Louisville Southern Indiana Ohio River Bridges

Time-of-Day Travel Demand Model Phase 1

December 28, 2010 | Final

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1.0 Project Overview

This document describes the first phase of the development of an interim time-of-day travel demand model by Wilbur Smith Associates (WSA) for the Louisville-Southern Indiana metropolitan study area. The project contained the first four tasks of the model development process:

- The development of an interim TOD model (Chapter 2);
- The model specification for an updated travel demand model (Chapter 3);
- The development and implementation of a data collection plan (Chapter 4); and
- The update of the model datasets (Chapter 5).

The next three tasks (Phase 2) required in the development of the time-of-day model are the model estimation, model validation and implementation tasks.

For clarification, definitions are given to the three models referenced in this document.

- **Existing KIPDA Model**: This is the basis for the INTERIM TOD Model and LSIORB Regional TOD Model. This model is the current model of record and was used for the long range transportation plan.

- **Interim TOD Model**: This model is being completed as part of Task 1 within the first phase. The model is based on the existing KIPDA model including the same base and forecast year assumptions. The existing model is being enhanced with the addition of period specific capacities and period traffic assignments.

- **LSIORB Regional TOD Model**: Enhanced model based on the existing model structure but enhanced to support the project analysis. The specification for this model and development of the datasets is being completed in Phase 1. The model estimation, scripting and validation are to be completed in Phase 2. It should be noted that the LSIORB Regional TOD Model is a new model, and is not what was used for the Toll Evaluation study recently completed.

2.0 LSIORB Interim Time of Day Model

2.1 Introduction

This document is to describe the Interim Time of Day Model developed by Wilbur Smith Associates using the KIPDA Travel Demand Model (Existing Model). The Interim TOD Model was developed to support short term toll analysis to be completed by December 2010. Future tolling analysis will be completed with the LSIORB Regional TOD Model being developed by Wilbur Smith Associates.

The scope for the development of the Interim TOD Model was defined as follows:

> On a separate path, WSA will be implementing a simple time of day (TOD) structure into the existing KIPDA model.
>
> As part of this task, the model will be revalidated to the existing base year of the model. All demographic and network assumptions will be based on the existing model.

The document provides information on the existing KIPDA model, the development and validation of the Interim TOD Model, and results for 2020 and 2030 using the Interim model.

2.2 Existing KIPDA Model

The intent of the Interim TOD Model is to be built using the same structure and assumptions as used by the existing KIPDA Daily Model. The disaggregation of trips into periods is performed after the reduction of trips for transit in the daily model stream. Prior to developing the Interim TOD Model, a review was completed of the structure, validation results and forecasts produced by the daily model.

2.2.1 Structure

The structure of the existing KIPDA model is described in the next sections by model step.

2.2.1.1 Trip Generation

- The model has three internal trip purposes: HBW, HBO and NHB.
- The three internal purposes use a cross classification production model and regression attraction models.
- The distribution of households into size and auto ownership and structure type categories is input to the model and not automatically generated.
- Attractions are adjusted for special generators.
- External Local traffic disaggregated into two components – work and non-work.
    - EI Work – HBW Attractions
    - EI Other – HBO and NHB Attractions
- NHB Productions are set equal to NHB Attractions.
- NHB utilizes cross-classification in the base year to determine total NHB productions.

- In the forecast years, NHB productions are set equal to NHB attractions after consideration of special generators.

2.2.1.2 Network Skimming

- Terminal Time (in minutes) is calculated using the following formula and added to centroid connectors:
    - 6.00 – FLOOR(Area/10) where Area refers to area type
- Speed and capacity is read into the network via a lookup table that uses facility type, area type and number of lanes.
- Turn Prohibitors and Penalties are included in the network skimming process
- Unique Intra State and Inter State skims are created, both based on free flow time.
- Skims are merged into a composite file and travel times are filtered for interstate and intrastate flows based on the origin-destination combinations.

2.2.1.3 Trip Distribution

- Gravity model is run for internal and external – internal purposes using composite time matrix.
- Friction factors are read from a table using travel time as the impedance.

2.2.1.4 Mode Share

- Vehicle person trips are based on person trips from trip distribution minus transit trips.
- Auto occupancy is applied to vehicle person trips to create vehicle trip table.
- Vehicle trips are sorted into intrastate and interstate trips.

2.2.1.5 Assignment

- Daily assignment is run using interstate and intrastate trip tables.
- Results from assignment including volume, speed, and congested time are written to the geographic highway network.

2.2.1.6 Feedback

- Highway skim is calculated using the congested skims from the assignment process for HBW and EI Work trip purposes. Other trip purposes still use free-flow skims.
- Intrastate and interstate composite time process is repeated with congested times.
- Gravity model is rerun with congested skims. (See comment for first statement above under Feedback.)
- Application of transit trips and auto occupancy as part of PA2OD is repeated on congested person trips.
- Highway assignment is repeated using new trip tables with free flow time in assignment.

2.2.2 Validation

To establish a benchmark of performance for the Interim TOD Model, simple validation statistics were calculated on the output of the 2000 daily model against the count data included in the network. The following statistics were computed:

- VMT Error by Facility Type, Area Type and County
- Percent RMSE by Volume Group
- Volume comparison on the Ohio River Bridges (I-64, I-65 and US 31)

The counts used for the calculating the validation statistics are discussed later in this report. In total, 257 count locations were identified in the 2000 model network.

Table 2-1: Existing Daily Model Validation: VMT Error by Facility Type

Facility	N	DAILY
Freeway	50	8.96
Div Art	13	2.67
UnDiv Art	131	1.83
External	53	-7.21
One Way	9	-12.49
Ramp	1	-3.53
Overall	257	8.81

Table 2-2: Existing Daily Model Validation: VMT Error by Area Type

AREA	N	DAILY
11	2	1.51
12	2	7.20
21	11	0.63
31	37	-23.91
41	101	0.23
43	12	44.60
45	2	174.78
53	7	46.65
55	83	22.85

Table 2-3: Existing Daily Model Validation: VMT Error by County

COUNTY	N	DAILY
Bullitt	31	30.95
Clark	28	-17.89
External	53	-7.21
Floyd	12	-16.64
Jefferson	110	5.92
Oldham	23	36.76

Table 2-4: Existing Daily Model Validation: Percent RMSE by Volume Group

VOL_CLASS	N	DAILY
Overall	263	51.51
<1,000	25	122.46
1,000-2,500	28	89.09
2,500-5,000	28	72.94
5,000-10,000	46	74.56
10,000-25,000	73	48.65
25,000-50,000	48	41.74
50,000+	15	22.74

2.2.3 Bridge Forecasts (Toll Free)

Table 2-5 reports the 2000 count, 2000 volume and 2020 and 2030 forecast produced by the existing KIPDA model on the Ohio River Bridge Crossings. These values are based on the KIPDA network and toll-free assignments. In 2020 the network includes the imbalance of the lanes on the I-65 bridge with 3 southbound and 6 northbound lanes. By 2030, the number of lanes is equal at 6 by direction. For the Interim TOD Model, the number of lanes in 2020 on the I-65 bridge will be set to 6 in each direction.

Table 2-5: Ohio River Bridge Crossing Volumes – Existing Daily Model (Source: KIPDA 09PlanA Results)

Bridges	COUNT	2000	2020	2030
I-64EB	40400	43354	47576	50786
I-64WB	40400	43258	45903	50967
Clark Mem.	19600	17723	16606	15006
I-65 SB	62375	65622	76146	89833
I-65 NB	62375	61000	66802	75111
East End Bridge SB			28617	31954
East End Bridge NB			27327	31488

With the change to the number of lanes on I-65 southbound for 2020, the resulting assigned volumes using the KIPDA existing daily model are shown below in Table 2-6.

Table 2-6: Ohio River Bridge Crossing Volumes – Corrected I-65 Southbound Lanes

Bridges	COUNT	2000	2020
I-64EB	40400	43354	44955
I-64WB	40400	43258	45521
Clark Mem.	19600	17723	14464
I-65 SB	62375	65622	80873
I-65 NB	62375	61000	66698
East End Bridge SB			28373
East End Bridge NB			27517

The I-65 SB volumes increase because of the reduced congestion with the corrected lanes. The forecast volume decreases on US 31 due to the increased capacity on I-65.

2.3 Interim Time of Day Model

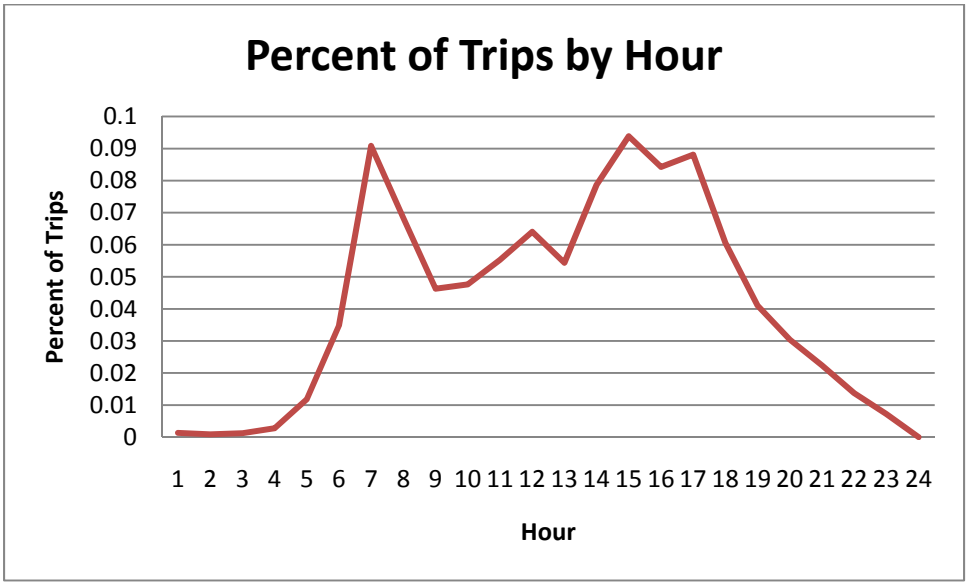
The Interim TOD Model was developed from the existing KIPDA model. The daily trip tables developed through the feedback process described in the previous section are disaggregated into the period specific trip tables for assignment. Work on the development of the model focused on estimating the time of day factors (diurnals) by period and purpose, and the TOD network attributes including capacity.

2.3.1 Time of Day Factors

The diurnal factors used for the Interim Time of Day Model were developed using the 2000 KIPDA Household Travel Survey and the 2007 hourly count data. The counts at the model area cordon were used to disaggregate the external through matrix into the respective periods as well as the external-internal trips. The household survey was used for the internal trip purposes including HBW, HBO, and NHB.

The first step in the defining the diurnal factors, was to develop the time of day periods to be used in the Interim TOD Model. Figure 2-1 displays the percent of trips (HBW, HBO and NHB) departing by hour based on the 2000 KIPDA Household Travel Survey. The morning and evening peaks are clearly visible in the graph. Of note is the significant mid day period and length of the pm peak over several hours.

Figure 2-1: Percent of Trips by Departure Hour (Source: 2000 KIPDA Household Survey)



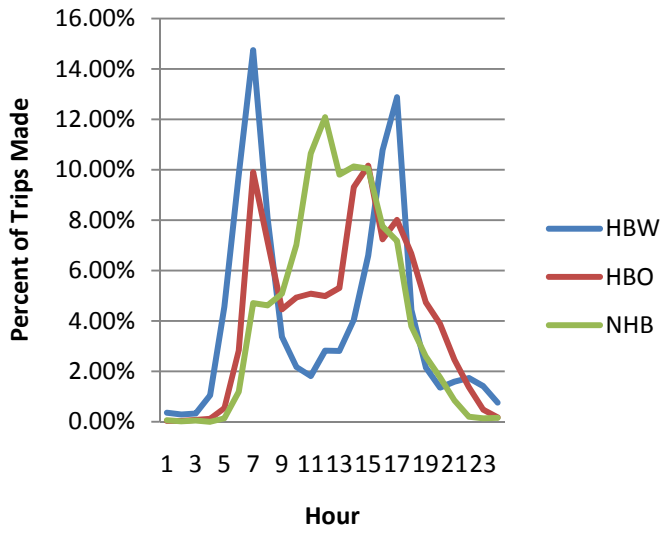
In defining periods for a Time of Day Model, the standard approach is to define a period to be at least one hour in length. In the case of the Interim TOD Model, the periods were defined based on the following criteria:

- Capturing majority of directional commuting trips
- Period allowed for all trips to be completed (period longer than longest trip)
- Capturing activities of trip purposes

Figure 2.2 shows the distribution of trips by trip purpose.

From the graph, the prominence of work trips being made in the am peak and pm peak periods becomes clear. As well, the high activity of NHB and HBO activity being made between the peak periods becomes clear.

Figure 2-2: Percent of Trips by Departure Hour by Purpose (Source: 2000 KIPDA Household Survey)



Hour	HBW	HBO	NHB
0	0.36%	0.03%	0.06%
1	0.29%	0.03%	0.02%
2	0.33%	0.07%	0.05%
3	1.05%	0.12%	0.00%
4	4.57%	0.54%	0.14%
5	9.80%	2.84%	1.19%
6	14.75%	9.90%	4.71%
7	8.10%	7.16%	4.62%
8	3.37%	4.46%	5.08%
9	2.17%	4.93%	7.02%
10	1.81%	5.08%	10.64%
11	2.83%	4.99%	12.09%
12	2.81%	5.31%	9.81%
13	4.04%	9.31%	10.13%
14	6.59%	10.16%	10.04%
15	10.78%	7.24%	7.75%
16	12.88%	8.01%	7.17%
17	4.46%	6.67%	3.78%
18	2.16%	4.74%	2.59%
19	1.36%	3.89%	1.77%
20	1.59%	2.46%	0.85%
21	1.74%	1.38%	0.20%
22	1.41%	0.48%	0.14%
23	0.76%	0.18%	0.15%

Based on a review of the information presented above, the following periods were identified for the Interim TOD Model:

- AM Period: 6am to 9am (3 Hours)
- Mid – Day: 9am to 3pm (6 Hours)
- PM Period: 3pm to 6pm (3 Hours)
- Overnight: 6pm to 6am (12 Hours)

Based on these periods, the directionality of the trips were defined using the household travel survey data. For home based trips, the orientation of trips from home to attraction and attraction to home were defined. This creates the directional movement of trips observed in reality in the model. Table 2-7 provides the distribution by direction by purpose. When reviewing the information, the direction of travel from home to work (DEP) for HBW appears in the AM Period with very low percentages of trips in the work to home (RTN) direction. In the PM period, this pattern is reversed as expected. The AM and PM periods are highlighted in the table.

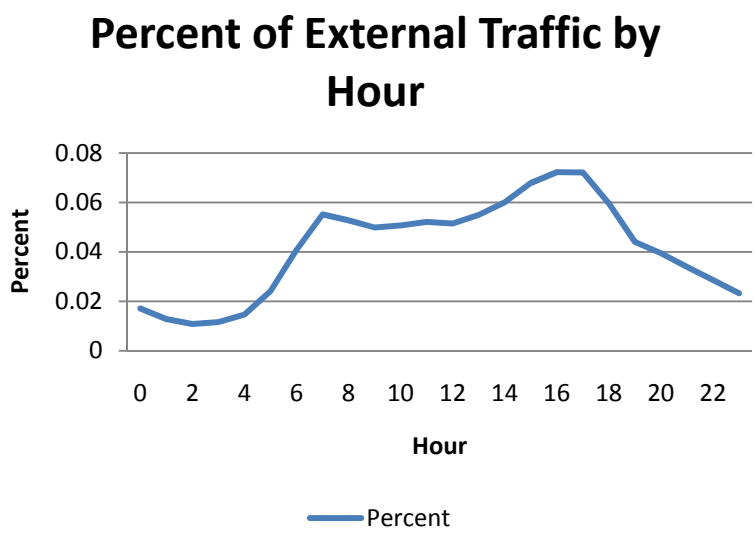
Table 2-7: Departure and Return Percentages by Hour (Source: 2000 KIPDA Household Survey)

HOUR	DEP_HBW	RTN_HBW	DEP_HBO	RTN_HBO	DEP_NHB	RTN_NHB	DEP_EXT	RTN_EXT
0	0.00	0.36	0.00	0.03	0.03	0.03	0.86	0.86
1	0.16	0.13	0.02	0.01	0.01	0.01	0.64	0.64
2	0.31	0.02	0.03	0.05	0.02	0.02	0.54	0.54
3	0.91	0.14	0.11	0.01	0.00	0.00	0.58	0.58
4	4.31	0.25	0.51	0.03	0.07	0.07	0.73	0.73
5	9.33	0.47	2.70	0.14	0.60	0.60	1.20	1.20
6	14.22	0.53	9.09	0.81	2.36	2.36	2.04	2.04
7	7.55	0.54	6.29	0.87	2.31	2.31	2.76	2.76
8	2.90	0.47	3.41	1.05	2.54	2.54	2.64	2.64
9	1.50	0.67	3.46	1.47	3.51	3.51	2.49	2.49
10	1.09	0.72	2.68	2.40	5.32	5.32	2.53	2.53
11	1.25	1.58	2.14	2.84	6.04	6.04	2.61	2.61
12	1.56	1.25	2.41	2.91	4.90	4.90	2.57	2.57
13	1.74	2.30	2.61	6.70	5.07	5.07	2.75	2.75
14	1.29	5.31	2.34	7.83	5.02	5.02	3.00	3.00
15	1.34	9.44	2.28	4.97	3.87	3.87	3.39	3.39
16	0.76	12.12	3.12	4.89	3.59	3.59	3.61	3.61
17	0.56	3.89	3.35	3.32	1.89	1.89	3.61	3.61
18	0.29	1.87	1.66	3.09	1.29	1.29	2.98	2.98
19	0.27	1.09	0.60	3.28	0.88	0.88	2.20	2.20
20	0.49	1.11	0.32	2.14	0.43	0.43	1.97	1.97
21	0.56	1.18	0.17	1.21	0.10	0.10	1.70	1.70
22	0.43	0.98	0.06	0.42	0.07	0.07	1.43	1.43
23	0.07	0.69	0.00	0.18	0.08	0.08	1.16	1.16

The distribution of external traffic (EXT) is based on a review of external count data on the Kentucky external stations.

Counts were identified at the major entry points to the KIPDA area including the interstates and US routes. The traffic at all stations was aggregated by hour and a resulting distribution was developed and is shown in Figure 2-3. An even distribution of traffic by direction was assumed resulting in an equal departure and return rate applied in Table 2-7.

Figure 2-3: External Count Distribution (Source: 2007 – 2009 KYTC Count Data)



HOUR	Total Volume	Percent
0	4745	1.7%
1	3551	1.3%
2	3004	1.1%
3	3216	1.2%
4	4051	1.5%
5	6665	2.4%
6	11290	4.1%
7	15279	5.5%
8	14614	5.3%
9	13802	5.0%
10	14035	5.1%
11	14432	5.2%
12	14258	5.1%
13	15225	5.5%
14	16631	6.0%
15	18779	6.8%
16	20003	7.2%
17	19970	7.2%
18	16501	6.0%
19	12197	4.4%
20	10917	3.9%
21	9394	3.4%
22	7919	2.9%
23	6434	2.3%

2.3.2 Capacity

The second element of the Interim TOD Model was the development of the capacities for each period. Following is a discussion of the origin of the KIPDA existing daily capacities and how the period capacities were derived.

2.3.2.1 Daily Capacity from Existing Model

The existing model being daily in nature uses a daily assignment and associated daily capacity. To maintain consistency with the existing model, it was decided that the period capacities would be based on the same data.

The source of the daily capacities in the existing model is the *2009 Florida Quality / Level of Service Handbook*.

KIPDA staff indicated they use the values for urbanized areas (Table 1, Chapter 5). The daily per lane capacities from the existing model are shown in Table 2-8. Blank cells indicate facility type and area type combinations not used in the 2000 model.

Table 2-8: Existing KIPDA Daily Capacity per Lane (Source; 2000 KIPDA Model 09PlanA)

Facility Type (FACT)			AREA TYPE									
			Urbanized Area Primary Central Business District (Louisville CBD)	Other Urbanized Area Central Business Districts (e.g. Jeffersonville CBD)	All Central Business District Fringe Areas	Other Outlying Business/Commercial Districts (e.g. Shopping Centers)	Other Developed Areas in the Urbanized Area (e.g. Residential Areas)	Transitioning Areas (between Area Type 41 and Area Type 45)	Undeveloped Portions of Urbanized Area	Significantly Developed Areas outside of the Urbanized Area	Small Developed Areas outside of the Urbanized Area	Undeveloped Areas outside of the Urbanized Area
			11	12	21	31	41	43	45	51	53	55
Freeways		11	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
High-Occupancy Vehicle Lanes		12	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Collector - Distributor Roads		17	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Div Arterial	Divided Arterial with a signal density < 0.5 signals/mile and a speed limit of 55 miles per hour	21	8500	8500	8500	8500	8500	8500	8500	8500	8500	8500
Div Arterial	Divided Arterial with a signal density < 0.5 signals/mile and a speed limit of 45 miles per hour	22	8500	8500	8500	8500	8500	8500	8500	8500	8500	8500
Div Arterial	Divided Arterial with a signal density >= 0.5 signals/mile and < 2.5 signals/mile	23	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500
Div Arterial	Divided Arterial with a signal density >= 2.5 signals/mile and <= 4.5 signals/mile	24	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500
Div Arterial	Divided Arterial with a signal density > 4.5 signals/mile	25	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500
UnDiv Arterial	Undivided Arterial with turning bays	31	6000	6000	6000	6000	7000	7000	7000	7000	7000	7000
UnDiv Arterial	Undivided Arterial without turning bays	35	5000	5000	5000	5000	6000	6000	6000	6000	6000	6000
UnDiv Arterial	Divided Collectors and Local Roads	41	5500	5500	5500	6000	6000	6000	6000	6000	6000	6000
UnDiv Arterial	Undivided Collectors and Local Roads	45	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500
UnDiv Arterial	Side streets used for bus routes	49	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
C C	Basic Centroid Connector	51	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000
C C	External Station Connector	52										100000
One Way	One-Way Street with a signal density < 0.5 signals/mile	61	7000	7000	7000	7000	7000	7000	7000			
One Way	One-Way Street with a signal density >= 0.5 signals/mile and < 2.5 signals/mile	62	7000	7000	7000	7000	7000	7000	7000			
One Way	One-Way Street with a signal density >= 2.5 signals/mile and <= 4.5 signals/mile	63	5000	5000	5000	5000	5000	5000	5000			

Facility Type (FACT)			AREA TYPE									
			Urbanized Area Primary Central Business District (Louisville CBD)	Other Urbanized Area Central Business Districts (e.g. Jeffersonville CBD)	All Central Business District Fringe Areas	Other Outlying Business/Commercial Districts (e.g. Shopping Centers)	Other Developed Areas in the Urbanized Area (e.g. Residential Areas)	Transitioning Areas (between Area Type 41 and Area Type 45)	Undeveloped Portions of Urbanized Area	Significantly Developed Areas outside of the Urbanized Area	Small Developed Areas outside of the Urbanized Area	Undeveloped Areas outside of the Urbanized Area
			11	12	21	31	41	43	45	51	53	55
	One-Way Street with a signal density > 4.5 signals/mile	64	5000	5000	5000	5000	5000	5000	5000			
Frontage	Frontage Road with a signal density < 0.5 signals/mile	65	7000	7000	7000	7000	7000	7000	7000			
Frontage	Frontage Road with a signal density >= 0.5 signals/mile and < 2.5 signals/mile	66	7000	7000	7000	7000	7000	7000	7000			
Frontage	Frontage Road with a signal density >= 2.5 signals/mile and <= 4.5 signals/mile	67	5000	5000	5000	5000	5000	5000	5000			
Frontage	Frontage Road with a signal density > 4.5 signals/mile	68	5000	5000	5000	5000	5000	5000	5000			
Ramps	High Speed (Generally straight) Ramp from freeway-type facility to surface street and vice versa	71	14000	14000	14000	14000	14000	14000	14000	14000	14000	14000
Ramps	Low Speed (Noticeably curved) Ramp from freeway-type facility to surface street and vice versa	72	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000
Ramps	High Speed (Generally straight) Ramp between freeway-type facility and another freeway-type facility	73	14000	14000	14000	14000	14000	14000	14000	14000	14000	14000
Ramps	Low Speed (Noticeably curved) Ramp between freeway-type facility and another freeway-type facility	74	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000

2.3.2.2 Period Capacity

KIPDA assumes a 10% factor to convert the daily capacities to a peak period. The 10% is considered high and is being considered in the development of the new KIPDA model. Based on this assumption, the Interim TOD Model period capacities are based on peak hour capacities that are 10% of the daily capacities. To define a period capacity, WSA completed extensive research on the state of the practice in period capacity in several models (Table 2-9).

Table 2-9: State of the Practice – Period Capacities

Model	Spreading	Total Peak Hours (am+pm)	Source
Metrolina	equal	6	Metrolina Model User's Manual, December 2007
Genesee County	equal	6	Genese County Urban TDM Improvements: Model Development and Validation Report, May 2009
Fresno County	equal	6	Fresno County Travel Demand Model 2003 Base, March 2010
H-GAC	equal	6	H-GAC Model Validation and Documentation Report, February 2001
Bannock	equal	2	Travel Demand Model 2006 Update: Travel Model Run Procedures for FY2007, February 2007
Rapid City	equal	2	Rapid City TDM Documentation and User's Guide, March 2004
Triangle Region	equal	4	Model Files
Asheville, NC	equal	2	NCHRP Report 365, Case Study, 1998
Douglas County	equal	2	Douglas County/Carson City Travel Demand Model: Final Report, May 2007
Charleston	equal	6	Model Files
CAMPO	equal	4	Model Files
Nashville	equal	4	Model Files
FSUTMS	n/a	0	FSUTMS-Cube Framework Phase 1: Default Model Parameters, Final Report, October 2006
Ohio	Varied	n/a	Travel Demand Forecasting Manual 1: Traffic Assignment Procedures, August 2001
LCATS	Varied	3	Travel Demand Forecasting Manual 1: Traffic Assignment Procedures, August 2001
Baltimore TDM	equal	3	BALTIMORE REGION TRAVEL DEMAND MODEL, VERSION 3.3, Performance Check & Analysis for 2005, December 2007
Metropolitan Washington	equal	3	Summary of the State of the Practice and State of the Art of Modeling Peak Spreading, November 2007
Other	n/a	n/a	Time of Day Modeling Procedures Report, TMIP

The result of the review indicated that standard practice is to multiply the hourly capacity times the number of hours. This assumes a flat distribution of traffic across the period.

Methodologies were considered that assumed a spreading technique resulting in a lower capacity. The downside to an approach of this type is the lack of data in forecasting what the factors should be in the future.

For this reason, an equal spreading methodology was assumed. The resulting period capacities are calculated as follows:

- AM Peak Period = (Daily Capacity / 10) * 3
- Mid Day Period = (Daily Capacity / 10) * 6
- PM Peak Period = (Daily Capacity / 10) * 3
- Over Night = Daily Capacity

2.3.3 Tolling

An important consideration in the design of the Interim TOD Model was the approach used for the analysis of the toll alternatives for the bridges. It was decided that a consistent methodology as was used in the daily model used by the toll and finance consultant would be assumed for the Interim TOD Model. In application, the toll is added to the travel times as a penalty for traversing specific links in the network. The toll cost is converted to a time using a value of time factor. The penalty value is added using the turn prohibits file. The resulting travel time is considered in the trip distribution phase of the model as well as in the path choice in traffic assignment. By including the toll time as a penalty in trip distribution, the toll has the impact of suppressing trip making between zone pairs that require the use of a toll link.

2.4 Validation of Interim Time of Day Model

As outlined in the scope of the Interim TOD Model, validation would be based on the following specifications:

- Aggregated period flows making for a 24 hour validation
- Counts used for the validation of the existing model will be used
- Validation will be based on the same measures as used by KIPDA for the original validation of the daily model

Validation was based on achieving similar results as those observed by the daily model using the same count data. Given the emphasis on the river crossings, the validation was focused on the three existing river crossings.

2.4.1 Validation Adjustments

Because of the nature of the Interim TOD Model being based on the existing daily model, limited validation adjustments were possible. WSA focused its effort on the following areas:

- Coefficients to the volume delay functions
- Assignment iterations and convergence
- Link penalty on the US 31 bridge

The validation effort included several runs, but is documented in seven runs where the above areas were varied and tested. The runs are summarized in the Table 2-10.

In the table "DAILY" refers to the settings used in the existing daily model. Run1 through Run7 document the changes tested as part of the validation process.

Table 2-10: Summary of Validation Runs

	DAILY	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
VDF	BPR	HCM	BPR	BPR	HCM	BPR	HCM 2	HCM 2
Iterations	100	100	100	100	100	100	100	100
Conv. Criteria	0.01	0	0	0.01	0	0	0	0.01
US 31	1.5	1.5	1.5	1.5	0	0	0	0

The adjustments tested in each validation varied the parameters as shown in the Table. The specifics of the adjustments are discussed below.

- VDF: changes the volume delay parameters
- Iterations: Number of assignment iterations
- Convergence Criteria: Convergence criteria used in the assignments
- US 31: Value of the time penalty imposed on US 31

2.4.1.1 Volume Delay Function Parameters

The existing daily model uses the typical Bureau of Public Roads (BPR) volume delay function assuming an alpha value of 0.15 and Beta of 4.0 on all links in the network. Part of the Interim TOD Model was to consider using different coefficients for the volume delay function that reflect the difference in operations of the various facility types. WSA utilized the Highway Capacity Manual to develop a series of parameters for freeways and arterials (Exhibit C30-1 and C30-2).

Table 2-11 displays the assumption made on the Arterial Class as used by HCM, and the resulting Alpha (A) and Beta (B) parameters used in the Interim TOD Model assignments.

Table 2-11: Interim TOD Model Volume Delay Parameters

Facility Type			Arterial Class	A	B
Freeways		11		0.25	9
High-Occupancy Vehicle Lanes		12		0.25	9
Collector - Distributor Roads		17		0.25	9
Div Arterial	Divided Arterial with a signal density < 0.5 signals/mile and a speed limit of 55 miles per hour	21	Class I	0.34	4
	Divided Arterial with a signal density < 0.5 signals/mile and a speed limit of 45 miles per hour	22	Class I	0.34	4
	Divided Arterial with a signal density >= 0.5 signals/mile and < 2.5 signals/mile	23	Class I	0.75	5
	Divided Arterial with a signal density >= 2.5 signals/mile and <= 4.5 signals/mile	24	Class I	1.16	6
	Divided Arterial with a signal density > 4.5 signals/mile	25	Class I	1.16	6

UnDiv Arterial	Undivided Arterial with turning bays	31	Class II	0.7	5
	Undivided Arterial without turning bays	35	Class II	0.7	5
	Divided Collectors and Local Roads	41	Class II	0.7	5
	Undivided Collectors and Local Roads	45	Class II	0.7	5
	Side streets used for bus routes	49	Class II	0.7	5
CC	Basic Centroid Connector	51		0.15	4
External	External Station Connector	52		0.15	4
One Way	One-Way Street with a signal density < 0.5 signals/mile	61	Class II	0.38	5
	One-Way Street with a signal density >= 0.5 signals/mile and < 2.5 signals/mile	62	Class II	0.7	5
	One-Way Street with a signal density >= 2.5 signals/mile and <= 4.5 signals/mile	63	Class II	1	5
	One-Way Street with a signal density > 4.5 signals/mile	64	Class II	1	5
Frontage	Frontage Road with a signal density < 0.5 signals/mile	65	Class I	0.34	4
	Frontage Road with a signal density >= 0.5 signals/mile and < 2.5 signals/mile	66	Class I	0.74	5
	Frontage Road with a signal density >= 2.5 signals/mile and <= 4.5 signals/mile	67	Class I	0.74	5
	Frontage Road with a signal density > 4.5 signals/mile	68	Class I	1.16	6
Ramps	High Speed (Generally straight) Ramp from freeway-type facility to surface street and vice versa	71		0.1	10
	Low Speed (Noticeably curved) Ramp from freeway-type facility to surface street and vice versa	72		0.1	10
	High Speed (Generally straight) Ramp between freeway-type facility and another freeway-type facility	73		0.1	10
	Low Speed (Noticeably curved) Ramp between freeway-type facility and another freeway-type facility	74		0.1	10

The HCM volume delay function parameters resulted in improved assignment performance as compared to the BPR VDF parameters. This assessment is based on improved validation results and comparison of the volumes on the bridges.

2.4.1.2 Assignment Convergence

In reviewing the existing model, it was found that the daily assignment is set to a maximum of 100 iterations, but defaults to convergence criteria of 0.01. This results in the assignment converging very quickly. In the 2000 daily model, the assignment reaches the 0.01 criteria in less than 10 iterations. Because of the increasing congestion as part of the Time of Day structure, testing a maximum of 100 iterations using convergence criteria of 0.0 was tested.

The assignments with more strict criteria resulted in an increase in the VMT assigned to the freeway system causing more error in the validation results as compared to the daily assignment.

2.4.1.3 US 31 Bridge Penalty

The final variable considered as part of the validation process was the time penalty added to the US 31, Clark Memorial Bridge. In the daily model, a 1.5 minute penalty is added to the crossing time. This penalty was added to improve the loadings on the I-65 bridge that parallels US 31.

During the validation process, removing the penalty was tested and resulted in significant improvement in the assigned volumes. With the penalty in place, the US31 bridge was under loading indicating the peak congestion was causing trips to use I-65 instead. By removing the penalty, the time paths improved.

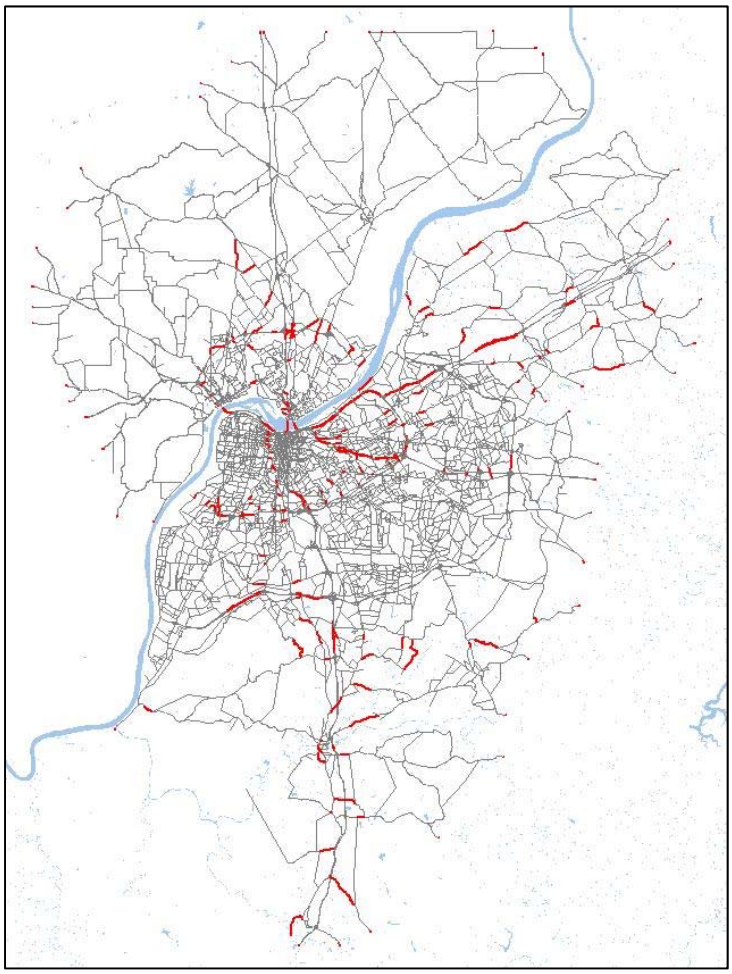
2.4.2 ADT Validation Results

The validation of the Interim TOD Model is based on the available 2000 count data that was provided in the network. The location of the links with counts is provided in Figure 2-4. In total, 263 count locations were used in the validation.

Prior to the validation effort, a review of the count data was completed. It was found that several of the counts in the 2000 network were not properly coded. Corrections that were made included:

- Creation of a Total Count field which was the sum of the AB_COUNT and BA_COUNT.
- Population of the BA_COUNT based on ½ of the AB_COUNT and replacing the AB_COUNT value. Most of the two count locations had counts coded in the AB_COUNT field only and based on a review of the data, they were two way volumes.
- Population of directional counts on directionally coded facilities. Example was on I-65 north of I-264 where the southbound mainlane was not populated with the value from the northbound mainlane. Value on northbound was confirmed to be ½ of ADT.

Figure 2-4: 2000 Count Locations



Using the count information, a GISDK macro was developed by WSA to easily compute validation statistics comparing the assigned volume to the observed counts. In the following series of tables, the results of the 7 validation runs are compared to the DAILY assignment validation. The statistics tested included:

- VMT Error by Facility Type Groups (Table 2-12)
- VMT Error by Area Type (Table 2-13)
- VMT Error by County (Table 2-14)

Percent RMSE by Volume Group and Overall (Table 2-15)

- Volume Comparison on Ohio River Crossings (Table 2-16)

The results indicate that the best performance of the Interim Model as compared to the validation statistics for the daily model was achieved with Run 7. The results from Run 7 are highlighted in the tables.

Table 2-12: VMT Error by Facility Type

Facility	N	DAILY	Run1	Run2	Run3	Run4	Run5	Run6	Run7
Freeway	50	8.96	16.57	12.65	12.21	16.27	12.22	16.24	8.96
Div Art	13	2.67	-4.39	4.23	4.56	-4.37	4.23	-4.16	2.72
UnDiv Art	131	1.83	-5.23	-3.64	-2.77	-4.68	-2.82	-4.73	1.39
External	53	-7.21	-7.21	-7.21	-7.21	-7.21	-7.21	-7.21	-7.21
One Way	9	-12.49	-18.30	-17.07	-17.32	-15.75	-13.45	-15.33	-10.91
Ramp	1	-3.53	3.37	1.86	3.38	3.42	1.92	3.29	-3.33
Overall	257	8.81	13.17	10.74	10.56	13.21	10.80	13.20	8.98

Table 2-13: VMT Error by Area Type

AREA	N	DAILY	Run1	Run2	Run3	Run4	Run5	Run6	Run7
11	2	1.51	10.03	13.33	14.30	4.04	4.16	4.06	-1.96
12	2	7.20	2.08	-2.97	-3.95	0.88	-4.29	0.86	5.98
21	11	0.63	-0.39	-7.53	-8.77	-1.37	-8.66	-1.46	0.39
31	37	-23.91	-19.49	-19.40	-19.86	-18.18	-17.52	-18.22	-22.91
41	101	0.23	3.36	2.34	2.46	3.35	2.34	3.32	0.29
43	12	44.60	54.25	48.38	47.76	54.27	48.37	54.32	45.24
45	2	174.78	104.70	99.68	98.92	105.09	99.75	105.09	173.60
53	7	46.65	47.02	49.19	49.66	47.03	49.19	47.03	46.28
55	83	22.85	26.31	21.40	21.36	26.27	21.39	26.27	22.50

Table 2-14: VMT Error by County

COUNTY	N	DAILY	Run1	Run2	Run3	Run4	Run5	Run6	Run7
Bullitt	31	30.95	33.46	32.29	32.35	33.43	32.30	33.45	30.8941
Clark	28	-17.89	-15.53	-13.65	-13.31	-15.89	-14.23	-15.91	-18.4847
External	53	-7.21	-7.21	-7.21	-7.21	-7.21	-7.21	-7.21	-7.20513
Floyd	12	-16.64	-17.72	-18.16	-17.33	-17.68	-17.75	-17.75	-16.9303
Jefferson	110	5.92	11.05	8.16	7.83	11.14	8.29	11.13	6.270009
Oldham	23	36.76	39.54	35.48	35.65	39.52	35.47	39.51	36.41023

Table 2-15: Percent RMSE by Volume Group

VOL_CLASS	N	DAILY	Run1	Run2	Run3	Run4	Run5	Run6	Run7
Overall	263	51.51	53.87	57.98	58.72	53.58	57.58	53.57	51.54
<1,000	25	122.46	121.37	127.32	125.51	122.33	127.45	122.26	122.50
1,000-2,500	28	89.09	85.21	102.54	102.69	88.54	105.08	88.49	89.05
2,500-5,000	28	72.94	77.42	64.79	70.83	76.48	63.90	76.43	73.29
5,000-10,000	46	74.56	75.44	75.16	74.07	75.59	75.73	71.83	73.78
10,000-25,000	73	48.65	39.62	46.64	45.79	39.45	46.31	40.65	48.63
25,000-50,000	48	41.74	43.65	46.68	41.42	43.64	46.67	43.68	41.88
50,000+	15	22.74	30.64	33.72	42.81	30.28	33.14	30.25	22.56

Table 2-16: Volume Comparison on River Crossings

Bridges	COUNT	DAILY	RUN1	RUN2	RUN3	RUN4	RUN5	RUN 6	Run7
I-64EB	40400	43354	41421	39598	39164	40533	38593	40527	40282
I-64WB	40400	43258	41042	38765	38407	40999	38746	40992	40641
Clark Mem.	19600	17723	11258	11253	10842	19864	23908	19851	19908
I-65 SB	62375	65622	72068	75855	76332	64560	64422	64570	64877
I-65 NB	62375	61000	65175	65492	66219	65235	65521	62521	65481

2.4.3 Reasonableness Comparisons

In addition to the ADT validation it is important to test the reasonableness of the Time of Day model results. Two areas to evaluate were the values of the trip percentages by period and a comparison of period model flows to available period specific traffic data. Both comparisons are recommended by the recently released *Travel Model Validation and Reasonability Checking Manual Second Edition* for Time of Day models.

