DIN 01611

Leigh Village Traffic Simulation Report

Durham-Orange Light Rail Transit Project

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 Leigh Village Traffic Simulation Report includes the 0.50 mile long corridor of NC 54 (Raleigh Road) that extends from Huntingridge Road to I-40 and Farrington Road within the City of Durham limits. The NC 54 corridor has four different build alternatives: C1/C1A, C2 and C2A. Each of the four alignments follows a different path crossing Little Creek before continuing towards the Leigh Village Station. Beyond the Leigh Village Station to the east, the D-O LRT has only one alignment and continues towards I-40 running through mainly undeveloped land with few residences or commercial properties. The proposed Leigh Village Station would be located southwest of the intersection of New E-W Street C and N-S Connector Road. 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.

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

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

It should be noted that under the Existing Conditions, the intersection of NC 54 and Huntingridge Road is a full access signalized intersection, which would be converted to right-in/right-out under the No-Build Conditions and Build Alternative. The existing NC 54 and Falconbridge Road intersection currently limits northbound and southbound movements to right turns only from Falconbridge Road. This intersection would be converted to a full access signalized intersection under the No-Build and Build Alternatives. The changes to the intersection geometry at Falconbridge Road and Huntingridge Road are part of TIP U-5324A. As part of the No-Build Conditions, Falconbridge Road is proposed to be constructed as a 4-lane roadway, north of NC 54, and continues as N-S Connector Road towards the Leigh Village Station and the new park-and-ride facility. This roadway also continues beyond the Leigh Village Station towards Ephesus Church Road. In addition, an I-40 EB Slip On-Ramp is proposed along Farrington Road as part of TIP U-5517.

All of the intersections along NC 54 include a state-maintained roadway and therefore the NCDOT Traffic Impact Criteria have been applied to those locations. The remaining locations are under the jurisdiction of the City of Durham and were evaluated accordingly. During the analysis, roadway modifications to improve traffic operations were incorporated into the LRT Build Alternative analysis models. The recommended modifications proposed as part of the LRT Alternatives are presented in Table ES-1.

Table ES-1: LRT Alternative Proposed Roadway Modifications

Intersection	Roadway Modification
New E-W Street C at N-S Connector Road	Construct new N-S Connector Road (from NC 54 to New E-W Street C)
	Construct New E-W Street C
	Signalize new intersection

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-2.

Table ES-2: Vissim Overall Intersection Analysis Summary – 2040 LRT Alternative vs 2040 No-Build

Intersection	2040 No-Build		2040 Build	
	AM	PM	AM	PM
Huntingridge Road at NC 54[1]	F	F	F	F
Falconbridge Road at NC 54[1]	E	E	E	E
New East-West Street C at N-S Connector Road[2] (Build Alternative only)	--	--	D	B
Farrington Road at I-40 Eastbound Slip On-Ramp[1]	F	E	F	E
Farrington Road at Ephesus Church Road[2]	D	B	D	B

Footnote:

1 - NCDOT Traffic Impact Criteria is applied

2 - City of Durham Traffic Impact Criteria is applied

Indicates Traffic Impact

Intersections along NC 54 are expected to operate at LOS E or F under the No-Build Alternative during both peak hours, suggesting a need for roadway improvements unrelated to the construction of D-O LRT. Traffic along the NC 54 corridor is metered by the traffic signal at the NC 54 and Falconbridge Road intersection and the Vissim analysis indicated queuing would occur along NC 54 under No-Build conditions. Spillback queues along NC 54 in turn would cause increased delays at the NC 54 and Huntingridge Road intersection. The unsignalized intersection of Farrington Road and I-40 Eastbound Slip On-Ramp would operate at LOS F and E during the AM and PM peak hours, respectively, as the heavy southbound left movement conflicts with the free following northbound through movement along Farrington Road. The intersection of Farrington Road and Ephesus Church Road is expected to operate at LOS D or better during both the peak hours under the No-Build Alternative meeting City of Durham Criteria.

Under the Build Alternative, overall intersection operations at these locations are the same as under the No-Build Conditions. At the New E-W Street C and N-S Connector Road intersection, railroad crossing gates were assumed to be installed at all approaches of this intersection to prevent conflicting LRT and vehicular movements. This proposed intersection is anticipated to operate at LOS D or better during both AM and PM peak hours. As the D-O LRT has minimal impacts to the study intersections, no other roadway modifications are recommended as a part of this report.

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 location)
- Crossing of New Hope Creek (NHC) and Sandy Creek between Patterson Place and South Square (i.e., NHC LPA and 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 Leigh Village 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 Leigh Village section of the proposed D-O LRT in light of the policies identified in the *Traffic Analysis Methodology Report*.

The goal of the study 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 projects are necessary to accommodate the background growth in traffic and which are necessary to mitigate additional impacts caused by the proposed D-O LRT project.

2.4 Leigh Village 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.

Preliminary designs were developed for the proposed D-O LRT alignment with the proposed Leigh Village Station located southwest of the intersection of New E-W Street C and N-S Connector Road as shown in the *Basis for Engineering Design* plans (Appendix B). It evaluated both AM and PM peak hour traffic volumes with the introduction of the proposed D-O LRT with the LRT system operating with 10 minute peak period frequency and 20 seconds of dwell time at each station for passenger boarding and alighting.

As shown in the *Basis for Engineering Design* plans, the NC 54 corridor has four different alternatives – C2A, C2 and C1/C1A. Beyond Woodmont Station, C2A and C2 run parallel to NC 54 before crossing NC 54 above-grade. Beyond the Friday Center Station, C1 and C1A alignment crosses NC 54 above-grade to run parallel to Meadowmont Lane. After crossing Meadowmont Lane at grade, the C1 and C1A alignments continue towards Leigh Village Station. All four alignments follow a different path crossing Little Creek before continuing towards Leigh Village Station. Beyond Leigh Village Station, the D-O LRT has only one alignment to the east. The proposed D-O LRT project would be elevated and would not interact with the NC 54 and Farrington Road corridor. The proposed D-O LRT would be at-grade in the Leigh Village section with a new at-grade crossing intersection (through the center of the intersection at New E-W

Street C at N-S Connector Road). The LRT alignment then continues towards I-40 running through mainly undeveloped land with very few residences or commercial properties. Regardless of the D-O LRT alignment alternative, all of the study intersections would be configured and operate consistently. Therefore, only the traffic analysis results for C2A alignment are presented in this report. Following are the intersections evaluated as part of this report and are also shown in Figure 1:

- NC 54 at Huntingridge Road
- NC 54 at Falconbridge Road
- New E-W Street C at N-S Connector Road (Build Alternative only)
- Farrington Road at I-40 Eastbound Slip On-Ramp
- Ephesus Church Road at Farrington Road

The D-O LRT would be elevated and not interact with the NC 54 and Farrington Road corridors. The LRT would cross at-grade at the Build proposed intersection of New E-W Street C and N-S Connector Road. For the purposes of this analysis it was assumed that the traffic signal at the intersection of New E-W Street C at N-S Connector Road will be programmed to operate with traffic signal preemption. Railroad crossing gates are proposed to be installed at this intersection to prevent conflict between vehicular and LRT movements. Triangle Transit will work with NCDOT to develop signal plans for this intersection during the Engineering phase of the project. The traffic signal plans will incorporate signal preemption or transit 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 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.

The proposed D-O LRT alignment would be at-grade and cross through the middle of the New E-W Street C and N-S Connector Road 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, traffic crossing the tracks must stop while traffic traveling parallel to the tracks can proceed. This may be accomplished by lengthening or shortening the traffic signal phases, typically by no more than 30 or 45 seconds. 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 cycle length at this intersection is assumed to be 120 seconds.

For purposes of this analysis, in the No-Build Alternative, per TIP U-5324A, the current 4-lane NC 54 section is widened to a 6-lane section from Barbee Chapel Road to I-40 by NCDOT. As part of the NC 54 widening, exclusive eastbound and westbound right turn lanes were assumed at the NC 54 and Huntingridge Road intersection, in addition to northbound and southbound right turns at NC 54 and Falconbridge Road intersection. Also, per TIP U-5517, an I-40 EB Slip On-Ramp is proposed to be constructed by NCDOT along Farrington Road under the No-Build Conditions. Both of these changes are also incorporated in the Build alternative.

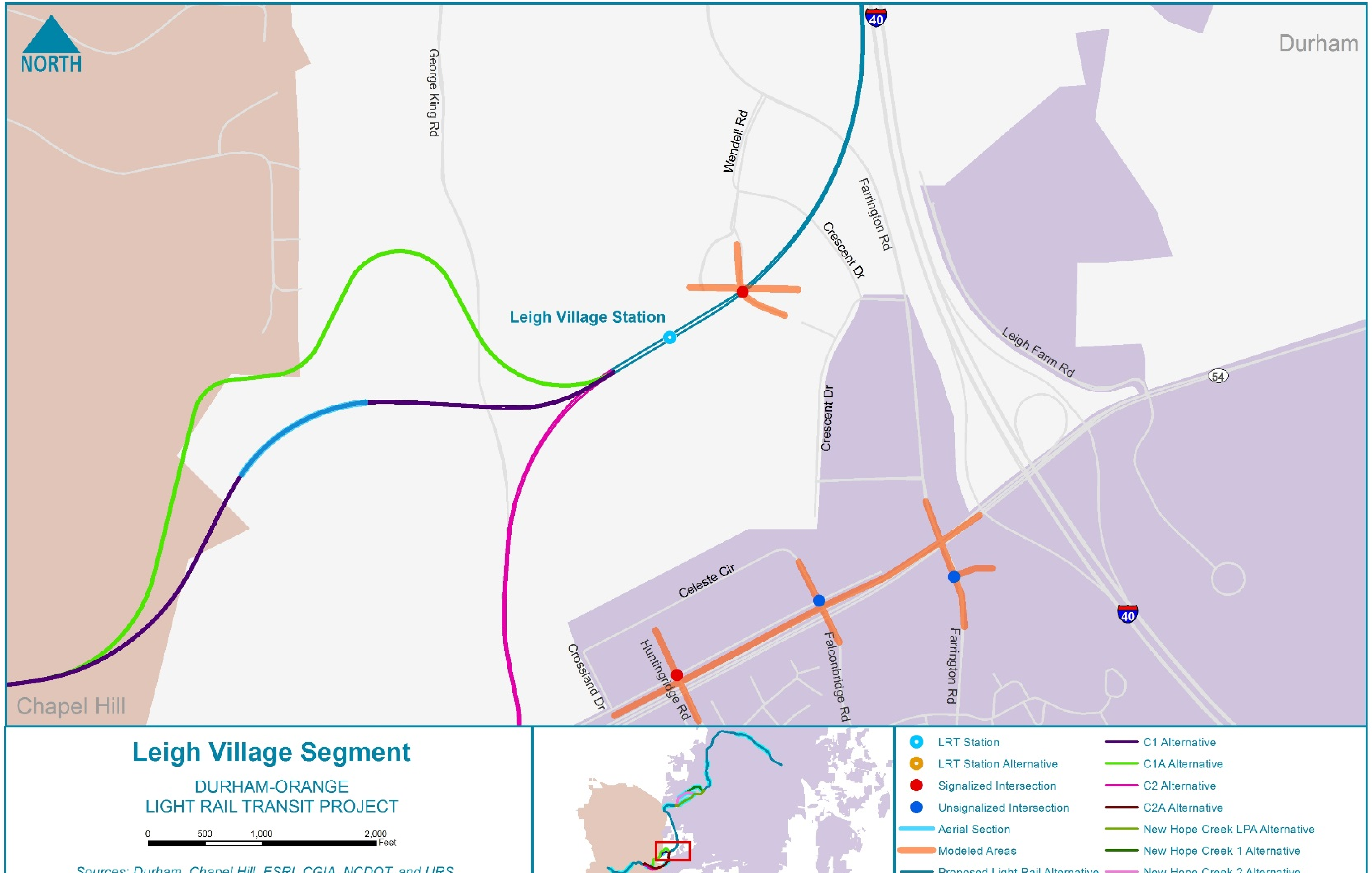
The park-and-ride facility to be constructed with the D-O LRT project is located south of the proposed New E-W Street C and N-S Connector Road intersection. Traffic accessing this intersection from the park-and-ride facility was accounted for under Build Alternative of the D-O LRT. The proposed specific roadway modifications for the Leigh Village segment are listed in Table 1 for the LRT Build Alternative.

Table 1: LRT Alternative Proposed Roadway Modifications

Intersection	Roadway Modification
New E-W Street C at N-S Connector Road	Construct new N-S Connector Road (NC 54 to new E-W Street C)
	Construct New E-W Street C
	Signalize new intersection

The AA study was conducted using the Synchro software package. Synchro is a deterministic traffic analysis tool with limited functionality to determine the impacts of a LRT alignment as well as limited ability to determine the spill back effects of one intersection on adjacent intersections. For the purpose of this analysis Vissim (version 5.40-08) software was used. Vissim is a more robust traffic simulation package that can not only provide level of service (LOS) information, but can also determine the true impact to vehicular traffic due to the proposed D-O LRT. By employing Vissim, the current traffic analysis was able to identify potential impacts to traffic and assist in the identification of potential mitigation strategies that revised and superseded the mitigation strategies identified in the AA.

Figure 1: Leigh Village Study Intersections



3. Description of Scenarios

Three scenarios were analyzed for this study. Those scenarios included an Existing Conditions scenario (2011 Base Year Scenario) that was also used for model calibration, a 2040 No-Build Alternative, and a 2040 Build alternative.

A brief description of the scenarios evaluated in Vissim, a comprehensive multimodal modeling software 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. This alternative also included a comparison to results from the Synchro analysis, conducted as part of the AA.

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 making modifications needed to meet NCDOT and City of Durham 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 (MOE)

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 acceptable levels for the future year MOEs were enumerated in the *Traffic Analysis Methodology Report*. Additional information regarding the base year MOEs can be found in section 5.1. Both NCDOT and City of Durham have 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.

For the study area within the City of Durham, Level of Service thresholds are summarized in Table 2. This data is obtained from the *Durham Comprehensive Plan Policy 8.1.2a, Traffic Level of Service (LOS) Standards*. Leigh Village is currently classified as a Suburban Tier. However, in accordance with the City of Durham, this area will be reclassified as a Compact Neighborhood Tier due to the presence of the proposed LRT station; hence LOS E is the threshold.

Table 2: City of Durham Traffic Level of Service Standards

Application	Level of Service Standard
Downtown Tier	LOS E
Compact Neighborhood Tier	LOS E
Urban Tier	LOS D
Suburban Tier	LOS D
Rural Tier	LOS C

Source: Durham Comprehensive Plan Policy 8.1.2a

In summary, Table 3 shows the traffic impact criteria applied to the various study intersections.

Table 3: Application of Traffic Impact Criteria

Segment	Location	Criteria Applied
NC 54	NC 54 at Huntingridge Road	NCDOT
NC 54	NC 54 at Falconbridge Road	NCDOT
Leigh Village	New East-West Street C at N-S Connector Road	City of Durham – Compact Neighborhood
Leigh Village	Farrington Road at I-40 Eastbound Slip On-Ramp	NCDOT
Leigh Village	Farrington Road at Ephesus Church Road	City of Durham – Compact Neighborhood

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 and the 2040 No-Build network are based on the current geometry of the intersection of Ephesus Church Road and Farrington Road. 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

Traffic signal and coordination plans were obtained from NCDOT and the City of Durham for the signals included in the study area and are included in Appendix C. These plans were used to input timing, phasing, and detectors for the following intersections in the base year:

- NC 54 at Huntingridge Road
- Ephesus Church Road and Farrington Road

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

It should be noted that under the existing conditions alternative, the NC 54 and Huntingridge Road intersection is a full access signalized intersection and is converted to right-in/right-out under the No-Build and Build Alternatives. Also, the existing NC 54 and Falconbridge Road intersection does not allow northbound or southbound left turn movements from Falconbridge Road. This intersection would be converted to a full access intersection under the No-Build and Build alternatives. The changes to the intersection geometry at Falconbridge Road and Huntingridge Road are part of TIP U-5324A. In the future conditions, Falconbridge Road is proposed to be constructed as a 4-lane roadway north of NC 54, and continues as N-S Connector Road towards Leigh Village Station and the new park-and-ride facility. This roadway also continues beyond the Leigh Village Station section towards Ephesus Church Road. In addition, an I-40 EB Slip On-Ramp is proposed along Farrington Road as part of TIP U-5517.

4.2.3 Speed Data

Weekday peak periods speed data was collected from INRIX (a mobile application pertaining to road traffic). This data was used to determine the average speed during the peak periods from the approximate time the initial count data was collected. This data was used in calibration of the model. While the desired speed distribution for roadways reflected 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 NC 54 and Farrington Road were based on a 45 mph posted speed with a range of 40 to 50 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. To accurately model the network, the volumes were developed into a balanced network. The traffic volumes for the proposed project were based on peak hour turning movement count data. Traffic volumes for the NC 54 corridor were balanced keeping the NC 54 and Falconbridge Road intersection as the control count. Ephesus Church Road and Farrington Road is an isolated intersection for all alternatives and was not balanced with any adjacent intersections.

Volumes for the 2011 Existing, the 2040 No-Build Alternative and the 2040 Build were created using the count data and the Triangle Regional Model (TRM) v5 as outlined in the *Traffic Analysis Methodology Report*. The NC 54 corridor, in particular, in this section undergoes numerous changes. As noted in section 5.1, the NC 54 intersections with Huntingridge Road and Falconbridge Road are converted to right-in/right-out and full access signalized intersections, respectively. Also, an I-40 EB Slip On-Ramp is proposed along Farrington Road. With the addition of the park-and-ride facility, traffic accessing the proposed intersection of New E-W Street C at N-S Connector Road was assigned. The balanced peak hour volumes for all scenarios are shown in Appendix D. The traffic volumes between the No-Build and Build alternatives for all movements are generally the same with negligible difference in volumes.

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 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 repetitions 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 historic INRIX speed data as described in the *Traffic Analysis Methodology Report*. INRIX speed data is collected by utilizing vehicle probes that collect and transmit the locations of probe vehicles within the network. 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. 2040 Simulation Results

5.1 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 future year No-Build and Build scenarios. As discussed in the *Traffic Analysis Methodology Report*, travel time and speed were calibrated.

Based on the data included in Table 4, the base model is considered to be calibrated and can be utilized as the basis for developing the future year alternatives/options. Three of four travel time values fell within the desirable range while one value was within the acceptable range.

Table 4: 2011 Existing Conditions - Calibrated Base Model Summary

Direction	Length (miles)	Peak Period	Calibrated Model		INRIX		Travel Time Difference (min)	Speed Difference (MPH)	Calibration Range
			Average Travel Time (min)	Average Speed (MPH)	Average Travel Time (min)	Average Speed (MPH)			
Eastbound (EB) Travel Time Summary									
NC 54 EB corridor wide	1.53	AM	2.36	38.86	2.30	39.97	0.06	-1.11	Within desirable
		PM	2.07	44.30	2.17	42.35	-0.10	1.95	Within desirable
Westbound (WB)Travel Time Summary									
NC 54 WB corridor wide	1.53	AM	2.17	42.40	2.41	38.13	-0.24	4.26	Within acceptable
		PM	2.11	43.51	2.17	42.35	-0.06	1.16	Within desirable

5.2 2040 No-Build Alternative

The 2040 No-Build Alternative model was developed based on the calibrated Existing Conditions model. The network geometry was modified to include background projects and the 2040 No-Build volumes were then input into the model. Per TIP U-5324A, the current 4-lane NC 54 section is proposed to be widened to 6-lanes under the No-Build alternative. Also, Per TIP U-5517 an I-40 EB Slip On-Ramp is proposed along Farrington Road under the No-Build alternative.

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 5 and Table 6 demonstrate the different levels of service for signalized and unsignalized intersections based on delay and volume to capacity ratio.

Table 5: 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 6: 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 7 lists turning movement volumes, delays, and LOS at intersections along NC 54 and Farrington Road during the AM and PM peak hours under the 2040 No-Build Conditions.

Table 7: 2040 No-Build Vissim Model Summary

Intersection	Movement	AM Peak			PM Peak		
		Volume (VPH)	Delay (sec)	LOS	Volume (VPH)	Delay (sec)	LOS
Huntingridge Road and NC54/Raleigh Road (Unsignalized Intersection)	NBR	144	362.5	F	150	234.9	F
	SBR	166	19.8	B	223	14.9	B
	EBT	2936	24.8	C	3159	24.5	C
	EBR	126	0.7	A	217	1.1	A
	WBT	3487	0.5	A	2314	0.3	A
	WBR	108	1.1	A	59	0.9	A
	Overall	**6967**	**362.5**	**F**	**6120**	**234.9**	**F**
Falconbridge Road and NC 54/Raleigh Road	NBL	306	150.5	F	72	77.7	E
	NBT	52	202.6	F	15	85.8	F
	NBR	504	142.8	F	160	22.2	C
	SBL	486	149.4	F	488	129.5	F
	SBT	11	107.5	F	56	95.3	F
	SBR	287	22.5	C	227	11.6	B
	EBL	239	360.5	F	274	94.6	F
	EBT	2754	23.1	C	2688	65.6	E
	EBR	58	6.5	A	314	38.1	D
	WBL	112	74.2	E	463	226.7	F
	WBT	3004	41.9	D	2071	33.3	C
	WBR	530	31.2	C	462	23.0	C
	Overall	**8341**	**61.1**	**E**	**7288**	**65.9**	**E**
Farrington Road and EB Slip On-Ramp (Unsignalized Intersection)	NBT	765	2.9	A	456	2.4	A
	NBR	275	1.8	A	292	1.2	A
	SBL	371	115.5	F	579	56.4	F
	SBT	278	1.0	A	318	1.1	A
	Overall	**1687**	**66.5**	**F**	**1644**	**36.8**	**E**
Farrington Road and Ephesus Church Road	NBL	163	70.6	E	284	5.3	A
	NBT	73	5.3	A	316	2.7	A
	SBT	257	23.8	C	285	15.1	B
	SBR	451	20.5	C	79	14.3	B
	EBL	271	77.1	E	92	36.7	D
	EBR	420	49.0	D	395	22.3	C
	Overall	**1634**	**42.0**	**D**	**1451**	**13.8**	**B**

As shown in Table 7, both the intersections studied along NC 54 operate at LOS E or worse during both the AM and PM peak hours. The results from the No-Build alternative analysis suggest that roadway improvements may be needed along NC 54 Corridor and its intersections unrelated to the construction of D-O LRT. The unsignalized intersection of Farrington Road/Eastbound Slip On-Ramp operates at LOS F and E during the AM and PM peak hours, respectively, as the heavy southbound left movement conflicts with the free following northbound through movement along Farrington Road. The intersection of Farrington Road and Ephesus Church Road is expected to operate at LOS D or better during both the peak hours.

