Appendix A: Developing Land Use Scenarios and Traffic Generation Forecasts

Since the way that land uses are configured and designed plays an important role in how many and what kind of trips are produced from those uses, an assessment of traffic generation potential was prepared citing both the 2000 decennial Census effort and the 2006 Household Travel Behavior Survey conducted for the Triangle Regional Travel Demand Modeling program. The following procedure for estimating trip reductions was utilized for this study.

Our study team considered closely a base year (2010) and two future year (2020 and 2030) build scenarios, with the latter focusing on the development and potential redevelopment of parcels of land inside the study area. While there is no guarantee that a particular parcel of land will develop or redevelop, this was the best estimate of how this area would grow and change over a 20-year period. Creating these land use scenarios was as important as any design concept for a road or public transportation service, so it is important to understand the role of land use in this effort in some detail. Figure A-1 illustrates the three land use scenarios developed by the study team in concert with the City of Raleigh planning staff.

Once these scenarios were created, trip generation figures were created not only from the anticipated number of new residents, employees, and customers visiting the area, but the land use typology also drove to a degree how many of these people would be driving or taking some other form of transportation. The following sections explain how these trip generation figures were calculated in detail.

Additionally, alternative land use scenarios have been considered in order to identify potential reductions in overall trip generators for the Crabtree Valley Study Area. These areas have been identified if FIGURE A-X with tables supporting the traffic generation numbers as a result of the projected land use changes. Two separate analyses were conducted to illustrate the potential signifigance of land use modifications on future trip generation.

