associated with the James River and Gillies Creek from I-95 through Rocketts Landing, as well as a small area of the RPA surrounding Gillies Creek and bordering the James River near Rocketts Landing. Like the No-Build Alternative, vehicles would travel in mixed traffic through this portion of the alignment; any pavement re-striping or other minor roadway improvements necessary to implement this service would be exempt from the CBPA.

Two new side platforms would be constructed at both the Main Street Station and the 25th Street Station, both within the RMA, but these platforms would be located in areas that are already paved and would not increase impervious surfaces at these stations. Likewise, Rocketts Landing Station within the RPA, would add one new side platform in a location that is already paved, which would not increase imperviousness or land disturbance on the site.

3.3 MINIMIZATION MEASURES AND RECOMMENDED MITIGATION

Best Management Practices would be used to minimize the potential for impacts to surface waters and to protect water quality. Stormwater Management (SWM) and Erosion and Sediment Control (ESC) plans will be prepared as required. This project likely meets the requirements to be covered under the Commonwealth's National Pollutant Discharge Elimination System (NPDES) General Permit. Full compliance with Coastal Zone Management regulations, and any associated mitigation if identified, will be established during project design and prior to any ground-disturbing activities.

BROAD STREET RAPID TRANSIT STUDY

ENVIRONMENTAL ASSESSMENT

APPENDIX A-16: Economic Impact Assessment Report

Note: At the time this technical memorandum was prepared, the opening year was anticipated to be 2015 and the operating plan assumed the BRT service would operate at 5 minute and 10 minute frequencies in the peak and off-peak periods, respectively. At the time this EA was completed, the opening year has been revised to 2017 and the operating plan has been revised to assume 10 minute peak and 15 minute off-peak frequencies. All references in the main EA document have been updated, but the information in the technical report remains relevant.

BROAD STREET RAPID TRANSIT STUDY ECONOMIC IMPACTS

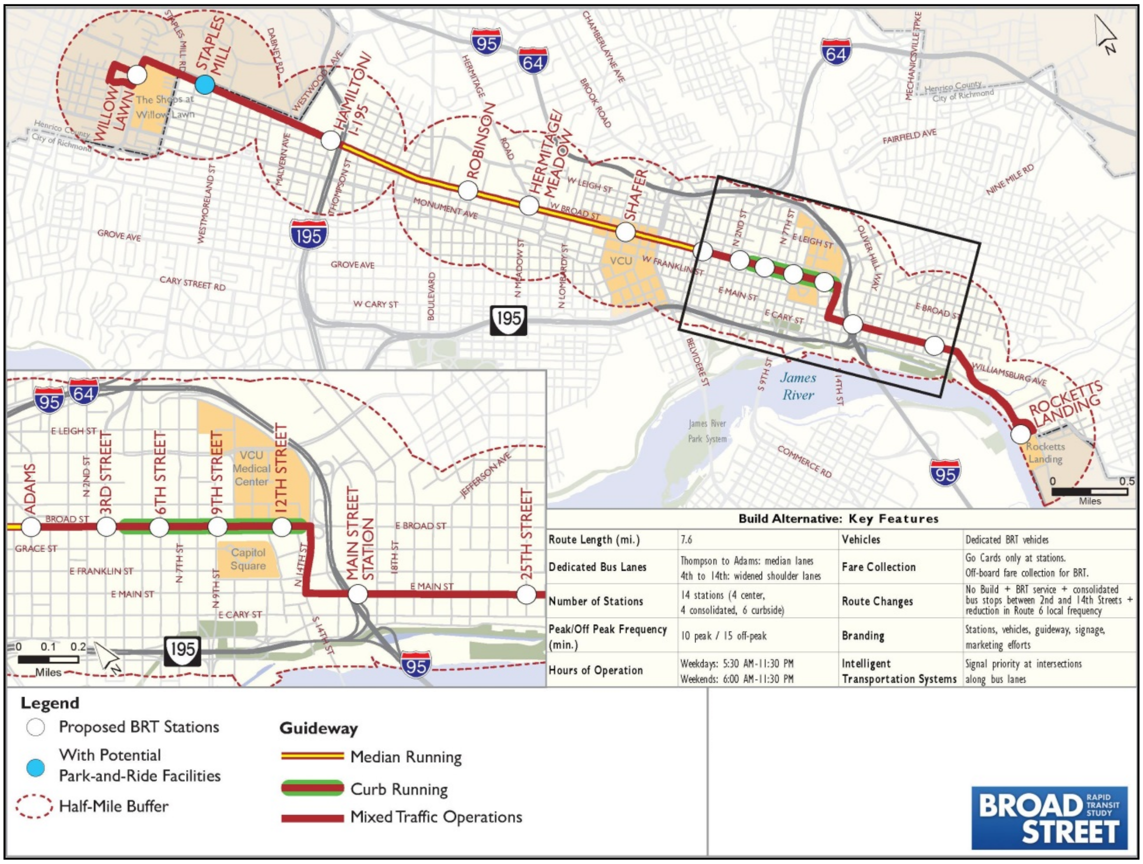
1. EXECUTIVE SUMMARY

Over the past decade, the Virginia Department of Rail and Public Transportation (DRPT), GRTC Transit System (GRTC), and the Richmond Area Metropolitan Planning Organization (RAMPO) have initiated various planning efforts with the aim of upgrading transit options in the Richmond region. Broad Street consistently emerges from those studies as an ideal candidate for public transit improvement. Broad Street remains one of the main thoroughfares in the region, with significant economic activities in the surrounding corridor. The corridor includes or is adjacent to large commercial centers, office parks, prominent entertainment and convention venues such as Richmond Center Stage and the Richmond Convention Center, various state and local government agencies such as the State Capitol and Richmond City Hall, and the academic and medical campuses of Virginia Commonwealth University. This corridor is currently supported by a high density of local bus routes, with as many as 48 buses in one segment of Broad Street during the peak hour. The current congested network of converging and overlapping transit routes contributes to inefficiencies in service and impedes traffic flow within the Broad Street Corridor. DRPT and GRTC are nearing completion of the Broad Street Rapid Transit Study which recommends the establishment of a bus rapid transit (BRT) route along the Broad Street Corridor.

The purpose of this technical memorandum is to identify the potential economic benefits derived from the Broad Street BRT Build Alternative, which is planned to run 7.6 miles from Willow Lawn to Rocketts Landing (Figure 1). Although the majority of the route resides within the City of Richmond, the western and eastern termini are located in Henrico County. The Build Alternative has several notable features. First, it will offer a dedicated bus lane from Thompson Street to 14th Street; thus buses will not compete with general street traffic for travel lanes. In addition, the Broad Street BRT will have signal prioritization at intersections. Those features make the BRT service faster and more efficient than the current bus service. The Broad Street BRT will have 14 stations, with 12 of them in the City of Richmond and 2 in Henrico County.

While BRT's capital and operational costs and benefits are often evaluated relative to competitive systems (ie: light rail and streetcar), less attention has been given to the economic impacts of bus rapid transit. This is due, in large part, to that to fact that on-street BRT is relatively new to the U.S. In efforts to compensate for the lack of representative data, this study expands on prior Broad Street Corridor research and draws on various case studies.

FIGURE 1



Build Alternative: Key Features

Route Length (mi.)	7.6	Vehicles	Dedicated BRT vehicles
Dedicated Bus Lanes	Thompson to Adams: median lanes 4th to 14th: widened shoulder lanes	Fare Collection	Go Cards only at stations. Off-board fare collection for BRT.
Number of Stations	14 stations (4 center, 4 consolidated, 6 curbside)	Route Changes	No Build + BRT service + consolidated bus stops between 2nd and 14th Streets + reduction in Route 6 local frequency
Peak/Off Peak Frequency (min.)	10 peak / 15 off-peak	Branding	Stations, vehicles, guideway, signage, marketing efforts
Hours of Operation	Weekdays: 5:30 AM-11:30 PM Weekends: 6:00 AM-11:30 PM	Intelligent Transportation Systems	Signal priority at intersections along bus lanes

Source: Environmental Assessment, Figure 2-4: Build Alternative Alignment and Features. DRPT and GRTC.

The case study analysis, discussed in **Section 2** and detailed in **Section 6**, reviews BRT systems in the following cities: Cleveland, Ohio; Eugene, Oregon; Kansas City, Missouri; and Boston, Massachusetts. While no two corridors are identical in form, level of investment, and function, Cleveland's Euclid Corridor, operating from the Central Business District (CBD) to East Cleveland and serving prominent educational and healthcare institutions, is perhaps the most comparable to Richmond's Broad Street Corridor. Discussions with transit professionals confirm this assumption.[1] As such, the Euclid Corridor findings are both qualitative and quantitative, highlighting the ways in which policy and partnerships stimulated investment along Euclid Avenue. In general, the Euclid Corridor has attracted substantial investment since BRT construction began in 2005. Property values have risen, incomes have increased and real estate development has endured in the corridor despite deteriorating economic conditions. **Section 3** evaluates the potential economic and fiscal impacts associated with Broad Street BRT. The study assesses the initial capital investment activities, the post-construction operational impacts, and the user benefits gained from efficiency improvements and motorists' cost savings. The results show that BRT increases employment, augments local spending and provides notable user benefits, such as reduced travel times and lower fuel and maintenance costs for those that elect to take BRT over the automobile. Finally, **Section 4** uses the Euclid Corridor data to analyze BRT's capacity to generate investment,

[1] Based on informal conversations and emails with staff from Arlington VA, Urban Land Institute and the American Public Transportation Association.

stimulate property values, and increase local real estate tax revenues over a 20-year time period. Although BRT itself is not a "rainmaker" for real estate development, the innovative system, when developed in conjunction with strategic land use policies and strong partnerships, can increase property values (and local tax revenues) and help catalyze development in a transit corridor.

To summarize, the $68.3 million capital investment could reasonably generate $51.2 million in regional spending and 507 regional jobs during the construction phase. The transit improvement would also foster regional economic activity through operations, leading to $10.2 million in annual spending and 23 jobs based on the approximately $5.0 million annual investment in the service. Efficiency improvements, captured through reduced travel times and motorist savings, would equate to an annual economic impact of $3.1 million. Meanwhile, the case study analysis of Cleveland's Euclid Corridor suggests that BRT helped boost property values by 2.4 percent (commercial properties) and 1.4 percent (residential properties) per year over a 6-year time period. This appreciation, when applied to the Broad Street Corridor, could increase property values by 11.4 to 12.6 percent over a 20-year period. The tax revenues generated by this appreciation equate to an average of $4.3 million per year for the City and $330,000 per year for the County. These tax revenue estimates, discussed in later sections, apply a six-year period of 'BRT premium' effect on property values, followed by average annual growth in revenue over the course of 20 years, creating an escalating difference between property values with and without BRT over time.

The following table provides a summary of the findings.

	City of Richmond	Henrico County	2-Locality Region [1]
One-time Impact from Initial Investment (2013-2014) [2]			
Spending	$43,600,000	$3,300,000	$51,200,000
Employment	441	23	507
Annual Impact of GRTC Expanded Operation [3]			
Spending	$9,100,000	$1,100,000	$10,200,000
Employment	22	1	23
Annual User Benefit (Region) [4]	NA	NA	$3,100,000
Estimated Percent Change in Property Values	11.4%	12.6%	NA
Average Annual Real Estate Tax Revenue Impacts [5]	$4,250,000	$330,000	NA

[1] The 2-locality regional impact is larger than the sum of the individual locality - impacts

[2] Includes direct, indirect and induced impacts (2015 dollars)

[3] Includes direct, indirect and induced impacts (2015 dollars)

[4] Measures the regional impacts (2015 dollars)

[5] Average is based 20-year projections for Conservative Scenario (discussed later). Figures implicitly include inflation

2. CASE STUDY REVIEW

The case study analysis reviews BRT systems in the following cities: Cleveland, Ohio; Eugene, Oregon; Kansas City, Missouri; and Boston, Massachusetts. Research institutes, municipal organizations, economic development professionals, and media analysts were instrumental in helping quantify the capital costs, operational benefits, funding sources, and potential returns on investment in the case study cities. With respect to the latter, most BRT researchers assess economic returns in the broader context of development activity. In doing so, they often acknowledge the challenges and limitations associated with linking BRT (and other transportation improvements) to subsequent development initiatives. In other words, some corridor investments could have occurred regardless of BRT's presence. As such, the following analysis hopes to provide an indication, not an absolute determination, of BRT's role in shaping growth and development along several key urban corridors. This section evaluates BRT systems in the case study cities, with particular attention to the Euclid Corridor, and concludes with an overview of some of the Lessons Learned. For more information on the case studies, see **Section 6**.

Cleveland, Ohio

Cleveland's "Healthline" corridor opened in 2008 and connects Public Square, located in the CBD, to East Cleveland, the most economically depressed city in Cuyahoga County, Ohio. The 9.8-mile route, operating along Euclid Avenue, is branded as the "HealthLine" due to a continued financial partnership with Cleveland Clinic and University Hospital. Ridership has increased by 60 percent since BRT implementation and buses operate at 12.5 miles per hour, compared to pre-BRT speeds of 9.3 miles per hour. The total project cost was $200 million. $168.4 million went to transit-related costs, of which $50.0 million was allocated for buses and stations – the remainder helped fund other corridor improvements, such as roadway development, utility replacement, and sidewalk installation. The project's cost breakdown is found below:

- <u>$200 million</u>: total project cost
  - <u>$168.4 million FFGA [1]</u>: buses, stations, corridor improvements such as roadways, utilities, sidewalks and street furniture
    - $82.2 million from the Federal Transit Administration
    - $50 million from the State of Ohio [2]
    - $17.6 million from GCRTA (Transit Authority)
    - $8 million from the City of Cleveland
    - $10 million from NOACA (Local MPO)
    - $0.6 million from FTA Rail Mode
  - <u>$31.6 million Non-FFGA</u>: non-transit improvements, including sidewalks, utilities, and public art.

Source: Greater Cleveland Regional Transit Authority. http://www.rtahealthline.com/project-overview-funding.asp
[1] A Full Funding Grant Agreement (FFGA) is a contract between the project sponsor and the Federal Transit Administration that formally establishes the maximum level of New Starts funding and outlines the terms and conditions of federal financial participation.
[2] Transportation Review Advisory Council, part of the Ohio Department of Transportation.

Since the HealthLine's planning phase (2001), the corridor has seen approximately $4.3 billion in development activity, equivalent to a 1,000 percent return on investment for the city.[2] Discussions with real estate professionals indicate that much of the development in Public Square-area of the CBD would have occurred regardless of BRT. Similarly, Cleveland Clinic, considered one of the world's preeminent hospitals, also continues to attract substantial investment to the corridor. However, the brokers also assert that BRT has undoubtedly helped MidTown attract technology firms, senior housing developments and residential townhomes. As such, the MidTown segment has recently branded itself the "Health-Tech" corridor. Meanwhile, the Greater Cleveland Regional Transit Authority (GCRTA) is cautious not to take

[2] The Cleveland Plain Dealer conducted a thorough analysis of development along the Euclid Corridor (2008). The following link shows the map of development activity: http://media.cleveland.com/pdextra/other/Euclid.pdf

all of the credit for the recent investments. Instead, Joe Calabrese, CEO of the GCRTA, recalls that "the success of our project in not what we did. It's what other people did in response to what we did. They really saw this as an opportunity to leverage investment."[3]

Various City and institutional initiatives have helped influence the nature of development along Euclid Avenue. In addition, the City offers a variety of tax abatements, credits and financial incentives to developers who engage in rehabilitation, conversion and new construction. Finally, the MidTown neighborhood recently adopted transit-oriented form-based zoning that aims "to encourage a compact land development pattern that incorporates a pedestrian-oriented mix of uses to support the GCRTA Euclid Corridor Transportation Project."[4] Under the new zoning rules, projects must be multi-story structures with the majority of the building fronting Euclid Avenue. In addition, ground floors must dedicate 60 percent of space to commercial or retail use and parking must be located behind the building. While form-based zoning policies have helped integrate land use and transit, institutions, such as Cleveland State University (CSU), have reoriented their campuses toward Euclid Avenue. This transformation is part of CSU's goal of becoming a more residential-based campus (as opposed to commuter-based). The university's land use policies have ultimately helped drive demand for residential development along the Euclid Corridor.[5]

While new investment is not necessarily all attributable to the Health Line, the case study research shows that BRT can act as a catalyst for new development initiatives and, in some cases, increase the pace of development. Despite the economic downturn in 2008, the MidTown district continued to attract investment. In fact, the total value of MidTown construction increased after the HealthLine opened in 2008. Prior to BRT operations, the neighborhood had $50 million in ongoing construction projects. These investments increased to $69 million after BRT operations began at the same time the nation entered economic recession, which is indicative of MidTown's capacity to draw investment despite deteriorating economic conditions.[6]

Creative entrepreneurship in MidTown ultimately led to the emergence of the "Health-Tech Corridor (HTC)." The three-mile, 1,600-acre section has attracted tremendous investment, including 210,000 square feet of new office, lab and flex space that is slated to open in 2012 at 80 percent occupancy. Baiju Shah, BioEnterprise President and co-creator of the HTC, remarked that "we wouldn't have expected this type of thing until five or so years out." He believes that the HealthLine BRT served as an impetus for developers looking to invest in projects along the corridor.[7] Finally, assessment data also indicate that the corridor's property values increased dramatically following BRT construction. **Section 4** of this memo details the property value impacts and uses them to help project potential real estate appreciation along the Broad Street Corridor.

