DIN 01612

UNC Hospitals Traffic Simulation Report

Durham-Orange Light Rail Transit Project

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July 24, 2015

The NEPA Preferred Alternative for the D-O LRT Project would generally follow NC 54, I-40, US 15-501, and the North Carolina Railroad (NCRR) Corridor in downtown Durham and east Durham. The alignment would begin at UNC Hospitals, parallel Fordham Boulevard, proceed east on NC 54, travel north on I-40, parallel US 15-501 before it turns east toward the Duke University campus along Erwin Road, and then follow the NCRR Corridor parallel to NC 147 through downtown Durham, before reaching its eastern terminus near Alston Avenue. The alignment would consist of at-grade alignment, fill and cut sections, and elevated structures. In two sections of the alignment, Little Creek and New Hope Creek, multiple Light Rail Alternatives are evaluated in the DEIS.

This technical report contains information for all alternatives analyzed in the DEIS. However, pursuant to MAP 21, the Moving Ahead for Progress in the 21st Century Act (P.L. 112-141), a NEPA Preferred Alternative has been developed, which recommends C2A in the Little Creek section of the alignment, NHC 2 in the New Hope Creek section of the alignment, the Trent/Flowers Drive station, and the Farrington Road Rail Operations and Maintenance Facility.

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List of Acronyms and Abbreviations

Acronym/Abbreviation	Definition
AA	Alternatives Analysis
AM	Ante meridian/before noon
DEIS	Draft Environmental Impact Statement
D-O	Durham-Orange
D-O LRT	Durham-Orange Light Rail Transit
EB	Eastbound
FHWA	Federal Highway Administration
I-40	Interstate 40
INRIX	A mobile computer application that pertains to road traffic
LOS	Level of Service
LPA	Locally Preferred Alternative
LRT	Light Rail Transit
MOE	Measures of Effectiveness
NB	Northbound
NC	North Carolina
NCDOT	North Carolina Department of Transportation
NCRR	North Carolina Railroad
NHC	New Hope Creek
PM	Post meridian/after noon
ROMF	Rail operations and maintenance facility
SB	Southbound
TRM	Triangle Regional Model
UNC	University of North Carolina
US	United States
VA	Veteran Affairs
WB	Westbound

1. Executive Summary

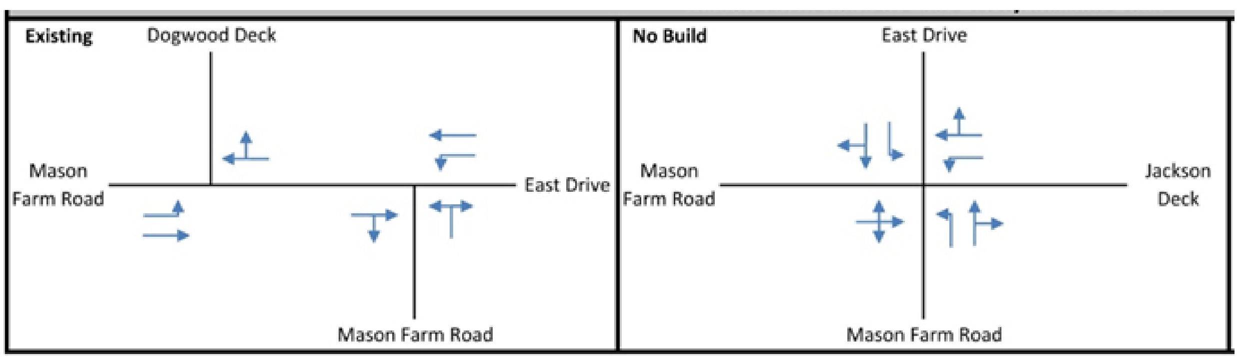
The study segment in this UNC Hospitals Traffic Simulation Report includes a 0.28-mile corridor of Mason Farm Road including the intersection of Mason Farm Road at East Drive/Dogwood Deck. This report evaluates the traffic conditions along this section under both Weekday AM and PM peak hours with the introduction of the proposed D-O LRT operating with 10 minute peak period frequency and 20 seconds of dwell time at each station for passenger boarding and alighting.

Traffic analysis was conducted using Vissim. The following scenarios were analyzed in this report:

- Existing Conditions
- 2040 No-Build Conditions
- 2040 Build LRT Conditions

Under the Existing Conditions, the western and southern legs of Mason Farm Road intersect with East Drive at a signalized intersection located immediately to the east of the Dogwood Deck entrance. As part of the UNC Campus Master Plan, Mason Farm Road is to be realigned and the signalized intersection would be shifted to the east and combined with the existing unsignalized intersection of East Drive and Jackson Deck entrance/exit and would include a new southern leg for Mason Farm Road. This planned design would provide a typical four-legged signalized intersection under the No-Build Conditions as shown in Figure ES-1.

Figure ES-1: Existing vs. Future Lane Configuration



The D-O LRT would be side-running parallel to Mason Farm Road and cross at-grade on the south side of the proposed intersection of Mason Farm Road at East Drive/Jackson Deck under the Build Alternative as shown in Figure ES-2. Railroad crossing gates are proposed to be installed along all intersection approaches to prevent LRT and vehicular conflicts. There are no proposed roadway modifications required as part of the Build Alternative if the realignment of the intersection shown in Figure ES-1 occurs prior to implementation of the D-O LRT Project.

Figure ES-2: Build Alternative Station and Intersection Configuration

The traffic analysis was conducted using the macro-level software Synchro for traffic signal optimization and the micro-simulation software Vissim was used to provide a comprehensive multimodal model capable of replicating traffic signal preemption and the interaction of vehicle, pedestrian and LRT operations. The 2040 No-Build and 2040 Build alternatives were evaluated using Vissim. The overall intersection results of the No-Build versus Build LRT alternatives Vissim analysis are shown in Table ES-1.

Table ES-1: VISSIM Overall Intersection Analysis Summary – 2040 LRT Alternatives vs. 2040 No-Build

Intersection	2040 No-Build		2040 Build	
	AM	PM	AM	PM
Mason Farm Road at East Drive/Jackson Deck	B	B	C	C

This overall intersection would operate at LOS C or better under both the No-Build Alternative and Build Alternative with the D-O LRT interaction, which are within the NCDOT LOS thresholds set per the *Traffic Analysis Methodology Report*.

Although there are LOS degradations for individual Build movements, all of these affected movements are expected to operate at mid-LOS D or better, which meets the threshold set forth by the NCDOT and the *Traffic Analysis Methodology Report*.

The construction of the D-O LRT project including the UNC Hospitals Station would have minimal impacts to traffic operations in this segment. Several individual movement maximum queue lengths may exceed the storage bay lengths at the southbound and eastbound approaches; however, the corresponding No-Build Conditions maximum queues lengths are similar or longer. Additionally, these maximum queue events are not expected to have operational impacts at adjacent signalized intersections. Therefore no roadway modifications are proposed for the UNC Hospitals study segment.

2. Introduction

Through the Alternatives Analysis (AA) process completed in April 2012 prior to preliminary design, which included extensive public outreach, a Locally Preferred Alternative (LPA) was selected to address the purpose and need of the Durham-Orange (D-O) Corridor. The proposed project is a 17.1 mile double-track light rail transit (LRT) line with 17 proposed stations that will greatly expand transit service in Durham and Orange Counties. The Durham-Orange Light Rail Transit (D-O LRT) project extends from its western terminus at the University of North Carolina at Chapel Hill (UNC) at the UNC Hospitals Station to the eastern terminus in Durham at the Alston Avenue Station. The proposed D-O LRT Project improves public transportation access to a range of educational, medical, employment, and other important activity centers, in the D-O Corridor including: UNC; UNC Hospitals; the William and Ida Friday Center for Continuing Education; Duke University; Durham Veterans Affairs (VA) Medical Center and Duke University Medical Center (DUMC); downtown and east Durham.

2.1 Description of the Proposed D-O LRT

The proposed D-O LRT alignment generally follows North Carolina (NC) Highway 54 (NC 54), Interstate 40 (I-40), United States (US) 15-501, and the North Carolina Railroad (NCRR) Corridor in downtown Durham and east Durham. The proposed alignment begins in Chapel Hill at UNC Hospitals, parallels Fordham Boulevard, proceeds eastward adjacent to NC 54, travels north along I-40, parallels US 15-501 before it turns east towards Duke University and runs within Erwin Road, and then follows the NCRR Corridor that parallels NC Highway 147 (NC 147) through downtown Durham, before reaching its eastern terminus in Durham near Alston Avenue. A total of 17 stations are planned, and approximately 5,000 parking spaces along the D-O LRT alignment will be provided. In addition, a rail operations and maintenance facility (ROMF) will be constructed to accommodate the D-O LRT fleet. It should be noted that the ROMF location is anticipated to generate minimal traffic during the peak hours. As such, those impacts were not evaluated as part of this report.

Bus routes will be modified to feed into the D-O LRT stations and headways will be adjusted to provide more frequent service and minimize transfer waiting times. These services will also connect LRT passengers with other area transportation hubs, including park-and-ride lots and transfer centers.

2.2 Proposed Project Alternatives

The Draft Environmental Impact Statement (DEIS) will examine the potential environmental impacts of the LRT alternative as well as a small number of alignment, station, and ROMF siting alternatives, including the following:

- Crossing of Little Creek between the Friday Center and the proposed Leigh Village Development (i.e., Alternatives C1, C1A, C2, C2A and associated station locations)
- Crossing of New Hope Creek (NHC) and Sandy Creek between Patterson Place and South Square (i.e., NHC-LPA, NHC Alternatives 1 and 2 and associated station locations)
- Station alternatives at Duke and Durham VA Medical Centers
- Five proposed locations for the ROMF

In addition to the LRT, the DEIS will consider a No-Build alternative, which includes the existing and programmed transportation network improvements, with the exception of planned rail improvements and associated bus network modifications.

2.3 Purpose of UNC Hospitals Traffic Simulation Report

The roadway network is a critical element of the transportation network, serving as a means to safely move people and goods and to support the economic development of an area. In an effort to balance safety and mobility with economic development and access, many owners of public roads have developed standards for determining the impacts of development on the roadway network and the level to which those impacts must be mitigated. The standards and mitigation levels governing projects in Durham and Orange Counties of North Carolina have been identified in the *Traffic Analysis Methodology Report* included in Appendix A.

The purpose of this technical memorandum is to analyze the traffic operations for the UNC Hospitals section of the proposed D-O LRT project in light of the policies identified in the *Traffic Analysis Methodology Report.* In this section the D-O LRT is side running parallel to Mason Farm Road and crosses at-grade on the south side of the intersection of Mason Farm at East Drive/Jackson Deck.

The goal of the traffic simulation is to provide decision makers with an evaluation of the ability of the transportation system to accommodate the future travel demand and to help determine which roadway network modifications are necessary to accommodate that demand and the LRT. As noted previously, modifications to the Build roadway network will be included in this evaluation to determine if reasonable mitigations can be made to accommodate the 2040 forecasted traffic volumes and the physical and operational changes LRT in accordance with the guiding policies. This study will also aim to determine which proposed roadway improvements are necessary to mitigate any additional impacts caused by the proposed D-O LRT project.

2.4 UNC Hospitals Traffic Simulation Description

This report describes the approach and summarizes the findings and results of the traffic analysis conducted on one section of the D-O LRT alignment. The studied section runs on the south side of Mason Farm Road within the Town of Chapel Hill limits. The project study area includes the intersection of Mason Farm Road at East Drive/Jackson Deck as shown in Figure 1.

Preliminary designs were developed for the proposed D-O LRT alignment near the UNC Hospitals Station and are included in the *Basis for Engineering Design* plans (Appendix B). The analysis evaluated both weekday AM and PM peak hour traffic volumes with the introduction of the proposed D-O LRT project. The LRT was assumed to operate in both directions with 10 minute peak period frequencies and 20 seconds of dwell time at each station for passenger boarding and alighting.

For the purposes of this analysis it was assumed that the traffic signal at the intersection of Mason Farm Road at East Drive/Jackson Deck would be programmed to operate with traffic signal preemption as part of the Build Alternative. Railroad crossing gates are proposed at this intersection to prevent conflicts between vehicular and LRT movements. Triangle Transit would work with the NCDOT and Town of Chapel Hill to develop signal plans for this intersection during the Engineering phase of the project. The Build traffic signal plans would incorporate signal preemption or signal priority to accommodate LRT operations at signalized intersections. Signal preemption interrupts the normal signal operations by preemptively transferring the traffic control signal to a special operation mode under certain events, such as an approaching train. Transit signal priority alters the normal signal operation process to better accommodate transit vehicles by extending a vehicle phase, e.g. green time will be lengthened by 15 seconds or red time will be reduced.

In the case of this study intersection, the proposed D-O LRT alignment is at-grade and is located on the south side of the intersection. As a result, when trains approach the intersection the normal traffic signal timing would be altered to allow the train to proceed uninhibited. While the train is in the intersection, all conflicting movements must stop, although traffic traveling parallel to the tracks can proceed with the train. Any difference in signal phase length as a result of the passing train is made up with one traffic signal cycle length after the train passes. A traffic signal cycle is all of the signal phases a particular traffic signal will go through before a signal phase is repeated. The existing cycle length of 120 seconds was used for the future No-Build and Build signal as well.

The No-Build Alternative includes the proposed realignment of Mason Farm Road, consistent with the UNC Campus Master Plan, to form a four-legged intersection with East Drive and the Jackson Deck parking garage entrance/exit.

The intersection lane configuration would remain unchanged between the No-Build Alternative and the Build LRT Alternative. One LRT station (UNC Hospitals Station) is proposed for implementation along this section of the project near Mason Farm Road.

Figure 1: UNC Hospitals Study Intersection

3. Description of Scenarios

Three scenarios were analyzed for this study. These scenarios included an Existing Conditions scenario (2011 Base Year Scenario) that was also used for model calibration, a Future Year No-Build alternative, and a Future Year Build alternative.

A brief description of the alternatives evaluated in Vissim, a comprehensive multimodal model capable of replicating traffic signal preemption and the interaction of vehicle, pedestrian and LRT operations, for traffic operations is as follows.

3.1 2011 Base Year Scenario

The 2011 Base Year Scenario simulated traffic conditions as they existed in 2011. The goal of the 2011 Base Year Scenario was to develop a calibrated model that would serve as the basis for the creation of the models for the future year No-Build and Build alternatives. As discussed in the *Traffic Analysis Methodology Report*, travel time and speed were calibrated.

3.2 2040 No-Build Alternative

This alternative examined what the traffic operations would be in the vicinity of the proposed D-O LRT project assuming the proposed project is not constructed. The No-Build Alternative assumed the local transportation system would evolve as currently planned, but without implementation of the proposed project.

3.3 2040 Build Alternative

The Build alternative analysis was performed to achieve the mitigation thresholds set forth in the *Traffic Analysis Methodology Report*. The Build alternative roadway network was developed from the No-Build network by adding the LRT and adjusting as needed to meet NCDOT analysis thresholds. Preliminary designs for the Build Alternative are included in Appendix B.

4. Methodology

The analysis followed the methodology documented in the *Traffic Analysis Methodology Report* for the Durham-Orange Light Rail Project developed in November 2013. Two traffic analytical software tools, Synchro and Vissim, were used to provide measures of effectiveness (MOE) necessary for the analysis. This study used Synchro Version 8.0 to develop optimized signal timing plans as input for microscopic simulation modeling.

