FEASIBILITY STUDY

I-77 from I-85 to Griffith Street

Mecklenburg County

Division 10

FS-0810B

Task Order No. 3

Use of I-77 Shoulders for Travel Lanes

Shoulder Operations Plan

Prepared For:

N.C. Department of Transportation

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1.0 INTRODUCTION

1.1 Purpose of Task Order No. 3

The purpose of Task Order No. 3 of the I-77 Feasibility Study was to determine the advisability and feasibility of converting the shoulders along I-77 to travel lanes for general purpose traffic on either a part-time or full-time basis. The study area covered the portion of I-77 between I-485 (Exit 19) and Catawba Avenue (Exit 28) in Cornelius. The Task Order identified operating strategies, design modifications, benefits and costs associated with I-77 shoulder use.

1.2 National Experience

1.2.1 Dedicated Shoulder Lanes

Since the 1950 publication of the *Highway Capacity Manual* and the 1957 *AASHTO Red Book*, 12-foot shoulders have been the interstate design standard for urban freeways. A minimum lateral clearance of four and one-half feet is required with six to eight feet recommended in the vicinity of pier structures. By the 1980s, many states began to use dedicated shoulder lanes, sometimes in conjunction with reduced lane widths, to address rising congestion and a lack of right-of-way for freeway widening. By the 1990s, four states used shoulders and/or narrow lanes extensively on freeways: California (Los Angeles and the San Francisco-Oakland areas), Texas (Houston), Virginia (Fairfax County) and Washington (Seattle).

The Minnesota Department of Transportation (Mn/DOT) used the shoulders along a portion of I-94 in Minneapolis to accommodate additional traffic from re-routing motorists from I-35W after the bridge collapse in 2007. The department resurfaced I-94, re-marked traffic lanes to 11 feet, and eliminated bus-only shoulder operations to provide four lanes of capacity in each direction. Mn/DOT added loop detection to this I-94 segment to monitor conditions in the new fourth lane obtained from shoulder conversion. The department completed the project over a weekend to minimize traffic disruption during weekday peak periods. The shoulder conversion enabled Mn/DOT to move an additional 1500 vehicles during the peak hour. **Figure 1-1** shows before and after conditions of eastbound I-94 at 25th Avenue.

Figure 1-1: Before and After Photos for I-94 in Minneapolis

For dedicated shoulder operations, either general purpose or high-occupancy vehicle (HOV) capacity has been added through permanent shoulder conversion. Most HOV applications use the interior lane for HOV operations while the outside shoulder is used by general purpose traffic in order to maintain the same number of general purpose lanes which existed prior to conversion. A typical HOV application would convert a three-lane freeway with 12-foot lanes, a 14-foot outside shoulder, and an 10-foot inside shoulder to three 11-foot general purpose lanes, a 11-foot HOV lane, a two-foot buffer separation, a 10-foot outside shoulder and a four-foot inside shoulder.

Other uses of shoulders in the United States include:

- To provide auxiliary lanes either between interchanges or in merge zones, particularly those that impeded upstream traffic on the mainline
- To provide exclusive lanes for transit operations
- To meet lane balancing requirements through bottlenecks
- To create uniform lane widths

In some instances, the implementing agency permits general purpose traffic to use the shoulders during peak periods only. The Virginia Department of Transportation (VDOT) allows general purpose traffic to use the shoulders along I-66 from 5:30 to 11:00AM in one direction and from 2:00 to 8:00PM in the reverse direction on weekdays (**Figure 1-2**). During this time, the interior general purpose lane is available only for HOV traffic. Extensive traffic signals and signage is used to inform motorists of the times when the shoulder is available for travel. In Massachusetts, all vehicles are permitted to use the shoulders along state highways 3 and 128 around Boston during peak periods only.

1.2.2 Bus on Shoulders

Bus on Shoulders (BOS) programs are a special-use application of dedicated shoulder lanes. They are often implemented as a means of increasing transit service reliability in congested corridors in order to encourage greater use by the public. This type of program has been implemented on 290 miles of freeways and arterials in the Minneapolis metropolitan area. As shown by **Figure 1-3**, BOS is an operational strategy that is relatively low-cost and quick to implement.

Figure 1-2: I-66 in Virginia HOV/Shoulder Use Adaptation

Figure 1-3: Buses on Shoulders in Minneapolis

1.3 Shoulder Use Objectives

The objectives established for Task Order No. 3 which involves the feasibility of allowing general purpose traffic to use shoulders on a part-time or full-time basis included:

- Reduce traffic congestion which, according to North Carolina Department of Transportation (NCDOT) standards, is traffic flowing at speeds below 40 miles per hour.
- Reduce travel time for all I-77 users.
- Operate a safe shoulder facility and preserve the safety of the I-77 general-purpose lanes.
- Maintain an incident clearance time comparable to previous years and the County-wide average for interstate highways.
- Test public acceptance of shoulder conversion to general purpose lanes.

The aforementioned objectives are consistent with those used by Mn/DOT to monitor operations along I-94 when this freeway's shoulders were converted to traffic lanes.

1.4 Measures of Effectiveness

In order to assess the objectives quantitatively, measures of effectiveness (MOEs) are applied based on available traffic and design data and forecasted operation and design conditions.

Planning level data associated with an I-77 shoulder operations would include:

- **Design** – Ability to convert a shoulder to a general purpose lane, ability for the design to permit incident response, and costs and impacts associated with the shoulder conversion.

- **Operations** – Forecast changes in congestion, travel time and speed for shoulder users and general purpose traffic.
- **Safety** – Comparison of various operational and design attributes that can influence safe operation, ability to respond to incidents, based on current and proposed concepts.
- **Agency and Public Attitudes** – Public perceptions of what would constitute project success. This would include results of affected federal, state and local agencies, focus group interviews and citizen surveys, phone calls, internet email comments, etc.

Table 1-1 provides a list of MOEs which will be applied to each objective using available data sources.

