TNCC Validation and Enhancement

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16. Abstract

The primary objective of this research project is to integrate Toll Network Capacity Calculator (TNCC), into a Decision Support System (DSS), with a Graphical User Interface (GUI). TNCC is a model for computing the maximum number of vehicles that can pass through a highway segment containing a toll collection facility. A secondary objective is to demonstrate the practical application of TNCC's DSS.

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Executive Summary

Modelling traffic at toll collection facilities has lead to the development of an appropriate standardized performance measure for toll plazas, No-Queue-Maximum-Throughput (NQMT). Current microscopic and macroscopic models of toll facilities either compute outputs too slowly or make too many assumptions leading to inaccurate outputs. Most are not generic enough to deal with a wide variety of situations and plazas. For given traffic characteristics such as the Electronic Toll Collection (ETC) usage rate and percent-trucks, NQMT is the maximum throughput in vehicles per hour at a plaza with a given lane configuration such that no queues exists in any of the lanes at the end of the hour.

This research has developed two very different hybrid models for traffic at toll collection facilities, SHAKER and Toll Network Capacity Calculator (TNCC), which were both implemented in java programs to predict NQMT. They also can be used to understand how throughput and other performance measures are dependent upon the characteristics of the approaching traffic to the plaza, how they are dependent upon the lane configuration of the plaza, and how they are dependent upon the properties of the traffic categories such as processing rates for the different categories. Both models were calibrated with real world data on a network of toll roads, maintained by the Orlando Orange County Expressway Authority (OOCEA). In addition, SHAKER is self-calibrating, so that it can be customized to predict NQMT of any plaza in any arbitrary region after making the proper field-measurements of the processing rates of the identified categories of traffic at that plaza.

Both models were made accessible by a login onto a Decision Support System (DSS), website, however, the DSS only integrates TNCC with hourly maps of the OOCEA network of toll roads. The maps have subdivided the OOCEA's highways into 299 highway segments, 20 of which contain toll collection facilities. These maps indicate with a color-code which segments on the Network are bottlenecks, near bottlenecks or potential bottlenecks. The capacity of every segment, except for these 20 segments, was calculated using the Highway Capacity manual (HCM) 2000, the standard for computing capacities for different types of highway segments and compared to the approach volumes. The NQMT, computed by TNCC, was used as the capacity values for the other 20 segments containing toll collection facilities; and these were then compared to the approach volumes to the plazas. If the approach volumes were larger than the capacity, the segment was identified as a bottleneck and became a red segment on the DSS's map. Hourly approach volumes were collected for 16 hours of a typical day so that hourly bottlenecks were identified once capacities for each of the hours were computed.

In the development of the DSS, it was found that ArcGIS software and maps provided the necessary backdrop for the Graphical User Interface (GUI). Programs connected the GUI with the Oracle Database and provided a "Form" interface in which users input changes to traffic and geometric data variables as well as changes in plaza lane configurations. Recalculated capacities are then compared to the newly inputted traffic volumes to identify and place on the maps the new bottlenecks and their locations. This assists operators in their hour-to-hour decisions concerning the lane configurations at the plaza.

Introduction

Every driver who has experienced driving through a toll plaza, especially one in a metropolitan area, knows that they often become bottlenecks and cause traffic jams. One reason for this problem is that there is no standard way for analyzing toll plazas even though their number is growing rapidly. This makes it difficult for planners to design and operators to intelligently respond to changing traffic conditions at the plaza.

Toll Collection Facilities consist of several lanes. The arriving traffic can be subdivided in certain customer types. Each lane is able to process one or more customer types. The lane configuration of a plaza specifies which types of customers can be processed in each of its lanes. The maximum processing rate for each lane depends on the composition of customer types in each lane. By modeling the queuing at toll collection facilities, the throughput (vehicles per unit time) of the entire plaza may be predicted. Suggestions to reconfigure existing lanes to allow specific customer types or recommendations to open or close lanes with certain allowed customer types at the plaza may increase hourly throughput and improve plaza performance.

The DSS, created by the UMass Dartmouth Research Team with the financial support from the Center for Advanced Transportation Systems Simulation (CATSS), is an interactive website that allows users to determine maximum hourly throughput of any plaza with a lane configuration of their own design. Hourly throughput has units of vehicles per hour (vph).

Accessible by a login, the DSS provides clients with Toll Network Capacity Calculator, TNCC, and SHAKER, two algorithms that compute NQMT, a plaza performance measure. NQMT is the maximum number of vehicles that can be processed by a given lane configuration in one hour such that no queues exists in any of its lanes at the end of the hour. In order to compute NQMT, both TNCC and SHAKER must be given the percentage of the hourly approach vehicles that belong to the individual categories of customer types along with their average hourly processing rate. For instance, 40% of the approach vehicles may belong to category X and 60% of the vehicles belong to category Y, where X vehicles are process at 600 vph and Y vehicles are processed at 1200 vph. The lane configuration of the plaza may look something like X_X_X_XY_XY_Y, which is a six lane plaza, three of which process X vehicles, one of which process Y vehicles and two of which process both X and Y vehicles.

In addition, the DSS has a GUI, using ARCGIS mapping software that allows clients to create scenarios on an entire network of toll roads. By manipulation of the Oracle database provided on the DSS, clients may change the highways' geometric design variables to increase or decrease capacities of the highway segments on the network. Approach traffic volumes can also be manipulated. A highway segment having an approaching traffic volume that exceeds its capacity will turn red on the GUI's map. Currently, the DSS provides 16 GUI maps, one map for each hour of the day from 5 a.m until 9 p.m. of the network of toll roads in Orange County, Florida, maintained by the OOCEA. The GUI's default lane configurations of the 20 unidirectional plazas on the network were taken from November 5, 2002, transaction data. The network is divided into 299 highway segments and their highway capacity input variables as well as their default approach volumes are stored in an Oracle database that is easily accessible by highlighting the interested segmented portion of the GUI's map. DSS users can observe

bottleneck formation and shifting by changing highway design, changing plaza lane configurations or changing the characteristics of the traffic.

In future work and with an expansion of the Oracle database, the DSS can be implemented real time. Transaction data and volume data at various network sites can provide the GUI with needed input so that bottleneck locations can be viewed real time. Using the DSS, engineers and operators can easily locate bottleneck trouble zones and near-bottlenecks and potential-bottlenecks. Planners can choose the appropriate time-of-day for maintenance and construction procedures. Operators can guide traffic during special events. And engineers can design or redesign plaza lane configurations, interchange sites and lane additions to highway widening sites.

Appendix J lists the entire acronym for the abbreviations used.

Study Objectives

The primary objective of this research study was to integrate TNCC, into a DSS, with a GUI. TNCC is a model for computing the maximum number of vehicles that, during one hour, can pass through a highway segment containing a toll collection facility. To support operators in their choice of lane configurations at various toll facilities, TNCC quantifies the toll network's ability to process traffic. This facilitates the identification and location of bottlenecks on a network of toll roads.

During the course of this project, TNCC's capabilities were expanded and TNCC now calculates capacities that include additional lane types. The GUI is a user-friendly interface that allows users to input several alternative lane configurations at the toll facilities. The GUI reports back the bottlenecks in a graphical mapping format using ArcGIS / ArcIMS software. This software is supported by the University of Massachusetts System and was not an expenditure of this project. The DSS uses TNCC's logic to formulate the capacity of highway segments on the network that contain toll collection facilities and the DSS uses traditional capacity calculating techniques from HCM 2000 to formulate the capacities of the basic highway segments located between toll facilities.

There are a total of 299 connected highway segments on the system of toll roads in this study, 20 of which contain toll facilities. The 10 plazas (directionally split so that there are 20 unidirectional plazas on 20 separate segments) are located on the OOCEA's, network of toll roads in Orange County, Florida. Real data collected on November 5, 2002, provided the highway-segment-properties required to compute the 299 capacities. Capacities were calculated for 16 consecutive hours on this day for all 299 segments, a total of 4784 capacities. Data used to make the computations was stored in a default Oracle Database, which is accessible by clients using the DSS. Maps for each of the 16 hours indicate by the segment color whether the segment is a bottleneck (red), a near-bottleneck (orange), or a potential bottleneck (yellow). Non-bottleneck segments on the maps are colored in green. The DSS also allows clients to temporarily modify data in the Oracle Database and save it separately, in other words, clients are able to change properties on any of the highway segments using the available input form and re-compute the new capacities on all 299 segments. A new map can then be generated. New maps may show that bottlenecks have been eliminated or that new bottlenecks have been created, or that bottleneck-locations have been shifted. Modifications of the segments with plazas are of prime interest. Changes in the lane configuration of a plaza during one of the 16 hours of the day,

for instance, may eliminate bottlenecks at the plaza segment and at the same time create bottlenecks downstream at other segments.

The DSS website is located at http://134.88.236.208:8080/dss_test/index1.html. The transportation engineering research group submitting this report will continue to provide administrative support for the DSS. However, installation of the DSS server may be set up in any location.

In addition to TNCC's expansion, another model was developed during the course of this project. SHAKER is based on a completely different methodology, which includes aspects of car following theory, the motion equations and probability. SHAKER has a wider set of capabilities besides computing the capacity of highways segments with toll facilities. These will be discussed in a following section of this final report. SHAKER and its code will be an additional deliverable of this project as stand-alone software. It is also available to clients accessing the DSS website as stand-alone software. A comparison study of the two models indicates that SHAKER's output, the predicted NQMT, is within 3% of TNCC's output most of the time. This is an amazing result considering the major differences in their methodologies.

A secondary objective of this research study was to demonstrate the practical application of TNCC and now SHAKER as well. The study applied TNCC and SHAKER to five plazas (ten unidirectional plazas) situated on the Florida Turnpike and to ten plazas (20 unidirectional plazas) situated on the OOCEA's network of toll roads. In this demonstration, the DSS provides a way for clients to choose the best lane configuration for these plazas. The lane configuration choice depends heavily on what portions of the approaching traffic belong to the various traffic categories: E users of ETC, A users of the Automatic Coin Machine (ACM), M users of the Manual users that are passenger cars paying cash and T users of the Manual users that are vehicles other than passenger cars paying cash. Traffic categories or customer groups being served at the five plazas of the FDOT Turnpike have been identified and their service times are comparable to existing customer groups on the OOCEA's network, already identified in the previous study.

Appendix A provides Comparison Tables of the output NQMT values generated by TNCC and SHAKER. The percent difference in the NQMT values computed by TNCC and SHAKER for all of the twenty unidirectional plazas on the OOCEA's network of toll roads for the morning peak hour of the day, from 7 to 8 a.m. is provided in Table 4 of Appendix A. Most percent differences lie below 5%, however, one of them is a high 9%. In order to explain some of the large percent differences in SHAKER's and TNCC's computation of NQMT, the differences in their traffic category definitions had to be examined, see Appendix A for a complete analysis

The NQMT values calculated by TNCC and SHAKER for all 16 hours for the West Bound (WB) Holland East Main Plaza located on the SR408 on the OOCEA's network, and for all 16 hours of the East Bound (EB) Dean Main Plaza located on the 528 and for all 16 hours for the South Bound (SB) University Main Plaza located on the 417 is provided Appendix A. Again, most percent differences lie below 5%, some, however, are high.

In addition, the percent difference in the NQMT values computed by TNCC and SHAKER for the ten unidirectional plazas on the Florida Turnpike are provided in Table 5 of Appendix A. Note that they are all less than 1%.

Literature Review

There are microscopic and macroscopic traffic flow models. Microscopic models simulate the situation by knowing the state (position, velocity, and sometimes additional information) of every vehicle [1] [2] [3] [5] [6]. In contrast, macroscopic models define variables of state such as average speed, volume, and density that describe the system or parts of the system. Car-following and cellular automata belong more to the microscopic domain whereas queuing theory can be viewed as more macroscopic. Van Dijk suggests hybrid models for most problems in practice [7]. He elaborated further on differences between constructing a plaza and re-configuring the lanes. He observed that simulating the toll plaza scenario before constructing the actual site helps better achieve the targets. He further suggested a combination of queuing and simulation models would be the most powerful strategy while designing a toll plaza. [7] Queuing provides the conceptual way of thinking and insights from which variants could be derived that may be modeled and analyzed by simulation. He shows this approach in the application at the Westerschelde Tunnel Toll Plaza [8]. The hybrid model TNCC is described in Zarrillo [9] [10] [12]. Zarrillo and Pietrzyk deal especially with the ETC aspect, implementation [11] [12], management [13], and practice [14]. Sastry evaluates car-following model Corridor Traffic Simulation Model (CORSIM) using Global Positioning System (GPS) field data [15]. Huang uses a cellular automata approach to model highway sections with tollbooths [16]. Webster simulates the impact of trucks on highway freeway sections [17]. Festa compares microscopic and macroscopic models for traffic flow [18].

In Al-Deek [19] the microscopic model DQUEUE, described in [3], is used to study the impact of introducing ETC. Simulation often is too complex, with high computational cost and too slow in practice. Lin uses the Toll Plaza Simulation (TPS) model described in [20] to develop a rather simple delay model, which is much simpler and easier to use [21].

The service time under a non-waiting condition is sometimes intuitively mistaken to be shorter than it really is. Under light traffic, the toll collectors may actually consume more time than when pressured with a queue. When toll collectors are under greater pressure from a growing queue, they tend to process transactions faster. [22] The number of coins that must be processed affects the actual service time. It may also be influenced by such factors as the experience of the toll collectors, the physical dimensions of tollgates, the methods of toll collection, and the presence of drivers with exact change. Manual booths with heavy-truck traffic normally have lower service volumes than those that are primarily for automobiles. Traffic congestion levels also affect service time. When queues develop, motorists have time to search for needed change before the transaction. [22]

Certain models pay attention to the geometrical aspects of the toll plaza. Astarita et al. have developed one such microscopic model, which is able to represent the traffic demand/supply interaction and the effects on traffic induced by the geometrical and functional characteristics of the infrastructure. [6] Such models are more useful again when building a toll plaza or to trouble-shoot the existing bottlenecks when comparing them to any other plaza that has same number and configuration of lanes but is more efficient.

Some of the work done on toll systems includes the effect of toll booths placed in the traffic stream. Also, a toll plaza itself has been simulated. Huang et al [16] presented one such model, where they study the traffic flow and the phase transition in the presence of tollbooths. They further conclude that the setup of a tollbooth influences the traffic flow significantly. As no

vehicles are allowed to bypass the tollbooth, the effect is not short ranged but can extend to the whole lattice especially when the periodic boundary condition is enforced. The tollbooths are seen as bottlenecks on the highways and the traffic flow saturates to a certain value in the presence of the tollbooths. [16] The same roads can handle increased volumes of traffic if the time that each vehicle stays on the road decreases. Increasing the speed limits on the roads can do this. A toll plaza on a free way is one of the many different types of bottlenecks that drivers encounter these days.

Researchers are also working on finding the equivalence factor for two different types of vehicles. One such example is a simulation study carried out by Webster and Elefteriadou. They think that trucks have an effect on the quality of traffic flow on freeways. The passenger car equivalency of a truck represents the number of passenger cars that would have an equivalent effect on the quality of the traffic flow. The research estimated truck passenger car equivalents using simulation, based on traffic density. [17]

The concept of Level of Service (LOS) is very common for all kind of traffic facilities. But there is still no standard way to define LOS for toll plazas. Woo and Hoel propose the traffic density as LOS criteria [22]. Lam [23] models whole networks but needs link capacities as inputs. Since these links contain toll plazas our study could help to provide those link capacities.

Another interesting question about the blocking probabilities of a general network is mathematically addressed in the paper of Chouhury [24]. Toll collection increased tremendously over the last several years. Hence, it is very important to understand their traffic flow in order to properly manage those facilities. Gazis calculates the social costs for only one rather small toll plaza. At a 3-lane highway with 25% to small gate capacity during rush hour 300 days a year he finds the social costs to be about $7.2 million yearly for one direction only [25]. This is much more than the tolls collected.

The model developed in SHAKER can handle five traffic categories, electronically paying cars- E_P, and trucks- E_T, ACM users- A, manual paying cars- M, and trucks- T. TNCC places all electronically paying vehicles in the same E category. The mixed lane problem was treated earlier in [9]. A cosine function was used to model the throughput of mixed lanes of the type AE or ME or MTE. This cosine function was used in TNCC [26] [27] [28] and although the model is quite accurate the cosine function had no fundamental basis. In the SHAKER model, car-following theory is used to derive a model for mixed lanes [29] [30] [31]. The cosine function was replaced by analytically solving a car-following problem. Although it was originally developed for non-ticketing systems this new model may be modified to handle ticketing systems also.

TNCC Development and Validation

TNCC computes the NQMT, maximum hourly throughput in vph such that queues do not exist in any of the plaza's lanes at the end of the hour. To begin the iterative computation of NQMT, TNCC allocates a large volume of traffic into the plaza, equivalent to the product of the number of lanes in the plaza and the hourly processing rate for the quickest category of traffic, ETC vehicles. This large hourly approach volume may, for example, have traffic characteristics such that 5% of the vehicles belong to the T category, 20% to the M category, 25% to the A category and 50% to the E category. Initially, all T vehicles are placed into MTE lanes and MT lanes equally. MTE lanes on the OOCEA's network are mixed lanes providing service to M, T and ETC customers. Other categories are similarly placed into their allowed lanes, with the exception of ETC vehicles, which are primarily placed into the dedicated ETC lane prior to the mixed lanes.

TNCC then computes the *allowed* time in an hour allocated to service all vehicles of one particular category in a lane. (Zarrillo, Radwan, Dowd, 2002) In order to do this, for each lane in the plaza, each percentage of the total vehicles placed in that lane that belong to a category must be found. By dividing the percentage of vehicles allocated in a lane that belong to that particular category by its processing rate as listed in Table 1, TNCC computes the portion of an hour allocated to processing vehicles in that category. In a mixed lane, TNCC sums up the times to service all categories in that lane and inverses this sum to determine the processing rates for that mixed lane in units of vph. The sum of the processing rates for all the lanes equates to the plaza's hourly throughput for that initial arbitrary distribution. The processing rate for ETC vehicles used in the division computation is 1560 vph if the lane is a dedicated lane for ETC vehicles. However, if the lane is mixed, in other words, if ETC vehicles are mixed in with M, A or T vehicles, then the processing rates for the ETC vehicles used in the computation ranges is value from a low value of the processing rate for the slowest traffic category in that lane to a high value of 1560 vph. If there is a small portion of vehicles in the lane that are ETC, then there will be a lower value used. The closer to 100% for the value of the portion of vehicles being ETC vehicles, the closer the processing rate is to 1560 vph in those mixed lanes.

TABLE 1 Hourly processing-rates for lanes under queuing conditions, S^X, providing service to a single category of traffic, X, measured in the field at the OOCEA's plazas (Zarrillo, 1998)

Type of Toll Service	X	S^X (vph)
Manual service for passenger cars	M	$S^M = 498 \pm 48$
Automatic Coin Machine	A	$S^A = 618 \pm 30$
Manual service for vehicles other than passenger cars	T	$S^T = 138 \pm 78$
A mixture of ETC passenger cars and ETC semi-trucks traveling at 35mph	E veh E_P and E_T	$S^E = 1560 \pm 120$

Note that there is no more than one hour available for processing; therefore, if there are more vehicles than can be processed in the hour, then TNCC either moves them into a lane that has not used up its entire hour, thus correcting the initial arbitrary distribution, or discards the leftover vehicles. It is important to emphasize that vehicles are discarded in a way that maintains the value for the given proportion of vehicles in each of the categories. In other words, for our example, 5% of the approaching traffic being of the T category is maintained, as is 20% being M vehicles, 25% being A vehicles and 50% being ETC vehicles. Remaining vehicles not discarded are considered the new approach volume to the plaza and the computation begins anew with a new distribution. During each computation, the approach volume is reduced and converges to an accurate plaza hourly maximum throughput such that there are no queues at the end of the hour in any of the plaza's lanes. At the same time, the lane-percentages of the different categories of traffic in each of the different mixed lanes converge to a more realistic value. For each consecutive iteration in the computation, the number of vehicles discarded after a computation becomes smaller. The program stops the cycle when this discard number reaches a threshold value close to zero. Finally, the NQMT becomes the approach volume when the number of discarded vehicles reaches this threshold and queues are also near zero in all lanes at the end of the processing hour.

TNCC underwent a thorough sensitivity analysis to enhance its validation. The TNCC flow chart is also provided in Appendix B.

SHAKER Model

SHAKER, like TNCC, computes the NQMT, maximum hourly throughput in vph such that queues do not exists in any of the plaza's lanes at the end of the hour. In addition, SHAKER also computes the hourly maximum throughput in vph even when queues exist at the end of the hour. In that case, the approach hourly volume is a necessary input to the algorithm.

SHAKER allocates a large volume of traffic using an arbitrary initial distribution of vehicles into each of the plaza's lanes based on the characteristics of the approaching traffic. For instance, if during the hour, 5% of the approaching traffic is of the T category, then 5% of the approach volume is dumped into the lanes servicing the T category, which on the OOCEA's network is an MTE lane, a lane that provides service to M, T and ETC customers. The distribution of vehicles determines the probability or frequencies of occurrence for the categories of traffic in each of the

lanes. SHAKER then determine the average time it takes to service a vehicle dumped in any of the lanes using the motion equations and probability, C for equations used and a more detailed presentation. (Schmitt, 2003) (Zarrillo, Radwan, Schmitt, 2004) In the case of a mixed lane, providing service to more than one category, servicing times for each of the categories are weighed by their probability or frequency of occurrence in that lane. SHAKER can also determine the Remaining-Queue-Numbers (RQN), or the number of vehicles remaining after one hour of time is used up to process these vehicles.

SHAKER inverses the value of the average servicing time for the vehicles in a lane in order to determine the processing rates in units of vph, for each of the lanes. The sum of the processing rates for all the lanes equates to the plaza's hourly throughput for that initial arbitrary distribution.

The arbitrary initial distribution most likely will not result in a throughput that is the maximum possible throughput and the "correct" distribution needs yet to be established. SHAKER bases the "correct" distribution on the stability of the lanes' computed RQN. For instance, comparing the RQN of two lanes, if after moving vehicles from one lane to another lane, from the lane with the larger RQN to the lane with the smaller RQN, SHAKER finds that the RQN for the two lanes changes very little in value, by less than 1.00 vph, then the program is nearer to finding the "correct" distribution. In other words, the "shaking", or moving of vehicles from one lane into another lane, with the intention of equalizing the RQN values, determines the "correct" distribution. Once the "shaking" process correctly distributes the arriving traffic into the plaza's lanes an accurate value for the average vehicle service time for all lanes can be established, thus leading to a "correct" value for the throughput. The "shaking" process also ensures that all lanes will be utilized as much as possible during the hour by moving vehicles from queued lanes into the lesser-queued lanes. (Schmitt, 2003) (Zarrillo, Radwan, Schmitt, 2004)

Input to the motion equations that determine the average time it takes to service a vehicle dumped in any of the plaza's lanes, includes the properties for the different categories of traffic listed in Table 2: the drivers' reaction time, the categories' stop-to-pay-time, the vehicles' average length and headways, and the vehicles' average acceleration and deceleration rates. The 5 categories of traffic, M, A, T, E_P and E_T, are described in Table 1. ETC vehicles may be split into two categories: passenger cars using ETC and vehicles other than passenger cars using ETC, such as trucks.

TABLE 2 SHAKER's Calibrated Vehicle-Properties for the 5 traffic categories at the toll facilities (Schmitt, 2003)

Vehicle-Property Description	Category X				
	M	**T**	**A**	$\mathbf{E_P}$	$\mathbf{E_T}$
l_X =Average vehicle Length (meters)	5.8	21	5.8	5.8	21
b_X=Distance between queued vehicles (meters)	2.0	3.0	2.0	2.0	3.0
a_X=Vehicles' Acceleration (meters/second^2)	2.0	0.25	2.0	2.0	0.25
d_X=Vehicles' Deceleration (meters/second^2)	2.0	0.25	2.0	2.0	0.25
$t_{stop\ X}$ = Stop-Time during payment (seconds)	1.5	4.7	0.075	0.0	0.0
t_R = Drivers' perception-reaction Time (seconds)	1.8	1.8	1.8	1.8	1.8

SHAKER's calibration is accomplished by adjusting the vehicle-properties for all five categories so that the model's output for the hourly throughput for a lane servicing only one category of traffic matches those measured in the field, listed in Table 1. SHAKER's latest version is self-calibrating. For a detailed discussion of the equations used in the SHAKER algorithm see Appendix C. In addition, SHAKER underwent a thorough sensitivity analysis to enhance its validation.

DSS Development and Testing

It was decided early on in the project that if the ArcGIS map of Florida could be acquired, it would be an excellent backdrop for the DSS's GUI. Additional map layers with additional information could then be constructed of the OOCEA toll roads and the Florida Turnpike plazas and overlaid on top of these ArcGIS maps of Florida. By connecting a database of information to the GUI maps, DSS users could view bottleneck locations as well as highway segment information on the toll network in a familiar mapping format.

In a previous study, also financed by CATSS, the OOCEA's network of toll roads in Orange County, Florida, had already been divided up into 299 highway segments according to specification in the HCM 2000. These segments had been drawn into AutoCAD and were used as the basis for the 16 maps to be overlaid onto the Florida ArcGIS map, one map for each hour of the busiest parts of the day 5 a.m. to 9 p.m. Because the lane configuration at the toll plazas varies for each hour of the day, 16 maps with the appropriate plaza lane configuration patterns for each of the 16 hours are required. As currently viewed on the Maps portion of the DSS, viewers see many layers including the backdrop layer of the ArcGIS map of the entire state of Florida. DSS users choose one of the 16 newly created AutoCAD maps layers and by zooming-in, views detailed segmenting of the highway in Orange County and additional plaza lane configuration patterns on the OOCEA's network. ArcIMS software allows viewers to turn off or

on the various layers. Ten unidirectional plazas located on the Florida Turnpike are also included on the 7 to 8 a.m. map.

The ArcGIS software ArcTools was used to convert the 16 AutoCAD files into ArcMaps that could be viewed using ArcIMS on the DSS. Five types of files are created for each map in this conversion process, two of which are most important, the *.shp files (shapes and polygons on the maps) and *.dbf files (the attribute table for the polygons). ArcIMS stores the attributes in a FoxPro database. One of these attributes is the color of the polygons. For all 16 maps, this color is green whenever traffic volumes do not exceed capacity values. There are 299 polygons that represent the 299 highway segments on the OOCEA's network of toll roads. JAVA software was written to compare the hourly capacity of the highway segment to the hourly volume of traffic approaching the segment. Approaching traffic volumes were collected and provided by Post, Buckley, Schuh and Jernigan, Inc., (PBS&J). If the volume exceeds the capacity for a particular segment for a particular hour of the day, the highway segment's polygon color attribute is converted from green to red, indicating a bottleneck's location on the DSS map. The color is converted to orange if the bottleneck is a near-bottleneck, or the approach volume is 90% of the segment capacity. The color is converted to yellow if the bottleneck is a potential bottleneck or the capacity of the previous (upstream) segment is larger than a segment's capacity. In other words, if the capacity of a segment is less than 99.9% of the previous segment's capacity, then it becomes a yellow potential-bottleneck. The network can be viewed as a whole and bottlenecks can be identified and located on the system for each of the 16 hours. To help summarize the networks bottlenecks, the DSS maps homepage allows users to view in Table format the number of red, orange, yellow and green polygons for each of the hours of the busiest 16-hour day. Out of the 299 highway segments studied in this research project, table 3 displays the number of bottlenecks located on the OOCEA's network of toll roads for the data in the default Oracle Database for the busiest 16 hours of the day November 5, 2002. The 16 Maps displaying these bottlenecks is provided in Appendix H. This summary table and the maps assist operators to access the performance of the network as a whole.

TABLE 3: Number of bottlenecks for the busiest 16 hours of the day November 5, 2002.

Hour of the Day on November 5, 2002	Number of Red Bottlenecks	Number of Orange Near-Bottlenecks	Number of Yellow Potential-Bottlenecks	Number of Green Polygons, No Bottlenecks
5 – 6 a.m.	0	0	69	174
6 – 7 a.m.	0	1	64	178
7 – 8 a.m.	1	6	53	183
8 – 9 a.m.	0	1	56	186
9 – 10 a.m.	0	0	59	184
10 – 11 a.m.	0	0	55	188
11 – 12 p.m.	0	0	62	181
12 – 1 p.m.	0	0	69	174
1 – 2 p.m.	0	0	56	187

2 – 3 p.m.	0	0	65	178
3 – 4 p.m.	0	0	56	187
4 – 5 p.m.	0	0	48	195
5 – 6 p.m.	0	1	45	197
6 – 7 p.m.	0	0	49	194
7 – 8 p.m.	0	0	50	193
8 – 9 p.m.	0	0	64	179

In order to facilitate decisions concerning the lane configuration design during particular hours of the day or decisions concerning the design of the highway geometry, DSS users are allowed to change the associated characteristics. Maps can be reloaded and the new bottleneck locations can be viewed. In addition, the DSS allows input of the future traffic volumes on the various highway segments. Again, maps can be reloaded and the new bottlenecks and their locations can be predicted. A complete user's guide is included on the menu bar of the DSS, labeled Help, and is included in Appendix D.

In this study, the default DSS maps identify bottleneck locations for each hour of 16 hours from 5:00 a.m until 9:00 p.m. for the November 5, 2002 day, a typical day on the OOCEA network of toll roads. All 16 maps for each of 16 hours of this day are provided in Appendix H. The original AutoCAD maps are provided in Appendix I. The evolution of bottleneck location sites during the 16-hour period is displayed on the GUI of the DSS and is easily accessible by clients of the DSS. For every hour of the 16 hour period, the 299 segments' approaching traffic volumes from this study were extracted from Tables provided by PBS&J and stored into the Oracle Database of the DSS along with the segments' properties and computed capacities. The DSS JAVA programs compare the computed capacities to these volumes and assign the correct map color to each of the segments. A complete logic flow chart of the DSS is included in Appendix E along with a list of all JAVA program and their functions.

A large effort was made to accurately compute capacities for the 299 highway segments on the OOCEA's network of toll roads for the November 5, 2002 day. Tables from a previous study containing some of these variables for the 7 to 8 a.m. for a typical day in August in the summer of 2000 hour are provided in Appendix G. For this research project, similar Tables were again created for each of 16 hours from 5 a.m to 9 p.m. for the November 5, 2002 date and stored in the Oracle Database on the DSS server. These Tables are also stored on the compact disc submitted with this report.

Appendix F describes the HCM 2000 methodology in more detail. Variables for the computation for all 299 segments for each hour of the 16-hour day were carefully acquired and placed into the database. Variables included an identification number, the type of segment (basic, plaza, exit ramp or entrance ramp segment), the number of traffic lanes on the segment, the number of interchanges per mile or interchange density, the ideal Free Flow Speed (70 or 75 mph depending up whether it is an urban or rural area) and the percentage of traffic that are trucks. Other variables, for capacity calculations of the plaza segments, were collected from transaction data for each hour of the 16-hour day. These included plaza lane configurations, ETC

usage rates, percentage of ETC users that were passenger cars, and the percentage of approaching traffic that used the ACM. All variables were first placed into Microsoft EXCEL Tables before implementing them into the DSS's Oracle database. Comparison of the capacity computations in the EXCEL Tables with the JAVA programs in the DSS validated that the DSS was computing capacities accurately. In order to test for accuracy, a program was written in JAVA, called ChkDiffInCapacities.java. It found no differences greater than 3 vehicles between the two computations. Therefore, the decision was made to set the default Oracle Database to values that exactly agreed with the JAVA programs.

Finally, scenarios have been created in which TNCC's DSS is employed for disruption management. Scenarios include fictitious lane closings, incidents or maintenance checks. Other scenarios demonstrate DSS-TNCC's ability to predict the impact of surging traffic volumes during special events and to predict the influence of forecasted growth in traffic volumes on the performance of the toll network of highways.

Fictitious Lane Closing:

Figure 1 displays the input form of the DSS with modifications of the number of lanes on portions of the OOCEA's westbound Route 408 at the peak morning rush hour from 7 to 8 a.m. Five of its highway segments have a lane reduction: WB 29, 30, 31, 32 and 33. Note that the capacity has been reduced from 9123 vph to 6798 vph for segment 29. Similarly, segments 30, 31, 32 and 33 lost over 2000 vph in their capacity values.

Figure 2 and 3 displays the resulting DSS maps before and after the lane has been closed. Note that the bottlenecks have changed. Segment 29 and 30 became bottlenecks; they went from a green to a red color. Segment 31 was a potential bottleneck and has also become a bottleneck; it went from a yellow to a red color. Segments 32 and 33 have become near-bottlenecks; they went from a green color to an orange color.

Lane closings can be caused by incidents or can be scheduled maintenance. The DSS indicates that the same lane closings at a different hour of the day, 9 a.m., have no negative impact, see Figure 4 and 5. At this later time, all segments remain unchanged: segments 29, 30, 32 and 33 remain green and segment 31 remains yellow. If the lane closers were due to scheduled maintenance or construction, then 9 a.m. would be a better time.

Surging Traffic Volumes:

Figure 6 displays the input forms of the DSS with modifications in the traffic volumes due to drivers entering Route 408 westbound between 9 and 10 a.m. A special event is scheduled for 10 a.m. in downtown Orlando, and 210 drivers are entering the highway each at segment 25, 26 and 29. ETC rates are lower; 15% of the approach is passenger cars with ETC rather than 58.53%. Figure 7 and 8 displays the resulting DSS maps before and after the surging traffic volumes. A red bottleneck has been created at the Holland East Main Plaza. After lane reconfiguration, this bottleneck becomes an orange near-bottleneck, as indicated by Figure 10. The DSS input form in Figure 9 shows the specific reconfiguration of the lanes: two of the dedicated ETC lanes became mixed MTE lanes and the one ME lane became an AE lane. This increases the plaza's capacity from 3090 to 3821 vph.

DSS - Capacity Analysis and Update Page - Microsoft Internet Explorer

Capacity Analysis Table

Hour of the day: 7 - 8 AM										
Segment ID (Type)	**408W - 29.0** (E Ramp)		**408W - 30.0** (X Ramp)		**408W - 31.0** (Basic)		**408W - 32.0** (E Ramp)		**408W - 33.0** (X Ramp)	
Parameter	*Default*	*Modified*	*Default*	*Modified*	*Default*	*Modified*	*Default*	*Modified*	*Default*	*Modified*
Capacity	9123	6798	9121	6796	6794	4500	9116	6793	9113	6791
Approach Volume	6843	6843	6843	6843	6053	6053	6255	6255	6255	6255
% Manual (non-passenger cars)	0.0043	0.0043	0.0044	0.0044	0.0044	0.0044	0.0045	0.0045	0.0046	0.0046
Number of Lanes	4	3	4	3	3	2	4	3	4	3
IPM	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Number of MTE Lanes										
Number of ME Lanes										
Number of AE Lanes										
Number of E Lanes										
% ETC (passenger cars)										
% ETC (non-passenger cars)	0.0107	0.0107	0.0109	0.0109	0.0111	0.0111	0.0113	0.0113	0.0115	0.0115
% ETC										
% ACM										
% Manual (passenger cars)										
Model Choice	**HCM**		**HCM**		**HCM**		**HCM**		**HCM**	

Reset values | Submit to maps | Write to database | Calculate capacity

DSS - Capacity Analysis and Update Page - Microsoft Internet Explorer

Capacity Analysis Table

Hour of the day: 9 - 10 AM										
Segment ID (Type)	**408W - 29.0** (E Ramp)		**408W - 30.0** (X Ramp)		**408W - 31.0** (Basic)		**408W - 32.0** (E Ramp)		**408W - 33.0** (X Ramp)	
Parameter	*Default*	*Modified*	*Default*	*Modified*	*Default*	*Modified*	*Default*	*Modified*	*Default*	*Modified*
Capacity	9030	6729	9029	6728	6727	4455	9026	6726	9024	6724
Approach Volume	4119	4119	4119	4119	3692	3692	3903	3903	3903	3903
% Manual (non-passenger cars)	0.0092	0.0092	0.0093	0.0093	0.0094	0.0094	0.0095	0.0095	0.0096	0.0096
Number of Lanes	4	3	4	3	3	2	4	3	4	3
IPM	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Number of MTE Lanes										
Number of ME Lanes										
Number of AE Lanes										
Number of E Lanes										
% ETC (passenger cars)										
% ETC (non-passenger cars)	0.0162	0.0162	0.0163	0.0163	0.0164	0.0164	0.0164	0.0164	0.0165	0.0165
% ETC										
% ACM										
% Manual (passenger cars)										
Model Choice	**HCM**		**HCM**		**HCM**		**HCM**		**HCM**	

Reset values | Submit to maps | Write to database | Calculate capacity

Figure 1: DSS modification form with a reduction in lanes on 5 highway segments for the 7 and 9 a.m. hours.

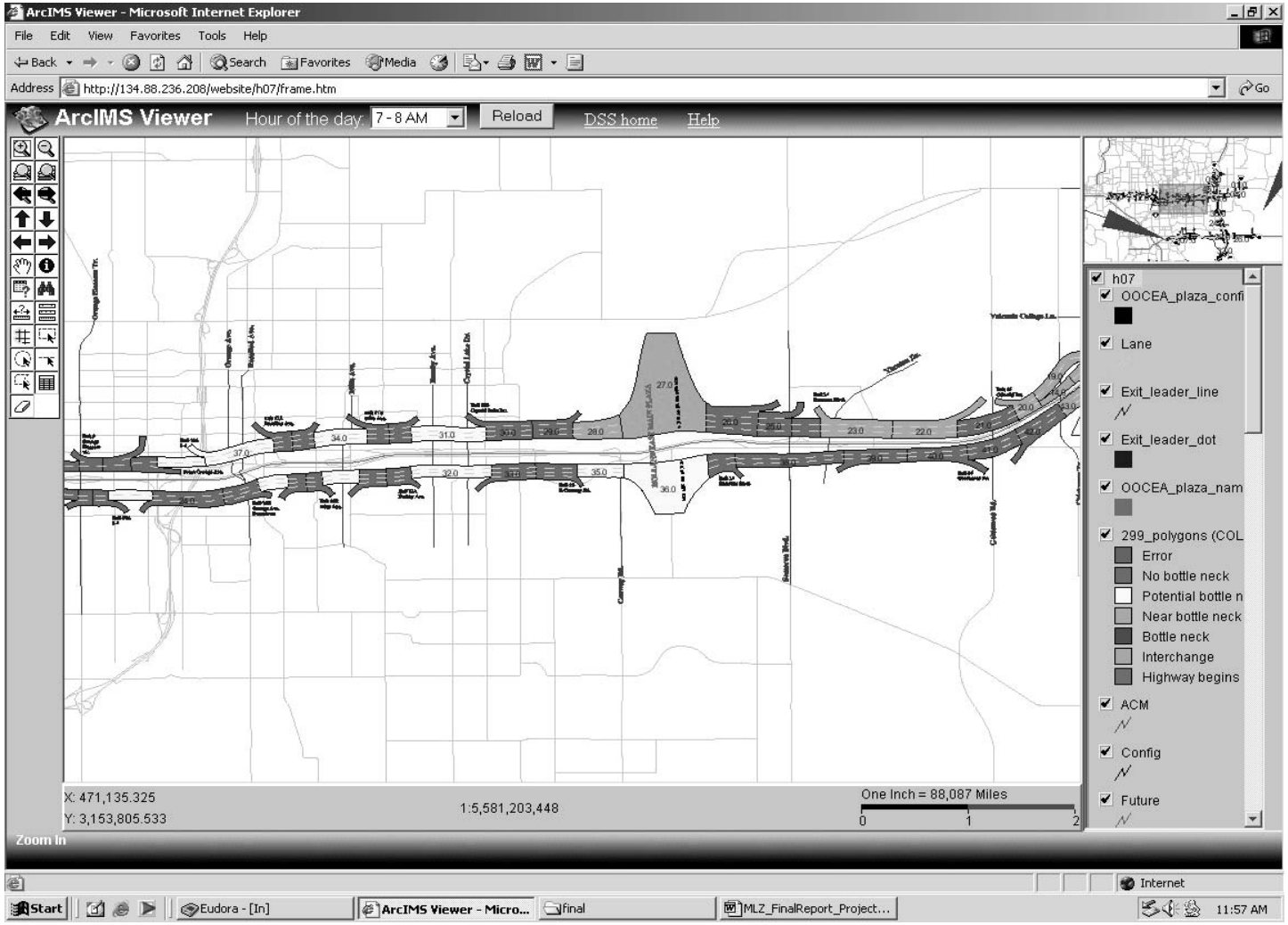

Figure 2: DSS map showing Rt. 408 at 7 am before the lane closure

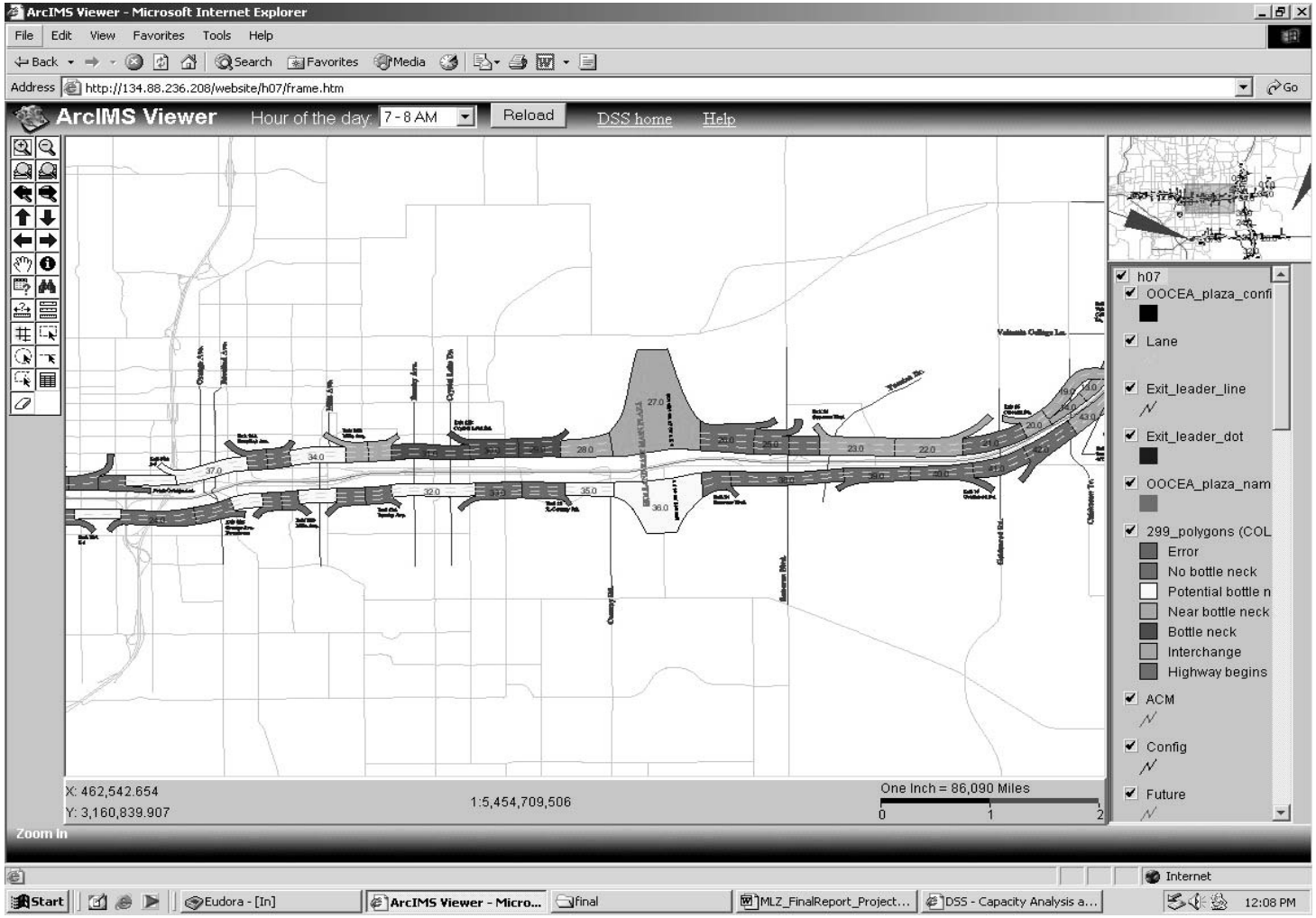

Figure 3: Lane closings on Rt. 408 increase bottlenecks at 7 a.m.

