PHASE 3 TRAFFIC SIGNAL SYSTEM OPTIMIZATION

MARCH 2020

PREPARED BY:

CITY OF LINCOLN NEBRASKA TRAFFIC ENGINEERING

IN COORDINATION WITH:

FELSBURG HOLT & ULLEVIG

GREEN LIGHT LINCOLN™

IT'S GO TIME

Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

EXECUTIVE SUMMARY

This report documents the results of traffic engineering work completed for the Green Light Lincoln – Phase 3 Traffic Signal System Optimization project. Phase 3 builds upon work completed in Phases 1 and 2 which included over 235 traffic signals. Phase 3 addressed 85 additional traffic signals and revised seven Phase 2 signals. The following areas were studied and evaluated for improved safety and traffic flow:

- Downtown (63 traffic signals)
  - 9th Street to 17th Street, Q Street to K Street
  - Including S. 8th Street with N Street
- South of Downtown (29 traffic signals)
  - S. 9th Street – K Street to South Street
  - S. 10th Street – K Street to Park Avenue (Pedestrian)
  - S. 13th Street – K Street to Van Dorn Street
  - S. 16th Street – K Street to South Street
  - S. 17th Street – K Street to Van Dorn Street
  - A Street – S. 9th Street to S. 20th Street (Pedestrian)
  - South Street – S. 9th Street to S. 20th Street (Pedestrian)

The primary objective of the project was to prepare and implement optimized traffic signal timing plans in the downtown network and to quantify the resulting changes in traffic operations. These timing plans were developed based on a data collection effort, industry research, field observations, operational / safety review, and detailed traffic engineering which included utilizing computerized software models (Synchro, SimTraffic, and Tru-Traffic). Study corridors and intersections were evaluated for many variables to bring the timing plans into conformance with current best practices including proper time-of-day schedule, desirable left-turn phasing type, cycle length, phase splits, and vehicle and pedestrian clearance intervals.

The new timing plans were then implemented with the help of City of Lincoln Traffic Engineering staff and fine-tuned in the field over the course of several weeks to achieve optimal results. Performance measures were documented in the form of travel time studies using StreetLight Data to compare data from before and after the updated signal timings were implemented and fine-tuned. Reductions in delay and fuel are estimated to save Lincoln motorists over 313,000 hours of delay and $4.7 million in time and fuel costs per year. These benefits are the direct result of improved traffic signal timings and equipment upgrades which achieved decreased travel time among users and vehicle fuel consumption savings. Additionally, the implementation of new timings also resulted in 18 countermeasures from the City of Lincoln 2012 and 2018 Crash Studies being implemented, which are expected to provide safety benefits to motorists.

It is recommended to continue retiming efforts throughout the city and retime corridors approximately every three to five years to further save Lincoln motorists time and money. Phase 3 of Green Light Lincoln produced a calculated benefit-to-cost ratio of 28:1 over the next five-year time frame.

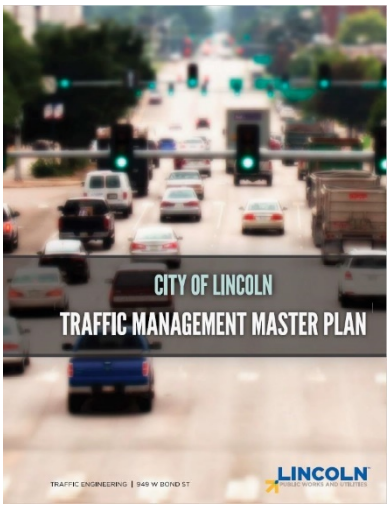
The report that follows documents in detail the Phase 3 Traffic Signal System Optimization objectives, processes, results, and benefits.

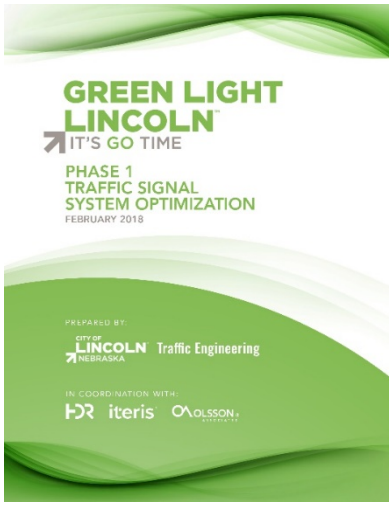
IT'S **GO** TIME!

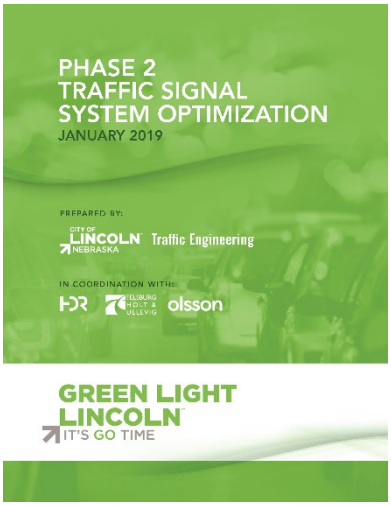
1.0 INTRODUCTION

This traffic signal system optimization project (Green Light Lincoln – Phase 3) is a continuation of collaborative efforts from City of Lincoln Traffic Engineering, City leaders, contractors, and consultants to improve travel in the City of Lincoln. The Green Light Lincoln initiative originated from a recommendation of the City of Lincoln's *Traffic Management Master Plan* (TMMP); a document that has provided insight on the status of citywide traffic systems to City leaders and has also set the vision for the future of traffic engineering in Lincoln. Several key components of the TMMP, including this project, are being addressed under the Green Light Lincoln initiative.

Green Light Lincoln – Phases 1 and 2 were successful endeavors, retiming over 235 traffic signals on or adjacent to 21 corridors. The total documented reductions in travel delay and fuel consumption for the first two phases were estimated to save Lincoln motorists over 840,000 hours of delay and $17.6 million in time and fuel costs per year. Phase 3 builds upon this success, addressing 85 new traffic signals and the overlap of seven Phase 2 signals, to further improve mobility and safety for Lincoln motorists.

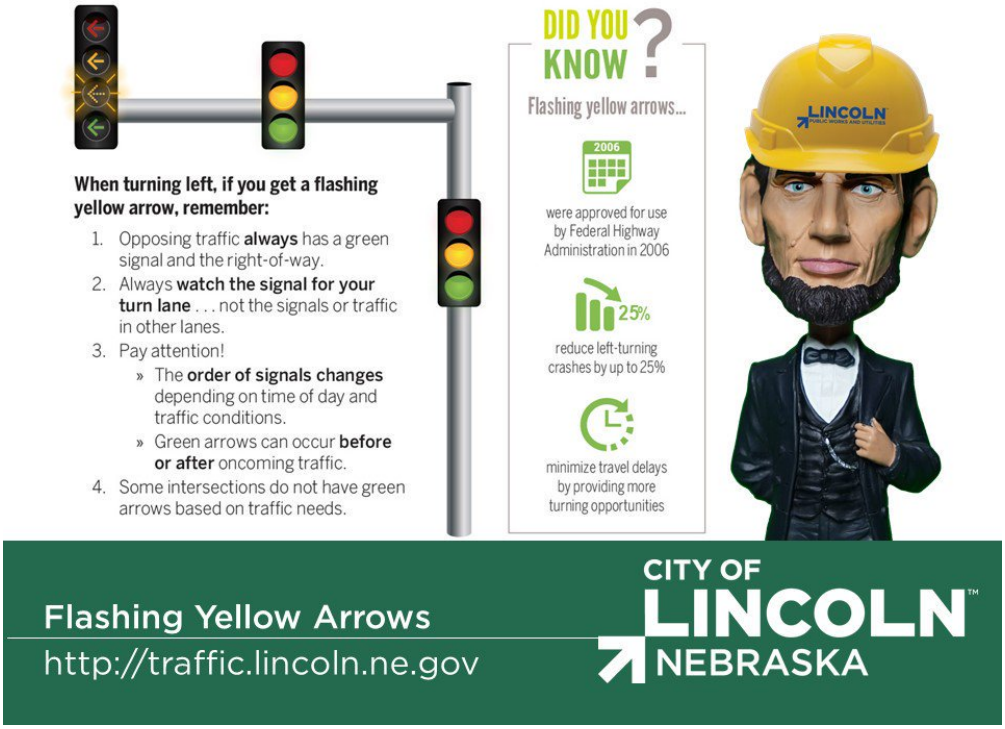






The overall purpose of this project was to prepare and implement optimized traffic signal timing plans for the downtown network, and to quantify and document the changes in traffic operations resulting from signal equipment upgrades and signal timing changes with "before" and "after" performance measures.

City forces and private contractors upgraded traffic signal controller cabinets, and fixed faulty detection in preparation for new signal timing plans. They also installed new signal heads, improved signal displays, and installed Flashing Yellow Arrow (FYA) indications to achieve uniformity across the city. Their collective efforts paved the way for the signal timing implementation portion of this project. An infographic from the City's website describing FYA operation is included on the following page.



One consultant team was tasked with signal timing changes and performance measure documentation: Felsburg Holt & Ullevig (FHU) and Albeck Gerken, Inc. (recently merged with Iteris). The consultant team was assigned the following area:

- Downtown (63 traffic signals)
  - 9th Street to 17th Street, Q Street to K Street
  - Including S. 8th Street with N Street
- South of Downtown (29 traffic signals)
  - S. 9th Street – K Street to South Street
  - S. 10th Street – K Street to Park Avenue (Pedestrian)
  - S. 13th Street – K Street to Van Dorn Street
  - S. 16th Street – K Street to South Street
  - S. 17th Street – K Street to Van Dorn Street
  - A Street – S. 9th Street to S. 20th Street (Pedestrian)
  - South Street – S. 9th Street to S. 20th Street (Pedestrian)

Figure 1 provides a map of the streets retimed as part of each phase of Green Light Lincoln. **Figure 2** provides a map of the Phase 3 study area. A complete list of intersections per corridor is provided in **Appendix A**.

The following standalone documents were prepared as part of Phase 3:

- Traffic Signal Warrants Review Memo
- ITE Clearance Interval Review Memo
- Cycle Track Literature Review Memo
- Green Light Lincoln Phases 1 and 2 Travel Time Review Memo

Figure 1: Study Network Map

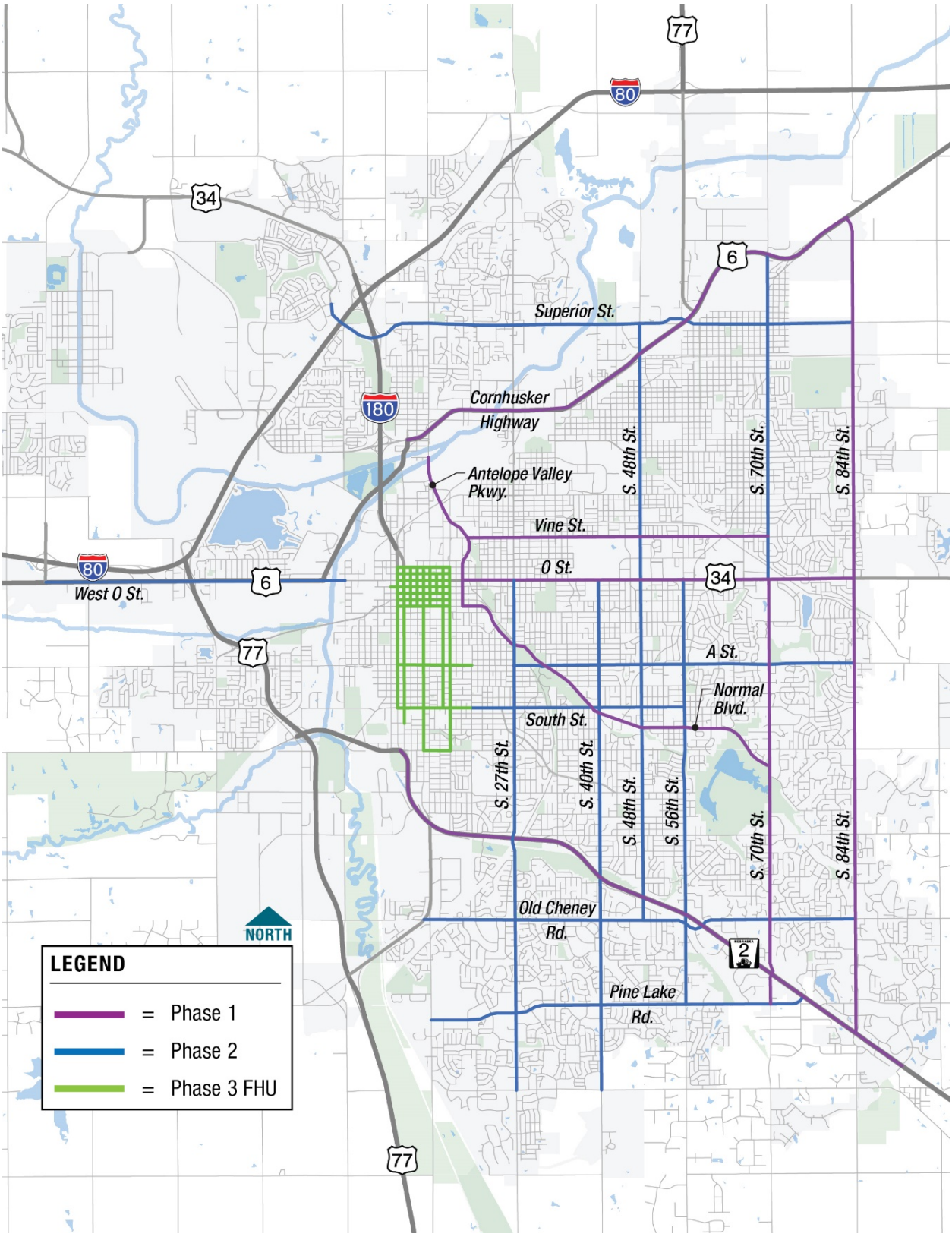
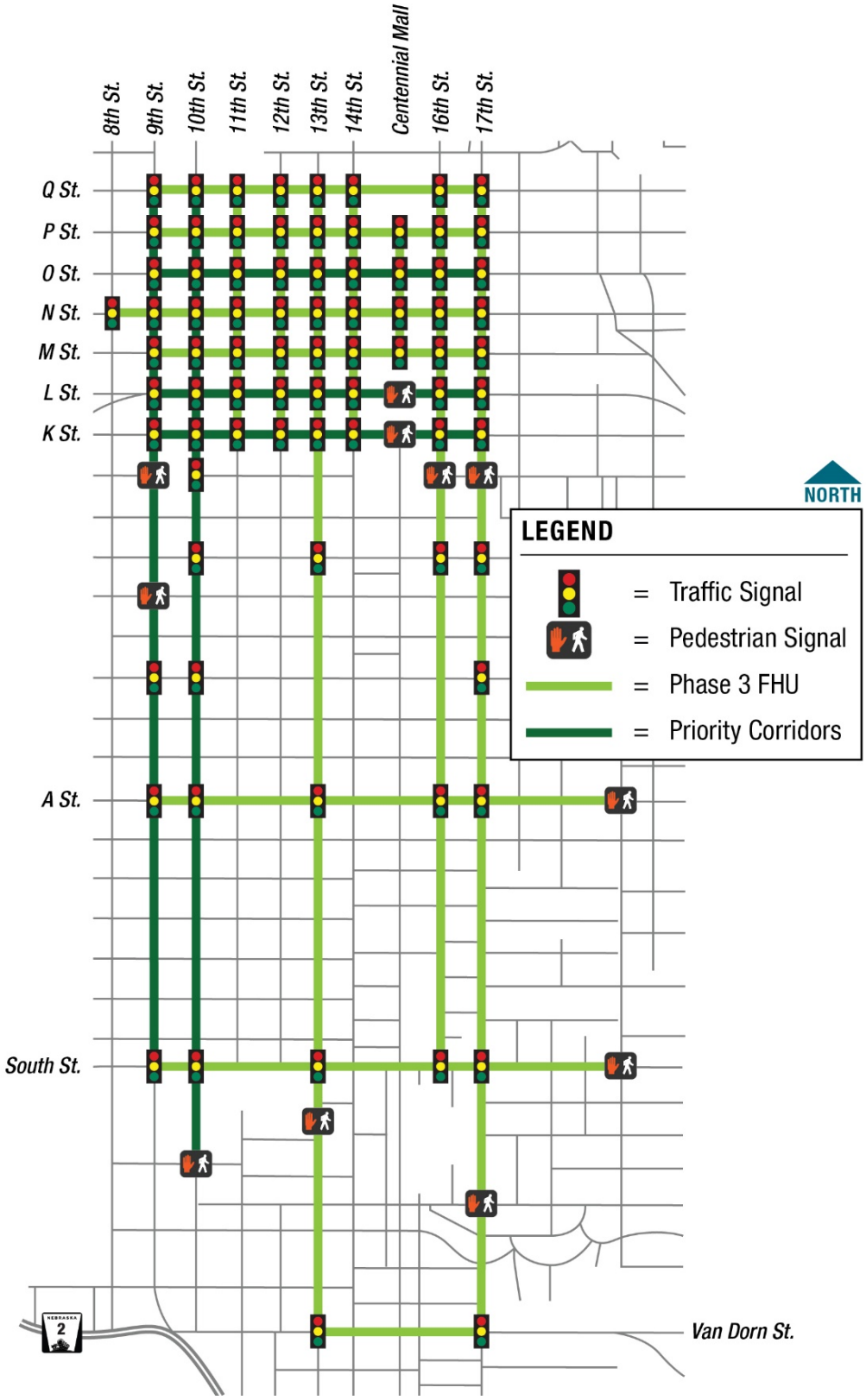


Figure 2: Study Intersection Map



2.0 Data Collection

Data collection and review efforts were completed for each study intersection. These efforts were dual-purposed. First, it yielded the characteristics and documentation necessary to perform calculations and support the development of new timing plans. Second, it provided the means to compare operations from updated conditions to baseline conditions.

2.1 City Provided Information

The City of Lincoln provided the following:

- City of Lincoln *Traffic Signal Timing Guidelines v2.0*
- City of Lincoln *2012 Crash Study*
- City of Lincoln *2018 Lincoln Crash Data Analysis*
- Existing timing plans via ATMS software (ACTRA)
- Synchro files
- Intersection Turning Movement Volumes (TMVs)
- 24-hour Traffic Volumes

2.2 Consultant Collected Information

Consultants collected the following for each intersection:

- Intersection lane configuration / utilization
- Pedestrian crossing distances (crosswalk lengths)
- Vehicle crossing distance (near to far side of intersection)
- Posted speed limits
- Distance between signalized intersections
- Intersection approach grades
- Turn restrictions
- Turn lane storage lengths
- Push button documentation
- Location of mast arm ends
- Intersection approach photographs
- Field observations of traffic operations
- Sight distance restrictions
- Deficient signal equipment
- Existing timing plans via Direct Connection

2.3 Network Description

Detailed field notes were conducted at each intersection and each area of the downtown network was driven to observe and document roadway characteristics and traffic operations. Desktop reviews were also conducted to bring all the information together and provide a comprehensive analysis of the overall network. Characteristics of each study area are provided below.

Downtown

The downtown grid network includes 63 traffic signals with single-block spacing from 9th Street to 17th Street, Q Street to K Street and includes the intersection of 8th Street with N Street. The area type is a central business district (CBD) and it is the core of downtown Lincoln. The downtown grid network is approximately 0.6 miles from east to west and 0.5 miles from north to south. The average 24-hour volumes range from 2,200 vehicles on S 12th Street to 29,300 vehicles on N. 9th Street according to the City's 2018 Estimated Average Daily Traffic Volumes.

South of Downtown

The area immediately south of downtown includes 29 traffic signals from S. 9th Street to S. 17th Street, J Street / Lincoln Mall to Van Dorn Street and includes the pedestrian signals on S. 20th Street at A Street and South Street. The area type is residential with some light commercial with traffic signals ranging from single-block spacing to half-mile spacing. South of downtown covers an area approximately 0.9 miles from east to west and 1.7 miles from north to south. The average 24-hour volumes range from 1,600 vehicles on D Street to 19,700 vehicles on S. 10th Street according to the City's 2018 Estimated Average Daily Traffic Volumes.

Priority Corridors

Priority corridors within the downtown and south of downtown network are 9th Street, 10th Street, K Street, L Street, and O Street. These corridors are considered a priority not only due to the volume of traffic they carry, but also for the function they serve moving traffic to and from downtown. Each of these corridors is described in more detail below.


9th Street


10th Street

9th Street joins Southbound I-180 just north of R Street. Traffic continues on 9th Street, a one-way southbound street with a six-lane cross-section from Q Street to P Street, a five-lane cross-section from P Street to O Street, a four-lane cross-section from O Street to K Street (which is five-lanes from N Street to M Street during peak hours via parking restriction), a three-lane cross-section from K Street to South Street, and a two-lane cross-section south of South Street. Between M Street and L Street, the posted speed limit changes from 25 mph to the north to 35 mph to the south.

10th Street was analyzed beginning from Van Dorn Street on the south, continuing through downtown to the origin of Northbound I-180 just north of R Street. 10th Street has

a three-lane cross-section from Van Dorn Street to G Street, a four-lane cross-section from G Street to L Street, a five-lane cross-section from K Street to O Street (with an auxiliary left-turn lane from L Street to N Street), a four-lane cross section from O Street to P Street, and a five lane cross section from P Street to Q Street. Between M Street and L street the posted speed limit changes from 35 mph to the south to 25 mph to the north.

K Street is the primary street for eastbound traffic to traverse downtown, which is known as Rosa Parks Way to the west and Capitol Parkway followed by Normal Boulevard to the east. It is the eastbound portion of a one-way pair with L Street and has a four-lane cross-section from S. 9th Street to S. 17th Street. The posted speed limit is 30 mph.