Eugene, Oregon

The City of Eugene launched the 4-mile EmX (2.5 miles of exclusive busway) in 2007. The EmX route connects Eugene with the City of Springfield, and provides access to major institutions such as the University of Oregon, Northwest Christian College and Sacred Heart Medical Center. Ridership has

[3] Institute for Sustainable Communities. Accelerating Bus Rapid Transit. 2012. Page 15.
[4] Ohio Law, EPA Region 5. Transit oriented Development; Pedestrian Oriented Design. http://www.landuse.law.pace.edu
[5] Partnership for Sustainable Communities. "Transit as Transportation: The Euclid Corridor in Cleveland." June 2012, Page 6. http://www.sustainablecommunities.gov/pdf/studies/cleveland-euclid-corridor.pdf
[6] Ibid.
[7] Hellendrung, Jason. HealthLine Drives Growth in Cleveland. Urban Land Institute. July 13, 2012.

increased by 20 percent along the corridor, while bus speeds have increased from 11.5 miles per hour to 15.0 miles per hour.

In a report delivered to the FTA, the National Bus Rapid Transit Institute highlighted BRT's role in increasing development interest along the corridor. In 2006, there was a $5.8 million acquisition and a $3.0 million investment purchase along the corridor. With respect to the latter, the investors plan to subdivide the 7-acre parcel into six campus industrial sites. Other than these two notable investments, it is challenging to quantify any additional development activity. As such, there are no concrete estimates for return on investment.

Kansas City, Missouri

In 2005, Kansas City opened its MAX BRT line along the city's Main Street corridor. The 6-mile route offers 3.75 miles of designated bus lanes and connects 150,000 jobs and thousands of convention visitors. In addition, the new route provides a 20 percent reduction in travel time from the prior conventional-bus route. Since implementation of BRT, the route has seen a 50 percent increase in ridership. The route's success encouraged city professionals and policy-makers to implement a new BRT line on the Troost Corridor.

A study, published by the Michigan Urban Land Institute, estimated that the MAX BRT yielded a 300 percent return on investment, equivalent to approximately $75 million in development projects. While the city's community improvement districts, complimentary streetscaping and attractive stations could potentially attract subsequent investment, there is little indication that BRT has been a direct catalyst for development activity. Metro Jacksonville, in a case study of Kansas City's BRT system, confirmed that there is little visual evidence of any transit-oriented economic development along the MAX corridor.

Boston, Massachusetts

After two failed attempts to secure federal funding for light rail, the Massachusetts Bay Transit Authority (MBTA) pursued the more cost-effective bus rapid transit alternative. The "Silver Line" began its Washington Street operations in 2002 and was the MBTA's first bus line to benefit from a robust marketing campaign (budgeted at $170,000). The BRT route is 2.4 miles (2.2 miles are exclusive) and connects Boston's South End neighborhood with South Station, a prominent hub for subway, commuter rail, Amtrak, Greyhound and other bus networks. Ridership is approximately 71 percent higher than on the previously used bus route 43, while travel times have been reduced by 9 percent.

Boston's Washington Street corridor has attracted substantial investment since the Silver Line's planning phase. The corridor has seen approximately $1.2 billion in development activity, much of which is residential. Specifically, there are roughly 1,700 new and renovated housing units, of which 900 have been designated as "affordable.[8]" In most cases, ground floor retail has complimented the large-scale residential developments. Overall, it is estimated that the corridor's extensive mixed-use development has created over 36 new and rehabilitated buildings, 65 businesses and approximately 500 new jobs[9].

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[8] Henke, Cliff. "Economic Development and BRT." John Noel Public Transit Discovery Conference, October 2010.
[9] National Bus Rapid Transit Institute (NBRTI). "Bus Rapid Transit and Development: Policies and Practices that Affect Development around Transit." December 1, 2009. Page 34.

The city contributed to the development activity through the renovation of two major properties, as well as a parking space freeze along the corridor. In addition, the Boston Redevelopment Authority reduced sales prices to developers in exchange for affordable housing. Since the inauguration of the Silver Line, the corridor's tax base has increased by 247 percent, significantly higher than the city average of 146 percent.[10] While the Silver Line appears to have catalyzed development along the Washington Street corridor, it is ultimately difficult to ascertain how much of this activity was driven by BRT implementation versus that of market forces.

Case Studies: Lessons Learned

The case studies illustrate some of the ways in which a community can best leverage a BRT investment. Several of these key findings are discussed below:

Involve the community early and establish partnerships at the beginning: The case study analysis indicates the importance of understanding the needs and priorities of businesses along BRT corridors. Following the Lane Transit District's (LTD) insufficient collaboration with small businesses during Eugene's EmX project, the agency now conducts robust outreach efforts to the business community. In addition, it is evident that strong partnerships are vital to the success of BRT systems. Institutions, such as hospitals and universities, can not only contribute to the project's success, but can also enhance the integration of land use and transportation along the corridor.

Influence the nature of development: A city's land use policies or practices can significantly impact the type and scale of development that occurs along transit corridors. In Cleveland, MidTown's form-base zoning provisions have helped encourage density and restrict parking, thus enhancing the integration of land use and transit.

Understand the role of perceived permanence: A 2008 survey of twelve developers suggests that BRT's "perceived permanence" is a critical factor when making investment decisions along a transit corridor.[11] Specifically, exclusive guideways and dedicated lanes, as well as the size and quality of stations, were thought to be the most important elements. Streetscape improvements were also considered beneficial, but to a lesser extent. The designated guideways in Cleveland and Eugene undoubtedly contribute to BRT's perceived permanence in their respective corridors. Meanwhile, Kansas City's attractive bus stations suggest that BRT remains an integral part of the urban infrastructure. Finally, the operational permanence of BRT, identified by improved headways (duration between bus arrivals), can contribute to users' confidence and faith in the system.

Focus on "Better Rapid Transit": In Cleveland's case, many city professionals attribute the success of BRT to the fact that it was designed more like a rail system than a bus system. Joe Calabrese, CEO of the GCRTA, recalls that, "We did everything that we could do to give it (HealthLine) that first-class rail-like image."[12] Ultimately, the HealthLine's design modifications helped overcome the generally accepted belief in Cleveland that "suits don't ride buses." Meanwhile, Boston's planners and policy makers have

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[10] Breakthrough Technologies Institute. "Bus Rapid Transit Oriented Development." April, 2008. Page 6.
[11] Breakthrough Technologies Institute. "Case Studies on Transit Oriented Development Around Bus Rapid Transit Systems in North America and Australia." April, 2008, Page 86.
[12] Ibid. Page 17.

marketed the Silver Line as an addition to Boston's rapid transit system. In fact, the Silver Line is the only bus route included on the metro area's rapid transit maps.[13]

3. CONSTRUCTION, OPERATIONS, USER BENEFITS, FISCAL IMPACTS

An investment of the magnitude proposed for the Broad Street BRT will have local and regional economic impacts. This section of the report examines the direct, indirect and induced economic impacts of three critical aspects of the proposed BRT investment: construction of the project, annual operation of the project, and the benefits to users of the project, particularly in terms of travel time savings. The differences between direct, indirect and induced impacts are also explained. Direct impacts relate most directly to the purchase of materials for construction and operations; indirect impacts result from wages paid for construction and operations; and induced impacts are the product of the materials and wage dollars rippling through the economy through expenditures on services, restaurants, shopping, and so forth.

Economic Impact of Initial Investment

The total capital cost to develop the Broad Street BRT is estimated to be $68.3 million (2015 dollars). These costs are allocated into different categories, such as vehicle purchase ($20.4 million), site work ($12.0 million), systems (including traffic signal, and communication system, $11.6 million), and professional services ($9.7 million). Since individual spending categories have different linkages with the local economy, these spending items were modeled separately before aggregating them into the overall economic impacts for the City of Richmond and Henrico County. The initial project development is expected to last for 24 months in 2013 and 2014, with the BRT beginning operations in 2015.[14]

The bulk of the initial investment activities will occur in the City of Richmond. Of the $68.3 million in total capital costs, 97 percent ($66.4 million) will be spent for work in the City of Richmond, while 3 percent ($1.8 million) will be spent for work in Henrico County, including building bus stops and conducting site work. However, it should be noted that some expenditures, such as bus purchases ($20.4 million), will occur outside of the two-locality region. Although the GRTC buses will be purchased and housed in the City, the money will be considered a leakage to out-of-region businesses since the City and the County are not home to any businesses that manufacture buses. The IMPLAN Pro model was used to estimate the percentage of capital cost that will be spent within each locality.

The model estimates several types of economic impacts. Direct impacts relate to the materials purchased for construction/operations (for example: guideways, bus stations); indirect impacts are derived from those industries supporting the construction activities (for example: raw material suppliers, equipment rental companies); and induced impacts apply to the added wages and spending in the region, generally for services and shopping. With respect to the latter, the wages of those employees involved in construction and operations presumably lead to additional (induced) spending in the region – possibly at grocery stores, shops and movie theaters.

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[13] Note: the Institute for Sustainable Communities was instrumental in identifying some of these "lessons learned." The organization's "Resource Guide For Local Leaders" can be found at http://www.iscvt.org/who_we_are/publications/Resource-Guide-Bus-Rapid-Transit-v1.pdf

[14] This time line is aggressive. It is unlikely that the Broad Street BRT will be operational in 2015. But the existing documents, such as Broad Street Rapid Transit Study, Alternative Analysis, lists 2015 as the year of BRT operation.

Table 2 presents the estimated economic impact of the initial investment activities of the Broad Street BRT project in the City of Richmond, Henrico County, and the combined 2-locality region. From 2013 to 2014, it is anticipated that the initial investment activities will generate total economic impacts (including direct, indirect, and induced impacts) of $51.2 million (2015 dollars) that can support 507 cumulative jobs in the 2-locality region. Among the total economic impacts, $29.7 million are derived from direct spending during the project development phase of the Broad Street BRT; this spending can directly support 288 cumulative jobs in the region in 2013 and 2014. The model also indicates that indirect impacts will account for $9.1 million in spending and 92 cumulative jobs. These impacts will primarily occur during the initial construction phase and are derived from support functions, such as equipment rental or truck transportation. Finally, the model estimates $12.4 million in induced impacts, which can support 126 cumulative jobs during the project development phase—these jobs are expected to be concentrated in consumer service-related industries such as restaurants, hospitals, and retail stores.

TABLE 2: ONE-TIME ECONOMIC IMPACT FROM INITIAL INVESTMENT ACTIVITIES (Cumulative 2013-14, in 2015 Dollars)

	Direct	Indirect	Induced	**Total**
City of Richmond				
Spending ($Million)	$27,900,000	$7,500,000	$8,200,000	**$43,600,000**
Employment	276	81	84	**441**
Henrico County				
Spending ($Million)	$1,800,000	$600,000	$900,000	**$3,300,000**
Employment	12	4	7	**23**
2-Locality Region [1]				
Spending ($Million)	$29,700,000	$9,100,000	$12,400,000	**$51,200,000**
Employment	288	92	126	**507**

Note: Numbers may not sum due to rounding

[1] The 2-locality regional impact is larger than the sum of the individual locality - impacts

Source: Chmura Economics & Analytics and IMPLAN Pro 2010

Since the majority of the capital expenditures will be spent in the City of Richmond, the one-time economic impact from the BRT's initial investment activities will be more substantial in the City than in Henrico County. During 2013 and 2014, the initial investment activities will generate a total economic impact (including direct, indirect, and induced impacts) of $43.6 million (in 2015 dollars), supporting 441 cumulative jobs in the City of Richmond. The total economic impact in Henrico County is estimated to be $3.3 million (in 2015 dollars), which can support 23 cumulative jobs during the project development phase.

Economic Impact of Expanded GRTC Operation

Following BRT's implementation in 2015, the GRTC transit system is expected to expand its operations significantly. Additional buses will be purchased, and more bus drivers and maintenance workers will be hired. Following implementation, the total operation and management (O&M) cost of GRTC is estimated to be $49.4 million (in 2010 dollars) or 12 percent more than the existing level of $44.1 million O&M cost.[15] Those figures imply that GRTC is expected to expand its O&M cost by $5.3 million in 2010

[15] Source: Broad Street Rapid Transit Study, Alternative Analysis, Table 4-7. Federal Transit Administration, Virginia Department of Rail and Public Transportation, GRTC Transit System, April 2012.

dollars. GRTC will add 19 additional bus drivers and auto-mechanics.[16] All of these jobs will be located in the City of Richmond.

The total annual economic impact (direct, indirect, and induced) of the expanded GRTC operations is estimated to be $10.2 million in 2015, which can support 23 permanent jobs in the 2-locality region each year (Table 3). With respect to direct impacts, the expanded operations of GRTC are estimated to equal $6.6 million in annual revenue, employing 19 permanent workers in 2015.[17] An additional indirect impact of $0.5 million and 1 job will benefit other regional businesses that support the expanded GRTC operations. The number of jobs created due to the induced impact is estimated to be 4 in 2015 with associated annual spending of $3.1 million. This induced impact is primarily created by GRTC employees spending their wages and salaries at restaurants, doctor's offices, and retail establishments in the 2-locality region.

All of the direct impacts, as well as the majority of indirect and induced impacts, will be generated in the City of Richmond. In 2015, the expanded GRTC operations are estimated to generate a total economic impact (including direct, indirect, and induced impacts) of $9.1 million, supporting 22 jobs in the City of Richmond. Henrico County will see some residual indirect and induced impacts from the expanded GRTC operations, which are much smaller in magnitude. However, Henrico County maintains a relatively higher share of induced impacts - a benefit acquired as a result of a higher concentration of retail and services.

TABLE 3: ANNUAL IMPACT OF GRTC EXPANDED OPERATIONS (2015 DOLLARS)

	Direct	Indirect	Induced	**Total**
City of Richmond				
Spending ($Million)	$6,600,000	$400,000	$2,100,000	**$9,100,000**
Employment	19	1	3	**22**
Henrico County				
Spending ($Million)	$0	$100,000	$1,000,000	**$1,100,000**
Employment	0	0	1	**1**
2-Locality Region				
Spending ($Million)	$6,600,000	$500,000	$3,100,000	**$10,200,000**
Employment	19	1	4	**23**

Note: Numbers may not sum due to rounding

Source: Chmura Economics & Analytics and IMPLAN Pro

GRTC User Benefits

Outside the expanded GRTC operations, the Broad Street BRT can also result in other ongoing benefits for users of the BRT system. For existing passengers, the Broad Street BRT will provide faster and more efficient transportation service. The BRT will help alleviate commuting delays, thus reducing the overall opportunity costs incurred by employees. In other words, the passengers (and their employers) could potentially experience higher economic activity due to the reduced time spent in transit. In addition, BRT will attract new users who would otherwise use personal vehicles for transportation. Using buses will provide savings in terms of vehicle operation costs for these new riders.

[16] The Broad Street BRT will have 16 total buses. This study assumes 16 full-time equivalent drivers. GRTC also estimated that it needed one mechanic for every 6.5 buses. Consequently, 2.5 mechanics will be needed to maintain 16 buses for the Broad Street BRT.

[17] This number is larger than the O&M cost because the direct impact is equivalent to total revenues of GRTC, which is larger than the O&M costs. In addition, the economic impact is expressed in 2015 dollars.

