FUNCTIONAL DESIGN REPORT

MASSACHUSETTS AVENUE (Route 3/2A)

Arlington, Massachusetts

Prepared for the

Town of Arlington

Prepared by

Fay, Spofford & Thorndike, LLC
Engineers • Planners

Burlington, Massachusetts

September 2009

Table of Contents

Appendix

-Traffic Counts
- Massachusetts Avenue/Foster Street /Linwood Street
- Massachusetts Avenue/Bates Road/Marion Road
- Massachusetts Avenue/Orvis Road /Grafton Street
- Massachusetts Avenue/Lake Street /Winter Street
- Massachusetts Avenue/Teel Street/Thorndike Street
- Massachusetts Avenue/Alewife Brook Parkway (Cambridge)

-ATRs-48 hour
-Capacity Analyses
- 2008 Existing
- 2018 No Build
- 2018 Build

-Intersection Crash Rate Forms
-Signal Warrant Analysis

List of Figures

List of Tables

INTRODUCTION

1.1 Overview

Under a contract with the Town of Arlington, Fay, Spofford & Thorndike (FST) has been retained to evaluate the traffic operations and safety conditions at a number of intersections along the study area corridor, which is defined for this phase of the project from Pond Lane on the west to Alewife Brook Parkway (Route 16) (in Cambridge) on the east end. The study corridor is located in the southern section of Arlington (See Figure 1), and includes a total of 31 intersecting streets, of which six (6) key locations are to be included in the study area of this report. These study area intersections are:

Signalized:

- Massachusetts Avenue/Foster Street/Linwood Street
- Massachusetts Avenue/Lake Street/Winter Street
- Massachusetts Avenue/Teel Street/Thorndike Street
- Massachusetts Avenue/Alewife Brook Parkway (Cambridge)

Unsignalized:

- Massachusetts Avenue/Bates Road/Marion Road
- Massachusetts Avenue/Orvis Road/Grafton Street

This report presents the findings of FST's study of the existing conditions, identifies operational and safety deficiencies and recommends improvement strategies to address the deficiencies. The recommended improvements may consist of roadway reconstruction to add turn lanes, the installation and/or the removal of traffic signals, channelization, traffic calming measures, sidewalk reconstruction, installation of new crosswalks, sidewalk bump-outs, and drainage improvements. No property acquisitions are anticipated with these improvement measures.

1.2 Data Collection, Seasonality and Traffic Projection

- *Primary Traffic Count Program*

In order to evaluate the existing and future traffic operations of the Massachusetts Avenue project intersections, a traffic count program was conducted during the week of October 20, 2008. This data collection program consisted of vehicle *Turning Movement Counts* (TMC), and vehicle *Automatic Traffic Recorder* (ATR) counts, as well as pedestrian and bicycle counts for the following time periods for weekdays and a Saturday, respectively:

TMCs

4 Hours (7:00 AM - 9:00 AM and 4:00 PM - 6:00 PM) weekdays TMCs were conducted at the following locations:

- Massachusetts Avenue/Foster Street /Linwood Street (signalized)
- Massachusetts Avenue/Bates Road/Marion Road

Schematic Diagram:
Not to Scale

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Figure 1
Study Area Corridor

Massachusetts Avenue
Town of Arlington, Massachusetts
September 2009

Signalized Intersection

- Massachusetts Avenue/Orvis Road /Grafton Street
- Massachusetts Avenue/Lake Street /Winter Street (signalized)
- Massachusetts Avenue/Teel Street/Thorndike Street (signalized)
- Massachusetts Avenue/Alewife Brook Parkway (signalized) in Cambridge

2 Hours (11:30 AM to 1:30 PM) Saturday Mid-Day TMCs were conducted only at the following locations:

- Massachusetts Avenue/Foster Street /Linwood Street
- Massachusetts Avenue/Lake Street /Winter Street
- Massachusetts Avenue/Teel Street/Thorndike Street

The 2 Hour TMCs were used to develop an understanding of the traffic fluctuations on a Saturday mid-day period, compared to a typical commuter weekday at the following three key intersections in the study area in Arlington: Massachusetts Avenue with Foster and Linwood Streets; Massachusetts Avenue with Lake and Winter Streets; and also Massachusetts Avenue with Teel and Thorndike Streets. These Saturday counts were conducted on October 18, 2008.

Based on the traffic counts collected at area intersections during the peak periods, the traffic volumes at study area intersections are listed in order of ranking below in Table 1.

TABLE 1 – Existing 2008 Traffic Volume Entering Area Intersections

Intersection	AM Peak Hour (vph)	PM Peak Period (vph)
Mass Ave./Alewife Brook Pkwy.	3,716	3,545
Mass Ave./Lake/Winter	2,210	2,005
Mass Ave./Bates/Marion	1,945	1,191
Mass Ave./Grafton/Orvis	1,917	1,880
Mass Ave./Foster/Linwood	1,692	1,714
Mass Ave./Thorndike/Teel	1,633	1,579

vph = vehicles per hour entering intersection

While the above data was presented for weekday peak hours, it was determined from the Saturday mid-day data that Saturday traffic volumes are 13% to 32% below the weekday peak hours.

ATRs

48 Hour ATRs were conducted at the following locations:

- Massachusetts Avenue, east and west of Linwood Street
- Foster Street, north of Massachusetts Avenue
- Massachusetts Avenue, east and west of Lake Street
- Lake Street, south of Massachusetts Avenue
- Massachusetts Avenue east and west of Thorndike Street
- Thorndike Street, south of Massachusetts Avenue
- Teel Street, north of Massachusetts Avenue

A graphic of these count locations is shown in Figure 2. Based on the traffic counts, project-wide peak hours were developed and used for the analysis of all six (6) intersections. It was determined that the morning peak hour for the Massachusetts Avenue east corridor occurs between 7:30 AM and 8:30 AM, and the evening peak hour occurs between 5:00 PM and 6:00 PM. The Saturday mid-day peak hour was found to vary but, generally, occurs from 11:45 AM to 12:45 PM. The ATR traffic volume summary is noted below in Table 2.

TABLE 2 – Existing 2008 ATR Traffic Volume Summary

ATR Location	Average Daily Traffic (VPD)	Peak Hour (vph)			
		AM	PM	Sat.	K (%)
Foster St, North of Mass Ave.	810	80	70	80	9.2
Mass Ave., west of Foster/Linwood	17,300	1,587	1,635	1,560	9.3
Mass Ave., east of Foster/Linwood	14,300	1,616	1,635	1,570	11.4
Lake St., south of Mass Ave.	8,950	787	770	569	11.5
Mass Ave., west of Lake/Winter	16,400	1,785	1,551	1,630	10.2
Mass Ave., east of Lake/Winter	15,100	1,663	1,593	1,254	10.8
Mass Ave., west of Thorndike/Teel	14,600	1,598	1,519	1,206	10.7
Mass Ave., east of Thorndike/Teel	15,900	1,575	1,522	1,202	9.8
Teel St., north of Mass Ave.	430	41	35	50	8.9
Thorndike St., south of Mass Ave.	490	52	52	41	10.6

VPD=vehicles per day; vph=vehicles per hour; ATR=automatic traffic recorder; k = percentage of peak hour volume versus ADT

In reviewing both the historical data secured from past studies and traffic data along Massachusetts Avenue, the indications are that from Lake Street to Alewife Brook Parkway during peak periods, traffic volumes have dropped 2% to 4% from 2001 to 2008, and west of Lake Street the volumes remain static.

To determine the effects of seasonality on the recently collected traffic count data, the MassHighway traffic volume database was reviewed. MassHighway permanent traffic counting Station 4798, on Route 2 in Lexington, and Station 8099 on I-93 in Medford, as well the MassHighway yearly published weekday seasonal factors were reviewed to determine if seasonal adjustments are required. Based on this information, it was determined that the October traffic volumes are above average and therefore, will not be seasonally adjusted. The Existing 2008 AM, PM, and Saturday mid-day peak hour traffic volumes are shown in Figure 3.