2.4.3.1 TOD Factors

The following figure is from the Validation Manual and provides data regarding the percent of trips made by purpose for the am and pm peak periods for 10 regions.

Figure 2-5: Time of Day Percentages (Source: TMIP Model Validation Guide, Second Edition)

Table 8.1 Time-of-Day Percentages for Urban Areas of Approximately 1 Million in Population

	HBW		HBNW		NHB		All Trips	
	7-9 a.m.	3-6 p.m.	7-9 a.m.	3-6 p.m.	7-9 a.m.	3-6 p.m.	7-9 a.m.	3-6 p.m.
Austin	32.3%	20.8%	12.5%	23.8%	6.9%	24.6%	13.6%	23.7%
Buffalo	23.7%	26.7%	9.3%	23.6%	5.9%	23.6%	9.7%	23.8%
Greensboro	30.3%	24.0%	12.2%	25.6%	8.1%	26.7%	12.7%	25.8%
Jacksonville	29.6%	24.7%	10.4%	24.4%	9.1%	27.1%	11.6%	25.3%
Hartford	26.0%	29.5%	9.2%	25.3%	7.2%	20.5%	10.4%	24.3%
Memphis	35.0%	18.2%	13.6%	25.6%	6.9%	27.2%	13.5%	25.4%
Nashville	32.7%	23.8%	10.1%	24.9%	7.5%	24.7%	10.4%	24.7%
Providence	28.9%	33.7%	11.8%	24.9%	7.9%	16.3%	11.8%	22.4%
Raleigh	32.4%	26.3%	12.0%	26.5%	8.0%	19.1%	12.2%	24.0%
Average	**30.1%**	**25.3%**	**11.2%**	**25.0%**	**7.5%**	**23.3%**	**11.8%**	**24.4%**

Source: 2001 National Household Travel Survey.

The period definition for the Interim Model does differ by including an additional hour in the AM period. In comparing the average values from Figure 2-5, to the information from the KIPDA Household Survey, HBO and NHB percent of trips in the PM period are very consistent. The HBW trips are higher as compared to the average, but are still within the range of values presented. When factoring for the shorter period in the Interim TOD Model, the AM comparison is very close.

Table 2-17: Interim TOD Model Percent of Trips (Source: 2000 KIPDA Household Survey)

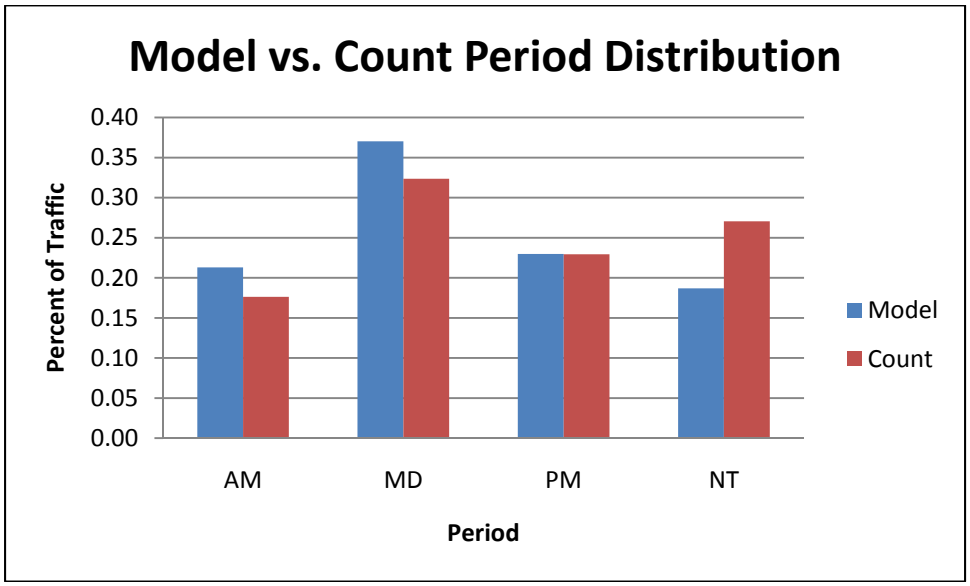
Period	HBW	HBO	NHB
Overnight	20.07%	20.60%	9.75%
AM (6 - 9)	32.64%	19.90%	10.52%
Mid (9 - 3)	17.03%	34.09%	54.77%
PM (3 - 6)	30.25%	25.42%	24.96%

2.4.3.2 Count Distribution

An additional measure to assess the reasonableness of the Interim TOD Model performance is by making a comparison of the resulting distribution of traffic on the model links by time period as compared to the observed distribution of traffic from the 2008 traffic counts.

This comparison was completed using the hourly distribution of traffic at 685 locations based on 2007, 2008 and 2009 counts provided by KYTC. At each count location, the distribution of traffic by period from the model was compared to the count data. The results are shown in Figure 2-6.

Figure 2-6: Model vs. Count Period Distribution



There are several explanations for the differences that exist between the count data and distribution of traffic from the Interim TOD Model. The first is the difference in time between the 2000 survey and the counts which are from 2007 to 2009. The difference in time may account for a shift in trip making to outside the PM and AM periods to the overnight to cope with increased congestion. Thus people are making their trips earlier or later. Secondly, the time of day factors for the Interim Model were estimated using the departure time of the trip. This is the typical approach taken. The difficulty and source of difference is that the trip may actually be on the network outside of its departure period. This may explain the higher NT percent of traffic in the count data as compared to the model distribution.

2.5 Application

The Interim TOD Model has been applied to a 2020 and 2030 forecast to generate daily and period volumes on the Ohio River Bridge Crossings. The socioeconomic data and assumptions regarding external traffic are consistent with those used in the KIPDA 09 Plan A forecasts.

2.5.1 Forecast Scenarios

The interim model was applied for 2020 and 2030 using the following assumptions regarding the Ohio River Bridges:

- US 31: 2 lanes by direction, removal of time penalty used in the KIPDA daily assignments
- I-65: 6 lanes by direction in both 2020 and 2030
- East End Bridge completed and open in 2020 – 3 lanes by direction.

All other network and land use assumptions are consistent with the KIPDA 09 Plan A forecast.

The parameters validated for the base year Interim TOD Model were applied to the forecasts including the volume delay parameters and elimination of the time penalty on US 31. Different from the 2000 Interim TOD Model is the assignment convergence criteria. KIPDA uses a convergence criteria of 0.001 in the 2020 and 2030 forecasts where in the 2000 model, a criteria of 0.01 was applied in the assignment. For consistency, the same methodology is applied in the Interim TOD Model forecasts.

Table 2-18: Interim TOD Model Forecast Parameters

Interim TOD Model Parameters	Value
Volume Delay Parameters	Modified HCM Parameters (Table 2-11)
Assignment Convergence Criteria	0.001
Assignment Iterations	100
US 31 Penalty	0

2.5.2 Results (Bridge Crossing Volumes)

Table 2-19 reports the results for the 2020 and 2030 Interim TOD Model on the Ohio River Bridge crossings.

The “KIPDA” columns show the results from the existing KIPDA daily assignments based on the -09PlanA forecasts. The “Period” columns present the aggregation of the period flows for each year.

Table 2-19: Ohio River Bridge Crossings Interim TOD Model Forecasts

	2000			2020		2030	
Location	Count	KIPDA	Period	KIPDA	Period	KIPDA	Period
Clark BA (SB)	19600	6502	11003	2149	11080	0	12130
Clark AB (NB)		11220	8904	14456	12962	15006	13679
I-65 SB	62375	65622	64877	76146	72545	89833	81126
I-65 NB	62375	61000	65481	66802	69994	75111	78523
I-64 EB	40400	43354	40282	47576	44442	50786	48069
I-64 WB	40400	43258	40641	45903	44817	50967	48483
East End SB				26617	27101	31954	32035
East End NB				27327	25658	31488	30614

The imbalance observed in the existing KIPDA model is removed with in the period based assignments as seen on US 31 and I-65. In discussions with KIPDA staff regarding these results, the issue with the 09PlanA imbalance is known by KIPDA and has been resolved in the recent updates to the model.

2.6 Interim TOD Model Development

As part of the development of the Interim TOD Model, WSA developed a generalized GISDK script and user interface to run the base and forecast year alternatives. The GISDK script was based on the KIPDA existing model methodologies and used much of the existing scripts provided by KIPDA.

The script was modified to be more generalized so the model can be applied to any year or set of alternative inputs without having to manually change the scripts themselves. Input files including the transit demand and external through matrices are read into the model based on the year embedded in the file names. Model year, network and zonal data are input to the model using the graphical user interface (Figure 2-7).

KIPDA file name conventions were maintained, with the addition of the period outputs. The output volumes are written to the geographic file and the highway network is copied to the output network.

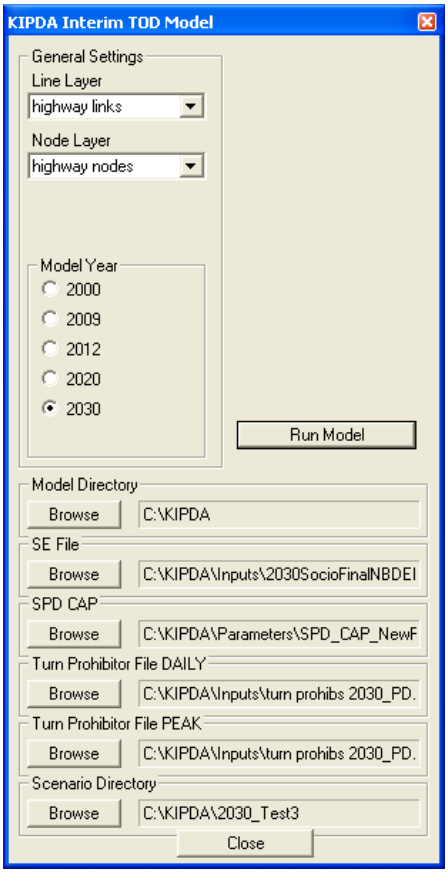
2.6.1 Graphical User Interface

WSA developed a custom graphical user interface for running the Interim TOD Model. The interface allows the user to select the following input files which were considered to be alternative specific:

- Scenario Year
- Socioeconomic Data
- Speed / Capacity Lookup Table
- Turn Prohibitor File

The interface is initiated once the desired alternative specific network is open in TransCAD. When defining a scenario, the path for the model directory is required, and the user has the opportunity to define the location of the scenario outputs.

Figure 2-7: Interim TOD Model Graphical User Interface



3.0 Specification of the Phase 2 Model

3.1 Introduction

As part of the Louisville – Southern Indiana Ohio River Bridge Time of Day Model Project, WSA has been charged with the development of a project specific travel demand model that will be used to support the NEPA analysis as well as provide the inputs to the future toll and revenue studies that will begin in 2011.

WSA used several sources of information to develop the recommended enhancements (specification of the phase 2 model). First a workshop was held at the KIPDA offices on September 24th in order to get feedback from the project model stakeholders which included the Kentucky Transportation Cabinet, the Bi-State Authority, CTS and KIPDA. This provided an invaluable source of information. This workshop pointed WSA to other sources such as the Purpose and Need Statement (reviewed in section 3.1.1).

After doing the necessary research, WSA developed a specification document which was reviewed by the stakeholders and which became the basis of this chapter.

The purpose of this document is to outline the enhancements that will be made to the existing KIPDA model to create the Louisville-Southern Indiana Ohio River Bridges Regional Time of Day Model (LSIORB Regional TOD Model or TOD Model).

3.1.1 Overview of Purpose and Need Statement

As outlined in the Environmental Impact Statement, the stated need for action is as follows (Source: EIS, Louisville – Southern Indiana Ohio River Bridges Project, Chapter 2):

- Inefficient mobility for existing and planned growth in population and employment in the Downtown area and in eastern Jefferson and southeastern Clark Counties;
- Traffic congestion on the Kennedy Bridge and within the Kennedy Interchange;
- Traffic safety problems within the Kennedy Interchange and on the Kennedy Bridge and its approach roadways;
- Inadequate cross-river transportation system linkage and freeway rerouting opportunities in the Eastern portion of the LMA; and
- Locally adopted transportation plans that call for two new bridges across the Ohio River and the reconstruction of the Kennedy Interchange.

The challenge for the LSIORB Regional TOD Model is to develop a tool that is sensitive to the action items and will provide an analysis platform for the EIS as well as the toll and revenue studies that will be required.

3.1.2 Specification Report

This chapter represents the framework for the Phase 2 work to be initiated by WSA at the end of Phase 1. Estimation and calibration of the model steps will be described in more detail as part of the Phase 2 model documentation.

3.2 Review of Existing KIPDA Model

WSA received the existing model from KIPDA. The model was calibrated using the 2000 Household Travel Survey and validated to 2000 traffic counts. In addition, forecast year scenarios were provided for 2009, 2012, 2020 and 2030. Following is a brief overview of the existing model structure in the KIPDA model.

3.2.1 Trip Generation

- The model has three internal trip purposes: HBW, HBO and NHB.
- The three internal purposes use a cross classification production model and regression attraction models.
- NHB utilizes the production cross classification only in the base year. In forecast years the productions are set equal to the NHB attractions.
- The distribution of households into size and auto ownership and structure type categories is input to the model and not automatically generated.
- Attractions are adjusted for special generators.
- External Local traffic disaggregated into two components – work and non-work.
    - EI Work – HBW Attractions
    - EI Other – HBO and NHB Attractions
- NHB Productions are set equal to NHB Attractions.
- NHB Productions are set equal to NHB Attractions.
- NHB utilizes cross-classification in the base year to determine total NHB productions.
- In the forecast years, NHB productions are set equal to NHB attractions after consideration of special generators.

3.2.2 Network Skimming

- Terminal Time (in minutes) is calculated using the following formula and added to centroid connectors:
    - 6.00 – FLOOR(Area/10) where Area refers to area type
- Speed and capacity is read into the network via a lookup table that uses facility type, area type and number of lanes.
- Turn Prohibitors and Penalties are included in the network skimming process
- Unique Intra State and Inter State skims are created, both based on free flow time.
- Skims are merged into a composite file and travel times are filtered for interstate and intrastate flows based on the origin-destination combinations.

3.2.3 Trip Distribution

- Gravity model is run for internal and external – internal purposes using composite time matrix.
- Friction factors are read from a table using travel time as the impedance.

3.2.4 Mode Share

- Vehicle person trips are based on person trips from trip distribution minus transit trips.
- Auto occupancy is applied to vehicle person trips to create vehicle trip table.
- Vehicle trips are sorted into intrastate and interstate trips.

3.2.5 Assignment

- Daily assignment is run using interstate and intrastate trip tables.
- Results from assignment including volume, speed, and congested time are written to the geographic highway network.

3.2.6 Feedback

- Highway skim is calculated using the congested skims from the assignment process for HBW and EI Work trip purposes. Other trip purposes still use free-flow skims.
- Intrastate and interstate composite time process is repeated with congested times.
- Gravity model is rerun with congested skims.
- Application of transit trips and auto occupancy as part of PA2OD is repeated on congested person trips.
- Highway assignment is repeated using new trip tables with free flow time in assignment.

3.3 Regional TOD Model Design Specification

Based on discussions held during the workshop conducted at KIPDA on September 24, 2010, five areas were identified for enhancement as compared to the KIPDA model. Those areas include:

- Trip purpose stratification
- Time of Day Structure
- Mode Choice
- Truck Model
- Traffic Assignment

The following section details the recommendations and implementation steps that will be taken in the development of the Regional TOD Model.

3.3.1 Changes from Existing KIPDA Model

In addition to the five enhancement areas, WSA is providing additional recommendations based on the review of the existing model. These enhancements will further support the needs of the Regional TOD model.

Model Step	Recommended Enhancement
Trip Generation Model	• Automation of the disaggregation of the zonal households into the trip generation market segmentation using a household disaggregation model.
Network Skimming	• Streamlining of the interstate and intrastate impedance calculations.
Mode Choice	• Application of a mode choice model as described below.
Traffic Assignment	• Additional volume delay functions by volume class. • Addition of trucks into assignment and volume dependent PCE factors. • Period assignments as described below.
Feedback	• Adding of a convergence based feedback model rather than fixed 1 iteration feedback.

3.3.2 External Models

Taking the data being collected as part of Phase 1, new external models will be developed for the Regional TOD Model. The external through matrix for autos and trucks will be based on the Video OD Survey. The external – internal models for both passenger vehicles and trucks will use the distribution of traffic at the external stations from the OD survey and new methodologies for estimating the internal end of the trips. Existing attraction models and friction factors used in the existing model will be reviewed and potentially used in the estimation process.

3.3.3 Model Years

As part of the Regional TOD Model, we will be establishing a new base year of 2007 for the model.

The base year is consistent with KIPDA's efforts for development of a new base year for the regional model. Socioeconomic data for the base year will be shared by KIPDA for use in the Regional TOD Model.

The forecast years to be tested will be agreed upon based on the needs of the application of the model.

Socioeconomic inputs for the forecast years will be based on information from KIPDA for consistency. Future year roadway improvements will be based on the regional plan as a base line.

3.3.4 GISDK Scripts and Graphical User Interface

As part of the development of the Regional TOD Model, a new GISDK script will be developed along with a graphical user interface to manage scenario input and output files. The actual design of the graphical user interface will be developed as part of the Phase 2 efforts but it will allow the user to specify the following information:

- Highway Geography
- Transit Network
- Land Use Information
- External Inputs
- Destination for outputs
- Ability to run the model in steps or incrementally

The GISDK scripts will be generalized to allow the model to be run based on the specified inputs and output directory. It is also anticipated that the GISDK scripts will include some basic reporting functionality to support the validation process.

3.3.5 Validation of the Regional TOD Model

As part of the model development process, a set of validation criteria will be developed for the Regional TOD Model. Input to the criteria will come from the existing KIPDA standards, work done on other models in Kentucky, and state of the practice for similar models. One resource that will be consulted will be the FHWA validation criteria. A validation plan will be developed that will consider this information as well as the intended use of the model and propose a set of criteria and thresholds to be applied.

3.3.6 Trip Purpose Stratification

Based on the Purpose and Need, and future toll and revenue studies, incorporating income into the model is an important component of the model. It is anticipated that zonal households will be stratified into income categories. The income of the trips will be tracked throughout the model. It is assumed that the distribution of trips by income will be retained through the model stream to include the opportunity to assign trips by income group as well as mode (SOV, HOV2 and HOV3+).

Recommendation	Implementation Steps
Introduction of income stratified trip purposes in the trip generation step of the model. For consistency with the existing KIPDA model, the trip generation rates will remain unchanged. Disaggregation of trips by income will be made to the production and attractions using a household disaggregation model. Distribution of trips by auto ownership will also be retained for mode choice. Allocation of attractions by income group will be investigated.	1) Define the income categories. Will be based on analysis of the survey. Maximum of 3 groups. 2) Calibrate income disaggregation model using zonal income. 3) Define methodology for allocation of attractions into income categories 4) Model steps: a) calculate hh income distribution, b) apply to productions, c) disaggregate attractions

3.3.7 Time of Day Structure

Identified goal of the ORB Regional TOD Model is an enhanced approach Time of Day structure to better account for:

- Period sensitivities to congestion
- Period pricing
- Network variation by period
- Difference in travel patterns by period

There are quite a few streets in the KIPDA model which are coded for AM and/or PM peak conditions, whichever has the greater number of lanes. For example, Bardstown Road between Highland Avenue and approximately Douglas Boulevard is coded two lanes in each direction. This is based on two lanes northbound in the AM peak period and two lanes in the PM peak period.

The actual number of travel lanes southbound in the AM peak period and northbound in the PM peak period is one with a continuous turn lane. In the midday and “overnight” off-peak periods, parking is allowed on both sides of the street. Therefore, the number of lanes is one in each direction (without a continuous center lane). The situation for most of the other streets where “parking is stripped” on one or both sides is not as complicated as Bardstown Road, but the number of these “other” streets is significant. As part of the Phase 2 model, the location of these types of facilities will need to be identified and coded into the network.

The LSIORB Time of Day structure will be static in that the factors applied to the trip purposes by period will be constant and not dependent on congestion or other factors. Alternative model designs where period selection for a given trip is based on choice models require significant data to estimate that is not available.

Recommendation	Implementation Steps
The Interim TOD Model developed applied the time of day factors prior to traffic assignment. By placing the distribution of trips to periods in the distribution phase as part of the ORB Model, the model will be able to capture differences in travel characteristics by period including trip length and route choice.	1) Define the periods for the model based on the household survey and traffic counts. 2) Review household survey to identify differences in travel characteristics by period (average trip length) 3) Develop methodology for assignment of attractions by period for trip distribution. 4) Calibrate period gravity models. 5) Develop period trip distribution models in model stream.

It is anticipated that the LSIORB Regional TOD Model will be based on periods that are greater than one hour to account for the longest trips and to capture the entire trip being completed in the period. Because static capacity factors will be used that do not account for peak spreading, WSA will consider develop independent hourly assignments of the peak periods (AM and PM) to account for the hours of heaviest congestion.

3.3.8 Mode Choice

To support the ability to test HOV and transit alternatives on the bridges, it is necessary to be able to estimate this vehicle demand.

Recommendation	Implementation Steps
It is recommended to add a mode choice model to the ORB TOD Model, based on a proven nesting structure developed for other similarly sized urban areas. The model coefficients will be borrowed, but the mode choice constants will be validated to local ridership and mode share.	1) Develop a transit network including routes, stops and route characteristics. 2) Develop the necessary skimming methodology for the transit network and highway network accounting for future tolling. 3) Implement the mode choice model. 4) Develop mode choice post processing steps to manage trip tables by mode and purpose for assignment.

3.3.9 Truck Model

Based on the intended use of the model, it is important to be able to capture the movement of trucks in the KIPDA region.

Recommendation	Implementation Steps
Implement to a two tier truck model: • External trucks based on the statewide models, truck counts and video OD surveys. • Local truck model to capture internal movements of goods.	1) Develop external location distribution of truck counts (EI, IE, EE, etc.) 2) Estimate the through movement of heavy trucks as a seed matrix to be applied to the count data. 3) Use statewide models to identify internal end of external movements. 4) Apply methodology for local truck model (QRFM) 5) Integrate into TOD model framework for simultaneous assignments. 6) Explore using a volume dependent PCE value in the assignment volume delay curves.

3.3.10 Traffic Assignment

Based on initial applications of the KIPDA model, routing issues have been observed in the downtown caused by inaccurate travel times as compared to using the Kennedy Interchange. As part of the LSIORB TOD Model, improved assignment algorithms may be an important toll to improve routing and loadings in the project area.

Recommendation	Implementation Steps
To address the routing issues through the downtown, the recommended approach is to build upon the work KIPDA is doing with signal density and move towards a signal location model. This model would account for signal delay in the travel time and capacity based on the presence of signals on the network. As part of this task, the free flow speed and capacity logic will be revised. Additional areas of enhancement for the assignment model include including a generalized cost function to account for tolling, HOV exclusion sets, options of assigning volume classes to include purpose, income etc.	1) Code location of signals in the network. 2) Develop speed and capacity logic to account for presence of signals. 3) Identify VDFs to account for uninterrupted link capacities. 4) Create assignment scripts to allow flexibility in trip purpose and volumes to assign.

4.0 Data Collection Results

This chapter provides an analysis of the traffic and travel patterns associated with the major river crossings in the Louisville area and other major routes within the KIPDA five-county area. The analysis includes traffic volumes by year, month, and hour, and vehicle classification trends, which characterize regional traffic patterns. Data was collected from historical KYTC and INDOT records, as well as data collection conducted by WSA and our sub consultant, The Traffic Group in September 2010.

4.1 Existing Data

WSA was provided the latest traffic data from the Kentucky Transportation Cabinet. This information included the most recent average annual daily traffic volumes, time of day volumes, and classification counts. There were 1,153 time of day counts provided for Bullitt, Jefferson, and Oldham Counties. The counts were conducted between 2007 and 2010. Classification data was provided separately as part of 1,629 counts collected between 1997 and 2010. The latest counts were collected from INDOT and included 214 counts throughout Clark and Floyd Counties. This information was summarized by hour into a spreadsheet and linked to the time of day model. Where available, truck percentages were provided. A sample of the data is provided in Appendix A.

4.2 September 2010 Data Collection

In September 2010, additional vehicle classification counts and turning movement counts were conducted to supplement existing KYTC and INDOT data. In addition, an Origin/Destination Survey was conducted. Each activity is described below.

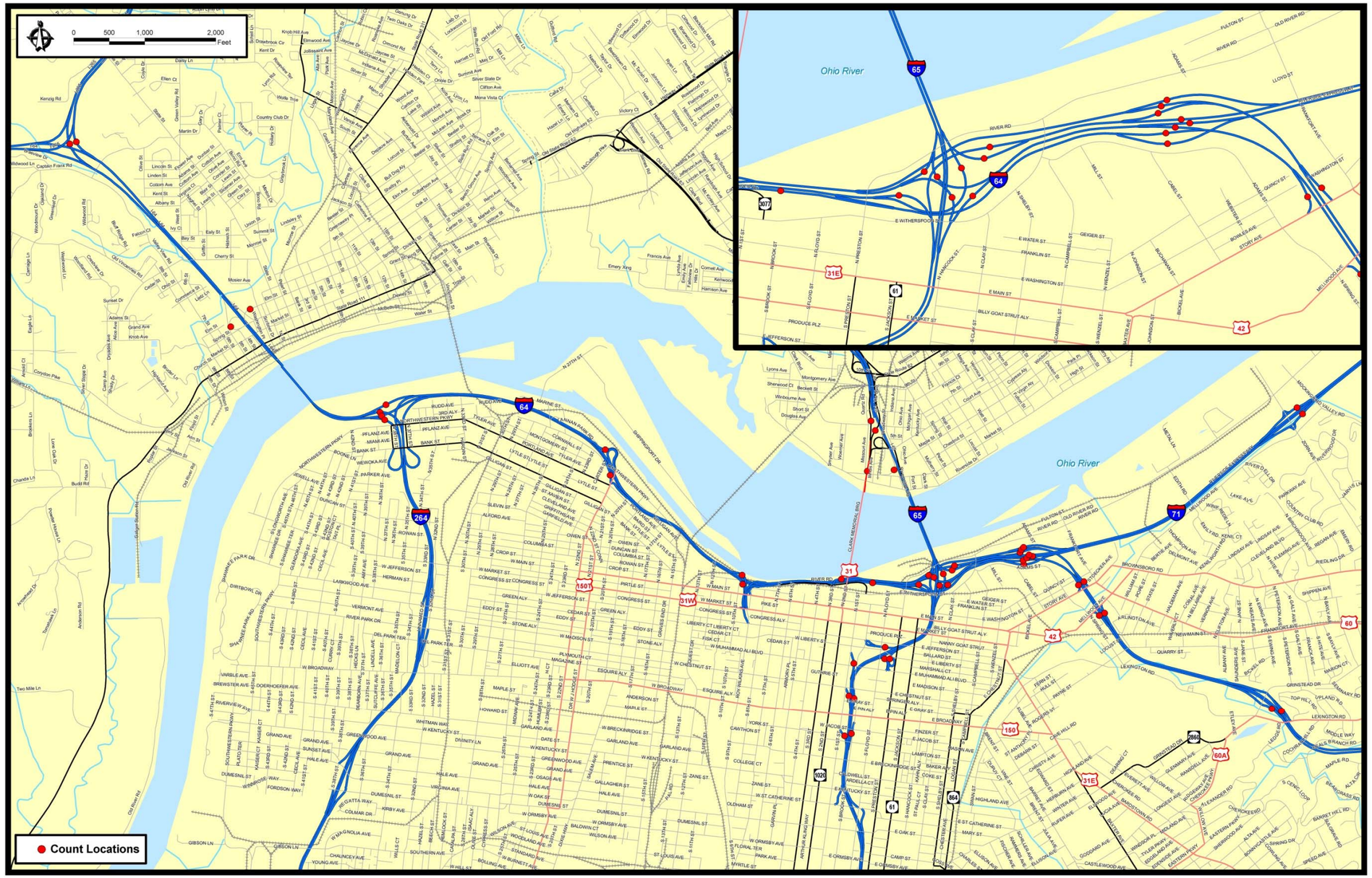
4.2.1 24-Hour Vehicle Classification Counts

To supplement data provided by KYTC and INDOT, 56 additional locations were counted on September 29, 2010. The majority of these locations represent critical ramp locations within the LSIORB study area or ramp locations directly impacted by diverting traffic. The ramp locations are illustrated in Figure 4.1 and more detail is shown in Appendix B. Six additional locations were counted along the interstate, one along I-65 at the Kennedy Bridge and five locations matching the Origin/Destination Survey.

The ramp counts were completed using road tubes and classified as the standard 13 vehicle classes. The six additional locations along the interstates were counted using non-evasive equipment that classified vehicles based on length. Three categories were summarized and generally represent cars, light trucks and heavy trucks based on the following breakdown:

1. Class group one through three is classified as a car;
2. Class group four through seven is classified as a light truck; and
3. Class group eight through 13 is classified as a heavy truck.

Figure 4-1: Ramps Downtown



4.2.2 Turning Movement Counts

Turning movement counts were conducted at three key locations. The counts were conducted in coordination with the Origin/Destination Survey and classification counts. This will provide a check and balance mechanism for all data collected. AM counts were conducted between 7:00 am and 9:00 am. Midday counts were conducted between 11:00 am and 1:30 pm. PM counts were conducted between 4:00 pm and 6:00 pm. Not all counts were conducted for the complete period. Each turning movement count was classified into three general vehicle classifications using the same breakdown described in the previous section. Turning movement counts were conducted at the following locations:

1. Clark Memorial Bridge (US 31) and Main Street in Downtown Louisville
2. I-64 3rd Street Exit and River Road in Downtown Louisville
3. Clark Memorial Bridge (US 31) and West Court Avenue in Indiana

The results are illustrated in Appendix C.

4.2.3 Origin/Destination Survey

The Origin/Destination Survey was conducted September 29, 2010, starting at Midnight and ending 24 hours later. The five sites, illustrated in Figure 4.2, were along I-65, I-64 and I-71 and positioned at the edge of the KIPDA five-county area with three exceptions.

- To avoid an ongoing construction zone, the East I-64 site was moved further east beyond Simpsonville and Exit 28.
- The South I-65 site was located north of the Bullitt County line because no suitable overpasses existed at the county line to mount equipment. The site was located between Exit 105 and Exit 112.
- The I-71 site was located west of Exit 17 due to a technician error. The external volumes will be adjusted to account for the additional LaGrange trips.

The study was conducted using camera systems capable of detecting and photographing license plates. Cars and trucks are differentiated along with direction.

4.3 Analysis

The data gathered from KYTC and INDOT and collected in September 2010 was analyzed and is summarized in the following sections.

4.3.1 Monthly Traffic Variation

Historic information on monthly traffic variation was collected from KYTC and INDOT. Table 4.1 shows the adjustment factors for both states. An adjustment factor, multiplied by the average daily traffic (ADT), produces the annual average daily traffic (AADT). Despite variations between data sources, traffic volumes tend to be higher in summer months and lowest in winter months. Because the adjustment factors were between 0.99 (Indiana) and 1.00 (Kentucky), no adjustment was made to the data collected in September.

Figure 4-2: Origin Destination Survey Locations

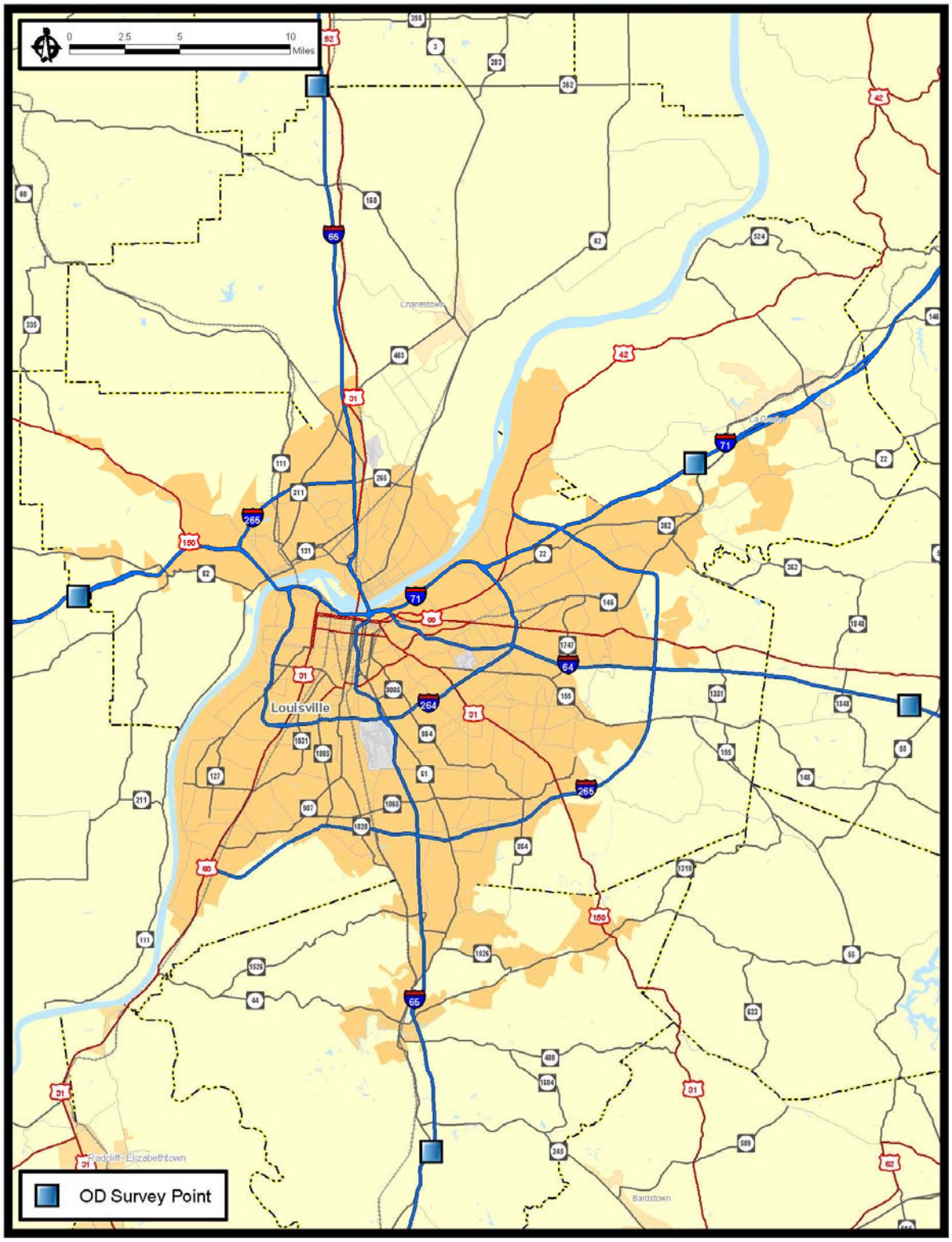


Table 4-1: Monthly Count Adjustment Factors

Source	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
2009 KY Statewide Urban Interstate Rate	1.05	1.03	0.96	0.94	0.97	0.97	0.99	1.00	1.00	1.00	1.03	1.07
2005-2009 Average IN Statewide Urban Interstate Rate	1.13	1.08	1.02	0.99	0.97	0.95	0.95	0.94	0.99	0.98	1.01	1.06

4.3.2 Annual Traffic Trends

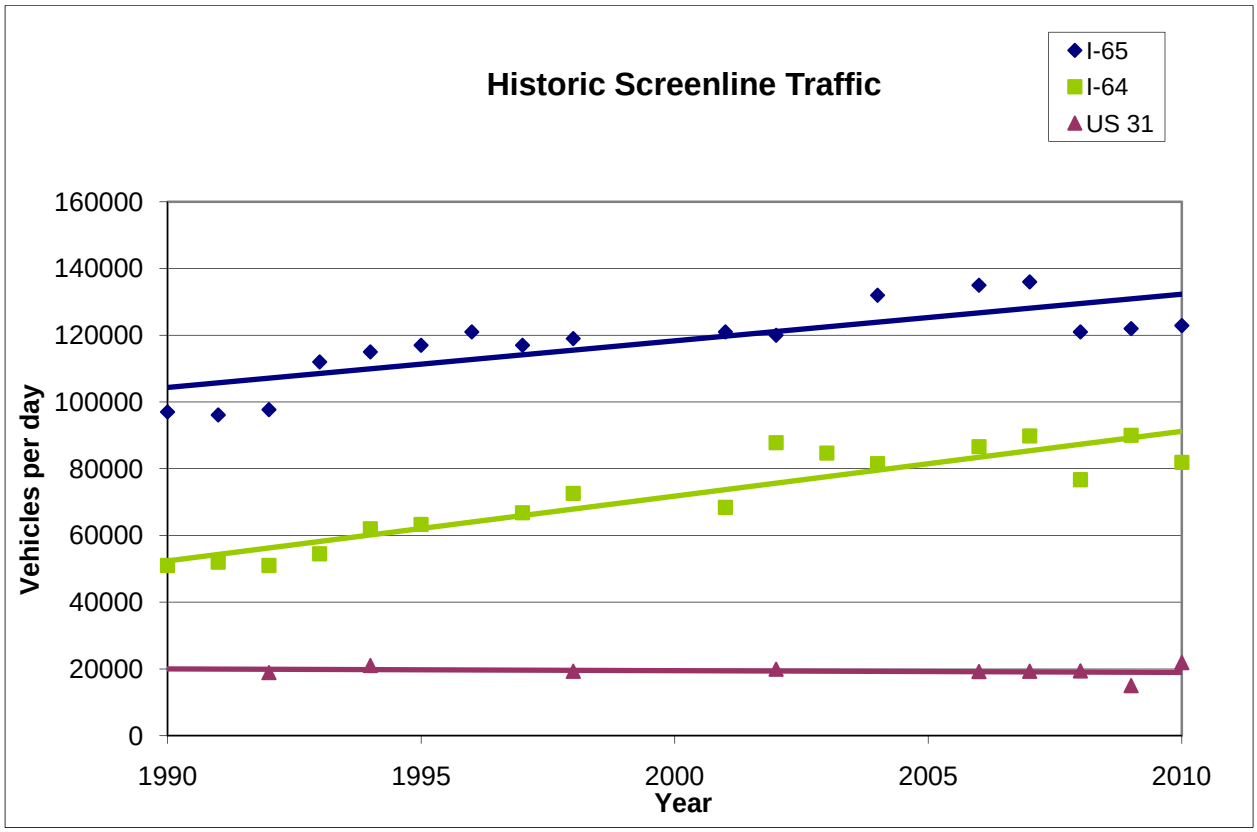
The Ohio River serves as a screenline, dividing the project area between Kentucky and Indiana. River crossings in the Louisville area are served by two primary interstate bridges. I-65 runs north-south through downtown Louisville, crossing the river at the John F. Kennedy Bridge. I-64 travels east-west between the river and downtown, crossing between states at the Sherman Minton Bridge. A third highway river crossing, the George Rogers Clark Memorial Bridge, lies on US 31 immediately west of the Kennedy Bridge.

As illustrated in Table 4.2, the 2010 average annual daily traffic (AADT) volumes for the I-65 Kennedy Bridge was 122,900 vehicles per day (VPD). This is consistent with 2008 and 2009 volumes, but lower than volumes recorded between 2004 and 2007. The recorded AADT for the I-64 Sherman Minton Bridge was 81,900 vpd. This volume was lower than 2006, 2007, and 2009 volumes, but consistent with 2008 volumes. Daily volumes on the US 31 Clark Memorial Bridge were 21,900 vehicles for 2010, which is higher than previous counts. Historic counts for all three bridges are illustrated in Figure 4.3.