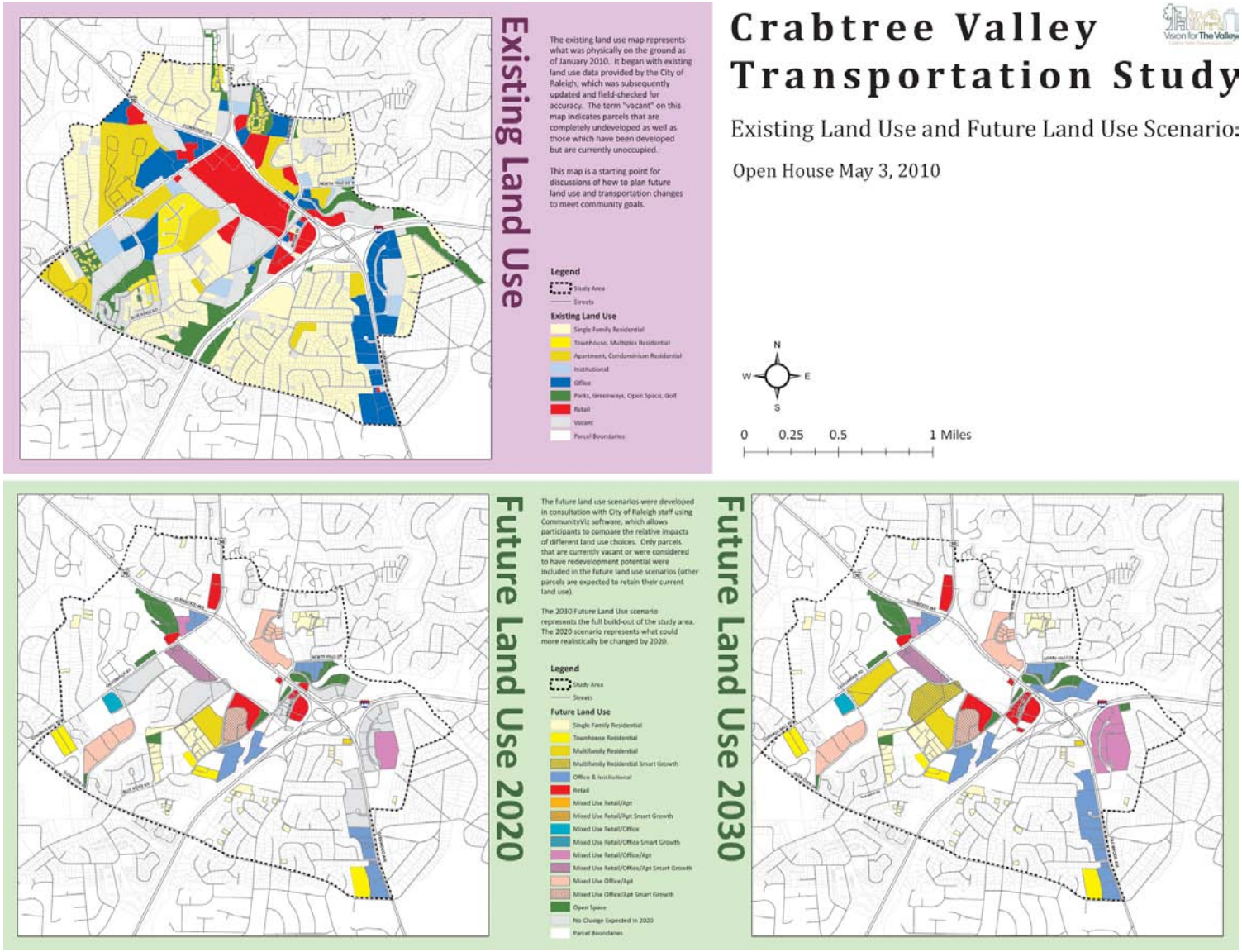

Figure A-1. Land Use Scenarios (Alternative Land Use Scenarios are presented later in this appendix)

While two key NCHRP (National Cooperative Highway Research Program) reports were not available for this effort,[4] many other research studies have been completed that examine the relationships between the built environment and impacts to travel behavior (and, consequently, to energy consumption, human / environmental health, and airborne emissions). Researchers have assessed these effects many ways over the past several decades, with the result being anywhere from negligible to 25% reductions in vehicle miles of travel. The focus on trip reductions, time allotted for research, and leveraging the limited understanding of these complex relationships in the Crabtree Valley Transportation Study narrows the relationships in the land use-transportation paradigm. Each measure reflects one major sub-type of development characteristic that has been shown to have a change impact to trip generation and mode split; additional benefits due to reductions in cold starts, trip lengths/vehicle miles of travel are also attributable to these same measures while exogenous variables like fuel price increases are not accounted for in this study. Some metrics that have been cited in many studies are not relevant to the unique conditions of this study area; for example, steep slopes are not a barrier to pedestrian travel or mode shares in the majority of the study area.

Table A-33. Crabtree Valley Automobile Trip Reduction Measures

Metric Name	Metric Definition
Density	Population / Acre
Diversity of Use	Residential/Retail at 4:1 Ratio Office/Retail at 6:1 Ratio Residential/Office/Retail at 3:3:1 Ratio
Pedestrian Design	Density of sidewalks (linear miles of sidewalk divided by area)
Bicycle Design	Density of greenways and bike facilities (linear miles of facility divided by area)
Transit Design	Density of transit routes (linear miles of transit route divided by area)
Connectivity	Number of street intersecting points divided by linear miles of street

2000 Census Journey-to-Work Dataset

In order to convert the metrics into usable values in a *Scenario360* model, staff closely examined US Census, City of Raleigh, and Capital Area MPO datasets to produce percentage reductions from the standard ITE Trip Generation Rates used for the basic categories of land use (low-, medium-, and high-density residential; office; and retail). Six different new land uses were created from (A) combinations of typical mixing patterns, and (B) those same mixed use development patterns augmented by multi-modal transportation choices. The mixed use trip reduction percentages (internal capture) were estimates based on historical research, while the additional trip reductions attributable to more sidewalks, transit service, and bicycle facilities[5] were calculated through the use of linear regression model where drive to work (alone or in a carpool) share was the dependent variable (y) and the metrics listed above were used as the independent variables (x) for the 262 US Census block groups in Wake County in the year 2000. While dated, this information was the best available for mode share splits at this level of detail. In general, these models work better for walk shares, and much less well for predicting driving shares although the coefficients directions and magnitudes are reasonable and intuitive with the possible exception of greenway density (number of miles of greenway contained within a traffic analysis zone (TAZ) which produced a negative impact on walk trips, for example. Some additional refinements were conducted to eliminate variables that were not contributing to the model (backward stepwise regression) to produce simpler models and further study the effects of each independent variable on the performance of the model and coefficient values.

[4] NCHRP Project 08-51, "Enhancing Internal Trip Capture Estimation for Mixed-Use Developments" and NCHRP Project 08-66, "Trip Generation Rates for Transportation Impact Analyses of Infill Developments"

[5] Connectivity, population density, and bicycle facilities (greenways and bike lanes) were not found to contribute to trip reductions. Note that this assessment might be different if only Raleigh or a subarea of Raleigh was used for the analysis instead of Wake County.