In order to evaluate the ability of the Massachusetts Avenue intersections to function with the anticipated traffic growth, it was necessary to project future traffic volumes. For this project, a 10-year horizon was selected based on consistency of MassHighway's design criteria for *Functional Design Reports*, and by following general planning principles. Future traffic volumes were developed based on an annual background growth rate and an estimation of traffic generated by planned developments. A background growth rate of 1% per year was determined to be appropriate by reviewing historic MassHighway traffic volumes, various studies completed in the area, and studies completed along Massachusetts Avenue for the Town. This is appropriate given that the surrounding area is built-out and densely populated.

Schematic Diagram:
Not to Scale

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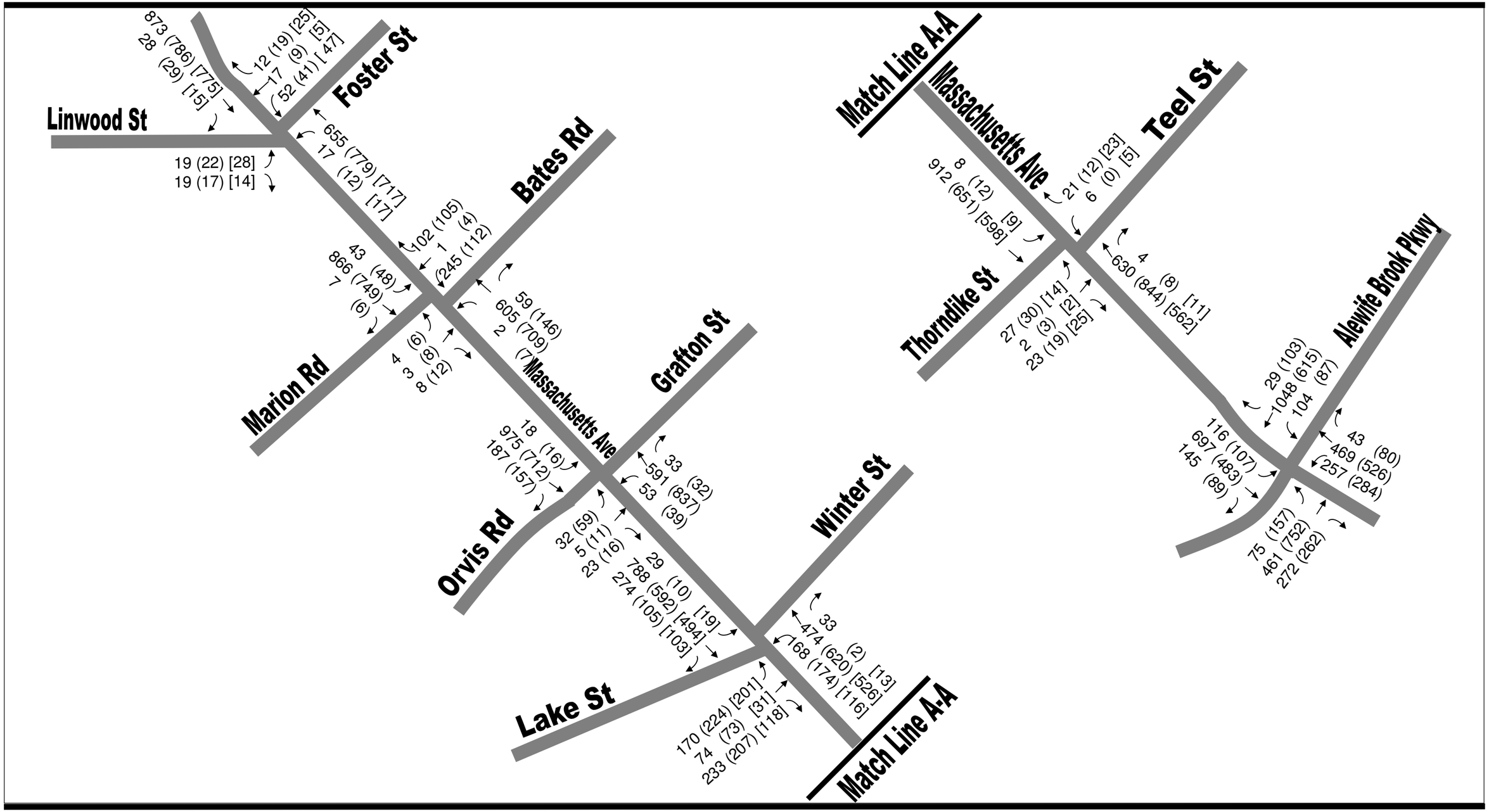
Figure 2
Traffic Count Locations

Massachusetts Avenue
Town of Arlington, Massachusetts
September 2009



Schematic Diagram:
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Figure 3
2008 Existing AM (PM) [Saturday Mid-day] Peak Hour Traffic Volumes

Massachusetts Avenue
Town of Arlington, Massachusetts

AM Peak Hour: 7:30 – 8:30
PM Peak Hour: 5:00 – 6:00
Sat Peak Hour: 11:45 – 12:45
Data Collected in October 2008
September 2009

Conversations with Town of Arlington planning officials indicated there were no major planned projects that would further impact traffic volumes in the project area within this 10-year time frame. In the planning stages is the extension of the Green Line to Somerville and Medford. However, it is likely that this extension will not occur within the 10-year time frame and impacts are not included in the background growth. The *Acorn Park* development in the adjacent communities of Belmont/Cambridge is also assumed to be included in the background growth rate. The background growth rate was applied to the 2008 traffic volumes to produce the projected 2018 No-Build and 2018 Build peak hour traffic volumes, which are shown in Figures 4 and 5, respectively.

Pedestrian Activity

In addition to the traffic counts, pedestrian activity was recorded at the study area intersections. Table 3, below, summarizes the total pedestrian activity at each study area intersection. It is noted that the highest volume of pedestrian activity is in the primary business district in the area of Lake Street. A graphic depicting these crossings is shown in Figure 6.

TABLE 3 – Existing 2008 Total Pedestrian Crossings at Area Intersections

Intersection	AM Peak Hour (pph)	PM Peak Period (pph)
Mass Ave./Alewife Brook Pkwy.	71	54
Mass Ave./Lake/Winter	132	95
Mass Ave./Bates/Marion	9	38
Mass Ave./Grafton/Orvis	57	54
Mass Ave./Foster/Linwood	49	55
Mass Ave./Thorndike/Teel	45	44