Table 4-2: 2010 Ohio River Bridge Counts

	I-65 Kennedy Bridge	I-64 Sherman Minton Bridge	US 31 Clark Memorial Bridge
AADT	122,900	81,900	21,900
Light Truck Percentages	8.4%	3.7%	1.5%
Heavy Truck Percentage	12.7%	7.3%	0.1%

Figure 4-3: Historic Traffic Volumes on Ohio River Bridges



Year 2010 volumes and truck percentages are illustrated on Figure 4.4 by direction and include the five origin/destination sites. Interstate locations outside the metro area decrease significantly when compared to bridge volumes, while truck percentages increase. Figure 4.5a and 4.5b illustrates more detail on the I-65, I-71 and I-64 ramps near the I-65 Kennedy Bridge. In addition to daily volumes, morning and evening peak volumes are illustrated.

Figure 4-4: Interstate Directional Volumes and Truck Percentages (2010)

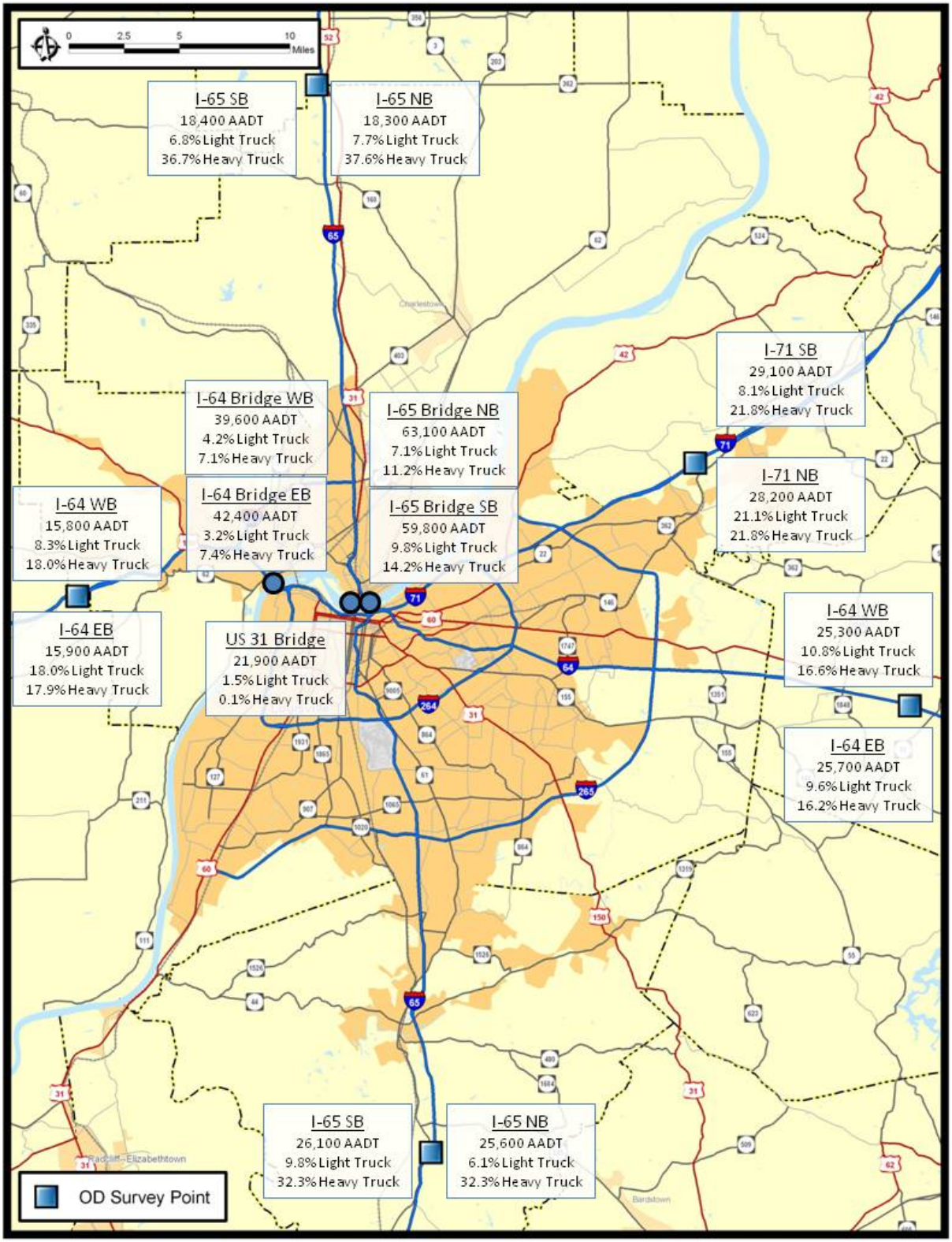


Figure 4-5a: I-64 and I-65 Ramp Volumes

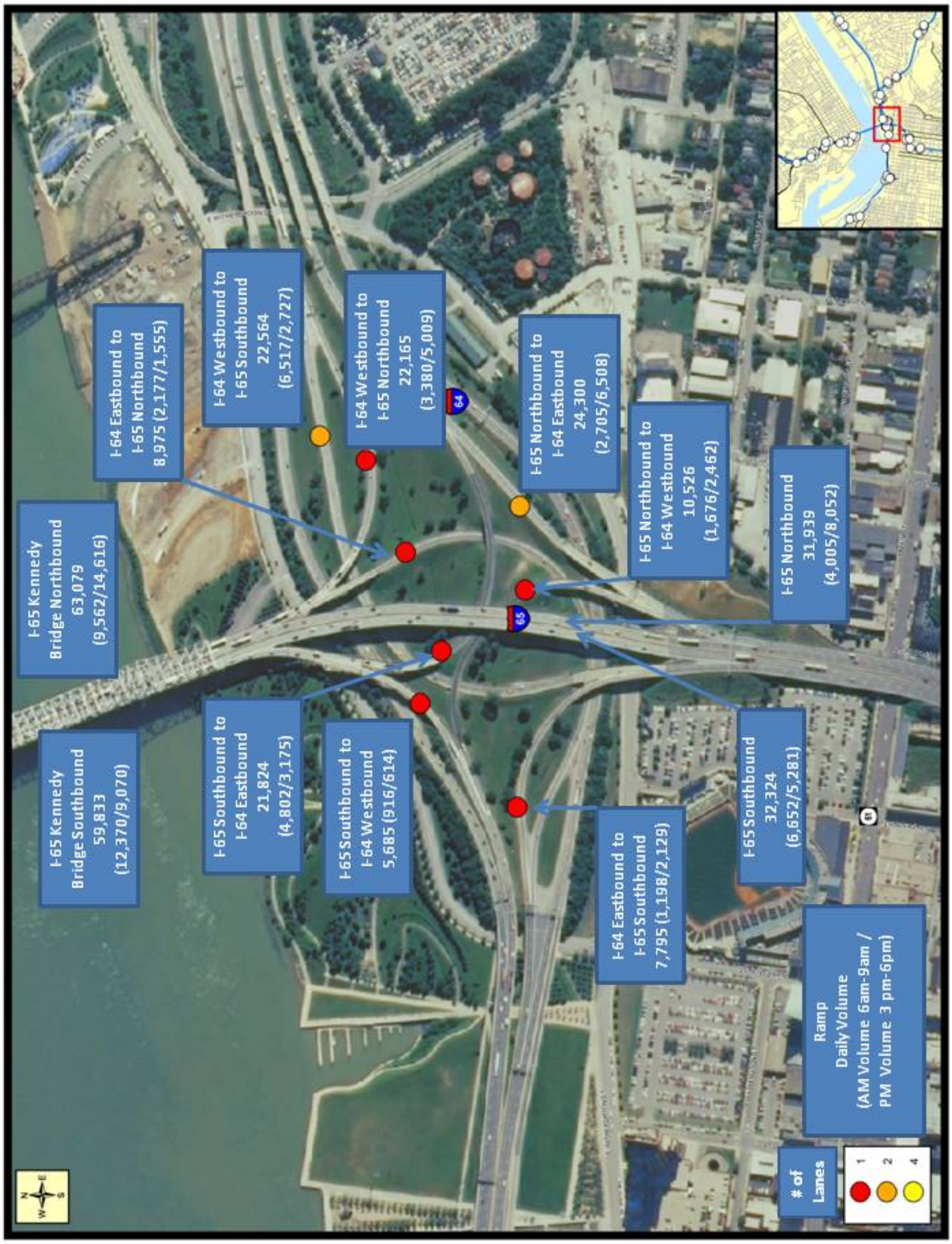
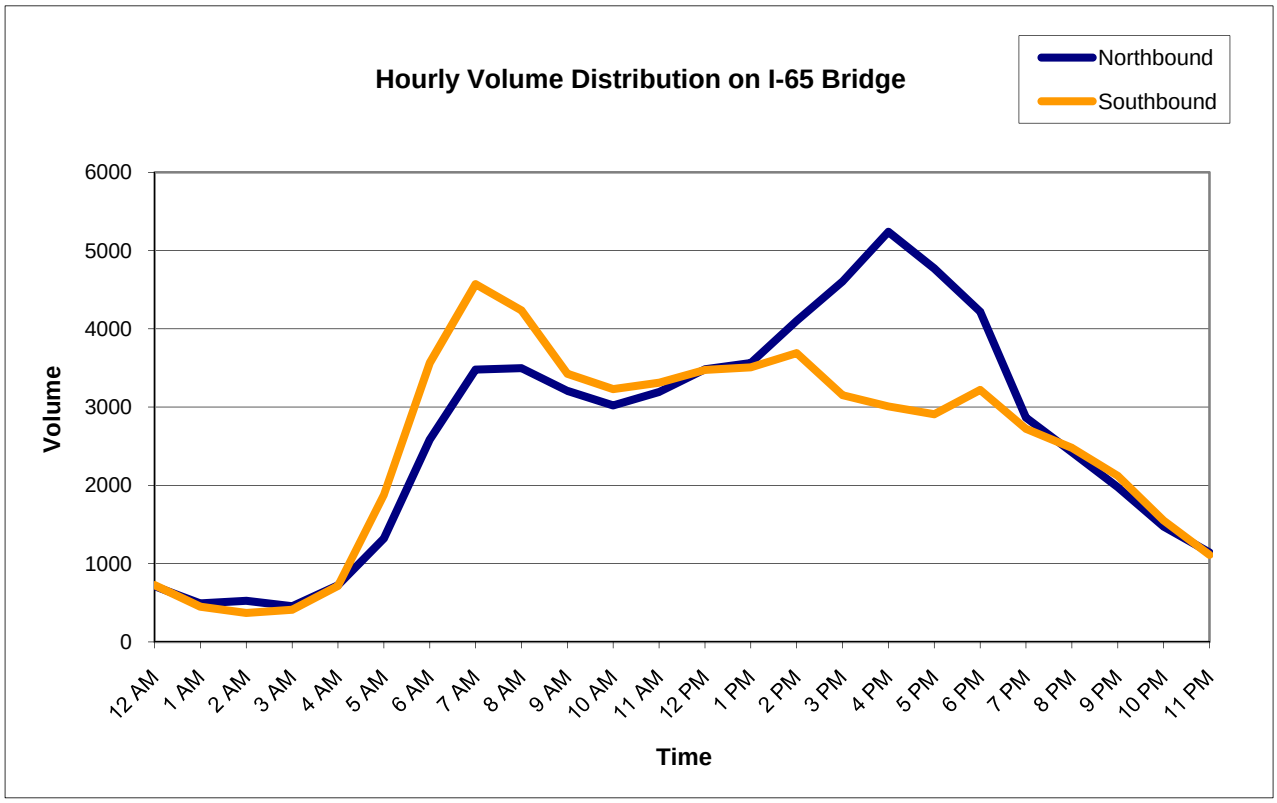


Figure 4-5b: I-64 and I-71 Ramp Volumes

4.3.3 Hourly Traffic Distribution

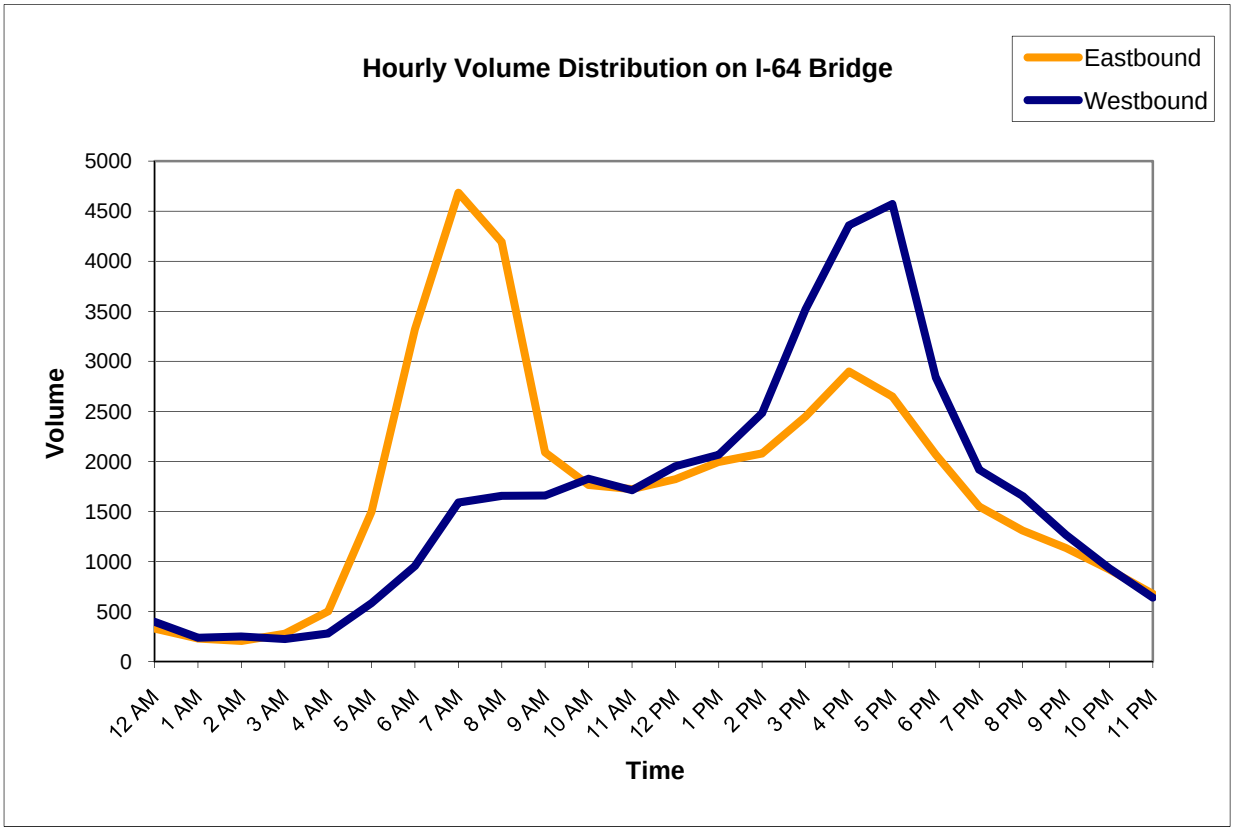
As part of the September 2010 data collection effort, traffic volumes were recorded at each of the highway river crossings. Directional hourly distributions presented in Figure 4.6 through 4.8 indicate an AM peak flow entering the city of Louisville and a strong PM peak flow leaving the city.

Figure 4-6: I-65 Bridge Hourly Distribution (I-65)



Less distinct peak times are observed along the Kennedy Bridge. As an interstate, I-65 carries a larger portion of long distance trips which do not vary as noticeably as local trips.

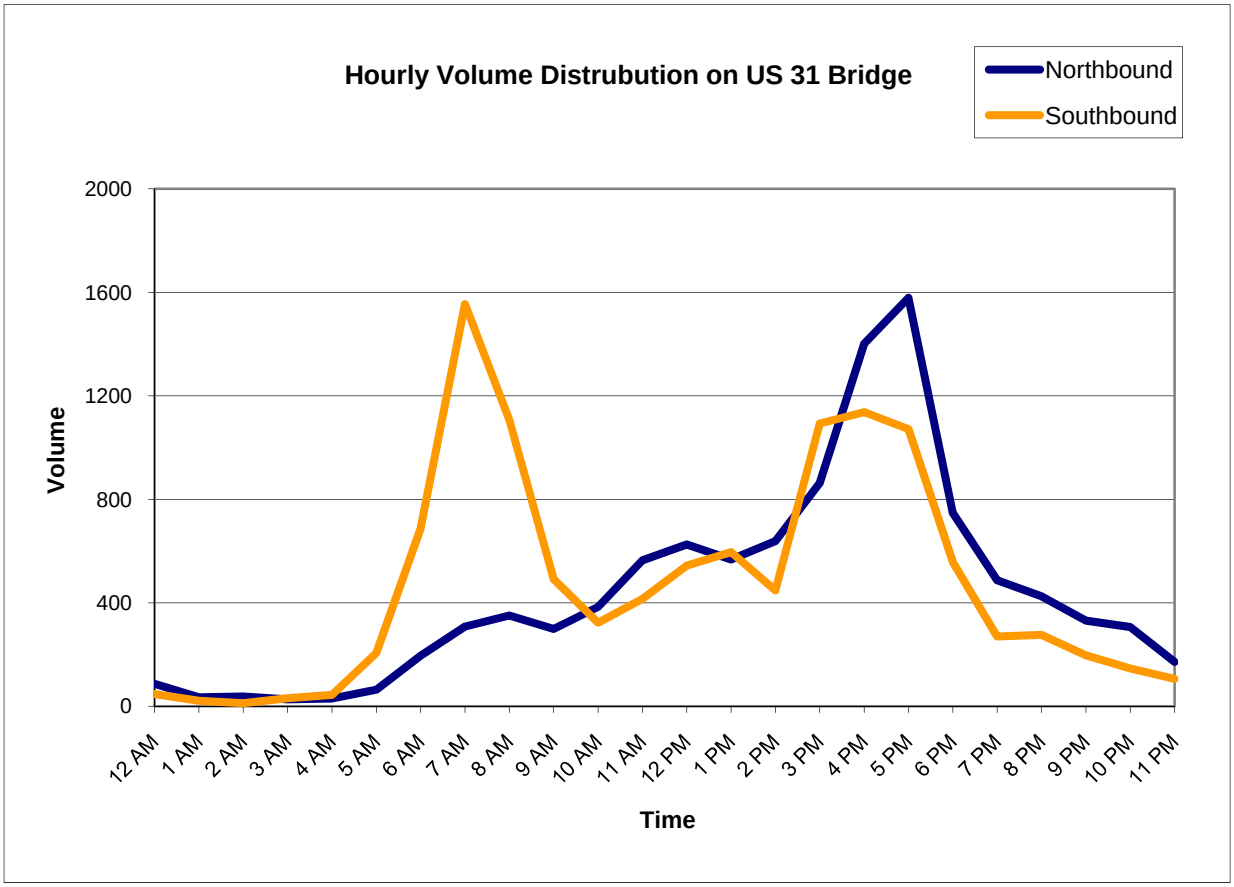
Figure 4-7: I-64 Bridge Hourly Distribution (I-64)



It appears I-64 contains a higher percentage of work trips than I-65 due to the higher percentage of AM and PM directional splits.

US 31, providing primarily local access, also exhibits a small but distinct midday peak period. The morning high volume period is concentrated from 7 AM to 8 AM and is localized in the southbound lanes. In contrast, the PM peak spreads over a longer time period (4 PM to 6 PM) and affects both directions.

Figure 4-8: US 31 Bridge Hourly Distribution (US 31)



4.3.4 Vehicle Classification

Vehicles traveling along I-65, I-64, and US 31 in the project area were summarized as one of three classification types: passenger cars (including motorcycles and four-tire trucks), light trucks (including buses and all other single-unit trucks), and heavy trucks (three or more axles excluding single-unit trucks). The distribution among these classes is presented in Tables 4.3 through 4.5 for each of the bridge traffic counts, collected in September 2010. The data is further divided by time period to illustrate variations in truck percentages during peak versus non-peak periods.

The interstate routes carry a larger portion of truck traffic, while US 31 provides more local access with a lower percentage of truck traffic, particularly heavy trucks. Bridge counts indicate the number of trucks traveling on I-65 is nearly triple the number on I-64. During the morning and evening peak periods, heavy truck percentages were generally lower than daily percentages and; however, no similar trend was observed for light trucks during peak conditions.

Table 4-3: I-65 Bridge Vehicle Classification Data

Kennedy Bridge/ I-65	Northbound		Southbound		Total	
Morning (6 am - 9 am)						
Cars	8,290	86.7%	10,131	81.9%	18,421	84.0%
Light Trucks	530	5.5%	1,176	9.5%	1,706	7.8%
Heavy Trucks	742	7.8%	1,063	8.6%	1,805	8.2%
Total	**9,562**		**12,370**		**21,932**	
Midday (9 am - 3 pm)						
Cars	16,297	79.2%	15,640	75.8%	31,937	77.5%
Light Trucks	1,814	8.8%	2,356	11.4%	4,170	10.1%
Heavy Trucks	2,458	12.0%	2,641	12.8%	5,099	12.4%
Total	**20,569**		**20,637**		**41,206**	
Evening (3 pm - 6 pm)						
Cars	12,260	83.9%	6,689	73.7%	18,949	80.0%
Light Trucks	1,219	8.3%	1,180	13.0%	2,399	10.1%
Heavy Trucks	1,137	7.8%	1,201	13.2%	2,338	9.9%
Total	**14,616**		**9,070**		**23,686**	
Daily						
Cars	51,534	89.3%	45,433	88.7%	96,967	89.0%
Light Trucks	4,493	3.2%	5,882	4.2%	10,375	3.7%
Heavy Trucks	7,052	7.4%	8,518	7.1%	15,570	7.3%
Total	**63,079**		**59,833**		**122,912**	

Table 4-4: I-64 Bridge Vehicle Classification Data

Minton Bridge/I-64	Eastbound		Westbound		Total	
Morning (6 am - 9 am)						
Cars	11,459	94.0%	3,613	86.1%	15,072	92.0%
Light Trucks	312	2.6%	261	6.2%	573	3.5%
Heavy Trucks	423	3.5%	323	7.7%	746	4.6%
Total	**12,194**		**4,197**		**16,391**	
Midday (9 am - 3 pm)						
Cars	9,858	85.9%	9,981	85.3%	19,839	85.6%
Light Trucks	558	4.9%	636	5.4%	1,194	5.2%
Heavy Trucks	1,056	9.2%	1,080	9.2%	2,136	9.2%
Total	**11,472**		**11,697**		**23,169**	
Evening (3 pm - 6 pm)						
Cars	7,170	89.7%	11,543	92.7%	18,713	91.5%
Light Trucks	243	3.0%	447	3.6%	690	3.4%
Heavy Trucks	582	7.3%	463	3.7%	1,045	5.1%
Total	**7,995**		**12,453**		**20,448**	
Daily						
Cars	37,839	81.7%	35,089	75.9%	72,928	78.9%
Light Trucks	1,371	7.1%	1,676	9.8%	3,047	8.4%
Heavy Trucks	3,147	11.2%	2,802	14.2%	5,949	12.7%
Total	**42,357**		**39,567**		**81,924**	

Table 4-5: US31 Bridge Vehicle Classification Data

US 31 Bridge	Northbound	Southbound		Total
Morning (6 am – 9 am)				
Cars	Not Available	3,300	98.5%	
Light Trucks		42	1.3%	
Heavy Trucks		7	0.2%	
Total	**855**	**3,349**		**4,204**
Midday (9 am – 3 pm)				
Cars	Not Available	2,756	97.8%	
Light Trucks		62	2.2%	
Heavy Trucks		0	0.0%	
Total	**3,079**	**2,818**		**5,897**
Evening (3 pm – 6 pm)				
Cars	Not Available	3,256	98.6%	
Light Trucks		42	1.3%	
Heavy Trucks		3	0.1%	
Total	**3,843**	**3,301**		**7,144**
Daily				
Cars	Not Available	11,200	98.4%	
Light Trucks		170	1.5%	
Heavy Trucks		12	0.1%	
Total	**10,524**	**11,382**		**21,906**

Note: Due to a tube being pulled up, classification data for the northbound direction is not available.

4.3.5 Origin/Destination Survey

The Origin/Destination Survey was successful in capturing an average of 80 percent of the passing license plates. Approximately eight percent of the captured plates were unusable due to plate quality. This could result from the plate being dirty, partially or completely blocked by another object or unreadable because of sun glare. A comparison of useable plates to ADT is provided in Table 4.6. Additional detail is provided by The Traffic Group in Appendix D.

Table 4-6: Origin / Destination Survey Statistics

Site	Useable Plates	ADT	Percent Utilized
1N:I-65 NB in Indiana	11,934	18,317	65.2%
1S: I-65 SB in Indiana	12,526	18,445	67.9%
2N: I-71 NB in Kentucky	23,288	28,167	82.7%
2S: I-71 SB in Kentucky	21,867	29,095	75.2%
3E: I-64 EB in Kentucky	22,124	25,730	86.0%
3W: I-64 WB in Kentucky	20,338	25,309	80.4%
4N: I-65 NB in Kentucky	21,646	25,582	84.6%
4S: I-65 SB in Kentucky	18,648	26,081	71.5%
5E: I-64 EB in Indiana	9,823	15,920	61.7%
5W: I-64 WB in Indiana	8,680	15,826	54.8%
Total	170,874	228,472	74.8%

The Origin/Destination Survey conducted by The Traffic Group is documented in Appendix D. The documentation contains a project description, origin/destination survey site location diagrams, an explanation of the matching process, photographs illustrating readable, partially readable, and unreadable passenger vehicles and trucks, a chart providing distances between each site, a comparison between OD results and traffic counts, and summary of the capture rates. In addition, an illustration of the 24-hour classification count locations was provided.

Results from the survey were adjusted for study area inbound and outbound movements and factored to match the recorded traffic count data. Expansion factors and the fratar process are used to adjust the survey license plate data into balanced external through movements between the five external stations for both passenger vehicles and heavy vehicles.

Appendix E contains the processed external station trips including the final trip matrices. The daily results for all external to external trips are presented in Tables 4.7 and 4.8.

Table 4-7: Daily Number of License Plates Captured at Downstream External Survey Site (Passenger Vehicles)

	1	2	3	4	5	Total
1	0	187	870	1,558	644	3,259
2	275	0	191	1,167	527	2,160
3	805	209	0	157	701	1,872
4	1,484	1,211	165	0	235	3,095
5	695	553	645	214	0	2,107
Total	3,258	2,160	1,872	3,095	2,107	**12,493**

Site 1 – I-65 in Indiana; Site 2 – I-71 in Kentucky; Site 3 – I-64 in Kentucky; Site 4 – I-65 in Kentucky; Site 5 – I-64 in Indiana

Table 4-8: Daily Number of License Plates Captured at Downstream External Survey Site (Light and Heavy Trucks)

	1	2	3	4	5	Total
1	0	148	1,028	2,071	395	3,642
2	158	0	150	2,623	773	3,704
3	1,003	162	0	259	1,176	2,601
4	2,111	2,535	229	0	241	5,115
5	371	860	1,193	161	0	2,585
Total	3,643	3,705	2,601	5,113	2,585	**17,647**

Site 1 – I-65 in Indiana; Site 2 – I-71 in Kentucky; Site 3 – I-64 in Kentucky; Site 4 – I-65 in Kentucky; Site 5 – I-64 in Indiana

5.0 Model Datasets

5.1 Introduction

Fundamental to every travel demand model are the data. These data are used by the model to define the demographics, economics, and transportation infrastructure of the region being modeled. The model uses these data to forecast regional travel behavior. In order for the model to make proper use of these data, they must be stored in properly formatted databases that can be processed by the model.

This section of the document describes five separate databases that have been prepared for the development for the Phase II model. Some of these databases have been developed as direct model input data while others exist to enhance the model input data sets. The five databases that have been developed are the:

1. Socioeconomic Database;
2. Highway Network Database;
3. Transit Network Database;
4. Traffic Count Database; and
5. Intersection Database.

5.2 Socioeconomic Database

The socioeconomic database for the LSIORB Phase II model is set to a 2007 base year. The socioeconomic data are stored in a TransCAD fixed format binary file for use as a data input into the model. The 2007 data were developed by interpolating socioeconomic data from preexisting 2000 and 2009 data sets. The result is an interim socioeconomic data set that will be used to develop the Phase II model. It is anticipated that prior to model validation an updated 2007 base year dataset will be made available from KIPDA. When that dataset becomes available, it will replace this interim set.

The socioeconomic database has 807 TAZs (24 in the CBD) and Table 5-1 shows the population, households, and employment for the years 2000, 2007, 2009, and 2030.

Table 5-1: Summary of Socioeconomic Data

	2000	2007	2009	2030
Population	947,150	996,465	1,010,555	1,131,733
Households	389,016	416,160	423,915	494,909
Employment	496,376	560,098	578,304	779,216

Table 5-2 lists the attributes contained in the socioeconomic database.

Table 5-2: Attributes in the Socioeconomic Database

Attribute	Definition
TAZ_ID	TAZ identification numbers
NONCBDFAC	indicates that a zone is not in the CBD
NGQPOP	population not in group quarters
TOTHH	total households
HHS10	number of 1 person households in single-family DUs with 0 autos
HHS11	number of 1 person households in single-family DUs with 1 auto
HHS12	number of 1 person households in single-family DUs with 2 autos
HHS13	number of 1 person households in single-family DUs with 3+ autos
HHM10	number of 1 person households in multi-family DUs with 0 autos
HHM11	number of 1 person households in multi-family DUs with 1 auto
HHM12	number of 1 person households in multi-family DUs with 2 autos
HHM13	number of 1 person households in multi-family DUs with 3+ autos
HHS20	number of 2 person households in single-family DUs with 0 autos
HHS21	number of 2 person households in single-family DUs with 1 auto
HHS22	number of 2 person households in single-family DUs with 2 autos
HHS23	number of 2 person households in single-family DUs with 3+ autos
HHM20	number of 2 person households in multi-family DUs with 0 autos
HHM21	number of 2 person households in multi-family DUs with 1 auto
HHM22	number of 2 person households in multi-family DUs with 2 autos
HHM23	number of 2 person households in multi-family DUs with 3+ autos
HHS30	number of 3 person households in single-family DUs with 0 autos
HHS31	number of 3 person households in single-family DUs with 1 auto
HHS32	number of 3 person households in single-family DUs with 2 autos
HHS33	number of 3 person households in single-family DUs with 3+ autos
HHM30	number of 3 person households in multi-family DUs with 0 autos
HHM31	number of 3 person households in multi-family DUs with 1 auto
HHM32	number of 3 person households in multi-family DUs with 2 autos
HHM33	number of 3 person households in multi-family DUs with 3+ autos
HHS40	number of 4 person households in single-family DUs with 0 autos
HHS41	number of 4 person households in single-family DUs with 1 auto
HHS42	number of 4 person households in single-family DUs with 2 autos
HHS43	number of 4 person households in single-family DUs with 3+ autos
HHM40	number of 4 person households in multi-family DUs with 0 autos
HHM41	number of 4 person households in multi-family DUs with 1 auto
HHM42	number of 4 person households in multi-family DUs with 2 autos
HHM43	number of 4 person households in multi-family DUs with 3+ autos
HHS50	number of 5+ person households in single-family DUs with 0 autos
HHS51	number of 5+ person households in single-family DUs with 1 auto
HHS52	number of 5+ person households in single-family DUs with 2 autos
HHS53	number of 5+ person households in single-family DUs with 3+ autos

Attribute	Definition
HHM50	number of 5+ person households in multi-family DUs with 0 autos
HHM51	number of 5+ person households in multi-family DUs with 1 auto
HHM52	number of 5+ person households in multi-family DUs with 2 autos
HHM53	number of 5+ person households in multi-family DUs with 3+ autos
INC1	percent of households earning low income
INC2	percent of households earning medium income
INC3	percent of households earning high income
TEMP	total employment
REMP	retail employment
SEMP	service employment
OEMP	office employment

Figure 5-1 depicts the TAZs in the model area. Figures 5-2 through 5-6 show details of the TAZs in each county. Figure 5-7 shows details of the TAZs in the downtown area. Figures 5-8 and 5-9 show the base year population densities in the model area. Figures 5-10 and 5-11 show the base year employment densities.

5.3 Highway Network Database

The LSIORB Phase II model will be developed with a base year of 2007. In order to keep this model as consistent as possible with other modeling efforts in the area, the Phase II model will use a highway network database provided by KIPDA. This highway network was developed by KIPDA as the base year network for the MPO's current model update effort. This database incorporates the appropriate mix of projects required to represent existing roadway conditions as of 2007. The database also reflects additional refinements to the facility type values in the network. These refined facility types allow for more precise coding of the highway network.

In addition to the attributes already established in the database by KIPDA, the following attributes have been added to facilitate the development of the Phase II model:

- *Link Data -*
  - Cnt_Stat_ID: count station identification number from the traffic count database
  - AM_COUNT: total AM period count
  - MD_COUNT: total MD period count
  - PM_COUNT: total PM period count
  - NT_COUNT: total NT period count
- *Node Data -*
  - Signal_ID: identification number from the signal database
  - CycleLength: time in seconds that a signal cycle lasts
  - Percent_Green: the percent of the cycle length that represents green time for the primary approach to the signal

Figures 5-12 and 5-13 show a map of the highway network. Table 5-3 lists the input attributes of the highway network and Table 5-4 lists the output attributes of the highway network.