Table 1-1: Matrix of Shoulder Conversion Objectives, MOEs and Data Sources

Objective	Measures of Effectiveness (MOEs)	Data Source
Ability of design to accommodate shoulder operation	Review of current design, pavement condition, costs to modify	Corridor as-built plans, field data, cost estimate data for ITS and unit quantities.
Reduce congestion	Travel demand and speeds	Forecasted shoulder lane and general purpose lane demand; travel speeds in peak hours
Reduce travel time	Comparative forecast travel times	Forecasted shoulder lane and general purpose lane travel times for peak hour
Operate a safe facility	Ability to provide emergency pull-out refuge areas	Corridor as-built plans compared to concept plans to convert shoulder to general purpose lane
	Transitions at termini-impacts to general purpose traffic	Shoulder and general purpose forecasted demand and weaves created by conversion concept
	Crossover conflicts at ramps	Number and level of crossover demand
	Traffic control device requirements	Comparative cost among concepts versus “do-nothing” alternative
	Design exceptions	Comparison of corridor as-built plans to concept plans to convert shoulder to general purpose lane
	Ability to maintain left side shoulder for emergency breakdowns and emergency vehicle access	Comparison of concepts
	Costs and environmental impacts	Cost estimates and identified environmental issues
	Crashes, crash rate & injury severity	Law enforcement DMV 349 reports and Mobility & Safety’s Traffic Safety Systems Section

Table 1-1: Matrix of Shoulder Conversion Objectives, MOEs and Data Sources (Continued)

Objective	Measures of Effectiveness (MOEs)	Data Source
Maintain acceptable incident clearance times	Incident frequency	Incident logs, TIMS & law enforcement records for existing determination. This rate is compared with future demand (extrapolated forward using number of anticipated minor/major incidents per million vehicle miles forecast)
Agency and public support	Agency attitudes	Feedback from Mecklenburg Traffic Incident Management Team; focus groups and one-on-one interviews
	Public attitudes	Citizen focus groups; telephone or web surveys

1.5 Enabling Legislation

Section 20-146.2 (b) of North Carolina General Statutes addresses *Temporary Peak Traffic Shoulder Lanes*:

> *"The Department of Transportation may modify, upgrade, and designate shoulders of controlled access facilities and partially controlled access facilities as temporary travel lanes during peak traffic periods. When these shoulders have been appropriately marked, it shall be unlawful to use these shoulders for stopping or emergency parking. Emergency parking areas shall be designated at other appropriate areas, off these shoulders, when available."*

1.6 Organization and Content

This task order's report includes the following:

- Chapter 2 – Agency Coordination – discusses coordination efforts among agency partners during the performance of Task Order No. 3.
- Chapter 3 – Freeway Design and Access – describes the modifications and improvements at a conceptual level for allowing general purpose traffic to use I-77 shoulders between I-485 (Exit 19) and Catawba Avenue (Exit 28). This chapter reviews design elements such as design principles, typical section, signing and marking concepts, access, lane transitions and costs.
- Chapter 4 – Operations – reviews eligibility policies, operating hours, and the results of CORSIM traffic simulation modeling for shoulder operations.
- Chapter 5 – Maintenance – identifies potential maintenance issues associated general purpose traffic using I-77 shoulders.
- Chapter 6 – Traffic Management, Enforcement and Incident Management – recommends changes to existing I-77 interfaces with NCDOT's Metrolina Regional Traffic Management Center (MRTMC) if shoulder operations are implemented. The chapter also reviews enforcement needs and coordination with current incident management plans.

- Chapter 7 – Appendices – includes preliminary sign and markings plans for I-77 shoulder use and a series of lane diagrams that show the results of the CORSIM simulation analyses along the I-77 corridor.

2.0 AGENCY COORDINATION

The following federal, state and local agencies were involved in the work activities of Task Order No. 3 of the I-77 Feasibility Study:

- **NCDOT.** The agency is the owner, designer and operator of I-77 and directed Task Order No. 3 through the Feasibility Studies Unit of its Planning and Programming Branch. Staff members from various NCDOT branches and units participated in this planning project. NCDOT's MRTMC manages traffic operations along I-77, including response to traffic incidents and special events. NCDOT's Incident Management Assistance Patrol (IMAP) provides assistance to motorists involved in traffic accidents or vehicle break-downs. The North Carolina Turnpike Authority (NCTA) is the NCDOT operating division authorized to collect tolls on turnpike projects in the state.
- **Federal Highway Administration (FHWA).** This federal department is a partnering agency that is responsible for overseeing the design and operation of the federal aid highway system, which includes I-77.
- **North Carolina State Highway Patrol (NCSHP).** This state department is the primary enforcement agency for I-77.
- **City of Charlotte.** The Charlotte Department of Transportation (CDOT) partners with NCDOT in highway operations planning. The City's Fire and Police Departments respond to emergencies along I-77 and participate in meetings and activities of the Mecklenburg County Traffic Incident Management Team.
- **Towns of Huntersville, Cornelius and Davidson.** These towns, which are located within the I-77 study area, also participate in meetings and activities of the Mecklenburg County Incident Management Team. Town enforcement agencies would respond to incidents and accidents occurring along I-77.

2.1 Coordination during Task Order No. 3

Throughout Task Order No. 3, a technical team provided input on study results and recommendations. The Technical Study Committee (TSC) consisted of representatives of the following agencies:

- NCDOT
- FHWA
- CDOT

The TSC met during the task order to review progress, discuss preliminary recommendations and offer suggestions. Technical committee members also served as study liaisons to their respective agencies.

On July 29, 2009, the Traffic Incident Management Team was briefed on Task Order No. 3 in order to obtain input from enforcement agencies and emergency responders on using shoulders for general purpose traffic.

3.0 FACILITY DESIGN AND ACCESS

This chapter describes the design features using I-77 shoulders for travel lanes. Task Order No. 3 examined the options of full-time or part-time shoulder use.

3.1 Design Principles for Shoulder Use

The design principles used for the I-77 shoulder use are based on what was implemented along I-66 in Virginia and I-94 in Minneapolis. When shoulder use lanes are active, vehicles traveling in the shoulder along I-77 will travel across entrance and exit ramps just as they would if they were in general purpose travel lanes. Design modifications on the shoulder will be made where fixed objects are adjacent to the shoulders (such as providing barriers at bridge piers) and/or modifying the length of ramp acceleration/deceleration lanes. .

Emergency pull-outs will be added help to improve safety and reduce travel disruption when shoulders are used to move general purpose traffic. The frequency of I-77 pull-outs depends on the length where shoulder operations are permitted and possible locations where it is safe to get off the shoulder. I-66 in Virginia includes both formal and "informal" pull-outs with the latter being locations where traffic can get off the shoulder and into a safe area. These pull-off areas are spaced (on average) at a frequency of one every three-quarters of a mile. The I-77 implementation replicates this spacing with formal emergency refuge areas of 300 feet in length (plus ingress and egress tapers) spaced every 4,000 feet.

3.2 Typical Section

Figure 3-1 illustrates the typical cross sections based on 1) total re-construction of the shoulder or 2) an overlay of the existing pavement. **Figure 3-2** shows a typical plan view of the paved and unpaved emergency refuge areas to be installed along I-77 as needed.