A 2040 No-Build Synchro-based model was developed. The projects included in Section 2.4 were added to the network geometry and the 2040 No-Build volumes were then input into the model. Intersection The Synchro output for this alternative can be found in Appendix E.

Based on the results of the Vissim Analysis the following intersections are anticipated to operate at LOS F conditions in at least one peak hour:

- NC 54 and Falconbridge Road
- NC 54 and Huntingridge Road*

* - Indicates unsignalized intersection with at least one movement operating at LOS F conditions.

It is important to note that these are background issues without the D-O LRT project. This will also have an impact on meeting the thresholds laid out in the City of Durham's Traffic LOS Standards and NCDOT's "*Policy on Street and Driveway Access to North Carolina Highways*".

5.3 2040 Build Alternative

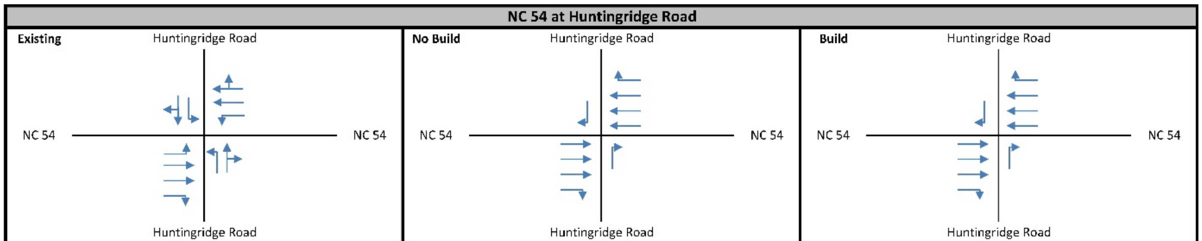
Based on the above model network elements and the methodologies defined under MOEs, the results from Vissim for the 2040 Build alternative were determined. It should be noted that the D-O LRT alignment would not interact with the NC 54 and Farrington Road corridors being above grade at these locations. The D-O LRT is at-grade in the vicinity of the Leigh Village park-and-ride and crosses the proposed intersection of New E-W Street C at N-S Connector at-grade. Per proposed preliminary design, all approaches at the intersection of New E-W Street C and N-S Connector Road have one exclusive left turn lane and one through lane with shared right turn. This configuration was used in the Build alternative analysis at this intersection. Railroad crossing gates were assumed to be installed at all approaches of this intersection to prevent conflicting LRT and vehicular movements.

Table 9 and Table 10 presents the Build Alternative results for AM and PM peak hour respectively. These provide volume comparison (modeled versus simulated), delays, LOS and queuing information for the No-Build and Build alternatives.

As shown in the tables, the traffic operations along the NC 54 and Farrington Road intersections are similar to the No-Build alternative as the D-O LRT has no interaction and is above-grade. The proposed intersection of New E-W Street C at N-S Connector operates at LOS D or better during the peak hours. As the D-O LRT has minimal impacts to the study intersections, no other capital improvements are recommended as a part of this report.

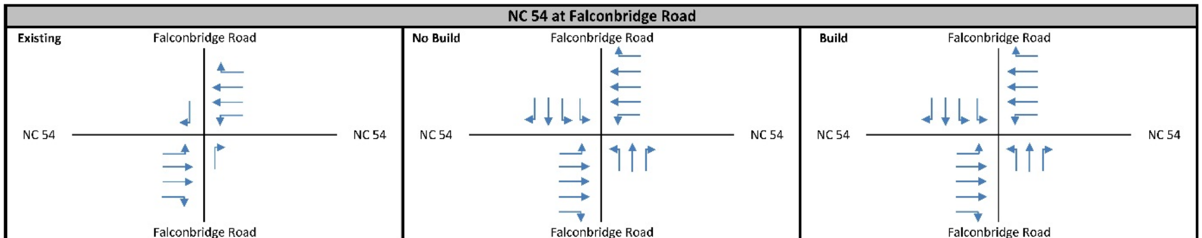
Table 8: 2040 LRT Signal & Lane Configuration Modifications

NC 54 at Huntingridge Road



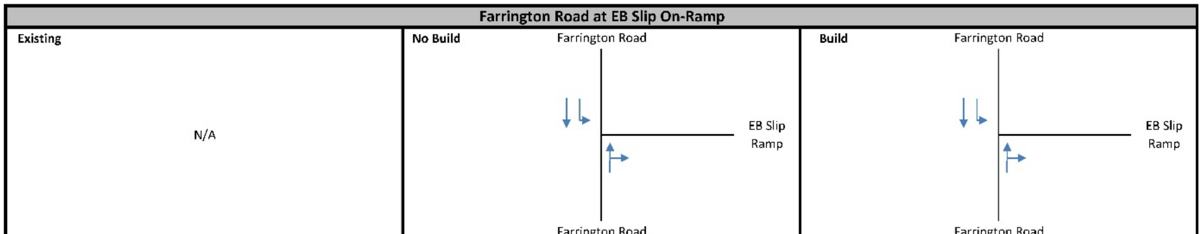
AM	Cycle Length	Phasing	PM	Cycle Length	Phasing
Existing to No Build	Signal removed under No Build.		Existing to No Build	Signal removed under No Build.	
No Build to Build	Unsignalized intersection.		No Build to Build	Unsignalized intersection.	

NC 54 at Falconbridge Road



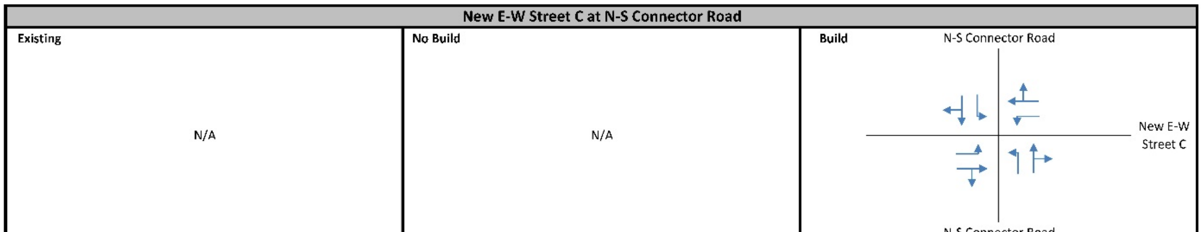
AM	Cycle Length	Phasing	PM	Cycle Length	Phasing
Existing to No Build	Intersection signalized with 180s cycle length.	All left-turning movements protected with lead-left phasing.	Existing to No Build	Intersection signalized with 180s cycle length.	All left-turning movements protected with lead-left phasing, except lagged NBL.
No Build to Build	No change.		No Build to Build	No change.	

Farrington Road at EB Slip On-Ramp



AM	Cycle Length	Phasing	PM	Cycle Length	Phasing
Existing to No Build	Unsignalized intersection added under No Build.		Existing to No Build	Unsignalized intersection added under No Build.	
No Build to Build	Unsignalized intersection.		No Build to Build	Unsignalized intersection.	

New E-W Street C at N-S Connector Road



AM	Cycle Length	Phasing	PM	Cycle Length	Phasing
Existing to No Build	Intersection does not exist.		Existing to No Build	Intersection does not exist.	
No Build to Build	Intersection signalized with 120s cycle length.	All left-turning movements protected with lead-left phasing. Transit Signal Preemption.	No Build to Build	Intersection signalized with 120s cycle length.	All left-turning movements protected with lead-left phasing. Transit Signal Preemption.

6. Summary of Results

The following section summarizes the VISSIM simulation results for the 2040 No-Build versus the 2040 Build LRT Alternative in a side by side manner. Table 9 and Table 10 include individual movement and overall intersection delays, LOS and queuing information as reported by Vissim for all future scenarios.

Table 9: D-O LRT: Leigh Village Segment – Vissim Intersection Analysis Output Summary - 2040 Build 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																
		Model	Demand	Model	Demand	Build	No-Build	Difference Absolute	Difference %	Build	No-Build	Build	No-Build	Difference Absolute	Difference %	Storage Space Available	Build	No-Build	Difference Absolute	Difference %
Huntingridge Road and NC54/Raleigh Road[1] (Unsignalized Intersection)	NBR	166	473	144	473	261.5	362.5	-101.0	-28%	F	F	1,081	1,133	-52	-5%	1350	1315	1326	-11	-1%
	SBR	164	166	166	166	17.7	19.8	-2.1	-11%	B	B	2	3	-2	-53%	720	80	122	-41	-34%
	EBT	2950	3293	2936	3293	22.6	24.8	-2.2	-9%	C	C	388	422	-34	-8%	920	1024	1007	17	2%
	EBR	126	140	126	140	0.7	0.7	0.0	0%	A	A	334	363	-29	-8%	515	919	903	17	2%
	WBT	3473	4142	3487	4142	0.6	0.5	0.1	17%	A	A	1	0	1	352%	1025	172	82	90	109%
	WBR	109	129	108	129	1.1	1.1	0.0	1%	A	A	1	0	1	352%	575	172	82	90	109%
	All	6987	8343	6967	8343	261.5	362.5	-101.0	-28%	F	F	301	320	-19	-6%		1,315	1,326	-11	-1%
Falconbridge Road and NC 54/Raleigh Road[1]	NBL	300	501	306	501	146.0	150.5	-4.5	-3%	F	F	810	812	-3	0%	920	964	963	1	0%
	NBT	50	87	52	87	204.8	202.6	2.2	1%	F	F	810	812	-3	0%	920	964	963	1	0%
	NBR	501	875	504	875	145.6	142.8	2.8	2%	F	F	590	593	-3	0%	300	744	743	1	0%
	SBL	490	507	486	507	140.3	149.4	-9.1	-6%	F	F	294	310	-17	-5%	400	681	703	-21	-3%
	SBT	11	11	11	11	122.5	107.5	15.0	14%	F	F	294	310	-17	-5%	700	681	703	-21	-3%
	SBR	287	290	287	290	22.6	22.5	0.1	1%	C	C	191	205	-14	-7%	400	569	590	-21	-4%
	EBL	241	335	239	335	346.1	360.5	-14.4	-4%	F	F	851	899	-48	-5%	950	1138	1137	0	0%
	EBT	2776	3359	2754	3359	23.5	23.1	0.3	1%	C	C	191	184	7	4%	1065	1085	1033	51	5%
	EBR	59	72	58	72	6.5	6.5	0.0	1%	A	A	44	42	3	6%	450	664	613	51	8%
	WBL	112	131	112	131	73.4	74.2	-0.9	-1%	E	E	45	47	-2	-4%	700	248	259	-11	-4%
	WBT	2995	3480	3004	3480	42.3	41.9	0.4	1%	D	D	1,018	1,002	16	2%	1630	1689	1691	-2	0%
	WBR	528	607	530	607	31.5	31.2	0.3	1%	C	C	659	649	11	2%	150	1219	1215	3	0%
	All	8349	10255	8341	10255	60.4	61.1	-0.7	-1%	E	E	560	570	-10	-2%		1,689	1,691	-2	0%

Table 9: D-O LRT: Leigh Village Segment – Vissim Intersection Analysis Output Summary - 2040 Build 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															
New EW Street C at N-S Connector Road[2]	NBL	11	10			95.5				F		352				375	583			
	NBT	690	721			60.0				E		352				550	583			
	NBR	11	10			65.5				E		352				550	583			
	SBL	11	10			73.9				E		168				320	456			
	SBT	559	562			42.8				D		168				500	456			
	SBR	10	10			49.7				D		168				500	456			
	EBL	9	10			117.5				F		7				500	51			
	EBT	10	10	N/A		21.3	N/A			C	N/A	7	N/A			900	51	N/A		
	EBR	10	10			20.2				C		7				900	51			
	EB LRT	6	6			7.7				N/A		N/A				N/A	N/A			
	WBL	10	10			124.4				F		8				490	62			
	WBT	11	10			19.2				B		8				640	62			
	WBR	9	10			19.9				B		8				640	62			
	WB LRT	6	6			2.1				N/A		N/A				N/A	N/A			
	All	1352	1383			53.0				D		115					583			
Farrington Road and EB Slip On-Ramp[1] (Unsignalized Intersection)	NBT	766	771	765	771	3.0	2.9	0.1	4%	A	A	0	0	0	0%	515	0	0	0	0%
	NBR	273	270	275	270	1.8	1.8	0.0	1%	A	A	0	0	0	0%	515	0	0	0	0%
	SBL	376	640	371	640	112.8	115.5	-2.8	-2%	F	F	788	800	-12	-1%	400	1144	1144	0	0%
	SBT	282	454	278	454	1.0	1.0	0.0	0%	A	A	0	0	0	0%	1175	0	0	0	0%
	All	1697	2135	1687	2135	64.9	66.5	-1.6	-2%	F	F	0	200	-200	-100%		1,144	1,144	0	0%
Farrington Road and Ephesus Church Road[2]	NBL	163	161	163	161	70.7	70.6	0.2	0%	E	E	72	72	0	0%	435	341	300	41	14%
	NBT	73	76	73	76	4.7	5.3	-0.7	-12%	A	A	72	72	0	0%	975	341	300	41	14%
	SBT	258	258	257	258	22.3	23.8	-1.5	-6%	C	C	107	110	-4	-3%	800	723	744	-21	-3%
	SBR	451	455	451	455	20.3	20.5	-0.1	-1%	C	C	107	110	-4	-3%	800	723	744	-21	-3%
	EBL	268	268	271	268	78.7	77.1	1.7	2%	E	E	192	177	15	8%	300	826	822	4	1%
	EBR	419	423	420	423	49.6	49.0	0.7	1%	D	D	189	187	3	1%	1090	994	1006	-12	-1%
	All	1631	1641	1634	1641	42.1	42.0	0.1	0%	D	D	123	121	2	1%		994	1,006	-12	-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 10: D-O LRT: Leigh Village Segment – Vissim Intersection Analysis Output Summary - 2040 Build Alternative vs. 2040 No-Build PM Peak Hour 5:00 - 6:00 PM

Intersection	Movement	Volumes (VPH)				Delay (seconds)				LOS		Average Queue Length (ft)				Maximum Queue Length (ft)				
		Build		No-Build		Build	No-Build	Absolute Difference	Difference %	Build	No-Build	Build	No-Build	Difference Absolute	Difference %	Storage Space Available	Build	No-Build	Difference Absolute	Difference %
		Model	Demand	Model	Demand															
Huntingridge Road and NC54/Raleigh Road[1] (Unsignalized Intersection)	NBR	141	178	150	178	254.1	234.9	19.3	8%	F	F	508	377	132	35%	1,350	1,059	854	205	24%
	SBR	223	224	223	224	14.7	14.9	-0.1	-1%	B	B	7	8	-1	-10%	720	156	164	-9	-5%
	EBT	3161	3952	3159	3952	24.5	24.5	0.0	0%	C	C	532	530	2	0%	920	1,018	1,014	5	0%
	EBR	217	269	217	269	1.1	1.1	0.0	-4%	A	A	480	477	3	1%	515	943	938	4	0%
	WBT	2316	2910	2314	2910	0.4	0.3	0.1	18%	A	A	1	0	0	456%	1,025	104	55	49	88%
	WBR	59	73	59	73	1.2	0.9	0.3	38%	A	A	1	0	0	456%	575	104	55	49	88%
	All	6116	7606	6120	7606	254.1	234.9	19.3	8%	F	F	255	232	23	10%		1,059	1,014	46	4%
Falconbridge Road and NC 54/Raleigh Road[1]	NBL	72	73	72	73	77.6	77.7	-0.1	0%	E	E	41	41	0	1%	920	199	204	-6	-3%
	NBT	15	16	15	16	87.2	85.8	1.4	2%	F	F	42	41	1	1%	920	198	204	-6	-3%
	NBR	160	159	160	159	22.8	22.2	0.6	3%	C	C	2	2	0	6%	300	82	87	-6	-6%
	SBL	489	498	488	498	128.0	129.5	-1.5	-1%	F	F	251	255	-4	-2%	400	708	740	-32	-4%
	SBT	56	59	56	59	95.2	95.3	-0.2	0%	F	F	251	255	-4	-2%	700	708	740	-32	-4%
	SBR	227	230	227	230	11.5	11.6	-0.1	-1%	B	B	134	139	-5	-3%	400	573	605	-32	-5%
	EBL	272	341	274	341	95.2	94.6	0.6	1%	F	F	171	171	0	0%	950	619	608	11	2%
	EBT	2680	3390	2688	3390	66.7	65.6	1.1	2%	E	E	633	655	-21	-3%	1,065	1,139	1,144	-6	0%
	EBR	313	398	314	398	38.1	38.1	0.0	0%	D	D	200	200	0	0%	450	505	504	1	0%
	WBL	465	693	463	693	225.9	226.7	-0.8	0%	F	F	1,437	1,433	4	0%	700	1,693	1,690	3	0%
	WBT	2073	2680	2071	2680	32.4	33.3	-0.9	-3%	C	C	610	687	-78	-11%	1,630	1,681	1,684	-3	0%
	WBR	461	593	462	593	21.8	23.0	-1.1	-5%	C	C	1,329	1,322	6	0%	150	1,690	1,688	3	0%
	All	7283	9130	7288	9130	65.9	65.9	0.0	0%	E	E	406	413	-8	-2%		1,693	1,690	3	0%

Table 10: D-O LRT: Leigh Village Segment – Vissim Intersection Analysis Output Summary - 2040 Build Alternative vs. 2040 No-Build PM Peak Hour 5:00 - 6:00 PM

Intersection	Movement	Volumes (VPH)				Delay (seconds)				LOS		Average Queue Length (ft)				Maximum Queue Length (ft)				
		Build		No-Build		Build	No-Build	Absolute Difference	Difference %	Build	No-Build	Build	No-Build	Difference Absolute	Difference %	Storage Space Available	Build	No-Build	Difference Absolute	Difference %
		Model	Demand	Model	Demand															
New EW Street C at N-S Connector Road[2]	NBL	12	10			32.5				C		97				375	580			
	NBT	758	762			17.5				B		97				550	580			
	NBR	11	10			18.4				B		97				550	580			
	SBL	12	10			35.2				D		55				320	430			
	SBT	528	531			16.5				B		55				500	430			
	SBR	11	10			16.1				B		55				500	430			
	EBL	10	10			30.3				C		5				500	53			
	EBT	11	10	N/A		35.9	N/A			D	N/A	5	N/A			900	53	N/A		
	EBR	10	10			27.0				C		5				900	53			
	EB LRT	6	6			7.4				N/A		N/A				N/A	N/A			
	WBL	10	10			34.9				C		5				490	63			
	WBT	11	10			33.0				C		5				640	63			
	WBR	9	10			36.9				D		5				640	63			
	WB LRT	6	6			0.8				N/A		N/A				N/A	N/A			
	All	1392	1393			18.1				B		35					580			
Farrington Road and EB Slip On-Ramp[1] (Unsignalized Intersection)	NBT	455	457	456	457	2.4	2.4	0.0	-2%	A	A	0	0	0	0%	515	0	0	0	0%
	NBR	290	290	292	290	1.2	1.2	0.0	-2%	A	A	0	0	0	0%	515	0	0	0	0%
	SBL	583	710	579	710	55.9	56.4	-0.5	-1%	F	F	929	963	-34	-4%	400	1,688	1,690	-1	0%
	SBT	320	405	318	405	1.1	1.1	0.0	2%	A	A	929	963	-34	-4%	1,175	1,688	1,690	-1	0%
	All	1649	1862	1644	1862	36.5	36.8	-0.3	-1%	E	E	465	482	-17	-4%		1,688	1,690	-1	0%
Farrington Road and Ephesus Church Road[2]	NBL	285	284	284	284	5.8	5.3	0.5	10%	A	A	6	5	1	12%	435	126	113	13	12%
	NBT	316	318	316	318	3.1	2.7	0.4	13%	A	A	6	5	1	12%	975	126	113	13	12%
	SBT	285	285	285	285	14.1	15.1	-1.0	-7%	B	B	21	23	-3	-11%	800	245	243	2	1%
	SBR	79	80	79	80	13.0	14.3	-1.3	-9%	B	B	21	23	-3	-11%	800	245	243	2	1%
	EBL	92	94	92	94	34.6	36.7	-2.1	-6%	C	D	18	18	-1	-5%	300	133	132	1	1%
	EBR	396	396	395	396	22.7	22.3	0.4	2%	C	C	49	48	0	1%	1,090	345	355	-10	-3%
	All	1452	1457	1451	1457	13.6	13.8	-0.1	-1%	B	B	20	21	-1	-4%		345	355	-10	-3%

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 following section discusses the traffic operation of each intersection studied in this report along with the modifications to the signal timings between the No-Build and Build alternatives.