Figure 5-1: Map of TAZs by County

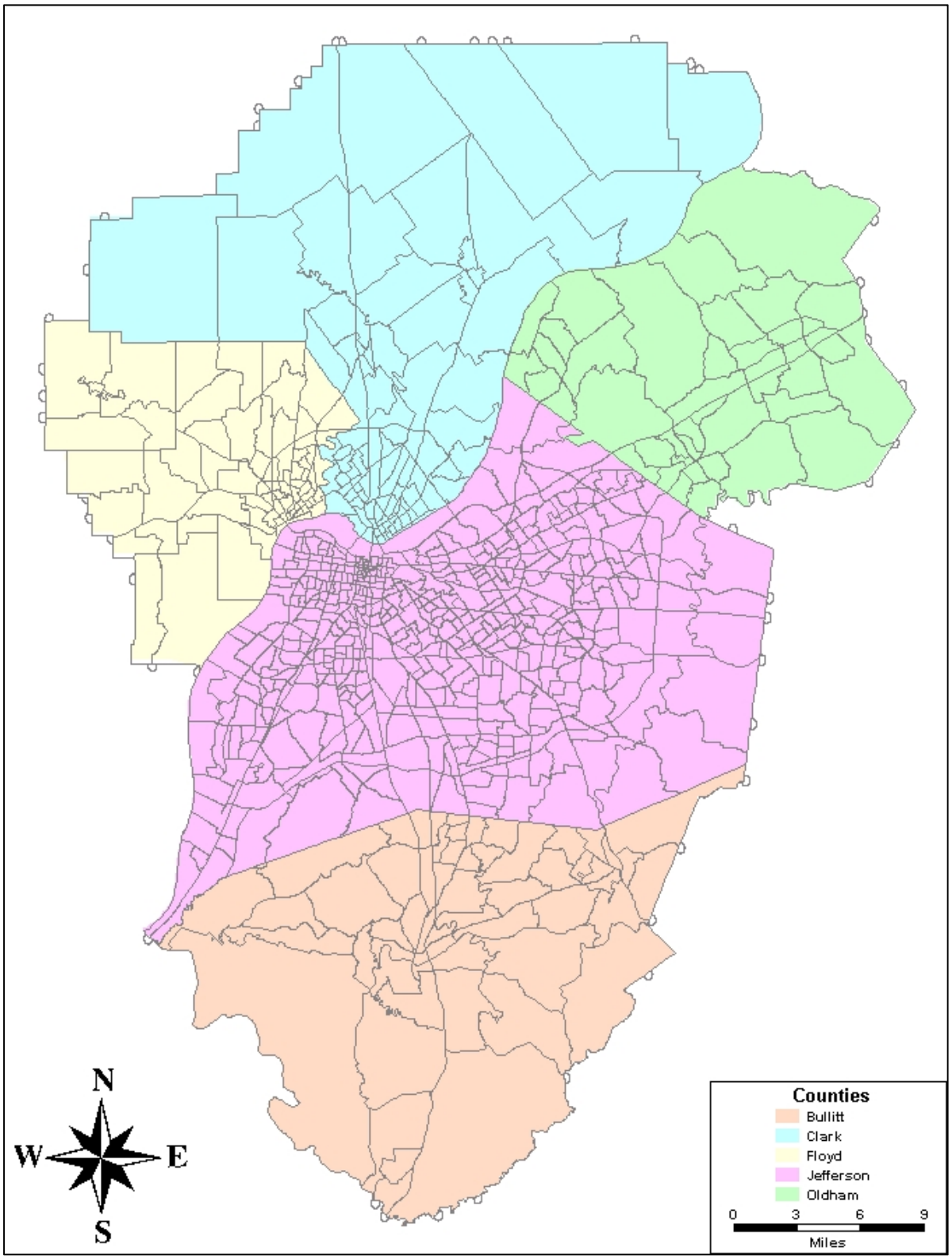


Figure 5-2: Bullitt County TAZs

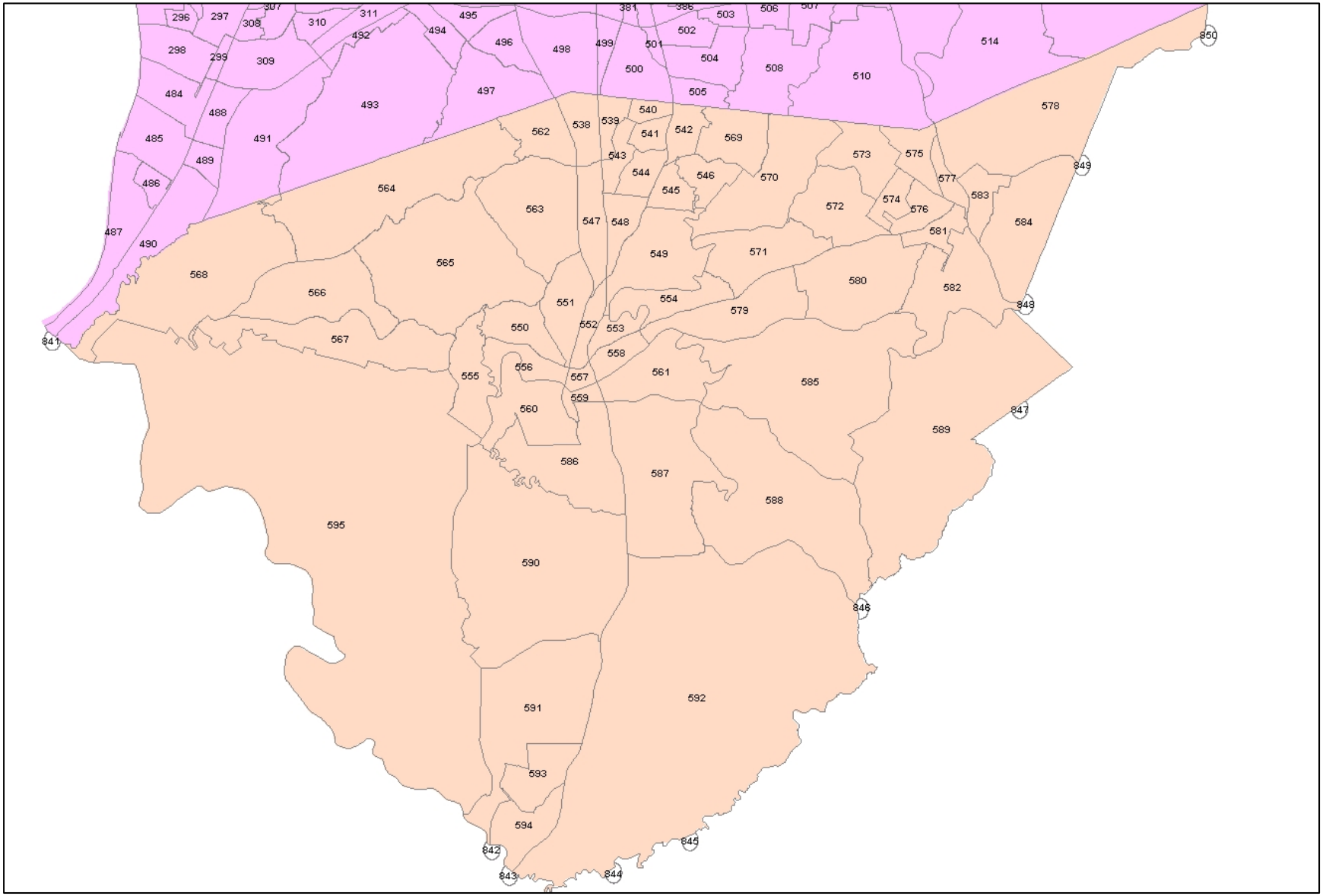


Figure 5-3: Clark County TAZs

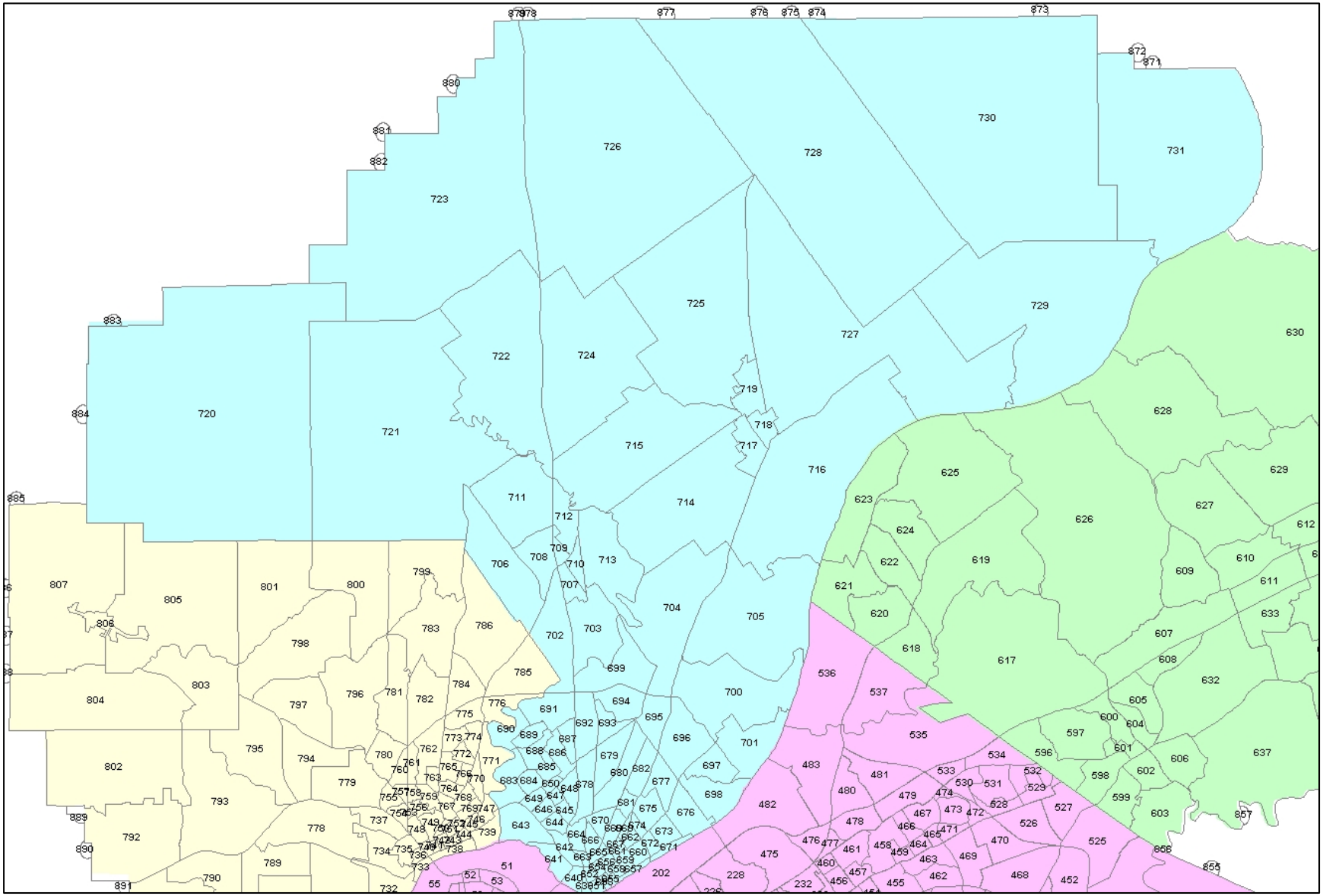


Figure 5-4: Floyd County TAZs

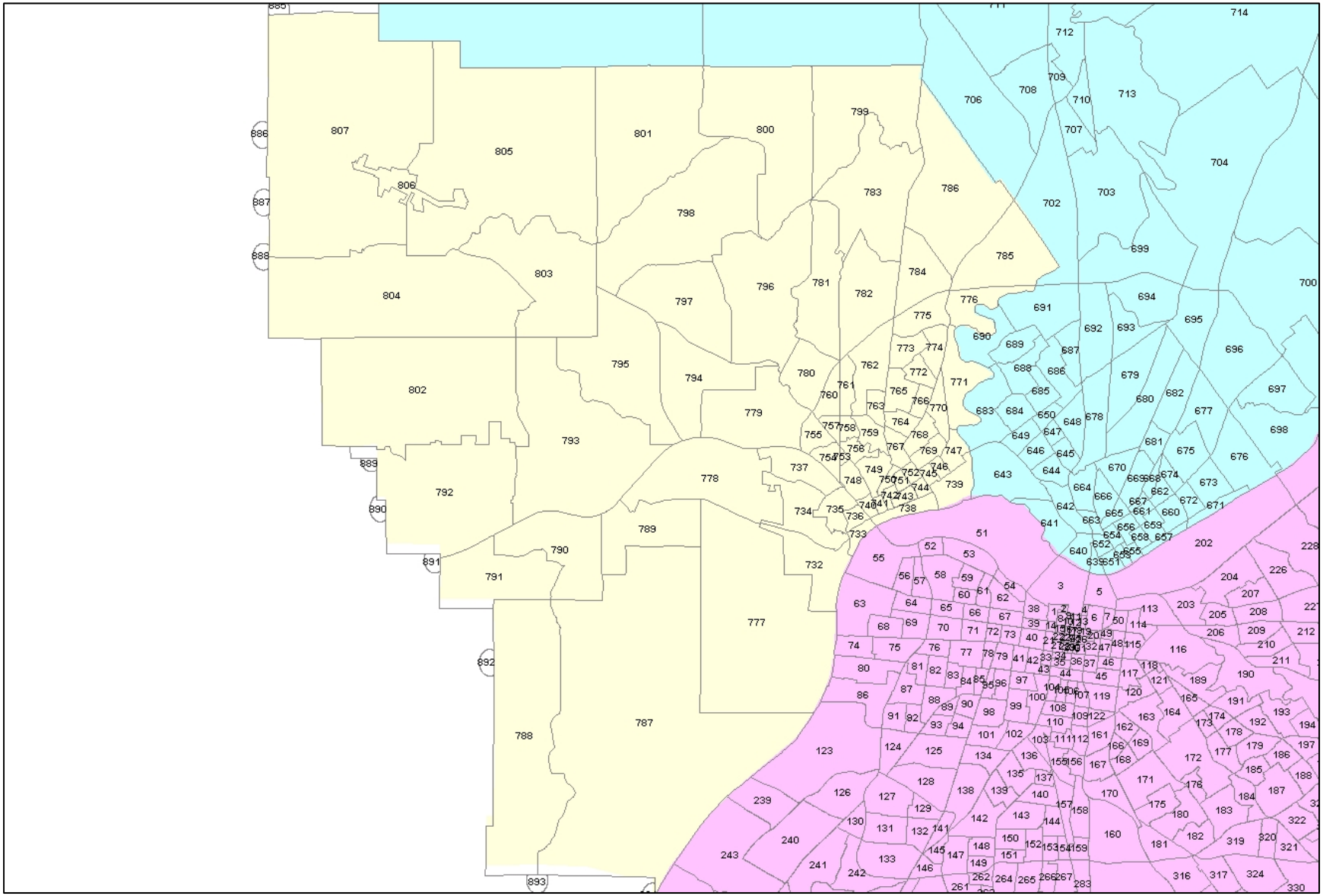


Figure 5-5: Jefferson County TAZs

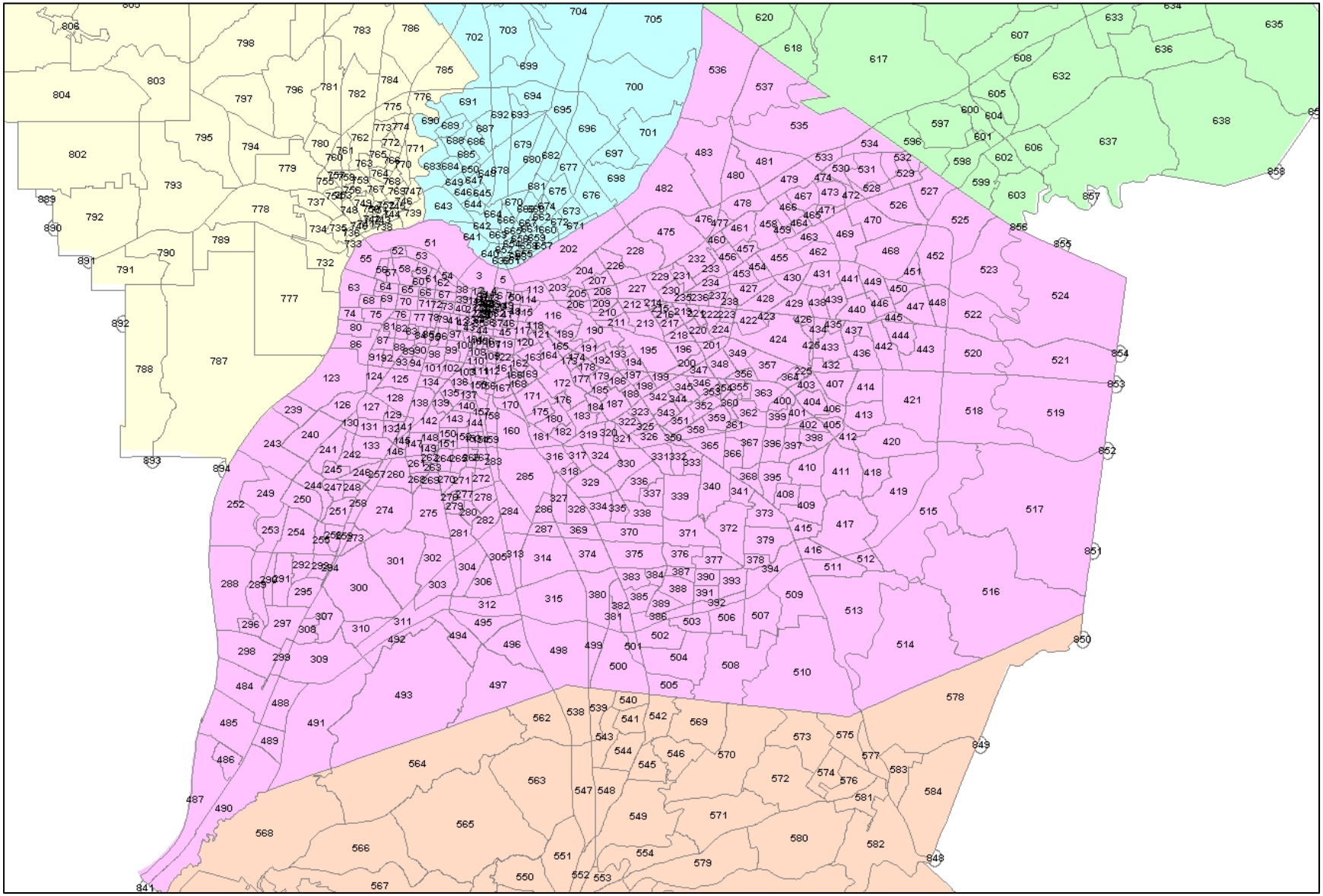


Figure 5-6: Oldham County TAZs

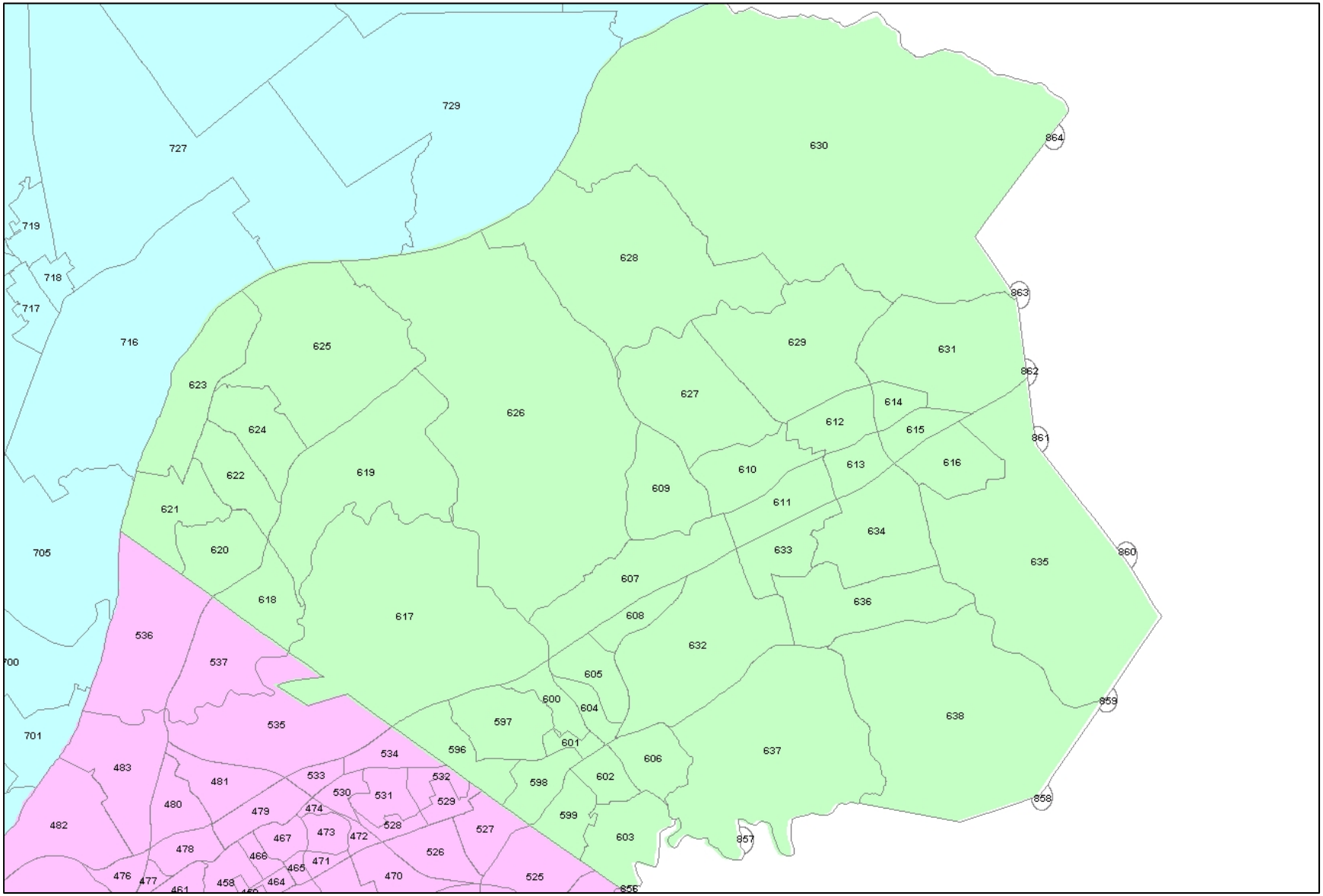


Figure 5-7: Downtown TAZs

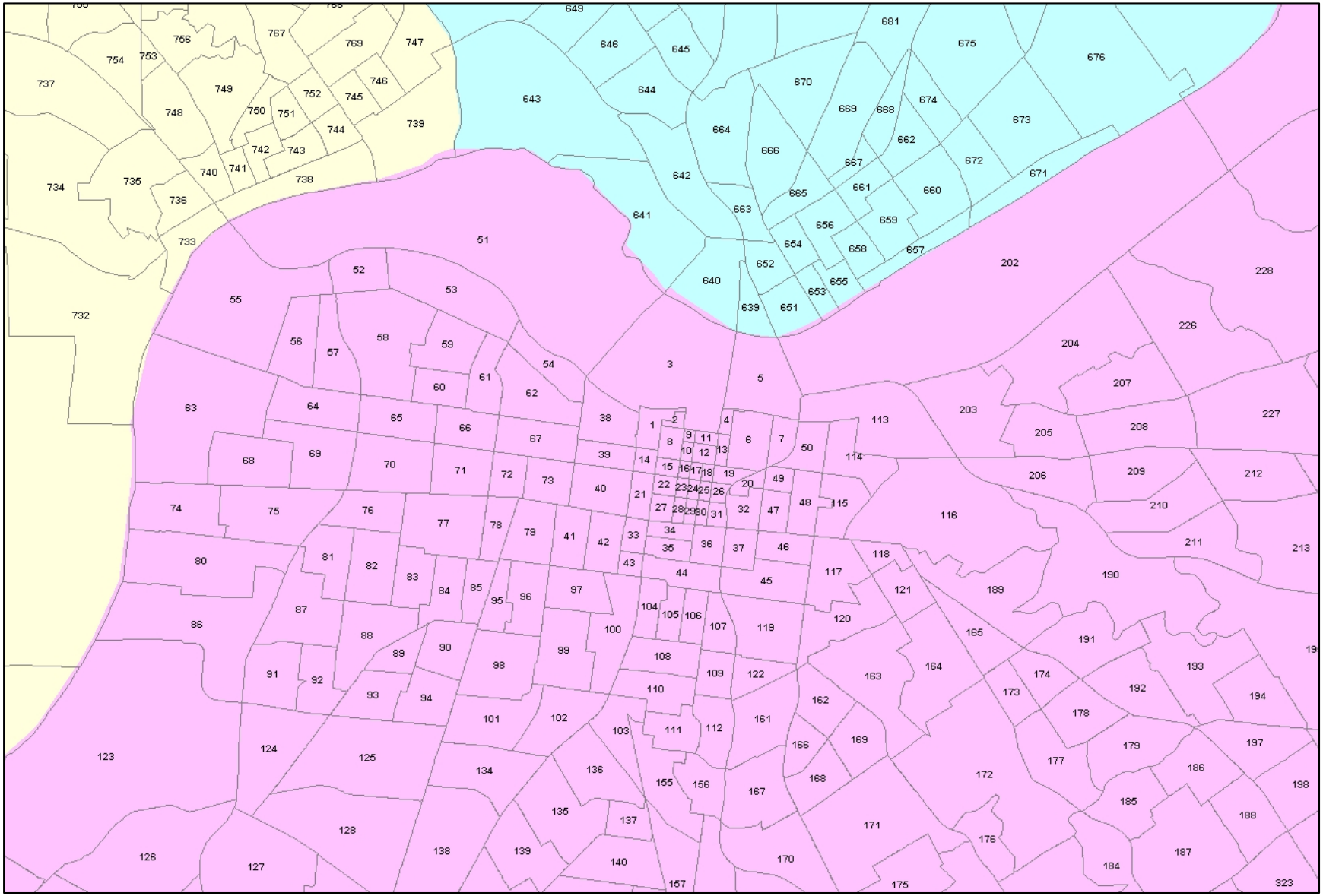


Figure 5-8: Map of 2007 Population Density

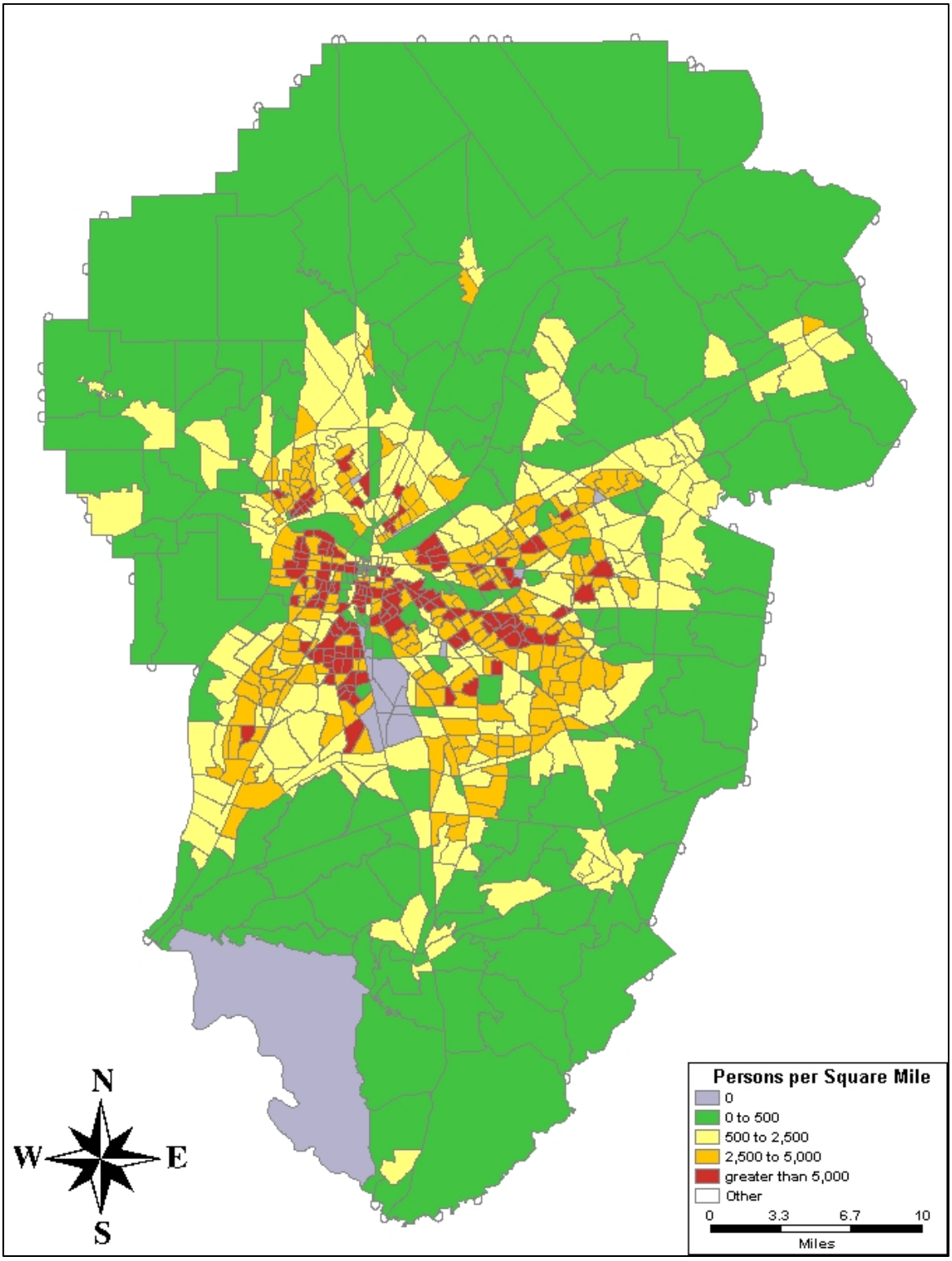


Figure 5-9: Map of 2007 Population Density in Downtown

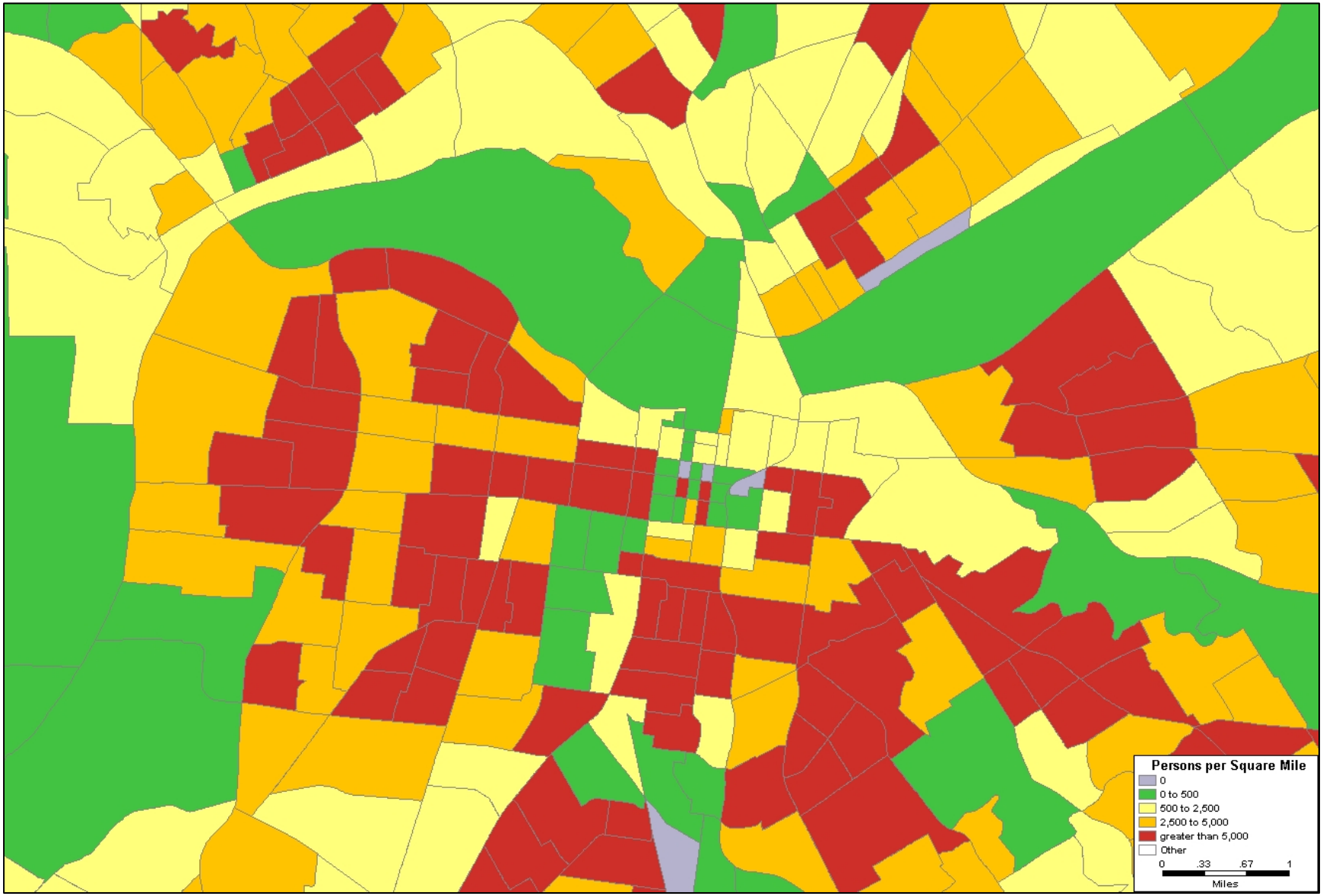


Figure 5-10: Map of 2007 Employment Density

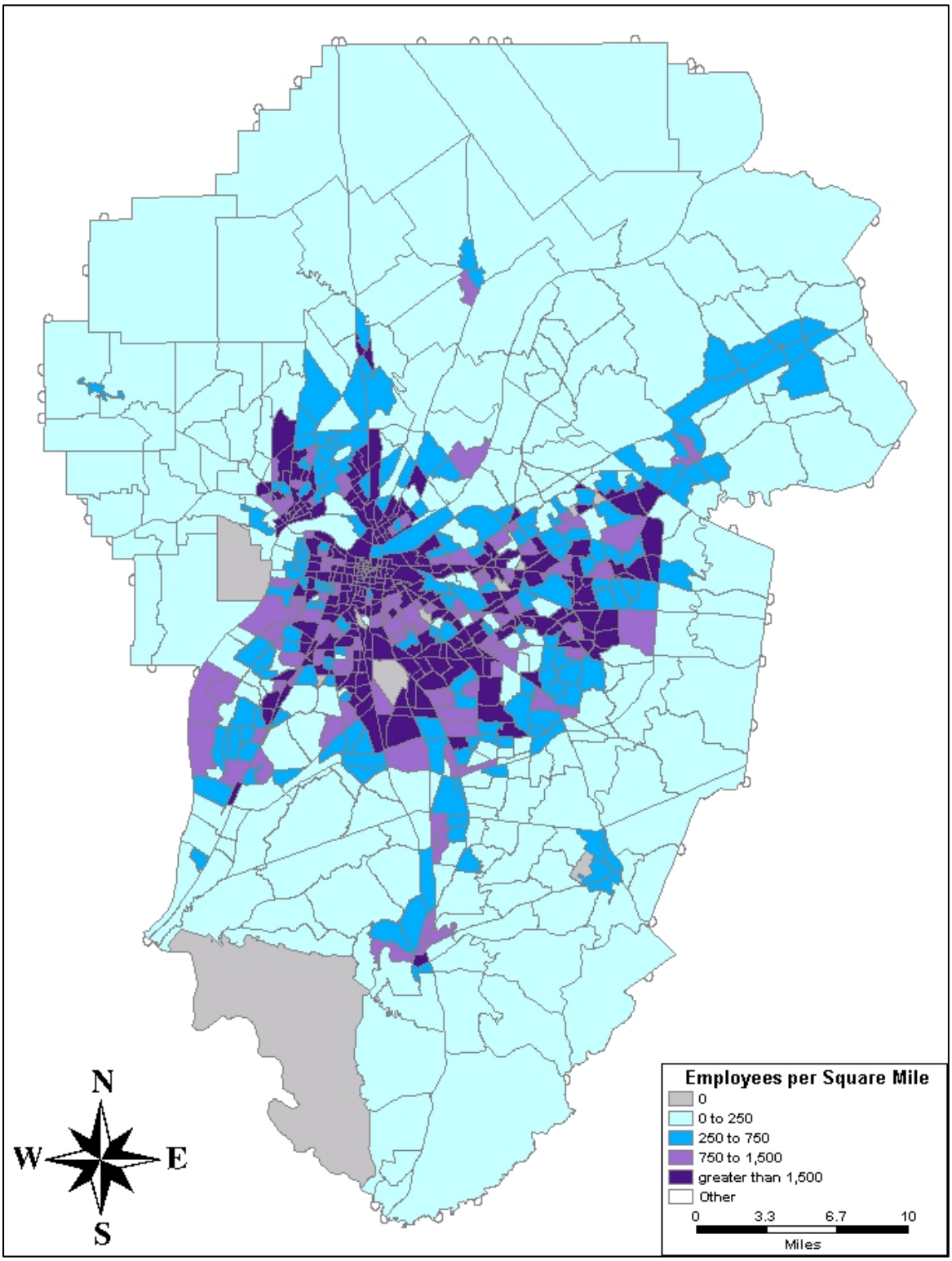


Figure 5-11: Map of 2007 Employment Density in Downtown

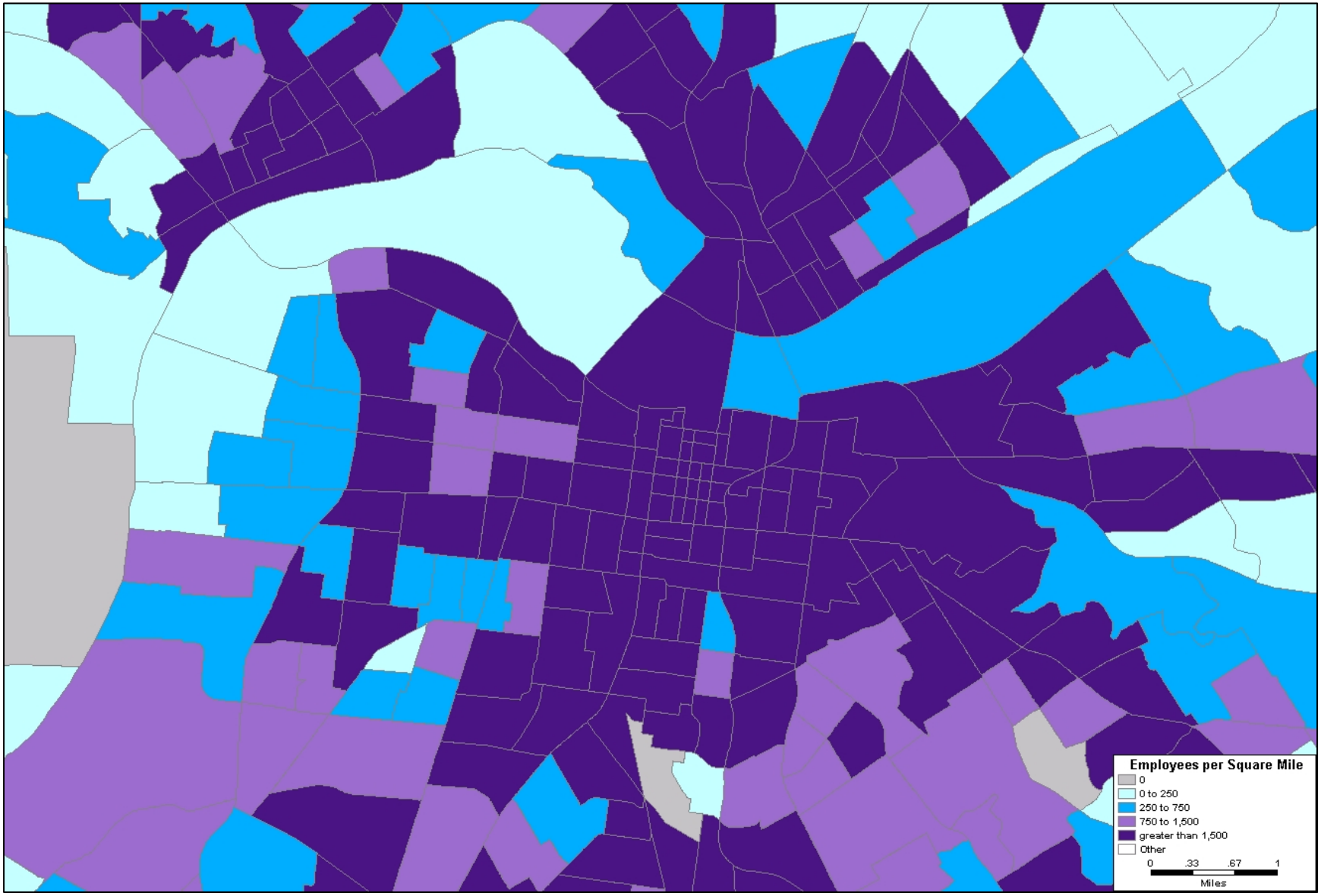


Figure 5-12: Map of Highway Network

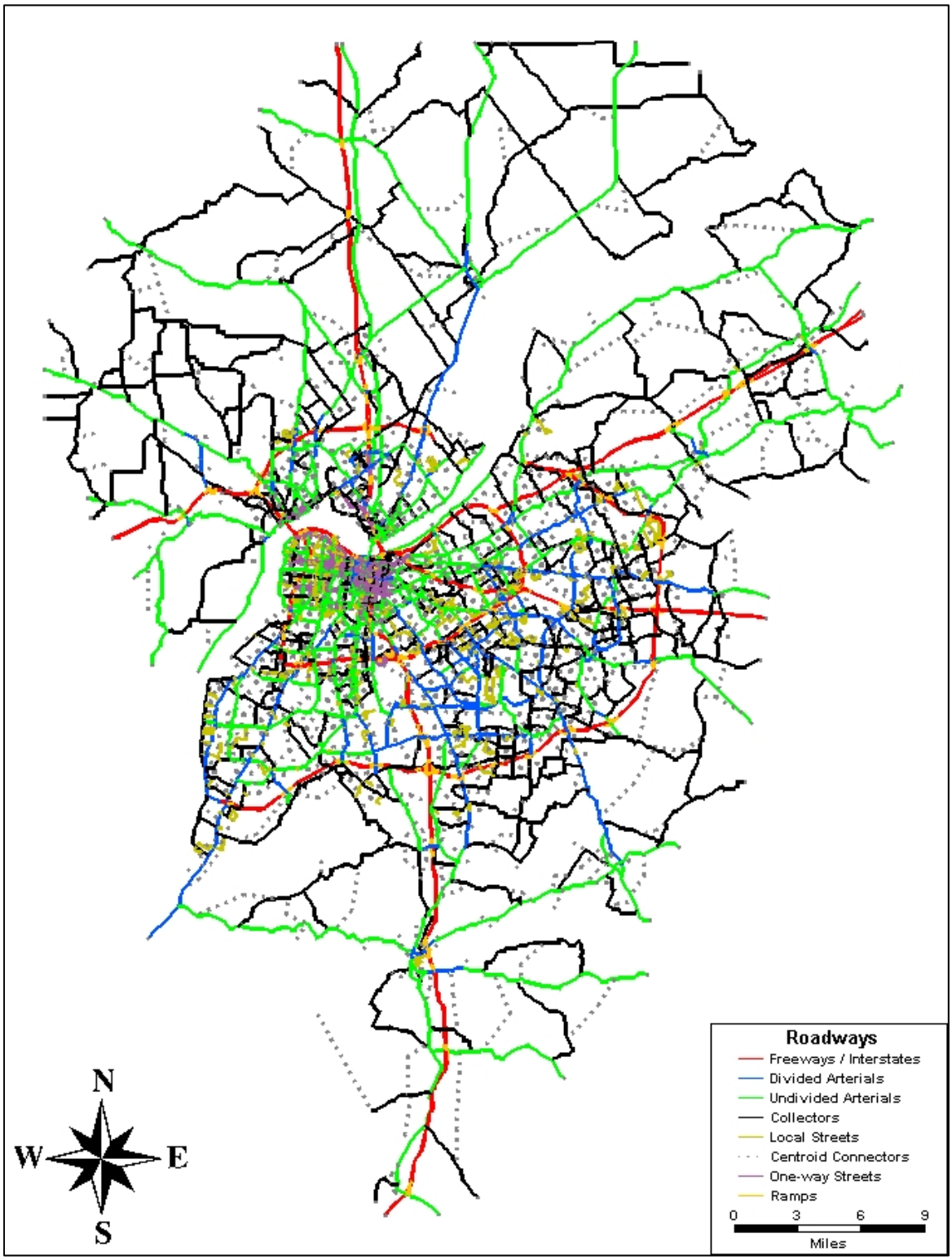


Figure 5-13: Map of Highway Network in Downtown

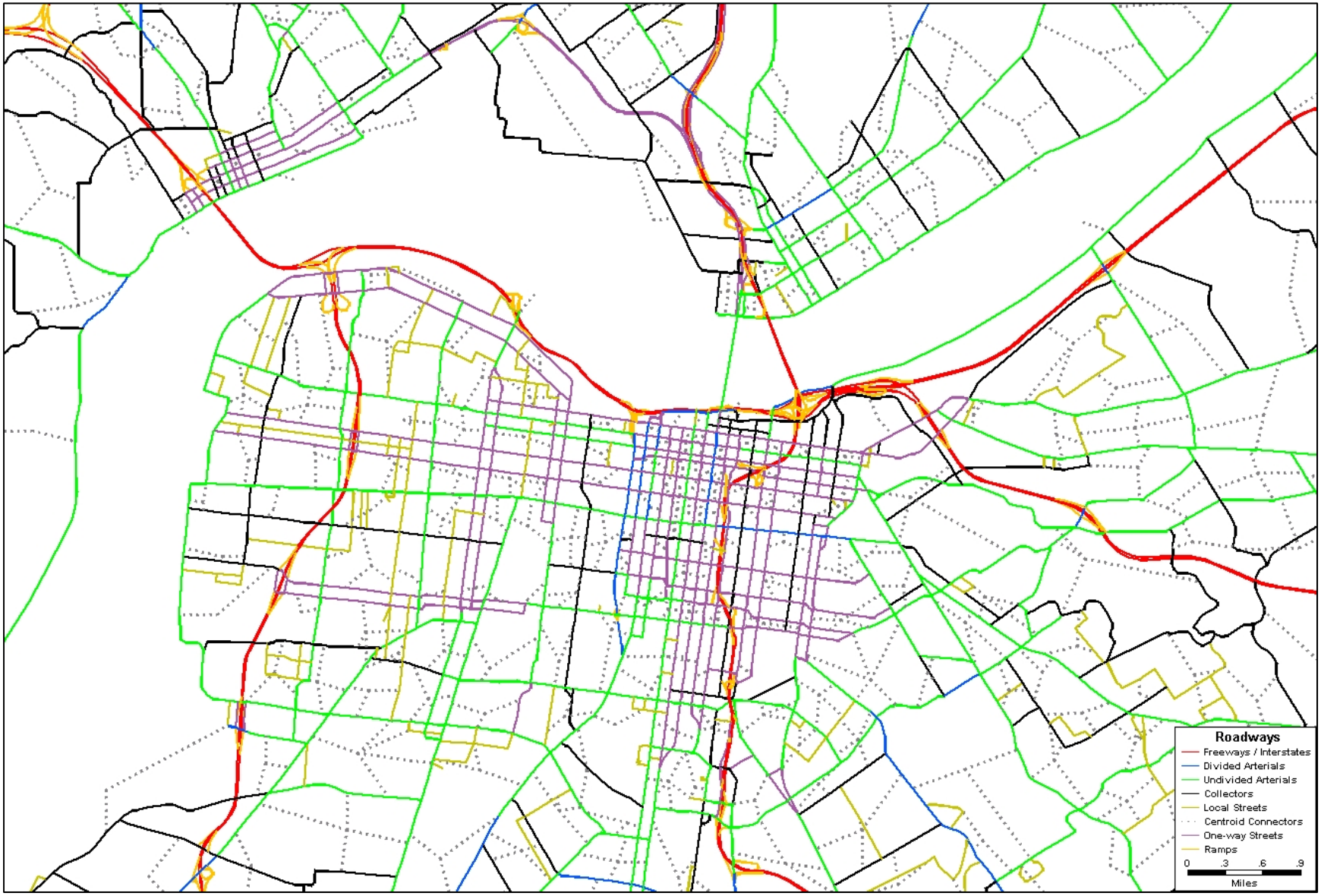


Table 5-3: Highway Network Input Attributes

Attribute	Definition
ID	Link identification number
Length	Length of link in miles
Dir	Directional code
Road_Name	Name of the road
AB_LANE	Number of lanes in the AB direction
BA_LANE	Number of lanes in the BA direction
AB_FACT	Facility type in the AB direction
BA_FACT	Facility type in the BA direction
AB_AREA	Area type in the AB direction
BA_AREA	Area type in the BA direction
AB_BRGHOV	Identifies an Ohio River Bridge link in the AB direction
BA_BRGHOV	Identifies an Ohio River Bridge link in the BA direction
FUNCL	Functional class
AB_FUNCL	Functional class in the AB direction
BA_FUNCL	Functional class in the BA direction
County	Name of the county in which link is found
AB_COUNT	Traffic count in the AB direction
BA_COUNT	Traffic count in the BA direction

Table 5-4: Highway Network Output Attributes

Attribute	Definition
AB_TermTime	Terminal time in minutes in the AB direction for a centroid connector
BA_TermTime	Terminal time in minutes in the BA direction for a centroid connector
AB_SPCA_CODE	Speed and capacity look-up index for the AB direction
BA_SPCA_CODE	Speed and capacity look-up index for the BA direction
AB_FFSPDCH	Look-up speed for the AB direction
BA_FFSPDCH	Look-up speed for the BA direction
AB_FFSPD	Free-flow speed in miles per hour for the AB direction
BA_FFSPD	Free-flow speed in miles per hour for the BA direction
AB_FFTIME	Free-flow travel time in minutes for the AB direction
BA_FFTIME	Free-flow travel time in minutes for the BA direction
AB_CAPDAYCH	Look-up capacity for the AB direction
BA_CAPDAYCH	Look-up capacity for the BA direction
AB_CAPDAY	Daily capacity for the AB direction
BA_CAPDAY	Daily capacity for the BA direction
AB_VOL_Int	Initial volumes in the AB direction
BA_VOL_Int	Initial volumes in the BA direction
Tot_VOL_Int	Total initial volumes
AB_TIME_Int	Initial congested travel time in minutes in the AB direction

Attribute	Definition
BA_TIME_Int	Initial congested travel time in minutes in the BA direction
Max_TIME_Int	Maximum initial congested travel time in minutes in either direction
AB_VOC_Int	Initial volume over capacity in the AB direction
BA_VOC_Int	Initial volume over capacity in the BA direction
Max_VOC_Int	Maximum initial volume over capacity in either direction
AB_SPD_Int	Initial congested speed in miles per hour in the AB direction
BA_SPD_Int	Initial congested speed in miles per hour in the BA direction
AB_VDF_Int	Initial result of the volume delay function in the AB direction
BA_VDF_Int	Initial result of the volume delay function in the BA direction
Max_VDF_Int	Maximum initial result of the volume delay function in either direction
AB_VOL_Fin	Final volumes in the AB direction
BA_VOL_Fin	Final volumes in the BA direction
Tot_VOL_Fin	Total final volumes
AB_TIME_Fin	Final congested travel time in minutes in the AB direction
BA_TIME_Fin	Final congested travel time in minutes in the BA direction
Max_TIME_Fin	Maximum final congested travel time in minutes in either direction
AB_VOC_Fin	Final volume over capacity in the AB direction
BA_VOC_Fin	Final volume over capacity in the BA direction
Max_VOC_Fin	Maximum final volume over capacity in either direction
AB_SPD_Fin	Final congested speed in miles per hour in the AB direction
BA_SPD_Fin	Final congested speed in miles per hour in the BA direction
AB_VDF_Fin	Final result of the volume delay function in the AB direction
BA_VDF_Fin	Final result of the volume delay function in the BA direction
Max_VDF_Fin	Maximum final result of the volume delay function in either direction
AB_VMT	Vehicle-miles-traveled in the AB direction
BA_VMT	Vehicle-miles-traveled in the BA direction
Tot_VMT	Total vehicle-miles-traveled
AB_VHT	Vehicle-hours-traveled in the AB direction
BA_VHT	Vehicle-hours-traveled in the BA direction
Tot_VHT	Total vehicle-hours-traveled
Tot_VMT_VHT_Ratio	Ratio of total vehicle-miles-traveled over total vehicle-hours-traveled

5.4 Transit Network Database

The transit network database used for the Phase II model was provided by KIPDA. KIPDA developed an initial transit network database to coincide with the 2007 base year model highway network that they developed for their current model update effort. The transit network database corresponds to a base year of 2007. WSA, working closely with the MPO staff, further enhanced the transit network database. These enhancements were focused on improving the correlation of the transit network to the highway network, validating transit stop locations, and including the attributes necessary to run a time-of-day mode choice model.