Figure 3-1: Typical Cross Section

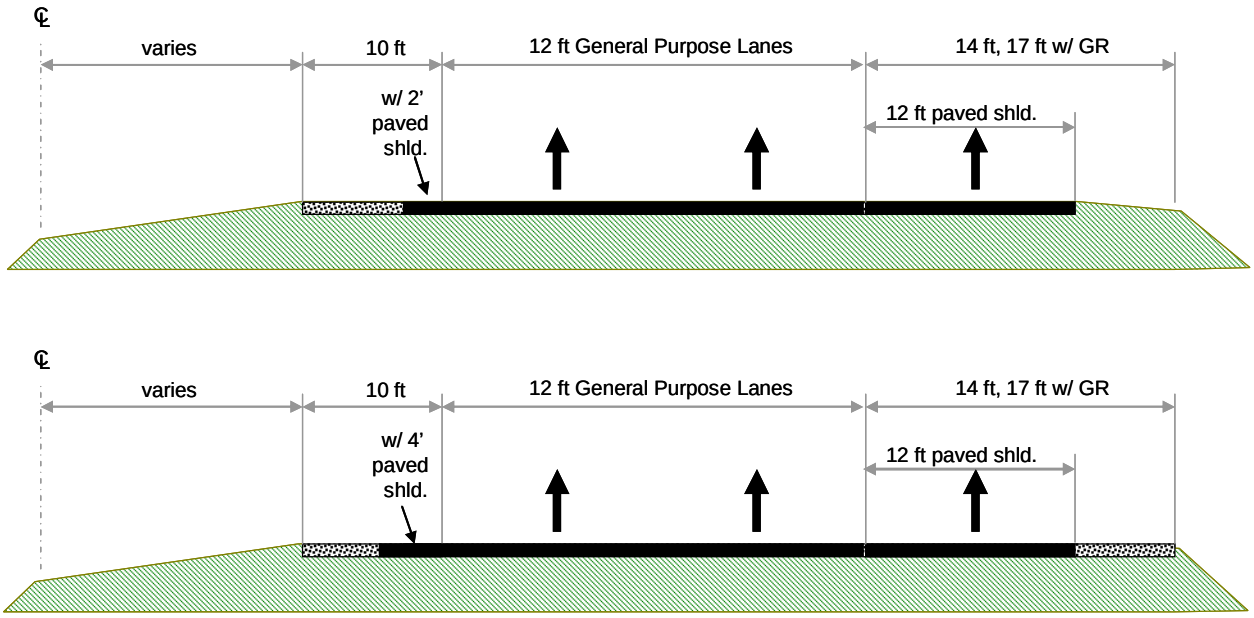
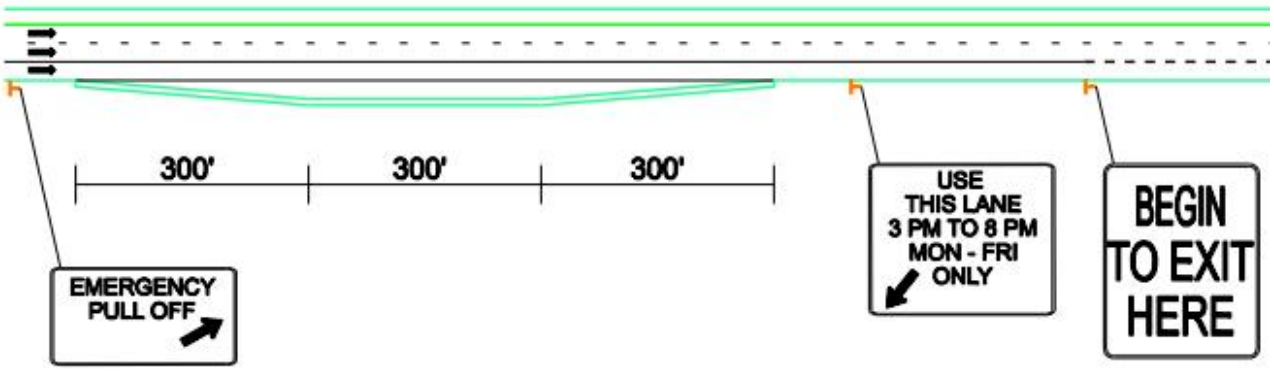


Figure 3-2: Typical Shoulder Refuge Area



3.3 Trade-offs in Accommodating Design Principles

Shoulder use lane projects often raise safety concerns. Several studies and crash history reports that safety concerns are often overstated. Safety depends highly on design and lighting conditions and the responsiveness of highway motorist assistance programs.

- A VDOT crash history study on I-66 shoulder use operations have shown there's no significant difference in crashes on I-66 when the shoulder is open and when it's closed[1].
- A 2008 Transportation Research Board study of the impact of using right-side shoulders for managed lane operations concluded that managed-lane strategies do not appear to significantly impact crash frequency on general purpose lanes or right-side shoulders [2]. This study also showed a higher statistical accident rates in locations with poor lighting conditions.

With the number of emergency pull-offs and an aggressive Incident Management Assistance Patrol (IMAP) program where shoulder use lanes are proposed, there is no evidence that there will be a significant negative safety impact to vehicles traveling on I-77.

3.4 Access and Termini Treatments

Based on the 2013 traffic volumes and CORSIM analysis, the appropriate limits of shoulder use lanes are:

- Northbound: from Exit 23, Gilead Road (lane would continue north instead of dropping at Gilead Road north of I-485) through Exit 28, Catawba Avenue (end as exit-only lane at this interchange)

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[1] Washington Post; Virginia Extending Shoulder Use on I-66; August 8, 2008

[2]; Safety Impacts of Freeway Managed-Lane Strategy: Inside Lane for High-Occupancy Vehicle Use and Right Shoulder Lane as Travel Lane during Peak Periods; Transportation Research Record 0361-1981 (2008)

- Southbound: from the Exit 28, Catawba Avenue, on-ramp though the addition of lanes north of Exit 19, the I-485 interchange

Determination of these limits was based on the high entry and exit volumes at Exit 28. With this improvement, the segments north of Exit 28 would operate at acceptable conditions.

3.5 Signing and Pavement Markings

For temporary shoulder use, overhead regulatory signs in combination with dynamic lane control signals would be installed. These overhead signs and traffic controls would be similar to VDOT's installations along I-66 and would be supplemented by ground-mounted regulatory signs providing 1) hours of operation, 2) locations of emergency pull-offs, and 3) beginning and ending locations of part-time shoulder operations. The pavement markings would be no different than normal travel lane to shoulder edge line marking except for additional or modified skip striping at ramp merge/diverge areas.

