

Final Report

# NOACA Signal Timing Optimization Program

Contract Number: Resolution 2017-041

## Warren Road/West 150<sup>th</sup> Street

Madison Avenue to Brookpark Road

## Madison Avenue

Victoria Avenue/Reveley Avenue to Lincoln Avenue

## Terminal Avenue

Interstate 71 Westbound Ramps to West 150<sup>th</sup> Street

## Alger Road

Lakewood Heights Boulevard to South Marginal Drive

Prepared for:

Northeast Ohio Areawide Coordinating Agency (NOACA)



Prepared by:



Albeck Gerken, Inc.  
225 Wilmington-West Chester Pike, Suite 200  
Chadds Ford, PA 19317

March 2019

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Professional Engineer: John Albeck  
Ohio PE No: 81605

## EXECUTIVE SUMMARY

Albeck Gerken, Inc. was retained by the Northeast Ohio Areawide Coordinating Agency (NOACA) to provide engineering services for the full retiming of 27 intersections within the cities of Lakewood, Cleveland and Brook Park, Ohio. The tasks involved in this project were:

- Collected existing geometric, volume, and traffic signal timing data.
- Conducted field visits to develop understanding of intersection and corridor issues.
- Developed existing traffic operations modeling to benchmark existing capacity analysis.
- Performed before travel time runs and observations of existing conditions.
- Conducted a crash analysis.
- Conducted a warrant analysis.
- Updated basic timing parameters.
- Developed appropriate timing patterns to address weekday and weekend traffic flow.
- Modified day plan schedule.
- Implemented new signal timing plans.
- Performed post-implementation observation and fine-tuning of timings and conducted travel time runs.
- Developed implemented operations models to compare and measure improvements.
- Evaluated capacity and operational improvements and provided recommendations as needed.
- Updated timing sheets.
- Documented all work performed and summarized findings in this final report.

The traffic signals included in this project are:

No.	Intersection	No.	Intersection
1	Warren Rd & Madison Ave	15	W 150th St & I-71 EB Ramps
2	Warren Rd & Athens Ave	16	W 150th St & Puritas Ave
3	Warren Rd & Delaware Ave	17	W 150th St & Coe Ave
4	Warren Rd & Lakewood Heights Blvd	18	W 150th St & Industrial Pkwy
5	Warren Rd & S Marginal Dr	19	W 150th St & I-480 WB Off-ramp
6	Warren Rd & Montrose Ave	20	W 150th St & Brookpark Rd
7	Warren Rd & Edgecliff Ave/Orchard Park Ave	101	Madison Ave & Victoria Ave/Reveley Ave
8	Warren Rd & W 155th St/Grapeland Ave	102	Madison Ave & Onondaga Ave*
9	Warren Rd & Munn Rd	103	Madison Ave & Belle Ave
10	Warren Rd & Triskett Rd	104	Madison Ave & Lincoln Ave
11	Warren Rd/W 150th St & Lorain Ave	401/402	Alger Rd & Lakewood Heights Blvd
12	W 150th St & Chatfield Ave	501	Alger Rd & S Marginal Dr
13	W 150th St & Emery Ave	1401	Terminal Ave & I-71 Ramps
14	W 150th St & Terminal Ave		

\*Emergency Signal Intersection, operates in FLASH mode.

### Traffic Operations Analysis Summary

Over the expected five-year life of the project and based upon calculated values, the implemented signal timing is estimated to decrease delay by 450,300 hours (23%), total stops by 24,306,100 (15.0%), and fuel consumption by 501,400 gallons (10.2%).

The United States Environmental Protection Agency (EPA) has provided a calculator for carbon dioxide (CO<sub>2</sub>) emissions. The calculator can be found at <http://www.epa.gov/cleanenergy> under the Clean Energy Resources heading. Based on the fuel analysis above, the implemented signal timing is estimated to reduce CO<sub>2</sub> emissions by 4,460 metric tons over the life of the project. In addition, emission pollutants for nitrogen oxides (NOx) are estimated to be reduced by 970 kg, fine particles (PM<sub>2.5</sub>) by 29 kg, and volatile organic compounds (VOC) by 890 kg.



**Benefit-Cost Ratio**

Comparing the anticipated benefits from savings in travel time and operating costs to the overall project costs, the anticipated benefit-cost ratio for this project is approximately 33:1.

**Recommendations**

Beyond optimizing traffic signal timing, other improvements such as safety enhancements or additional capacity can further improve the performance of an intersection and roadway network.

West 150th Street & Interstate 480 Westbound Off-ramp

- Consider installing supplemental signal heads for the northbound movement along West 150th Street on the south side of the Interstate 480 Overpass. The overpass is located immediately to the south of this intersection, potentially blocking the view of traffic signals for the northbound approach. An analysis of crashes for the years 2015 – 2017 indicates that six (6) crashes occurred at this intersection over this span. Of the crashes, four (4) were rear end crashes, one (1) was a right turn crash, and one (1) was a fixed object crash. None of the crashes occurred along the northbound approach. While the three (3) year crash history at this intersection does not indicate a safety issue resulting from poor signal visibility, the installation of supplemental signal heads on the south side of the I-480 overpass is still recommended to prevent future crash patterns for northbound traffic.

Warren Road & Madison Avenue

- Consider implementing a northbound protected/permissive left-turn phase at this intersection. Currently, this movement is permissive only and during the during the PM peak hour there are 139 left turns along the northbound approach. With optimized signal timings, this lane group operates at LOS F. The implementation of protected/permitted phasing for northbound left turns improves LOS for this lane group from F to D during the PM peak hour and reduces LOS from A to C during the AM peak hour. Additionally, level of service during the AM peak hour is still at favorable levels (LOS D or better).
- The addition the northbound protected/permissive left-turn phase is suggested for the AM and PM peak hours. The cycle lengths would not need to change and the split for the AM peak and PM peak would be 12 seconds. The phase is not required for other time periods, but this short 12 second split could be maintained for other time periods without negative impacts to other movements.

Various intersections

- Consider installing backplates with retroreflective backplate borders and/or retroreflective backplate borders only, as needed, on all signal heads to increase visibility at all intersections.
- As per ODOT's Traffic Engineering Manual, Section 420-4.11, consider installing auxiliary signal indications on the right-side signal support. Large trucks often block the view of the overhead signal indications and these auxiliary signals would help improve visibility for these locations. In particular, the intersections on the southern end of the study area would benefit from this as they have higher truck traffic.
- At locations where crosswalks are not provided on all approaches, it is recommended to install pedestrian warning signs to provide positive guidance.
- Several locations as described in Section 3.4 have recalls for pedestrian movements. Consider updating vehicle and pedestrian detection at these locations.
- Consider adding remote communication to the systems near interchanges to allow for monitoring and the deployment of coordinated patterns, such as those for diversion routes.
- Countdown Pedestrian Signal Indications should be considered at locations where they currently do not exist. The following intersections have some or no countdown indications (refer to section 3.4). This table is sorted by the total number of pedestrians to prioritize those intersections with higher needs.

<b>Intersection</b>	<b>Total Pedestrians (excludes bikes)</b>
Madison Ave & Victoria Ave/ Reveley Ave	830
Madison Ave & Lincoln Ave	605
Madison Ave & Belle Ave	598
W 150th St & Puritas Ave	319
Warren Rd & W 155th St/Grapeland Ave	218
Warren Rd & Montrose Ave	184
Warren Rd & Athens Ave	168
Warren Rd & Edgecliff Ave/Orchard Park Ave	156
W 150th St & I-71 EB Ramps	122
W 150th St & Coe Ave	71
W 150th St & Terminal Ave	67
Alger Rd & Lakewood Heights Blvd	67
Warren Rd & Lakewood Heights Blvd	64
Warren Rd & Delaware Ave	55
W 150th St & Emery Ave	25
W 150th St & Industrial Pkwy	25
W 150th St & Brookpark Rd	23
Alger Rd & S Marginal Dr	23
W 150th St & I-480 WB Off-ramp	21
Warren Rd & S Marginal Dr	15
W 150th St & Chatfield Ave	15

- Leading Pedestrian Indications (LPIs) have been shown to be an effective safety measure for pedestrians when the intersection has particularly high pedestrian traffic, a history of pedestrian crashes, and a high number of turning movements. The following locations could consider LPIs based on this criterion:

<b>Intersection</b>	<b>Total Pedestrians</b>	<b>Ped Crashes</b>	<b>Percent Turning Vehicles</b>
W 150th St & Puritas Ave	331	9	47%
W 150th St/Warren Rd & Lorain Ave	274	2	32%
Warren Rd & Munn Rd	110	1	35%
W 150th St & I-71 EB Ramps	126	1	53%
Warren Rd & Triskett Rd	156	1	29%
Warren Rd & Madison Ave	792	1	32%

- Consider installing GPS units at the following locations to ensure a common time sync throughout the system. These signals are either isolated and/or serve as a master to other nearby intersections.

<b>Intersection</b>	<b>Type</b>	<b>Intersection</b>	<b>Type</b>
Warren Rd & Madison Ave	Master	W 150th St & Terminal Ave	Master
Warren Rd & Athens Ave	Isolated	W 150th St & Coe Ave	Isolated Master
Warren Rd & Delaware Ave	Isolated	W 150th St & Industrial Pkwy	Master
Warren Rd & Lakewood Heights Blvd	Master	W 150th St & Brookpark Rd	Master
Warren Rd & Triskett Rd	Master	Alger Rd S Marginal Dr	Isolated

- Currently, the Flashing Yellow Arrow display is not to be used on ODOT maintained traffic signals. However, the OMUTCD allows their use, and ODOT intends to allow them in the future. Flashing Yellow Arrows are recommended at the following intersections to replace existing five-section heads to allow lead/lag operation and variable left-turn phasing type by time of day.

<b>Intersection</b>	<b>Movement</b>	<b>Intersection</b>	<b>Movement</b>
Warren Rd & Lakewood Heights Blvd	NBL	W 150th St & I-71 Ramps	SBL
Warren Rd & S Marginal Dr	SBL	W 150th St & Puritas Ave	All left turns
Warren Rd & Munn Rd	NBL	W 150th St & Industrial Pkwy	NBL
Warren Rd & Triskett Rd	All left turns	W 150th St & I-480 WB Off-ramp	WBL
Warren Rd & Lorain Ave	All left turns	W 150th St & Brookpark Rd	EBL & WBL
W 150th St & Emery Ave	NBL & SBL		

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## 1.0 INTRODUCTION

### 1.1 Purpose

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The portion of Warren Road/West 150th Street within the scope of this project is approximately 4.3 miles long. Warren Road/West 150th Street is primarily a two-lane undivided roadway between Madison Avenue and Lakewood Heights Boulevard and a four-lane undivided roadway between Lakewood Heights Boulevard and Brookpark Road. Madison Avenue within the scope of this project is approximately 0.4 miles long and is a two-lane undivided roadway. Figure 1 on page 3 illustrates the locations of the study intersections.

### 1.2 Project Stakeholders

As previously noted, the project area spanned three (3) municipalities. The successful completion of the project required the participation and assistance from numerous individuals from NOACA, ODOT, the municipalities and their engineering consultants. The following individuals actively participated in the project (in no particular order): Andrew Cross, Dominic Martino and Richard Tutie (City of Cleveland); Jay Boyer and Mark Papke (City of Lakewood); Sgt. Jim Stopiak and Tony D'Amico (City of Brook Park); Brian Blayney, Grace Gallucci and Kathy Sarli (NOACA); Antoine Buie, Jason Lee, and Jeffrey Macko (GCRTA); Tony Toth and Keith Hamilton (ODOT).



### 1.3 NOACA Signal Timing Optimization Program

The Northeast Ohio Areawide Coordinating Agency (NOACA) is a Cleveland-based transportation and environmental planning organization that serves as the metropolitan planning organization (MPO) and designated areawide water quality management agency for the counties of Cuyahoga, Geauga, Lake, Lorain, and Medina in Ohio.

NOACA is directed by a 45-member Board of Directors, representing the City of Cleveland and all five NOACA counties and their communities, plus transit agencies, the Northeast Ohio Regional Sewer District (NEORS), the Cleveland-Cuyahoga County Port Authority, the Ohio Environmental Protection Agency (Ohio EPA), and the Ohio Department of Transportation (ODOT). The NOACA region is home to 2.1 million people and over 150 units of government. The region is anchored by several urban core cities with the largest being Cleveland. More information about NOACA is available at [www.noaca.org](http://www.noaca.org).

Today, there are more than 272,000 traffic signals in the United States. They play an important role in the transportation network and are a source for significant frustration for the public when not operated efficiently. As the era of freeway building draws to a close, urban arterials are being called upon to carry more users than ever before at a time when the users of these facilities are growing more complex (older and more distracted drivers, larger vehicles, etc.) and the demand for such use continues to outpace transportation supply. Traffic signal timing efficiency degrades over time as volume patterns and magnitude change, development occurs, or infrastructure changes. Outdated or poor traffic signal timing accounts for a significant portion of traffic delay on urban arterials and traffic signal optimization is one of the most cost-effective ways to reduce emissions, improve mobility, reduce delays and improve corridor safety.

One solution to inefficient traffic signal timing is NOACA's signal timing optimization program (STOP). NOACA retained Albeck Gerken, Inc. to implement signal timing to improve the safe and efficient operation of the Warren Rd/West 150th Street traffic signal systems.

The goals of the STOP are to help Northeast Ohio achieve the following outcomes:

1. **Goal: Improve air quality** through decreased motor vehicle emissions and fuel consumption.
2. **Goal: Improve reliability** and predictability of travel along arterials.
3. **Goal: Improve the safety** of motorists, pedestrians, and bicyclists.

#### 1.3.1 Additional Studies

In addition to this STOP project, several other relevant studies exist, and include, but are not limited to the following:

- CUY-90-9.09 Safety Study
- CUY-10-10.14 Safety Study

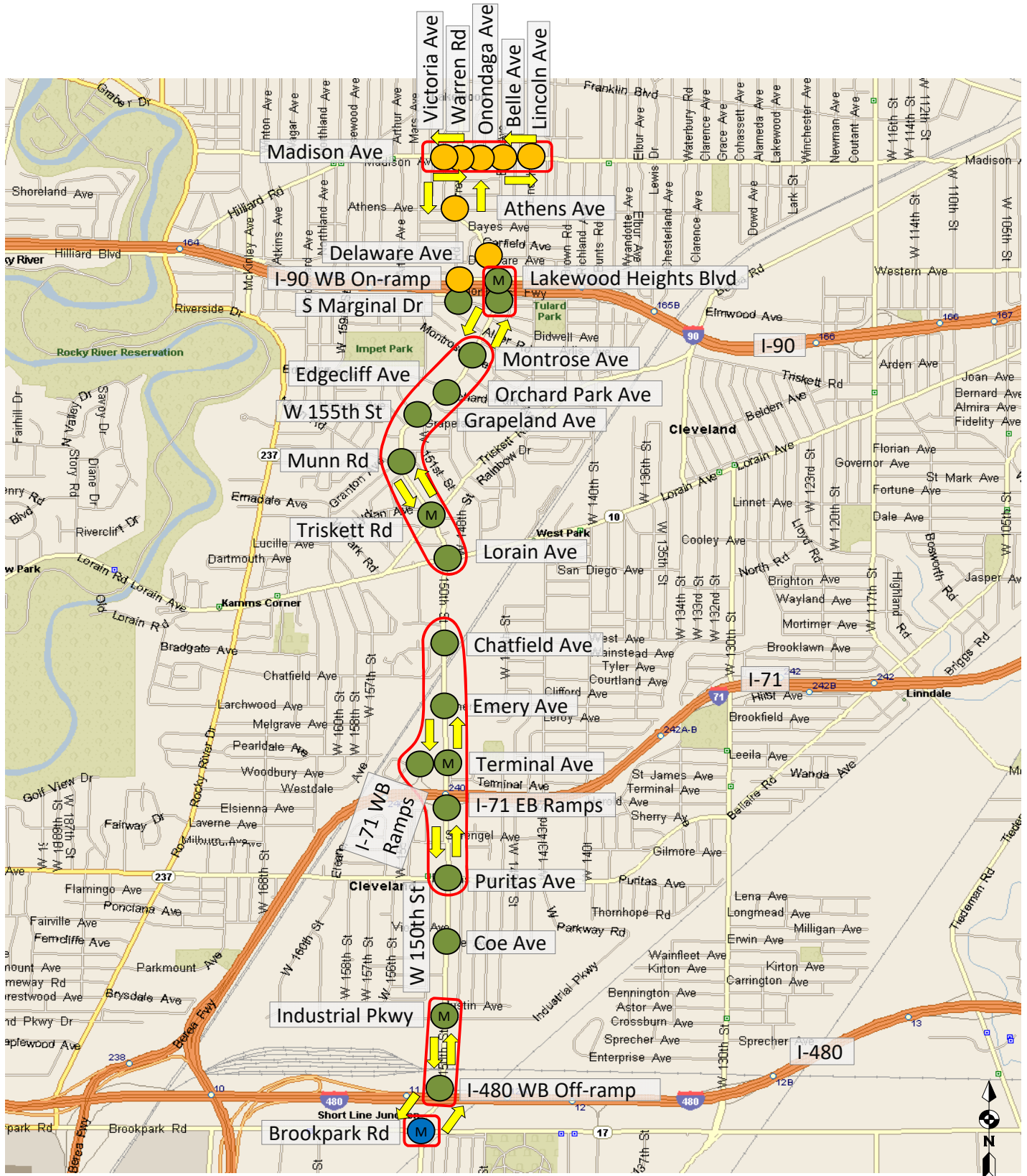
#### 1.3.2 Project Memorandums

Two technical memorandums were created in support of this STOP project assignment. These can be found at the following website, [www.albeckgerken.com/st-warren-rd](http://www.albeckgerken.com/st-warren-rd) and include:

- NOACA STOP Roadway Improvement Evaluation
- NOACA STOP Signalized Intersection Warrant Analysis

#### 1.3.3 Transit and Bicycles

In addition to passenger vehicle and pedestrian traffic, the Warren Road/West 150th Street corridor is relevant to transit and biking modes. The Greater Cleveland Regional Transit Authority's (GCRTA) Route 83 runs along Warren Road from Lorain Avenue through Madison Avenue and to the north. Route 86 also operated on Warren Road between Munn Road and Lorain Avenue.



- 7-Day, 24-Hour Count Location:
- City of Lakewood Study Intersection:
- City of Cleveland Study Intersection:
- City of Brook Park Study Intersection:
- Master Controller:
- System Boundary:

**Figure 1**  
 Traffic Signal Locations  
 Warren Rd/W 150th St



## 2.0 DATA COLLECTION

### 2.1 24-Hour Volumes

The 24-hour segment counts were conducted by the Mannik and Smith Group (MSG) staff during May of 2018. These counts were conducted at seven locations along Warren Road/West 150th Street to illustrate the various traffic patterns that occur during a typical day. The weekday Average Daily Traffic (ADT) volume along Warren Road between Madison Avenue and Triskett Road is approximately 18,400 and the ADT for weekends is approximately 15,900. The weekday ADT volume along West 150th Street between Emery Avenue and Brookpark Road is approximately 24,400 and the ADT for weekends is approximately 17,600. The weekday ADT volume along Madison Avenue between Victoria Avenue/Reveley Avenue and Lincoln Avenue is approximately 10,900 and the ADT for weekends is approximately 9,050. The highest volume collected was at the count location on West 150th Street north of Interstate 71 and has a weekday ADT of 33,350 and weekend ADT of 26,800. Figure 2 through Figure 14 on pages 5 – 17 depict the weekday hourly volumes, Saturday hourly volumes, and hourly volumes by day for each location.

### 2.2 Turning Movement Counts

Turning movement counts (TMCs) were conducted by Loukas Engineering staff during May of 2018. TMCs were collected from 6:00 am – 8:00 am, 12:00 pm – 2:30 pm, 3:00 pm – 5:30 pm, and 6:15 pm – 7:15 pm on weekdays. On Saturdays, the intersections were counted from 8:30 am – 10:00 am, 10:00 am – 3:30 pm, and 6:00 pm – 7:00 pm. TMC diagrams illustrating hourly volumes for each developed timing pattern can be found in the Traffic Operations Analysis figures in the [Appendix](#).

Detailed TMC data can also be found in the [Appendix](#). The TMCs include passenger and heavy vehicles, along with pedestrian/bicycle volumes. Video units were used to obtain the counts. The video and a variety of reports can be viewed or downloaded from <https://datalink.miovision.com/projects/1VjATzm2bAWqHEfaj1HdPLvV>.

### 2.3 Traffic Signal Timing and Phasing

Existing controller data were obtained via either direct connect in the field or from a central system, which was the case for the five signals long Madison Avenue.

### 2.4 Field Notes & Approach Photographs

Field notes were collected by Albeck Gerken, Inc. staff at each intersection on various signal and traffic characteristics to assist in model development and signal optimization. For each approach, vehicle and pedestrian clearance distances and median widths were measured. Vehicle detection was checked and pedestrian push buttons (if present) were tested for proper operation. Other unusual or unique characteristics were also recorded. Field notes and approach photos can be found in the [Appendix](#).

### 2.5 Aerial Photographs

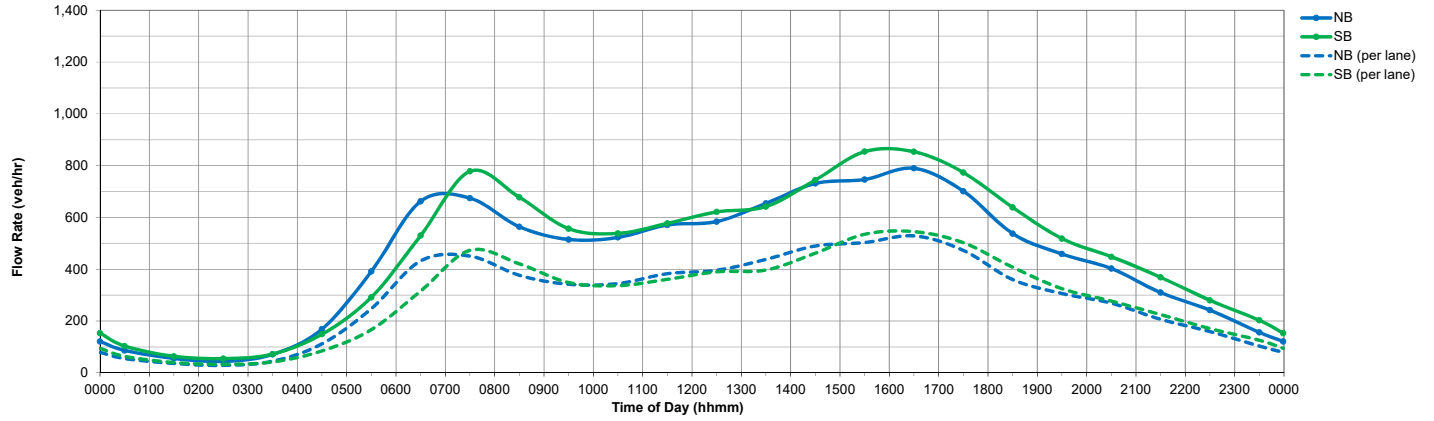
Aerial photographs (accessed from various online sources such as Google Earth) were utilized to gain a wider perspective of the intersections and corridors. The type of land use along the corridor and the number and location of access points (driveways and unsignalized intersections) between signalized intersections were observed using aerial photographs, which can be found in the [Appendix](#).

### 2.6 Travel Time Runs

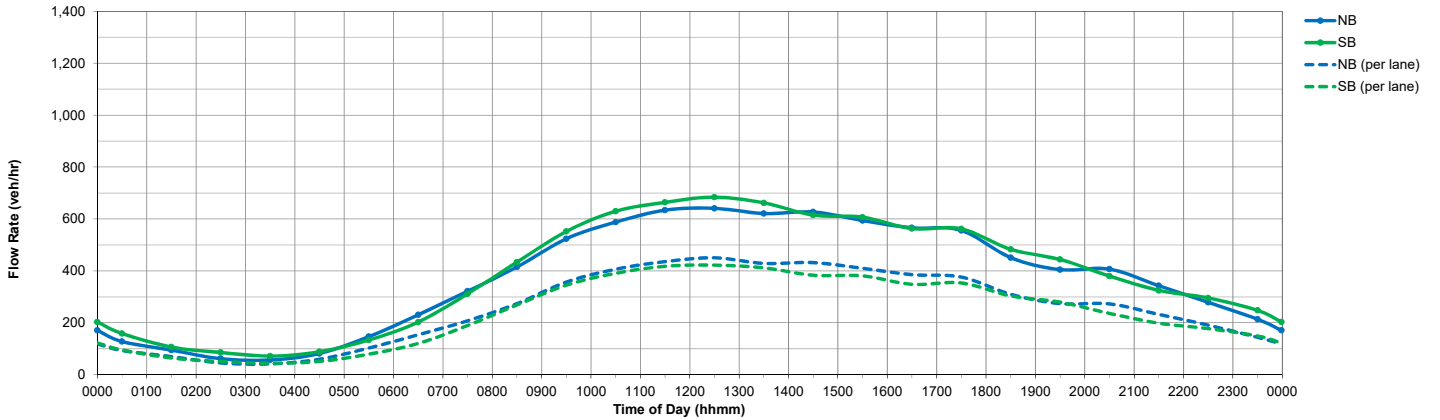
Travel time runs were conducted during each period under existing and implemented signal timings. These data were collected to provide a field-measured metric by which existing and implemented signal timing can be compared. Travel time runs were also conducted during implementation to fine-tune splits and offsets. Travel time data is presented in Section 8.4 of this report. Complete travel time data can be found in the [Appendix](#).

Hourly Volumes - Warren Rd/W 150th St - Average from Madison Ave to Brookpark Rd

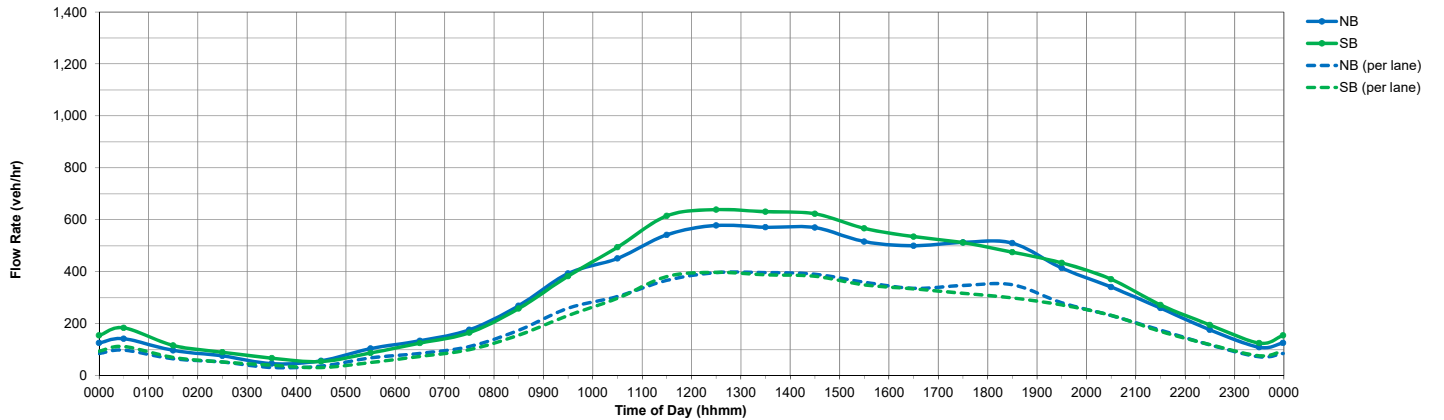
Weekday Average Hourly Volumes



Saturday Hourly Volumes



Sunday Hourly Volumes



Hourly Volumes by Day

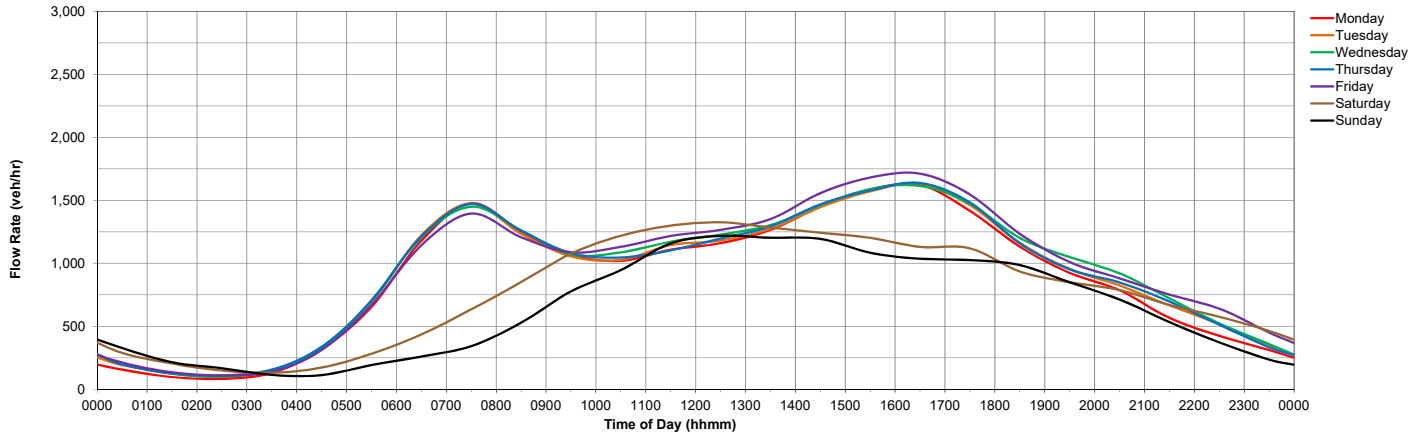


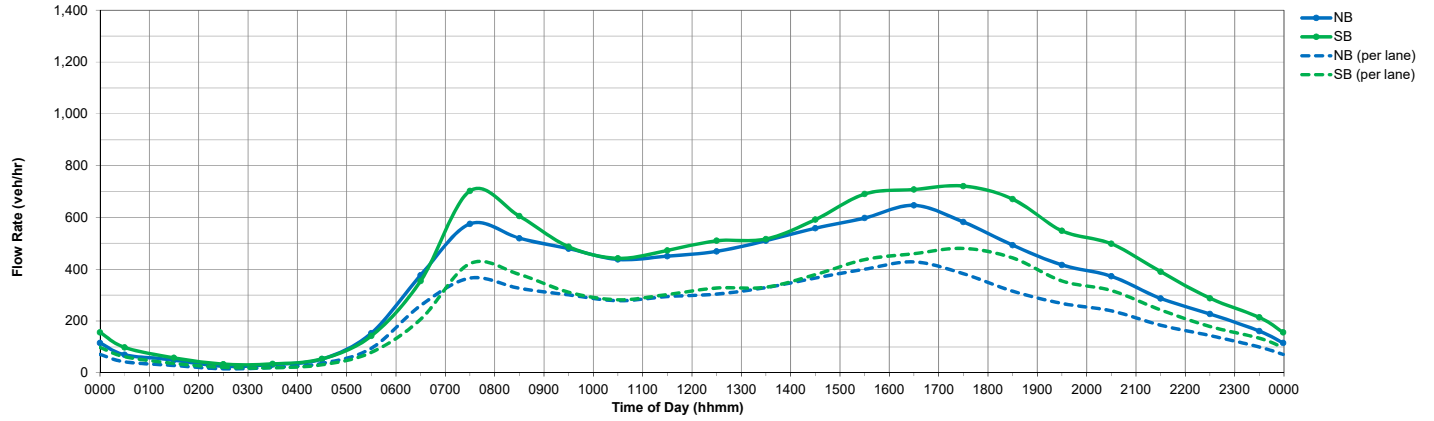
Figure 2

7-Day, 24-Hour Volumes

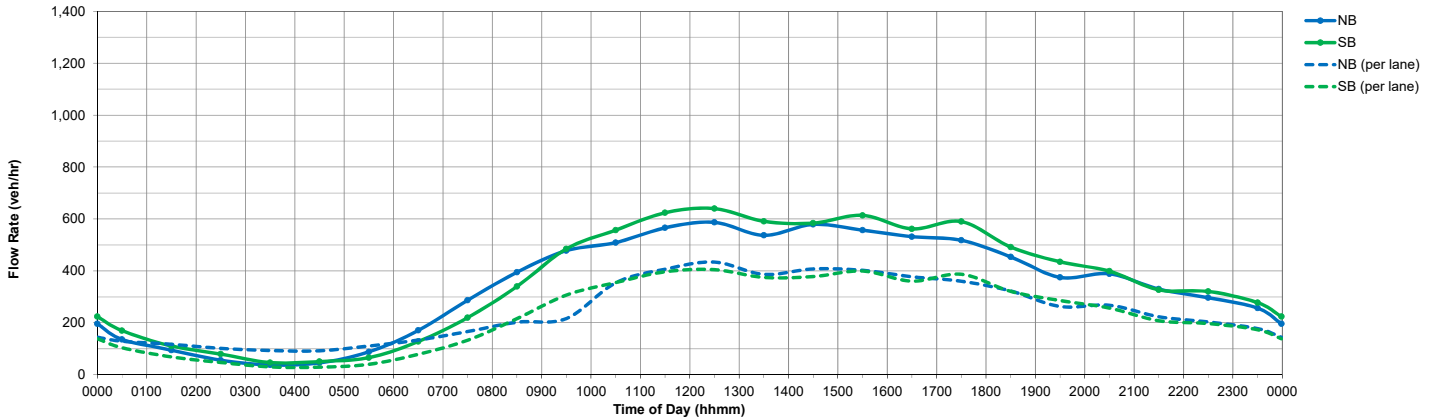
Warren Rd/W 150th St - Average from Madison Ave to Brookpark Rd