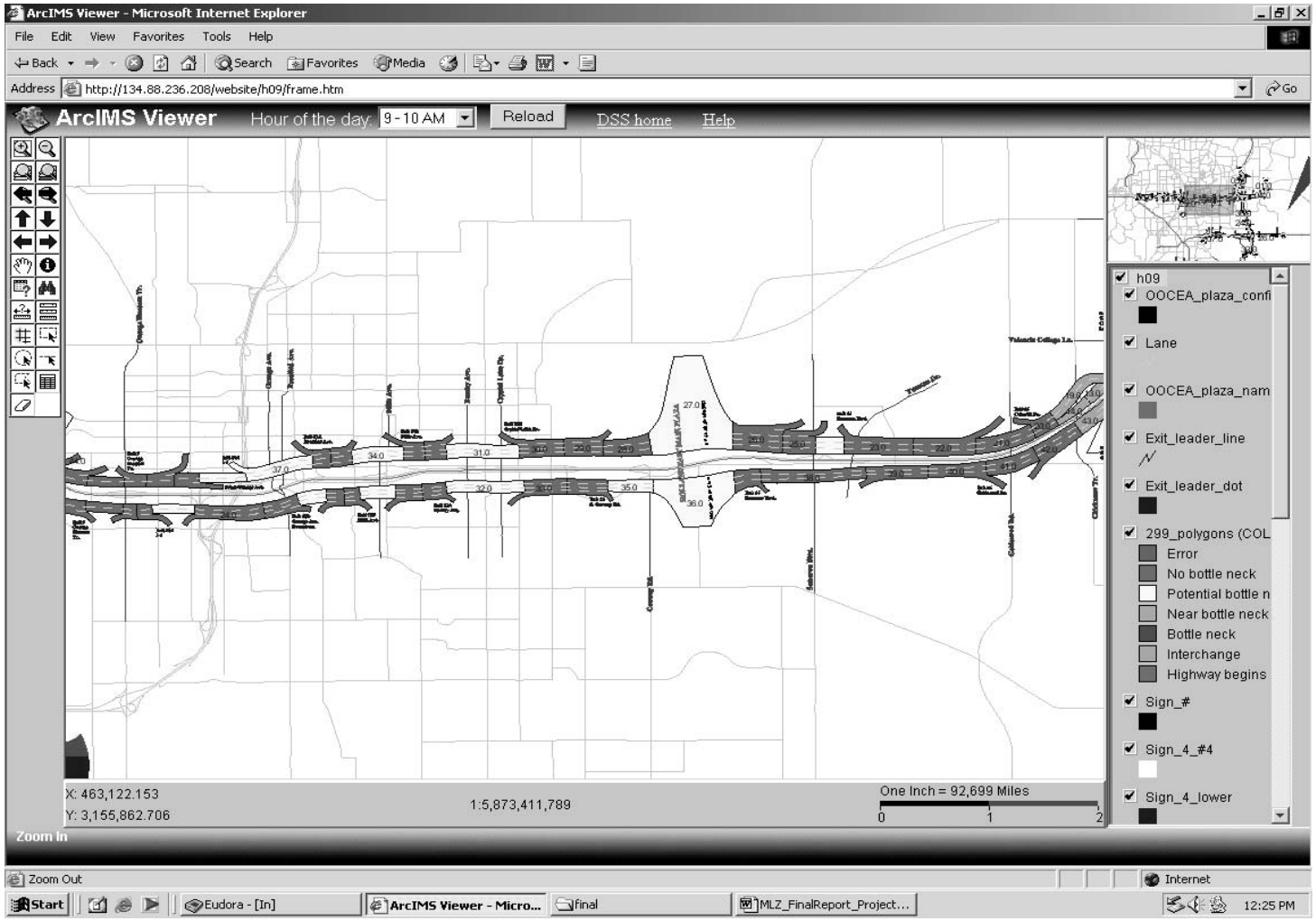

Figure 4: DSS map showing Rt. 408 at 9 am before the lane closure

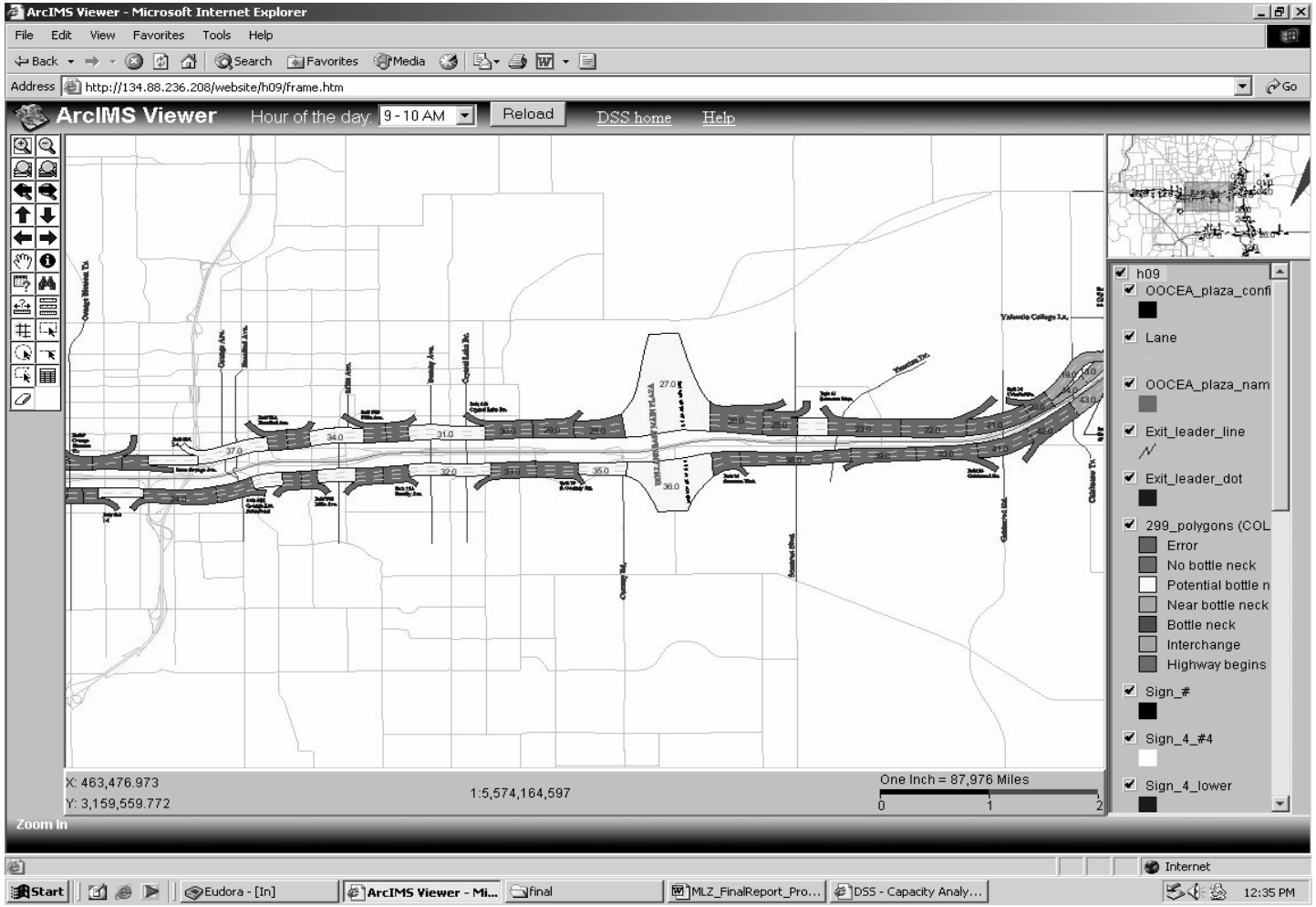

Figure 5: Lane closings on Rt. 408 do not increase bottlenecks at 9 a.m.

DSS - Capacity Analysis and Update Page - Microsoft Internet Explorer

Capacity Analysis Table

Hour of the day: 9 - 10 AM										
Segment ID (Type)	**408W - 25.0** (E Ramp)		**408W - 26.0** (E Ramp)		**408W - 27.0** (Plaza)		**408W - 28.0** (Basic)		**408W - 29.0** (E Ramp)	
Parameter	*Default*	*Modified*	*Default*	*Modified*	*Default*	*Modified*	*Default*	*Modified*	*Default*	*Modified*
Capacity	9034	9034	9034	9033	4868	4869	6730	6730	9030	9031
Approach Volume	2971	2971	3384	3384	3384	3384	3728	3728	4119	4119
% Manual (non-passenger cars)	0.0089	0.0089	0.0090	0.0090	0.0090	0.0090	0.0091	0.0091	0.0092	0.0092
Number of Lanes	4	4	4	4			3	3	4	4
IPM	1.9	1.9	1.9	1.9			1.9	1.9	1.9	1.9
Number of MTE Lanes					2	2				
Number of ME Lanes					1	1				
Number of AE Lanes					2	2				
Number of E Lanes					2	2				
% ETC (passenger cars)					0.5853	0.5853				
% ETC (non-passenger cars)	0.0161	0.0161	0.0161	0.0161	0.016	0.016	0.0161	0.0161	0.0162	0.0162
% ETC					0.6013	0.6013				
% ACM					0.1153	0.1153				
% Manual (passenger cars)					0.2744	0.2744				
Model Choice	**HCM**		**HCM**		**TNCC**		**HCM**		**HCM**	

Reset values | Submit to maps | Write to database | Calculate capacity

DSS - Capacity Analysis and Update Page - Microsoft Internet Explorer

Capacity Analysis Table

Hour of the day: 9 - 10 AM										
Segment ID (Type)	**408W - 25.0** (E Ramp)		**408W - 26.0** (E Ramp)		**408W - 27.0** (Plaza)		**408W - 28.0** (Basic)		**408W - 29.0** (E Ramp)	
Parameter	*Default*	*Modified*	*Default*	*Modified*	*Default*	*Modified*	*Default*	*Modified*	*Default*	*Modified*
Capacity	9034	9034	9034	9033	4868	3090	6730	6730	9030	9031
Approach Volume	2971	3181	3384	3804	3384	3804	3728	3090	4119	3300
% Manual (non-passenger cars)	0.0089	0.0089	0.0090	0.0090	0.0090	0.0090	0.0091	0.0091	0.0092	0.0092
Number of Lanes	4	4	4	4			3	3	4	4
IPM	1.9	1.9	1.9	1.9			1.9	1.9	1.9	1.9
Number of MTE Lanes					2	2				
Number of ME Lanes					1	1				
Number of AE Lanes					2	2				
Number of E Lanes					2	2				
% ETC (passenger cars)					0.5853	0.15				
% ETC (non-passenger cars)	0.0161	0.0161	0.0161	0.0161	0.016	0.016	0.0161	0.0161	0.0162	0.0162
% ETC					0.6013	0.166				
% ACM					0.1153	0.40				
% Manual (passenger cars)					0.2744	0.425				
Model Choice	**HCM**		**HCM**		**TNCC**		**HCM**		**HCM**	

Reset values | Submit to maps | Write to database | Calculate capacity

Figure 6: Traffic volumes have increased and ETC rates are reduced on the DSS input form causing a bottleneck at the plaza, volume > capacity.

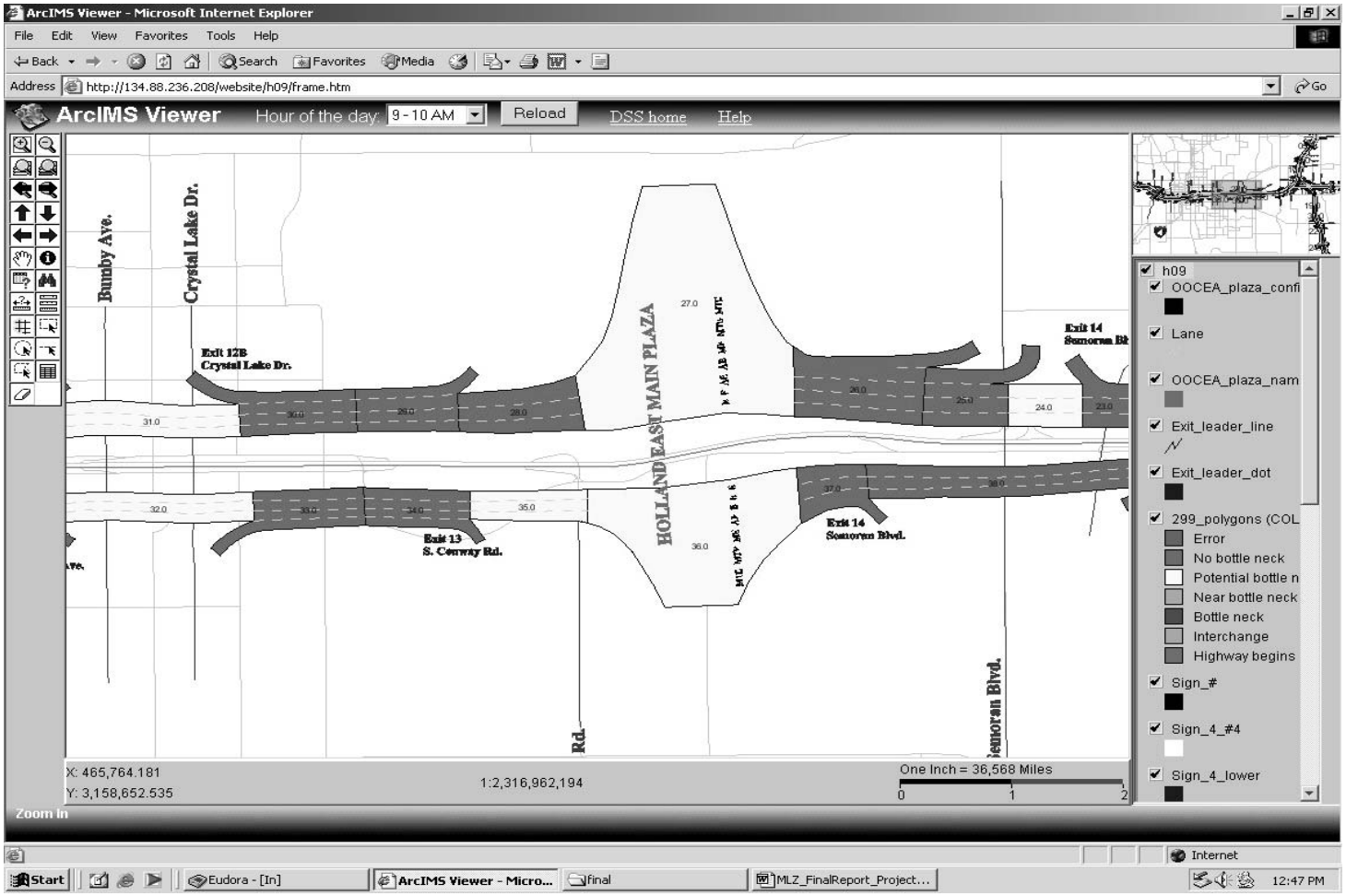

Figure 7: DSS map showing the before surging traffic volume toward downtown

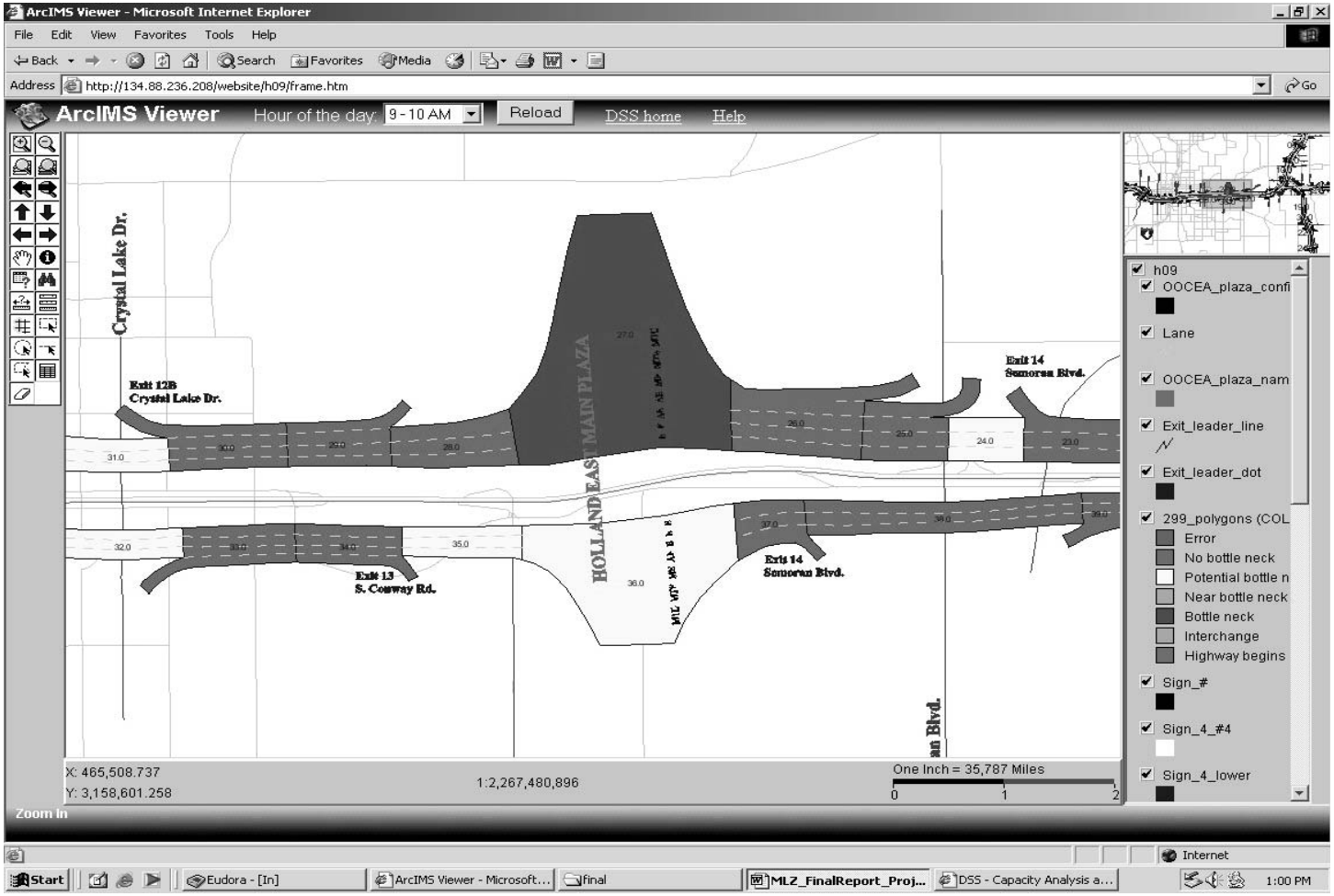

Figure 8: DSS Map showing the bottleneck created at the Holland East main Plaza due to surging traffic volume toward downtown

DSS - Capacity Analysis and Update Page - Microsoft Internet Explorer

Capacity Analysis Table

Hour of the day: 9 - 10 AM										
Segment ID (Type)	**408W - 25.0** (E Ramp)		**408W - 26.0** (E Ramp)		**408W - 27.0** (Plaza)		**408W - 28.0** (Basic)		**408W - 29.0** (E Ramp)	
Parameter	*Default*	*Modified*	*Default*	*Modified*	*Default*	*Modified*	*Default*	*Modified*	*Default*	*Modified*
Capacity	9034	9034	9034	9033	4868	3821	6730	6730	9030	9031
Approach Volume	2971	3181	3384	3804	3384	3804	3728	3090	4119	3300
% Manual (non-passenger cars)	0.0089	0.0089	0.0090	0.0090	0.0090	0.0090	0.0091	0.0091	0.0092	0.0092
Number of Lanes	4	4	4	4			3	3	4	4
IPM	1.9	1.9	1.9	1.9			1.9	1.9	1.9	1.9
Number of MTE Lanes					2	4				
Number of ME Lanes					1	0				
Number of AE Lanes					2	3				
Number of E Lanes					2	0				
% ETC (passenger cars)					0.5853	0.15				
% ETC (non-passenger cars)	0.0161	0.0161	0.0161	0.0161	0.016	0.016	0.0161	0.0161	0.0162	0.0162
% ETC					0.6013	0.166				
% ACM					0.1153	0.40				
% Manual (passenger cars)					0.2744	0.425				
Model Choice	**HCM**		**HCM**		**TNCC**		**HCM**		**HCM**	

Reset values | Submit to maps | Write to database | Calculate capacity

Figure 9: The plaza becomes a near-bottleneck after lane reconfiguration on the DSS input form converting an ME lane to an AE lane and the 2 ETC lanes into 2 MTEs.

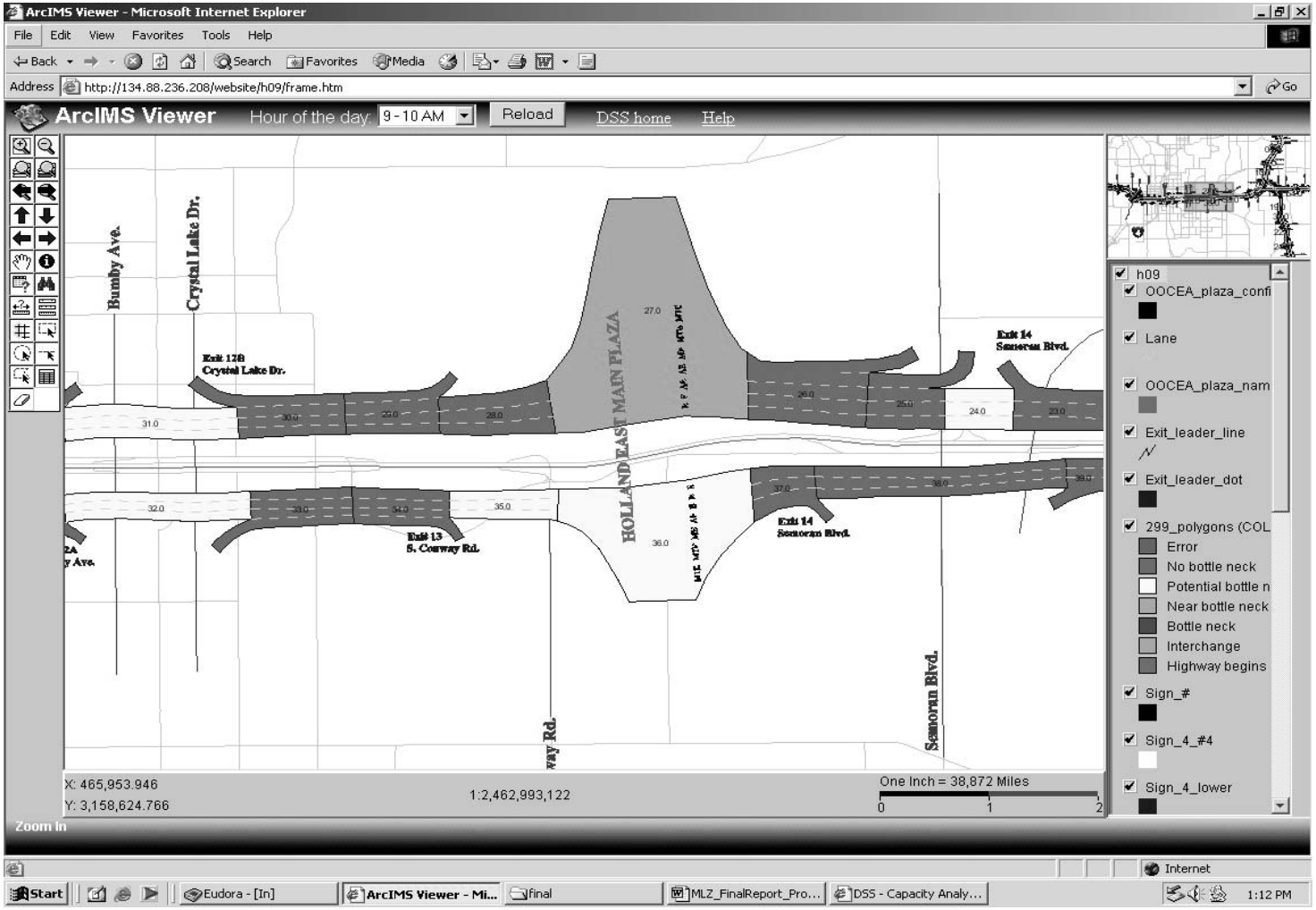

Figure 10: DSS map showing the plaza becoming a near-bottleneck after lane reconfiguration

Summary and Conclusions

This pilot study shows that tools can be devised to assist engineers and operators make decisions concerning a network of toll roads. Connecting the DSS's Oracle Database to a real time data collection situation would provide operators on-line with tools that could assist with their hour-to-hour decisions as well as their day-to-day decisions. Operators could plan for special scheduled events in which traffic volumes are known to surge. Engineers could design lane configurations at toll facilities that could meet traffic requirements. Engineers could also design new interchange locations and predict the effect on toll plazas segments. They could also predict the effect of adding additional lanes to busy highway segments. Highway operators could determine the effects of an incident or other unscheduled lane closing at one of the 16 hours of the day. Furthermore, they could schedule maintenance and lane closures for construction at hours of the day in which bottlenecks are at a minimum.

In summary, the DSS is an interactive website providing decision tools for engineers operating and designing networks of highways with toll collection facilities. Two of its tools are TNCC and SHAKER. Both algorithms measure the performance of toll collection facilities with a Measure of Effectiveness (MOE) called NQMT in units of vph. NQMT is the maximum throughput such that at the end of one hour there are no queues in any of the lanes at the plaza. NQMT values can be compared for different plaza designs to determine what lane configuration pattern best matches the traffic needs at a particular location on a toll highway.

In addition, the DSS has an Oracle Database containing highway segment variables used in the computation of highway segment capacities using algorithms from the HCM 2000. Specifically, the Database contains information on each of 299 highway segments located on the OOCEA's network of toll roads in Orange County, Florida. The database also contains approach traffic volumes for each of 16 hours of a typical day on this same network on November 5, 2002. Programs written in JAVA compare volumes to capacities to determine bottlenecks, near-bottlenecks and potential bottlenecks for each hour of that day between the hours of 5 a.m. and 9 p.m. Each highway segment is represented as a polygon on one ArcGIS map, whose color property is stored in a FoxPro Database attached to the DSS. Polygons on the map turn red, if the highway segment is a bottleneck, and orange, if it is a near-bottleneck, and yellow, if it is a potential bottleneck. Otherwise all polygons or highway segments appear green in color.

The DSS's mapping page contains many layers of information of Florida's highway system via an ArcIMS interface. Zooming-in to Orange County, 16 of the layers provide sixteen maps of the OOCEA's network of toll roads, each representing one of the sixteen hours of the November 5, 2002, traffic data and highway geometry data. The toll roads are divided into 299 polygons, all displayed on these 16 layers, representing the 299 highway segments according to the HCM 2000 specification for dividing highways into segments. The lane configurations for the 10 plaza (20 unidirectional plaza segments) change from hour to hour, which is also displayed on the maps. JAVA programs access TNCC in order to compute the NQMT or capacity of these 20 plaza segments. If the approach volumes to the plazas are greater than the NQMT values, the plaza segments are considered bottlenecks and their polygons become a red color. The other 279 highway segments use the algorithms in the HCM 2000 to compute their capacities. These segments also become red in color when JAVA programs find the approach traffic volumes greater than their capacities.

DSS users have options to change variables in the Database, reload the hourly maps, and identify new locations of red, orange and yellow polygons, or bottlenecks on any of the 16 maps. DSS users first highlight the portion of the highway on the map, then input changes to the variables and submit and store the changes in a separate user database. Maps are reloaded and may be compared to other maps with different variables. Variables include the approach traffic volume to the segment, the interchange density along the segment's portion of highway, the percentage of trucks in the traffic stream, the number of lanes in that segment and the ideal free flow speed on that segment. If the segment is a plaza segment, variables include the number of lanes, the types of lanes (or what types of customer categories are serviced in the lanes), ETC usage rates, and other category-percentages, such as the percentage of ACM users.

Finally, one of the 16 map layers, the 7 to 8 a.m. map, contains five plazas (10 unidirectional) located on the Florida Turnpike. Their lane configurations for this hour are also displayed. TNCC has an easy drop-down menu that uploads plaza segment information such as lane configuration and computes the NQMT or capacity for these 10 unidirectional plazas. All hourly maps for the OOCEA and all of the Florida Turnpike Plaza Maps are provided in Appendix H.

Recommendations for Further Work: Real-Time-Intelligent DSS

Toll collection facilities often become bottlenecks. At present, there is no accepted standard to compute the capacity of highway segment in which a facility is situated, thus, it is difficult for planners to design facilities and difficult for operators to intelligently respond to changing conditions at the plaza. SHAKER and TNCC are models that were developed to have this capability. Using a snapshot of real data, both models have been successfully applied to 20 toll facilities on the OOCEA's network of toll roads in Orange County, Florida, for each of 16 hours during a typical day, November 5, 2000. Decision makers, engineers and operators of toll collection facilities have a need for these models, real time. This problem statement proposes to integrate TNCC and SHAKER with real-time data from the toll facilities to assist in the traffic operations of the OOCEA network of toll roads in Orange County, Florida.

The primary objective of this research study will be to integrate TNCC and SHAKER, Toll Network Capacity Calculator, into a Real Time Intelligent (RTI) – DSS, with a user friendly GUI. Currently TNCC and SHAKER are models for computing the maximum number of vehicles that can pass through a highway segment containing a toll collection facility. Although both models are based on completely different methodologies, they predict maximum throughput values within 3% of each other. It has been shown in a pilot study of sixteen hours of historical transaction data from November 5, 2000, that TNCC and SHAKER, applied to 20 of the plazas on the OOCEA network of toll roads in Orange County, Florida, are able to facilitate the identification and location of bottlenecks on the network. It has also been shown that TNCC and SHAKER are able to support operators in their choice of lane configurations for the toll facilities on this network and that bottleneck can be alleviated once the appropriate configuration has been implemented. The GUI of the proposed RTI-DSS system is user-friendly and allows users to investigate possible bottleneck-scenario outcomes by changing the input parameters that feed TNCC and SHAKER.

RTI-DSS identifies bottlenecks on the network, by using the logic of TNCC and SHAKER to formulate the capacity of highway segments containing toll collection facilities and it uses traditional capacity calculating techniques from HCM 2000 to formulate the capacities of the basic highway segments located between toll facilities. The GUI then reports bottlenecks in a graphical ArcGIS mapping format. Apart from being real-time, another novel feature of RTI-DSS is that it is intelligent, in the sense that it learns from its interactions with the user and it uses this intelligence to help the user find a desired plaza lane configuration. RTI-DSS bases its intelligence on its ability to remember state, which is twofold: (a) **Session state**. During a session on RTI-DSS, the user is able to investigate a large number of traffic scenarios on the RTI-DSS, which will give variable bottleneck-scenario outcomes. The values of the GUI input parameters for each one these scenarios, as well as the bottleneck-scenario outcomes will be saved in a dynamic (run-time) way on the RTI-DSS server, in order to delay computationally expensive database read/write operations until the user has reached a decision. At the end of the user's session, the RTI-DSS server will present to the user a ranked list of the bottleneck-scenario outcomes he/she has tried. At that time, the user will choose the desired configuration and commit his/her changes in the lane configuration in the database. (b) **Application state**. RTI-DSS will save in a persistent way (database) the best results of various users' sessions. When a user starts a new session and enters the input parameters, RTI-DSS will search the feature space

of input parameters, for a close neighbor with desirable bottleneck-scenario outcome, and will propose it to the user.

In the previous study bottleneck locations were identified for each hour of a 16-hour typical day from 5:00 a.m. until 9:00 p.m. on November 5, 2000. The evolution of the bottlenecks' location during the 16-hour period is presented on the DSS webpage using an ArcGIS mapping format. Bottleneck situations occur when approaching traffic volumes exceed segment capacity and appear red. *Near* bottleneck situations occur when approaching traffic is just below segment capacity and appear orange. *Potential* bottleneck situations occur when the capacity of a segment unjustifiably and substantially drops below the capacity of the previous adjacent segment without a possibility for traffic to exit. These appear to be yellow on the mapping interface. In the current DSS analysis, segment capacities are compared to volumes extracted from a 2001 study by PBS&J, on OOCEA's network of toll roads. The new proposed RTI-DSS will use real time data as input. Bottlenecks locations will appear real time on the DSS ArcGIS map GUI.

As with the DSS, the RTI-DSS can still be employed for disruption management. Scenarios include fictitious lane closings, incidents or maintenance checks. Other scenarios can demonstrate the RTI-DSS's ability to predict the impact of surging traffic volumes during special events and to predict the influence of forecasted growth in traffic volumes on the performance of the toll network of highways.

Bottlenecks, both their number and severity will influence the performance and/or LOS, of a network of toll roads. SHAKER's and TNCC's RTI-DSS will quantify the performance of a toll network by quantifying both the number and type (severity) of bottlenecks on the toll network real-time given a database with current geometric and traffic characteristics of the network.

It will assist engineers designing toll facilities to adequately serve highway systems. The RTI-DSS can also be employed to assess capacity of working toll networks under representative rush hour scenarios. In addition, it can be used for performance and capacity assessment of networks undergoing sudden changes in their geometric or traffic characteristics.

There are circumstances in which the RTI-DSS can be of great use to toll facility managers. For instance, consider lane closures. Whenever lanes must close at a toll collection facility due to maintenance or incidents, disruption in traffic flow occurs due to a reduction in capacity. The RTI-DSS may assist in disruption management. It may determine the impact of a lane closure and assist operators in the adjustment of the remaining lane configuration. To help alleviate the disruption, the RTI-DSS may suggest opening up or closing the remaining lanes at a toll facility. It will suggest the types of toll collection service in each of the remaining toll facility lanes required to optimize network throughput. Traffic characteristics such as the percent ETC usage, manual usage or ACM usage, all serve as input to the RTI-DSS.

Another circumstance in which the RTI-DSS can be of great use is when a planned special event occurs in the region and heavy usage of the toll facilities is expected, possibly increasing volumes in manual usage. The changes in the proportion of customer-groups arriving to the toll facility will change the capacity. In this case, the RTI-DSS will serve as an assessment tool of the toll collection facility under these new constraints.

The RTI-DSS can also be used in the design and planning process of a new toll network of roads. Capacities of alternative designs using the predicted traffic usage and characteristics can

be computed. Roadways between consecutive plazas can also be designed to match plaza capacities and thus accommodate travelers by reducing the bottlenecks on the network.

Finally, the RTI-DSS may help establish an accepted standard for calculating plaza capacity in the HCM. Toll facility operators require this standard especially with the arrival of ETC. The benefits of ETC are enormous and have been documented by many. What has not been established, however, is an accepted methodology in the calculation of the capacity of a toll collection facility having ETC, having both dedicated lanes and mixed lanes.

This project is in line with the theme of CATSS. The planning, design, operation, management, safety and environmental aspect of ETC systems benefit greatly from a capability to determination the capacity of the toll networks that employ them. Finally, the benefits of establishing a MOE for ETC deployment on a network of toll roads provides a valuable tool that can be used by operations engineers who determine the optimal toll configuration patterns within the network. It can also be valuable to design engineers as well as to the engineers managing the deployment of one of ITS's most successful technologies, ETC.

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Appendix A: Comparison of NQMT values for TNCC and SHAKER

The percent difference in the NQMT values computed by TNCC and SHAKER for all of the twenty unidirectional plazas on the OOCEA's network of toll roads for the morning peak hour of the day, from 7 to 8 a.m. is provided in Table 4. Most percent differences lie below 5%, however, one of them is a high 9%.

The NQMT values calculated by TNCC and SHAKER for all 16 hours for the WB Holland East Main Plaza located on the 408 on the OOCEA's network is provided in Figure 7(a). The NQMT values calculated by TNCC and SHAKER for all 16 hours for the EB Dean Main Plaza located on the 528 is provided in Figure 7(b). The NQMT values calculated by TNCC and SHAKER for all 16 hours for the SB University Main Plaza located on the 417 is provided Figure 7(c). Again, most percent differences lie below 5%, however, some of them are high.

The percent difference in the NQMT values computed by TNCC and SHAKER for the ten unidirectional plazas on the Florida Turnpike are provided in Table 5. Note that they are all less than 1%.

In order to explain some of the large percent differences in SHAKER's and TNCC's computation of NQMT, the differences in the categories has to be examined. SHAKER splits up the approaching ETC traffic volumes into two categories, one for passenger cars approaching the plaza and one for vehicles other than passenger cars approaching the plaza. TNCC places both categories into one. Under most circumstances, this does not seem to play a large role in the computation of the NQMT. Percent differences between the TNCC and the SHAKER computations are lower than 4% in 313 of the 320 cases evaluated on the OOCEA's network of toll roads. However, whenever there is a substantially large ETC usage rate and the plaza does not dedicate at least one lane to ETC users, TNCC overestimates the NQMT.

TNCC's methodology dumps ETC vehicles into the AE lanes whenever there are no dedicated ETC lanes at the plaza. This includes both passenger cars using ETC and vehicles other than passenger cars using ETC such as trucks. However, trucks are not allowed to use the faster AE lanes on the OOCEA's toll network and should be dumped into the slower MTE lanes. TNCC thus computes an inaccurately high processing rate for the ETC trucks.

SHAKER, on the other hand, splits up the ETC category into two; thus the model can more accurately reflect the policy that trucks are prohibited from using the AE lanes. SHAKER restricts all trucks to the slower MTE lanes, both ETC trucks and non-ETC trucks. The Dean Main Plaza illustrated this point. From the hours of 10 a.m. to 2 p.m., the lane configuration eliminated dedicated ETC lanes. NQMT values were overestimated by TNCC and were 14% to 16% higher than they should have been. SHAKER is thus the more accurate model of the two models for computing the maximum number of vehicles possibly processed in one hour at a toll collection facility such that no queues exists at the end of the hour.

Finally, it was found that there are three significant factors that impact the maximum number of vehicles possibly processed at the plaza during an hour. These include the addition or subtraction of a lane at the plaza, the changing of the plazas lane-configurations and/or the significant change in the percentages of arriving vehicles belonging to the different categories of traffic.

Table 4: the percent difference in the NQMT values computed by TNCC and SHAKER for all of the twenty unidirectional plazas on the OOCEA's network of toll roads for the morning peak hour of the day, from 7 to 8 a.m.

Plaza Name and traffic direction (NB, SB, EB, WB)	Lane Configuration	Approach Traffic Characteristics: Percentages for categories X					NQMT (vph)		% Diff.
		M	A	T	E_P	E_T	SHAKER	TNCC	
John Young Parkway Main Plaza NB	E_MTE_MTE	53.3%	0.0%	0.6%	44.6%	1.6%	1795	1795	0.0%
Boggy Creek Main Plaza NB	E_MTE_MTE	48.2%	0.0%	1.0%	48.6%	2.2%	1929	1929	0.0%
Curry Ford Main Plaza NB	E_MTE_MTE	37.0%	0.0%	0.5%	60.7%	1.8%	2566	2522	1.7%
University Main Plaza NB	E_AE_MTE_MTE	28.8%	4.4%	0.5%	65.2%	1.1%	3234	3233	0.0%
University Main Plaza SB	E_E_ME_MTE_MTE	25.6%	0.0%	0.5%	72.6%	1.2%	4816	4586	4.8%
Curry Ford Main Plaza SB	E_AE_MTE_MTE	20.6%	9.6%	0.5%	67.3%	2.0%	3460	3505	-1.3%
Boggy Creek Main Plaza SB	E_MTE_MTE	30.9%	0.0%	1.0%	65.2%	3.0%	2605	2512	3.6%
John Young Parkway Main Plaza SB	E_ME_MTE_MTE	44.3%	0.0%	0.6%	53.3%	1.9%	3089	3007	2.6%
Hiawassee Main Plaza EB	E_E_AE_MTE_MTE	19.5%	11.7%	0.8%	66.4%	1.6%	4454	4452	0.0%
Holland West Main Plaza EB	E_E_AE_AE_MTE_MTE	19.3%	17.4%	0.6%	61.3%	1.4%	4672	4670	0.0%
Holland East Main Plaza EB	E_E_AE_ME_MTE_MTE	30.5%	10.6%	0.4%	57.5%	1.0%	4643	4666	-0.5%
Dean Main Plaza EB	E_MTE_MTE	37.7%	0.0%	0.3%	61.2%	0.8%	2565	2535	1.2%
Dean Main Plaza WB	E_E_AE_MTE_MTE	21.3%	10.4%	0.3%	67.1%	0.9%	4447	4446	0.0%
Holland East Main Plaza WB	E_E_E_AE_AE_ME_MTE_MTE	21.5%	14.8%	0.4%	62.2%	1.0%	6458	6490	-0.5%
Holland West Main Plaza WB	E_E_AE_AE_MTE_MTE	26.4%	12.4%	0.6%	59.2%	1.4%	3508	3507	0.0%
Hiawassee Main Plaza WB	E_MTE_MTE	41.5%	0.0%	0.8%	56.3%	1.3%	2245	2244	0.0%
Airport Plaza EB	E_AE_ME_ME_MTE_MTE	40.3%	11.9%	1.1%	44.9%	1.7%	4202	4083	2.8%
Bee Line Main Plaza EB	E_E_ME_MTE_MTE	40.2%	0.0%	1.6%	54.1%	4.0%	3229	2938	9.0%
Bee Line Main Plaza WB	E_MTE_MTE	32.4%	0.0%	1.6%	61.5%	4.6%	2507	2454	2.1%
Airport Plaza WB	E_AE_ME_ME_MTE_MTE	31.1%	8.4%	1.1%	57.2%	2.2%	4505	4423	1.8%

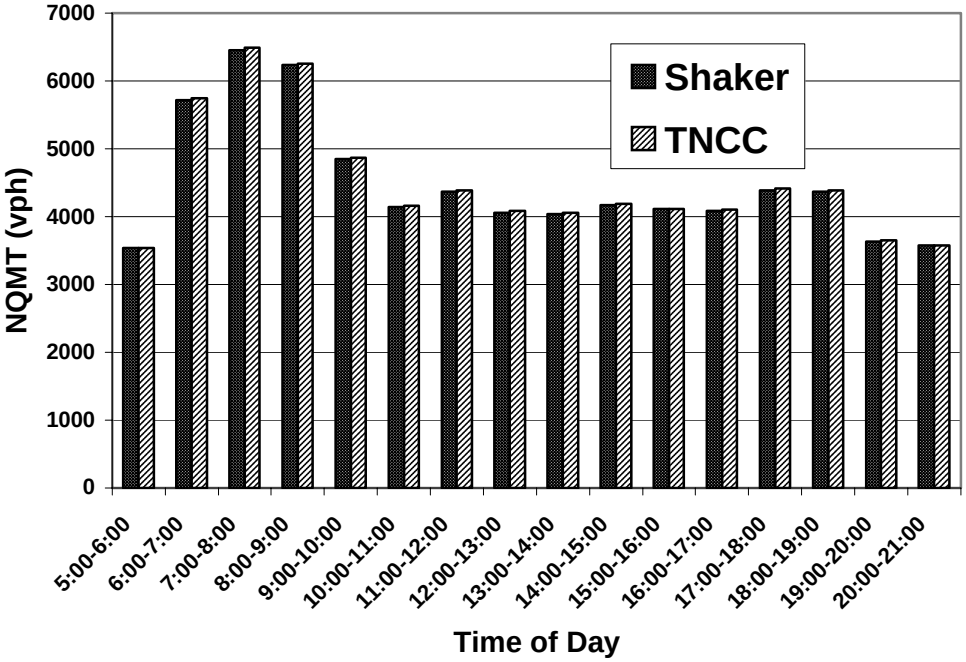


Figure 7(a) NQMT values for the WB Holland East Main Plaza located on the 408

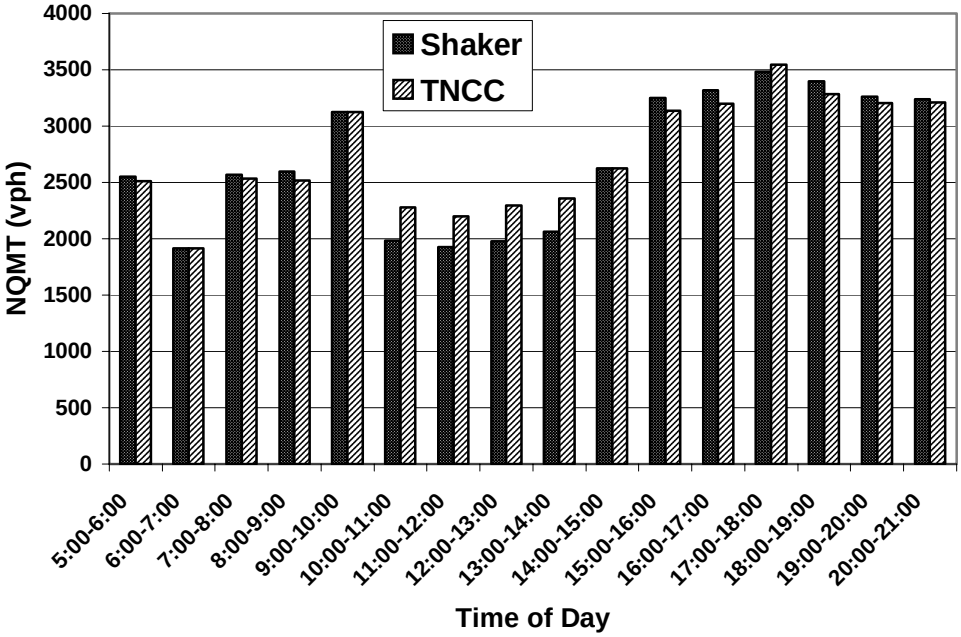


Figure 7(b) NQMT values for the EB Dean Main Plaza located on the 528

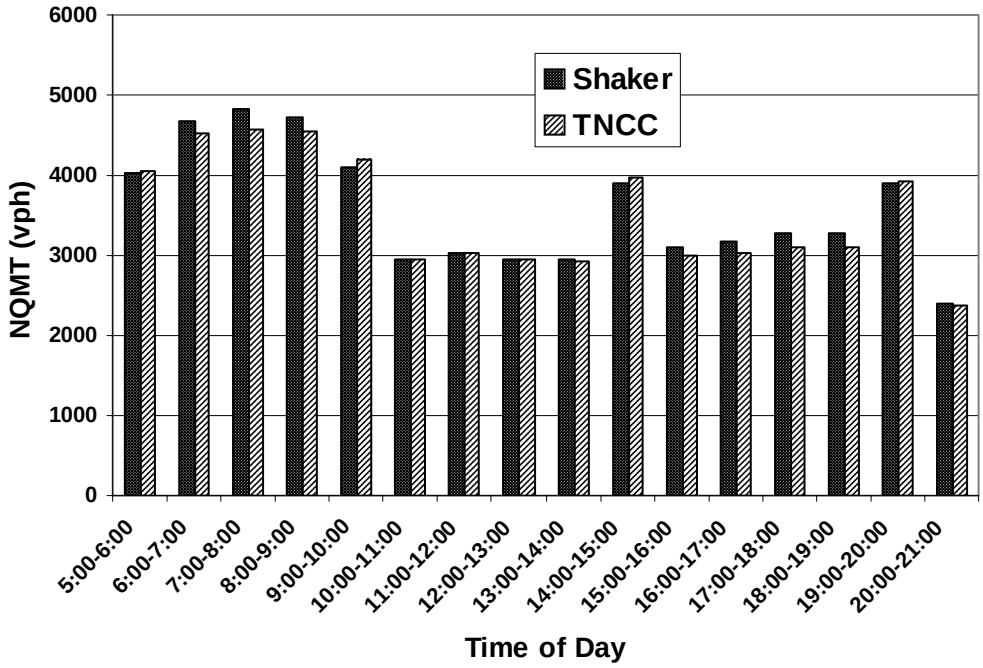
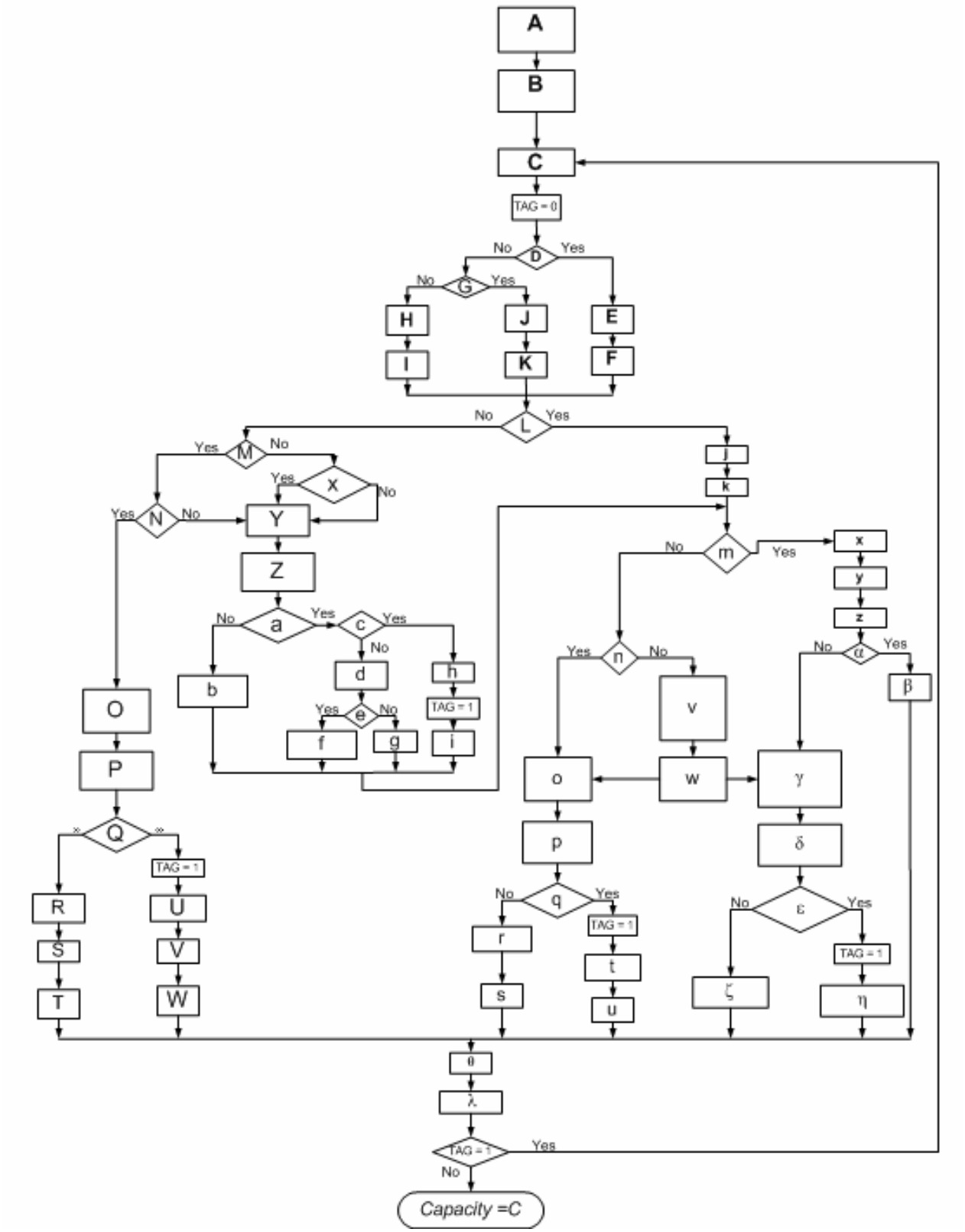