For full-time shoulder use, ground-mounted regulatory signs would be added to notify motorists of 1) the prohibition of stopping on the shoulder, 2) locations of emergency pull-offs, and 3) beginning and ending locations of shoulder operations. The pavement markings would be a single white skip line just like the rest of the general purpose lane markings.

Appendix A shows the types of signs that would be used for shoulder operations.

3.6 Illumination

In addition to standard illumination at ramps and within interchange areas, illumination is recommended at the termini of the shoulders where general purpose traffic is allowed, particularly if full-time shoulder use lanes are implemented.

3.7 Capital Costs

3.7.1 Methodology Overview

Construction cost estimates for replacing the existing shoulder along I-77 used cost data from NCDOT's latest construction cost index, and estimates are provided in current year dollars. NCDOT staff approved the construction cost estimates, projected quantities, and unit prices. Estimates were prepared for full-time and part-time shoulder use.

3.7.2 Cost Estimates

Table 3-1 summarizes estimated capital costs for the shoulder use option. There are two sets of costs: minimum cost that does not require rebuilding the shoulder and a cost that assumes a full rebuilding of the shoulder. These costs were based on shoulder improvements between Exit 19 and Exit 28. All costs are expressed in 2009 dollars.

Table 3-1: Capital Costs (2009 Dollars)

Description	Full-Rebuild	No-Rebuild
Clearing and Grubbing	780,000	100,800
Fine Grading	174,000	16,050
Pavement Widening	5,252,000	556,400
Pavement Resurfacing	1,474,200	2,001,300
Fencing	-	-
Erosion Control	1,406,400	810,000
Signing Interchanges	-	-
Shoulder Use Specific Signing	500,000	500,000
Traffic Control	2,243,500	-
Thermo and Markers	192,300	192,300
Utility Construction	-	-
Misc. & Mob (45% Functional)	5,410,080	1,879,583
Contract Cost	17,432,480	6,056,433
E. & C. 15%	2,614,872	908,465
Construction Cost	**20,047,352**	**6,964,897**

4.0 OPERATIONS

This chapter presents the operating policies which could be applied for the use of I-77 shoulders as travel lanes. These policies would vary based on whether the shoulders are used on a full-time or part-time basis.

4.1 User Requirements

I-77 shoulders would be open to all vehicles except a motor vehicle with three or more axles. Trucks would only use the shoulder in order to get on or off I-77 at I-485 (Exit 19), Gilead Road (Exit 23), NC-73 (Exit 25) and Catawba Avenue (Exit 28).

4.2 Hours of Operation

The traffic benefits from I-77 shoulder use are primarily realized during peak periods; however, full-time use of the shoulder would remove any driver uncertainty of lane exits and alignments.

4.3 Traffic Operational Analysis

4.3.1 Methodology

Task Order No. 3 included traffic simulation along a freeway network consisting of the segment of I-77 between La Salle Street (Exit 12) and Griffith Street (Exit 30) and the portion of I-85 between Beatties Ford Road (Exit 37) and Statesville Road (Exit 39). The traffic simulation and analysis package used for the analysis was CORSIM, which was developed for the Federal Highway Administration (FHWA). CORSIM has the capability to analyze traffic flows on both freeways and surface street systems and to indicate the effects of additional lanes, transit service, accidents, and on-street parking. The CORSIM simulation package was used to:

- Assess the impact of adding an auxiliary lane to I-77 operations
- Assess the system impacts on a comprehensive scale
- Determine freeway residual impacts, if any, resulting from the proposed freeway modifications

The CORSIM network for Task Order No. 3 was prepared from the base existing conditions network. Using the existing network, the use of shoulders for general purpose traffic was analyzed between I-485 and Catawba Avenue in both directions. These limits were based on input provided by the Technical Steering Committee for the I-77 Feasibility Study. The volumes for this task order came from the Metrolina travel demand model. Traffic analysis was performed based on modeling for possible 2013 opening year conditions which provided AM and PM peak hour volume conditions.

4.3.2 Results and Analysis

Southbound AM Peak Hour

Within the area influenced by the addition of shoulder use lane implementation, the level of service will improve from a level of service “F” to a level of service “D” at on and off ramp locations and from level of service “E” to level of service “C” along the freeway mainline.

The average speed to travel south along the entire CORSIM network between Griffith Street (Exit 30) to La Salle Street (Exit 12) would improve by 8 miles per hour (mph), from 42 mph to 50 mph. Overall vehicular delay time for vehicles traveling along I-77 would drop from 47 minutes to 30 minutes, a reduction of 17 minutes (36 percent).

Northbound PM Peak Hour

For northbound PM peak hour conditions along I-77, the level of service would again improve from a level of service “F” to a level of service “D” at on and off ramp locations and from level of service “E” to level of service “C” along the freeway mainline.

The average speed to travel the entire 18-mile I-77 CORSIM network would improve by 6 miles per hour (mph), from 44 mph to 50 mph. Overall vehicular delay time for vehicles traveling along I-77 would drop from 51 minutes to 35 minutes, a reduction of 16 minutes (31 percent improvement).

Traffic Operations Analysis Lane Diagrams

Appendix B includes a series of lane diagrams that depict the results of the CORSIM simulation analyses along the I-77 corridor. The lane diagrams show forecasted peak hour volumes, projected density and speed for mainline sections and modeled peak hour volumes for entrance and exit ramps.

5.0 MAINTENANCE

NCDOT's Division 10 would be responsible for maintaining the shoulders which would be used for general purpose traffic similar to current operations along existing I-77. Roadway maintenance cost estimates are based on a current State estimate of about $9,000 per lane-mile per year. This cost would cover surface upkeep, sign repair, snow removal, fence repair, landscaping and other related expenses.

Damage to traffic control and safety devices located adjacent to the shoulder would be monitored for increased occurrences. NCDOT procedures used for median maintenance could be adapted for shoulder operations. Part-time traffic operations along shoulders would present less of a problem in conducting ongoing freeway maintenance.

6.0 TRAFFIC MANAGEMENT, ENFORCEMENT AND INCIDENT MANAGEMENT

This chapter highlights changes to existing interfaces between I-77 operations and NCDOT's Metrolina Regional Traffic Management Center (MRTMC) if shoulder use is permitted. The chapter also reviews enforcement needs and coordination with current incident management plans.

6.1 Traffic Management Needs and Points of Interface

NCDOT's MRTMC monitors and manages traffic along the existing I-77 HOV facility using closed circuit television (CCTV) surveillance, out-of-pavement traffic detectors and dynamic message signs (DMS). **Figure 6-1** identifies the location of existing and funded ITS features along I-77.