All existing bus riders in the Broad Street Corridor can benefit from faster travel service brought on by the Broad Street BRT. It will take bus riders less time to travel along the BRT route from Willow Lawn to Rocketts Landing. Under the No Build Alternative, the estimated travel time for the entire length of the route is 36.4 minutes. With the BRT, the travel time is reduced to 22.4 minutes, a savings of 14 minutes.[18] However, not all riders will travel the entire route. Data from GRTC indicate that a typical rider in the GRTC system traveled an average of 3.2 miles per trip in 2012. Assuming riders in the Broad Street Corridor travel a similar length, an average rider can save about 6 minutes. The estimated number of riders per day on existing routes in the corridor will be 3,900 in 2015 if BRT is not developed.[19] This study removed both personal and recreational travelers to estimate the benefit of efficiency gains for regional businesses. An on-board rider survey, conducted by the GRTC, estimated that commuters represented 51 percent of all riders. The remaining 49 percent of riders were individuals who traveled by bus for personal reasons such as going to school, shopping, or visiting friends and families.[20] Using the above assumptions, the Broad Street BRT can save current riders a total of 49,428 business hours per year. In 2010, the average economic output of the regional workforce was $71.9 per hour.[21] The On-Board survey indicated that a large percentage of bus riders were from low-income households. Those commuters may have a lower average output per hour than the regional average. Adjusting for the differences in output using differences in median household income of bus riders and the regional average, the average output per hour for bus riders is estimated to be $56.4 per hour in 2015. The value of efficiency gains is thus assumed to be $2.8 million in 2015 (Table 4).

TABLE 4: BRT ANNUAL USER BENEFIT (2015 DOLLARS)

Efficiency Improvement	$2,786,393
Motorist Operation Cost	$378,837
Total	**$3,055,960**

Source: Chmura Economics & Analytics

The total estimated number of daily riders on the Broad Street BRT is 5,500 in 2015. Compared with 3,900 in the No Build Alternative, the additional 1,600 riders are those who are attracted to the bus service due to the BRT. Those are “choice riders” who would otherwise use personal vehicles for commuting or other personal purposes. For them, BRT may increase travel time over the automobile, but those riders are also able to reduce automobile usage, thus saving vehicle maintenance costs such as fuel, and vehicle wear and tear. Prior studies implied that the average maintenance cost for each vehicle is $0.17 per mile in 2012.[22] By taking a bus, those new “choice riders” can reduce total vehicle miles by 1.9 million miles in 2015. As a result, the estimated annual operational cost savings are $378,837 in 2015.

The majority of user benefits will apply to the residents of the City of Richmond. The 2006 On-Board Survey conducted by GRTC indicated that 86 percent of the bus riders lived in the City of Richmond, 7.6 percent in Henrico County, and the remainder in other localities. Assuming the ridership on the Broad Street BRT will follow a similar pattern, the $2.9 million of the $3.1 million user benefits will be for the

[18] Source: Broad Street Rapid Transit Study, Alternative Analysis, Table 3-1. Federal Transit Administration, Virginia Department of Rail and Public Transportation, GRTC Transit System, April 2012.
[19] Ibid.
[20] Source: On-Board Survey, 2006, Vanasse Hangen Brustlin, Inc.
[21] This is estimated from IMPLAN Pro Model 2010. The average output per worker is $149,721 per year in Henrico County and City of Richmond.
[22] This is the estimate by AAA. http://www.piercetransit.org/rideshare/costs.htm.

residents in the City, $257,000 for Henrico County residents, and the remainder for residents in other localities.

There are other benefits that are not quantified in this study. For example, some motorists may enjoy faster travel times as more people utilize the Broad Street BRT. Fewer vehicles on the road system could reduce accidents in the region and also result in environmental and health benefits. However, quantifying those benefits requires data from travel simulation models not only for the Broad Street Corridor but also for other roads in the region. Collecting and analyzing those data are beyond the scope of this study. Similarly, travelers using the BRT instead of cars to reach downtown destinations would save on parking costs, but insufficient data on parking fees and usage are available to quantify those impacts.

Fiscal Impacts for Local Governments

The GRTC System is a not-for-profit agency and consequently does not pay local taxes such as personal property or business, professional, and occupational licenses (BPOL) taxes. As such, the fiscal impacts for local governments will be derived from the initial investment activities associated with the Broad Street BRT project, particularly as companies hired for the project will pay (BPOL) tax to local governments. To be conservative, only tax revenue from these direct impacts is estimated.[23]

The City's tax rates for contractor expenditures and business and professional services vary according to the type of spending. This study applied different rates based on spending items in the City of Richmond (site work, station construction, and professional services). The total BPOL taxes for the City in 2013 and 2014 are estimated to be $58,698. Henrico County charges the same BPOL tax rate for all those activities. Thus, the BPOL tax revenue related to the BRT impacts is estimated to be $2,062 in 2013 and 2014.

In the long term, the City of Richmond and Henrico County could potentially see increased tax revenues from the Broad Street Corridor resulting from the new development and redevelopment in the corridor. Those development activities, some of which are discussed in the following sections of the memorandum, can potentially increase local property, sales, meal, admission, and lodging taxes.

4. PROPERTY VALUES, TAX REVENUES AND DEVELOPMENT ACTIVITY

Introduction

As mentioned above, very little research has been dedicated to understanding the economic impacts associated with bus rapid transit systems. Given these data constraints, this study conducted a much more exhaustive quantitative analysis of one particular BRT route: the Euclid Corridor (HealthLine BRT) in Cleveland, Ohio. The Euclid findings, highlighted below and discussed in detail in **Section 6**, were applied to specific components of the Broad Street analysis.

This data analysis was supplemented by interviews with planning and economic professionals in the City of Richmond and Henrico County. The study ultimately estimated BRT's induced impacts on property values and real estate tax revenues. Spin-off activity (new construction and rehabilitation) was also considered in this analysis; however, given the unpredictable nature of real estate development and the

[23] This approach is recommended by Burchell and Listokin in *The Fiscal Impact Handbook*.

lack of supportive data, any quantitative projections would be highly speculative. As mentioned above, the following findings are meant to provide an indication, not an absolute determination, of the potential impacts generated by bus rapid transit.

Property Values and Real Estate Tax Revenues

Real estate was studied in the Broad Street and Euclid corridors to measure property value growth with, and without BRT. For the Broad Street Corridor, anticipated growth was based on two different scenarios (Conservative and Aggressive), both of which rely on historic trend data. Meanwhile, the Euclid study, comparing property value appreciation in the BRT corridor to that in the surrounding cities, was used to measure BRT's potential impact on property values. This impact, when annualized, was subsequently applied to the Broad Street Corridor's Build Alternative.

Prior to analyzing BRT's role in stimulating property values (and tax revenues) along the Broad Street Corridor, this study first attempted to forecast property value appreciation under current, baseline conditions. In doing so, the study evaluated growth under two different scenarios – an approach that accounts for long-term national trends, as well as local market conditions. The first, a Conservative Scenario, utilized 100-year national trend data and assumes an average annual increase of roughly 3.4 percent.[24] The second, an Aggressive Scenario, relied on Richmond and Henrico assessment data (1990-2011). This local trend data, when integrated with parcel-specific data for the Broad Street Corridor (2005-2009), reasonably indicate that Richmond study-area parcels increase in value by roughly 7.9 percent annually (using Compound Annual Growth Rates - CAGR), while Henrico study-area parcels increase by 5.8 percent annually (CAGR).[25] The growth rates from the Conservative and Aggressive scenarios were applied to the retail, office and residential markets and ultimately represented the baseline growth estimates for the Build and No Build Alternatives.[26]

Meanwhile, the study also compared the property value appreciation along the Euclid Corridor to that in Cleveland and East Cleveland, thereby providing an indication of BRT's capacity to increase property values. The Euclid Corridor findings, measuring BRT's annual induced impact (CAGR) over six years (2005 to 2011), were applied to the study area's Build Alternative. This approach accounted for post-BRT trends in Cleveland, as well as local trends in the Broad Street Corridor. Finally, the jurisdictional property tax rates, held constant for the entire 20-year study period, were applied to the induced property values to calculate the Build Alternative's potential net gain in tax revenues.

Cleveland's Euclid Corridor has seen a surge in property values since 2005 (year of HealthLine construction), particularly when compared to the corridor's surrounding cities (Cleveland and East Cleveland). The detailed assessment findings, discussed in the next paragraph, are relatively consistent with that of light rail. A recent University of Oregon study highlights evidence of light rail's impacts on property values, showing that single-family properties located near a station sell at premiums of upward

[24] The Conservative Scenario relied on estimates from the Case-Shiller Home Price Indices, which measure 100-year national housing trends. The Case-Shiller estimates an average annual growth rate of roughly 3.35 percent. This rate is consistent with that used by Henrico County for property value projections. Source: Schiff, Peter. "Home Prices are Still Too High." Wall Street Journal. December 2010. http://online.wsj.com/article/SB10001424052702304173704575578190261574342.html

[25] The difference between the study area values and jurisdictional values (2005-2009) was applied as a premium to the jurisdictions' historic assessment data. This approach accounted for both study-area nuances and historic trends.

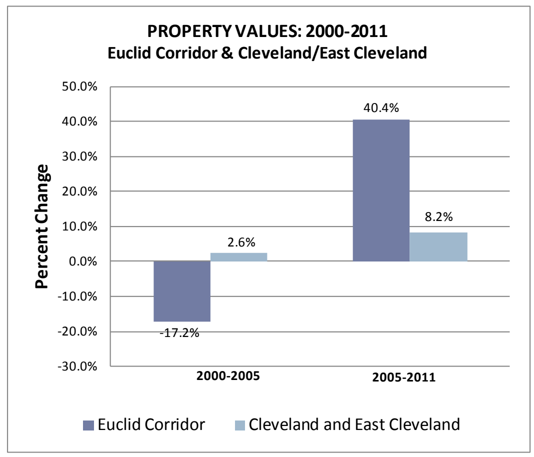
[26] Compound Annual Growth Rate (CAGR): Captures the year-over-year growth rate of appreciation and accounts for compounding.

to 10 percent.[27] Multi-family homes and commercial properties (near stations) have exhibited even higher property value premiums. Meanwhile, the *Columbia Pike Transit Initiative- Return on Investment Study*, projected impacts based on a conservative scenario (4 percent premium) and an aggressive scenario (10 percent premium).[28]

Cuyahoga County's assessment database was analyzed in geographic information system (GIS) software to compare the aggregate property value growth (Per Square Foot – PSF) in the Euclid Corridor (study area) to that of Cleveland and East Cleveland, as a whole.[29] The data indicate that study-area property values declined by 17.2 percent from 2000 to 2005, while the cities' property values increased by 2.6 percent over the same time period (Figure 2). However, the study-area property values increased dramatically by 40.4 percent from 2005 to 2011, while the cities' property values increased marginally by 8.2 percent. From 2003 to 2008, it was reported that the value of an acre of land in the MidTown district increased from $200,000 to $400,000.[30]

When segmented by land use, commercial property values (PSF) increased by 45.2 percent in the Euclid Corridor and by 26.9 percent in the cities. Meanwhile, residential property values (PSF) increased by 9.1 percent in the corridor and by 0.6 percent in the cities. When annualized at a compounded rate (CAGR), the corridor's commercial properties (including office) received a 2.4 percent annual premium *over* the cities' comparable market segment. The corridor's residential properties received a 1.4 percent annual premium over the cities' residential properties. The Euclid Corridor premiums, measuring the potential induced impact of the BRT investment, were subsequently applied to Richmond's Build Alternative.

FIGURE 2



Source: Cuyahoga County Auditor, Fiscal Officer

Finally, a 3 percent discount rate was applied to the anticipated revenue streams for the Build and No Build alternatives. Discounting future cash flows recognizes the inherent opportunity costs associated with collecting the revenues over a long period of time. It is worth noting, however, that the tax revenues also implicitly include historic inflation. Comparing these values to long-term GRTC operating costs would require an in-depth cash flow analysis, which is beyond the scope of this study.

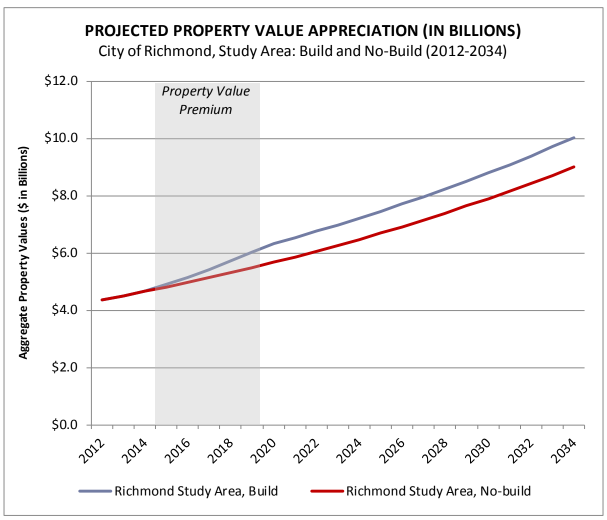
The City of Richmond Study Area, Induced Impacts: The results, when applied to the Conservative and Aggressive baseline scenarios, indicate that BRT could reasonably increase commercial property values by $367 million - $1.2 billion, office values $312 million - $1.0 billion, and residential property values by $349 million - $1.2 billion (see Table 5 below). These impacts represent a 7.7 to 8.4 percent increase in property values over the 20-year period. In addition, the higher property values would conservatively

[27] Ickler, Megen; Hodel, Peter. "The Value of Bus Rapid Transit: Hedonic Price Analysis of the EmX in Eugene, Oregon." Department of Economics; Honors Papers. University of Oregon, 2012.
[28] Fairfax County, Virginia; Arlington County, Virginia; Washington Metropolitan Area Transit Authority. "Columbia Pike Transit Initiative: Return on Investment Study. July 2012.
[29] The "study area" properties were analyzed at a ¼ mile buffer from the Euclid Avenue HealthLine
[30] Haviland, Jim. Executive director of MidTown Cleveland, Inc., quoted in: http://blog.cleveland.com/pdextra/2008/05/big_price_tag_on_big_renovatio.html. 5/16/08

contribute to an average annual tax revenue return of $4.3 million. Figure 3 (below) illustrates the Conservative projections for Richmond study-area's property values, both with and without BRT.

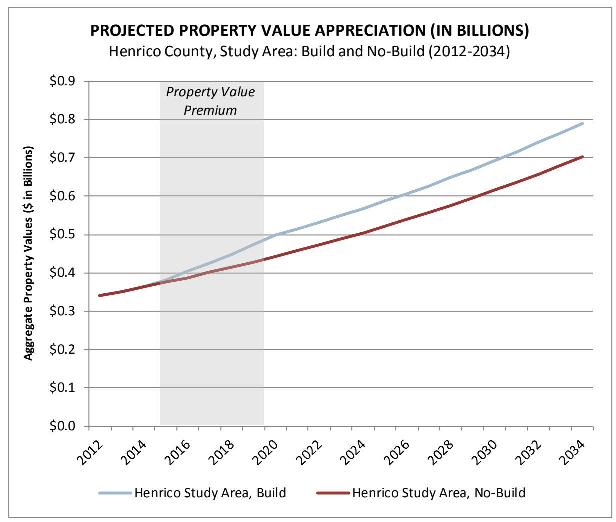
Henrico County Study Area, Induced Impacts: While BRT produces proportionately equivalent impacts in Henrico County, the net increases in property values and taxes are substantially lower due to the proposed BRT's limited presence in the County. In addition, Henrico County offers a lower tax rate ($0.87 per $100 of assessed value) than that of the City ($1.20 per $100 of assessed value). Using the Conservative Scenario's assumptions to project property value growth, to be consistent with typical forecasting practices by the County, commercial, office and residential property values increase by 14.5 percent ($28.0 million), 14.5 percent ($44.0 million) and 8.1 percent ($17.0 million), respectively with the BRT investment. The total anticipated tax revenue generated by this appreciation would equate to approximately $6.6 million over the 20-year period (an average annual revenue return of $330,000). Figure 4 (below) shows the Conservative projections for the Henrico study-area's property values, both with and without BRT.