Figure 7(c) NQMT values for the SB University Main Plaza located on the 417

Table 5: the percent difference in the NQMT values computed by TNCC and SHAKER for the ten unidirectional plazas on the Florida Turnpike are all less than 1%

Plaza Name		P_M	P_A	P_T	E_P	E_T	E	N_E	N_A	N_{AE}	N_{MT}	N_{MTE}	TNCC	SHAKER	% diff.
Anclote-Suncoast Mainline	SB/WB	0.592	0.000	0.014	0.376	0.018	0.395	2	0	0	6	2	6213	6197	**-0.26**
Anclote-Suncoast Mainline	NB/EB	0.626	0.000	0.019	0.327	0.028	0.355	2	0	0	0	2	1436	1436	**0.00**
Anderson Road	SB/WB	0.304	0.245	0.004	0.443	0.003	0.446	1	1	1	2	1	4413	4399	**-0.32**
Anderson Road	NB/EB	0.372	0.347	0.026	0.228	0.028	0.255	1	1	1	2	1	3214	3218	**0.12**
Polk Parkway - Western	SB/WB	0.753	0.000	0.016	0.203	0.029	0.231	1	0	0	3	1	2456	2453	**-0.12**
Polk Parkway - Western	NB/EB	0.724	0.000	0.030	0.222	0.023	0.246	1	0	0	3	1	2389	2383	**-0.25**
Lake Jesup - Mainline	SB/WB	0.493	0.000	0.009	0.409	0.089	0.498	1	0	0	2	1	2841	2833	**-0.28**
Lake Jesup - Mainline	NB/EB	0.457	0.000	0.012	0.515	0.015	0.531	1	0	0	2	1	2959	2980	**0.70**
Bee Line West - Mainline	SB/WB	0.288	0.262	0.009	0.380	0.062	0.442	1	1	1	1	1	3124	3108	**-0.51**
Bee Line West - Mainline	NB/EB	0.319	0.247	0.029	0.310	0.095	0.405	1	1	1	2	1	3526	3517	**-0.26**

Appendix B: Flow Chart for TNCC



A	*Collect Traffic Characteristics for input to NQMC* $\eta_E, \eta_{AE}, \eta_{ME}, \eta_{MTE}$ $\mu_E, \mu_A, \mu_M, \mu_T$ $\rho_E, \rho_A, \rho_M, \rho_T$
B	*Initializing the variables* $K_E = \mu_E \times \eta_E$ $K_{AE} = \mu_E \times \eta_{AE}$ $K_{ME} = \mu_E \times \eta_{ME}$ $K_{MTE} = \mu_E \times \eta_{MTE}$ $C = K_E + K_{AE} + K_{ME} + K_{MTE}$
C	*Calculate Number of vehicles in each customer group* $T = P_T C$ $M = P_M C$ $A = P_A C$ $E = P_E C$
D	$\eta_E = 0$
E	$K_E = 0$
F	$LOEK_{AE} = LOEK_E$
G	$e >= \eta_E \times \mu_E$
H	$K_{AE} = e$
I	$LOEK_{AE} = 0$
J	$K_{AE} = \eta_E \times \mu_E$
K	$LOEK_{AE} = e - K_E$
L	$\eta_{AE} = 0$
M	$\eta_{ME} = 0$
N	$\eta_{MTE} = 0$
O	$\rho_A^{AE} = \dfrac{A}{A + LOEK_{AE}}$ $\rho_E^{AE} = \dfrac{LOEK_{AE}}{A + LOEK_{AE}}$

P	$\upsilon_1^{AE} = \frac{\mu_E + \mu_A}{2}$ $\upsilon_2^{AE} = \frac{\mu_E - \mu_A}{2}$ $\mu_E^{AE} = \upsilon_1^{AE} - \upsilon_2^{AE} \cos(\pi \times \rho_E^{AE})$
Q	$\frac{A}{\eta_{AE}\mu_A} + \frac{LOEK_{AE}}{\eta_{AE}\mu_E^{AE}} > 1.0001$
R	$K_{AE} = A + LOEK_{AE}$
S	$K_{ME} = 0$
T	$K_{MTE} = 0$
U	$K_{AE} = \frac{\eta_{AE}}{\left(\frac{\rho_A^{AE}}{\mu_A} + \frac{\rho_E^{AE}}{\mu_E^{AE}}\right)}$
V	$K_{ME} = 0$
W	$K_{MTE} = 0$
X	$\eta_{MTE} = 0$
Y	$\rho_A^{AE} = \frac{A}{K_{AE}}$ $\rho_E^{AE} = 1 - \rho_A^{AE}$ $\rho_E^{AE} = 0 \;\; if \;\; \rho_E^{AE} < 0$
Z	$\upsilon_1^{AE} = \frac{\mu_E + \mu_A}{2}$ $\upsilon_2^{AE} = \frac{\mu_E - \mu_A}{2}$ $\mu_E^{AE} = \upsilon_1^{AE} - \upsilon_2^{AE} \cos(\pi \times \rho_E^{AE})$
a	$\frac{A}{\eta_{AE}\mu_A} + \frac{LOEK_{AE}}{\eta_{AE}\mu_E^{AE}} > 1.0001$
b	$LOEK_{ME} = LOEK_{AE} + A$
c	$\frac{A}{\eta_{AE}\mu_A} > 1.0001$
d	$K_{AE} = \frac{\eta_{AE}}{\left(\frac{\rho_A^{AE}}{\mu_A} + \frac{\rho_E^{AE}}{\mu_E^{AE}}\right)}$
e	$K_{AE} > A$
f	$LOEK_{ME} = LOEK_{AE} - (K_{AE} - A)$
g	$LOEK_{ME} = LOEK_{AE}$

h	$K_{AE} = \eta_{AE}\mu_A$
i	$LOEK_{ME} = LOEK_{AE}$
j	$K_{AE} = 0$
k	$LOEK_{ME} = LOEK_{AE}$
l	$\eta_{ME} = 0$
m	$\eta_{ME} = 0$
n	$\eta_{MTE} = 0$
o	$\rho_M^{ME} = \dfrac{LOMK_{ME}}{LOMK_{ME} + LOEK_{ME}}$ $\rho_E^{ME} = \dfrac{LOEK_{ME}}{LOMK_{ME} + LOEK_{ME}}$
p	$\upsilon_1^{ME} = \dfrac{\mu_E + \mu_M}{2}$ $\upsilon_2^{ME} = \dfrac{\mu_E - \mu_M}{2}$ $\mu_E^{ME} = \upsilon_1^{ME} - \upsilon_2^{ME}\cos(\pi \times \rho_E^{ME})$
q	$\dfrac{M}{\eta_{ME}\mu_M} + \dfrac{LOEK_{ME}}{\eta_{ME}\mu_E^{ME}} > 1.0001$
r	$K_{ME} = LOMK_{ME} + LOEK_{ME}$
s	$K_{MTE} = 0$
t	$K_{ME} = \dfrac{\eta_{ME}}{\left(\dfrac{\rho_M{}^{ME}}{\mu_M} + \dfrac{\rho_E{}^{ME}}{\mu_E{}^{ME}}\right)}$
u	$K_{MTE} = 0$
v	$TLOEK_{ME} = LOEK_{ME}$ $TLOMK_{ME} = LOMK_{ME}$ $T_x = 1.0001 - \dfrac{T}{\eta_{MTE} \times \mu_T}$ $P_y = \dfrac{1}{1 + T_x}$ $P_z = \dfrac{T_x}{1 + T_x}$
w	$LOEK_{ME} = P_y \times TLOEK_{ME}$ $LOMK_{ME} = P_y \times TLOEK_{ME}$ $LOEK_{MTE} = Pz \times TLOMK_{MTE}$ $LOMK_{MTE} = Pz \times TLOMK_{MTE}$

x	$K_{ME} = 0$
y	$LOEK_{MTE} = LOEK_{ME}$
z	$LOMK_{MTE} = LOMK_{ME}$
α	$\eta_{MTE} = 0$
β	$K_{MTE} = 0$
γ	$\rho_M^{MTE} = \frac{LOMK_{MTE}}{LOMK_{MTE} + T + LOEK_{MTE}}$ $\rho_T^{MTE} = \frac{T}{LOMK_{MTE} + T + LOEK_{MTE}}$ $\rho_E^{MTE} = \frac{LOEK_{MTE}}{LOMK_{MTE} + T + LOEK_{MTE}}$
δ	$\upsilon_1^{MTE} = \frac{\mu_E + \mu_M}{2}$ $\upsilon_2^{MTE} = \frac{\mu_E - \mu_M}{2}$ $\mu_E^{MTE} = \upsilon_1^{MTE} - \upsilon_2^{MTE} \cos(\pi \times \rho_E^{MTE})$
ε	$\frac{T}{\eta_{MTE}\mu_T} + \frac{LOMK_{MTE}}{\eta_{MTE}\mu_M} + \frac{LOEK_{MTE}}{\eta_{MTE}\mu_E^{MTE}} > 1.0001$
ζ	$K_{MTE} = LOMK_{MTE} + T + LOEK_{MTE}$
η	$K_{MTE} = \frac{\eta_{MTE}}{\left(\frac{\rho_T^{MTE}}{\mu_T} + \frac{\rho_M^{MTE}}{\mu_M} + \frac{\rho_E^{MTE}}{\mu_E^{MTE}}\right)}$
θ	$i = i + 1$
λ	$C = K_E + K_{AE} + K_{ME} + K_{MTE}$

LEGEND for Symbols in the Equations

η_E	Number of dedicated ETC Lanes
η_{AE}	Number of mixed AE Lanes
η_{ME}	Number of mixed ME Lanes
η_{MTE}	Number of mixed MTE Lanes
E	Electronic Toll Collection Lane
AE	Lane offering ACM as well as ETC
ME	Lane offering manual toll collection for Passenger cars as well as ETC
MTE	Lane offereing manual toll collection for Passenger cars and Trucks as well as ETC
μ_M	Processingrate for manual service to vehicles other than semi - trucks (vphpl)
μ_T	Processingrate for manual service to semi - trucks (vphpl)
μ_A	Processingrate for automatic coin machine users (vphpl)
μ_E^{MAX}	Maximum Observed ProcessingRate for vehicles using ETC (vphpl)
μ_E^{AE}	Observed ProcessingRate for vehicles using ETC in the AE Lane (vphpl)
μ_E^{ME}	Observed Processing Rate for vehicles using ETC in the ME Lane (vphpl)
μ_E^{MTE}	Observed Processing Rate for vehicles using ETC in the MTE Lane (vphpl)
ρ_E	Percent ETC usage at the plaza
ρ_T	Percent users at the plaza that are semi - trucks and do not use ETC
ρ_A	Percent users at the plaza that are automatic coin machine users
ρ_M	Percent users at the plaza that are manual users but do not use ETC
ρ_E^{AE}	Percent users in an AE lane that are ETC users
ρ_A^{AE}	Percent users in an AE lane that are Automatic Coin Machine users
ρ_M^{MTE}	Percent users in an MTE lane that are manual users and are not semi - trucks
ρ_T^{MTE}	Percent users in an MTE lane that are semi - trucks and do not use ETC
ρ_E^{MTE}	Percent users in an MTE lane that are ETC users.
ρ_E^{ME}	Percent users in an ME lane that are ETC users and are not semi - trucks.
ρ_M^{ME}	Percent users in an ME lane that are manual users and are not semi - trucks
T_x	Time available in the MTE Lane after all Trucks have been processed
P_y	Percents of M and ETC vehicles expected to go to ME lane
P_z	Percents of M and ETC vehicles expected to go to MTE lane
T	Number of semi - truck arrivals not using ETC processed in one hour
A	Number of automatic coin mahine users processed in one hour
M	Number of manual users processed in one hour
E	Number of ETC users processed in one hour
υ_1^{AE}	Upper value of the cosine function for AE lane
υ_2^{AE}	Lower value of the cosine function for AE lane
υ_1^{ME}	Upper value of the cosine function for ME lane
υ_2^{ME}	Lower value of the cosine function for ME lane
υ_1^{MTE}	Upper value of the cosine function for MTE lane
υ_2^{MTE}	Lower value of the cosine function for MTE lane
i	number of iteration
tag	one or zero. The tag starts out as zero. If at the completion of an iteration, the tag still has a value of zero, than no more itreations are necessary and i has reached its maximum integer value. If, on the others hand, tag has a value of one at the comlete of an iteration, then another iteration is necessary and the capacity calculation is not complete.
K_E	The capacity of all dedicated ETC lanes at the plaza
K_{AE}	The capacity of all AE lanes at the plaza
K_{ME}	The capacity of all ME lanes at the plaza
K_{MTE}	The capacity of all MTE lanes at the plaza
C	The capacity of the plaza at the end of iteration number i
$LOEK_{AE}$	Number of ETC users not able to utilize the dedicated ETC lanes because they are full and go to AE Lane
$LOEK_{ME}$	Number of ETC users not able to utilize the dedicated ETC lanes because they are full and go to ME Lane
$LOEK_{MTE}$	Number of ETC users not able to utilize the dedicated ETC lanes because they are full and go to MTE Lane
$LOMK_{ME}$	Number of Manual users at the plaza that are cars and use ME lane
$LOMK_{MTE}$	Number of Manual users at the plaza that are care and use MTE lane
$TLOEK_{ME}$	Temporary $LOEK_{ME}$
$TLOMK_{ME}$	Temporart $LOMK_{ME}$

Appendix C: Equations used in SHAKER

Hourly throughput for a lane under queuing conditions can be calculated using the basic equations of motion as will be demonstrated in this appendix. However, the lane-percentages or the relative frequency of occurrence must be known and used as input to these equations. Therefore, a method for distributing the approaching traffic into the available lanes is required. The "shaking" method is incorporated. The "Shaking" process moves around the players, in this case vehicles, from one place to another until a "correct" distribution is established. The determination of the "correct" distribution is based on the stability of an outcome measure, such as hourly throughput, queue length or delay. The "shaking" process has a set of conditions, constraints or rules that must be obeyed, for instance, the model only allows vehicles to be placed, "shook" or queued in a lane in which their category has available service. If there is more than one lane available as a possible choice, then SHAKER uses one of four types of criteria upon which drivers may base their decision:

1. drivers may prefer lanes that have the smallest number of remaining vehicles in the queue
2. drivers may prefer lanes that have the smallest remaining queue length
3. drivers may prefer lanes that have the shortest wait time in the remaining queue
4. drivers may prefer lanes that have the fastest moving remaining queue

Currently, SHAKER requires that all drivers use one of these four decision processes. Future expansion of the model will allow the drivers to use various combinations of the four decision processes. The "shaking" process continues as long as the output measure changes in value. Once stability is reached, the "shaking" stops.

SHAKER moves vehicles from one lane to another or "shakes" them one at a time, hence changing how the hourly approach vehicles are distributed in the lanes of the plaza. "Shaking" begins after some initial distribution and continues until a "correct" distribution and accordingly a stable throughput is found. The final "correct" distribution and the most stable throughput are independent of the initial distribution. If, during the hour, the number of approach vehicles in a lane (NAV), is greater than the computed throughput for that lane, S^{lane} , then whatever vehicles remain unprocessed in the lane, after the throughput is subtracted out, is the value of the remaining-queue-number, RQN^{lane}. This is displayed by equation (1).

During the "shaking" process, the value of the RQN^{lane} determines which lane looses and which lane gains a vehicle. For instance, under decision process #1, SHAKER moves a vehicle from a lane with the largest RQN^{lane} into a lane with the smallest RQN^{lane}. One "shake" is performed for each category. Under decision process #2, SHAKER first computes, for each lane, using equation (2), the remaining-queue-length(RQL), RQL^{lane}, by multiplying the RQN^{lane} by the average spacing, listed in the vehicle-properties of Table 2. This average spacing between vehicles will be the sum of the spacing for each category X, $(b_X + l_X)$, weighed by the category's relative frequency of occurrence, P_X. SHAKER then moves a vehicle from a lane with the largest RQL^{lane} into a lane with the smallest RQL^{lane}. Again, one "shake" is performed for each category. Under decision process #3, SHAKER first computes, for each lane, using equation (3), the waiting-time-in-the-queue (WTQ), WTQ^{lane}, by dividing the RQN^{lane} by the computed maximum hourly throughput for that lane, S^{lane} . SHAKER then moves a vehicle from a lane with the longest WTQ^{lane} into a lane with the shortest WTQ^{lane}. Again, one "shake" is

performed for each category. Under decision process #4, SHAKER first computes, for each lane, using equation (4), the speed of the remaining queue (SRQ), SRQ^{lane}, by inverting the computed WTQ^{lane}. SHAKER then moves a vehicle from a lane with the slowest SRQ^{lane} into a lane with the fastest SRQ^{lane}.

$$RQN^{lane} = NAV^{lane} - S^{lane} \tag{1}$$

$$RQL^{lane} = RQN^{lane} \times \sum_{X} P_X \left(b_X + l_X \right) \tag{2}$$

$$WTQ^{lane} = \frac{RQN^{lane}}{S^{lane}} \tag{3}$$

$$SRQ^{lane} = \frac{1}{WTQ^{lane}} \tag{4}$$

After each "shake", the throughput equations are applied to each lane individually. If the throughput has remained stable for several iterations, "shaking" is complete and a stable distribution of the approach vehicles has been found. In the case where a lane is underutilized and there are no remaining vehicles or the RQN^{lane} is zero, then the throughput equations don't apply and the throughput for that lane becomes the number of vehicles that were distributed into that lane.

Equation (5) is used to compute the maximum hourly throughput for any of the dedicated ETC lanes in the toll facility. Input requirements include the percentage of ETC vehicles in the lane, P_{E_P} and P_{E_T}, the speed limit at the plaza, v_{limit}, and the properties listed in Table 2 for ETC vehicles. The denominator of equation (5) is the average processing-time for a vehicle in an E_PE_T lane. The contribution from each of the two categories is weighed by their corresponding lane-percentage or relative frequency of occurrence within the lane. The model assumes ETC vehicles are traveling at the speed limit throughout the tolling area, and therefore their contribution to the average processing-time is determined by the vehicle's distance traveled over the speed limit. If 100% of the vehicles are passenger cars and the speed limit is 35 mph, equation (5) computes a maximum hourly throughput of 1658 vph. If 0% of the vehicles are passenger cars, in other words, if all the vehicles belong to the E_T category, then equation (5) computes a maximum hourly throughput of 1146 vph. If these results do not match measured field values for a specific toll facility, they can be corrected by proper adjustment of the vehicle-properties as well as the plaza's speed limit. This re-calibration may be necessary whenever some time has elapsed and the average vehicle-properties for a category have changed or when applying the model to networks other than the OOCEA's network of toll roads.

$$S^{dedicated\text{-}ETC\text{-}lane} = \frac{1}{\left(P_{E_P} \left(t_R v_{limit} + l_{E_P} \right) \Big/ v_{limit} \right) + \left(P_{E_T} \left(t_R v_{limit} + l_{E_T} \right) \Big/ v_{limit} \right)} \times 3600 \frac{s}{hr} \tag{5}$$

Equation (6) is used to compute the maximum hourly throughputs for the mixed lanes in the toll facility. Equation (7), (8), (9), (10) and (11) feed into the denominator of equation (6) and calculate the vehicles' contribution to the average processing-time, *H, J, K, L* and *M,* in a mixed

lane. Input requirements include the speed limit at the plaza, v_{limit}, the vehicle-properties listed in Table 2, and the percentage of vehicles in the lane that belong to each of the categories, P_M, P_A, P_T, P_{E_P} and P_{E_T}. In each individual lane, the sum of all the percentages is 100% and the sum of P_{E_P} and P_{E_T} is denoted as P_E.

$$S^{\text{Mixed Lane}} = \textit{Maximum Throughput} \text{ for one mixed lane (vph)} = \frac{1}{H+J+K+L+M} \times 3600 \frac{s}{hr} \tag{6}$$

Equation (7) defines *H* in units of seconds per vehicle. It computes the average processing-time contribution from non-ETC vehicles in a mixed lane. The time contributions from the M, T and A categories are weighed by their relative frequency of occurrence within the mixed lane, P_M, P_T and P_A. It is assumed that the vehicles accelerate throughout half the spacing between vehicles, $\frac{1}{2}(b_X + l_X)$, where X represents the vehicle's category, M, T or A, and decelerate throughout the other half. The total time to process one of these vehicles is the sum of three factors, one of which is the time it takes the driver to react, t_R. Drivers need time to recognize and react to the vehicle it follows. The second factor is the time to accelerate and decelerate toward the toll booth and the third factor is the time to pay the toll, $t_{stop\,X}$.

$$H = \sum_{X=M,T,A} \left\{ P_X \times \left[t_R + t_{stop\,X} + \sqrt{\frac{(b_X + l_X)}{a_X}} + \sqrt{\frac{(b_X + l_X)}{d_X}} \right] \right\} \tag{7}$$

Using the calibrated vehicle-properties listed in Table 2, for a lane containing only M vehicles, equation (7) computes a processing-time, *H*, of 7.23 seconds, which results in a maximum hourly throughput of 498 vph, using equation (6). This value matches the value of the processing-rate under queuing conditions measured in the field for the M category, listed in Table 1. Similarly, using the calibrated vehicle-properties listed in Table 2, for the vehicles in the A and T categories, calculations produce processing-times of 5.83 and 26.1 seconds, respectively, which results in computed maximum hourly throughputs of 618 and 138 vph. Again, these values match the values of the processing-rates under queuing conditions measured in the field, listed in Table 1.

Values for *J*, *K*, *L* and *M*, are computed by equation (8), (9), (10) and (11), in units of seconds per vehicle. They represent the average processing-time contribution from ETC vehicles in a mixed lane when the ETC vehicles are situated within a train of ETC vehicles where the train follows a slower non-ETC vehicle. Trains of ETC vehicles in the mixed lanes have a count of "n" ETC vehicles, and each train has a different frequency of occurrence within the stream of approaching vehicles. Several cases must be considered. For instance, "short" trains of ETC vehicles are defined to be trains in which the last vehicle in the train never reaches the speed limit within the tolling area. "Long" trains of ETC vehicles are defined to be trains in which the last vehicle/vehicles in the train reach the speed limit and maintain that speed within the tolling area. In addition, there are ETC trains that consist only of passenger cars or vehicles within the E_P category. And then there are ETC trains that have at least one vehicle that is not a passenger car and belongs to the E_T category.

Equation (8) defines *J*, the average processing-time contribution from ETC vehicles situated within a "short" train in which all ETC vehicles are passenger cars. All ETC vehicles must stop while the leader of the train, the non-ETC vehicle, pays the toll. Once the leading non-ETC vehicle is processed, the average time for an ETC vehicle in the train to be processed is 1/n times

the time it takes the last vehicle in the "short" train to be processed. Drivers have a perception-reaction time period in which they recognize that the vehicle in front of them is now moving. There is also the time spent in which the vehicle accelerates through the tolling area. Therefore, the average time for ETC vehicles in the "short" train to be processed is 1/n times the sum of two factors: all drivers' perception-reaction times, $n \times t_R$, and the time it takes the last ETC vehicle in the train to accelerate throughout the entire length of the train, $n(spacing\#1)$, where $(spacing\#1)$ is $\left(b_{E_P} + l_{E_P}\right)$. The time required to accelerate throughout the entire length of the train is derived from the basic motion equation that asserts that one half the acceleration times the time squared is equivalent to the distance traveled during that time and thus the time is $\sqrt{\frac{2n(spacing\#1)}{a_{E_P}}}$. Average processing-times for all lengths of trains are weighed by their relative frequency of occurrence, $Occurrence\#1$, and summed over all possible counts "n" from 1 to n_{speed}. The frequency of finding a train consisting entirely of passenger cars equals the frequency of finding any train at all following a non-ETC vehicle, $P_E{}^n(1-P_E)$, times the chance that the ETC vehicles are all passenger cars, $\left(\frac{P_{E_P}}{P_E}\right)^n$.

The longest of the "short" trains has a count of n_{speed} vehicles in the train. This count of n_{speed} is derived from the basic motion equation that asserts that the final speed-attained squared, $(v_{limit})^2$, is equivalent to twice the acceleration times the distance traveled, $2a_{E_P} \times n_{speed}\left(b_{E_P} + l_{E_P}\right)$. The word *floor* in equation (8) indicates that n_{speed} is the value of the integer immediately below the computed value in brackets. For 35 mph speed limits and using the calibrated vehicle-properties listed in Table 2, a value of n_{speed} becomes *floor*[7.8] or 7 vehicles. In other words, if the seventh vehicle were the last vehicle in the train, it would still not reach the speed limit of 35 mph while passing through the tolling area. The train would have to be longer than seven ETC vehicles in order for its end vehicle to reach speeds exceeding the speed limit within the tolling area.

$$J = \sum_{n=1}^{n_{speed}} \left\{ Occurrence\#1 \times \frac{1}{n}\left[n \times t_R + \sqrt{\frac{2n(spacing\#1)}{a_{E_P}}} \right] \right\} \qquad n_{speed} = floor\left[\frac{v_{limit}{}^2}{2a_{E_P}[spacing\#1]} \right]$$

$$spacing\#1 \equiv \left(b_{E_P} + l_{E_P}\right) \qquad Occurrence\#1 \equiv P_E{}^n(1-P_E)\left(\frac{P_{E_P}}{P_E}\right)^n \tag{8}$$

For "short" trains containing at least one ETC vehicle that is not a passenger car, equation (9) is used rather than equation (8), and defines *K*. Again, the average processing-times are weighed by their relative frequency of occurrence, $Occurrence\#2$, and summed over all possible counts "n" from 1 to $n_{speed\,T}$. The frequency of finding a train with at least one ETC vehicle that is not a passenger car equals the frequency of finding any train at all, $P_E{}^n(1-P_E)$, times the chance that at least one of the ETC vehicles is not a passenger-car, $\left(1-\left(\frac{P_{E_P}}{P_E}\right)^n\right)$. The length of the

train, $n(spacing\#2)$, is now a combined sum of the spacing between vehicles in the E_T category as well as the E_P category. The time required to accelerate throughout the entire length of the train is computed in a similar fashion except that acceleration a_{E_T} is used rather than a_{E_P}, thus the time is $\sqrt{\frac{2n(spacing\#2)}{a_{E_T}}}$. Acceleration also affects the value of $n_{speed\ T}$. For example, at 35 mph speed limits, a value of $n_{speed\ T}$ becomes *floor*[44.3] or 44 vehicles at a value of 50% for the ETC usage rate where P_{E_P} is 40% and P_{E_T} is 10%. In other words, if the forty-fourth vehicle were the last vehicle in a train containing at least one ETC vehicle that was not a passenger car, it would still not reach the speed limit of 35 mph while passing through the tolling area. The train would have to be longer than forty-four ETC vehicles in order for its end vehicle to reach speeds exceeding the speed limit within the tolling area. It is evident that there is quite a negative impact on the throughput of a mixed lane whenever an ETC vehicle in the mixed lane is not a passenger car.

$$K = \sum_{n=1}^{n_{speed\ T}} \left\{ Occurrence\#2 \times \frac{1}{n}\left[n \times t_R + \sqrt{\frac{2n(spacing\#2)}{a_{E_T}}} \right] \right\} \qquad n_{speed\ T} = floor\left[\frac{v_{limit}^{\ 2}}{2a_{E_T}[spacing\#2]} \right] \tag{9}$$

$$spacing\#2 \equiv \left(\frac{P_{E_P}}{P_E}\left(b_{E_P} + l_{E_P}\right) + \frac{P_{E_T}}{P_E}\left(b_{E_T} + l_{E_T}\right) \right) \qquad Occurrence\#2 \equiv P_E^{\ n}(1 - P_E)\left(1 - \left(\frac{P_{E_P}}{P_E}\right)^n\right)$$

Equation (10) defines *L*, the average processing-time contribution from ETC vehicles situated within a "long" train where all ETC vehicles are passenger cars. The model assumes that the last ETC vehicle or vehicles in these "long" trains reach and maintain their speed at the default speed limit of 35 mph. Therefore, the average processing-time for ETC vehicles in the "long" train is 1/n times the sum of three factors: all drivers' perception-reaction times, $n \times t_R$, the time it takes the last "end" ETC vehicle in the train to accelerate up to the speed limit, v_{limit}/a_{E_P} ,and the time that the same "end" vehicle travels at the speed limit throughout the rest of the tolling area. The rest of the tolling area is the difference between the total space traveled, $n(spacing\#1)$, and the distance traveled while accelerating $\left(v_{limit}^{\ 2}/2a_{E_P}\right)$. Average processing-times for all lengths of trains are weighed by their relative frequency of occurrence, $Occurrence\#1$, and summed over all possible counts "n" from a value of (1 + n_{speed}) to infinity. The JAVA program, SHAKER, cannot sum to infinity and limits the summation to a finite calculation, neglecting the contribution of the *very* long trains. This is possible as long as the value for P_E does not equal 100% because very long trains have a relative frequency of occurrence that approaches zero as the count "n" increases, and thus contribute less to the average processing-time.

For "long" trains containing at least one ETC vehicle that is not a passenger car, equation (11) is used rather than equation (10), and defines *M*. Again, the average processing-times are weighed by their relative frequency of occurrence, $Occurrence\#2$, and summed over all possible counts "n" from a value of (1 + $n_{speed\ T}$) to infinity. Also, acceleration a_{E_T} is used rather than a_{E_P}.

$$L = \sum_{n=1+n_{speed}}^{\infty} \left\{ Occurrence\#1 \times \frac{1}{n} \left[n \times t_R + \frac{v_{limit}}{a_{E_P}} + \frac{1}{v_{limit}} \left(n(spacing\#1) - \left(\frac{v_{limit}^{\ 2}}{2a_{E_P}} \right) \right) \right] \right\} \tag{10}$$

$$M = \sum_{n=1+n_{speed\ T}}^{\infty} \left\{ Occurence\#2 \times \frac{1}{n} \left[n \times t_R + \frac{v_{limit}}{a_{E_T}} + \frac{1}{v_{limit}} \left(n(spacing\#2) - \left(\frac{v_{limit}^{\ 2}}{2a_{E_T}} \right) \right) \right] \right\} \tag{11}$$

Appendix D: Users Guide for the DSS

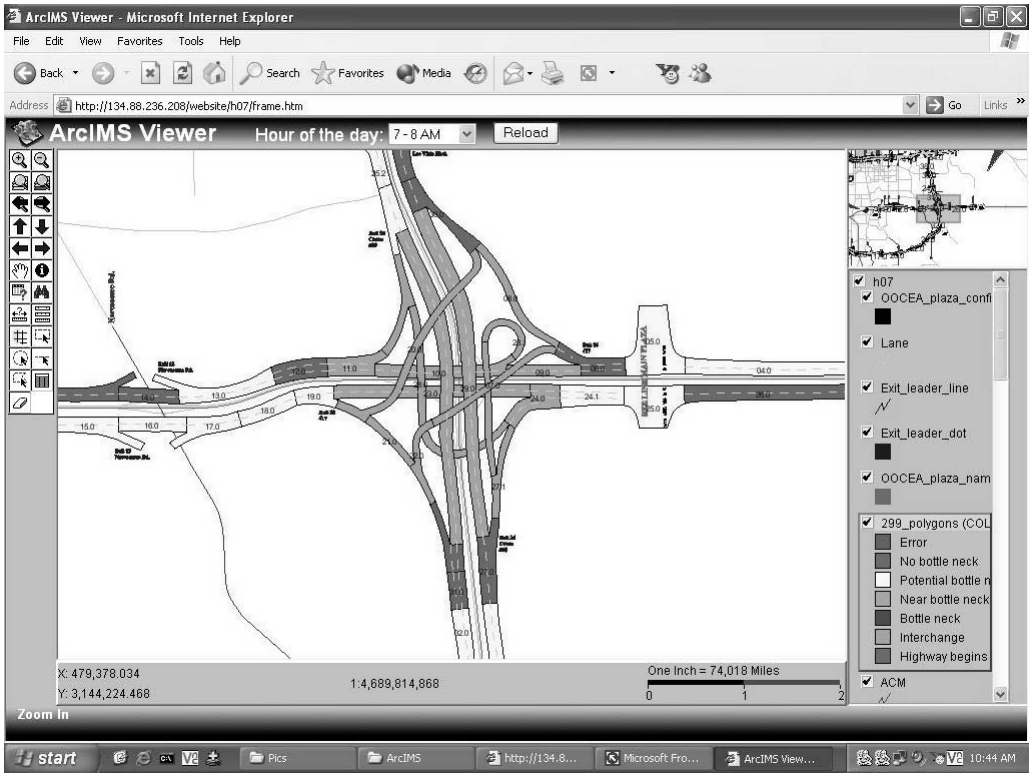
Follow the instructions below to reach the Form for Capacity Analysis:

1. Go to the Menu Bar provided on the left side of the Maps Main page.

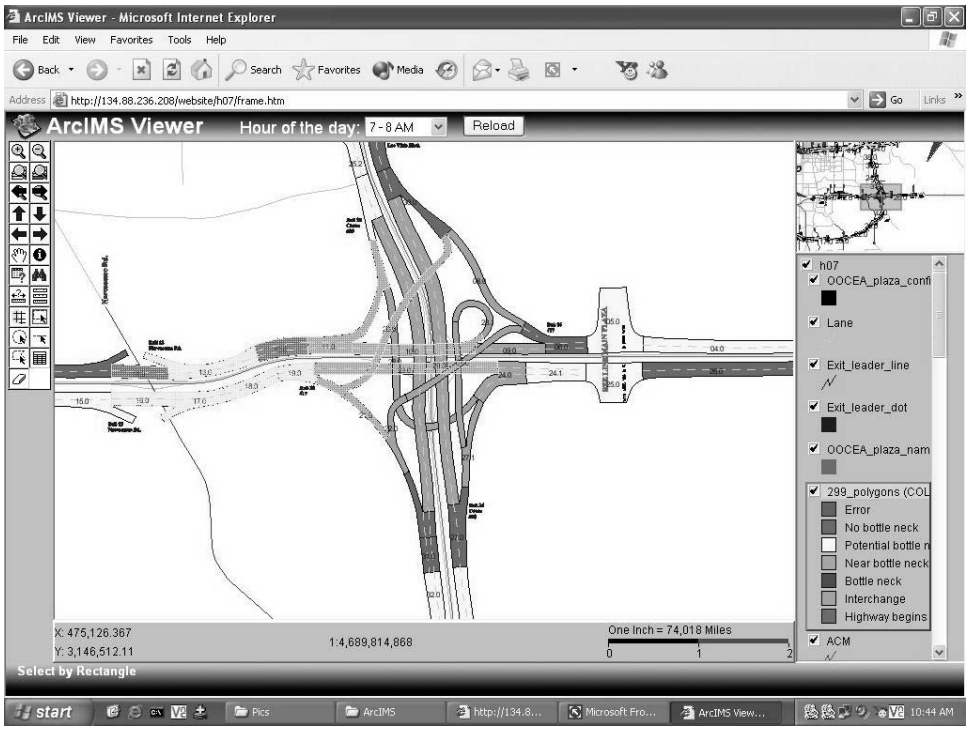
2. Select the "Zoom in" tool to Magnify the OOCEA maps or to reach the Florida Turnpike Plazas. Its easier to reach the required segment by keeping the left mouse key pressed and dragging the mouse to your right and down, after the Zoom in tool has been selected.

3. Go to the Layer Selection Menu on the Right side of the Maps Page.

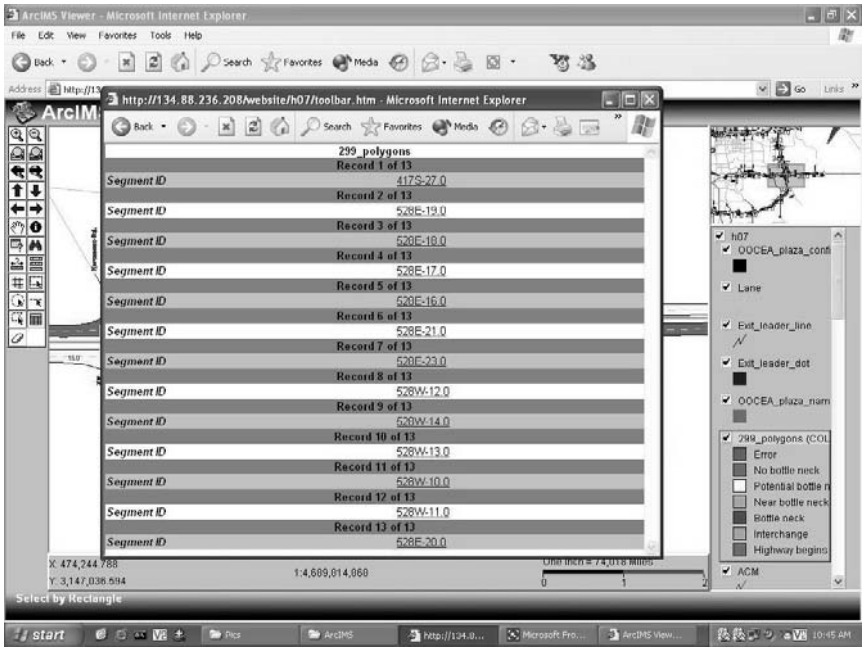
4. Click on the "299_polygons Layer". This action will activate or select the layer and you will notice that the layer name has been highlighted.



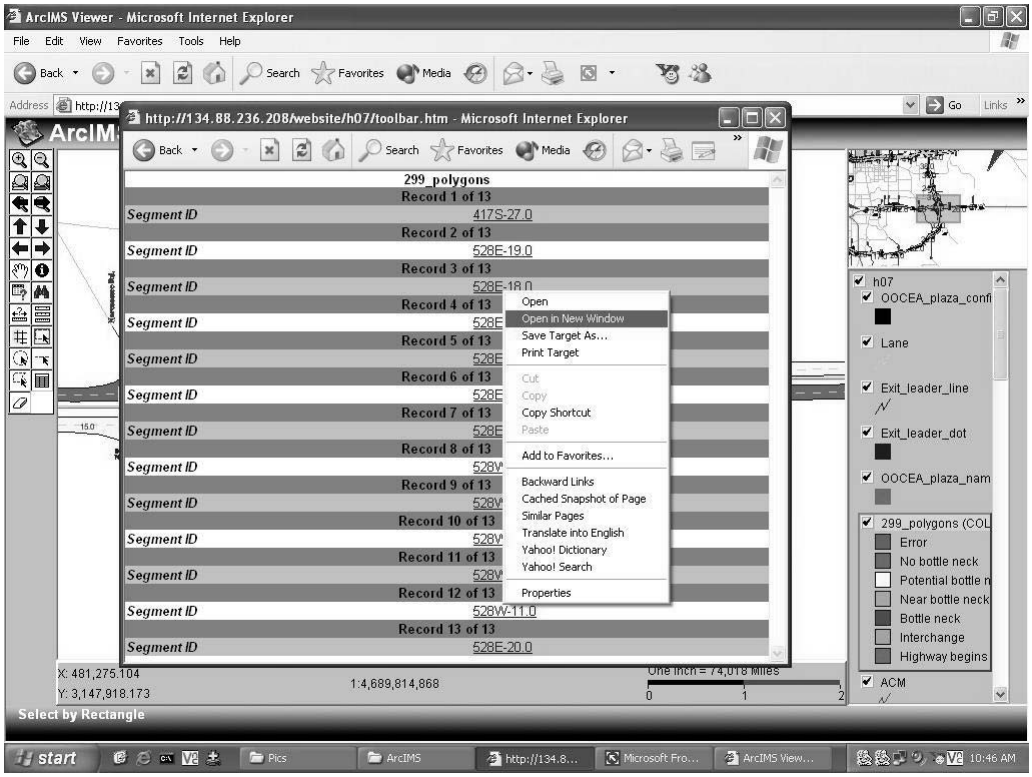
5. Click on the "Select Area" tool on the Menu Bar. Drag Mouse on the map with the left mouse button clicked to select the segments on the highway you want to do analysis on.



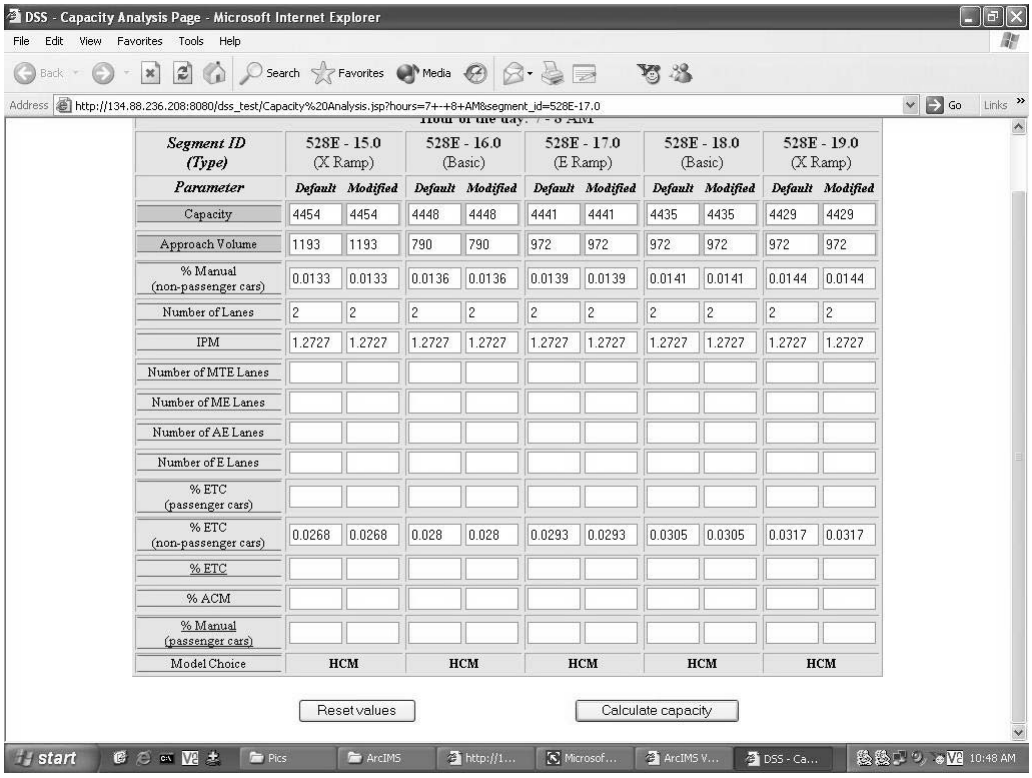
6. Now click on the "Attributes" tool on the Menu Bar on the Left side of the Maps. This action will open an Attributes Table with Segment IDs as links to the Capacity Analysis Form.



7. You can either open the form in the same window or you can open it in a separate window. If you opt to click directly on the link, the form will pop up in the same window. Otherwise, by doing a right mouse click on one of the segments and clicking on "Open in new window" will open the form in a new window.



8. The form shows five segments with the one you opted to open in the middle.

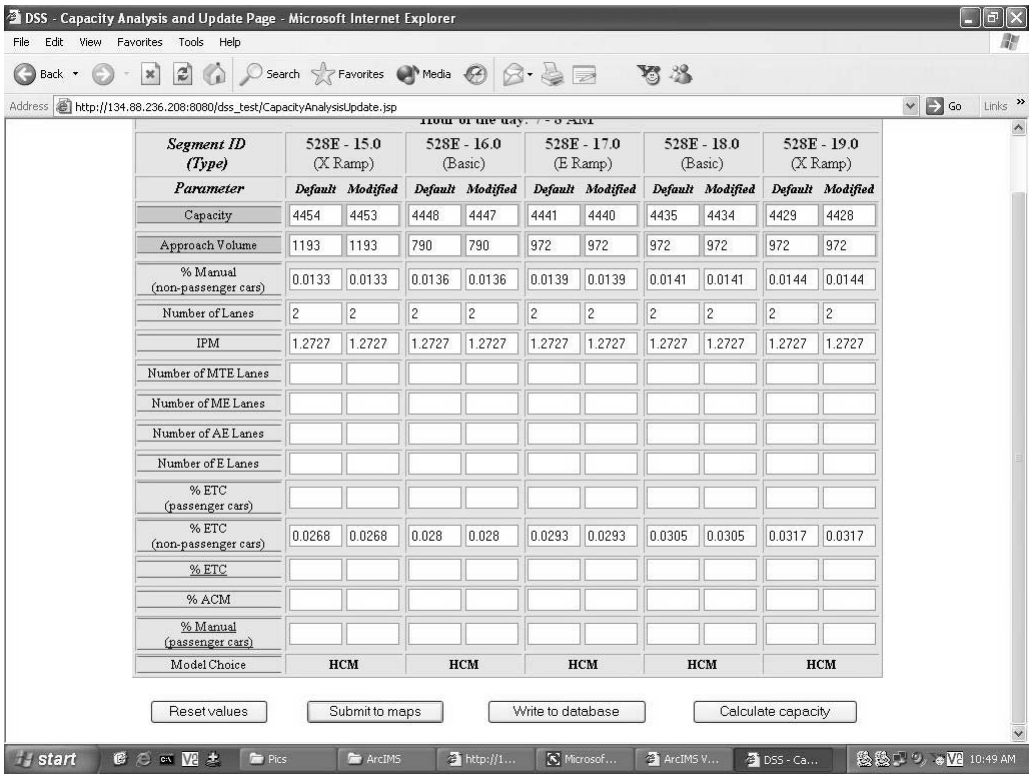


Segment ID (Type)	528E - 15.0 (X Ramp)		528E - 16.0 (Basic)		528E - 17.0 (E Ramp)		528E - 18.0 (Basic)		528E - 19.0 (X Ramp)	
Parameter	Default	Modified	Default	Modified	Default	Modified	Default	Modified	Default	Modified
Capacity	4454	4454	4448	4448	4441	4441	4435	4435	4429	4429
Approach Volume	1193	1193	790	790	972	972	972	972	972	972
% Manual (non-passenger cars)	0.0133	0.0133	0.0136	0.0136	0.0139	0.0139	0.0141	0.0141	0.0144	0.0144
Number of Lanes	2	2	2	2	2	2	2	2	2	2
IPM	1.2727	1.2727	1.2727	1.2727	1.2727	1.2727	1.2727	1.2727	1.2727	1.2727
Number of MTE Lanes										
Number of ME Lanes										
Number of AE Lanes										
Number of E Lanes										
% ETC (passenger cars)										
% ETC (non-passenger cars)	0.0268	0.0268	0.028	0.028	0.0293	0.0293	0.0305	0.0305	0.0317	0.0317
% ETC										
% ACM										
% Manual (passenger cars)										
Model Choice	HCM		HCM		HCM		HCM		HCM	

9. Capacity Analysis cannot be done on those segments of the highways that are interchanges.

10. After making the changes on the some of the parameters on the form, you can hit "Calculate" Button on the forms. This brings up the new or the modified capacity on the form.