Hourly Volumes - Warren Rd - Average from Madison Ave to Triskett Rd

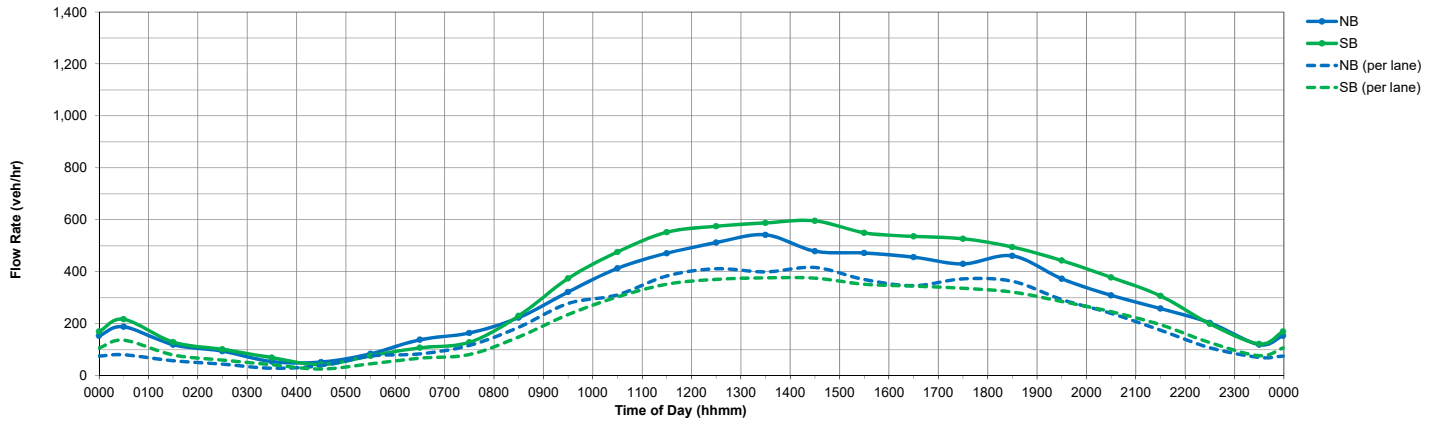
Weekday Average Hourly Volumes



Saturday Hourly Volumes



Sunday Hourly Volumes



Hourly Volumes by Day

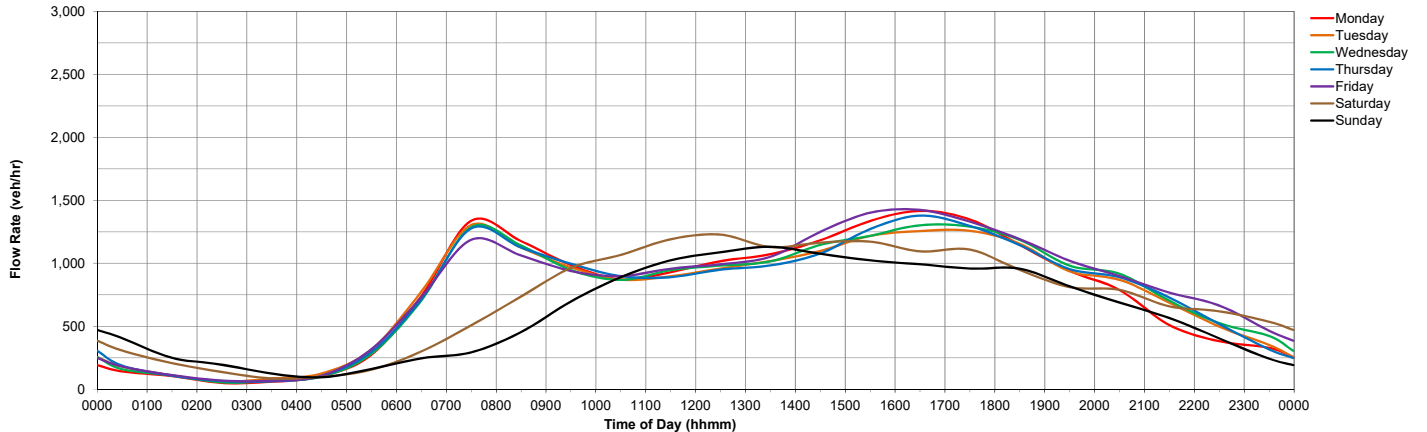


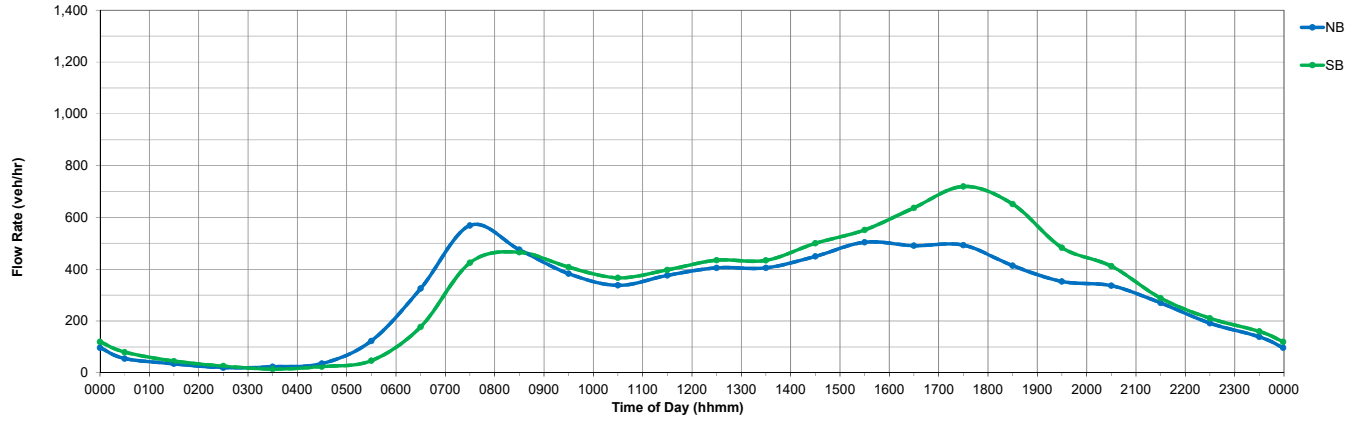
Figure 3

7-Day, 24-Hour Volumes

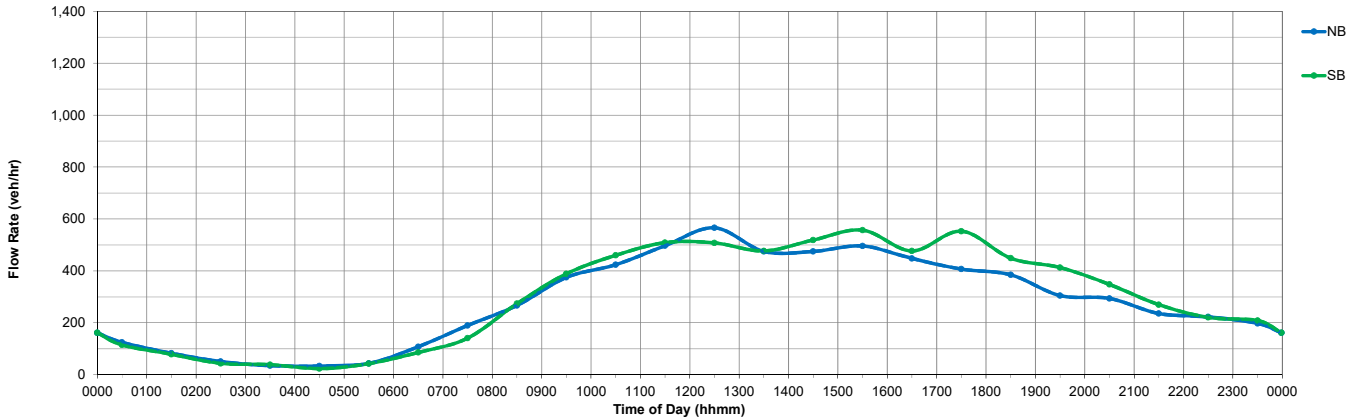
Warren Rd - Average from Madison Ave to Triskett Rd

Hourly Volumes - Warren Rd between Madison Ave and Athens Ave

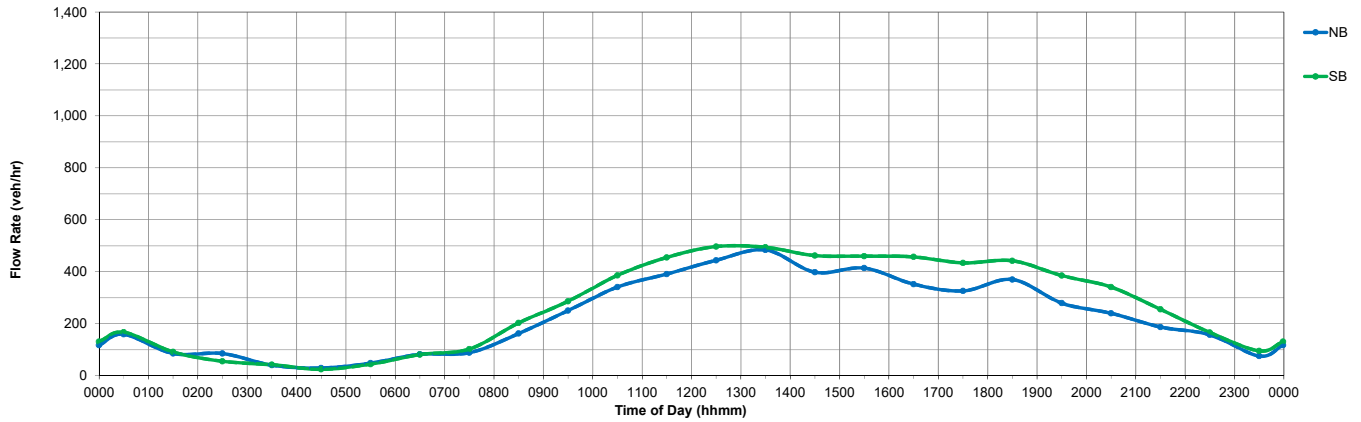
Weekday Average Hourly Volumes



Saturday Hourly Volumes



Sunday Hourly Volumes



Hourly Volumes by Day

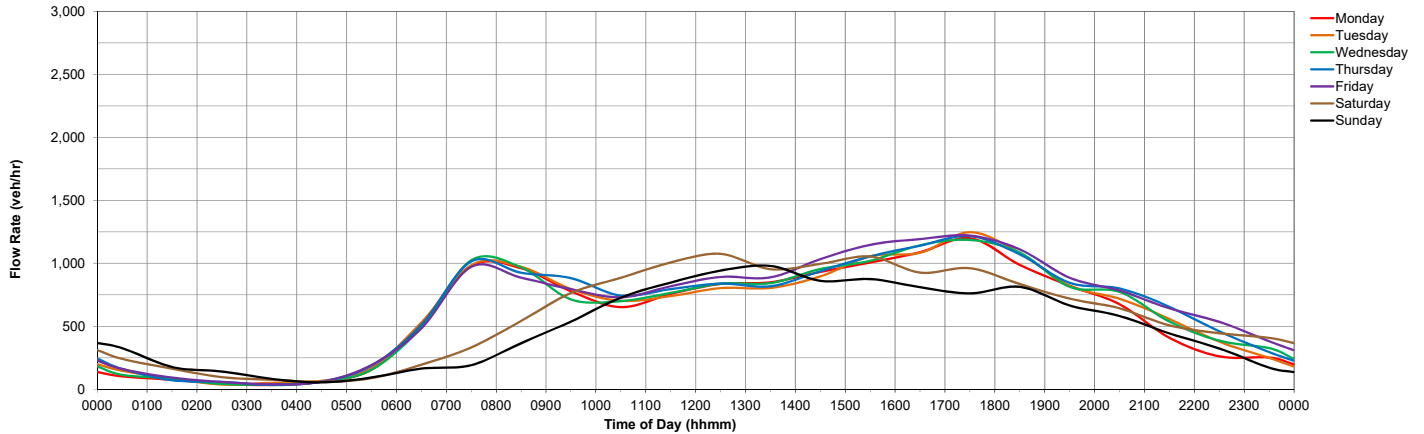
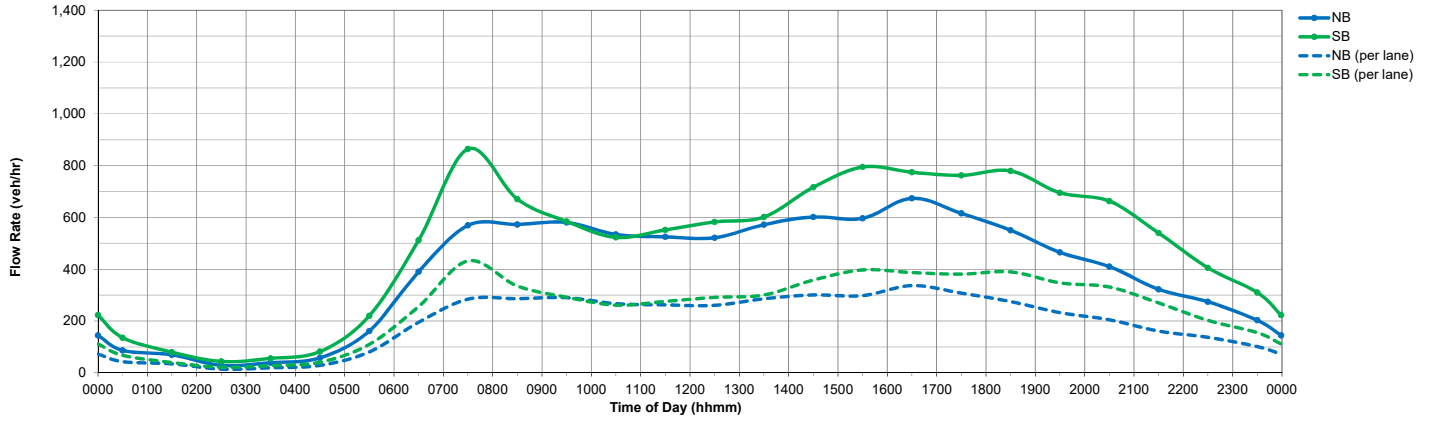


Figure 4  
7-Day, 24-Hour Volumes  
Warren Rd between Madison Ave and Athens Ave

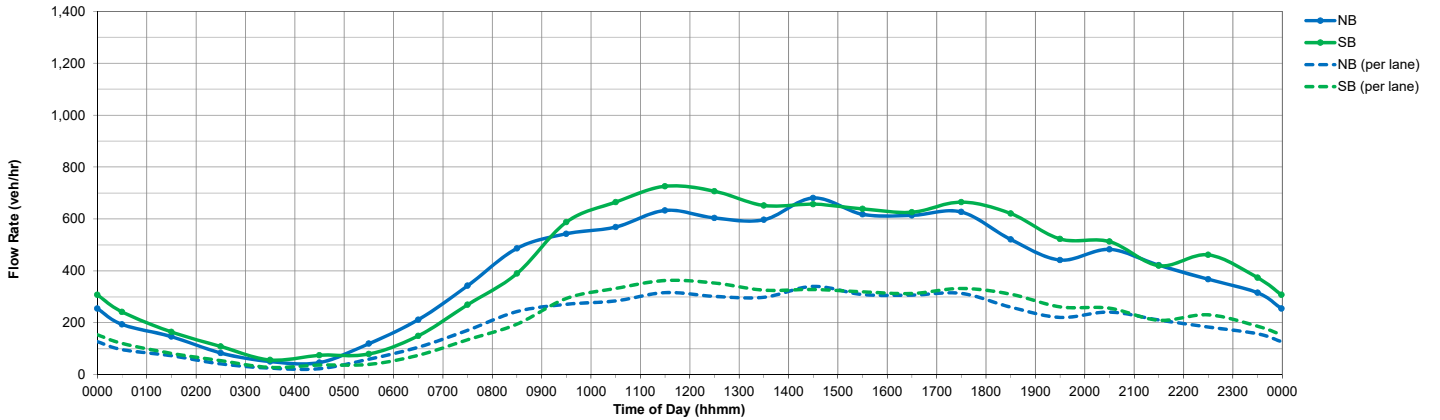


Hourly Volumes - Warren Rd South of Interstate 90

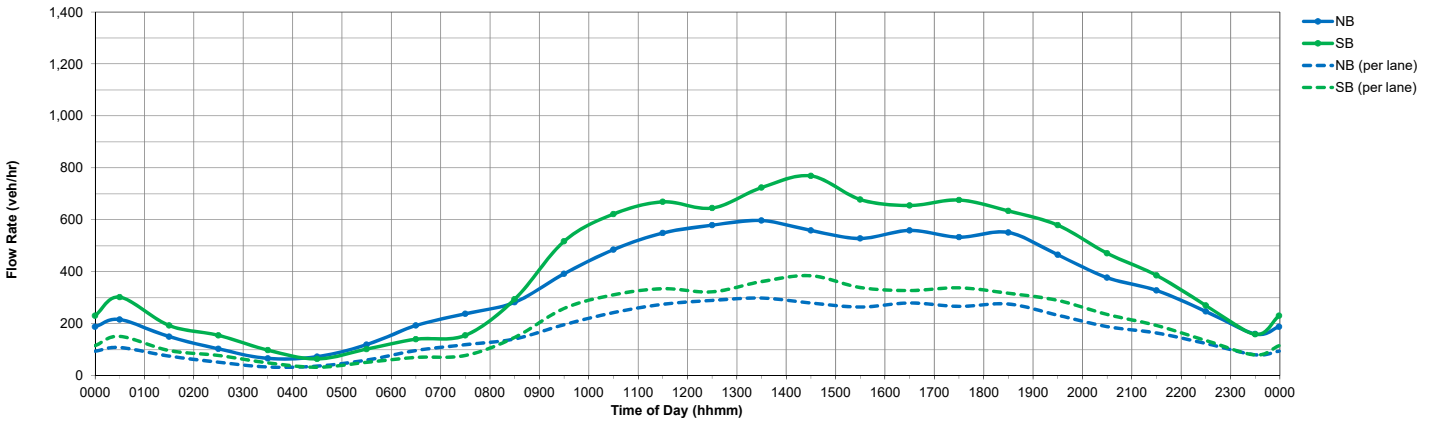
Weekday Average Hourly Volumes



Saturday Hourly Volumes



Sunday Hourly Volumes



Hourly Volumes by Day

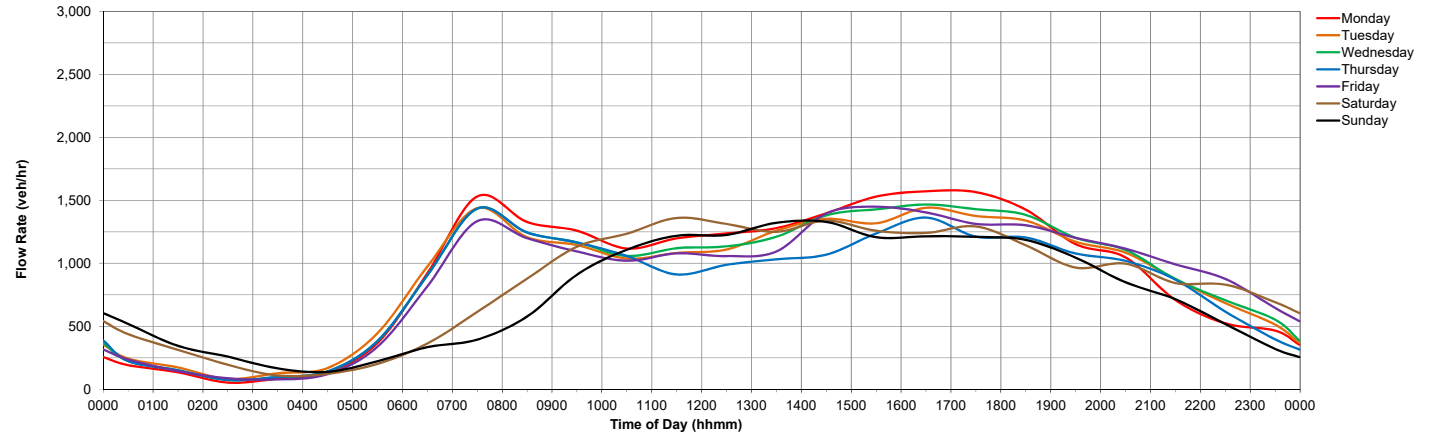
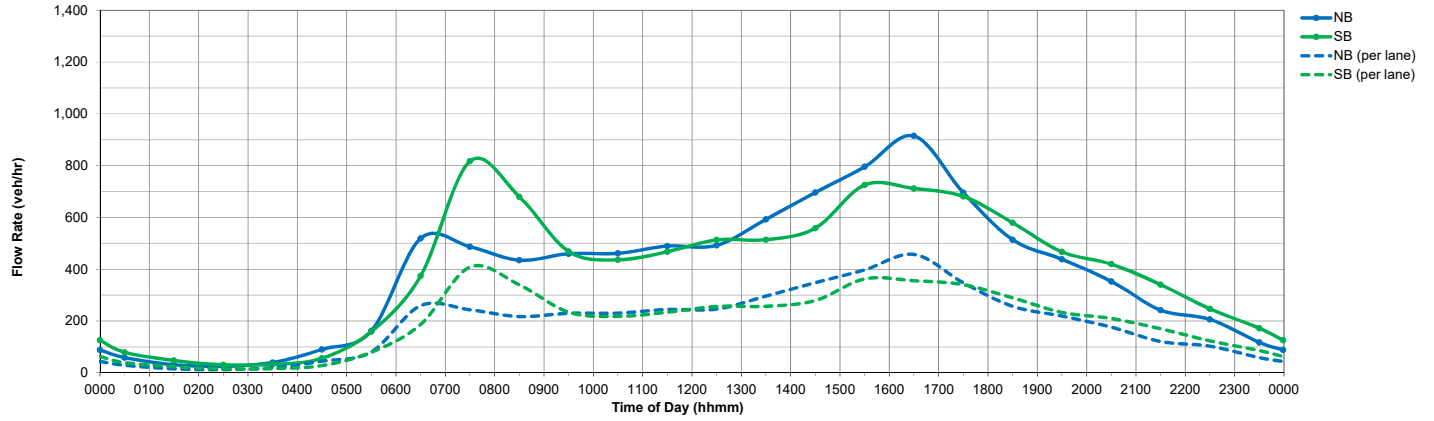


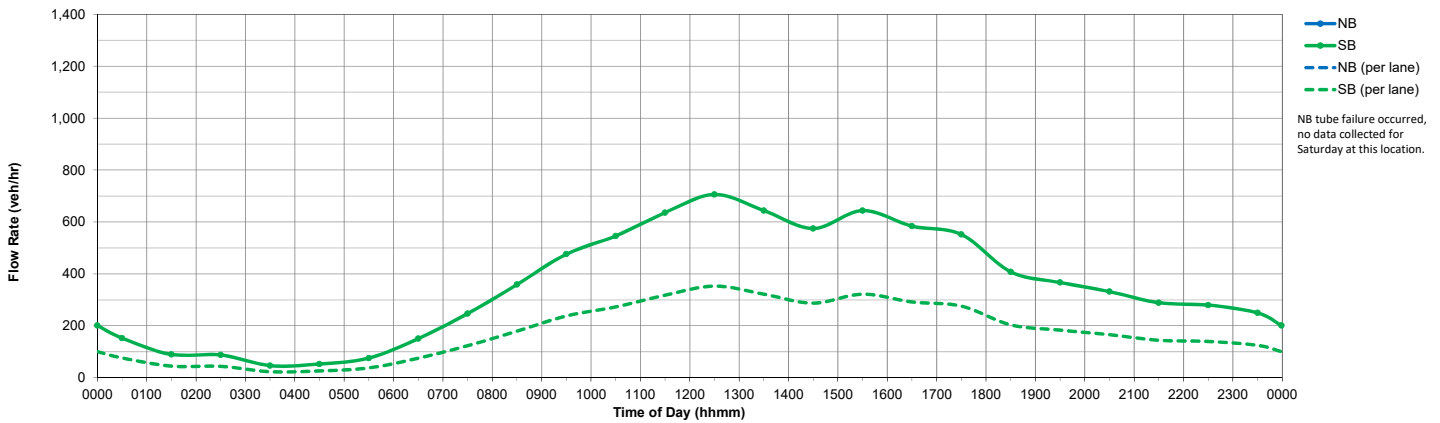
Figure 5  
7-Day, 24-Hour Volumes  
Warren Rd South of Interstate 90