FIGURE 3



Property Value Premiums:
Applied to "Build" Alternative (2015-2020)
Commercial Properties: 2.4% CAGR
Residential Properties: 1.4% CAGR

FIGURE 4



Property Value Premiums:
Applied to "Build" Alternative (2015-2020)
Commercial Properties: 2.4% CAGR
Residential Properties: 1.4% CAGR

TABLE 5: INDUCED PROPERTY VALUE APPRECIATION AND REAL ESTATE TAX REVENUE IMPACTS
(20 Year Period, 2012 Dollars)

	Property Value Appreciation [1]		Average Annual Real Estate Tax Revenue [2]	
	Conservative Scenario	Aggressive Scenario	Conservative Scenario Discounted @ 3%	Aggressive Scenario Discounted @ 3%
City of Richmond				
Retail/other commercial	$367,000,000	$1,224,000,000	$1,520,000	$3,630,000
Office	$312,000,000	$1,041,000,000	$1,290,000	$3,090,000
Residential	$349,000,000	$1,163,000,000	$1,440,000	$3,460,000
Total	**$1,028,000,000**	**$3,428,000,000**	**$4,250,000**	**$10,190,000**
Henrico County				
Retail/other commercial	$28,000,000	$54,000,000	$100,000	$170,000
Office	$44,000,000	$84,000,000	$160,000	$260,000
Residential	$17,000,000	$32,000,000	$60,000	$100,000
Total	**$88,000,000**	**$170,000,000**	**$330,000**	**$530,000**

Note: "Induced" refers to expected impacts resulting from appreciation over the No-build Alternative

Note: Numbers may not sum due to rounding

[1] Represent difference between end-year (2034) values for no-build (baseline) and build scenarios

[2] Discount rate was applied to account for the opportunity costs associated with collecting revnues over a long period of time

[3] Average is based on 20-year projections, which implicitly includes historic inflation of property values

Source(s): City of Richmond and Henrico County, Case Shiller Housing Indices, Euclid Corridor Findings, Weldon Cooper

Development and Redevelopment

In the long term, the City of Richmond and Henrico County could see increased tax revenues generated by new development and redevelopment in the corridor. These development activities can potentially increase local property, sales, meal, admission, and lodging taxes. While the Cuyahoga County (Cleveland Metro-area) assessment database provides reasonable estimates for anticipated property value appreciation along the Euclid BRT Corridor, the database is rather limited in its capacity to identify new construction and rehabilitation. This is due in large part to ongoing development projects which are not yet evident in the county assessment records. As such, the Broad Street Economic Impact study does not quantify the anticipated development impacts generated by the proposed BRT. The following discussion provides a baseline market assessment of the corridor and draws on case study research to help identify BRT's potential impacts on the surrounding area.

The Broad Street Corridor can benefit from additional residential and commercial development. Following BRT construction, the Euclid Corridor in Cleveland attracted substantial investment.[31] As discussed earlier, the Euclid Corridor and the Broad Street corridor share many similarities. As was the case with certain sections of Euclid Avenue, downtown Broad Street was the former commercial anchor of the region, with multiple flagship department stores. However, with the rise of suburban shopping malls and increased reliance on automobiles of area residents, this once-vibrant segment experienced continuing decline. In recent years, some of those empty store fronts have been redeveloped into hotels

[31] The Cleveland Plain Dealer conducted a thorough analysis of development along the Euclid Corridor (2008). The following link shows the map of development activity: http://media.cleveland.com/pdextra/other/Euclid.pdf

and condominiums, especially in the vicinity of the Richmond Convention Center and Richmond Center Stage.

Bus rapid transit, if implemented effectively, could further enhance the corridor’s image and stimulate residential demand, particularly for those residents seeking to reduce their dependence on automobiles. Given increased demand, residential vacancy will continue to fall, potentially paving the way for additional development and redevelopment. In fact, market activity suggests that this urban residential demand already exists. Discussions with real estate brokers confirm this trend.[32] For example, 700 City Centre, located two blocks from Broad Street, represents a significant mixed-use project. In addition, developers recently announced plans to convert the 9.6 acre Interbake facility (near Broad Street and the Boulevard) to approximately 180 apartments and nearly 40,000 square feet in retail. Conversations with the City also indicate that Scott’s Addition, located north of Broad Street between I-195 and the Boulevard, could continue to attract investment, particularly as developers and creative entrepreneurs convert historic properties to residential uses.[33]

BRT will also increase mobility and accessibility for Henrico County residents, particularly as new projects come to fruition in the corridor. In addition to the activity at Rocketts Landing (the County’s first Urban Mixed Use Project), several other notable projects have been proposed near the proposed BRT route.[34] The Faison School, located west of Willow Lawn, could see an additional 45 residential units and 10,000 square feet of commercial space. Meanwhile, Staples Mill Centre, located within ¾ mile of the proposed Willow Lawn terminus, represents a $434 million mixed use project and is scheduled to offer apartments (1,096 units), condos (571 units), townhouses (267 units), 60,000 square feet of office and 109,000 square feet of retail. The future residents of Staples Mill Centre will inevitably benefit from the availability of BRT service in the County.

Furthermore, BRT can help increase sales at current establishments and potentially trigger additional retail development. Willow Lawn, an outdoor shopping center with grocery stores, pharmacies, and restaurants, could see higher sales due to enhanced accessibility. In addition, continued residential development may lead to increased demand for retail, restaurants and services. Ultimately, higher retail sales and additional business development will yield higher taxes (sales, meal, admission, and BPOL) for the local governments.

While news of the proposed BRT route is not necessarily stimulating current investments, the case study research shows that BRT can act as a catalyst for new development initiatives and, in some cases, increase the pace of development. As seen in Cleveland, BRT helped cultivate development in MidTown, which had previously been a neglected segment of the Euclid Corridor. The creative investments ultimately led to the emergence of the “Health-Tech Corridor (HTC).” The three-mile, 1,600-acre section has attracted tremendous investment, including 210,000 square feet of new office, lab and flex space that is slated to open in 2012 at 80 percent occupancy. Baiju Shah, BioEnterprise President and co-creator of the HTC, remarked that “we wouldn’t have expected this type of thing until five or so years out.” He

[32] This is based on informal conversations with local residential and commercial brokers (CB Richard Ellis).
[33] Based on discussions with the City’s Planning Department, and Economic and Community Development Department.
[34] Source: Henrico County Planning Department.

believes that the HealthLine BRT served as an impetus for developers looking to invest in projects along the corridor.[35]

BRT's success as a development catalyst ultimately depends on complementary land use policies, supportive economic development strategies and the type of service which is provided.[36] Local market conditions will also determine the timing and magnitude of development. As residential activity increases in downtown Richmond, the retail market will likely respond to the increased demand for local goods and services. Commercial activity such as retail, restaurants, entertainment venues, and hotels, will ultimately yield additional tax revenues. These tax revenues can come in the form of sales, meal, admission, lodging, and BPOL taxes.

The proposed BRT investment, with 14 stations, 5-minute headways in the peak period and 10-minute headways the remainder of the day, over 3 miles of dedicated lanes, and amenities that resemble light rail service, represents a substantial and permanent transportation investment that has the ability to be a catalyst for higher density growth and greater commercial activity in the corridor. To reach its full potential, however, the lessons learned from other BRT systems indicate that community partnerships are essential, as are the complementary policies and investments noted above.

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[35] Hellendrung, Jason. HealthLine Drives Growth in Cleveland. Urban Land Institute. July 13, 2012.
[36] Peterson, Sarah Jo. Bus Rapid Transit and Land Use. Urban land Institute (ULI). July/August 2010. Page 81.

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6. CASE STUDIES DETAILS AND RELEVANT RESEARCH

Research institutes, municipal organizations, economic development professionals, and media analysts, were instrumental in helping quantify the capital costs, operational benefits, funding sources, and potential returns on investment in the case study cities. With respect to the latter, most BRT researchers assess economic returns in the broader context of development activity. In doing so, they often acknowledge the challenges and limitations associated with linking BRT (and other transportation improvements) to subsequent development initiatives. In other words, some corridor investments could have occurred regardless of BRT's presence. As such, the following analysis hopes to provide an indication, not an absolute determination, of BRT's role in shaping growth and development along several key urban corridors.

The case study analysis reviews BRT systems in the following cities: Cleveland, Ohio; Eugene, Oregon; Kansas City, Missouri; and Boston, Massachusetts. While no two corridors are identical in form, level of investment, and function, Cleveland's Euclid Corridor, operating from the Central Business District (CBD) to East Cleveland and serving prominent educational and healthcare institutions, is perhaps the most comparable to Richmond's Broad Street Corridor. Discussions with transit professionals confirm this assumption. As such, the Euclid Corridor findings are much more in-depth and are ultimately used to help reasonably project BRT's potential induced impacts on property values and real estate tax revenues along the Broad Street corridor (See Memorandum).

Cleveland, Ohio

Cleveland's "Healthline" corridor opened in 2008 and connects Public Square, located in the CBD, to East Cleveland, the most economically depressed city in Cuyahoga County, Ohio. The 9.8-mile route, operating along Euclid Avenue, is branded as the "HealthLine" due to a continued financial partnership with Cleveland Clinic and University Hospital. Ridership has increased by 60 percent since BRT implementation and buses operate at 12.5 miles per hour, compared to pre-BRT speeds of 9.3 miles per hour. The total project cost $200 million. $168.4 million went to transit-related costs, of which $50.0 million was allocated for buses and stations – the remainder helped fund other corridor improvements, such as roadway development, utility replacement, and sidewalk installation. The project's cost breakdown is found below:

- <u>$200 million:</u> total project cost
  - <u>$168.4 million FFGA [1]</u>: buses, stations, corridor improvements such as roadways, utilities, sidewalks and street furniture
    - $82.2 million from the Federal Transit Administration
    - $50 million from the State of Ohio [2]
    - $17.6 million from GCRTA (Transit Authority)
    - $8 million from the City of Cleveland
    - $10 million from NOACA (Local MPO)
    - $0.6 million from FTA Rail Mode
  - <u>$31.6 million Non-FFGA</u>: non-transit improvements, including sidewalks, utilities, and public art.

Source: Greater Cleveland Regional Transit Authority. http://www.rtahealthline.com/project-overview-funding.asp
[1] A Full Funding Grant Agreement (FFGA) is a contract between the project sponsor and the Federal Transit Administration that formally establishes the maximum level of New Starts funding and outlines the terms and conditions of federal financial participation.
[2] Transportation Review Advisory Council, part of the Ohio Department of Transportation.

Since the HealthLine's planning phase (2001), the corridor has seen approximately $4.3 billion in development activity, equivalent to a 1,000 percent return on investment for the city.[37] Discussions with real estate professionals indicate that much of the development in Public Square-area of the CBD would have occurred regardless of BRT. Similarly, Cleveland Clinic, considered one of the world's preeminent hospitals, also continues to attract substantial investment to the corridor. However, the brokers also assert that BRT has undoubtedly helped MidTown attract technology firms, senior housing developments and residential townhomes. As such, the MidTown segment has recently branded itself the "Health-Tech" corridor. Meanwhile, the Greater Cleveland Regional Transit Authority (GCRTA) is cautious not to take all of the credit for the recent investments. Instead, Joe Calabrese, CEO of the GCRTA, recalls that "the success of our project in not what we did. It's what other people did in response to what we did. They really saw this as an opportunity to leverage investment."[38]

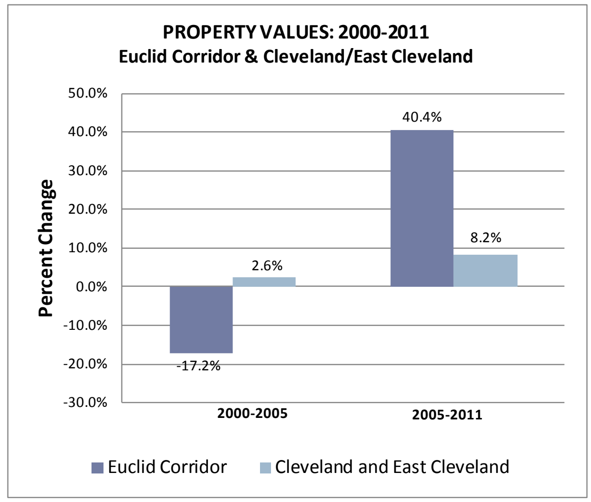
Various City initiatives have helped influence the nature of development along Euclid Avenue. In addition, the City offers a variety of tax abatements, credits and financial incentives to developers who engage in rehabilitation, conversion and new construction. Finally, the MidTown neighborhood recently adopted transit-oriented form-based zoning that aims "to encourage a compact land development pattern that incorporates a pedestrian-oriented mix of uses to support the GCRTA Euclid Corridor Transportation Project."[39] Under the new zoning rules, projects must be multi-story structures with the majority of the building fronting Euclid Avenue. In addition, ground floors must dedicate 60 percent of space to commercial or retail use and parking must be located behind the building. While form-based zoning policies have helped integrate land use and transit, institutions, such as Cleveland State University (CSU), have reoriented their campuses toward Euclid Avenue. This transformation is part of CSU's goal of becoming a more residential-based campus (as opposed to commuter-based). The university's land use policies have ultimately helped drive demand for residential development along the Euclid Corridor.[40]

Cuyahoga County's assessment database was analyzed in GIS to compare the aggregate property value growth (PSF) in the Euclid Corridor (study area) to that of Cleveland and East Cleveland, as a whole.[41] The data indicate that study-area property values declined by 17.2 percent from 2000 to 2005, while the cities' property values increased by 2.6 percent over the same time period (Figure 1 below). However, the study-area property values increased dramatically by 40.4 percent from 2005 to 2011, while the cities'

[37] The Cleveland Plain Dealer conducted a thorough analysis of development along the Euclid Corridor (2008). The following link shows the map of development activity: http://media.cleveland.com/pdextra/other/Euclid.pdf
[38] Institute for Sustainable Communities. Accelerating Bus Rapid Transit. 2012. Page 15.
[39] Ohio Law, EPA Region 5. Transit oriented Development; Pedestrian Oriented Design. http://www.landuse.law.pace.edu
[40] Partnership for Sustainable Communities. "Transit as Transportation: The Euclid Corridor in Cleveland." June 2012, Page 6. http://www.sustainablecommunities.gov/pdf/studies/cleveland-euclid-corridor.pdf
[41] The "study area" properties were analyzed at a ¼ mile buffer from the Euclid Avenue HealthLine

property values increased marginally by 8.2 percent. From 2003 to 2008, it was reported that the value of an acre of land in the MidTown district increased from $200,000 to $400,000.[42]

FIGURE 5



Source: Cuyahoga County Assessment Database, GIS.

When segmented by land use, commercial property values (PSF) increased by 45.2 percent in the Euclid Corridor and by 26.9 percent in the cities. Meanwhile, residential property values (PSF) increased by 9.1 percent in the corridor and by 0.6 percent in the cities. When annualized at a compounded rate (CAGR), the corridor's commercial properties (including office) received a 2.4 percent annual premium *over* the cities' comparable market segment. The corridor's residential properties received a 1.4 percent annual premium over the cities' residential properties.

While the HealthLine is not necessarily attributable to all new investment, the case study research shows that BRT can act as a catalyst for new development initiatives and, in some cases, increase the pace of development. Despite the economic downturn in 2008, the MidTown district continued to attract investment. In fact, the total value of MidTown construction increased after the HealthLine opened in 2008. Prior to BRT operations, the neighborhood had $50 million in ongoing construction projects. These investments increased to $69 million after BRT operations, which is indicative of MidTown's capacity to draw investment despite deteriorating economic conditions.

Creative entrepreneurship in MidTown ultimately led to the emergence of the "Health-Tech Corridor (HTC)." The three-mile, 1,600-acre section has attracted tremendous investment, including 210,000 square feet of new office, lab and flex space that is slated to open in 2012 at 80 percent occupancy. Baiju Shah, BioEnterprise President and co-creator of the HTC, remarked that "we wouldn't have expected this type of thing until five or so years out." He believes that the HealthLine BRT served as an impetus for developers looking to invest in projects along the corridor.[43]

While the Cuyahoga County assessment database provides reasonable estimates for anticipated property value appreciation, the database shows very little evidence of additional square footage. This finding potentially indicates that the corridor's prominent investments were primarily rehabilitation projects, rather than new construction initiatives. This finding is consistent with national trends where commercial tenants, in efforts to capitalize on lower lease rates, have upgraded from Class C to Class B space and from Class B to Class A space. The subsequent vacant Class C and Class B commercial spaces are often converted to residential units. In addition, many projects along the Euclid Corridor remain under construction and are yet to be incorporated into the county's assessment database.