The Transit Authority for River City (TARC) is the agency responsible for providing public transportation in the Louisville area. The TARC system is comprised of approximately 50 routes with a mix of service including local and express bus routes. These routes have been entered into a database for use in the Phase II model.

An initial review of the transit network database revealed a number of locations where the transit routes did not coincide with the underlying highway network. These route segments were realigned to conform to existing highway network links.

The following attributes are used by the transit route system database:

- Route_ID: transit route ID number used by the model
- Route_Name: name of the transit route
- Route_Number:
- Run_Number:
- [AM Headway]: AM period headway in minutes
- [MD Headway]: MD period headway in minutes
- [PM Headway]: PM period headway in minutes
- [NT Headway]: NT period headway in minutes
- Fare: price to board the transit system in dollars
- [Transfer Cost]: price to transfer from one transit route to another in dollars
- Mode: identifies the mode of the route
- [Service time]: time it takes for the route to complete one run from beginning to end

Figure 5-14 shows the TARC transit system throughout the model area. Figure 5-15 shows a detail of the transit system in downtown.

Figure 5-14: Map of TARC Transit System

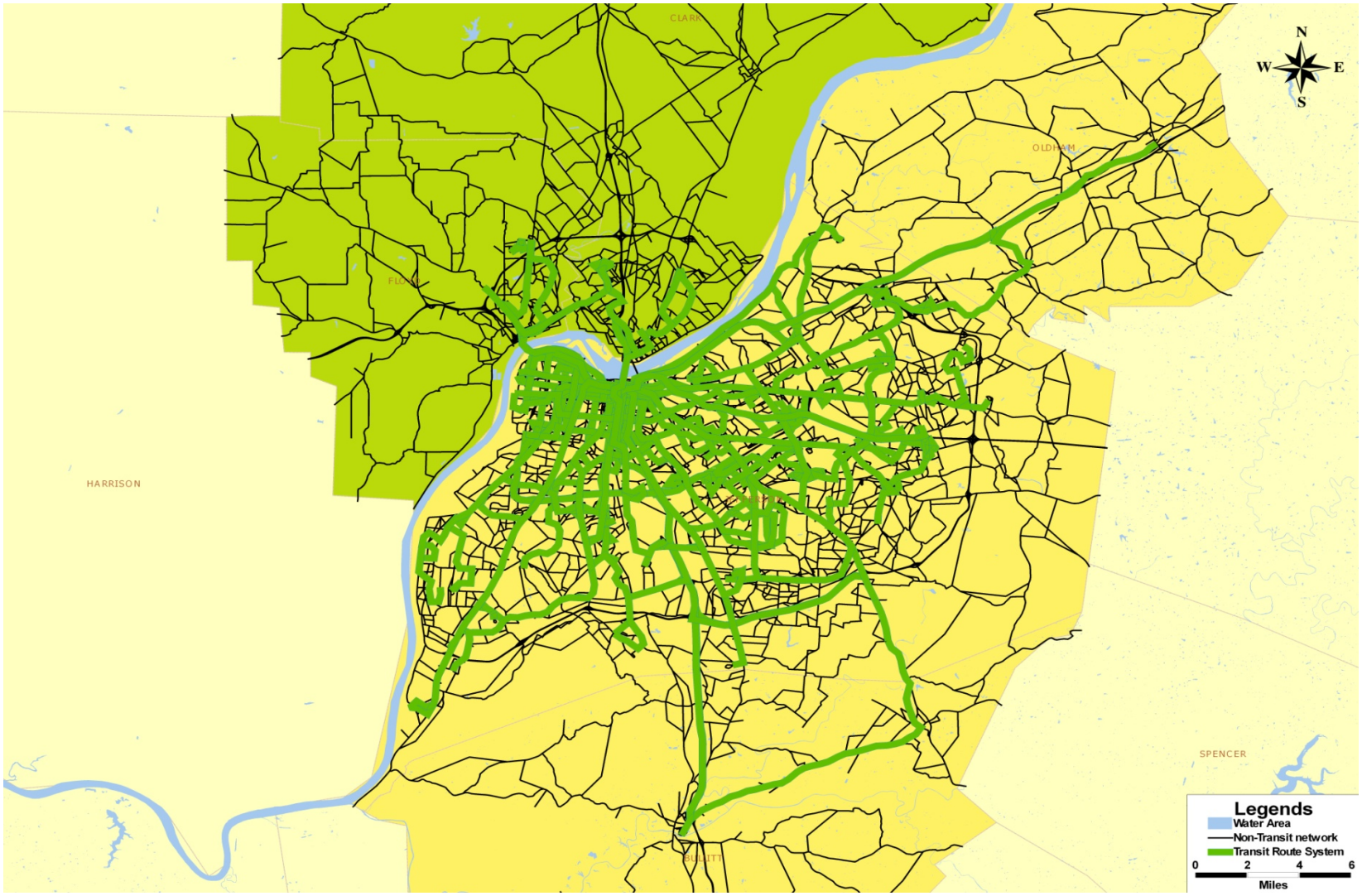
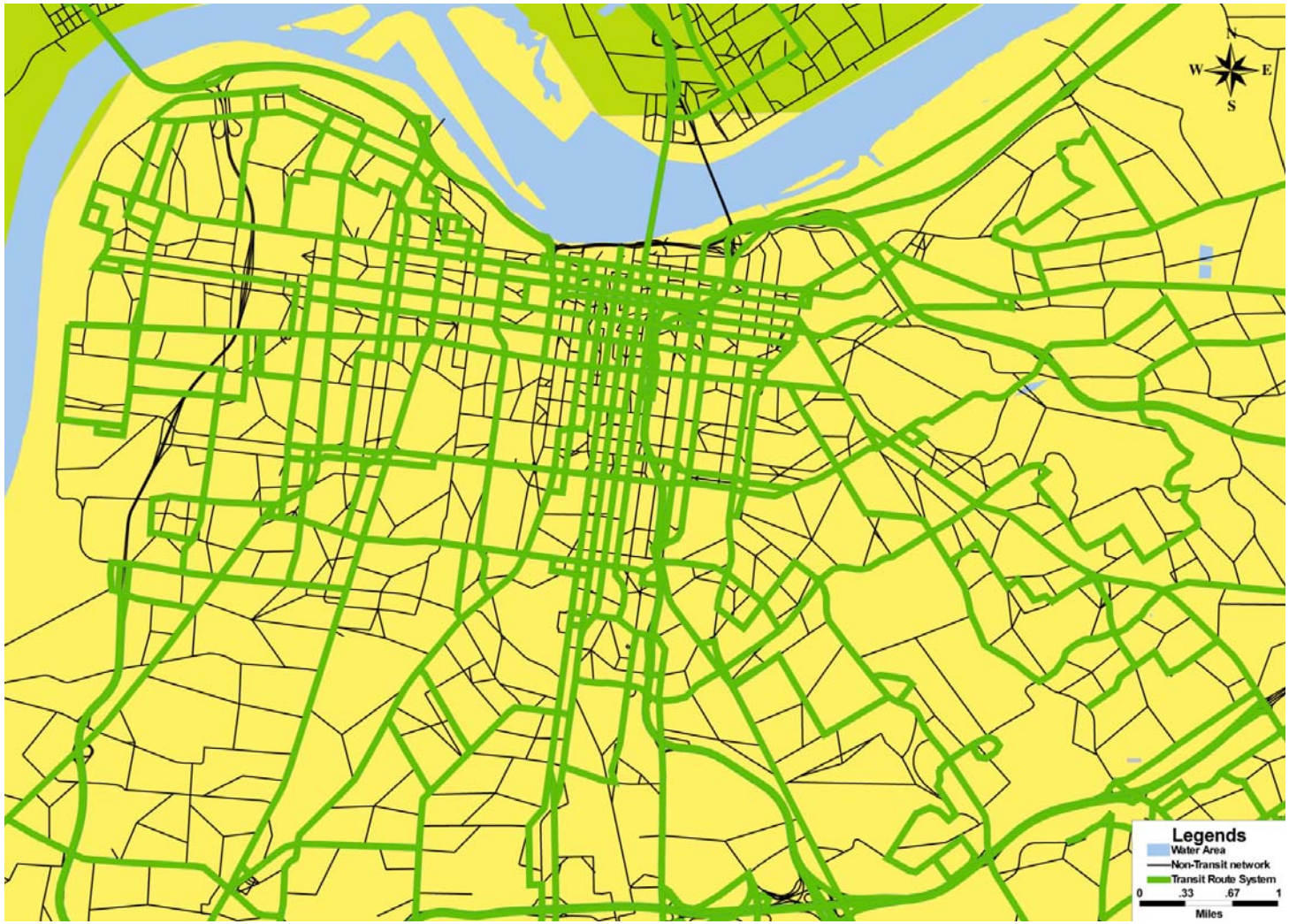


Figure 5-15: Map of TARC Transit System in Downtown



5.5 Traffic Count Database

A central traffic count database was created. This database was designed so that traffic count data for the modeling area could be stored in single database. Since the model area covers portions of two different states, traffic counts were acquired from both the Indiana Department of Transportation and the Kentucky Transportation Cabinet. This effort was part of the data collection process discussed in Chapter 4 of this report. These counts were placed onto a single database that was also a TransCAD point geographic file.

Figures 5-16 and 5-17 show the traffic count locations in the database color coded by the amount of daily traffic recorded at each station.

This point file was developed to allow for the traffic counts to be transferred onto any highway network geographic file as needed. A separate point was developed for each count location. For traffic count stations at locations corresponding to dualized lane coding (e.g. interstate highways), two separate points were created, one for each direction. As a result, some traffic count stations are represented by multiple points. This is the reason why there are more records in the database than there are traffic count locations. For points representing separate directions of the same traffic count station, a directional code as been incorporated into the station's identification number to make this clear.

Though the Phase II model's base year is 2007, not all of the traffic counts entered into this database were available for 2007. The collection years for the counts at each station range from various years to 2010. Some of the Indiana traffic counts were available in 2007. Traffic counts collected in Jefferson County, Kentucky were collected primarily in either 2007 or 2008. Traffic counts collected in Bullitt and Oldham Counties, Kentucky were collected in years ranging from 2008 to 2010, though some older counts exist as well. During the Phase II development process, all counts will be factored to a 2007 equivalent. A methodology will be developed that looks at historical count data and countywide growth rates to factor traffic counts back to 2007 conditions for those stations with post-2007 counts.

Figures 5-18 and 5-19 show the traffic count locations by year of data collected.

Each point has associated with it daily traffic counts and, where available, hourly traffic counts. Hourly traffic counts will be used to create period traffic counts. These period traffic counts will be used to assist with the validation of the time-of-day component of the Phase II model. Not all traffic count stations have hourly count data and the ones that do are primarily on the Kentucky side of the model. Truck counts are also available at some locations.

Figures 5-20 and 5-21 show the count stations for which hourly data are available.

In order to allow for accurate tagging of count data from the traffic count database, a unique identification number was developed. Each point has a specific ID number that is composed of three parts with each part separated by a hyphen. The identification number has the following form:

XX-XXXXXXX-XX

Figure 5-16: Map of Traffic Count Locations by Daily Traffic Counts

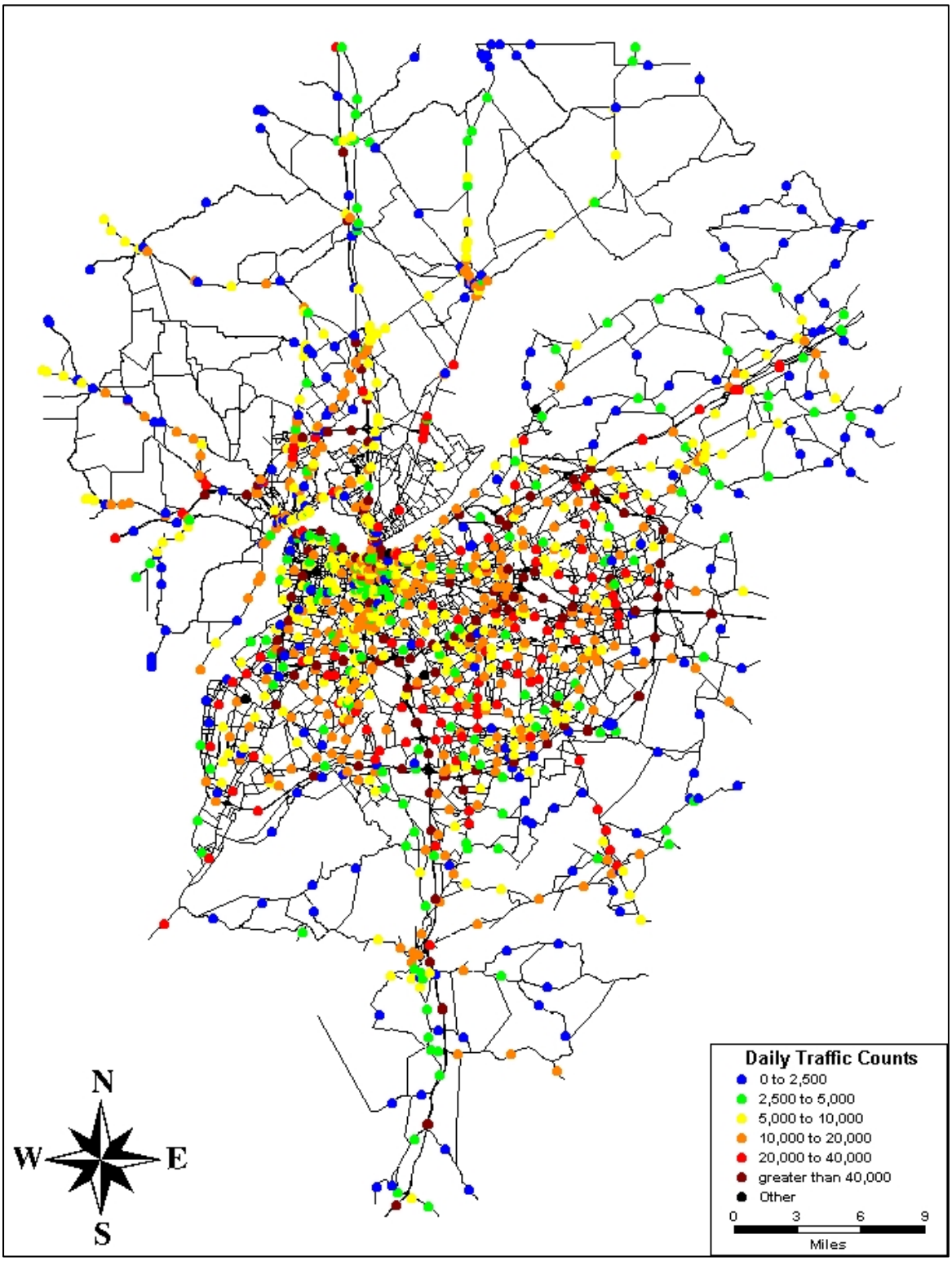


Figure 5-17: Map of Traffic Count Locations by Daily Traffic Counts in Downtown

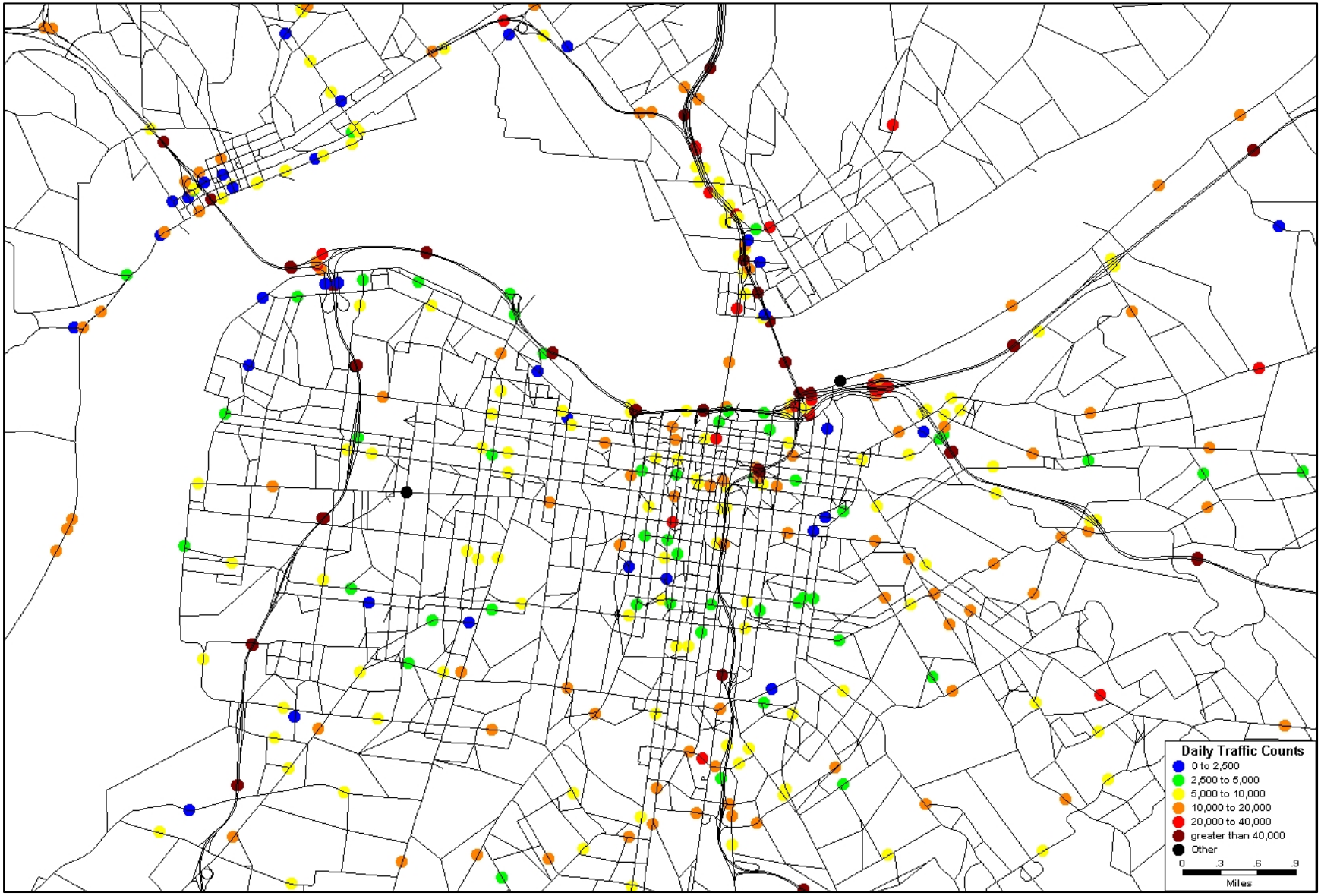


Figure 5-18: Map of Traffic Count Stations by Year of Count

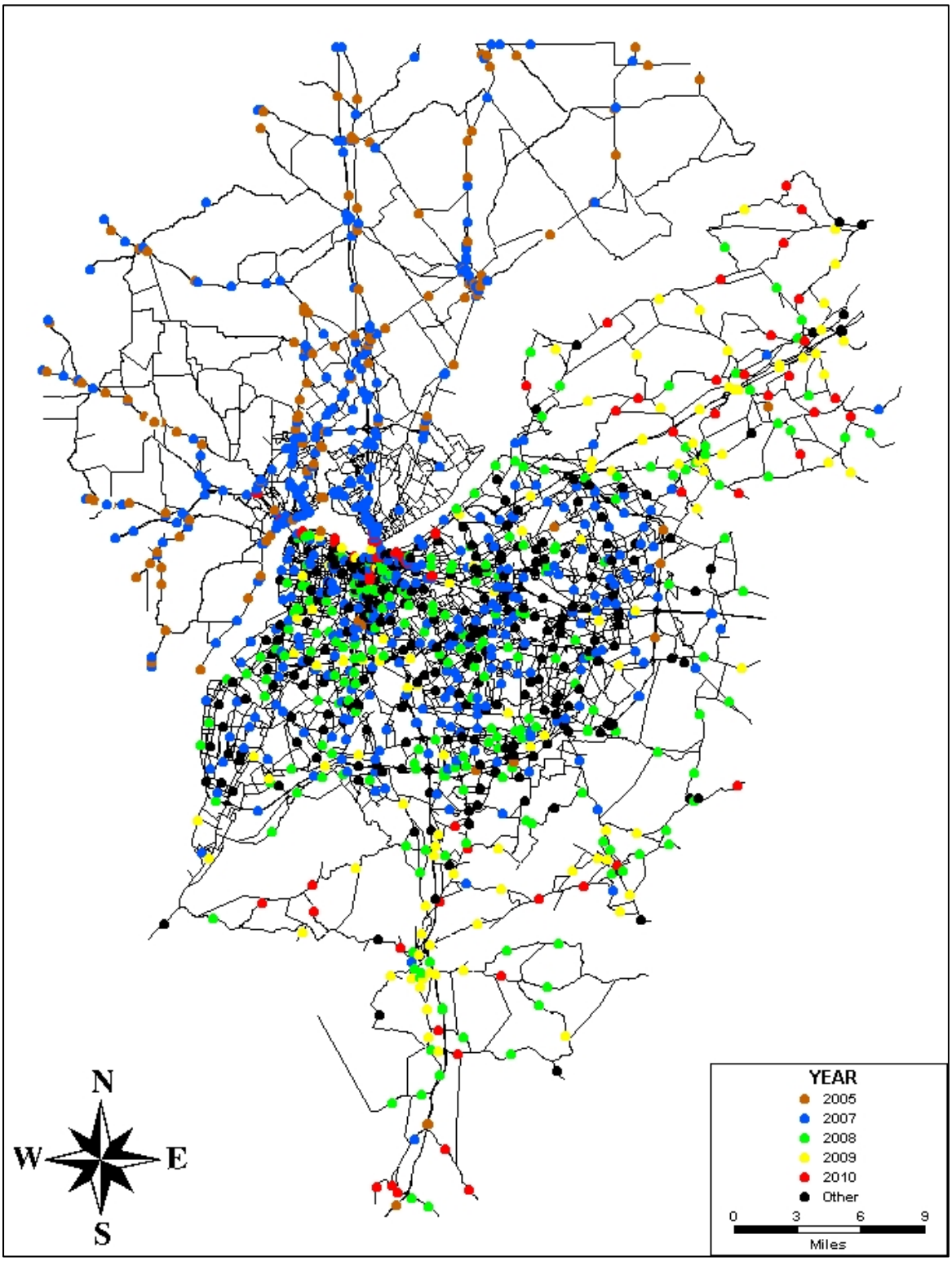


Figure 5-19: Map of Traffic Count Stations by Year of Count in Downtown

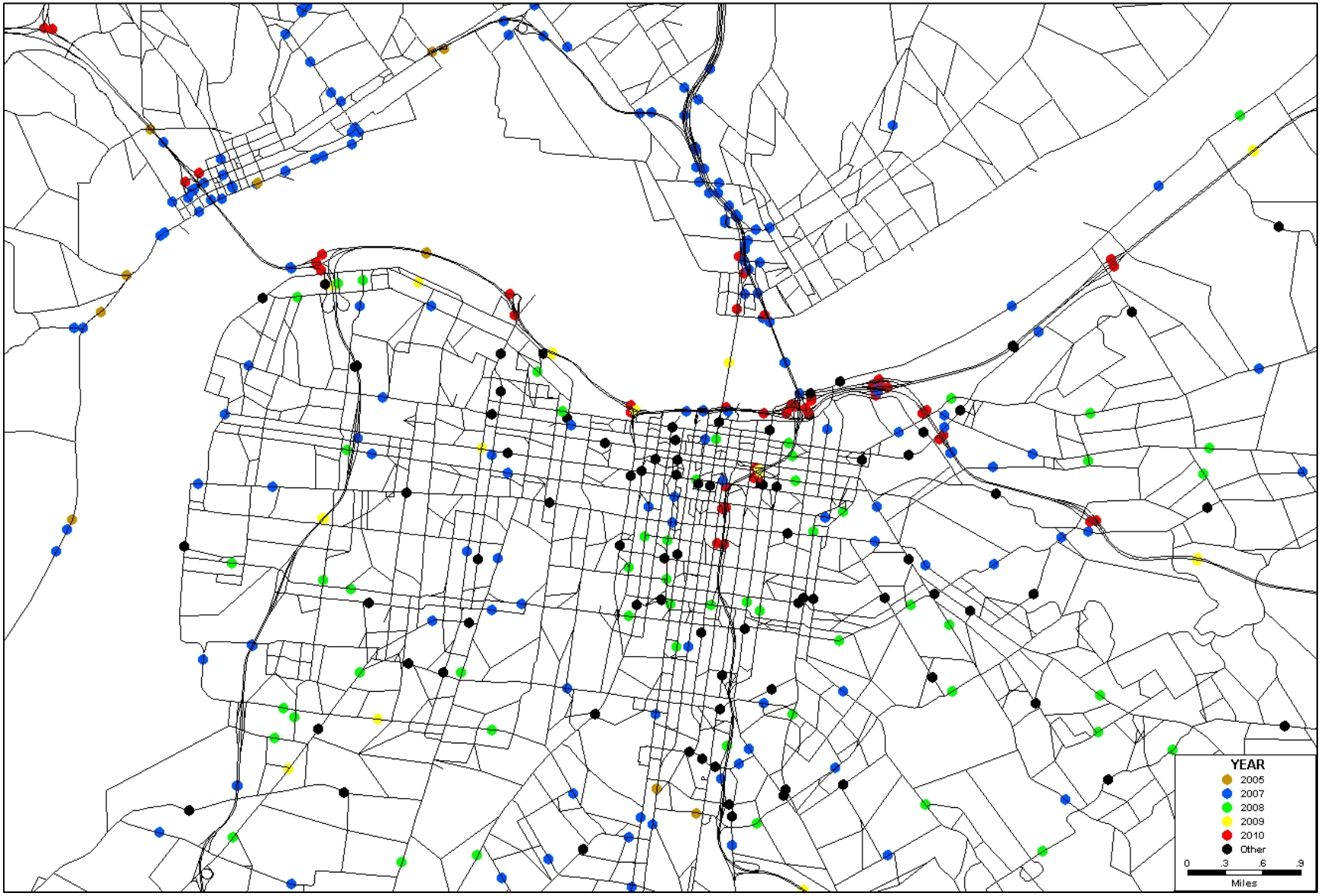


Figure 5-20: Map of Count Stations with Hourly Count Data

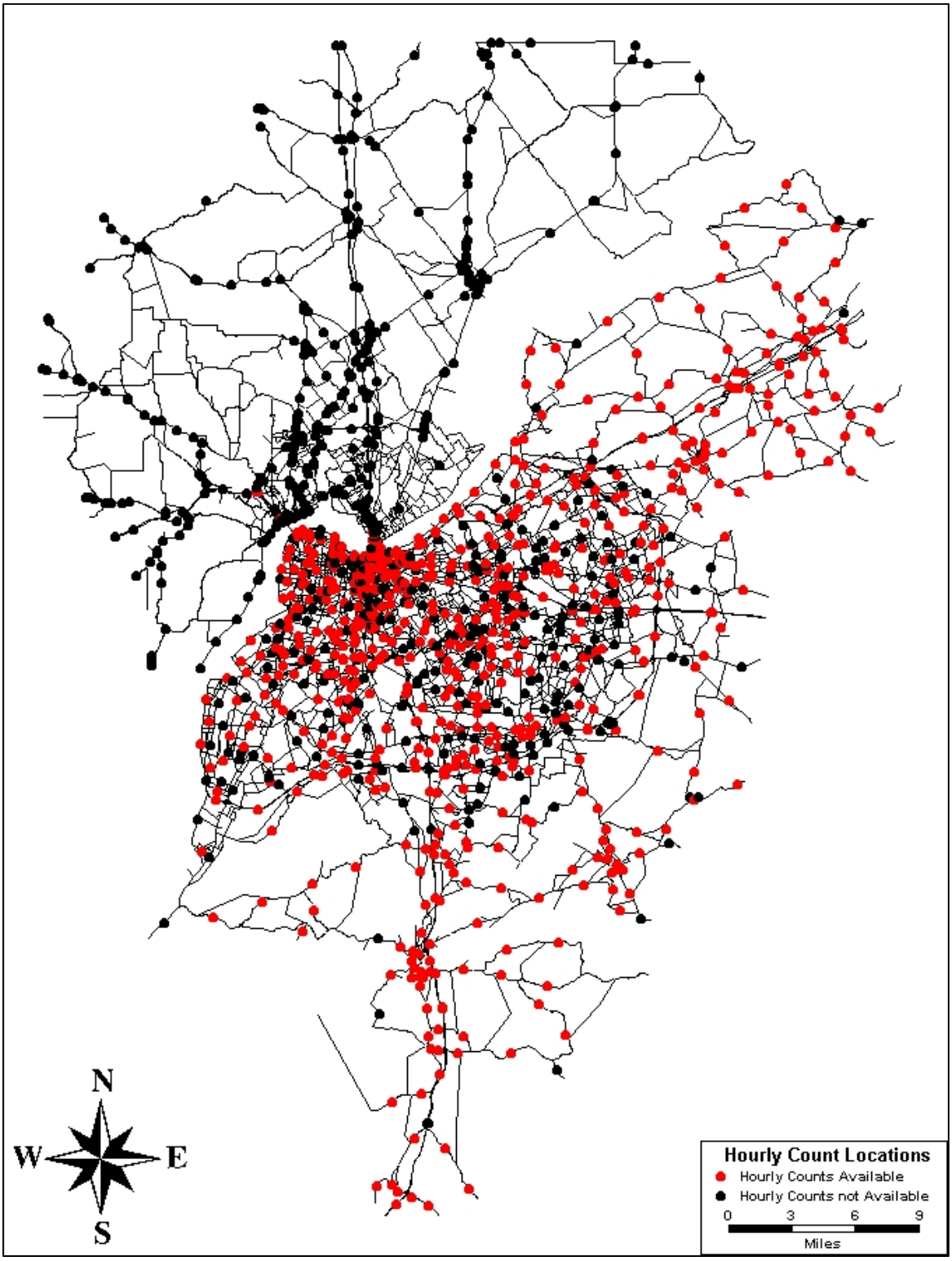
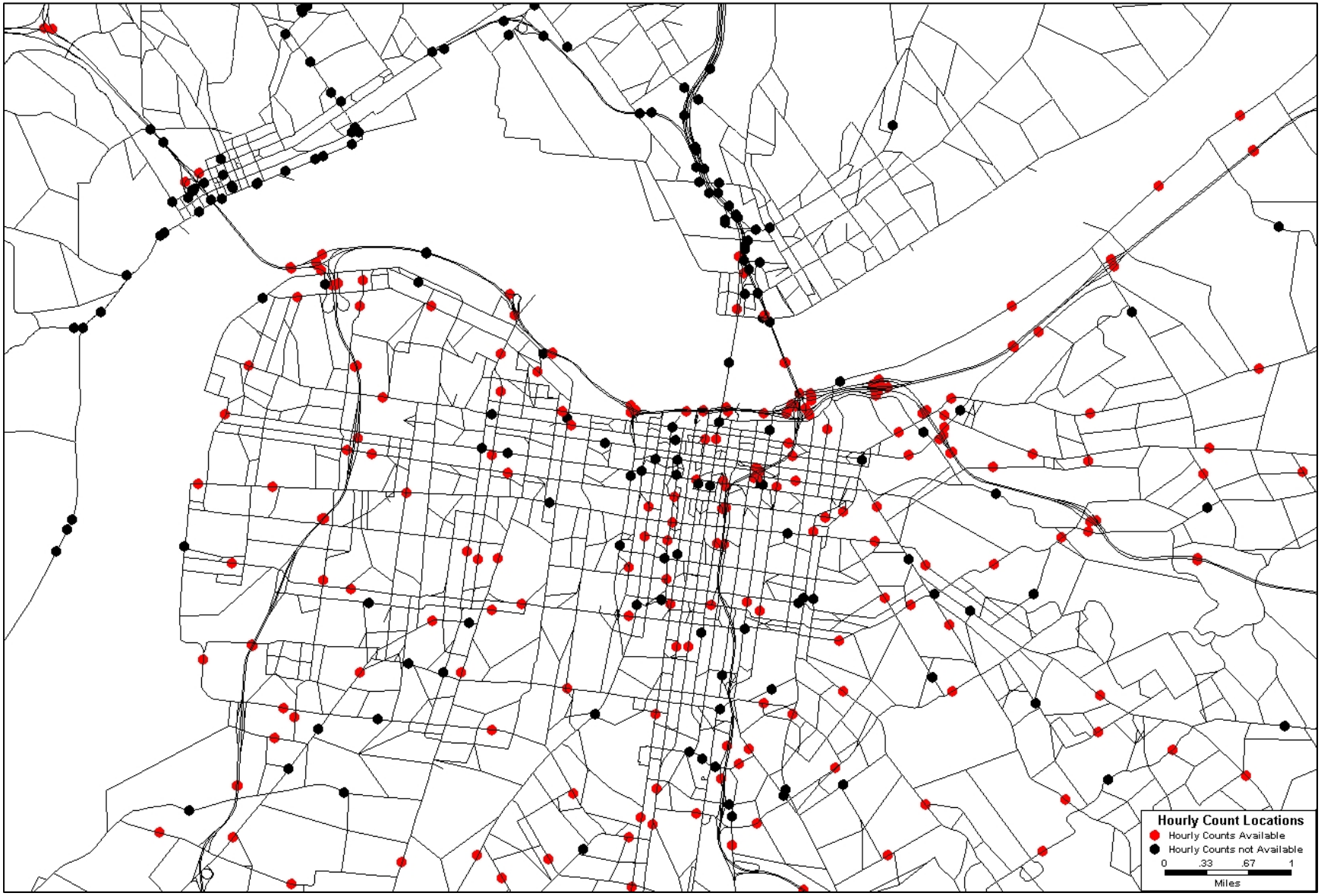


Figure 5-21: Map of Count Stations with Hourly Count Data in Downtown



The first portion designates the state that the count location is in. This portion is composed of the two character postal abbreviation for each state in the model area: IN for Indiana and KY for Kentucky.

The second portion is either six characters long for Kentucky traffic count stations or nine characters long for Indiana traffic count stations. The nine character code for Indiana stations is a route segment identification number corresponding to the location of the traffic count. The six character code for Kentucky is a combination of the first three characters corresponding to a county FIPS code for each of the three Kentucky counties in the model and the second three characters corresponding to a traffic count station identification number.

The last portion, consisting of two characters is not present on every station. These two characters correspond to the direction of traffic flow and are used for traffic count locations where the highway network links are coded as a set of parallel one-way links for each direction. The characters are NB, SB, EB, or WB for Northbound, Southbound, Eastbound, and Westbound respectively.

5.6 Intersection Database

There is an issue in the current KIPDA travel demand model that will have an impact on the LSIORB Phase II model. During highway assignment, trips are avoiding certain interchange movements particularly in the area corresponding to downtown Louisville. This behavior arises from a lesser impedance in the model on downtown surface streets. This is most likely due to the model not adequately accounting for travel delay encountered in the area. To overcome this issue and to provide more accurate highway assignments, the Phase II LSIORB model will include delay adjustments based on the location of signalized intersections in the model.