Hourly Volumes - Warren Rd between Munn Rd and Triskett Rd

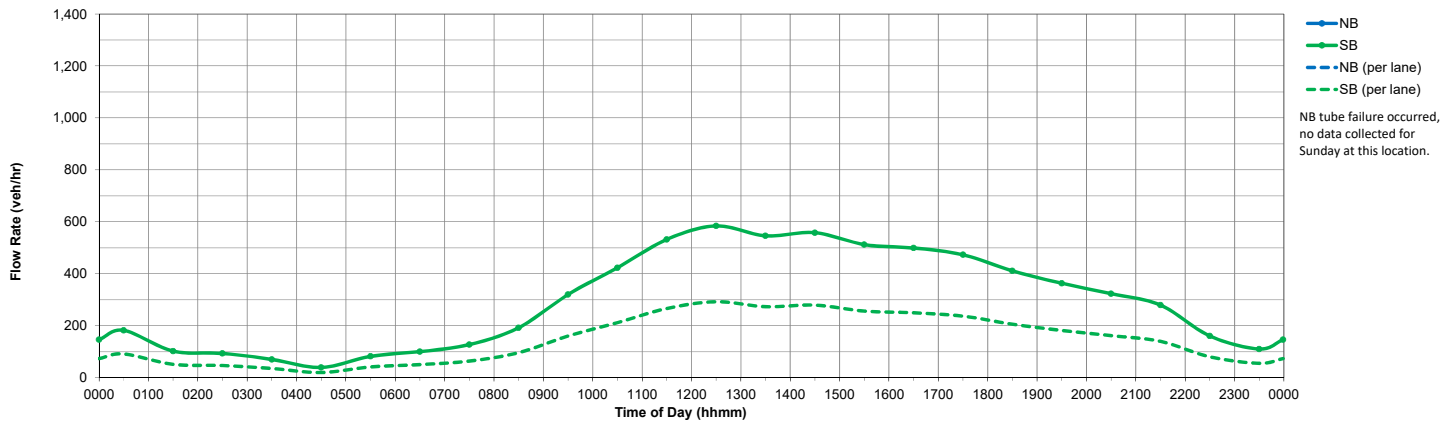
Weekday Average Hourly Volumes



Saturday Hourly Volumes



Sunday Hourly Volumes



Hourly Volumes by Day

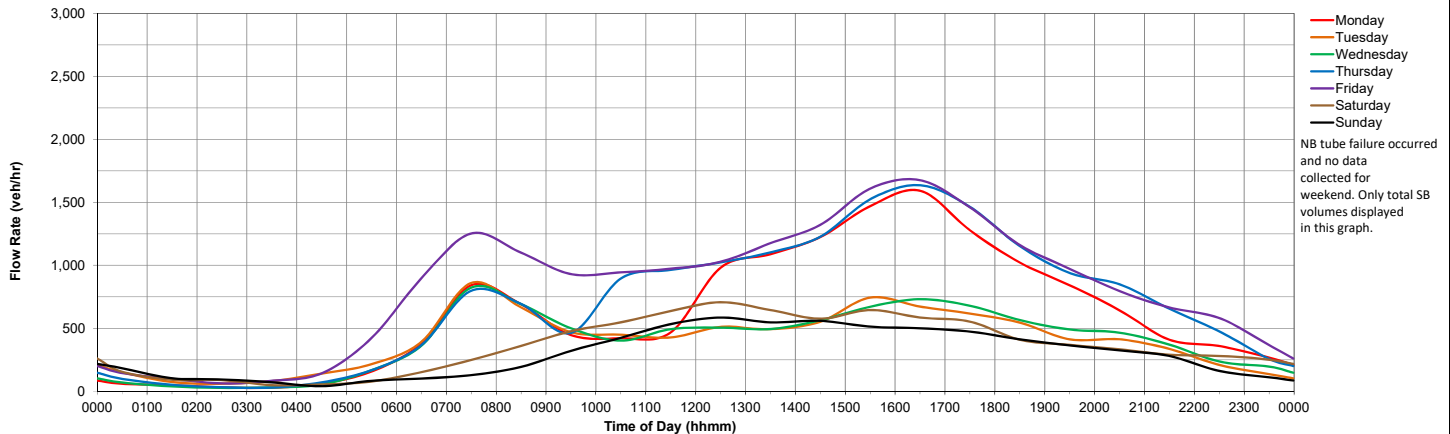
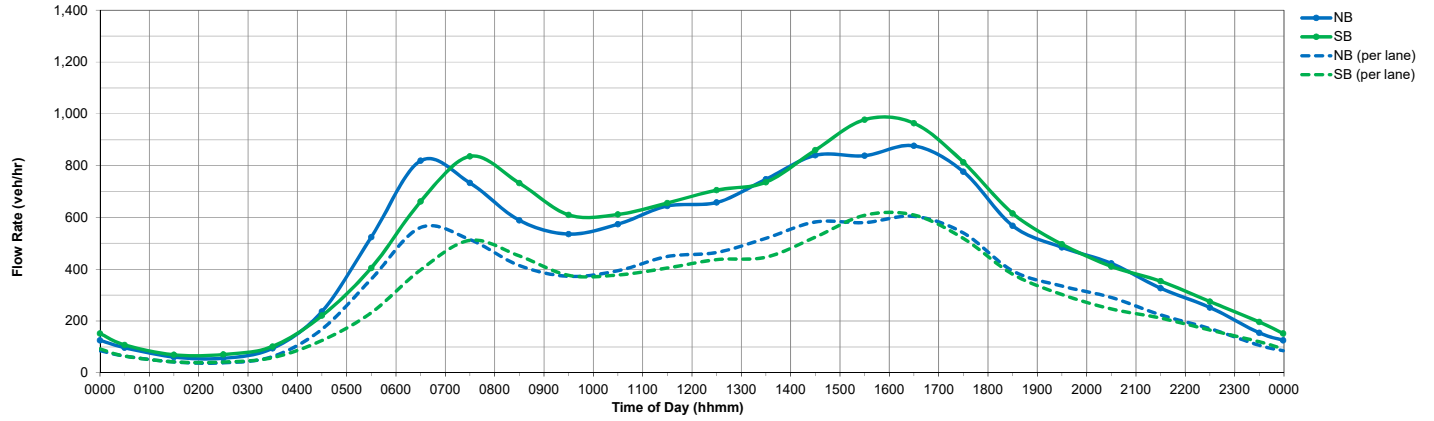


Figure 6  
7-Day, 24-Hour Volumes  
Warren Rd between Munn Rd and Triskett Rd

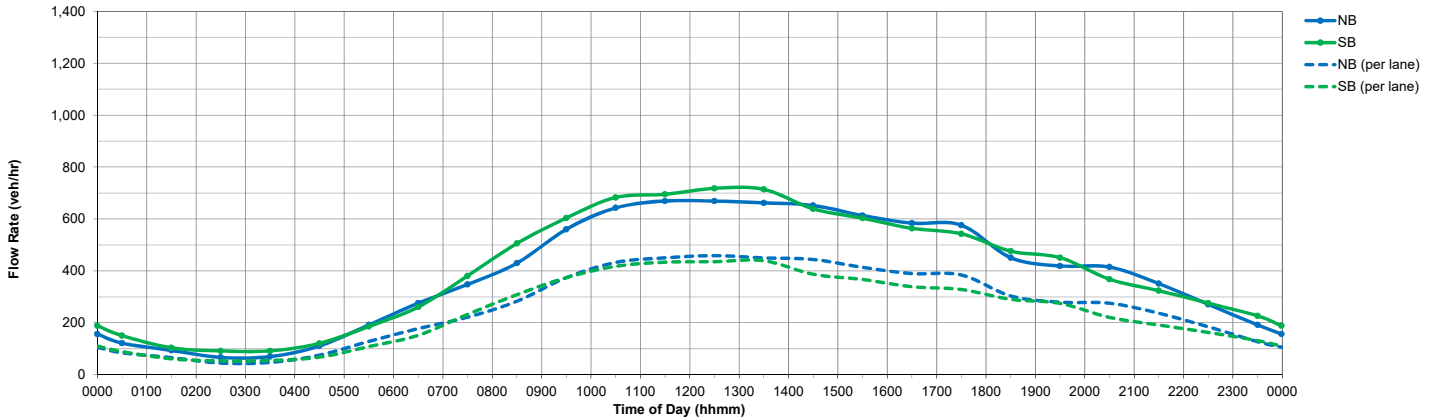


Hourly Volumes - W 150th St - Average from Emery Ave to Brookpark Rd

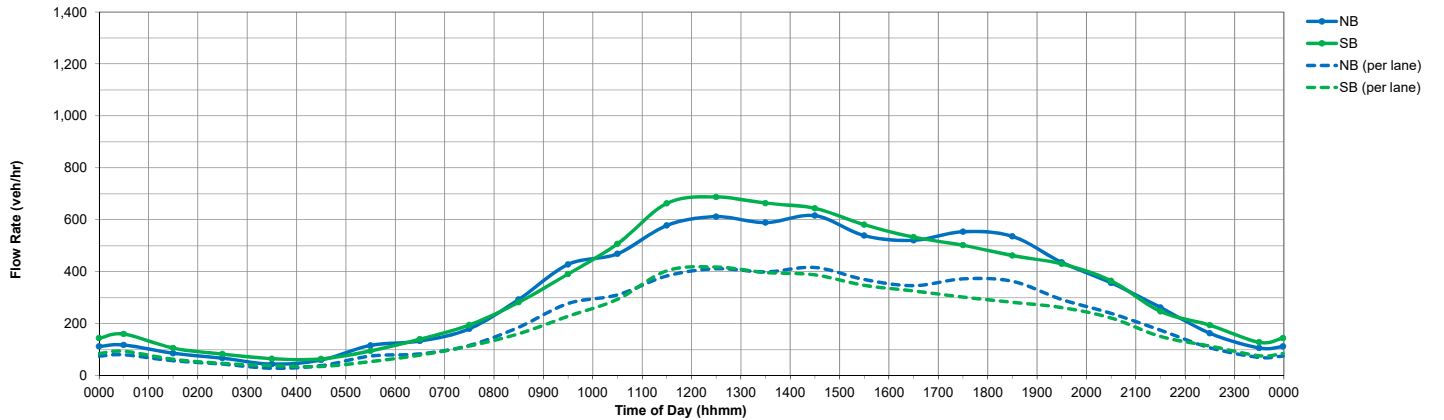
Weekday Average Hourly Volumes



Saturday Hourly Volumes



Sunday Hourly Volumes



Hourly Volumes by Day

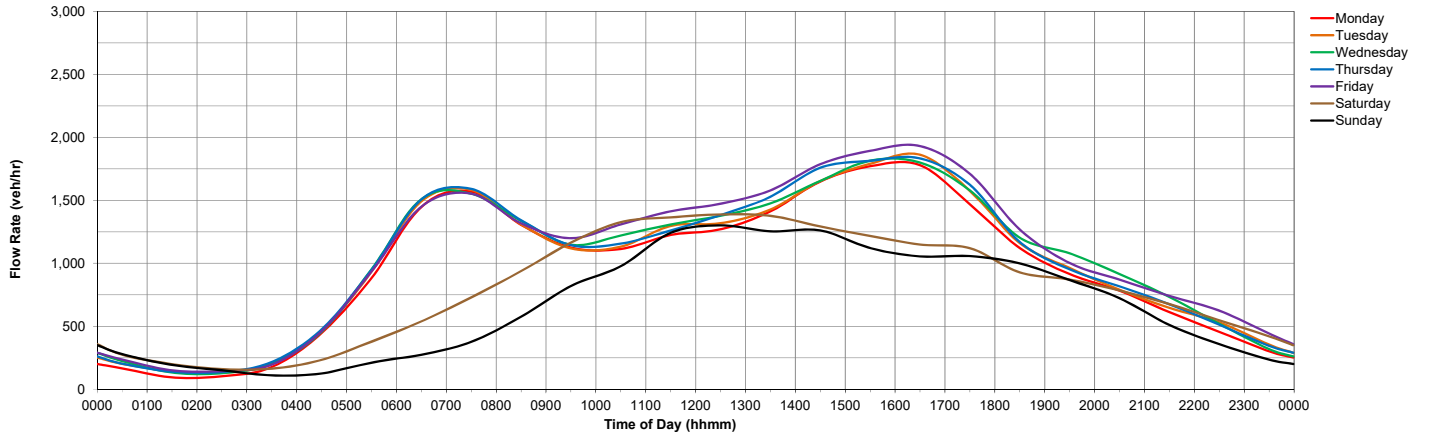


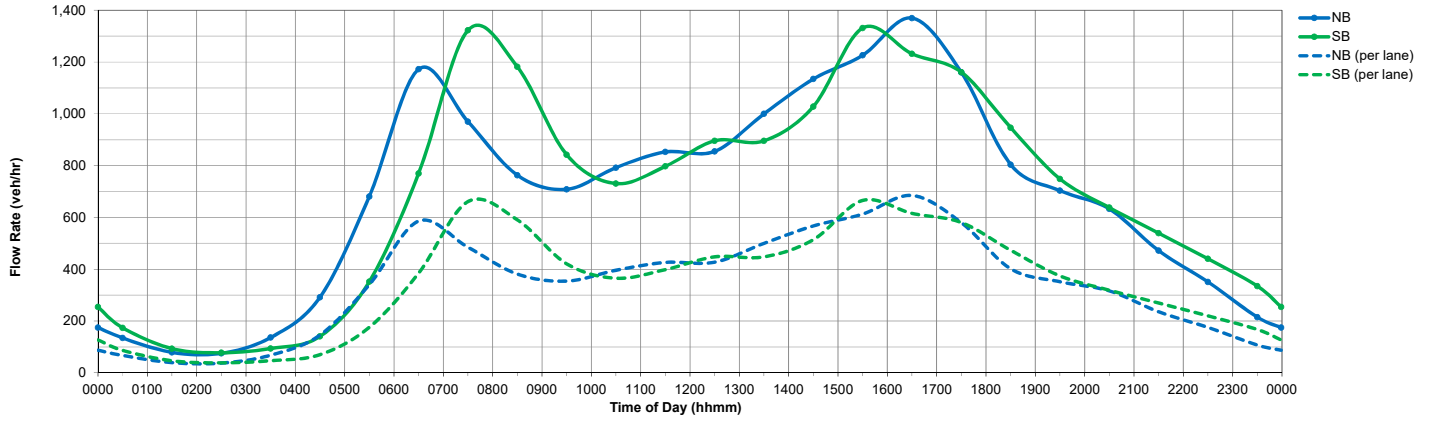
Figure 7

7-Day, 24-Hour Volumes

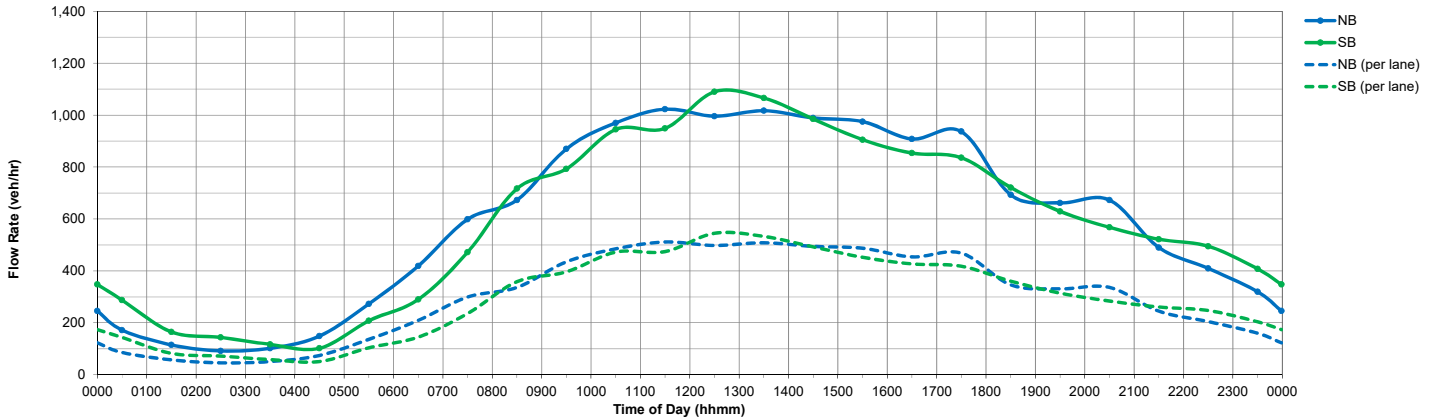
W 150th St - Average from Emery Ave to Brookpark Rd

### Hourly Volumes - W 150th St North of Interstate 71

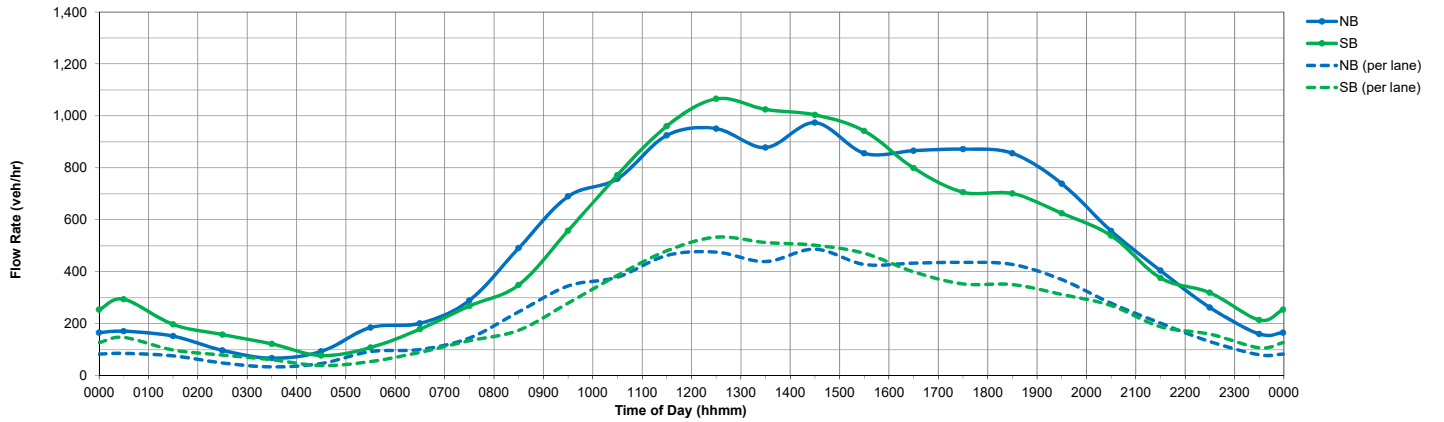
#### Weekday Average Hourly Volumes



#### Saturday Hourly Volumes



#### Sunday Hourly Volumes



#### Hourly Volumes by Day

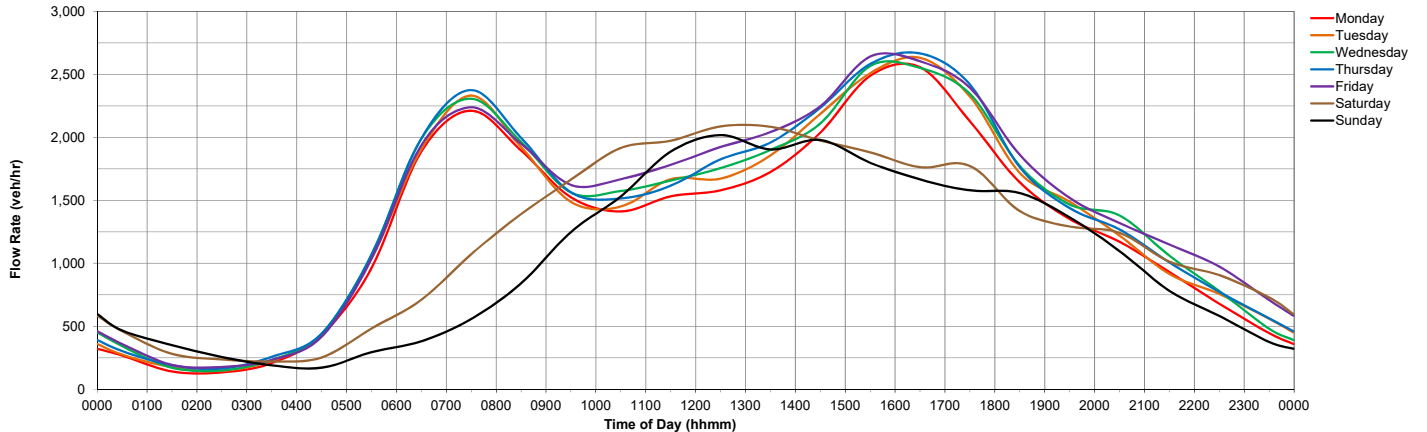
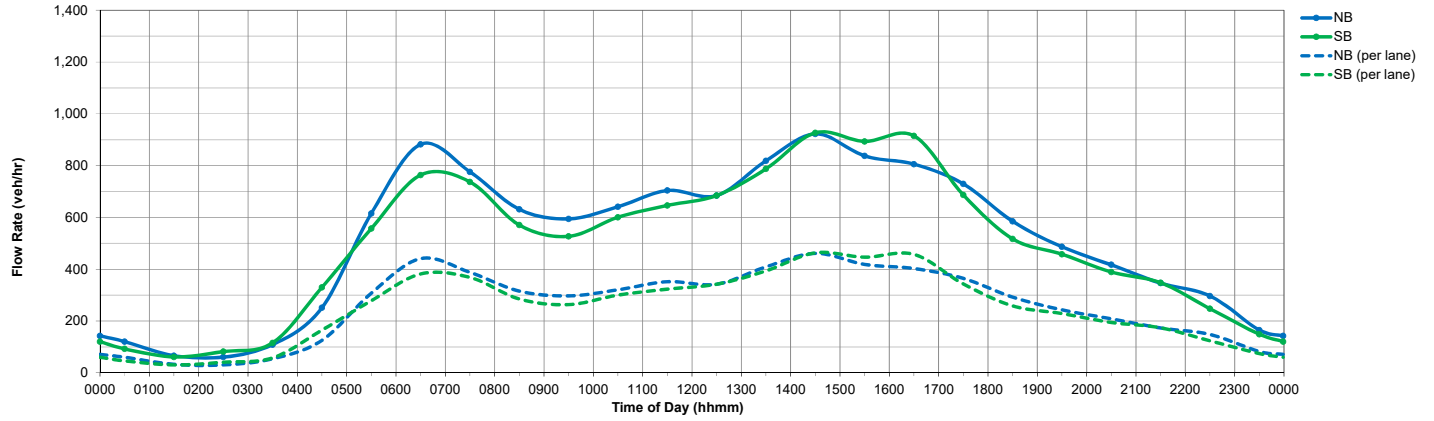


Figure 8

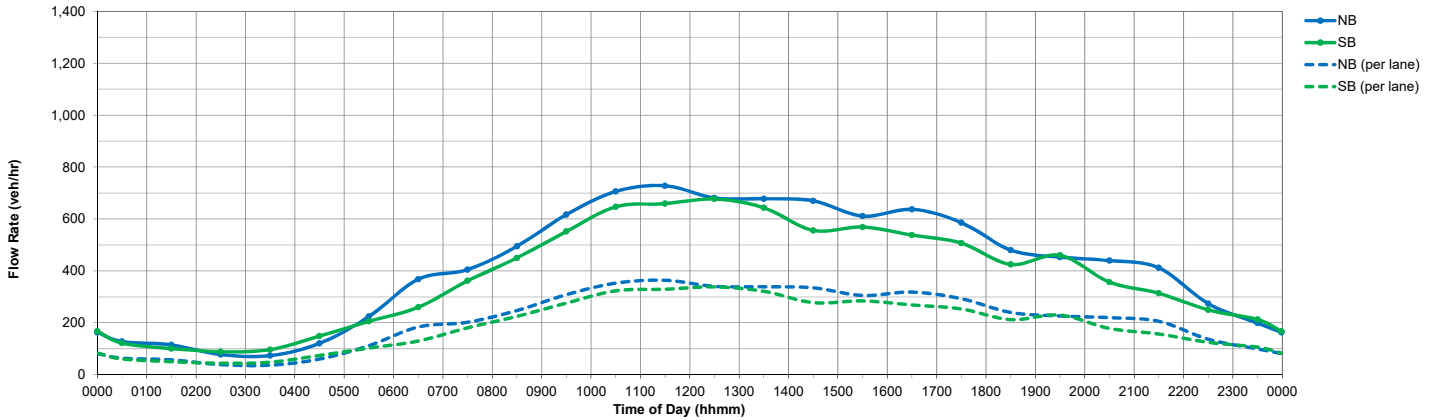
7-Day, 24-Hour Volumes  
W 150th St North of Interstate 71

Hourly Volumes - W 150th St South of Interstate 71

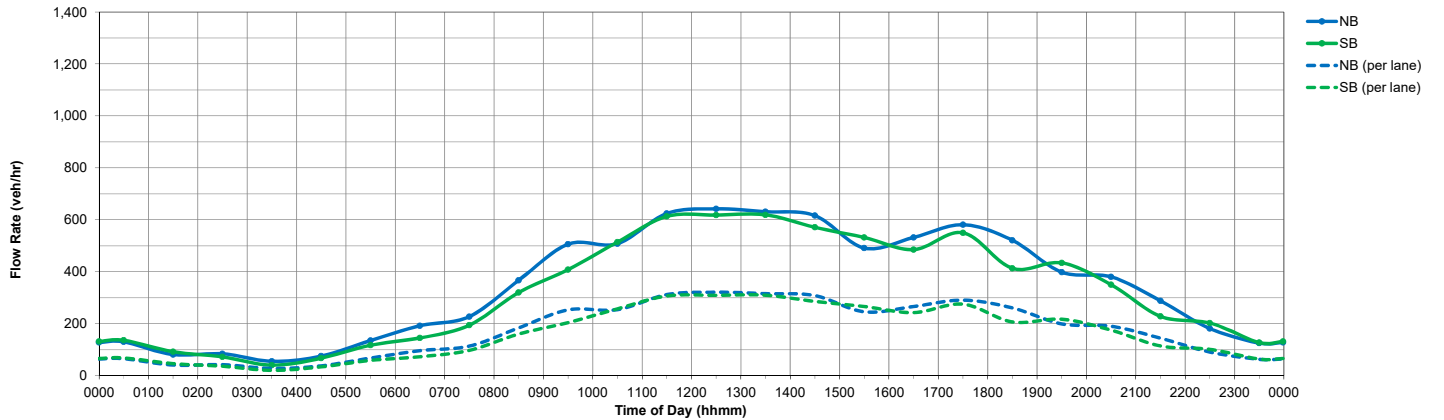
Weekday Average Hourly Volumes



Saturday Hourly Volumes



Sunday Hourly Volumes



Hourly Volumes by Day

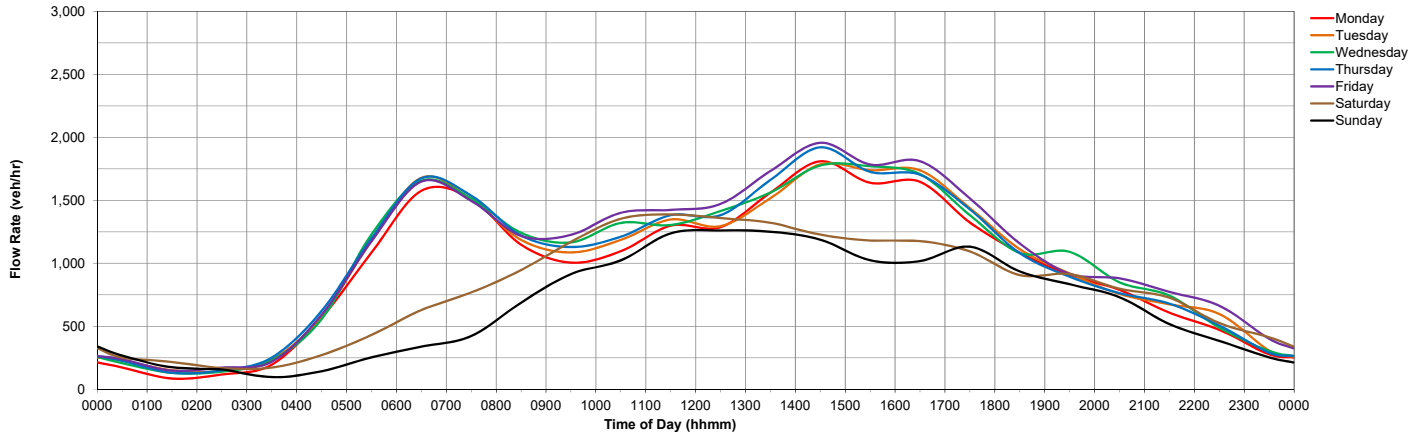
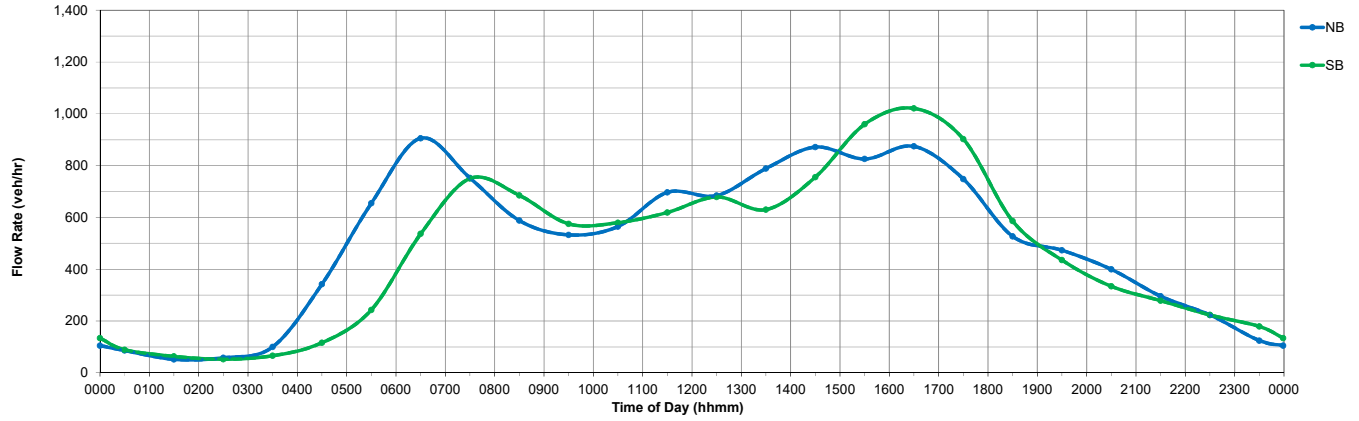


Figure 9

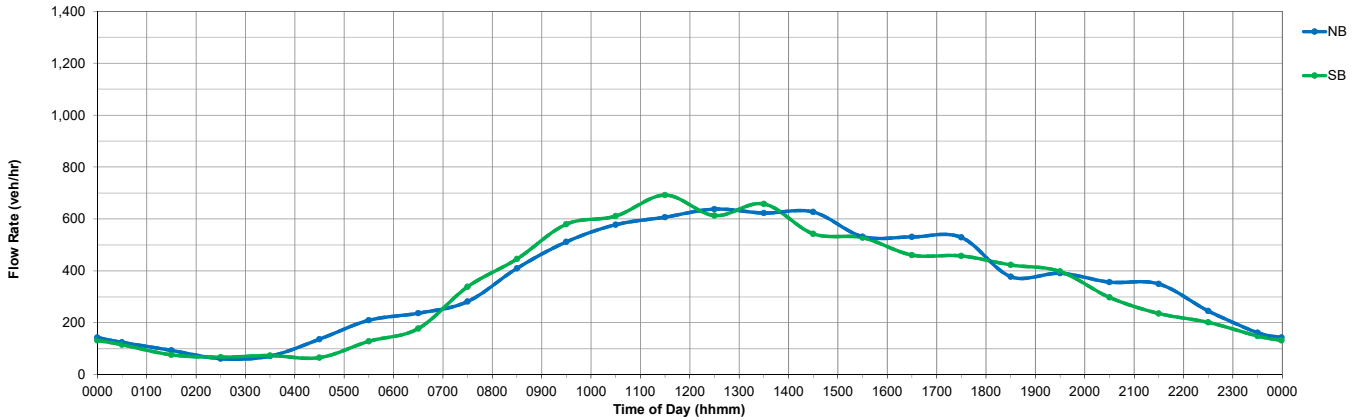
7-Day, 24-Hour Volumes  
W 150th St South of Interstate 71