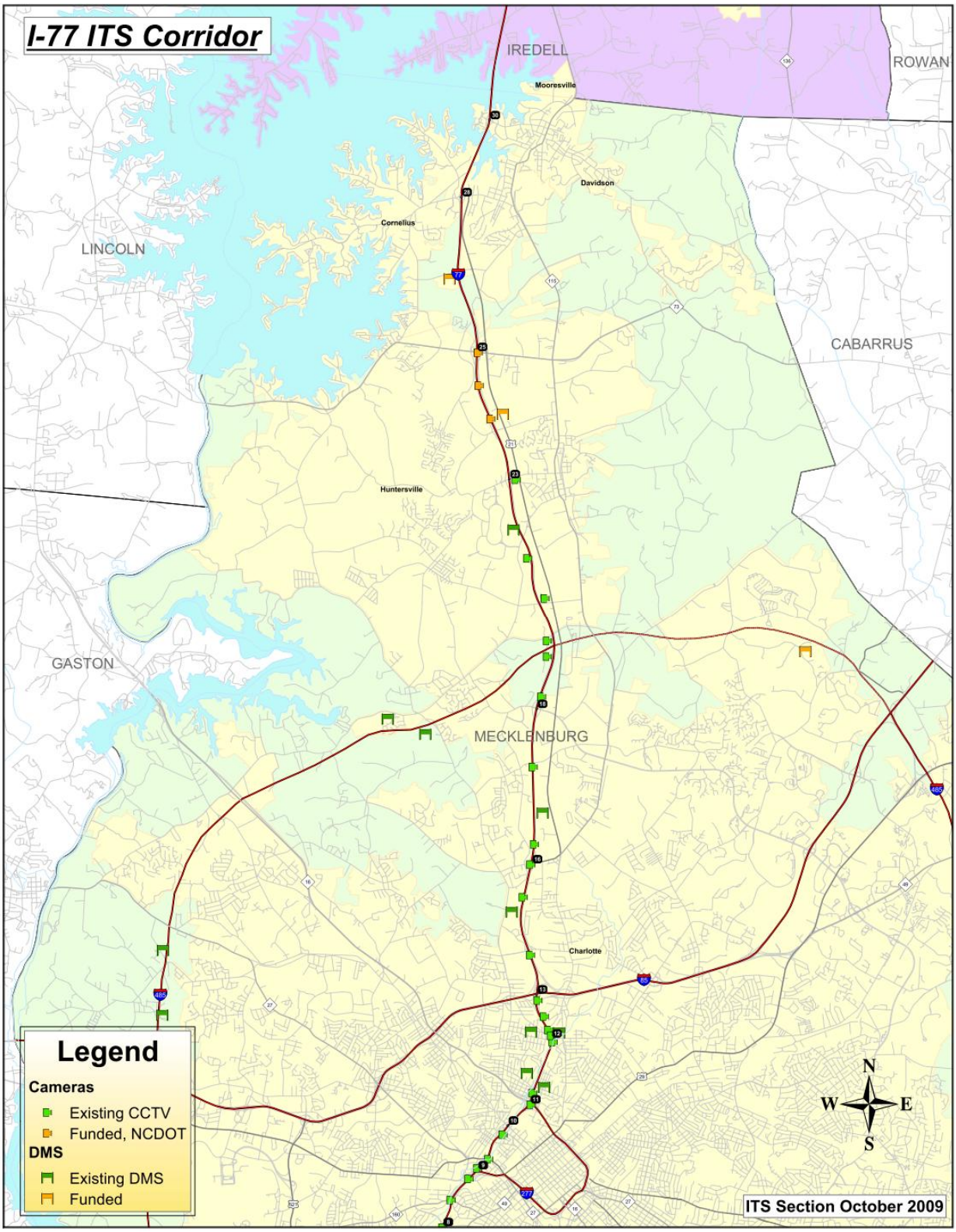
Implementation of the programmed ITS improvements will be integral to maintaining the interface between the MRTMC and the potential shoulder operations. Additional CCTV surveillance and installation of more traffic detectors between NC-73 (Exit 25) and Catawba Avenue (Exit 28) would be helpful to ensure early identification of freeway incidents along any of the I-77 lanes along this segment, particularly on the shoulders. CCTV surveillance under all bridges also is needed.

6.2 Enforcement Needs

As discussed in Chapter 1, Section 20-146.2 (b) makes it unlawful to use shoulders for stopping or emergency parking when they are in use for as travel lanes. Conversely, motorists would be prohibited from traveling along the shoulder during those periods when they are intended for emergency purposes. NCSHP officers would be responsible for monitoring and enforcing I-77 sections where shoulders are in use.

The average cost for an enforcement patrol was estimated at $105,000 per year based on input from the NCSHP. The yearly cost to enforce full-time I-77 shoulder operations is estimated at $120,000, which includes a 15 percent contingency. If part-time shoulder operations are implemented, the equivalent of a patrol assigned to the corridor 50 percent of the time will be necessary to monitor vehicle's stopping when the shoulders are used for travel lanes. Annual enforcement costs would be reduced by half, to $60,000, if this option is selected.

Figure 6-1: Existing and Funded ITS Features



6.3 Incident Management

The Mecklenburg County Incident Management Team would assist in developing procedures for handling different types of traffic incidents along I-77 where shoulders are used by general purpose traffic. Strategies similar to those implemented by the Florida Department of Transportation (FDOT) to maintain safety along I-95 when the inside shoulder of this freeway was converted to a managed lane include:

- Expanded CCTV coverage with dedicated MRTMC staffing to monitor traffic activity along the I-77 sections where shoulders are used and to facilitate quick response to incidents.
- Increased NCSHP presence when shoulders are used by general purpose traffic.
- Dedicated Incident Management Assistance Patrol (IMAP) vehicles to clear breakdowns rapidly. For the Triangle Expressway, a toll facility which is currently under construction, NCDOT/NCTA has contracted with the IMAP for incident management services. NCTA's proposed contract for IMAP services equals about $11,400 per lane-mile annually. A unit cost of 80 percent of this estimate was assumed for I-77 shoulder operations because IMAP service is already being provided along I-77 and the cost to increase service frequency would be less than operating service where it had not been previously provided. Based on a unit cost of $9,200 per year per lane-mile for IMAP service, annual incident management services are estimated at $190,000 along I-77 shoulders between I-485 and Catawba Avenue.
- Information provided to motorists using signage, internet, and other marketing approaches on what to do in the event of an incident. This could include special telephone numbers to notify NCSHP and IMAP.

7.0 APPENDICES

Appendix A shows a typical signs that would be used for shoulder operations. There is very little difference in part-time versus full-time use.