pph = pedestrians per hour

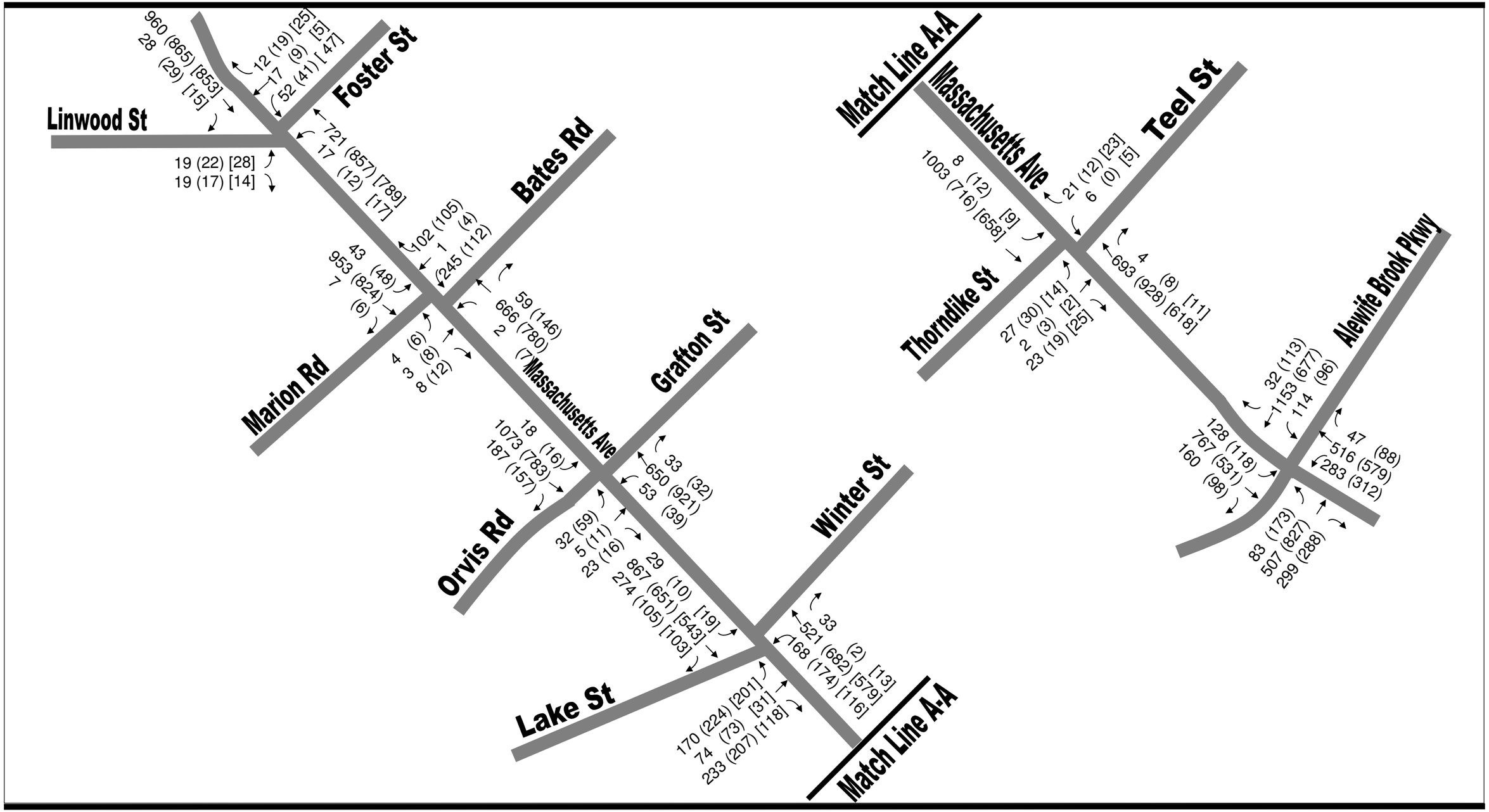
Bicycle Activity

Besides traffic and pedestrian activity, bicycle activity was also recorded at study area intersections during the peak hours. The bicycle patterns displayed a distinct commuter pattern, with the heavy flows eastbound in the morning peak period and westbound in the evening peak period. This total peak hour bicycle volume entering each intersection is summarized in Table 4, below. A graphic depicting this bicycle activity is shown in Figure 7.

TABLE 4 – Existing 2008 Bicycle Volumes Entering Area Intersections

Intersection	AM Peak Hour (bph)	PM Peak Period (bph)
Mass Ave./Alewife Brook Pkwy.	62	38
Mass Ave./Lake/Winter	58	35
Mass Ave./Bates/Marion	48	39
Mass Ave./Grafton/Orvis	59	42
Mass Ave./Foster/Linwood	51	34
Mass Ave./Thorndike/Teel	69	40

bph=bicycles per hour entering intersection



Schematic Diagram:
Not to Scale

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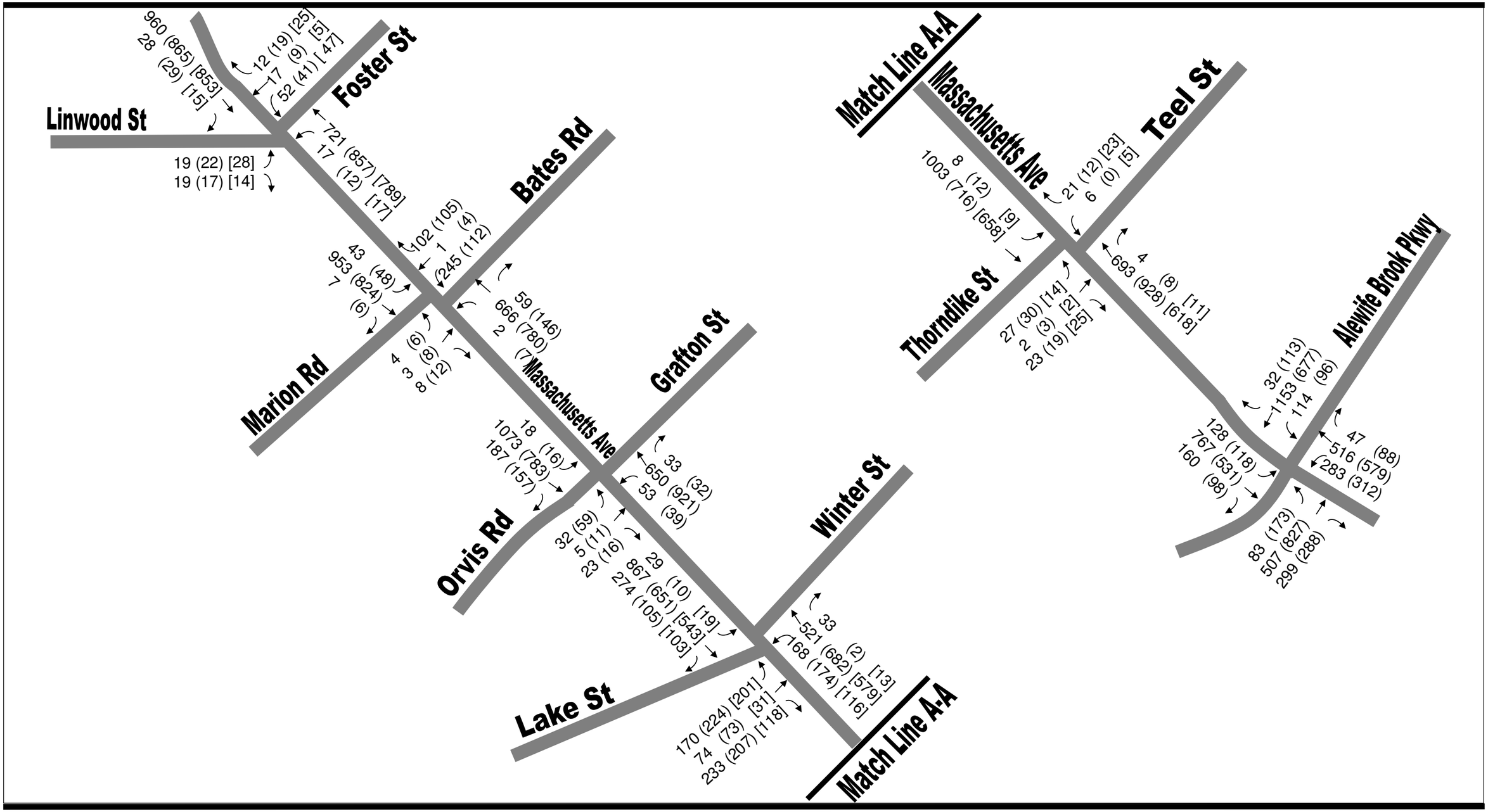
Figure 4
2018 No-Build AM (PM) [Saturday Mid-day] Peak Hour Traffic Volumes