Hourly Volumes - W 150th St South of Industrial Pkwy

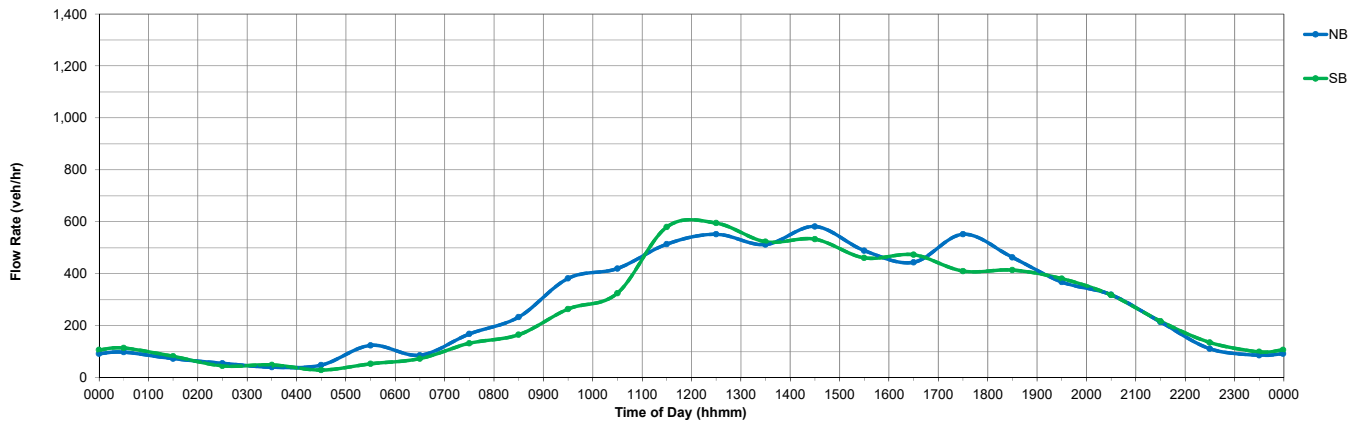
Weekday Average Hourly Volumes



Saturday Hourly Volumes



Sunday Hourly Volumes



Hourly Volumes by Day

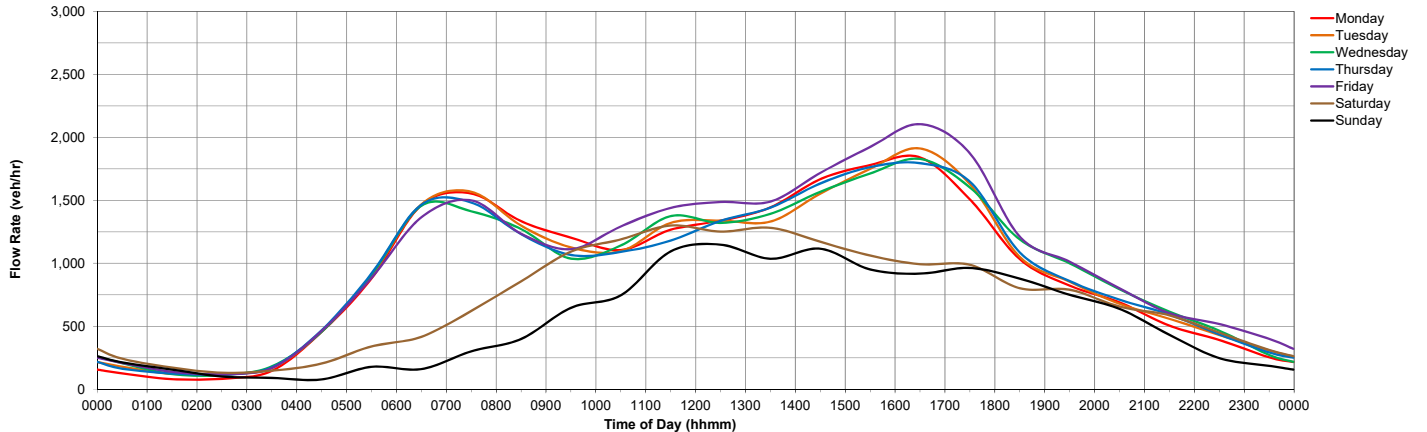
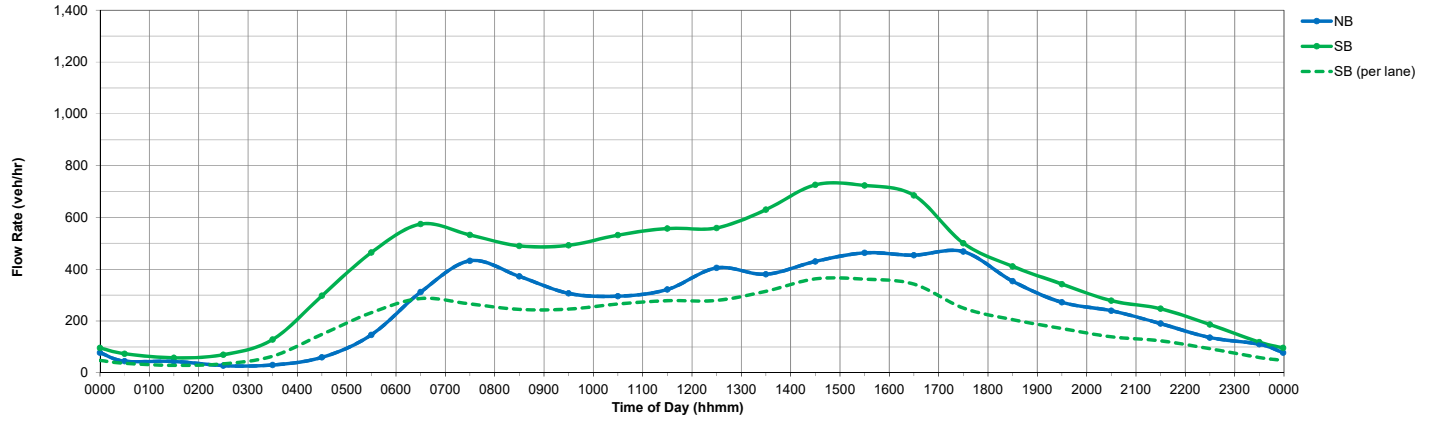


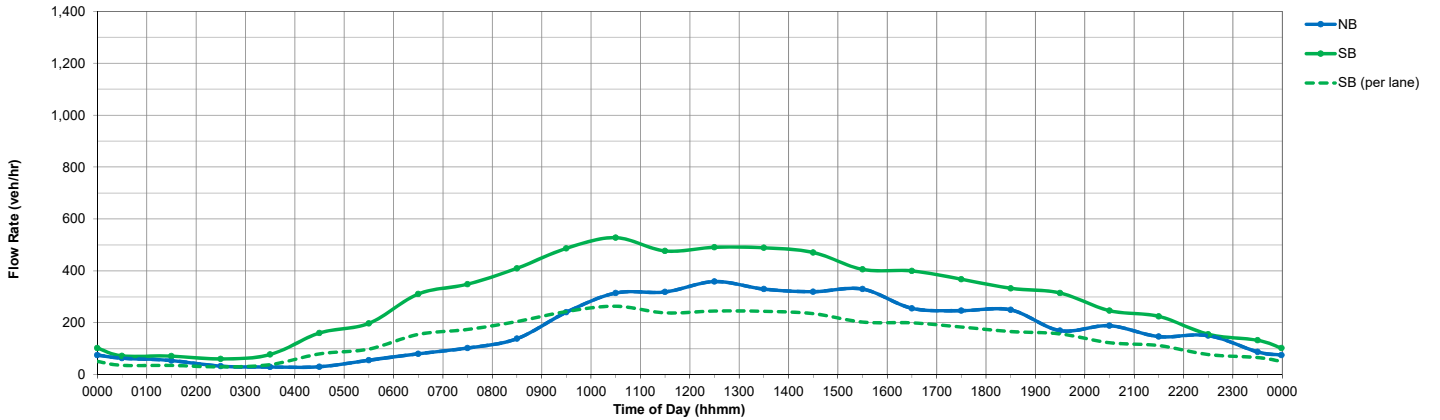
Figure 10  
7-Day, 24-Hour Volumes  
W 150th St South of Industrial Pkwy

Hourly Volumes - W 150th St North of Brookpark Rd

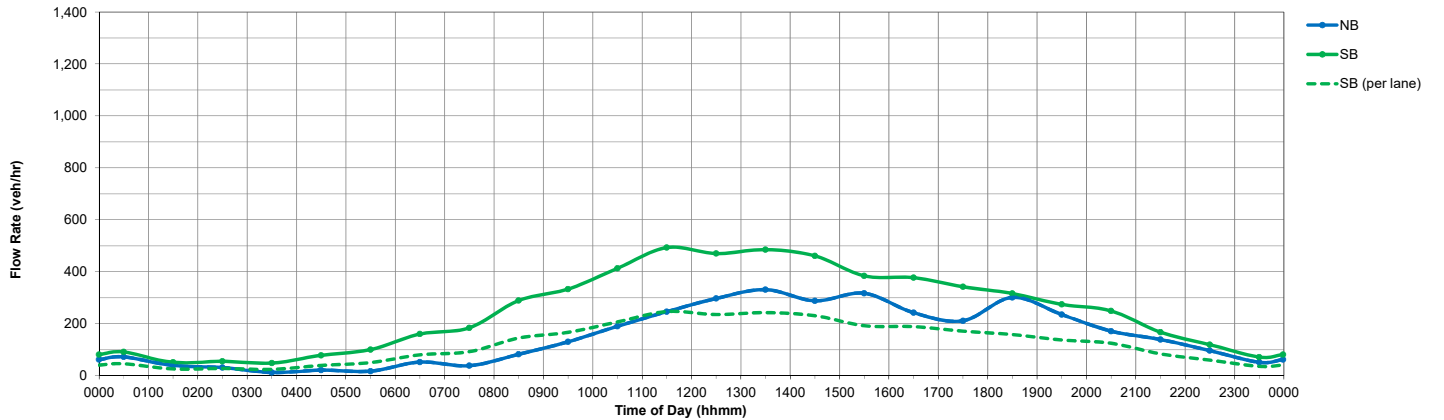
Weekday Average Hourly Volumes



Saturday Hourly Volumes



Sunday Hourly Volumes



Hourly Volumes by Day

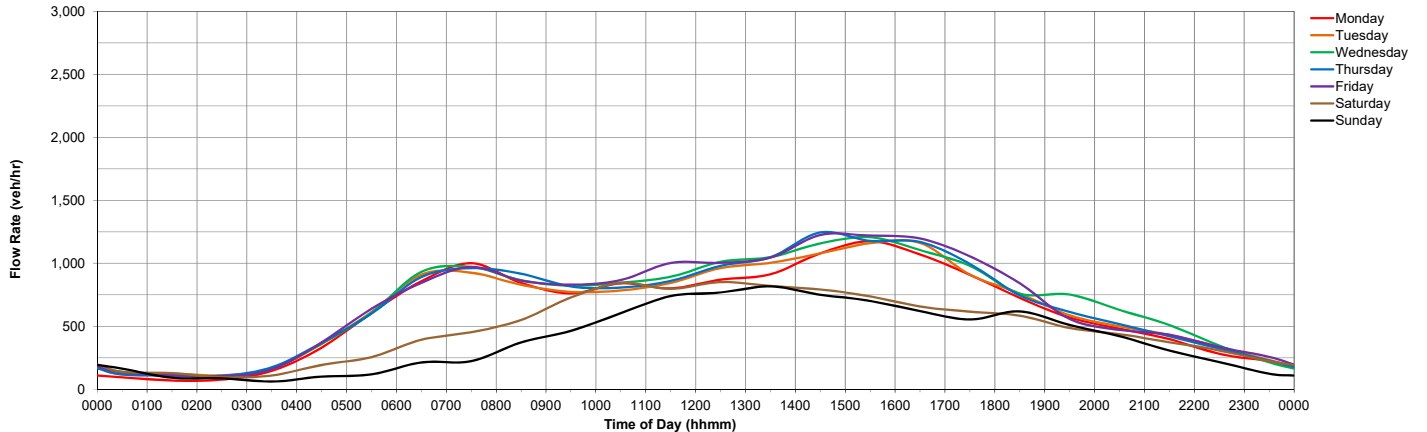
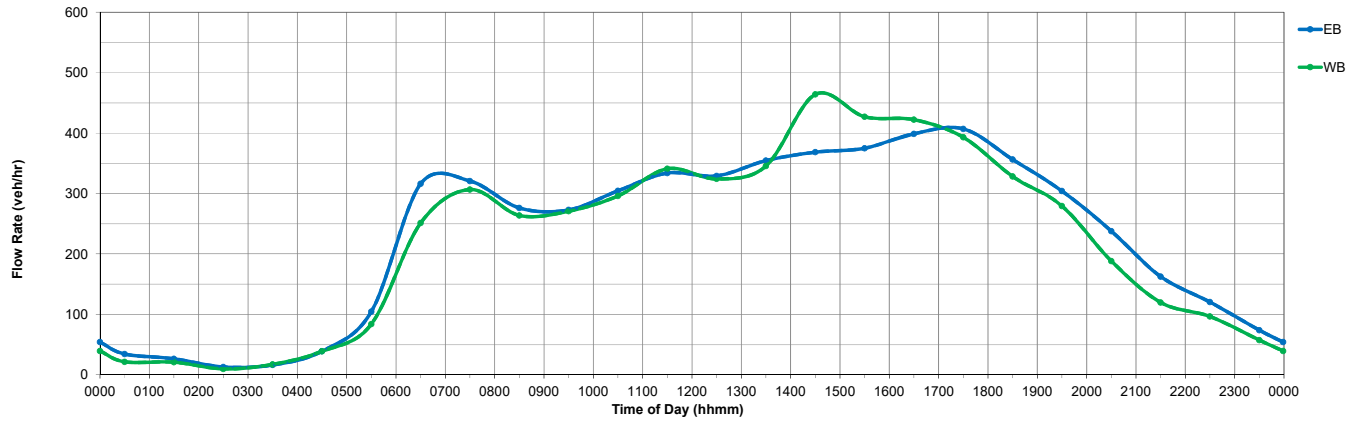


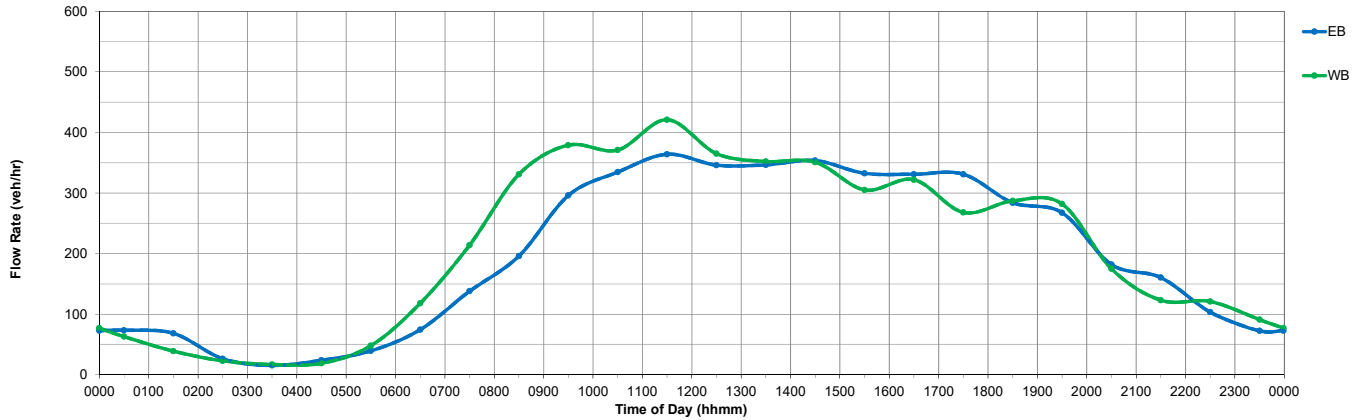
Figure 11  
7-Day, 24-Hour Volumes  
W 150th St North of Brookpark Rd

Hourly Volumes - Madison Ave - Average from Victoria Ave/Reveley Ave to Lincoln Ave

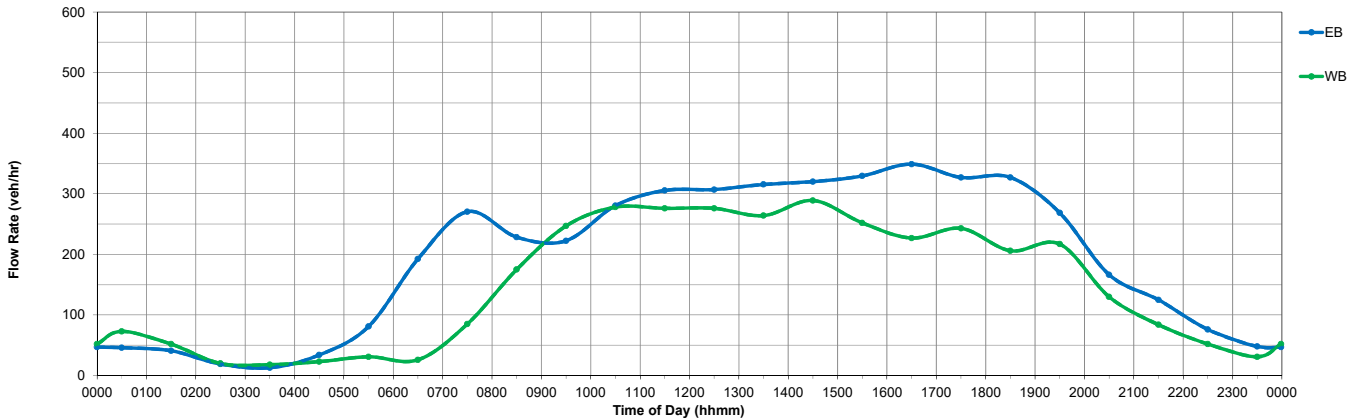
Weekday Average Hourly Volumes



Saturday Hourly Volumes



Sunday Hourly Volumes



Hourly Volumes by Day

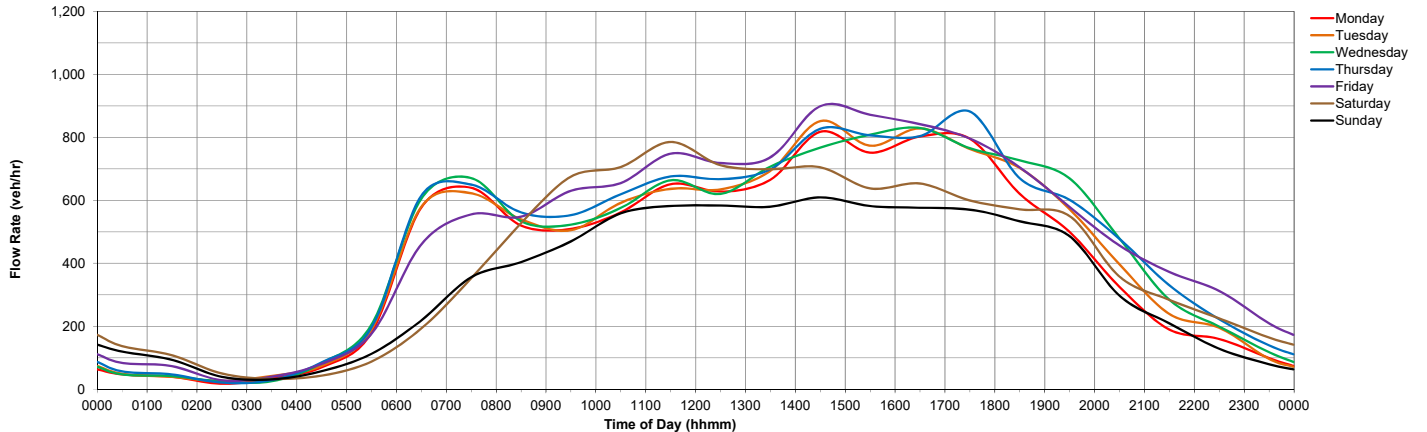


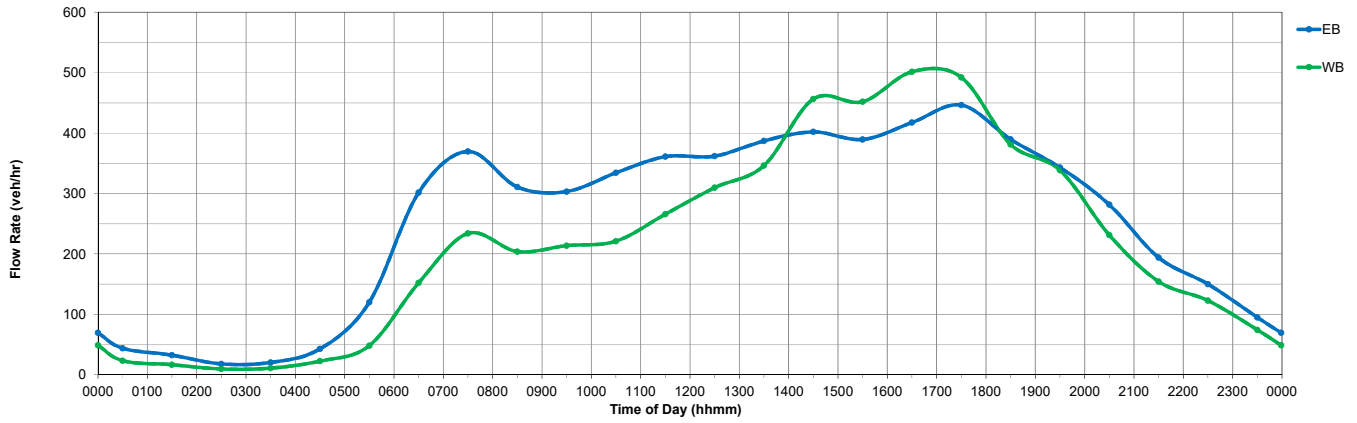
Figure 12

7-Day, 24-Hour Volumes

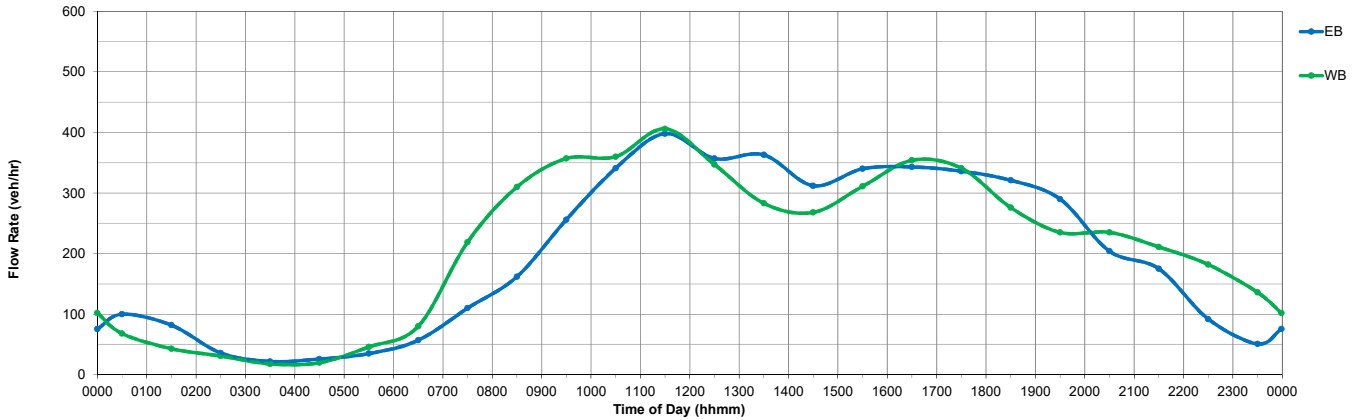
Madison Ave - Average from Victoria Ave/Reveley Ave to Lincoln Ave

Hourly Volumes - Madison Ave between Victoria Ave/Reveley Ave and Warren Rd

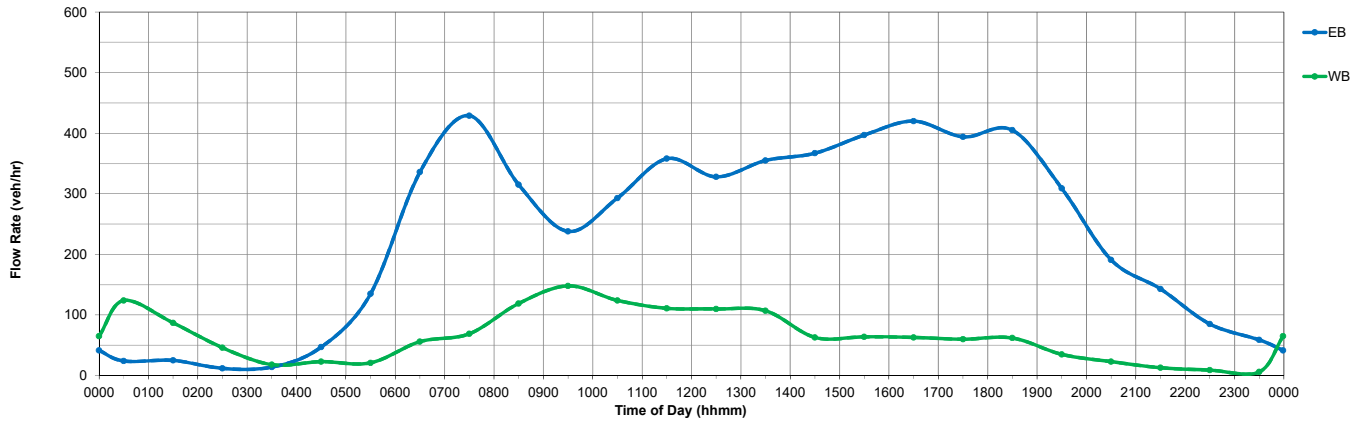
Weekday Average Hourly Volumes



Saturday Hourly Volumes



Sunday Hourly Volumes



Hourly Volumes by Day

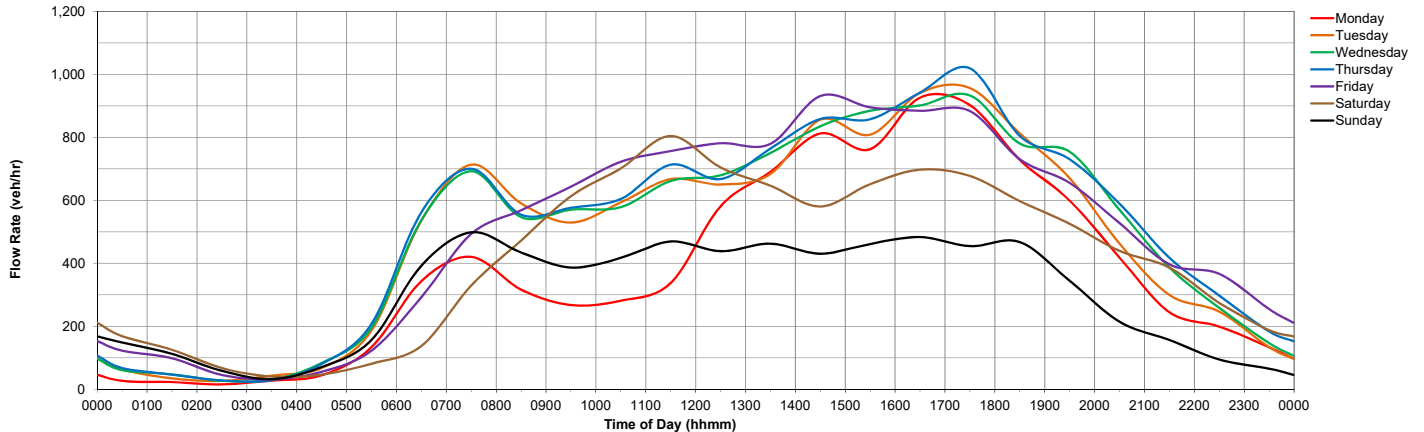


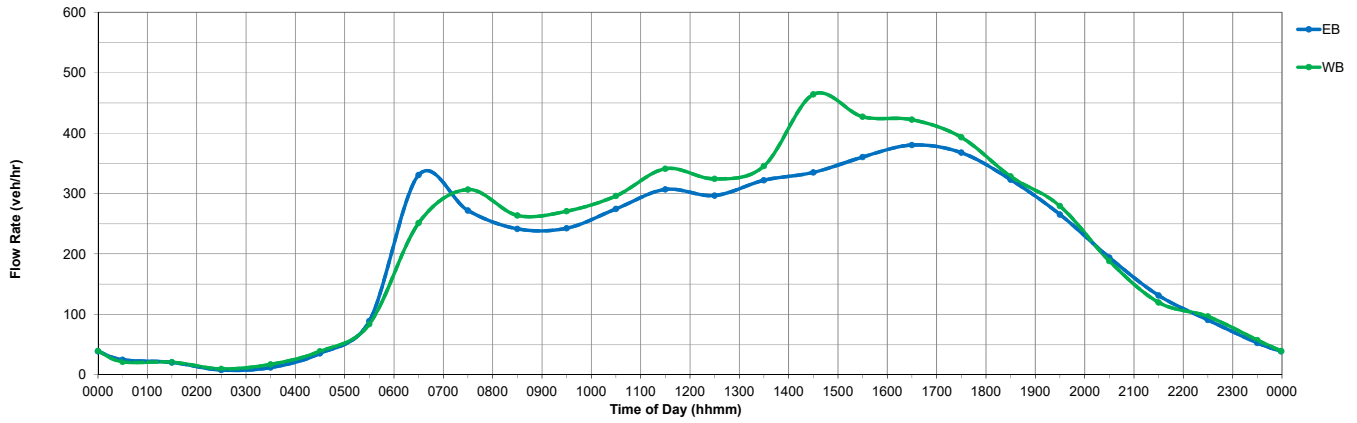
Figure 13

7-Day, 24-Hour Volumes

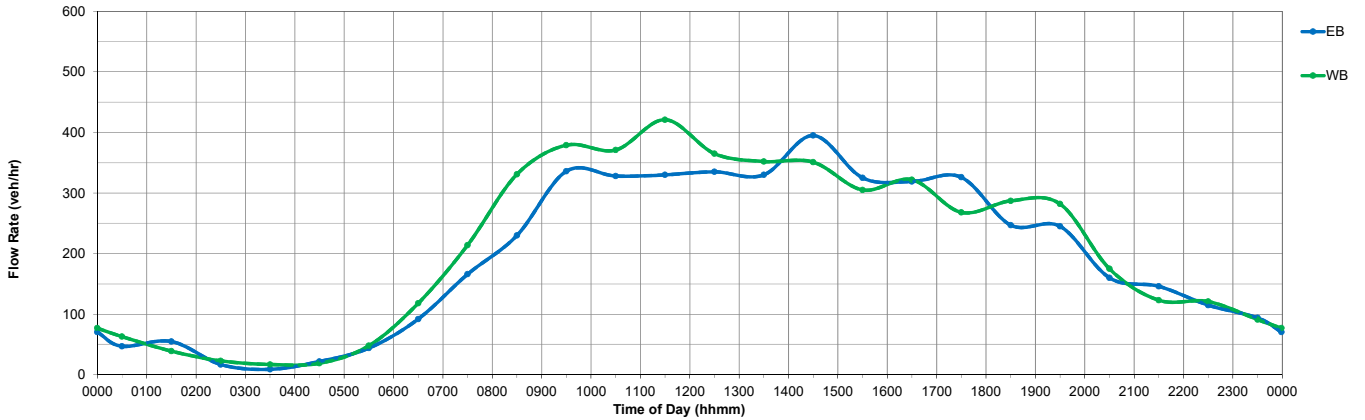
Madison Ave between Victoria Ave/Reveley Ave and Warren Rd

Hourly Volumes - Madison Ave between Belle Ave and Lincoln Ave

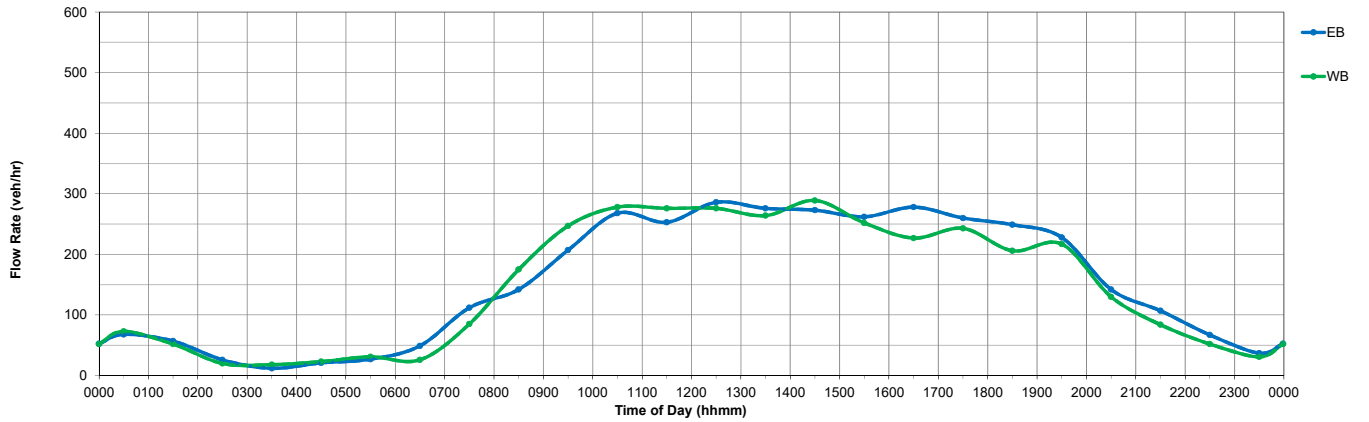
Weekday Average Hourly Volumes



Saturday Hourly Volumes



Sunday Hourly Volumes



Hourly Volumes by Day

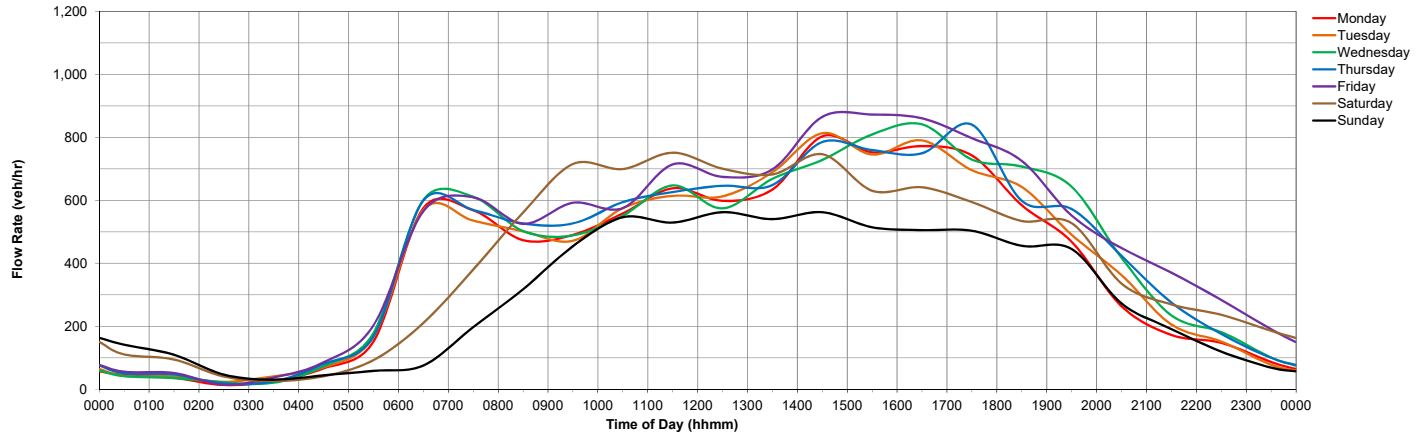


Figure 14

7-Day, 24-Hour Volumes

Madison Ave between Belle Ave and Lincoln Ave



### 3.0 SITE SURVEY

Prior to conducting any analysis, a site survey was performed to observe the signal equipment in the cabinet and operation of the traffic signal as well as the geometric, traffic, and signal timing characteristics of each intersection. Observations were conducted in April and June of 2018 during the proposed analysis periods to develop an understanding of traffic characteristics and issues in the corridor and determine potential modifications that could improve corridor operation.