Multiple intersections and movements are expected to exceed the capacity limits under the No-Build and Build Alternatives. Each intersection is discussed below in regards to the NCDOT and City of Durham traffic impact criteria thresholds.

6.1.1 NC 54 at Huntingridge Road

The NCDOT traffic impact criteria are applied to the signalized intersection of NC 54 at Huntingridge Road. Currently, this is a full access signalized intersection. As part of the No-Build project (TIP U-5324A), this intersection would be unsignalized by providing eastbound/westbound NC 54 through and right turn movements and the northbound/southbound Huntingridge Road movements would be limited to right turns only under all alternatives. As shown in Table 7, the overall intersection operates at LOS F during the AM and PM peak hours, under No-Build Conditions. The lane configuration at this intersection remains the same between the No-Build and Build Alternatives with no interaction with the D-O LRT.

Under the Build Alternative, the maximum queue length for the following movements will exceed their available storage space by more than 10 feet:

- Eastbound NC 54 through movement exceeds storage space by 104 feet in AM
- Eastbound NC 54 right turn exceeds storage space by 404 feet in AM

Minor changes in maximum queue lengths (less than one car length) are expected at this intersection between the No-Build and Build Alternatives. However, the maximum queue events are considered infrequent occurrences, whereas the movement's average queue is expected to be much shorter and contained within the storage area. No roadway modifications to the intersection are proposed as part of the D-O LRT project.

6.1.2 NC 54 at Falconbridge Road

The NCDOT traffic impact criteria are applied to the signalized intersection of NC 54 at Falconbridge Road. Currently this intersection does not permit outbound left turns and is proposed to be converted to a full access signalized intersection with geometric changes to the approaches (TIP U-5324A) under the No-Build Alternative. The cycle length of the traffic signal at this intersection is 180 seconds with protected phasing for all left turning movements, and was assumed to be the same for the No-Build and Build Alternatives. As shown in Table 7, the overall intersection operates at LOS E during the AM and PM peak hours, under No-Build conditions. The lane configuration at this intersection remains the same between the No-Build and Build Alternatives with no interaction with D-O LRT.

Heavy volumes along NC 54 are controlled and metered by the traffic signal at this intersection which could potentially influence the traffic operations at adjacent intersections.

Under the Build Alternative, the maximum queue length for the following movements will exceed their available storage space by more than 10 feet:

- Eastbound NC 54 through movement exceeds storage space by 20 feet in AM

- Eastbound NC 54 right turn exceeds storage space by 214 feet in AM

Minor increases in maximum queue lengths (two car lengths for both impacted movements in the AM peak hour) are expected at this intersection between the No-Build and Build Alternatives. However, the maximum queue events are considered infrequent occurrences, whereas the movements' average queues are expected to be much shorter and contained within the respective storage areas. Therefore, no geometric modifications to the intersection are proposed as part of the D-O LRT project.

6.1.3 New E-W Street C at N-S Connector Road

The City of Durham - Compact Neighborhood Tier traffic impact criteria are applied to the signalized intersection of New E-W Street at N-S Connector Road, as both roadways are under city jurisdiction. A park-and-ride facility is proposed to be constructed adjacent to the Leigh Village Station in the vicinity of this intersection. The D-O LRT alignment is at-grade and crosses through the middle of this intersection. Railroad crossing gates would be installed at all approaches to prevent conflicting LRT and vehicular movements. This intersection was assumed to be a signalized intersection in the Build Alternative with a cycle length of 120 seconds. It was also assumed that all left turns at this intersection would have protected phase times of 15 seconds.

Even with the at-grade crossing, the overall intersection is expected to operate at LOS D or better during the peak hours. For the LRT Build Alternative, several individual movements at this proposed intersection are expected to operate with LOS F including the northbound N-S Connector Road left turn in the AM peak hour only, the eastbound New E-W Street C left turn in the AM peak hour only, and the westbound New E-W Street C left turn in the AM peak hour only. However, the expected future build demand for all these movements during the AM peak hour are 10 vehicles per hour, and therefore no additional roadway improvements were recommended given the low level of volumes.

For the LRT Build Alternative, the maximum queue length for the following movements will exceed their available storage space by more than 10 feet:

- Northbound N-S Connector Road left turn exceeds storage space by 208 feet in AM and by 205 feet in PM
- Northbound N-S Connector Road through movement exceeds storage space by 33 feet in AM and by 30 feet in PM
- Northbound N-S Connector Road right turn exceeds storage space by 33 feet in AM and by 30 feet in PM
- Southbound N-S Connector Road left turn exceeds storage space by 136 feet in AM and by 110 feet in PM

The southbound N-S Connector Road left turn maximum queue may exceed the turn bay storage space; however, it would be contained within the overall southbound approach. Although the maximum queue length exceeds the storage space for the above movements, this is considered a rare occurrence and the same movements' average queue lengths would be shorter than their available storage space. No additional roadway modifications are recommended as a part of this project.

6.1.4 Farrington Road at Eastbound I-40 Slip On-Ramp

The NCDOT traffic impact criteria are applied to the unsignalized intersection of Farrington Road at the Eastbound I-40 Slip On-Ramp, as the slip ramp is under NCDOT jurisdiction. Re-aligned Farrington Road is proposed to have access to eastbound I-40 via a slip On-Ramp (Per TIP U-5517) under the No-Build and Build Alternatives. This intersection is a proposed intersection and does not appear in the Existing Conditions. As shown in Table 7, the overall intersection operates at LOS F and LOS E during the AM and PM peak hours, respectively, under No-Build Conditions.

The D-O LRT does not impact the traffic operations at this intersection. The overall intersection is expected to operate at LOS F during the AM peak hour under both the No-Build and Build Alternatives due to the heavy southbound Farrington Road left turn movement, which conflicts with the free flowing northbound movements. No roadway modifications to the intersection are proposed as part of the D-O LRT project.

6.1.5 Farrington Road at Ephesus Church Road

The City of Durham - Compact Neighborhood Tier traffic impact criteria are applied to the signalized intersection of Farrington Road at Ephesus Church Road, as both roadways are under city jurisdiction. There are no proposed changes to the roadway geometry at this intersection from Existing to No-Build Conditions. As shown in Table 7, the overall intersection would operate at LOS D and LOS B during the No-Build Conditions AM and PM peak hours, respectively. The lane configuration and signal timings at this intersection remain the same between the No-Build and Build Alternatives as the intersection would have no interaction with the D-O LRT.

The overall intersection is expected to operate at LOS D or better during both Build Alternative peak hours and would meet the City of Durham thresholds. Therefore, no roadway modifications to the intersection are proposed as part of the D-O LRT project.

7. Conclusions/Recommendations

The D-O LRT alignment would not interact with the NC 54 and Farrington Road corridors, so there are limited project-related impacts to the intersections within the Leigh Village study area. Several modifications are proposed to NC 54 and Farrington Road as part of TIP U-5324A and U-5517, respectively. The No-Build analysis of these corridors indicated that improvements may be needed at the following intersections regardless of the construction of the proposed D-O LRT project:

- Huntingridge Road at NC 54
- Falconbridge Road at NC 54
- Farrington Road at I-40 EB Slip On-Ramp

However, the LRT project would not substantially impact these locations and therefore no roadway modifications are proposed as part of the D-O LRT project. Intersections along NC 54 are expected to operate at LOS E or F under the No-Build Alternative during both peak hours, suggesting a need for roadway improvements unrelated to the construction of D-O LRT. Traffic along the NC 54 corridor is metered by the traffic signal at the NC 54 and Falconbridge Road intersection and the Vissim analysis indicated queuing would occur along NC 54 under No-Build conditions. Spillback queues along NC 54 in turn would cause increased delays at the NC 54 and Huntingridge Road intersection. The unsignalized intersection of Farrington Road and I-40 Eastbound Slip On-Ramp would operate at LOS F and E during the AM and PM peak hours, respectively, as the heavy southbound left movement conflicts with the free following northbound through movement along Farrington Road.

The D-O LRT has no interaction with the intersection of Ephesus Church Road and Farrington Road. The intersection of Farrington Road and Ephesus Church Road is expected to operate at LOS D or better during both the peak hours under the No-Build Alternative meeting City of Durham Criteria. Therefore no roadway modifications are required at this location.

The D-O LRT would be at-grade and cross through the middle of the intersection of New E-W Street C at N-S Connector Road. Railroad crossing gates are proposed to be installed at all approaches to prevent conflicting LRT and vehicular movements. The overall intersection operates at LOS D or better during both Build LRT Alternative peak hours, so no other roadway modifications are recommended as a part of this report.