A database of traffic signal locations was compiled for the Phase II model. These traffic signals were correlated to specific highway network nodes. During Phase II model development, the highway links corresponding to the intersection approaches will be manually coded to account for such intersection data as cycle length and green time. This information will then be used to calculate the appropriate modifications to delay for each traffic link. The database currently contains information on 1,119 signals in the model area.

Figures 5-22 and 5-23 show a map of signal locations throughout the model area.

The database has been developed to allow for different cycle lengths by time-of-period. Since detailed knowledge of signal timings can only be derived from a thorough examination of the signal timing plans and because such an effort would not be feasible under the scope of this effort, the information concerning cycle lengths entered into the database has been generalized from basic assumptions about the local transportation system. All cycle lengths are currently coded in the same way for each period with the exception of slight changes in the evening peak periods to some of the signals. During the Phase II development effort, these timings may be modified as needed.

Figure 5-22: Map of Signal Locations

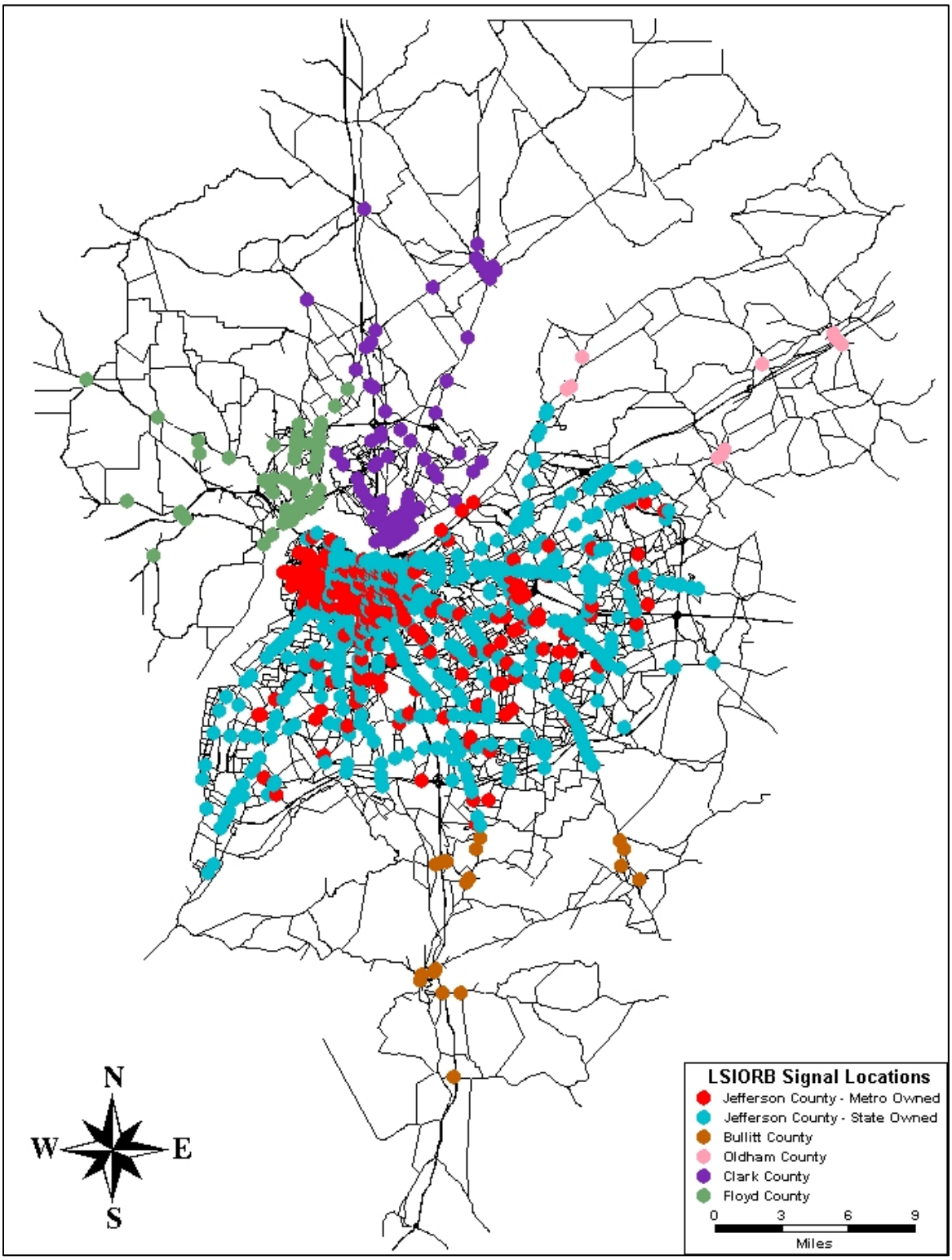
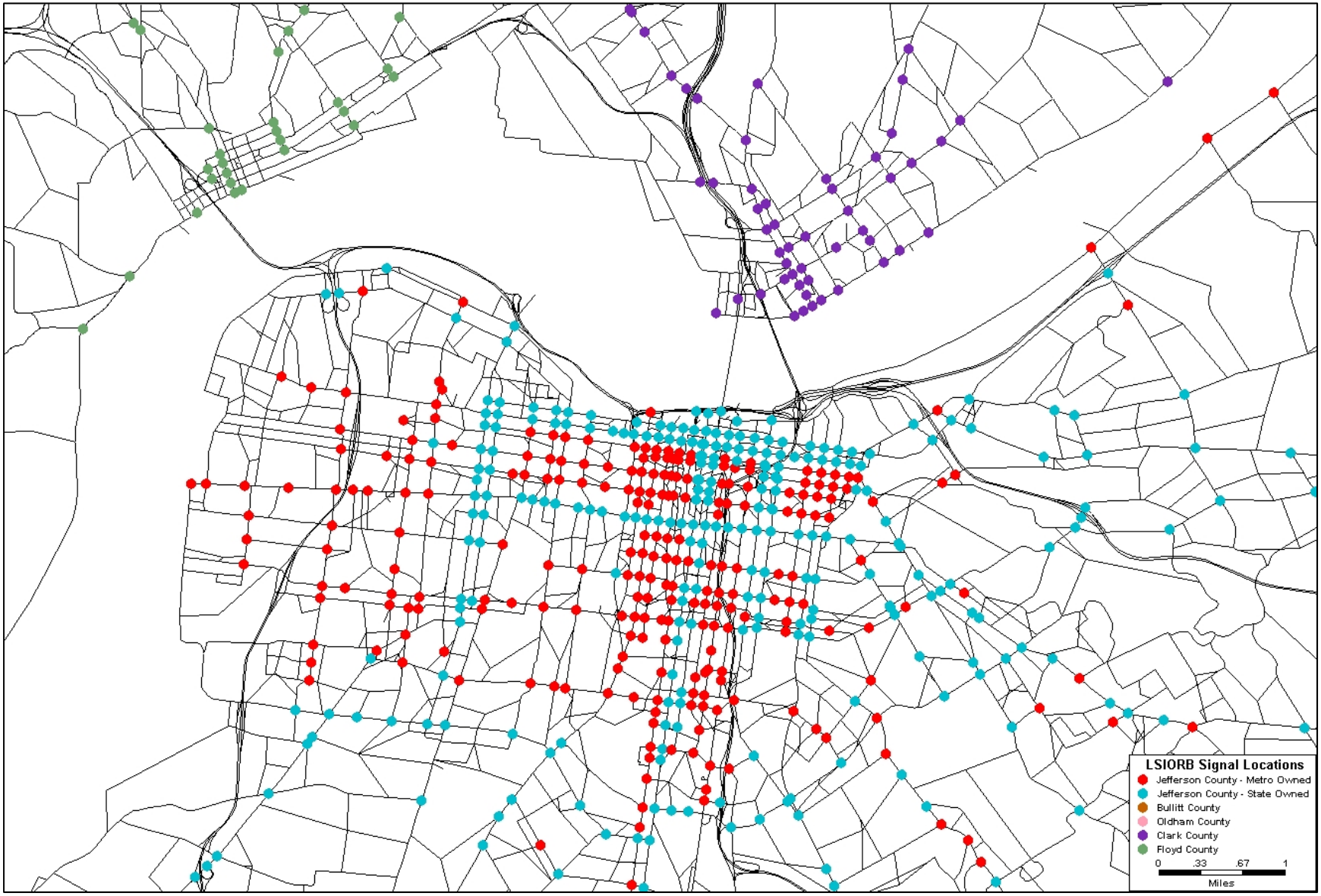


Figure 5-23: Map of Signal Locations in Downtown



Figures 5-24 and 5-25 show the maps for signal cycle lengths.

The current database contains the following attributes of note:

- Signal_ID: a unique identification number for each signal taking either the form of:
  - CC_XXX for Kentucky intersections where CC is a county identifier and XXX is a signal identifier of up to three characters; or,
  - CC_XX-XXX-XXX for Indiana intersections where CC is a county identifier and XX-XXX-XXX is an identifier of up to two characters followed by a hyphen followed by three characters followed by a hyphen followed by three characters.
- PHASES: number of phases in a cycle
- AM_CYCLE_L: cycle length in seconds for the AM period
- MD_CYCLE_L: cycle length in seconds for the MD period
- PM_CYCLE_L: cycle length in seconds for the PM period
- NT_CYCLE_L: cycle length in seconds for the NT period

Table 5-5 shows the various sources of traffic signal data collected for the database and gives a few brief notes on the data collected from each source.

Table 5-5: Sources of Traffic Signal Data

Source	Location	Notes
KYTC/District 5	Bullitt and Oldham Counties	signal locations, not geo-coded, no cycle lengths
Louisville Metro Govt., Department of Public Works	Jefferson County	signal locations, lat-long coordinates, some cycle lengths
Indiana DOT	Clark and Floyd Counties	signal locations, cycle lengths
KIPDA	Clark and Floyd Counties	supplemental signal locations, no cycle lengths

Figure 5-24: Map of Cycle Lengths

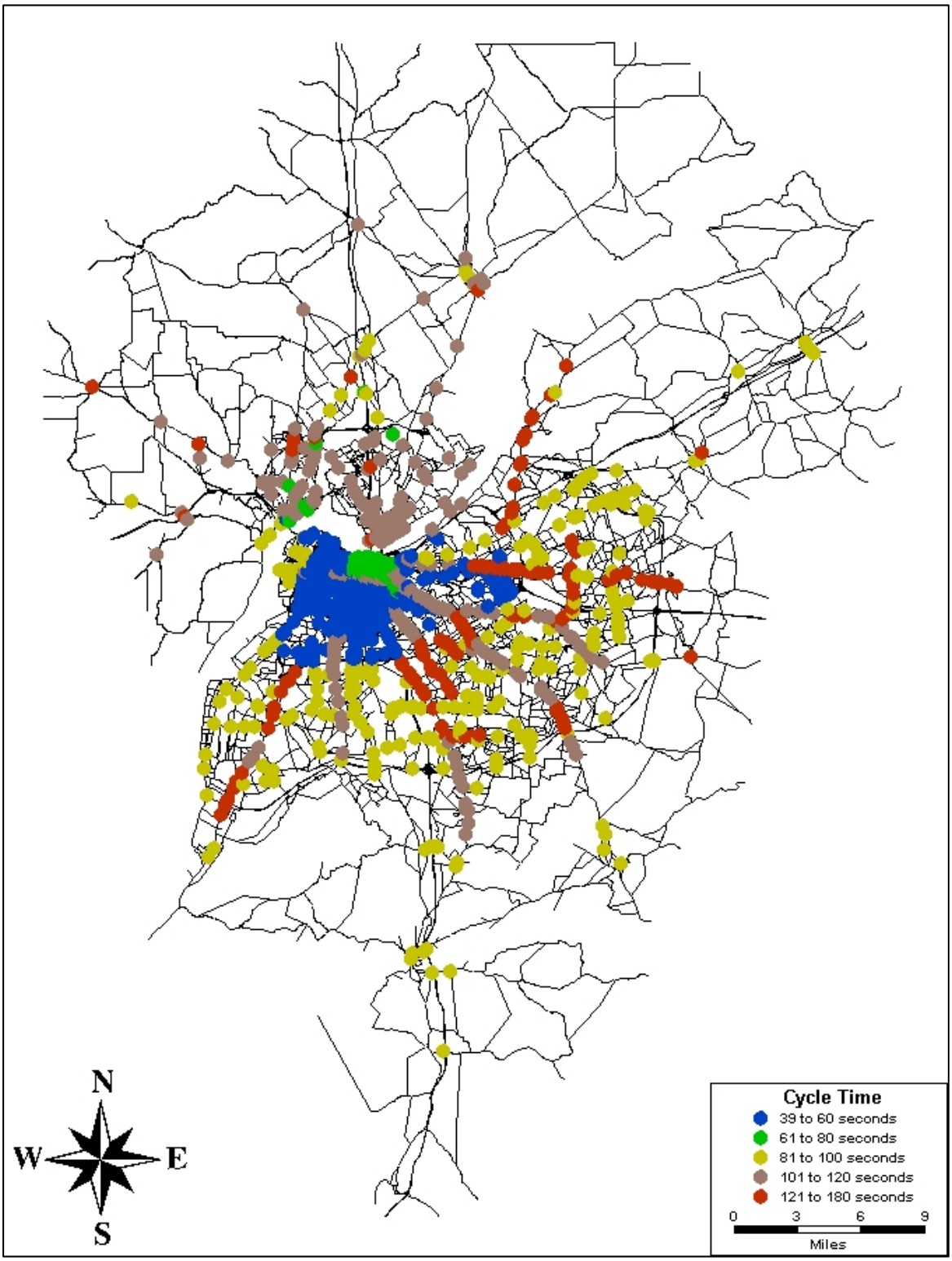
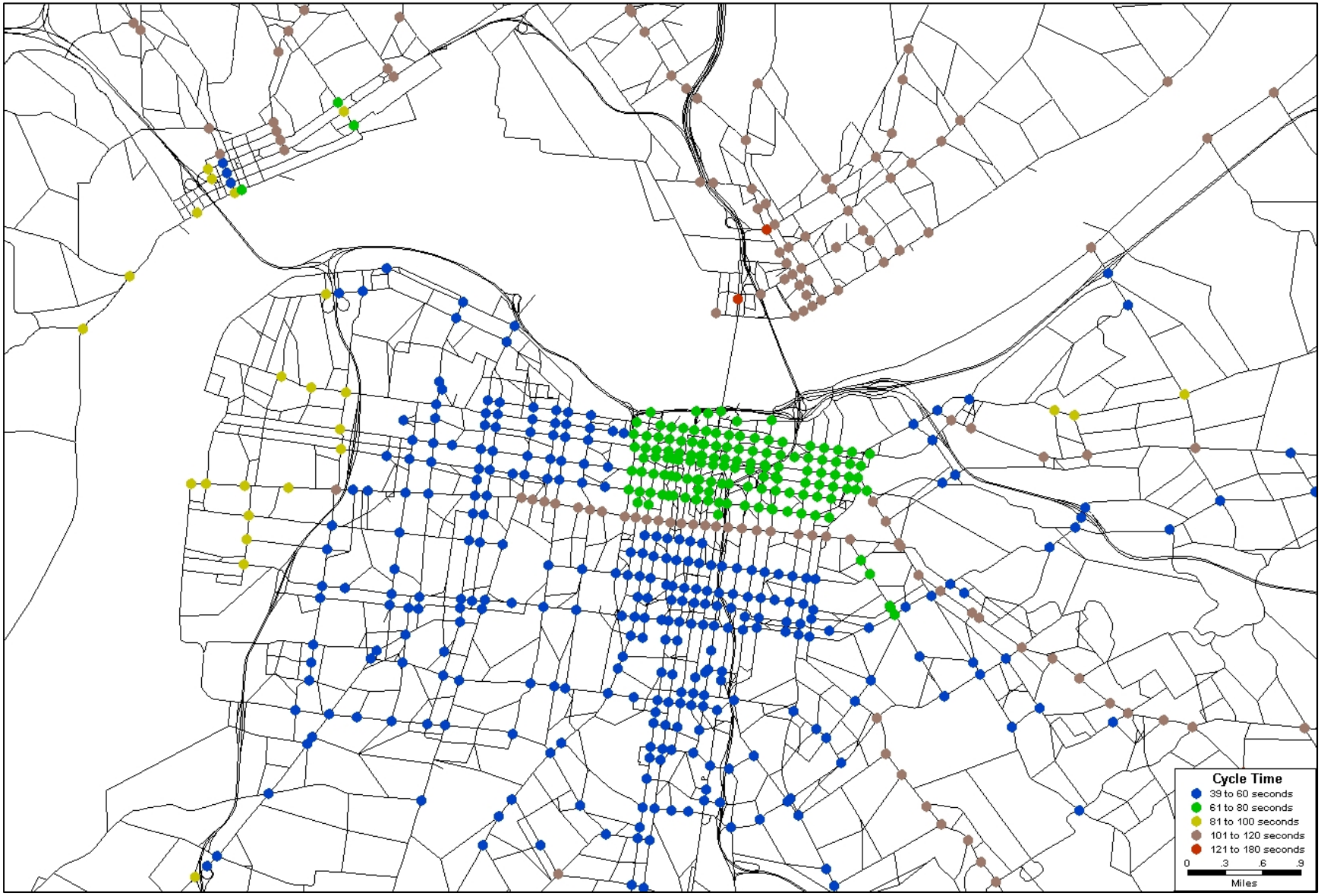


Figure 5-25: Map of Cycle Lengths in Downtown



Appendix A

KYTC Counts Summary Table

Station	Route	County	RSEUnique	MP	12-1AM	1-2AM	2-3AM	3-4AM	4-5AM	5-6AM	6-7AM	7-8AM	8-9AM	9-10AM	10-11AM	11-12PM	12-1PM	1-2PM	2-3PM	3-4PM	4-5PM	5-6PM	6-7PM	7-8PM	8-9PM	9-10PM	10-11PM	11-12AM	Monthly	Axle	Date
836	CS5036	Bullitt	015-CS-5036	0.6	59	31	28	27	39	70	131	248	214	267	296	332	429	426	416	467	540	603	541	435	414	324	194	113	99	100	2010
753	I0065 - NB LANE 1	Bullitt	015-I - 0065	116.0	273	222	182	232	310	495	902	1094	934	789	753	798	804	802	822	1017	938	958	774	616	541	475	408	377	98	100	2008
753	I0065 - NB LANE 3	Bullitt	015-I - 0065	116.0	36	23	18	25	63	240	777	888	636	476	366	420	477	476	484	568	590	551	386	219	191	138	109	75	98	100	2008
753	I0065 - SB LANE 1	Bullitt	015-I - 0065	116.0	62	43	27	34	43	86	202	350	389	375	415	406	406	425	594	777	961	1013	556	323	290	263	148	106	98	100	2008
753	I0065 - SB LANE 2	Bullitt	015-I - 0065	116.0	291	215	181	194	232	325	537	691	786	776	812	827	818	831	927	1014	1088	1058	831	652	633	578	464	382	98	100	2008
753	I0065 - SB LANE 3	Bullitt	015-I - 0065	116.0	278	217	175	167	196	337	681	682	763	690	712	753	788	829	1013	1046	1135	1179	933	739	711	616	509	370	98	100	2008
753	I0065 -NB LANE 2	Bullitt	015-I - 0065	116.0	221	169	152	181	306	579	954	1089	1000	885	837	840	886	879	855	934	965	927	805	597	561	488	400	332	98	100	2008
762	I0065 - NB LANE 1	Bullitt	015-I - 0065	113.0	217	160	144	182	247	387	605	652	611	575	541	544	550	568	560	559	582	577	502	431	390	382	323	269	98	100	2008
762	I0065 - NB LANE 2	Bullitt	015-I - 0065	113.0	213	174	157	169	267	509	946	1021	913	808	771	747	826	811	825	866	907	863	770	560	522	454	398	299	98	100	2008
762	I0065 - NB LANE 3	Bullitt	015-I - 0065	113.0	33	16	19	22	50	195	675	769	581	449	348	387	429	455	469	536	562	528	389	238	179	156	116	83	98	100	2008
762	I0065 - SB LANE 1	Bullitt	015-I - 0065	113.0	57	34	24	32	32	65	174	297	350	320	347	351	336	347	455	561	696	724	432	243	216	193	134	101	98	100	2008
762	I0065 - SB LANE 2	Bullitt	015-I - 0065	113.0	286	219	191	186	218	326	490	689	755	750	786	786	730	779	839	949	1019	991	775	578	561	537	436	366	98	100	2008
762	I0065 - SB LANE 3	Bullitt	015-I - 0065	113.0	262	192	146	157	166	220	332	483	491	522	551	564	591	628	716	854	979	996	738	582	526	482	371	308	98	100	2008
503	I 65	Bullitt	015-I -0065	104.2	1713	1313	1106	1146	1333	1842	2717	3097	3351	3518	3711	3739	3599	3913	4252	4689	4709	4580	4122	3129	2944	2618	2453	2150	98	72	2008
752	I 65	Bullitt	015-I -0065	118.7	1943	1496	1306	1409	1748	2919	4940	6013	5520	4982	5216	3015	5148	5360	5973	6750	6935	7189	5652	4238	3847	3582	2952	2520	97	86	2008
Z03	I 0065 RAMP	Bullitt	015-I -0065	0.1	66	50	37	32	59	91	176	274	254	261	282	324	350	385	490	691	810	599	420	287	239	205	158	128	96	100	2010
Z04	I 0065 RAMP	Bullitt	015-I -0065	0.1	8	2	2	6	2	21	69	65	39	38	36	39	36	39	52	59	66	39	35	19	12	13	16	6	96	100	2010
Z05	I 0065 RAMP	Bullitt	015-I -0065	0.1	6	9	4	6	14	20	45	54	36	39	40	45	43	43	58	68	67	68	47	24	23	17	12	15	96	100	2010
Z06	I 0065 RAMP	Bullitt	015-I -0065	0.1	40	24	25	38	133	425	828	886	601	430	350	364	382	380	399	373	411	393	302	178	154	141	139	73	96	100	2010
002	KY0044	Bullitt	015-KY-0044	23.6	69	36	27	31	76	204	665	776	756	563	526	548	623	678	803	964	1005	1015	843	639	572	418	248	134	98	100	2008
002	KY0044	Bullitt	015-KY-0044	23.6	69	36	27	31	76	204	665	776	756	563	526	548	623	678	803	964	1005	1015	843	639	572	418	248	134	98	100	2008
002	KY0044	Bullitt	015-KY-0044	24.0	98	48	39	28	62	191	338	514	487	451	439	484	553	513	563	634	754	808	698	520	491	448	247	149	97	96	2010
035	KY0044	Bullitt	015-KY-0044	18.9	115	57	62	49	100	289	633	950	811	664	712	776	780	788	837	942	1100	1182	1010	729	637	555	318	200	97	96	2010
767	KY0044	Bullitt	015-KY-0044	25.8	24	13	14	12	23	79	210	260	132	196	176	172	204	215	231	255	313	348	262	183	150	137	67	45	98	100	2008
779	KY0044	Bullitt	015-KY-0044	1.6	25	11	7	13	15	85	197	134	167	119	105	116	108	135	184	246	247	224	191	126	119	109	63	35	95	97	2008
831	KY0044	Bullitt	015-KY-0044	8.3	25	13	7	11	33	100	212	205	171	146	163	179	183	183	222	297	305	266	181	143	107	95	66	43	97	97	2009
A02	KY0044	Bullitt	015-KY-0044	13.1	112	74	61	54	354	402	1147	1746	1496	1175	1087	1210	1328	1384	1735	1799	1923	1928	1403	1036	891	675	456	258	99	95	2008
A02	KY0044 - EB LANE 1	Bullitt	015-KY-0044	13.4	49	27	25	31	69	270	700	1018	795	715	596	660	663	700	968	813	801	825	677	539	392	291	154	85	96	100	2009
A02	KY0044 - LANE 2	Bullitt	015-KY-0044	13.4	3	5	3	5	9	46	29	34	105	50	18	30	31	43	18	34	51	26	15	11	5	7	6	5	96	100	2009
A02	KY0044 - WB LANE 3	Bullitt	015-KY-0044	13.4	74	56	37	27	49	104	419	642	452	476	470	566	663	728	772	1001	1147	1112	787	638	522	392	212	131	96	100	2009
A02	KY0044 - EB LANE 1	Bullitt	015-KY-0044	13.2	55	37	38	24	87	293	586	845	753	661	639	701	715	688	636	653	710	700	587	453	353	279	176	126	97	100	2010
A02	KY0044 - LANE 2	Bullitt	015-KY-0044	13.2	2	1	2	0	1	10	9	29	16	15	10	16	18	14	12	11	12	10	14	7	10	6	6	3	97	100	2010
A02	KY0044 - WB LANE 3	Bullitt	015-KY-0044	13.2	90	61	33	38	36	87	181	399	430	509	561	623	683	682	720	816	955	968	722	551	471	386	252	152	97	100	2010
A03	KY0044	Bullitt	015-KY-0044	12.5	124	79	61	76	126	361	780	1061	1027	921	906	921	1111	1067	1222	1279	1282	1254	1061	863	817	642	451	279	99	95	2008
A03	KY0044 - EB LANE 1	Bullitt	015-KY-0044	12.5	60	27	26	32	78	193	469	528	431	410	397	511	528	512	514	509	542	560	454	364	349	266	146	98	96	100	2009
A03	KY0044 - LANE 2	Bullitt	015-KY-0044	12.5	4	3	1	1	3	5	16	39	67	40	60	68	153	94	125	114	127	171	130	38	36	23	15	14	96	100	2009
A03	KY0044 - WB LANE 3	Bullitt	015-KY-0044	12.5	66	44	32	28	31	104	241	443	474	429	417	505	568	547	643	640	607	627	580	477	411	334	226	124	96	100	2009
A03	KY0044 - EB LANE 1	Bullitt	015-KY-0044	12.6	55	37	34	43	85	220	355	424	406	441	433	514	526	492	518	505	507	478	440	342	272	260	160	112	97	100	2010
A03	KY0044 - LANE 2	Bullitt	015-KY-0044	12.6	4	6	1	3	5	10	16	27	28	34	38	54	56	50	47	51	43	46	49	33	25	21	22	12	97	100	2010
A03	KY0044 - WB LANE 3	Bullitt	015-KY-0044	12.6	76	63	33	38	49	105	234	361	399	400	462	482	597	559	539	540	518	578	510	427	348	311	217	129	97	100	2010
A10	KY0044	Bullitt	015-KY-0044	11.8	100	75	47	63	103	287	516	648	630	579	568	664	720	727	811	871	973	1052	958	738	610	577	323	226	97	97	2010
A43	KY0044	Bullitt	015-KY-0044	15.6	69	46	33	38	73	220	556	804	750	589	588	599	625	677	729	862	977	1005	749	639	473	371	205	124	96	100	2009
C03	KY0044	Bullitt	015-KY-0044	23.0	167	98	75	79	134	374	652	1028	938	936	976	1126	1253	1223	1234	1373	1450	1522	1488	1129	1044	937	559	301	97	96	2010
C28	KY0044	Bullitt	015-KY-0044	22.5	115	59	59	61	157	367	926	1244	1218	948	912	972	1121	1119	1351	1501	1627	1736	1523	1277	1082	744	408	212	95	96	2008
C34	KY0044	Bullitt	015-KY-0044	21.3	139	89	63	49	109	323	630	934	865	830	935	968	1016	1005	1038	1193	1363	1434	1314	940	878	751	408	247	97	96	2010
514	KY0061	Bullitt	015-KY-0061	4.3	15	10	9	9	14	44	96	117	89	99	94	124	129	138	149	179	194	214	169	111	124	85	55	34	97	100	2010
529	KY0061	Bullitt	015-KY-0061	0.4	23	18	13	26	37	143	364	311	209	156	143	182	184	161	264	354	290	303	216	164	143	86	127	112	98	96	2008
750	KY0061	Bullitt	015-KY-0061	8.8	18	12	6	16	37	123	251	310	284	209	222	196	226	240	269	378	423	390	315	223	207	142	82	51	98	99	2008
759	KY0061	Bullitt	015-KY-0061	17.7	99	60	56	60	102	226	664	1138	1123	914	882	951	967	976	1148	1289	1332	1271	1046	764	778	560	364	190	95	99	2008
759	KY0061	Bullitt	015-KY-0061	17.3	46	36	26	17	27	83	204	351	397	373	414	444	490	509	516	553	616	592	460	331	337	299	157	118	97	99	2010
767	KY0061	Bullitt	015-KY-0061	20.6	130	87	58	47	68	214	395	635	740	747	927	994	1148	1050	1110	1221	1405	1429	1326	992	862	690	382	259	97	98	2010
801	KY0061	Bullitt	015-KY-0061	18.6	94	56	40	53	93	237	617	909	868	664	654	701	764	780	958	1038	1089	1114	854	708	599	474	283	199	97	100	2009
811	KY0061	Bullitt	015-KY-0061	9.7	20	12	14	14	28	94	202	300	254	218	243	215	232	257	289	374	399	397	346	250	207	139	78	50	98	99	2008
832	KY0061	Bullitt	015-KY-0061	12.0	34	16	7	4	26	76	188	308	268	228	252	271	278	313	363	416	439	376	298	239	197	157	85	53	97	99	2009
846	KY0061	Bullitt	015-KY-0061	10.0	21	14	5	2	12	52	133	213	202	185	185	214	207	262	286	309	329	289	221	168	142	119	61	40	97	100	2009
A06	KY0061	Bullitt	015-KY-0061	14.6	96	58	42	50	58	144	408	696	771	781	790	837	891	888	1014	1146	1126	1001	834	628	613	470	325	236	95	99	2008
A08	KY0061	Bullitt	015-KY-0061	14.0	119	75	50	57	89	242	484	687	621	615	604	706	736	764	840	902	1031	1035	938	712	655	567	335	237	97	100	2010
A28	KY0061	Bullitt	015-KY-0061	13.6	33	19	11	12	24	80	233	399	355	310	345	356	386	402	440	517	579	504	361	290	239	183	93	76	97	99	2009
A34	KY0061	Bullitt	015-KY-0061	15.1	62	33	28	26	52	148	361	605	588	637	663	736	794	782	923	951	994	874	675	545	465	353	194	135	96	99	2009
A50	KY0061	Bullitt	015-KY-0061	12.7	34	22	6	7	31	81	204	357	309	267	308	318	328	362	424	487	504	436	338	264	220	192	101	72	97	99	2009
E07	KY0061	Bullitt	015-KY-0061	2.1	101	40	25	15	15	35	61	185	233	188	179	182	225	239	211	260	318	268	302	250	197	226	154	127	97	99	2010
E16	KY0061	Bullitt	015-KY-0061	1.4	36	36	33	41	53	168	506	477	292	195	205	281	271	236	410	528	373	397	287	224	177	110	267	243	98	100	2008
267	KY0245	Bullitt	015-KY-0245	3.3	112	72	53	77	140	408	854	1011	729	540	512	495	524	521	626	818	956	962	569	400	340	308	203	165	98	100	2008
751	KY0245	Bullitt	015-KY-0245	6.8	23	15	13	11	35	138	297	373	256	198	201	218	240	269	283	344	423	388	242	193	153	114	91	52	97	96	2009
751	KY0245	Bullitt	015-KY-0245	0.2	25	14	18	18	59	148	316	335	242	230	254	227	238	247	300	373	424	376	298	174	163	126	101	55	96	100	2010
812	KY0245	Bullitt	015-KY-0245	6.0	88	57	46	58	136	353	609	674	564	487	620	661	687	698	780	942	1075	1099	699	398	311	270	223	174	96	100	2010

Appendix B

24-Hour Class Count Locations

N
W
E
S
RIVER RD
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FRANKLIN ST
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N MARLESTON ST
N HANCOCK ST
N CLAY ST
N STILES ST
31E
61
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S PRESTON ST
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S CLAY ST
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PULTON ST
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ADAMS ST
RIVER RD
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N CAMPBELL ST
MILL ST
CABEL ST
QUINCY ST
E WASHINGTON ST
E WASHINGTON ST
E WASHINGTON ST
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BOWLES AVE
WEBSTER ST
N SPRING ST
GEIGER ST
FRANKLIN ST
E WATER ST
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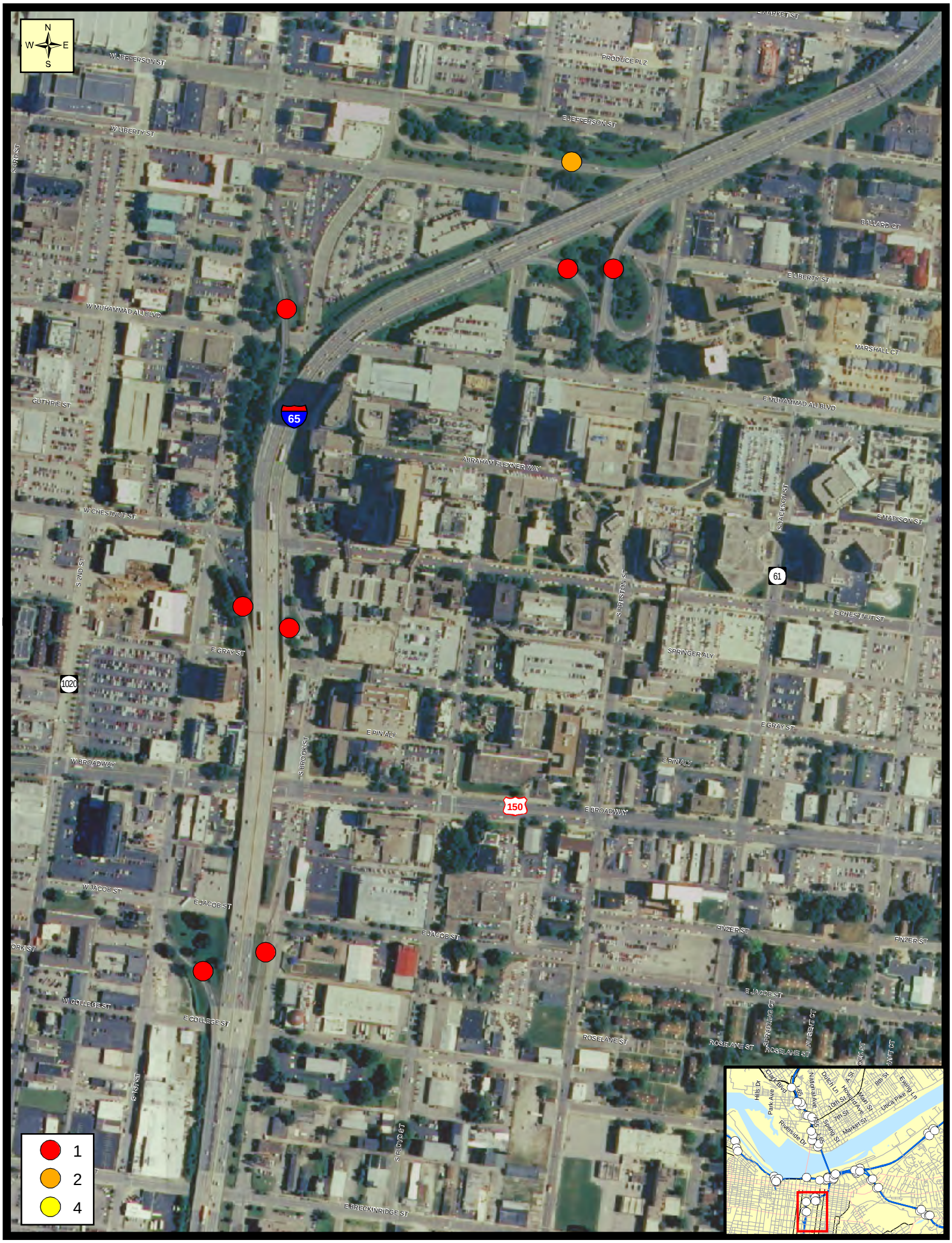
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BALLARD CT
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MARSHALL CT
GUTHRIE ST
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65
ABRAHAM FLEXNER WAY
W CHESTNUT ST
S JACKSON ST
E MADISON ST
61
S PRESTON ST
E CHESTNUT ST
E GRAY ST
SPRINGER ALY
1020
E GRAY ST
E PIN ALY
S BROOK ST
W BROADWAY
E PIN ALY
150
E BROADWAY
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E JACOB ST
E JACOB ST
FINZER ST
FINZER ST
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ROSE AVE ST
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65
31
Sparks Ave
State Route 62
I-65
10th St
Newman Ave
Montgomery Ave
Clark Blvd
6th St
Jim Davis St
Center St
Missouri Ave
Silver Ave
Lucille Ave
United States Highway 31
Illinois Ave
CLARK MEMORIAL BRG
Ohio Ave
Indiana Ave
Broadway St
Michigan Ave
Kentucky Ave
Court Ave
Market St
Maple St
Chestnut St
Pearl St
Riverside Dr
Rail St
Spring St
Wall St
Lewis St
Miami Ave
Oriental Blvd
Pennsylvania Ave
Rockefeller Drive Ave