#### 3.1 Existing System Operation

As previously noted, the project includes 27 signalized intersections. The current system operation includes six closed loop systems along with five stand-alone intersections. Refer to Figure 1.

The first system includes five intersections along Madison Ave from Victoria Ave to Lincoln Ave, all within Lakewood. The master controller is located at Madison Ave & Hilliard Rd with a hardwire connection to each local intersection. The master controller intersection is not a part of this study. All the local intersections are communicating with the master controller.

The second system includes two intersection along Madison Ave from Lakewood Heights Blvd to S. Marginal Dr, both within Cleveland. The master controller is at Madison Ave & Lakewood Heights Blvd and is communicating via a hardwire connection with the local controllers.

The third system includes six intersections along Madison Ave/W 150<sup>th</sup> St from Montrose Ave to Lorain Ave, all are within Cleveland. The master controller is at W 150<sup>th</sup> St & Triskett Rd with a hardwire connection to each local intersection. All the local intersections are communicating with the master.

The fourth system includes five intersections along W 150<sup>th</sup> St from Chatfield Ave to Puritas Ave and the intersection of Terminal Ave & I-71 Ramp for a total of six intersections all within Cleveland. The master controller is located at W 150<sup>th</sup> St & Terminal Ave with a hardwire connection to each local. The master is communicating with all the local intersections.

The fifth system includes two intersection along W 150<sup>th</sup> St from Industrial Pkwy to I-480 WB Off-ramp, both within Cleveland. The master controller is at W 150<sup>th</sup> St & Industrial Pkwy and is communicating via a hardwire connection with the local controllers.

The final system includes just one intersection in the study. This intersection is W 150<sup>th</sup> St & Brookpark Rd and it does include the master controller.

The following five intersections are standalone:

- Warren Rd & Athens Ave
- Warren Rd & Delaware Ave
- Alger Rd & Lakewood Heights Blvd
- Alger Rd & S Marginal Dr
- W 150<sup>th</sup> St & Coe Ave

#### 3.2 Intersection Observation

A general observation of the interaction between traffic, the signal, and intersection design was also made during the site survey. The purpose of these observations was to note any characteristics (such as low lane utilization) that may not be inferred from any other available data sources but could significantly affect the performance of the new signal timings. Any potential safety hazards observed during the site survey, such as missing, damaged, or obstructed signs, signals, or pavement markings were also noted. An observation of all signals was conducted during daytime operation.

### 3.3 Summary of Field Observations

The following observations were noted during the site survey:

#### Warren Road & Madison Avenue

- During the PM peak period, northbound queues extend up to approximately 600 feet, resulting in cycle failures.
- During the PM peak period, westbound queues extend up to approximately 500 feet, resulting in cycle failures.

#### Warren Road & Delaware Avenue

- This signal is running in free operation during all times and is only approximately 500 feet north of the intersection of Warren Road & Lakewood Heights Boulevard. This results in abrupt stops for large platoons of vehicles and many vehicles ending up in dilemma zones.

#### West 150th Street & Triskett Road

- During the PM peak period, westbound through queues extend up to approximately 500 feet, resulting in cycle failures.

#### Warren Road/West 150th Street & Lorain Avenue

- During the AM peak period, southbound through queues extend up to approximately 500 feet, resulting in cycle failures.
- During the PM peak period, northbound through queues extend up to approximately 750 feet, resulting in cycle failures.
- During the AM, PM and weekend MD peak periods, northbound left turn queues extend up to approximately 300 feet, resulting in cycle failures.

#### West 150th Street & Terminal Avenue

- During the AM and PM peak periods, northbound queues extend up to approximately 800 feet, which is through the intersection of West 150th Street & Interstate 71 Eastbound Ramps, resulting in cycle failures.
- During the AM and PM peak periods, southbound right turn queues extend up to 600 feet, exceeding the storage and blocking the adjacent southbound through lane.

#### West 150th Street & Interstate 71 Eastbound Ramps

- During the PM peak period, the northbound storage space between Terminal Avenue and this intersection fills while serving the eastbound Interstate 71 EB Off-ramp movement, leaving no storage space for vehicles coming off the ramp. This results in vehicles frequently being stuck in the middle of the intersection and wasting green time for the eastbound movement. There is significant queuing on the off-ramp and the intersection is often blocked during the protected portion of the southbound left turn protected/permissive phase, resulting in cycle failures.

#### West 150th Street & Puritas Avenue

- During the AM and PM peak periods, northbound queues extend up to approximately 600 feet, resulting in cycle failures.
- During the AM and PM peak periods, southbound left turn queues intermittently extend up to approximately 250 feet, resulting in cycle failures.

#### West 150th Street & Coe Avenue

- There is heavy pedestrian activity during the school ingress and egress times. There are crossing guards present during these peak times.

West 150th Street & Industrial Parkway

- During the AM peak period, northbound left turn queues extend up to approximately 200 feet, resulting in cycle failures. This is largely due to the high percentage of heavy vehicles making this turn.

West 150th Street & Interstate 480 Westbound Ramp

- The Interstate 480 Overpass is just south of this intersection and the signal heads are mounted to a mast arm on the north side of the intersection, making it difficult for drivers to see and process the signal heads until they are close to the intersection.

West 150th Street & Brookpark Road

- During the AM and PM peak periods, southbound left turn queues extend up to approximately 300 feet, resulting in cycle failures.
- Poor lane utilization was observed for the northbound through movement. The northbound lane assignments are a dedicated left, through and shared through and right but the through only lane is used significantly more than the through and right shared lane. This is likely due to the outside through lane north of the intersection tapering off approximately 200 feet north of this signal.

Alger Road & Lakewood Heights Boulevard

- This signal is running in free operation during all times and is only approximately 900 feet west of the intersection of Warren Road & Lakewood Heights Boulevard. This results in abrupt stops for large platoons of vehicles and many vehicles ending up in dilemma zones.

Alger Road & South Marginal Drive

- This signal is running in free operation during all times and is only approximately 900 feet west of the intersection of Warren Road & South Marginal Drive. This results in abrupt stops for large platoons of vehicles and many vehicles ending up in dilemma zones.

Terminal Avenue & Interstate 71 Westbound Ramps

- During the AM and PM peak periods, westbound left turn queues extend into the intersection of West 150th Street & Terminal Avenue, which is only approximately 450 feet east of this intersection. This results in the southbound right turn at West 150th Street & Terminal Avenue intermittently extending beyond the available storage space and blocking the adjacent through lane.

### 3.4 Modal Split Observations

During data collection activities (see Section 2), information regarding multi-modal use was gathered. The TMCs included the following classifications with the following corridor total percentages:

- Articulated Trucks – 0.5%
- Pedestrians – 0.8%
- Bicycles on Road – 0.2%
- Buses – 0.4%
- Single-Unit Trucks – 1.2%
- Lights – 96.9%

The total pedestrian/bike volumes by intersection for the count periods identified in Section 2.2 are as follows:

ID	Intersection	Total	Weekday	Weekend
1	Warren Rd & Madison Ave	792	404	388
2	Warren Rd & Athens Ave	243	113	130
3	Warren Rd & Delaware Ave	73	39	34
4	Warren Rd & Lakewood Heights Blvd	71	42	29
5	Warren Rd & S Marginal Dr	43	25	18
6	Warren Rd & Montrose Ave	201	157	44
7	Warren Rd & Edgecliff Ave/Orchard Park Ave	169	103	66
8	Warren Rd & W 155th St/Grapeland Ave	232	128	104
9	Warren Rd & Munn Rd	110	62	48
10	Warren Rd & Triskett Rd	156	94	62
11	Warren Rd/W 150th St & Lorain Ave	274	128	146
12	W 150th St & Chatfield Ave	18	12	6
13	W 150th St & Emery Ave	34	19	15
14	W 150th St & Terminal Ave	74	58	16
15	W 150th St & I-71 EB Ramps	126	64	62
16	W 150th St & Puritas Ave	331	182	149
17	W 150th St & Coe Ave	76	59	17
18	W 150th St & Industrial Pkwy	34	26	8
19	W 150th St & I-480 WB Off-ramp	40	29	11
20	W 150th St & Brookpark Rd	41	27	14
101	Madison Ave & Victoria Ave/Reveley Ave	974	444	530
102	Madison Ave & Onondaga Ave	649	332	317
103	Madison Ave & Belle Ave	759	417	342
104	Madison Ave & Lincoln Ave	781	431	350
401/402	Alger Rd & Lakewood Heights Blvd	74	39	35
501	Alger Rd & S Marginal Dr	30	13	17
1401	Terminal Ave & I-71 Ramps	21	12	9

As observed, the pedestrian activity is highest on Madison Avenue. Also, there is heavy pedestrian and bicycle activity around the schools near the intersections on Warren Road/West 150th Street at Montrose Avenue, Puritas Avenue and Coe Avenue. The single highest pedestrian activity is at the intersection of Madison Avenue & Victoria Avenue/Reveley Avenue. Madison Avenue is a downtown section that borders residential areas and has heavy pedestrian volumes throughout the limits of this project. Higher pedestrian volumes were also observed around GCRTA bus stops.

The data, including classifications plots are included in the [Appendix](#). The video data collection can also be observed by visiting, <https://datalink.miovision.com/projects/1VjATzm2bAWqHEfaj1HdPLvV>.

In addition to classification counts, field notes were collected as described in section 2.4. During these field visits, all pedestrian amenities were checked (push buttons, indications, etc.). Issues were reported to the maintaining municipalities who corrected them. The following page shows a summary of the existing pedestrian amenities.

The following multi-modal observations were noted during site visits:

- Throughout this system, most signals have no pedestrian detection for primary main street movements and operate in recall.
- There were several intersections with countdown pedestrian indications, primarily on Madison Avenue.
- Based on observations, bicycle activity was primarily confined to sidewalks and crossings in the crosswalks. Bicycles on the sidewalks are counted as pedestrians.
- RTA bus stops are placed at roughly 6 stops per mile per RTA guidelines. Locations include both near and far side of traffic signal stops.
- Several locations used recall due to broken push buttons.

ID	Intersection	Pedestrian Indications?	Countdown?	Push Buttons?	Comments
1	Warren Rd & Madison Ave	Yes	Yes	Yes/No	Push buttons present only for N/S pedestrian movements. E/W pedestrian movements in recall.
2	Warren Rd & Athens Ave	Yes	Yes/No	Yes/No	Countdown heads only on NW and SE corner for N/S pedestrians. Push buttons only present for E/W pedestrian movements.
3	Warren Rd & Delaware Ave	Yes	Yes/No	Yes	Countdown only for phase 2 head on NW corner. Push buttons only for E and W pedestrian movements. N/S movements in recall.
4	Warren Rd & Lakewood Heights Blvd	Yes	No	No	Crosswalk present but no indications present for south leg. All pedestrian movements in recall, no detection.
5	Warren Rd & S Marginal Dr	Yes	No	No	No crossing on north leg. All pedestrian movements in recall, no detection.
6	Warren Rd & Montrose Ave	Yes	No	Yes/No	Functional buttons present for E/W pedestrian phases but all pedestrian phases in recall.
7	Warren Rd & Edgecliff Ave/Orchard Park Ave	Yes	No	No	All pedestrian movements in recall, no detection.
8	Warren Rd & W 155th St/Grapeland Ave	Yes	No	No	All pedestrian movements in recall, no detection.
9	Warren Rd & Munn Rd	Yes	Yes	Yes/No	No crossing on south leg. Push buttons only present for W pedestrian phase. S movement in recall.
10	Warren Rd & Triskett Rd	Yes	Yes	Yes/No	Push buttons only present for E/W pedestrian phases. N/S movements in recall.
11	W 150th St/Warren Rd & Lorain Ave	Yes	Yes	No	All pedestrian movements in recall, no detection.
12	W 150th St & Chatfield Ave	Yes	No	Yes/No	No crossing on south leg. Functional push buttons only present for W movement but stuck during implementation. N pedestrian movement in recall.
13	W 150th St & Emery Ave	Yes	No	Yes/No	No crossing on south leg. Functional push buttons only for W movement. N/S movements in recall.
14	W 150th St & Terminal Ave	Yes	No	Yes/No	No crossing on south leg. Push buttons present only for W movement. N/S movements in recall.
15	W 150th St & I-71 EB Ramps	Yes	No	Yes/No	No crossing on north leg. Push buttons present only for E movement. N/S movements in recall.
16	W 150th St & Puritas Ave	Yes	No	Yes/No	Push buttons present only for E/W movements. N/S movements in recall.
17	W 150th St & Coe Ave	Yes	No	No	All pedestrian movements on recall, no detection.
18	W 150th St & Industrial Pkwy	Yes	No	Yes/No	Push buttons present only for E/W movements. N/S movements in recall.
19	W 150th St & I-480 WB Off-ramp	Yes	No	Yes/No	No crossing on north leg. Push buttons present only for E movement. N/S movements in recall.
20	W 150th St & Brookpark Rd	Yes	No	No	Push buttons only for N/S movements. E/W movements in recall.
101	Madison Ave & Victoria Ave/Reveley Ave	Yes	No	Yes	Push buttons only for N/S movements. E/W movements in recall.
102	Madison Ave & Onondaga Ave	No	N/A	N/A	No pedestrian crossings
103	Madison Ave & Belle Ave	Yes	No	Yes	Push buttons only for N/S movements. E/W movements in recall.
104	Madison Ave & Lincoln Ave	Yes	No	Yes	Push buttons only for N/S movements. E/W movements in recall.
401/402	Alger Rd & Lakewood Heights Blvd	Yes	No	No	No crossing on south leg. All pedestrian movements on recall, no detection.
501	Alger Rd & S Marginal Dr	Yes	No	No	No crossing on north leg. All pedestrian movements on recall, no detection.
1401	I-71 Ramp & Terminal Ave	No	N/A	N/A	No pedestrian crossings

## 4.0 CRASH ANALYSIS

Police crash reports and collision diagrams were provided by NOACA for the project intersections. Three years of data were provided and summarized in a tabular format. Table 1 summarizes the crash severity while Table 2 of page 24 summarizes crash types for all project intersections.

**Table 1 – Crash Severity**

Intersection	PDO	Injury	Fatal	Total
Warren Rd & Madison Ave	15	9	0	24
Warren Rd & Athens Ave	12	7	0	19
Warren Rd & Delaware Ave	7	4	0	11
Warren Rd & Lakewood Heights Blvd	16	10	0	26
Warren Rd & S Marginal Dr	27	18	0	45
Warren Rd & Montrose Ave	1	4	0	5
Warren Rd & Edgecliff Ave/Orchard Park Ave	19	8	0	27
Warren Rd & W 155th St/Grapeland Ave	7	6	0	13
Warren Rd & Munn Rd	17	7	0	24
Warren Rd & Triskett Rd	36	16	0	52
W 150th St/Warren Rd & Lorain Ave	53	28	0	81
W 150th St & Chatfield Ave	6	3	0	9
W 150th St & Emery Ave	18	12	0	30
W 150th St & Terminal Ave	10	1	0	11
W 150th St & I-71 EB Ramps	16	3	0	19
W 150th St & Puritas Ave	65	38	0	103
W 150th St & Coe Ave	7	7	0	14
W 150th St & Industrial Pkwy	11	5	0	16
W 150th St & I-480 WB Off-ramp	4	2	0	6
W 150th St & Brookpark Rd	17	5	0	22
Madison Ave & Victoria Ave/Reveley Ave	6	1	0	7
Madison Ave & Onondaga Ave	0	1	0	1
Madison Ave & Belle Ave	8	6	0	14
Madison Ave & Lincoln Ave	3	1	0	4
Alger Rd & Lakewood Heights Blvd	7	4	0	11
Alger Rd & S Marginal Dr	2	1	0	3
I-71 Ramp & Terminal Ave	0	0	0	0

*Based on the most recent three years of available data (2015-2017).*

**Table 2 – Number of Crashes by Crash Type**

Intersection	Number of Crashes									
	Head On	Rear End	Left Turn	Right Turn	Angle	Side-Swipe	Ped	Fixed Object	Other	Total
Warren Rd & Madison Ave	0	5	3	1	8	3	1	2	1	24
Warren Rd & Athens Ave	1	6	1	0	2	5	0	2	2	19
Warren Rd & Delaware Ave	0	1	0	0	5	1	0	0	4	11
Warren Rd & Lakewood Heights Blvd	1	6	0	3	9	2	0	3	2	26
Warren Rd & S Marginal Dr	0	11	8	0	18	6	0	1	1	45
Warren Rd & Montrose Ave	0	2	1	0	1	0	0	1	0	5
Warren Rd & Edgecliff Ave/ Orchard Park Ave	0	3	13	1	4	3	0	0	3	27
Warren Rd & W 155th St/ Grapeland Ave	2	5	4	0	1	1	0	0	0	13
Warren Rd & Munn Rd	1	4	4	0	0	7	1	4	3	24
Warren Rd & Triskett Rd	0	27	9	2	2	8	1	1	2	52
W 150th St/Warren Rd & Lorain Ave	1	32	9	8	13	13	2	2	1	81
W 150th St & Chatfield Ave	0	5	0	0	1	1	0	1	1	9
W 150th St & Emery Ave	0	16	3	2	3	2	1	0	3	30
W 150th St & Terminal Ave	0	6	0	2	0	2	0	1	0	11
W 150th St & I-71 EB Ramps	0	5	2	2	4	3	1	1	1	19
W 150th St & Puritas Ave	3	39	19	5	13	9	9	2	4	103
W 150th St & Coe Ave	0	10	1	0	0	3	0	0	0	14
W 150th St & Industrial Pkwy	0	12	1	0	1	1	0	0	1	16
W 150th St & I-480 WB Off-ramp	0	4	0	1	0	0	0	1	0	6
W 150th St & Brookpark Rd	0	9	3	1	2	5	0	2	0	22
Madison Ave & Victoria Ave/ Reveley Ave	0	2	0	0	0	0	0	0	5	7
Madison Ave & Onondaga Ave	0	0	0	0	0	0	0	0	1	1
Madison Ave & Belle Ave	0	6	1	1	2	2	0	0	2	14
Madison Ave & Lincoln Ave	0	2	1	0	0	0	0	0	1	4
Alger Rd & Lakewood Heights Blvd	0	3	0	0	7	0	0	1	0	11
Alger Rd & S Marginal Dr	0	0	1	0	1	1	0	0	0	3
I-71 Ramp & Terminal Ave	0	0	0	0	0	0	0	0	0	0
Total	9	221	84	29	97	78	16	25	38	597
Percent	1.5%	37.0%	14.1%	4.9%	16.2%	13.1%	2.7%	4.2%	6.4%	100.0%

The highest percentage of crashes are rear end (~ 37%). This is common for signalized intersections as vehicles will be in a “decision zone” during the yellow clearance interval. The optimization of the signals can be expected to reduce the number of vehicles in the decision zone as they are traveling through in green bands.

The second highest crash type is angle crashes at just over 16%. This timing project included updates to clearance intervals (yellow, red and pedestrian timing). The updates are anticipated to reduce the number of angle crashes, along with the left turn (~ 14%) and pedestrian (~ 3%) crash types.

There are a high number of pedestrian crashes at the intersection of West 150th St & Puritas Avenue. The number of pedestrians exceeds 300 for the count period and the turns are over 50% of all movements.

Safety recommendations based on field observations in Section 3.2, and crash data above, are discussed in Section 10.1. The original crash report memo is found in the [Appendix](#).

## 5.0 WARRANT ANALYSIS

The need for a traffic signal was investigated at several candidate intersections using the warrants contained in the Ohio Manual on Uniform Traffic Control Devices. Table 3 is a summary of the warrant analysis. Ten intersections were investigated. The additional intersections were not investigated given that they had volumes that clearly exceed the requirements for signal warrants.

**Table 3 – Warrant Analysis Summary**

Intersection	Warren Rd & Athens Ave	Warren Rd & Delaware Ave	Warren Rd & Montrose Ave	Warren Rd & W 155th St/ Grapeland Ave	W 150th St & Chatfield Ave	W 150th St & Coe Ave	Madison Ave & Victoria Ave/Reveley Ave	Madison Ave & Belle Ave	Madison Ave & Lincoln Ave	Alger Rd & Marginal Dr	
Warrant 1 – Eight-Hour Vehicular Volume	No	No	No	No	No	No	No	No	No	No	
Warrant 2 – Four-Hour Vehicular Volume	No	No	No	No	No	No	No	No	No	No	
Warrant 3 – Peak Hour	No	No	No	No	No	No	No	No	No	No	
Warrant 4 – Pedestrian Warrant	No	No	No	No	No	No	No	No	No	No	
Warrant 5 – School Crossing	No	No	Yes	N/A*	N/A*	Yes	N/A*	N/A*	N/A*	N/A*	
Warrant 6 – Coordinated Signal System	No	No	Warrant 5 met, additional warrants not performed	No	No	Warrant 5 met, additional warrants not performed	No	No	No	No	
Warrant 7 – Crash Experience	No	No		No	No		No	No	No	No	No
Warrant 8 – Roadway Network	N/A*	N/A		N/A*	N/A*		N/A*	N/A*	N/A*	N/A*	N/A*
Warrant 9 – Grade Crossing	N/A*	N/A		N/A*	N/A*		N/A*	N/A*	N/A*	N/A*	N/A*

\*Warrant not applicable at this location

Eight intersections do not currently meet warrants. These intersections are:

- Warren Road & Athens Avenue
- Warren Road & Delaware Avenue
- Warren Road & West 155th Street/Grapeland Avenue
- West 150th Street & Chatfield Avenue
- Madison Avenue & Victoria Avenue/Reveley Avenue
- Madison Avenue & Belle Avenue
- Madison Avenue & Lincoln Avenue
- Alger Road & South Marginal Drive

The OMUTCD, Section 4B.02 states the following regarding the removal of traffic signals:

“If the engineering study indicates that the traffic control signal is no longer justified, removal may be accomplished using the following steps:

- Determine the appropriate traffic control to be used after removal of the signal.
- Remove any sight-distance restrictions as necessary.
- Inform the public of the removal study, for example by installing an informational sign (or signs) with the legend TRAFFIC SIGNAL UNDER STUDY FOR REMOVAL at the signalized location in a position where it is visible to all road users.
- Flash or cover the signal heads for a minimum of 90 days, and install the appropriate stop control or other traffic control devices.
- Remove the signal if the engineering data collected during the removal study period confirms that the signal is no longer needed. Instead of total removal of the traffic control signal, the poles and cables may remain in place for 1 year after removal of the signal heads for continued analysis.”

The unwarranted traffic signals could be considered for removal.



## 6.0 SIGNAL TIMING OPTIMIZATION

### 6.1 Model Development

Synchro and SimTraffic models were developed for each analysis period. The process of coding the models and the criteria that were used are discussed below. The basic link-node structure of the roadway network in Synchro was built on a coordinate-specific image of the roadways. Once volumes, existing geometries and signal timings were validated, and "before" travel time runs performed, new signal timings were developed.

### 6.2 Basic Signal Timing Parameters

The basic timing parameters for each traffic signal phase are discussed in greater detail below:

#### Minimum Green

Minimum green values were reviewed and updated as necessary.

#### Yellow Change

The yellow change interval was determined based on the ODOT *Traffic Engineering Manual (TEM)*, Section 403-2, 2016 revision, utilizing approach speed limits and intersection geometry, with additional guidance and direction from the TEM.

#### Red Clearance

The red clearance interval was determined based on the ODOT *Traffic Engineering Manual (TEM)*, Section 403-2, 2016 revision, utilizing approach speed limits and intersection geometry, with additional guidance and direction from the TEM.

#### Walk Time

A minimum value of seven seconds was used at each location throughout this system.

#### Pedestrian Clearance (Flashing Don't Walk)

The length of this interval is a function of the crosswalk length (curb to curb and pedestrian push button to the far curb), seven seconds of walk interval, three seconds of buffer time, and a standard pedestrian walking speed of 3.5 ft/sec, in accordance with the Ohio Manual on Uniform Traffic Control Devices (OMUTCD). The OMUTCD does allow other walking rates (i.e., 4 ft/sec where an extended push button press function has been installed). The 3.5 ft/sec value favors pedestrian traffic. A walking rate of 3.0 ft/sec was used for crosswalks within school zones.

### 6.3 Phasing

During the optimization process, it may be determined that the basic phasing structure of the intersection should be changed or further evaluated to improve the operation and/or safety of the intersection or corridor. If such a change could not be made during implementation, it will be listed as a recommendation.

### 6.4 Day Plan Schedules

Under the implemented day plan schedule, the traffic signals included in this project will operate four patterns during the weekdays and three patterns during the weekends. Figure 15 through Figure 17 on pages 28 – 30 illustrate the existing and implemented day plan schedules.

## 6.5 Pattern Optimization

The list below summarizes information regarding each pattern that was developed.