The use of microscopic traffic simulation was completed using Vissim (version 5.4). Vissim is a microscopic, behavior-based multi-purpose traffic simulation program that evaluates each vehicle individually every model time step and then assigns the appropriate behavior logic according to the traffic operations that the specific vehicle encounters. For many engineering disciplines, simulation has become an indispensable instrument for the optimization of complex technical systems. This is also true for transportation planning and traffic engineering, where simulation is an invaluable and cost-reducing tool. The microscopic simulation model was developed for the studied section of the project and was based on a calibrated base model for the area.

The methodology for microscopic simulation begins with a base model developed from data collected for the transportation network. The base model is then calibrated against data measured in the field to arrive at a calibrated base model. Once the base model is calibrated, future year alternatives can be developed and analyzed for impact study. As in real-life operations, microscopic simulation models are constrained to the capacity of a given roadway, and as such the model can only load traffic up to the capacity of a facility, with excess vehicles being denied entry and queue up outside the model network. This can happen for future scenarios when demand has been forecasted to outgrow the capacity of the existing roadways.

4.1 Measures of Effectiveness

Measures of Effectiveness (MOE) are system performance statistics that allow for comparisons between alternatives. The MOEs for microscopic simulation can be abundant due to the nature of the analysis. The primary MOEs for urban arterials are typically average speed and vehicle density for individual segments as well as average travel time and speed for individual origin-destination pairs within the network. On an overall network level MOEs such as average system speed, average system delay, and number of stops can provide overall indications of the operations of a network.

As discussed in the *Traffic Analysis Methodology Report*, corridor-level MOEs including average speed and travel time were used as the method for calibrating the base year model. Control delay, which is utilized to determine intersection LOS, and queuing were the MOEs for the future year models. The concept of Highway Capacity Manual's (HCM) Level of Service was adopted here for the purpose of simply categorizing the delays. Please note that the calculation methods of HCM delay and Vissim delay are different, as Vissim delay includes control delay as well as queue delay, whereas, HCM includes control delay only. The LOS grades are based on Vissim delays, which will provide a more conservative result than the HCM-based delays.

The acceptable levels for the future year MOEs were enumerated in the *Traffic Analysis Methodology Report*. The NCDOT has established guidelines that specify when chosen MOEs meet the required thresholds. The NCDOT's "*Policy on Street and Driveway Access to North Carolina Highways (July 2003)*" states that when comparing base network conditions to project conditions, mitigation improvements to the roadway network are required if at least one of the following conditions exist:

- The total average delay at an intersection or an individual approach increases by 25% or greater, while maintaining the same Level of Service
- The Level of Service degrades by at least one level
- Level of Service is F
- Additionally, at intersections if the maximum queue for individual movements exceeds both its available storage space and its respective peak hour No-Build maximum queue length by 10 feet.

For the purposes of this analysis, traffic impacts were considered for mitigation if the Build alternative delay was at or above a middle LOS D, or 45.0 seconds or greater for a signalized intersection. Those overall intersections or movements that reported delays greater than 45.0 seconds and experienced a LOS degradation or increase in delay greater than 25% compared to the No-Build alternative were highlighted in the Vissim LOS tables with orange. For those intersections or movements that reported a Build LOS better than middle D or less than 45.0 seconds, the impacts would not warrant roadway modifications and were highlighted with yellow.

The Town of Chapel Hill does not have established traffic impact criteria and, therefore, the NCDOT criteria noted above were followed. In summary, Table 1 shows the traffic impact criterion applied to the study intersection.

Table 1: Application of Traffic Impact Criteria

Segment	Location	Criteria Applied
Mason Farm Road	Mason Farm Road at East Drive/Jackson Deck	NCDOT

4.2 Network Development

4.2.1 Geometry

The basis for developing the geometric data was a combination of aerial photographs and contour maps. Aerial photography was used as a background to digitize the network into the simulation model. The three-dimensional attributes and grades were determined based on a contour map of the study area.

The geometry in the 2011 Base Year network is based on the existing geometry of the intersections analyzed in this report. The network was created using aerials from NC OneMap, Google Maps, field verification, and contour maps from the North Carolina Department of Transportation (NCDOT).

4.2.2 Traffic Control

Signal and coordination plans were obtained from the Town of Chapel Hill for the intersection included in the study area and are included in Appendix C. These plans were used to input timing, phasing, and detectors for the intersection of the Mason Farm Road at East Drive/Dogwood Deck entrance.

Field verification of the signal timings was performed at the study intersection. The signalized intersection for the future year networks was input into Synchro for optimization prior to being input into Vissim. The future year signal timings were based on existing year signal timings and then re-optimized based on the 2040 traffic volumes.

It should be noted that under the Existing Conditions, the western leg of Mason Farm Road intersects with the eastern leg of East Drive and southern leg of Mason Farm Road immediately to the east of the Dogwood Parking Deck entrance. As part of the UNC Campus Master Plan, Mason Farm Road is to be realigned and the signalized intersection would be shifted to the east and combined with the existing unsignalized intersection of East Drive and Jackson Deck entrance/exit, which would also include a new southern leg for Mason Farm Road, forming a four-legged intersection with the Jackson Deck entrance/exit, under the No-Build alternative. Current signal timings from the existing signalized intersection were utilized at the new realigned intersection.

4.2.3 Speed Data

The *Traffic Analysis Methodology Report* indicated that the existing Vissim model would be calibrated using historical speed data from INRIX (a mobile application pertaining to vehicle traffic). However, INRIX speed data was not available for this study area. Therefore, speed calibration was performed to the posted speed limit. The desired speed distribution for turning vehicles at intersections was assumed to be 10 mph with a standard deviation of 3 mph for right turns and 15 mph with a standard deviation of 3 mph for left turns. The speed distributions used for Mason Farm Road were based on a 25 mph posted speed with a range of 20 to 30 mph in Vissim.

4.2.4 Driving Behavior Parameters

The driver behavior parameters were used to guide vehicles through the network during the simulation models. Both the car-following and lane-change models in Vissim use an extensive range of parameters. Some of these may be adapted by the user to change basic driving behavior. Vissim uses five driving behavior models, of which only one was used in the base model: Urban (motorized). The Urban (motorized) parameters were used to model the surface streets within the network and were based on the Wiedemann 74 model. The Wiedemann 74 model includes three parameters which can be calibrated based on the data collected. Default values were used in developing the base model and any modifications made to the parameters were documented in the calibration section of this report.

4.2.5 Estimated Traffic Volumes

Simulation models are capable of using unbalanced input volumes and their own internal algorithms to balance the network; however using this method of traffic volume input can produce inaccuracies in actual processed volumes at particular locations. The traffic volumes for the proposed project were based on peak hour turning movement count data. The existing traffic volumes were based on peak hour count data that was balanced with the adjacent intersections by keeping the Manning Drive and East Drive/Gravely Drive intersection as the control count.

Volumes for the 2011 Existing, the 2040 No-Build Alternative and the 2040 Build Alternative were created using the count data and the Triangle Regional Travel Demand Model (TRM) v5 as outlined in the *Traffic Analysis Methodology Report*. With the realignment of Mason Farm Road to form a four-legged intersection with East Drive and Jackson Deck under the No-Build alternative, the traffic volumes for respective movements were adjusted accordingly. The balanced peak hour volumes for all scenarios (Existing, No-Build, and Build Conditions) are shown in Appendix D. There was no change in travel pattern between the No-Build Alternative and future year Build Alternative. Therefore, traffic volumes between the two alternatives remained the same.

4.2.6 Simulation Settings and Repetitions

Each simulation was run for one hour with 15 minutes of seeding time for the network to load.

The number of simulation runs was based on the process described in Appendix B of the Federal Highway Administration (FHWA) Traffic Analysis Toolbox Volume III. The average speed of each simulation run was used as a basis for determining the number of required repetitions, with a confidence level of 95% and a confidence interval of 5 mph. It was calculated that each alternative would need to be run with 10 random seeds each for both the AM and PM peak periods.

4.2.7 Output

The output data was extracted from the model using the Travel Time evaluation and Data Collection. The Travel Time evaluation provided average travel times for user defined start and end points within the network. The Intersection Node module provided several outputs including vehicle volume, movement and intersection delay, and average/maximum queues which were utilized to determine intersection LOS.

4.2.8 Base Year Calibration

The 2011 Existing Conditions base year model was calibrated by comparing modeled travel times versus the posted speed limit of 25 miles per hour on the 0.28 mile long Mason Farm Road corridor. Speed calibration targets of +/- 2.5 mph (desirable) and +/- 5 mph (acceptable) were set as described in the *Traffic Analysis Methodology Report*. No changes to the base Vissim parameters were made for calibrating the base year model to replicate the current existing conditions.

5. Simulation Results

5.1 2040 No-Build Alternative

The 2040 No-Build Alternative model was based on the calibrated Existing Conditions model. The No-Build network geometry was modified to include the UNC Campus Master Plan roadway modifications to Mason Farm Road and the 2040 No-Build volumes were then input into the model.

The Highway Capacity Manual defines LOS for signalized and unsignalized intersections as a function of the average vehicle control delay. LOS may be calculated per movement or per approach for any intersection configuration, but LOS for the intersection as a whole is only defined for signalized and all-way stop configurations. Table 2 and Table 3 demonstrate the different HCM levels of service for signalized and unsignalized intersections based on delay and volume to capacity ratio.

Table 2: Level of Service - Signalized Intersections

Level of Service	Delay (seconds)	Description
A	≤10	This level is typically assigned when the volume-to capacity ratio is low and either progression is exceptionally favorable or the cycle length is very short. If it is due to favorable progression, most vehicles arrive during the green indication and travel through the intersection without stopping.
B	>10-20	This level is typically assigned when the volume-to-capacity ratio is low and either progression is highly favorable or the cycle length is short. More vehicles stop than with LOS A.
C	>20-35	This level is typically assigned when progression is favorable or the cycle length is moderate. Individual *cycle failures* (i.e., one or more queued vehicles are not able to depart as a result of insufficient capacity during the cycle) may begin to appear at this level. This number of vehicles stopping is significant, although many vehicles still pass through the intersection without stopping.
D	>35-55	This level is typically assigned when the volume-to-capacity ratio is high and either progression is ineffective or the cycle length is long. Many vehicles stop and individual cycle failures are noticeable.
E	>55-80	This level is typically assigned when the volume-to-capacity ratio is high, progression is unfavorable, and the cycle length is long. Individual cycle failures are frequent.
F	>80	This level is typically assigned when the volume-to-capacity ratio is very high, progression is very poor, and the cycle length is long. Most cycles fail to clear the queue.

Source: Highway Capacity Manual, 2010

Table 3: Level of Service - Unsignalized Intersections

Level of Service	Delay (seconds)
A	≤10
B	>10-15
C	>15-25
D	>25-35
E	>35-50
F	>50

Source: Highway Capacity Manual, 2010

Table 4 lists the Vissim analysis turning movement volumes, delays, and LOS at the study intersection during the AM and PM peak hours under the 2040 No-Build Conditions.

Table 4: 2040 No-Build VISSIM Model Summary

Intersection	Movement	AM Peak			PM Peak		
		Volume (VPH)	Delay (sec)	LOS	Volume (VPH)	Delay (sec)	LOS
Mason Farm Road at East Drive/Jackson Deck[1] (Signalized Intersection)	NBL	112	8.7	A	409	13.4	B
	NBT	161	7.2	A	367	13.1	B
	NBR	6	7.7	A	47	9.6	A
	SBL	4	6.3	A	19	60.0	E
	SBT	80	9.7	A	59	7.1	A
	SBR	405	9.6	A	41	7.0	A
	EBL	258	22.4	C	264	27.3	C
	EBT	0	0.0	A	0	0.0	A
	EBR	111	23.9	C	121	25.8	C
	WBL	5	24.3	C	3	32.9	C
	WBT	5	20.3	C	20	23.6	C
	WBR	5	8.3	A	46	11.6	B
	Overall	**1152**	**13.5**	**B**	**1394**	**17.0**	**B**

As seen in Table 4, under No-Build Conditions the overall intersection is expected to operate at LOS B in both peak hours. The majority of individual movements would provide LOS C or better operations, except for the southbound East Drive left turn which would operate at LOS E in the PM peak hour only.

A 2040 No-Build Synchro-based model was developed to further investigate the potential signal optimization in the micro-simulation software to improve traffic operation. The roadway geometry was modified to include the reconfiguration of the Mason Farm Road at East Drive/Jackson Deck and the

2040 No-Build volumes were then input into the model. The Synchro output for all future alternatives can be found in Appendix E.

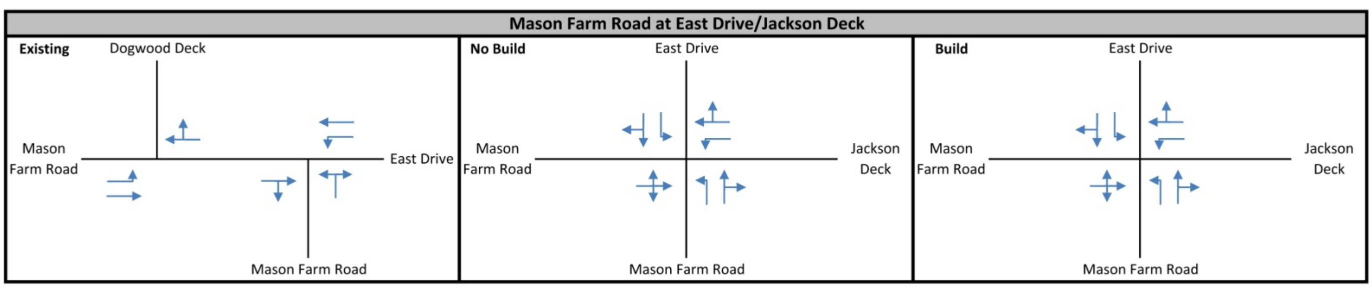
5.2 2040 Build Alternative

This study determined what the traffic operations would be like in the vicinity of the proposed project if the light rail is constructed. The Build analysis roadway network was developed from the No-Build network by adding the LRT and modifying the signal operations. The roadway geometry and LRT alignment for the Build Alternative are shown in the *Basis for Engineering Design* plans in Appendix B. No roadway modifications were recommended as part of the Vissim traffic analysis.

Intersection signal timing changes from 1) Existing to No-Build and from 2) No-Build to Build are shown in Table 6 for the 2040 LRT Alternative. Table 5 also includes the lane configuration modifications that are proposed between Existing to No-Build, and No-Build to Build Conditions.

Based on the above model network elements and the methodologies defined under the MOE section, the Vissim results for the 2040 Build LRT Alternative were determined. Detailed traffic delays at individual movement level and overall intersection level were compared to the No-Build scenarios in Table 6 (AM peak hour) and Table 7 (PM peak hour) in Section 6. Queuing information for the 2040 Build LRT Alternative is also included in the comparison tables

Table 5: 2040 LRT Alternative Signal & Lane Configuration Modifications



AM	Cycle Length	Phasing	PM	Cycle Length	Phasing
Existing to No Build	Intersection signalized with 120s cycle length.	Split phasing for EB/WB. NBL permissive, SBL protected-permissive.	Existing to No Build	Intersection signalized with 120s cycle length.	Split phasing for EB/WB. NBL permissive, SBL protected-permissive.
No Build to Build	No change.	Transit Signal Preemption.	No Build to Build	No change.	Transit Signal Preemption.

6. Summary of Results

The following sections summarize the Vissim simulation results for the 2040 No-Build Conditions versus the 2040 Build Alternative in a side by side manner. Tables 6 and 7 include overall intersection and individual movement delays, LOS and queuing information as report by Vissim for the future scenarios.