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

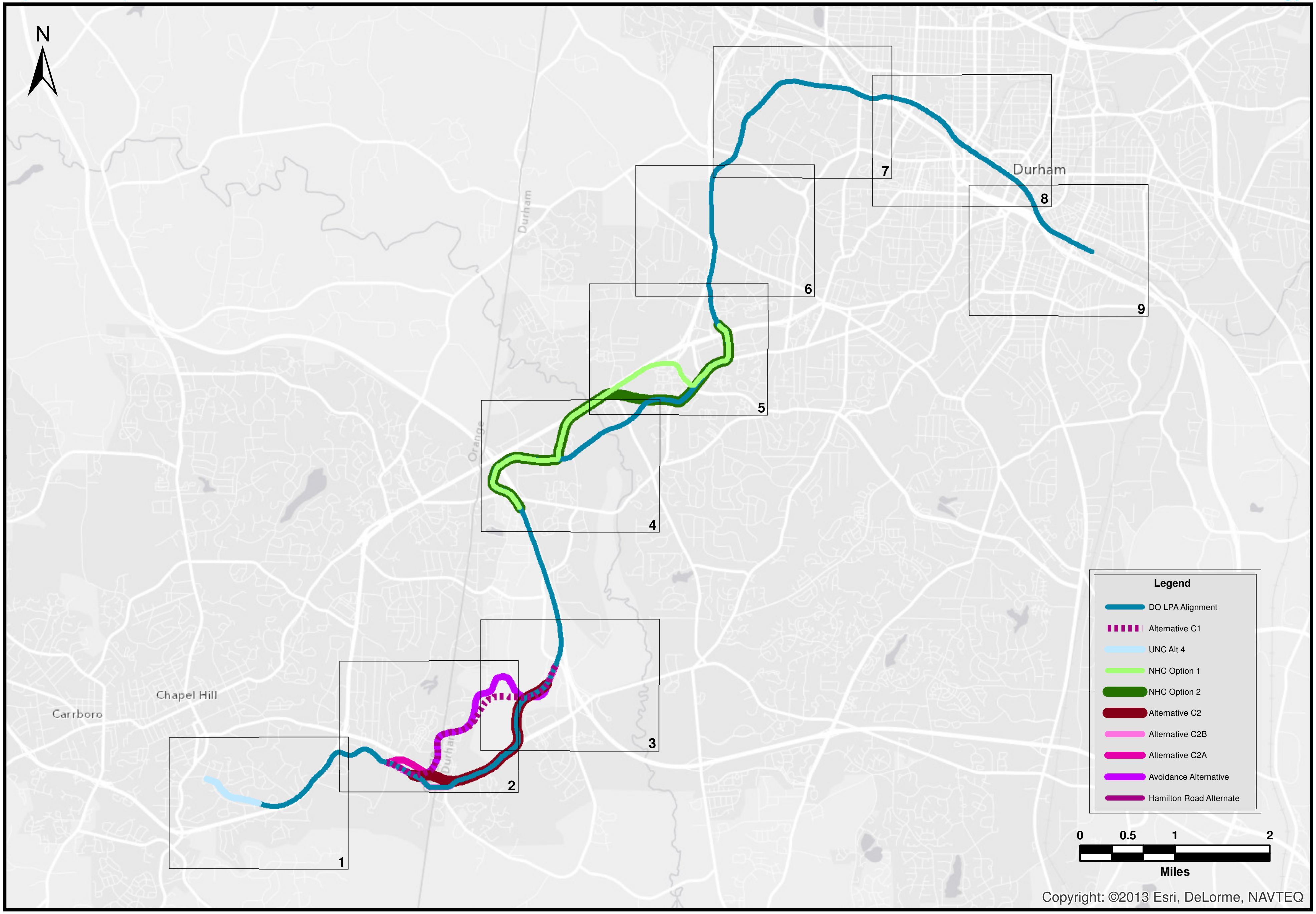
2.4 Pedestrian And Bicycle Volumes

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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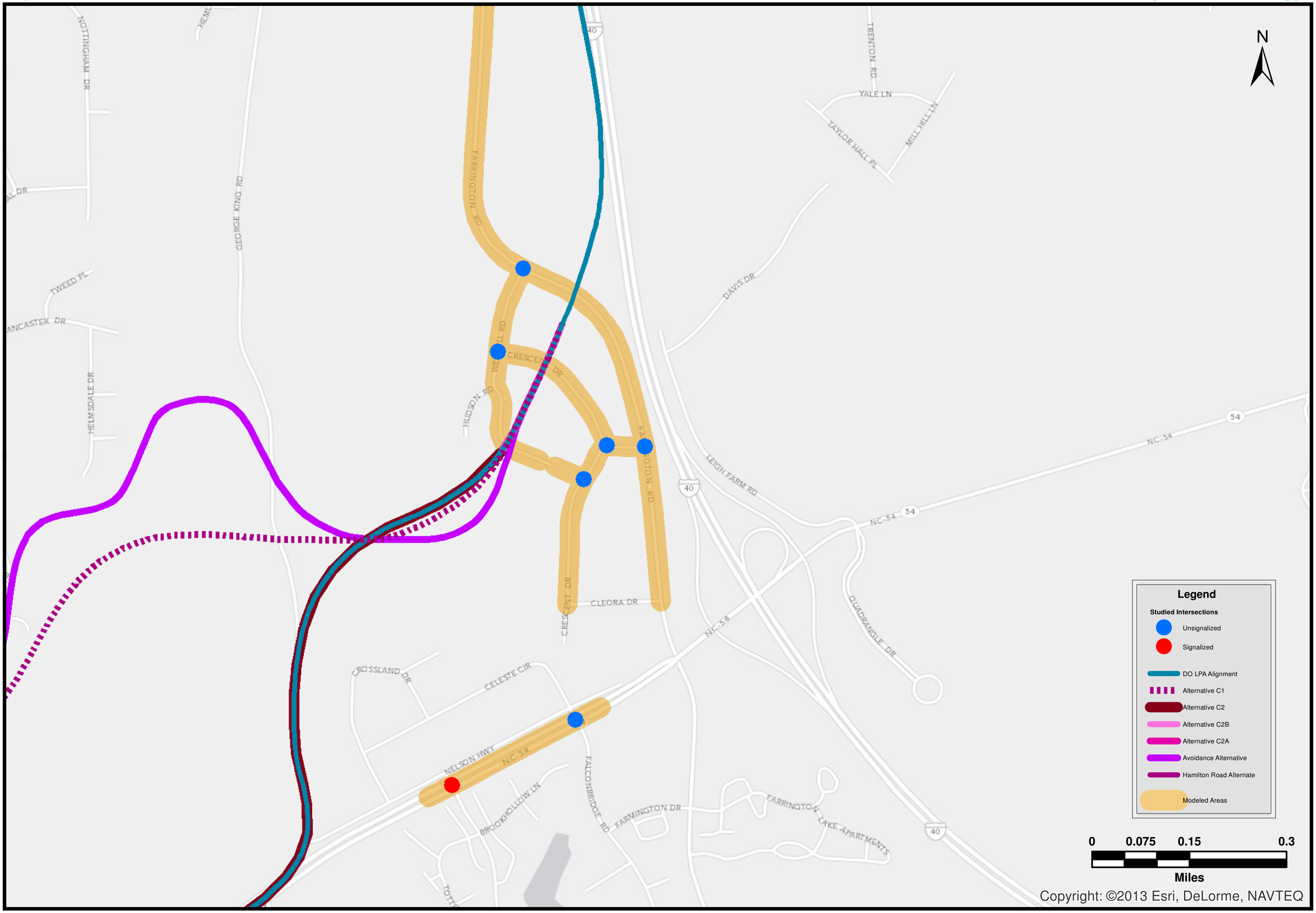
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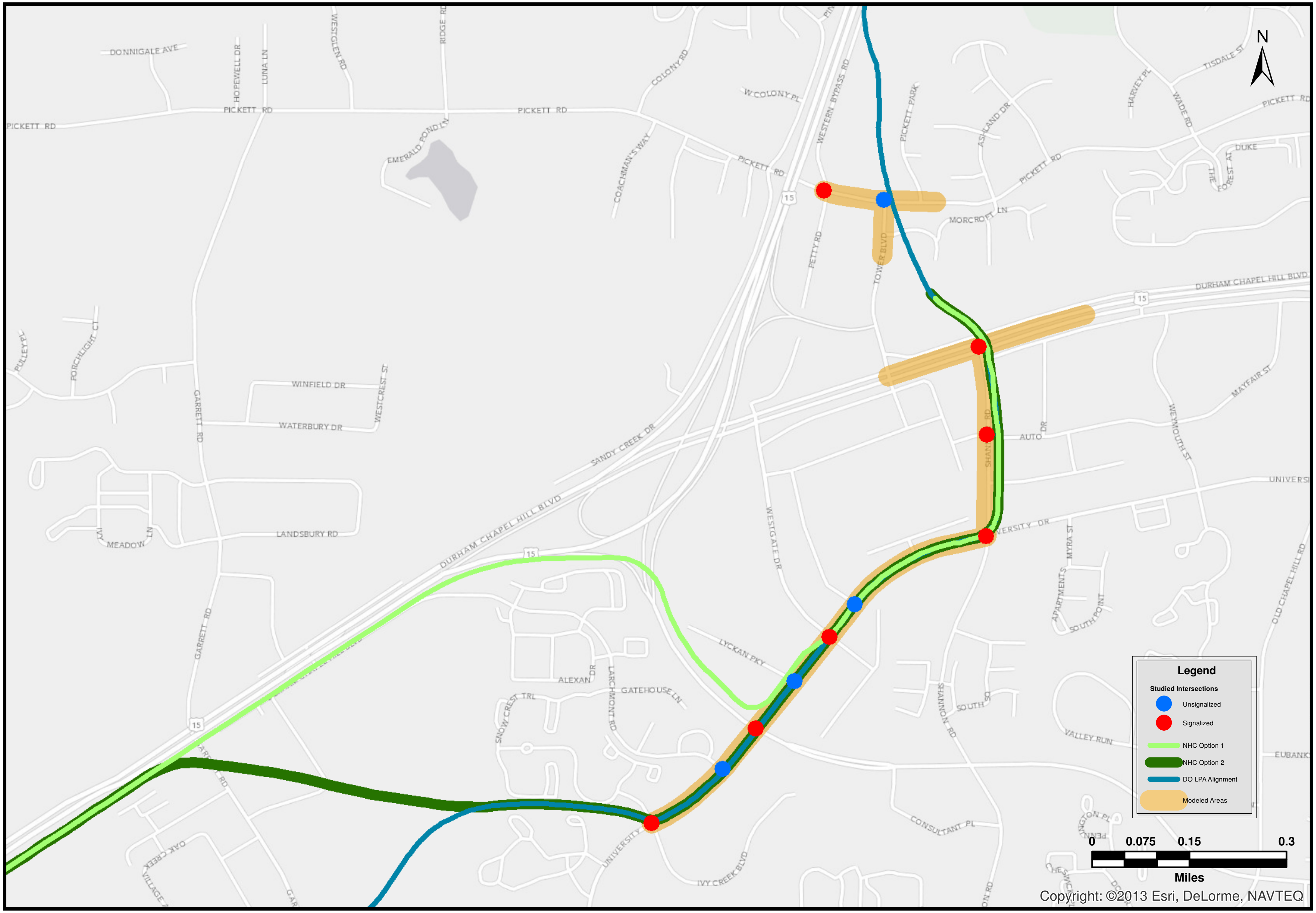
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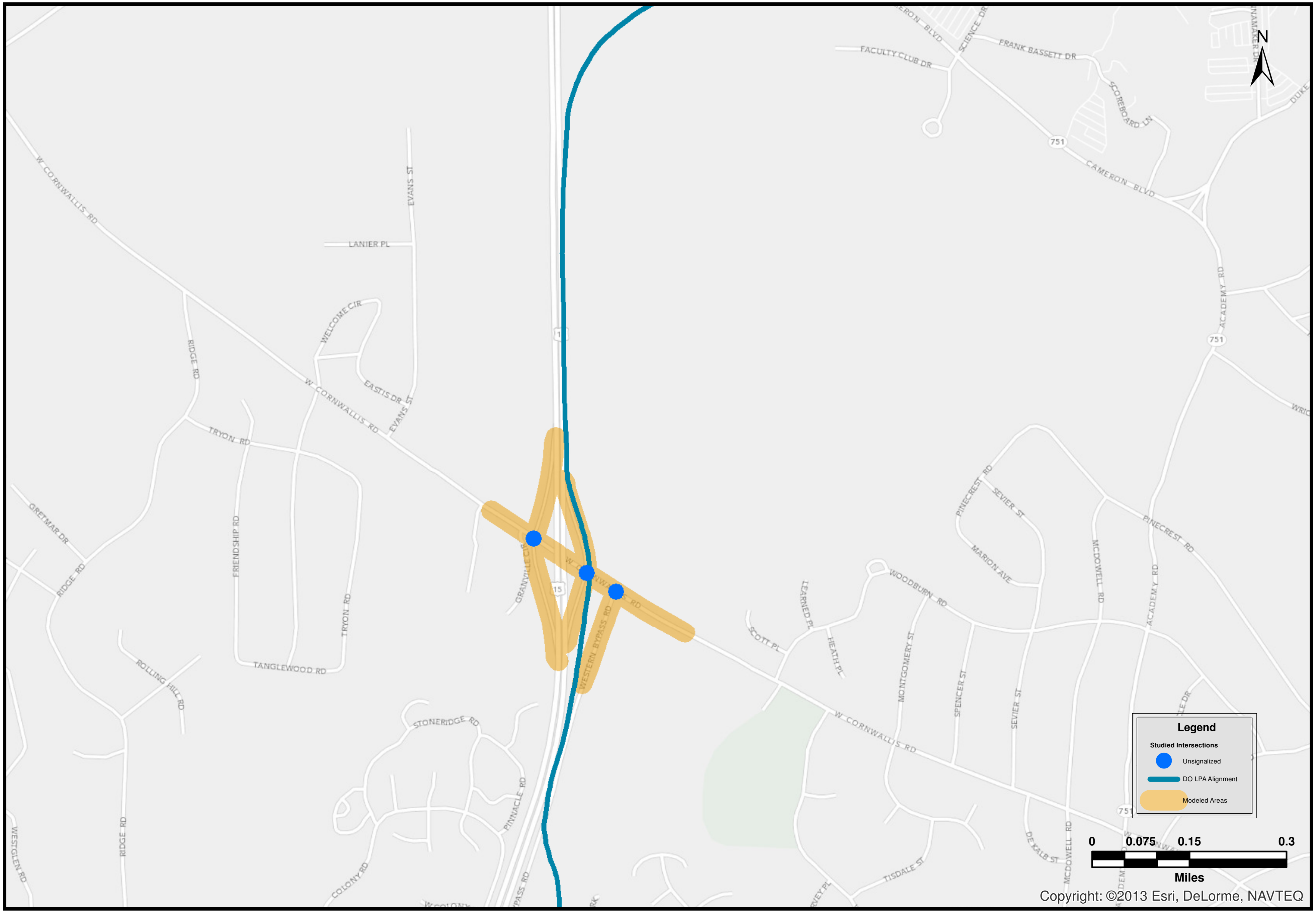
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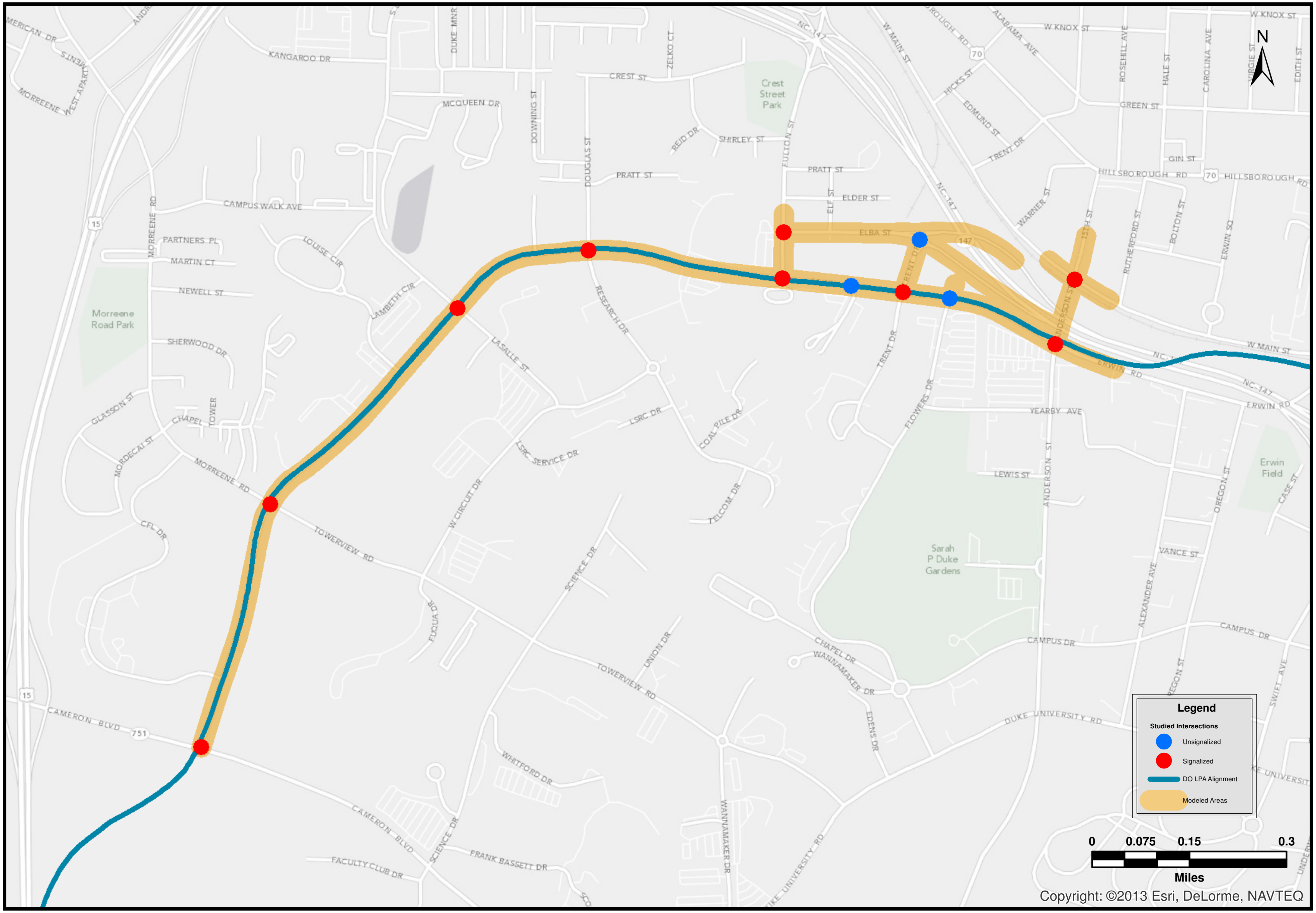
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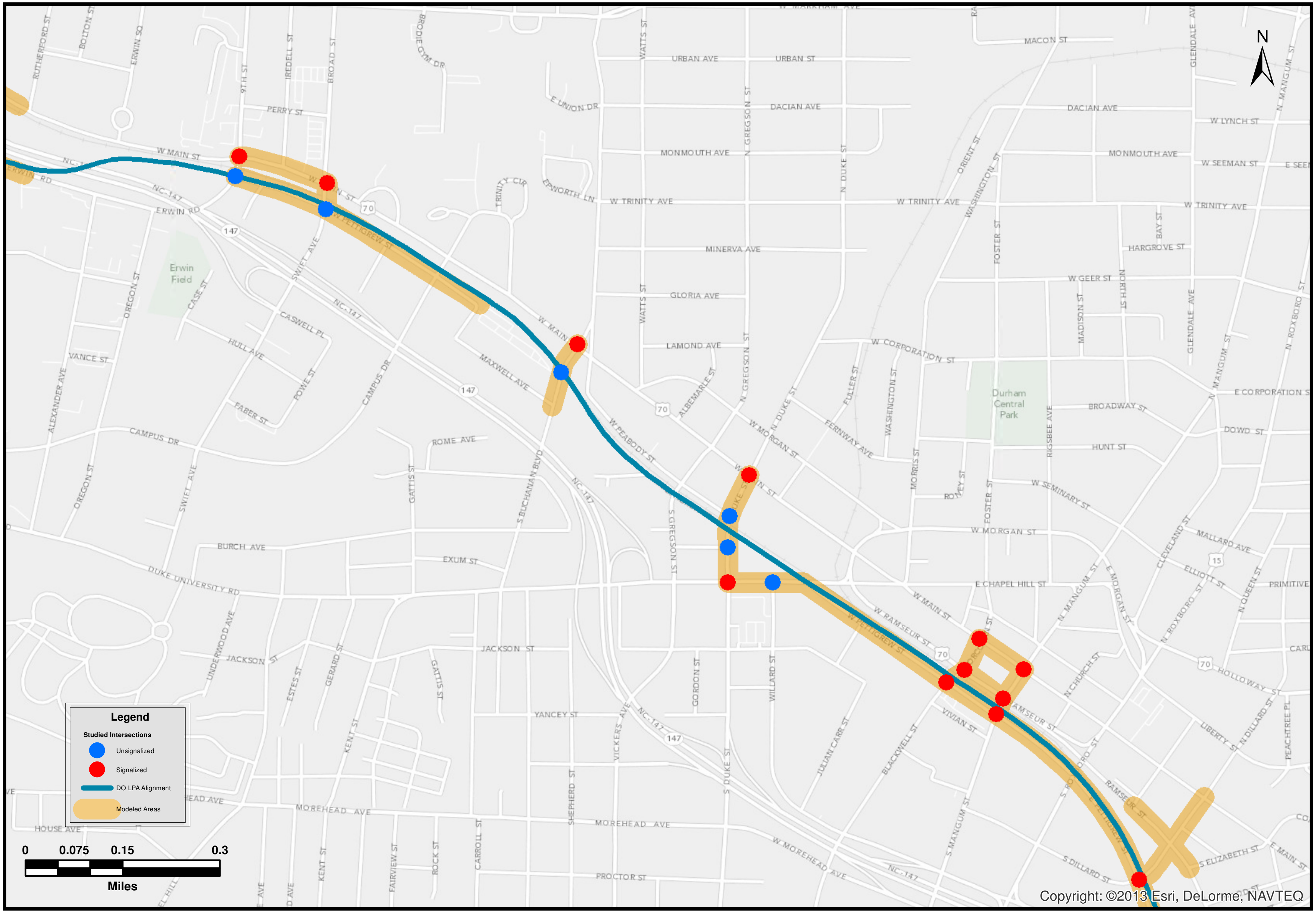
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FOSTER ST
W GEER ST
NORTH ST
MADISON ST
HARGROVE ST
BAY ST
GLENDALE AVE
W LYNCH ST
W SEEMAN ST
Durham Central Park
BROADWAY ST
HUNT ST
RIGSBEE AVE
W SEMINARY ST
W MORGAN ST
E CHAPEL HILL ST
W RAMSEUR ST
VIVIAN ST
S MANGUM ST
N MANGUM ST
E MORGAN ST
N CHURCH ST
CLEVELAND ST
MALLARD AVE
ELLIOTT ST
N ROXBORO ST
N QUEEN ST
E CORPORATION ST
DOWD ST
PRIMITIVE
HOLLOWAY ST
LIBERTY ST
N DILLARD ST
PEACHTREE PL
S DILLARD ST
S ELIZABETH ST
E MAIN ST
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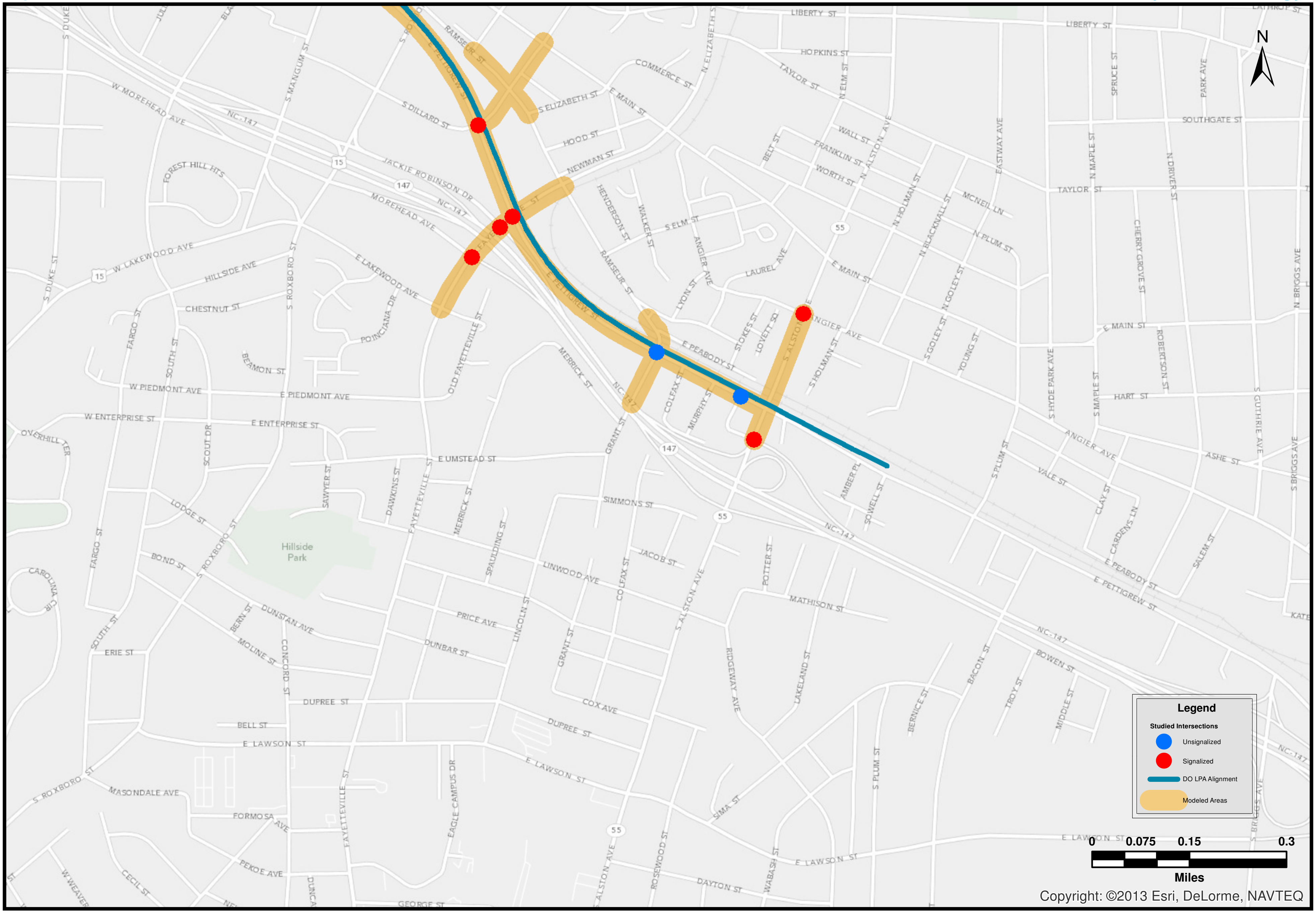
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Legend
Studied Intersections
Unsignalized
Signalized
DO LPA Alignment
Modeled Areas
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Miles
Copyright: ©2013 Esri, DeLorme, NAVTEQ

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.

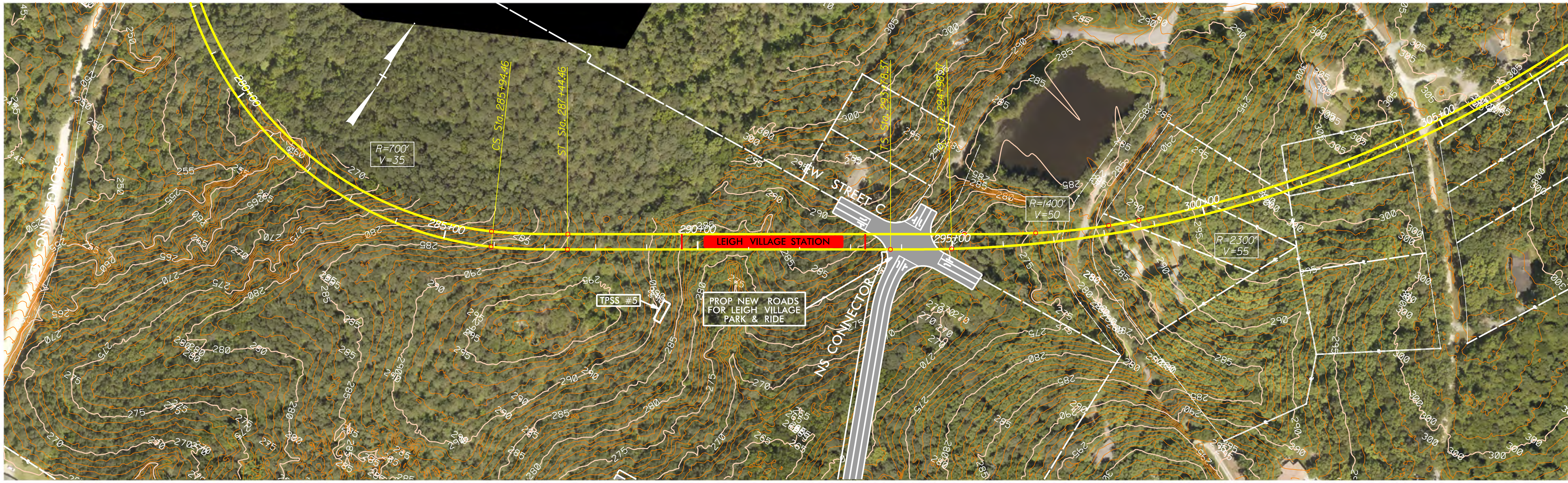
For this potential improvement, as well as similar improvements that create alternative paths, we are proposing to continue the use of static traffic assignment. Routing decisions will be updated such that traffic will be diverted to the new route and the model will be re-run and data on travel times 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.

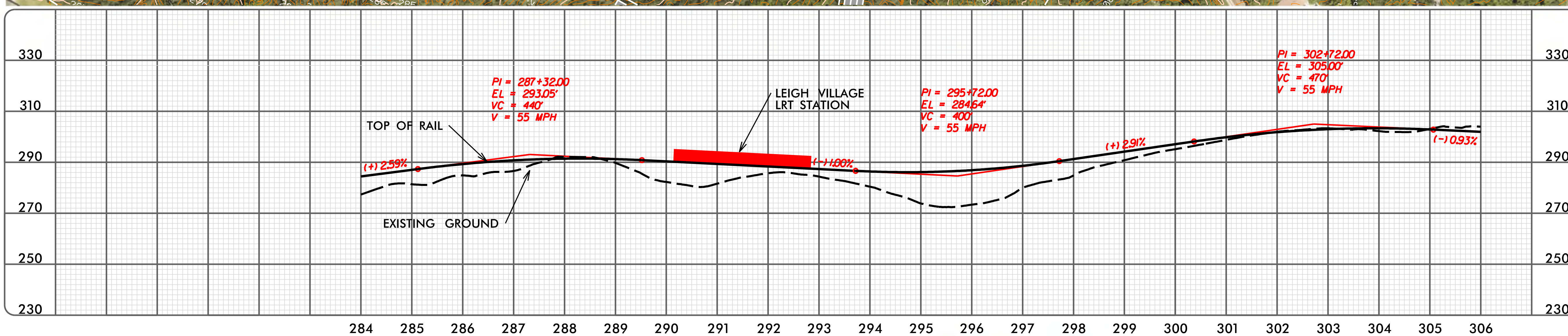
Appendix B
Basis for Engineering Plans
(LRT Alternatives Design Plans)

Build C1/C1A
Build C2
Build C2A

SEGMENT C - C1A ALTERNATIVE

LEIGH VILLAGE STATION – C1A ALTERNATIVE





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PROFILE (VERTICAL)