11. Now hit "Submit to Maps" Button on the form.

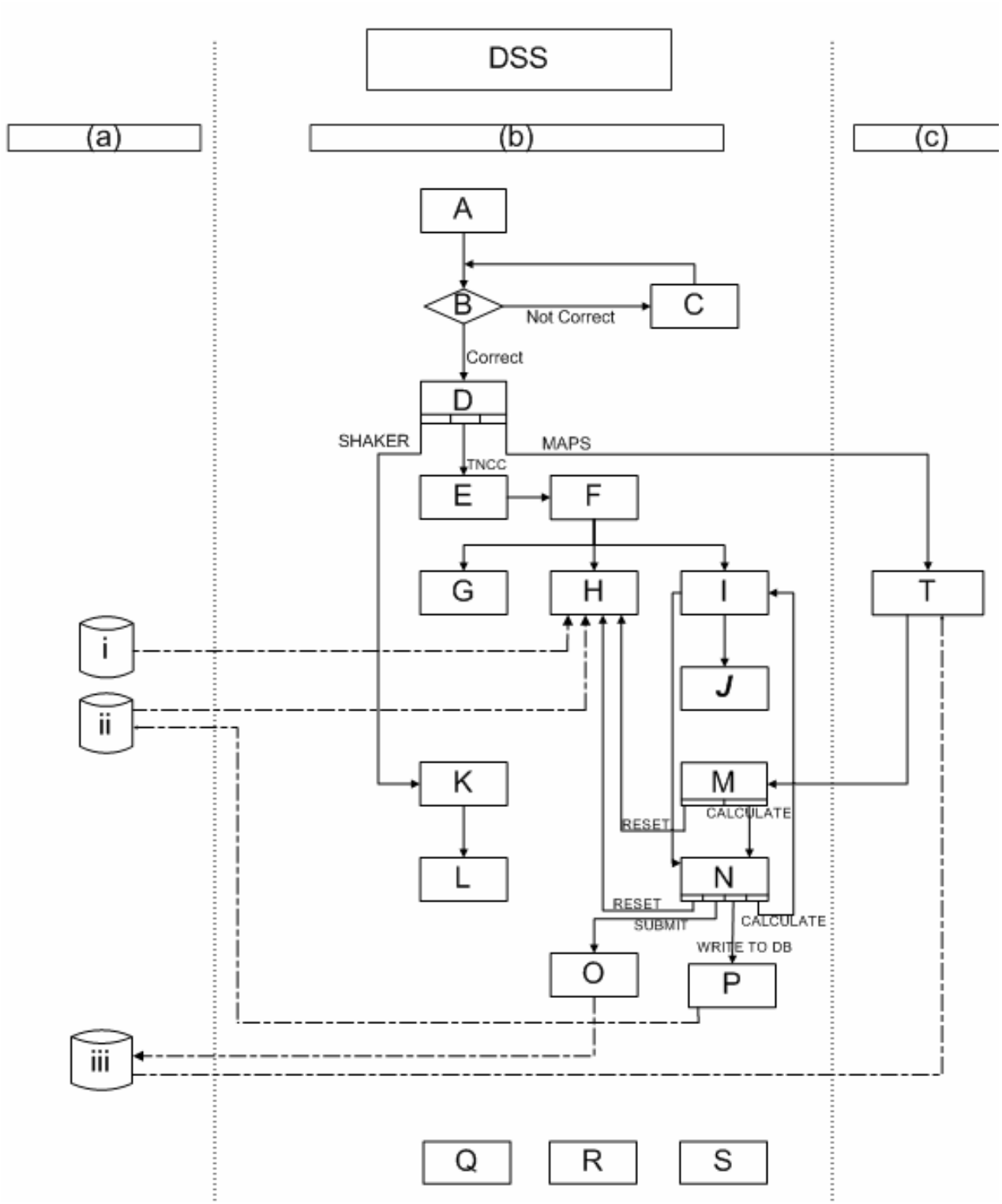


Segment ID (Type)	528E - 15.0 (X Ramp)		528E - 16.0 (Basic)		528E - 17.0 (E Ramp)		528E - 18.0 (Basic)		528E - 19.0 (X Ramp)	
Parameter	Default	Modified	Default	Modified	Default	Modified	Default	Modified	Default	Modified
Capacity	4454	4453	4448	4447	4441	4440	4435	4434	4429	4428
Approach Volume	1193	1193	790	790	972	972	972	972	972	972
% Manual (non-passenger cars)	0.0133	0.0133	0.0136	0.0136	0.0139	0.0139	0.0141	0.0141	0.0144	0.0144
Number of Lanes	2	2	2	2	2	2	2	2	2	2
IPM	1.2727	1.2727	1.2727	1.2727	1.2727	1.2727	1.2727	1.2727	1.2727	1.2727
Number of MTE Lanes										
Number of ME Lanes										
Number of AE Lanes										
Number of E Lanes										
% ETC (passenger cars)										
% ETC (non-passenger cars)	0.0268	0.0268	0.028	0.028	0.0293	0.0293	0.0305	0.0305	0.0317	0.0317
% ETC										
% ACM										
% Manual (passenger cars)										
Model Choice	HCM		HCM		HCM		HCM		HCM	

12. Go back to the Maps page and hit "Reload" button on the Maps top Menu (next to the Hour of Day selection). You will be able to see the effect of Capacity change on the segment of the highway you selected earlier.

13. In case you are unable to see the changes or if the Maps Applets are not fully loaded on the web-page you are viewing, close your browser window and open it again.

Appendix E: Flow Chart for the DSS



The DSS flowchart is split into three columned layers as seen above by the dotted vertical lines.

(a) The Oracle / FoxPro Database Layer is located on IP 134.88.236.99 (Oracle 9i) and IP 134.88.236.208 (Foxpro). There are two Oracle databases: one to which DSS users has read/write privileges and one permanent default database. This database contains three types of data: highway segment input parameters to compute highway segment capacity values for November 5, 2002, traffic characteristics for the highway segments such as percent trucks, and the approaching traffic volumes for all segments. The two Oracle databases are labeled i and ii respectively. The FoxPro database is labeled iii and contains attributes of all polygons on the maps, such as the color of the polygon.

(b) The Web Server / Tomcat Server Interfacing Layer located on IP 134.88.236.208 which contains most of the DSS logic written in JAVA code.

(c) And the ArcIMS Server or the Map Layers located on IP134.88.236.208 labeled **T** on the flow chart.

The DSS flowchart has two types of flow.

1. The solid line indicates logic flow

2. And the dashed line indicates reading and writing to the databases.

A: index.html - The default file that loads when the website is visited. Asks for username and password
B: CheckLogin.java - The servlet to verify the username and password stored in Oracle database with the ones entered on webpage.
C: error.html - User is redirected to this webpage after he/she enters invalid username/password.
D: index1.html - The main file for the project that has the options of taking the user either to the maps (and the form manipulation), SHAKER, or TNCC.
E: tncc_main.html - The main file for TNCC manipulations.
F: TNCC_CapacityAnalysis.jsp - The JSP file used to read information on the 20 highway segments from Oracle database and calculate capacities.
G: PlazaBean.java - File used to store details on 20 OOCEA plaza segments and 10 Florida Turnpike plaza segments.
H: FormPopulatorBean.java - The Java file used to read highway segment information from Oracle database and populate the main form and TNCC form.
I: CapacityCalculatorBean.java - The Java file used to calculate the capacity of the current highway segment. Uses HCM algorithm for non-plazas and TNCC for plazas.
J: tncc package - Collection of all files related to TNCC calculations. Main file is called ChooseAlgo.java and this file uses the help of other files like algo_Cas0.java, algo_Cas1.java etc.
K: shaker_main.html - The main file for SHAKER manipulations.
L: WebstartSHAKER.jnlp - The Java Web Start application file for SHAKER.
M: CapacityAnalysis.jsp - The JSP file used to create a dynamic form for the selected segments from the maps so that capacity analyses can be done on them.

N: CapacityAnalysisUpadate.jsp - The JSP file used to manipulate values on the previous file. The web page rendered from this program can read Oracle database, write to it, submit color info to FoxPro, and calculate newer capacities.
O: FoxProWriterBean.java - The Java program used to calculate colors based on the segment's capacity, the approach volume, and write this color information to FoxPro database.
P: OracleWriterBean.java - The Java program used to write newer values (capacities, volume, etc) back to Oracle database.
Q: ReadOracle.java - A standalone Java application used to read the Oracle database (for example when we want to verify values written to database or just read some particular values.)
R: ReadDBF.java - A standalone Java application used to read DBF files (FoxPro databases) using JDBC-ODBC bridge.
S: Updatemap.java - A standalone Java application used to read capacity and approach volume from the Oracle database, calculate the specific color for the segment, and write the color to the FoxPro database so that these colors can be viewed in ArcIMS viewer (maps). This program is executed 16 times for the 16 hours of the segments to initialize the maps to their initial configurations.

Appendix F: Methodology for Capacity Calculations

Methodology

Capacities, in passenger cars per hour (pcph), are converted to service flows, in vph. This allows a comparison analysis to volume values, also in vph. If a highway segment's approaching traffic volume is larger than the segment's service flow, then a bottleneck is identified.

Calculated capacities, in pcph, and service flows, in vph, are based on traffic and roadway conditions of August 16, 2000. Plaza lane configurations are also those lane patterns on this day at that time. Traffic volumes leaving the plazas are also taken from transaction data at the plazas from 7 to 8 a.m. on August 16, 2000 provided by the OOCEA. Volumes on highway segments between the plazas, on the other hand, are 2001 traffic volumes, also from 7:00 a.m. to 8:00 a.m., extracted from tables provided by PBS&J. Most all volumes are Wednesday volumes, except a few are taken on Tuesdays. All approach traffic volumes to each of the 295 highway segments are from 7:00 a.m. to 8:00 a.m.

It is emphasized that bottlenecks identified in this analysis are only for the morning commuter traffic. For the evening commuter traffic, a new analysis would produce a different set of bottlenecks and bottleneck locations. As will be proposed here, and as an expansion to this project, this study could be used as a foundation, in which evening commuter traffic bottlenecks could easily and rapidly be identified. Sixteen consecutive hours can be analyzed, resulting in bottleneck location shifts during the day from 6 a.m. to 10 p.m. A time simulation of these sixteen hours could graphically illustrate bottleneck location shifts on the network map during a typical day.

Segment Identification

Segment identification numbers refer to the maps that follow. Microsoft Excel spreadsheets, Tables 6, 7, 8, 9, 10 and 11 are also in Appendix G. They contain a list of all the highway segments on the network, their identification numbers, their capacities or service flow rates and the approach traffic volumes. Comparing the two columns (the approach volume column and the service flow rate column) immediately identifies bottlenecks. Segments in all Tables that are highlighted in dark green indicate a bottleneck, in other words, the approach volumes are larger than the segment capacity. Light green indicates a *near* bottleneck; the approach volumes are just below the segment capacity. Light blue indicates a *potential* bottleneck; the capacity significantly decreases along the direction of traffic flow. Yellow indicates that the traffic volume data is taken on Tuesdays rather than Wednesdays. Darker blue indicates that the volume data may not be valid. Segments highlighted in gray are interchange ramps that do not lie on the mainline. Both the approach volume columns and service flow columns are highlighted in soft orange to assist the reader with a visual comparison of their values for the same highway segment.

Every segment was assigned an identification number, ID#. This consisted of nine names/numbers connected by dashes: the Highway Number & Direction – Segment Number – Exit or Entrance Number linked to the Segment – Number of Lanes on the Segment – Design Speed of the Segment – whether a Plaza exists on the Link – Service Flow Rate – Approach Volume - Map number. For computer programming purposes, the pound sign fills in spaces so that there are always four spaces in the first three names. For example, segment 417S-01.0-

37#X-2-65-PP-4587-2926-01 is the first segment, 01.0, on the freeway traveling south on the 417. The third name in the identification number, 37#X, indicates that Exit 37 is linked to this segment and leads drivers off of the 417. If there is an entrance ramp associated with Exit 37, then the X for exit ramp becomes an N for entrance ramp. In other words, the nomenclature becomes 37#N. If the exit or entrance number is 14B, then the nomenclature becomes either 14BX or 14BN. If there is no exit or entrance associated with a segment, then the nomenclature for the third name of that segment is #NA#. In this example, here are 2 lanes on the segment and the design speed is 65 miles per hour. The exit ramp connected to this segment also contains a toll ramp plaza, indicated by the name PP. If a plaza is situated on the segment, the identification will also carry PP. This becomes NP for all other cases. This first segment on the 417 South has a capacity or service flow rate of 4587 vph and an approach volume of 2926 vph. The last name in the ID # indicates on what map the segment is illustrated. There are 22 such maps. There is also one large map that pastes all 22 smaller maps together, similar to Figure 8. These maps are in Appendix I.

Capacity Calculations

Traditional methods, taken from the HCM 2000, were used to calculate capacities of the segments between the plazas. The number of lanes along any one segment is constant along any one segment, as is the lane width and right lateral clearance. The heavy vehicle factor and driver population adjustment factor were also uniform within each segment. Freeway segments did not include more than one entrance or exit. Entrance ramp freeway segments included the region 1500 feet downstream of the on-ramp. Exit ramp freeway segments included the region 1500 feet upstream of the off-ramp. No regions were found in which further division would be necessary where there were speed limit changes or whenever grades were larger than 2% and prevailed a distance longer than a quarter of a mile.

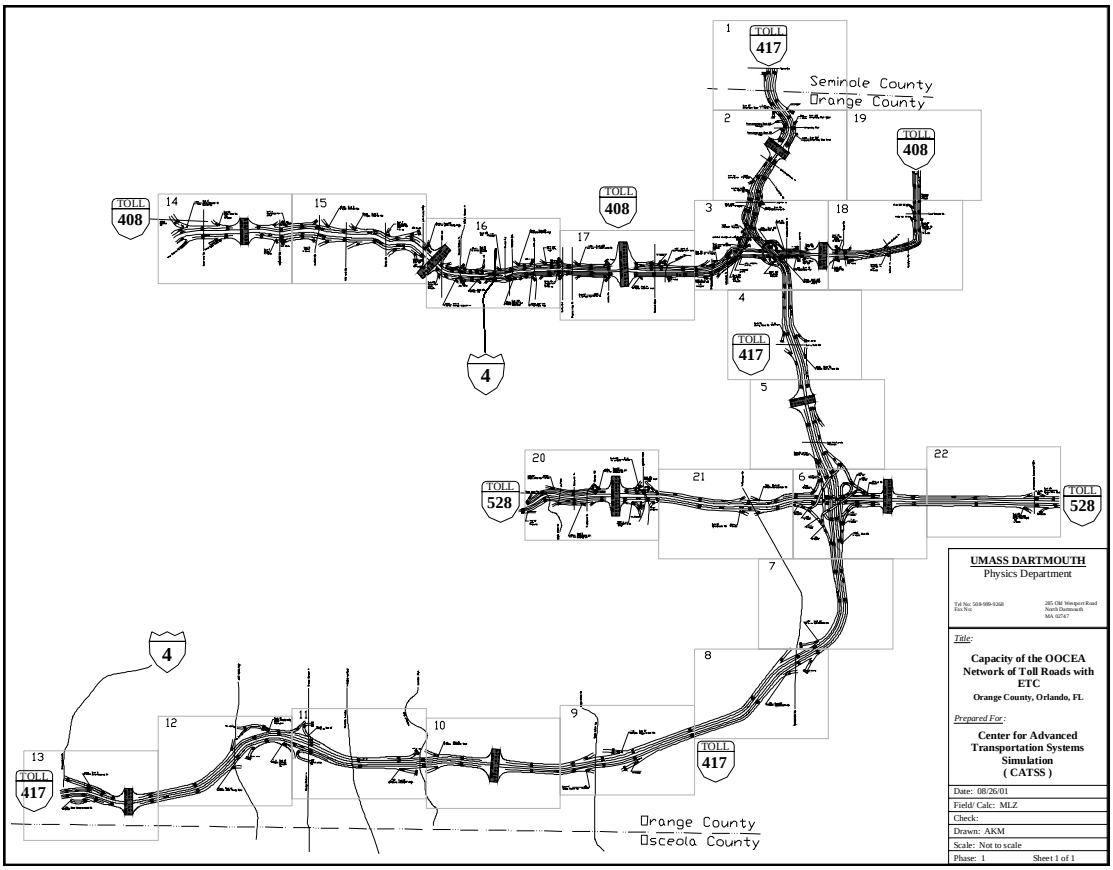


Figure 8. Toll Road network under study, not to scale.

Figure 9 is a sample view of the network that contains a basic freeway segment, identification number 417S-21.0-#NA#-2-65-NP-4548-2230-04. Equation (1) was used for the capacity calculation of the basic freeway segments in pcph, for E - LOS. It is the product of the number of lanes, N, and the Maximum Service Flow, MSF, under ideal conditions listed in the HCM 2000. Multiplying this by the heavy vehicle factor, f_{HV}, and the driver population factor, f_P, result in the Service Flow, SF, rate in vph, as illustrated by equation (2). SF is the Service Flow rate during the peak 15 minutes for LOS E.

Terrain is best described as somewhere between level and rolling. This is because some of the time, heavy vehicles on the basic freeway segments are able to maintain the same speed as passenger cars. In addition, the freeway segments consist mostly of terrain that includes short grades of no more than 2%. Thus, the passenger car equivalent for a heavy vehicle is taken to be a value of 2.0. Finally, most drivers are commuters and familiar with the facility so that a value of 1.0 is taken for the driver population factor, f_P.The ideal freeway Free Flow Speeds, FFS_{ideal}, of 70 mph in the urban environment and 75 mph in the more rural environment are used. Corrections are applied to the FFS_{ideal}, resulting in the Free Flow Speed, FFS, described by equation (3), also in mph. Appropriate Speed Flow Curves for basic freeway segments determine the Maximum Service Flow, MSF, rate, for LOS E. The lanes are 12 feet wide so there is no need for a lane width adjustment; f_{lw} has a value of 0.0. In addition, no adjustments are made for right lateral clearance; f_{lc} has a value of 0.0. There are few obstructions and those are continuous and drivers have become accustomed to them so that their influence on traffic flow is negligible.

On some of the basic freeway segments, however, a correction was necessary due to the number of lanes. Two, three and four lanes on a basic freeway segment reduce the FFS_{ideal} by 4.5, 3.0 and 1.5 mph respectively; f_n is described by equation (4). In addition, a reduction in FFS_{ideal} is necessary due to the interchange density. This interchange density factor correction, f_{id}, also taken from the HCM 2000, is described by equation (5) where IPM is the number of interchanges per mile.

(pcph) (1)

g (vph) (2)

$$FFS = FFS_{ideal} - f_{id} - f_n - f_{lc} - f_{lw} \quad (3)$$

$$f_n = 7.5 - 1.5N \quad (4)$$

$$f_{id} = 5 \times IPM - 2.5 \quad (5)$$

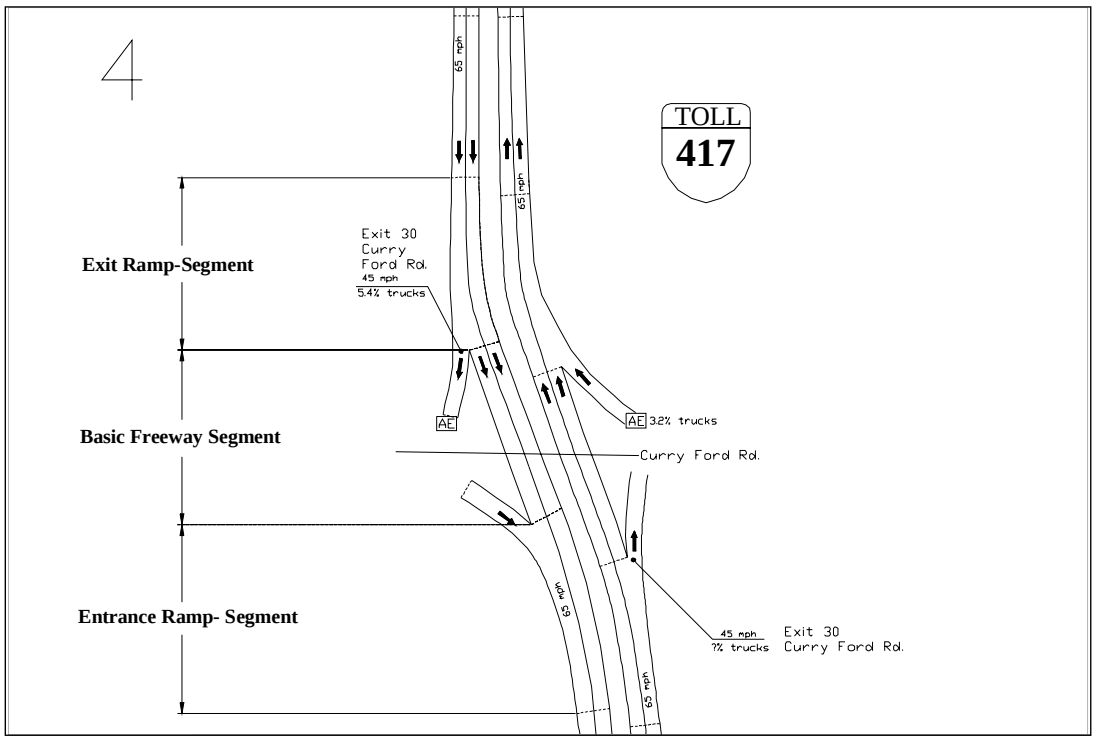


Figure 9: Sample view of the network containing typical freeway segments.

Appendix G: Approach Volumes & Capacity Calculations

» 7 to 8 a.m. Volumes and Service Flow Rates for highway segments for August 2000 typical day on the OOCEA's network of toll roads

Volumes were collected and Service Flow Rates were computed for 15 additional hours and are not included in this appendix. These other hours are included on the cd included with this report.

Table 6: the Central Florida Greeneway 417 eastbound

Table 7: the Central Florida Greeneway 417 westbound

Table 8: the East-West Expressway 408 eastbound

Table 9: the East-West Expressway 408 westbound

Table 10: the Bee Line Expressway 528 eastbound

Table 11: the Bee Line Expressway 528 westbound

Table 6: Traveling North on the 417, Central FL Greeneway

SECTION NAME - highway name & direction - segment number - exit number X, entrance N - no. of lanes in segment - speed limit on segment - plaza PP or no plaza NP - map number on which it is located	SF is the service flow rate during pk 15 min.for LOS E $FFS=FFS_{ideal}-f_{id}-f_n-f_{lc}-f_{lw}$ $f_{id}=5*(ipm)-2.5$ $f_n=7.5-1.5N$ $f_{lc} = f_{lw} = 0.0$ MSF=10*FFS+1700 $SF=N*MSF*f_{HV}*f_p$ $SF=Capacity*f_{HV}*f_p$ $f_p = 1.00$ $f_{HV}=1/(1+P_T(E_T-1.0))$ (vph)	from TNCC Plaza SF (vph)	PBS&J Enterning Volumes (vph) TOTAL	Ramp Plaza Capacity (vph)	
417N-01.0-#NA#-2-65-NP-13	4682		327		
417N-02.0-06#N-3-65-NP-13	7067		469		International Dr. (entrance #6)
417N-03.0-#NA#-2-65-NP-13	4682		469		
417N-04.0-#NA#-3-30-PP-13		1394	469	John Young Parkway Main Plaza (north)	
417N-05.0-#NA#-2-65-NP-13	4677		411		
417N-06.0-10#X-2-65-NP-12	4671		411		John Young Parkway (SR 423) (exit #10)
417N-07.0-#NA#-2-65-NP-12	4666		388		
417N-08.0-10#N-2-65-PP-12	4661		549	918	John Young Parkway (SR 423) (entrance #10)
417N-09.0-11#X-2-65-NP-12	4655		549		Orange Blossom Trail (exit #11)
417N-10.0-#NA#-2-65-NP-11	4650		510		
417N-11.0-11#N-3-65-PP-11	7011		612	780	Orange Blossom Trail (entrance #11)
417N-12.0-#NA#-2-65-NP-11	4639		612		in future - Florida's Turnpike (exit 12) ?
417N-13.0-14#X-2-65-PP-11	4634		612	1060	Landstar Blvd. (exit #14)
417N-14.0-#NA#-2-65-NP-11	4629		561		
417N-15.0-14#N-2-65-NP-10	4624		988		Landstar Blvd. (entrance #14)
417N-16.0-#NA#-2-65-NP-10	4618		988		
417N-17.0-#NA#-3-30-PP-10		1529	988	Boggy Creek Main Plaza (north)	
417N-18.0-#NA#-2-65-NP-10	4616		623		
417N-19.0-17#X-2-65-NP-09	4619		623		Boggy Creek Rd. (exit #17)
417N-20.0-#NA#-2-65-NP-09	4623		660		
417N-21.0-17#N-2-65-PP-09	4626		755	820	Boggy Creek Rd. (entrance #17)
417N-22.0-#NA#-2-65-NP-08	4629		755		
417N-23.0-22#X-2-65-NP-08	4632		755		Narcoosee Rd. (exit #22)
417N-24.0-#NA#-2-65-NP-08	4635		523		
417N-25.0-22#N-2-65-PP-08	4638		729	1518	Narcoosee Rd. (entrance #22)
417N-26.0-#NA#-2-65-NP-07	4536		729		
417N-27.0-26#X-2-65-NP-06	4539		729		Interchange 528 (exit #26 to EB & WB)
417N-27.1-26EX-1-45-NP-06	2255		123		to 528 EB
417N-28.0-26WX-1-45-NP-06	2255		5		to 528 WB
417N-28.1-#NA#-1-45-NP-06	2255		5		to 528 WB
417N-29.0-#NA#-2-65-NP-06	4542		606		
417N-30.0-26#N-2-65-NP-05	4545		1281		Interchange 528 (entrance #26 from EB & WB)
417N-31.0-#NA#-2-65-NP-05	4548		1281		
417N-32.0-####-3-65-NP-05	6871		1307		in future-Lee Vista Blvd. (exit #27) ?
417N-33.0-#NA#-3-30-PP-05		1966	1307	Curry Ford Main Plaza (north)	
417N-34.0-#NA#-2-65-NP-05	4557		1181		
417N-35.0-30#X-2-65-NP-04	4560		1181		Curry Ford Rd. (SR552) (exit #30)
417N-36.0-#NA#-2-65-NP-04	4563		1159		
417N-37.0-30#N-2-65-PP-04	4565		1463	977	Curry Ford Rd. (SR552) (entrance #30)
417N-38.0-#NA#-2-65-NP-04	4568		1463		
417N-39.0-33AX-2-65-NP-03	4571		1463		Interchange 408 (exit 33A to EB)
417N-40.0-33BX-2-65-NP-03	4574		1115		Interchange 408 (exit 33A to WB)
417N-41.0-#NA#-2-65-NP-03	4576		629		
417N-42.0-18#N-2-65-NP-03	4579		858		Interchange 408 (entrance 33A from WB)
417N-43.0-#NA#-2-65-NP-03	4582		858		
417N-44.0-#NA#-4-65-NP-03	9287		1616		Interchange 408 (merge entrance from EB)
417N-45.0-34#X-4-65-PP-03	9292		1616	1150	East Colonial Drive (exit #34)
417N-46.0-#NA#-3-65-NP-03	6929		1464		
417N-47.0-#NA#-2-65-NP-02	4593		1356		
417N-48.0-34#N-3-65-NP-02	6938		1462		East Colonial Drive (entrance #34)
417N-49.0-#NA#-3-65-NP-02	6942		1462		
417N-50.0-#NA#-2-65-NP-02	4601		1462		
417N-51.0-#NA#-3-30-PP-02		1960	1462	University Main Plaza (north)	
417N-52.0-37AX-3-65-NP-02	6950		1326		University Blvd. (exit #37A to EB)
417N-53.0-37BX-3-65-NP-02	6950		1077		University Blvd. (exit #37B to WB)
417N-54.0-#NA#-2-65-NP-02	4604		953		
417N-55.0-37#N-2-65-PP-01	4604		1194	836	University Blvd. (entrance #37)

	Bottlenecks
	Near Bottlenecks
	Potential Bottlenecks
	Tues' data rather than Wed
	Segment not on the Mainline
	Volume and SF columns
	Volumes are uncertain

Table 7: Traveling South on the 417, Central FL Greeneway

SECTION NAME - highway name & direction - segment number - exit number X, entrance N - no. of lanes in segment - speed limit on segment - plaza PP or no plaza NP - map number on which it is located	SF is the service flow rate during pk 15 min.for LOS E $FFS=FFS_{ideal}-f_{id}-f_n-f_{lc}-f_{lw}$ $f_{id}=5*(ipm)-2.5$ $f_n=7.5-1.5N$ $f_{lc} = f_{lw} = 0.0$ MSF=10*FFS+1700 $SF=N*MSF*f_{HV}*f_p$ $SF=Capacity*f_{HV}*f_p$ $f_p = 1.00$ $f_{HV}=1/(1+P_T(E_T-1.0))$ (vph)	from TNCC Plaza SF (vph)	PBS&J Enterning Volumes (vph) TOTAL	Ramp Plaza Capacity (vph)	
417S-01.0-37#X-2-65-PP-01	4587		2926	830	University Blvd. (exit #37)
417S-02.0-#NA#-2-65-NP-02	4587		2604		
417S-03.0-37AN-3-65-NP-02	6925		3237		University Blvd. (entrance #37 from WB)
417S-04.0-37BN-3-65-NP-02	6925		3371		University Blvd. (entrance #37 from EB)
417S-05.0-#NA#-5-30-PP-02		4006	3371	University Main Plaza (south)	
417S-06.0-#NA#-2-65-NP-02	4584		3517		
417S-07.0-34#X-2-65-NP-02	4581		3517		East Colonial Drive (exit #34)
417S-08.0-#NA#-2-65-NP-02	4578		3204		
417S-09.0-34#N-3-65-PP-02	6906		3617	1293	East Colonial Drive (entrance#34)
417S-10.0-33BX-3-65-NP-03	6901		3617		Interchange 408 (diverge exit to WB)
417S-11.0-01#X-2-65-NP-03	4571		2147		Valencia College Lane (exit #1)
417S-12.0-#NA#-2-65-NP-03	4571		1438		
417S-13.0-01#N-2-65-PP-03	4571		1682	1252	Valencia College Lane (entrance #1)
417S-14.0-#NA#-1-65-NP-03	2271		2258	single left merge lane onto 408 WB from 417 SB	
417S-15.0-#NA#-2-65-NP-03	4568		1733		
417S-16.0-33AX-2-65-NP-03	4564		1733		Interchange 408 (exit #33A to EB)
417S-17.0-#NA#-2-65-NP-03	4561		1484		
417S-18.0-33AN-2-65-NP-03	4558		2331		Interchange 408
417S-19.0-#NA#-2-65-NP-03	4555		2331		(entrance #33A from EB & WB)
417S-20.0-30#X-2-65-PP-04	4551		2331	771	Curry Ford Road (SR552) (exit #30)
417S-21.0-#NA#-2-65-NP-04	4548		2230		
417S-22.0-30#N-2-65-NP-04	4545		3275		Curry Ford Road (entrance #30)
417S-23.0-#NA#-2-65-NP-04	4542		3275		
417S-24.0-#NA#-5-30-PP-05		4022	3275	Curry Ford Main Plaza (south)	
417S-25.0-#NA#-2-65-NP-05	4535		2929		in future-Lee Vista Blvd. (entrance #27)
417S-26.0-26#X-2-65-NP-05	4532		2533		Interchange 528 (exit #26 to EB & WB)
417S-27.0-26WX-1-45-NP-06	2252		1794		to 528 WB
417S-28.0-26EX-1-45-NP-06	2252		283		to 528 EB
417S-29.0-#NA#-2-65-NP-06	4529		739		
417S-30.0-26#N-2-65-NP-06	6833		955		Interchange 528
417S-31.0-#NA#-3-65-NP-07	7028		955		(entrance #26 from EB & WB)
417S-32.0-#NA#-2-65-NP-07	4653		955		
417S-33.0-22#X-2-65-PP-07	4650		955	1913	Narcoossee Rd. (exit #22)
417S-34.0-#NA#-2-65-NP-08	4647		851		
417S-35.0-22#N-2-65-NP-08	4644		966		Narcoossee Rd. (entrance #22)
417S-36.0-#NA#-2-65-NP-08	4641		966		
417S-37.0-17#X-2-65-PP-09	4638		966	852	Boggy Creek Rd. (exit #17)
417S-38.0-#NA#-2-65-NP-09	4637		875		
417S-39.0-17#N-2-65-NP-09	4634		1028		Boggy Creek Rd. (entrance #17)
417S-40.0-#NA#-2-65-NP-10	4630		1028		
417S-41.0-#NA#-3-30-PP-10		2107	1028	Boggy Creek Main Plaza (south)	
417S-42.0-#NA#-2-65-NP-10	4631		934		
417S-43.0-14#X-2-65-NP-10	4636		934		Landstar Blvd. (exit #14)
417S-44.0-#NA#-2-65-NP-10	4641		858		
417S-45.0-14#N-3-65-PP-11	7013		1151	909	Landstar Blvd. (entrance #14)
417S-46.0-#NA#-2-65-NP-11	4652		1151		in future - Florida's Turnpike (exit 12)
417S-47.0-11#X-3-65-PP-11	7029		1151	1194	Orange Blossom Trail (exit #11)
417S-48.0-#NA#-3-65-NP-11	7037		1010		
417S-49.0-11#N-3-65-NP-12	7045		1233		Orange Blossom Trail (entrance #11)
417S-50.0-10#X-3-65-PP-12	7053		1233	1096	John Young Parkway (SR423) (exit #10)
417S-51.0-#NA#-2-65-NP-12	4678		1040		
417S-52.0-10#N-2-65-NP-12	4683		1417		John Young Parkway (entrance #10)
417S-53.0-#NA#-2-65-NP-12	4689		1417		
417S-54.0-#NA#-3-30-PP-13		1767	1417	John Young Parkway Main Plaza (south)	
417S-55.0-#NA#-2-65-NP-13	4694		1528		
417S-56.0-06#X-3-65-NP-13	7085		1528		International Dr. (exit #6)
417S-57.0-#NA#-2-65-NP-13	4694		656		

Bottlenecks
Near Bottlenecks
Potential Bottlenecks
Tues' data rather than Wed
Segment not on the Mainline
Volume and SF columns
Volumes are uncertain

Table 8: Traveling East on the 408, East-West Expressway

SECTION NAME - highway name & direction - segment number - exit number X, entrance N - no. of lanes in segment - speed limit on segment - plaza PP or no plaza NP - map number on which it is located	SF is the service flow rate during pk 15 min.for LOS E $FFS=FFS_{ideal}-f_{id}-f_n-f_{lc}-f_{lw}$ $f_{id}=5*(ipm)-2.5$ $f_n=7.5-1.5N$ $f_{lc} = f_{lw} = 0.0$ MSF=10*FFS+1700 $SF=N*MSF*f_{HV}*f_p$ $SF=Capacity*f_{HV}*f_p$ $f_p = 1.00$ $f_{HV}=1/(1+P_T(E_T-1.0))$ (vph)	from TNCC Plaza SF (vph)	PBS&J Enterning Volumes (vph) TOTAL	Ramp Plaza Capacity (vph)	
408E-02.0-01#N-1-##-NP-14	2231				West Colonial Dr./Clarke Rd. (entrance #1)
408E-03.0-#NA#-2-65-NP-14	4492		2431		
408E-04.0-02#N-2-65-NP-14	4492		3068		Good Homes Rd. (entrance #2)
408E-05.0-#NA#-4-30-PP-14		3023	3068	Hiawassee Main Plaza (east)	
408E-06.0-04#X-2-65-NP-14	4492		2594		Hiawassee Road (exit #4)
408E-07.0-#NA#-2-65-NP-14	4492		2718		
408E-08.0-04#N-3-65-PP-14	6781		3454	1061	Hiawassee Road (entrance #4)
408E-09.0-05#X-3-65-NP-15	6781		3454		Kirkman Rd. (exit #5)
408E-10.0-#NA#-2-55-NP-15	4491		2837		
408E-11.0-05#N-2-55-NP-15	4491		3303		Kirkman Rd. (entrance #5)
408E-12.0-06#N-2-55-NP-15	4491		3695		Pine Hill Rd. (entrance #6)
408E-13.0-07#N-2-45-NP-15	4491		3982		Mercy Dr. (entrance #7)
408E-14.0-08AX-2-45-PP-15	4491		3982	1260	John Young Parkway (SR423) (exit #8A)
408E-15.0-#NA#-2-45-NP-15	4490		3586		
408E-16.0-08AN-2-45-NP-15	4490		3901		John Young Parkway (SR423) (entrance #8
408E-17.0-#NA#-6-30-PP-15		3882	3901	Holland West Main Plaza (east)	
408E-18.0-08BX-2-55-NP-16	4492		3473		Tampa Ave. (exit #8B)
408E-19.0-09#X-2-55-NP-16	4493		3475		Orange Blossom Trail (exit #9)
408E-20.0-#NA#-2-55-NP-16	4495		3268		
408E-21.0-09#N-3-55-PP-16	6788		3424	1178	Orange Blossom Trail (entrance #9)
408E-22.0-10AX-3-55-NP-16	6791		3424		Interstate-4 (exit #10A)
408E-23.0-#NA#-2-55-NP-16	4499		2412		
408E-24.0-10AN-3-55-NP-16	6795		3651		Interstate-4 (entrance #10A)
408E-25.0-10BX-4-55-NP-16	9122		3651		Orange Ave. (exit 10B)
408E-26.0-#NA#-3-55-NP-16	6800		2729		
408E-27.0-11AN-4-55-NP-16	9129		2779		Orange Ave. (entrance 10B)
408E-28.0-11BX-4-55-PP-16	9132		2779	921	Mills Avenue (exit #11B)
408E-29.0-#NA#-3-55-NP-16	6807		2700		
408E-30.0-11BN-4-55-NP-16	9138		3196		Mills Avenue (entrance #11B)
408E-31.0-12AX-4-55-PP-16	9141		3196	1276	Bumby Avenue (exit #12A)
408E-32.0-#NA#-3-55-NP-17	6814		2896		
408E-33.0-12BN-4-55-NP-17	9147		3103		Crystal Lake Dr. (entrance #12B)
408E-34.0-13#X-4-55-PP-17	9150		3103	1173	Conway Road (exit #13)
408E-35.0-#NA#-3-55-NP-17	6821		2917		
408E-36.0-#NA#-5-30-PP-17		3777	2917	Holland East Main Plaza (east)	
408E-37.0-14#X-3-55-NP-17	6821		3371		Semoran Blvd. (SR436) (exit #14)
408E-38.0-#NA#-3-55-NP-17	6818		2663		
408E-39.0-14#N-3-55-PP-17	6816		2881	1236	Semoran Blvd. (SR436) (entrance #14)
408E-40.0-16#X-3-55-NP-03	6814		2881		Goldenrod Rd. (exit #16)
408E-41.0-#NA#-3-55-NP-03	6811		2155		
408E-42.0-16#N-3-65-NP-03	6809		2503		Goldenrod Rd. (entrance #16)
408E-43.0-18AX-3-65-NP-03	6807		2503		Interchange 417 (diverge exit 18A to NB)
408E-44.0-01#X-2-65-PP-03	4507		983	699	Valencia College Lane (exit #1)
408E-45.0-#NA#-2-65-NP-03	4505		876		
408E-46.0-01#N-2-65-NP-03	4504		934		Valencia College Lane (entrance #1)
408E-47.0-18BX-2-65-NP-03	4502		1722		Interchange 417 (exit 18A to SB)
408E-48.0-#NA#-2-65-NP-03	4500		1511		
408E-49.0-33AN-2-65-NP-03	4499		1639		Interchange 417 (entrance 18A from NB)
408E-50.0-33AN-3-65-NP-03	6790		1567		Interchange 417 (entrance 18A from SB)
408E-51.0-19#X-3-65-PP-03	6788		1567	616	Dean Road (exit #19)
408E-52.0-#NA#-2-65-NP-03	4494		1359		
408E-53.0-19#N-2-65-NP-03	4493		3036		Dean Road (entrance #19)
408E-54.0-#NA#-4-30-PP-03		2304	3036	Dean Main Plaza (east)	
408E-55.0-20#X-2-55-NP-18	4491		1494		Rouse Road (exit #20)
408E-56.0-#NA#-2-55-NP-18	4491		1463		
408E-57.0-20#N-2-55-PP-18	4491		1518	757	Rouse Road (entrance #20)
408E-58.0-21#X-2-55-NP-18	4491		1518		Alafaya Trail (exit #21)
408E-59.0-#NA#-2-55-NP-18	4491		1046		
408E-60.0-23#X-2-55-NP-18	4491		1046		Colonial Dr. (exit #23)
408E-61.0-#NA#-2-55-NP-18	4491		503		
408E-62.0-#NA#-2-45-NP-19	4491		503		

Bottlenecks
Near Bottlenecks
Potential Bottlenecks
Tues' data rather than Wed
Segment not on the Mainline
Volume and SF columns
Volumes are uncertain

Table 9: Traveling West on the 408, East-West Expressway

SECTION NAME - highway name & direction - segment number - exit number X, entrance N - no. of lanes in segment - speed limit on segment - plaza PP or no plaza NP - map number on which it is located	SF is the service flow rate during pk 15 min.for LOS E $FFS=FFS_{ideal}-f_{id}-f_n-f_{lc}-f_{lw}$ $f_{id}=5*(ipm)-2.5$ $f_n=7.5-1.5N$ $f_{lc} = f_{lw} = 0.0$ MSF=10*FFS+1700 $SF=N*MSF*f_{HV}*f_p$ $SF=Capacity*f_{HV}*f_p$ $f_p = 1.00$ $f_{HV}=1/(1+P_T(E_T-1.0))$ (vph)	from TNCC Plaza SF (vph)	PBS&J Enterning Volumes (vph) TOTAL	Ramp Plaza Capacity (vph)	Bottlenecks Near Bottlenecks Potential Bottlenecks Tues' data rather than Wed Segment not on the Mainline Volume and SF columns Volumes are uncertain
408W-01.0-#NA#-2-45-NP-19	4481		84		
408W-02.0-23AN-2-55-NP-18	4481		1266		Colonial Dr. (entrance #23 from WB)
408W-03.0-23BN-2-65-NP-18	4481		1506		Colonial Dr. (entrance #23 from EB)
408W-04.0-#NA#-2-65-NP-18	4481		1506		
408W-05.0-21#N-2-65-NP-18	4481		2954		Alafaya Trail (entrance #21)
408W-06.0-#NA#-2-65-NP-18	4481		2954		
408W-07.0-20#N-3-65-NP-18	6766		3115		Rouse Road (entrance #20)
408W-08.0-20#X-3-65-PP-18	6766		3115	422	Rouse Road (exit #20)
408W-09.0-#NA#-3-65-NP-18	6766		3083		
408W-10.0-#NA#-4-30-PP-03		3159	3083	Dean Main Plaza (west)	
408W-11.0-19#X-2-65-NP-03	4483		3083		Dean Road (exit #19)
408W-12.0-#NA#-2-65-NP-03	4485		1725		
408W-13.0-19#N-3-65-PP-03	6775		2481	606	Dean Road (entrance #19)
408W-14.0-18#X-3-65-NP-03	6777		2481		Interchange 417 (exit #18 to NB & SB)
408W-14.1-18#X-3-45-NP-03	2230		801		Interch'ge 417 (diverge lane to NB & SB)
408W-15.0-18NX-1-35-NP-03	2230		229		Interchange 417 (lane to NB)
408W-16.0-18SX-1-35-NP-03	2230		572		Interchange 417 (lane to SB)
408W-17.0-#NA#-2-65-NP-03	4491		1680		
408W-18.0-18#N-2-65-NP-03	4492		3488		Interchange 417 (entrance #18 from NB)
408W-19.0-#NA#-2-65-NP-03	4494		3488		Interchange 417 (entrance #18 from SB)
408W-20.0-16#X-3-65-NP-03	6788		6293		Goldenrod Rd. (exit #16)
408W-21.0-#NA#-3-55-NP-03	6791		4902		
408W-22.0-16#N-3-55-NP-03	6794		6323		Goldenrod Rd. (entrance #16)
408W-23.0-14#X-3-55-PP-17	6797		6323	1395	Semoran Boulevard (exit #14)
408W-24.0-#NA#-3-55-NP-17	6800		5963		
408W-25.0-14NN-4-55-NP-17	9129		5749		Semoran Blvd. (entance #14 from NB)
408W-26.0-14SN-4-55-NP-17	9133		6295		Semoran Blvd. (entance #14 from SB)
408W-27.0-#NA#-9-30-PP-17		6777	6295	Holland East Main Plaza (west)	
408W-28.0-#NA#-3-55-NP-17	6806		6530		
408W-29.0-13#N-4-55-PP-17	9130		7241	1257	Conway Road (entrance #13)
408W-30.0-12BX-4-55-NP-17	9127		7241		Crystal Lake Dr. (exit 12B)
408W-31.0-#NA#-3-55-NP-17	6798		6053		
408W-32.0-12AN-4-55-PP-16	9120		6278	1203	Bumby Avenue (entrance #12A)
408W-33.0-11BX-4-55-NP-16	9117		6278		Mills Avenue (exit #11B)
408W-34.0-#NA#-3-55-NP-16	6791		5544		
408W-35.0-11BN-4-55-PP-16	9111		5593	751	Mills Avenue (entrance #11B)
408W-36.0-11AX-4-55-NP-16	9107		5593		Rosalind Ave. (exit #11A)
408W-37.0-10AX-3-55-NP-16	6784		4069		Interstate-4 (exit #10A)
408W-38.0-#NA#-2-55-NP-16	4491		2239		
408W-39.0-10LN-2-55-NP-16	4490		2406		Orange Ave. (entrance)
408W-40.0-10AN-2-55-NP-16	4488		2782		Interstate-4 (entrance #10A)
408W-41.0-09#X-2-55-PP-16	4487		2782	1452	Orange Blossom Trail (exit #9)
408W-42.0-#NA#-2-55-NP-16	4485		2091		
408W-43.0-09#N-2-45-NP-16	4484		2413		Orange Blossom Trail (entrance #9)
408W-44.0-08BN-2-45-NP-16	4482		2239		Tampa Ave. (entrance #8B)
408W-45.0-#NA#-6-30-PP-16		4353	2239	Holland West Main Plaza (west)	
408W-46.0-08AX-3-55-NP-16	6765		2289		John Young Parkway (exit #8A)
408W-47.0-#NA#-3-55-NP-15	6765		1904		
408W-48.0-#NA#-2-55-NP-15	4481		1904		
408W-49.0-08AN-2-55-PP-15	4481		2026	1346	John Young Parkway (entrance #8A)
408W-50.0-07#X-2-55-NP-15	4481		2026		
408W-51.0-06#X-2-55-NP-15	4481		1818		Mercy Dr. (exit #7)
408W-52.0-05#X-2-55-NP-15	4481		1626		Pine Hill Rd. (exit #6)
408W-53.0-#NA#-2-65-NP-15	4481		1237		Kirkman (exit #5)
408W-54.0-05#N-3-65-NP-15	6766		1362		Kirkman (entrance #5)
408W-55.0-04#X-3-65-PP-14	6767		1362	1301	Hiawassee Road (exit #4)
408W-56.0-#NA#-2-65-NP-14	4482		1063		
408W-57.0-04#N-2-65-NP-14	4482		1243		Hiawassee Road (entrance #4)
408W-58.0-#NA#-3-30-PP-14		1714	1243	Hiawassee Main Plaza (west)	
408W-59.0-02#X-2-65-NP-14	4482		1074		Good Home Rs. (exit #2)
408W-60.0-01#X-2-65-NP-14	4482		1201		West Colonial Dr./Clarke Rd. (exit #1)
408W-61.0-#NA#-2-65-NP-14	4482		752		