The available storage shown in the tables for the through lanes represents the available distance to the adjacent intersection. For the turn bays, it is the available storage of that particular lane. The NCDOT criteria identifies the 95th percentile queue as the critical metric to be provided sufficient storage space. It is important to note that Vissim provides the “average” queue length and the “maximum” queue length. The maximum queue is based on the worst case scenario in the microsimulation model, even though this event is likely to occur only once in a peak hour. An evaluation of these MOE tables indicates a substantial difference between the average queue lengths and the maximum queue lengths. The 95th percentile queue length lies somewhere in between the two. In many cases there is a substantial difference between the No-Build maximum queue and the Build maximum queue. This can be attributed to the occasional interruption of normal signal operations by the passage of an LRV. This traffic analysis emphasized the overall intersection LOS with a focus on maximum queue lengths versus storage requirements. If the Build average queue movement and the maximum No-build queue were satisfied with the storage provided then it was assumed there was no impact.

Table 6: D-O LRT: UNC Hospitals Segment – Vissim Intersection Analysis Output Summary – 2040 Build LRT Alternative vs. 2040 No-Build AM Peak Hour 8:00 – 9:00 AM

Intersection	Movement	Volumes (VPH)				Delay (sec)				LOS		Average Queue Length (ft)				Maximum Queue Length (ft)				
		Build		No-Build		Build	No-Build	Difference Absolute	Difference %	Build	No-Build	Build	No-Build	Difference Absolute	Difference %	Storage Space Available	Build	No-Build	Difference Absolute	Difference %
		Model	Demand	Model	Demand															
Mason Farm Road at East Drive/Jackson Deck[1] (Signalized Intersection)	NBL	112	112	112	112	17.1	8.7	8.4	96%	B	A	8	8	-1	-7%	235	132	110	22	20%
	NBT	160	162	161	162	13.0	7.2	5.8	81%	B	A	8	8	-1	-7%	320	132	110	22	20%
	NBR	6	5	6	5	7.0	7.7	-0.7	-8%	A	A	8	8	-1	-7%	320	132	110	22	20%
	SBL	5	5	4	5	26.6	6.3	20.3	325%	C	A	87	12	75	654%	220	618	610	7	1%
	SBT	80	80	80	80	26.6	9.7	16.9	174%	C	A	87	12	75	654%	450	618	610	7	1%
	SBR	422	429	405	429	23.6	9.6	14.1	147%	C	A	87	8	79	973%	450	618	610	8	1%
	EBL	258	259	258	259	27.7	22.4	5.3	24%	C	C	76	59	17	29%	280	321	312	9	3%
	EBT	0	0	0	0	0.0	0.0	0.0	0%	A	A	76	59	17	29%	280	321	312	9	3%
	EBR	113	114	111	114	27.7	23.9	3.8	16%	C	C	76	59	17	29%	280	321	312	9	3%
	EB LRT	6	6	N/A	N/A	5.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	WBL	6	5	5	5	28.0	24.3	3.7	15%	C	C	0	1	-1	-80%	190	30	45	-15	-33%
	WBT	5	5	5	5	26.0	20.3	5.7	28%	C	C	1	1	0	-8%	400	29	46	-17	-37%
	WBR	4	5	5	5	8.1	8.3	-0.2	-2%	A	A	0	0	0	-100%	400	0	3	-3	-100%
	WB LRT	6	6	N/A	N/A	0.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	All	1172	1181	1152	1181	22.9	13.5	9.4	70%	C	B	38	19	18	93%		618	610	8	1%

Footnote:
[1] - **NCDOT Traffic Impact Criteria is applied**
[2] - **City of Durham Traffic Impact Criteria is applied**
Indicates LRT Movement
Indicates Traffic Impact
Indicates Traffic Impact below Mid-D

Table 7: D-O LRT: UNC Hospitals Segment – Vissim Intersection Analysis Output Summary – 2040 Build LRT Alternative vs. 2040 No-Build PM Peak Hour 5:00 – 6:00 PM

Intersection	Movement	Volumes (VPH)				Delay (sec)				LOS		Average Queue Length (ft)				Maximum Queue Length (ft)				
		Build		No-Build		Build	No-Build	Difference Absolute	Difference %	Build	No-Build	Build	No-Build	Difference Absolute	Difference %	Storage Space Available	Build	No-Build	Difference Absolute	Difference %
		Model	Demand	Model	Demand															
Mason Farm Road at East Drive/Jackson Deck[1] (Signalized Intersection)	NBL	412	411	409	411	17.3	13.4	3.9	29%	B	B	61	42	19	44%	235	187	349	-162	-46%
	NBT	364	370	367	370	15.7	13.1	2.6	20%	B	B	61	43	18	41%	320	187	351	-164	-47%
	NBR	46	46	47	46	13.9	9.6	4.3	44%	B	A	61	12	49	416%	320	187	255	-69	-27%
	SBL	22	20	19	20	67.5	60.0	7.5	12%	E	E	14	7	7	111%	220	144	82	62	76%
	SBT	60	59	59	59	19.1	7.1	12.0	168%	B	A	14	7	7	111%	450	144	82	62	76%
	SBR	42	40	41	40	14.3	7.0	7.4	106%	B	A	9	1	9	1006%	450	143	55	88	160%
	EBL	253	261	264	261	33.8	27.3	6.5	24%	C	C	117	79	38	49%	280	310	318	-7	-2%
	EBT	0	0	0	0	0.0	0.0	0.0	0%	A	A	117	79	38	49%	280	310	318	-7	-2%
	EBR	127	125	121	125	31.0	25.8	5.2	20%	C	C	117	79	38	49%	280	310	318	-7	-2%
	EB LRT	6	6	N/A	N/A	5.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	WBL	3	3	3	3	42.8	32.9	9.9	30%	D	C	5	2	2	108%	190	87	70	17	23%
	WBT	18	20	20	20	32.3	23.6	8.8	37%	C	C	5	3	1	49%	400	87	71	16	22%
	WBR	48	46	46	46	9.6	11.6	-2.0	-17%	A	B	1	0	0	165%	400	55	25	30	121%
	WB LRT	6	6	N/A	N/A	0.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	All	1394	1401	1394	1401	22.0	17.0	4.7	28%	C	B	42	29	13	43%		310	351	-40	-13%

Footnote: [1] **- NCDOT Traffic Impact Criteria is applied**
[2] **- City of Durham Traffic Impact Criteria is applied**
Indicates LRT Movement
Indicates Traffic Impact
Indicates Traffic Impact below Mid-D

6.1 Analysis of LOS Thresholds

The 2040 Build LRT Alternative was compared to the respective No-Build scenario at the intersection of Mason Farm Road and East Drive/Jackson Deck by overall and individual movement levels.

NCDOT traffic impact criteria were applied to this intersection which is under the Town of Chapel Hill jurisdiction. Under the No-Build alternative, Mason Farm Road is to be realigned to intersect with East Drive and the Jackson Deck entrance/exit, forming a four-legged signalized intersection. For the Build alternative, the D-O LRT would run parallel to the east/west oriented segment of Mason Farm Road, crossing at-grade on the south side of this intersection. The UNC Hospitals Station is proposed immediately to the west of the intersection of Mason Farm Road and East Drive/Jackson Deck.

Even with the at-grade LRT crossing, the overall intersection is expected to operate at LOS C during both peak hours under the Build Alternative and would therefore meet NCDOT criteria.

As shown in Table 7 and Table 8, although there are LOS degradations for individual Build movements, all of these affected movements (highlighted in yellow) are expected to operate at mid-LOS D or better, which meets the threshold set forth by the NCDOT and this report. All of the other individual intersection movements would also meet NCDOT criteria for LOS and delay.

For the 2040 Build LRT Alternative, there are no maximum queue length impacts expected at the intersection of Mason Farm Road at East Drive/Jackson Deck. The eastbound and southbound approaches may experience maximum queue lengths that exceed their storage space, however, the No-Build maximum queue lengths are expected to be similar in length or longer.

7. Conclusions/Recommendations

As part of the Vissim traffic simulation analysis, traffic impacts associated with the implementation of the LRT were identified in the forms of delay, LOS, and queues. Any movement showing impacts were investigated to determine the significance of the impact and whether there was a feasible roadway modification to eliminate or reduce the impact.

The Vissim results for the 2040 Build Alternatives indicate that the intersection of Mason Farm Road and East Drive/Jackson Deck would operate at LOS C during both peak hours and would satisfy NCDOT criteria without requiring any Build roadway modifications.

As shown in Table 6 and Table 7, although there are LOS degradations for individual Build movements, all of these affected movements are expected to operate at mid-LOS D or better, which meets the threshold set forth by the NCDOT and this report.

The construction of the D-O LRT project including the UNC Hospitals Station would have minimal impacts to this segment. Several individual movement maximum queue lengths may exceed the storage bay lengths at the southbound and eastbound approaches; however, the corresponding No-Build Conditions maximum queues lengths are similar or longer. Additionally, these maximum queue events are not expected to have operational impacts at adjacent signalized intersections. Therefore no roadway modifications were proposed for the UNC Hospitals study segment.

Appendices

Appendix A
Traffic Analysis Methodology Report

TRAFFIC ANALYSIS METHODOLOGY

Durham-Orange Light Rail Transit Project

OurTransit FUTURE

November 2013

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List of Figures

1. Introduction

The proposed Triangle Transit Durham-Orange Light Rail Transit Draft Environmental Impact Statement (D-O LRT Draft EIS) will address existing and future transportation conditions along the proposed corridor and quantify the transportation impacts of the No-Build and Build Alternatives as well as some transportation system management (TSM) improvements. For the purposes of this study the No-Build and TSM scenarios will be combined. The project will potentially have transportation and traffic impacts that will include impacts to streets and highways, bikeways, parking, railroad operations, and public transit.

Following is a description of the proposed methodology for evaluating the potential impacts to traffic and transportation services and facilities that could occur due to the implementation of the proposed D-O LRT. This proposal includes analysis methodologies used to describe existing and future travel patterns and the transportation environment, estimation of forecast year traffic volumes under the No-Build and Build Alternatives, and the analysis of impacts of the light rail operations at intersections and railroad/highway at-grade crossings.

Generally, data required for the traffic and transportation analyses will be developed by the study team, or will be provided by either Triangle Transit, the Town of Chapel Hill, City of Durham, Durham-Chapel Hill-Carrboro Metropolitan Planning Organization (DCHC MPO), or the North Carolina Department of Transportation (NCDOT). Data from other agencies, if needed, is noted in the task descriptions. Triangle Transit will provide information on existing and planned transit services and performance. Existing conditions traffic data from the previous Alternatives Analysis (AA) study will be utilized for the base year analysis and future year volumes will be developed based on travel demand analysis completed by other members of the project teams. The analysis will include both regional travel demand data as well as specific transit route ridership forecasts. The base year for the analysis will be 2011 and the design year will be 2040 in order to be consistent with the DCHC MPO's *2040 Metropolitan Transportation Plan*.

The project team will use the Triangle Regional Travel Demand Model V5 (TRTDM) for this project. The model is based on the traditional four-step travel demand process of trip generation, trip distribution, mode split, and traffic assignment. Documentation for the model development and calibration process is maintained by NCDOT and the Institute for Transportation Research and Engineering (ITRE).

2. Existing Conditions

Following is a description of the elements that will be used to define existing transportation conditions, and the procedures to be used in developing that definition.

Calibrated base models will be constructed and validated using VisSim. The calibration and validation process is described below. For this study 2011 will serve as the base year for analysis.

2.1 Identification Of Simulation Areas

Specific segments of the D-O LRT corridor where the proposed LRT interacts with the roadway network will be analyzed. Along much of the D-O LRT corridor the track is not at grade or is routed in areas that are not near the roadway network. As such, there is no interaction between the proposed D-O LRT and the current or planned roadway network. The segments that are proposed for analysis are as follows:

- Mason Farm Road – East Drive to US 15-501
- NC 54 – Hamilton Road to Downing Creek including Prestwick Road and Meadowmont Lane (Alternative C-1)
- Leigh Village – Includes crossings of proposed Leigh Village as well as Ephesus Church Road and Farrington Road intersection if needed
- Patterson Place – McFarland Drive from Mt. Moriah Road to Witherspoon Boulevard as well as any crossing of Garrett Road
- South Square – Including University Drive from Snow Creek Trail to Shannon Road, Shannon Road from University Drive to US 15-501, and Tower Road from US 15-501 northbound ramps to Pickett Road
- Cornwallis Road – At Grade crossing near US 15/501 (as needed)
- Erwin Road – Cameron Drive to Anderson Street/15th Street, Fulton Street and Trent Drive, and Elba Street as needed
- Pettigrew Street – Erwin Road/9th Street to Sumter Street and Chapel Hill Street to Alston Avenue and proximate intersections as needed
- Peabody Street – Gregson Street to Duke Street

Maps of the proposed simulation areas and intersections are shown in Figures 1 and 2. The selection of the studied areas and intersection was based on the results from the AA. Potential changes to alignment and sunsequently crossings may require revision and correction of the current selection.

2.2 Balanced Volume Data

For the traffic analysis portion of the D-O LRT Draft EIS we will employ the data collected as part of the AA phase of the project, including peak hour turning movements for all intersections identified. Traffic counts from 2008 or before will be increased based on the growth of background traffic to represent base year conditions. If significant changes in street configuration or roadway geometry have occurred since the count was taken then newer counts in these areas reflecting such changes will be collected and used for the traffic anysis.

Background growth will be based on data from the NCDOT traffic volume maps (http://www.ncdot.gov/travel/statemapping/trafficvolumemaps/). After developing the raw peak hour turning volumes for the base year, the volumes will be balanced across the networks. Sink and source nodes will be added where necessary to account for mid-block changes in traffic volumes due to major origins or destinations. Input data for the loading points will be developed based on the balanced volumes.