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C1A – 06

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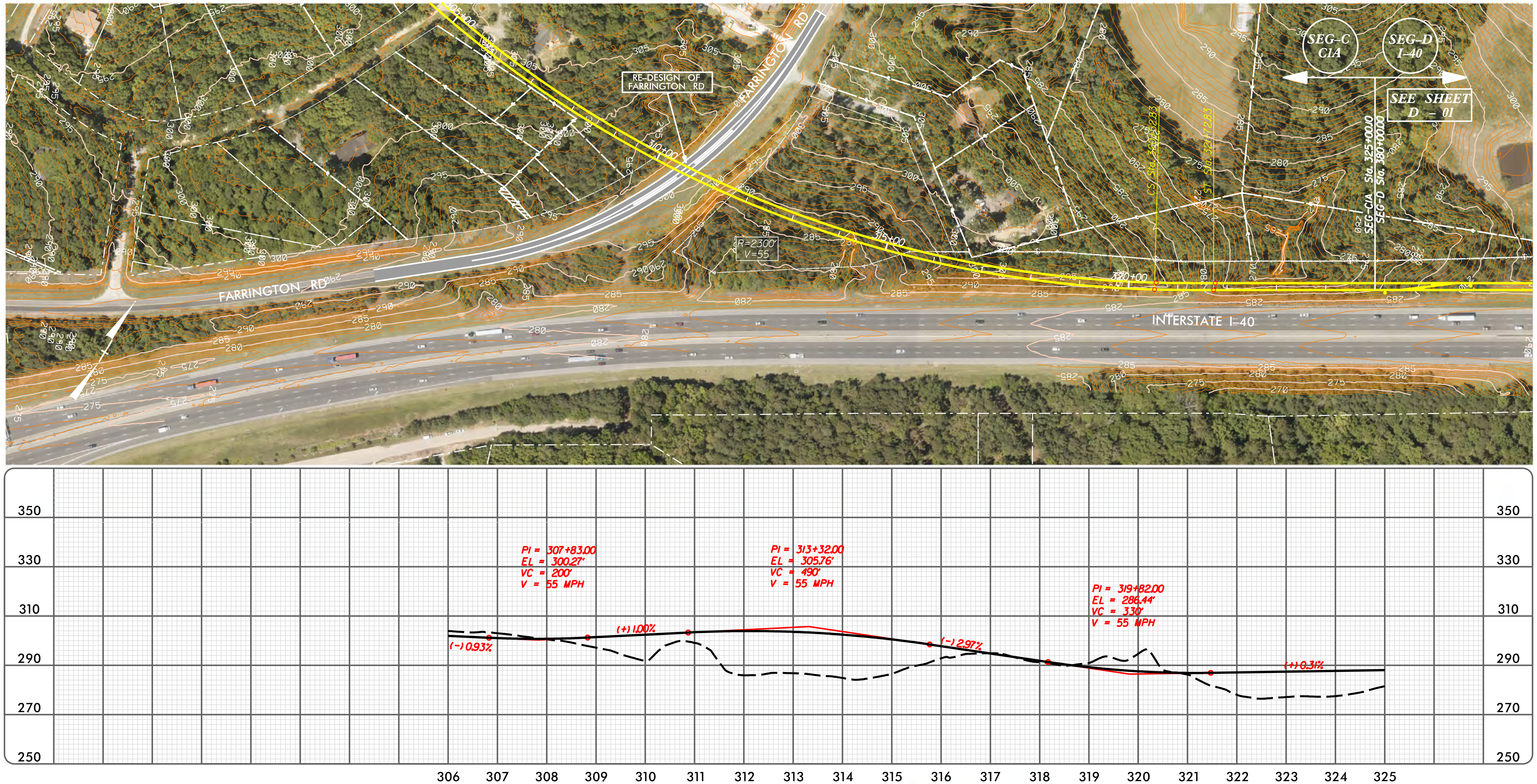
ALONG INTERSTATE 40 – C1A ALTERNATIVE



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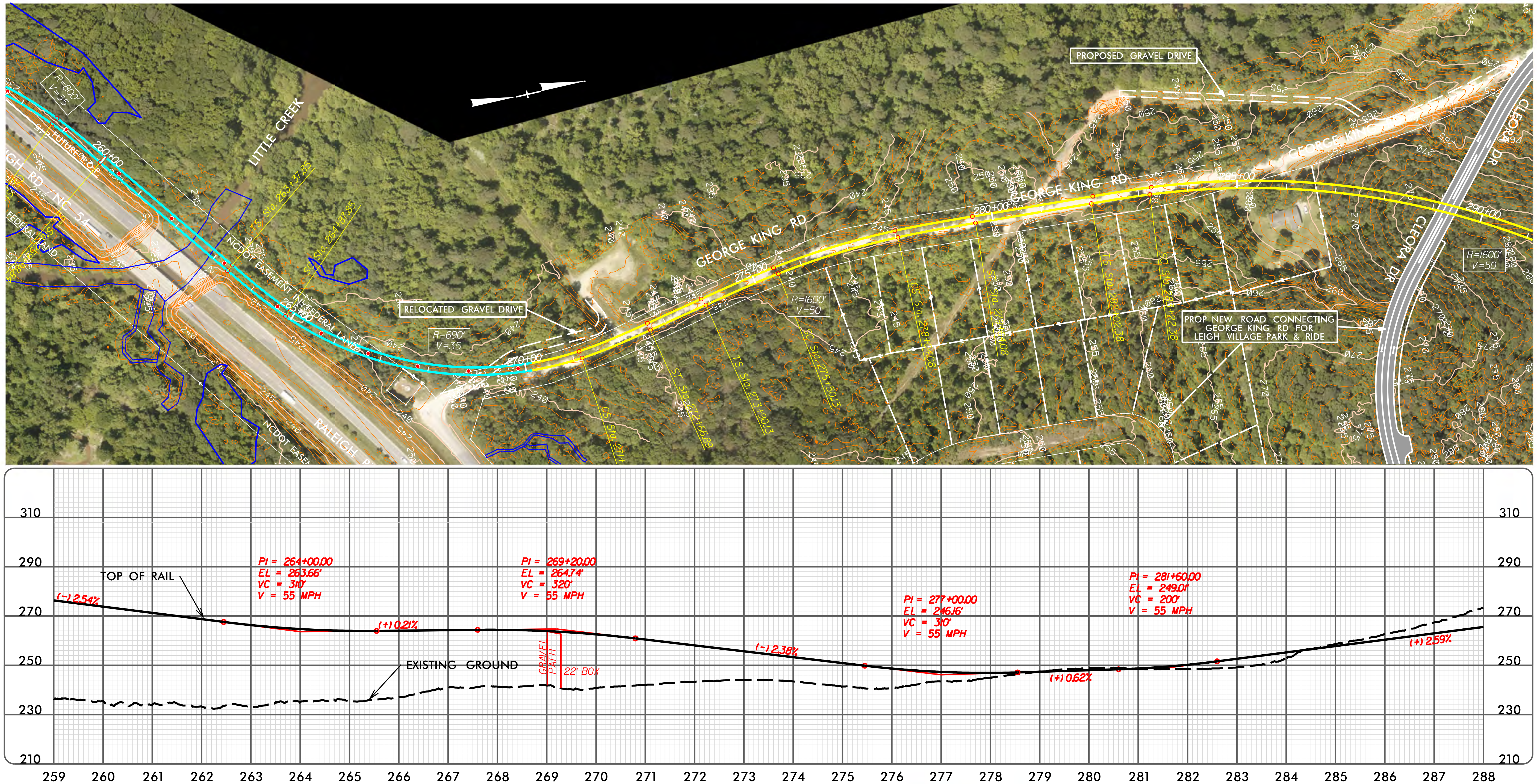
SEGMENT C – C2 ALTERNATIVE

GEORGE KING ROAD – C2 ALTERNATIVE



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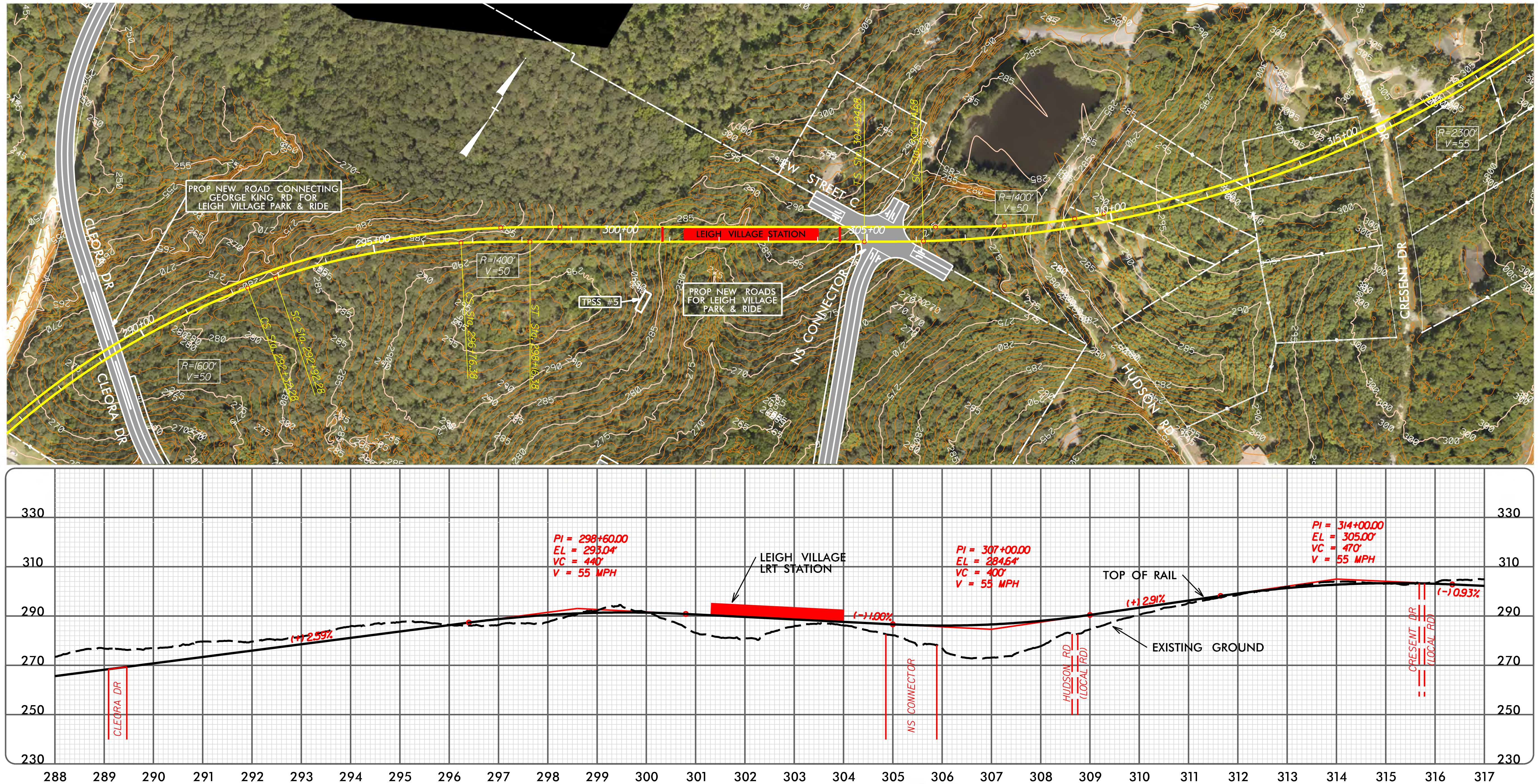
LEIGH VILLAGE STATION – C2 ALTERNATIVE



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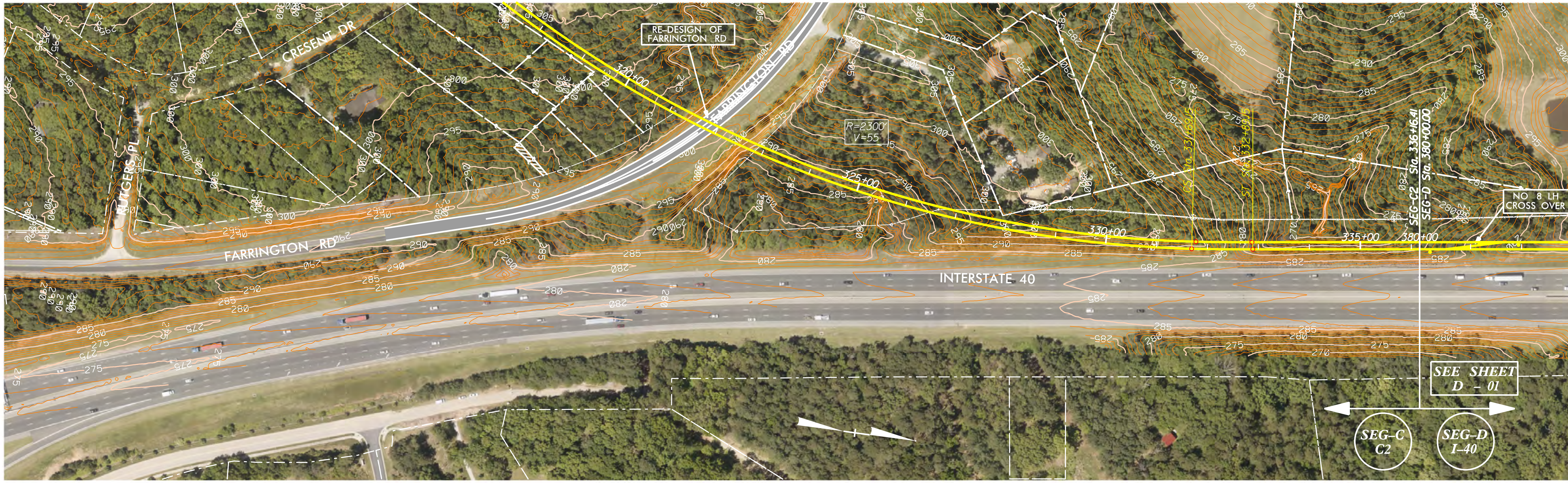

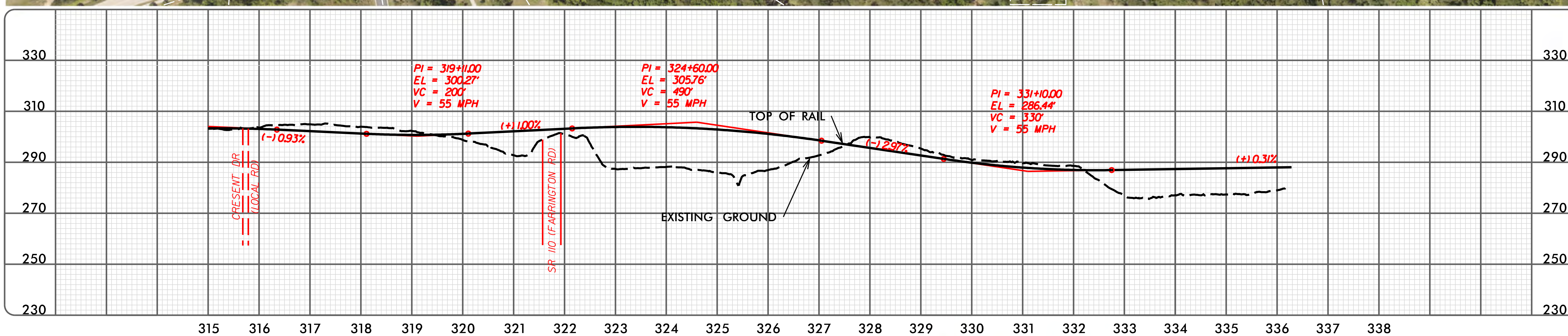

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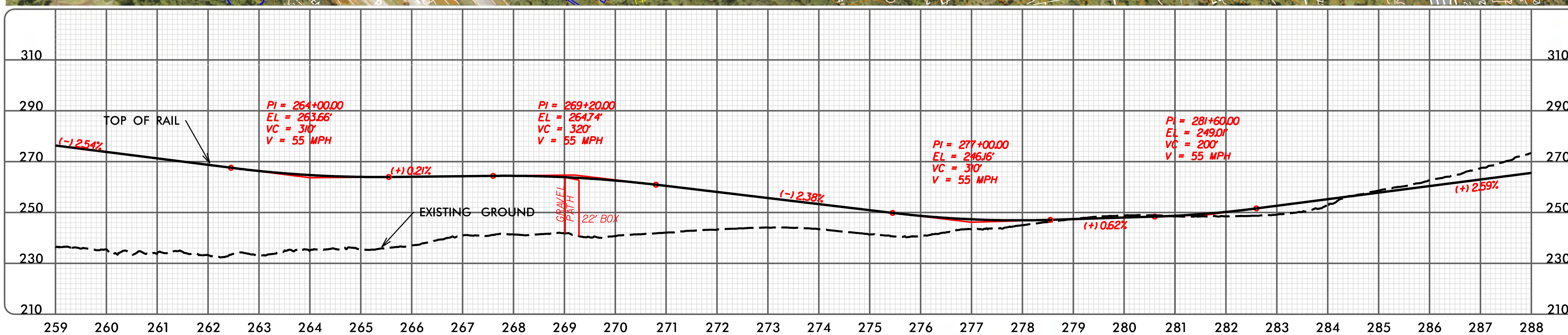

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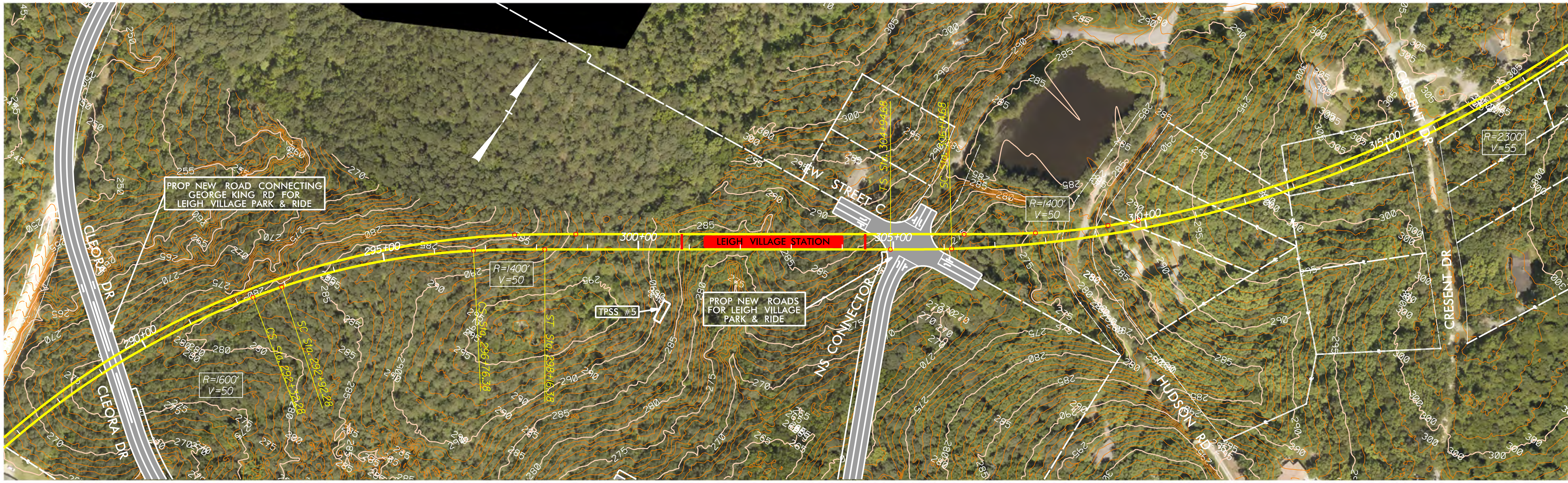

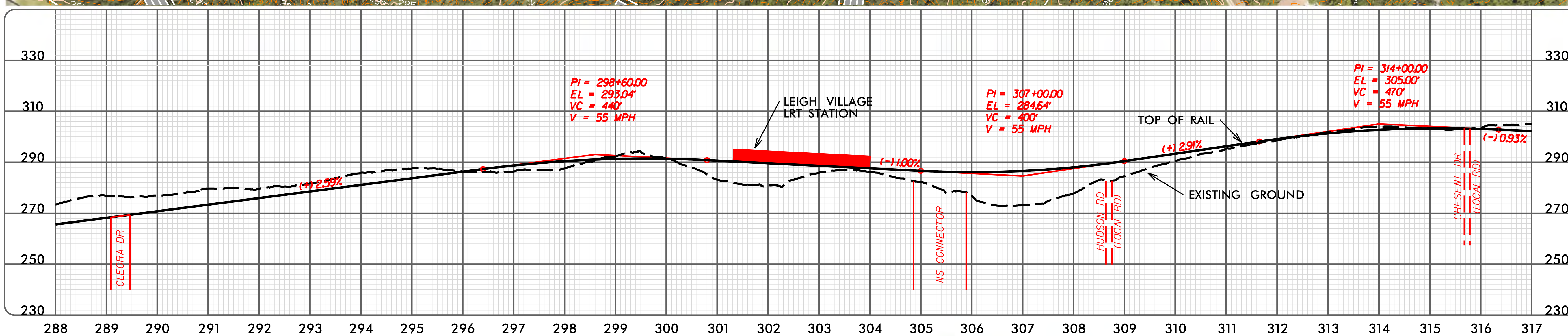

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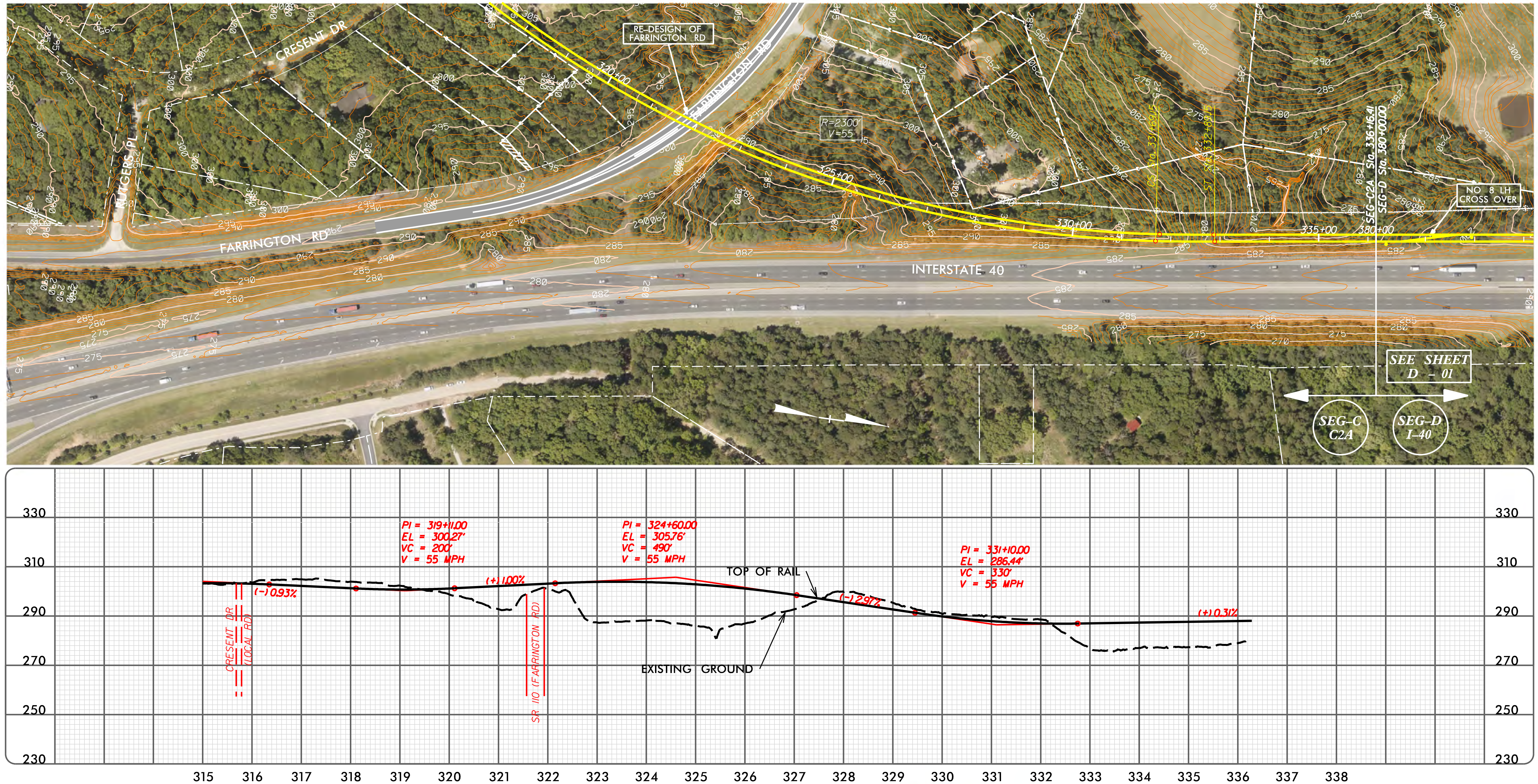