Massachusetts Avenue
Town of Arlington, Massachusetts
September 2009



Schematic Diagram:
Not to Scale

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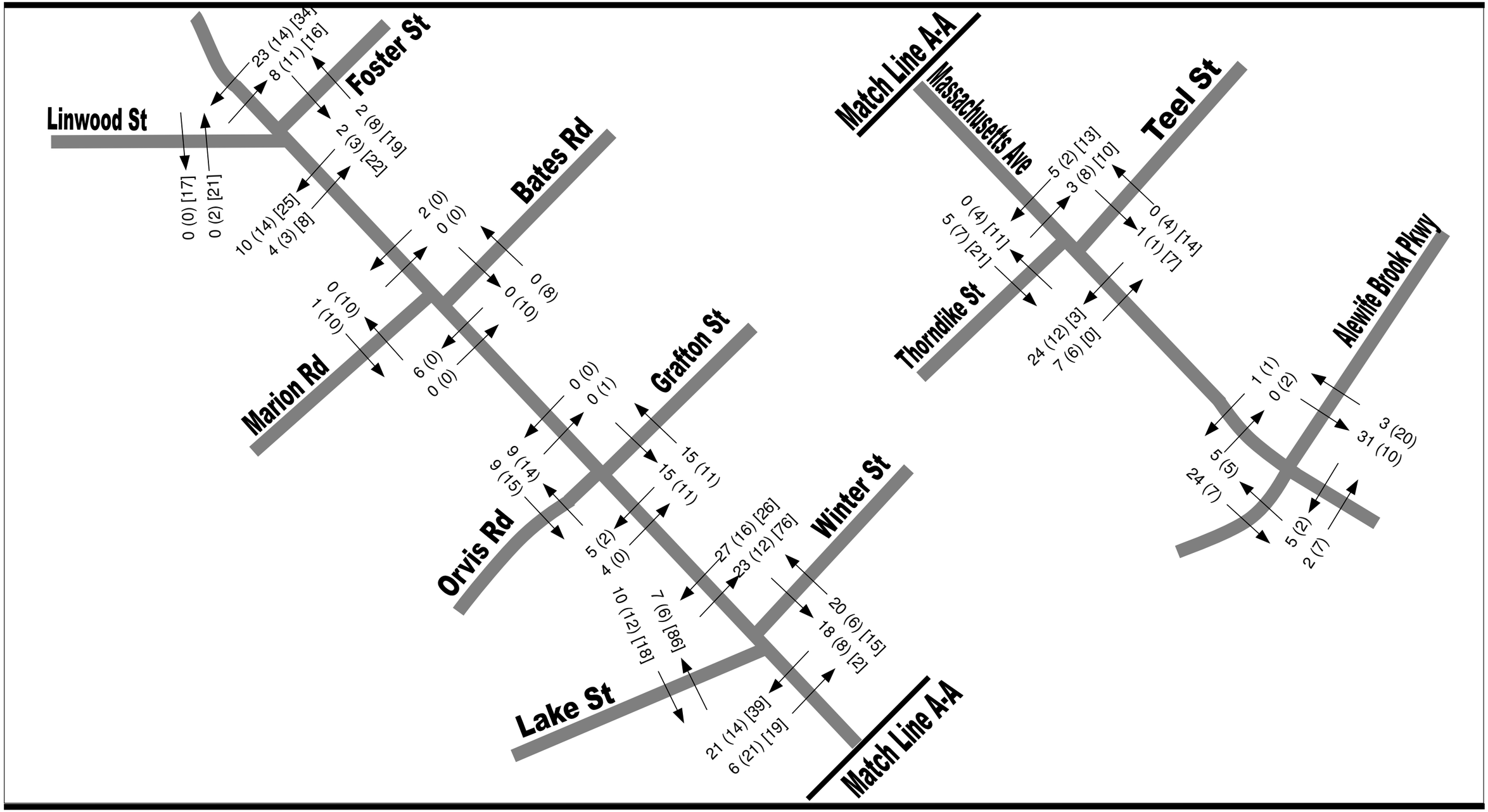
Figure 5
2018 Build AM (PM) [Saturday Mid-day]
Peak Hour Traffic Volumes

Massachusetts Avenue
Town of Arlington, Massachusetts
September 2009



Schematic Diagram:
Not to Scale

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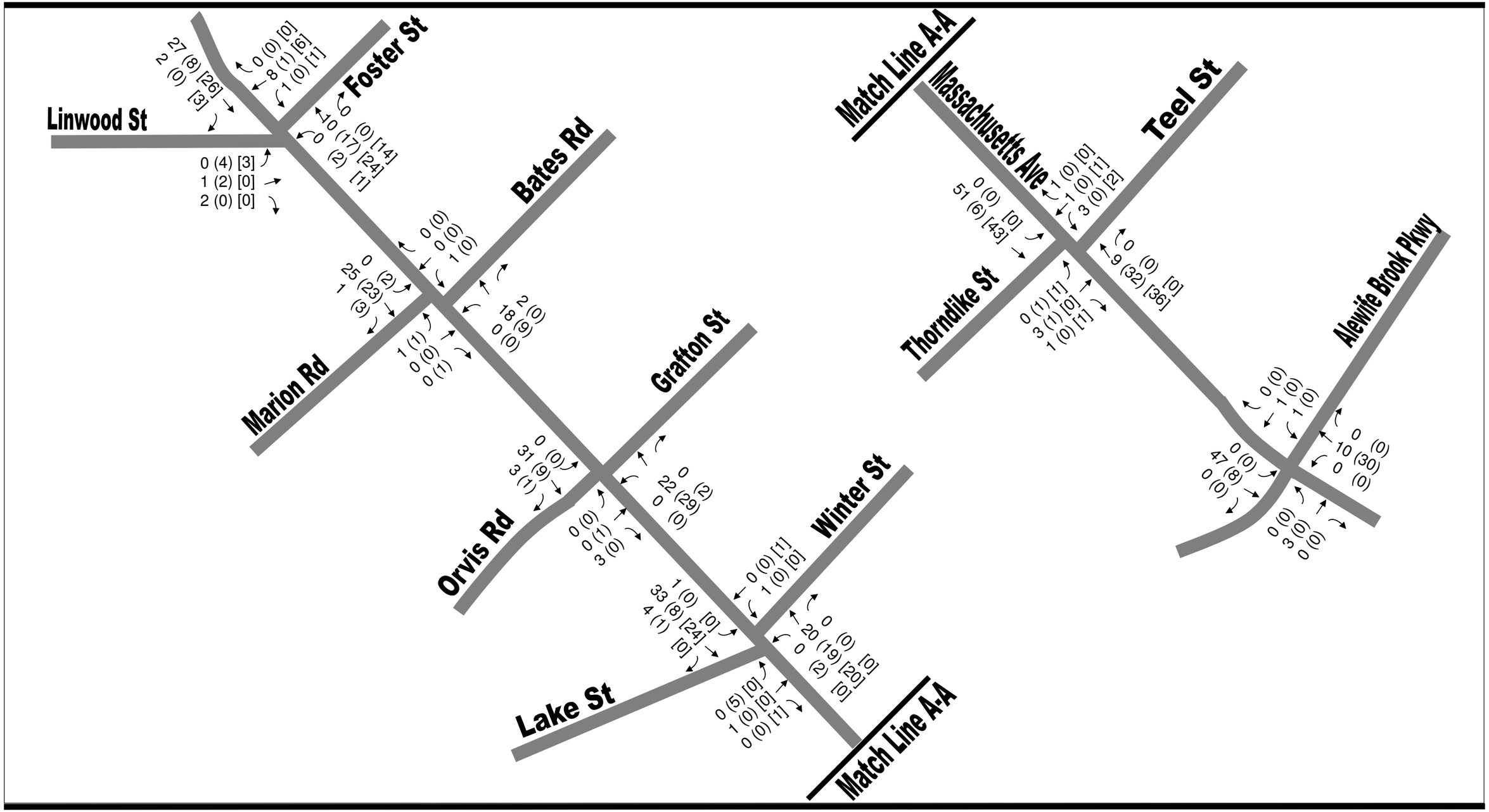
Figure 6
2008 Existing AM (PM) [Saturday Mid-day] Peak Hour Pedestrian Volumes

Massachusetts Avenue
Town of Arlington, Massachusetts

AM Peak Hour: 7:30 – 8:30
PM Peak Hour: 5:00 – 6:00
Sat Peak Hour: 11:45 – 12:45
Data Collected in October 2008
September 2009



Schematic Diagram:
Not to Scale

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Figure 7
2008 Existing AM (PM) [Saturday Mid-day] Peak Hour Bicyclist Volumes

Massachusetts Avenue
Town of Arlington, Massachusetts

AM Peak Hour: 7:30 – 8:30
PM Peak Hour: 5:00 – 6:00
Sat Peak Hour: 11:45 – 12:45
Data Collected in October 2008
September 2009

Supplemental Traffic Count Program

At the request of the Town, under concerns from local residents, FST conducted a supplemental traffic count program conducted in May 2009. Data was collected at only the following locations:

TMC's

- Massachusetts Avenue/Foster Street /Linwood Street (weekday 4-6 & Saturday 11-1PM)

These turning movement counts included vehicles, bicycles and pedestrians.