2.3 Model Development

For the development of the base model in VisSim, the following will be completed:

- Develop base data including acceleration, speed distributions, vehicle classes, vehicle distributions, and link behavior types
- Develop link geometric data
- Input traffic demand data based on outcome of previous step
- Input origin-destination routing
- Input traffic control data at intersections, including signal timings
- Input traffic operations and management data for links
- Input driver behavior data
- Set simulation run control
- Code network outputs

Data Needs:

Signal Plans from Chapel Hill, Durham, and NCDOT

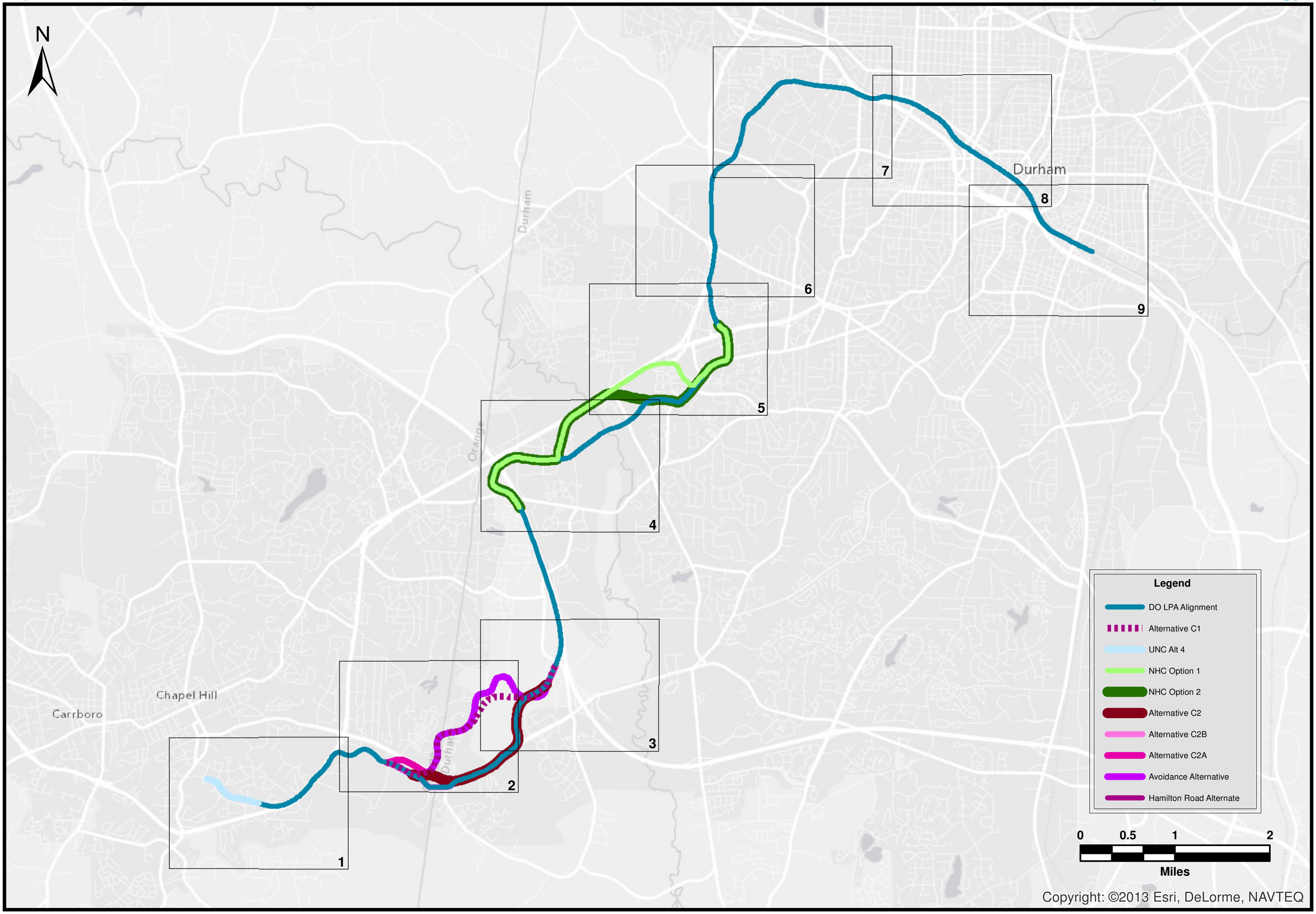
2.4 Pedestrian And Bicycle Volumes

Where necessary, pedestrian and bicycle data will be collected and utilized in the model stream. To guide this effort, *Effects of Pedestrians on Capacity of Signalized Inersections* by Milazzo et al published in Transportation Research Record 1646 was reviewed. This article serves as the basis for determining the impact of pedestrians on saturation flow rates at signalized intersections as described in chapter 31 of the *2010 Highway Capacity Manual* published by the Transportation Research Board. In that review it was found that pedestrian conflicts reduce saturation flow in a linear manner from 0 to 1000 conflicting pedestrians per hour of green time. The reduction in saturation flow at 1000 conflicting pedestrains per hour of green time is 50%. A threshold of 20% reduction in saturation flow rate will be utilized for this analysis based on the previously referenced items. This 20% reduction threshold corresponds to 400 conflicting pedestrians per hour of green time. If a conservative assumption is made that turning movements are provided green time equal to 25% of the cycle length, then we can interpolate that for a 20% reduction in turning movement saturation flow rate there must be at least 100 conflicting pedestrians for that particular movement in the peak hour. As such, we are proposing to include only pedestrian movements in the simulation where pedestrian volumes are greater than 100 conflicting pedestrians in the peak hour. To reach that threshold either the volume of conflicting pedestrians on a single crosswalk must be greater than 100 pedestrians in the peak hour or the combined volume of conflicting pedestrians of two adjacent crosswalks must be greater than 100 pedestrians in the peak hour.

A partial field review was conducted to determine locations where pedestrian and bicycle volumes were above the 100 pedestrians per hour threshold. Initial review of the proposed areas revealed that the intersection of Erwin Road and Fulton Street meets this threshold in the base year. Additional examination will be conducted later.