Table 10: Traveling East on the 528, Bee Line Expressway

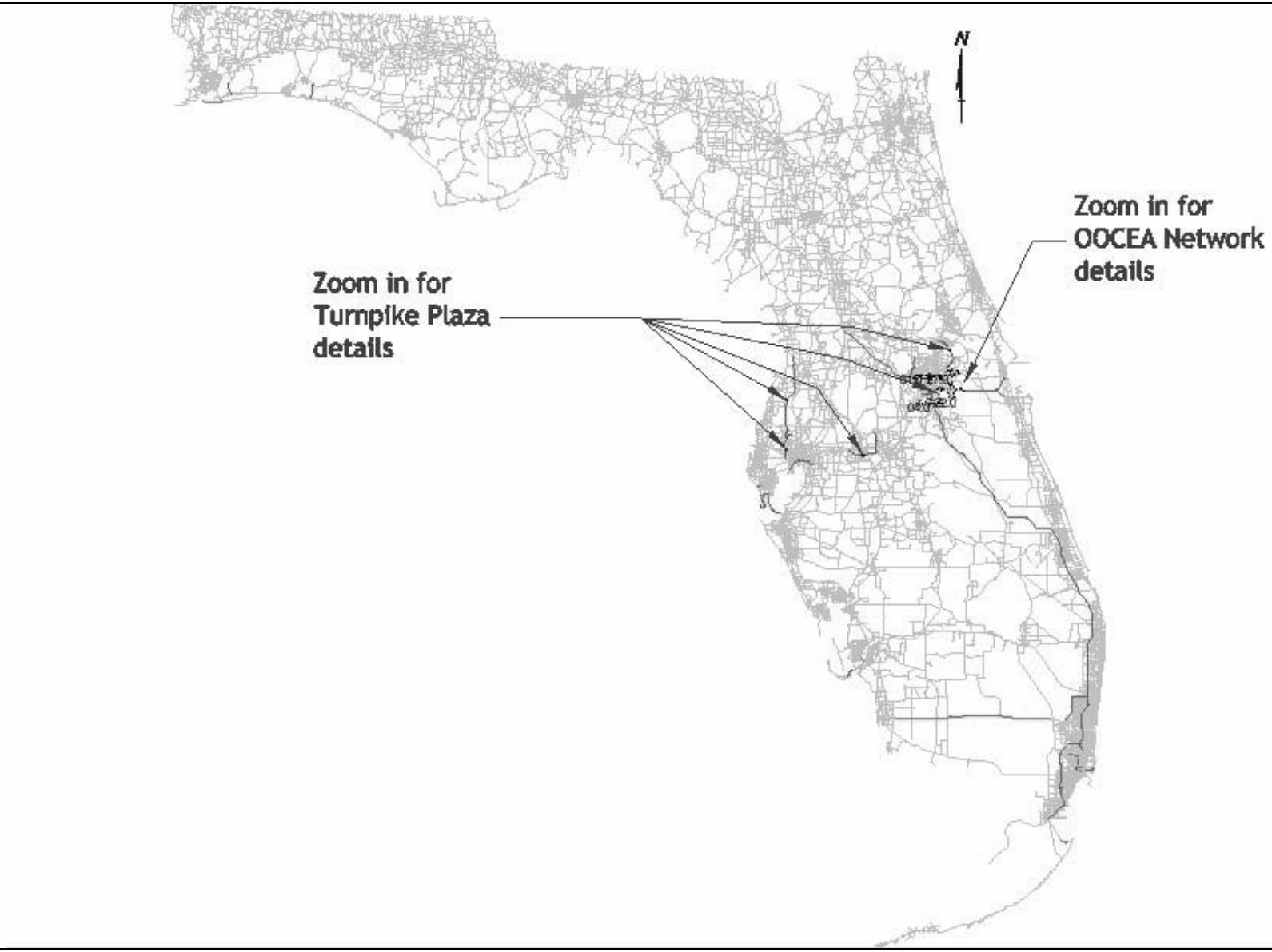
SECTION NAME - highway name & direction - segment number - exit number X, entrance N - no. of lanes in segment - speed limit on segment - plaza PP or no plaza NP - map number on which it is located	SF is the service flow rate during pk 15 min.for LOS E $FFS=FFS_{ideal}-f_{id}-f_n-f_{lc}-f_{lw}$ $f_{id}=5*(ipm)-2.5$ $f_n=7.5-1.5N$ $f_{lc} = f_{lw} = 0.0$ $MSF=10*FFS+1700$ $SF=N*MSF*f_{HV}*f_p$ $SF=Capacity*f_{HV}*f_p$ $f_p = 1.00$ $f_{HV}=1/(1+P_T(E_T-1.0))$ (vph)	from TNCC Plaza SF (vph)	PBS&J Enterning Volumes (vph) TOTAL	Ramp Plaza Capacity (vph)	Bottlenecks Near Bottlenecks Potential Bottlenecks Tues' data rather than Wed Segment not on the Mainline Volume and SF columns Volumes are uncertain Mistake in PBS&J Volume Study 1193 should be at least 1646 Both: March 21,'01, 7-8a.m.
528E-01.0-08#X-3-55-NP-20	6740				Sand Lake Rd. (exit #8)
528E-02.0-#NA#-3-55-NP-20	6740		1096		
528E-03.0-08#N-4-55-NP-20	9045		1721		Boggy Creek Rd. (entrance #8)
528E-04.0-09#X-4-55-NP-20	9045		1721		Tradeport Rd. (exit #9)
528E-05.0-#NA#-3-55-NP-20	6740		1272		
528E-06.0-09#N-3-55-NP-20	6740		1355		Tradeport Rd. (entrance #9)
528E-07.0-#NA#-6-30-PP-20		3723	1355	Airport Plaza (east)	
528E-08.0-11#X-3-55-NP-20	6706		1203		Semoran Blvd. (exit #11)
528E-09.0-11AX-1-30-NP-20	2207		862		Semoran Blvd. (exit #11 to SB)
528E-10.0-11BX-1-30-NP-20	2207		261		Semoran Blvd. (exit #11 to NB)
528E-11.0-#NA#-2-55-NP-20	4420		341		
528E-12.0-11#N-2-55-NP-20	4397		1646		Semoran Blvd. (entrance #11 from SB)
528E-13.0-11AN-2-55-NP-20	4375		1193		Semoran Blvd. (entrance #11 from NB)
528E-14.0-#NA#-2-65-NP-21	4354		1193		
528E-15.0-13#X-2-65-NP-21	4332		1193		Narcoossee Rd. (exit #13)
528E-16.0-#NA#-2-70-NP-21	4311		790		
528E-17.0-13#N-2-70-NP-21	4290		972		Narcoossee Rd. (entrance #13)
528E-18.0-#NA#-2-70-NP-21	4269		972		
528E-19.0-16#X-2-70-NP-06	4248		972		Interchange 417 (exit # 16 to NB & SB)
528E-20.0-16NX-1-45-NP-06	2110		385		Interchange 417 (exit lane to NB)
528E-21.0-16SX-1-45-NP-06	2110		7		Interchange 417 (exit lane to SB)
528E-22.0-16SN-1-45-NP-06	2110		216		Interchange 417 (merge lane to SB)
528E-23.0-#NA#-2-70-NP-06	4228		587		
528E-24.0-16#N-3-70-NP-06	6352		964		Interchange 417(entrance from NB & SB)
528E-24.1-#NA#-3-70-NP-06	6322		964		
528E-25.0-#NA#-4-30-PP-06		2763	964	Bee Line Main Plaza (east)	
528E-26.0-#NA#-2-70-NP-22	4168		840		
528E-27.0-20#X-2-70-NP-22	4168		840		International Corporate Park (exit #20)
528E-28.0-#NA#-2-70-NP-22	4168		755		
528E-29.0-20#N-2-70-PP-22	4168		760	959	Intern'l Corporate Park (entrance #20)

Table 11: Traveling West on the 528, Bee Line Expressway

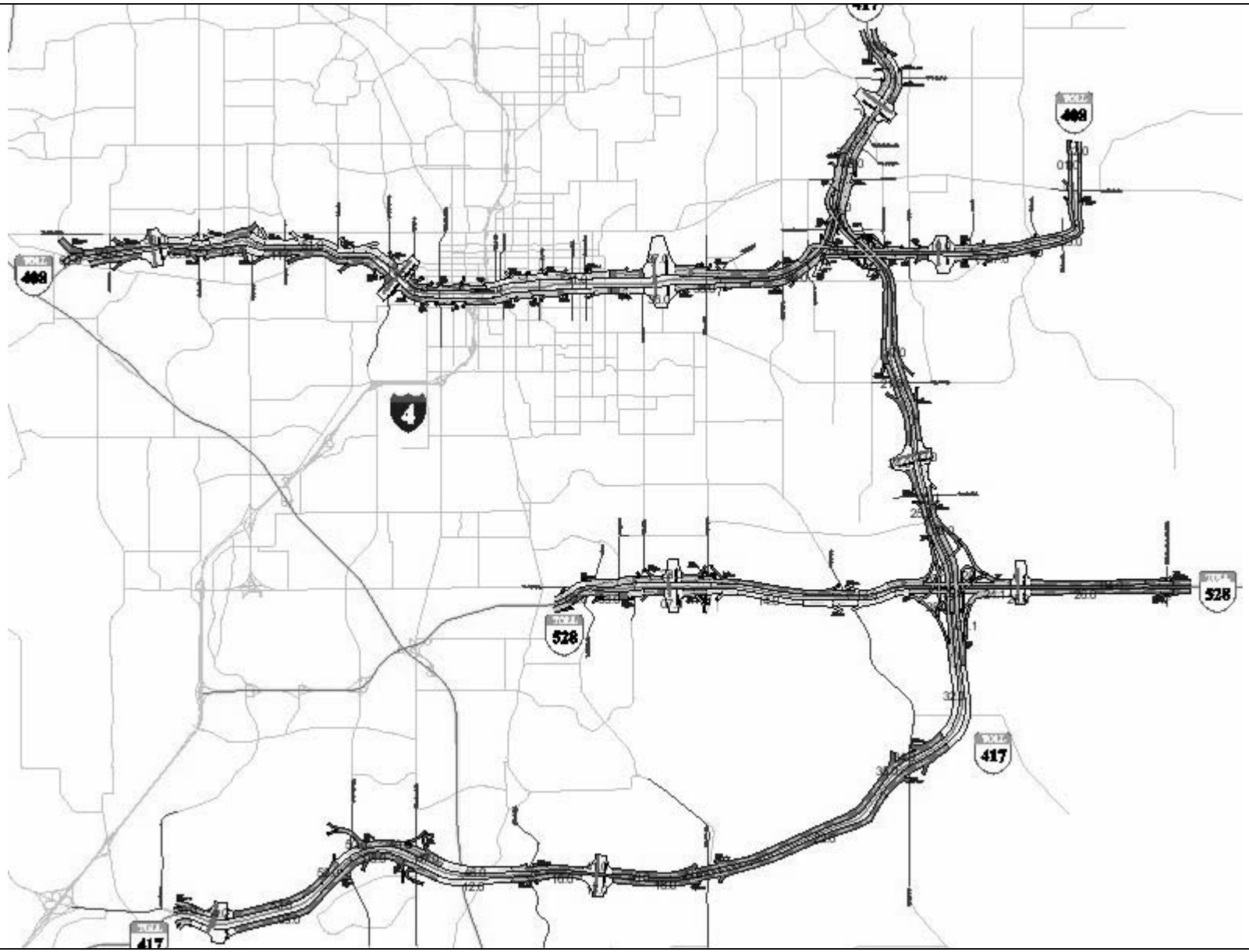
SECTION NAME - highway name & direction - segment number - exit number X, entrance N - no. of lanes in segment - speed limit on segment - plaza PP or no plaza NP - map number on which it is located	SF is the service flow rate during pk 15 min.for LOS E $FFS=FFS_{ideal}-f_{id}-f_n-f_{lc}-f_{lw}$ $f_{id}=5*(ipm)-2.5$ $f_n=7.5-1.5N$ $f_{lc} = f_{lw} = 0.0$ MSF=10*FFS+1700 $SF=N*MSF*f_{HV}*f_p$ $SF=Capacity*f_{HV}*f_p$ $f_p = 1.00$ $f_{HV}=1/(1+P_T(E_T-1.0))$ (vph)	from TNCC Plaza SF (vph)	PBS&J Enterning Volumes (vph) TOTAL	Ramp Plaza Capacity (vph)	
528W-01.0-20#X-2-70-PP-22	4168		1323	788	International Corporate Park (exit #20)
528W-02.0-#NA#-2-70-NP-22	4168		1269		
528W-03.0-20#N-2-70-NP-22	4168		1286		Intern'l Corporate Park (entrance #20)
528W-04.0-#NA#-2-70-NP-22	4168		1286		
528W-05.0-#NA#-4-30-PP-06		2689	1286	Bee Line Main Plaza (west)	
528W-06.0-16#X-3-70-NP-06	6318		1427		Interchange 417 (exit # 16 to NB & SB)
528W-07.0-16SX-1-45-NP-06	2079		209		
528W-08.0-16NX-1-45-NP-06	2079		297		
528W-09.0-#NA#-2-70-NP-06	4203		921		
528W-10.0-16NN-2-70-NP-06	4220		943		Interchange 417 (entrance # 16 from NB)
528W-11.0-16SN-3-70-NP-06	6398		2454		Interchange 417 (entrance # 16 from SB)
528W-12.0-#NA#-3-70-NP-21	6426		2454		
528W-13.0-13#X-2-70-NP-21	4274		2454		Narcoossee Rd. (exit #13)
528W-14.0-#NA#-2-70-NP-21	4293		2138		
528W-15.0-13#N-2-65-NP-21	4311		2632		Narcoossee Rd. (entrance #13)
528W-16.0-#NA#-2-65-NP-21	4330		2632		
528W-17.0-11AX-2-65-NP-20	4348		2632		Semoran Blvd. (exit #11A to NB)
528W-18.0-#NA#-2-65-NP-20	4367		2681		
528W-19.0-11AN-2-65-NP-20	4386		3011		Semoran Blvd. (entrance #11 from NB)
528W-20.0-11BX-2-65-NP-20	4406		3011		Semoran Blvd. (exit #11 to SB)
528W-21.0-#NA#-2-65-NP-20	4425		2489		
528W-22.0-11BN-3-65-NP-20	6710		3115		Semoran Blvd. (entrance #11 from SB)
528W-23.0-#NA#-6-30-PP-20		4123	3115	Airport Plaza (west)	
528W-24.0-09#X-3-55-NP-20	6740		2881		Tradeport Dr./Conway Rd. (exit #9)
528W-25.0-#NA#-3-55-NP-20	6740		2407		
528W-26.0-09#N-4-55-NP-20	9045		3161		Tradep't Dr./Conway Rd. (entrance #9)
528W-27.0-#NA#-4-55-NP-20	9045		3161		
528W-28.0-08#X-4-55-NP-20	9045		3161		Sand Lake Rd. (exit #8)
528W-29.0-#NA#-3-55-NP-20	6740		1905		
528W-30.0-08#N-3-55-NP-20	6740				Sand Lake Rd. (entrance #8)

	Bottlenecks
	Near Bottlenecks
	Potential Bottlenecks
	Tues' data rather than Wed
	Segment not on the Mainline
	Volume and SF columns
	Volumes are uncertain

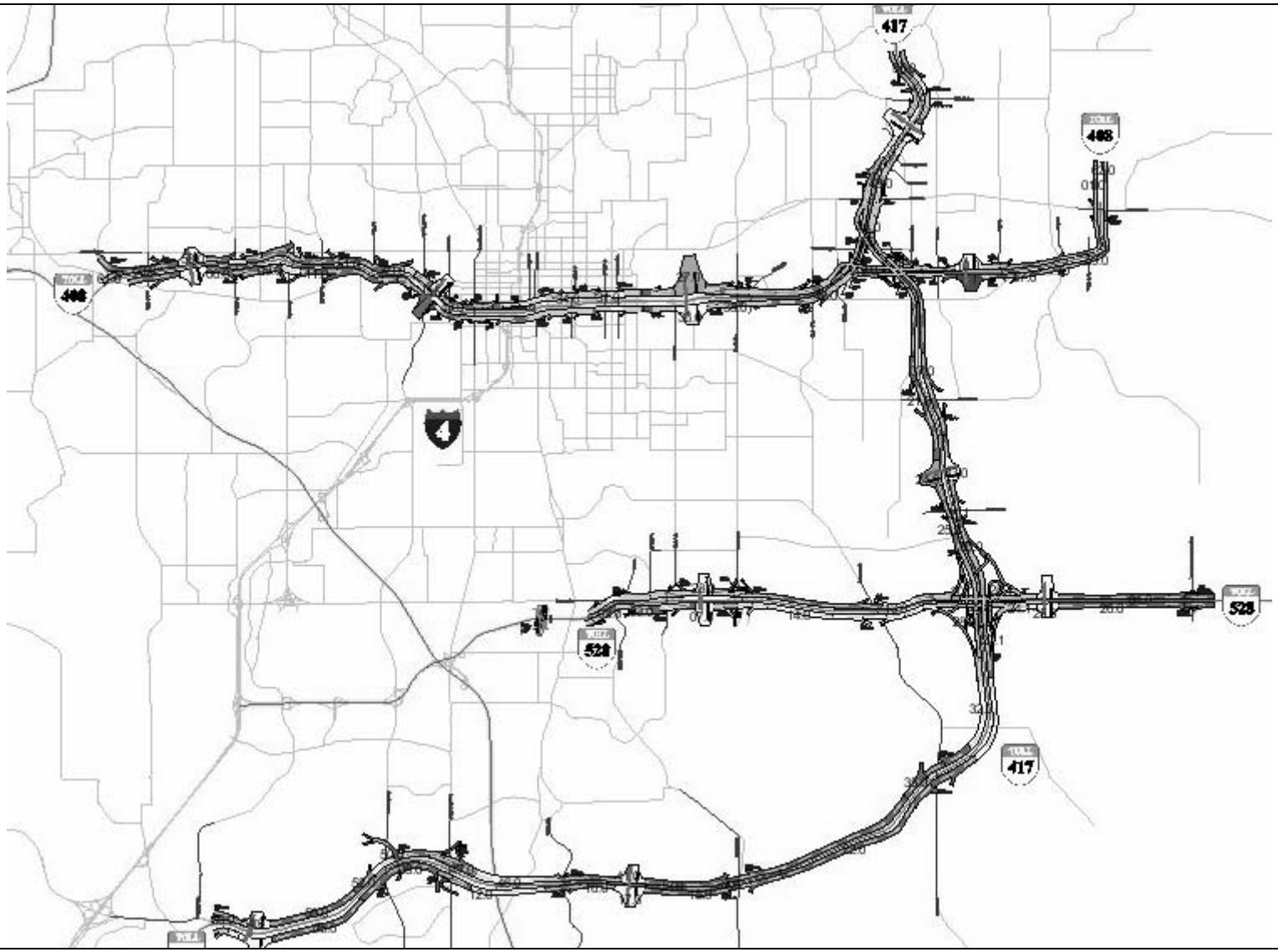
Appendix H: 16 DSS OOCEA Maps & 5 FT Plaza Maps



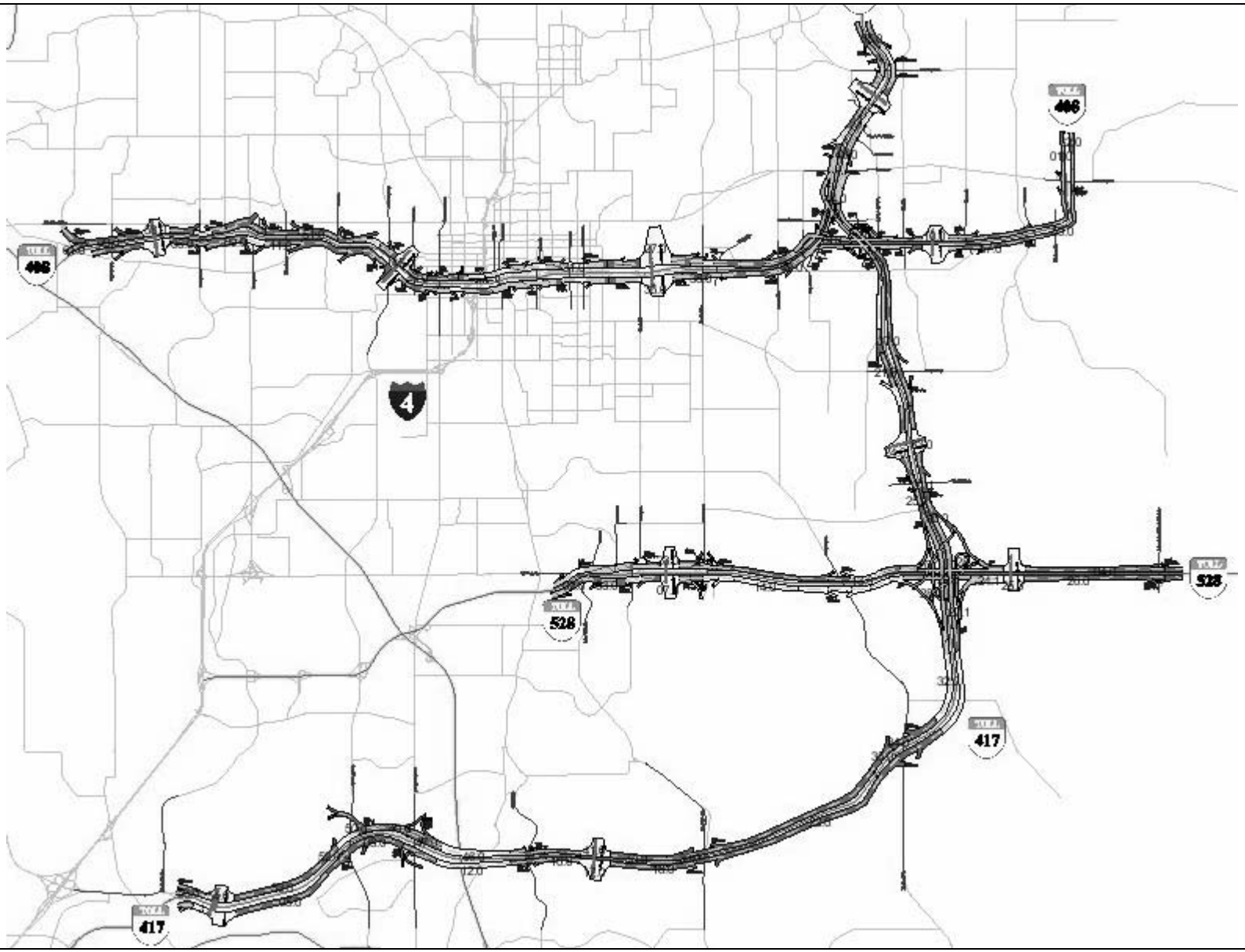
Florida ArcMap with additional layers of the OOCEA's network of toll roads in Orange County and 5 plazas on the Florida Turnpike.



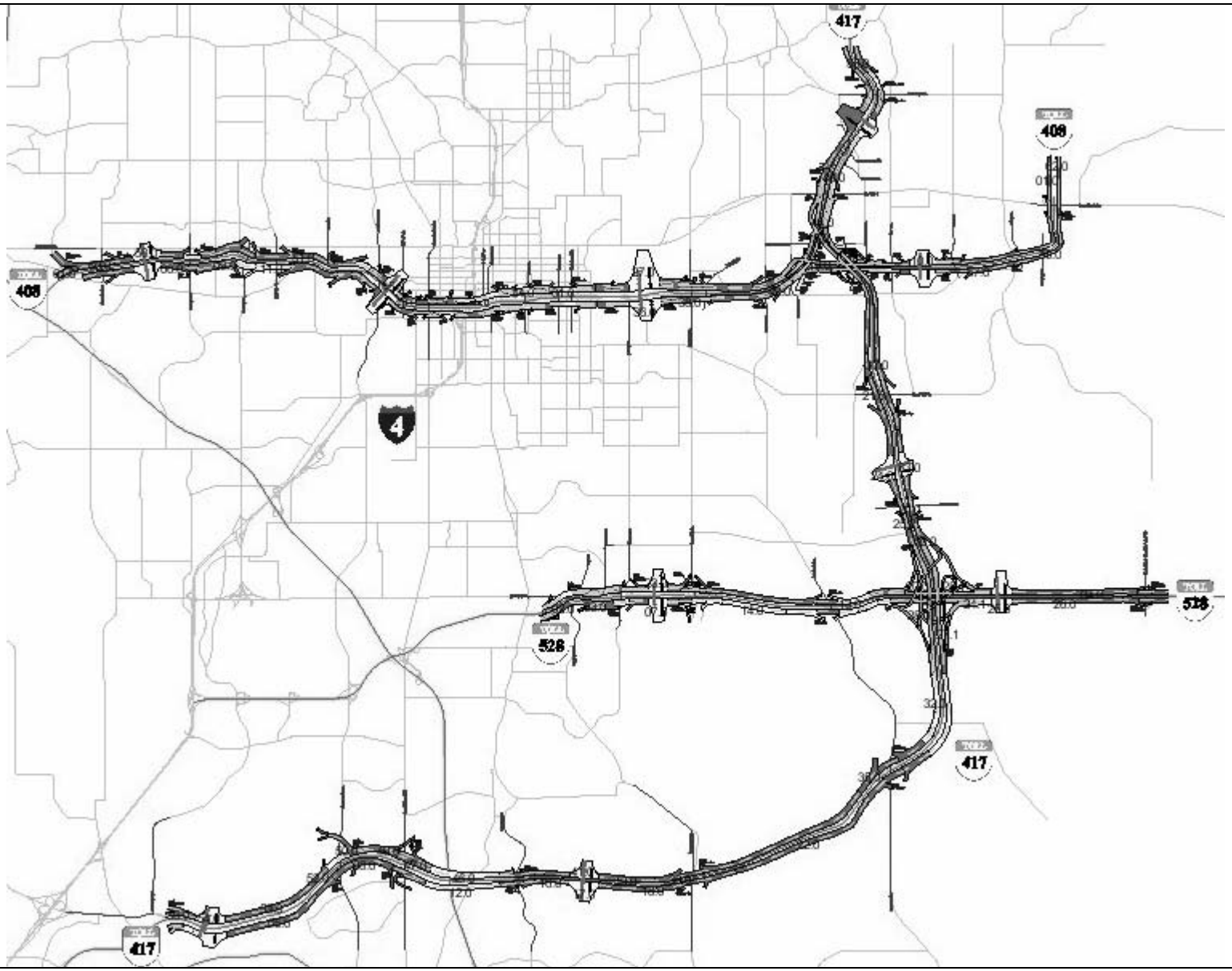
The OOCEA's network of toll roads at 5:00 – 6:00 a.m. on November 5, 2002.



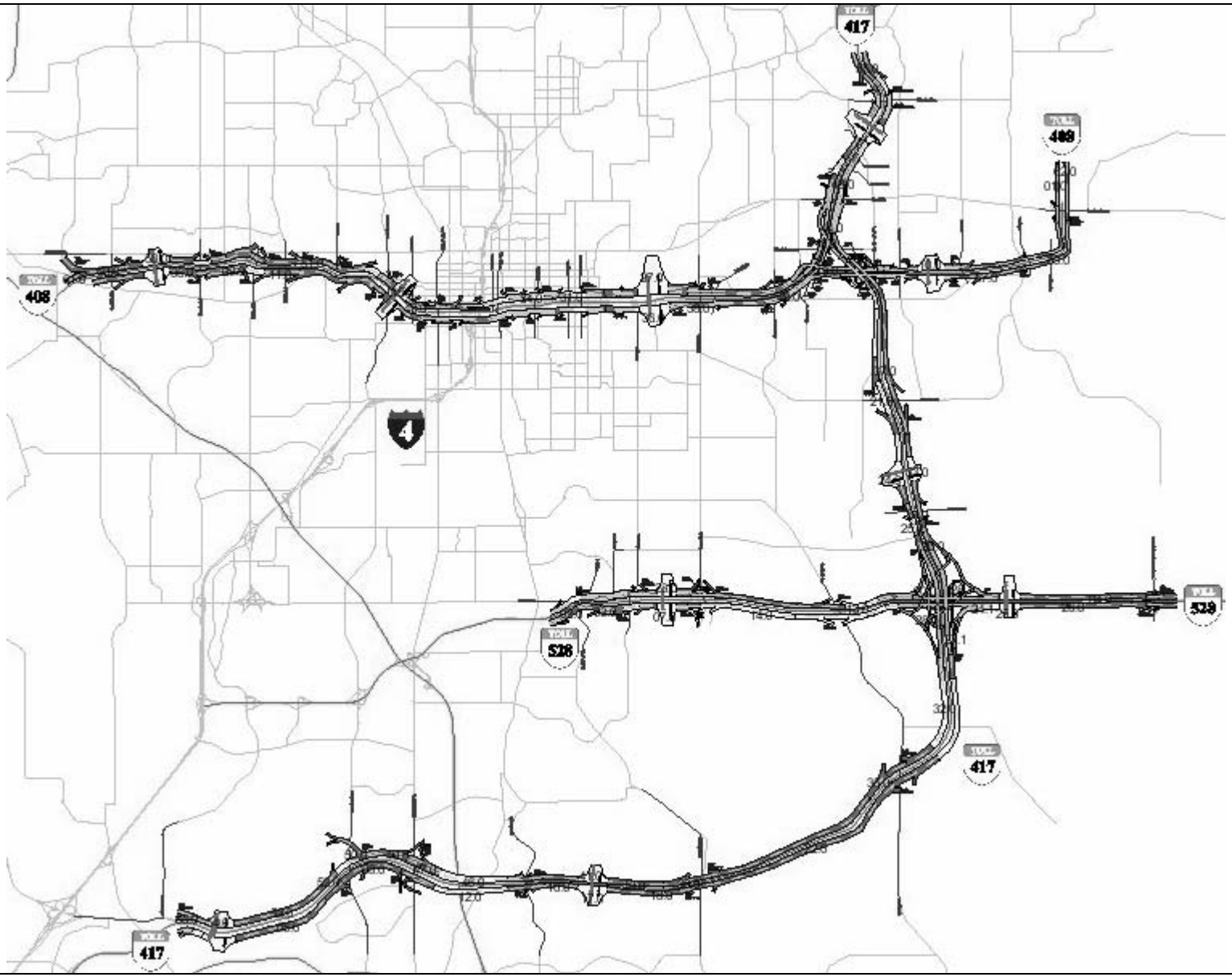
The OOCEA's network of toll roads at 7:00 – 8:00 a.m. on November 5, 2002.



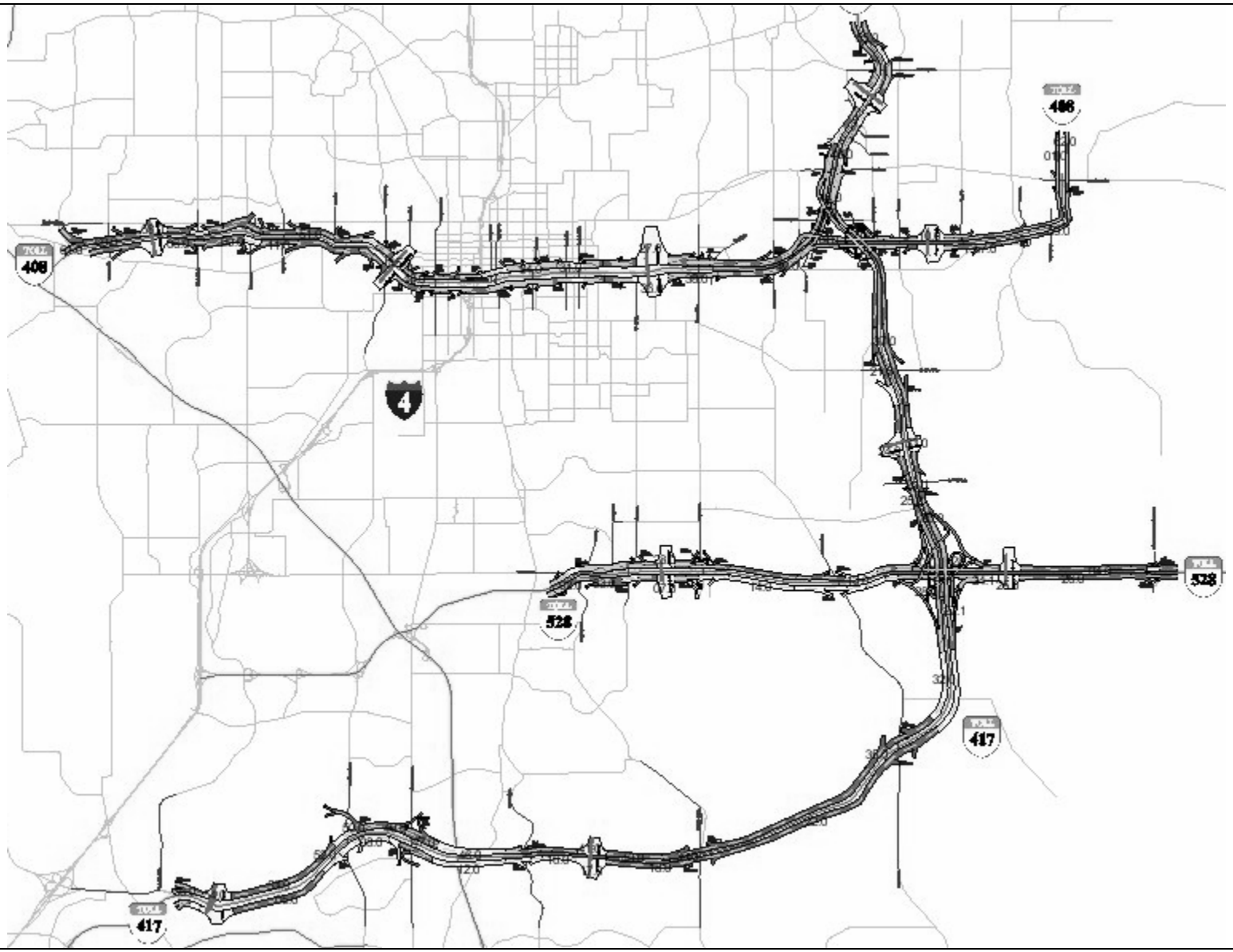
The OOCEA's network of toll roads at 9:00 – 10:00 a.m. on November 5, 2002.



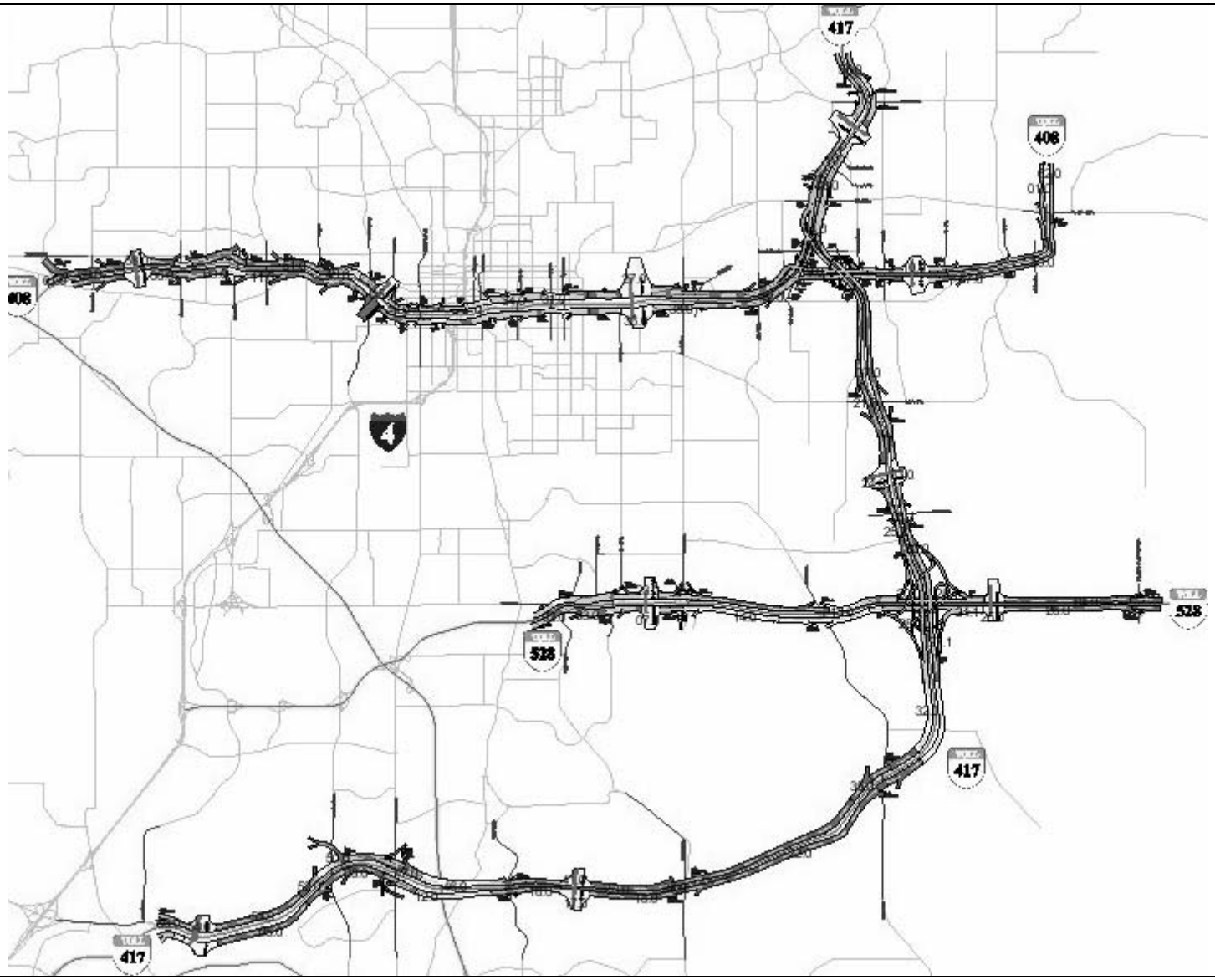
The OOCEA's network of toll roads at 10:00 – 11:00 a.m. on November 5, 2002.



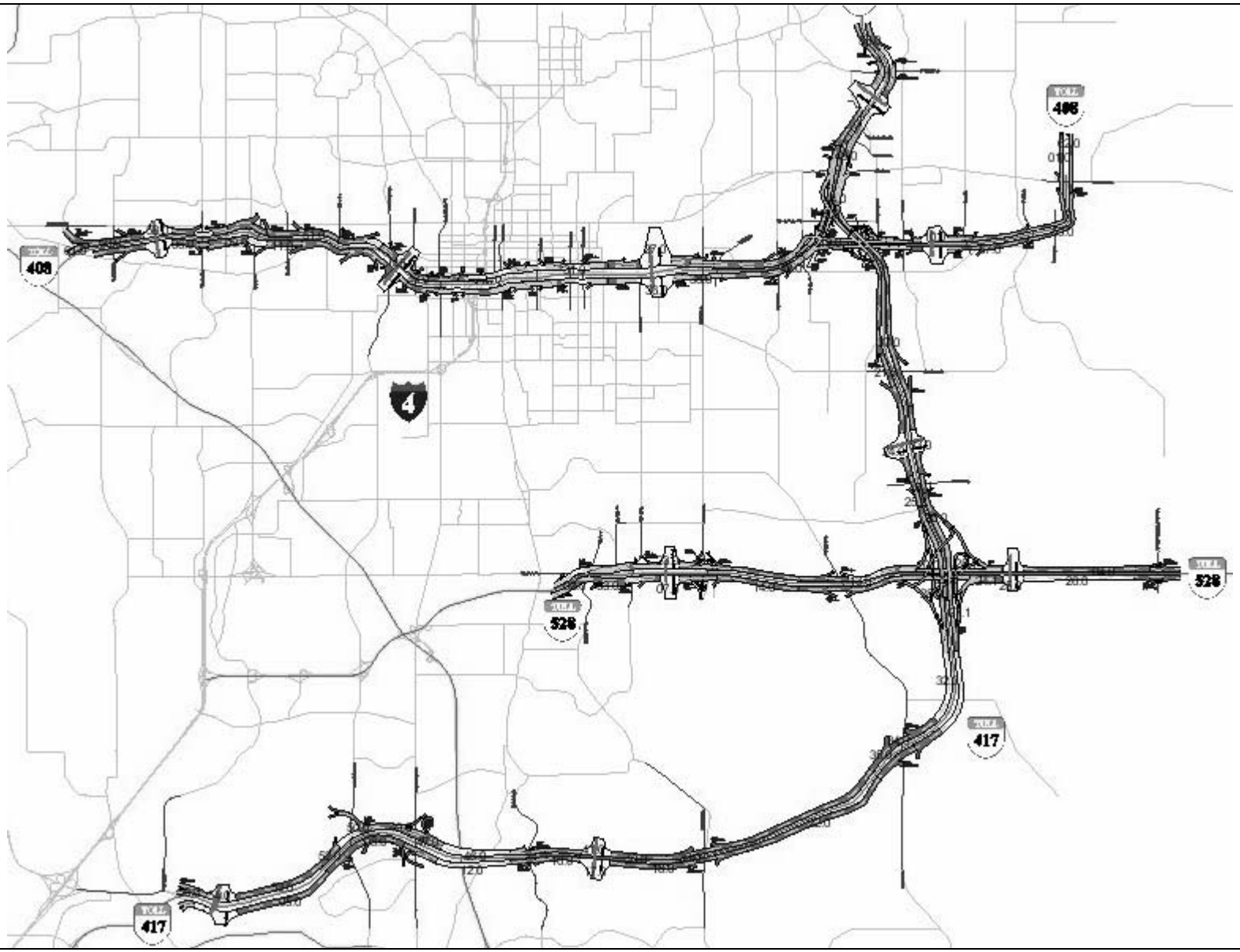
The OOCEA's network of toll roads at 11:00 – 12:00 p.m. on November 5, 2002.



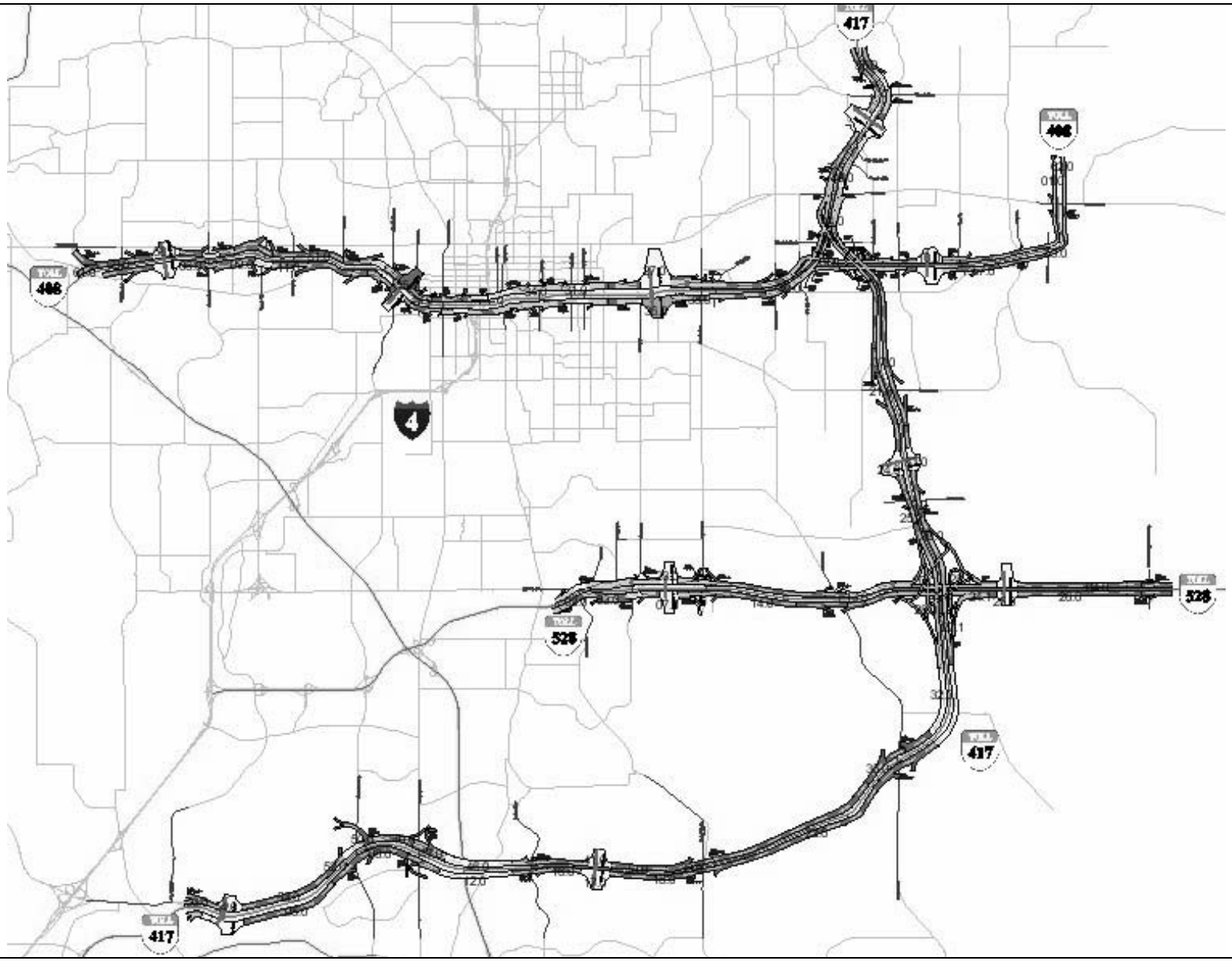
The OOCEA's network of toll roads at 12:00 – 1:00 p.m. on November 5, 2002.