ATR's

- Foster Street, north of Massachusetts Avenue (7 days)
- Linwood, south of Massachusetts Avenue (7 days)
- Massachusetts Avenue, east and west of Foster Street /Linwood Street (7 days)
- Bates Road, north of Massachusetts Avenue (7 days)
- Massachusetts Avenue, east of Thorndike Street/Teel Street (7 days)

ATR Volume Comparison

The traffic volumes presented in Table 5 below is a comparison of the two separate count periods.

TABLE 5– October 2008 and May 2009 Daily Traffic Volume Comparison

ATR Location	Oct. 2008 Average Daily Traffic (VPD)	May 2009 Average Daily Traffic (VPD)	Percent Difference (2009 to 2008)
Foster St, North of Mass Ave.	810	810	0
Linwood St, south of Mass Ave	NR	1,005	-
Mass Ave., west of Foster/Linwood	17,300	14,800	-13%
Mass Ave., east of Foster/Linwood	14,300	14,200	-0.01%
Bates Ave, north of Mass Ave	NR	4,520	-
Mass Ave., east of Thorndike/Teel	15,900	14,300	-9%

VPD=vehicles per day; ATR=automatic traffic recorder; NR = not recorded

In reviewing the above data, it can be seen that for Foster Street and Mass Ave, east of Foster/Linwood, the daily traffic volumes are about the same. For the other two locations on Mass Ave, the May volumes are 9% and13% below the October 2008 data. In review of the MassHighway permanent traffic counting station data in nearby Medford and Lexington, both the October and May data are above the yearly regional averages and therefore do not require seasonal adjustments. Thus the October data is appropriate and subsequently used in the analysis presented in this FDR.

TMC Comparison

A comparison of the traffic, pedestrian, and bicycle data from October 2008 and May 2009 at the Foster Street/Linwood Street intersection is included in Tables 6-8 below.

TABLE 6 – Comparison of Total Vehicles Entering Foster/Linwood Intersection+

Time Period	October 2008	May 2009	Percent Difference (2009 to 2008)
Weekday 5-6 PM	1,714 vph	1,715 vph	0
Saturday 11:30AM – 12:30 PM	1,643 vph	1,625 vph	-1%

+Sum of traffic entering intersection from all approaches for the peak hour; vph = vehicles per hour

TABLE 7 – Comparison of Total Pedestrians at Foster/Linwood Intersection+

Time Period	October 2008	May 2009	Percent Difference (2009 to 2008)
Weekday 5-6 PM	55 pph (42)	90 pph (43)	+64%
Saturday 11:30AM – 12:30 PM	162 pph (83)	110 pph (80)	-32%

+Sum of pedestrians crossing intersection at all approaches for the peak hour; pph = pedestrians per hour; (xx) = Pedestrians crossing Mass Ave during the peak hour

TABLE 8 – Comparison of Total Bicycles at Foster/Linwood Intersection+

Time Period	October 2008	May 2009	Percent Difference (2009 to 2008)
Weekday 5-6 PM	34 bph	99 bph	+191%
Saturday 11:30AM – 12:30 PM	78 bph	63 bph	-19%

+Sum of bicycles entering intersection from all approaches for peak hour; bph = bicycles per hour

Data indicates there are no changes from the peak hour October 2008 to May 2009 data in both the weekday PM and the Saturday mid-day periods. The pedestrian volumes are higher in May during the weekday, but lower on Saturday compared to the October data. The bicycles volumes are considerably higher during the weekday May 2009 period likely due to spring conditions with warmer weather which creates more bicycle commuters. As noted earlier, the October data will be used for traffic analysis and presentation in this FDR.

1.3 Level of Service Criteria

Level of Service (LOS), an expression of the quality of traffic flow, is a commonly used and accepted measure of effectiveness for peak hour traffic operating conditions. It takes into account such factors as automobile and truck volumes, roadway width, speed, grades, parking restrictions, pedestrian activity, and traffic control devices.

LOS is designated in a range from Level "A", which is the optimal condition where roadway operating conditions are at their best to Level "F", which indicates traffic jam conditions. Levels "A" through "D" are typically associated with acceptable levels of peak hour traffic operation, with LOS "D" marking the boundary between acceptable and unacceptable traffic conditions. At Level "E", the ratio of the approach volume to capacity, or v/c ratio of an intersection, is between 90 and 100 percent of its theoretical capacity. Traffic congestion is considered to be unacceptable at Level of Service "F".

All capacity analysis of individual intersections for the Massachusetts Avenue corridor were performed in accordance with the methodologies set forth in the 2000 *Highway Capacity Manual* (HCM). As defined in the HCM, LOS for signalized and unsignalized intersections, is based on an average control delay in seconds per vehicle approaching the intersection for the peak 15-minute analysis period of a peak hour. The delay criteria, and their associated LOS rankings for signalized and unsignalized intersections, are given in Table 9 below.

TABLE 9 – Intersection Level-of-Service Criteria

Level of Service	Unsignalized Control Delay (sec/veh)	Signalized Control Delay (sec/veh)
A	Less than or equal to 10.0	Less than or equal to 10.0
B	10.1 to 15.0	10.1 to 20.0
C	15.1 to 25.0	20.1 to 35.0
D	25.1 to 35.0	35.1 to 55.0
E	35.1 to 50.0	55.1 to 80.0
F	Greater than 50.0	Greater than 80.0

Source: 2000 Highway Capacity Manual

The HCM analysis is based on the assumption that intersections are isolated, and does not reflect the interaction of closely spaced intersections. *SimTraffic*, a microscopic simulation model accounts for the interaction of adjacent intersections; particularly, the impact of vehicle queues. The *SimTraffic* model was used to augment the HCM analyses for the Massachusetts Avenue corridor intersections.

The 2008 existing and 2018 projected No-Build projected traffic volumes, shown on Figures 3 and 4, were used to conduct a capacity analysis of the intersections with the current geometry and signal phasing and timing. The results of this analysis are summarized for each intersection in the following sections.

2.0 EXISTING CONDITIONS

2.1 Geometrics

Massachusetts Avenue is typically a four-lane road classified as a *Principal Arterial*, under the jurisdiction of the Town of Arlington. The roadway generally runs in an east-west direction (northwest-southeast) in the study area and connects to the City of Cambridge at Alewife Brook Parkway (Route 16) to the east, and to the Lexington Town Line, to the west. The East Arlington section of Massachusetts Avenue, which is our study area, and runs from Pond Street to Alewife Brook Parkway, is approximately one mile in length from Alewife Brook Parkway (Route 16) to Pond Street.

Within the project limits, Massachusetts Avenue is 66' +/- in the Pond Lane section and 80' +/- wide within the East Arlington Business District, in the vicinity of Lake Street. There are typically two travel lanes in each direction, with parallel parking on both sides of street. Along most of the corridor, lane delineations are unmarked. There are no designated turn lanes along the corridor, except at the Massachusetts Avenue/Alewife Brook Parkway (Route 16) intersection.