2006 Household Travel Survey Dataset

After the initial analyses conducted with Journey-to-Work data shown above, another analysis was completed using the 2006 household travel behavior survey conducted to calibrate the Triangle Regional Model; the data was provided by the Institute for Transportation Research and Education (ITRE). Approximately 5,000 data points (people travel diaries) were collected to represent the travel behavior of the multi-county Triangle Region; this translates in 10,835 trips in the 493 Raleigh traffic analysis zones. The lowest number of trips recorded for any particular zone is 0; the largest number of trips is 135. It was thought that this dataset might produce better (higher R^2) regression results than the older Journey-to-Work data since all trips, not just work, were represented and the data was more contemporaneous with the land use and transportation network information. However, the results for this assessment did not produce better correlations for any mode (car, walk, bike, public transportation). The best model was for walk trips R^2 (adjusted) was 18.5, and thus is still considered inadequate for predictive purposes on its own. The strongest correlations between the percentage of walk trips were noted for sidewalk density, intersection density, and street density. Table A-2, below, indicates the results of the regression analysis and correlation study between the percentage of walk trips and other variables. Cooler, green colors indicate lower correlation values while hotter, red colors indicate higher degrees of correlation between variables.

Table A-2. Walk Percentage Assessment

Regression Statistics	
Multiple R	0.44221
R Square	0.19555
Adjusted R Square	0.185598
Standard Error	0.097407
Observations	492

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	6	1.118614	0.186436	19.64941	1.427E-20
Residual	485	4.601731	0.009488		
Total	491	5.720345			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	-0.02	0.02	-1.24	0.22	-0.05	0.01	-0.05	0.01
popdens	0.00	0.00	0.18	0.86	0.00	0.00	0.00	0.00
intrsctden	0.00	0.00	2.58	0.01	0.00	0.00	0.00	0.00
transitden	-0.23	0.10	-2.23	0.03	-0.44	-0.03	-0.44	-0.03
streetdens	0.72	0.65	1.11	0.27	-0.56	2.01	-0.56	2.01
swalkdens	1.70	0.30	5.69	0.00	1.11	2.28	1.11	2.28
gwaydens	3.04	1.56	1.95	0.05	-0.02	6.11	-0.02	6.11

Correlation

	walk_p	*popdens*	*intrsctden*	*transitden*	*streetdens*	*swalkdens*	*gwaydens*
walk_p	1						
popdens	0.14	1					
intrsctden	0.30	0.26	1				
transitden	0.16	0.30	0.29	1			
streetdens	0.33	0.28	0.56	0.48	1		
swalkdens	0.40	0.34	0.47	0.59	0.70	1	

Notes
Walk_p = percent of walk trips
Popdens = population density
Intrsctden = density of intersections (at-grade, non-freeway ramp)
Streetdens = density of streets measured by centerline miles
Swalkdens = density of sidewalks measured by total miles
Gwaydens = density of greenways measured by centerline miles

Table A-3 shows the assumed percentage reductions in automobile trips from sites in the Crabtree Valley Transportation Study area based in part on the results of the previous analyses and in part based upon national experiences and studies (internal capture). Table A-3 indicates values that are quite conservative, although traditionally acceptable. Some studies have found much larger effects.

Table A-3. Recommended Trip Reduction Factors by Land Use Action

Mixed Use Type	Internal Capture	Street Density	Sidewalk Density	Transit Density	Combination	Total Trip Reduction
Mixed Use: Retail/Office	**-4%**	*-0.7%*	*-1.8%*	*-1.9%*	**-4.4%**	**-8.4%**
Mixed Use: Retail/Residential	**-5%**	*-0.7%*	*-1.8%*	*-1.9%*	**-4.4%**	**-9.4%**
Mixed Use: Office/Retail/Residential	**-7%**	*-0.7%*	*-1.8%*	*-1.9%*	**-4.4%**	**-11.4%**

For the purposes of alternative scenario development, the following elasticity values are recommended (Table A-4) for various transportation actions.

Table A-4. Trip Reduction Factors by Transportation Action

Action Type within a TAZ *Increase…*	Action Degree *By…*	Action Result *Reduces Car Trips By…*
Sidewalk Density	1 linear mile	0.8%
Surface Street Density	1 centerline mile	5.2%
Greenway Density	1 linear mile	1.1%
Public Transportation Route Density	1 linear fixed route mile	0.1%

In total, approximately 11% reductions were used for new and redeveloped properties inside the study area to account for better land use and transportation networks that would facilitate more non-automotive travel.