L Street is the primary street for westbound traffic to traverse downtown, which is known as Normal Boulevard followed by Capital Parkway to the east and Rosa Parks Way to the west. It is the westbound portion of a one-way pair with K Street and has a four-lane cross-section from S. 17th Street to S. 13th Street and a three-lane cross-section from S. 13th Street to S. 9th Street (with an auxiliary right-turn lane from S. 11th Street to S. 10th Street). The posted speed limit is 30 mph.

O Street (US 34) is the major two-way street through the downtown core. It has a four-lane cross-section, with auxiliary lanes, from 9th Street to 17th Street and a posted speed limit of 25 mph. On-street parking is available along most of the corridor along with high pedestrian activity, reducing travel speeds due to side friction.

3.0 Traffic Signal System Optimization

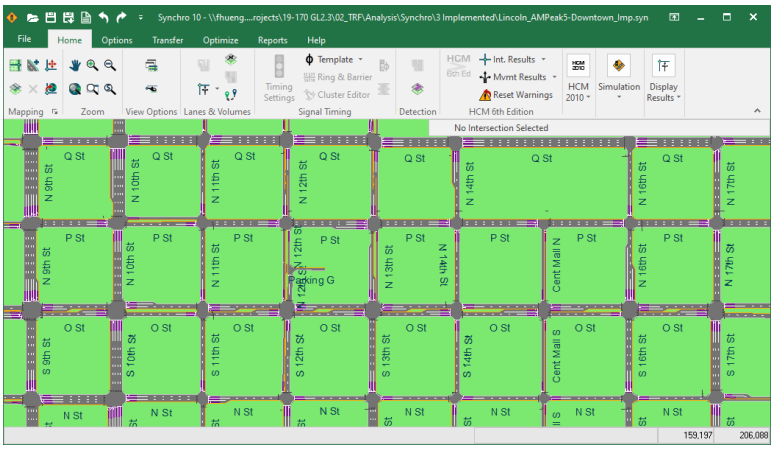
This section discusses the development of optimized traffic signal timing plans and associated tasks for the project corridors. Specifically, existing timings were reviewed and included in the existing conditions Synchro model, then the project team developed optimized timings for the network by conducting analyses of the cycle length, phasing, and timing parameters described below. Optimized timings were developed for three time periods, which are:

- Morning (AM) peak period
- Midday (MD) period
- Afternoon (PM) peak period

Prior to optimization, traffic signal warrants were reviewed for select intersections and detailed in a standalone document provided to the City.

3.1 Synchro Network Development

Base Synchro models developed by the City of Lincoln for the AM, MD, and PM peak periods were provided to the consultant team. These base Synchro models included changes that had been incorporated as part of Phases 1 and 2 of the Green Light Lincoln project. The Synchro models were reviewed by the consultant team to verify the accuracy of lane configurations, speed limits, turn restrictions, volume, and timing information utilizing the data provided by the City of Lincoln and collected in-field by the consultant team. Synchro models were then updated and provided to the City along with a list of what was updated.



The City of Lincoln incorporated the updated models for Phase 3 back into the citywide Synchro models. Based on local knowledge of the area and minimum split requirements for pretimed operations with pedestrian recalls, it was determined the MD pattern would operate during off-peak and weekend time periods. Given the pretimed operations, a single pattern was considered for use during all time periods. This was reviewed during the optimization process and it was determined the improvements gained from the slight differences in each pattern was worth moving forward with a unique timings for the AM, MD, and PM time periods.

3.2 Operational Analysis

Prior to signal timing development, a review of operations was conducted to identify spot improvements at study intersections to be implemented with the new signal timings or considered for future implementation. The following sections provide a summary of the evaluation of operational characteristics for the study intersections along the project corridors. The operational analysis included review of lane configurations and roadway geometry, including reduction of dual turn lanes to single turn

lanes, review of left-turn storage bay lengths and vehicle queues, left-turn phasing analysis including the use of FYA indications, and operational deficiencies noted during field review.

3.2.1 Lane Configuration and Roadway Geometry

A cursory review of the provided Synchro files was performed to note left-turn and right-turn movements where operations could be improved with the addition of an exclusive turn lane or the removal of exclusive or shared turn lane. No movements were identified as benefiting from an additional exclusive turn lane. Movements where safety could be improved with the removal of an exclusive or shared turn lane to provide a single turn lane are shown in **Table 1**. These lane reductions should be considered during the planning of future improvements. Additional components to consider before removing the lanes are identified in the justification column of the **Table 1**. These considerations include, but are not limited to, parking, turning radius, pedestrian conflicts, and signing. If an exclusive turn lane is removed in the future, consideration should be given to constructing a bulb-out at the intersection to reduce the pedestrian crossing distance and provide clear guidance to drivers.

Table 1: Auxiliary Lane Reductions

Intersection	Reduced Lane	Justification
S. 9th St & N St	WB Left	Movement approximately 250 vph. Remains in place due to capacity constraints with the conflicting cycle track phase.
S. 9th St & M St	SB Left	Movement approximately 300 vph. The shared through/left-turn lane can be converted to through only if some parking is removed on S. 9th St to provide adequate storage and deceleration.
10th St & O St	WB Right	Movement approximately 200 vph. Need to consider truck turning radius, signage implementation issues, and turn bay length.
S. 10th St & N St	WB Right	Movement approximately 450 vph. Need to consider the bus loading area and parking garage as well as pedestrian conflicts and westbound right-turn flow rate on green.
S. 10th St & N St	NB Left	Movement approximately 350 vph. Need to consider event traffic, issues related to West Haymarket, and lane utilization.
N. 11th St & Q St	WB Left	Movement approximately 300 vph. Will remain one lane once construction is complete.
S. 13th St & K St	SB Left	Movement approximately 150 vph. Current geometry does not lend itself to an easy conversion. Lane reduction will be considered with conversion to two-way traffic on 13th Street.

Table 1: Auxiliary Lane Reductions (Continued)

Intersection	Reduced Lane	Justification
S. 16th St & M St	EB Right	Movement approximately 400 vph. Need to consider significant conflicting pedestrian volume. Reduction of an EB right-turn lane may result in excessive queueing during the PM peak hour.
S. 16th St & K St	SB Left	Movement approximately 450 vph. Need to consider significant conflicting pedestrian volume. Reduction of a SB left-turn lane may result in excessive queueing during the PM peak hour.
S. 17th St & L St	WB Right	Movements approximately 300 vph. Need to consider the lane utilization of the shared through/right-turn lane as well as signage for implementation.

3.2.2 Left-Turn Storage Length

During field observations, locations where the turn bay length is not sufficient to store queued vehicles during peak volume times of the day were noted if present. Occasionally, these locations have additional median length available upstream of the turn lane that could be used to extend the turn lane and reduce queues that spill into the adjacent lane. There are no recommendations for additional turn bay length for Phase 3 of the Green Light Lincoln project.

3.2.3 Left-Turn Phasing

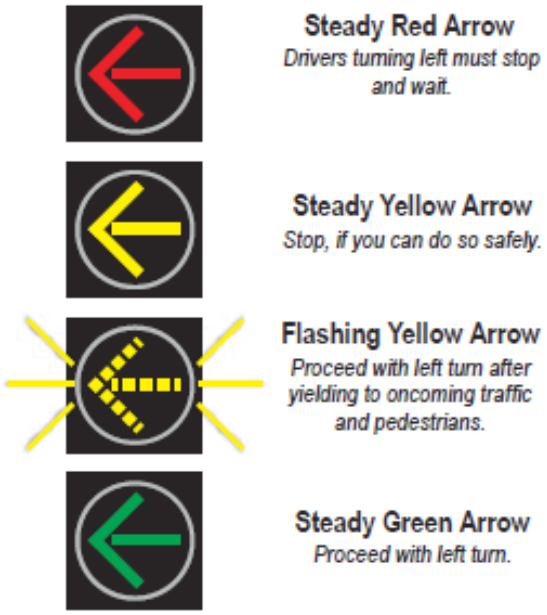
An analysis of left-turn phasing was conducted to determine the least restrictive level of control that could be used to operate left-turn movements efficiently and safely. This analysis was conducted based on the guidance provided in the City of Lincoln *Traffic Signal Timing Guidelines*. The results of the analysis were used to generate initial left-turn phasing that was implemented with the new signal timings. The implemented left-turn phasing was reviewed in the field and further adjusted as necessary. However, there were very few locations to apply this analysis due to short mast arm lengths and one-way streets in the downtown network.

3.2.4 Flashing Yellow Arrow (FYA) Analysis

The City of Lincoln is in the process of implementing FYA signal heads for left-turn movements throughout the city, where appropriate. Benefits of the FYA signal heads include:

- Flexibility to use any type of left-turn operation (i.e., permissive, protected/permissive, protected)
- Provides an exclusive signal indication to left-turning motorists
- The ability to operate signals with lead/lag left-turn phasing without the safety concern of a yellow trap

In the past, the City of Lincoln had predominantly used dog-house or three-section signal heads for left-turn movements. Dog-house signal heads were installed on the lane line between the exclusive left-turn lane and the adjacent through lane. Guidance in the Manual on Uniform Traffic Control Device (MUTCD) suggests that FYA signal heads should be installed over the center of the left-turn lane. Based on this criteria, field reviews were conducted at each intersection approach and noted the length of the mast arm.



The FYA analysis was done independently of the left-turn operation analysis to assess if the existing mast arms could accommodate the installation of FYA signal heads. In some instances, the FYA analysis indicated that some approaches are suitable for FYA while the operational analysis states that the movement should operate as protected only. Ultimately, the results of the left-turn operation analysis determined the operation of the left-turns at an intersection approach and the FYA analysis determined which approaches could have FYA signal heads installed. There were very few locations to apply the FYA analysis due to short mast arm lengths and one-way streets in the downtown network.

3.2.5 Field Observations

Consultant staff were in the field to conduct field reviews and inventories of study intersections, to conduct travel time studies, and to implement and fine-tune the new timings. Additional operational notes from time in the field are noted below.

- N. 10th Street & Q Street – There is a high volume of pedestrian traffic crossing the north leg of the intersection and a heavy westbound right-turn movement. Consider eliminating the north crosswalk, similar to the west leg of 9th Street & O Street, to improve traffic operations at the intersection.
- N. 10th Street & Q Street – The westbound approach has poor lane utilization as traffic heavily favors the shared through/right-turn lane. The primary reason is this lane serves as access to northbound Interstate 180, but it also feeds into the only westbound through lane at N. 9th Street to access the Haymarket District. Consider evaluating an alternative to convert the shared through/right-turn lane into an exclusive right-turn lane.
  The westbound approach at N. 9th Street would then be converted from two left-turn lanes and one through lane to one left-turn lane and a single through lane; the north curb lane converted to parking or striped out. The middle lane would become the through lane and would need to jog slightly north through the intersection with N. 9th Street to connect with the receiving lane entering the Haymarket District. Curb extensions could be constructed on either side of the block to reinforce the intended drive-paths for vehicles, allow for additional

on-street parking, reduce pedestrian crossing distances, and potentially allow for implementation of a leading pedestrian interval.

- O Street – Significant friction due to pedestrian activity and on-street parking create an inconsistent flow rate on O Street with occasional unexpected stops in the outside lane. Additionally, delivery trucks occasionally block the outside lane, including during the AM peak hour. Although this was not frequently observed, consider establishing time-of-day delivery restrictions with enforcement if they are not already in place or increase enforcement to discourage this activity.
- 9th Street & O Street – Vehicles performing an eastbound right-turn movement from the shared through/right-turn lane occasionally need to stop for a pedestrian crossing S. 9th Street. This blocks one of the two through lanes, resulting in cycle failures during the peak hours that can take several cycles to recover from. This was mitigated to the best extent possible as part of this signal optimization project.
- 10th Street & O Street – The eastbound left-turn queue occasionally spills into the through lane during the peak hours. This blocks one of the two through lanes, resulting in eastbound cycle failures at 9th Street that can take several cycles to recover from. This was mitigated to the best extent possible as part of this signal optimization project. The eastbound left-turn bay cannot be extended to the presence of the westbound left-turn bay for S. 9th Street.
- S. 9th Street & K Street – During the AM peak hour, the eastbound approach experiences cycle failures which result in queues extending onto the viaduct. This begins between 7:45 am and 7:50 am and ends between 8:00 am and 8:05 am. This was mitigated to the best extent possible as part of this signal optimization project.
- S. 9th Street & South Street – There are no pavement markings to distinguish the two westbound receiving lanes available for the two westbound through lanes at this intersection. Consider modifying the west leg of the intersection to provide approximately 75 feet of two lanes width followed by a transition of approximately 75 feet to single lane, similar to the eastbound lanes of the approach.

3.3 Intersection Crash Analysis

The City of Lincoln conducts periodic crash studies of intersections with high crash rates to identify potential safety improvements. As part of this project, the City of Lincoln *2012 Crash Study* and *2018 Lincoln Crash Data Analysis* were reviewed for recommendations specific to project intersections. A field review was conducted at those locations to determine if the recommendations had been implemented and if not, if they were still applicable. Findings from the field review were summarized and submitted to the City of Lincoln. The majority of countermeasures recommended from the crash studies at project intersections involve signal timing updates and/or phasing changes. Those countermeasures that involved traffic signal related improvements were implemented as part of this project, which resulted in the implementation of 18 countermeasures. The countermeasures implemented as part of this project are summarized in **Appendix B**.

3.4 Traffic Signal Timing Development

Traffic signal timing development was completed through multiple steps. This process included calculation or determination of intersection basic timing parameters (minimum green, yellow change, red clearance, walk, flashing don't walk, and vehicle recall), cycle lengths, splits, and offsets. Timings were then refined

in the field based on observations of traffic operations. A brief overview on how these parameters were developed and modified is described in the following sections.

3.4.1 Basic Signal Timing Parameters

Basic timing parameters of minimum green, yellow change, red clearance, walk, flashing don't walk, and vehicle recall were evaluated based on information in the City of Lincoln *Traffic Signal Timing Guidelines*. Cycle track clearance values were timed for bicycle speeds with red clearance values allowed to exceed 3.0 seconds. Data collected from the intersection inventory and aerial photography were used to calculate these parameter values. Calculated values reflect current industry practices which are based on new research that is intended to improve the safety of intersection operations. The initial intersection calculation file for each intersection was submitted to the City of Lincoln for their review and approved prior to the development of optimized timing plans. The approved timing parameters were then coded into Synchro by the consultant team for use in creating the new timing plans. Final intersection basic signal timing parameters were submitted to the City of Lincoln with the final project deliverables. Additional information regarding cycle track phasing and a comparison of the City's current *Traffic Signal Timing Guidelines* with ITE's *Guidelines for Determining Traffic Signal Change and Clearance Intervals* from May 2019 can be found in separate standalone documents provided to the City.

3.4.2 Cycle Length

An optimum cycle length provides sufficient green time to efficiently serve all movements at an intersection while providing efficient flow of traffic along a corridor from one intersection to the next. Long cycle lengths generally accommodate efficient flow of traffic (progression), however, they generally cause greater delays for pedestrians and the minor street approaches. Short cycle lengths sometimes work well to reduce delay for pedestrians and minor street approaches, however, the progression along the corridor can be easily disrupted. An optimum cycle length balances these two considerations of delay and progression. Additionally, it is important to consider how selection of a cycle length at an intersection affects operations at adjacent intersections. System-wide coordination would be accomplished by using complementary cycle lengths throughout the system or grouping of intersections. The optimum cycle length is the merging of the following factors:

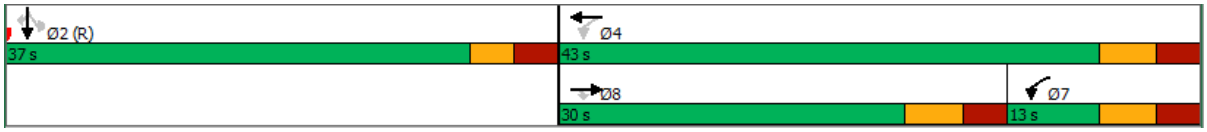
- System-wide coordination
- Proximity of study corridors to other major corridors in the system
- Intersection vehicular demand (through and turning movements)
- Pedestrian and bicyclist volumes
- Minimum cycle length
- Overall intersection delay and level of service
- Intersection approach/movement delays
- Progression

Various cycle lengths were considered and evaluated against the items listed above with consideration given to performance of existing cycle lengths. The selection of a standard cycle length for all the project corridors allows the potential for cross coordination of corridors that intersect each other. To complement the 120 second cycle length selected for the Phase 1 and Phase 2 AM and PM peak periods, 60 second and 120 second cycle lengths were considered. The 60 second cycle length did not satisfy the minimum cycle length at every intersection and did not provide enough capacity for the priority corridors. The 120 second cycle length would create excessive pedestrian and side-street delays and potentially cause gridlock in the tightly spaced downtown network. Ultimately, the existing 75 second cycle length was raised to 80 seconds to provide some additional capacity on 9th Street and 10th Street as well as to provide a level of coordination with a two-thirds cycle length relative to the 120 second cycle length on the nearby Antelope Valley Parkway traffic signals.

The MD cycle length selected for Phase 1 and Phase 2 was 100 seconds. However, a 50 second cycle length would not satisfy the minimum cycle length requirement at all intersections and a 100 second cycle length would be unnecessarily high, creating excess delay for pedestrians and side-streets. With minimal benefit to selecting a lower cycle length that still satisfied minimum cycle length requirements, the 80 second cycle length was maintained during the MD time period. This greatly reduced transition requirements and minimized disruption to the coordinated progression between time periods, which is very valuable with single-block signal spacing.

3.4.3 Splits and Offsets

Synchro software was used to develop the initial proposed timing plans. Intersection splits and offsets were determined after model development and selection of proposed cycle lengths. Synchro provided initial splits and offsets for each intersection through its optimization function. From these initial



values, a review of each intersection's splits was conducted to make the most efficient use of the overall cycle length. Changes were made as necessary to satisfy system standards, lower intersection/movement delay and improve coordination along the corridors.

Intersection offsets were determined using a combination of Synchro and Tru-Traffic software. Coordination along the corridors was determined based on directional traffic flow trends by time-of-day with progression favored in the direction of travel having notably higher traffic volumes. In general, 9th Street and 10th Street traffic flow was given the highest priority, followed by K Street, L Street, and O Street. In cases where traffic volumes were similar, the offsets were set to maximize traffic flow on both streets. Proposed timing plans were submitted to the City of Lincoln for review, discussion, revision, and approval prior to implementation.

3.4.4 Time-of-Day Schedule

A schedule was developed to operate the proposed timing plans based on patterns from 24-hour volumes throughout downtown. **Figure 3** provides a graphical illustration of 24-hour volume data, which shows the variation in traffic volumes throughout the day that was used as the basis for developing the time-of-day schedule. The spikes seen in the AM and PM peak periods of the graph are typical of weekday traffic, as commuters are traveling to and from work. For consistency with the Phase 1 and Phase 2 corridors and because it worked well for the downtown network, the same time-of-day plan was utilized for Phase 3. **Table 2** illustrates the implemented time-of-day schedule.

Figure 3: Weekday 24-Hour Count Data Graph

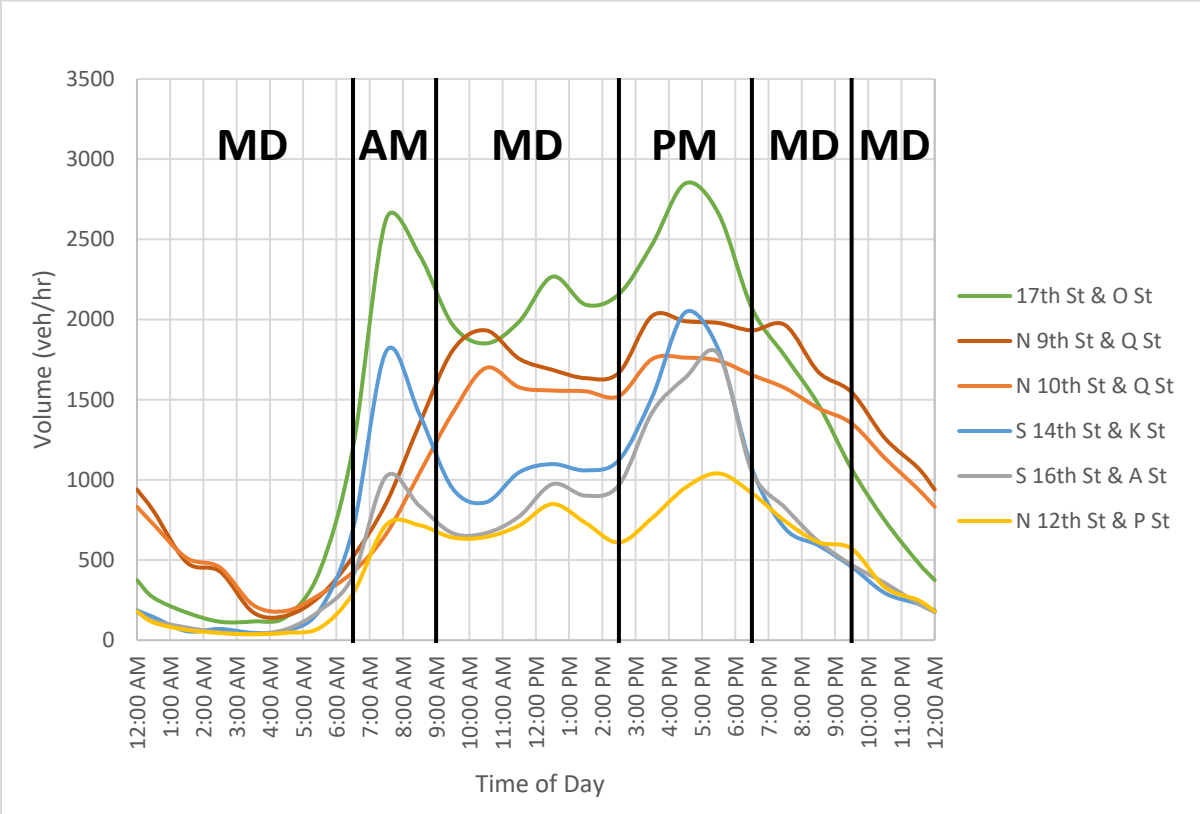


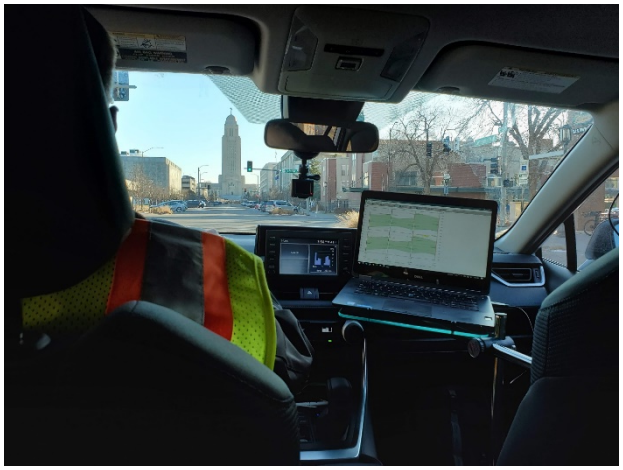
Table 2: Time-of-Day Schedule

Days	Timing Plan	Time-of-Day
Weekday	AM	6:30 AM – 9:00 AM
	MD	9:00 AM – 2:30 PM 6:30 PM – 9:30 PM
	PM	2:30 PM – 6:30 PM
	MD	9:30 PM – 6:30 AM
Weekend	MD	6:30 AM – 9:30 PM
	MD	9:30 PM – 6:30 AM

3.4.5 Implementation and Field Fine-Tuning

Implementation was conducted jointly by Consultant and City staff. Consultant staff directly connected to intersections that were not communicating with the City's central system software while City staff connected to the intersections that were communicating. This iterative process was conducted over the course of two days to minimize disruption to traffic in the downtown core. Implementation was completed on September 16th and 17th, 2019. Fine-tuning continued in the weeks following the initial implementation to address operational deficiencies that were not anticipated during the optimization process and based upon citizen comments.