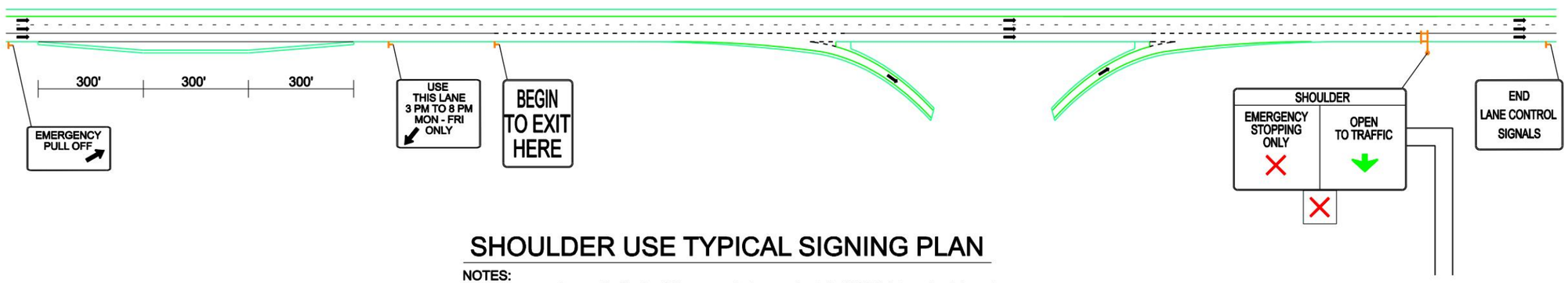
Appendix B includes a series of lane diagrams that depict the results of the CORSIM simulation analyses along the I-77 corridor. The lane diagrams show forecasted peak hour volumes, projected density and speed for mainline sections and modeled peak hour volume for entrance and exit ramps.

Appendix A: Typical Signing Plan for Shoulder Operation

Prepared In the Office of:
PB
121 WEST TRADE STREET
SUITE 1950
CHARLOTTE, NC 28202

SHEET NO.

I-77 SHOULDER USE



SHOULDER USE TYPICAL SIGNING PLAN

NOTES:

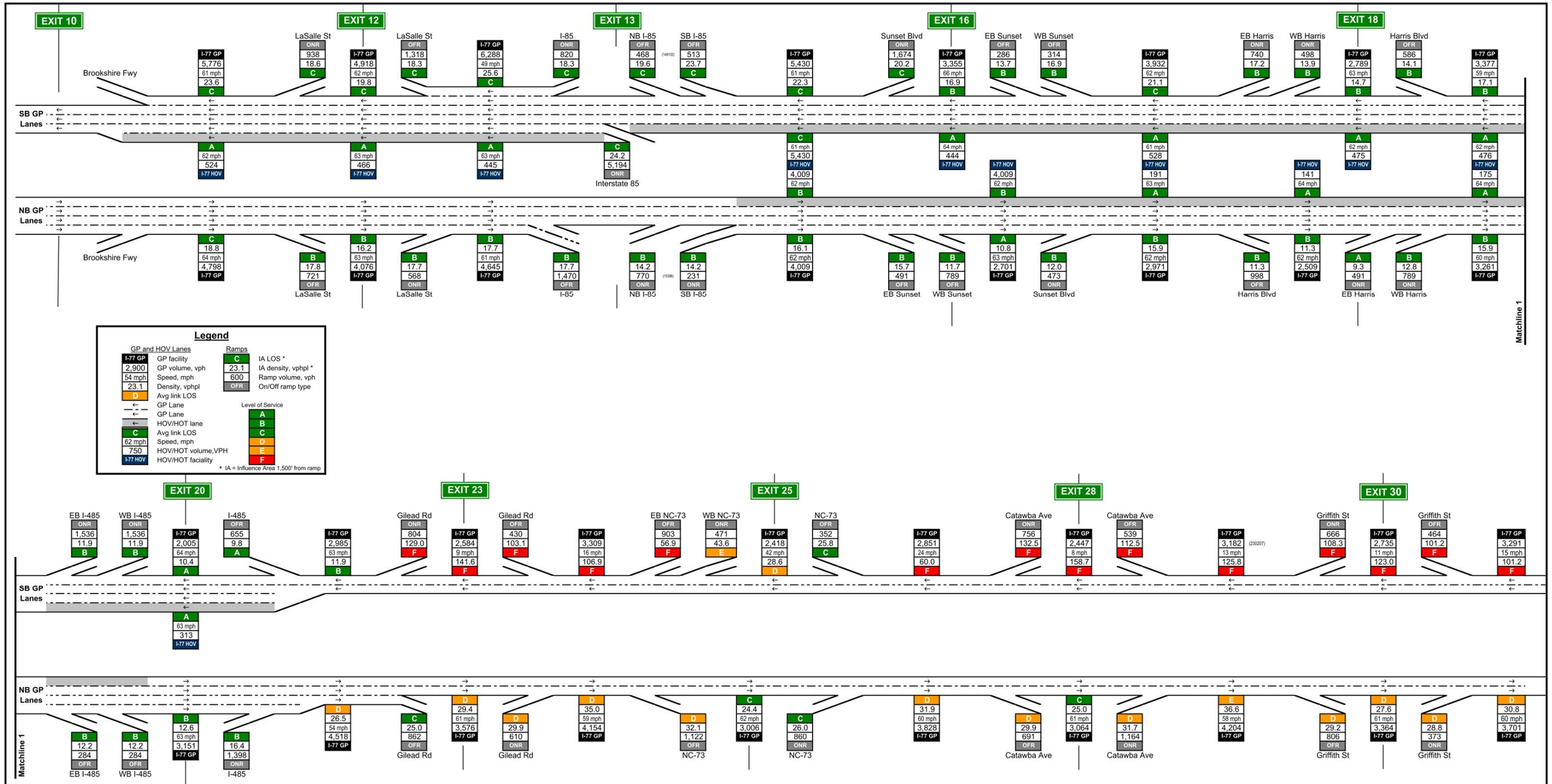
1. Emergency refuge pull-offs should be spaced at approximately 1600 ft. intervals. Adequate distance between ramp terminals, available right of way and existing structures should be considered when selecting pull-off locations.

2. Existing Ramps may be slight modification to ensure adequate acceleration and deceleration distances.

3. For full time shoulder use, striping should be modified similiar to an additional lane. Additional signing is recommended to notify drivers that no breakdown shoulder exists.