The final table on the following page (Table A-5) indicates the regression/correlation results for car trips using the 2006 Household Travel Survey dataset.

Table A-5. Regression and Correlation Results for Auto Trip Percentages by TAZ

Regression Statistics	
Multiple R	0.231446
R Square	0.0535673
Adjusted R Square	0.0418588
Standard Error	0.2311783
Observations	492

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	6	1.467052	0.244509	4.575096	0.00015708
Residual	485	25.92005	0.053443		
Total	491	27.3871			

	Coefficients	*andard Erı*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Ipper 95.0%*
Intercept	0.92	0.04	24.67	0.00	0.85	1.00	0.85	1.00
popdens	0.00	0.00	-1.34	0.18	0.00	0.00	0.00	0.00
intrsctden	0.00	0.00	1.50	0.13	0.00	0.01	0.00	0.01
transitden	0.47	0.25	1.89	0.06	-0.02	0.96	-0.02	0.96
streetdens	-5.21	1.55	-3.35	0.00	-8.26	-2.16	-8.26	-2.16
swalkdens	-0.78	0.71	-1.10	0.27	-2.17	0.61	-2.17	0.61
gwaydens	-1.12	3.71	-0.30	0.76	-8.41	6.16	-8.41	6.16

Correlation

	car_p	*popdens*	*intrsctden*	*transitden*	*streetdens*	*swalkdens*	*gwaydens*
car_p	1						
popdens	-0.10	1					
intrsctden	-0.07	0.26	1				
transitden	-0.04	0.30	0.29	1			
streetdens	-0.20	0.28	0.56	0.48	1		
swalkdens	-0.16	0.34	0.47	0.59	0.70	1	
gwaydens	0.01	-0.08	-0.03	-0.10	-0.12	-0.03	1

Alternative Land Use Scenario Analyses

Analysis #1

In order to provide a comparison against a lower-intensity future development scenario, an alternative to the Proposed 2030 build-out solution was devised in accordance with the current land use plan adopted by the City of Raleigh. While the analyzed scenario considered zoning, known or probable development actions, and compatibility with preconceived ideas of the future of the area, the low-intensity build-out scenario considered only what was likely under the (then) newly adopted land use plan for the study area. The low intensity scenario considered changes to five specific sections of the study area, which are mapped on the following pages. The following table compares the existing land use, proposed future, and low intensity scenarios.

Table A-6. Low Intensity Land Use Scenarios

	Total Trips Produced					
Study Area Section	**Existing Land Use**		**Proposed Future Land Use (3/8/10)**		**"Low Intensity" Future Land Use (6/8/10)**	
	Land Use	Trips	Land Use	Trips	Land Use	Trips
A (West side of Glenwood Ave)	Mostly office, one retail parcel, one vacant parcel, one institutional parcel	5,496	Office & Institutional (assuming redevelopment)	5,058	Same as existing (no redevelopment)	5,496
B (East side of Glenwood Ave @ 440)	Mostly office, one vacant parcel	3,029	Mixed Use Retail/Office/Apt	8,026	Mixed Use Office/Apt	3,233
C (Arrow Drive)	Motels and gas station, single family residential, vacant parcels	4,023	Retail	14,566	Office & Institutional	1,607
D (South side of Blue Ridge Rd)	Single family residential, vacant	30	Office & Institutional	1,414	Townhouse Residential	747
E (North side of Creedmoor Rd)	Office	26	Retail	2,755	Office & Institutional	304
TOTAL		**12,604**		**31,819**		**11,387**

Overall the number of trips in the Low Intensity scenario is slightly below the estimated trips generated by the current land uses on these parcels, and about one third of the trips from the Proposed scenario. The reason for the significant reduction in trips between the two future scenarios is the shift from retail uses to office, institutional and residential uses, all of which have fewer estimated trips per day for the same amount of acreage.