Fine-tuning further improved operations throughout the system. Movements found to need more time were addressed based on the tradeoff between improving movement operations and the impact to the overall coordination amongst the downtown street network. Offsets and sequences are adjusted by driving the corridor with GPS connected Tru-Traffic software to dynamically view how the system is performing. All revisions made during the fine-tuning process were recorded and revised in the Synchro and Tru-Traffic files. Final Synchro and Tru-Traffic files were submitted to the City of Lincoln with the final project deliverables.



3.4.6 Event Timing Plans

The City has developed event timing plans to facilitate the arrival and departure of traffic during Nebraska football games. Each event is slightly different based on time-of-day, day of the week, and what other events are going on at the same or similar time. One of the more critical events is the Nebraska football game egress. The timing plan for this event was updated from a 110 second cycle length to a 120 second cycle length to tie in with nearby signals and the citywide cycle length selected as part of Phase 1.

4.0 Corridor Performance Evaluation

The study corridors were evaluated to determine the effectiveness of the retiming effort. The corridor evaluations consisted of comparing performance measures from "before" and "after" studies that were conducted before and after implementation of new signal timings. This section provides details on the methodology used to evaluate corridor performance and the results of those evaluations.

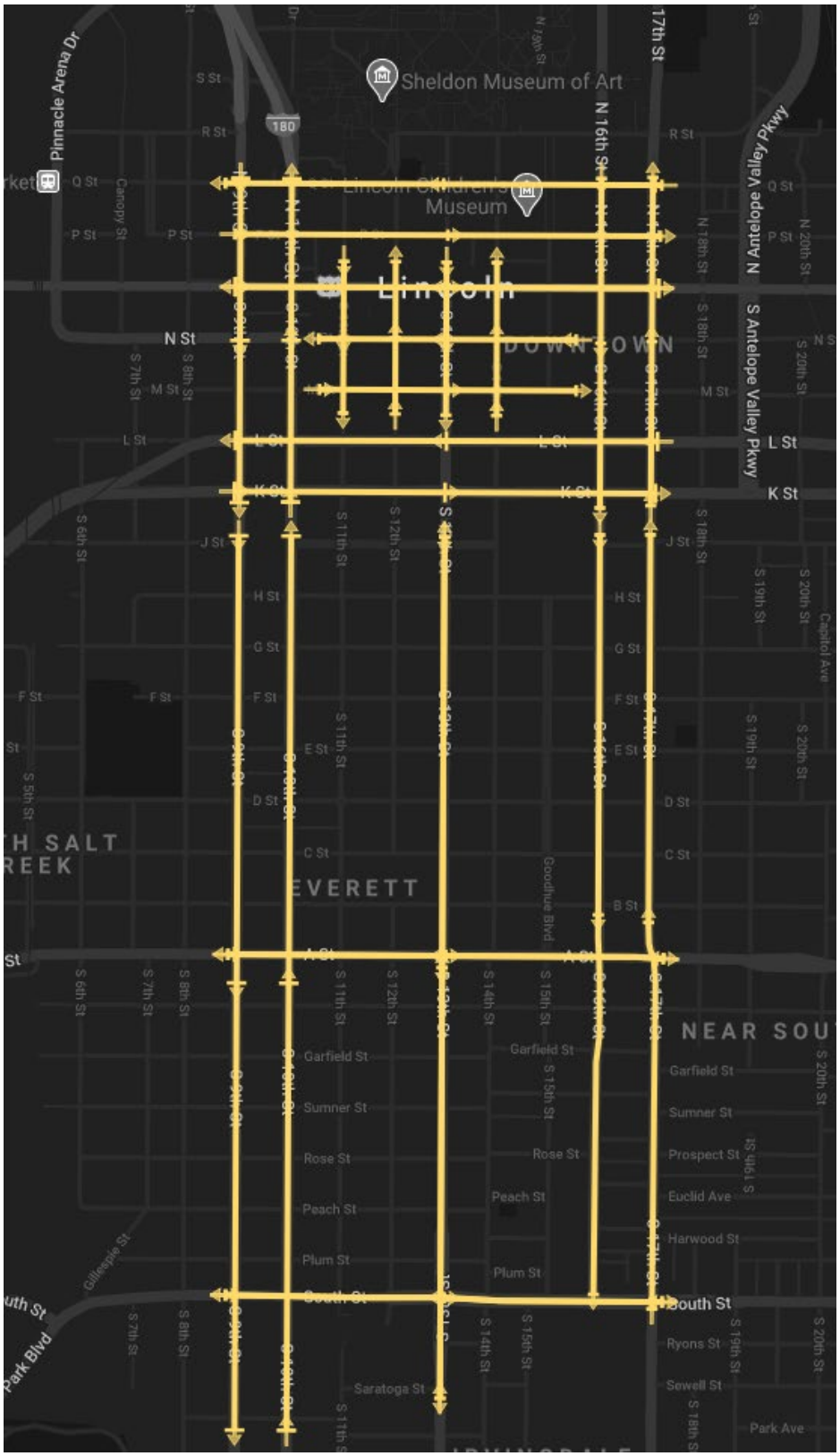
4.1 Performance Evaluation Data

Travel time study data were used to calculate a variety of performance measures. Corridor performance results were based on data from before and after the new signal timings were implemented. The data was then used to calculate reductions in metrics such as delay, stops, fuel consumption, and emissions. The corridor data was volume weighted and summed up to provide overall network improvements.

StreetLight Data was used to collect the travel time data. The data consists of location-based services collected from smartphone applications. The data is anonymized and compiled to provide a robust data set. Utilizing this data source, travel time data was able to be collected from each street in the downtown network and provide an accurate representation of the overall changes to the network. **Figure 4** illustrates the extents of each segment analyzed.

Three weeks of "before" data and three weeks of "after" data were analyzed. The "before" period analyzed was August 26th through September 15th, 2019. The "after" period analyzed was September 30th through October 13th, 2019 and October 21st through October 27th, 2019. The week of October 14th through October 20th, 2019 was excluded in order to include an equal number of Nebraska football home games in the "before" and "after" data set. Additionally, the weeks were also chosen for the overall similarity in volume levels based on the StreetLight Index. The StreetLight Index is a normalized value based on sample trip counts but does not estimate real-world counts. It can be used to compare relative volume levels of different analysis segments or relative volume levels over time.

Figure 4: StreetLight Data Segments



4.2 Performance Measures

The following performance measures were identified to be reported for this project:

- **Travel Time** – The time to travel from one end of a study corridor to the other
- **Corridor Performance**
  - **Delay** – The amount of time corridor traffic is slowed or stopped by traffic signals on a trip from one end of a study corridor to the other
  - **Fuel Consumption** – The estimated amount of fuel consumed by traffic on a trip from one end of a study corridor to the other
  - **Emissions** – The estimated emissions produced by traffic on a trip from one end of a study corridor to the other

The number of stops is not provided as a performance measure due to the use of StreetLight Data as the source for corridor performance measures rather than Tru-Traffic. StreetLight Data allows for data to be collected on multiple corridors simultaneously, which is ideal for studying a downtown network or other large study area, but does not provide the level of detail collected with traditional methods.

Performance measures were summarized for all hours of the day during each day in the "before" and "after" time periods. This means that benefits derived from the peak hours as well as off-peak hours overnight are reported.

4.3 User Savings Analysis

The travel time performance measure was reported as the change in travel time between "before" and "after" conditions by comparing the average time to travel from one end of a study corridor to the other end during the study periods. Travel time was extracted from the StreetLight Data platform for the "before" and "after" conditions. Time is of value to all people. A reduction in travel time, delay, and fuel consumption keep dollars in the pockets of motorists. These direct savings were tracked and quantified to determine community savings.

Corridor performance measures of delay, fuel consumption, and emissions were calculated using output from StreetLight Data, year 2018 local demographics, and procedures outlined in the City of Lincoln *Traffic Signal Timing Guidelines v2.0*. Each of the corridor performance measures was reported as the change between "before" and "after" conditions.

4.4 Summary of Performance Measures and User Savings

Results from the performance evaluation show that new signal timings in the downtown network produced substantial benefits to the community.

4.4.1 Travel Time Results

The average travel time in the downtown network was reduced by nearly 10% from "before" to "after" conditions. Changes in travel time are shown in **Table 3**. However, not all streets experienced a decrease in travel time. Some increases in travel time can be attributed to enhanced safety treatments through updated pedestrian and vehicle clearance times at intersections included with the new signal timings. Other increases resulted from the complex interactions of each street within the tightly spaced grid network. Occasionally, decisions had to be made to favor a busier or more

critical street, resulting in slight travel time increases on minor or less critical streets. More detailed travel time results, showing the total corridor travel time savings, is provided in the **Appendix**.

Table 3: Travel Time Savings

Corridor	Travel Time Savings (sec)		
	Weekday	Weekend	Total
9th Street (SB): K St – Q St	7	92	99
9th Street (SB): Park Ave - K St	5	62	67
10th Street (NB): K St – Q St	6	71	77
10th Street (NB): Park Ave - K St	10	1	11
K Street (EB): 9th St – 17th St	36	1	37
L Street (WB): 9th St – 17th St	(15)	91	76
O Street (EB): 9th St – 17th St	16	27	43
O Street (WB): 9th St – 17th St	(13)	48	35
16th Street (SB): K St – Q St	(35)	53	18
16th Street (SB): South St - K St	(12)	(13)	(25)
17th Street (NB): K St – Q St	14	(53)	(39)
17th Street (NB): South St - K St	8	(24)	(16)
P Street (EB): 9th St – 17th St	66	95	161
Q Street (WB): 9th St – 17th St	5	53	58
11th Street (SB): L St – P St	1	47	48
12th Street (NB): L St – P St	39	37	76
13th Street (SB): L St – P St	13	1	14
14th Street (NB): L St – P St	40	51	91
13th Street (NB): Saratoga - K St	(13)	(69)	(82)
13th Street (SB): Saratoga - K St	(30)	(26)	(56)
M Street (EB): 10th St – 16th St	42	40	82
N Street (WB): 10th St – 16th St	(3)	(74)	(77)
A Street (EB): 9th St – 17th St	1	20	21
A Street (WB): 9th St – 17th St	(42)	(30)	(72)
South Street (EB): 9th St – 17th St	17	18	35
South Street (WB): 9th St – 17th St	22	17	39

4.4.2 Annual Performance Results

The total benefits to network performance from "before" to "after" conditions, shown in **Table 4**, were quantified from the StreetLight Data analysis and summarized on an annual basis. The network performance results show sizable reductions for motorist delay, fuel consumption, and emissions. The reductions to delay and fuel are estimated to save Lincoln motorists over 313,000 hours of delay and $4.7 million in user (time and fuel) costs per year. More detailed corridor performance measures, including a breakdown by study time period, are provided in the **Appendix**.

Table 4: Performance Results

Corridor	Annual Total Savings (From "Before" to "After" Conditions)				
	Delay (Veh-Hours)	Fuel (Gallons)	Delay Savings ($)	Fuel Savings ($)	User Savings[1] ($)
9th Street (SB): K St – Q St	74,250	18,465	$1,044,376	$45,978	$1,090,354
9th Street (SB): Park Ave - K St	30,405	7,556	$427,788	$18,816	$446,603
10th Street (NB): K St – Q St	55,748	13,732	$778,906	$34,192	$813,098
10th Street (NB): Park Ave - K St	12,747	3,228	$194,563	$8,039	$202,601
K Street (EB): 9th St – 17th St	27,779	6,723	$410,269	$16,741	$427,011
L Street (WB): 9th St – 17th St	9,496	2,318	$116,066	$5,771	$121,837
O Street (EB): 9th St – 17th St	24,482	6,008	$354,760	$14,960	$369,720
O Street (WB): 9th St – 17th St	2,341	576	$15,192	$1,434	$16,626
16th Street (SB): K St – Q St	(10,448)	(2,524)	($166,762)	($6,285)	($173,047)
16th Street (SB): South St - K St	(8,349)	(2,043)	($121,706)	($5,088)	($126,794)
17th Street (NB): K St – Q St	(2,501)	(608)	($18,366)	($1,514)	($19,880)
17th Street (NB): South St - K St	199	49	$8,538	$122	$8,660
P Street (EB): 9th St – 17th St	55,006	13,723	$810,187	$34,169	$844,356
Q Street (WB): 9th St – 17th St	14,577	3,637	$206,254	$9,055	$215,309
11th Street (SB): L St – P St	4,543	1,184	$65,793	$2,947	$68,741
12th Street (NB): L St – P St	16,089	3,976	$236,844	$9,900	$246,744
13th Street (SB): L St – P St	6,036	1,525	$92,005	$3,797	$95,802
14th Street (NB): L St – P St	17,820	4,460	$263,688	$11,104	$274,792
13th Street (NB): Saratoga - K St	(13,883)	(3,437)	($197,687)	($8,559)	($206,246)
13th Street (SB): Saratoga - K St	(16,664)	(4,062)	($243,032)	($10,115)	($253,147)
M Street (EB): 10th St – 16th St	14,931	3,735	$221,883	$9,300	$231,183
N Street (WB): 10th St – 16th St	(7,618)	(1,921)	($107,688)	($4,784)	($112,472)
A Street (EB): 9th St – 17th St	3,175	768	$43,371	$1,912	$45,284
A Street (WB): 9th St – 17th St	(22,273)	(5,430)	($325,726)	($13,521)	($339,247)
South Street (EB): 9th St – 17th St	12,192	2,961	$176,714	$7,372	$184,086
South Street (WB): 9th St – 17th St	13,011	3,307	$196,443	$8,236	$204,678
TOTALS	313,091	77,904	$4,482,673	$193,981	$4,676,653

4.4.3 Cycle Track Results

The cycle track on N Street from S. 8th Street to S. 16th Street was optimized to provide an improved user experience for cyclists. A design speed of 14 mph was used with a focus on reducing the number of stops. Based on count data and field observations, directionality by time-of-day was also considered. Westbound flow was favored during the AM period, Eastbound flow was favored during the PM period, and a balanced flow was favored during the MD period.

However, consideration was also given to vehicular traffic, which only flows westbound. Because of this, similar to the "before" condition, the cycle track does flow better in the westbound direction

than the eastbound direction throughout the day. To quantify the changes made to the cycle track, travel time runs were conducted on a bicycle using GPS connected software.

"Before" travel time runs were conducted on September 11th and 12th, 2019 and "after" travel time runs were conducted on October 23rd, 2019 and November 20th, 2019. The "before" condition metrics match during all time periods because a single timing plan was operated in the "before" condition. A summary of cycle track travel time results by time-of-day is shown in **Table 5**.

Table 5: Cycle Track Travel Time Results

		AM Period		MD Period		PM Period	
		Travel Time (sec)	Stops (#)	Travel Time (sec)	Stops (#)	Travel Time (sec)	Stops (#)
Eastbound	Before	412	7.6	412	7.6	412	7.6
	After	416	6.8	417	6.6	357	5.4
	Difference	**4**	**-0.8**	**5**	**-1**	**-55**	**-2.2**
	% Difference	**1.0%**	**-10.5%**	**1.2%**	**-13.2%**	**-13.3%**	**-28.9%**
Westbound	Before	283	2.6	283	2.6	283	2.6
	After	209	2.2	195	1.2	281	3.3
	Difference	**-74**	**-0.4**	**-88**	**-1.4**	**-2**	**0.7**
	% Difference	**-26.1%**	**-15.4%**	**-31.1%**	**-53.8%**	**-0.7%**	**26.9%**

4.5 Study Benefit-to-Cost

A benefit-to-cost analysis was completed for the overall study area to understand the return benefit based on City investment. The annual benefit of the project is estimated to be $4.7 million. The costs for the project are outlined below:

- Consultant services = $ 250,000
- Equipment = $ 360,000
- Contractor services = $ 240,000
- Total = $ 850,000

The Federal Highway Administration (FHWA) recommends that signal timings be updated at least every three to five years. Based on the FHWA's recommendation, the quantified benefits are assumed to be realized each year for the next five years. The benefits over five years are expected to be $23.4 million.

The benefit-to-cost ratio is calculated to be 28:1. This shows a significant return on investment through delay and fuel savings to Lincoln motorists. Additionally, the reduction to stops and emissions, both of which were not monetized, provide a benefit to the air quality in Lincoln. The reduction in stops is also expected to provide added safety benefits by reducing crashes. As a result, the total benefit-to-cost ratio if all benefits were to be monetized would be greater than the reported 28:1.

5.0 SUMMARY/CONCLUSION

The overall purpose of this project was to prepare and implement optimized traffic signal timing plans in downtown Lincoln and to quantify the changes in traffic operations resulting from signal equipment upgrades and signal timing changes with "before" and "after" performance measures. Data analysis and travel time studies conducted after the new signal timings were implemented showed a decrease in travel times from the "before" conditions. Additionally, updates to pedestrian and vehicle clearance times at study intersections enhance safety at these locations.

The reductions to delay incurred and fuel consumed are estimated to save Lincoln motorists over 313,000 hours of delay and 73,900 gallons of fuel per year, equating to $4.7 million annual user savings. The benefit-to-cost ratio over a five-year period (recommended period between retiming efforts) is 28:1. These savings are only inclusive of travel time and fuel consumption, safety and emissions benefits as well as cycle track improvements were not monetized. The implementation of new timings also resulted in 18 countermeasures from the *2012 Crash Study* and *2018 Crash Analysis* being implemented, which should provide additional safety benefits to Lincoln motorists.

A summary of benefits and costs for Phases 1, 2, and 3 of the Traffic Signal System Optimization effort are shown in **Table 6**. Phase 2 resulted in similar benefits to those achieved with Phase 1. The biggest difference between Phases 1 and 2 was the higher project cost of Phase 2. The higher cost of Phase 2 was the result of having more total signals included in Phase 2 and more improvements/repairs to signal equipment.

Table 6: Summary of Benefits and Costs for Phases 1, 2, and 3

Variable	Phase 1	Phase 2	Phase 3	Total of Phases 1, 2, 3
Annual Delay Savings (Veh-Hours)	437,200	403,000	313,100	1,153,300
Annual Fuel Savings (Gallons)	575,000	538,700	77,900	1,191,600
Annual User Savings[1] ($)	$8,766,200	$8,859,600	$4,676,700	$22,302,500
Project Cost	$2,325,100	$3,173,700	$850,000	$6,348,800
Benefit-to-Cost Ratio[2]	19:1	14:1	28:1	18:1

[1] Savings based on reductions in delay, fuel, and local demographic information.

[2] Benefits calculated for five years based on FHWA recommendation for signal retiming.

The next phase of Traffic Signal System Optimization (Phase 4) is slated for 2020 and will continue the effort to improve safety and mobility in Lincoln. It is recommended to continue retiming efforts throughout the city and retime corridors approximately every three to five years to further save Lincoln motorists time and money.