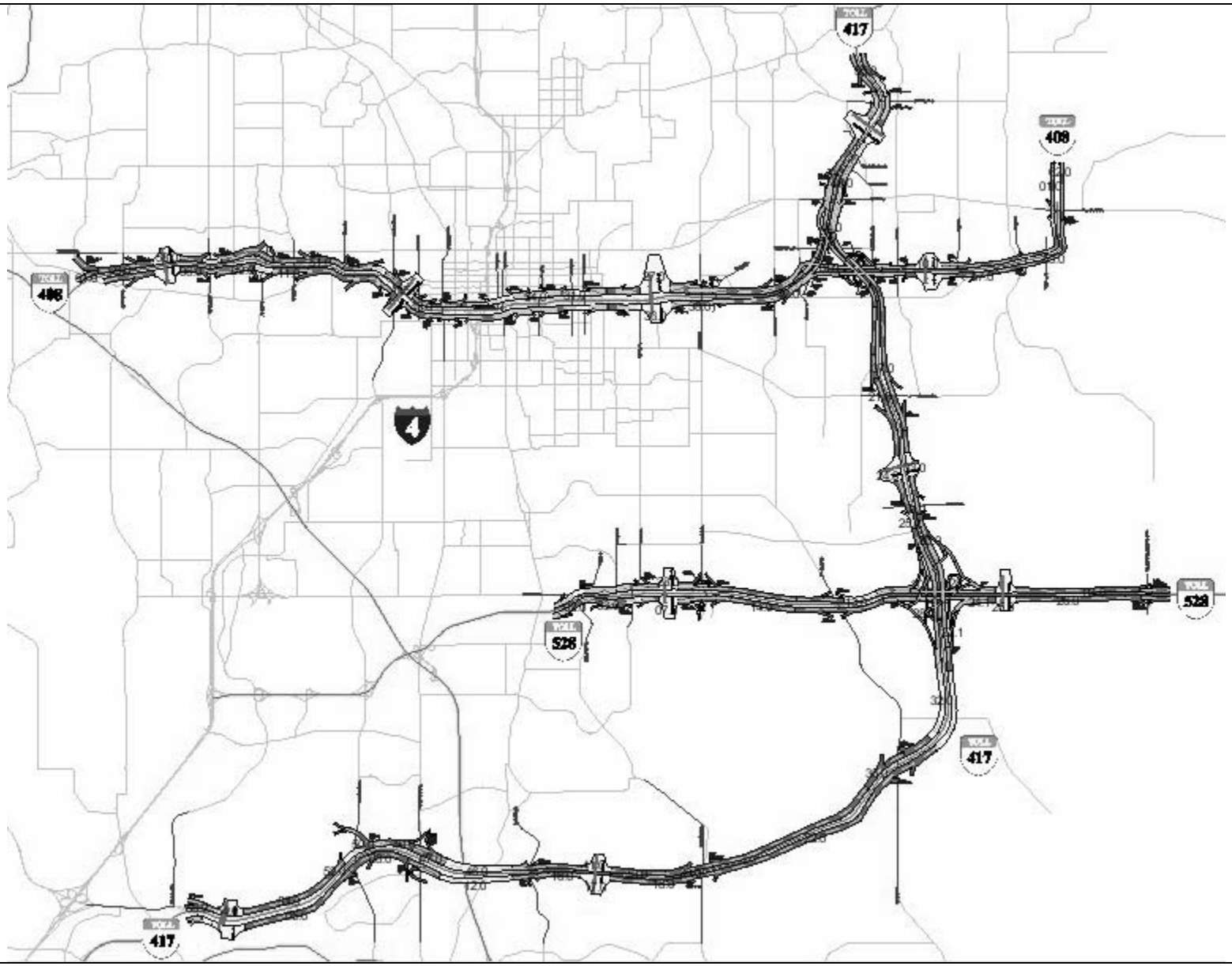
The OOCEA's network of toll roads at 1:00 – 2:00 p.m. on November 5, 2002.



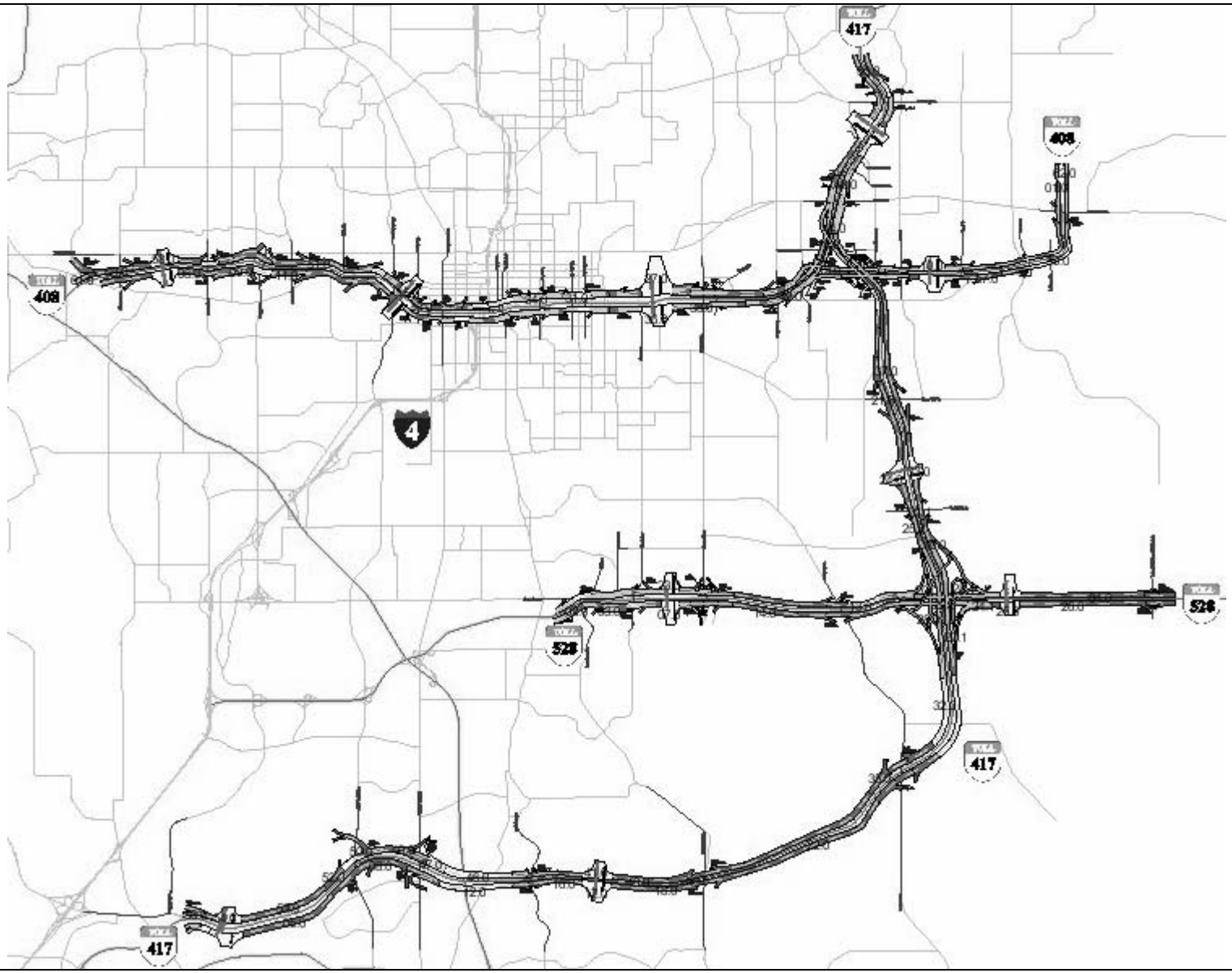
The OOCEA's network of toll roads at 4:00 – 5:00 p.m. on November 5, 2002.



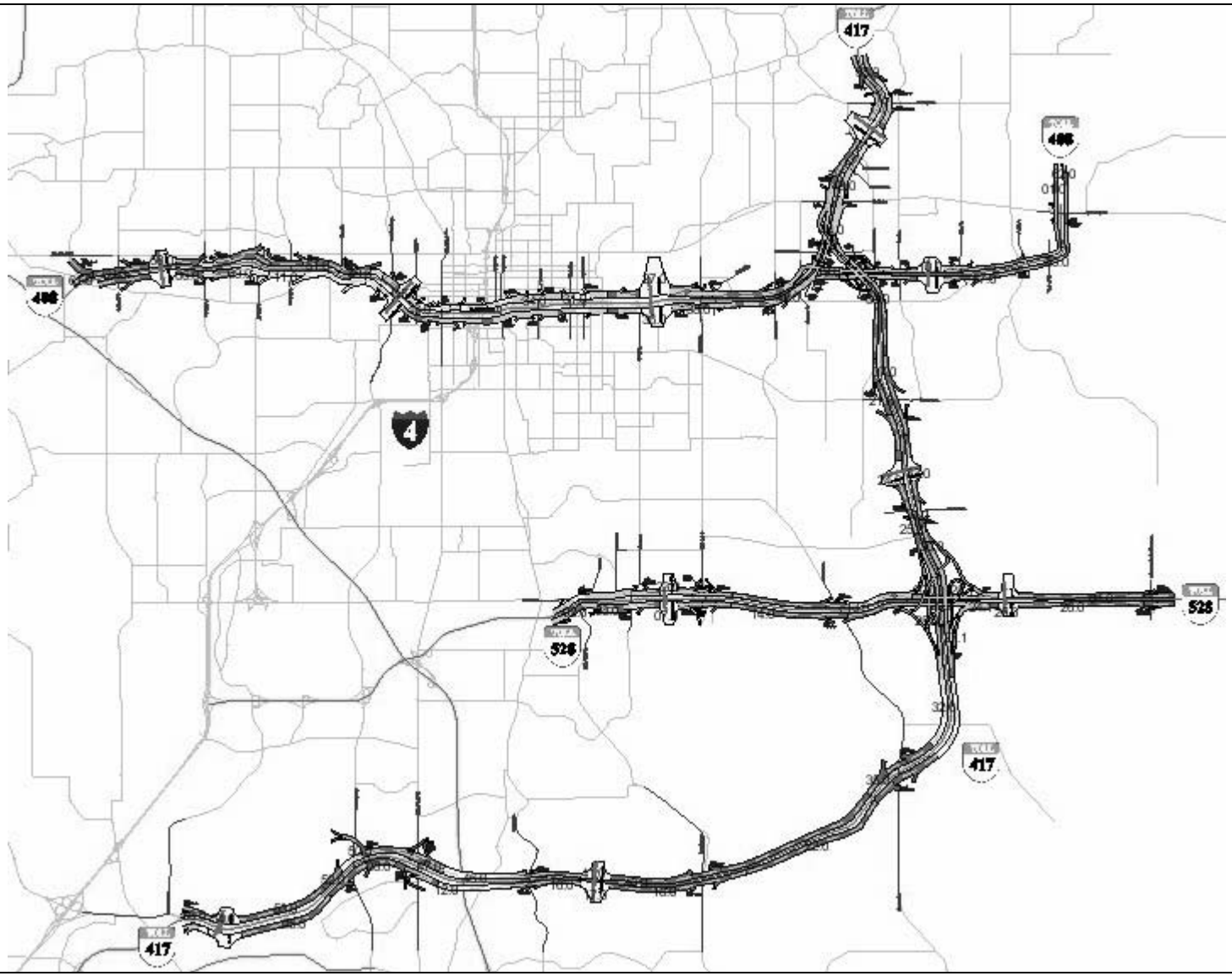
The OOCEA's network of toll roads at 5:00 – 6:00 p.m. on November 5, 2002.



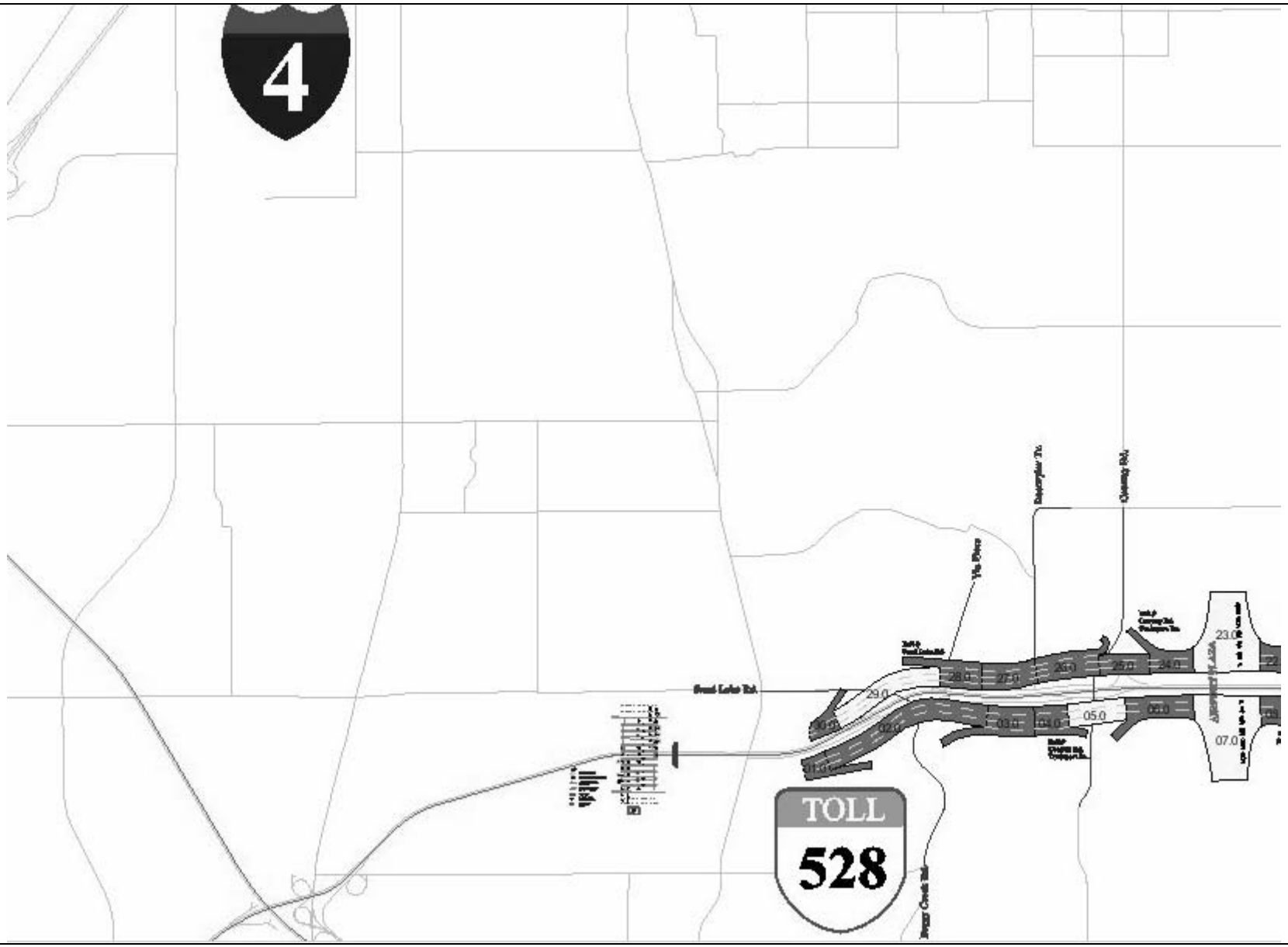
The OOCEA's network of toll roads at 6:00 – 7:00 p.m. on November 5, 2002.



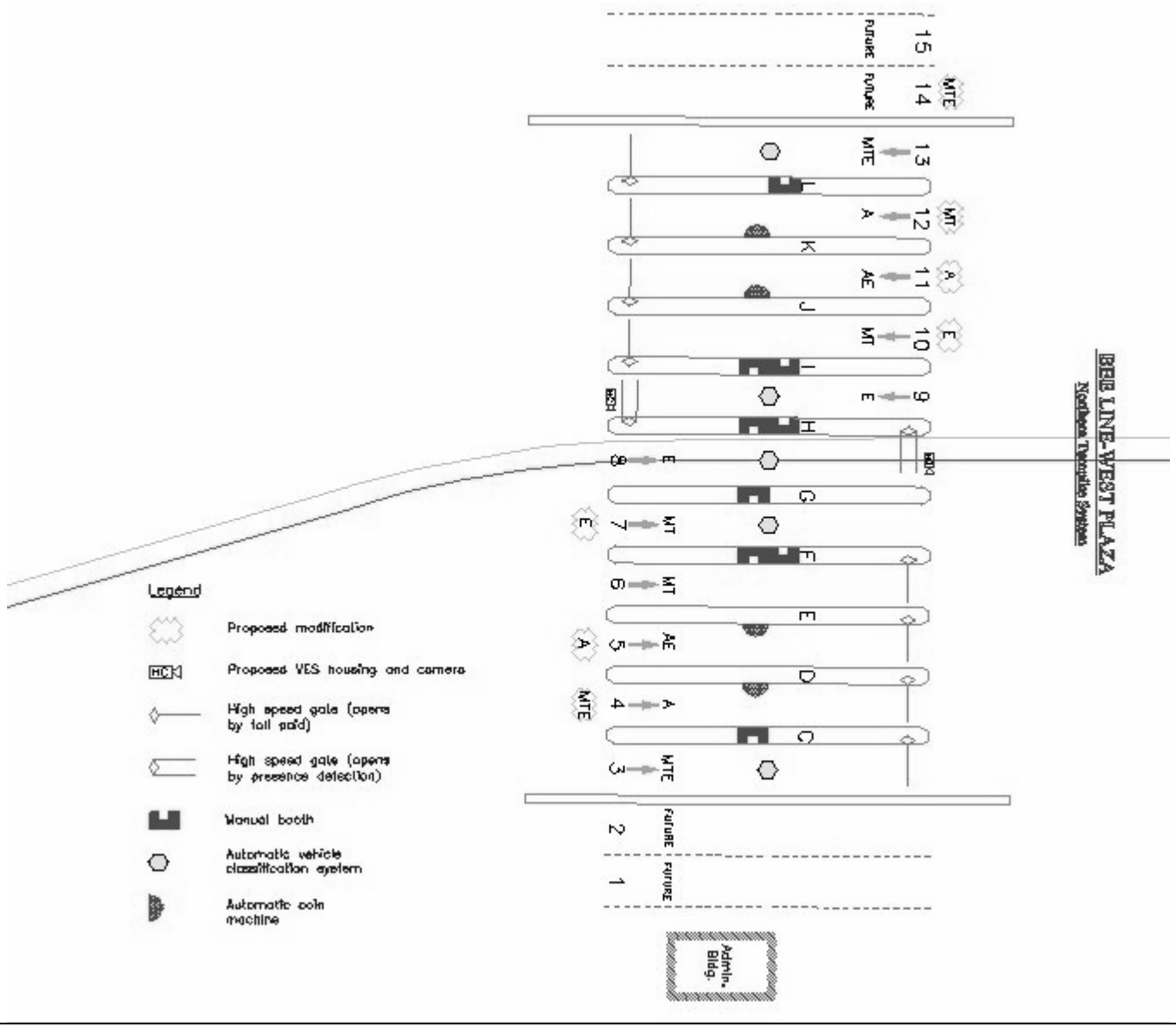
The OOCEA's network of toll roads at 7:00 – 8:00 p.m. on November 5, 2002.



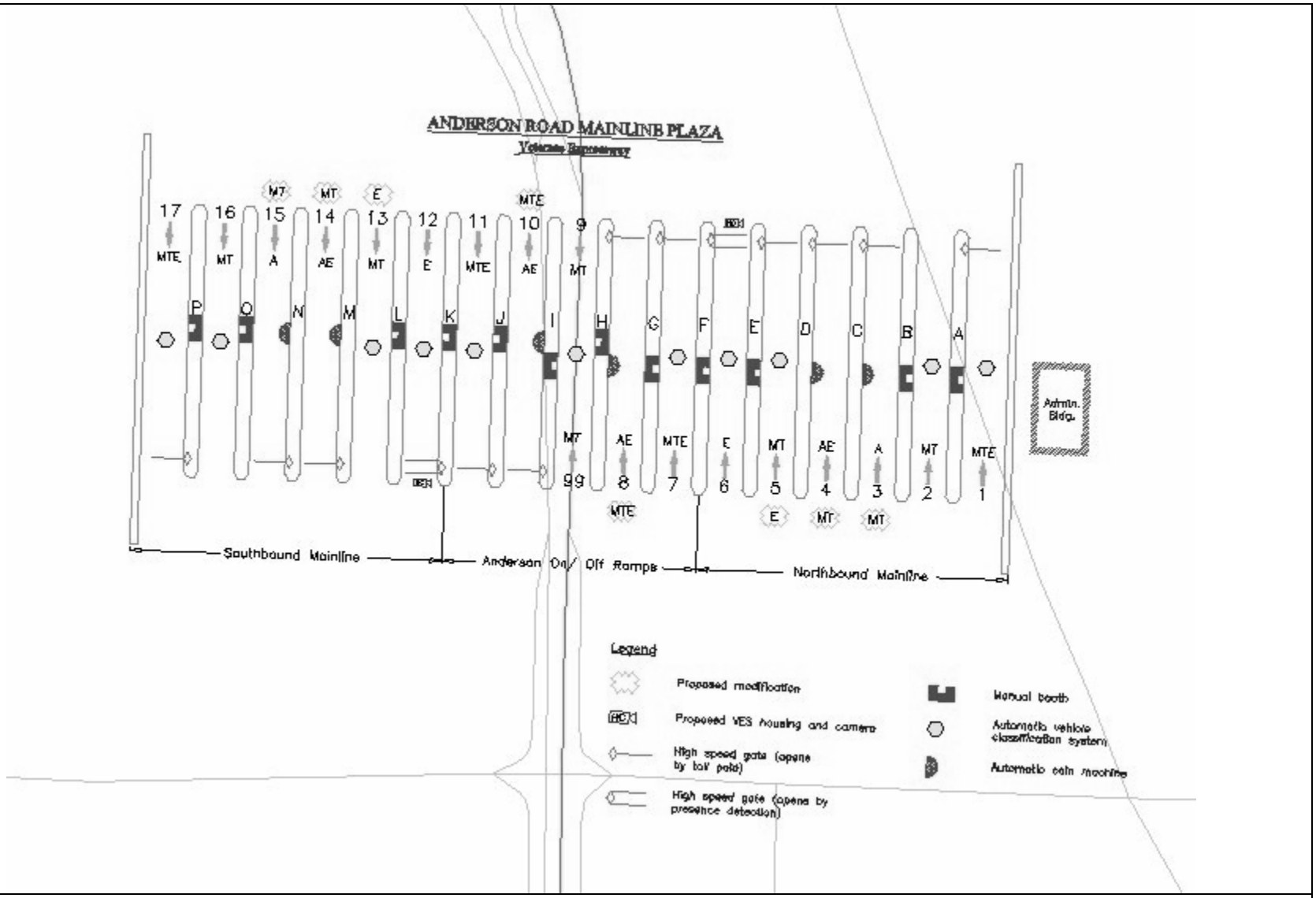
The OOCEA's network of toll roads at 8:00 – 9:00 p.m. on November 5, 2002.



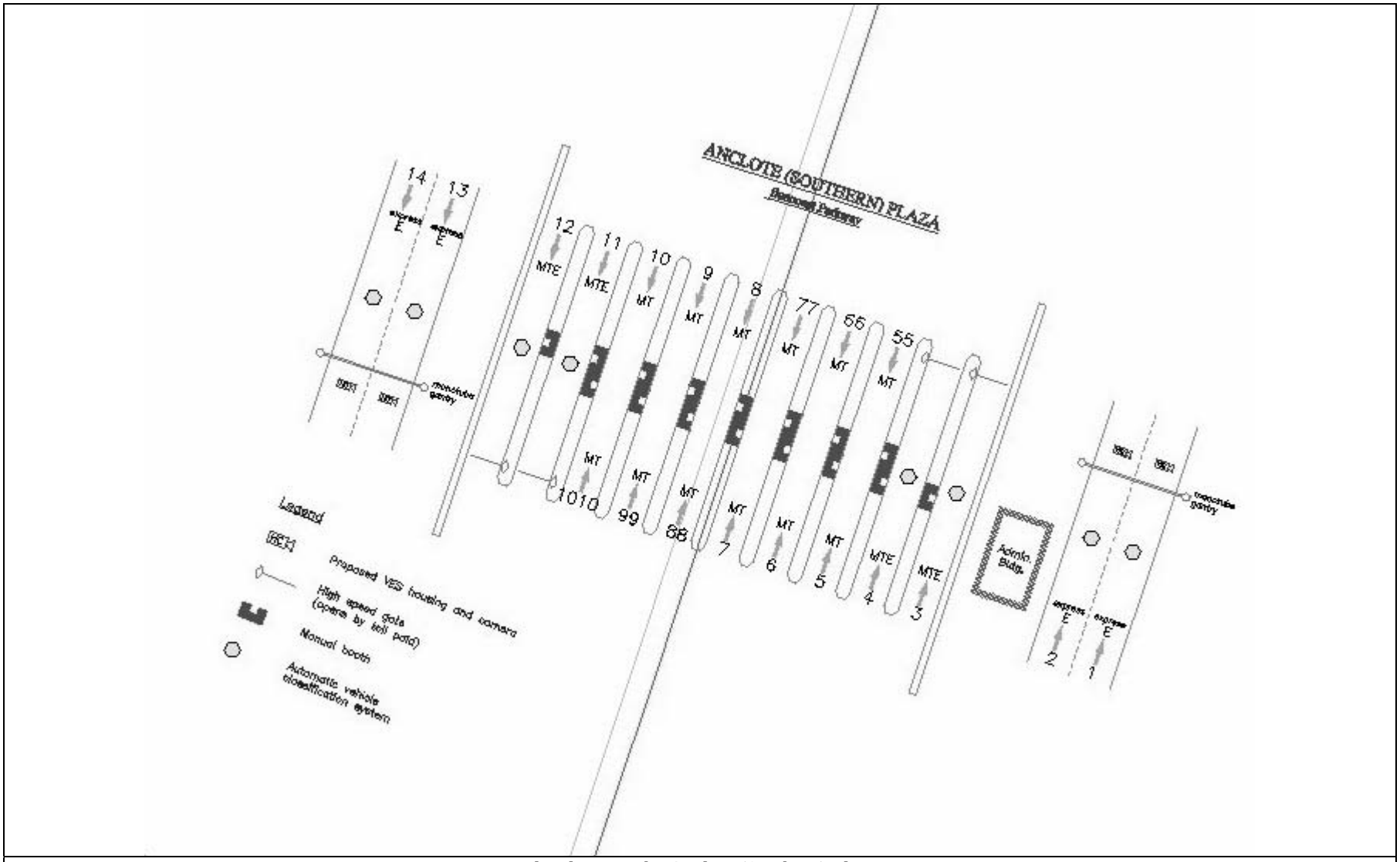
Florida Turnpike Bee Line West – Mainline



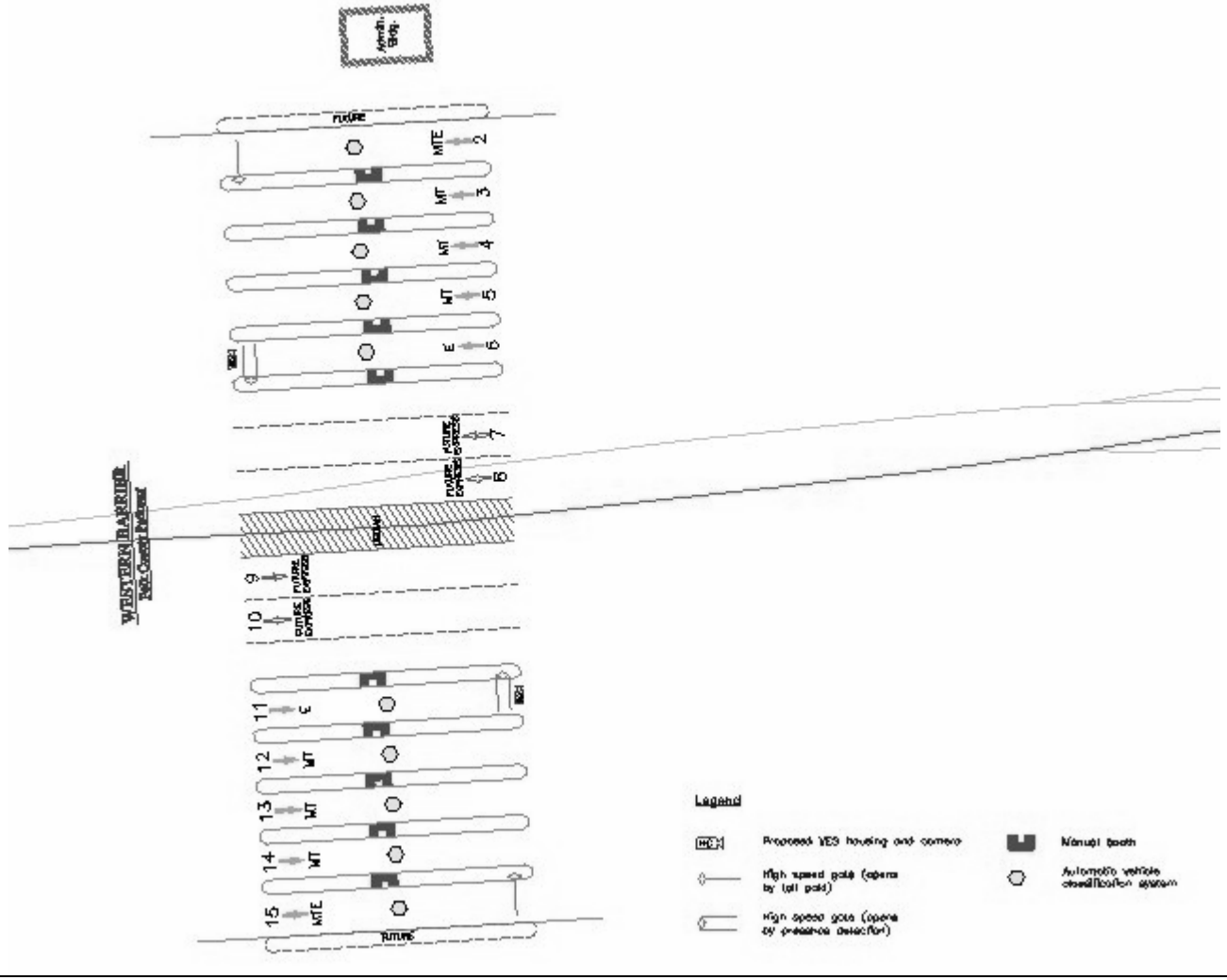
Florida Turnpike Bee Line West – Mainline



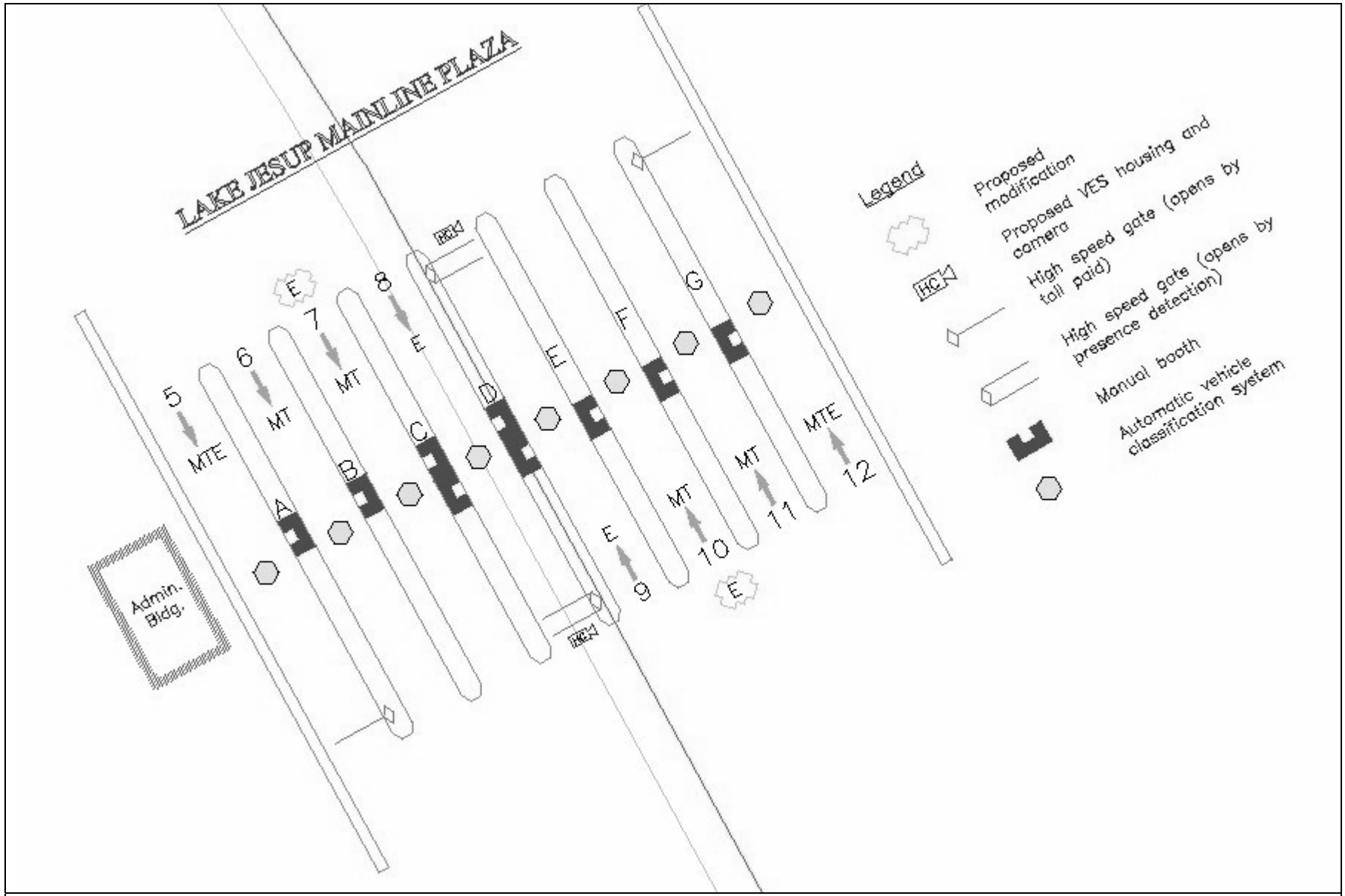
Florida Turnpike Anderson Road Mainline Plaza



Florida Turnpike Anclote (Southern) Plaza

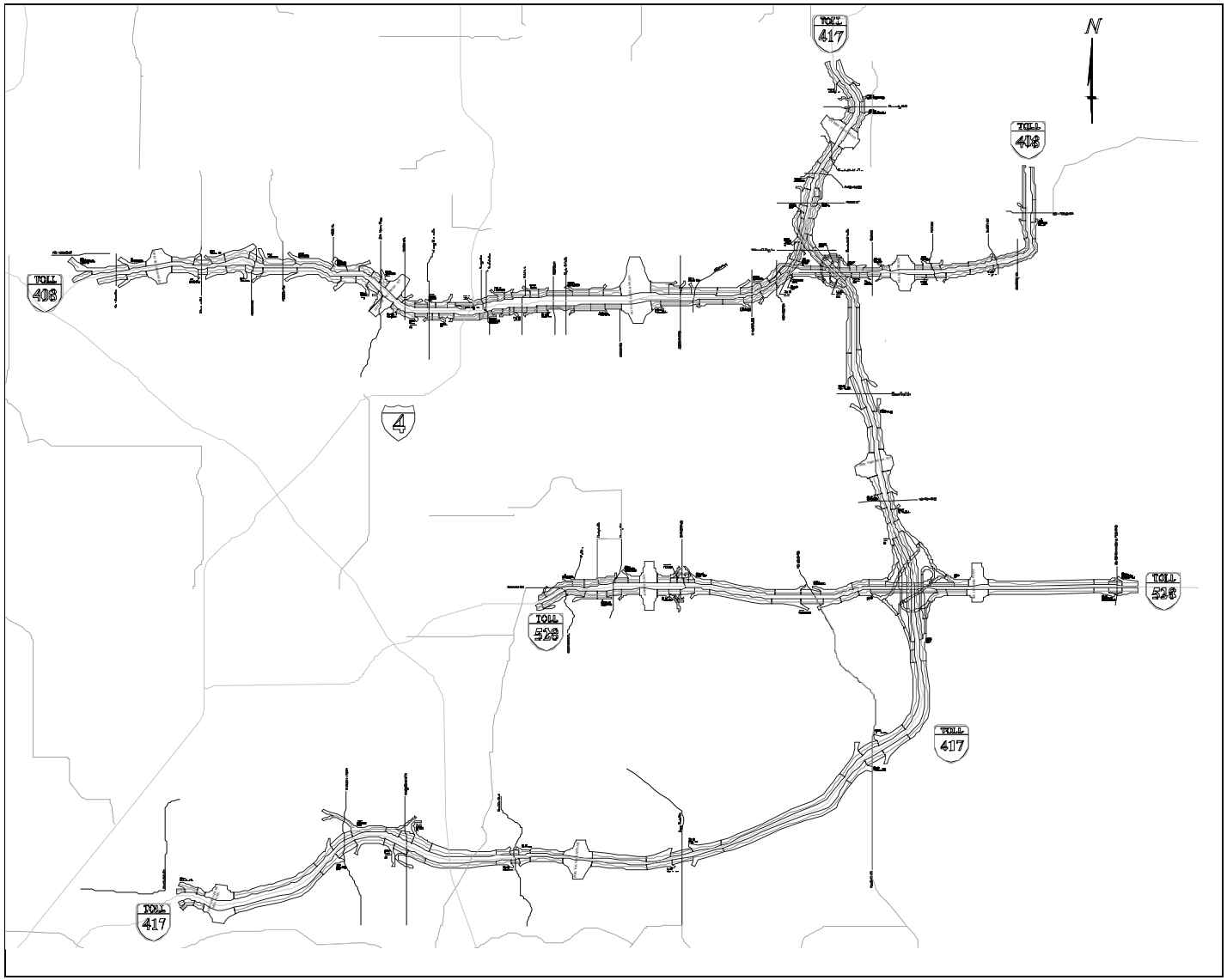


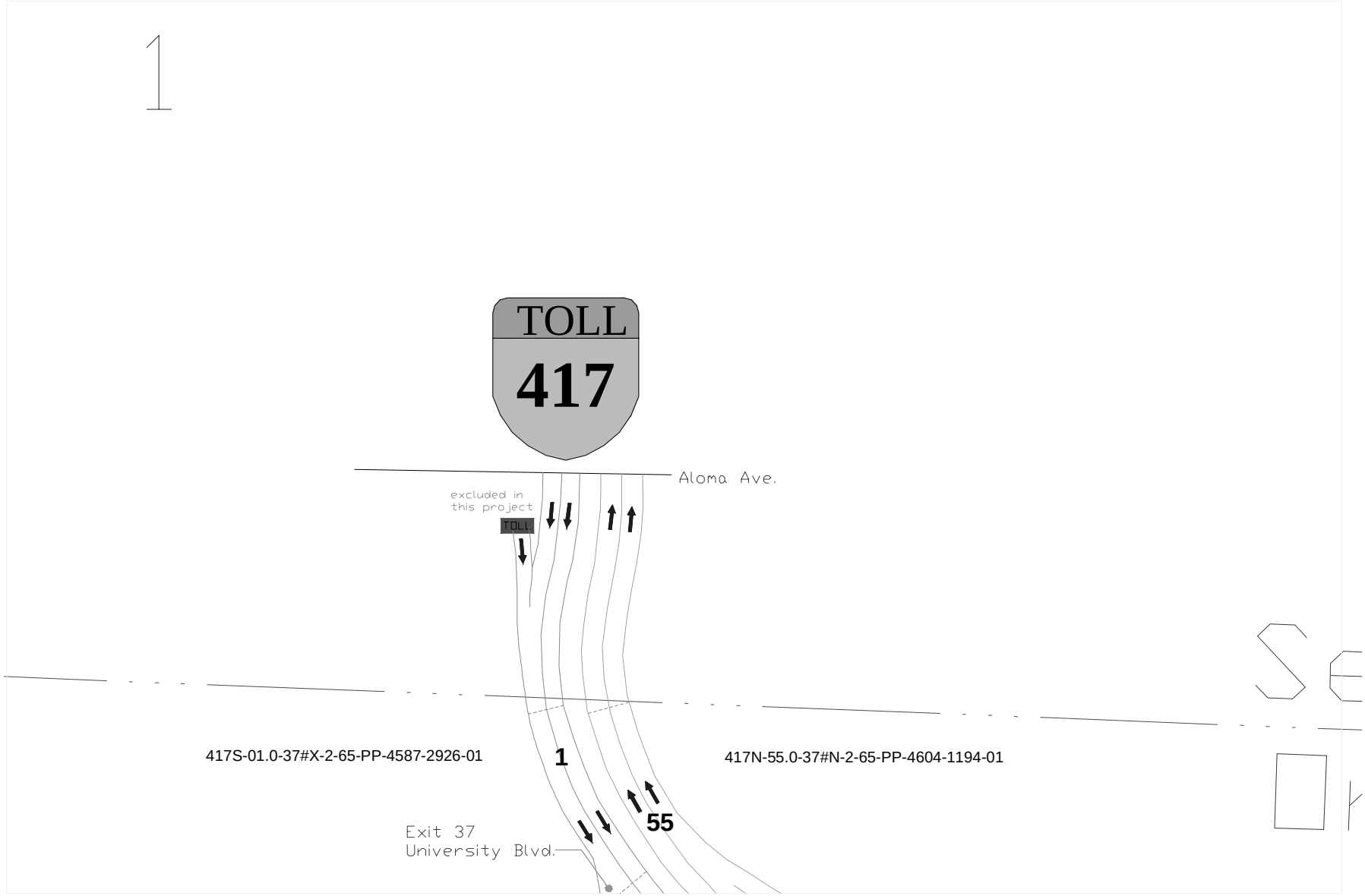
Florida Turnpike Western Barrier Polk Parkway

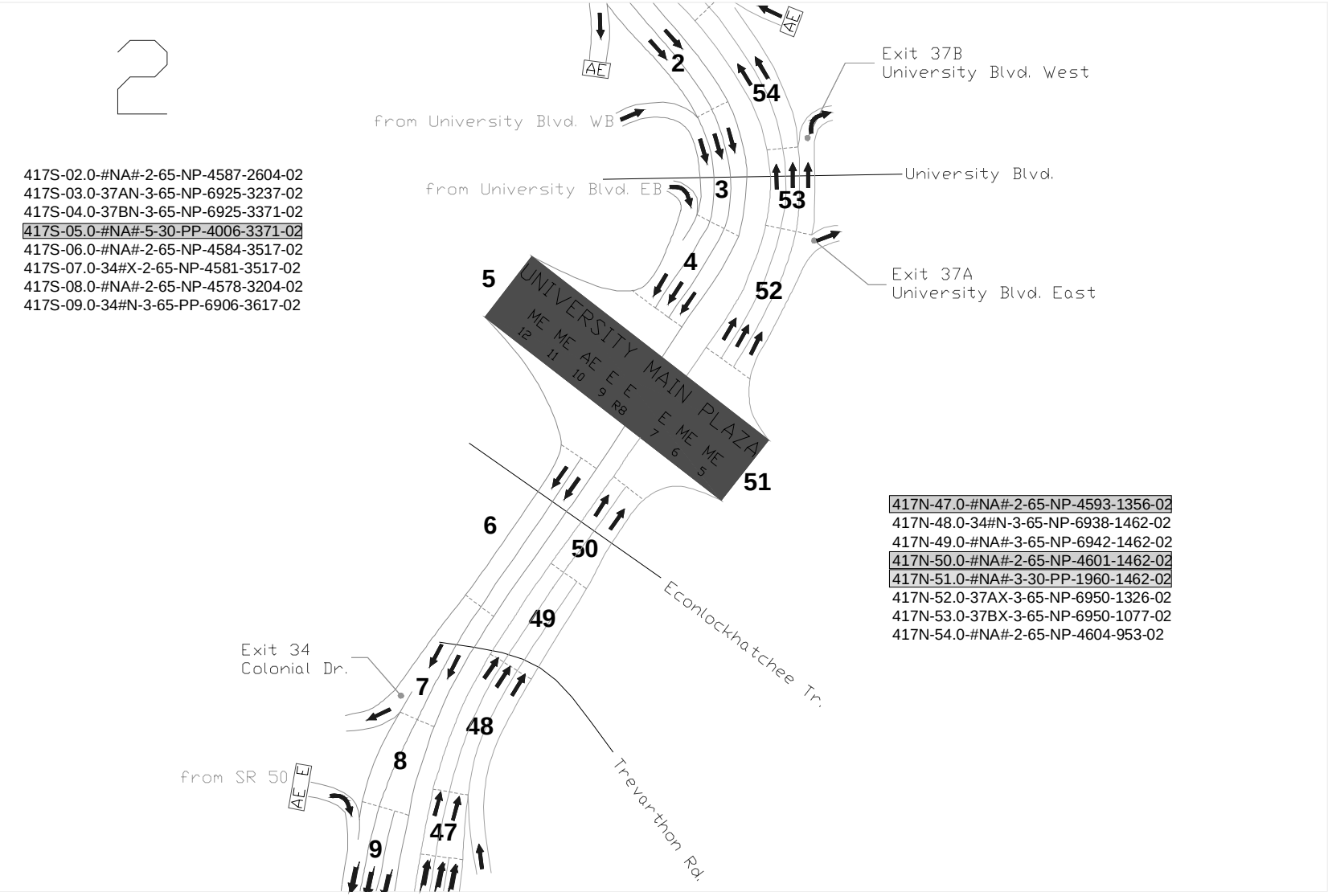


Florida Turnpike Lake Jesup Mainline Plaza

Appendix I: Original AutoCAD Maps




TOLL
417
Aloma Ave.
excluded in
this project
TOLL
417S-01.0-37#X-2-65-PP-4587-2926-01
1
417N-55.0-37#N-2-65-PP-4604-1194-01
55
Exit 37
University Blvd.