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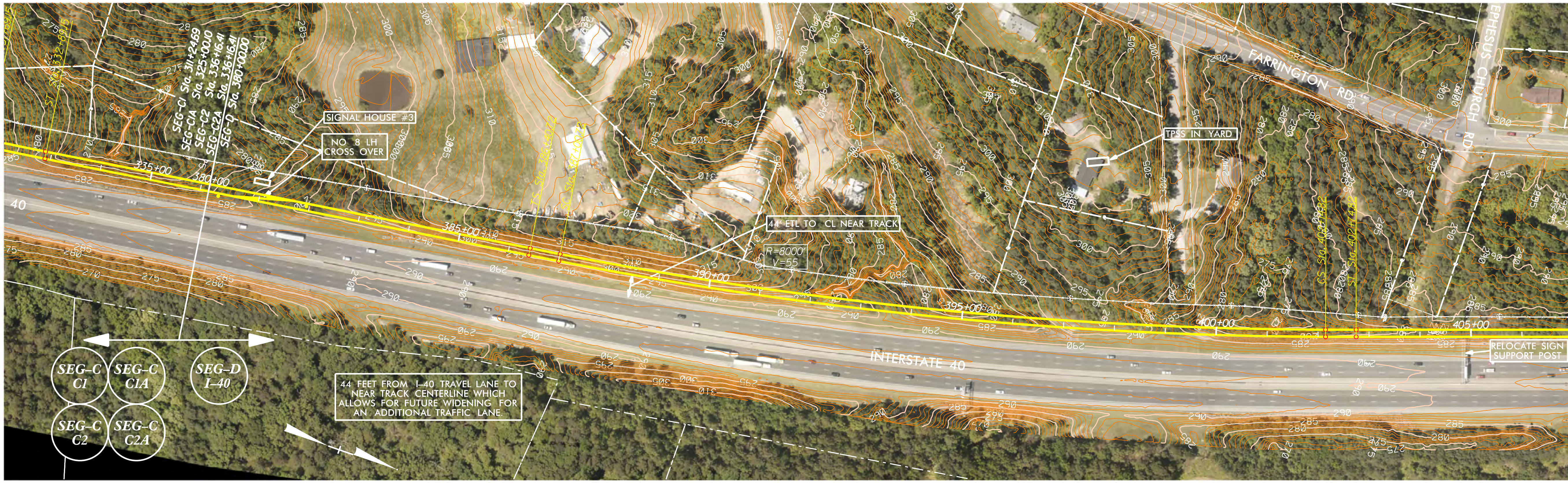

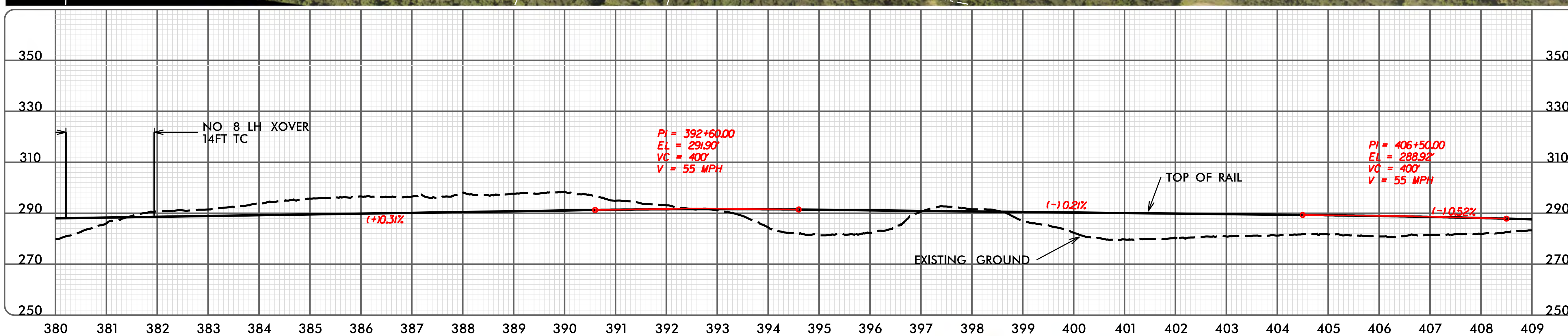

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SEGMENT D

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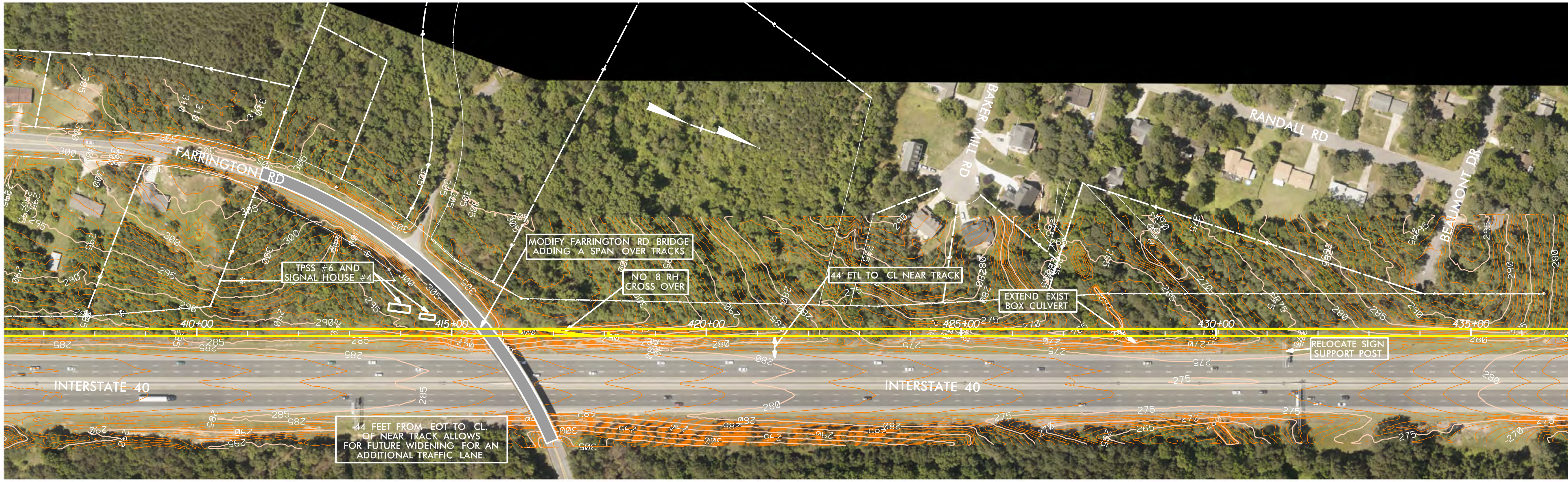
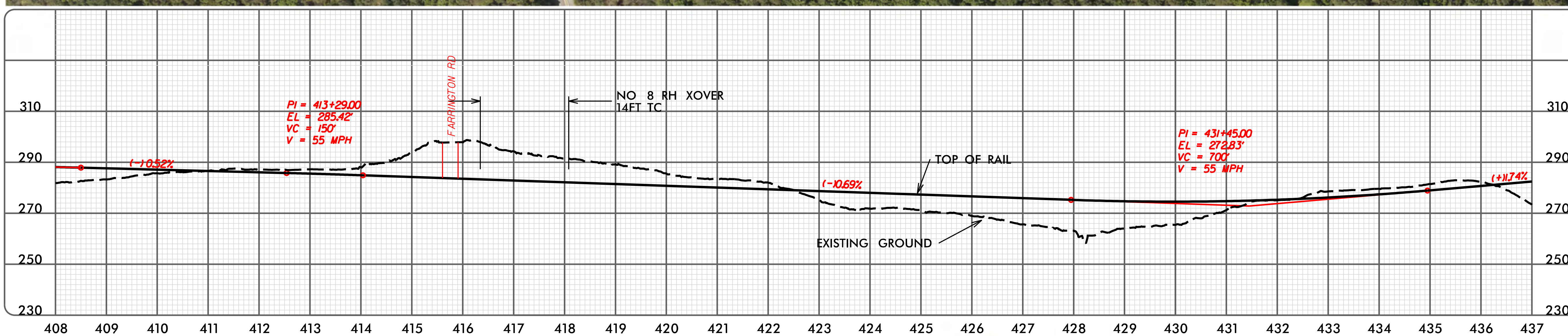
INTERSTATE 40





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SEGMENT D

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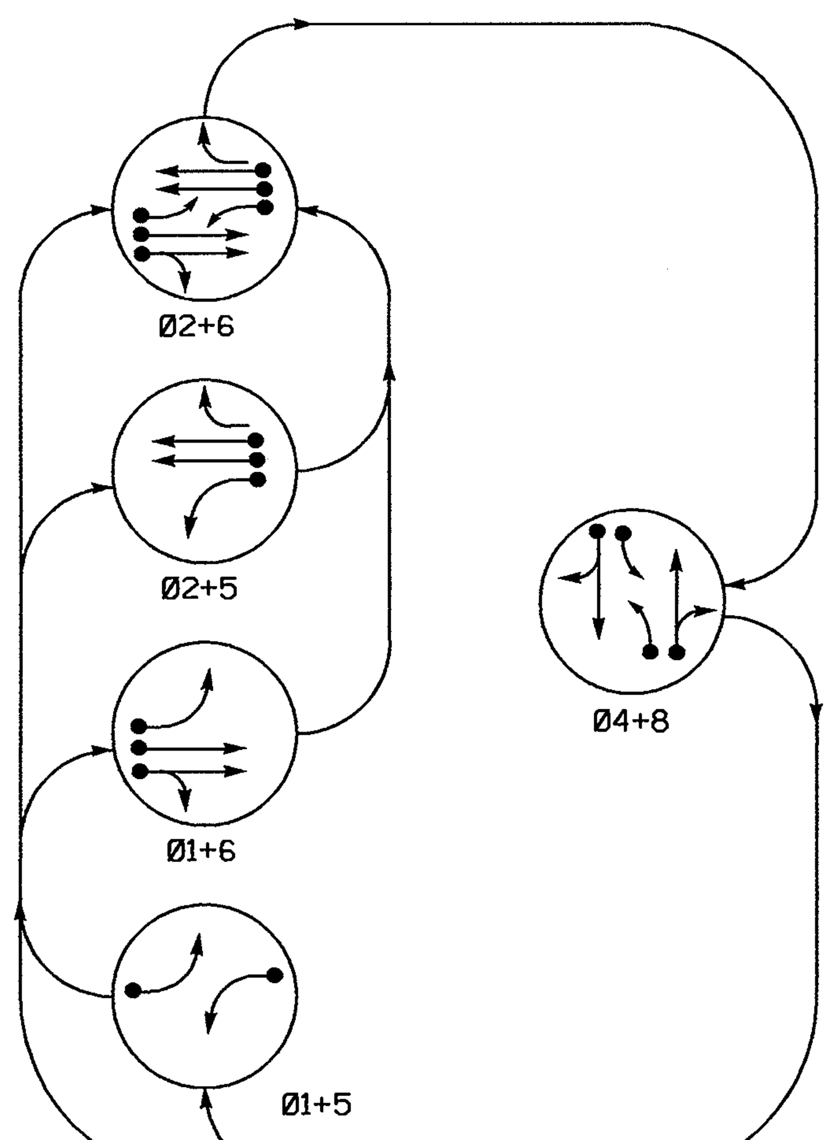
SHEET: D – 02

Appendix C
Existing Traffic Signal Timing Plans

PROJECT REFERENCE NO.	SHEET NO.
N/A	SIG. 1

PHASING DIAGRAM



PHASING DIAGRAM DETECTION LEGEND

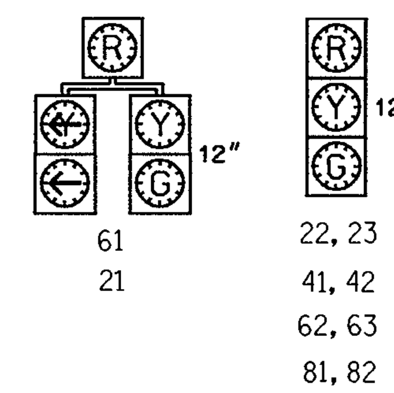
- DETECTED MOVEMENT
- UNDETECTED MOVEMENT (OVERLAP)
- UNSIGNALIZED MOVEMENT
- PEDESTRIAN MOVEMENT

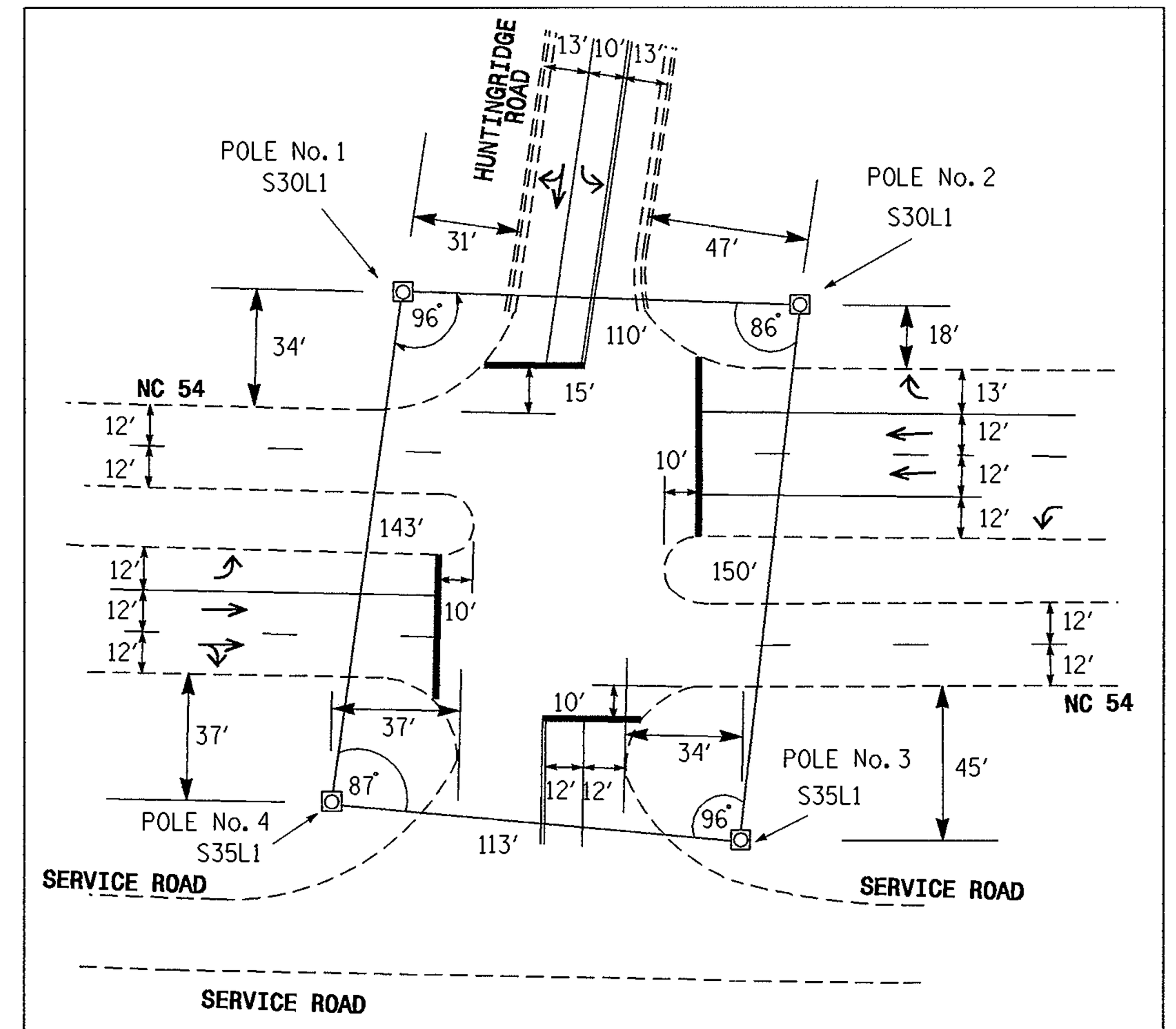
TABLE OF OPERATION

SIGNAL FACE	PHASE Ø1+5	Ø1+6	Ø2+5	Ø2+6	Ø4+8	FLASH
21	R	R	G	G	R	Y
22, 23	R	R	G	G	R	Y
61	R	G	R	G	R	Y
62, 63	R	G	R	G	R	Y
41, 42	R	R	R	R	G	R
81, 82	R	R	R	R	G	R

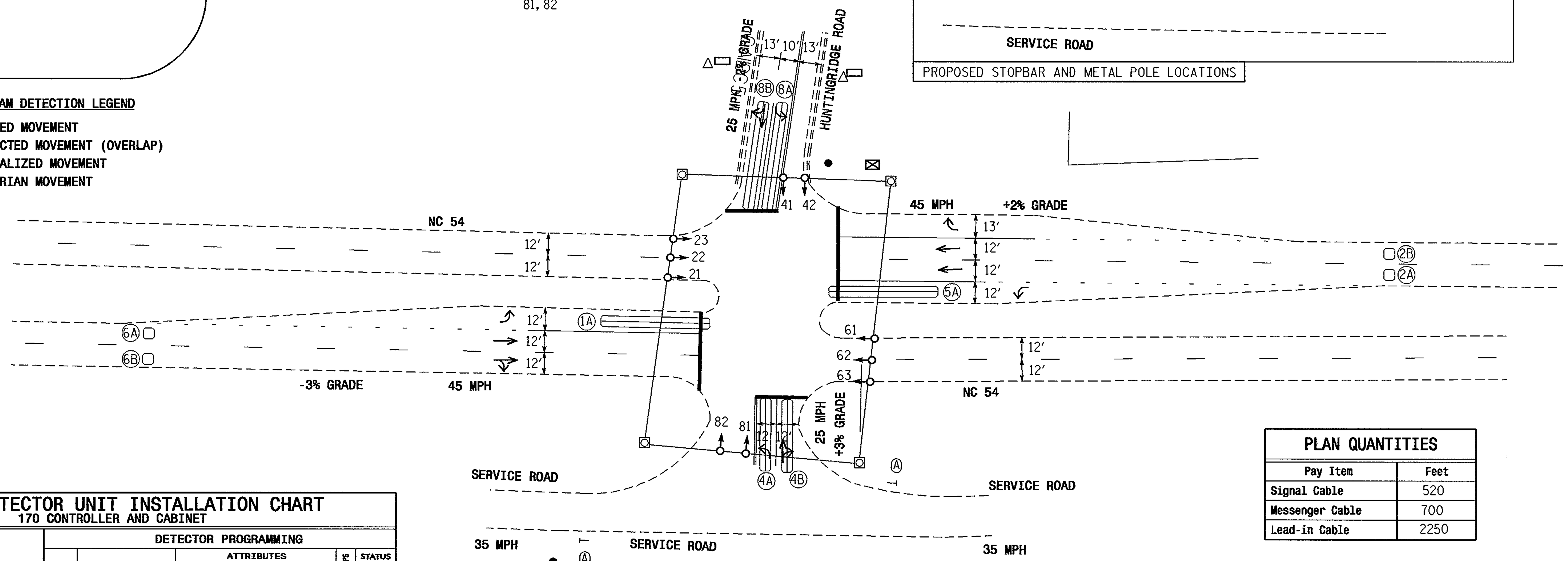
SIGNAL FACE I.D.

Denotes L.E.D.