APPENDIX A

Intersection List

Study Intersections

Study Intersections		
S. 8th St & N St	N. 12th St & Q St	N. 16th St & Q St
N. 9th St & Q St	N. 12th St & P St	N. 16th St & P St
N. 9th St & P St	12th St & O St	16th St & O St
9th St & O St	S. 12th St & N St	S. 16th St & N St
S. 9th St & N St	S. 12th St & M St	S. 16th St & M St
S. 9th St & M St	S. 12th St & L St	S. 16th St & L St
S. 9th St & L St	S. 12th St & K St	S. 16th St & K St
S. 9th St & K St	N. 13th St & Q St	S. 16th St & J St Ped
S. 9th St & J St Ped	N. 13th St & P St	S. 16th St & G St
S. 9th St & F St Ped	13th St & O St	S. 16th St & A St
S. 9th St & D St	S. 13th St & N St	S. 16th St & South St[1]
S. 9th St & A St	S. 13th St & M St	N. 17th St & Q St
S. 9th St & South St[1]	S. 13th St & L St	N. 17th St & P St
N. 10th St & Q St	S. 13th St & K St	17th St & O St
N. 10th St & P St	S. 13th St & G St	S. 17th St & N St
10th St & O St	S. 13th St & A St	S. 17th St & M St
S. 10th St & N St	S. 13th St & South St[1]	S. 17th St & L St
S. 10th St & M St	S. 13th St & Saratoga St Ped[1]	S. 17th St & K St
S. 10th St & L St	S. 13th St & Van Dorn St	S. 17th St & J St Ped
S. 10th St & K St	N. 14th St & Q St	S. 17th St & G St
S. 10th St & Lincoln Mall	N. 14th St & P St	S. 17th St & D St
S. 10th St & G St	14th St & O St	S. 17th St & A St
S. 10th St & D St	S. 14th St & N St	S. 17th St & South St[1]
S. 10th St & A St	S. 14th St & M St	S. 17th St & Lake St Ped
S. 10th St & South St[1]	S. 14th St & L St	S. 17th St & Van Dorn St
S. 10th St & Park Ave Ped	S. 14th St & K St	S 20th St & A St Ped
N. 11th St & Q St	Centennial Mall & P St	S 20th St & South St Ped[1]
N. 11th St & P St	Centennial Mall & O St	
11th St & O St	Centennial Mall & N St	
S. 11th St & N St	Centennial Mall & M St	
S. 11th St & M St	Centennial Mall & L St Ped	
S. 11th St & L St	Centennial Mall & K St Ped	
S. 11th St & K St		

[1] Phase 2 Intersection

APPENDIX B

Implemented 2012 Crash Study & 2018 Crash Analysis Countermeasures

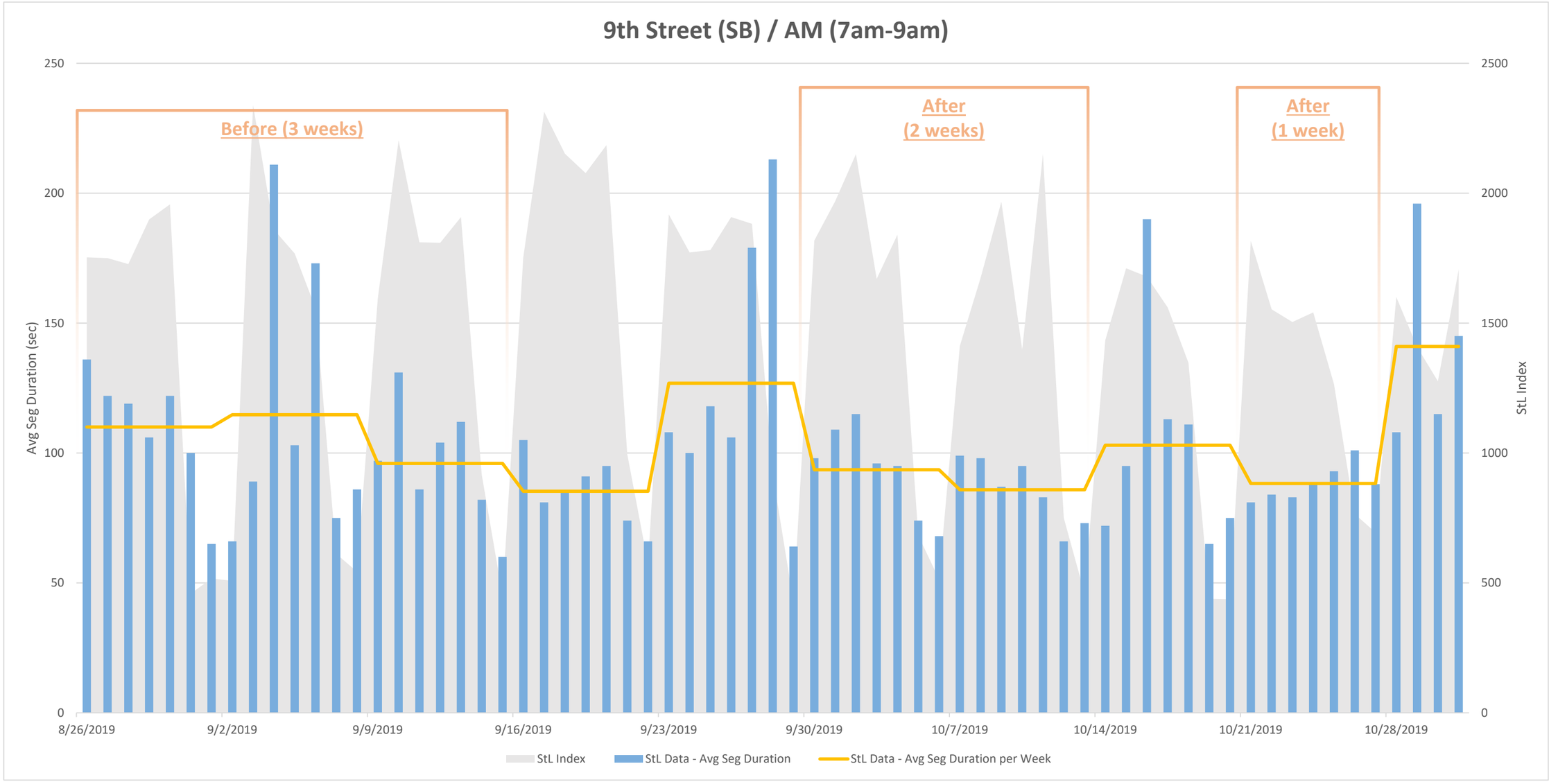
Implemented 2012 Crash Study & 2018 Crash Analysis Countermeasures

Intersection	Crash Pattern	Countermeasure	Phase 3 Improvement
S. 16th Street & A Street	Rear End, Right Angle	Review signal timing and clearance intervals	Clearance intervals updated, Signal timings reviewed and updated
S. 16th Street & A Street	EB Rear Ends	Update signal timing to improve EB coordination with 17th St in the afternoon	Signal timings reviewed and updated to improve coordination
S. 17th Street & K Street	NB & EB Right Angle	Modify progression in the EB and NB directions	EB and NB progression updated
S. 17th Street & K Street	NB & EB Right Angle	Review signal timing and clearance intervals	Clearance intervals updated, Signal timings reviewed and updated
S. 11th Street & L Street	SB & WB Right Angle	Install additional signal heads on SB and WB approaches	Additional signal heads to be installed
S. 20th Street & South Street	Right Angle and Rear End	Review signal timing and clearance intervals	Clearance intervals updated, Signal timings reviewed and updated
S. 10th Street & South Street	NB Right Angle	Review signal timing and clearance intervals	Clearance intervals updated, Signal timings reviewed and updated
S. 16th Street & K Street	SB Left Turn	Implement lane geometric signing on mast arm	Lane geometric signing implemented.
S. 16th Street & K Street	SB Left Turn	Install additional pole-mounted signal head for SB left turn lane	Additional signal head installed.
17th Street & O Street	NB Right Angle	Review signal timing clearance intervals	Clearance intervals updated, Signal timings reviewed and updated
17th Street & O Street	EB Right Angle	Install additional signal head on mast arm for EB approach	Additional signal head installed.
17th Street & O Street	NB Right Angle	Install additional signal head on NB approach	Additional signal head installed.
17th Street & O Street	NB Left Turn	Install lane control signs on mast arm for NB left turn	Lane control signs installed.
11th Street & O Street	EB Rear End	No deficiencies observed	Clearance intervals updated, Signal timings reviewed and updated
10th Street & O Street	N/A	Review and update signal timings, lag left turns.	Clearance intervals updated, Signal timings reviewed and updated, left turns lagged
N. 10th Street & Q Street	N/A	Review and update signal timings	Clearance intervals updated, Signal timings reviewed and updated, left turns lagged
17th Street & O Street	N/A	Review and update signal timings	Clearance intervals updated, Signal timings reviewed and updated
S. 17th Street & K Street	N/A	Review and update signal timings	Clearance intervals updated, Signal timings reviewed and updated

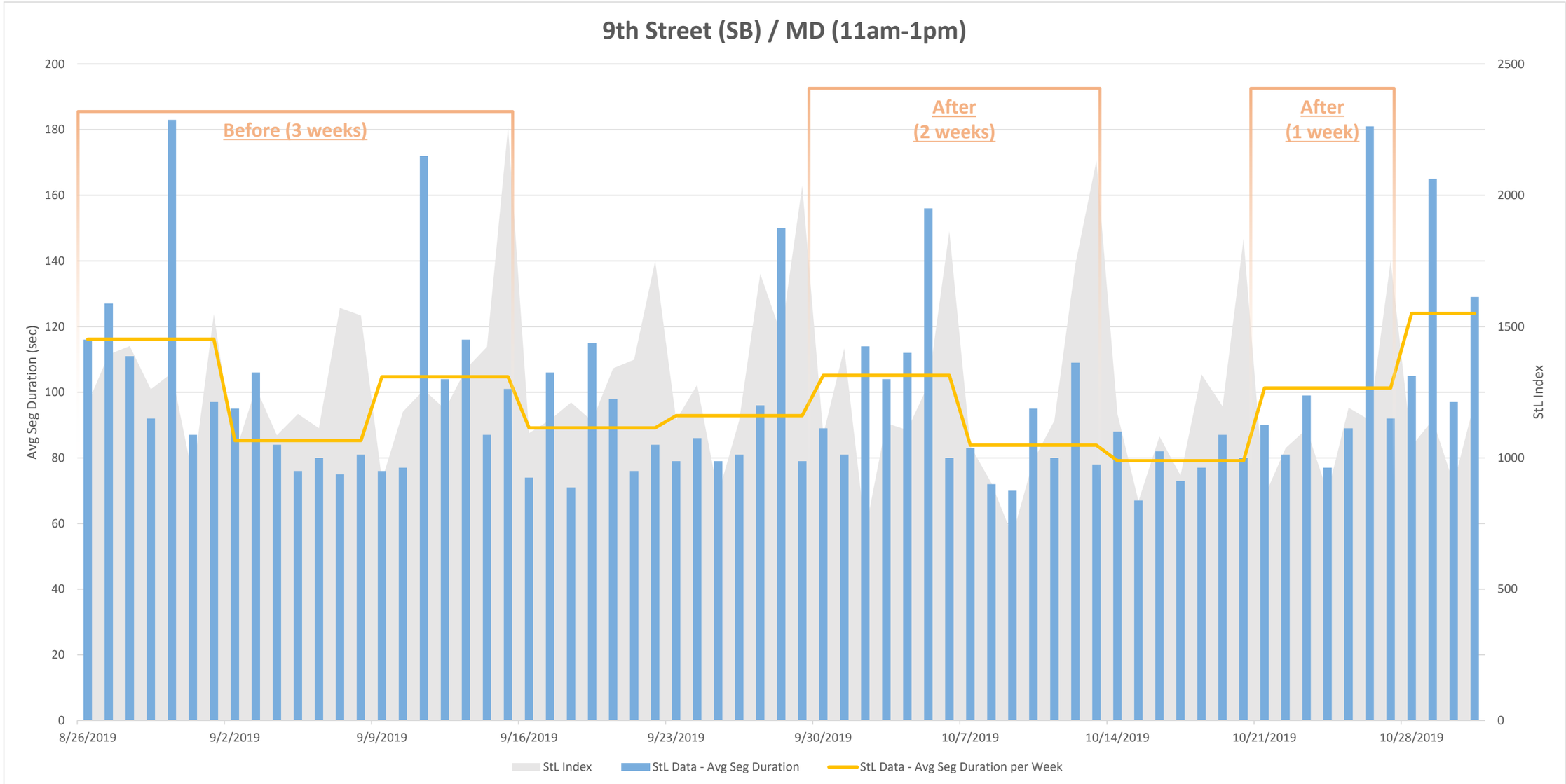
APPENDIX C

Priority Corridor Travel Time Results

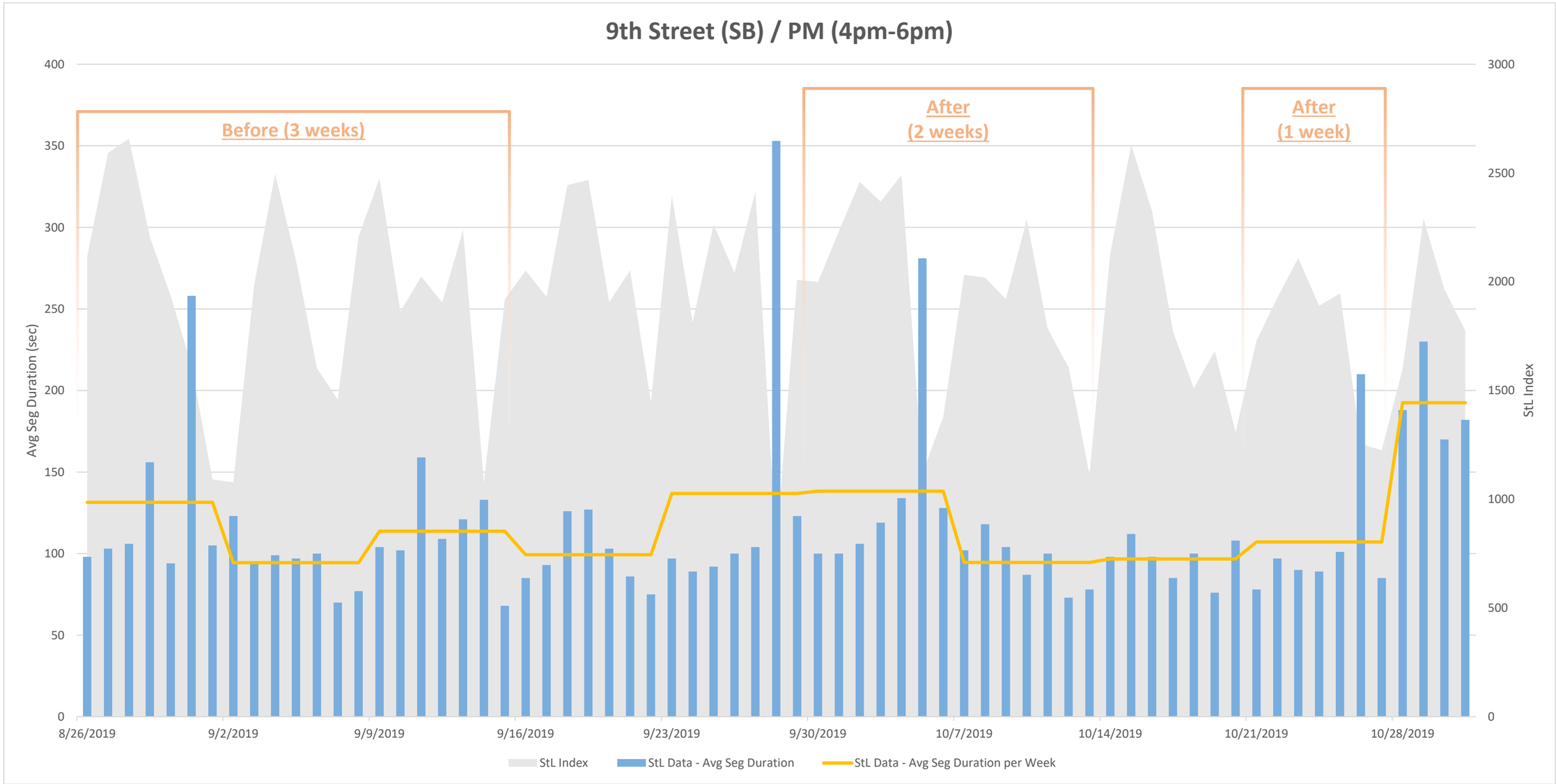
9th Street Southbound Travel Time Results – AM Peak



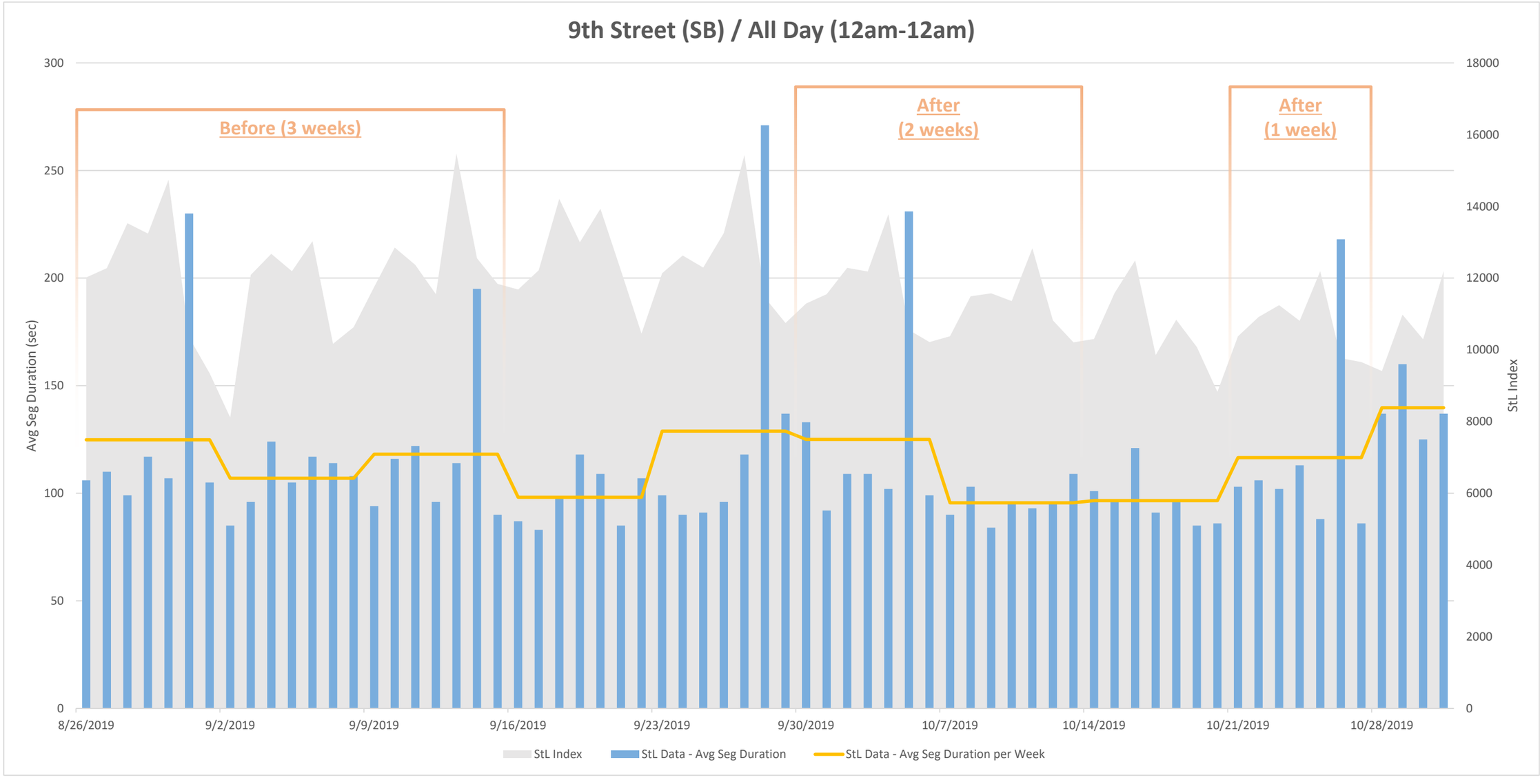
9th Street Southbound Travel Time Results – MD Peak