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264
NORTHWESTERN PKWY
PFLANZ AVE
MAIN AVE
BANK ST
BOONE LN
WEWOKA AVE
PARKER AVE
GARFIELD AVE
RUDD AVE
CEDAR GROVE CT
3RD ALY
N 4TH ST
N 5TH ST
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MONTGOMERY ST
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CARTER ST
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PORTLAND AVE
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LYTLE ST
BANK ST
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PORTLAND AVE
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N 18TH ST
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GILLIGAN ST
BANK ST
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HIGH ST
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ROWAN ST
N 11TH ST
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W MAIN ST
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S 12TH ST
CHAPEL ST
S 10TH ST
31W
CONGRESS ST
W WASHINGTON ST
N 9TH ST
N 8TH ST
ROY WILKINS AVE
RIVER RD
3077
N 7TH ST
PIKE ST
W MARKET ST
S 7TH ST
S 8TH ST
CONGRESS ALY
1
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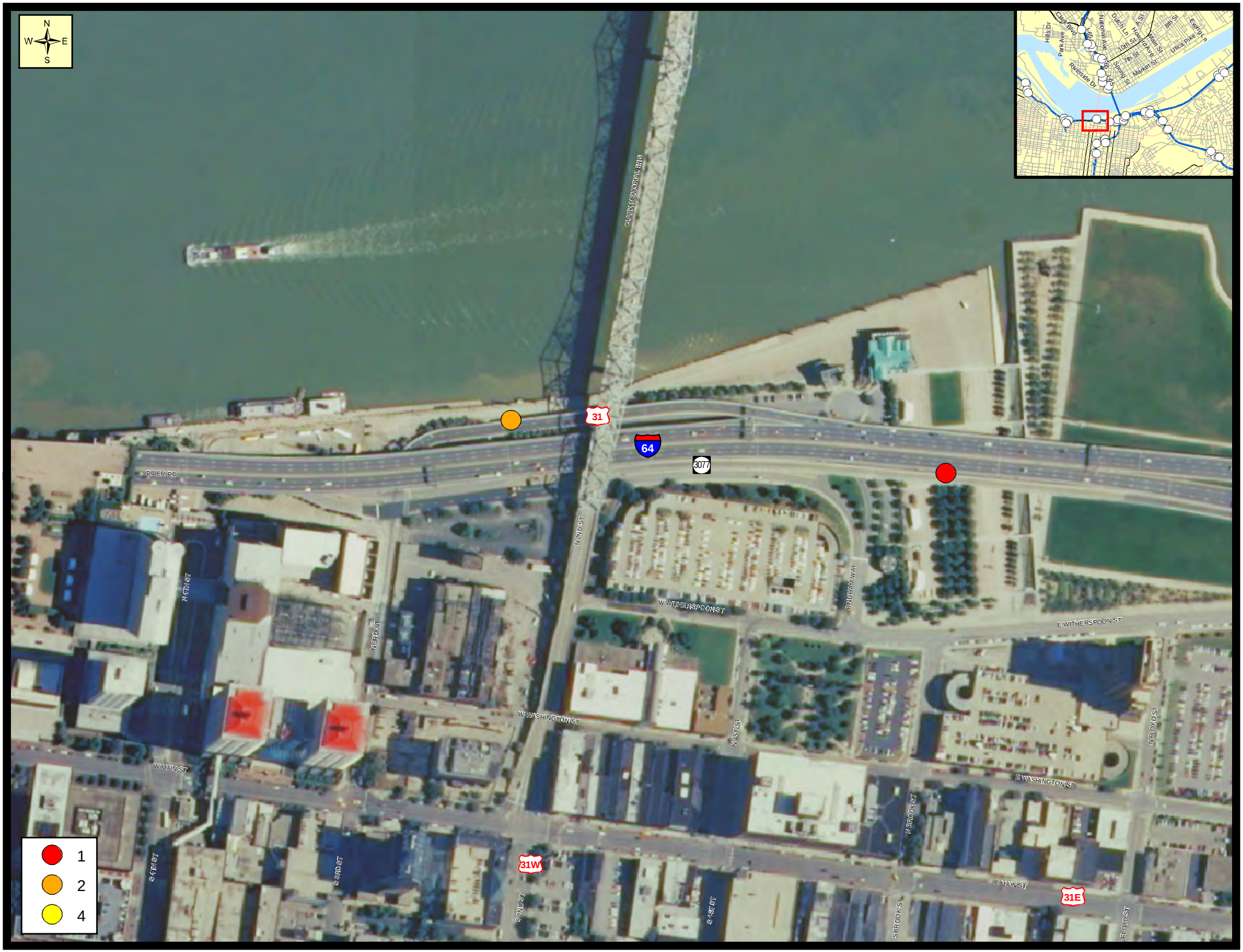
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CLARK MEMORIAL BRG
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3077
RIVER RD
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GATEWAY WAY
E WITHERSPOON ST
W WASHINGTON ST
N 1ST ST
W MAIN ST
E WASHINGTON ST
N BROOK ST
N FLOYD ST
31W
S 6TH ST
S 4TH ST
S 2ND ST
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S BROOK ST
S FLOYD ST
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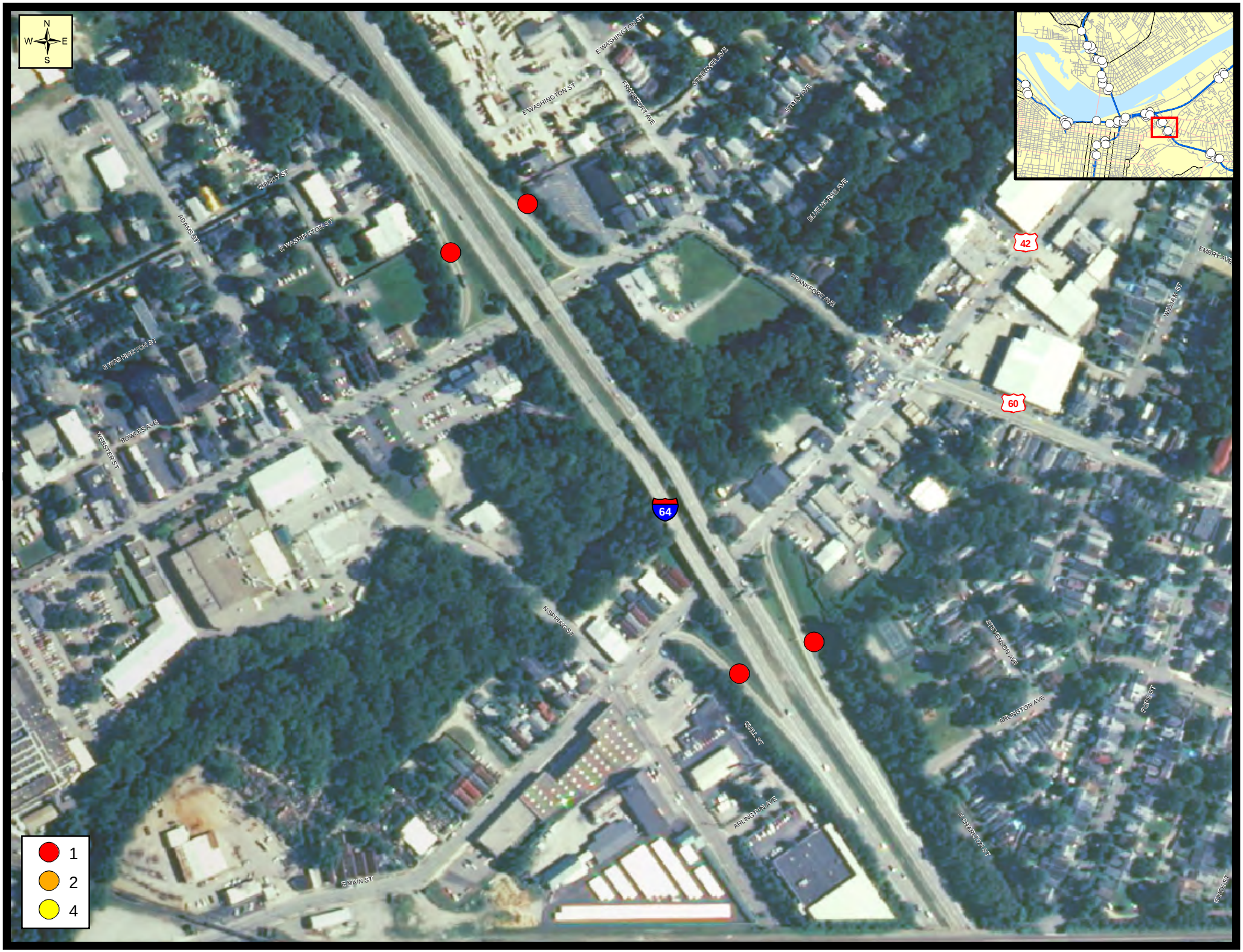
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FRANKFORT AVE
STOLLINGER AVE
STOLLY AVE
ELLEMORE AVE
ADAMS ST
QUINCY ST
BOWLESS AVE
WEBSTER ST
N SPRING ST
QUILL ST
ARLINGTON AVE
STEVENSON AVE
N CLARKSTON ST
E MAIN ST
WILLIAM ST
EMORY AVE
RUFFEST
42
60
64
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W
E
S
SAINT JOHN AVE
RICKEL RD
LOOKVIEW PARK DR
LOOKVIEW CT
CRESCENT SPRING DR
GRINSTEAD DR
JOPLIN DR
CROSS HILL RD
TOP HILL RD
64
RALEIGH LN
LEXINGTON RD
LEXINGTON RD
ETLEY AVE
60A
GRINSTEAD DR
OLD BLACK DR
1
2
4

N
W
E
S
ZOR AVE
RIVER RD
RIVERSIDE EXPRESSWAY
71
HILLWOOD AVE
MOCKINGBIRD VALLEY RD
MOCKINGBIRD TERRACE DR
GREENRIDGE LN
GREENSPUR LN
1
2
4

Appendix C

September Turning Movement Counts

Start Time	Southbound			Northbound			Westbound			Eastbound		
	Left	Thru	Right	Left	Thru	Right	Left	Thru	Right	Left	Thru	Right
US 31 @ Main Street in Louisville												
7:00 AM	0	139	110	32	40	0	16	81	12	0	0	0
7:15 AM	0	188	127	53	33	0	27	144	25	0	0	0
7:30 AM	0	199	135	53	42	0	27	149	25	0	0	0
7:45 AM	0	208	122	48	66	0	48	217	24	0	0	0
8:00 AM	0	203	119	62	45	0	57	186	34	0	0	0
8:15 AM	0	211	117	64	37	0	57	175	33	0	0	0
8:30 AM	0	173	74	66	61	0	47	173	20	0	0	0
8:45 AM	0	220	87	71	59	0	49	177	19	0	0	0
7:00-8:00	0	734	494	186	181	0	118	591	86	0	0	0
8:00-9:00	0	807	397	263	202	0	210	711	106	0	0	0
7:30-8:30	0	821	493	227	190	0	189	727	116	0	0	0
US 31 @ Main Street in Louisville												
11:00 AM	0	56	30	45	68	0	11	140	26	0	0	0
11:15 AM	0	50	35	53	111	0	8	142	26	0	0	0
11:30 AM	0	52	35	52	98	0	24	108	42	0	0	0
11:45 AM	0	62	30	67	102	0	18	120	39	0	0	0
12:00 PM	0	75	34	55	102	0	22	144	52	0	0	0
12:15 PM	0	73	43	59	104	0	22	115	38	0	0	0
12:30 PM	0	90	51	63	123	0	17	124	28	0	0	0
12:45 PM	0	90	51	68	90	0	24	131	33	0	0	0
11:00-12:00	0	220	130	217	379	0	61	510	133	0	0	0
12:00-1:00	0	328	179	245	419	0	85	514	151	0	0	0
US 31 @ Main Street in Louisville												
4:00 PM	0	77	54	60	192	0	22	126	104	0	0	0
4:15 PM	0	95	53	52	169	0	18	151	92	0	0	0
4:30 PM	0	133	57	56	192	0	30	103	85	0	0	0
4:45 PM	0	170	67	63	257	0	37	88	124	0	0	0
5:00 PM	0	183	95	48	209	0	30	117	139	0	0	0
5:15 PM	0	185	102	47	259	0	17	139	189	0	0	0
5:30 PM	0	191	134	68	258	0	18	126	184	0	0	0
5:45 PM	0	196	130	64	227	0	4	128	146	0	0	0
4:00-5:00	0	475	231	231	810	0	107	468	405	0	0	0
5:00-6:00	0	755	461	227	953	0	69	510	658	0	0	0

Start Time	Southbound			Northbound			Westbound			Eastbound		
	Left	Thru	Right	Left	Thru	Right	Left	Thru	Right	Left	Thru	Right
US 31 @ Court in Jeffersonville												
7:00 AM	10	237	1	0	39	13	70	9	2	1	0	4
7:15 AM	10	346	1	1	31	21	78	8	2	0	1	7
7:30 AM	21	361	7	7	37	27	67	11	4	2	1	17
7:45 AM	19	284	10	11	31	37	78	35	0	0	0	7
8:00 AM	27	240	11	6	46	18	68	45	0	1	3	5
8:15 AM	21	207	9	8	48	23	70	22	1	3	2	6
8:30 AM	24	198	5	3	41	19	64	19	3	3	1	4
8:45 AM	30	146	10	7	50	16	54	17	8	0	3	2
7:00-8:00	60	1228	19	19	138	98	293	63	8	3	2	35
8:00-9:00	102	791	35	24	185	76	256	103	12	7	9	17
7:15-8:15	77	1231	29	25	145	103	291	99	6	3	5	36
US 31 @ Court in Jeffersonville												
11:15 AM	23	60	5	6	67	44	24	22	4	3	12	7
11:30 AM	23	54	1	6	71	48	35	17	2	9	7	6
11:45 AM	37	65	7	8	80	50	41	19	3	7	7	6
12:00 PM	23	59	9	7	101	57	43	23	5	10	14	13
12:15 PM	19	73	8	3	85	45	54	12	8	7	9	4
12:30 PM	38	82	7	11	62	25	51	24	8	4	3	7
12:45 PM	23	65	5	6	63	32	70	11	6	0	1	13
1:00 PM	32	88	8	15	65	41	56	25	4	4	3	11
1:15 PM	23	93	11	5	78	29	57	20	3	3	2	3
12:00-1:00	103	279	29	27	311	159	218	70	27	21	27	37
11:45-12:45	117	279	31	29	328	177	189	78	24	28	33	30
US 31 @ Court in Jeffersonville												
4:45 PM	35	184	9	15	260	84	93	18	1	7	4	16
5:00 PM	35	215	10	23	250	77	81	15	10	10	5	26
5:15 PM	29	215	5	22	251	118	68	15	8	6	3	23
5:30 PM	27	158	8	11	238	83	70	10	6	5	3	25
5:45 PM	48	107	12	17	227	84	61	8	8	5	6	8
5:00-6:00	139	695	35	73	966	362	280	48	32	26	17	82
4:45-5:45	126	772	32	71	999	362	312	58	25	28	15	90

Start Time	Southbound			Northbound			Westbound			Eastbound		
	Left	Thru	Right	Left	Thru	Right	Left	Thru	Right	Left	Thru	Right
3rd Street Exit												
7:00 AM	35	66	231	0	0	1	2	12	0	0	21	1
7:15 AM	62	127	307	0	0	12	5	28	0	0	30	1
7:30 AM	46	132	321	0	0	11	3	53	0	0	53	4
7:45 AM	30	120	375	1	0	9	1	69	0	0	40	4
8:00 AM	41	124	364	0	0	2	3	105	0	0	33	0
8:15 AM	38	109	346	0	0	4	7	112	0	0	40	1
8:30 AM	47	83	345	0	0	7	3	111	0	0	39	2
8:45 AM	42	55	365	0	0	3	1	89	0	0	34	2
7:00-8:00	173	445	1234	1	0	33	11	162	0	0	144	10
8:00-9:00	168	371	1420	0	0	16	14	417	0	0	146	5
7:15-8:15	179	503	1367	1	0	34	12	255	0	0	156	9
3rd Street Exit												
11:30 AM	36	0	197	0	0	0	0	11	0	0	62	2
11:45 AM	29	0	163	0	0	0	0	12	0	0	79	0
12:00 PM	28	1	102	1	0	0	0	13	0	0	81	0
12:15 PM	30	1	103	0	0	1	0	10	0	0	67	1
12:30 PM	45	2	130	0	0	2	0	11	0	0	57	0
12:45 PM	48	0	124	0	0	0	0	14	0	0	58	1
1:00 PM	43	1	117	0	0	0	0	18	0	0	91	0
1:15 PM	29	2	135	0	0	2	0	10	0	0	108	1
12:00-1:00	151	4	459	1	0	3	0	48	0	0	263	2
12:30-1:30	165	5	506	0	0	4	0	53	0	0	314	2
3rd Street Exit												
4:45 PM	10	56	47	0	0	58	2	20	0	0	216	0
5:00 PM	22	58	48	1	0	53	8	18	0	0	210	5
5:15 PM	16	63	37	0	0	48	1	20	0	0	268	10
5:30 PM	26	58	40	0	1	69	1	22	0	0	246	5
5:45 PM	34	61	50	0	0	44	1	14	0	0	195	3
5:00-6:00	98	240	175	1	1	214	11	74	0	0	919	23
4:45-5:45	74	235	172	1	1	228	12	80	0	0	940	20

Appendix D

Louisville ALPR Report

Introduction and Project Details

The Traffic Group, Inc. conducted a License Plate Recognition and Origin & Destination study on September 29, 2010 in the City of Louisville, Kentucky and the surrounding area (Exhibit A).

The study was conducted for a 24 hour period from midnight on September 29, 2010 to midnight on September 30, 2010. Overall, five locations of data were collected along both directions of the various roadways that will be detailed below.

Automatic License Plate Recognition (ALPR) cameras were installed at the following locations:

- Station 1 – I-65 at Hebron Church Road Overpass. (Exhibit B)
- Station 2 – I-71 at Jericho Road Overpass. (Exhibit C)
- Station 3 – I-64 at Joyes Station Road Overpass. (Exhibit D)
- Station 4 – I-65 at Pioneer Drive Overpass. (Exhibit E)
- Station 5 – I-64 at Farnsley Road Overpass. (Exhibit F)

The Traffic Group, Inc. utilized 22 License Plate Recognition cameras (ALPR) and all other associated equipment including but not limited to laptop computers, mounting hardware, and gasoline powered generators.

All of the ALPR cameras were mounted overhead on bridge structures utilizing specialized brackets to position the cameras to capture vehicle license plates of the below passing traffic.

The Traffic Group, Inc. also conducted length based vehicle classification counts using Wavetronix HD equipment at each of the ALPR stations. Additionally, we conducted mechanical traffic counts at 51 locations (Exhibit G). We utilized 1 Wavetronix HD non-intrusive sensor for the interstate level traffic locations while the other 50 ramp locations were collected using pneumatic road tube sensors and either Peek ADR 1000 traffic counters or Metrocount 5600 traffic counters.

Overall we utilized 12 field personnel during the conduct of the 24 hour License Plate Origin and Destination Study.

Exhibit A

Louisville_ALPR_Final

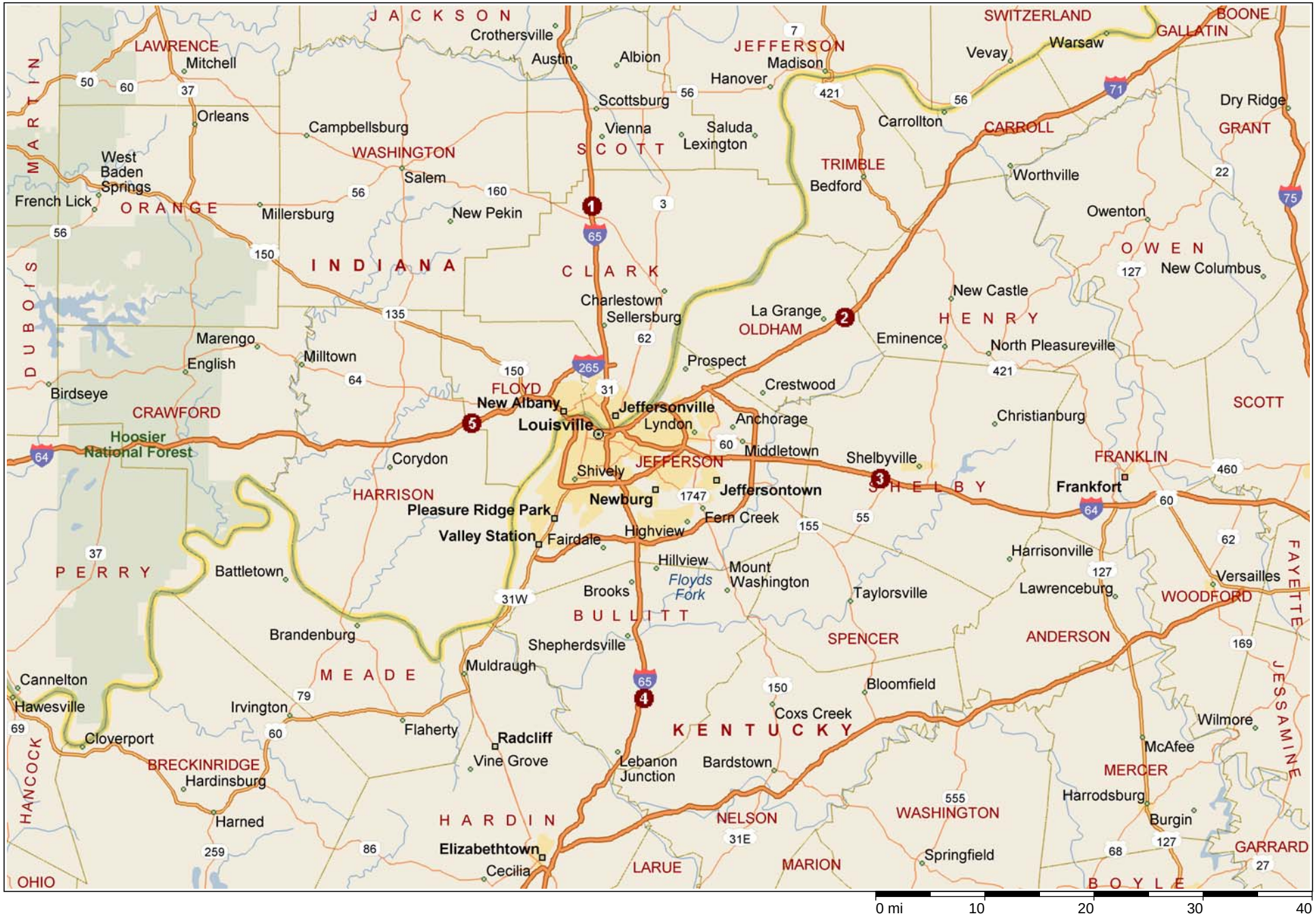

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Exhibit B

NOTES:

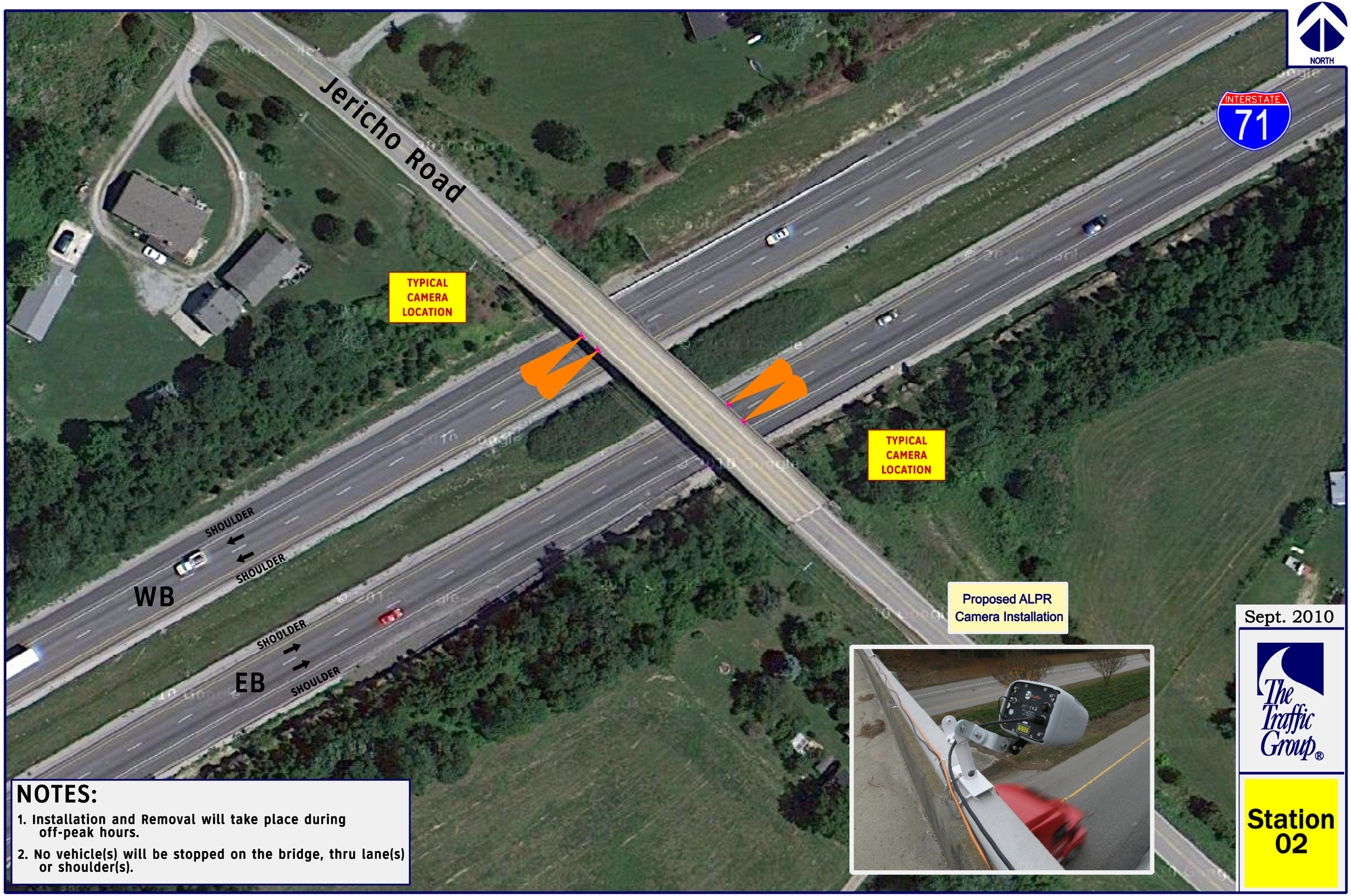
1. Installation and Removal will take place during off-peak hours.
2. No vehicle(s) will be stopped on the bridge, thru lane(s) or shoulder(s).

Sept. 2010

The Traffic Group®

Station 01

Exhibit C



NOTES:

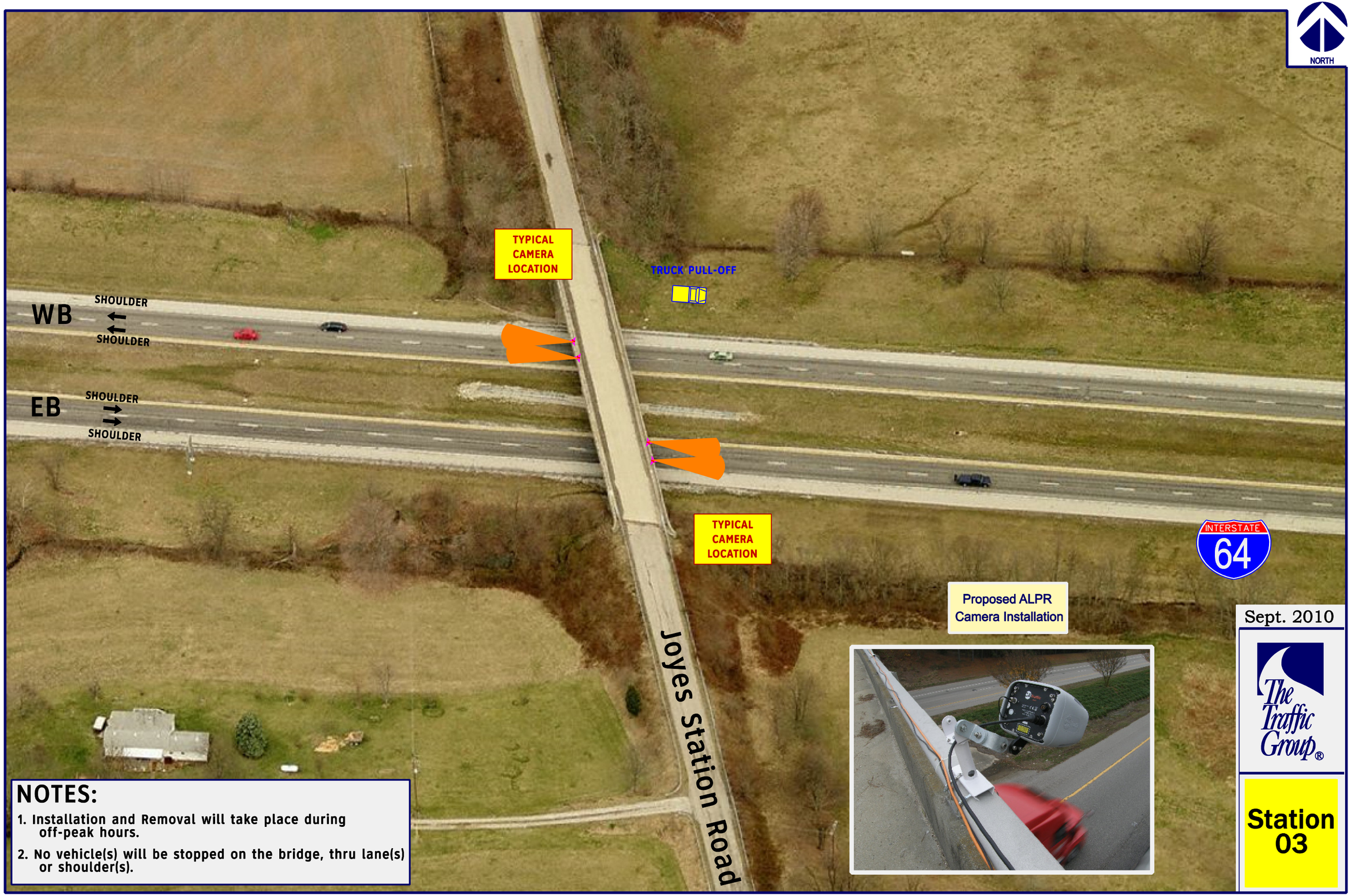
1. Installation and Removal will take place during off-peak hours.
2. No vehicle(s) will be stopped on the bridge, thru lane(s) or shoulder(s).

Sept. 2010

The Traffic Group®

Station 02

Exhibit D



NOTES:

1. Installation and Removal will take place during off-peak hours.
2. No vehicle(s) will be stopped on the bridge, thru lane(s) or shoulder(s).

Sept. 2010

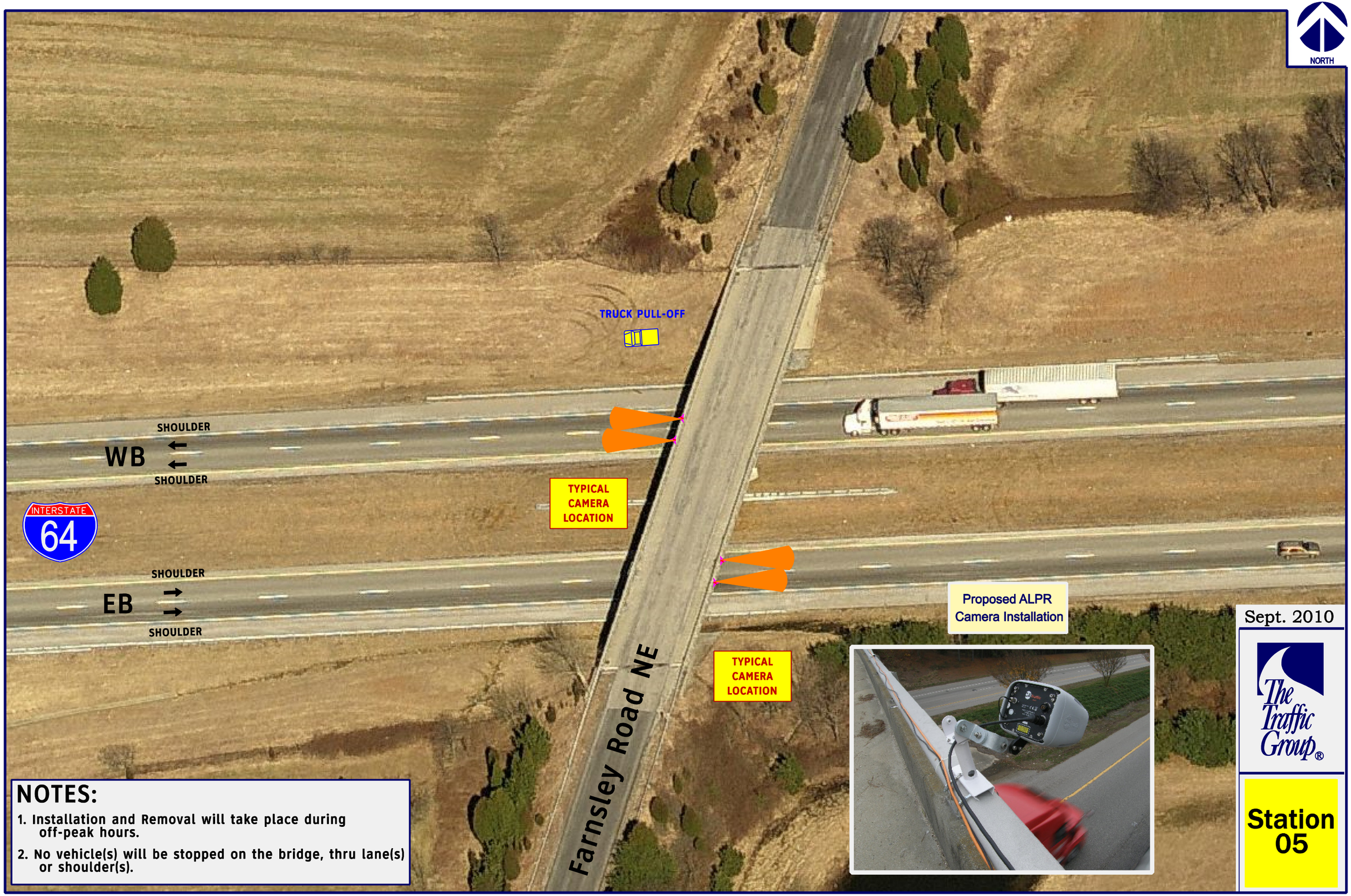
The Traffic Group®

Station 03

NOTES:

1. Installation and Removal will take place during off-peak hours.
2. No vehicle(s) will be stopped on the bridge, thru lane(s) or shoulder(s).

Exhibit F



NOTES:

1. Installation and Removal will take place during off-peak hours.
2. No vehicle(s) will be stopped on the bridge, thru lane(s) or shoulder(s).

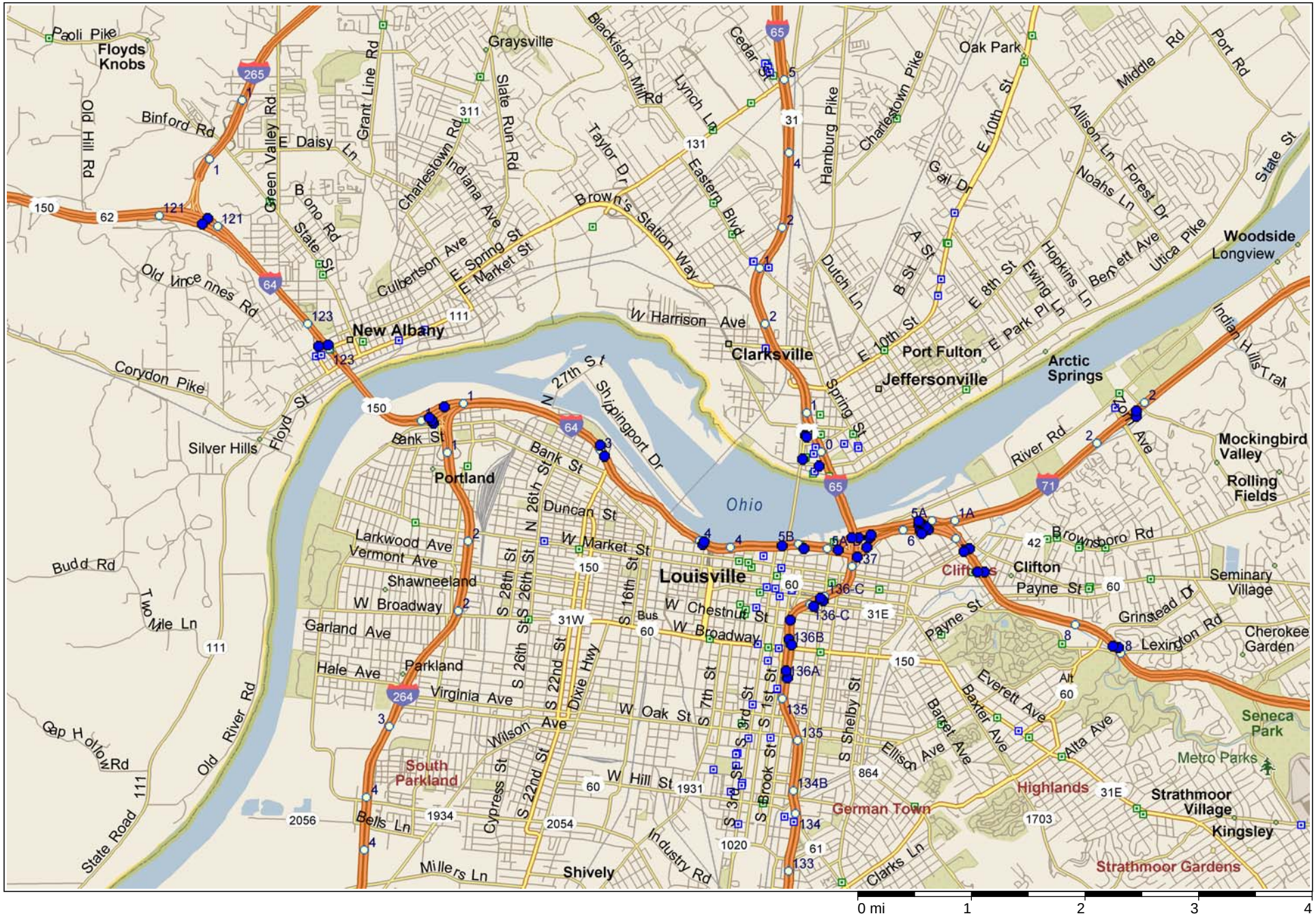
Sept. 2010

The Traffic Group®

Station 05

Exhibit G

Mechanical Classification Count Locations



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Manual Review Process

The Traffic Group, Inc. manually verified all license plate images for accuracy. During this manual verification process, we correct and classify the license plate image. Based upon the picture, we are able to determine the correct license plate number as well as the vehicle type (Passenger Vehicle versus Heavy Truck).

During our manual review process, we use the pound sign (#) for a partial plate and the dollar sign ($) for any unreadable character that was found during the manual review process (Exhibit H). We use the letter "P" is used to symbolize a Passenger Vehicle while the letter "T" is used to symbolize a Heavy Truck (Exhibit I). The "@" symbol was used to indicate the plate was reviewed. The file name contains information on every plate that was collected including the location, date, time, and the license plate number that the license plate was captured. The following is an example of a reviewed license plate image and its associated file name:

kSite4nbln2_09292010_144250_707_08921_P@7068CS.jpg

The designation of "UR" was used for any vehicle that had a license plate but the license plate was unreadable. Some license plates are unreadable based upon the location of the license plate, the license plate quality, and license plate material. Exhibit J and Exhibit K show several examples of unreadable plates.

We used the word "UNKNOWN" as the license plate number if the captured picture was only part of the vehicle. These unknown images occur for many reasons. The ALPR equipment is calibrated to take multiple images of the same vehicle based upon reflectivity. These "unknown" images account for the extra pictures taken while "looking" for an actual license plate number. Exhibit L shows several examples of "unknown" images.

The following are some statistics calculated based upon the 5 station; 24 hour; 22 camera Louisville Kentucky license plate project:

- 321,343 total images collected
- 21,060 duplicate license plate images
- 3,353 license plates deleted due to too many unreadable characters
- 170,872 license plate numbers used in matching

- 14,627 unreadable license plates removed
- 111,431 images did not contain a license plate

There was one specific issue that was identified after the study was conducted. The Indiana license plate with the blue background and white letters was difficult to capture. After speaking with CA Traffic (the camera manufacturer), they explained the issue probably comes from the quality and material used in the manufacturing of the license plate. Based upon there infra-red testing, the paint does not appear to be as reflective as the paint used in Indiana's white background and dark letters.

Overall, we were successful in capturing an average of 80% of the passing license plates. This capture percentage was lowered by Station 1 (average 76%) and Station 5 (average 66%). These two stations were actually located in Indiana.