PROPOSED STOPBAR AND METAL POLE LOCATIONS



5-PHASE
FULLY ACTUATED
(DURHAM CITY SIGNAL SYSTEM

NOTES

1. Refer to "Roadway Standard Drawings NCDOT" dated January 2002 and "Standard Specifications for Roads and Structures" dated January 2002.
2. Locate new cabinet so as not to obstruct sight distance of vehicles turning right on red.
3. Do not program signal for late night flashing operation unless otherwise directed by the Engineer.
4. Maximum times shown in timing chart are for free-run operation only. Coordinated signal system timing values shall supersede these values.
5. Set all detector units to presence mode.
6. Program phase 1 as protected/permitted.
7. Program phase 5 as protected/permitted.
8. Program controller to clear from phase 2+6 to phase 1and/or 5 by progressing through phase 4+8 (see Electrical Details).
9. Add signal head no. 63 in order to cover the future widening for an exclusive right turn lane.

LEGEND

PROPOSED		EXISTING
	Traffic Signal Head	
	Modified Signal Head	N/A
	Sign	
	Pedestrian Signal Head With Push Button & Sign	
	Signal Pole with Guy	
	Signal Pole with Sidewalk Guy	
	Inductive Loop Detector	
	Controller & Cabinet	
	Junction Box	
	2-in Underground Conduit	
N/A	Right of Way with Marker	
	Directional Arrow	
Ⓐ	"Stop" Sign (R1-1)	Ⓐ

PLAN QUANTITIES

Pay Item	Feet
Signal Cable	520
Messenger Cable	700
Lead-in Cable	2250

LOOP & DETECTOR UNIT INSTALLATION CHART
170 CONTROLLER AND CABINET

LOOP NO.	SIZE (ft)	TURNS	DIST. FROM STOPBAR (ft)	NEW	EXISTING	NEMA PHASE	DELAY	CARRY (STRETCH)	1 FULL TIME DELAY	2 PEDESTRIAN CALL	3 RESERVED	4 COUNT	5 EXTENSION	6 TYPE 3	7 CALLING	8 ALTERNATE	SYSTEM LOOPS	STATUS NEW	STATUS EXISTING
1A	6X60	2-4-2	+5	X		1	15 SEC.	SEC.					X		X			X	
						6	3 SEC.	SEC.	X				X		X			X	
						4	15 SEC.	SEC.							X			X	
2A	6X6	4	300	X		2	SEC.	SEC.				X	X		X			X	
2B	6X6	4	300	X		2	SEC.	SEC.				X	X		X			X	
4A	6X40	2-4-2	0	X		4	SEC.	SEC.					X		X			X	
4B	6X40	2-4-2	0	X		4	10 SEC.	SEC.					X		X			X	
5A	6X60	2-4-2	+5	X		5	15 SEC.	SEC.					X		X			X	
						2	3 SEC.	SEC.	X				X		X			X	
						4	15 SEC.	SEC.							X			X	
6A	6X6	4	300	X		6	SEC.	SEC.				X	X		X			X	
6B	6X6	4	300	X		6	SEC.	SEC.				X	X		X			X	
8A	6X60	2-4-2	0	X		8	SEC.	SEC.					X		X			X	
8B	6X60	2-4-2	0			8	10 SEC.	SEC.					X		X			X	

TIMING CHART
170 CONTROLLER

PHASE	Ø1	Ø2	Ø4	Ø5	Ø6	Ø8
MINIMUM INITIAL	7 SEC.	12 SEC.	7 SEC.	7 SEC.	12 SEC.	7 SEC.
VEHICLE EXTENSION	1 SEC.	6 SEC.	1 SEC.	1 SEC.	6 SEC.	1 SEC.
YELLOW CHANGE INT.	4.0 SEC.	4.7 SEC.	4.0 SEC.	4.0 SEC.	4.7 SEC.	4.0 SEC.
RED CLEARANCE	2.0 SEC.	1.5 SEC.	2.5 SEC.	2.5 SEC.	1.5 SEC.	2.5 SEC.
MAXIMUM LIMIT	15 SEC.	90 SEC.	20 SEC.	15 SEC.	90 SEC.	20 SEC.
RECALL POSITION	NONE	MIN. RECALL	NONE	NONE	MIN. RECALL	NONE
VEHICLE CALL MEMORY	NONLOCK	LOCK	NONLOCK	NONLOCK	LOCK	NONLOCK
DOUBLE ENTRY	OFF	OFF	ON	OFF	OFF	ON
WALK	– SEC.	– SEC.	– SEC.	– SEC.	– SEC.	– SEC.
FLASHING DON'T WALK	– SEC.	– SEC.	– SEC.	– SEC.	– SEC.	– SEC.
TYPE 3 LIMIT	– SEC.	– SEC.	– SEC.	– SEC.	– SEC.	– SEC.
ALTERNATE EXTENSION	– SEC.	– SEC.	– SEC.	– SEC.	– SEC.	– SEC.
ADD PER VEHICLE	– SEC.	1.8 SEC.	– SEC.	– SEC.	1.8 SEC.	– SEC.
MAXIMUM INITIAL	– SEC.	34 SEC.	– SEC.	– SEC.	34 SEC.	– SEC.
MAXIMUM GAP	1 SEC.	7.0 SEC.	1 SEC.	1 SEC.	7.0 SEC.	1 SEC.
REDUCE 0.1 SEC EVERY	– SEC.	1.5 SEC.	– SEC.	– SEC.	1.5 SEC.	– SEC.
MINIMUM GAP	1 SEC.	3.2 SEC.	1 SEC.	1 SEC.	3.2 SEC.	1 SEC.

NEW INSTALLATION

Prepared in the Offices of:
Traffic Engineering and Safety Systems Branch
Signals and Geometrics Section
122 N. McDowell St., Raleigh, NC 27603

SCALE 0 40
1"=40'

NC 54 AT HUNTING RIDGE ROAD/ SERVICE ROAD

DIVISION 05 DURHAM COUNTY DURHAM

PLAN DATE: AUGUST, 2004	REVIEWED BY:
PREPARED BY: MONIF BAZZARIE	REVIEWED BY:

REVISIONS	INIT.	DATE

SEAL
NORTH CAROLINA PROFESSIONAL ENGINEER SEAL 25475 BONIFACE MADUABUCHUKWU

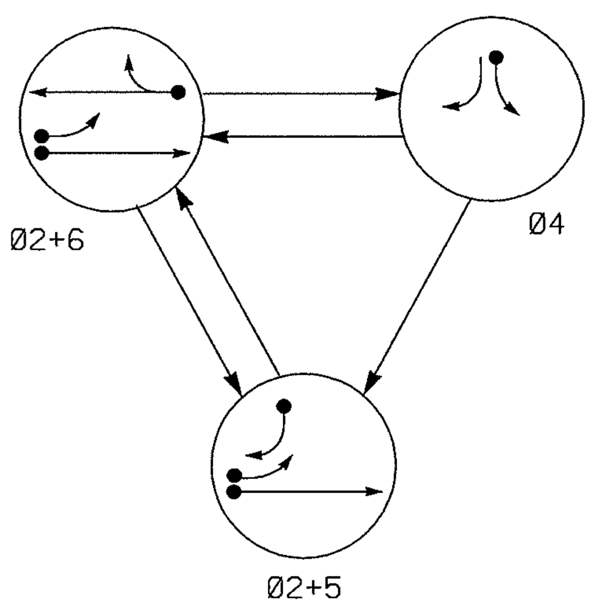
Boniface Madu 9/1/04
SIGNATURE DATE

SIG. INVENTORY NO. 05-1744

18-AUG-2004 11:01
mbazzarie

PROJECT REFERENCE NO.	SHEET NO.
36249.2731	Sig.1

PHASING DIAGRAM



PHASING DIAGRAM DETECTION LEGEND

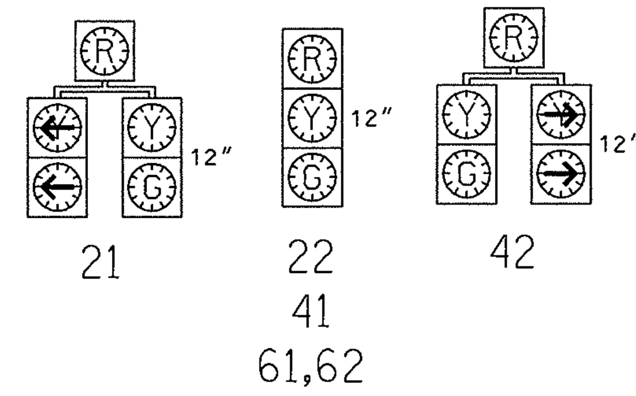
- DETECTED MOVEMENT
- UNDETECTED MOVEMENT (OVERLAP)
- UNSIGNALIZED MOVEMENT

TABLE OF OPERATION

SIGNAL FACE	PHASE Ø2+5	PHASE Ø2+6	PHASE Ø4	PHASE FLASH
21	G	G	R	Y
22	G	G	R	Y
41	R	R	G	R
42	R	R	G	R
61,62	R	G	R	Y

SIGNAL FACE I.D.

Denotes L.E.D.



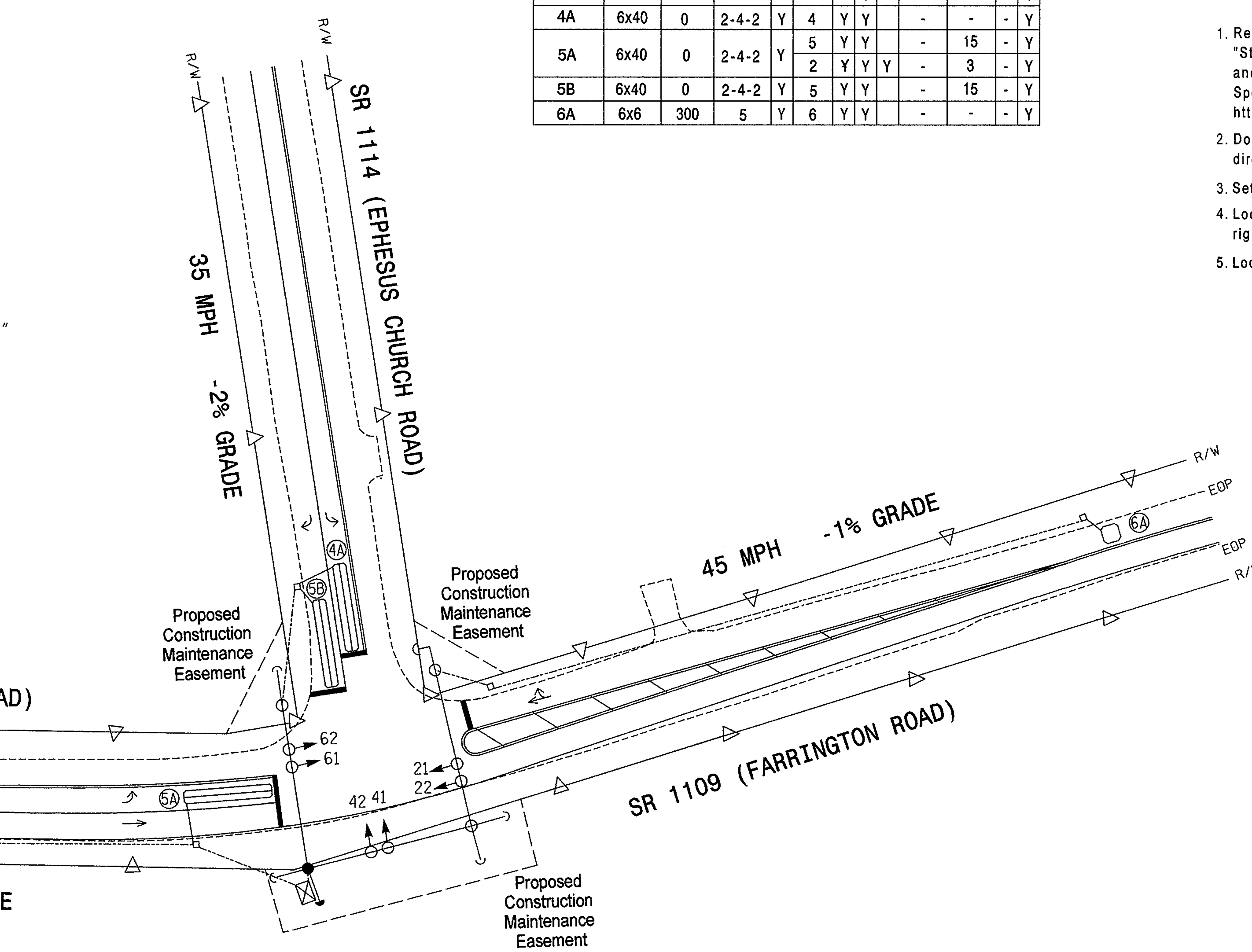
2070L LOOP & DETECTOR INSTALLATION

LOOP	SIZE (FT)	DISTANCE FROM STOPBAR (FT)	TURNS	NEW LOOP	PHASE	CALLING	EXTENSION	FULL TIME DELAY	STRETCH TIME	DELAY TIME	SYSTEM LOOP	NEW CARD
INDUCTIVE LOOPS					DETECTOR PROGRAMMING							
2A	6x6	300	4	Y	2	Y	Y		-	-	-	Y
4A	6x40	0	2-4-2	Y	4	Y	Y		-	-	-	Y
5A	6x40	0	2-4-2	Y	5	Y	Y		-	15	-	Y
					2	Y	Y	Y	-	3	-	Y
5B	6x40	0	2-4-2	Y	5	Y	Y		-	15	-	Y
6A	6x6	300	5	Y	6	Y	Y		-	-	-	Y

3 PHASE
FULLY ACTUATED
(ISOLATED)

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 operation unless otherwise directed by the Engineer.
3. Set all detector units to presence mode.
4. Locate new cabinet so as not to obstruct sight distance of vehicles turning right on red.
5. Locate all underground utilities prior to pole drilling and conduit trenching.



LEGEND

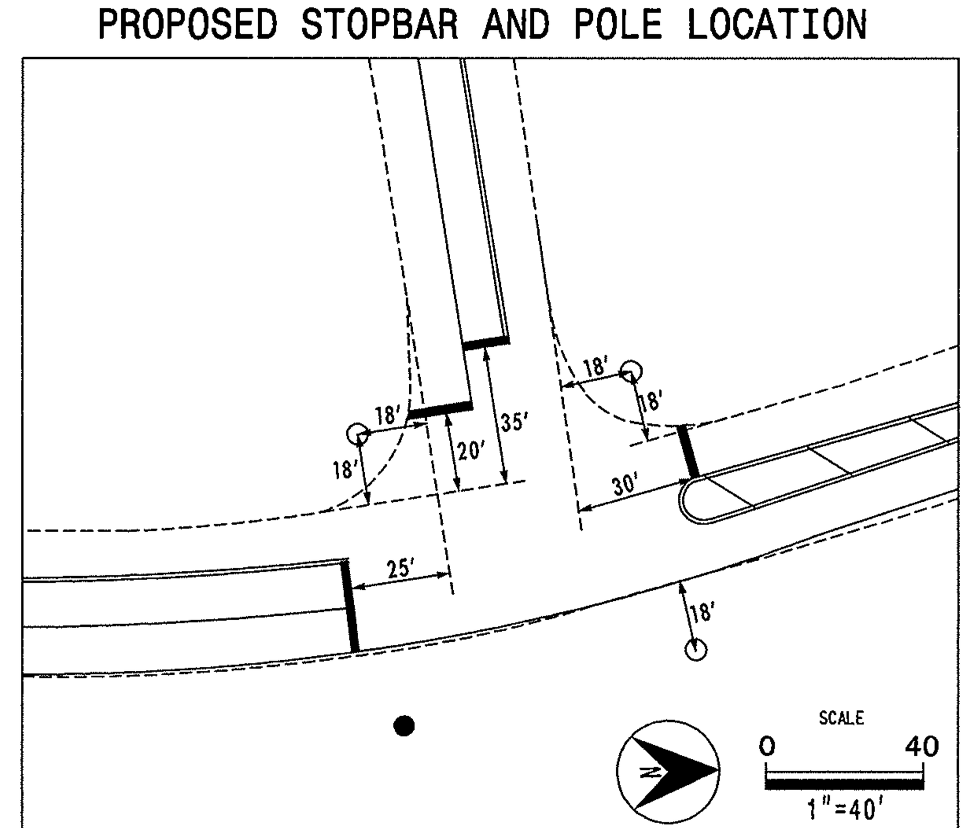
PROPOSED		EXISTING
	Traffic Signal Head	
	Modified Signal Head	N/A
	Sign	
	Pedestrian Signal Head With Push Button & Sign	
	Signal Pole with Guy	
	Signal Pole with Sidewalk Guy	
	Inductive Loop Detector	
	Controller & Cabinet	
	Junction Box	
	2-in Underground Conduit	
N/A	Right of Way	
	Directional Arrow	
	Pavement Marking Arrow	

2070L TIMING CHART

FEATURE	PHASE Ø2	PHASE Ø4	PHASE Ø5	PHASE Ø6
Min Green 1 *	12	7	7	12
Extension 1 *	6.0	1.0	1.0	6.0
Max Green 1 *	90	20	35	90
Yellow Clearance	4.3	3.3	3.1	4.6
Red Clearance	1.0	1.8	1.7	1.0
Walk 1 *	-	-	-	-
Don't Walk 1	-	-	-	-
Seconds Per Actuation *	2.5	-	-	2.5
Max Variable Initial *	34	-	-	34
Time Before Reduction *	15	-	-	15
Time To Reduce *	30	-	-	30
Minimum Gap	3.0	-	-	3.0
Recall Mode	MIN RECALL	-	-	MIN RECALL
Vehicle Call Memory	YELLOW	-	-	YELLOW
Dual Entry	-	-	-	-
Simultaneous Gap	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.

PROPOSED STOPBAR AND POLE LOCATION



NC DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
FINAL DRAWING Date: 7/7/08
Traffic Engineering Branch

NEW INSTALLATION

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

750 N. Greenfield Pkwy, Garner, NC 27529

SCALE 0 40 1"=40'

SR 1109 (FARRINGTON ROAD)
AT
SR 1114 (EPHESUS CHURCH ROAD)

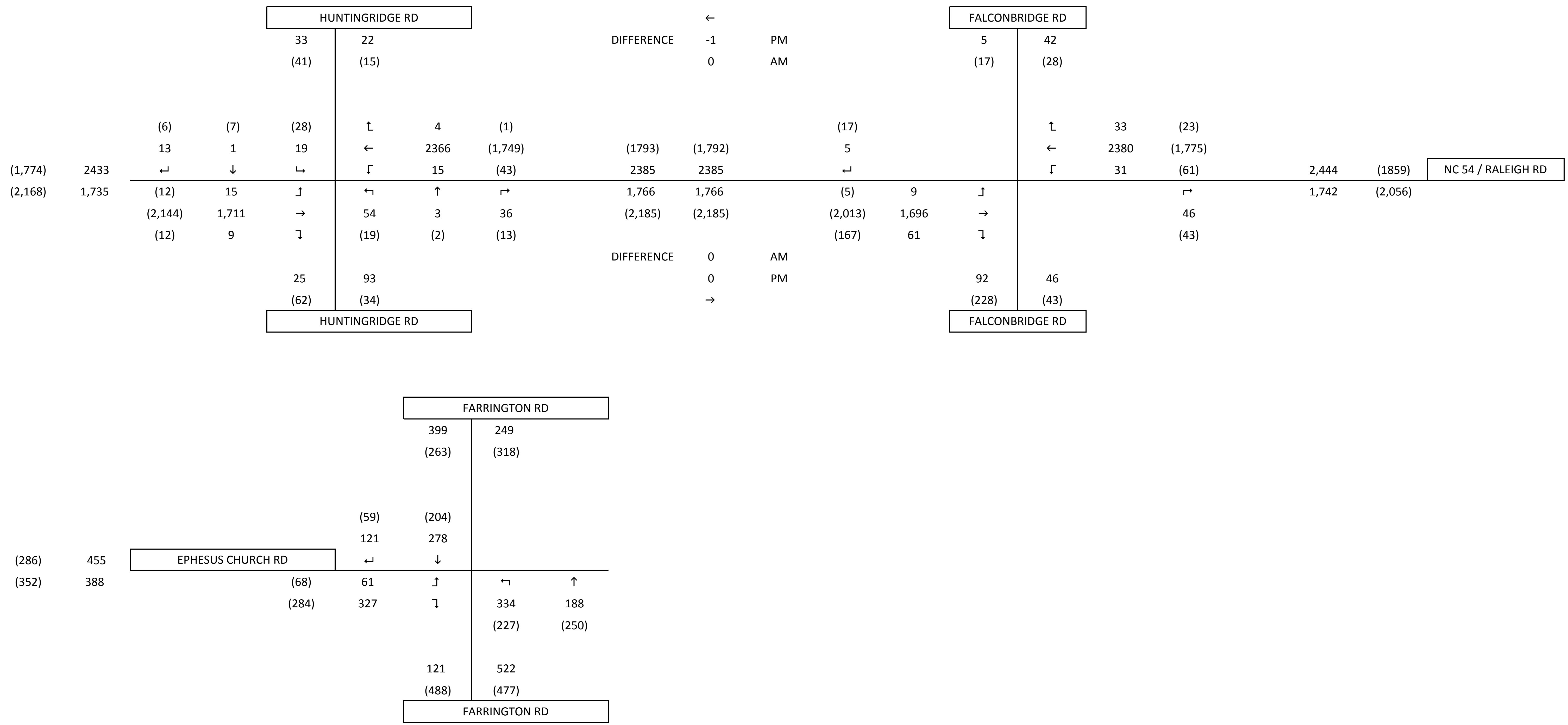
DIVISION 5	DURHAM COUNTY		DURHAM
PLAN DATE: 07/03/2008		REVIEWED BY: JLL	
PREPARED BY: JM		REVIEWED BY:	
REVISIONS		INIT.	DATE