2.5 Calibration Of Model

Once the model is created and visually validated, model data will be extracted to ensure that the model is accurately representing base year conditions. The model will be pre-loaded for 15 minutes with volumes that are 75% of those anticipated for the peak hour. Model outputs will be compared to INRIX traffic data from the base year to ensure relatively similar travel times. The models will be considered calibrated when the travel speeds are within 5 mph of the data obtained from INRIX. That said, reasonable efforts will be made to reduce the difference between model travel time speeds and INRIX data to be within 2.5 mph. Given that INRIX data is aggregated over a period of time and that the model run is for one specific day it may not be possible to achieve the narrower band for the purposes of calibration. The model will be run for a sufficient number of iterations to ensure calibration based on Federal Highway Administration (FHWA) guidelines. The number of iterations necessary to achieve calibration for each corridor will be recorded and future year models will be run utilizing the same number of iterations. Models will be run using static trip assignment.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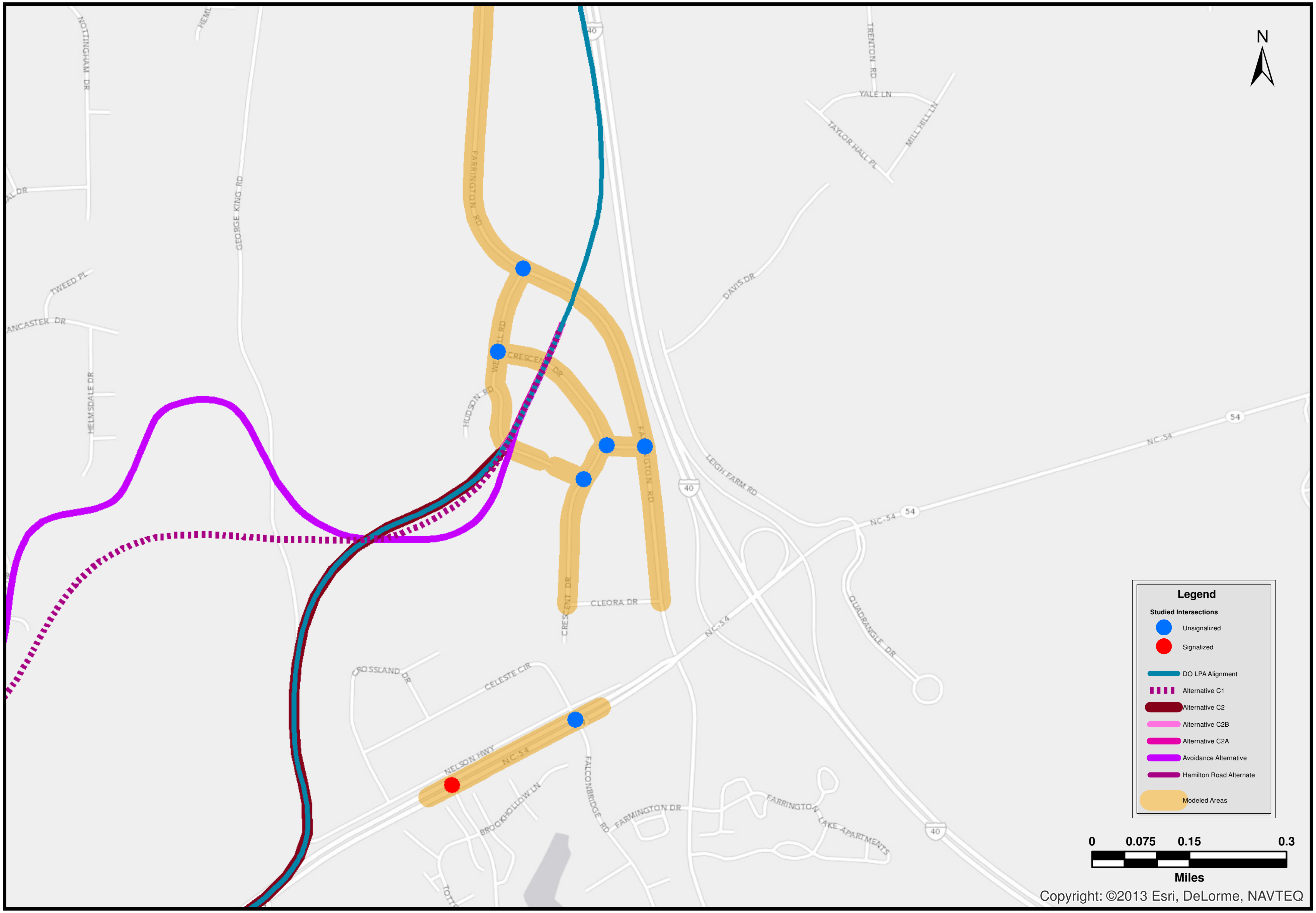
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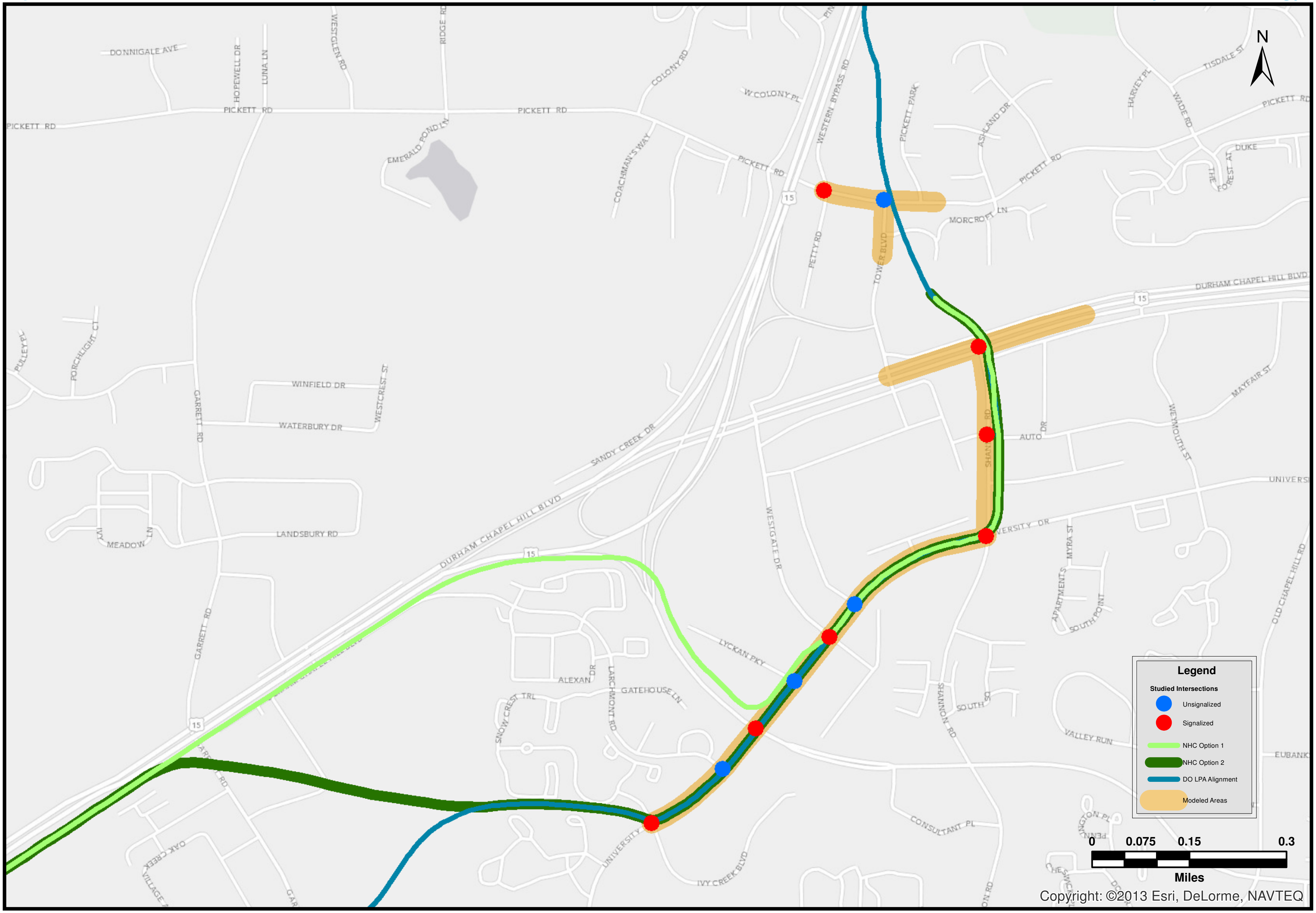
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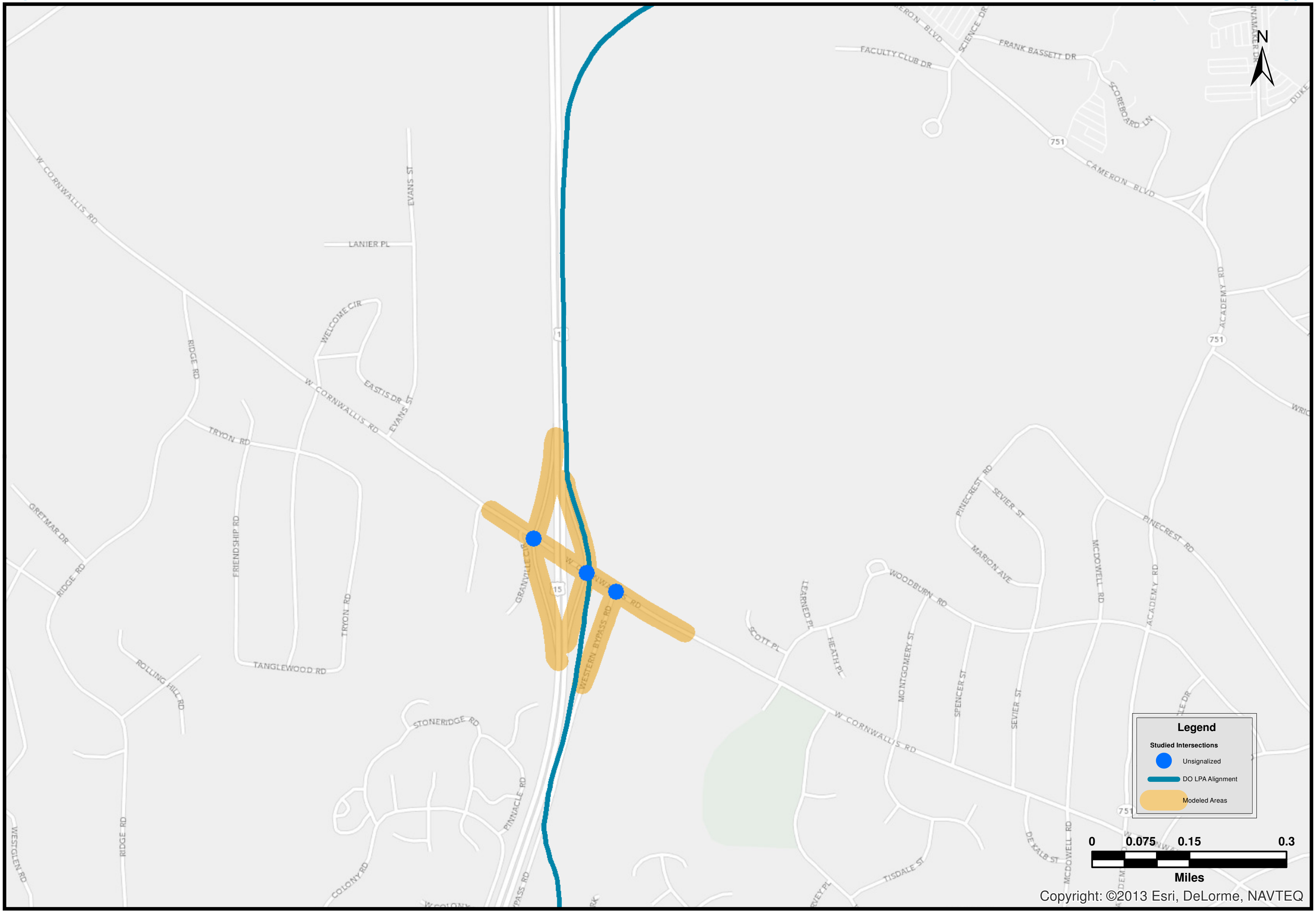
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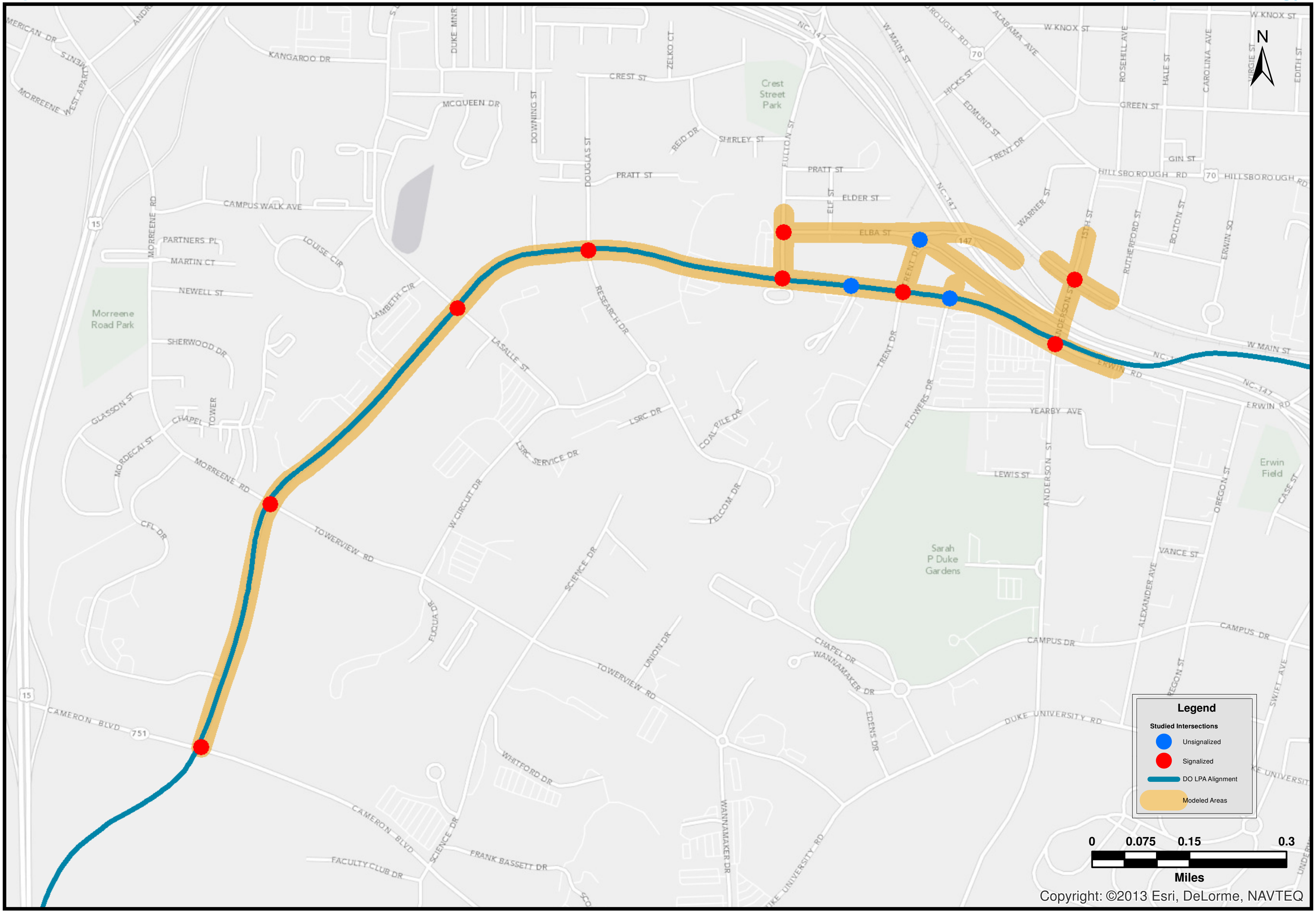
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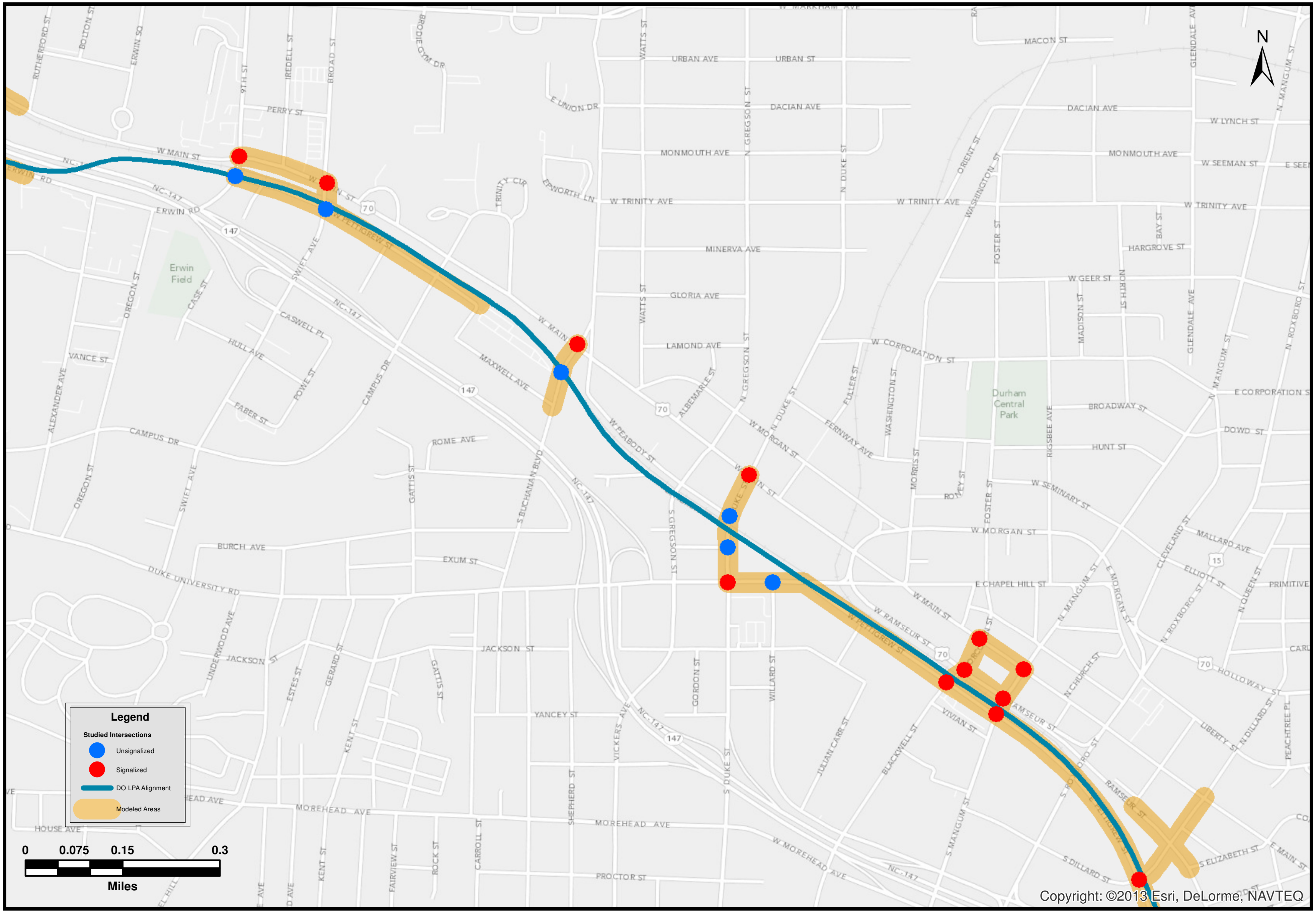
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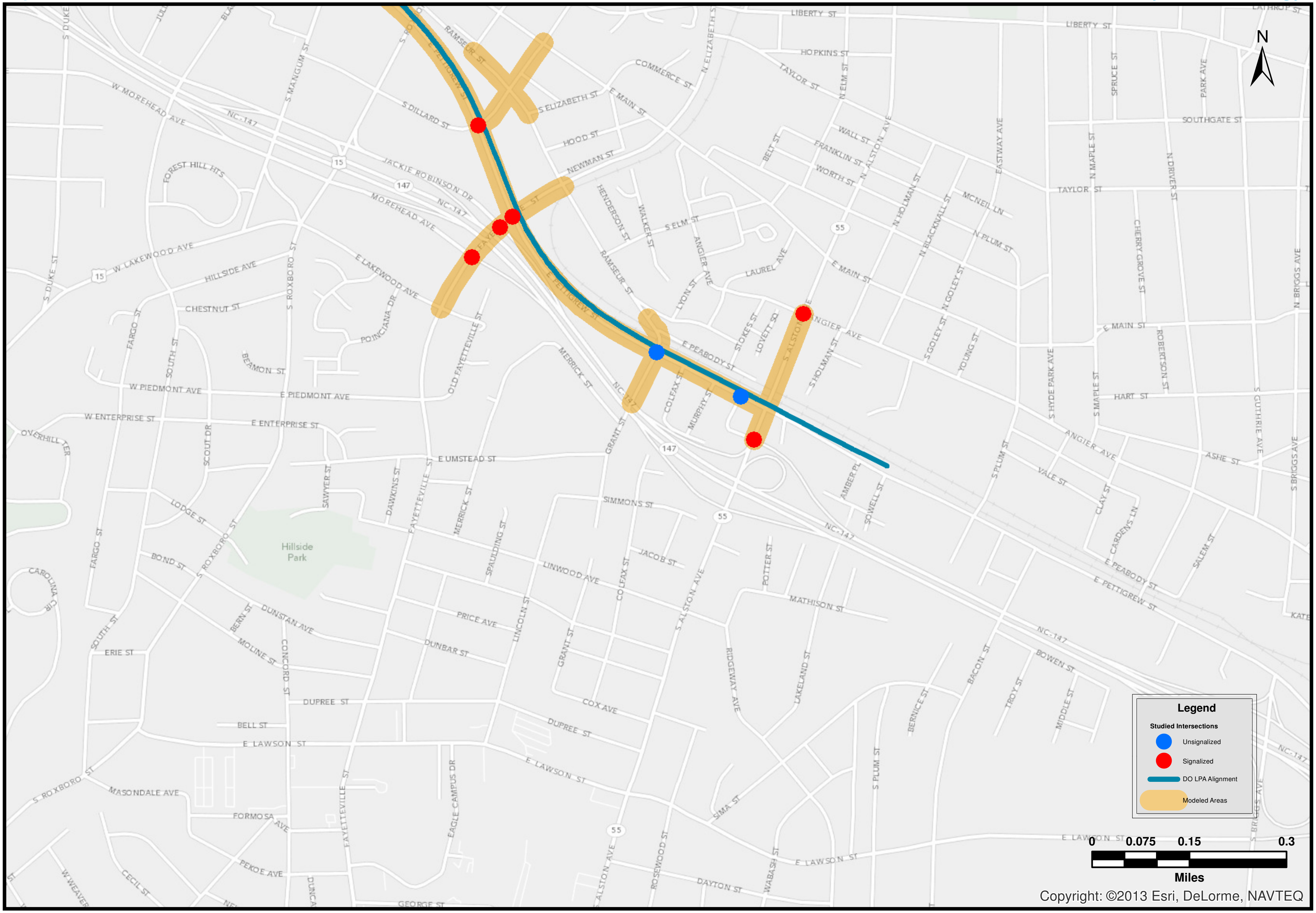
W GEER ST
W CORPORATION ST
E CORPORATION ST
Durham Central Park
BROADWAY ST
DOWD ST
HUNT ST
W SEMINARY ST
W MORGAN ST
E CHAPEL HILL ST
MALLARD AVE
ELLIOTT ST
PRIMITIVE
HOLLOWAY ST
W RAMSEUR ST
VIVIAN ST
S DILLARD ST
S ELIZABETH ST
E MAIN ST
Erwin Field
CASWELL PL
HULL AVE
FABER ST
CAMPUS DR
VANCE ST
ALEXANDER AVE
OREGON ST
SWIFT AVE
MAXWELL AVE
W PEABODY ST
ROME AVE
S BUCHANAN BLVD
BURCH AVE
EXUM ST
DUKE UNIVERSITY RD
JACKSON ST
YANCEY ST
MOREHEAD AVE
W MOREHEAD AVE
PROCTOR ST
HOUSE AVE
S GREGSON ST
S DUKE ST
WILLARD ST
GORDON ST
JULIAN CARR ST
BLACKWELL ST
S MANGUM ST
FERNWAY AVE
FOSTER ST
MORRIS ST
RIGSBEE AVE
GLENDALE AVE
N MANGUM ST
N ROXBORO ST
N QUEEN ST
LIBERTY ST
N DILLARD ST
PEACHTREE PL


N
Legend
Studied Intersections
Unsignalized
Signalized
DO LPA Alignment
Modeled Areas
0 0.075 0.15 0.3
Miles
Copyright: ©2013 Esri, DeLorme, NAVTEQ

3. Future Year No-Build/TSM Model

The No-Build and TSM alternatives are being combined as the traffic volumes are expected to be roughly similar. A future year No-Build/TSM model will be developed for each of the areas identified in section 2.1. These models will examine future conditions that could occur if the D-O LRT line were not constructed. As part of this analysis some projected deficiencies of the roadway network could be discovered. This analysis will not aim to categorize those deficiencies or to develop mitigation strategies. This analysis will be limited to determining likely future year conditions.

3.1 Develop Future Year No-Build/Tsm Volume Data

The balanced volumes developed for the base year analysis will be employed as the starting point for developing the future year No-Build/TSM volume data. Based on the balanced base-year peak-hour turning-movement, data link volumes will be generated for both the AM and PM peak hours. Data from the TRTDM will be used to obtain an appropriate growth factor for every link and this growth factor will be applied to base year link volumes to forecast future year No-Build/TSM peak-hour link volumes for the AM and PM peak hours. Data utilized for this will include daily volume growth, daily percentage growth, peak hour volume growth, and peak hour percentage growth. It will be critical to examine the peak hour data as well as the daily volume data as some peak spreading is likely to occur along the D-O LRT corridor given the developed nature of the corridor and the limited right-of-way available for additional roadway expansion. Engineering judgment will be employed to ensure that appropriate growth rates are extracted from the model.

Growth rates and projected link volumes will be reviewed in light of planned improvements in the area including projected development and changes to parking and transit operations. The model will be reviewed to determine which changes may have already been included within the socio-economic assumptions in the TRTDM. Forecasted link volumes will then be adjusted as necessary to reflect known changes that were not captured in the TRTDM.