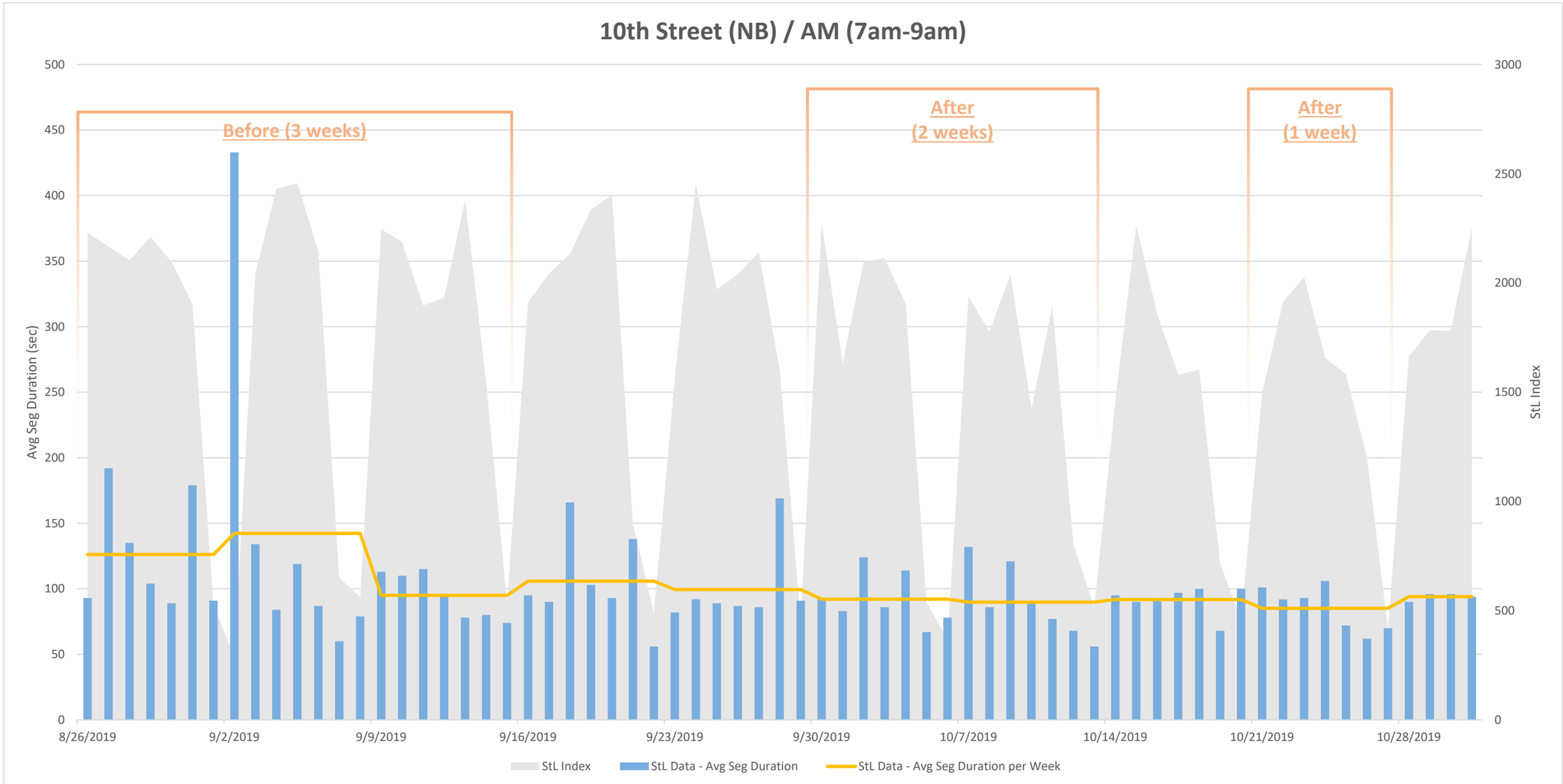
9th Street Southbound Travel Time Results – PM Peak



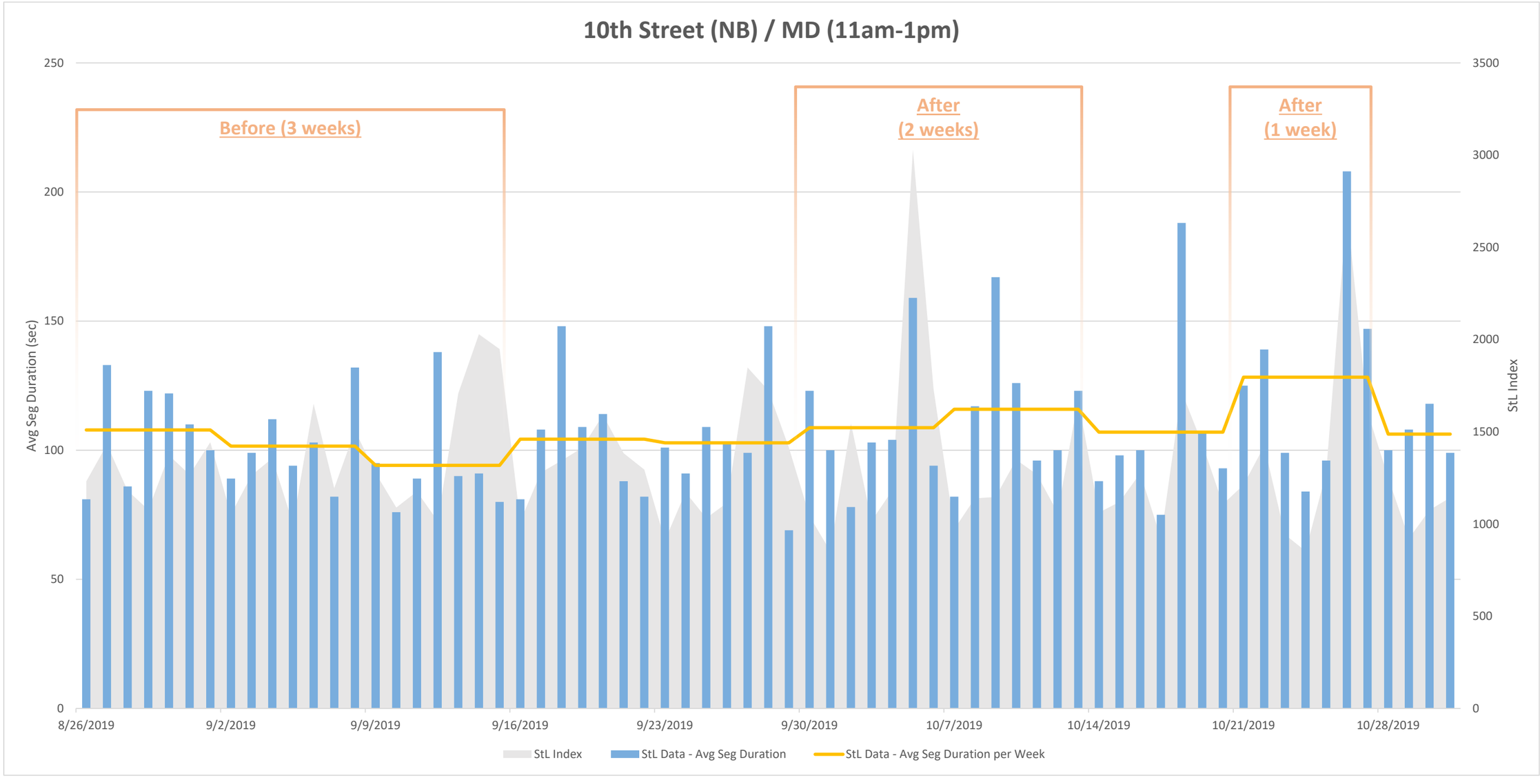
9th Street Southbound Travel Time Results – All Day



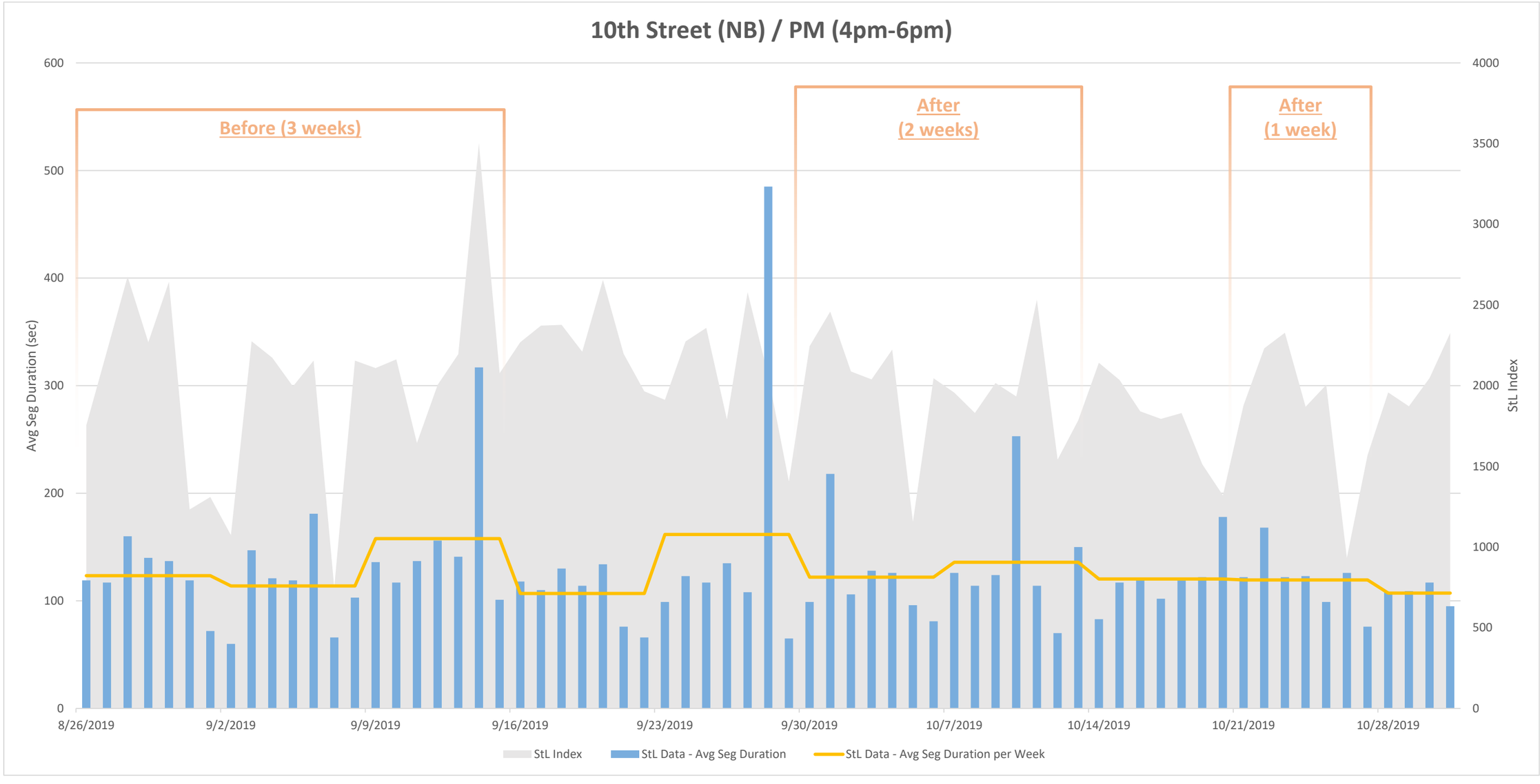
10th Street Northbound Travel Time Results – AM Peak



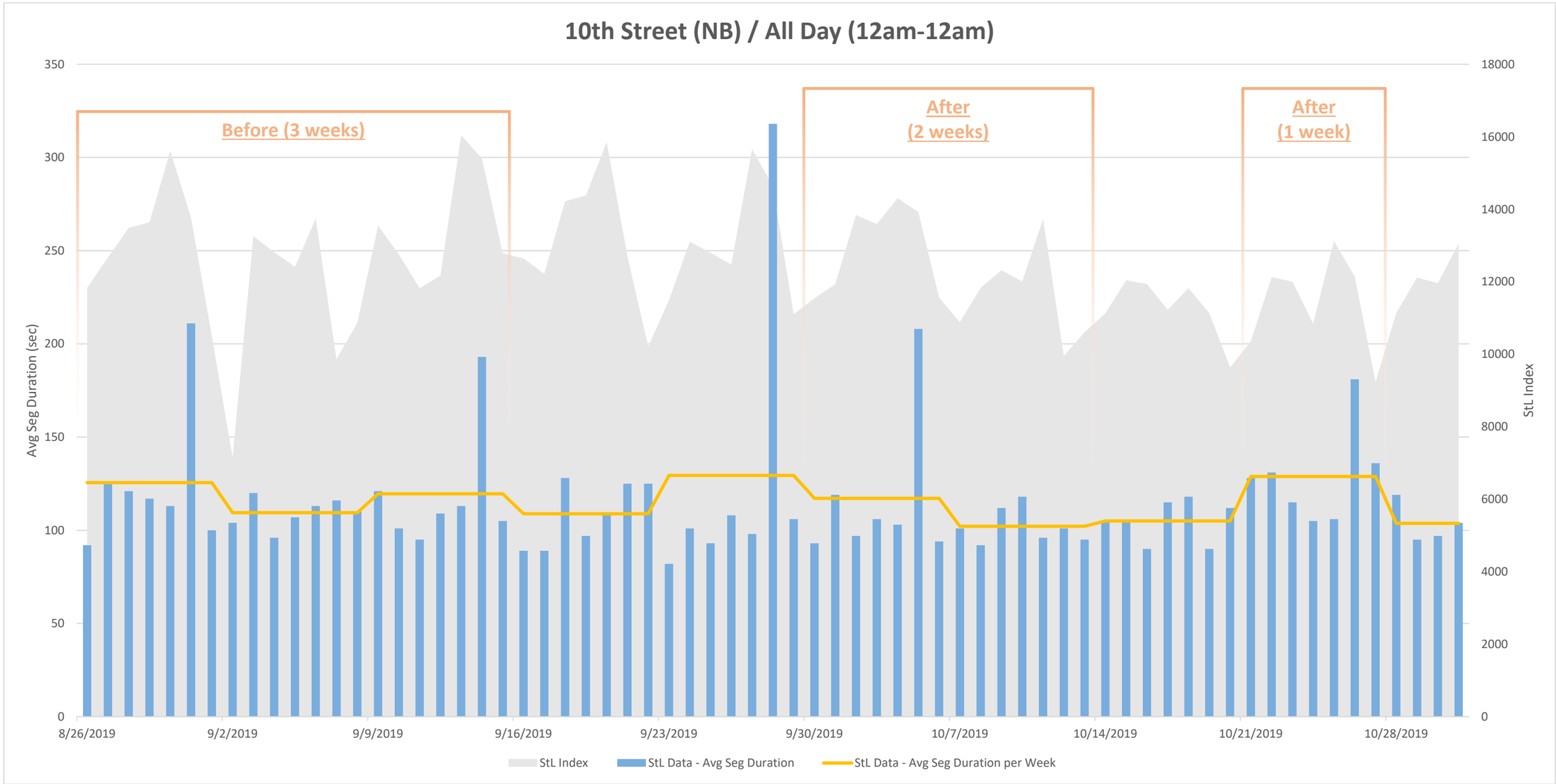
10th Street Northbound Travel Time Results – MD Peak



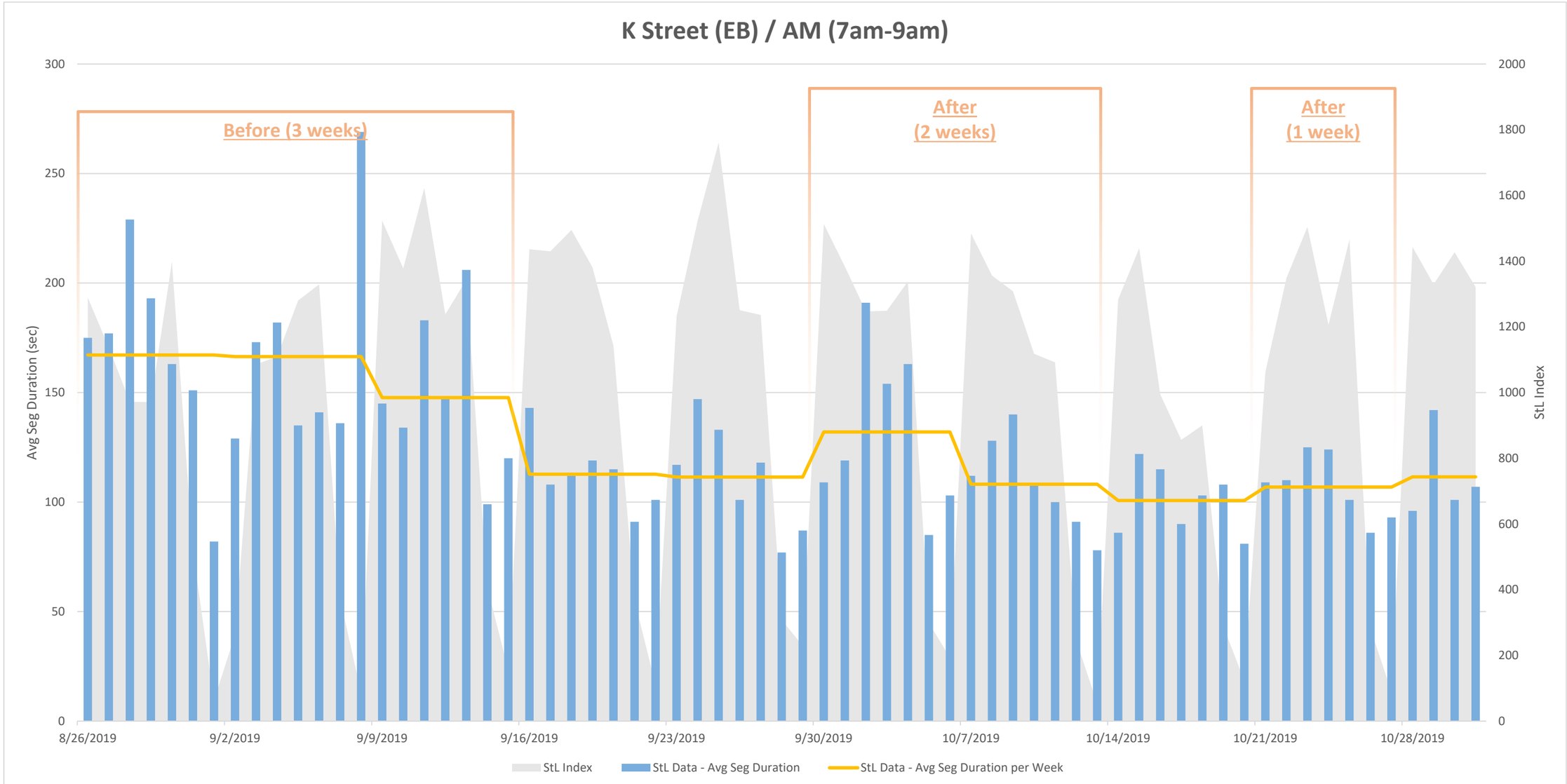
10th Street Northbound Travel Time Results – PM Peak



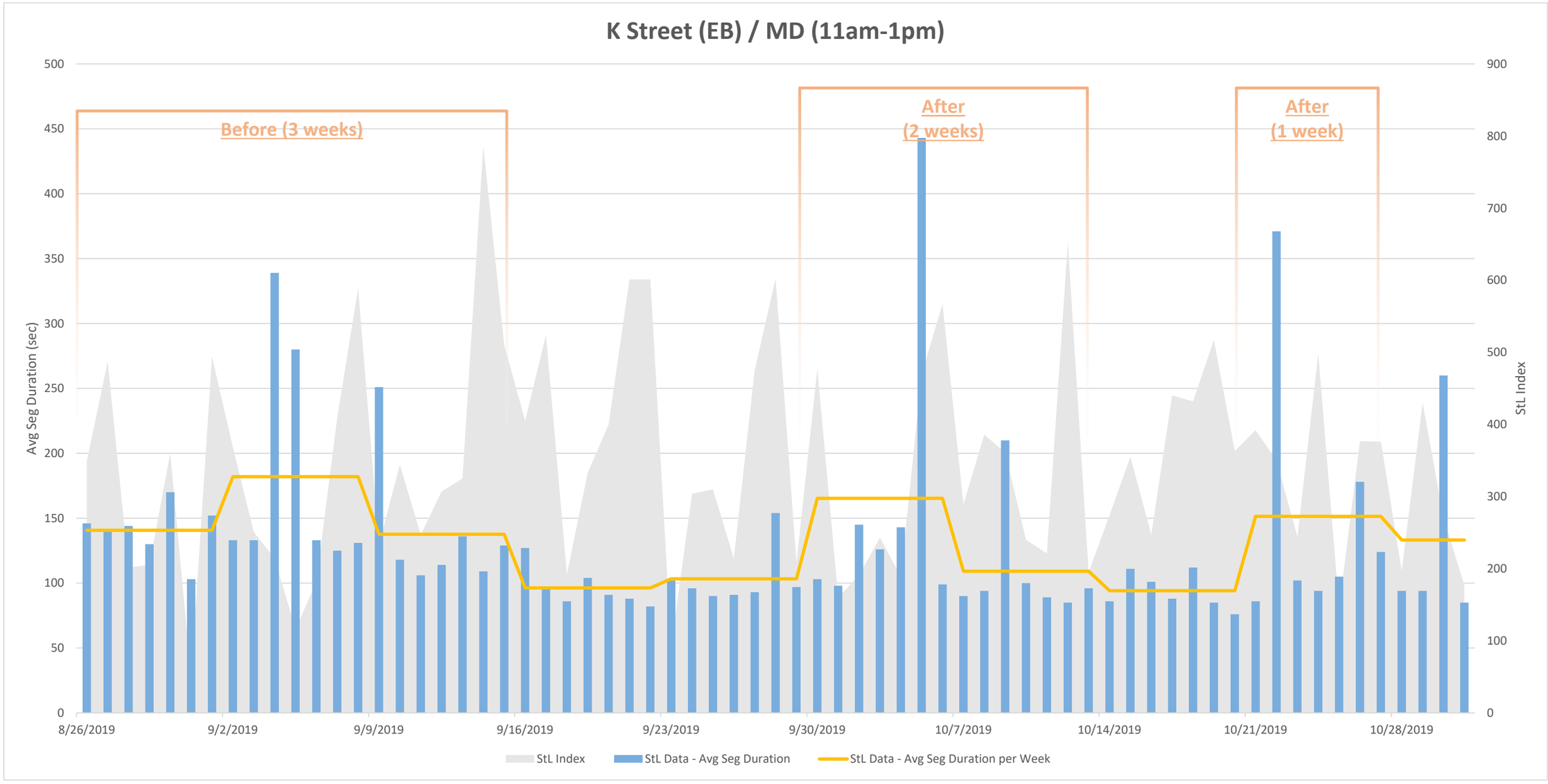
10th Street Northbound Travel Time Results – All Day