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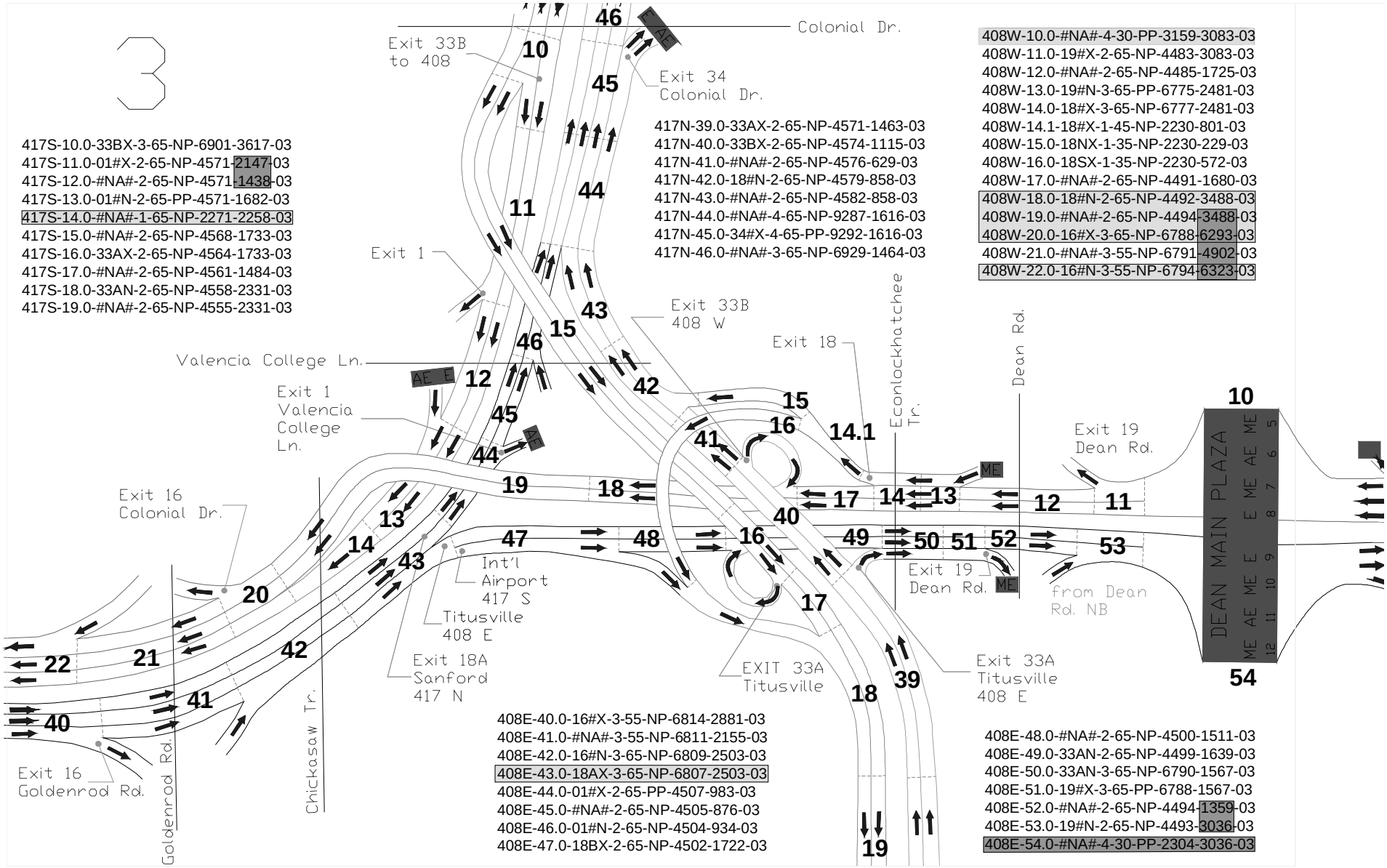
417S-04.0-37BN-3-65-NP-6925-3371-02
417S-05.0-#NA#-5-30-PP-4006-3371-02
417S-06.0-#NA#-2-65-NP-4584-3517-02
417S-07.0-34#X-2-65-NP-4581-3517-02
417S-08.0-#NA#-2-65-NP-4578-3204-02
417S-09.0-34#N-3-65-PP-6906-3617-02

417N-47.0-#NA#-2-65-NP-4593-1356-02
417N-48.0-34#N-3-65-NP-6938-1462-02
417N-49.0-#NA#-3-65-NP-6942-1462-02
417N-50.0-#NA#-2-65-NP-4601-1462-02
417N-51.0-#NA#-3-30-PP-1960-1462-02
417N-52.0-37AX-3-65-NP-6950-1326-02
417N-53.0-37BX-3-65-NP-6950-1077-02
417N-54.0-#NA#-2-65-NP-4604-953-02


3
Colonial Dr.
Exit 33B to 408
Exit 34 Colonial Dr.
Exit 1
Exit 33B 408 W
Valencia College Ln.
Exit 1 Valencia College Ln.
Exit 18
Econlockhatchee Tr.
Dean Rd.
Exit 19 Dean Rd.
Exit 16 Colonial Dr.
Int'l Airport 417 S
Titusville 408 E
Exit 18A Sanford 417 N
EXIT 33A Titusville
Exit 33A Titusville 408 E
Exit 19 Dean Rd.
from Dean Rd. NB
DEAN MAIN PLAZA
Exit 16 Goldenrod Rd.
Goldenrod Rd.
Chickasaw Tr.
417S-10.0-33BX-3-65-NP-6901-3617-03
417S-11.0-01#X-2-65-NP-4571-2147-03
417S-12.0-#NA#-2-65-NP-4571-1438-03
417S-13.0-01#N-2-65-PP-4571-1682-03
417S-14.0-#NA#-1-65-NP-2271-2258-03
417S-15.0-#NA#-2-65-NP-4568-1733-03
417S-16.0-33AX-2-65-NP-4564-1733-03
417S-17.0-#NA#-2-65-NP-4561-1484-03
417S-18.0-33AN-2-65-NP-4558-2331-03
417S-19.0-#NA#-2-65-NP-4555-2331-03
417N-39.0-33AX-2-65-NP-4571-1463-03
417N-40.0-33BX-2-65-NP-4574-1115-03
417N-41.0-#NA#-2-65-NP-4576-629-03
417N-42.0-18#N-2-65-NP-4579-858-03
417N-43.0-#NA#-2-65-NP-4582-858-03
417N-44.0-#NA#-4-65-NP-9287-1616-03
417N-45.0-34#X-4-65-PP-9292-1616-03
417N-46.0-#NA#-3-65-NP-6929-1464-03
408W-10.0-#NA#-4-30-PP-3159-3083-03
408W-11.0-19#X-2-65-NP-4483-3083-03
408W-12.0-#NA#-2-65-NP-4485-1725-03
408W-13.0-19#N-3-65-PP-6775-2481-03
408W-14.0-18#X-3-65-NP-6777-2481-03
408W-14.1-18#X-1-45-NP-2230-801-03
408W-15.0-18NX-1-35-NP-2230-229-03
408W-16.0-18SX-1-35-NP-2230-572-03
408W-17.0-#NA#-2-65-NP-4491-1680-03
408W-18.0-18#N-2-65-NP-4492-3488-03
408W-19.0-#NA#-2-65-NP-4494-3488-03
408W-20.0-16#X-3-65-NP-6788-6293-03
408W-21.0-#NA#-3-55-NP-6791-4902-03
408W-22.0-16#N-3-55-NP-6794-6323-03
408E-40.0-16#X-3-55-NP-6814-2881-03
408E-41.0-#NA#-3-55-NP-6811-2155-03
408E-42.0-16#N-3-65-NP-6809-2503-03
408E-43.0-18AX-3-65-NP-6807-2503-03
408E-44.0-01#X-2-65-PP-4507-983-03
408E-45.0-#NA#-2-65-NP-4505-876-03
408E-46.0-01#N-2-65-NP-4504-934-03
408E-47.0-18BX-2-65-NP-4502-1722-03
408E-48.0-#NA#-2-65-NP-4500-1511-03
408E-49.0-33AN-2-65-NP-4499-1639-03
408E-50.0-33AN-3-65-NP-6790-1567-03
408E-51.0-19#X-3-65-PP-6788-1567-03
408E-52.0-#NA#-2-65-NP-4494-1359-03
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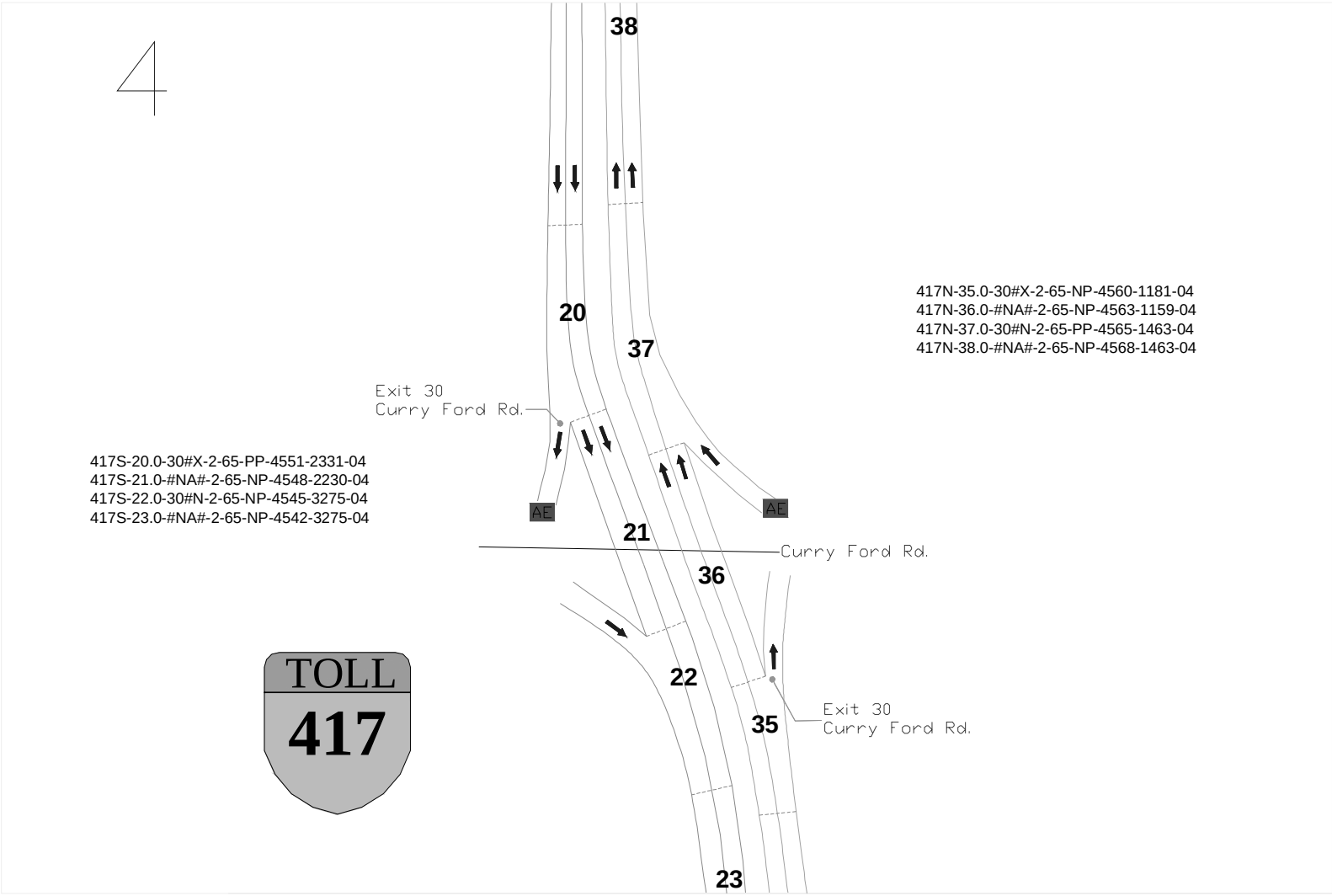
408E-54.0-#NA#-4-30-PP-2304-3036-03


4
38
20
37
Exit 30
Curry Ford Rd.
417S-20.0-30#X-2-65-PP-4551-2331-04
417S-21.0-#NA#-2-65-NP-4548-2230-04
417S-22.0-30#N-2-65-NP-4545-3275-04
417S-23.0-#NA#-2-65-NP-4542-3275-04
AE
AE
21
Curry Ford Rd.
36
22
35
Exit 30
Curry Ford Rd.
23
TOLL
417
417N-35.0-30#X-2-65-NP-4560-1181-04
417N-36.0-#NA#-2-65-NP-4563-1159-04
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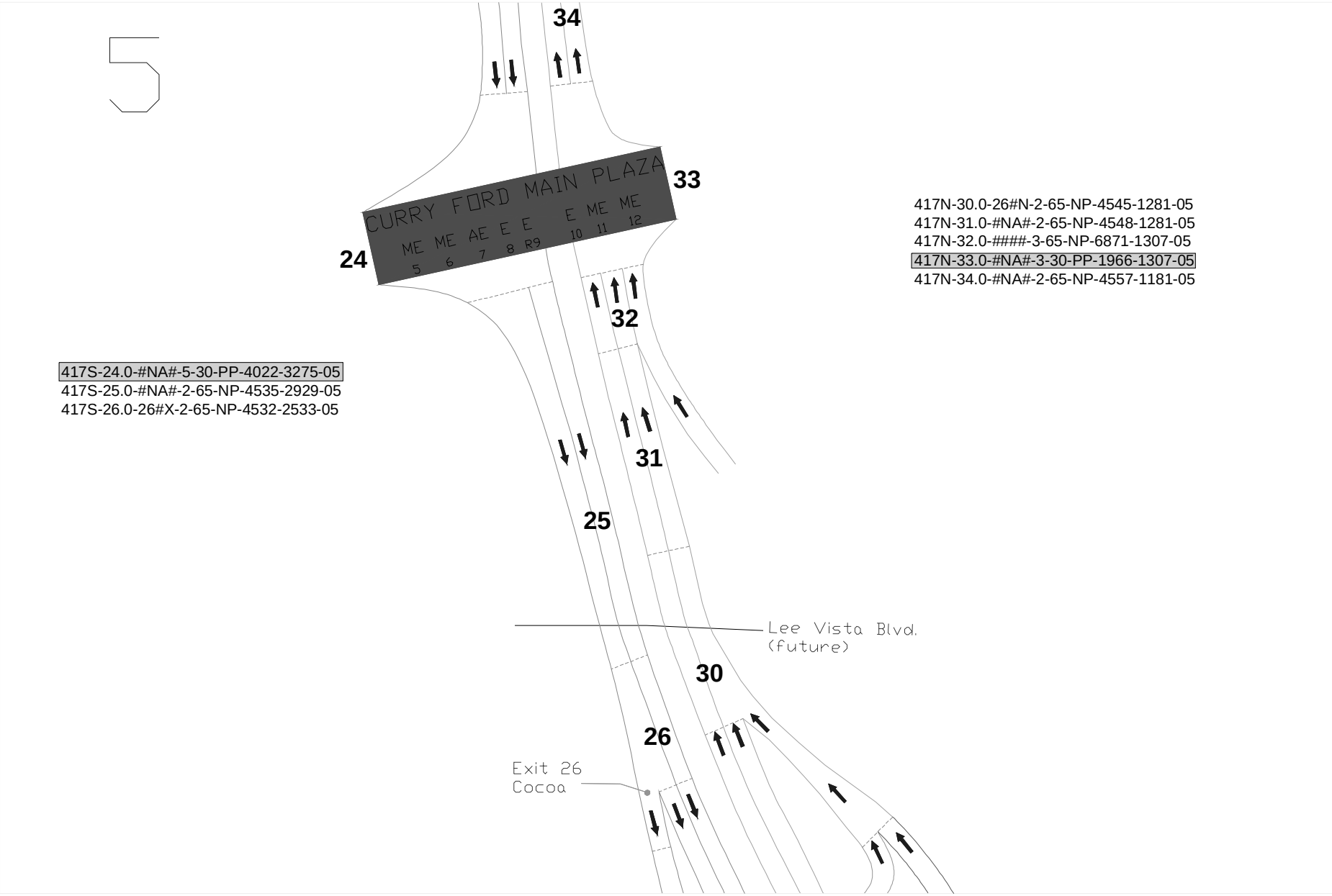
417N-38.0-#NA#-2-65-NP-4568-1463-04



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417S-26.0-26#X-2-65-NP-4532-2533-05

417N-30.0-26#N-2-65-NP-4545-1281-05
417N-31.0-#NA#-2-65-NP-4548-1281-05
417N-32.0-####-3-65-NP-6871-1307-05
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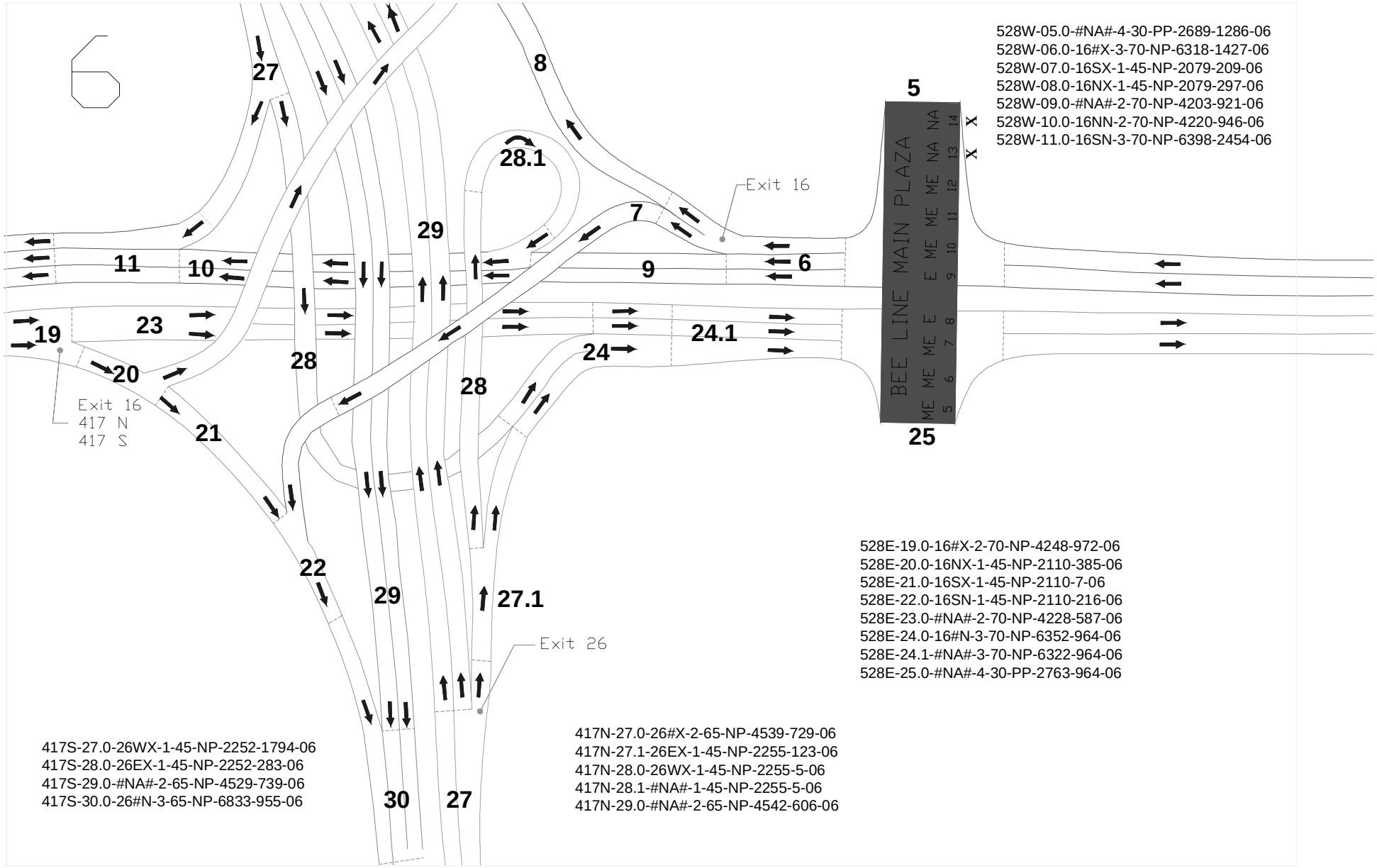
417N-34.0-#NA#-2-65-NP-4557-1181-05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528W-08.0-16NX-1-45-NP-2079-297-06
528W-09.0-#NA#-2-70-NP-4203-921-06
528W-10.0-16NN-2-70-NP-4220-946-06
528W-11.0-16SN-3-70-NP-6398-2454-06
BEE LINE MAIN PLAZA
ME ME ME E E ME ME ME NA NA
5 6 7 8 9 10 11 12 13 14
X X
Exit 16
Exit 16
417 N
417 S
Exit 26
528E-19.0-16#X-2-70-NP-4248-972-06
528E-20.0-16NX-1-45-NP-2110-385-06
528E-21.0-16SX-1-45-NP-2110-7-06
528E-22.0-16SN-1-45-NP-2110-216-06
528E-23.0-#NA#-2-70-NP-4228-587-06
528E-24.0-16#N-3-70-NP-6352-964-06
528E-24.1-#NA#-3-70-NP-6322-964-06
528E-25.0-#NA#-4-30-PP-2763-964-06
417S-27.0-26WX-1-45-NP-2252-1794-06
417S-28.0-26EX-1-45-NP-2252-283-06
417S-29.0-#NA#-2-65-NP-4529-739-06
417S-30.0-26#N-3-65-NP-6833-955-06
417N-27.0-26#X-2-65-NP-4539-729-06
417N-27.1-26EX-1-45-NP-2255-123-06
417N-28.0-26WX-1-45-NP-2255-5-06
417N-28.1-#NA#-1-45-NP-2255-5-06
417N-29.0-#NA#-2-65-NP-4542-606-06
5
6
7
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9
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11
19
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22
23
24
24.1
25
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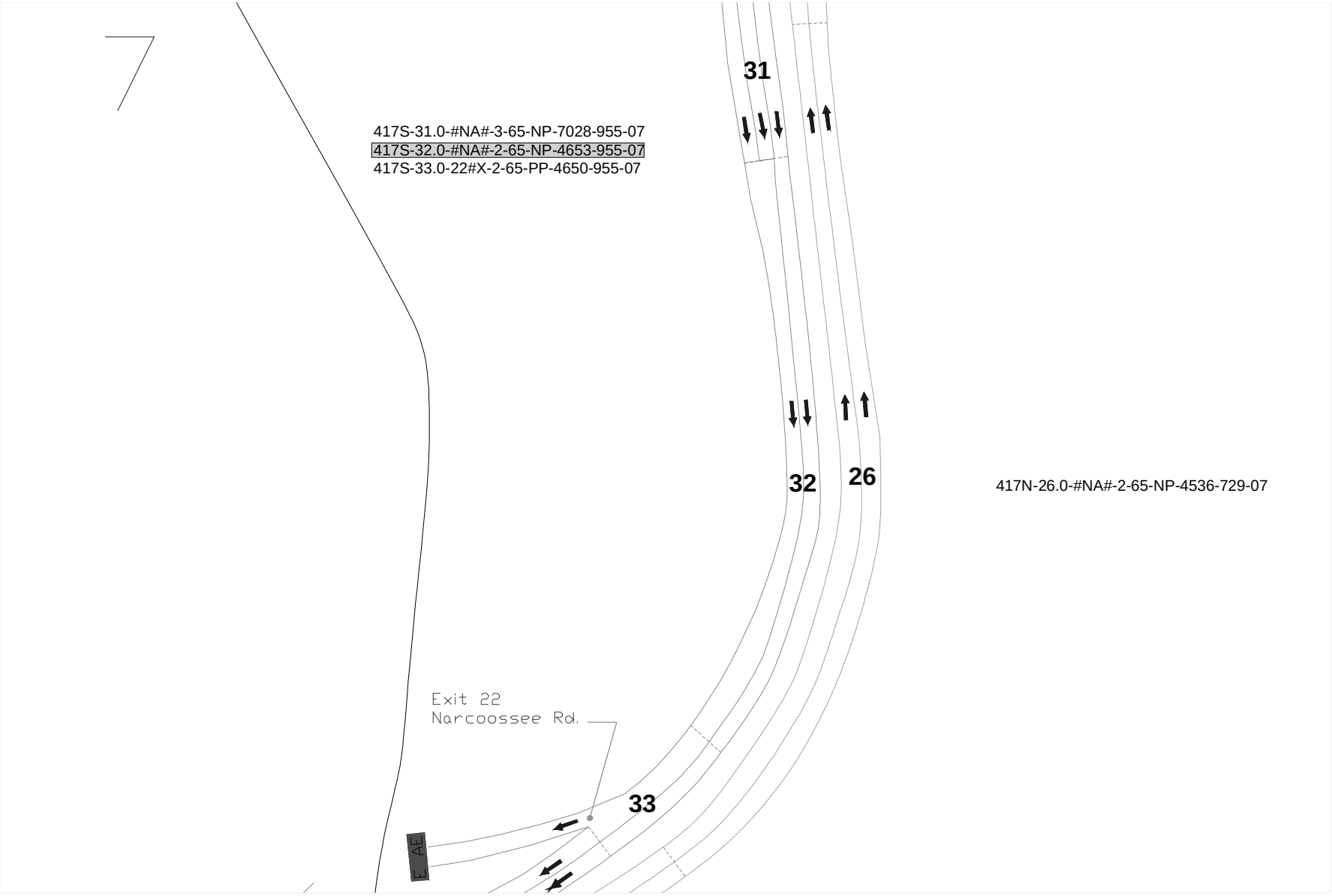
27.1
28
28.1
29
30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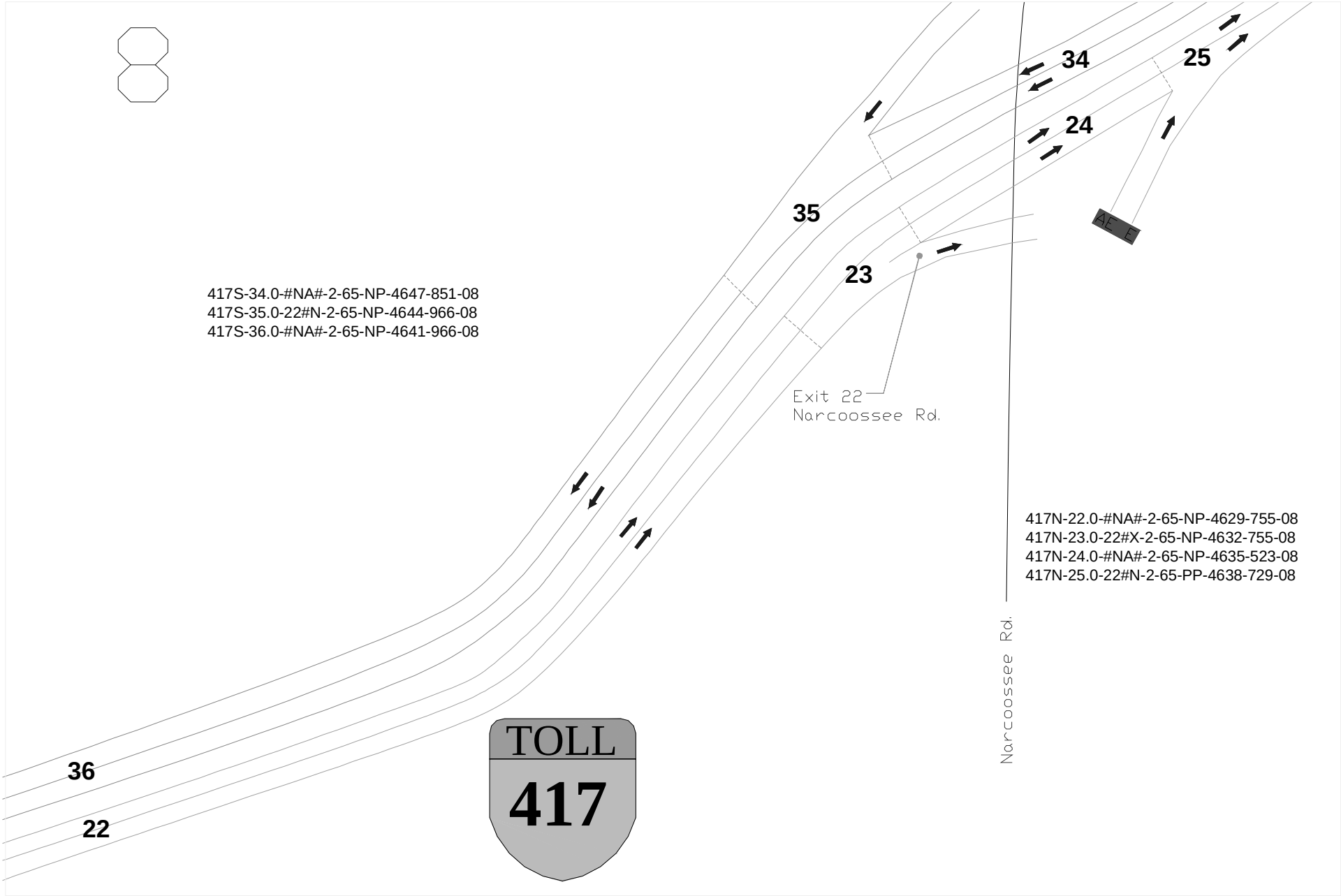
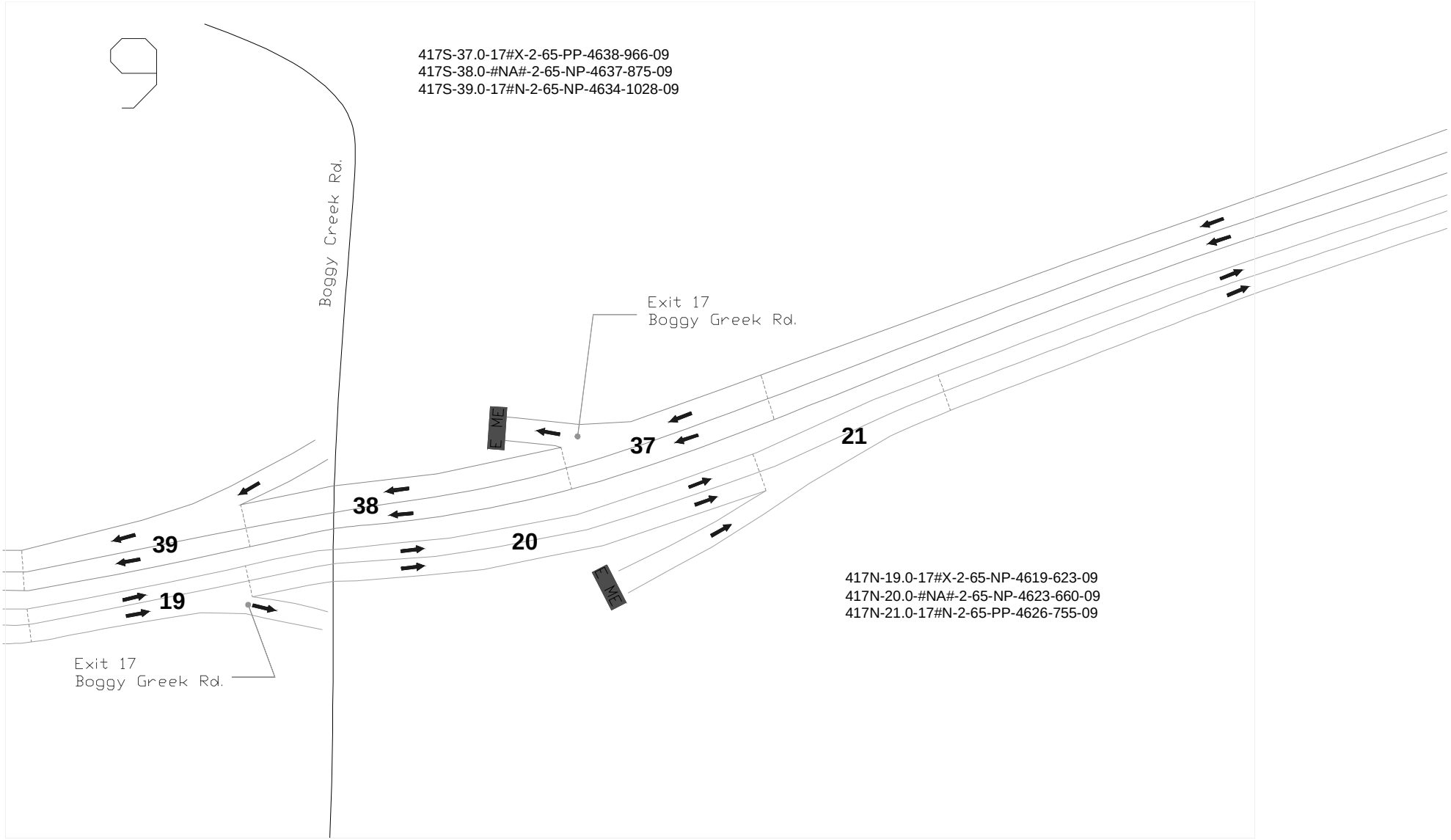
32
26
417N-26.0-#NA#-2-65-NP-4536-729-07
Exit 22
Narcoossee Rd.
33
E AE


34
25
24
35
23
AE E
417S-34.0-#NA#-2-65-NP-4647-851-08
417S-35.0-22#N-2-65-NP-4644-966-08
417S-36.0-#NA#-2-65-NP-4641-966-08
Exit 22
Narcoossee Rd.
417N-22.0-#NA#-2-65-NP-4629-755-08
417N-23.0-22#X-2-65-NP-4632-755-08
417N-24.0-#NA#-2-65-NP-4635-523-08
417N-25.0-22#N-2-65-PP-4638-729-08
Narcoossee Rd.
36
22
TOLL
417


417S-37.0-17#X-2-65-PP-4638-966-09
417S-38.0-#NA#-2-65-NP-4637-875-09
417S-39.0-17#N-2-65-NP-4634-1028-09
Boggy Creek Rd.
Exit 17
Boggy Greek Rd.
E ME
37
21
38
39
20
19
E ME
417N-19.0-17#X-2-65-NP-4619-623-09
417N-20.0-#NA#-2-65-NP-4623-660-09
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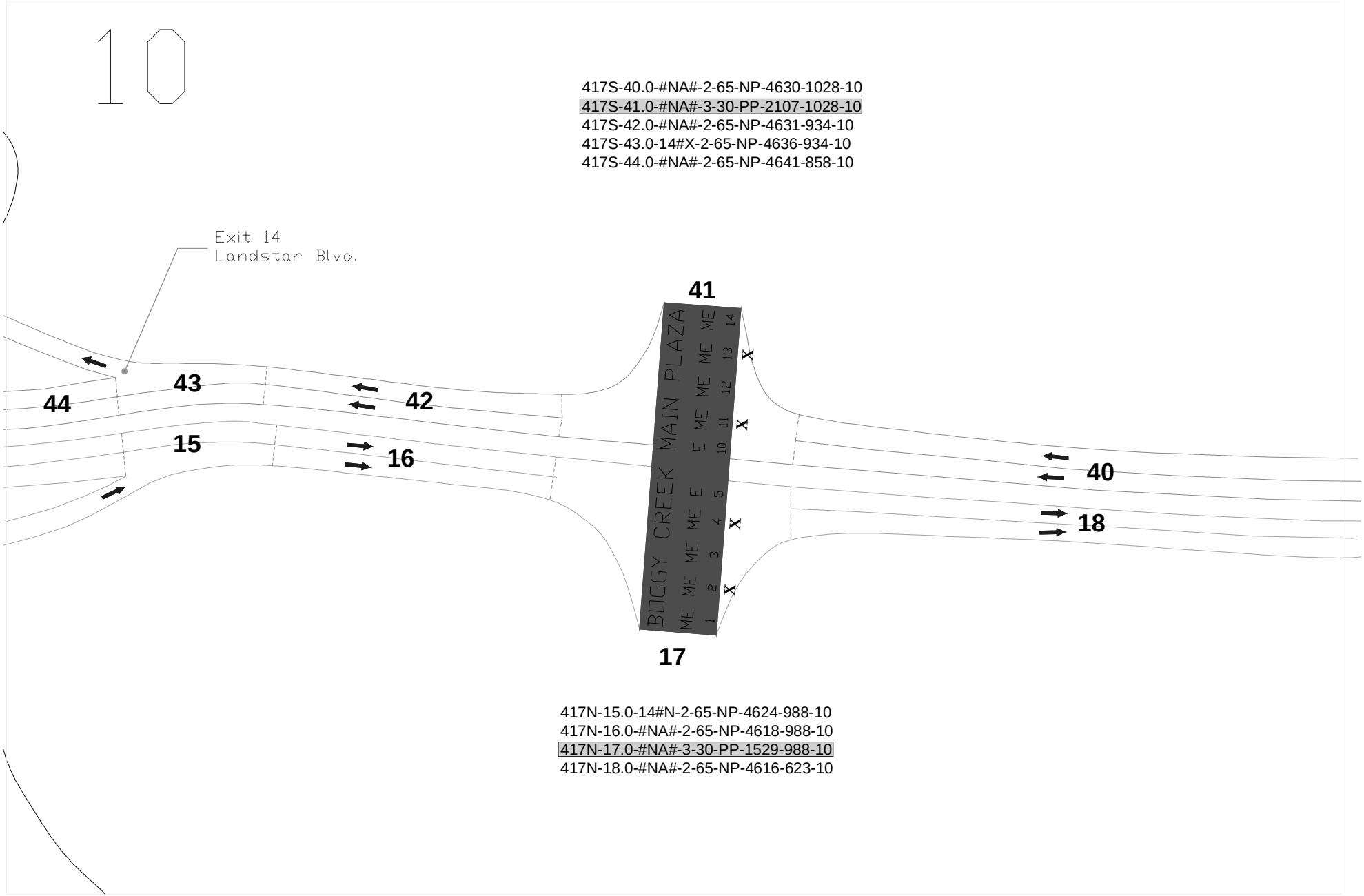
Exit 17
Boggy Greek Rd.


10
417S-40.0-#NA#-2-65-NP-4630-1028-10
417S-41.0-#NA#-3-30-PP-2107-1028-10
417S-42.0-#NA#-2-65-NP-4631-934-10
417S-43.0-14#X-2-65-NP-4636-934-10
417S-44.0-#NA#-2-65-NP-4641-858-10
Exit 14
Landstar Blvd.
41
43
44
42
15
16
40
18
BOGGY CREEK MAIN PLAZA
ME ME ME E E ME ME ME
1 2 3 4 5 10 11 12 13 14
X
X
X
X
17
417N-15.0-14#N-2-65-NP-4624-988-10
417N-16.0-#NA#-2-65-NP-4618-988-10
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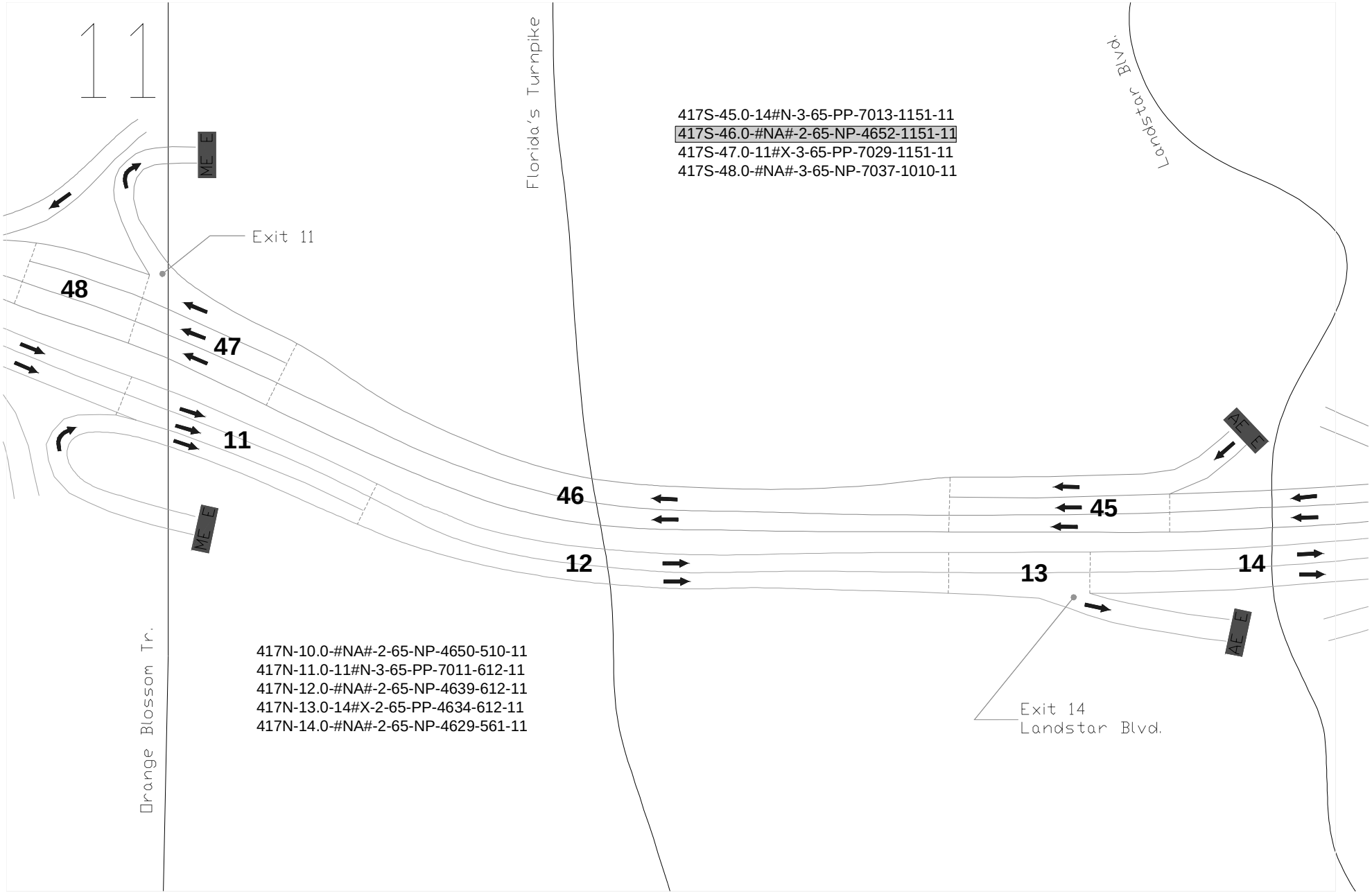
11
ME E
Exit 11
48
47
11
ME E
Orange Blossom Tr.
Florida's Turnpike
417S-45.0-14#N-3-65-PP-7013-1151-11
417S-46.0-#NA#-2-65-NP-4652-1151-11
417S-47.0-11#X-3-65-PP-7029-1151-11
417S-48.0-#NA#-3-65-NP-7037-1010-11
Landstar Blvd.
AE E
46
45
12
13
14
AE E
417N-10.0-#NA#-2-65-NP-4650-510-11
417N-11.0-11#N-3-65-PP-7011-612-11
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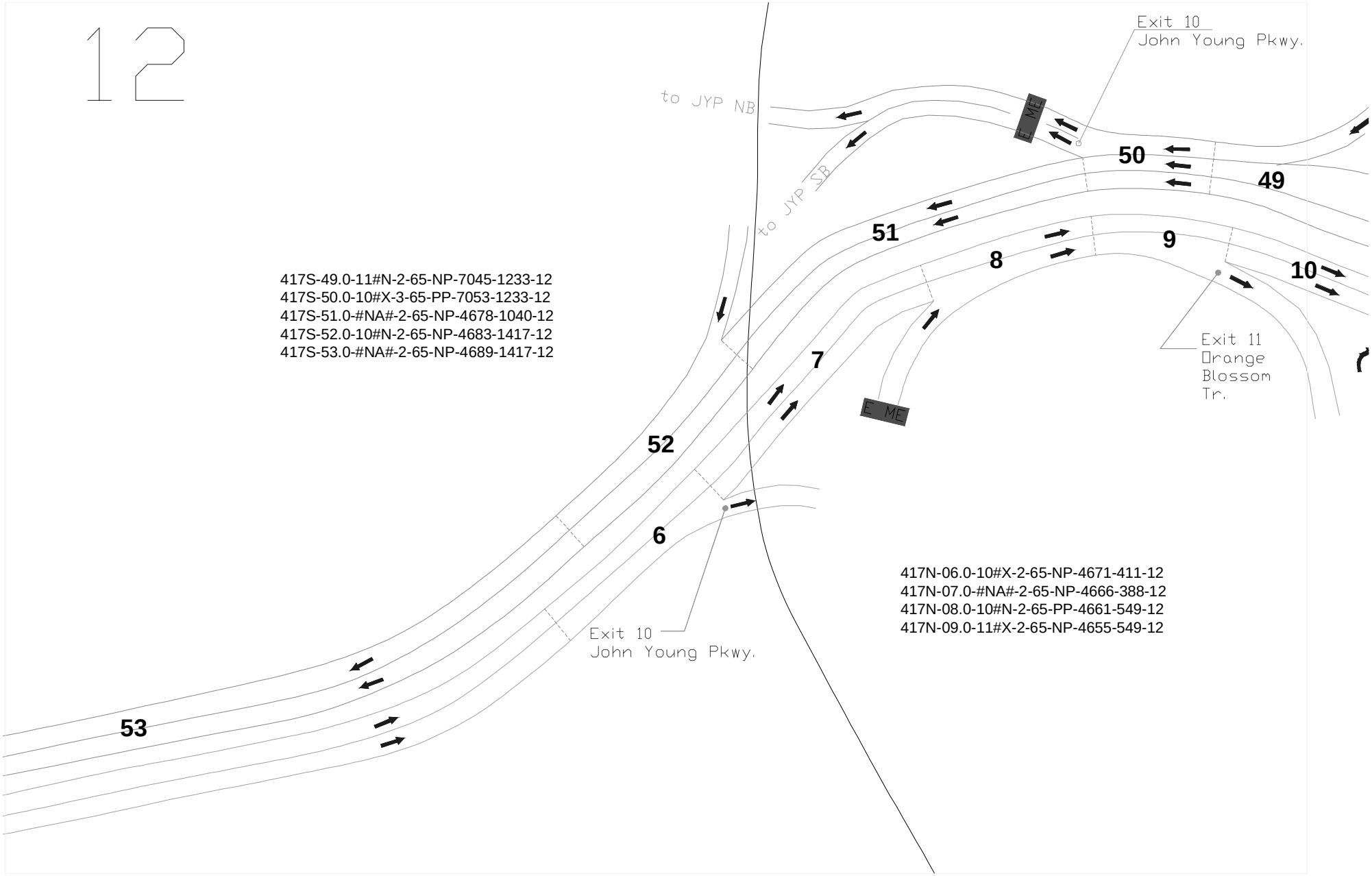
Exit 14
Landstar Blvd.