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[42] Haviland, Jim. Executive Director of MidTown Cleveland, Inc., quoted in The Cleveland Plain Dealer. May 16, 2008. http://blog.cleveland.com/pdextra/2008/05/big_price_tag_on_big_renovatio.html.
[43] Hellendrung, Jason. HealthLine Drives Growth in Cleveland. Urban Land Institute. July 13, 2012.

Despite substantial real estate investments along the HealthLine, the corridor's population still declined by 12.0 percent from 2000 to 2010.[44] This decline is perhaps symptomatic of Cleveland's historical pattern of population redistribution. After all, the City of Cleveland experienced a 17.1 percent decline over the same time period. Nevertheless, the population living *and* working along the corridor increased from 20.3 percent in 2002 to 26.3 percent in 2010.[45] This finding potentially indicates that the Euclid Corridor has become increasingly "livable," offering a range of attractive housing and employment options.

Eugene, Oregon

The City of Eugene launched the 4-mile EmX (2.5 miles of exclusive busway) in 2007. The EmX route connects Eugene with the City of Springfield, and provides access to major institutions such as the University of Oregon, Northwest Christian College and Sacred Heart Medical Center. Ridership has increased by 20 percent along the corridor, while bus speeds have increased from 11.5 miles per hour to 15.0 miles per hour.

In a report delivered to the FTA, the National Bus Rapid Transit Institute highlighted BRT's role in increasing development interest along the corridor. In 2006, there was a $5.8 million acquisition and a $3.0 million investment purchase along the corridor. With respect to the latter, the investors plan to subdivide the 7-acre parcel into six campus industrial sites. Other than these two notable investments, it is challenging to quantify any additional development activity. As such, there are no concrete estimates for return on investment.

Kansas City, Missouri

In 2005, Kansas City opened its MAX BRT line along the city's Main Street corridor. The 6-mile route offers 3.75 miles of designated bus lanes and connects 150,000 jobs and thousands of convention visitors. In addition, the new route provides a 20 percent reduction in travel time from the prior conventional-bus route. Since implementation of BRT, the route has seen a 50 percent increase in ridership. The route's success encouraged city professionals and policy-makers to implement a new BRT line on the Troost Corridor.

A study, published by the Michigan Urban Land Institute, estimated that the MAX BRT yielded a 300 percent return on investment, equivalent to approximately $75 million in development projects. While the city's community improvement districts, complimentary streetscaping and attractive stations could potentially attract subsequent investment, there is little indication that BRT has been a direct catalyst for development activity. Metro Jacksonville, in a case study of Kansas City's BRT system, confirmed that there is little visual evidence of any transit-oriented economic development along the MAX corridor.

Boston, Massachusetts

After two failed attempts to secure federal funding for light rail, the Massachusetts Bay Transit Authority (MBTA) pursued the more cost-effective bus rapid transit alternative. The "Silver Line" began its Washington Street operations in 2002 and was the MBTA's first bus line to benefit from a robust

[44] U.S. Census, 2000, 2010.
[45] U.S. Census. LED, On the Map. 2002-2010.

marketing campaign (budgeted at $170,000). The BRT route is 2.4 miles (2.2 miles are exclusive) and connects Boston's South End neighborhood with South Station, a prominent hub for subway, commuter rail, Amtrak, Greyhound and other bus networks. Ridership is approximately 71 percent higher than on the previously used bus route 43, while travel times have been reduced by 9 percent.

Boston's Washington Street corridor has attracted substantial investment since the Silver Line's planning phase. The corridor has seen approximately $1.2 billion in development activity, much of which is residential. Specifically, there are roughly 1,700 new and renovated housing units, of which 900 have been designated as "affordable.[46]" In most cases, ground floor retail has complimented the large-scale residential developments. Overall, it is estimated that the corridor's extensive mixed-use development has created over 36 new and rehabilitated buildings, 65 businesses and approximately 500 new jobs[47].

The city contributed to the development activity through the renovation of two major properties, as well as a parking space freeze along the corridor. In addition, the Boston Redevelopment Authority reduced sales prices to developers in exchange for affordable housing. Since the inauguration of the Silver Line, the corridor's tax base has increased by 247 percent, significantly higher than the city average of 146 percent.[48] While the Silver Line appears to have catalyzed development along the Washington Street corridor, it is ultimately difficult to ascertain how much of this activity was driven by BRT implementation versus that of market forces.

Additional Findings

A 2009 study of Pittsburgh's East Busway suggests that every 100 feet closer to a station increases the market value of a single-family home by $1,600.[49]

The 14-mile Orange Line, operating on a fixed-guideway through Los Angeles' San Fernando Valley, has appeared to help increase densities along the corridor. Time-series employment data shows an increase in resident worker population densities throughout the corridor.

The Ottawa Transitway, perhaps one of the most extensive BRT systems in North America, has helped stimulate over $1.4 billion in investment since operations began in 1983. Interestingly, the St. Laurent Mall has the highest gross sales revenue (PSF) in Ottawa and 30 percent of the mall's patrons arrive by BRT.

Lessons Learned

The case studies illustrate some of the ways in which a community can best leverage a BRT investment. Several of these key findings are discussed below:

Involve the community early and establish partnerships at the beginning: The case study analysis indicates the importance of understanding the needs and priorities of businesses along BRT corridors. Following the Lane Transit District's (LTD) insufficient collaboration with small businesses during Eugene's EmX project, the agency now conducts robust outreach efforts to the business community. In

[46] Henke, Cliff. "Economic Development and BRT." John Noel Public Transit Discovery Conference, October 2010.
[47] National Bus Rapid Transit Institute (NBRTI). "Bus Rapid Transit and Development: Policies and Practices that Affect Development around Transit." December 1, 2009. Page 34.
[48] Breakthrough Technologies Institute. "Bus Rapid Transit Oriented Development." April, 2008. Page 6.
[49] Henke, Cliff. "Economic Development and BRT." John Noel Public Transit Discovery Conference, October 2010.

addition, it is evident that strong partnerships are vital to the success of BRT systems. Institutions, such as hospitals and universities, can not only contribute to the project's success, but can also enhance the integration of land use and transportation along the corridor.

Influence the nature of development: A city's land use policies or practices can significantly impact the type and scale of development that occurs along transit corridors. In Cleveland, MidTown's form-base zoning provisions have helped encourage density and restrict parking, thus enhancing the integration of land use and transit.

Understand the role of perceived permanence: A 2008 survey of twelve developers suggests that BRT's "perceived permanence" is a critical factor when making investment decisions along a transit corridor.[50] Specifically, exclusive guideways and dedicated lanes, as well as the size and quality of stations, were thought to be the most important elements. Streetscape improvements were also considered beneficial, but to a lesser extent. The designated guideways in Cleveland and Eugene undoubtedly contribute to BRT's perceived permanence in their respective corridors. Meanwhile, Kansas City's attractive bus stations suggest that BRT remains an integral part of the urban infrastructure. In addition, the operational permanence of BRT, identified by improved headways (duration between bus arrivals), can contribute to users' confidence and faith in the system.

Embrace the technical leaders, as well as policy leaders: In Eugene, the BRT project encountered a substantial technical obstacle when planning for some of the state-owned facilities along the University of Oregon campus[51]. Simply put, the state's engineering and congestion standards differed greatly from those of the Lane Transit District (LTD). The City of Eugene's traffic engineer assumed an integral role in the ensuing coordination and ultimately helped initiate the new signal prioritization procedures. As Tom Schwetz, LTD's Planning and Development Director, recalls, "there were champions in the policy-making sector…but we needed champions at the technical level as well."[52]

Focus on "Better Rapid Transit": In Cleveland's case, many city professionals attribute the success of BRT to the fact that it was designed more like a rail system than a bus system. Joe Calabrese, CEO of the GCRTA, recalls that "we everything that we could do to give it (HealthLine) that first-class rail-like image."[53] Ultimately, the HealthLine's design modifications helped overcome the generally accepted belief in Cleveland that "suits don't ride buses." Meanwhile, Boston's planners and policy makers have marketed the Silver Line as an addition to Boston's rapid transit system. In fact, the Silver Line is the only bus route included on the metro area's rapid transit maps.[54]

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[50] Breakthrough Technologies Institute. "Case Studies on Transit Oriented Development Around Bus Rapid Transit Systems in North America and Australia." April, 2008, Page 86.
[51] Institute for Sustainable Communities. *Accelerating Bus Rapid Transit: A Resource Guide for Local Leaders*. 2012. Page 34.
[52] Ibid, Page 34.
[53] Ibid. Page 17.
[54] Note: the Institute for Sustainable Communities was instrumental in identifying some of these "lessons learned." The organization's "Resource Guide For Local Leaders" can be found at http://www.iscvt.org/who_we_are/publications/Resource-Guide-Bus-Rapid-Transit-v1.pdf

Documentation

TABLE A1: EUCLID CORRIDOR STUDY: ASSESSMENT DATA
(Used to Project BRT's Induced Impact on Property Values)

Euclid Corridor: Study Area - *parcels within 1/4 mile of the BRT route*

Study Area - Square Feet (SF)

				Percent change in square footage			
	2000	2005	2011	2000-2011	2000-2005	2005-2011	Annualized 2005-2011
Residential	9,807,238	9,998,349	10,126,770	3.3%	1.9%	1.3%	0.2%
Total Commercial	20,140,427	20,400,279	20,497,208	1.8%	1.3%	0.5%	0.1%
Total (all uses)*	47,327,089	47,798,961	48,168,523	1.8%	1.0%	0.8%	0.1%

Study Area - Property Values

				Percent change in property values			
	2000	2005	2011	2000-2011	2000-2005	2005-2011	Annualized 2005-2011
Residential	$83,284,100	$123,937,300	$136,892,900	64.4%	48.8%	10.5%	1.7%
Total Commercial	$2,303,049,600	$1,966,544,760	$2,868,332,700	24.5%	-14.6%	45.9%	6.5%
Total (all uses)*	$2,583,604,300	$2,160,844,660	$3,057,949,800	18.4%	-16.4%	41.5%	6.0%
Residential Value ($) PSF	$8.49	$12.40	$13.52	59.2%	46.0%	9.1%	1.5%
Commercial Value ($) PSF	$114.35	$96.40	$139.94	22.4%	-15.7%	45.2%	6.4%
Total Value ($) PSF	$54.59	$45.21	$63.48	16.3%	-17.2%	40.4%	5.8%

Cities: Cleveland and East Cleveland - *serving as "control" for the study*

Cities - Square Feet (SF)

				Percent change in square footage			
	2000	2005	2011	2000-2011	2000-2005	2005-2011	Annualized 2005-2011
Residential	838,773,706	847,382,115	852,966,160	1.7%	1.0%	0.7%	0.1%
Total Commercial	138,601,553	145,274,255	152,057,271	9.7%	4.8%	4.7%	0.8%
Total (all uses)*	1,200,965,651	1,225,050,503	1,240,973,487	3.3%	2.0%	1.3%	0.2%

Cities - Property Values

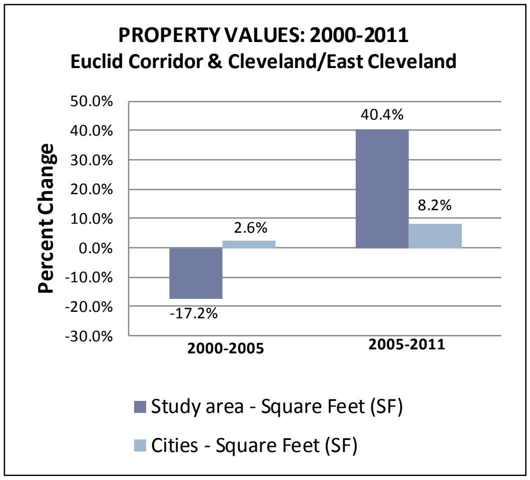
				Percent change in property values			
	2000	2005	2011	2000-2011	2000-2005	2005-2011	Annualized 2005-2011
Residential	$6,925,591,600	$8,455,492,960	$8,564,565,917	23.7%	22.1%	1.3%	0.2%
Total Commercial	$5,163,274,700	$5,112,052,750	$6,792,118,400	31.5%	-1.0%	32.9%	4.8%
Total (all uses)*	$14,538,178,330	$15,210,418,070	$16,677,989,187	14.7%	4.6%	9.6%	1.5%
Residential Value ($) PSF	$8.26	$9.98	$10.04	21.6%	20.9%	0.6%	0.1%
Commercial Value ($) PSF	$37.25	$35.19	$44.67	19.9%	-5.5%	26.9%	4.1%
Total Value ($) PSF	$12.11	$12.42	$13.44	11.0%	2.6%	8.2%	1.3%

Compounded Property Value Premium, 2005-2011 - *Applied to Broad Street's Build Alternative, Derived from $/SF*

	CAGR
Residential	**1.4%**
Total Commercial	**2.4%**
Total (all uses)*	**4.5%**

*Note: "total - all uses" reflects residential, commercial and all other uses and was not used as an input for the Broad Street Corridor
Source: Cuyahoga County Assessment Data; 2000, 2005, 2011

FIGURE A-1



Source: Cuyahoga County Assessment Database, GIS.

BROAD STREET RAPID TRANSIT STUDY

ENVIRONMENTAL ASSESSMENT

APPENDIX A-17: Noise and Vibration Technical Report

BROAD STREET CORRIDOR EA
REPORT ON NOISE AND VIBRATION FINDINGS

1 NOISE AND VIBRATION FUNDAMENTALS

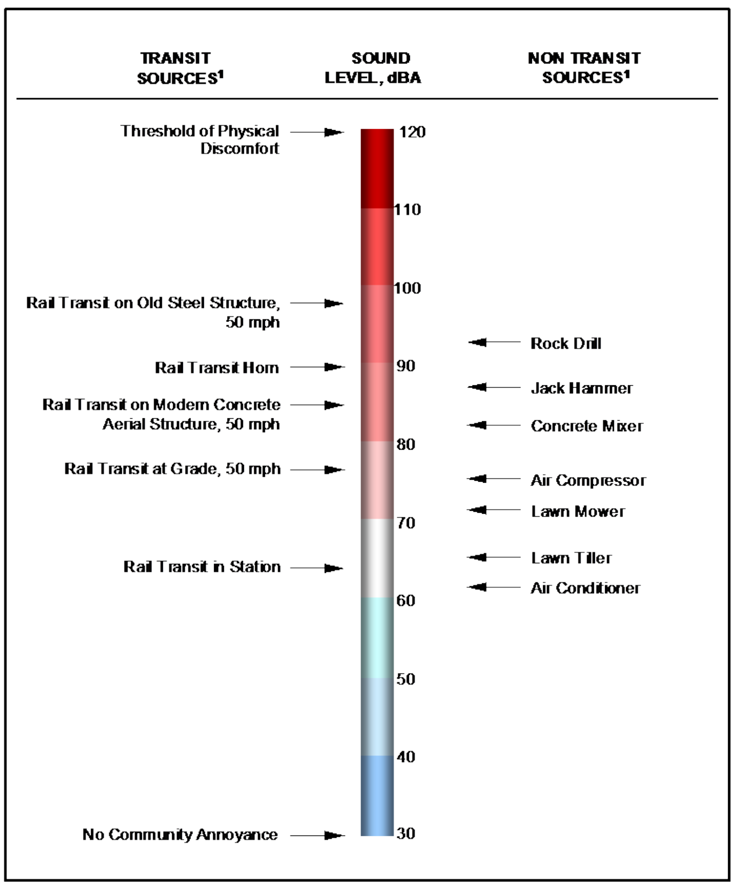
This section describes the basic terminologies of noise and vibration used in this report. This information will provide background for the assessment procedures described in the later sections.

1.1 NOISE DESCRIPTORS

Noise is usually defined as sound that is undesirable because it interferes with speech communication and hearing, or is otherwise annoying. Under certain conditions, noise may cause hearing loss, interfere with human activities, and in various ways may affect people's health and well-being.

The decibel (dB) is the accepted standard unit for measuring the amplitude of sound because it accounts for the large variations in sound pressure amplitude. When describing sound and its effect on a human population, A-weighted (dBA) sound pressure levels are typically used to account for the response of the human ear. The term "A-weighted" refers to a filtering of the noise signal in a manner corresponding to the way the human ear perceives sound. The A-weighted noise level has been found to correlate well with people's judgments of the noisiness of different sounds and has been used for many years as a measure of community noise. Figure 1-1 illustrates typical A-weighted sound pressure levels for different transit and various noise sources.