<b>Pattern Name</b>	<b>Abbreviation</b>	<b>Network Peak Hour</b>
AM Peak	AM	7:00 am – 8:00 am
MD Peak	MD	1:30 pm – 2:30 pm
PM Peak	PM	4:30 pm – 5:30 pm
PM Off-peak	PO	6:15 pm – 7:15 pm
Weekend AM Peak	WA	9:00 am – 10:00 am
Weekend MD Peak	WM	11:45 am – 12:45 pm
Weekend PM Peak	WP	6:00 pm – 7:00 pm

## 6.6 Phase Sequence Diagrams

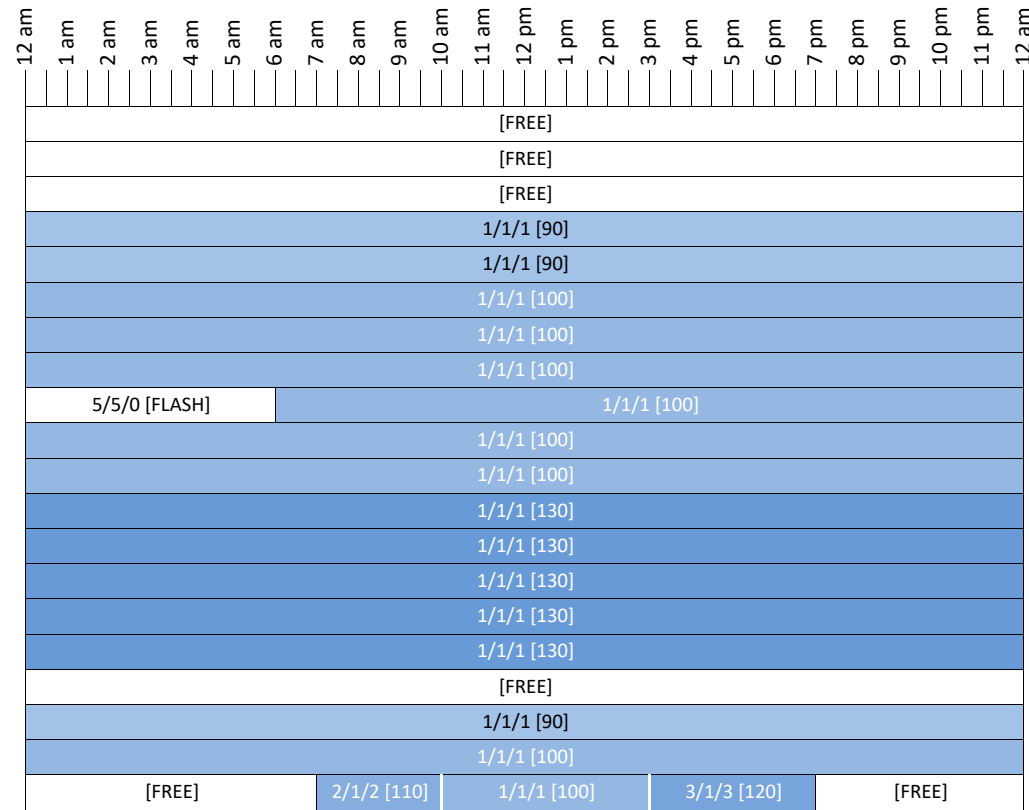
Phase sequence diagrams for each intersection being coordinated are shown in Figure 18 through Figure 24 on pages 31 – 37. These diagrams illustrate the phasing at each intersection as well as the sequences that are used with existing and implemented timing patterns.



**EXISTING SCHEDULES  
SATURDAY**

**Warren Rd/W 150th St**

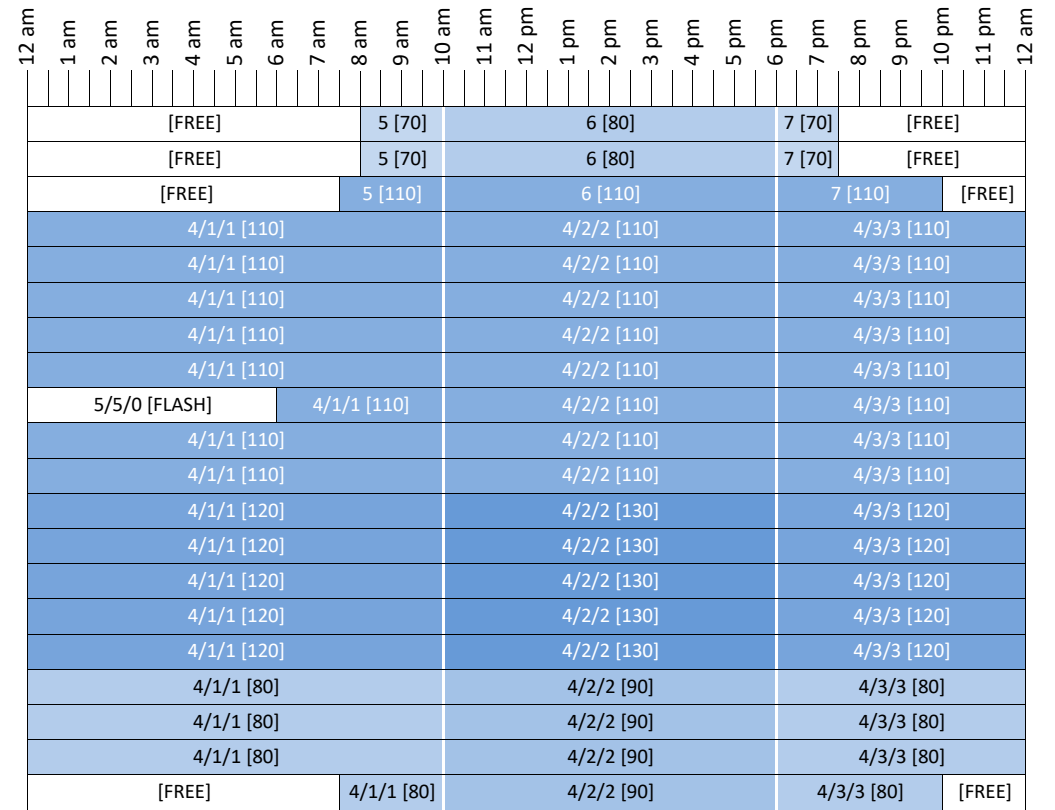
- 1 Madison Ave
- 2 Athens Ave
- 3 Delaware Ave
- 4 Lakewood Heights Blvd
- 5 S Marginal Dr
- 6 Montrose Ave
- 7 Edgecliff Ave/Orchard Park Ave
- 8 W 155th St/Grapeland Ave
- 9 Munn Rd
- 10 Triskett Rd
- 11 Lorain Ave
- 12 Chatfield Ave
- 13 Emery Ave
- 14 Terminal Ave
- 15 I-71 EB Ramps
- 16 Puritas Ave
- 17 Coe Ave
- 18 Industrial Pkwy
- 19 I-480 WB Off-ramp
- 20 Brookpark Rd



**IMPLEMENTED SCHEDULES  
SATURDAY**

**Warren Rd/W 150th St**

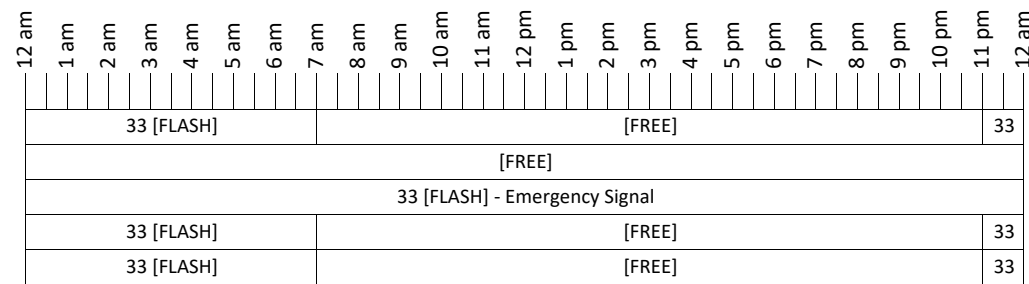
- 1 Madison Ave
- 2 Athens Ave
- 3 Delaware Ave
- 4 Lakewood Heights Blvd
- 5 S Marginal Dr
- 6 Montrose Ave
- 7 Edgecliff Ave/Orchard Park Ave
- 8 W 155th St/Grapeland Ave
- 9 Munn Rd
- 10 Triskett Rd
- 11 Lorain Ave
- 12 Chatfield Ave
- 13 Emery Ave
- 14 Terminal Ave
- 15 I-71 EB Ramps
- 16 Puritas Ave
- 17 Coe Ave
- 18 Industrial Pkwy
- 19 I-480 WB Off-ramp
- 20 Brookpark Rd



**EXISTING SCHEDULES  
SATURDAY**

**Madison Ave**

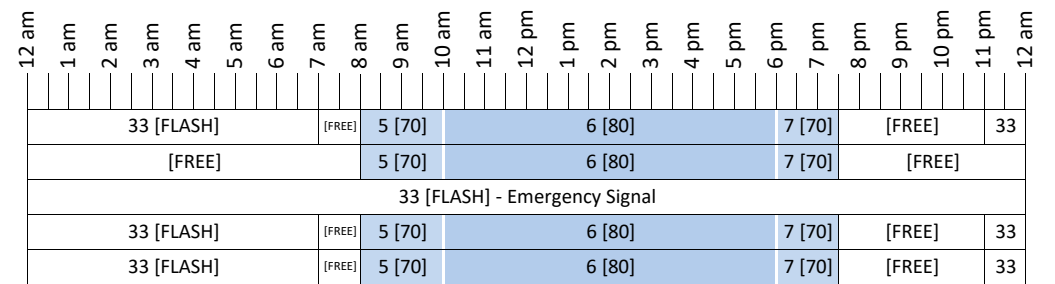
- 101 Victoria Ave/Reveley Ave
- 1 Warren Rd
- 102 Onondaga Ave
- 103 Belle Ave
- 104 Lincoln Ave



**IMPLEMENTED SCHEDULES  
SATURDAY**

**Madison Ave**

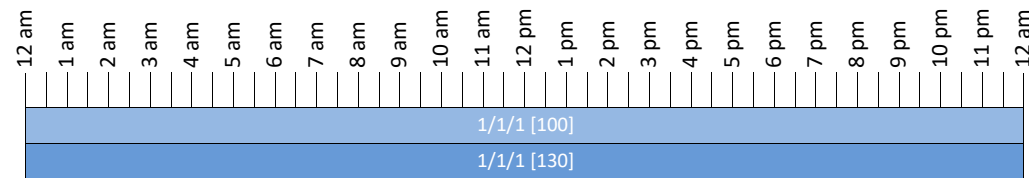
- 101 Victoria Ave/Reveley Ave
- 1 Warren Rd
- 102 Onondaga Ave
- 103 Belle Ave
- 104 Lincoln Ave



**EXISTING SCHEDULES  
SATURDAY**

**Terminal Ave**

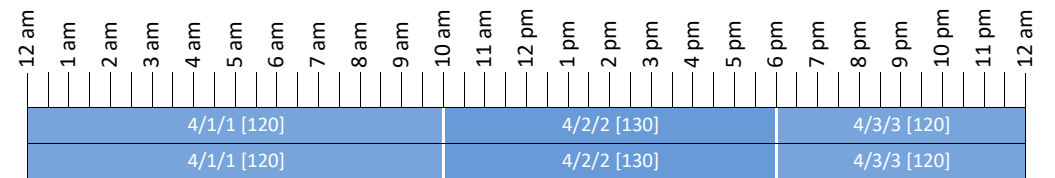
- 1401 I-71 Ramps
- 14 W 150th St



**IMPLEMENTED SCHEDULES  
SATURDAY**

**Terminal Ave**

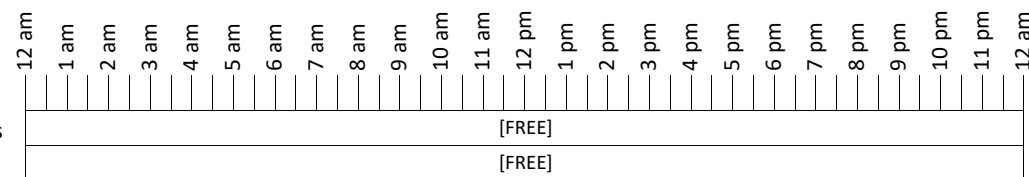
- 1401 I-71 Ramps
- 14 W 150th St



**EXISTING SCHEDULES  
SATURDAY**

**Alger Rd**

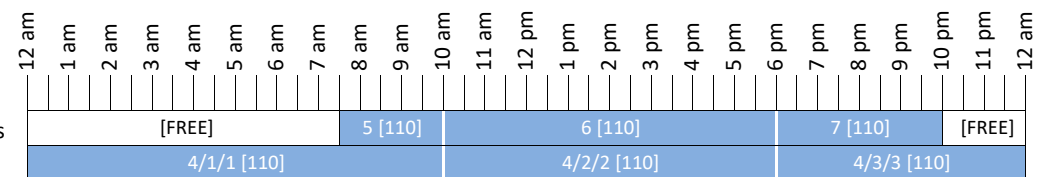
- 401/402 Lakewood Heights Blvd/I-90 Ramps
- 501 S Marginal Dr



**IMPLEMENTED SCHEDULES  
SATURDAY**

**Alger Rd**

- 401/402 Lakewood Heights Blvd/I-90 Ramps
- 501 S Marginal Dr



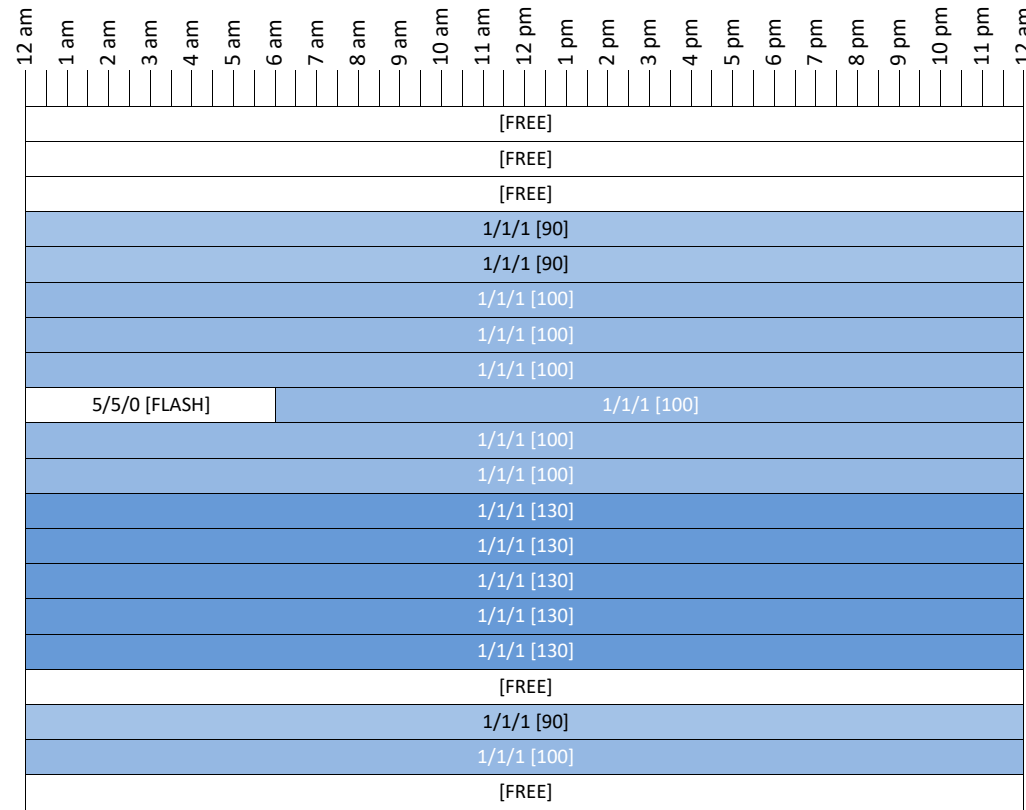
**LEGEND**  
 A white box indicates FREE or FLASH operation, as labeled, and a shaded box indicates coordinated operation.  
 The number(s) outside the brackets represent the format used to call each pattern within each database. Where there are three numbers, these values represent the Cycle/Offset/Split, respectively. Where there is only one number, this is the pattern number.  
 The number [in brackets] represents the cycle length (s).  
 Darker shades represent a longer cycle length.

**Figure 16**  
 Saturday Day Plan Schedules  
 Warren Rd/W 150th St

**EXISTING SCHEDULES  
SUNDAY**

**Warren Rd/W 150th St**

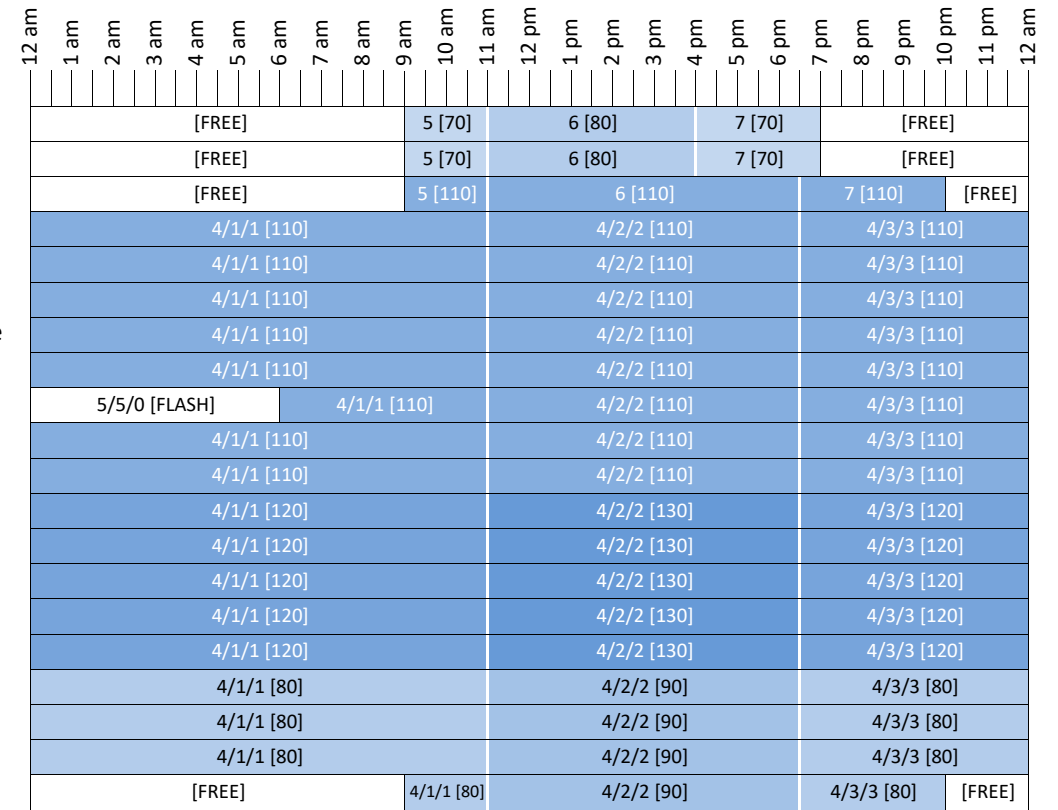
- 1 Madison Ave
- 2 Athens Ave
- 3 Delaware Ave
- 4 Lakewood Heights Blvd
- 5 S Marginal Dr
- 6 Montrose Ave
- 7 Edgecliff Ave/Orchard Park Ave
- 8 W 155th St/Grapeland Ave
- 9 Munn Rd
- 10 Triskett Rd
- 11 Lorain Ave
- 12 Chatfield Ave
- 13 Emery Ave
- 14 Terminal Ave
- 15 I-71 EB Ramps
- 16 Puritas Ave
- 17 Coe Ave
- 18 Industrial Pkwy
- 19 I-480 WB Off-ramp
- 20 Brookpark Rd



**IMPLEMENTED SCHEDULES  
SUNDAY**

**Warren Rd/W 150th St**

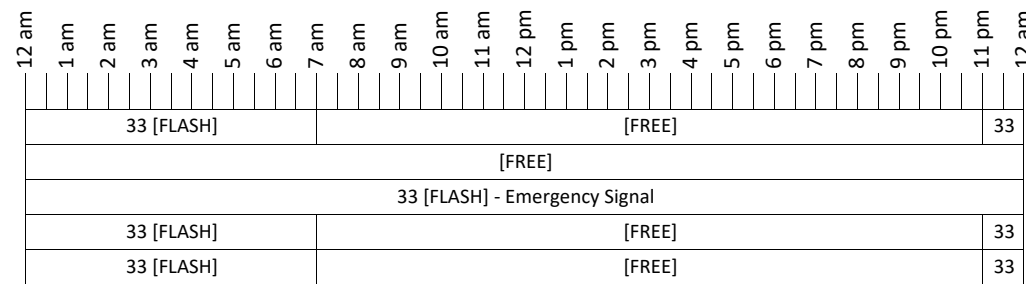
- 1 Madison Ave
- 2 Athens Ave
- 3 Delaware Ave
- 4 Lakewood Heights Blvd
- 5 S Marginal Dr
- 6 Montrose Ave
- 7 Edgecliff Ave/Orchard Park Ave
- 8 W 155th St/Grapeland Ave
- 9 Munn Rd
- 10 Triskett Rd
- 11 Lorain Ave
- 12 Chatfield Ave
- 13 Emery Ave
- 14 Terminal Ave
- 15 I-71 EB Ramps
- 16 Puritas Ave
- 17 Coe Ave
- 18 Industrial Pkwy
- 19 I-480 WB Off-ramp
- 20 Brookpark Rd



**EXISTING SCHEDULES  
SUNDAY**

**Madison Ave**

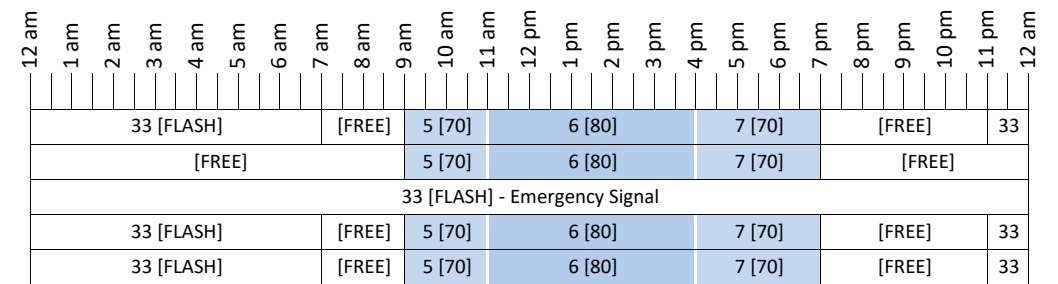
- 101 Victoria Ave/Reveley Ave
- 1 Warren Rd
- 102 Onondaga Ave
- 103 Belle Ave
- 104 Lincoln Ave



**IMPLEMENTED SCHEDULES  
SUNDAY**

**Madison Ave**

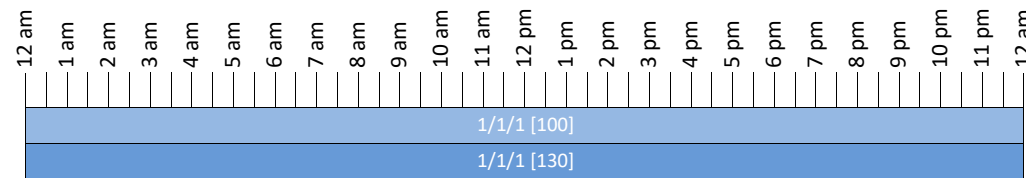
- 101 Victoria Ave/Reveley Ave
- 1 Warren Rd
- 102 Onondaga Ave
- 103 Belle Ave
- 104 Lincoln Ave



**EXISTING SCHEDULES  
SUNDAY**

**Terminal Ave**

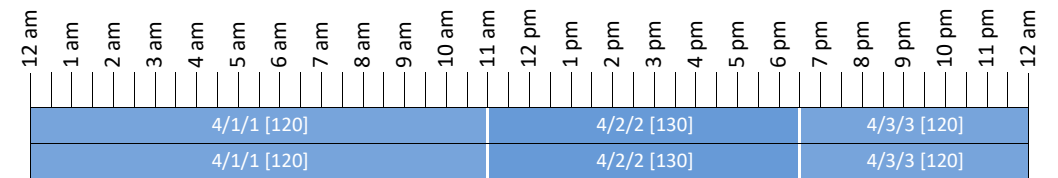
- 1401 I-71 Ramps
- 14 W 150th St



**IMPLEMENTED SCHEDULES  
SUNDAY**

**Terminal Ave**

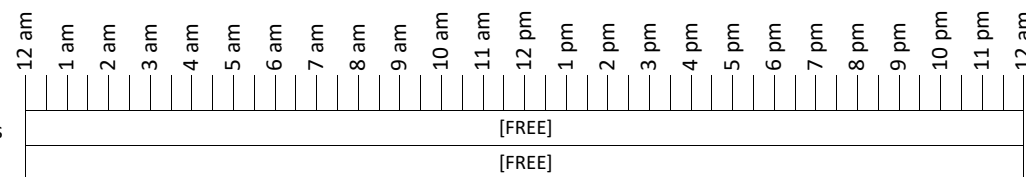
- 1401 I-71 Ramps
- 14 W 150th St



**EXISTING SCHEDULES  
SUNDAY**

**Alger Rd**

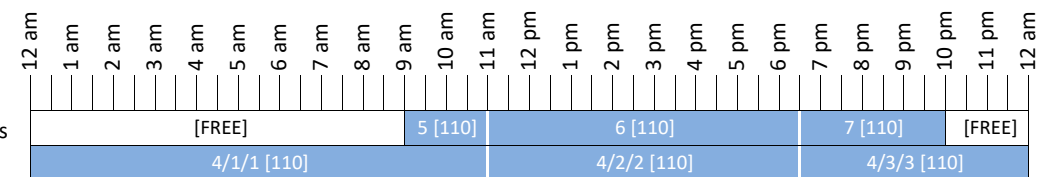
- 401/402 Lakewood Heights Blvd/I-90 Ramps
- 501 S Marginal Dr



**IMPLEMENTED SCHEDULES  
SUNDAY**

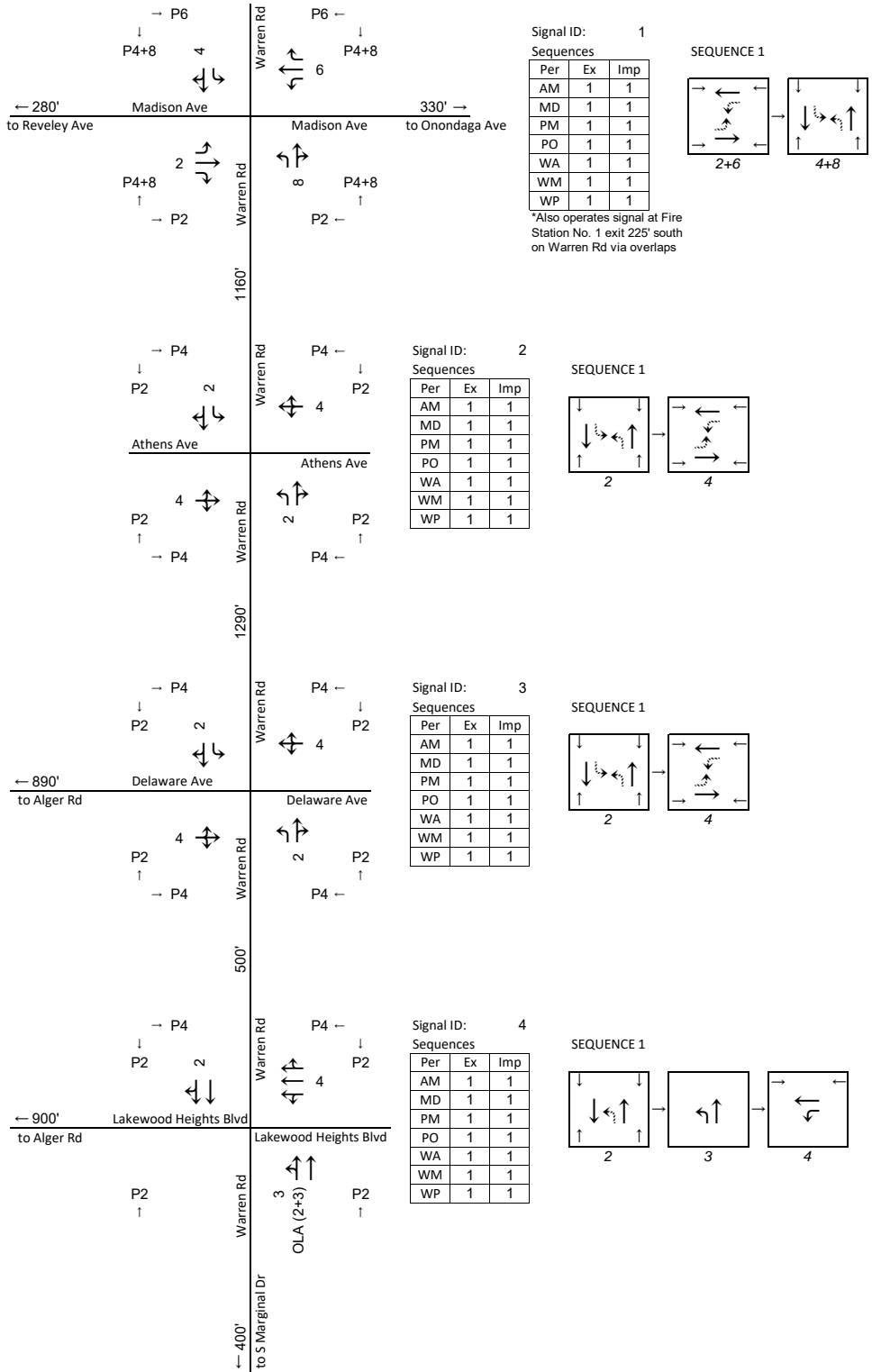
**Alger Rd**

- 401/402 Lakewood Heights Blvd/I-90 Ramps
- 501 S Marginal Dr



**LEGEND**  
 A white box indicates FREE or FLASH operation, as labeled, and a shaded box indicates coordinated operation.  
 The number(s) outside the brackets represent the format used to call each pattern within each database. Where there are three numbers, these values represent the Cycle/Offset/Split, respectively. Where there is only one number, this is the pattern number.  
 The number [in brackets] represents the cycle length (s).  
 Darker shades represent a longer cycle length.