Peak-hour turning volumes will be forecasted based on the peak-hour link volumes. Using the *TurnsW32* program (http://www.kittelson.com/toolbox/turnsw32) and the future year peak-hour link volumes and the base-year turning movements as input data, future year turning movements will be generated. These volumes will then be balanced in a manner similar to that used in the base year, although this process is likely to be less intensive.

Lastly, the sink and source nodes developed for the base year will be revisited. Based on existing development, planned development, and, to a lesser extent, sink and source nodes for the future year, a No-Build/TSM scenario will be developed.

3.2 Pedestrian And Bicycle Volumes

Local pedestrian and bicycle plans will be examined and proposed improvements that intersect the corridor will be noted. Qualitative estimates of the extent to which pedestrian and bicycle traffic will interact with the roadway network will be developed based on base year conditions and proposed developments. For this analysis cyclists will be assumed to cross at crosswalks and will not be included in the vehicular flow. At those locations where pedestrian and bicycle traffic is expected be above the 100 conflicting pedestrians per hour data will be developed and added to the model. The intersection Erwin Road and Fulton Street will include pedestrian or bicycle flow data in keeping with the base year calibration process. Additional intersections, particularly in downtown Durham or near either of the major college campuses, may also include pedestrian data in the future year No-Build/TSM analysis.

3.3 Future Year No-Build/Tsm Model Development

The base year model will be updated based on expected improvements to the roadway network. For this process the State Transportation Improvement Plan (STIP), the Metropolitan Transportation Improvement Plan (MTIP), various Capitol Improvement Plans (CIP), and bond packages will be reviewed to ensure that anticipated improvements are included in the future year model network. Unsignalized intersections will be given a cursory examination to determine if signalization is appropriate for future year conditions based on the volumes developed in the previous steps.

Signal timings will be updated using either Synchro or Vistro and the projected volumes and geometries. These new timings will be added to the model. Regardless of the development of pedestrian and bicycle data from the previous step all signals will be optimized to allow for safe pedestrian crossings.

Lastly routing information will be updated as needed to reflect changes in the roadway network based on proposed changes.

3.4 Model Simulation And Output Extraction

Upon developing the future year No-Build/TSM model, the model will run for the number of iterations necessary to achieve base year calibration. Models will be run using static trip assignments. The following data will be extracted and analyzed:

- Intersection Level of Service (LOS)
- Queuing
- Control delay
- Travel time
- Travel speeds
- Network delay (total and average per vehicle)

3.5 Comparison To Synchro

The Synchro analysis completed in the Alternative Analysis phase will be updated with new traffic volumes. The data from Synchro will be compared to the VisSim output. Differences will be noted and explained.

4. Future Year Build Models

A future year Build model will be developed for each of the areas identified in section 2.1. As noted in section 3.0 this analysis may reveal potential deficiencies in the future year roadway network. Only those areas negatively impacted above a certain threshold will be identified as part of this analysis. Areas anticipated to be deficient regardless of construction of the D-O LRT will not be identified nor will any potential mitigation strategy be developed.

4.1 Develop Future Year Build Volume Data

The balanced volumes developed for the future year No-Build/TSM analysis will be used as the starting point for developing the future year build volume data. Based on the balanced future-year No-Build/TSM turning-movement data, peak-hour link volumes will be generated for both the AM and PM peak hours. Data from the TRTDM will be used to obtain an appropriate diversion factor for every link for the AM and PM peak hours. Data utilized for this will include daily volume diversion, daily percentage diversion, peak hour volume diversion, and peak hour percentage diversion. It will be critical to examine the peak hour data as well as the daily data as some peak spreading is likely to occur along the D-O LRT corridor given the developed nature of the corridor and the limited right-of-way available for additional roadway expansion. Engineering judgment will be employed to ensure that appropriate growth rates are extracted from the model. A check will also be done between the Build and No-Build/TSM volume data to see if patterns suggested by the TRTDM are reflected in the volume data.

Growth rates and projected link volumes will be reviewed in light of planned improvements in the area including projected development and changes to parking and transit operations. The model will be reviewed to determine which changes may have already been included within the socio-economic assumptions in the TRTDM. Forecasted link volumes will then be adjusted as necessary to reflect known changes that were not captured in the TRTDM.

Peak-hour turning volumes will be forecast based on the peak-hour link volumes. Using the *TurnsW32* program (http://www.kittelson.com/toolbox/turnsw32) and the future year peak hour link volumes and the base year turning movements as input data future year turning movements will be generated. These volumes will then be balanced in a manner similar to that used in the base year, although this process is likely to be less intensive.

Lastly, the sink and source nodes developed for the base year will be revisited. Based on existing development, planned development, and, to a lesser extent, sink and source nodes for the future year, a Build scenario will be developed.

4.2 Pedestrian And Bicycle Volumes

In addition to data collected in section 3.2, station area data and ridership information will be examined to determine which areas may need to include pedestrian and bicycle flows in the analysis. The increase in pedestrian traffic due to the proposed D-O LRT will be above and beyond any increase due to future year land use. Qualitative estimates of pedestrian and bicycle flows will be developed based on base year conditions and proposed developments. In keeping with the future year No-Build/TSM analysis cyclists will be assumed to cross at crosswalks and will not be included in the vehicular flow. At those locations where pedestrians and bicycles are expected to be above the 100 conflicting pedestrians in the peak hour, data will be developed and added to the model.

4.3 Future Year Build Model Development

The future year Build model will be updated based on the proposed D-O LRT. Unsignalized intersections will be given a cursory examination to determine if signalization is appropriate for future year conditions based on the volumes developed in the previous steps.

Prior to signal optimization the project team will meet with local officials to discuss preferred interactions between the LRT and nearby signals. This will include discussions of both transit signal priority (TSP) and pre-emption. An interaction strategy for each individual signal will be identified.

Signal timings will be updated utilizing either Synchro or Vistro and the projected volumes and geometries and interaction strategy. These new timings will be added to the model. Regardless of the development of pedestrian and bicycle data from the previous step all signals will be optimized to allow for safe pedestrian crossings.

Lastly routing information will be updated as needed to reflect changes in the roadway network based on proposed changes.

4.4 Model Simulation And Output Extraction

Upon developing the future year Build model, the model will run for the number of iteration necessary to achieve base year calibration. Models will be run utilizing static trip assignment. The following data will be extracted and analyzed:

- Intersection LOS
- Queuing
- Control delay
- Travel time
- Travel speeds
- Network delay (total and average per vehicle)

4.5 Identify D-O LRT Impacts

Future year build output will be compared to future year no-build data. Those intersections that are expected to increase delay above a certain threshold will be identified. For the purposes of this study NCDOT's Policy on Street and Driveway, Chapter 5, Section J will be used to identify intersections on facilities owned by NCDOT and in the Town of Chapel Hill. The *Durham Comprehensive Plan Policy 8.1.2a, Traffic Level of Service (LOS) Standards* from the City of Durham will be applied to identify intersections on facilities owned by the City of Durham. Mitigation strategies to address the degradation in LOS and control delay will be developed for those identified intersections in the next phase of the project.

5. Friday Center Drive and Barbee Chapel Road Grade Separation Analysis

A grade separation analysis will be conducted to determine the benefit of grade separating the LRT crossings at Friday Center Drive and Barbee Chapel Road, both near NC 54. These locations were determined based on an analysis completed during the AA portion of the project and due to recent adjustments to the proposed D-O LRT alignment. The AA included a high level review of grade-separated and at-grade crossings and made definitive recommendations for the other crossings. The analysis for the Friday Center Drive and Barbee Chapel Road crossings could not be completed during the AA phase because of the more limited data available in this phase. This analysis will include altering the future year build network in the area to include a grade separated LRT crossing at Friday Center Drive. The model will then be re-run and new data will be extracted. The new model run data will be compared to the previous future year build data to determine the benefits of grade separating at this crossing. If necessary the analysis will review both alternative C1 and C2 to determine the benefits of grade separation.

6. Mitigation Plan

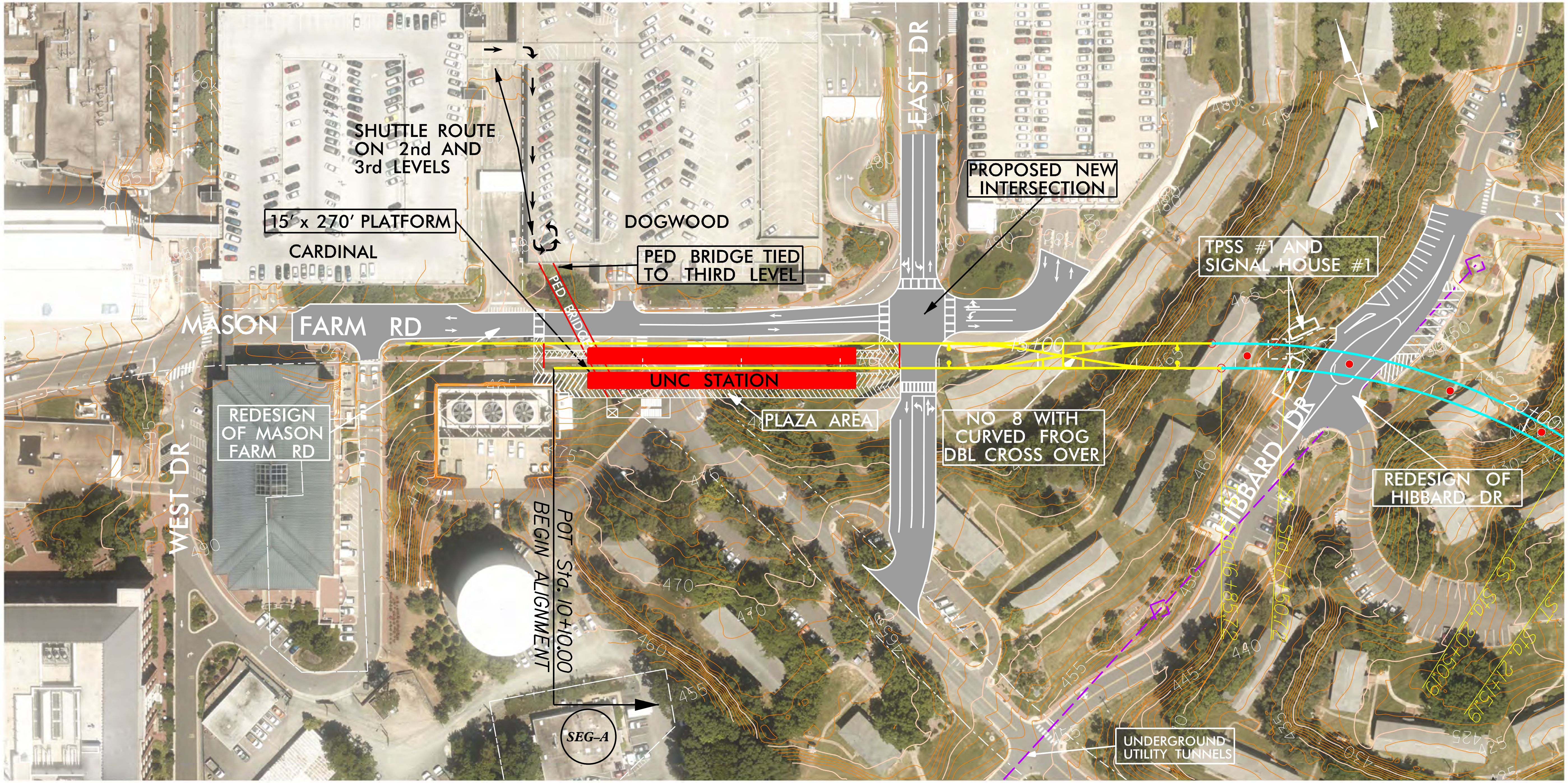
As noted above, a list of intersections expected to experience an increase in control above given thresholds will be developed. To reduce the impact of the D-O LRT, mitigation strategies will be identified for these locatoins. Such strategies could include additional turn lanes, improvements to alternative paths, alterations to travel patterns reducing delay, and improvements that do not add capacity such as improved wayfinding. These strategies will be tested utilizing VisSim to the extent possible. The modeled networks will be altered to include the roadway improvements or, in the case of strategies that alter travel patterns, the routing and volume data will be adjusted to reflect those new paths. The effectiveness of the strategies will be determined based on model results.

While the sections simulated are generally corridors, it is possible that some mitigation strategies may include the creation or improvement of alternative paths. Such an improvement may require the use of dynamic traffic assignment. A previously proposed mitigation strategy that would create an alternative path is the conversion of the Trent Drive and Elba Street intersection from the current configuration to a roundabout. Currently traffic on northbound Trent Drive cannot continue to westbound Elba Street. The conversion of this intersection to a roundabout would allow traffic on northbound Trent Drive to continue to westbound Elba Street. This conversion would provide an alternative path to the right-turning traffic from westbound Erwin Road to northbound Fulton Street, thus allowing this stream of traffic the opportunity to bypass the Erwin Road and Fulton Street intersection.

For this potential improvement, as well as similar improvements that create alternative paths, we are proposing to continue the use of static traffic assignment. Routing decisions will be updated such that traffic will be diverted to the new route and the model will be re-run and data on travel times extracted. The congested travel time of the new path will be compared to the existing path for the runs with the shifted traffic. If the travel time for the new path is still less than that for the existing path then no additional analysis will be required. In a case like this dynamic traffic assignment would shift all traffic to the new path as it is the shortest path. If the travel time for the new path is greater than the travel time for the existing path then dynamic traffic assignment will be used to provide the appropriate balance between traffic that will use the new path and traffic that will use the existing path. It is under this, and only this, condition that dynamic traffic assignment would be employed.