FIGURE 1-1
TYPICAL A-WEIGHTED SOUND LEVELS



Community noise levels usually change continuously during the day. The equivalent continuous A-weighted sound pressure level (L_{eq}) is normally used to describe community noise. The L_{eq} is the equivalent steady-state A-weighted sound pressure level that would contain the same acoustical energy as the time-varying A-weighted sound pressure level during the same time interval. The maximum sound pressure level (L_{max}) is the greatest instantaneous sound pressure level observed during a single noise measurement interval.

Another descriptor, the day-night average sound pressure level (L_{dn}), was developed to evaluate the total daily community noise environment. The L_{dn} is a 24-hour average sound pressure level with a 10-dB time-of-day weighting added to sound pressure levels that occur during the nine nighttime hours from 10:00 p.m. to 7:00 a.m. This nighttime 10-dB adjustment is an effort to account for the increased sensitivity to nighttime noise events. The Federal Transit Administration (FTA) uses L_{dn} and L_{eq} to evaluate transit noise impacts at the surrounding communities (FTA, 2006).

1.2 VIBRATION DESCRIPTORS

Vibration is an oscillatory motion, which can be described in terms of displacement, velocity, or acceleration. Displacement, in the case of a vibrating floor, is simply the distance that a point on the floor moves away from its static position. The velocity represents the instantaneous speed of the floor movement, and acceleration is the rate of change of the speed. The response of humans, buildings, and equipment to vibration is normally described using velocity or acceleration. In this report, velocity will be used in describing ground-borne vibration.

Vibration amplitudes are usually expressed as either peak particle velocity (PPV) or the root mean square (RMS) velocity. The PPV is defined as the maximum instantaneous peak of the vibration signal in inches per second. The RMS of a signal is the average of the squared amplitude of the signal in inches per second. Although PPV is appropriate for evaluating the potential of building damage, it is not suitable for evaluating human response. Since it takes some time for the human body to respond to vibration signals, RMS amplitude is more appropriate to evaluate human response to vibration than PPV. FTA uses the abbreviation, "VdB" for vibration decibels to reduce the potential for confusion with sound decibel (FTA, 2006) and the reference value to covert PPV and RMS into VdB is 1 micro-inch per second. For sources such as trains, PPV VdB levels are typically 4 to 5 dB higher than RMS levels.

Decibel notation acts to compress the range of numbers required in measuring vibration. Similar to the noise descriptors, L_{eq} and L_{max} can be used to describe the average vibration and the maximum vibration level observed during a single vibration measurement interval.

FIGURE 1-2
TYPICAL LEVELS OF GROUND-BORNE

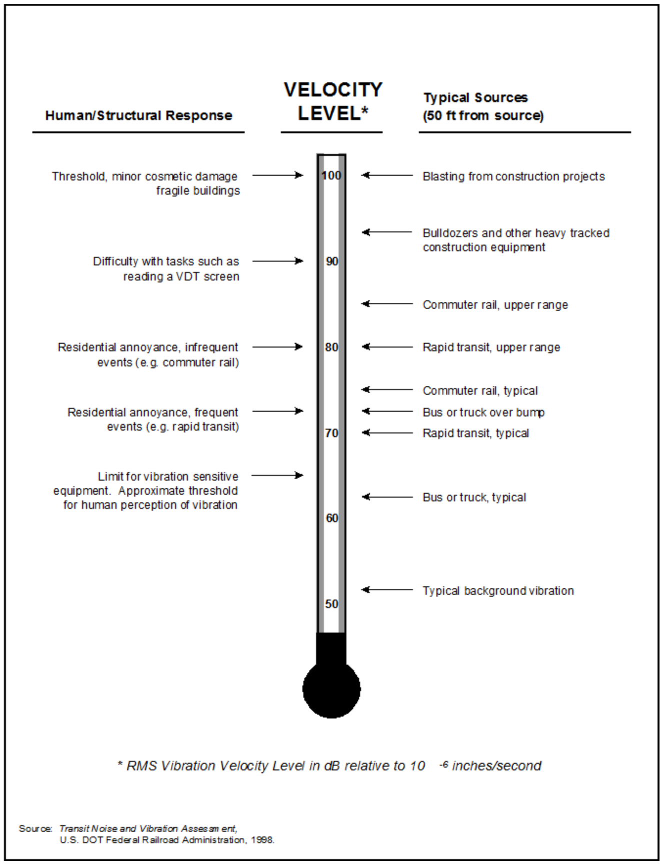


Figure 1-2 illustrates common vibration sources and the human and structural responses to ground-borne vibration. As shown in Figure 1-2, the threshold of perception for human response is approximately 65 VdB; however, human response to vibration is not usually significant unless the vibration exceeds 70 VdB. Vibration tolerance limits for sensitive instruments such as MRI or electron microscopes could be much lower than the human vibration perception threshold.

2 IMPACT CRITERIA

This section presents the guidelines, criteria, and regulations used to assess noise and vibration impacts associated with the proposed project.

2.1 OPERATION NOISE IMPACT CRITERIA

The criteria in *Transit Noise and Vibration Impact Assessment* (FTA, 2006) were used to assess existing ambient noise levels and future noise impacts from bus rapid transit operations and fixed facilities for the project. They are founded on well-documented research on community reaction to noise and are based on change in noise exposure using a sliding scale. The amount that rapid transit projects are allowed to change the overall noise environment is reduced with increasing levels of existing noise. The FTA noise impact criteria descriptors for human annoyance depend on land use and are defined in Table 2-1.

L_{dn} is used to characterize noise exposure for residential areas and hotels (Category 2) to account for the increased sensitivity to nighttime noise events for these types of land uses. The maximum 1-hour L_{eq} is used to characterize noise exposure for areas where the increase sensitivity to noise is during the period that the facility is in open such as school buildings and parks (Categories 1 and 3). The noise impact criteria for human annoyance are based on comparison of the existing outdoor noise levels and the future outdoor noise levels from proposed transit operations and fixed facilities for the project. The noise impact criteria incorporate activity interference noise caused by the transit operations alone and annoyance due to the change in the future noise environment caused by the project. As shown in Figure 2-1, there are two levels of impact included in the FTA criteria:

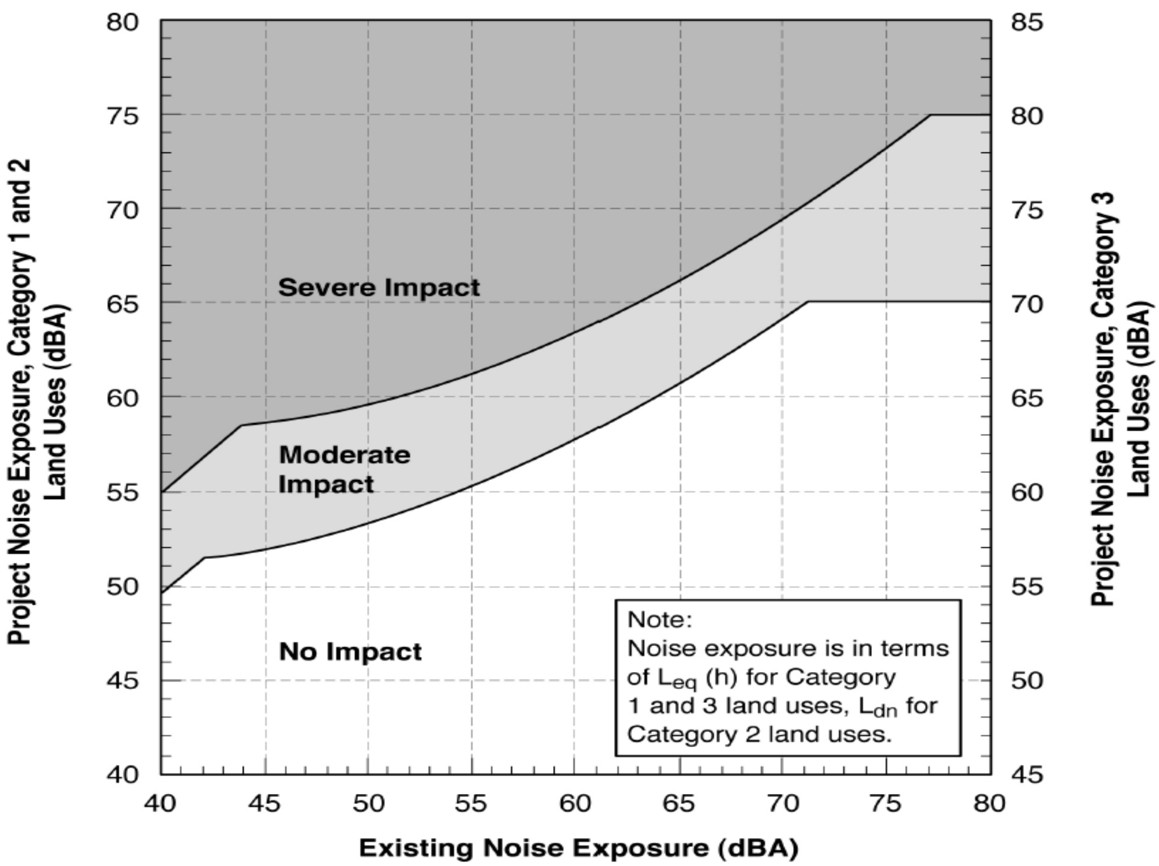
- **Severe**: Project noise above the upper curve is considered to cause Severe Impact since a significant percentage of people would be highly annoyed by the new noise. This curve flattens out at 75 dBA for Category 1 and 2 land use and 80 dBA for Category 3, noise levels associated with an unacceptable living environment per each perspective category land use. FTA encourages specified noise mitigation for severe impact areas unless there is no practical method of mitigating the noise.
- **Moderate**: The change in the cumulative noise level is noticeable to most people, but it may not be sufficient to cause strong, adverse reactions from the community. In this transitional area, other project-specific factors must be considered to determine the magnitude of the impact and the need for mitigation, such as the existing level, predicted level of increase over existing noise levels, and the types and numbers of noise-sensitive land uses affected. This curve flattens out at 65 dBA for Category 1 and 2 land use and 70 dBA for Category 3, maximum noise levels allowed and not be considered adverse to an acceptable living environment noise level per each perspective category land use.

TABLE 2-1: LAND USE CATEGORIES AND METRICS FOR NOISE IMPACT CRITERIA

Land Use Category	Noise Metric	Description of Land Use Category
1	Outdoor L_{eq}(h)*	Land where quiet is an essential element in their intended purpose. This category includes lands set aside for serenity and quiet, and such land uses as outdoor amphitheaters and concert pavilions, as well as National Historic Landmarks with significant outdoor use.
2	Outdoor L_{dn}	Residences and buildings where people normally sleep. This category includes homes, hospitals, and hotels where a nighttime sensitivity to noise is assumed to be of utmost importance.
3	Outdoor L_{eq}(h)*	Institutional land uses with primarily daytime and evening use. This category includes schools, libraries, and churches where it is important to avoid interference with such activities as speech, meditation, and concentration on reading material. Buildings with interior spaces where quiet is important, such as medical offices, conference rooms, recording studios, and concert halls fall into this category. Places for meditation or study associated with cemeteries, monuments, and museums. Certain historical sites, parks, and recreational facilities are also included.

Source: FTA, 2006.
* Leq for the noisiest hour of activity during hours of noise sensitivity.

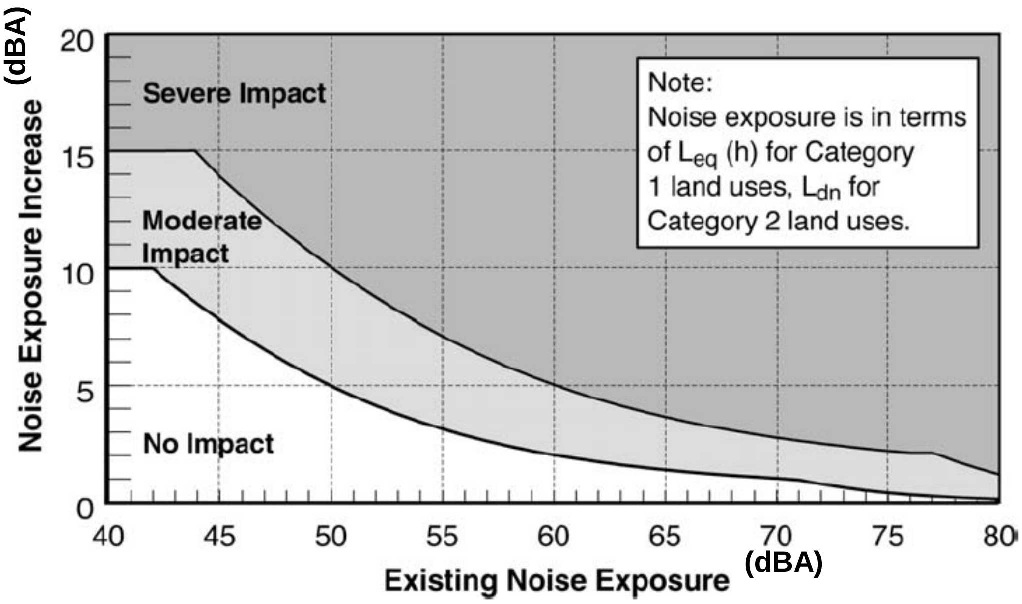
FIGURE 2-1
NOISE IMPACT CRITERIA FOR TRANSIT PROJECTS



Source: FTA, 2006.

Although the curves in Figure 2-1 are defined in terms of the project noise exposure and the existing noise exposure, it is important to emphasize that the increase in the cumulative noise – when the project noise is added to existing noise – is the basis for the criteria. Figure 2-2 shows the noise impact criteria for Category 1 and 2 land uses in terms of the allowable increase in the cumulative noise exposure.

FIGURE 2-2



INCREASE IN CUMULATIVE NOISE LEVELS ALLOWED BY CRITERIA

Source: FTA, 2006.

Figure 2-2 shows that the criterion for impact allows a noise exposure increase of 10 dBA if the existing noise exposure is 42 dBA or less but only a 1 dBA increase when the existing noise exposure is 70 dBA. As the existing level of ambient noise increases, the allowable level of project noise increases, but the total allowable increase in community noise exposure is reduced. As a result, project noise exposure levels that are less than the existing noise exposure can still cause an impact.

2.2 CONSTRUCTION NOISE CRITERIA

The proposed Broad Street BRT project alignment construction would be under the jurisdiction of the City of Richmond and Henrico County. Neither Richmond nor Henrico County has a specific noise ordinance that addresses construction noise level limits. Henrico County does have nighttime restriction on when construction work can be conducted (11 PM to 6 AM); however, road work construction is exempt from this restriction. Therefore, FTA recommended daytime and nighttime construction noise levels will be used for the Broad Street BRT project. Table 2-2 presents the recommended FTA noise limits for the proposed Broad Street project. These limits are for 8-hour average noise levels (L_{eq}) at the property line of the nearest location to the construction site.

TABLE 2-2: FTA CONSTRUCTION NOISE IMPACT CRITERIA

Land Use	8-hour Leq, dBA		Ldn, dBA
	Day	Night	30-day Average
Residential	80	70	75[1]
Commercial	85	85	80[2]
Industrial	90	90	85[2]

Source: FTA, 2006.
Notes: In urban areas with very high ambient noise levels (Ldn>65), Ldn from construction operations should not exceed existing ambient +10 dB. Twenty-four-hour Leq, not Ldn.

2.3 OPERATION VIBRATION IMPACT CRITERIA

The criteria in *Transit Noise and Vibration Impact Assessment* (FTA, 2006) were used to evaluate vibration impacts from bus operations. The evaluation of vibration impacts can be divided into two categories: (1) human annoyance, and (2) building damage. Table 2-3 presents the criteria for various land use categories as well as the frequency of events. The criteria are related to ground-borne vibration causing human annoyance or interfering with the use of vibration sensitive equipment. The criteria for acceptable ground-borne vibration are expressed in terms of RMS velocity levels in VdB and are based on the maximum levels for a single event (L_{max}).

All of the sensitive receptors within the project area, (i.e., residences, churches, historical buildings, and cemeteries) fall under Land Use Category 2 or 3.