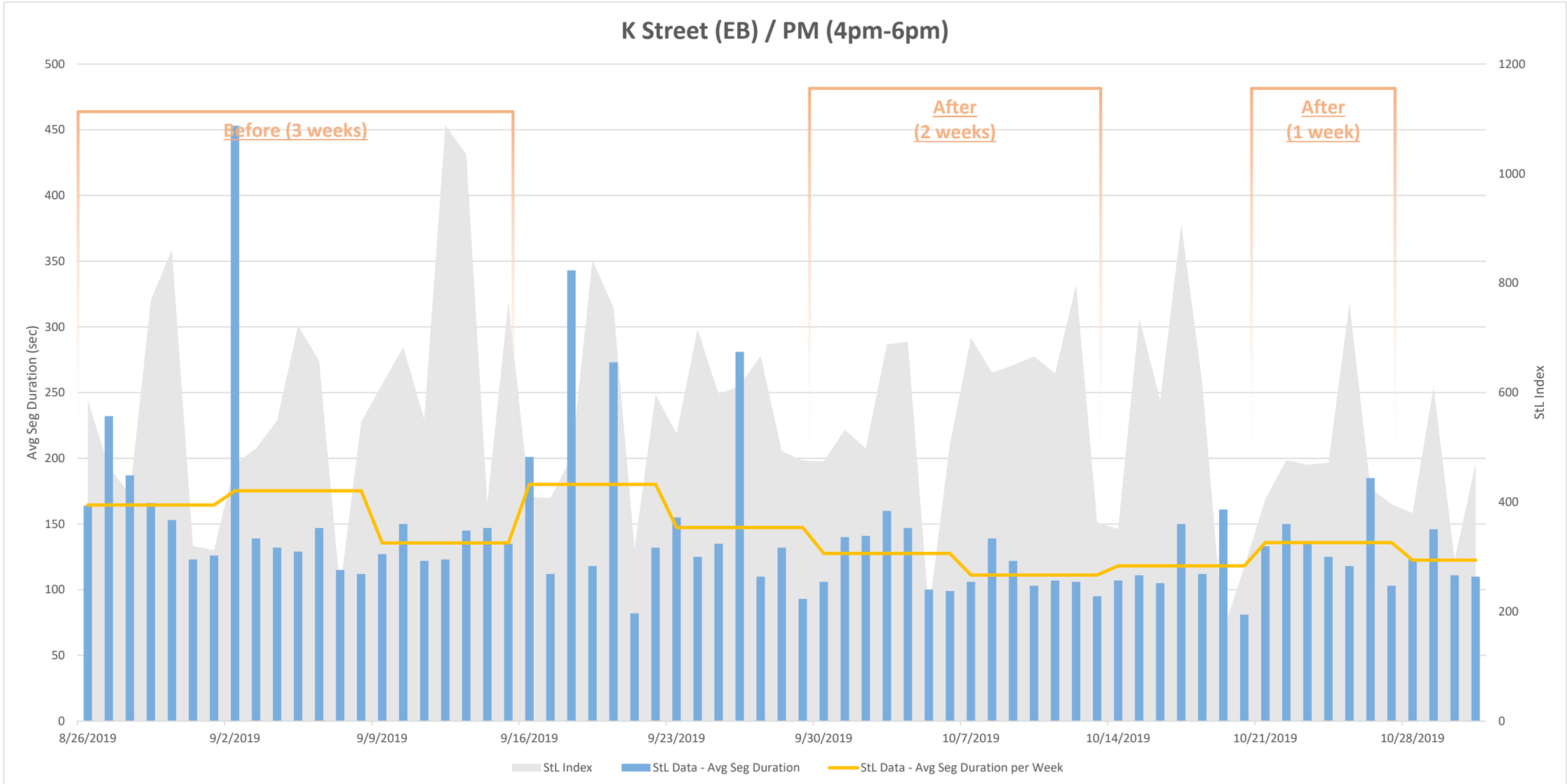
K Street Eastbound Travel Time Results – AM Peak



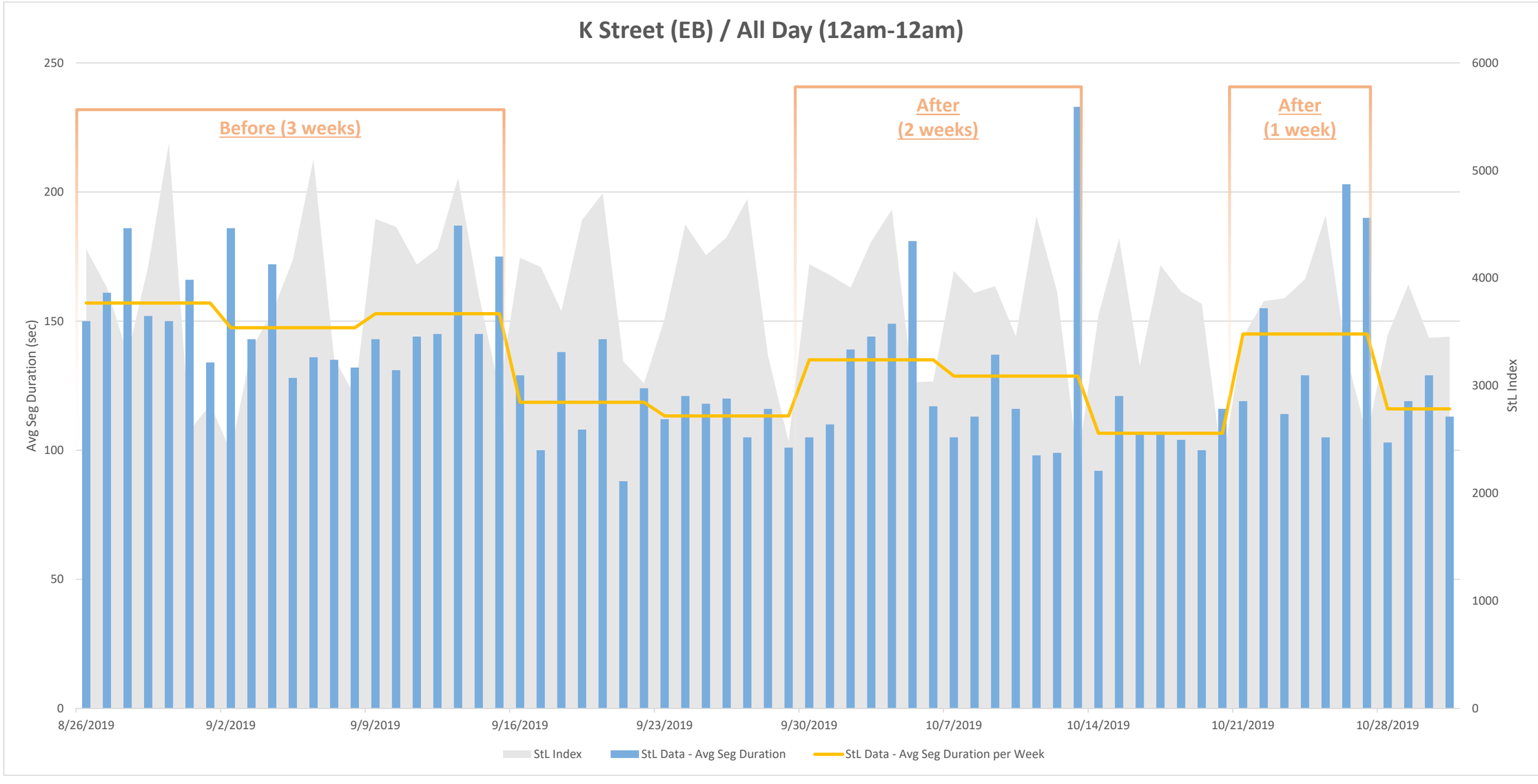
K Street Eastbound Travel Time Results – MD Peak



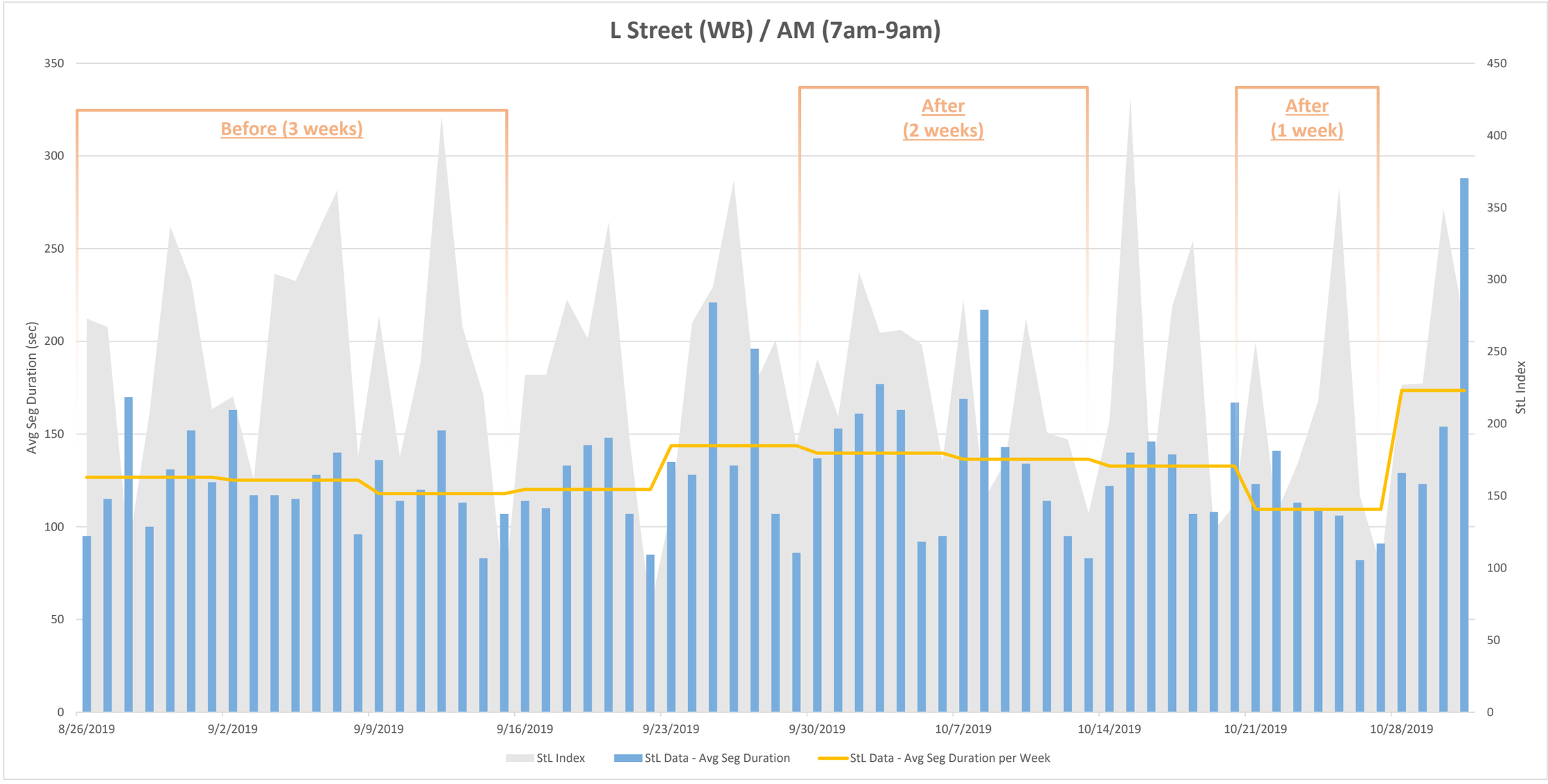
K Street Eastbound Travel Time Results – PM Peak



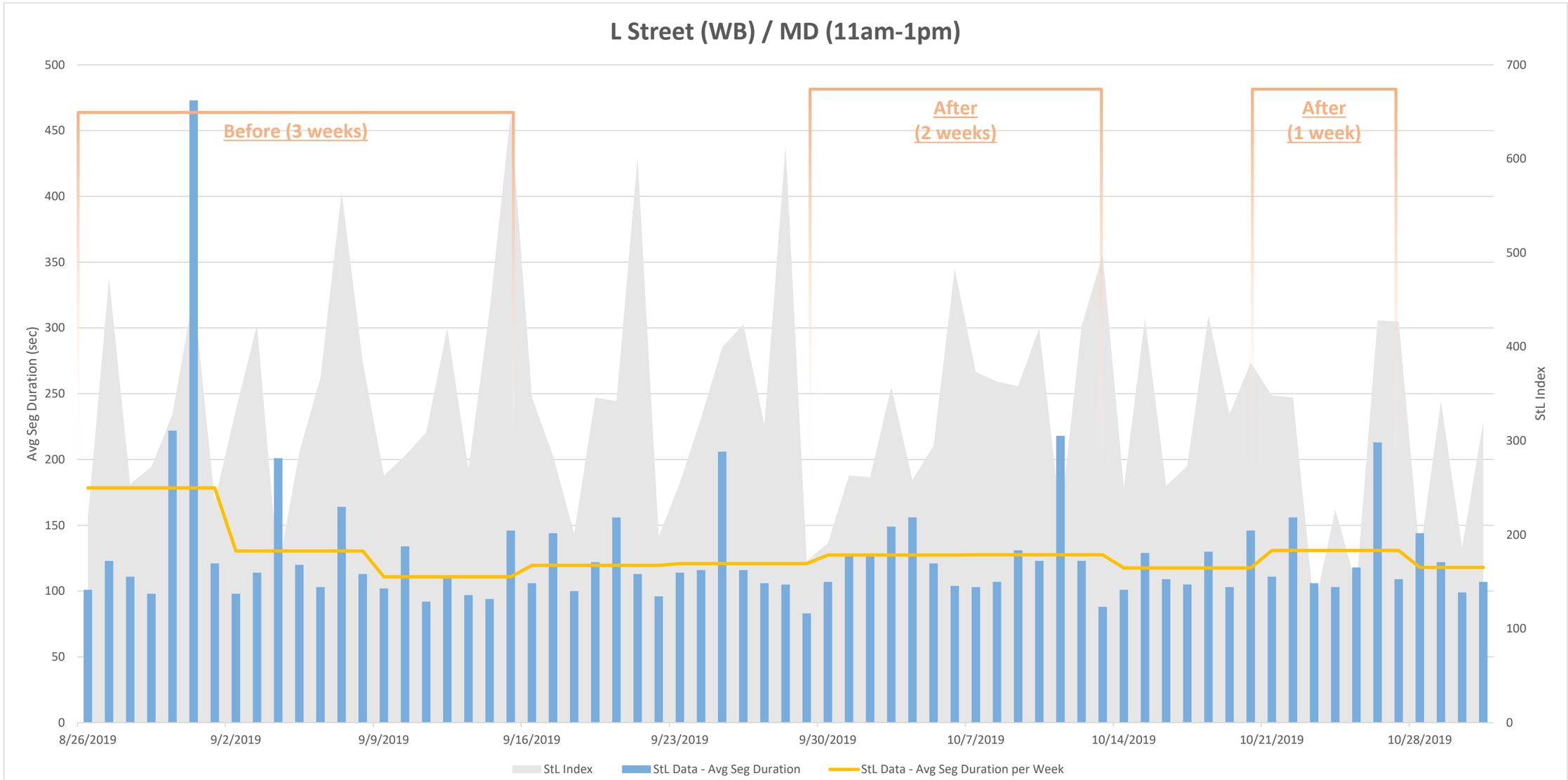
K Street Eastbound Travel Time Results – All Day



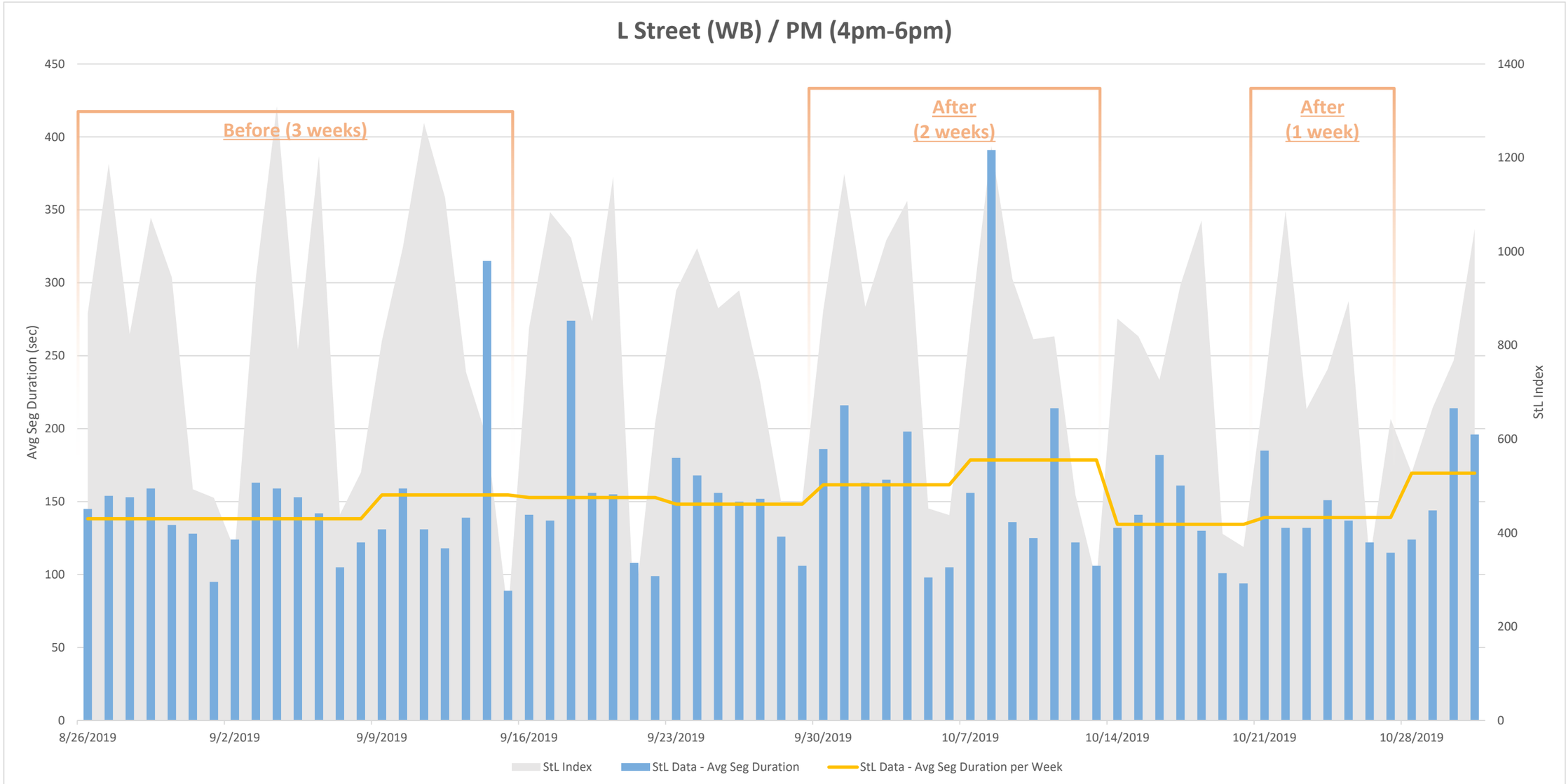
L Street Westbound Travel Time Results – AM Peak



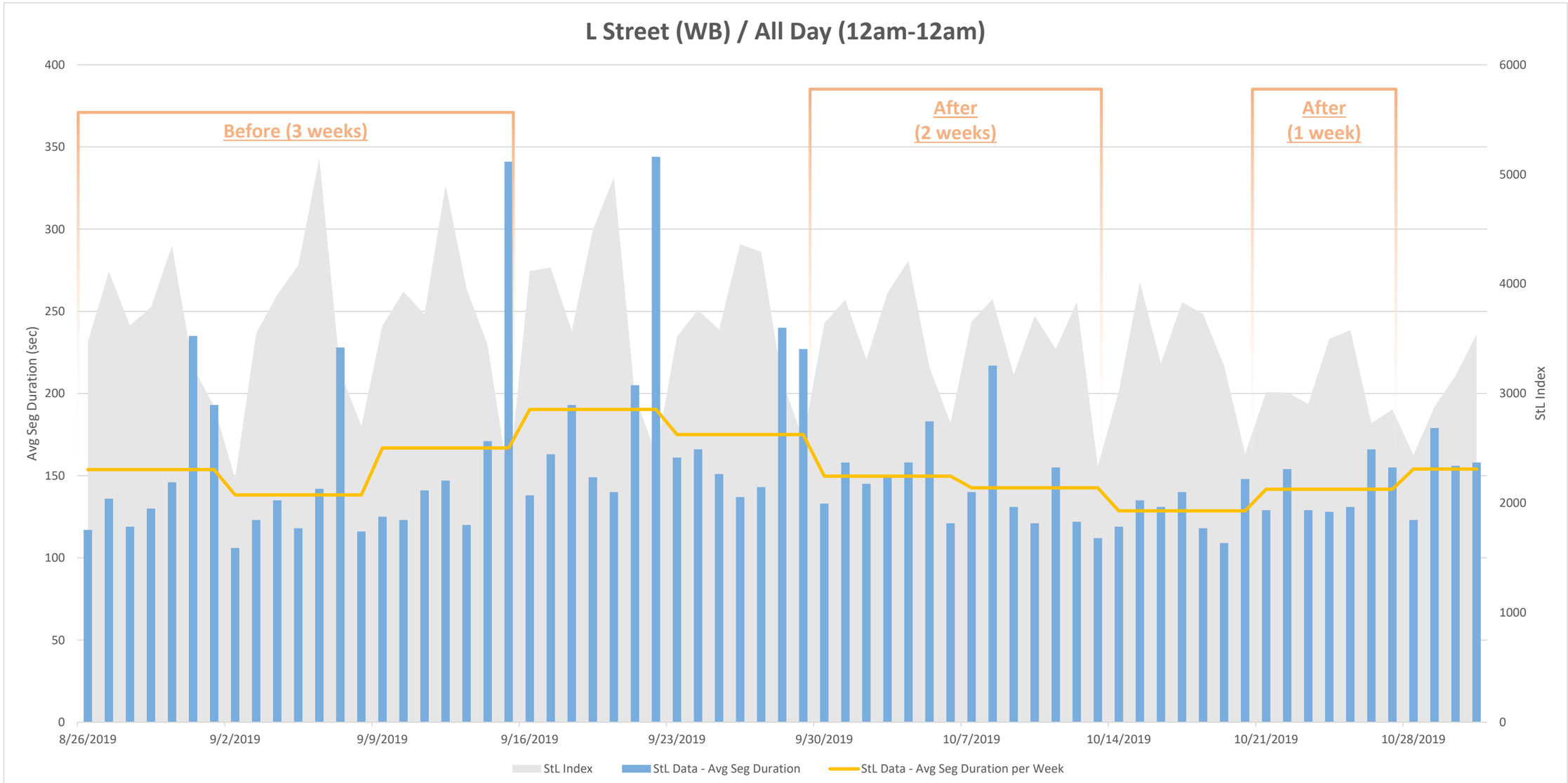
L Street Westbound Travel Time Results – MD Peak