Appendix B
Basis for Engineering Plans
(LRT Alternatives Design Plans)

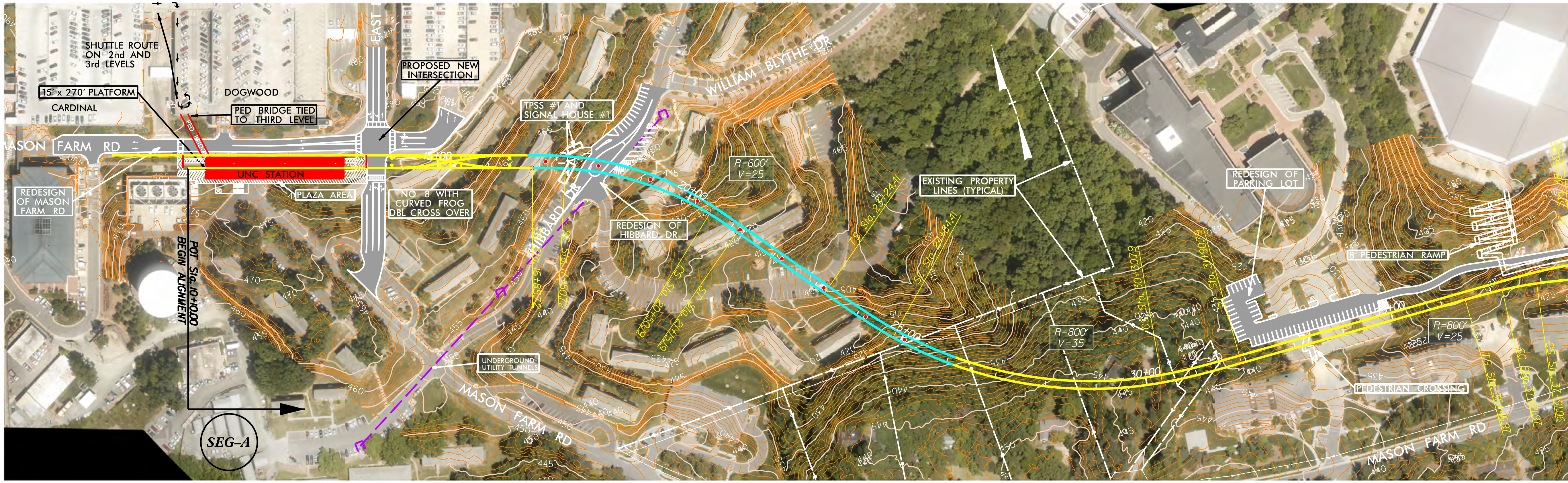
UNC STATION

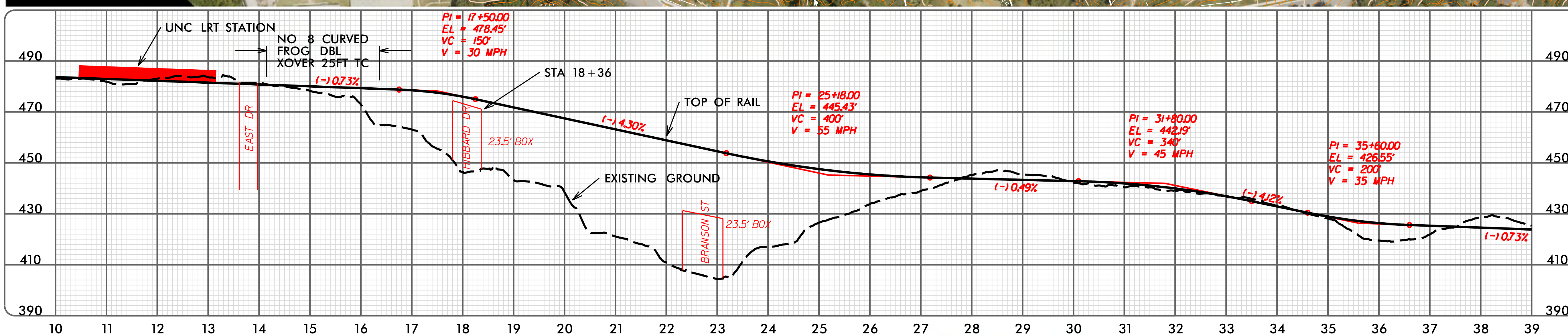


GRAPHIC SCALES		LEGEND			PLAN AND PROFILE
100 0 50 100 PLAN	CONCEPT PLANS ONLY DO NOT USE FOR CONSTRUCTION INCOMPLETE PLANS DO NOT USE FOR R/W ACQUISITION	BRIDGE PIERS AT-GRADE TRK ELEVATED TRK WETLANDS STATION	OurTransit FUTURE Prepared In the Office of URS URS Corporation – North Carolina 1600 Perimeter Park Drive, Suite 400 Morrisville, North Carolina 27560 Phone (919)461-1100 Fax (919)461-1415 NC Lic.# C-2243	CH ENGINEERING 3220 GLEN ROYAL RD. RALEIGH, NC 27617 TELE 919.788.0224 FAX 919.788.0232 NC LICENSE #P-0189	SEGMENT A DWG: PLAN SHEET: A – 01

3/3/2015

UNC HOSPITALS





GRAPHIC SCALES

100 0 100 200
PLAN

100 0 100 200
PROFILE (HORIZONTAL)

20 10 0 20 40
PROFILE (VERTICAL)

3/3/2015

CONCEPT PLANS ONLY
DO NOT USE FOR CONSTRUCTION

INCOMPLETE PLANS
DO NOT USE FOR R/W ACQUISITION

LEGEND

● (red dot)	*BRIDGE PIERS*
(yellow line)	*AT-GRADE TRK*
(cyan line)	*ELEVATED TRK*
(blue line)	*WETLANDS*
(red bar)	*STATION*

OurTransit FUTURE

Prepared In the Office of

URS

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PLAN AND PROFILE

SEGMENT A

PLAN & PROFILE

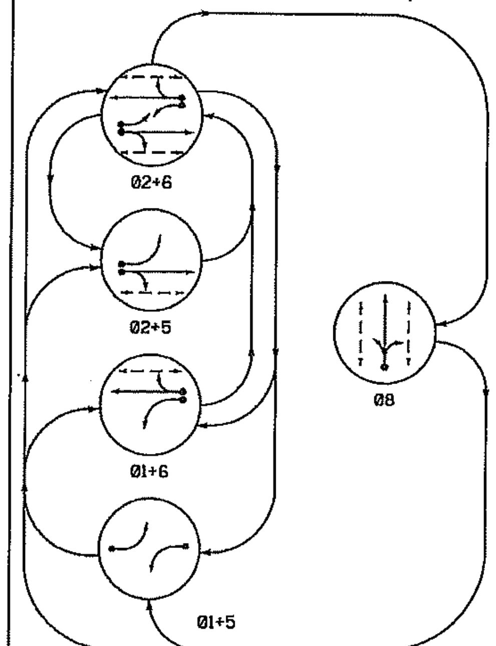
SHEET: A – 02

Appendix C
Existing Traffic Signal Timing Plans

5 PHASES FULLY ACTUATED (CHAPEL HILL SIGNAL SYSTEM)

PHASING DIAGRAM

(Backup Protect with Red Revert)



PHASING DIAGRAM DETECTION LEGEND

- DETECTED MOVEMENT
- UNDETECTED MOVEMENT (OVERLAP)
- UNSIGNALIZED MOVEMENT
- PEDESTRIAN MOVEMENT

TABLE OF OPERATION

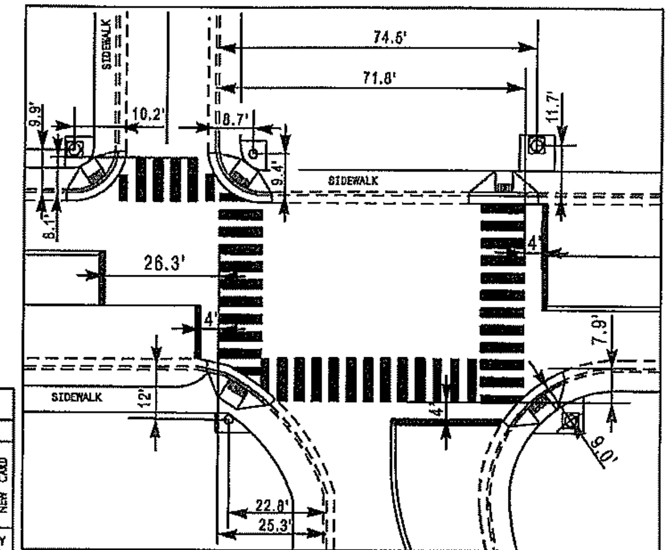
SIGNAL FACE	Ø1+5	Ø1+6	Ø2+5	Ø2+6	Ø8	FLASH
21	↘R	R	↘G	G	R	Y
22	R	R	G	G	R	Y
61	↘R	↘G	R	G	R	Y
62	R	G	R	G	R	Y
81, 82	R	R	R	R	G	R
P21, P22	DW	DW	W	W	DW	DRK
P61, P62	DW	W	DW	W	DW	DRK
P81, P82, P83, P84	DW	DW	DW	DW	W	DRK

W-WALK
DW-DON'T WALK
DRK-DARK

2070L LOOP & DETECTOR INSTALLATION

INDUCTIVE LOOPS					DETECTOR PROGRAMMING							
LOOP	SIZE (FT)	DISTANCE FROM STOPBAR (FT)	TURNS	NEW LOOP	PHASE	CALLING	EXTENSION	FULL TIME DELAY	STRETCH TIME	DELAY TIME	SYSTEM LOOP	NEW CARD
1A	6X40	0	2-4-2	Y	1	Y	Y	-	-	15	-	Y
					6	Y	Y	-	-	-	-	Y
2A	6X6	70	3	Y	2	Y	Y	-	-	-	-	Y
2B*	6X6 Diagonal	0	2-4-2	Y	2	Y	Y	-	-	10	-	Y
5A	6X40	0	2-4-2	Y	2	Y	Y	-	-	-	-	Y
					5	Y	Y	-	-	15	-	Y
6A	6X6	70	3	Y	6	Y	Y	-	-	-	-	Y
6B*	6X6 Diagonal	0	2-4-2	Y	6	Y	Y	-	-	10	-	Y
8A	6X40	16	2-4-2	Y	8	Y	Y	-	-	10	-	Y
8B*	6X6 Diagonal	0	2-4-2	Y	8	Y	Y	-	-	10	-	Y

* See Detail A. Set Sensitivity to appropriate level to detect a bicycle.

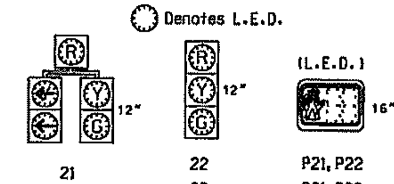


PROPOSED STOPBAR AND POLE LOCATION

Note: Dimensions are from face of curb to center of signal pole.

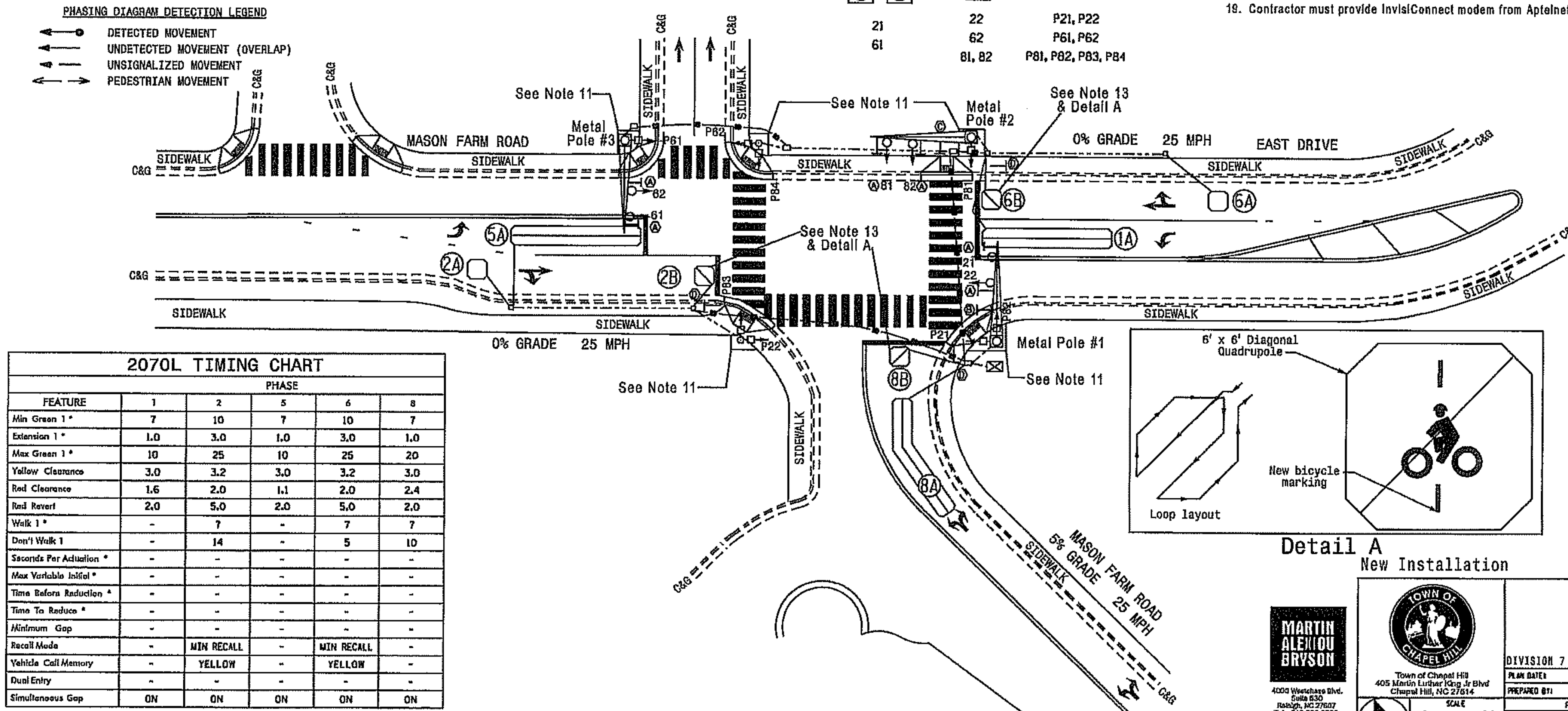
SIGNAL FACE I.D.

Denotes L.E.D.



NOTES

1. Refer to "Roadway Standard Drawings NCDOT" dated July 2006, and "Standard Specifications for Roads and Structures" dated July 2006, and all applicable sections of the latest version of the generic Project Special Provisions. The PSP can be accessed at the following website: http://www.ncdot.org/doh/preconstruct/traffic/ITSS/
2. Do not program signal for late night flashing operations unless otherwise directed by Town of Chapel Hill.
3. Enable backup protect for phase 2+6 to allow the controller to clear from phase 2+6 to phase 1+6 or 2+5 by progressing through all red display.
4. Set all detector units to presence mode.
5. Locate new cabinet so as not to obstruct sight distance of vehicles turning right on red.
6. Omit "WALK" and flashing "DON'T WALK" with no pedestrian calls.
7. Program pedestrian heads to countdown the flashing "Don't Walk" time only.
8. Locate all underground utilities prior to pole drilling and conduit trenching.
9. Maximum times shown in timing chart are for free-run operation only. Coordinated signal system timing values supersede these values.
10. The pedestrian pedestals, signal poles and mast arms must be colored dark green(RAL 6012). The exterior surfaces of the housings, doors and visors for traffic signal heads, pedestrian signal heads and pedestrian pushbuttons must be colored black.
11. Install sidewalk as necessary to provide ADA access between wheelchair ramps and pedestrian pushbuttons. The sidewalk for pushbutton ADA accessbility shall be 5' wide, with 5'X5' level landing area for wheelchair turning.
12. Install ADA accessible wheel chair ramps with detectable warning domes per NCDOT standards, Town of Chapel Hill standards and North Carolina Accessibility Code 1999, Section 4.7. Refer to Sheet C6(SIG-6) for North Carolina Accessibility Code 1999 requirements.
13. Paint new bicycle markings (as shown on Page 9C-9, 2003 edition of MUTCD) in the middle of the sawcuts for new loops 2B, 6B and 8B. Refer to Detail A.
14. Provide the power meter and the electric power disconnect on a combination panel with pedestal extension. Refer to Sheet C5(SIG-5) for details.
15. Street name signs will be provided by Town of Chapel Hill and installed by the contractor.
16. The contractor must make the controller and Econolite OASIS software available to the Town of Chapel Hill.
17. The contractor must provide and install the following GPS timing unit and accessory per manufacturer specifications: Acutime Gold GPS Smart Antenna-Part No. 39091-00 and Interface Cable (50') for Acutime-Part No. 60148.
18. Design of signal poles, mast arms, pedestrian pedestals and foundations must be sealed by a licensed engineer and presented to the Town for approval before construction.
19. Contractor must provide InvisiConnect modem from Apteinet for communication as per Town's specifications.