12
to JYP NB
to JYP SB
Exit 10
John Young Pkwy.
E ME
50
49
51
9
8
10
7
52
6
53
Exit 11
Orange
Blossom
Tr.
417S-49.0-11#N-2-65-NP-7045-1233-12
417S-50.0-10#X-3-65-PP-7053-1233-12
417S-51.0-#NA#-2-65-NP-4678-1040-12
417S-52.0-10#N-2-65-NP-4683-1417-12
417S-53.0-#NA#-2-65-NP-4689-1417-12
417N-06.0-10#X-2-65-NP-4671-411-12
417N-07.0-#NA#-2-65-NP-4666-388-12
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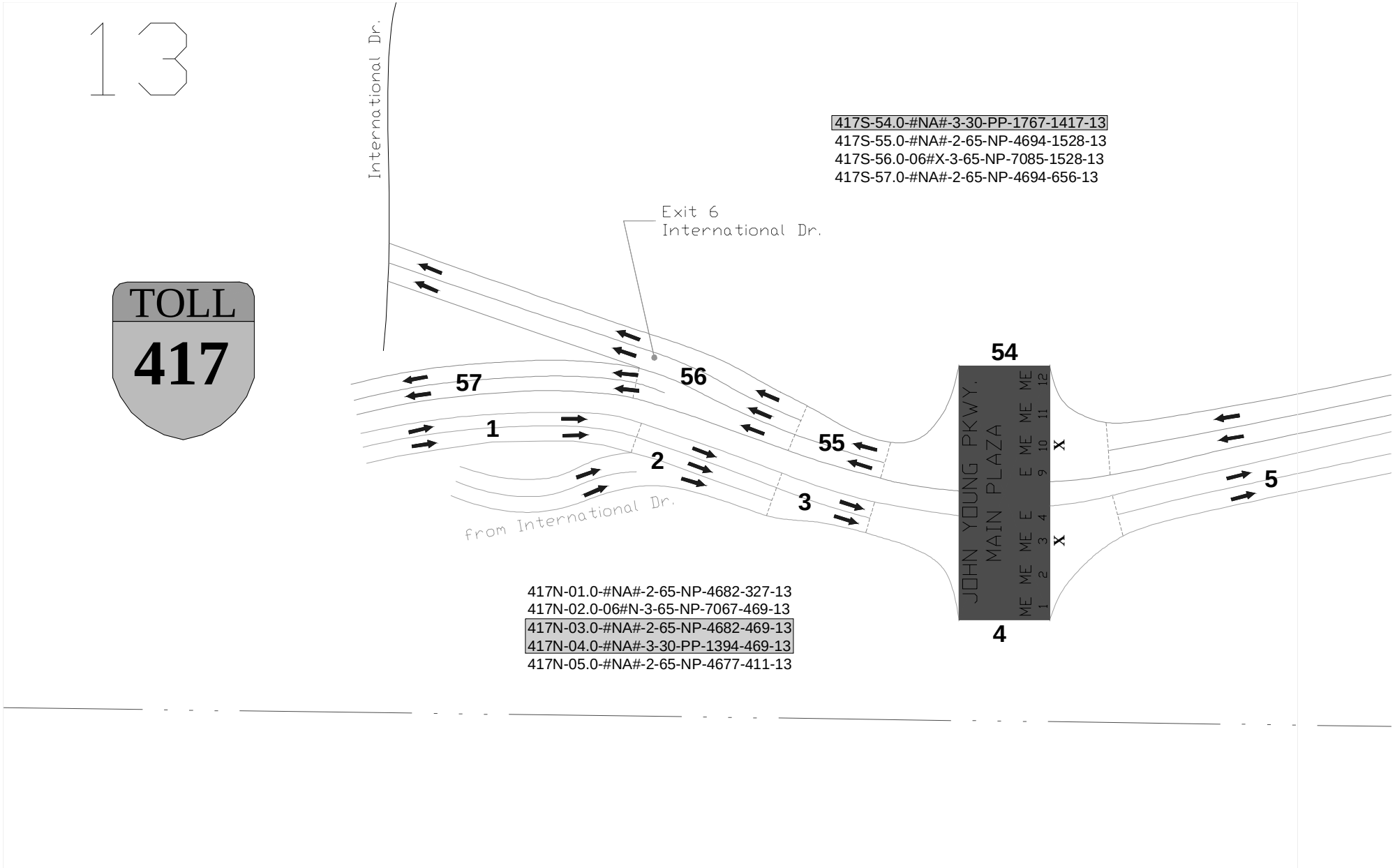
Exit 10
John Young Pkwy.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TOLL
417
International Dr.
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417S-55.0-#NA#-2-65-NP-4694-1528-13
417S-56.0-06#X-3-65-NP-7085-1528-13
417S-57.0-#NA#-2-65-NP-4694-656-13
Exit 6
International Dr.
54
57
56
1
55
2
3
5
from International Dr.
JOHN YOUNG PKWY.
MAIN PLAZA
ME ME ME E E ME ME ME
1 2 3 4 9 10 11 12
X
X
4
417N-01.0-#NA#-2-65-NP-4682-327-13
417N-02.0-06#N-3-65-NP-7067-469-13
417N-03.0-#NA#-2-65-NP-4682-469-13
417N-04.0-#NA#-3-30-PP-1394-469-13
417N-05.0-#NA#-2-65-NP-4677-411-13

14

408W-55.0-04#X-3-65-PP-6767-1362-14
408W-56.0-#NA#-2-65-NP-4482-1063-14
408W-57.0-04#N-2-65-NP-4482-1243-14
408W-58.0-#NA#-3-30-PP-1714-1243-14
408W-59.0-02#X-2-65-NP-4482-1074-14
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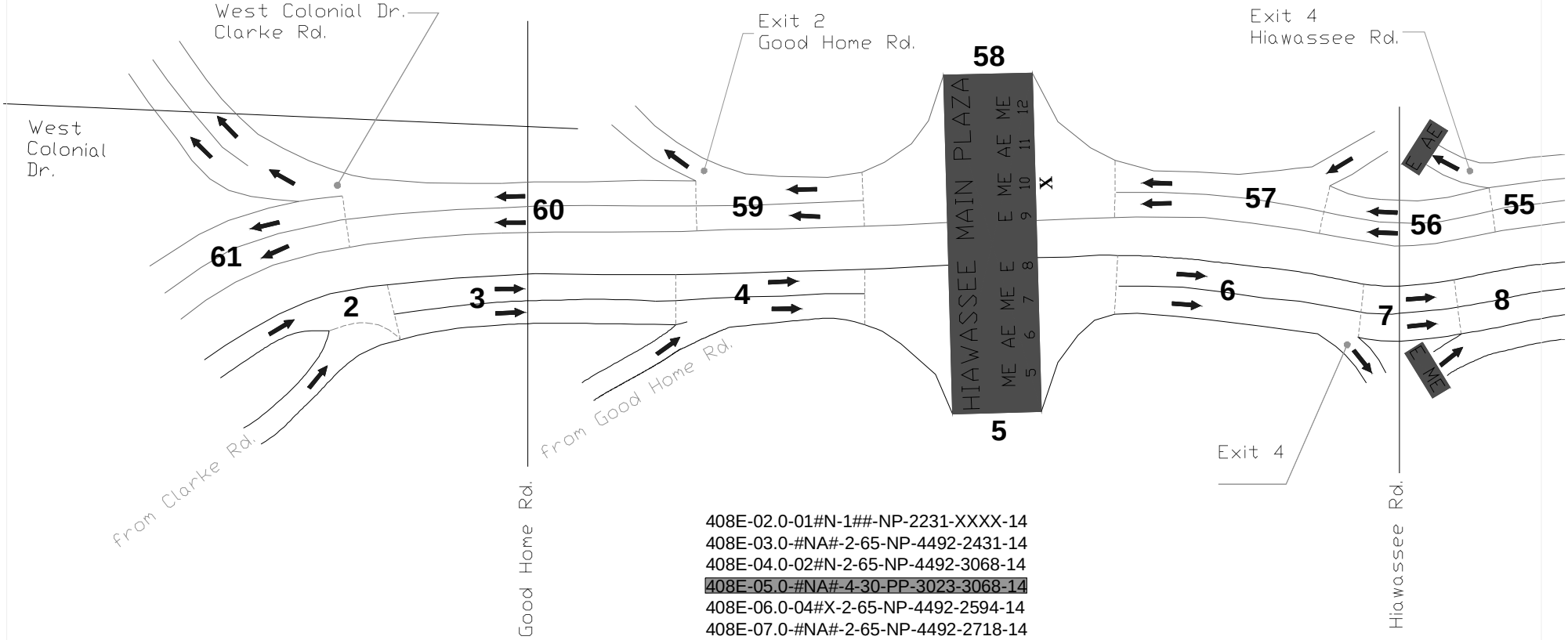

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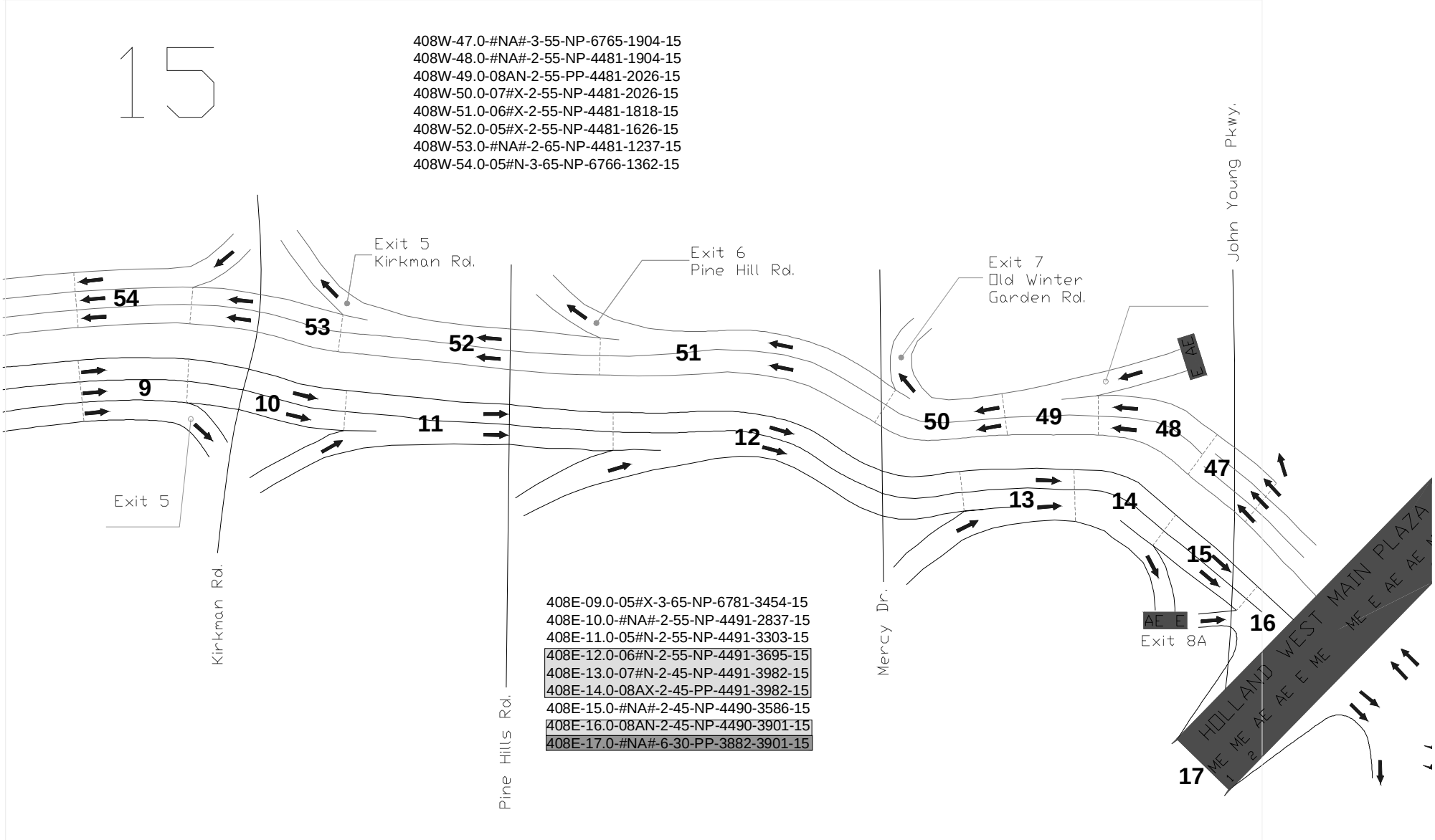
408E-05.0-#NA#-4-30-PP-3023-3068-14
408E-06.0-04#X-2-65-NP-4492-2594-14
408E-07.0-#NA#-2-65-NP-4492-2718-14
408E-08.0-04#N-3-65-PP-6781-3454-14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408W-48.0-#NA#-2-55-NP-4481-1904-15
408W-49.0-08AN-2-55-PP-4481-2026-15
408W-50.0-07#X-2-55-NP-4481-2026-15
408W-51.0-06#X-2-55-NP-4481-1818-15
408W-52.0-05#X-2-55-NP-4481-1626-15
408W-53.0-#NA#-2-65-NP-4481-1237-15
408W-54.0-05#N-3-65-NP-6766-1362-15
Exit 5
Kirkman Rd.
Exit 6
Pine Hill Rd.
Exit 7
Old Winter
Garden Rd.
John Young Pkwy.
54
53
52
51
9
10
11
12
50
49
48
47
13
14
15
16
17
Exit 5
Kirkman Rd.
Pine Hills Rd.
Mercy Dr.
AE E
Exit 8A
HOLLAND WEST MAIN PLAZA
408E-09.0-05#X-3-65-NP-6781-3454-15
408E-10.0-#NA#-2-55-NP-4491-2837-15
408E-11.0-05#N-2-55-NP-4491-3303-15
408E-12.0-06#N-2-55-NP-4491-3695-15
408E-13.0-07#N-2-45-NP-4491-3982-15
408E-14.0-08AX-2-45-PP-4491-3982-15
408E-15.0-#NA#-2-45-NP-4490-3586-15
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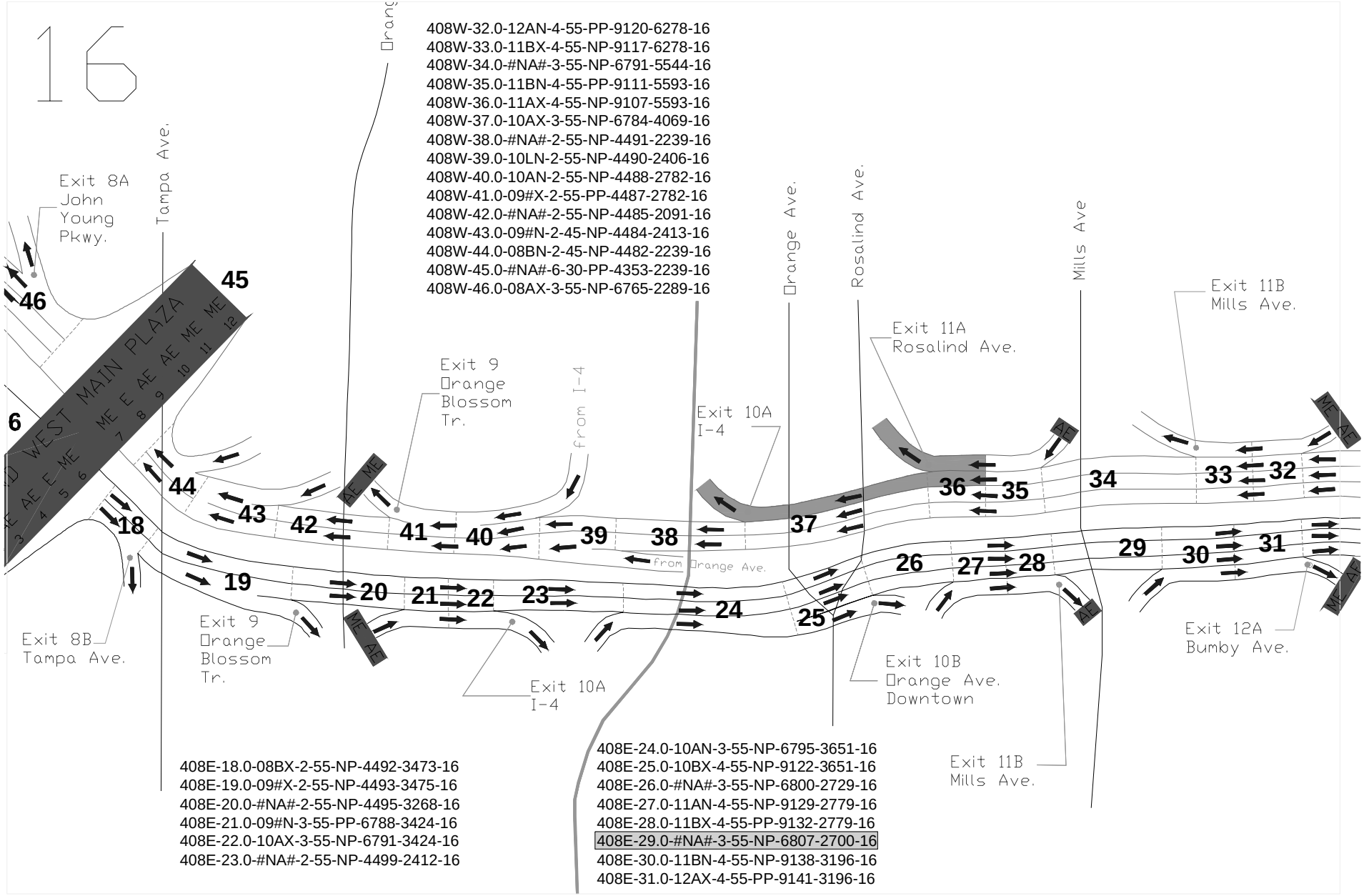

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408W-37.0-10AX-3-55-NP-6784-4069-16
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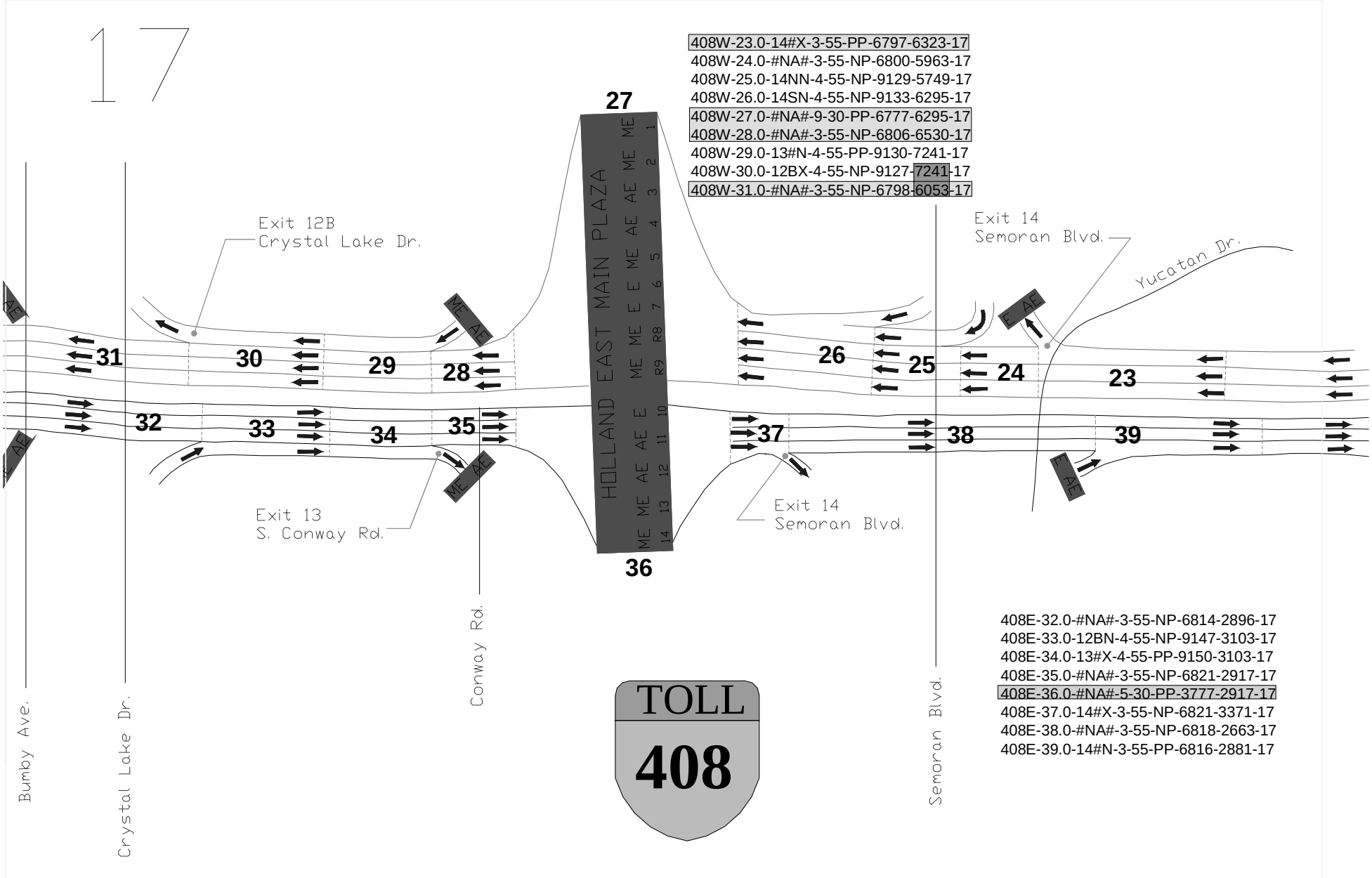
408W-42.0-#NA#-2-55-NP-4485-2091-16
408W-43.0-09#N-2-45-NP-4484-2413-16
408W-44.0-08BN-2-45-NP-4482-2239-16
408W-45.0-#NA#-6-30-PP-4353-2239-16
408W-46.0-08AX-3-55-NP-6765-2289-16

408E-18.0-08BX-2-55-NP-4492-3473-16
408E-19.0-09#X-2-55-NP-4493-3475-16
408E-20.0-#NA#-2-55-NP-4495-3268-16
408E-21.0-09#N-3-55-PP-6788-3424-16
408E-22.0-10AX-3-55-NP-6791-3424-16
408E-23.0-#NA#-2-55-NP-4499-2412-16

408E-24.0-10AN-3-55-NP-6795-3651-16
408E-25.0-10BX-4-55-NP-9122-3651-16
408E-26.0-#NA#-3-55-NP-6800-2729-16
408E-27.0-11AN-4-55-NP-9129-2779-16
408E-28.0-11BX-4-55-PP-9132-2779-16
408E-29.0-#NA#-3-55-NP-6807-2700-16
408E-30.0-11BN-4-55-NP-9138-3196-16
408E-31.0-12AX-4-55-PP-9141-3196-16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408W-25.0-14NN-4-55-NP-9129-5749-17
408W-26.0-14SN-4-55-NP-9133-6295-17
408W-27.0-#NA#-9-30-PP-6777-6295-17
408W-28.0-#NA#-3-55-NP-6806-6530-17
408W-29.0-13#N-4-55-PP-9130-7241-17
408W-30.0-12BX-4-55-NP-9127-7241-17
408W-31.0-#NA#-3-55-NP-6798-6053-17
27
HOLLAND EAST MAIN PLAZA
ME ME AE AE E ME ME E E ME AE AE ME ME
1 2 3 4 5 6 7 R8 R9 10 11 12 13 14
36
Exit 12B
Crystal Lake Dr.
Exit 13
S. Conway Rd.
Exit 14
Semoran Blvd.
Exit 14
Semoran Blvd.
Yucatan Dr.
31
30
29
28
32
33
34
35
26
25
24
23
37
38
39
Bumby Ave.
Crystal Lake Dr.
Conway Rd.
Semoran Blvd.
TOLL
408
408E-32.0-#NA#-3-55-NP-6814-2896-17
408E-33.0-12BN-4-55-NP-9147-3103-17
408E-34.0-13#X-4-55-PP-9150-3103-17
408E-35.0-#NA#-3-55-NP-6821-2917-17
408E-36.0-#NA#-5-30-PP-3777-2917-17
408E-37.0-14#X-3-55-NP-6821-3371-17
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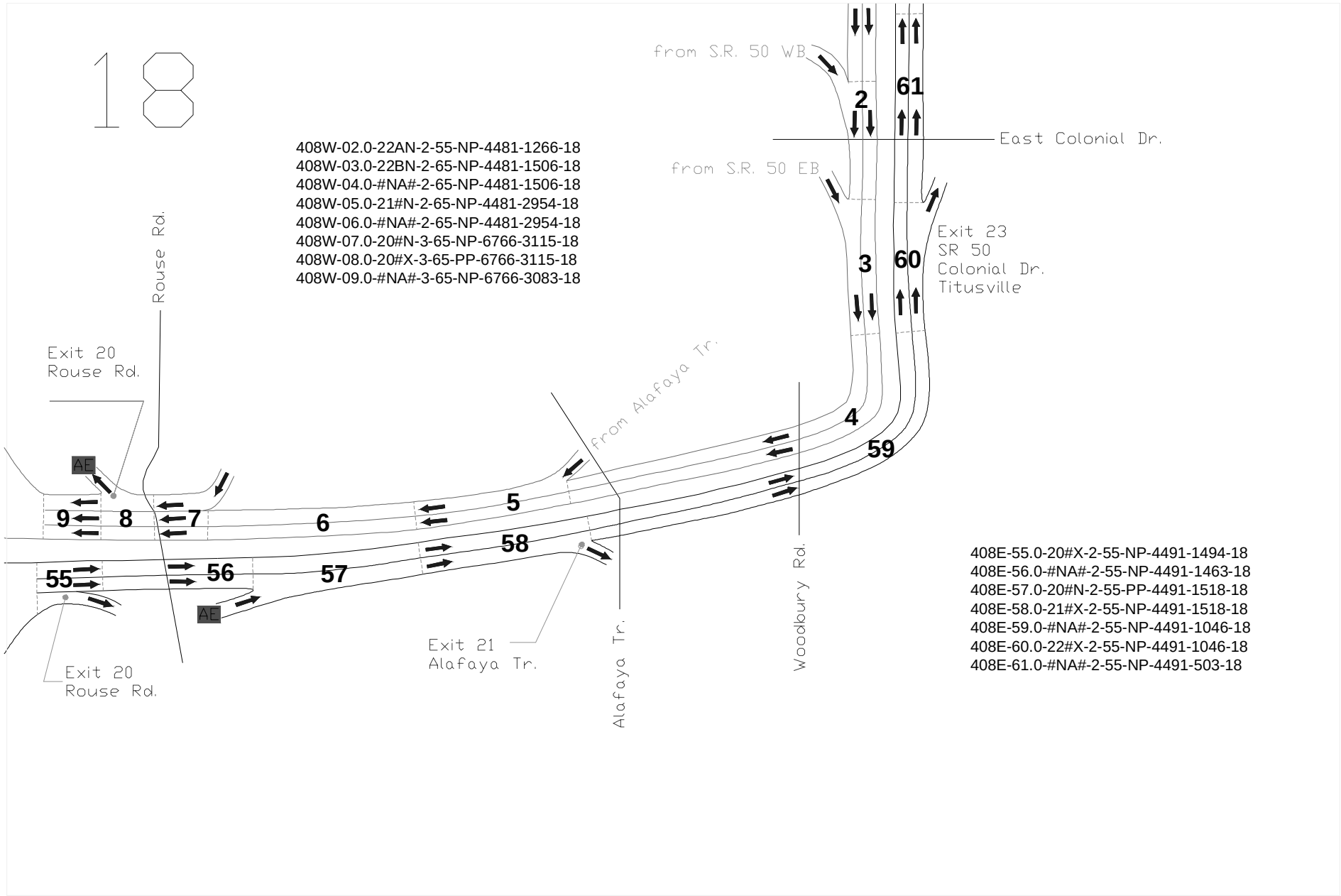
408E-39.0-14#N-3-55-PP-6816-2881-17


18
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408W-08.0-20#X-3-65-PP-6766-3115-18
408W-09.0-#NA#-3-65-NP-6766-3083-18
from S.R. 50 WB
from S.R. 50 EB
East Colonial Dr.
Exit 23
SR 50
Colonial Dr.
Titusville
Rouse Rd.
Exit 20
Rouse Rd.
from Alafaya Tr.
AE
AE
Exit 21
Alafaya Tr.
Alafaya Tr.
Woodbury Rd.
Exit 20
Rouse Rd.
2
61
3
60
4
59
5
58
6
57
7
56
8
55
9
408E-55.0-20#X-2-55-NP-4491-1494-18
408E-56.0-#NA#-2-55-NP-4491-1463-18
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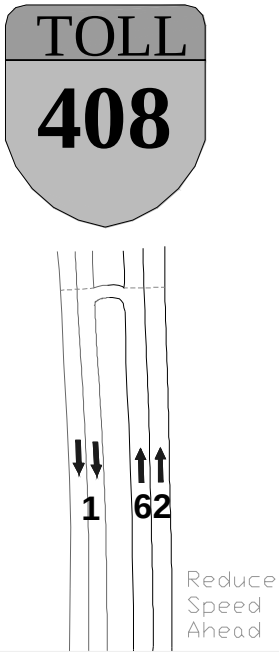
19



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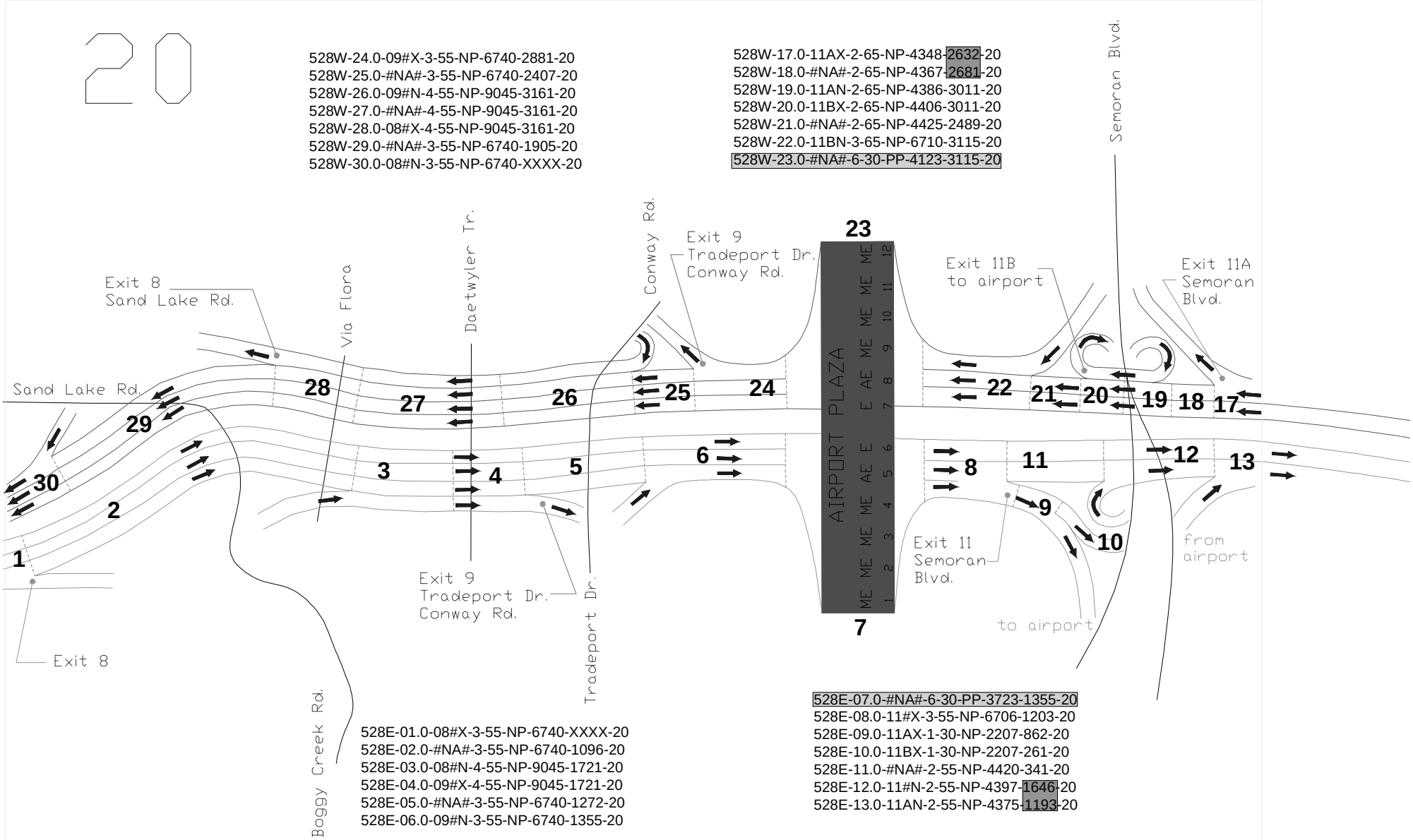
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528W-29.0-#NA#-3-55-NP-6740-1905-20
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528W-18.0-#NA#-2-65-NP-4367-2681-20
528W-19.0-11AN-2-65-NP-4386-3011-20
528W-20.0-11BX-2-65-NP-4406-3011-20
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528W-22.0-11BN-3-65-NP-6710-3115-20
528W-23.0-#NA#-6-30-PP-4123-3115-20
Semoran Blvd.
Exit 8
Sand Lake Rd.
Via Flora
Daetwyler Tr.
Conway Rd.
Exit 9
Tradeport Dr.
Conway Rd.
Exit 11B
to airport
Exit 11A
Semoran
Blvd.
Sand Lake Rd.
AIRPORT PLAZA
ME ME ME ME AE E
E AE ME ME ME ME
1 2 3 4 5 6 7 8 9 10 11 12
23
7
1
2
3
4
5
6
8
9
10
11
12
13
17
18
19
20
21
22
24
25
26
27
28
29
30
Exit 11
Semoran
Blvd.
from
airport
to airport
Exit 9
Tradeport Dr.
Conway Rd.
Tradeport Dr.
Exit 8
Boggy Creek Rd.
528E-01.0-08#X-3-55-NP-6740-XXXX-20
528E-02.0-#NA#-3-55-NP-6740-1096-20
528E-03.0-08#N-4-55-NP-9045-1721-20
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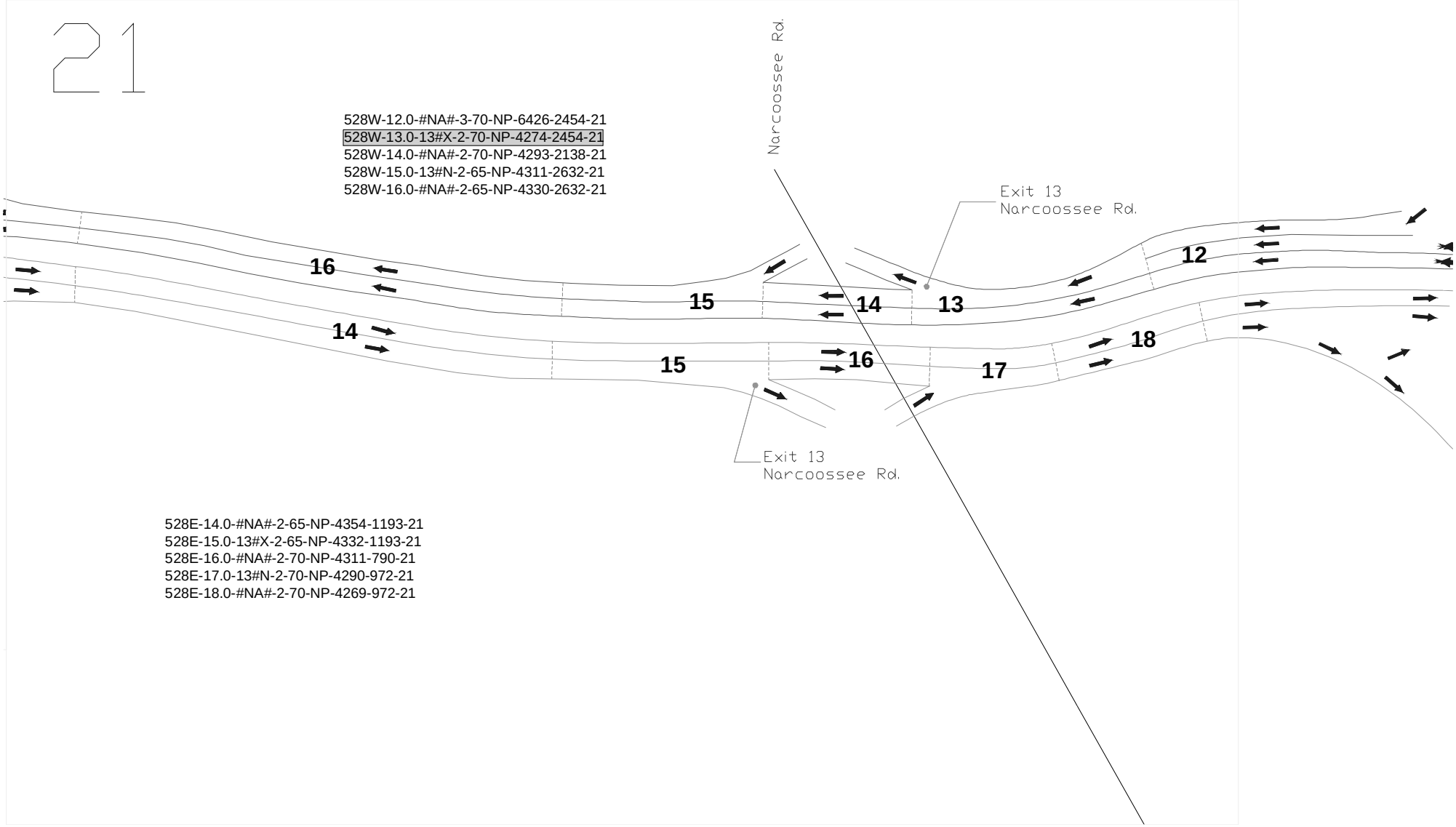
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528W-15.0-13#N-2-65-NP-4311-2632-21
528W-16.0-#NA#-2-65-NP-4330-2632-21
Narcoossee Rd.
Exit 13
Narcoossee Rd.
16
15
14
13
12
14
15
16
17
18
Exit 13
Narcoossee Rd.
528E-14.0-#NA#-2-65-NP-4354-1193-21
528E-15.0-13#X-2-65-NP-4332-1193-21
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528E-18.0-#NA#-2-70-NP-4269-972-21

22

528W-01.0-20#X-2-70-PP-4168-1323-22
528W-02.0-#NA#-2-70-NP-4168-1269-22
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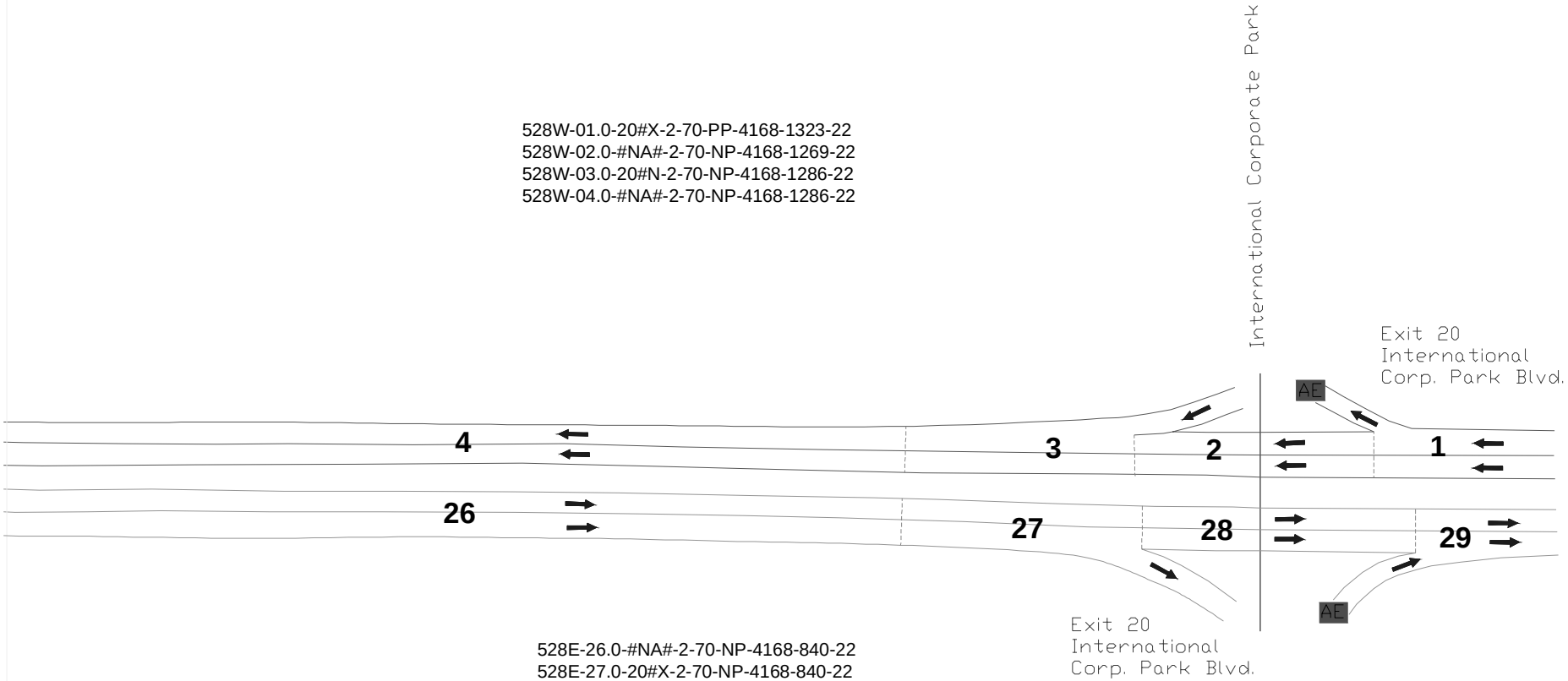

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528E-27.0-20#X-2-70-NP-4168-840-22
528E-28.0-#NA#-2-70-NP-4168-755-22
528E-29.0-20#N-2-70-PP-4168-760-22

Appendix J: Acronyms

ETC = Electronic Toll Collection
ACM = Automatic Coin Machine
DSS GUI = Decision Support System Graphical User Interface
OOCEA = Orlando Orange County Expressway Authority
MOE = Measure of Effectiveness
HCM = Highway Capacity Manual
LOS = Level of Service
vph = Vehicle per Hour
TNCC = Toll Network Capacity Calculator
RQN = Remaining Queue Number
RQL = Remaining Queue Length
WTQ = Waiting Time in the Queue
SRQ = Speed of the Remaining Queue

Traffic Categories
ETC – Electronic Toll Collection
E – category of vehicles containing vehicles using ETC at the plazas
E_P – category containing passenger cars using ETC at the plazas
E_T – category containing vehicles other than passenger cars using ETC at the plazas
ACM – Automatic Coin Machines
A – category containing vehicles using ACM at the plazas
M – category containing passenger cars using the Manual service at the plazas
T – category containing vehicles other than passenger cars using ETC at the plazas

NQMT – No Queue Maximum Throughput [the maximum throughput, in vehicles per hour, or largest possible number of vehicles able to be processed in one hour at a plaza such that there are no queues in any of the lanes at the end of the hour and given three types of input: lane configuration, vehicle and driver characteristics, processing rates for calibration, and a breakdown of arrival traffic volumes into their categories (percentages)].

Lane Types used to describe Plaza Lane Configurations
AE lanes – Allow A and E type transactions
ME lanes – Allow M and E transactions
MTE lanes – Allow M, T and E type transactions
AE_P - Allow A and EP type transactions
ME_P lanes – Allow M and EP transactions
MTE_P lanes – Allow M, T and EP type transactions
MTE_PE_T lanes – Allow M, T, EP and ET type transactions

NE or NE_PE_T – Number of lanes in a plaza dedicated to only ETC transactions
NAE – Number of AE lanes in a plaza
NME – Number of ME lanes in a plaza
NMTE – Number of MTE lanes in a plaza

Vehicle and Driver Characteristics:
l_X – average vehicle length for vehicle in category X
b_X – average distance between vehicles in category X
a_X – average vehicle acceleration of vehicles in category X
d_X – average vehicle deceleration of vehicles in category X
$tstop_X$ – average stop-time at time of payment for vehicles in category X
t_R – average driver's reaction time

Processing Rates for Calibration Purposes

S^Y – the Processing Rate of a lane Y
S_M – the maximum Processing Rate for M vehicles at the plaza
S_A – the maximum Processing Rate for A vehicles at the plaza
S_T – the maximum Processing Rate for T vehicles at the plaza
S_E^{MAX} – the maximum observed Processing Rate for ETC vehicles at the plaza
S_E^{AE} – the Processing Rate for E vehicles in an AE lane at the plaza
S_E^{ME} – the Processing Rate for E vehicles in an ME lane at the plaza
S_E^{MTE} – the Processing Rate for E vehicles in an MTE lane at the plaza

Breakdown of Arrival Traffic Volumes into their Categories (Percentages)

For TNCC, Toll Network Capacity Calculator
P_E – percent ETC usage at the plaza
P_E^{AE} – percent ETC usage in an AE lane at the plaza
P_E^{ME} – percent ETC usage in an ME lane at the plaza
P_E^{MTE} – percent ETC usage in an MTE lane at the plaza
P_{EP} – percent E_P usage at the plaza
P_{ET} – percent E_T usage at the plaza
P_A – percent A usage at the plaza
P_M – percent M usage at the plaza
P_T – percent T usage at the plaza

For SHAKER (not an acronym)
P_A^{AEP} – percent A usage in an AE_P lane at the plaza
P_{EP}^{AEP} – percent E_P usage in an AE_P lane at the plaza
P_M^{MEP} – percent M usage in an ME_P lane at the plaza
P_{EP}^{MEP} – percent E_P usage in an ME_P lane at the plaza
P_M^{MEPET} – percent M usage in an ME_PE_T lane at the plaza
P_{EP}^{MEPET} – percent E_P usage in an ME_PE_T lane at the plaza
P_{ET}^{MEPET} – percent E_T usage in an ME_PE_T lane at the plaza
P_M^{MTEPET} – percent M usage in an MTE_PE_T lane at the plaza
P_T^{MTEPET} – percent T usage in an MTE_PE_T lane at the plaza
P_{EP}^{MTEPET} – percent E_P usage in an MTE_PE_T lane at the plaza
P_{ET}^{MTEPET} – percent E_T usage in an MTE_PE_T lane at the plaza