I-77 SHOULDER USE SIGNAGE

Appendix B: CORSIM Results



I-77 HOV Study: CORISIM Model Volume Density and Speed Results

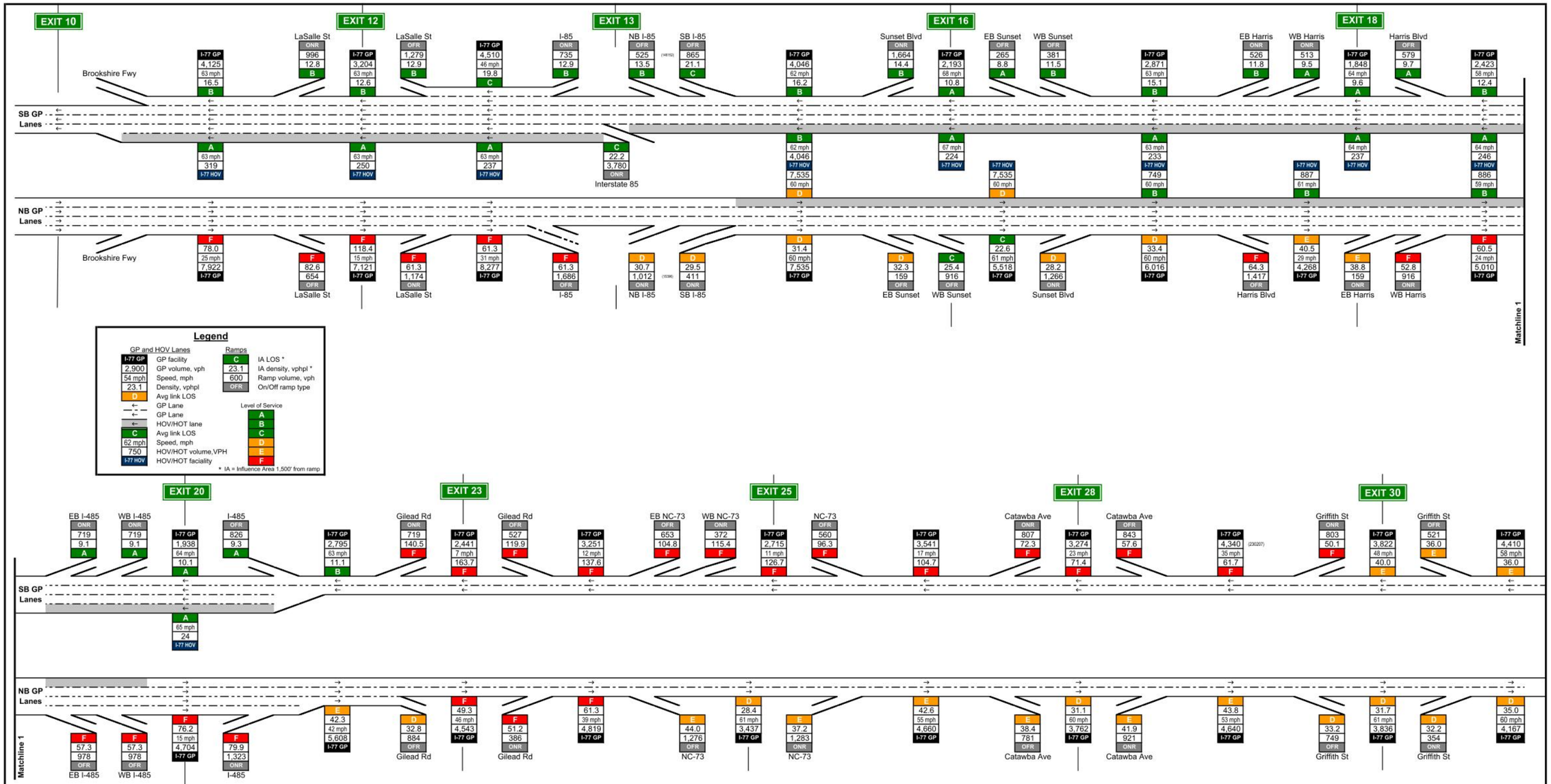
2013 AM No-Build

Figure A-1

Location : I-77 between Exit 10 (Brookshire Freeway) and Exit 30 (Griffith Street)
AM Peak Period (7:00 a.m. to 8:00 a.m.)

Date: October 20, 2009

Created by: Dhiraj Goverdhanam
Approved by: Jonathan Reid



I-77 HOV Study: CORISIM Model Volume Density and Speed Results

2013 PM No-Build

Figure A-2

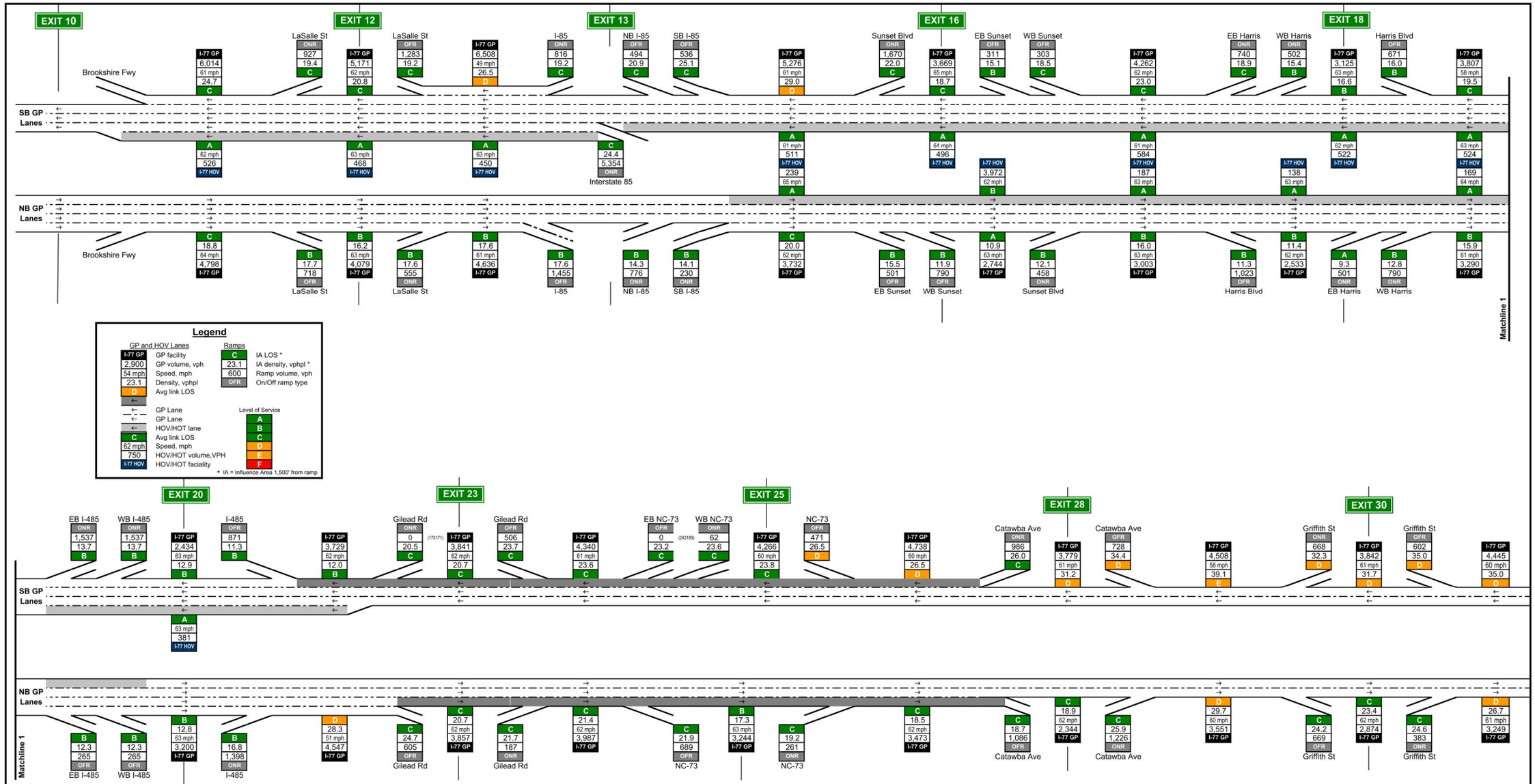
Location : I-77 between Exit 10 (Brookshire Freeway) and Exit 30 (Griffith Street)