**Figure 17**  
 Sunday Day Plan Schedules  
 Warren Rd/W 150th St



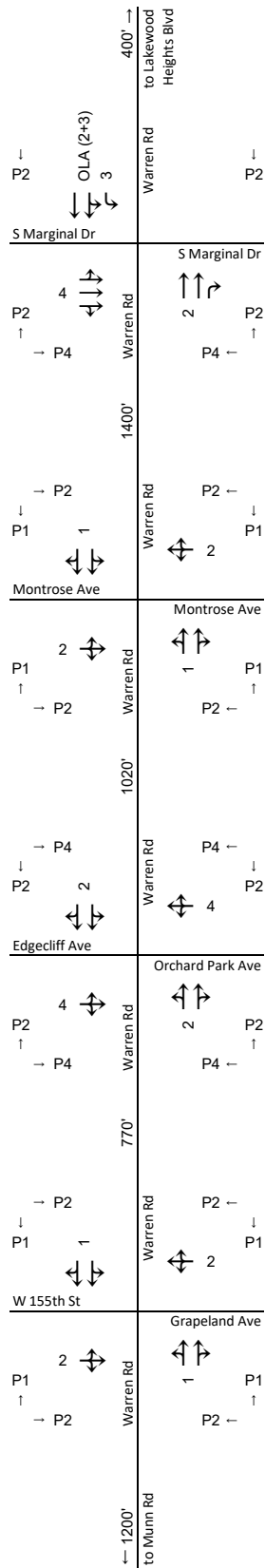
\*Also operates signal at Fire Station No. 1 exit 225' south on Warren Rd via overlaps



Figure 18

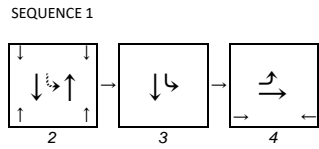
Phase Sequence Diagrams

Warren Rd - Madison Ave to Lakewood Heights Blvd



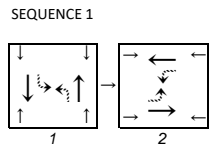
Signal ID: 5  
Sequences

Per	Ex	Imp
AM	1	1
MD	1	1
PM	1	1
PO	1	1
WA	1	1
WM	1	1
WP	1	1



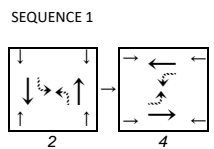
Signal ID: 6  
Sequences

Per	Ex	Imp
AM	1	1
MD	1	1
PM	1	1
PO	1	1
WA	1	1
WM	1	1
WP	1	1



Signal ID: 7  
Sequences

Per	Ex	Imp
AM	1	1
MD	1	1
PM	1	1
PO	1	1
WA	1	1
WM	1	1
WP	1	1



Signal ID: 8  
Sequences

Per	Ex	Imp
AM	1	1
MD	1	1
PM	1	1
PO	1	1
WA	1	1
WM	1	1
WP	1	1

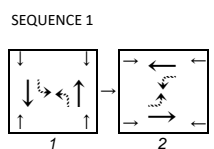
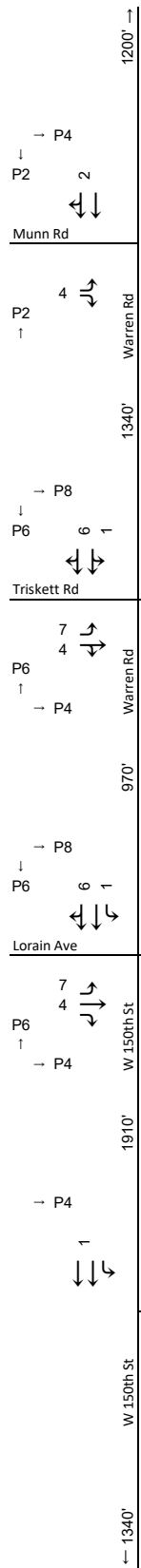


Figure 19

Phase Sequence Diagrams

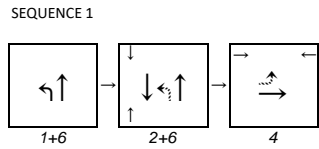
Warren Rd - S Marginal Dr to W 155th St/Graveland Ave



Signal ID: 9

Sequences

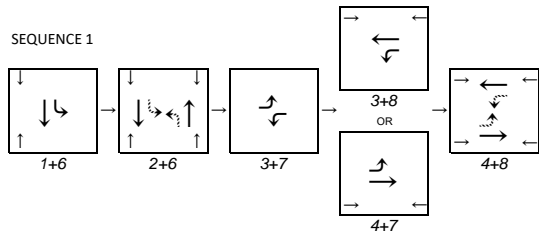
Per	Ex	Imp
AM	1	1
MD	1	1
PM	1	1
PO	1	1
WA	1	1
WM	1	1
WP	1	1



Signal ID: 10

Sequences

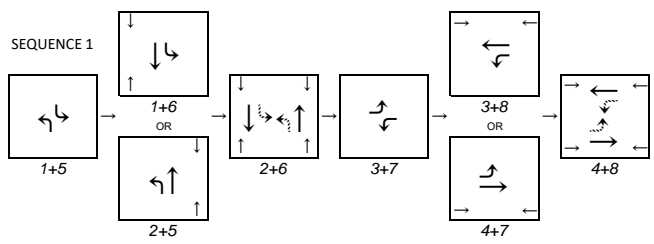
Per	Ex	Imp
AM	1	1
MD	1	1
PM	1	1
PO	1	1
WA	1	1
WM	1	1
WP	1	1



Signal ID: 11

Sequences

Per	Ex	Imp
AM	1	1
MD	1	1
PM	1	1
PO	1	1
WA	1	1
WM	1	1
WP	1	1



Signal ID: 12

Sequences

Per	Ex	Imp
AM	1	1
MD	1	1
PM	1	1
PO	1	1
WA	1	1
WM	1	1
WP	1	1

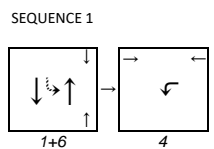
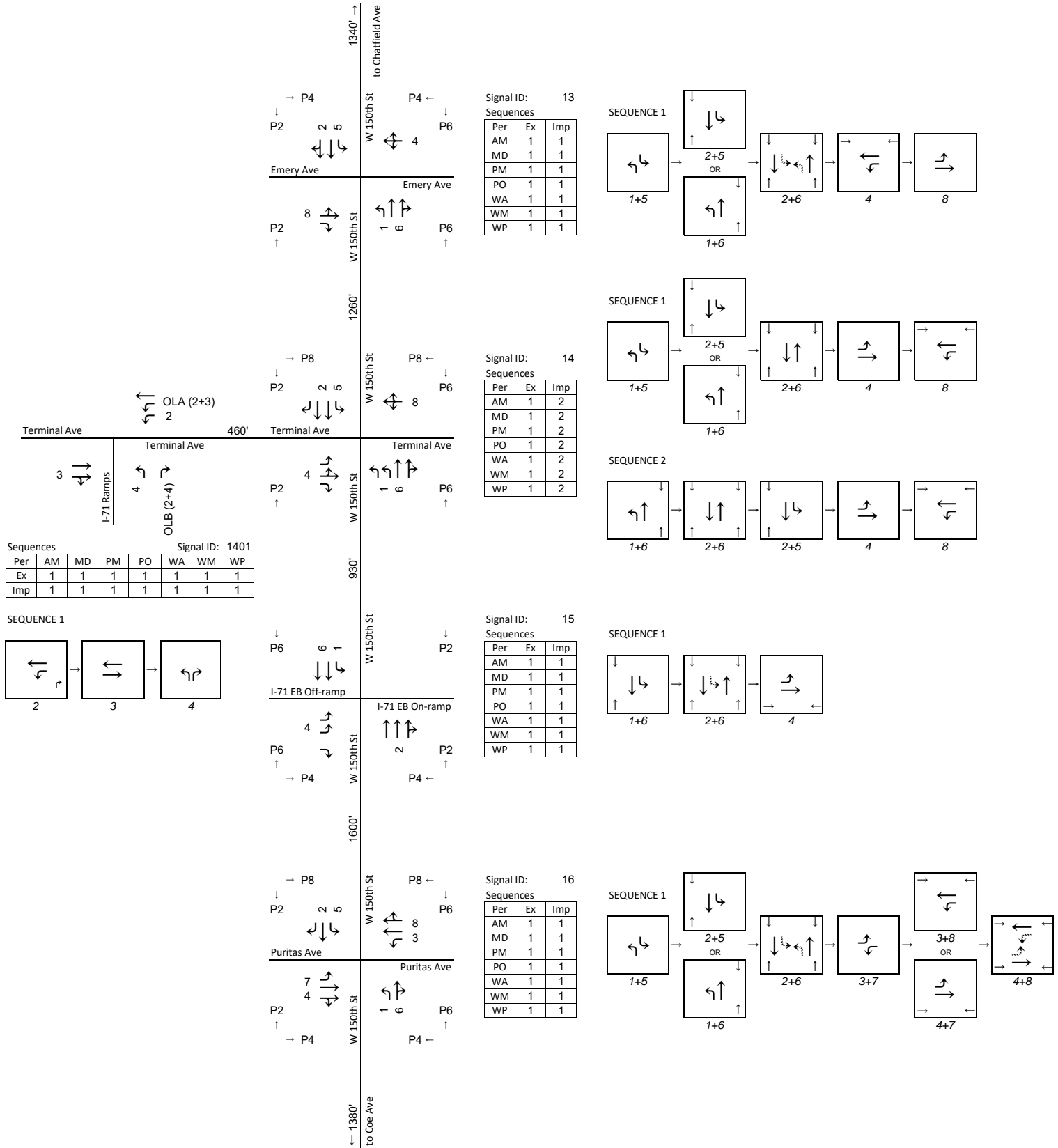


Figure 20  
Phase Sequence Diagrams





Signal ID: 13

Sequences

Per	Ex	Imp
AM	1	1
MD	1	1
PM	1	1
PO	1	1
WA	1	1
WM	1	1
WP	1	1

Signal ID: 14

Sequences

Per	Ex	Imp
AM	1	2
MD	1	2
PM	1	2
PO	1	2
WA	1	2
WM	1	2
WP	1	2

Signal ID: 1401

Sequences

Per	AM	MD	PM	PO	WA	WM	WP
Ex	1	1	1	1	1	1	1
Imp	1	1	1	1	1	1	1

Signal ID: 15

Sequences

Per	Ex	Imp
AM	1	1
MD	1	1
PM	1	1
PO	1	1
WA	1	1
WM	1	1
WP	1	1

Signal ID: 16

Sequences

Per	Ex	Imp
AM	1	1
MD	1	1
PM	1	1
PO	1	1
WA	1	1
WM	1	1
WP	1	1

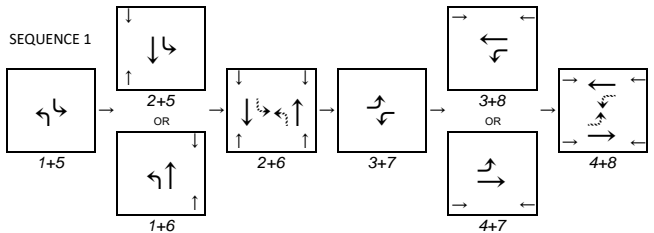
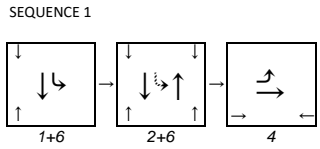
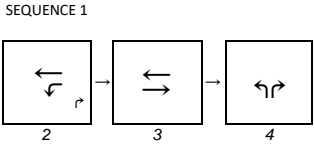
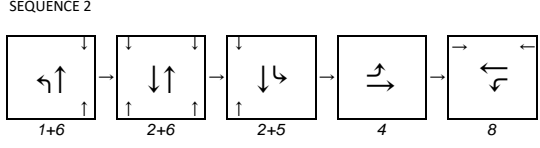
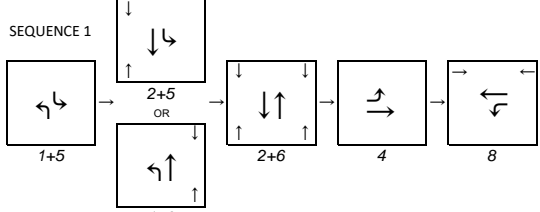
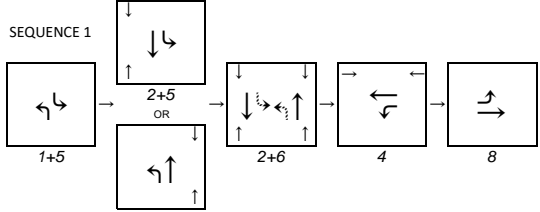


Figure 21  
Phase Sequence Diagrams

W 150th St - Emery Ave to Puritas Ave

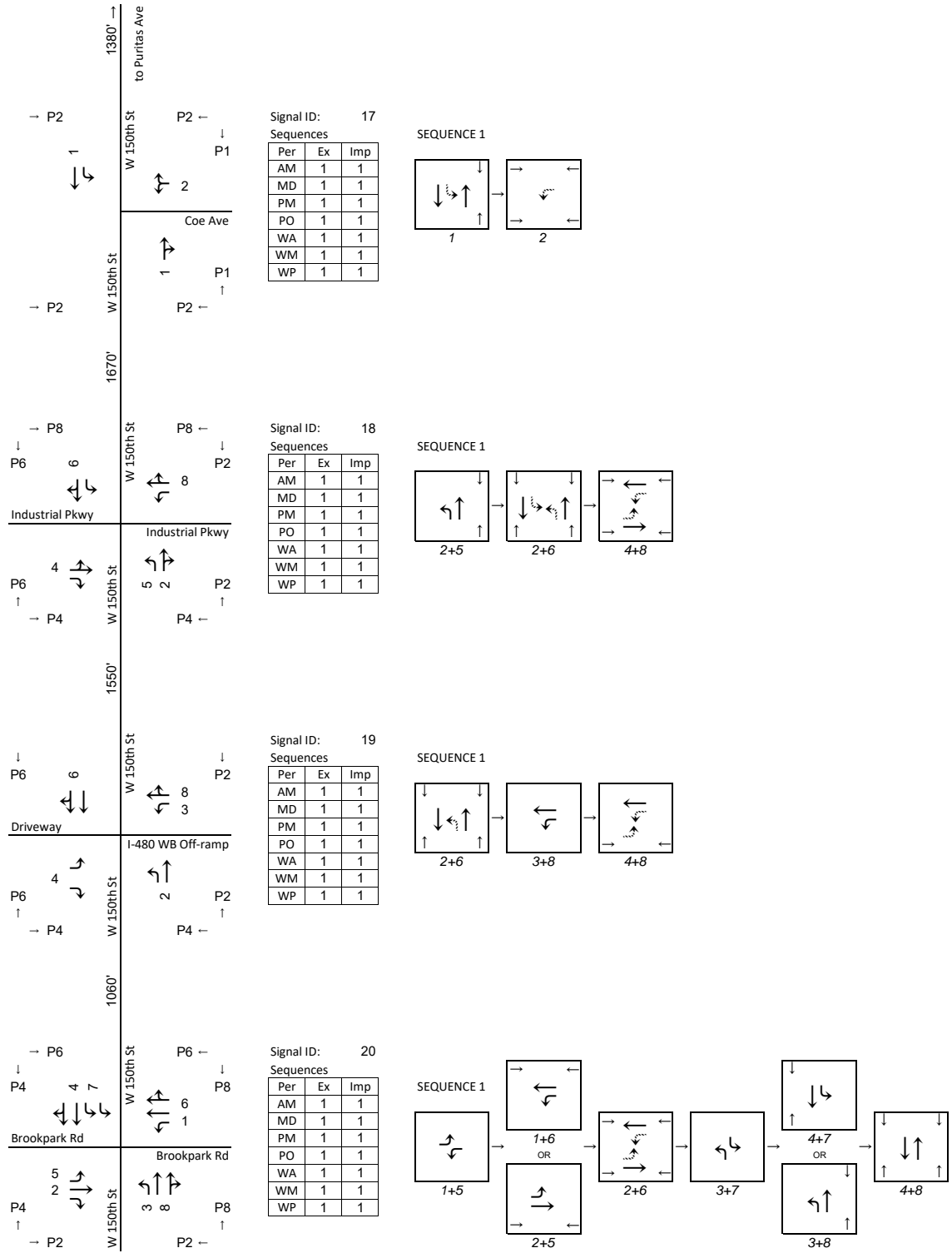
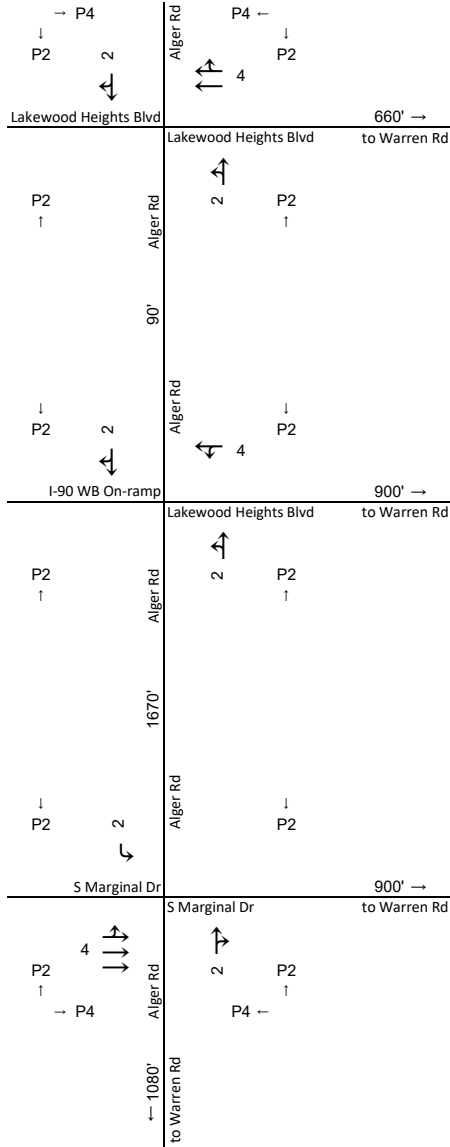


Figure 22

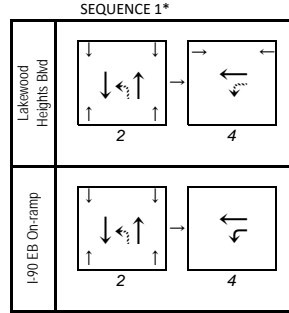
Phase Sequence Diagrams

W 150th St - Coe Ave to Brookpark Rd



Signal ID: 401/402

Sequences		
Per	Ex	Imp
AM	1	1
MD	1	1
PM	1	1
PO	1	1
WA	1	1
WM	1	1
WP	1	1



\*Operates on one controller

Signal ID: 501

Sequences		
Per	Ex	Imp
AM	1	1
MD	1	1
PM	1	1
PO	1	1
WA	1	1
WM	1	1
WP	1	1

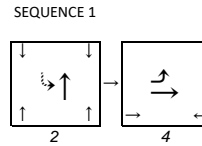
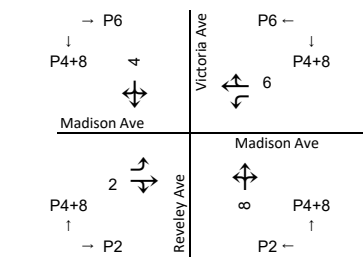


Figure 23

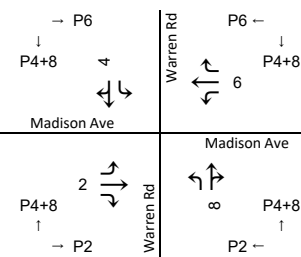
Phase Sequence Diagrams

Alger Rd - Lakewood Heights Blvd to S Marginal Dr



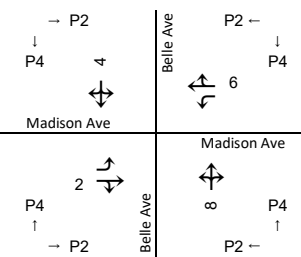
Sequences Signal ID: 101

Per	AM	MD	PM	PO	WA	WM	WP
Ex	1	1	1	1	1	1	1
Imp	1	1	1	1	1	1	1



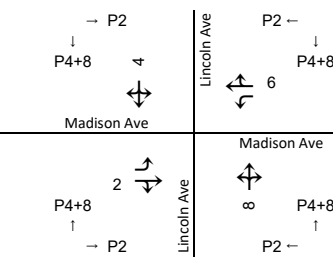
Sequences Signal ID: 102

Per	AM	MD	PM	PO	WA	WM	WP
Ex	FLASH	FLASH	FLASH	FLASH	FLASH	FLASH	FLASH
Imp	FLASH	FLASH	FLASH	FLASH	FLASH	FLASH	FLASH



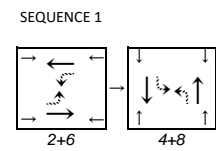
Sequences Signal ID: 103

Per	AM	MD	PM	PO	WA	WM	WP
Ex	1	1	1	1	1	1	1
Imp	1	1	1	1	1	1	1



Sequences Signal ID: 19

Per	AM	MD	PM	PO	WA	WM	WP
Ex	1	1	1	1	1	1	1
Imp	1	1	1	1	1	1	1



Sequences Signal ID: 1

Per	AM	MD	PM	PO	WA	WM	WP
Ex	1	1	1	1	1	1	1
Imp	1	1	1	1	1	1	1

\*Also operates signal at Fire Station No. 1 exit 225' south on Warren Rd via overlaps

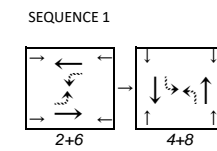
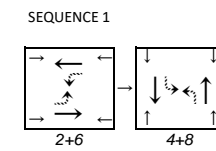
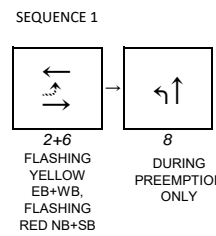
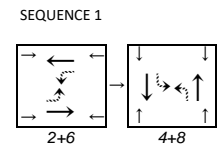


Figure 24

Phase Sequence Diagrams

Madison Ave - Victoria Ave/Reveley Ave to Lincoln Ave

## 7.0 SIGNAL TIMING IMPLEMENTATION

### 7.1 Controller Programming

After the basic timing parameters were updated, optimized signal timings were developed, and a day plan schedule was created. This information was downloaded via direct connect in the field. At this point, the signals were observed for proper operation and the controller was observed to address any issues that could have occurred during the data transfer.

### 7.2 Fine-Tuning of Signal Timings

In October of 2018, each new timing plan was observed at each intersection during its respective peak hour to ensure each phase split was appropriate for the traffic conditions present. The fine-tuning process involved a multi-day review including Saturday and Sunday operations. If a movement or intersection is over capacity, split adjustments may be required to manage queue spillback and blockage. The fine-tuning changes were made directly in the controller in the field.

In addition to fine-tuning splits, offset adjustments often have a larger effect on the performance of the network. Offsets were adjusted at the coordinated intersections by conducting travel time runs along the corridor. Travel time runs were conducted using Tru-Traffic (v10) in conjunction with a direct connect GPS unit which tracks the location of the test vehicle within the traffic signal system. This provides the user dynamic information about the performance of the traffic signal system such as travel time and delay. Results of the travel time runs under existing timings (the “before” runs) and implemented signal timings (the “after” runs) are discussed in the next section of this report.

## 8.0 TRAFFIC OPERATIONS ANALYSIS

### 8.1 Intersection Performance Measures

Operations analysis was conducted using the traffic models for each of the periods with existing signal timings. This analysis established a benchmark by which traffic operations with implemented signal timings are compared.

Synchro (v10) was used to determine the delay (in seconds per vehicle) for each lane group as well as the delay and level of service (LOS) for the intersection. The intersection capacity utilization (ICU) and LOS were also determined for each intersection. The delay, LOS, and ICU for each intersection can be found in the Traffic Operations Analysis figures in the [Appendix](#).

The figures illustrate traffic operations at the same intersection for the various periods and scenarios analyzed. The first row illustrates the TMC data for each period analyzed. The second row illustrates each period with existing signal timings. The third row illustrates each period with implemented signal timings. The last row, if present, represents operational recommendations. This arrangement allows for easy comparison of traffic operations across all periods and scenarios.

In general, intersections may experience an increase in overall intersection delay when 1) the cycle length is significantly adjusted from its optimal cycle length to provide coordination, 2) green times are allocated with the objective of providing maximum progression on the major street, or 3) vehicle and pedestrian change and clearance times are increased.

Table 4 summarizes the number of intersections that experienced an increase or decrease in overall intersection delay during each period.

**Table 4 – Summary of Changes in Intersection Delay**

Number of intersections where:	AM	MD	PM	PO	WA	WM	WP
delay decreased	20	17	20	19	16	18	16
delay increased ≤ 5 sec/veh	5	8	4	6	9	7	10
delay increased > 5 sec/veh	1	1	2	1	1	1	0

Table 5 summarizes the intersections where delay increased greater than 5 seconds/vehicle. However, the intersections listed below continue to operate at an acceptable level of service in implemented conditions. The cycle length for the Warren Road was slightly increased during the PM peak period to allow for coordination for not just east-west Madison Avenue but also with Warren Road & Athens Avenue. There is also a clearance overlap for the northbound movement at Madison Avenue from the northbound movement at fire station signal approximately 250 feet to the south, so the splits required to maintain coordination were larger than what was programmed under existing conditions.

There were also large delays for the westbound movement Delay at the intersection of Alger Road & Lakewood Heights Boulevard increased during several time periods. This signal was operating in free operation under existing conditions, despite Lakewood Heights Boulevard carrying significant volumes throughout the day and being only being approximately 650 feet from Warren Road. Coordinated timings were implemented at this signal, which increased overall delay at this one signal, but improved overall system delay and will improve safety conditions, since rear end crashes will be reduced with coordination along Lakewood Heights Blvd.

**Table 5 – Intersections with Delay Increase Greater than 5 seconds per Vehicle**

Intersection	Period	Existing Delay (s/veh) - LOS	Implemented Delay (s/veh) - LOS
Warren Rd & Madison Ave	PM	24 - C	30 - C
Alger Rd & Lakewood Heights Blvd	AM	14 - B	24 - C
	MD	10 - B	17 - B
	PM	12 - B	20 - B
	PO	11 - B	17 - B
	WA	11 - B	19 - B
	WM	11 - B	20 - B

Table 6 summarizes the overall intersection LOS for the existing (ex) vs. implemented (imp) time periods. As noted in these tables, overall the LOS has improved for the study area intersections. It is also noted that the existing LOS for most intersections is LOS D or better for both the existing and implemented conditions. The intersections with a LOS worse than D are highlighted in Table 6, which both occurred at W 150th Street & Terminal Avenue under existing conditions. These were both improved to LOS C under implemented conditions.

**Table 6 – Overall Existing vs. Implemented Intersection LOS Summary**

Intersection	AM		MD		PM		PO		WA		WM		WP	
	Ex	Imp	Ex	Imp	Ex	Imp	Ex	Imp	Ex	Imp	Ex	Imp	Ex	Imp
Warren Rd & Madison Ave	B	B	B	B	C	C	B	B	B	B	B	B	B	B
Warren Rd & Athens Ave	B	B	B	A	C	B	C	B	B	A	B	A	B	A
Warren Rd & Delaware Ave	B	B	A	A	A	A	A	A	A	A	A	A	A	A
Warren Rd & Lakewood Heights Blvd	C	C	B	C	D	D	C	C	B	C	C	C	B	C
Warren Rd & S Marginal Dr	C	C	B	B	C	B	B	B	B	B	B	B	B	B
Warren Rd & Montrose Ave	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Warren Rd & Edgecliff Ave/Orchard Park Ave	A	A	B	B	B	B	B	B	B	B	B	B	B	B
Warren Rd & W 155th St/Grapeland Ave	B	A	B	A	B	A	B	A	A	A	B	A	A	A
Warren Rd & Munn Rd	B	B	B	A	B	A	B	A	B	A	B	A	B	A
Warren Rd & Triskett Rd	D	D	C	C	D	C	C	C	B	B	B	C	B	B
Warren Rd/W 150th St & Lorain Ave	D	D	C	C	D	D	D	C	C	C	D	C	C	C
W 150th St & Chatfield Ave	A	A	A	A	A	A	A	A	A	A	A	A	A	A
W 150th St & Emery Ave	C	C	B	A	D	C	B	A	A	A	B	A	A	A
W 150th St & Terminal Ave	E	C	D	C	F	C	D	C	C	C	D	C	D	B
W 150th St & I-71 EB Ramps	C	C	C	C	D	D	C	C	B	B	C	C	C	C
W 150th St & Puritas Ave	D	D	C	C	D	D	C	C	C	C	C	C	C	C
W 150th St & Coe Ave	B	A	A	A	B	A	A	A	A	A	A	A	A	A
W 150th St & Industrial Pkwy	D	D	A	A	C	C	B	B	A	A	B	B	A	A
W 150th St & I-480 WB Off-ramp	C	B	B	B	C	B	B	B	A	A	B	B	A	A
W 150th St & Brookpark Rd	D	D	C	C	D	D	D	C	C	C	D	C	D	C
Madison Ave & Reveley Ave	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Madison Ave & Belle Ave	B	B	B	A	B	B	B	A	B	A	C	A	B	A
Madison Ave & Lincoln Ave	B	A	A	A	B	B	A	A	A	A	B	B	A	A
Alger Rd & Lakewood Heights Blvd	B	C	B	B	B	B	B	B	B	B	B	B	A	B
Alger Rd & S Marginal Dr	B	A	A	B	B	B	B	B	B	B	B	B	B	B
Terminal Ave & I-71 Ramp	B	B	B	B	B	B	B	B	B	B	B	B	B	A

### 8.2 Network Performance Measures

While the figures in Section 8.1 summarize performance of individual intersections by delay, LOS, and ICU, the tables in this section combine and summarize four performance measures for all intersections in the network: total delay, total stops, total travel time, and total fuel consumption. The tables also summarize the percent change of each measure, which illustrates the overall change to the network with the implemented signal timings. The performance measures were calculated (not field-measured) by the Synchro and SimTraffic models. The models summarize data for all vehicles in the network. Network performance measures developed by Synchro and SimTraffic can be found in Table 7 and Table 8, respectively.

**Table 7 – Network Performance Measures (Synchro)**

	AM Peak			MD Peak					
	Existing	Implemented	Difference	Existing	Implemented	Difference			
Total Delay (hr)	398	312	-21.6%	197	171	-13.2%			
Total Stops	29,692	25,387	-14.5%	21,144	17,849	-15.6%			
Total Travel Time (hr)	739	652	-11.8%	466	440	-5.6%			
Fuel Consumed (gal)	918	825	-10.1%	622	580	-6.8%			
	PM Peak			PM Off-peak					
	Existing	Implemented	Difference	Existing	Implemented	Difference			
Total Delay (hr)	556	391	-29.7%	250	191	-23.6%			
Total Stops	35,854	31,248	-12.8%	24,182	20,306	-16.0%			
Total Travel Time (hr)	947	783	-17.3%	543	484	-10.9%			
Fuel Consumed (gal)	1,140	986	-13.5%	708	638	-9.9%			
	Weekend AM Peak			Weekend MD Peak			Weekend PM Peak		
	Existing	Implemented	Difference	Existing	Implemented	Difference	Existing	Implemented	Difference
Total Delay (hr)	135	113	-16.3%	252	207	-17.9%	157	124	-21.0%
Total Stops	15,385	13,055	-15.1%	26,135	21,090	-19.3%	17,563	14,557	-17.1%
Total Travel Time (hr)	348	325	-6.6%	562	517	-8.0%	387	354	-8.5%
Fuel Consumed (gal)	465	433	-6.9%	745	678	-9.0%	519	475	-8.5%

**Table 8 – Network Performance Measures (SimTraffic)**

	AM Peak			MD Peak					
	Existing	Implemented	Difference	Existing	Implemented	Difference			
Total Delay (hr)	535	349	-34.8%	217	181	-16.3%			
Total Stops	31,394	25,036	-20.3%	19,850	16,877	-15.0%			
Total Travel Time (hr)	1,023	914	-10.7%	592	551	-6.9%			
Fuel Consumed (gal)	577	554	-4.0%	417	402	-3.5%			
	PM Peak			PM Off-peak					
	Existing	Implemented	Difference	Existing	Implemented	Difference			
Total Delay (hr)	921	538	-41.6%	272	206	-24.3%			
Total Stops	37,502	33,459	-10.8%	24,013	18,664	-22.3%			
Total Travel Time (hr)	1,642	1,083	-34.0%	692	607	-12.4%			
Fuel Consumed (gal)	746	660	-11.5%	476	437	-8.1%			
	Weekend AM Peak			Weekend MD Peak			Weekend PM Peak		
	Existing	Implemented	Difference	Existing	Implemented	Difference	Existing	Implemented	Difference
Total Delay (hr)	137	119	-13.4%	272	228	-16.4%	163	130	-20.1%
Total Stops	14,422	12,255	-15.0%	24,013	19,768	-17.7%	16,441	13,263	-19.3%
Total Travel Time (hr)	422	405	-3.8%	692	647	-6.5%	474	440	-7.1%
Fuel Consumed (gal)	311	305	-2.0%	476	462	-2.8%	342	329	-3.9%



The results of the Synchro analysis show a decrease in total delay, total stops, total travel time, and fuel consumed for all time periods. The SimTraffic analysis also shows an improvement across all measures of effectiveness throughout all time periods and yielded similar results to the Synchro analysis.