Detail A
New Installation

LEGEND

PROPOSED		EXISTING
	Traffic Signal Head	
	Sign	
	Pedestrian Signal Pedestal	
	Pedestrian Signal Head With Push Button & Sign	
	Metal Pole with Mastarm	
	Inductive Loop Detector	
	Controller & Cabinet	
	Junction Box	
	Oversize Junction Box	
	2-in Underground Conduit	
N/A	Right of Way	
	Directional Arrow	
	Pavement Marking Arrow	
	New Directional Drilled Conduit	N/A

Ⓐ "TURNING TRAFFIC MUST YIELD TO PEDESTRIANS" Ⓐ Sign (R10-15)

Ⓑ MASON FARM Ⓑ

Ⓒ MASON FARM EAST Ⓒ

Ⓓ R10-22 (12"X18") Ⓓ

2070L TIMING CHART

FEATURE	PHASE 1	2	5	6	8
Min Green 1 *	7	10	7	10	7
Extension 1 *	1.0	3.0	1.0	3.0	1.0
Max Green 1 *	10	25	10	25	20
Yellow Clearance	3.0	3.2	3.0	3.2	3.0
Red Clearance	1.6	2.0	1.1	2.0	2.4
Red Revert	2.0	5.0	2.0	5.0	2.0
Walk 1 *	-	7	-	7	7
Don't Walk 1	-	14	-	5	10
Seconds Per Actuation *	-	-	-	-	-
Max Variable Initial *	-	-	-	-	-
Time Before Reduction *	-	-	-	-	-
Time To Reduce *	-	-	-	-	-
Minimum Gap	-	-	-	-	-
Recall Mode	-	MIN RECALL	-	MIN RECALL	-
Vehicle Call Memory	-	YELLOW	-	YELLOW	-
Dual Entry	-	-	-	-	-
Simultaneous Gap	ON	ON	ON	ON	ON

* These values may be field adjusted. Do not adjust Min Green and Extension times for phases 2 and 6 lower than what is shown. Min Green for all other phases should not be lower than 4 seconds.

PROJECT REFERENCE NO. | SHEET NO. SIG-1

This plan supersedes plan signed and sealed on 04/20/2009.

MARTIN ALEXIOU BRYSON
4000 Westchase Blvd. Suite 530 Raleigh, NC 27607 Tel. 919.829.0328 Fax. 919.829.0329

TOWN OF CHAPEL HILL
Town of Chapel Hill 405 Martin Luther King Jr Blvd Chapel Hill, NC 27514

SCALE 0 20 1"=20'

East Drive at Mason Farm Road

DIVISION 7 | ORANGE COUNTY | CHAPEL HILL
PLAN DATE: 02/15/2011 | REVIEWED BY: JLL
PREPARED BY: JH | REVIEWED BY:
REVISIONS | INIT. | DATE

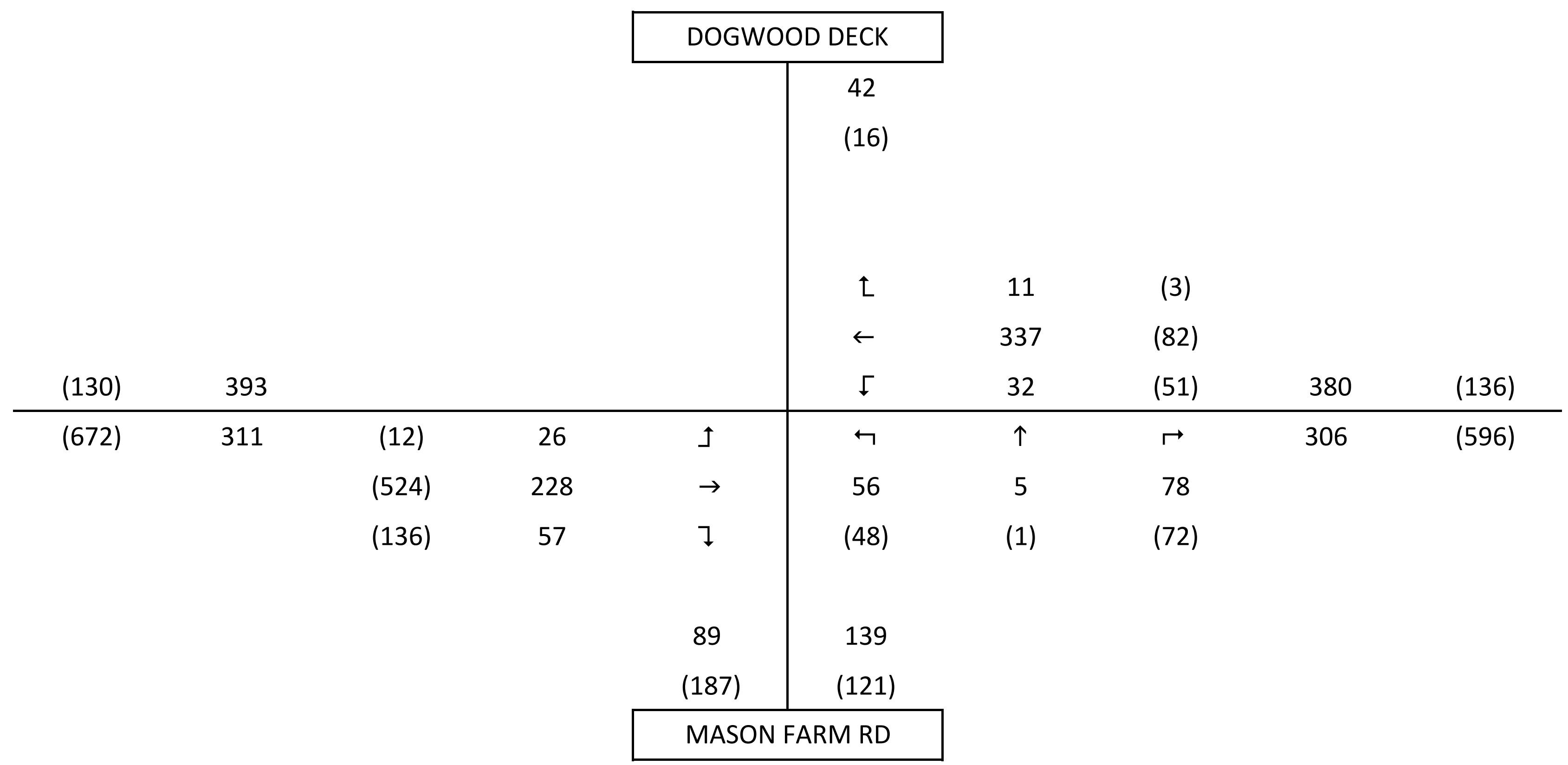
SEAL
NORTH CAROLINA PROFESSIONAL ENGINEER SEAL 033108 JIANXIN MA
SIGNATURE 2/15/2011 DATE

SIG. INVENTORY NO. CH-0222

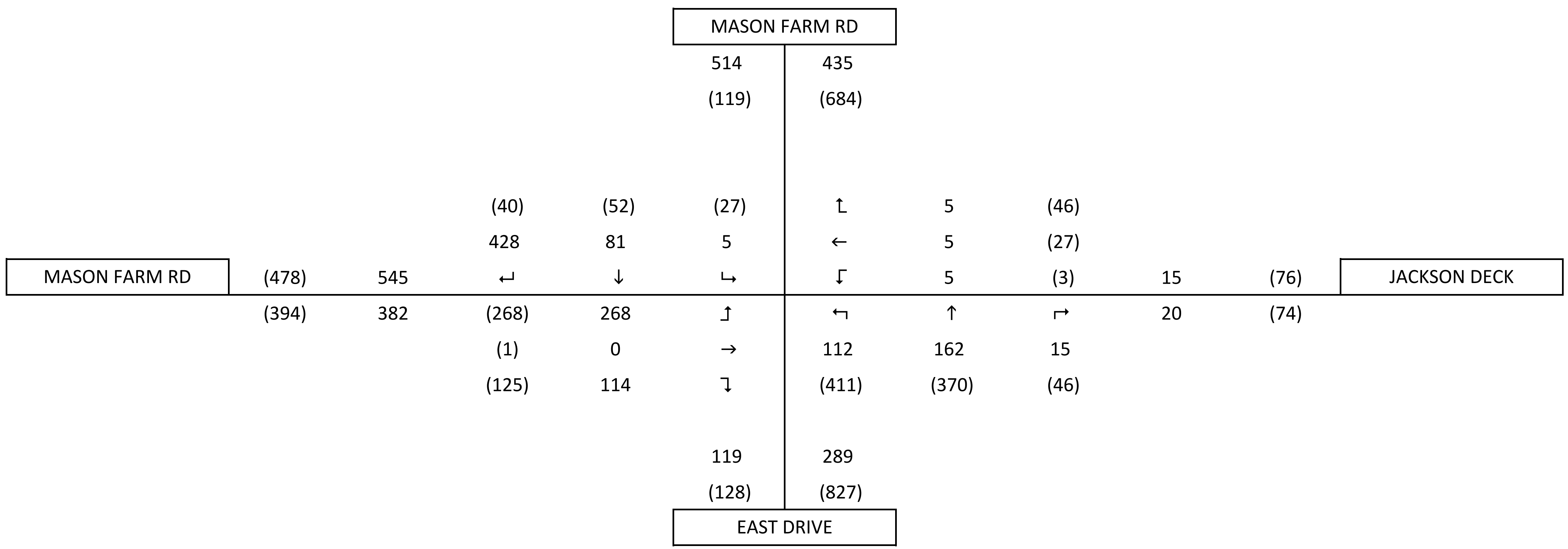
Appendix D
Balanced Peak Hour Volumes

2011 Base Year AM
2011 Base Year PM
2040 No-Build AM
2040 No-Build PM
2040 Build AM
2040 Build PM

2011 Existing Balanced Volumes



2040 No Build / TSM Scenario Balanced Volumes



2040 Build Scenario Balanced Volumes

					MASON FARM RD						
				514		435					
				(119)		(684)					
			(40)	(52)	(27)	↰	5	(46)			
			428	81	5	←	5	(27)			
MASON FARM RD	(478)	545	↵	↓	↳	↲	5	(3)	15	(76)	JACKSON DECK
	(394)	382	(268)	268	↱	↰	↑	↱	20	(74)	
			(1)	0	→	112	162	15			
			(125)	114	↴	(411)	(370)	(46)			
					119	289					
					(128)	(827)					
					EAST DRIVE						

Appendix E
2040 Synchro Outputs

2040 No-Build AM
2040 No-Build PM

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	268	0	114	5	5	5	112	162	15	5	81	428
Ideal Flow (vphpl)	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
Total Lost time (s)		7.0		7.0	7.0		7.0	7.0		7.0	7.0	
Lane Util. Factor		1.00		1.00	1.00		1.00	1.00		1.00	1.00	
Frt		0.96		1.00	0.93		1.00	0.99		1.00	0.87	
Flt Protected		0.97		0.95	1.00		0.95	1.00		0.95	1.00	
Satd. Flow (prot)		1636		1676	1632		1676	1742		1676	1542	
Flt Permitted		0.78		0.60	1.00		0.39	1.00		0.95	1.00	
Satd. Flow (perm)		1328		1066	1632		681	1742		1676	1542	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Adj. Flow (vph)	298	0	127	6	6	6	124	180	17	6	90	476
RTOR Reduction (vph)	0	69	0	0	4	0	0	2	0	0	128	0
Lane Group Flow (vph)	0	356	0	6	8	0	124	195	0	6	438	0
Turn Type	Perm	NA		Perm	NA		Perm	NA		Prot	NA	
Protected Phases		4			8			2		1	6	
Permitted Phases	4			8			2					
Actuated Green, G (s)		37.6		37.6	37.6		60.6	60.6		0.8	68.4	
Effective Green, g (s)		37.6		37.6	37.6		60.6	60.6		0.8	68.4	
Actuated g/C Ratio		0.31		0.31	0.31		0.51	0.51		0.01	0.57	
Clearance Time (s)		7.0		7.0	7.0		7.0	7.0		7.0	7.0	
Vehicle Extension (s)		3.0		3.0	3.0		3.0	3.0		3.0	3.0	
Lane Grp Cap (vph)		416		334	511		343	879		11	878	
v/s Ratio Prot					0.00			0.11		0.00	c0.28	
v/s Ratio Perm		c0.27		0.01			0.18					
v/c Ratio		0.86		0.02	0.02		0.36	0.22		0.55	0.50	
Uniform Delay, d1		38.7		28.5	28.4		18.0	16.6		59.4	15.5	
Progression Factor		1.00		1.00	1.00		1.00	1.00		1.00	1.00	
Incremental Delay, d2		15.8		0.0	0.0		2.9	0.6		45.6	2.0	
Delay (s)		54.4		28.5	28.4		20.9	17.1		105.0	17.5	
Level of Service		D		C	C		C	B		F	B	
Approach Delay (s)		54.4			28.5			18.6			18.4	
Approach LOS		D			C			B			B	

Intersection Summary			
HCM 2000 Control Delay	30.1	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.67		
Actuated Cycle Length (s)	120.0	Sum of lost time (s)	21.0
Intersection Capacity Utilization	87.9%	ICU Level of Service	E
Analysis Period (min)	15		
c Critical Lane Group			

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	268	1	125	3	27	46	411	370	46	27	52	40
Ideal Flow (vphpl)	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
Total Lost time (s)		7.0		7.0	7.0		7.0	7.0		7.0	7.0	
Lane Util. Factor		1.00		1.00	1.00		1.00	1.00		1.00	1.00	
Frt		0.96		1.00	0.91		1.00	0.98		1.00	0.94	
Flt Protected		0.97		0.95	1.00		0.95	1.00		0.95	1.00	
Satd. Flow (prot)		1634		1676	1598		1676	1735		1676	1651	
Flt Permitted		0.75		0.58	1.00		0.69	1.00		0.95	1.00	
Satd. Flow (perm)		1261		1022	1598		1220	1735		1676	1651	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Adj. Flow (vph)	298	1	139	3	30	51	457	411	51	30	58	44
RTOR Reduction (vph)	0	14	0	0	33	0	0	3	0	0	20	0
Lane Group Flow (vph)	0	424	0	3	48	0	457	459	0	30	82	0
Turn Type	Perm	NA		Perm	NA		Perm	NA		Prot	NA	
Protected Phases		4			8			2		1	6	
Permitted Phases	4			8			2					
Actuated Green, G (s)		41.9		41.9	41.9		54.7	54.7		2.4	64.1	
Effective Green, g (s)		41.9		41.9	41.9		54.7	54.7		2.4	64.1	
Actuated g/C Ratio		0.35		0.35	0.35		0.46	0.46		0.02	0.53	
Clearance Time (s)		7.0		7.0	7.0		7.0	7.0		7.0	7.0	
Vehicle Extension (s)		1.0		1.0	1.0		5.0	5.0		1.0	5.0	
Lane Grp Cap (vph)		440		356	557		556	790		33	881	
v/s Ratio Prot					0.03			0.26		c0.02	0.05	
v/s Ratio Perm		c0.34		0.00			c0.37					
v/c Ratio		0.96		0.01	0.09		0.82	0.58		0.91	0.09	
Uniform Delay, d1		38.3		25.5	26.2		28.4	24.2		58.7	13.7	
Progression Factor		1.00		1.00	1.00		1.00	1.00		1.00	1.00	
Incremental Delay, d2		33.1		0.0	0.0		12.9	3.1		116.4	0.2	
Delay (s)		71.4		25.5	26.2		41.3	27.3		175.0	13.9	
Level of Service		E		C	C		D	C		F	B	
Approach Delay (s)		71.4			26.2			34.2			50.5	
Approach LOS		E			C			C			D	

Intersection Summary			
HCM 2000 Control Delay	45.5	HCM 2000 Level of Service	D
HCM 2000 Volume to Capacity ratio	0.88		
Actuated Cycle Length (s)	120.0	Sum of lost time (s)	21.0
Intersection Capacity Utilization	72.8%	ICU Level of Service	C
Analysis Period (min)	15		
c Critical Lane Group			