Although there was not a companion traffic simulation or analysis done under the Low Intensity future scenario, the impacts of that scenario may not be as significant as they appear based on trip generation alone. For example, traditional traffic analysis depends on peak period (often the worst hour) assessments. Assuming that 10% of the daily trips occur in a single, worst peak hour – a conservative assumption given the number of retail-related trips that occur in this area – the 20,000 daily trips that separate the two future scenarios become only 2,000 trips in the analysis. These trips are then distributed all across the roadways in the study, with a certain percentage of the trips traveling in one direction down the road and the remaining percentage traveling in the other direction. This has the effect of splitting apart the trips both by roadway and by direction in the traffic analysis. The lower-intensity option also does not facilitate the kind of denser development that supports alternative modes to the private automobile, namely walking, bicycling and the use of public transportation services. The lack of people using these services that would otherwise be likely to use them in a higher-density future scenario, while not

foreseen today as particularly significant except to those persons that lack access to their own car, would nevertheless offset the differences in trip generation by 2% to 10% depending on future conditions of these systems and the energy environment that the nation and the world are in by 2030.

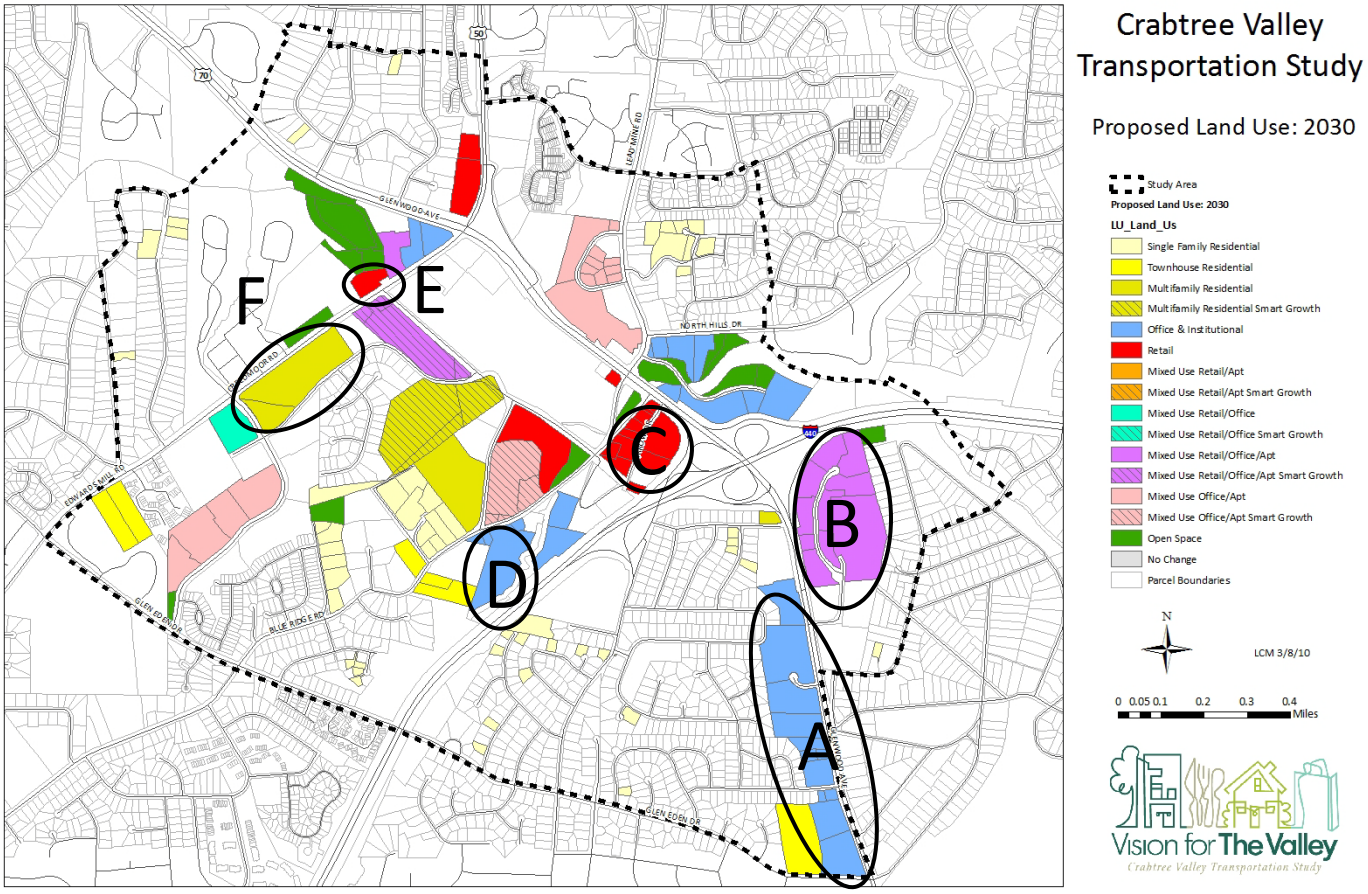

Figure A-2. Proposed Future Land Use Scenario

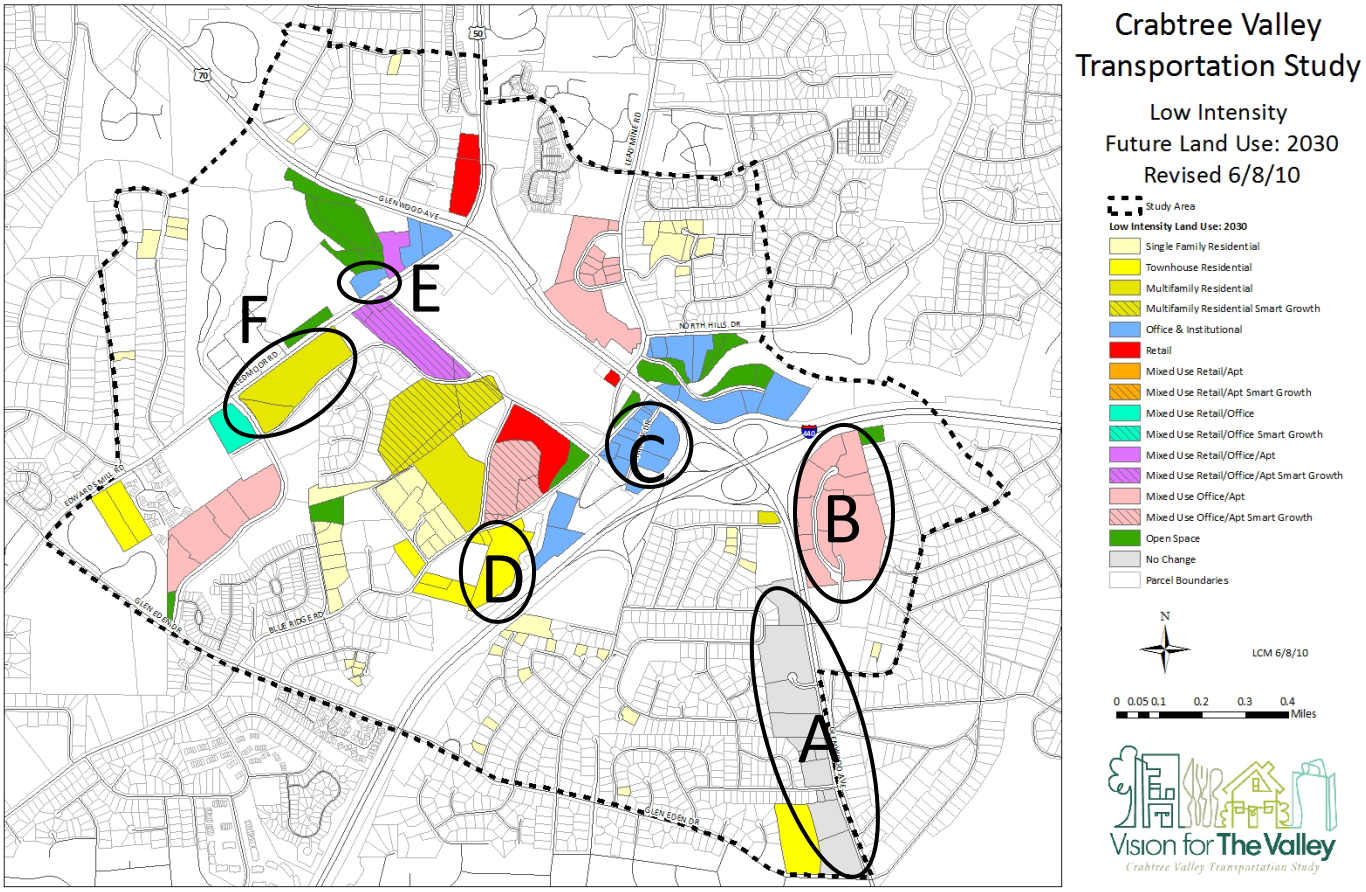

Figure A-3. Low Intensity Future Land Use Scenario

Analysis #2

Two additional changes to the proposed future land use were suggested, marked as areas F and G in the following table and maps.