PM Peak Period (5:00 p.m. to 6:00 p.m.)

Date: October 20, 2009

Created by: Dhiraj Goverdhanam

Approved by: Jonathan Reid



I-77 HOV Study: CORISIM Model Volume Density and Speed Results

2013 AM (Alt # 1) Shoulder Lane Option

Figure A-3

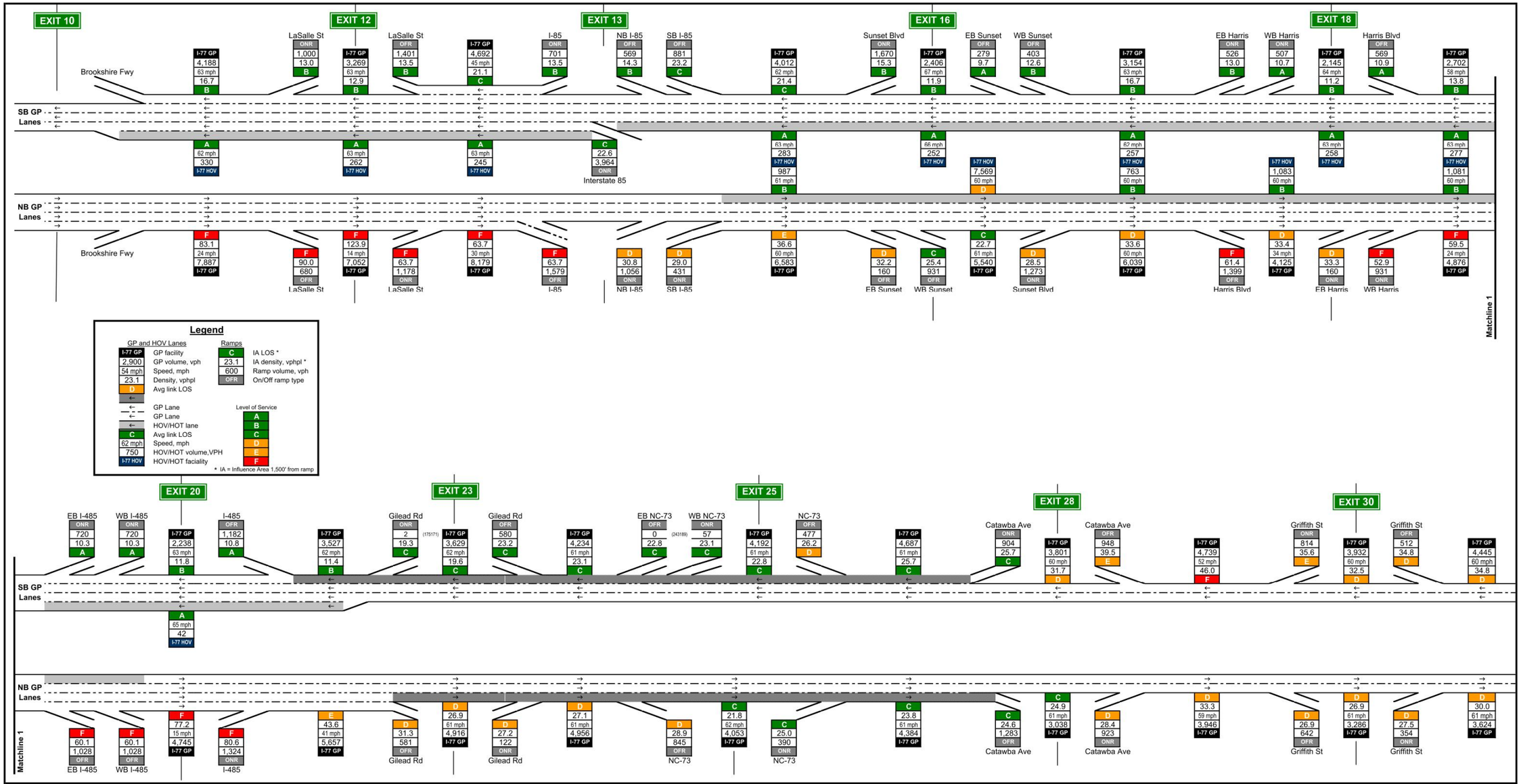
Location : I-77 between Exit 10 (Brookshire Freeway) and Exit 30 (Griffith Street)

AM Peak Period (7:00 a.m. to 8:00 a.m.)

Date: October 20, 2009

Created by: Dhiraj Goverdhanam

Approved by: Jonathan Reid



I-77 HOV Study: CORISIM Model Volume Density and Speed Results

2013 PM (Alt # 1) Shoulder Lane Option

Figure A-4

Location : I-77 between Exit 10 (Brookshire Freeway) and Exit 30 (Griffith Street)
PM Peak Period (5:00 p.m. to 6:00 p.m.)

Date: October 20, 2009

Created by: Dhiraj Goverdhanam
Approved by: Jonathan Reid