Over the expected five-year life of the project and based upon calculated values, the implemented signal timing is estimated to decrease delay by 450,300 hours (23%), total stops by 24,306,100 (15.0%), and fuel consumption by 501,400 gallons (10.2%).

The United States Environmental Protection Agency (EPA) has provided a calculator for carbon dioxide (CO<sub>2</sub>) emissions. The calculator can be found at <http://www.epa.gov/cleanenergy> under the Clean Energy Resources heading. Based on the fuel analysis above, the implemented signal timing is estimated to reduce CO<sub>2</sub> emissions by 4,460 metric tons over the life of the project. In addition, emission pollutants for nitrogen oxides (NO<sub>x</sub>) are estimated to be reduced by 970 kg, fine particles (PM<sub>2.5</sub>) by 29 kg, and volatile organic compounds (VOC) by 890 kg.

### 8.3 Time-Space Diagrams

Time-space diagrams can be used as a tool for fine-tuning splits and offsets and maximizing corridor bandwidth and progression. Time-space diagrams for each of the implemented timing patterns for each roadway are included in the [Appendix](#).

### 8.4 Travel Time Runs

Travel time runs were conducted as a tool for fine-tuning. Additionally, travel time runs also provide the analyst field-measured metrics such as delay and travel time reductions. While only travel time and delay are summarized in this report, information on other measures such as the number of stops, stopped delay, and average speed can be found in the [Appendix](#).

Travel time runs were completed on Warren Road/West 150th Street before and after the new signal timings were implemented. The average of the “existing” runs was compared to the average of the “implemented” runs to determine travel time savings on the corridor. These performance data are field-measured and apply only to vehicles on the main corridor. Figure 25 on page 43 illustrates the average cumulative travel time on the corridor for each direction with existing and implemented signal timings.

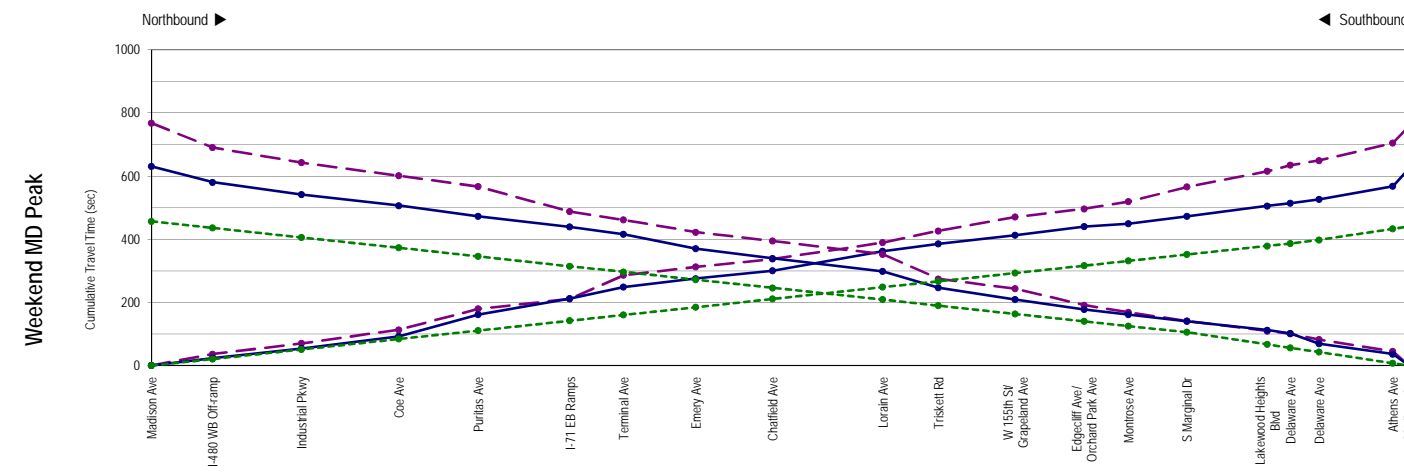
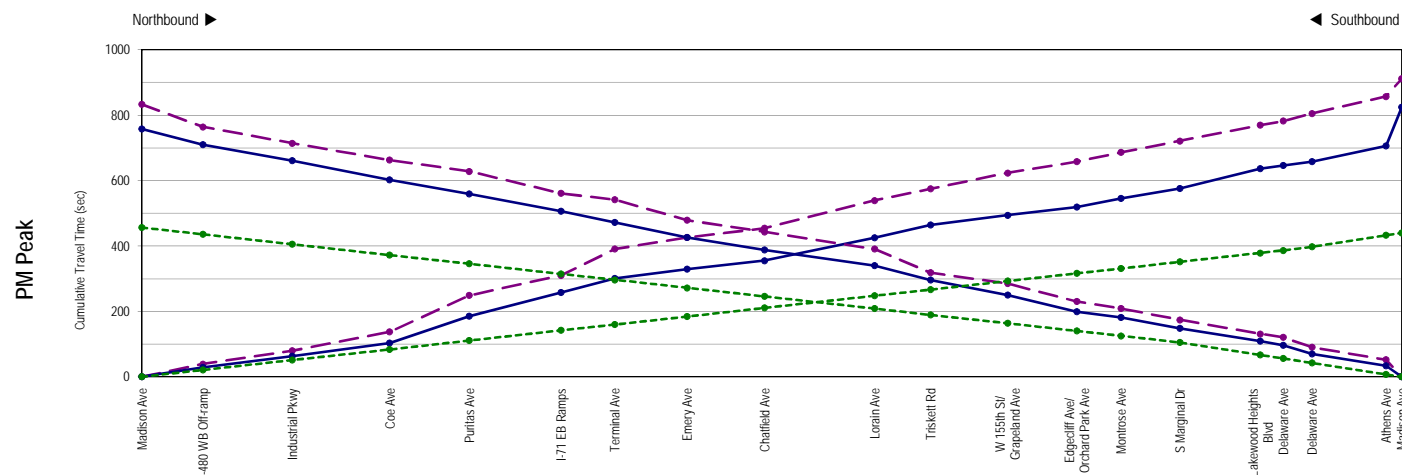
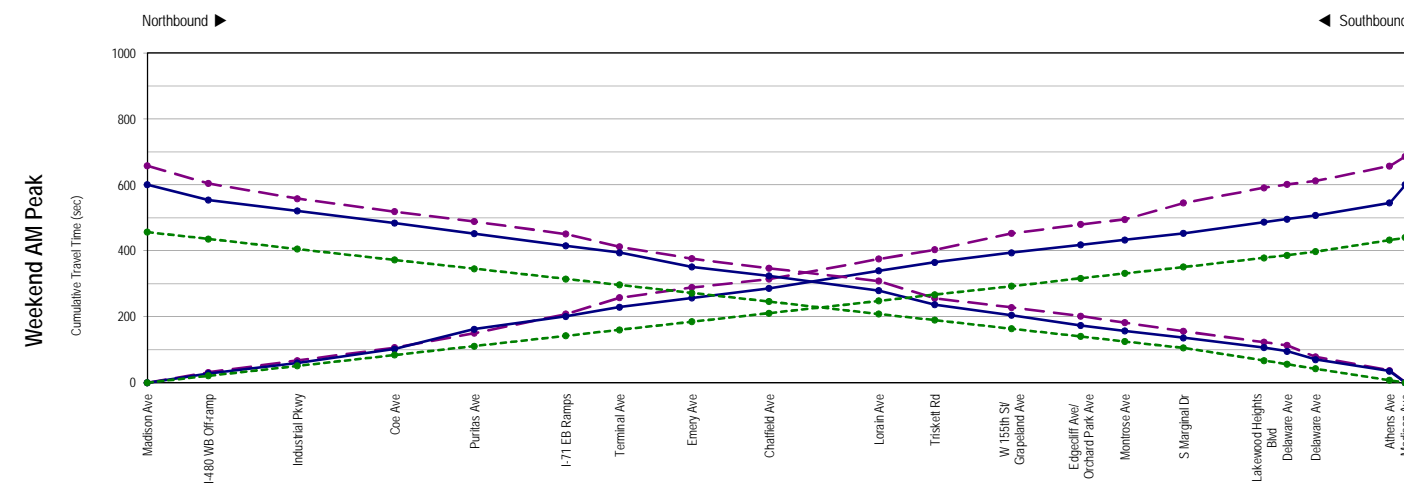
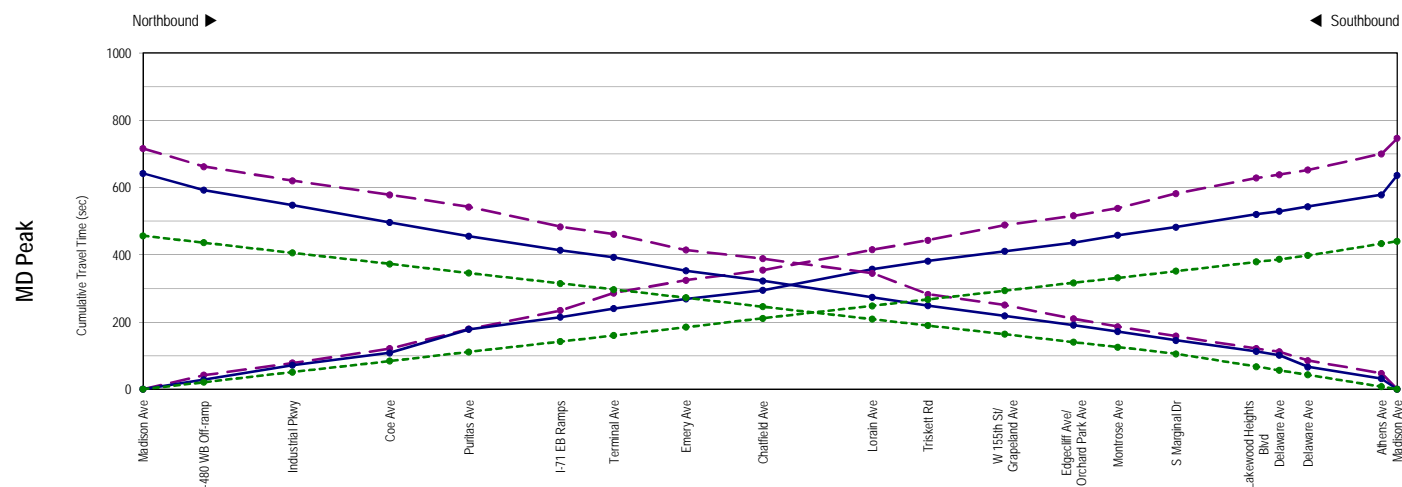
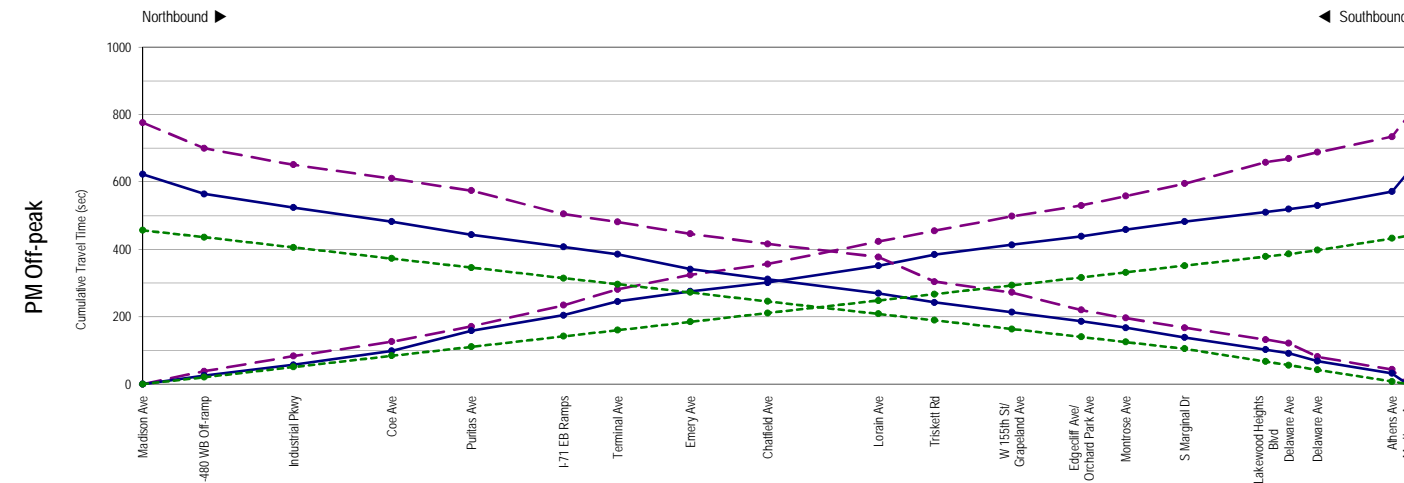
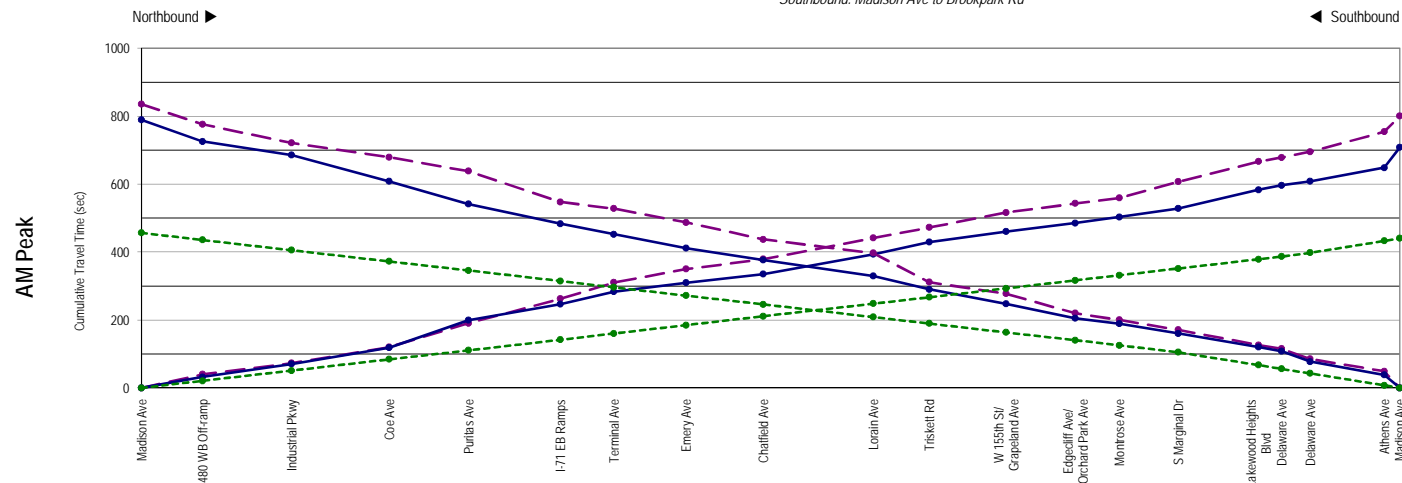
In the northbound direction on Warren Road/West 150th Street, weekday delay decreased up to 166 seconds (50%) during the PM Off-peak and weekend delay decreased up to 135 seconds (46%) during the weekend MD peak. In the southbound direction, weekday delay decreased up to 153 seconds (50%) during the PM Off-peak period while weekend delay decreased up to 137 seconds (46%) during the weekend MD peak.

Average Total Travel Time & Delay

Warren Rd/W 150th St: 4.1 miles

	AM Peak		MD Peak		PM Peak		PM Off-peak		Weekend AM Peak		Weekend MD Peak	
	Travel Time (s)	Delay (s)	Travel Time (s)	Delay (s)	Travel Time (s)	Delay (s)	Travel Time (s)	Delay (s)	Travel Time (s)	Delay (s)	Travel Time (s)	Delay (s)
Northbound	800	335	746	282	911	446	793	329	686	222	757	293
Implemented	708	244	636	172	824	360	627	162	600	135	622	157
Difference		-92		-110		-87		-166		-86		-135
% Difference	-11.5%	-27.2%	-14.7%	-39.0%	-9.5%	-19.5%	-20.9%	-50.5%	-12.5%	-38.7%	-17.8%	-46.1%
Southbound	835	365	716	246	833	363	776	306	658	188	767	297
Implemented	789	319	642	172	758	288	623	153	600	130	630	160
Difference		-46		-74		-75		-153		-58		-137
% Difference	-5.5%	-12.6%	-10.3%	-30.1%	-9.0%	-20.7%	-19.7%	-50.0%	-8.8%	-30.9%	-17.9%	-46.1%

Northbound: Brookpark Rd to Madison Ave  
Southbound: Madison Ave to Brookpark Rd



Existing  
Implemented  
Free Flow



Figure 25

Average Travel Time & Delay

Warren Rd/W 150th St

## 9.0 TRAFFIC SIGNAL RETIMING BENEFIT-COST ANALYSIS

The purpose of this analysis is to establish a project's merit by economically quantifying the benefits and costs associated with the project over its lifetime. According to the ITE, "signal retiming is a beneficial method for maintaining efficient traffic signal operations" and "is the most cost-effective technique to reduce congestion, improve air quality, and potentially reduce accidents." The following discusses the methodology used to determine the benefits and costs of implementing new signal timings at the intersections within the scope of this project.

There are two types of benefits as they relate to transportation improvements. User benefits, or direct benefits, are enjoyed directly by travelers and are determined by a reduction in three distinct travel costs: travel time costs, operating costs, and crash costs. The second type of benefit is non-user benefits, or indirect benefits. These benefits include environmental impacts, air quality, and reduced motorist frustration.

### 9.1 Travel Time and Operations Benefit-Cost Analysis

Travel time benefits were calculated by modeling delay with existing and implemented signal timings during each hour modeled. Benefits were also estimated for non-peak hours during which implemented timings are in operation. The total delay was multiplied by a value-of-time and auto occupancy to determine the total weekly benefit as a result of reduction in travel time as shown in Table 9 below.

**Table 9 – Weekly Benefit for Change in Travel Time Costs**

Delay (h)	AM	MD	PM	PO	WA	WM	WP	
Existing Timings	398	197	556	250	135	252	157	
Implemented Timings	312	171	391	191	113	207	124	
Change	-86	-26	-165	-59	-22	-45	-33	
Estimated Change during other hours					-177			
Total Daily Change					-513			
Total Weekly Change in Delay					-2,565			
							Auto	Truck
Vehicle Type							98%	2%
Value-of-Time (\$/hr) <sup>1,2</sup>							\$9.25	\$95.61
Auto Occupancy <sup>1</sup>							1.25	1.00
Total							\$32,693	\$5,519
Weekly Benefit for Change in Travel Time Costs								\$38,212

<sup>1</sup> Taken from Urban Mobility Report, Texas Transportation Institute, 2012 and adjusted based on Consumer Price Index

<sup>2</sup> Adjusted for trip type per AASHTO User Benefit Analysis for Highways, 2003

Benefits for the reduction in operating costs were calculated by modeling fuel consumption with existing and implemented signal timings during each peak hour and estimating fuel consumption during non-peak hours. The total change in fuel consumption was multiplied by the twelve-month average fuel cost. The weekly benefit for change in operating costs is shown in Table 10.

**Table 10 - Weekly Benefit for Change in Operating Costs**

Fuel Consumption (gal)	AM	MD	PM	PO	WA	WM	WP
Existing Timings	918	622	1,140	708	465	745	519
Implemented Timings	825	580	986	638	433	678	475
Change	-93	-42	-154	-70	-32	-67	-44
Estimated Change during other hours					-192		
Total Daily Change					-551		
Total Weekly Change					-2,755		
Fuel Cost <sup>3</sup>							\$2.56
Weekly Benefit for Change in Operating Costs							\$8,250

<sup>3</sup> 52-week average fuel cost, US Energy Information Administration Gasoline Prices for the City of Cleveland, November 2018 - www.eia.gov

Based upon the previous tables, the total weekly benefit from the changes in travel time and operating costs is approximately \$46,460.

In order to calculate the total lifetime benefit present value, it was assumed the life of this project will be five years. It was also assumed that 100% of the total daily benefit will be realized in Year 1. However, as traffic volumes change, the daily benefit will likely decrease. Therefore, benefits in subsequent years are reduced by 20% each year. Table 11 summarizes the annual benefits over the project life.

**Table 11 – Summary of Annual Travel Time and Operations Benefits**

Year	Annual Benefit Present Value
Year 1	\$2,379,483
Year 2	\$1,848,142
Year 3	\$1,345,735
Year 4	\$871,026
Year 5	\$422,828

Using a 3% discount rate, the present value of annual benefits over the project life is approximately \$6,867,200.

## 9.2 Overall Benefit-Cost Analysis

Anticipated travel time and operations benefits were utilized to conduct an overall benefit-cost analysis. According to the benefits described in Sections 9.1, the present value of all calculated benefits for this project is approximately \$6,867,200.

### Costs

The total cost to conduct all the tasks for the intersections within the scope of this project (including data collection) was \$230,000.

### Benefit-Cost Ratio

Given the anticipated benefits and costs described above, the overall benefit-cost ratio for this project is 33:1.

### Net Present Value

Accounting for future benefits and current project costs, the overall anticipated net present value of this project is \$6,637,200.

## 10.0 RECOMMENDATIONS

### 10.1 Recommendations for Safety Improvements

Based on the field observations in Section 3, the following improvements are recommended to improve corridor safety. A full analysis of potential recommendations is included in the [Appendix](#).

#### West 150th Street & Interstate 480 Westbound Off-ramp

- Consider installing supplemental signal heads for the northbound movement along West 150th Street on the south side of the Interstate 480 Overpass. The overpass is located immediately to the south of this intersection, potentially blocking the view of traffic signals for the northbound approach. An analysis of crashes for the years 2015 – 2017 indicates that six (6) crashes occurred at this intersection over this span. Of the crashes, four (4) were rear end crashes, one (1) was a right turn crash, and one (1) was a fixed object crash. None of the crashes occurred along the northbound approach. While the three (3) year crash history at this intersection does not indicate a safety issue resulting from poor signal visibility, the installation of supplemental signal heads on the south side of the I-480 overpass is still recommended to prevent future crash patterns for northbound traffic.

#### Various intersections

- Consider installing backplates with retroreflective backplate borders and/or retroreflective backplate borders only, as needed, on all signal heads to increase visibility at all intersections.
- As per ODOT's Traffic Engineering Manual, Section 420-4.11, consider installing auxiliary signal indications on the right-side signal support. Large trucks often block the view of the overhead signal indications and these auxiliary signals would help improve visibility for these locations. In particular, the intersections on the southern end of the study area would benefit from this as they have higher truck traffic.
- At locations where crosswalks are not provided on all approaches, it is recommended to install pedestrian warning signs to provide positive guidance.
- Countdown Pedestrian Signal Indications should be considered at locations where they currently do not exist. The following intersections have some or no countdown indications (refer to section 3.4). This table is sorted by the total number of pedestrians to prioritize those intersections with higher needs.

Intersection	Total Pedestrians (excludes bikes)
Madison Ave & Victoria Ave/ Reveley Ave	830
Madison Ave & Lincoln Ave	605
Madison Ave & Belle Ave	598
W 150th St & Puritas Ave	319
Warren Rd & W 155th St/Grapeland Ave	218
Warren Rd & Montrose Ave	184
Warren Rd & Athens Ave	168
Warren Rd & Edgecliff Ave/Orchard Park Ave	156
W 150th St & I-71 EB Ramps	122
W 150th St & Coe Ave	71
W 150th St & Terminal Ave	67
Alger Rd & Lakewood Heights Blvd	67
Warren Rd & Lakewood Heights Blvd	64
Warren Rd & Delaware Ave	55
W 150th St & Emery Ave	25
W 150th St & Industrial Pkwy	25
W 150th St & Brookpark Rd	23
Alger Rd & S Marginal Dr	23
W 150th St & I-480 WB Off-ramp	21
Warren Rd & S Marginal Dr	15
W 150th St & Chatfield Ave	15

- Leading Pedestrian Indications (LPIs) have been shown to be an effective safety measure for pedestrians when the intersection has particularly high pedestrian traffic, a history of pedestrian crashes, and a high number of turning movements. The following locations could consider LPIs based on this criterion:

Intersection	Total Pedestrians	Ped Crashes	Percent Turning Vehicles
W 150th St & Puritas Ave	331	9	47%
W 150th St/Warren Rd & Lorain Ave	274	2	32%
Warren Rd & Munn Rd	110	1	35%
W 150th St & I-71 EB Ramps	126	1	53%
Warren Rd & Triskett Rd	156	1	29%
Warren Rd & Madison Ave	792	1	32%

## 10.2 Recommendations for Capacity and Operational Improvements

Beyond optimizing traffic signal timing, other capacity or operational improvements can further improve the performance of an intersection and roadway network. Based on current capacity and operations, the following improvements are recommended at this time. Consideration should be given to additional improvements required by future traffic growth and costs of right-of-way, design, construction, etc. However, these considerations are not included in the scope of this project.

### Warren Road & Madison Avenue

- Consider implementing a northbound protected/permissive left-turn phase at this intersection. Currently, this movement is permissive only and during the during the PM peak hour there are 139 left turns along the northbound approach. With optimized signal timings, this lane group operates at LOS F. The implementation of protected/permitted phasing for northbound left turns improves LOS for this lane group from F to D during the PM peak hour and reduces LOS from A to C during the AM peak hour. Additionally, level of service during the AM peak hour is still at favorable levels (LOS D or better).
- The addition the northbound protected/permissive left-turn phase is suggested for the AM and PM peak hours. The cycle lengths would not need to change and the split for the AM peak and PM peak would be 12 seconds. The phase is not required for other time periods, but this short 12 second split could be maintained for other time periods without negative impacts to other movements.
- Table 12 below summarizes the LOS and delay both under existing operation and with implemented operations.

**Table 12 – Warren Rd & Madison Ave Recommendation Level-of-Service (Delay) Summary**

Location	Approach	Lane Group	No Improvements (w/Optimized Timing)		Improvements (w/Optimized Timing)	
			AM Peak	PM Peak	AM Peak	PM Peak
Warren Rd & Madison Ave Implement NB Prot/Perm phasing	Northbound (Warren Road)	Left	<b>A (9.6)</b>	<b>F (149.0)</b>	<b>C (24.2)</b>	<b>D (37.9)</b>
		Thru/Right	B (11.6)	B (15.4)	B (11.6)	A (6.8)
		Approach	B (11.3)	D (47.7)	B (13.7)	B (14.3)
	Intersection Overall	B (15.5)	C (29.8)	C (29.8)	C (25.8)	

Various intersections

- Several locations as described in Section 3.4 have recalls for pedestrian movements. Consider updating vehicle and pedestrian detection at these locations.
- Consider installing GPS units at the following locations to ensure a common time sync through the system. These signals are either isolated and/or serve as a master to other nearby intersections.

<u>Intersection</u>	<u>Type</u>	<u>Intersection</u>	<u>Type</u>
Warren Rd & Madison Ave	Master	W 150th St & Terminal Ave	Master
Warren Rd & Athens Ave	Isolated	W 150th St & Coe Ave	Isolated Master
Warren Rd & Delaware Ave	Isolated	W 150th St & Industrial Pkwy	Master
Warren Rd & Lakewood Heights Blvd	Master	W 150th St & Brookpark Rd	Master
Warren Rd & Triskett Rd	Master	Alger Rd S Marginal Dr	Isolated

- Consider adding remote communication to the systems near interchanges to allow for monitoring and the deployment of coordinated patterns, such as those for diversion routes.
- Currently, the Flashing Yellow Arrow display is not to be used on ODOT maintained traffic signals. However, the OMUTCD allows their use, and ODOT intends to allow them in the future. Flashing Yellow Arrows are recommended at the following intersections to replace existing five-section heads to allow lead/lag operation and variable left-turn phasing type by time of day.

<u>Intersection</u>	<u>Movement</u>	<u>Intersection</u>	<u>Movement</u>
Warren Rd & Lakewood Heights Blvd	NBL	W 150th St & I-71 Ramps	SBL
Warren Rd & S Marginal Dr	SBL	W 150th St & Puritas Ave	All left turns
Warren Rd & Munn Rd	NBL	W 150th St & Industrial Pkwy	NBL
Warren Rd & Triskett Rd	All left turns	W 150th St & I-480 WB Off-ramp	WBL
Warren Rd & Lorain Ave	All left turns	W 150th St & Brookpark Rd	EBL & WBL
W 150th St & Emery Ave	NBL & SBL		

## 11.0 APPENDIX

The Appendix documents are electronic only and can be found at the following website:

<http://www.albeckgerken.com/st-warren-rd/appendix>

Documents included on the site include:

- A. [7-day, 24-hour directional volume counts](#)
- B. [Turning movement counts](#)
- C. [Existing and implemented timing sheets](#)
- D. [Clearance calculations](#)
- E. [Aerial photographs](#)
- F. [Intersection approach photographs](#)
- G. [Cabinet photographs](#)
- H. [Field notes](#)
- I. [Synchro models with existing and implemented signal timings](#)
- J. [Synchro & SimTraffic report files with existing and implemented signal timings](#)
- K. [Traffic Operations Analysis reports](#)
- L. [Tru-Traffic files and reports](#)
- M. [Time-space Diagrams](#)
- N. [Warrant Analysis](#)
- O. [Roadway Improvement Evaluation](#)
- P. [Crash Analysis Summary](#)
- Q. [Final report](#)