Table A-7. Alternative Land Use Scenarios Analysis #2

	Total Trips Produced					
Study Area Section	**Existing Land Use**		**Proposed Future Land Use (3/8/10)**		**Revised Future Land Use (9/23/10)**	
	Land Use	Trips	Land Use	Trips	Land Use	Trips
F (South side of Creedmoor Rd)	Apartments, vacant	714	Multi-family Residential	1,047	Mixed Use Office/Apt Smart Growth	1,486
G (East side of Glenwood Ave @ Woman's Club Dr)	Office	311	Mixed Use Retail/Office/Apt	635	Mixed Use Retail/Office Smart Growth	758
TOTAL		**1,025**		**1,682**		**2,244**

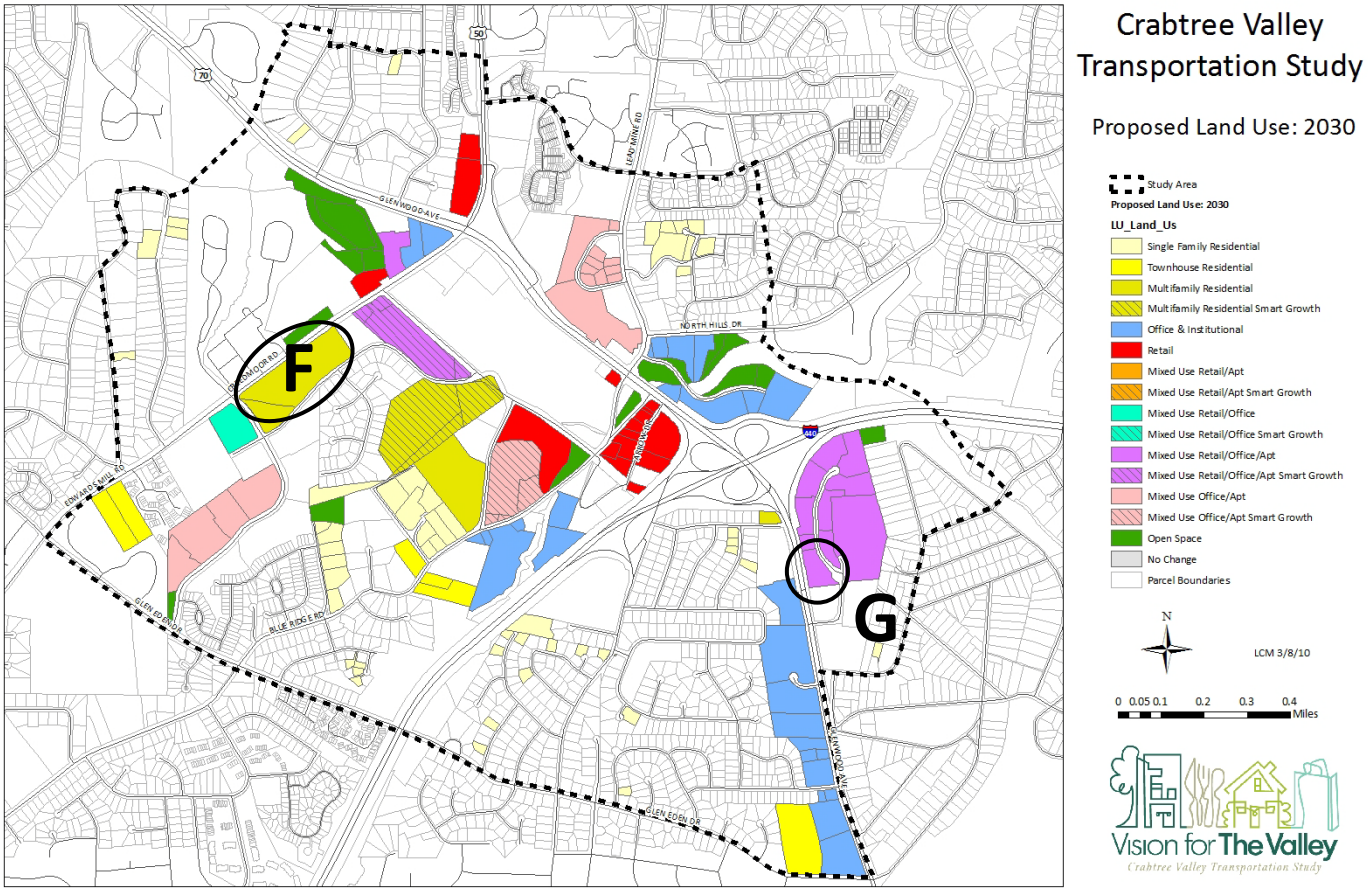

Figure A-4. Proposed Future Land Use Scenario

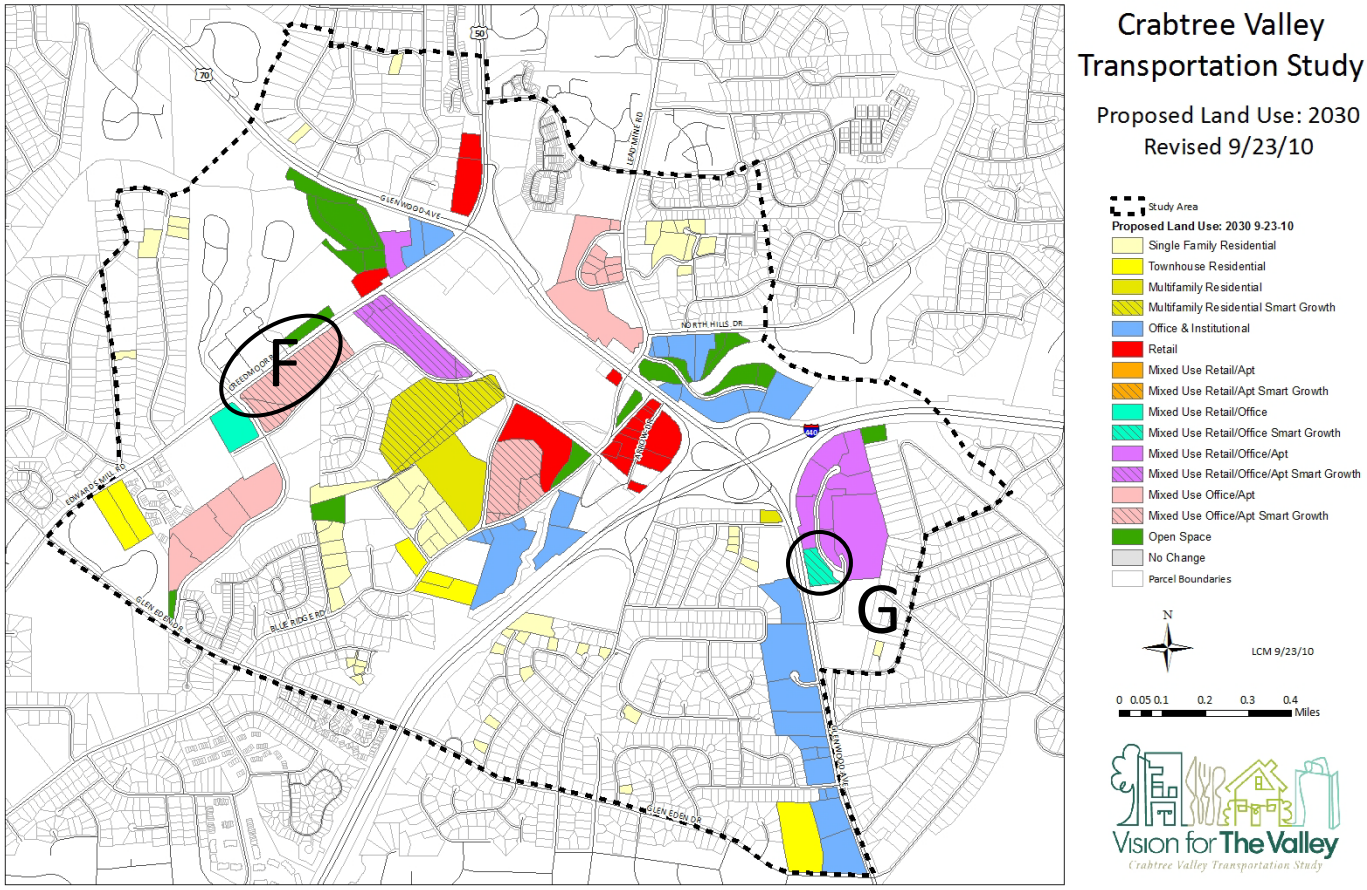

Figure A-5. Revised Future Land Use Scenario 9-23-10