Concrete sidewalks, varying in width from 6'-9' feet are on both sides of Massachusetts Avenue, with granite curbing along the entire length of the project. Public transportation is provided, as there are three MBTA bus routes along the study area corridor. They are: Bus No. 77, running from Arlington Heights to Harvard Square; Bus No. 79 from Arlington Heights to Alewife Station, and Bus No. 350 that runs from Burlington to Alewife Station. There are eight (8) bus stops along the corridor to accommodate passenger pick-up/drop-offs. These bus stop locations are Foster Street/Linwood Street, Everett Street, Lake Street, Milton Street, Thorndike, and Boulevard**.**

Crosswalks along the corridor are located at all of the six (6) study area intersections and at selected striped mid-block locations along the corridor. These mid-block locations are at Tufts Street, Marathon Street, Varnum Street, and Lafayette Street.

The speed limit on many of the side streets in the area is posted for 20-25 mph, while the speed limit along the Massachusetts Avenue corridor area, while not posted along the entire corridor is posted in selected locations for 30 mph. A speed study was done during the off-peak period using the floating car method and results indicated vehicles are traveling above the posted speed limit in both directions with recorded speeds of 36-39 mph.

2.2 Traffic Operations

The existing (2008) and projected (2018 No-Build) peak hour traffic volumes, shown on Figures 3 and 4, were used to conduct a capacity analysis of the Massachusetts Avenue intersections, with the current geometry, signal phasing and timing. The results of this analysis, summarized in Table 10, indicate that presently, traffic at the signalized intersection of Massachusetts Avenue and Lake Street operates at an overall LOS F in the morning and

afternoon peak hours, with over-capacity conditions (i.e., volume to capacity ratio greater than 1.00) for both peak periods. At selected times during peak period field observations, vehicle queues blocked the intersection so that vehicles could not turn in and out of Lake Street. Field investigations along Lake Street indicate the traffic signal at Brooks Avenue, near the Hardy School is not coordinated with the Lake Street signal at Massachusetts Avenue. It is likely that the lack of coordination contributes to the constant vehicle queues and blockage along Lake Street. It may be prudent to study this Lake Street/Brooks Avenue location at some future period.

The other signalized intersections along the corridor in Arlington (Foster/Linwood and Thorndike/Teel), operate at LOS A, during both weekday peak hours. Vehicle delays are computed to be less than 10 seconds of delay at both of these locations. In addition to Level of Service and vehicle delay, the analysis results also summarized vehicle queues at the signalized intersections. To corroborate analysis results of computed vehicle queues with actual field conditions, we recorded vehicle queue during the peak periods. These actual results are also noted in Tables 10 and 11. As can be seen, computed results compare quite favorably with actual conditions for the weekday periods. It also can be seen that the intersection of Massachusetts Avenue/Lake Street operates at a better Level of Service (LOS D) during the Saturday mid-day period.

The busiest intersection in the study area, the Massachusetts Avenue/Alewife Brook Parkway, operates at LOS E/D for the peak periods with long vehicle queues calculated on all approaches. This intersection was also determined to have near or over-capacity conditions (i.e. v/c near 1.00). During field observations, it was noted that some of the lane approaches do not clear the green signal indication during the peak periods. This is most evident with vehicles in the left turn lanes. This intersection is under control of the Department of Conservation and Recreation (DCR), although the City of Cambridge occasionally makes adjustments to the timing of the signal. Discussions with the City indicted that controller was not timed properly during our traffic count period. The City indicated the control would be replaced with a more efficient unit in the near future.

For the two unsignalized intersections in the study area, (Massachusetts Avenue/Bates Road/Marion Road and Massachusetts Avenue/Orvis Street /Grafton Street) the analysis shows that both locations experience long delays (LOS F) from the side streets during both peak periods. It is likely that many of the side street intersections along the corridor also experience long delays as well.

In 2018, <u>without</u> any mitigation or roadway improvements, the operating conditions at the Massachusetts Avenue intersections will continue at LOS F at Lake Street and drop to LOS E at the Alewife Brook Parkway signalized intersection during both peak periods. These results can be seen in Table 12. In addition, the unsignalized locations of Massachusetts Avenue/Bates Road/Marion Road and Massachusetts Avenue/Orvis Road/Grafton Street will still operate with long delays from the side streets, i.e. LOS F in both peak periods.

TABLE 10 – 2008 Existing Weekday Peak Hour Intersection Level of Service

Massachusetts Avenue (NB/SB) Intersection	Movement	AM Peak Delay[1]	LOS	V/c[2]	Queue[3] 50%	Queue[3] 95%	Obs.[4]	PM Peak Delay[1]	LOS	v/c[2]	Queue[3] 50%	Queue[3] 95%	Obs.[4]
Signalized Intersections													
Linwood Street / Foster Street													
	Northbound Lt/Th	3.2	A	0.47	39	57	50	2.6	A	0.36	45	65	125
	Southbound Th/Rt	2.7	A	0.36	66	75	50	2.5	A	0.34	44	64	75
	Linwood Street Eastbound	32.5	C	0.25	10	41	25	32.5	C	0.27	11	40	25
	Foster Street Westbound	51.7	D	0.72	38	78	25	39.3	D	0.60	31	38	50
	OVERALL	**6.4**	**A**	**0.50**				**5.7**	**A**	**0.60**			
Lake Street / Winter Street													
	Northbound Lt/Th/Rt	111.1	F	2.51	237	347	175	78.1	F	1.35	271	385	250
	Southbound Lt/Th	49.8	D	0.98	246	345	250	24.3	C	0.65	155	194	175
	Southbound Rt	37.4	D	0.80	145	246	250	19.2	B	0.26	43	78	175
	Lake Street Eastbound	611.4	F	2.26	412	553	175	387.9	F	1.77	451	544	350
	OVERALL	**201.9**	**F**	**1.53**				**146.8**	**F**	**1.35**			
Thorndike Street / Teel Street													
	Northbound	1.7	A	0.26	24	36	25	1.5	A	0.32	36	52	100
	Southbound	2.4	A	0.45	47	66	75	1.4	A	0.28	27	41	75
	Thorndike Street Eastbound	42.6	D	0.54	20	6	25	55.8	E	0.62	21	39	25
	Teel Street Westbound	36.2	D	0.16	5	30	25	39.3	D	0.02	0	0	25
	OVERALL	**4.7**	**A**	**0.45**				**3.9**	**A**	**0.34**			
Alewife Brook Parkway													
	Northbound Lt	92.8	F	0.97	217	389	250	71.4	E	0.90	231	388	275
	Northbound Th/Rt	33.5	C	0.52	194	252	175	34.5	C	0.59	227	296	325
	Southbound Lt	60.6	E	0.72	126	146	175	57.4	E	0.62	83	143	75
	Southbound Th/Rt	55.6	E	0.92	357	481	350	49.9	D	0.80	248	320	225
	Parkway Eastbound Lt	135.1	F	0.96	69	163	125	71.7	E	0.83	137	239	200
	Parkway Eastbound Th/Rt	43.6	D	0.82	322	354	300	53.4	D	0.95	444	587	350
	Parkway Westbound Lt	74.6	E	0.77	92	178	150	76.0	E	0.78	90	138	125
	Parkway Westbound Th/Rt	60.4	E	0.98	478	632	350	41.6	D	0.79	312	373	350
	OVERALL	**56.3**	**E**	**0.96**				**50.2**	**D**	**0.87**			
Unsignalized Intersections													
Marion Road / Bates Road													
	Marion Road Eastbound	80.0	F	0.38	N/A	37	-	91.3	F	0.51	N/A	54	50
	Bates Road Westbound	-	F	4.13	N/A	-	-	732.5	F	2.43	N/A	588	75
Orvis Road / Grafton Street													
	Orvis Road Eastbound	428.4	F	1.52	N/A	192	-	371.4	F	1.47	N/A	220	1