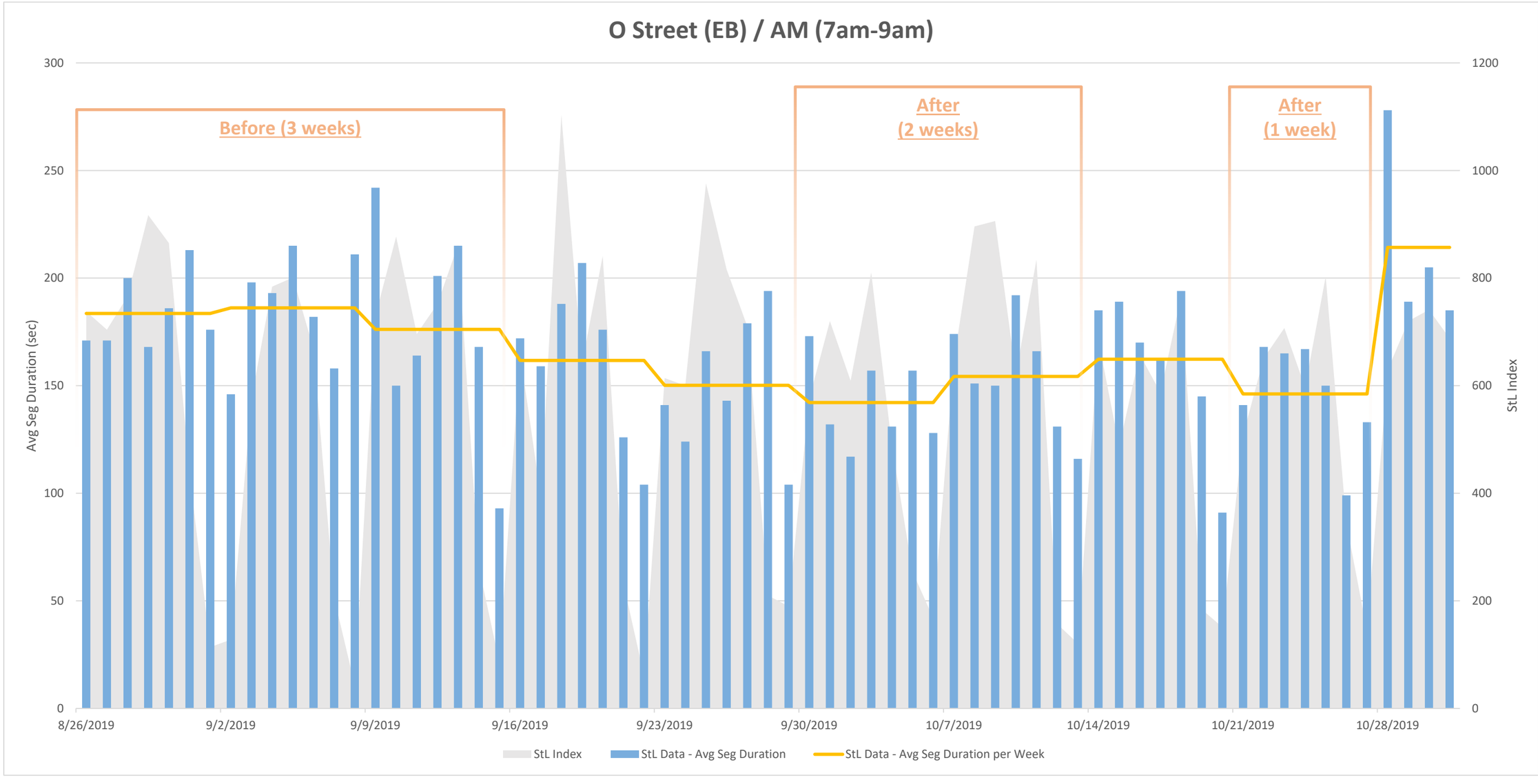
L Street Westbound Travel Time Results – PM Peak



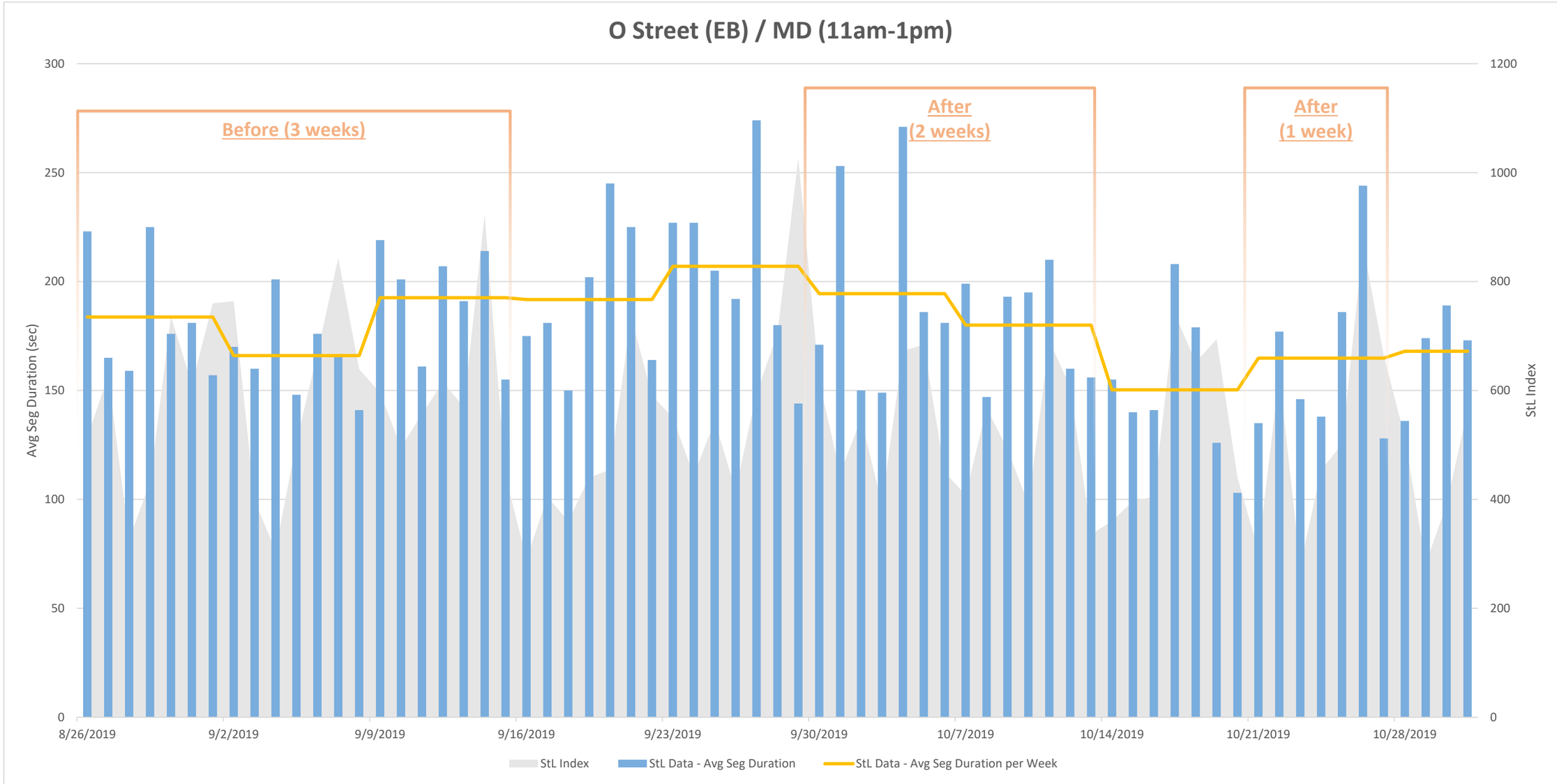
L Street Westbound Travel Time Results – All Day



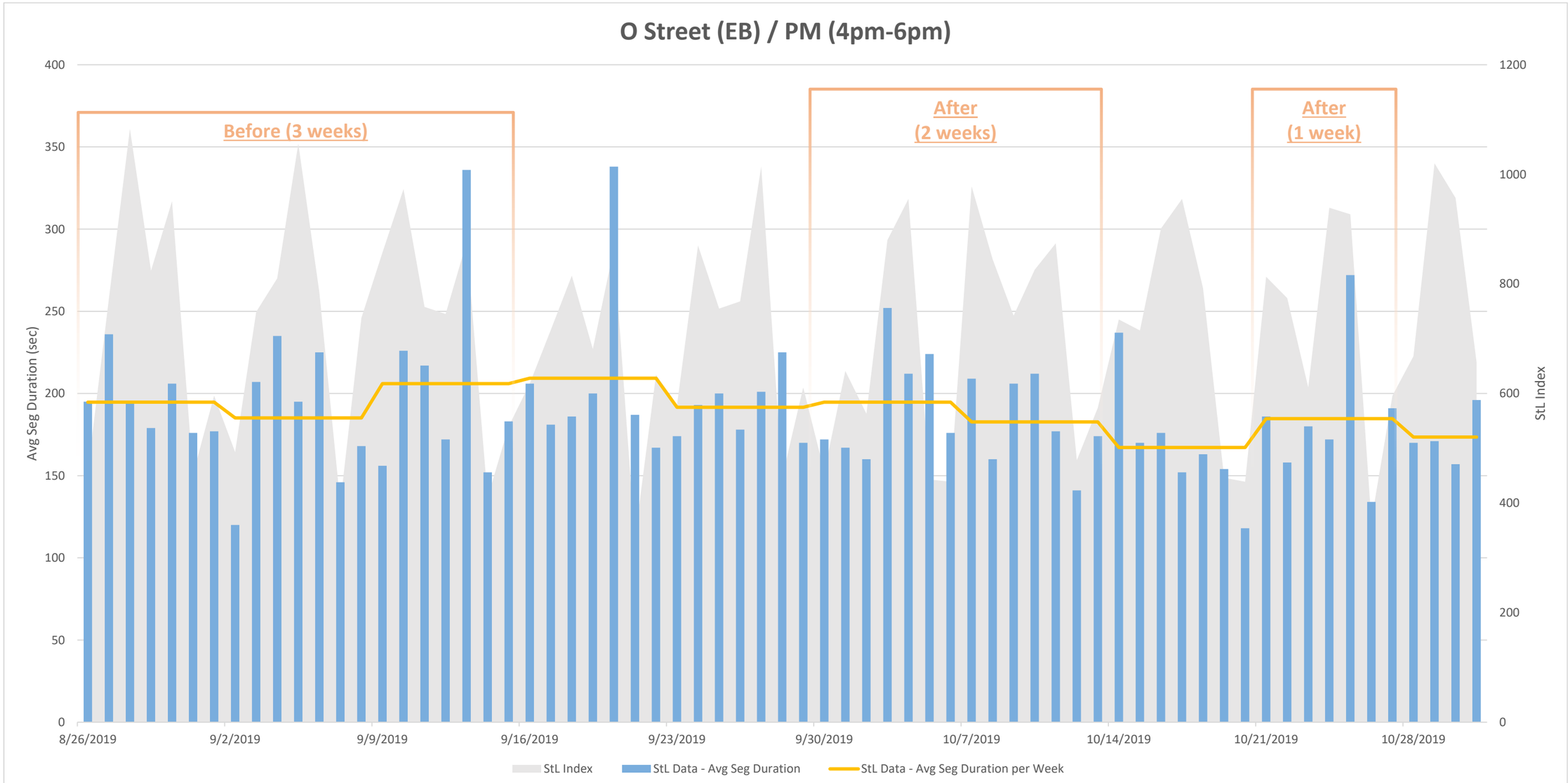
O Street Eastbound Travel Time Results – AM Peak



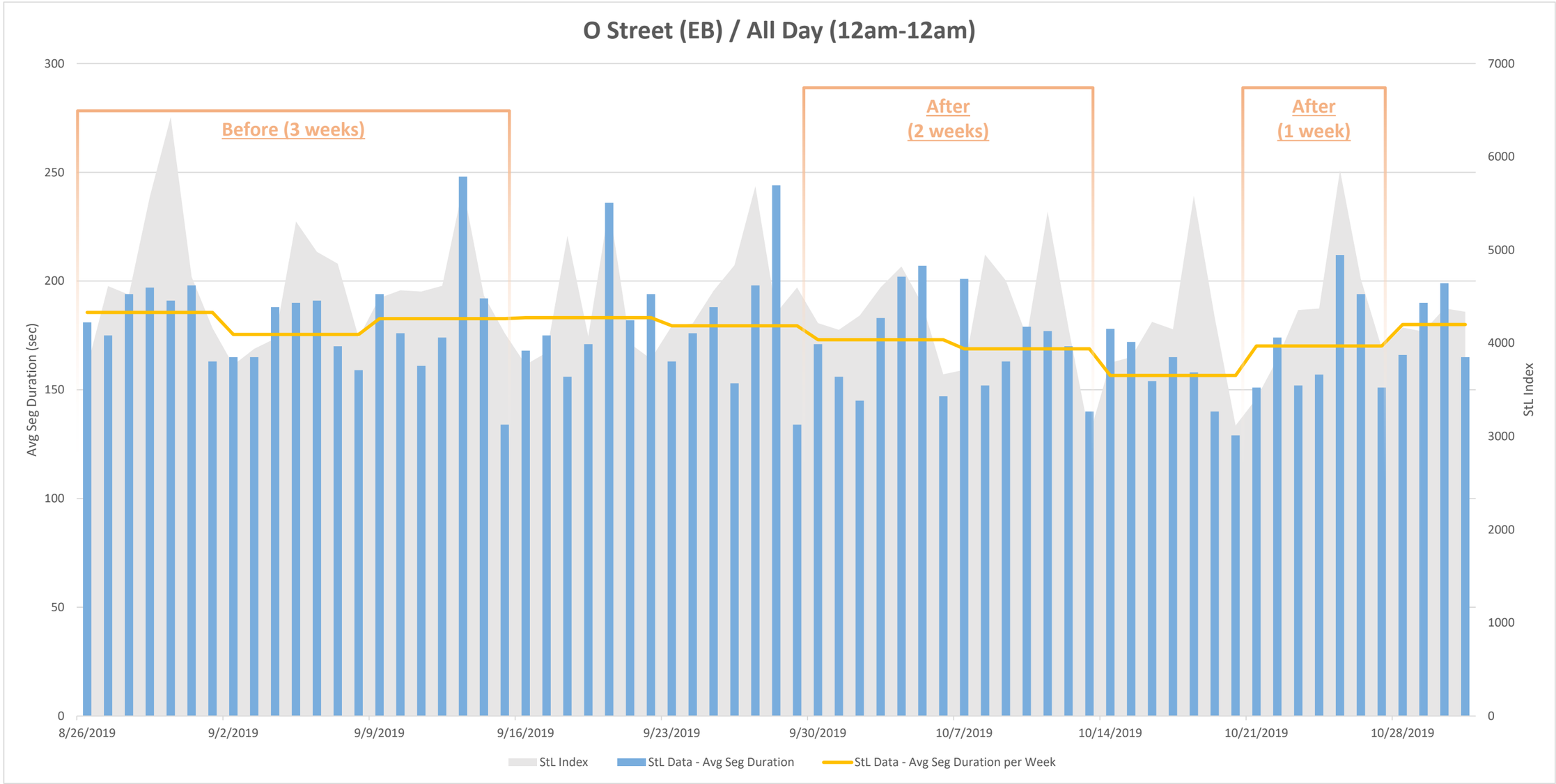
O Street Eastbound Travel Time Results – MD Peak



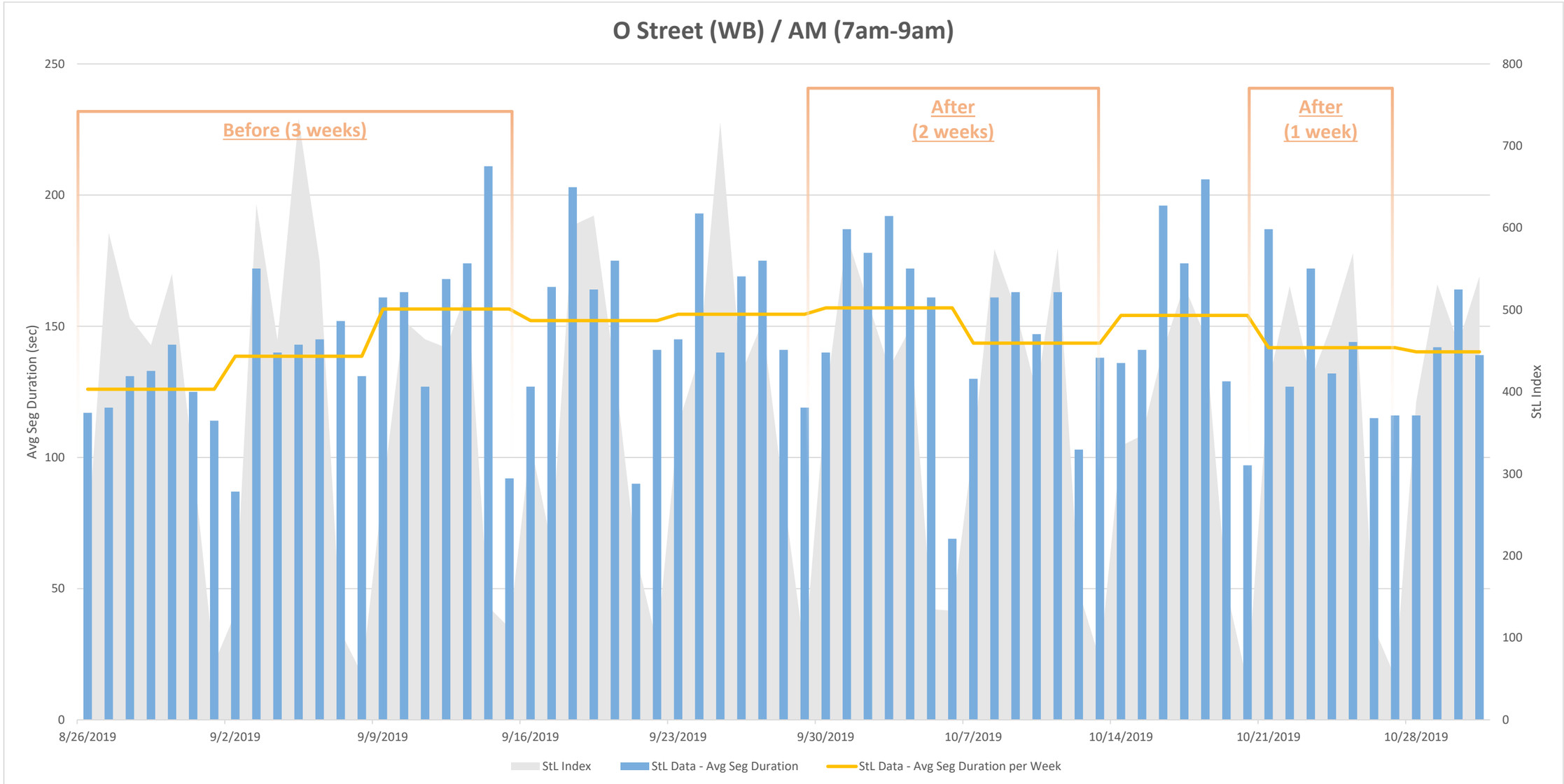
O Street Eastbound Travel Time Results – PM Peak