SEAL
NORTH CAROLINA PROFESSIONAL SEAL 033108 ENGINEER JIANXIN MA
7/3/2008
SIGNATURE DATE
SIG. INVENTORY NO. 05-2338

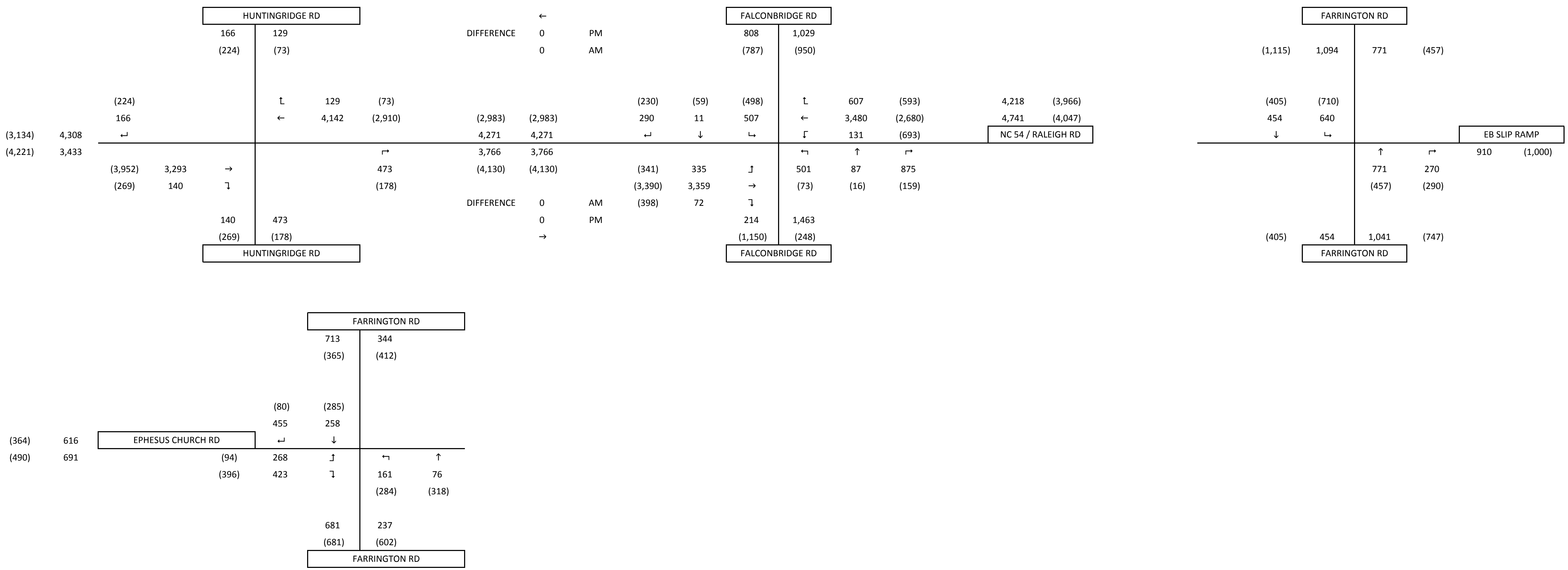
Appendix D
Balanced Peak Hour Volumes

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

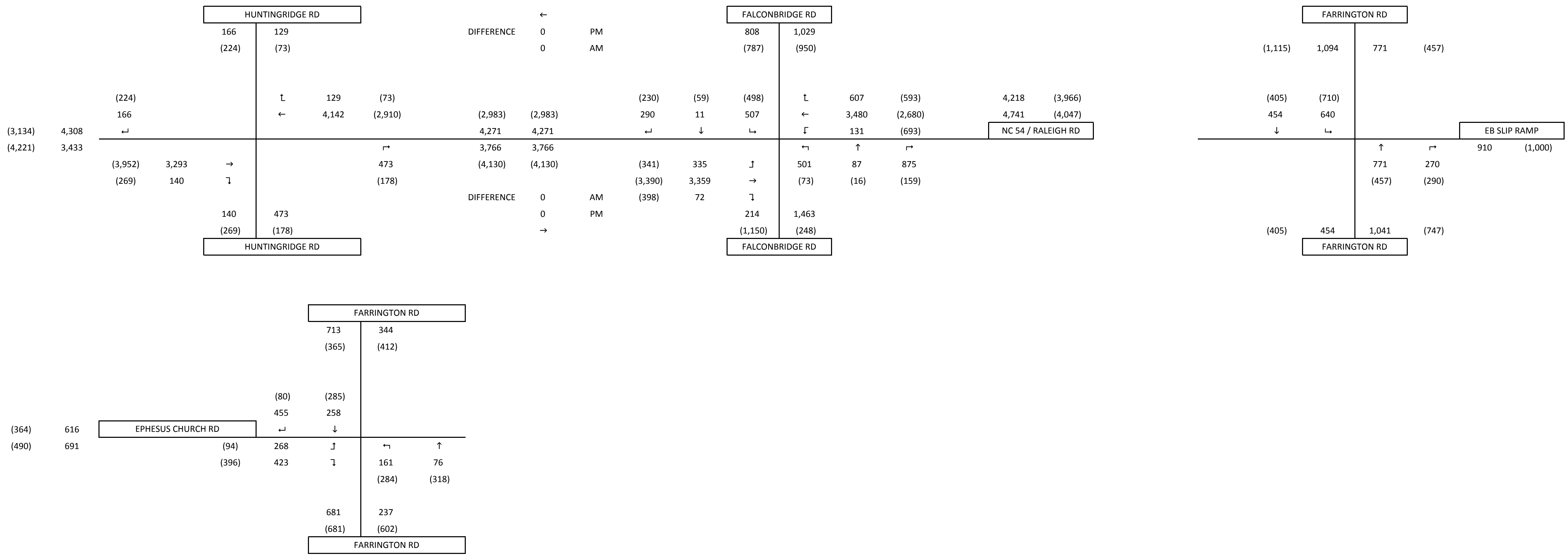
2011 Existing Balanced Volumes



2040 No Build / TSM Scenario Balanced Volumes



2040 Build Scenario Balanced Volumes



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 (veh/h)	0	3293	140	0	4142	129	0	0	473	0	0	116
Sign Control		Free			Free			Stop			Stop	
Grade		0%			0%			0%			0%	
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Hourly flow rate (vph)	0	3659	156	0	4602	143	0	0	526	0	0	129
Pedestrians												
Lane Width (ft)												
Walking Speed (ft/s)												
Percent Blockage												
Right turn flare (veh)												
Median type		None			None							
Median storage veh)												
Upstream signal (ft)					1192							
pX, platoon unblocked	0.47						0.47	0.47		0.47	0.47	0.47
vC, conflicting volume	4746			3814			5400	8482	1297	6419	8488	1606
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	5021			3814			6410	12956	1297	8575	12969	0
tC, single (s)	4.1			4.1			7.5	6.5	6.9	7.5	6.5	6.9
tC, 2 stage (s)												
tF (s)	2.2			2.2			3.5	4.0	3.3	3.5	4.0	3.3
p0 queue free %	100			100			100	100	0	0	100	75
cM capacity (veh/h)	8			52			0	0	152	0	0	511

Direction, Lane #	EB 1	EB 2	EB 3	WB 1	WB 2	WB 3	NB 1	SB 1
Volume Total	1464	1464	887	1841	1841	1064	526	129
Volume Left	0	0	0	0	0	0	0	0
Volume Right	0	0	156	0	0	143	526	129
cSH	1700	1700	1700	1700	1700	1700	152	511
Volume to Capacity	0.86	0.86	0.52	1.08	1.08	0.63	3.45	0.25
Queue Length 95th (ft)	0	0	0	0	0	0	Err	25
Control Delay (s)	0.0	0.0	0.0	0.0	0.0	0.0	Err	14.4
Lane LOS							F	B
Approach Delay (s)	0.0			0.0			Err	14.4
Approach LOS							F	B

Intersection Summary			
Average Delay	570.5		
Intersection Capacity Utilization	108.0%	ICU Level of Service	G
Analysis Period (min)	15		

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	335	3359	72	131	3480	607	501	87	875	507	11	290
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	7.0	7.0	7.0	7.0	7.0
Lane Util. Factor	1.00	0.91	1.00	1.00	0.91	1.00	1.00	1.00	1.00	0.97	1.00	1.00
Frt	1.00	1.00	0.85	1.00	1.00	0.85	1.00	1.00	0.85	1.00	1.00	0.85
Flt Protected	0.95	1.00	1.00	0.95	1.00	1.00	0.95	1.00	1.00	0.95	1.00	1.00
Satd. Flow (prot)	1676	4818	1500	1676	4818	1500	1676	1765	1500	3252	1765	1500
Flt Permitted	0.95	1.00	1.00	0.95	1.00	1.00	0.95	1.00	1.00	0.95	1.00	1.00
Satd. Flow (perm)	1676	4818	1500	1676	4818	1500	1676	1765	1500	3252	1765	1500
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)	372	3732	80	146	3867	674	557	97	972	563	12	322
RTOR Reduction (vph)	0	0	19	0	0	46	0	0	104	0	0	144
Lane Group Flow (vph)	372	3732	61	146	3867	628	557	97	869	563	12	178
Turn Type	Prot	NA	pm+ov	Prot	NA	pm+ov	Prot	NA	Perm	Prot	NA	Perm
Protected Phases	1	6	3	5	2	7	3	8		7	4	
Permitted Phases			6			2			8			4
Actuated Green, G (s)	15.0	100.0	129.0	14.0	99.0	119.0	29.0	18.0	18.0	20.0	9.0	9.0
Effective Green, g (s)	15.0	100.0	129.0	14.0	99.0	119.0	29.0	18.0	18.0	20.0	9.0	9.0
Actuated g/C Ratio	0.08	0.56	0.72	0.08	0.55	0.66	0.16	0.10	0.10	0.11	0.05	0.05
Clearance Time (s)	7.0	7.0	7.0	7.0	7.0	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	3.0	3.0	3.0	3.0	3.0
Lane Grp Cap (vph)	139	2676	1133	130	2649	1050	270	176	150	361	88	75
v/s Ratio Prot	c0.22	0.77	0.01	0.09	c0.80	0.07	c0.33	0.05		0.17	0.01	
v/s Ratio Perm			0.03			0.35			c0.58			0.12
v/c Ratio	2.68	1.39	0.05	1.12	1.46	0.60	2.06	0.55	5.79	1.56	0.14	2.37
Uniform Delay, d1	82.5	40.0	7.5	83.0	40.5	17.1	75.5	77.2	81.0	80.0	81.8	85.5
Progression Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	774.5	179.9	0.0	115.8	209.0	0.9	490.9	3.7	2169.9	265.0	0.7	654.7
Delay (s)	857.0	219.9	7.5	198.8	249.5	18.0	566.4	80.9	2250.9	345.0	82.5	740.2
Level of Service	F	F	A	F	F	B	F	F	F	F	F	F
Approach Delay (s)		272.5			214.7			1544.4			483.3	
Approach LOS		F			F			F			F	

Intersection Summary			
HCM 2000 Control Delay	446.8	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	2.23		
Actuated Cycle Length (s)	180.0	Sum of lost time (s)	28.0
Intersection Capacity Utilization	158.5%	ICU Level of Service	H
Analysis Period (min)	15		
c Critical Lane Group			

Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Volume (vph)	268	423	161	76	258	455
Ideal Flow (vphpl)	1800	1800	1800	1800	1800	1800
Total Lost time (s)	7.0	7.0	7.0	7.0	7.0	
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00	
Frt	1.00	0.85	1.00	1.00	0.91	
Flt Protected	0.95	1.00	0.95	1.00	1.00	
Satd. Flow (prot)	1676	1500	1676	1765	1613	
Flt Permitted	0.95	1.00	0.95	1.00	1.00	
Satd. Flow (perm)	1676	1500	1676	1765	1613	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90
Adj. Flow (vph)	298	470	179	84	287	506
RTOR Reduction (vph)	0	326	0	0	43	0
Lane Group Flow (vph)	298	144	179	84	750	0
Turn Type	Prot	pm+ov	Prot	NA	NA	
Protected Phases	4	5	5	2	6	
Permitted Phases		4				
Actuated Green, G (s)	26.4	43.0	16.6	99.6	76.0	
Effective Green, g (s)	26.4	43.0	16.6	99.6	76.0	
Actuated g/C Ratio	0.19	0.31	0.12	0.71	0.54	
Clearance Time (s)	7.0	7.0	7.0	7.0	7.0	
Vehicle Extension (s)	1.0	1.0	1.0	6.0	6.0	
Lane Grp Cap (vph)	316	535	198	1255	875	
v/s Ratio Prot	c0.18	0.03	c0.11	0.05	c0.46	
v/s Ratio Perm		0.06				
v/c Ratio	0.94	0.27	0.90	0.07	0.86	
Uniform Delay, d1	56.1	36.6	60.9	6.1	27.3	
Progression Factor	1.00	1.00	1.00	1.00	1.00	
Incremental Delay, d2	35.4	0.1	37.6	0.1	10.6	
Delay (s)	91.4	36.7	98.5	6.2	37.9	
Level of Service	F	D	F	A	D	
Approach Delay (s)	58.0			69.0	37.9	
Approach LOS	E			E	D	

Intersection Summary			
HCM 2000 Control Delay	50.8	HCM 2000 Level of Service	D
HCM 2000 Volume to Capacity ratio	0.88		
Actuated Cycle Length (s)	140.0	Sum of lost time (s)	21.0
Intersection Capacity Utilization	86.4%	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 (veh/h)	0	4080	279	0	3611	73	0	0	178	0	0	224
Sign Control		Free			Free			Stop			Stop	
Grade		0%			0%			0%			0%	
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Hourly flow rate (vph)	0	4533	310	0	4012	81	0	0	198	0	0	249
Pedestrians												
Lane Width (ft)												
Walking Speed (ft/s)												
Percent Blockage												
Right turn flare (veh)												
Median type		None			None							
Median storage veh)												
Upstream signal (ft)					1192							
pX, platoon unblocked	0.48						0.48	0.48		0.48	0.48	0.48
vC, conflicting volume	4093			4843			6275	8782	1666	5762	8896	1378
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	3654			4843			8190	13403	1666	7123	13641	0
tC, single (s)	4.1			4.1			7.5	6.5	6.9	7.5	6.5	6.9
tC, 2 stage (s)												
tF (s)	2.2			2.2			3.5	4.0	3.3	3.5	4.0	3.3
p0 queue free %	100			100			100	100	0	0	100	52
cM capacity (veh/h)	29			19			0	0	86	0	0	521

Direction, Lane #	EB 1	EB 2	EB 3	WB 1	WB 2	WB 3	NB 1	SB 1
Volume Total	1813	1813	1217	1605	1605	884	198	249
Volume Left	0	0	0	0	0	0	0	0
Volume Right	0	0	310	0	0	81	198	249
cSH	1700	1700	1700	1700	1700	1700	86	521
Volume to Capacity	1.07	1.07	0.72	0.94	0.94	0.52	2.31	0.48
Queue Length 95th (ft)	0	0	0	0	0	0	453	64
Control Delay (s)	0.0	0.0	0.0	0.0	0.0	0.0	704.6	18.0
Lane LOS							F	C
Approach Delay (s)	0.0			0.0			704.6	18.0
Approach LOS							F	C

Intersection Summary			
Average Delay	15.3		
Intersection Capacity Utilization	108.1%	ICU Level of Service	G
Analysis Period (min)	15		

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	353	3493	412	874	3381	748	73	16	159	498	59	230
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	7.0	7.0	7.0	7.0	7.0
Lane Util. Factor	1.00	0.91	1.00	1.00	0.91	1.00	1.00	1.00	1.00	0.97	1.00	1.00
Frt	1.00	1.00	0.85	1.00	1.00	0.85	1.00	1.00	0.85	1.00	1.00	0.85
Flt Protected	0.95	1.00	1.00	0.95	1.00	1.00	0.95	1.00	1.00	0.95	1.00	1.00
Satd. Flow (prot)	1676	4818	1500	1676	4818	1500	1676	1765	1500	3252	1765	1500
Flt Permitted	0.95	1.00	1.00	0.95	1.00	1.00	0.95	1.00	1.00	0.95	1.00	1.00
Satd. Flow (perm)	1676	4818	1500	1676	4818	1500	1676	1765	1500	3252	1765	1500
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)	392	3881	458	971	3757	831	81	18	177	553	66	256
RTOR Reduction (vph)	0	0	54	0	0	22	0	0	78	0	0	118
Lane Group Flow (vph)	392	3881	404	971	3757	809	81	18	99	553	66	138
Turn Type	Prot	NA	pm+ov	Prot	NA	pm+ov	Prot	NA	pm+ov	Prot	NA	pm+ov
Protected Phases	1	6	3	5	2	7	3	8	5	7	4	1
Permitted Phases			6			2			8			4
Actuated Green, G (s)	29.6	77.2	91.3	49.6	97.2	120.6	14.1	1.8	51.4	23.4	11.1	40.7
Effective Green, g (s)	29.6	77.2	91.3	49.6	97.2	120.6	14.1	1.8	51.4	23.4	11.1	40.7
Actuated g/C Ratio	0.16	0.43	0.51	0.28	0.54	0.67	0.08	0.01	0.29	0.13	0.06	0.23
Clearance Time (s)	7.0	7.0	7.0	7.0	7.0	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	3.0	3.0	3.0	3.0	3.0
Lane Grp Cap (vph)	275	2066	760	461	2601	1063	131	17	486	422	108	339
v/s Ratio Prot	0.23	c0.81	0.04	c0.58	0.78	0.10	c0.05	0.01	0.06	c0.17	0.04	0.07
v/s Ratio Perm			0.23			0.44			0.01			0.03
v/c Ratio	1.43	1.88	0.53	2.11	1.44	0.76	0.62	1.06	0.20	1.31	0.61	0.41
Uniform Delay, d1	75.2	51.4	29.9	65.2	41.4	20.0	80.3	89.1	48.8	78.3	82.3	59.4
Progression Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	211.3	397.2	0.7	505.2	202.2	3.3	8.4	238.2	0.2	155.8	9.8	0.8
Delay (s)	286.5	448.6	30.6	570.4	243.6	23.3	88.7	327.3	49.0	234.1	92.2	60.2
Level of Service	F	F	C	F	F	C	F	F	D	F	F	E
Approach Delay (s)		394.7			267.8			78.8			172.5	
Approach LOS		F			F			E			F	

Intersection Summary			
HCM 2000 Control Delay	308.4	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	1.86		
Actuated Cycle Length (s)	180.0	Sum of lost time (s)	28.0
Intersection Capacity Utilization	161.5%	ICU Level of Service	H
Analysis Period (min)	15		
c Critical Lane Group			

Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Volume (vph)	94	396	284	318	285	80
Ideal Flow (vphpl)	1800	1800	1800	1800	1800	1800
Total Lost time (s)	7.0	7.0	7.0	7.0	7.0	
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00	
Frt	1.00	0.85	1.00	1.00	0.97	
Flt Protected	0.95	1.00	0.95	1.00	1.00	
Satd. Flow (prot)	1676	1500	1676	1765	1712	
Flt Permitted	0.95	1.00	0.95	1.00	1.00	
Satd. Flow (perm)	1676	1500	1676	1765	1712	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90
Adj. Flow (vph)	104	440	316	353	317	89
RTOR Reduction (vph)	0	273	0	0	5	0
Lane Group Flow (vph)	104	167	316	353	401	0
Turn Type	Prot	pm+ov	Prot	NA	NA	
Protected Phases	4	5	5	2	6	
Permitted Phases		4				
Actuated Green, G (s)	12.2	42.6	30.4	113.8	76.4	
Effective Green, g (s)	12.2	42.6	30.4	113.8	76.4	
Actuated g/C Ratio	0.09	0.30	0.22	0.81	0.55	
Clearance Time (s)	7.0	7.0	7.0	7.0	7.0	
Vehicle Extension (s)	1.0	1.0	1.0	6.0	6.0	
Lane Grp Cap (vph)	146	531	363	1434	934	
v/s Ratio Prot	c0.06	0.07	c0.19	0.20	c0.23	
v/s Ratio Perm		0.04				
v/c Ratio	0.71	0.32	0.87	0.25	0.43	
Uniform Delay, d1	62.2	37.5	52.9	3.1	18.9	
Progression Factor	1.00	1.00	1.00	1.00	1.00	
Incremental Delay, d2	12.8	0.1	19.2	0.4	1.4	
Delay (s)	75.0	37.6	72.1	3.5	20.3	
Level of Service	E	D	E	A	C	
Approach Delay (s)	44.7			35.9	20.3	
Approach LOS	D			D	C	

Intersection Summary			
HCM 2000 Control Delay	35.0	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.57		
Actuated Cycle Length (s)	140.0	Sum of lost time (s)	21.0
Intersection Capacity Utilization	60.9%	ICU Level of Service	B
Analysis Period (min)	15		
c Critical Lane Group			