1. Delay in seconds per vehicle.
2. Volume to capacity ratio.
3. Queue in feet per lane (25 feet per vehicle).
4. Observed; NA = not applicable

TABLE 11 – 2008 Existing Saturday Mid-Day Intersection Level of Service

Massachusetts Avenue (NB/SB) Intersection	Movement	Delay[1]	LOS	Mid-day v/c[2]	Queue[3] 50%	Queue[3] 95%
Signalized Intersections						
Linwood Street / Foster Street						
	Northbound Lt/Th	2.6	A	0.34	41	60
	Southbound Lt/Th	2.5	A	0.34	44	62
	Linwood Street Eastbound	32.5	C	0.29	13	42
	Foster Street Westbound	44.4	D	0.67	34	48
	OVERALL	**6.3**	**A**	**0.38**		
Lake Street / Winter Street						
	Northbound Lt/Th	42.8	D	0.94	190	294
	Southbound Lt/Th	23.5	C	0.61	137	164
	Southbound Rt	19.6	B	0.28	47	74
	Lake Street Eastbound	186.1	F	1.30	274	316
	OVERALL	**65.5**	**E**	**1.06**		
Thorndike Street / Teel Street						
	Northbound Lt/Th	1.4	A	0.22	21	32
	Southbound Lt/Th	1.4	A	0.24	23	34
	Thorndike Street Eastbound	39.3	D	0.35	12	16
	Teel Street Westbound	37.4	D	0.19	5	30
	OVERALL	**4.6**	**A**	**0.24**		

1. Delay in seconds per vehicle.
2. Volume to capacity ratio.
3. Queue in feet per lane (25 feet per vehicle).

TABLE 12 – 2018 Future No-Build Intersection Level of Service

Massachusetts Avenue (NB/SB) Intersection	Movement	AM Peak Delay[1]	LOS	v/c[2]	Queue[3] 50%	Queue[3] 95%	PM Peak Delay[1]	LOS	v/c[2]	Queue[3] 50%	Queue[3] 95%
Signalized Intersections											
Linwood Street / Foster Street											
	Northbound Lt/Th	2.8	A	0.37	45	66	2.8	A	0.40	52	74
	Southbound Lt/Th	3.5	A	0.52	77	86	2.7	A	0.38	57	72
	Linwood Street Eastbound	32.5	C	0.23	10	41	32.5	C	0.27	11	40
	Foster Street Westbound	51.7	D	0.72	78	67	39.3	D	0.60	31	38
	OVERALL	**6.4**	**A**	**0.54**			**5.6**	**A**	**0.60**		
Lake Street / Winter Street											
	Northbound Lt/Th	141.1	F	2.51	266	377	148.0	F	1.57	311	428
	Southbound Lt/Th	77.0	E	1.08	315	396	25.9	C	0.71	175	218
	Southbound Rt	37.4	D	0.80	145	246	19.2	B	0.26	43	78
	Lake Street Eastbound	611.4	F	2.26	542	553	387.9	F	1.77	451	544
	OVERALL	**213.9**	**F**	**1.58**			**160.4**	**F**	**1.43**		
Thorndike Street / Teel Street											
	Northbound Lt/Th	1.7	A	0.26	24	36	1.6	A	0.36	42	59
	Southbound Lt/Th	2.4	A	0.45	50	66	1.5	A	0.30	32	45
	Thorndike Street Eastbound	42.6	D	0.54	20	6	55.8	E	0.62	21	39
	Teel Street Westbound	36.2	D	0.16	5	30	39.3	D	0.02	0	0
	OVERALL	**4.7**	**A**	**0.45**			**4.0**	**A**	**0.37**		
Alewife Brook Parkway											
	Northbound Lt	121.4	F	1.07	263	442	84.0	F	0.96	259	443
	Northbound Th/Rt	35.3	D	0.58	222	279	37.1	D	0.65	259	331
	Southbound Lt	63.2	E	0.76	139	159	60.8	E	0.67	92	157
	Southbound Th/Rt	74.5	E	1.02	449	563	60.1	E	0.90	280	388
	Parkway Eastbound Lt	169.1	F	1.07	84	182	86.3	F	0.90	153	275
	Parkway Eastbound Th/Rt	51.6	D	0.91	366	400	76.7	E	1.04	547	685
	Parkway Westbound Lt	82.4	F	0.83	101	199	90.1	F	0.86	100	159
	Parkway Westbound Th/Rt	89.5	F	1.08	596	734	47.3	D	0.87	355	420
	OVERALL	**73.5**	**E**	**1.08**			**62.2**	**E**	**0.95**		
Unsignalized Intersections											
Marion Road / Bates Road											
	Marion Road Eastbound	131.6	F	0.52	N/A	50	151.1	F	0.69	N/A	72
	Bates Road Westbound	-	F	5.52	N/A	-	-	F	3.17	N/A	-
Orvis Road / Grafton Street											
	Orvis Road Eastbound	698.5	F	2.05	N/A	222	573.8	F	1.88	N/A	254

1. Delay in seconds per vehicle.
2. Volume to capacity ratio.
3. Queue in feet per lane (25 feet per vehicle); N/A = not applicable

2.3 Safety

MassHighway's crash history for the Massachusetts Avenue study area corridor was investigated for the three-year period of 2004, 2005, and 2006, and the results are shown in Table 13. During the time period investigated, there were 29 crashes or an average of almost 10 per year at the Massachusetts Avenue/Alewife Brook Parkway intersection. At the Massachusetts Avenue/Thorndike Street/Teel Street intersection, there were 5 crashes. At the Massachusetts Avenue/Lake Street/Winter Street intersection, there were 12 crashes. At the Massachusetts Avenue/Orvis Road/Grafton Street intersection, there were 8 crashes. At the Massachusetts Avenue/Marion Road/Bates Road intersection, there were 3 crashes. There were 2 crashes at the Massachusetts Avenue/Linwood Street/Foster Street intersection.

A review of the crash history shows 13 of the crashes at the Massachusetts Avenue/Alewife Brook Parkway intersection are the angle collision type. This is possibly due to the limited lane capacity and inadequate signal phasing and timing. The remaining accidents were evenly divided with angle, head-on, rear-end, and sideswipe collisions. The Massachusetts Avenue/Lake Street/Winter Street intersection has the majority of pedestrian and bicycle accidents. This is due to the fact that the majority of pedestrian and bicycle activity occurs at this intersection in addition to the signal running an exclusive pedestrian phase regardless of pedestrian demand. In addition, the side streets (Lake Street and Winter Street) are offset from each other. This may cause problems between pedestrians/bicyclists and drivers with the offset condition.

A crash analysis was also completed for the areas between the intersections or roadway links shown in Table 14 with 23 accidents occurring between the Massachusetts Avenue/Lake Street/Winter Street and Massachusetts Avenue/Thorndike Street/Teel Street intersections. The large number of minor streets, their close proximity, and the lack of traffic signals may cause these accidents; however, there was no major type of collision identified. There were 2 accidents involving pedestrians or bicyclists possibly because only two crosswalks are located between these intersections that allow crossing Massachusetts Avenue. These accidents may also occur because of Massachusetts Avenue's excessive road width, leaving pedestrians unprotected along the corridor.

Although the number of crashes alone is important, the actual exposure or potential for an individual driver being involved in an accident is reflected in the crash rate. The crash rates for the Massachusetts Avenue intersections were developed using MassHighway's Crash Rate Worksheet (see appendix), and compared to the District 4 average crash rate of 0.88 crashes for every million entering vehicles (MEV) for a signalized intersection and 0.63 crashes for every million vehicles entering an unsignalized intersection. The intersection of Massachusetts Avenue and Alewife Brook Parkway has a crash rate greater (0.88 MEV) than the MassHighway average. The Massachusetts Avenue/Thorndike Street/Teel Street intersection has a crash rate of 0.31 MEV, the Massachusetts Avenue/Lake Street/Winter Street intersection has a crash rate of 0.75 MEV, the Massachusetts Avenue/Orvis Road/Grafton Street intersection has a crash rate of 0.46 MEV, the Massachusetts Avenue/Marion Road/Bates Road has a crash rate of 0.17 MEV, and the Massachusetts Avenue/Linwood Street/Foster Street intersection has a crash rate of 0.13 MEV.