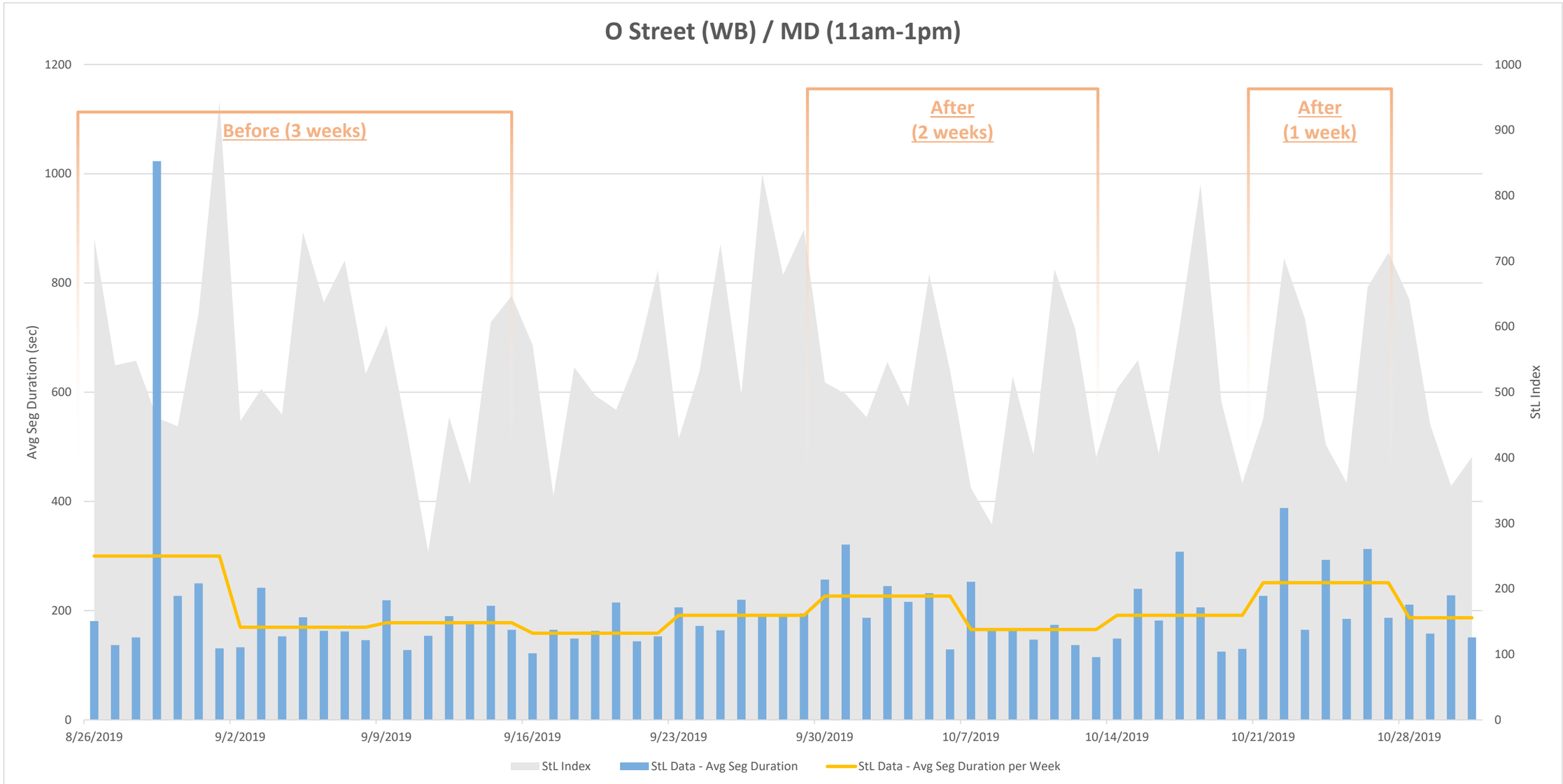
O Street Eastbound Travel Time Results – All Day



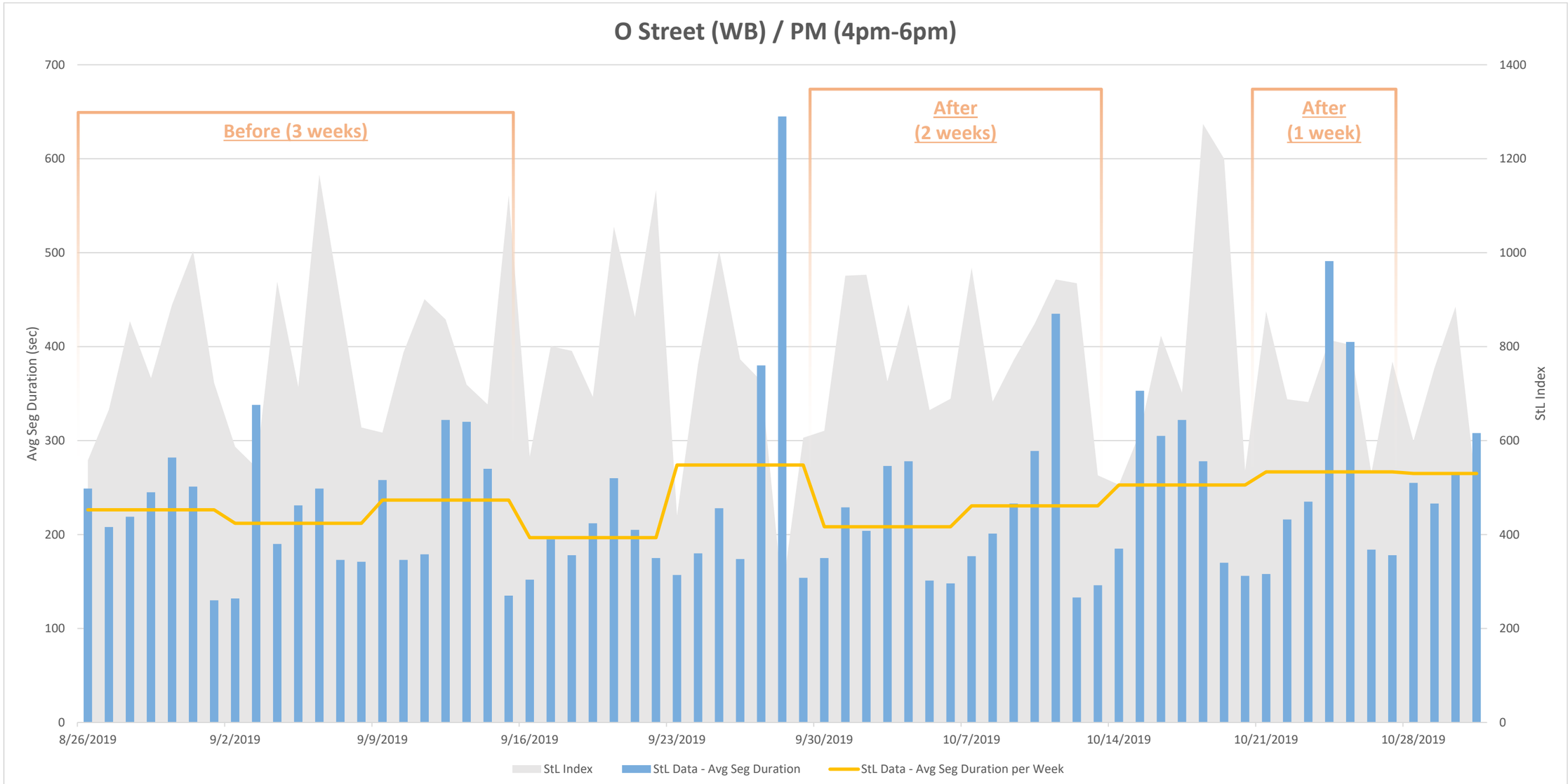
O Street Westbound Travel Time Results – AM Peak



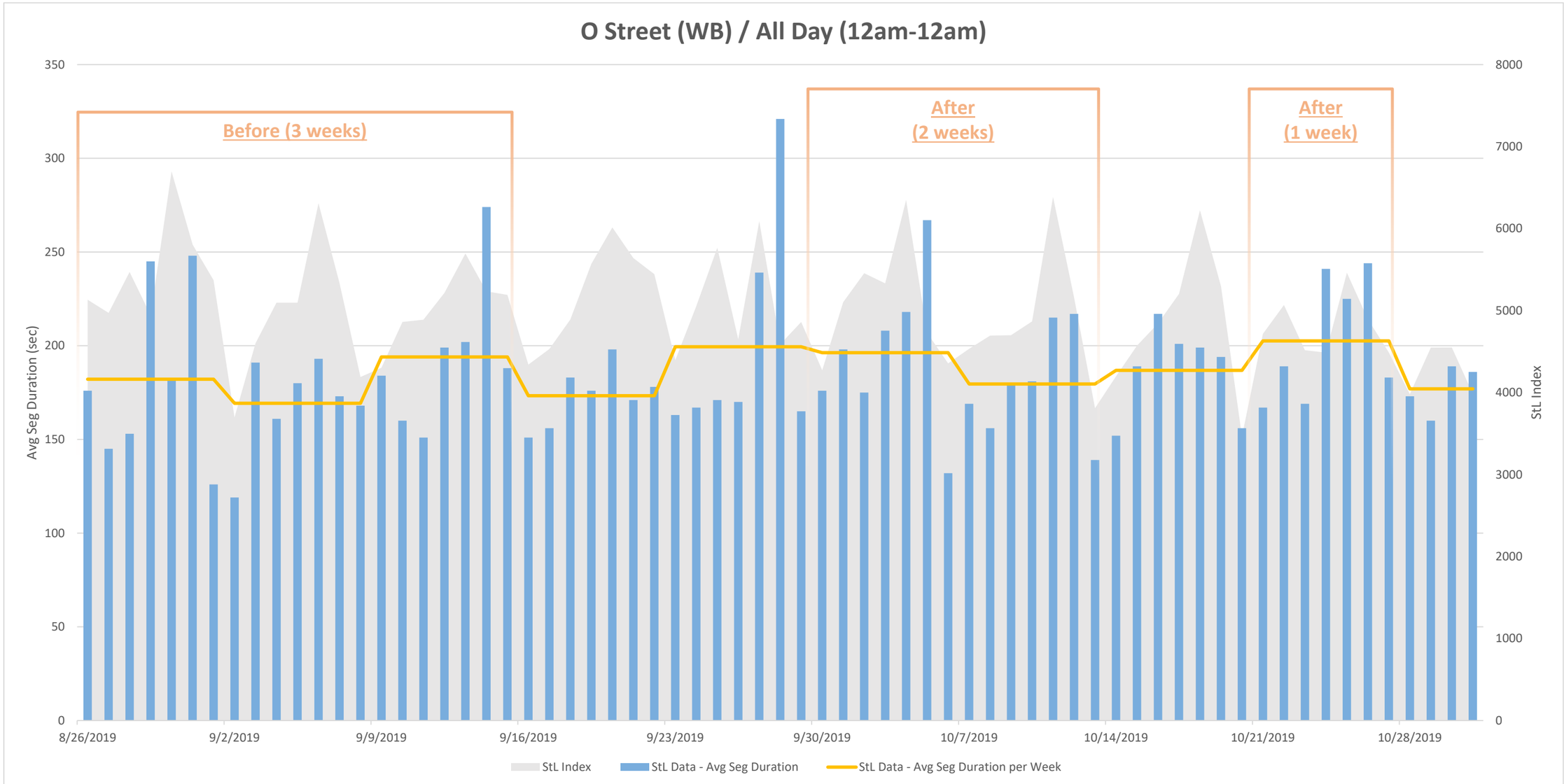
O Street Westbound Travel Time Results – MD Peak



O Street Westbound Travel Time Results – PM Peak



O Street Westbound Travel Time Results – All Day



APPENDIX D

Network Performance Measures

Estimated Corridor Volumes and Travel Time Savings

Corridor	StL Estimated AADT		Truck %	Travel Time Savings (sec)		
	Weekday	Weekend*		Weekday	Weekend	Total
9th Street (SB): K St – Q St	28192	22554	1.8%	7	92	99
9th Street (SB): Park Ave - K St	16935	13548	1.8%	5	62	67
10th Street (NB): K St – Q St	26855	21484	1.3%	6	71	77
10th Street (NB): Park Ave - K St	17039	13631	2.8%	10	1	11
K Street (EB): 9th St – 17th St	10550	8440	0.4%	36	1	37
L Street (WB): 9th St – 17th St	9350	7480	0.9%	(15)	91	76
O Street (EB): 9th St – 17th St	13723	10978	1.1%	16	27	43
O Street (WB): 9th St – 17th St	14030	11224	1.3%	(13)	48	35
16th Street (SB): K St – Q St	7960	6368	0.3%	(35)	53	18
16th Street (SB): South St - K St	7133	5706	1.0%	(12)	(13)	(25)
17th Street (NB): K St – Q St	11914	9531	0.7%	14	(53)	(39)
17th Street (NB): South St - K St	7858	6286	1.2%	8	(24)	(16)
P Street (EB): 9th St – 17th St	7890	6312	2.0%	66	95	161
Q Street (WB): 9th St – 17th St	9183	7346	2.0%	5	53	58
11th Street (SB): L St – P St	3921	3137	4.3%	1	47	48
12th Street (NB): L St – P St	4369	3495	1.5%	39	37	76
13th Street (SB): L St – P St	6251	5001	2.7%	13	1	14
14th Street (NB): L St – P St	4369	3495	2.2%	40	51	91
13th Street (NB): Saratoga - K St	5472	4378	1.6%	(13)	(69)	(82)
13th Street (SB): Saratoga - K St	6003	4802	0.8%	(30)	(26)	(56)
M Street (EB): 10th St – 16th St	3751	3001	2.1%	42	40	82
N Street (WB): 10th St – 16th St	3952	3162	2.6%	(3)	(74)	(77)
A Street (EB): 9th St – 17th St	5937	4750	0.4%	1	20	21
A Street (WB): 9th St – 17th St	5958	4766	0.8%	(42)	(30)	(72)
South Street (EB): 9th St – 17th St	7396	5917	0.6%	17	18	35
South Street (WB): 9th St – 17th St	6545	5236	3.0%	22	17	39
WEIGHTED AVERAGE	9713	7770	1.5%	6.6	32.9	39.5

*Weekend AADT assumed to be 80% of Weekday AADT

Estimated Weekday Savings

Corridor	Annual Weekday Savings (From "Before" to "After" Conditions)				
	Delay (Veh-Hours)	Fuel (Gallons)	Delay Savings ($)	Fuel Savings ($)	User Savings[1] ($)
9th Street (SB): K St – Q St	14,307	3,558	$215,890	$8,860	$224,750
9th Street (SB): Park Ave - K St	6,139	1,526	$92,588	$3,799	$96,387
10th Street (NB): K St – Q St	11,682	2,877	$174,987	$7,165	$182,152
10th Street (NB): Park Ave - K St	12,353	3,129	$189,031	$7,790	$196,822
K Street (EB): 9th St – 17th St	27,536	6,664	$406,979	$16,594	$423,574
L Street (WB): 9th St – 17th St	(10,168)	(2,482)	($151,246)	($6,179)	($157,425)
O Street (EB): 9th St – 17th St	15,919	3,907	$237,783	$9,728	$247,511
O Street (WB): 9th St – 17th St	(13,223)	(3,254)	($197,937)	($8,103)	($206,040)
16th Street (SB): K St – Q St	(20,199)	(4,880)	($298,114)	($12,150)	($310,264)
16th Street (SB): South St - K St	(6,206)	(1,519)	($92,502)	($3,782)	($96,284)
17th Street (NB): K St – Q St	12,093	2,940	$179,366	$7,322	$186,688
17th Street (NB): South St - K St	4,558	1,120	$68,137	$2,788	$70,925
P Street (EB): 9th St – 17th St	37,754	9,419	$571,063	$23,452	$594,516
Q Street (WB): 9th St – 17th St	3,329	830	$50,352	$2,068	$52,420
11th Street (SB): L St – P St	284	74	$4,446	$184	$4,630
12th Street (NB): L St – P St	12,353	3,053	$185,498	$7,601	$193,099
13th Street (SB): L St – P St	5,892	1,488	$89,981	$3,706	$93,687
14th Street (NB): L St – P St	12,670	3,171	$192,113	$7,895	$200,009
13th Street (NB): Saratoga - K St	(5,157)	(1,277)	($77,556)	($3,179)	($80,736)
13th Street (SB): Saratoga - K St	(13,057)	(3,183)	($194,045)	($7,926)	($201,971)
M Street (EB): 10th St – 16th St	11,422	2,857	$173,126	$7,114	$180,240
N Street (WB): 10th St – 16th St	(860)	(217)	($13,110)	($540)	($13,650)
A Street (EB): 9th St – 17th St	430	104	$6,359	$259	$6,618
A Street (WB): 9th St – 17th St	(18,142)	(4,423)	($269,627)	($11,013)	($280,640)
South Street (EB): 9th St – 17th St	9,116	2,214	$135,074	$5,512	$140,586
South Street (WB): 9th St – 17th St	10,439	2,654	$160,203	$6,608	$166,811
TOTALS	121,264	30,351	$1,838,839	$75,575	$1,914,414

Estimated Weekend Savings

Corridor	Annual Weekend Savings (From "Before" to "After" Conditions)				
	Delay (Veh-Hours)	Fuel (Gallons)	Delay Savings ($)	Fuel Savings ($)	User Savings[1] ($)
9th Street (SB): K St – Q St	59,942	14,907	$828,486	$37,118	$865,604
9th Street (SB): Park Ave - K St	24,266	6,031	$335,200	$15,017	$350,217
10th Street (NB): K St – Q St	44,066	10,854	$603,919	$27,027	$630,946
10th Street (NB): Park Ave - K St	394	100	$5,531	$248	$5,780
K Street (EB): 9th St – 17th St	244	59	$3,290	$147	$3,437
L Street (WB): 9th St – 17th St	19,664	4,799	$267,311	$11,950	$279,262
O Street (EB): 9th St – 17th St	8,563	2,102	$116,977	$5,233	$122,209
O Street (WB): 9th St – 17th St	15,564	3,830	$213,129	$9,537	$222,666
16th Street (SB): K St – Q St	9,750	2,355	$131,352	$5,865	$137,217
16th Street (SB): South St - K St	(2,143)	(524)	($29,204)	($1,306)	($30,510)
17th Street (NB): K St – Q St	(14,593)	(3,548)	($197,732)	($8,836)	($206,568)
17th Street (NB): South St - K St	(4,359)	(1,071)	($59,598)	($2,666)	($62,265)
P Street (EB): 9th St – 17th St	17,253	4,304	$239,124	$10,717	$249,841
Q Street (WB): 9th St – 17th St	11,248	2,806	$155,902	$6,987	$162,889
11th Street (SB): L St – P St	4,259	1,110	$61,347	$2,763	$64,110
12th Street (NB): L St – P St	3,736	923	$51,346	$2,299	$53,645
13th Street (SB): L St – P St	144	36	$2,025	$91	$2,116
14th Street (NB): L St – P St	5,150	1,289	$71,574	$3,209	$74,783
13th Street (NB): Saratoga - K St	(8,726)	(2,160)	($120,131)	($5,379)	($125,510)
13th Street (SB): Saratoga - K St	(3,607)	(879)	($48,987)	($2,190)	($51,177)
M Street (EB): 10th St – 16th St	3,509	878	$48,757	$2,186	$50,943
N Street (WB): 10th St – 16th St	(6,759)	(1,704)	($94,578)	($4,244)	($98,822)
A Street (EB): 9th St – 17th St	2,744	664	$37,012	$1,653	$38,665
A Street (WB): 9th St – 17th St	(4,131)	(1,007)	($56,100)	($2,508)	($58,607)
South Street (EB): 9th St – 17th St	3,077	747	$41,640	$1,860	$43,501
South Street (WB): 9th St – 17th St	2,571	654	$36,240	$1,628	$37,868
TOTALS	191,827	47,553	$2,643,834	$118,406	$2,762,239

Estimated Total Savings

Corridor	Annual Total Savings (From "Before" to "After" Conditions)				
	Delay (Veh-Hours)	Fuel (Gallons)	Delay Savings ($)	Fuel Savings ($)	User Savings[1] ($)
9th Street (SB): K St – Q St	74,250	18,465	$1,044,376	$45,978	$1,090,354
9th Street (SB): Park Ave - K St	30,405	7,556	$427,788	$18,816	$446,603
10th Street (NB): K St – Q St	55,748	13,732	$778,906	$34,192	$813,098
10th Street (NB): Park Ave - K St	12,747	3,228	$194,563	$8,039	$202,601
K Street (EB): 9th St – 17th St	27,779	6,723	$410,269	$16,741	$427,011
L Street (WB): 9th St – 17th St	9,496	2,318	$116,066	$5,771	$121,837
O Street (EB): 9th St – 17th St	24,482	6,008	$354,760	$14,960	$369,720
O Street (WB): 9th St – 17th St	2,341	576	$15,192	$1,434	$16,626
16th Street (SB): K St – Q St	(10,448)	(2,524)	($166,762)	($6,285)	($173,047)
16th Street (SB): South St - K St	(8,349)	(2,043)	($121,706)	($5,088)	($126,794)
17th Street (NB): K St – Q St	(2,501)	(608)	($18,366)	($1,514)	($19,880)
17th Street (NB): South St - K St	199	49	$8,538	$122	$8,660
P Street (EB): 9th St – 17th St	55,006	13,723	$810,187	$34,169	$844,356
Q Street (WB): 9th St – 17th St	14,577	3,637	$206,254	$9,055	$215,309
11th Street (SB): L St – P St	4,543	1,184	$65,793	$2,947	$68,741
12th Street (NB): L St – P St	16,089	3,976	$236,844	$9,900	$246,744
13th Street (SB): L St – P St	6,036	1,525	$92,005	$3,797	$95,802
14th Street (NB): L St – P St	17,820	4,460	$263,688	$11,104	$274,792
13th Street (NB): Saratoga - K St	(13,883)	(3,437)	($197,687)	($8,559)	($206,246)
13th Street (SB): Saratoga - K St	(16,664)	(4,062)	($243,032)	($10,115)	($253,147)
M Street (EB): 10th St – 16th St	14,931	3,735	$221,883	$9,300	$231,183
N Street (WB): 10th St – 16th St	(7,618)	(1,921)	($107,688)	($4,784)	($112,472)
A Street (EB): 9th St – 17th St	3,175	768	$43,371	$1,912	$45,284
A Street (WB): 9th St – 17th St	(22,273)	(5,430)	($325,726)	($13,521)	($339,247)
South Street (EB): 9th St – 17th St	12,192	2,961	$176,714	$7,372	$184,086
South Street (WB): 9th St – 17th St	13,011	3,307	$196,443	$8,236	$204,678
TOTALS	313,091	77,904	$4,482,673	$193,981	$4,676,653

FELSBURG HOLT & ULLEVIG

321 S. 9th Street
Lincoln, NE 68508
402-438-7530

fhueng.com