TABLE 2-3: GROUND-BORNE VIBRATION IMPACT CRITERIA FOR HUMAN ANNOYANCE

Land Use Category	Ground-Borne Vibration Impact Levels, VdB*		
	Frequent Events[1]	Occasional Events[2]	Infrequent Events[3]
Category 1: Buildings where vibration would interfere with interior operations.	65 VdB[4]	65 VdB[4]	65 VdB[4]
Category 2: Residences and buildings where people normally sleep.	72 VdB	75 VdB	80 VdB
Category 3: Institutional land uses with primarily daytime use.	75 VdB	78 VdB	83 VdB

Source: FTA, 2006.
Notes: 1. "Frequent Events" is defined as more than 70 vibration events of the same source per day.
2. "Occasional Events" is defined as between 30 and 70 vibration events of the same source per day.
3. "Infrequent Events" is defined as more than 30 vibration events of the same kind per day.
4. This criterion limit is based on levels that are acceptable for most moderately sensitive equipment, such as optical microscopes. Vibration-sensitive manufacturing or research will require detailed evaluation to define the acceptable vibration levels.
* Root-mean-square velocity in decibels (VdB) re: 1 micro-inch per second.

Normally, vibration resulting from a bus passby would not cause building damage. However, damage to fragile historic buildings located near the right-of-way can be a concern.

Vibrations generated by surface transportation are mainly in the form of surface or Raleigh waves. Studies have shown that the vertical component of transportation-generated vibrations is the strongest, and that peak particle velocity (PPV) correlates best with building damage and complaints.

The FTA provides a vibration damage threshold criterion of 13 mm/s (0.50 in/sec, approximately 102 VdB) PPV for fragile buildings and 3 mm/s (0.12 in/sec, approximately 90 VdB) PPV for extremely fragile historic buildings, for typical construction equipment operation (FTA, 2006).

2.4 CONSTRUCTION IMPACT CRITERIA

Construction activities can result in varying degrees of ground vibration, depending on the equipment and method employed. The vibration associated with typical transit construction is not likely to damage building structures, but it may cause cosmetic building damage. The construction vibration is generally assessed in terms of PPV. Table 2-4 summarizes the construction vibration limits shown in FTA guidelines.

TABLE 2-4: CONSTRUCTION VIBRATION DAMAGE CRITERIA

Building Category	PPV (in/sec)	Approximate Lv*
I. Reinforced-concrete, steel, or timber (no plaster)	0.5	102
II. Engineered concrete and masonry (no plaster)	0.3	98
III. Non-engineered timber and masonry buildings	0.2	94
IV. Buildings extremely susceptible to vibration damage	0.12	90

Source: FTA, 2006.
Notes: * RMS velocity in decibels (VdB) re 1 micro-inch/second

3 EXISTING SETTING

The project corridor runs through several noise-sensitive land use areas along a 7.5-mile stretch of Broad Street through the core of the downtown. For the purpose of this study noise sensitive receptors were grouped by their proximity to Broad Street and by their current land use as follows: Willow Lawn Shopping Mall to The Fan, The Fan to Downtown Richmond, Downtown Richmond, and Downtown Richmond to Shockoe Bottom.

The project corridor runs through several noise-sensitive land use areas along a 7.5-mile stretch of Broad Street through the core of the downtown. For the purpose of this study noise sensitive receptors were grouped by their proximity to Broad Street and by their current land use as follows: Willow Lawn Shopping Mall to The Fan, The Fan to Downtown Richmond, Downtown Richmond, and Downtown Richmond to Shockoe Bottom.

Willow Lawn Shopping Mall to The Fan

The propose bus corridor follows along Broad Street between Byrd Avenue and North Avenue. The immediate surrounding land uses of this section of the proposed alignment are a high density mix of commercial retail properties due to the Willow Lawn Shopping Mall, single and multi-family residences, schools, churches, motel, as well as, the Virginia Department of Game and Fisheries and Este Express corporate headquarter.

The Fan to Downtown Richmond

In general, the Fan neighborhood of the project area along Broad Street between North Avenue and Belvidere Street is urban with a heavy mix of residential and industrial/commercial properties, with the Broad Street area being more of an urban land uses environment consisting of a higher density of multi-family and single family residents and a central walking area consisting of several restaurants and bars that are located near the alignment. Virginia Commonwealth University (VCU) has presence in this area and several building near Broad Street. Also, several of the commercial properties along Broad Street have second and third floors that are being converted into multi-family residential properties.

Downtown Richmond

The propose bus corridor follows along Broad Street and Main Street between Belvidere Street and The Richmond Main Street Train Terminal. The immediate surrounding land uses of this section proposed alignment are a high density mix of federal, state, and local government buildings and museums due to Richmond status as the state's capital, as well as, several hotels and motels due the downtown convention center and the central location of the VCU medical school and hospital.

Downtown Richmond to Shockoe Bottom

The proposed bus corridor follows along Main Street from The Richmond Main Street Train Terminal to the Rocketts Landing Apartment Complex. Shockoe Bottom neighborhood is major nightlife, dining, and entertainment center for the City of Richmond consisting of several restaurants, bars, museums, and Libbie Hill Park that are located near the alignment, as well as, River Lofts and Rocketts Landing apartment complexes.

3.1 NOISE MEASUREMENTS

The noise environment in the vicinity of the Broad Street Alignment is comprised of automobile, truck, and bus pass-by noise with intervals of motor vehicle horn noise as well as clatter from street level pedestrian and commercial activities.

To establish the existing noise conditions, noise measurements were collected at locations along the Broad Street project alignment between Willow Lawn Mall and Rocketts Landing. A total of nine long-term and eight short-term measurements were conducted between September 28 and October 1, 2010. Long-term measurement equipment was left at the measurement site at least 24 hours to record day-night levels (L_{dn}). Short-term measurements were at least 15 minutes in length. The noise measurement sites and results are listed in Table 3-1 and the locations of the measurement sites are shown on Figure 3-1.

The selected noise measurement sites used for determining the existing noise levels for the entire area within the project limits, represented first-row residences and noise-sensitive day time use facilities. Most of these measurement sites were identified to assess the existing noise levels at the property line of noise-sensitive areas along the alignment and to measure existing noise sources.

Noise levels at the short-term sites were adjusted to reflect the L_{dn} for their areas. The short-term noise measurements were converted into L_{dn} by adjusting the short-term measurement results with the results of 24-hour long-term noise measurements at near-by sites with similar geometries. Results of the adjusted short-term noise measurements are presented in Table 3-1. Existing L_{dn} noise levels along the project alignment range from 59 to 78 dBA and peak-hour noise levels range from 46 to 80 dBA.

The measured values were used to estimate existing noise levels at all other sensitive receptors along the alignment and the existing noise environment for the four categorized land use groups are described in the next section.

Noise measurements were conducted using the following ANSI Type 1 instrumentation: Larson Davis (LD) Model 820 sound level meters and LD Model 812 sound level meters. The microphones used with these systems were LD Model 2559. All noise measurement systems were calibrated using either a LD model CAL200 acoustical calibrator. The instruments were calibrated and operated according to the manufacturer's specifications.

Willow Lawn Shopping Mall to The Fan

The ambient noise sources in this area include traffic on various urban surface streets, traffic on I-95 and industrial/ commercial activities. The immediate surrounding land uses of the proposed alignment are industrial, commercial, and scattered residential. L_{dn} in the area, as indicated by the measurement results at monitoring sites LT1 to LT3 and ST1, ranged from 60 to 64 dBA.

The Fan to Downtown Richmond

The ambient noise sources in this area are traffic on various urban surface streets, as well as, foot and bike traffic due to nearby restaurants, boutiques, and the VCU Campus. Clusters of family and single family residents, commercial retail property are located along this portion of the alignment. L_{dn} in the area, as indicated by the measurement results at monitoring sites LT4 to LT6, ST2 and ST3, ranged from 60 to 76 dBA.

Downtown Richmond

The ambient noise source in this area is traffic on various urban surface streets. The immediate surrounding land uses near the proposed alignment are federal, state, and local government buildings, museums, and hotels. L_{dn} in the area, as indicated by the measurement results at Monitoring Sites LT7 and ST4, ranged from 69 to 78 dBA.

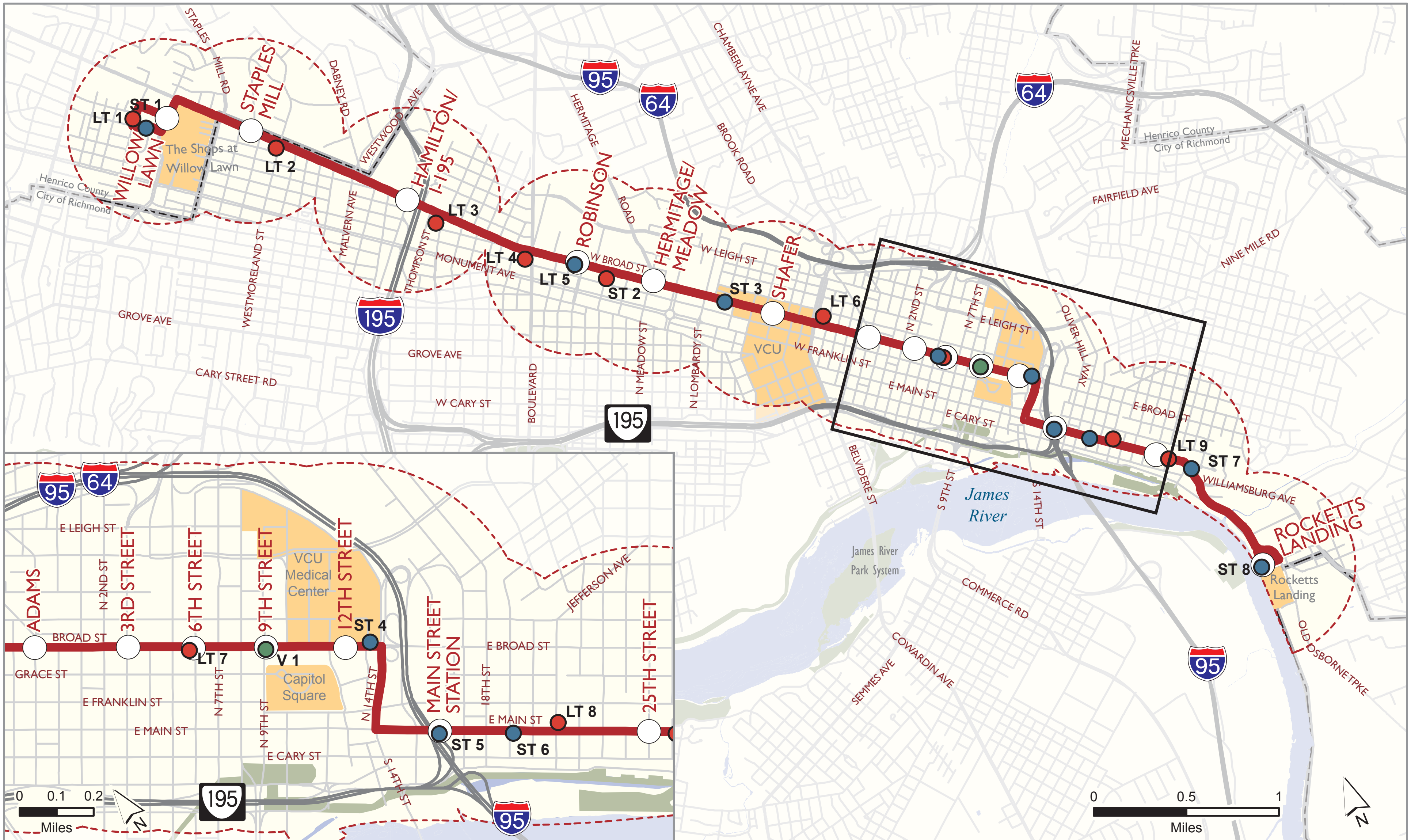
Downtown Richmond to Shockoe Bottom

The ambient noise sources in this area are traffic on various urban surface streets, as well as, foot and bike traffic due to nearby restaurants, boutique, and museums. Clusters of multi-family and single family residents, commercial retail property are located along this portion of the alignment. L_{dn} in the area, as indicated by the measurement results at Monitoring Sites LT8 and LT9 and ST5 to ST8, ranged from 59 to 75 dBA.

3.2 VIBRATION MEASUREMENTS

A vibration measurement was taken in the Downtown area. The locations of the measurement site with the background vibration measurement are listed in Table 3-2 and shown in Figure 3-1.

The vibration measurement was conducted using a GeoSonic 3000EZplus portable seismograph. Vibration levels were measured on the vertical, transverse, and longitudinal axes, and the highest of the three was used for this analysis. The seismograph has an internal calibration sequence and was operated according to the manufacturer's specifications. Peak particle velocity vibrations (in inches per second) were recorded to assess potential building damage impacts based on FTA procedures and guidelines. When converting from peak particle velocity measurements into VdB a correction factor of -12 VdB was added to the passby measurements and a correction factor of -6 VdB was added to the background measurements.



Legend

- Proposed BRT Stations
- Proposed BRT Alignment
- Half-Mile Buffer

Monitoring Locations

- Long-Term Noise
- Short-Term Noise
- Vibration

Sources: VGIN RCL (Roads)

Environmental Assessment

Figure 3-1: Noise and Vibration Monitoring Locations

BROAD STREET RAPID TRANSIT STUDY

TABLE 3-1: EXISTING NOISE MEASUREMENT RESULTS

Site No.	ADDRESS	Land Use	Type of Measurement	DATE	Start Time	Duration	L_{eq}	L_{dn}[1]
LT1	3301 Old Richmond Rd., Richmond, VA	SFR	Long Term	9/28/10	10 AM	24 hours		60.2
LT2	4600 Radford Ave., Richmond, VA	SFR	Long Term	9/28/10	11 AM	24 hours		63.8
LT3	3404 Cutshaw Ave., Richmond, VA	SFR	Long Term	9/30/10	1 PM	24 hours		61.5
LT4	2804 W. Grace St., Richmond, VA	SFR	Long Term	9/30/10	2 PM	24 hours		61.1
LT5	2238 W. Grace St., Richmond, VA	SRF	Long Term	9/28/10	12 PM	24 hours		60.5
LT6	513 W. Marshall St., Richmond, VA	MFR	Long Term	9/28/10	1 PM	24 hours		62.3
LT7	Hilton Gardens Inn Hotel, Richmond, VA	MOT	Long Term	9/30/10	2 PM	24 hours		69.2
LT8	7 N. 21st St., Richmond, VA	MFR	Long Term	9/28/10	11 AM	24 hours		59.4
LT9	2603 E. Main St. Millie's Diner, Richmond, VA	COM	Long Term	9/30/10	12 PM	28 hours		71.6
ST1	1516 Cutshaw Pl., Richmond, VA	SFR	Short Term	9/29/10	9 AM	20 Minutes	61.7	61.0
ST2	William Byrd Apartments, Richmond, VA	MFR	Short Term	9/29/10	8 AM	15 Minutes	68.3	71.1
ST3	1333 W. Broad St., Richmond, VA	MFR	Short Term	9/29/10	11 AM	20 Minutes	70.9	75.8
ST4	1228 E. Broad St., Richmond, VA	SCH	Short Term	10/1/10	10 AM	20 Minutes	75.1	77.3
ST5	1500 E. Main St., Richmond, VA	COM	Short Term	10/1/10	9 AM	20 Minutes	75.4	77.0
ST6	1401 E. Main St., Richmond, VA	COM	Short Term	10/1/10	9 AM	20 Minutes	73.2	74.8
ST7	Libbie Hill Park, Richmond, VA	Park	Short Term	10/1/10	10 AM	20 Minutes	67.5	71.0
ST8	Rocketts Landing, Richmond, VA	COM	Short Term	9/30/10	3 PM	20 Minutes	58.4	61.6

Notes:

STxx – short-term measurement location; LTxx – long-term measurement location.

1. SFR – single-family residence; MFR – multi-family residence; COM – Commercial Building; MOT: motel/hotel SCH – school/university.
2. For all short-term measurement sites, L_{dn} levels were estimated by comparing hourly noise levels at a nearby long-term monitoring site and applying adjustment factor.

TABLE 3-2: EXISTING VIBRATION MEASUREMENT RESULTS

Site No.	Site Location	Land Use	Date	Time	Peak Particle Velocity PPV, in/sec		
					Long	Vert	Trans
V1	1201 E Broad Street, Richmond, VA	Commercial	10/1/10	11 AM	0.008	0.008	0.008

Source: Parsons, 2010.

4 ENVIRONMENTAL CONSEQUENCES

The results of the noise and vibration assessments from project construction and operation are presented in this section.