DODGE
4X4

manac
manac

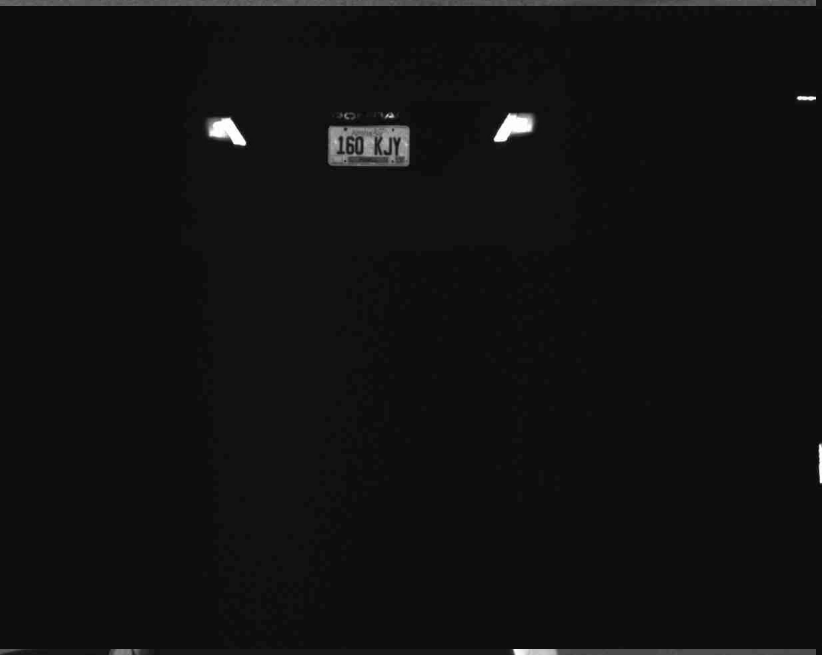
INDIANA
2750

1529

TOYOTA T100
SR5
9457

192 DGR

536608
T899644

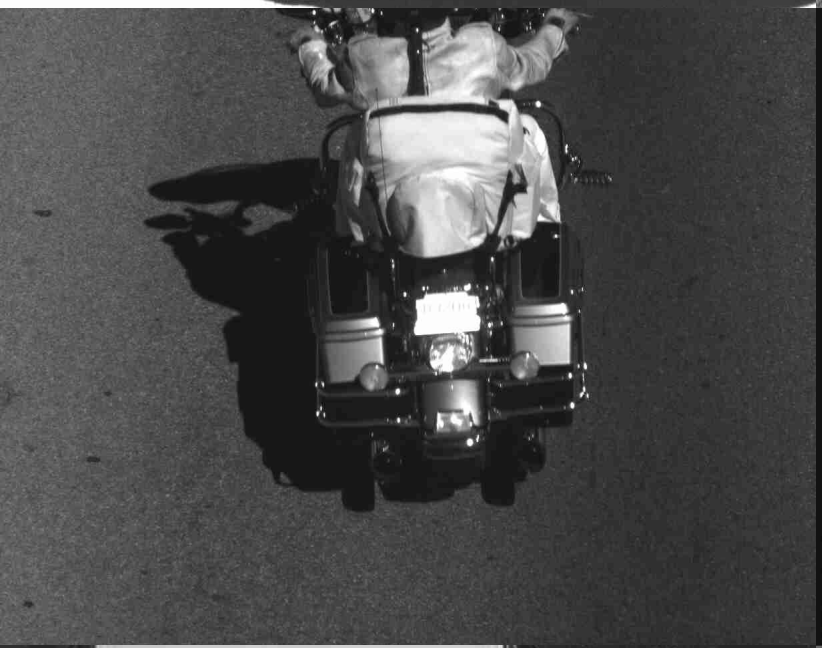

160 KJY

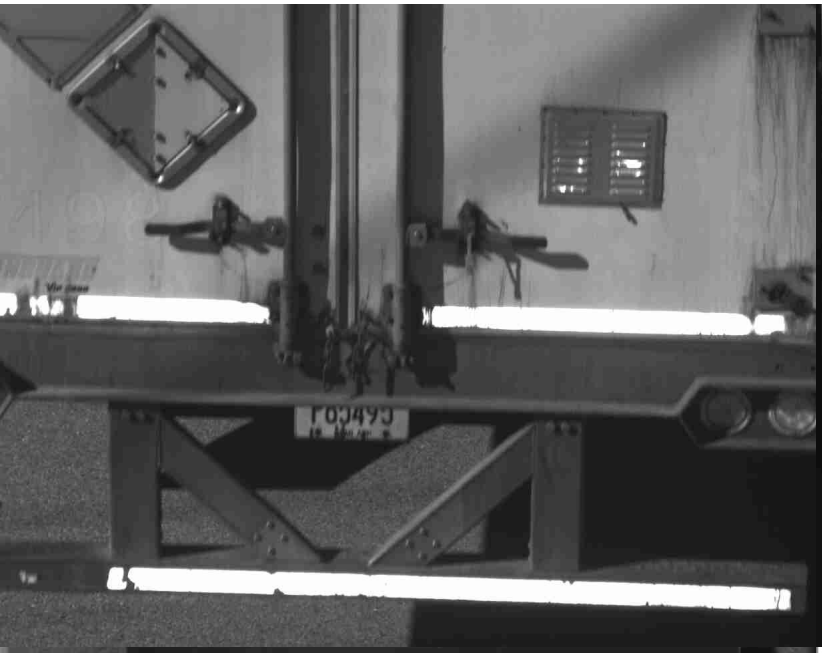
TPO 4341

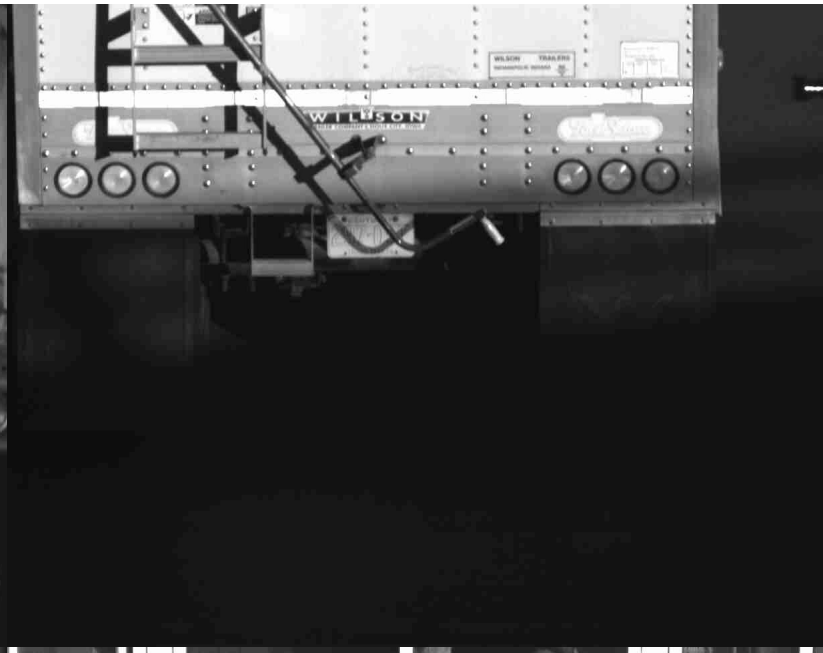
317 BXF

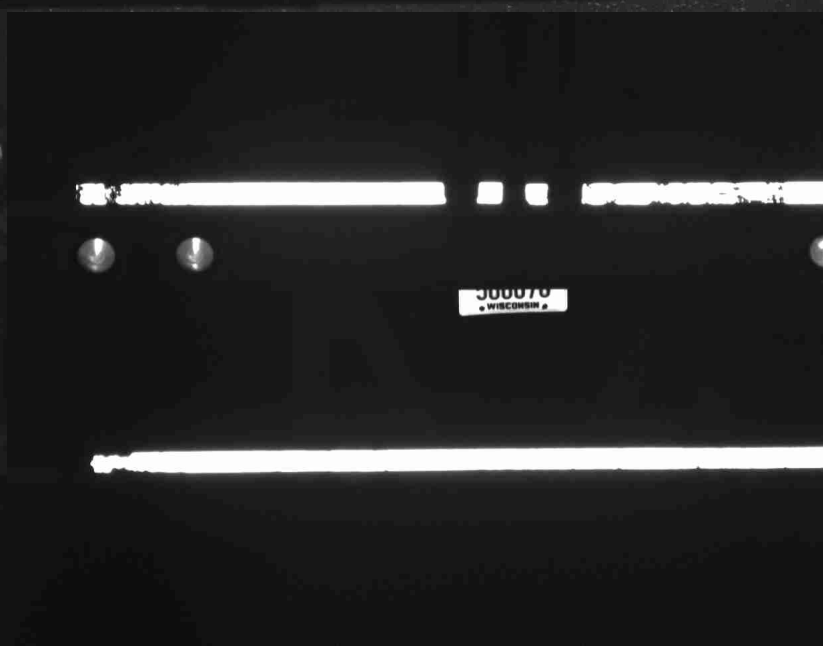
B256344

Jeep






WILSON


WISCONSIN

VENTU
LOGIS
1-888-561-
Jayco
DHL

Matching Procedure

For this ALPR Origin and Destination study, we wrote specific algorithms using Visual Basic programming. Microsoft Excel macros were used to verify proper formatting, remove unacceptable license plate numbers, and match license plate numbers between the five stations.

In programming, consistency amongst data is critical. We wrote macros to check the format consistency of our data. The date, time, and vehicle type columns were checked for formatting consistency.

The Traffic Group, Inc. created two separate data sets, one for Passenger Vehicles and one for Heavy Trucks.

We proceeded to remove license plate numbers for the following reasons:

- Duplicate license plate number: If the same license plate number was recorded within 60 records, it was removed. Also, if a license plate number was identical to another license plate number with the exception of a "#" or "$" it was considered to be a duplicate and it was removed.
- Too few characters: If a license plate number contained less than 4 characters, it was removed from the data set.
- Too many unknown symbols: If a license plate number contains more than 1 unreadable symbol ($ or #) the record is removed

License plate numbers "UR" and "UNKNOWN" records never were included in the data set.

We then identified the most likely travel routes between the 5 stations and used a macro to begin matching between the stations.

Using Microsoft Excel and Visual Basic, each license plate image was matched or not matched between all of the stations. We created logs for each license plate matched and its travel pattern based on time. Below is a sample log for 6 Heavy Trucks:

```
51,"2","09/29/2010","00:24:52","TNX8677","HV","Unknown","6","02:26:48","TNX8677",122
52,"2","09/29/2010","00:25:50","#7707ST","HV","Unknown","8","01:14:02","377707ST",48
53,"2","09/29/2010","00:25:53","HR47784","HV","Unknown","8","10:33:55","HR47784",608
54,"2","09/29/2010","00:26:18","4EH3708","HV","Unknown","1","10:10:49","4EH3708",585
54,"2","09/29/2010","00:26:18","4EH3708","HV","Unknown","6","09:22:57","4EH3708",537
54,"2","09/29/2010","00:26:18","4EH3708","HV","Unknown","5","01:15:24","4EH3708",49
55,"2","09/29/2010","00:26:54","HR86718","HV","Unknown","1","10:10:56","HR86718",584
55,"2","09/29/2010","00:26:54","HR86718","HV","Unknown","5","01:16:20","HR86718",49
56,"2","09/29/2010","00:27:12","SP125ACG","HV","Unknown","8","01:22:41","SP125ACG",55
```

The following is the legend to the above data:

Data Set 1: Match number
Data Set 2: Origin station

Data Set 3: Date
Data Set 4: Origin Time
Data Set 5: License Plate Number
Data Set 6: Vehicle Type
Data Set 7: Registration State
Data Set 8: Destination Station
Data Set 9: Destination Time
Data Set 10: License Plate Number
Data Set 11: Elapse Time

Based upon the matched vehicle log, we identified the vehicles first time in and last time out. Below is a sample log for same 6 Heavy Trucks as shown above:

```
51,"2","6",122,"09/29/2010","00:24:52","TNX8677","Last-Out of a trip"
52,"2","8",48,"09/29/2010","00:25:50","#7707ST","Last-Out of a trip"
53,"2","8",608,"09/29/2010","00:25:53","HR47784","Last-Out of a trip"
54,"2","1",49,"09/29/2010","00:26:18","4EH3708","Last-Out of a trip"
55,"2","1",49,"09/29/2010","00:26:54","HR86718","Last-Out of a trip"
56,"2","8",55,"09/29/2010","00:27:12","SP125ACG","Last-Out of a trip"
```

The following is the legend to the above data:

Data Set 1: Match number
Data Set 2: Origin station
Data Set 3: Destination station
Data Set 4: Elapsed Time
Data Set 5: Date
Data Set 6: Origin Time
Data Set 7: License Plate Number
Data Set 8: Type of Reporting

Finally, we used Microsoft Excel and customized macros to create the matching matrix tables based upon the Vehicle Type (Passenger Vehicle or Heavy Truck). The matrix tables were populated using the Vehicles First Origin and the Vehicles Final Destination (within the 24 hour period). The Microsoft Excel workbook is further defined into hour intervals. These intervals detail the number of vehicles that enter the system within that specific hour and are matched during some point within the study period (midnight to midnight).

APPENDIX

- Distance Chart
- Comparison Chart – Camera vs. Wavetronix Sensor
- Unreadable plate detail

Louisville ALPR Project

Mileage Chart

	Site 1	Site 2	Site 3	Site 4	Site 5
Site 1		48	51	48	33
Site 2	48		24	52	43
Site 3	51	24		46	47
Site 4	48	52	46		45
Site 5	33	43	47	45	

License Plate Comparison Sheet

	ALPR Camera Site 1						Wavetronix Sensor Site 1						Comparison Site 1					
Time	NB-PC	SB-PC	NB-HV	SB-HV	NB	SB	NB-PC	SB-PC	NB-HV	SB-HV	NB	SB	NB-PC	SB-PC	NB-HV	SB-HV	NB	SB
0:00	37	59	140	159	177	218	105	82	222	216	327	298	35%	72%	63%	74%	54%	73%
1:00	33	50	120	140	153	190	74	68	171	207	245	275	45%	74%	70%	68%	62%	69%
2:00	26	35	130	97	156	132	80	56	172	175	252	231	33%	63%	76%	55%	62%	57%
3:00	35	26	146	110	181	136	103	43	195	166	298	209	34%	60%	75%	66%	61%	65%
4:00	32	51	128	146	160	197	81	87	189	208	270	295	40%	59%	68%	70%	59%	67%
5:00	80	126	161	172	241	298	152	224	216	255	368	479	53%	56%	75%	67%	65%	62%
6:00	146	197	195	239	341	436	258	454	270	336	528	790	57%	43%	72%	71%	65%	55%
7:00	272	307	171	219	443	526	458	607	267	310	725	917	59%	51%	64%	71%	61%	57%
8:00	291	282	241	220	532	502	410	584	372	331	782	915	71%	48%	65%	66%	68%	55%
9:00	338	386	270	258	608	644	475	645	419	380	894	1025	71%	60%	64%	68%	68%	63%
10:00	380	480	295	321	675	801	532	676	471	473	1003	1149	71%	71%	63%	68%	67%	70%
11:00	400	503	296	290	696	793	498	664	459	410	957	1074	80%	76%	64%	71%	73%	74%
12:00	453	502	300	278	753	780	575	617	458	410	1033	1027	79%	81%	66%	68%	73%	76%
13:00	444	460	354	251	798	711	642	613	514	378	1156	991	69%	75%	69%	66%	69%	72%
14:00	566	547	301	320	867	867	763	710	453	462	1216	1172	74%	77%	66%	69%	71%	74%
15:00	606	559	330	288	936	847	793	723	501	451	1294	1174	76%	77%	66%	64%	72%	72%
16:00	556	512	239	283	795	795	859	764	439	423	1298	1187	65%	67%	54%	67%	61%	67%
17:00	417	488	213	296	630	784	754	761	423	414	1177	1175	55%	64%	50%	71%	54%	67%
18:00	436	387	295	263	731	650	690	570	465	375	1155	945	63%	68%	63%	70%	63%	69%
19:00	311	326	231	294	542	620	488	458	352	407	840	865	64%	71%	66%	72%	65%	72%
20:00	247	241	214	286	461	527	427	339	348	377	775	716	58%	71%	61%	76%	59%	74%
21:00	196	198	209	234	405	432	345	283	329	323	674	606	57%	70%	64%	72%	60%	71%
22:00	155	153	218	214	373	367	261	230	306	285	567	515	59%	67%	71%	75%	66%	71%
23:00	90	107	190	166	280	273	185	165	298	250	483	415	49%	65%	64%	66%	58%	66%
TOTAL	6547	6982	5387	5544	11934	12526	10008	10423	8309	8022	18317	18445	59%	66%	66%	69%	64%	67%

License Plate Comparison Sheet

	ALPR Camera Site 2						Wavetronix Sensor Site 2						Comparison Site 2					
Time	NB-PC	SB-PC	NB-HV	SB-HV	NB	SB	NB-PC	SB-PC	NB-HV	SB-HV	NB	SB	NB-PC	SB-PC	NB-HV	SB-HV	NB	SB
0:00	137	149	139	132	276	281	123	245	226	212	349	457	111%	61%	62%	62%	79%	61%
1:00	85	59	105	91	190	150	72	103	165	174	237	277	118%	57%	64%	52%	80%	54%
2:00	112	56	95	83	207	139	103	85	163	152	266	237	109%	66%	58%	55%	78%	59%
3:00	67	60	107	123	174	183	56	95	170	174	226	269	120%	63%	63%	71%	77%	68%
4:00	74	117	108	95	182	212	66	172	194	173	260	345	112%	68%	56%	55%	70%	61%
5:00	205	294	109	64	314	358	187	507	230	231	417	738	110%	58%	47%	28%	75%	49%
6:00	499	965	139	184	638	1149	429	1067	371	365	800	1432	116%	90%	37%	50%	80%	80%
7:00	841	1782	201	201	1042	1983	820	2102	494	465	1314	2567	103%	85%	41%	43%	79%	77%
8:00	1020	1497	203	186	1223	1683	969	1732	578	487	1547	2219	105%	86%	35%	38%	79%	76%
9:00	752	1294	273	200	1025	1494	656	1325	652	427	1308	1752	115%	98%	42%	47%	78%	85%
10:00	759	1010	281	287	1040	1297	634	1048	642	520	1276	1568	120%	96%	44%	55%	82%	83%
11:00	828	970	247	276	1075	1246	705	1047	612	443	1317	1490	117%	93%	40%	62%	82%	84%
12:00	1020	977	288	303	1308	1280	819	1034	681	518	1500	1552	125%	94%	42%	58%	87%	82%
13:00	1067	920	285	263	1352	1183	886	1027	691	473	1577	1500	120%	90%	41%	56%	86%	79%
14:00	1217	986	302	266	1519	1252	966	1099	760	500	1726	1599	126%	90%	40%	53%	88%	78%
15:00	1551	1069	300	274	1851	1343	1228	1225	825	542	2053	1767	126%	87%	36%	51%	90%	76%
16:00	1819	1135	275	239	2094	1374	1505	1419	873	477	2378	1896	121%	80%	32%	50%	88%	72%
17:00	1916	1333	238	203	2154	1536	1701	1568	775	459	2476	2027	113%	85%	31%	44%	87%	76%
18:00	1301	838	301	180	1602	1018	1246	1017	762	376	2008	1393	104%	82%	40%	48%	80%	73%
19:00	943	592	242	187	1185	779	881	774	613	362	1494	1136	107%	76%	39%	52%	79%	69%
20:00	782	497	217	191	999	688	738	629	547	356	1285	985	106%	79%	40%	54%	78%	70%
21:00	630	345	171	169	801	514	631	467	416	313	1047	780	100%	74%	41%	54%	77%	66%
22:00	419	270	202	150	621	420	403	370	374	268	777	638	104%	73%	54%	56%	80%	66%
23:00	256	171	160	134	416	305	242	246	287	225	529	471	106%	70%	56%	60%	79%	65%
TOTAL	18300	17386	4988	4481	23288	21867	16066	20403	12101	8692	28167	29095	113%	79%	45%	52%	81%	71%

License Plate Comparison Sheet

	ALPR Camera Site 3						Wavetronix Sensor Site 3						Comparison Site 3					
Time	EB-PC	WB-PC	EB-HV	WB-HV	EB	WB	EB-PC	WB-PC	EB-HV	WB-HV	EB	WB	EB-PC	WB-PC	EB-HV	WB-HV	EB	WB
0:00	124	86	74	94	198	180	156	80	129	134	285	214	79%	108%	57%	70%	69%	84%
1:00	80	61	71	78	151	139	111	61	108	114	219	175	72%	100%	66%	68%	69%	79%
2:00	79	67	63	85	142	152	107	51	110	115	217	166	74%	131%	57%	74%	65%	92%
3:00	65	114	76	66	141	180	77	116	121	109	198	225	84%	98%	63%	61%	71%	80%
4:00	136	158	66	70	202	228	146	148	118	104	264	252	93%	107%	56%	67%	77%	90%
5:00	377	437	109	102	486	539	408	407	158	183	566	590	92%	107%	69%	56%	86%	91%
6:00	757	904	127	128	884	1032	768	860	277	267	1045	1127	99%	105%	46%	48%	85%	92%
7:00	1288	1486	176	169	1464	1655	1283	1530	403	339	1686	1869	100%	97%	44%	50%	87%	89%
8:00	1216	1187	167	199	1383	1386	1234	1202	386	400	1620	1602	99%	99%	43%	50%	85%	87%
9:00	999	812	227	203	1226	1015	1033	938	455	437	1488	1375	97%	87%	50%	46%	82%	74%
10:00	854	933	188	249	1042	1182	907	895	391	437	1298	1332	94%	104%	48%	57%	80%	89%
11:00	934	699	219	172	1153	871	964	858	410	456	1374	1314	97%	81%	53%	38%	84%	66%
12:00	873	880	228	236	1101	1116	877	892	376	409	1253	1301	100%	99%	61%	58%	88%	86%
13:00	946	1006	220	290	1166	1296	959	975	391	467	1350	1442	99%	103%	56%	62%	86%	90%
14:00	1087	1094	208	243	1295	1337	1056	1095	396	432	1452	1527	103%	100%	53%	56%	89%	88%
15:00	1373	1236	190	229	1563	1465	1294	1236	363	416	1657	1652	106%	100%	52%	55%	94%	89%
16:00	1735	935	169	54	1904	989	1656	1597	402	424	2058	2021	105%	59%	42%	13%	93%	49%
17:00	1726	1091	170	90	1896	1181	1676	1636	331	343	2007	1979	103%	67%	51%	26%	94%	60%
18:00	1228	1114	187	168	1415	1282	1334	1218	360	273	1694	1491	92%	91%	52%	62%	84%	86%
19:00	810	819	132	172	942	991	853	853	251	276	1104	1129	95%	96%	53%	62%	85%	88%
20:00	735	636	123	162	858	798	786	687	235	252	1021	939	94%	93%	52%	64%	84%	85%
21:00	552	472	107	118	659	590	650	492	182	205	832	697	85%	96%	59%	58%	79%	85%
22:00	407	324	103	124	510	448	457	352	160	186	617	538	89%	92%	64%	67%	83%	83%
23:00	254	188	89	98	343	286	288	197	137	155	425	352	88%	95%	65%	63%	81%	81%
TOTAL	18635	16739	3489	3599	22124	20338	19080	18376	6650	6933	25730	25309	93%	96%	55%	55%	83%	83%

License Plate Comparison Sheet

	ALPR Camera Site 4						Wavetronix Sensor Site 4						Comparison Site 4					
Time	NB-PC	SB-PC	NB-HV	SB-HV	NB	SB	NB-PC	SB-PC	NB-HV	SB-HV	NB	SB	NB-PC	SB-PC	NB-HV	SB-HV	NB	SB
0:00	115	165	199	240	314	405	129	160	266	333	395	493	89%	103%	75%	72%	79%	82%
1:00	82	125	195	174	277	299	115	118	216	222	331	340	71%	106%	90%	78%	84%	88%
2:00	71	88	148	202	219	290	86	102	210	246	296	348	83%	86%	70%	82%	74%	83%
3:00	81	94	149	156	230	250	83	97	199	211	282	308	98%	97%	75%	74%	82%	81%
4:00	156	99	194	192	350	291	181	106	248	239	429	345	86%	93%	78%	80%	82%	84%
5:00	453	197	210	210	663	407	440	175	266	265	706	440	103%	113%	79%	79%	94%	93%
6:00	949	498	243	230	1192	728	984	510	326	338	1310	848	96%	98%	75%	68%	91%	86%
7:00	1061	739	260	286	1321	1025	1137	721	343	409	1480	1130	93%	102%	76%	70%	89%	91%
8:00	840	822	347	343	1187	1165	916	840	423	475	1339	1315	92%	98%	82%	72%	89%	89%
9:00	767	839	366	371	1133	1210	807	783	489	606	1296	1389	95%	107%	75%	61%	87%	87%
10:00	733	782	367	347	1100	1129	742	751	515	543	1257	1294	99%	104%	71%	64%	88%	87%
11:00	799	807	318	379	1117	1186	828	871	434	599	1262	1470	96%	93%	73%	63%	89%	81%
12:00	866	510	398	213	1264	723	876	888	555	586	1431	1474	99%	57%	72%	36%	88%	49%
13:00	834	507	428	221	1262	728	877	826	564	574	1441	1400	95%	61%	76%	39%	88%	52%
14:00	883	613	449	225	1332	838	923	1009	570	548	1493	1557	96%	61%	79%	41%	89%	54%
15:00	695	760	301	268	996	1028	1106	1172	548	645	1654	1817	63%	65%	55%	42%	60%	57%
16:00	1143	928	433	265	1576	1193	1184	1366	595	692	1779	2058	97%	68%	73%	38%	89%	58%
17:00	1129	855	458	289	1587	1144	1119	1350	586	626	1705	1976	101%	63%	78%	46%	93%	58%
18:00	874	731	369	313	1243	1044	972	973	513	613	1485	1586	90%	75%	72%	51%	84%	66%
19:00	616	620	362	329	978	949	662	613	480	502	1142	1115	93%	101%	75%	66%	86%	85%
20:00	494	553	303	332	797	885	556	594	420	462	976	1056	89%	93%	72%	72%	82%	84%
21:00	439	454	302	353	741	807	479	456	404	453	883	909	92%	100%	75%	78%	84%	89%
22:00	277	372	265	285	542	657	308	378	347	405	655	783	90%	98%	76%	70%	83%	84%
23:00	129	88	96	179	225	267	242	242	313	388	555	630	53%	36%	31%	46%	41%	42%
TOTAL	14486	12246	7160	6402	21646	18648	15752	15101	9830	10980	25582	26081	90%	87%	73%	62%	83%	75%

License Plate Comparison Sheet

	ALPR Camera Site 5						Wavetronix Sensor Site 5						Comparison Site 5					
Time	EB-PC	WB-PC	EB-HV	WB-HV	EB	WB	EB-PC	WB-PC	EB-HV	WB-HV	EB	WB	EB-PC	WB-PC	EB-HV	WB-HV	EB	WB
0:00	33	36	58	38	91	74	42	98	97	64	139	162	79%	37%	60%	59%	65%	46%
1:00	22	24	40	41	62	65	28	70	66	65	94	135	79%	34%	61%	63%	66%	48%
2:00	20	23	45	26	65	49	24	52	64	52	88	104	83%	44%	70%	50%	74%	47%
3:00	36	20	45	39	81	59	54	54	80	55	134	109	67%	37%	56%	71%	60%	54%
4:00	82	26	63	57	145	83	126	61	108	88	234	149	65%	43%	58%	65%	62%	56%
5:00	289	45	58	43	347	88	401	91	190	95	591	186	72%	49%	31%	45%	59%	47%
6:00	542	140	83	78	625	218	837	239	350	164	1187	403	65%	59%	24%	48%	53%	54%
7:00	650	264	104	86	754	350	1130	462	381	209	1511	671	58%	57%	27%	41%	50%	52%
8:00	472	317	100	118	572	435	834	466	302	216	1136	682	57%	68%	33%	55%	50%	64%
9:00	374	369	107	136	481	505	583	488	311	233	894	721	64%	76%	34%	58%	54%	70%
10:00	359	414	146	160	505	574	555	503	313	267	868	770	65%	82%	47%	60%	58%	75%
11:00	309	377	128	180	437	557	495	476	314	291	809	767	62%	79%	41%	62%	54%	73%
12:00	368	382	133	140	501	522	510	544	325	277	835	821	72%	70%	41%	51%	60%	64%
13:00	422	432	149	124	571	556	532	628	373	270	905	898	79%	69%	40%	46%	63%	62%
14:00	526	455	125	122	651	577	570	724	309	241	879	965	92%	63%	40%	51%	74%	60%
15:00	550	624	140	139	690	763	601	1019	334	278	935	1297	92%	61%	42%	50%	74%	59%
16:00	634	708	148	146	782	854	645	1269	353	276	998	1545	98%	56%	42%	53%	78%	55%
17:00	506	643	135	107	641	750	568	1402	331	215	899	1617	89%	46%	41%	50%	71%	46%
18:00	315	363	136	101	451	464	498	917	272	212	770	1129	63%	40%	50%	48%	59%	41%
19:00	300	236	123	72	423	308	357	646	235	141	592	787	84%	37%	52%	51%	71%	39%
20:00	235	230	84	83	319	313	312	551	169	144	481	695	75%	42%	50%	58%	66%	45%
21:00	179	171	72	68	251	239	233	422	154	129	387	551	77%	41%	47%	53%	65%	43%
22:00	125	110	84	42	209	152	165	265	145	95	310	360	76%	42%	58%	44%	67%	42%
23:00	85	84	84	41	169	125	110	210	134	92	244	302	77%	40%	63%	45%	69%	41%
TOTAL	7433	6493	2390	2187	9823	8680	10210	11657	5710	4169	15920	15826	75%	53%	46%	53%	63%	53%

Unreadable Plate Statistics

Site	Unreadable - PC	Unreadable - HV	Unreadable - Total	Partial Unreadable	Total Unused Plates (Due to Plate Quality)
1N	669	726	1395	589	1984
1S	407	774	1181	286	1467
2N	350	721	1071	355	1426
2S	427	853	1280	341	1621
3E	377	337	714	277	991
3W	471	418	889	256	1145
4N	446	988	1434	340	1774
4S	459	1027	1486	353	1839
5E	641	351	992	289	1281
5W	511	321	832	267	1099
TOTAL	4758	6516	11274	3353	14627

Plate Capture Statistics

Site	Usable Plates	Unusable Plates	Total	Machine Volume	% Captured
1N	11934	1984	13918	18317	76%
1S	12526	1467	13993	18445	76%
2N	23288	1426	24714	28167	88%
2S	21867	1621	23488	29095	81%
3E	22124	991	23115	25730	90%
3W	20338	1145	21483	25309	85%
4N	21646	1774	23420	25582	92%
4S	18648	1839	20487	26081	79%
5E	9823	1281	11104	15920	70%
5W	8680	1099	9779	15826	62%
TOTAL	170874	14627	185501	228472	80%

Appendix E

EE Methodology

Overview

This report describes the data and methodology used to develop external-to-external through trips for five major external stations of the LSIORB study area. The external-to-external through trips are developed based on origin-destination survey data and traffic counts collected by The Traffic Group, Inc. in September of 2010. For each external station surveyed, traffic counts and license plate counts as well as the plate-to-count ratio are reported for total vehicles, passenger vehicles, and heavy vehicles. This data is shown in the **Table 1**.

Table 1: Observed Traffic Counts and Recorded License Plates

	Traffic Count via Sensor			Plates Recorded & Used			Count / Plates - Expansion		
Station	Total Count	Passenger Count	HV Count	Total Plates	Passenger Plates	HV Plates	Total Factor	PC Factor	HV Factor
1N	18,317	10,008	8,309	11,934	6,547	5,387	1.535	1.529	1.542
1S	18,445	10,423	8,022	12,526	6,982	5,544	1.473	1.493	1.447
2N	28,167	16,066	12,101	23,288	18,300	4,988	1.210	0.878	2.426
2S	29,095	20,403	8,692	21,867	17,386	4,481	1.331	1.174	1.940
3E	25,730	19,080	6,650	22,124	18,635	3,489	1.163	1.024	1.906
3W	25,309	18,376	6,933	20,338	16,739	3,599	1.244	1.098	1.926
4N	25,582	15,752	9,830	21,646	14,486	7,160	1.182	1.087	1.373
4S	26,081	15,101	10,980	12,246	12,246	6,402	2.130	1.233	1.715
5E	15,920	10,210	5,710	9,823	7,433	2,390	1.621	1.374	2.389
5W	15,826	11,657	4,169	8,680	6,493	2,187	1.823	1.795	1.906
TOTAL	**228,472**	**147,076**	**81,396**	**164,472**	**125,247**	**45,627**	**1.389**	**1.174**	**1.784**

Results from the license plate recognition and matching survey were adjusted for study area inbound and outbound movements and factored to match the recorded traffic count data. Expansion factors and the fratar process are used to adjust the survey license plate data into balanced external through movements between the five external stations for both passenger vehicles and heavy vehicles. Note that heavy vehicles include both light and heavy trucks. The below sections describe the procedures for developing external-to-external through trips for passenger and heavy vehicles.

Passenger Vehicles

The origin-destination survey conducted by The Traffic Group, Inc. provided data on external trip movements by direction including external-to-external (EE) and external-to-internal (EI) movements for passenger vehicles. This data is shown in the **Table 2**. The license plates were matched for at the first and last location only throughout the 24-hour period. Thus, some illogical movements between the directional external stations are recorded.

For example, the southbound trips from external station 1 (1S) going to southbound station 2 (2S) or to northbound station 4 (4N) is not a direct movement but there are other external-to-internal movements not recorded within these two endpoints that compose this trip chain. Therefore, these trips are considered EI trips. Similarly, the matrix diagonal highlighted in light orange are EI trips where a license plate was recorded initially but no match was found. In other words, a trip entered or exited the study area but did not return.

Table 2: Directional External Passenger Vehicle Matched License Plates

	1N	1S	2N	2S	3E	3W	4N	4S	5E	5W	Total
1N	4,844	778	142	79	151	105	82	110	101	155	6,547
1S	906	3,580	141	59	817	80	67	920	107	305	6,982
2N	176	56	13,278	4,048	124	136	82	147	95	158	18,300
2S	210	61	6,897	8,291	262	103	101	1,005	92	364	17,386
3E	209	60	163	117	13,029	4,605	101	115	85	151	18,635
3W	716	55	268	93	5,980	8,754	67	157	85	564	16,739
4N	1,131	74	1,328	94	225	91	7,806	3,494	81	162	14,486
4S	176	55	226	63	134	72	2,434	8,886	88	112	12,246
5E	369	113	423	76	614	97	70	128	4,009	1,534	7,433
5W	198	66	138	61	130	65	58	76	1,063	4,638	6,493
Total	8,935	4,898	23,004	12,981	21,466	14,108	10,868	15,038	5,806	8,143	125,247

There are a total of 125,247 passenger vehicle trips recorded by the origin-destination license plate matching survey. In comparison to **Table 1**, the sum of the rows (productions) match the number of plates recorded for passenger vehicles. The sum of the columns (attractions) does not match the number of plates recorded and shows an imbalance of trips. The trip imbalance could be a result of the low plate matching rate for external station five. Additional details can be seen in the Automatic License Plate Recognition and Origin & Destination Study report developed by The Traffic Group, Inc.

The directional external passenger vehicle trips were condensed to only the logical external station movements between the five external stations.

Based on the location of the stations, the locations of 1S, 2S, 3W, 4N, and 5E are entry points to the study area and the locations of 1N, 2N, 3E, 4S, and 5W are exit points to the study area. A matrix table was developed that includes the survey external trips from entry points to exit points for passenger vehicles. This table is shown in **Table 3**.

Table 3: External Passenger Vehicle Matched License Plates

	1N	2N	3E	4S	5W	Total
1S	906	141	817	920	305	3,089
2S	210	6,897	262	1,005	364	8,738
3W	716	268	5,980	157	564	7,685
4N	1,131	1,328	225	3,494	162	6,340
5E	369	423	614	128	1,534	3,068
Total	3,332	9,057	7,898	5,704	2,929	28,920

The external passenger vehicle trips were further condensed to only the EE trips between the five external stations and all EI trips were removed. See **Table 4**.

Table 4: External-to-External Passenger Vehicle Matched License Plates

	1N	2N	3E	4S	5W	Total
1S	0	141	817	920	305	2,183
2S	210	0	262	1,005	364	1,841
3W	716	268	0	157	564	1,705
4N	1,131	1,328	225	0	162	2,846
5E	369	423	614	128	0	1,534
Total	2,426	2,160	1,918	2,210	1,395	**10,109**

The EE trips were then expanded to match the observed counts using expansion factors. The expansion factors are shown in **Table 1** as the count-to-plate ratios. **Table 5** shows the expansion of the EE productions and attractions. Note that external station 2N has a decreasing expansion rate. The issue of the decreasing expansion rate for station 2N (attraction) as well as the imbalance of the attraction trip totals (Table 2) to the matched plates (Table 1) results in some uncertainty with the attraction trips. Therefore, due to more confidence in the production data, the expanded external trip productions are used to fratar the survey EE passenger trips to the expanded EE trips to be used in the LSIORB travel demand model.

Table 5: Expanded Passenger Vehicle External-to-External Trip Productions and Attractions

Productions				Attractions			
	Survey EE Trips	Expansion Factor	Expanded Productions		Survey EE Trips	Expansion Factor	Expanded Attractions
1S	2,183	1.473	3,259	**1N**	2,426	1.529	3,708
2S	1,841	1.174	2,160	**2N**	2,160	0.878	1,896
3W	1,705	1.098	1,872	**3E**	1,918	1.024	1,964
4N	2,846	1.087	3,095	**4S**	2,210	1.233	2,725
5E	1,534	1.374	2,107	**5W**	1,395	1.795	2,504
Total	**10,109**	n/a	**12,493**	**Total**	**10,109**	n/a	**12,798**

The TransCAD modeling software was used to fratar the raw survey data of EE trips (Table 4) with the sum of the expanded EE productions (Table 5) for passenger vehicles. The result of the fratar procedure is a daily external-to-external trip matrix. As shown in **Table 6** there are approximately 12,500 external through trips for passenger vehicles in the LSIORB study area.

Table 6: LSIORB Passenger Vehicle External-to-External Trips

	1	2	3	4	5	Total
1	0	187	870	1,558	644	3,259
2	275	0	191	1,167	527	2,160
3	805	209	0	157	701	1,872
4	1,484	1,211	165	0	235	3,095
5	695	553	645	214	0	2,107
Total	3,258	2,160	1,872	3,095	2,107	**12,493**

Heavy Vehicle Truck

The origin-destination survey conducted by The Traffic Group, Inc. provided data on external trip movements by direction including external-to-external (EE) and external-to-internal (EI) movements for heavy vehicles. Heavy vehicles include both light and heavy trucks. This data is shown in the **Table 7**. As with the passenger vehicle trips, the heavy vehicle license plates were matched for at the first and last location only throughout the 24-hour period. Thus, illogical movements between the directional external stations are recorded. For example, the southbound trips from external station 1 (1S) going to southbound station 2 (2S) or to northbound station 4 (4N) is not a direct movement but there are other external-to-internal movements not recorded within these two endpoints that compose this trip chain.

Therefore, these trips are considered EI trips. Similarly, the matrix diagonal highlighted in light orange are EI trips where a license plate was recorded initially but no match was found. In other words, a trip entered or exited the study area but did not return.

Table 7: Directional External Heavy Vehicle Matched License Plates

	1N	1S	2N	2S	3E	3W	4N	4S	5E	5W	Total
1N	4,733	240	55	29	68	29	57	109	21	46	5,387
1S	496	2,351	142	40	681	52	59	1,517	29	177	5,544
2N	65	42	4,291	286	34	25	58	122	20	44	4,987
2S	125	36	484	1,920	75	27	72	1,448	32	261	4,480
3E	98	35	53	28	2,688	415	27	51	21	73	3,489
3W	739	45	109	22	388	1,732	34	133	28	369	3,599
4N	1,685	82	1,844	72	115	58	2,785	409	28	82	7,160
4S	154	55	174	48	46	38	388	5,446	29	24	6,402
5E	199	30	420	28	403	28	20	60	1,005	197	2,390
5W	87	20	86	18	45	17	18	19	147	1,730	2,187
Total	8,381	2,936	7,658	2,491	4,543	2,421	3,518	9,314	1,360	3,003	45,625

There are a total of 45,625 heavy vehicle trips recorded by the origin-destination license plate matching survey. In comparison to **Table 1**, the sum of the rows (productions) match the number of plates recorded for heavy vehicles. The sum of the columns (attractions) does not match the number of plates recorded and shows an imbalance of trips. The trip imbalance could be a result of the low plate matching rate for external station five. Additional details can be seen in the Automatic License Plate Recognition and Origin & Destination Study report developed by The Traffic Group, Inc.

The directional external heavy vehicle trips were condensed to only the logical external station movements between the five external stations. Based on the location of the stations, the locations of 1S, 2S, 3W, 4N, and 5E are entry points to the study area and the locations of 1N, 2N, 3E, 4S, and 5W are exit points to the study area.

A matrix table was developed that includes the survey external trips from entry points to exit points for heavy vehicles. This table is shown in **Table 8**.

Table 8: External Heavy Vehicle Matched License Plates

	1N	2N	3E	4S	5W	Total
1S	496	142	681	1,517	177	3,013
2S	125	484	75	1,448	261	2,393
3W	739	109	388	133	369	1,738
4N	1,685	1,844	115	409	82	4,135
5E	199	420	403	60	197	1,279
Total	3,244	2,999	1,662	3,567	1,086	12,558

The external heavy vehicle trips were further condensed to only the EE trips between the five external stations and all EI trips were removed. See **Table 9**.

Table 9: External-to-External Heavy Vehicle Matched License Plates

	1N	2N	3E	4S	5W	Total
1S	0	142	681	1,517	177	2,517
2S	125	0	75	1,448	261	1,909
3W	739	109	0	133	369	1,350
4N	1,685	1,844	115	0	82	3,726
5E	199	420	403	60	0	1,082
Total	2,748	2,515	1,274	3,158	889	**10,584**

The EE trips were then expanded to match the observed counts using expansion factors. The expansion factors are shown in **Table 1** as the count-to-plate ratios. **Table 10** shows the expansion of the EE productions and attractions. Similar to the issues with the heavy vehicle trip attractions and due to more confidence in the production data, the expanded external trip productions are used to fratar the survey EE heavy trips to the expanded EE trips to be used in the LSIORB travel demand model.

Table 10: Expanded Heavy Vehicle External-to-External Trip Productions and Attractions

Productions				Attractions			
	Survey EE Trips	Expansion Factor	Expanded Productions		Survey EE Trips	Expansion Factor	Expanded Attractions
1S	2,517	1.447	3,642	**1N**	2,748	1.542	4,239
2S	1,909	1.940	3,704	**2N**	2,515	2.426	6,103
3W	1,350	1.926	2,601	**3E**	1,274	1.906	2,428
4N	3,726	1.373	5,115	**4S**	3,158	1.715	5,416
5E	1,082	2.389	2,585	**5W**	889	1.906	1,695
Total	**10,584**	n/a	**17,647**	**Total**	**10,584**	n/a	**19,880**

The TransCAD modeling software was used to fratar the raw survey data of EE trips (Table 9) with the sum of the expanded EE productions (Table 10) for heavy vehicles. The result of the fratar procedure is a daily external-to-external trip matrix. As shown in **Table 11** there are approximately 17,600 external through trips for heavy vehicles in the LSIORB study area.

Table 11: LSIORB Heavy Vehicle External-to-External Trips

	1	2	3	4	5	Total
1	0	148	1,028	2,071	395	3,642
2	158	0	150	2,623	773	3,704
3	1,003	162	0	259	1,176	2,601
4	2,111	2,535	229	0	241	5,115
5	371	860	1,193	161	0	2,585
Total	3,643	3,705	2,601	5,113	2,585	**17,647**