4.1 NOISE

An assessment was conducted using the FTA guidelines for both operational and construction period noise. The proposed future BRT vehicle fleet is expected to include some compressed natural gas (CNG) vehicles. However, to assure a conservative analysis, noise modeling was performed using the model's diesel bus option, as diesel buses would be the noisiest. For the worst-case analysis, the project buses were assumed to operate at the posted speed limits of 25, 30, and 35 miles per hour (mph). In practice, the operating speed would vary in the vicinity of proposed passenger stations as the bus approaches and departs from a station; however speeds would not be expected to exceed the speed limit. Also, while BRT travel between stations would be enhanced by traffic signal priority and signal optimization, travel speeds for any given bus trip would still be affected at some intersections due to red lights.

The number of buses for a 24 hour period used in the analysis is 160 with 136 buses during daytime hours (7 AM to 10 PM) and 24 buses during nighttime hours (10 PM to 7 AM). These numbers are based on the Broad Street BRT projected operating conditions and were projected to reflect worst case conditions in 2035.

No-Build Alternative

Noise effects would not result under the No-Build Alternative as a result of the Broad Street Rapid Transit Project.

Build Alternative

Noise levels were calculated for the future design condition bus traffic for the Build Alternative and compared to the existing conditions noise level measurements along the alignment. Based on the FTA model, distance-to-impact contours were developed for the different land use categories and existing noise levels. These distances were then used to tabulate the noise impacts that would occur as a result of the Broad Street Rapid Transit Project.

The results of the modeling for the Build Alternative for the Category 2 and 3 land uses are presented in Tables 4.1 and 4.2.

TABLE 4-1: SUMMARY OF NOISE IMPACTS FOR CATEGORY 2 LAND USES FOR THE BUILD ALTERNATIVE

Site No.	Noise Level due to Project, Ldn (dBA)	Noise Impact Criteria (Moderate/Severe) Ldn (dBA)	Site Distance from Centerline of Alignment/ Guideway (ft)	Distance to Moderate Impact (ft)	Distance to Severe Impact (ft)	Impact
Willow Lawn to I-195[1]						
LT1	57	58/63	40	38	16	None
ST1	56	58/64	25	19	8	None
LT2	49	60/65	140	26	11	None
I-195 and 2nd Street[1]						
LT3	45	58/64	260	32	14	None
LT4	45	58/64	270	35	15	None
ST2	55	65/70	60	12	6	None
LT5	47	58/63	200	38	16	None
ST3	55	65/73	55	13	4	None
LT6	43	59/64	220	20	9	None
2nd Street and 14th Street[2]						
LT7	53	64/69	50	10	4	None
ST4	52	65/75	60	8	2	None
14th Street and Rocketts Landing[1]						
ST5	54	65/75	40	8	2	None
ST6	56	65/72	32	8	3	None
LT8	47	57/63	130	26	11	None
LT9	54	65/70	40	8	4	None
ST7	59	65/70	25	10	5	None

Notes: [1] Mixed Traffic Operations; [2] Curb Running Operations

Source: Parsons, 2011.

TABLE 4-2: SUMMARY OF NOISE IMPACTS FOR CATEGORY 3 LAND USES FOR THE BUILD ALTERNATIVE

Site No.	Noise Level due to Project, Leq (dBA)	Noise Impact Criteria (Moderate/Severe) Leq (dBA)	Site Distance from Centerline of Alignment/ Guideway (ft)	Distance to Moderate Impact (ft)	Distance to Severe Impact (ft)	Impact
Willow Lawn to I-195[1]						
LT1	56	66/71	40	9	4	None
I-195 and 2nd Street[1]						
LT3	44	63/68	260	15	6	None
LT4	44	64/69	270	13	5	None
ST2	54	68/73	60	7	3	None
ST3	54	69/74	55	5	2	None
LT6	42	65/70	220	7	3	None
2nd Street and 14th Street[2]						
LT7	52	69/74	50	3	2	None
ST4	51	70/78	60	3	1	None
14th Street and Rocketts Landing[1]						
ST5	53	70/78	40	3	1	None
ST6	55	70/78	32	3	1	None
LT8	46	65/70	130	7	3	None
LT9	53	70/78	40	3	1	None
ST7	58	67/72	25	6	3	None

Notes: [1] Mixed Traffic Operations; [2] Curb Running Operations
Source: Parsons, 2011.

There are no severe or moderate noise impacts predicted for the operations of the Build Alternative.

Construction noise varies greatly depending on the construction process, type and condition of equipment used, and layout of the construction site. Many of these factors are traditionally left to the contractor's discretion, which makes it difficult to accurately estimate levels of construction noise. Overall, construction noise levels are governed primarily by the noisiest pieces of equipment. The engine, which is usually diesel, is the dominant noise source for most construction equipment.

Table 4-3 summarizes typical construction noise emission levels (L_{max}) of construction equipment operating at full power at a reference distance of 50 feet, and an estimated equipment usage factor (UF) based on experience with other similar construction projects. The usage factor is a fraction that accounts for the total time during an eight-hour day in which a piece of construction equipment is producing noise under full power. Although the noise levels in Table 4-3 represent typical values, there can be wide fluctuations in the noise emissions of similar equipment. Distance (D) is also considered in the construction noise analysis. In all areas between the BRT alignment and sensitive receptors, a ground factor (G) of 0.0 was used. This factor represents an acoustically hard ground cover, which represents the ground effect as the sound propagates from the source to the receptor. The calculation used to determine average construction noise exposure for each piece of equipment is based on the above factors using the following equation:

$$L_{eq} = L_{max} + 10 \text{ Log(UF)} – 20 \text{ Log(D/50)} – 10 \text{ G Log(D/50)}$$

where:

L_{eq} is the 8-hour average noise level in A-weighted decibels, dBA,
L_{max} is the maximum noise level at 50 feet in A-weighted decibels, dBA,
UF is the usage factor of the construction equipment,
D is the distance to the affected noise sensitive area, and
G is the ground factor characterizing the sound absorption of the ground between the source and the receiver.

After calculating the noise exposure for each piece of equipment, the noise exposures for all equipment being used in a construction stage were combined together to assess the total noise level.

TABLE 4.3: ESTIMATED CONSTRUCTION NOISE LEVELS

Equipment Type	Max Equip. Noise Level at 50 ft (dBA)	8 Hour Equivalent Noise Level at 25 ft (dBA[1])	8 Hour Equivalent Noise Level at 50 ft (dBA[1])	8 Hour Equivalent Noise Level at 75 ft (dBA[1])
Curb and Gutter				
Excavator	83	84	78	74
Front Loader	76	77	71	67
Heavy Duty Dump Trucks	77	75	69	65
Combined L_{eq} (h)	--	85	79	76
Grading				
Excavator	83	84	78	74
Backhoe	75	76	70	66
Front Loader	76	77	71	67
Blade	77	78	72	68
Asphalt Cutter	81	79	73	69
Heavy Duty Dump Trucks	77	75	69	65
Combined L_{eq} (h)	--	86	80	77
Paving				
Smooth Drum Roller	76	74	68	64
Backhoe	75	76	70	66
Asphalt Paver	79	81	75	71
Ready Mix Trucks	81	82	76	72
Heavy Duty Dump Trucks	77	75	69	65
Flatbed Truck	70	65	59	55
Combined L_{eq} (h)	--	86	80	76

Source: Parsons, 2011.
Notes: [1]Predicted noise levels are from the center of the construction activity. Noise levels shown represent typical values; however, there can be wide fluctuations in the noise emissions of similar equipment.

The equipment noise levels within a particular construction stage were combined together to obtain a total noise exposure for each stage; however, it would not be appropriate to combine noise levels of different stages because the different stages would not occur at the same time in a given area. Because of the distance between the closest noise-sensitive receptors and the construction site could be as close as 25 ft, the trucks and machinery used for construction produce noise may affect some land uses and activities during the construction period. Individuals inhabiting the homes along the project corridor would at some time experience perceptible construction noise from implementation of the project.

TABLE 4.3: ESTIMATED CONSTRUCTION NOISE LEVELS

Equipment Type	Max Equip. Noise Level at 50 ft (dBA)	8 Hour Equivalent Noise Level at 25 ft (dBA[1])	8 Hour Equivalent Noise Level at 50 ft (dBA[1])	8 Hour Equivalent Noise Level at 75 ft (dBA[1])
Curb and Gutter				
Excavator	83	84	78	74
Front Loader	76	77	71	67
Heavy Duty Dump Trucks	77	75	69	65
Combined L_{eq} (h)	--	85	79	76
Grading				
Excavator	83	84	78	74
Backhoe	75	76	70	66
Front Loader	76	77	71	67
Blade	77	78	72	68
Asphalt Cutter	81	79	73	69
Heavy Duty Dump Trucks	77	75	69	65
Combined L_{eq} (h)	--	86	80	77
Paving				
Smooth Drum Roller	76	74	68	64
Backhoe	75	76	70	66
Asphalt Paver	79	81	75	71
Ready Mix Trucks	81	82	76	72
Heavy Duty Dump Trucks	77	75	69	65
Flatbed Truck	70	65	59	55
Combined L_{eq} (h)	--	86	80	76

Source: Parsons, 2011.
Notes: [1]Predicted noise levels are from the center of the construction activity. Noise levels shown represent typical values; however, there can be wide fluctuations in the noise emissions of similar equipment.

4.2 VIBRATION

An assessment was conducted using the FTA guidelines for both operational and construction period vibration.

No Build Alternative

Vibration effects would not result under the No Build Alternative as a result of the Broad Street Rapid Transit Project.

Build Alternative

Significant vibration impact from rubber tire-fitted vehicles is extremely rare. This is because rubber tire-fitted vehicles are not as massive as railway vehicles. They are additionally typically well-isolated by the vehicle suspension design and rubber tires which act as a highly effective barrier to vibration transmission from the vibration-generating carriage and the main propagation medium for vibration excitation, the ground. Potential vibration impact from rubber tire-fitted vehicles such as those used in BRT projects can be reasonably dismissed under general conditions (FTA, 2006). No further assessment is needed for vehicle induced vibration.

Two types of construction vibration impact were analyzed: (1) human annoyance and (2) building damage. Human annoyance occurs when construction vibration rises significantly above the threshold of human perception for extended periods of time. Building damage can be cosmetic or structural. Fragile buildings such as historical structures are generally more susceptible to damage from ground vibration. Normal buildings that are not particularly fragile would not experience any cosmetic damage (e.g., plaster cracks) at distances beyond 30 feet based on typical construction equipment vibration levels. This distance can vary substantially depending on the soil composition and underground geological layer between vibration source and receiver. In addition, not all buildings respond similarly to vibration generated by construction equipment. The potential for vibration annoyance and building damage was analyzed for major vibration producing construction equipment that would be used on this project.
Vibration levels produced by construction equipment were obtained from Transit Noise and Vibration Impact Assessment (FTA, 2006) and from field measurements (See Table 4-4). Based on these levels and consideration of the criteria, calculations were performed to determine the distances at which vibration impacts would occur. Table 4-5 shows the results of those calculations. The distances listed in Table 4-5 are the maximum distances at which short-term construction vibration impacts may occur. Mitigation measures would need to be considered if construction equipment were to operate near wood-framed buildings within the distances shown in Table 4-5.
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TABLE 4-4: VIBRATION SOURCE LEVELS FOR CONSTRUCTION EQUIPMENT

Equipment	PPV[1] at 25 feet (in/sec)	Approximate Velocity Level[2] at 25 ft (VdB)
Large bulldozer	0.089	87
Loaded trucks	0.076	86
Vibratory compactor/roller	0.210	94

Source: USDOT, 2006.
Note:

1. Peak particle ground velocity measured at 25 feet unless noted otherwise.
2. RMS ground velocity in VdB referenced to 1 micro-inch/second.

TABLE 4-5: CONSTRUCTION EQUIPMENT VIBRATION IMPACT DISTANCES

Equipment	Distance to Vibration Annoyance [1] feet	Distance to Vibration Building Damage [2] feet
Large bulldozer	43	15
Loaded trucks	40	13
Vibratory compactor/roller	73	26

Notes:

1. This is the distance at which the RMS velocity level is 80 VdB or less at the inside of the building structure. When propagating from the ground surface to the building structure foundation, there is a vibratory coupling loss of approximately 5 dB; however, this loss is offset by the building amplification in light-frame construction. Thus, no additional adjustments are applied.
2. This is the distance at which the peak particle velocity is 0.20 inch/sec or less.

-- Distance is less than 10 feet.

5 MITIGATION

This section discusses the possible mitigation measures that can be implemented to either reduce or mitigate the impacts generated by the construction of the proposed project. Due to lack of impacts, noise and vibration mitigation measures for project operation are not considered necessary.

5.1 MITIGATION DURING CONSTRUCTION

Noise and vibration impacts caused by construction activities are temporary and intermittent. However, standard construction mitigation measures may be required to minimize these impacts. Construction activities conducted during daytime hours will have a lesser impact than nighttime construction. However, there may be locations where nighttime construction would be unobtrusive, such as commercial areas where the land use is unoccupied during nighttime hours, or industrial areas that are generally not sensitive to noise and vibration. Nighttime construction may be necessary to avoid unacceptable disruptions to current rail operations or street traffic during daytime hours. Once details of the construction activities become available, the contractor would need to work with local authorities to develop an acceptable approach to minimize interference with the business and residential communities, traffic disruptions, and the total duration of the construction.

There are a number of measures that can be taken to minimize intrusion without placing unreasonable constraints on the construction process or substantially increasing costs. These include noise and vibration monitoring to ensure that contractors take all reasonable steps to minimize impacts when near sensitive areas; noise testing and inspection of equipment to ensure that all equipment on the site is in good condition and effectively muffled; and an active community liaison program. The community liaison program should keep residents informed about construction plans so they can plan around periods of particularly high noise or vibration levels and should provide a conduit for residents to express any concerns or complaints.

Standard construction mitigation measures may be required to address the temporary and intermittent noise and vibration caused by construction activities. The following are possible control measures that can be implemented in order to minimize noise and vibration disturbances at sensitive areas during construction:

- Use of newer equipment with improved noise muffling and ensuring that all equipment items have the manufacturers' recommended noise abatement measures, such as mufflers, engine covers, and engine vibration isolators intact and operational.
- Inspection of equipment on a regular basis to ensure proper maintenance and presence of noise control devices (e.g., mufflers and shrouding, etc.).
- Performing construction in a manner to minimize noise and vibration. Utilize construction methods or equipment that will provide the lowest level of noise and ground vibration impact. The contractor should be required to select construction processes and techniques that create the lowest noise levels.

- Performing independent noise and vibration monitoring to demonstrate compliance with the noise limits, especially in particularly sensitive areas. Requiring contractors to modify and/or reschedule their construction activities if monitoring determines that maximum limits are exceeded at residential land uses.
- Conducting truck loading, unloading and hauling operations so that noise and vibration are kept to a minimum by carefully selecting routes to avoid going through residential neighborhoods to the greatest extent possible.
- Limiting use of construction equipment that creates high vibration levels, such as vibratory rollers and hammers, operating within 75 feet of occupied building structures.
- Constructing lay-down or staging areas should be selected in industrially zoned districts. If industrially zoned areas are not available, commercially zoned areas may be used, or locations that are at least 100 feet from any noise sensitive land use such as residences, hotels and motels. Ingress and egress to and from the staging areas should be on collector streets or greater (higher street designations are preferred).
- Turning off idling equipment.
- Minimizing construction activities during evening, nighttime, weekend, and holiday periods.

It is expected that ground-borne vibration from construction activities would cause only intermittent localized intrusion along the project corridor. Processes such as earth moving with bulldozers, the use of vibratory compaction rollers can create annoying vibration. There are cases where it may be necessary to use this type of equipment in close proximity to residential buildings. Following are some procedures that can be used to minimize the potential for annoyance or damage from construction vibration:

- When possible, limit the use of construction equipment that creates high vibration levels, such as vibratory rollers and hammers, operating within 75 feet of occupied building structures.
- Require vibration monitoring during vibration-intensive activities.
- Restrict the hours of vibration-intensive equipment or activities such as vibratory rollers so that impacts to residents are minimal (e.g., weekdays during daytime hours only when as many residents as possible are away from home).

A combination of the mitigation techniques for equipment noise and vibration control as well as administrative measures, when properly implemented, can be selected to provide the most effective means to minimize the effects of construction activity impacts. Application of the mitigation measures will reduce the construction impacts; however, temporary increases in noise and vibration would likely occur at some locations.

6 REFERENCES

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