Massachusetts Avenue Intersections 3-Year Crash History
Table 13

	Linwood St /Foster St	Marion Rd /Bates Rd	Massachusetts Avenue at: Orvis Rd/ Grafton St	Lake St/ Winter St	Thorndike St/Teel St	Alewife Brook Pkwy	Total
Signalized?	Yes	No	No	Yes	Yes	Yes	
Year							
2004	1	1	2	8	0	5	17
2005	1	1	3	1	5	14	25
2006	0	1	3	3	0	10	17
Total	2	3	8	12	5	29	59
Collision Type							
Angle	1	1	2	1	3	13	21
Head-on	0	0	0	0	0	2	2
Rear-end	1	0	3	5	2	8	19
Sideswipe	0	1	1	1	0	4	7
Unknown	0	1	2	5	0	2	10
Total	2	3	8	12	5	29	59
Severity							
Fatality	0	0	0	0	0	0	0
Hit and Run	0	0	0	0	0	0	0
Injury	1	1	1	5	2	13	23
Property	1	2	5	6	2	14	30
Bicyclist	0	0	0	0	0	0	0
Pedestrian	0	0	0	1	0	0	1
Unknown	0	0	2	0	1	2	5
Total	2	3	8	12	5	29	59
Time of Day							
7:00 AM – 9:00 AM	1	1	0	1	1	2	6
9:01 AM – 3:59 PM	0	1	5	4	1	12	23
4:00 PM – 6:00 PM	1	0	1	1	2	1	6
6:01 PM – 6:59 AM	0	1	2	6	1	14	24
Total	2	3	8	12	5	29	59
Day of Week							
Monday-Friday	2	2	5	10	4	19	42
Saturday-Sunday	0	1	3	2	1	10	17
Total	2	3	8	12	5	29	59
Pavement Conditions							
Dry	1	2	6	5	3	23	40
Wet	0	1	1	6	2	4	14
Snow	0	0	0	0	0	1	1
Ice	1	0	0	0	0	0	1
Unknown	0	0	1	1	0	1	3
Total	2	3	8	12	5	29	59
Intersection Crash Rate	0.125	0.171	0.464	0.753	0.313	0.876	N/A
Above MHD Crash Rate?	No	No	No	No	No	Yes	

Massachusetts Avenue Roadway Links 3-Year Crash History
Table 14

	Between Linwood St & Marion Rd	Between Marion Rd & Orvis Rd	Between Orvis Rd & Lake St	Between Lake St & Teel St	Between Teel St & Alewife Brook	Total
Year						
2004	0	0	0	5	1	6
2005	3	1	4	8	7	25
2006	0	0	1	8	2	11
Total	3	1	5	23	10	42
Collision Type						
Angle	1	0	3	7	2	13
Head-on	0	0	0	2	0	2
Rear-end	2	0	1	5	6	14
Sideswipe	0	0	0	4	1	5
Unknown	0	1	1	5	1	8
Total	3	1	5	23	10	42
Severity						
Fatality	0	0	0	0	0	0
Hit and Run	0	0	0	0	0	0
Injury	3	1	3	6	2	15
Property	0	0	0	9	3	12
Bicyclist	0	0	0	1	0	1
Pedestrian	0	0	0	1	0	1
Unknown	0	0	2	6	5	13
Total	3	1	5	23	10	42
Time of Day						
7:00 AM – 9:00 AM	0	0	1	3	1	5
9:01 AM – 3:59 PM	1	1	4	13	4	23
4:00 PM – 6:00 PM	1	0	0	3	1	5
6:01 PM – 6:59 AM	1	0	0	4	4	9
Total	3	1	5	23	10	42
Day of Week						
Monday-Friday	3	1	3	21	6	34
Saturday-Sunday	0	0	2	2	4	8
Total	3	1	5	23	10	42
Pavement Conditions						
Dry	2	0	2	19	8	31
Wet	0	0	3	3	0	6
Snow	0	0	0	1	1	2
Ice	0	0	0	0	0	0
Other	0	0	0	0	0	0
Unknown	1	1	0	0	1	3
Total	3	1	5	23	10	42

2.4 Traffic Signal Warrant Analysis-Existing

Based on peak period field observations and existing level of service results of the four (4) signalized intersections along the study area corridor, it was determined to conduct a traffic signal warrant analysis of the signalized intersections along the corridor. In particular, the *Massachusetts Avenue/Linwood Street/Foster Stree*t intersection and the *Massachusetts Avenue/Thorndike Street/Teel Street* intersection were reviewed in detail. Both 4-way intersections have one-way streets entering Massachusetts Avenue, have low side street volumes (400-800 vehicles per day) and both operate at LOS A during both peak periods for Existing 2008 conditions and 2018 No Build conditions. Indications from Town officials are that both of these signals were installed years ago to service the now-defunct schools on Foster and Teel Streets respectively.

The Manual on Uniform Traffic Control Devices (MUTCD) lists eight (8), traffic signal warrants for consideration for possible signalization at an intersection. These warrants are:

- Warrant 1 - Eight Hour Vehicular Volume
- Warrant 2 - Four Hour Vehicular Volume
- Warrant 3 – Peak Hour
- Warrant 4 - Pedestrian Volume
- Warrant 5 – School Crossing
- Warrant 6 – Coordinated Signal System
- Warrant 7 – Crash Experience
- Warrant 8 - Roadway Network

MassHighway has adopted these warrants and typically requires, at a minimum, Warrants 1 and 2 to be met for consideration of a signal. For the above two locations, we tested Warrants 1, 2, 3, 4 and 7. Warrants 5 and 6 are not applicable and therefore were not analyzed. Review of the crash rates at both locations indicate that both intersections are below the Statewide and MassHighway District crash rates. It may be that a change in land use in the area or a crash history may have contributed to these locations being signalized years ago. This is not the case today.

Warrant analysis indicates that Warrants 1-4 and 7 were <u>not</u> satisfied at either location.

The Town has received considerable input from local residents and businesses about maintaining the signals at Linwood Street/Foster Street and the Thorndike Street/Teel Street intersection. In light of these locations not meeting MUTCD signal warrant criteria today and the fact that both of these locations have been signalized for decades, meetings were held with MassHighway officials to discuss maintaining, but upgrading both signalized locations. Recent indications are that both signalized locations can remain, but be maintained to current MUTCD standards.

Also, based on the excessive traffic volumes and high crash rates at the intersections of Lake Street and Alewife Book Parkway, signal warrants at these locations were not analyzed, but are likely satisfied.

3.0 IMPROVEMENTS

3.1 Signal Warrant Analysis

To determine if traffic signals are warranted at the two unsignalized intersections of Massachusetts Avenue/Bates Road/Marion Road and Massachusetts/Orvis Road/Grafton Street, a traffic signal warrant analysis using MUTCD criteria and existing 2008 traffic volumes was conducted at these locations. Analysis indicates that the Massachusetts Avenue/Bates Road/Marion Road intersection warrants a traffic signal based on Warrant 1-Eight Hour Vehicle Volume (Condition A –Minimum Vehicle Volume and Condition B - Interruption of Continuous Traffic), Warrant 2-Four Hour Volume Warrant, and Warrant 3-Peak Hour Warrant. Thus, this location is a candidate for signalization.

For the Massachusetts/Orvis Road Grafton Street intersection, only Condition B-Interruption of Continuous Traffic of Warrant 1-the Eight Hour Volume Warrant is satisfied. Based on the fact that only one warrant is satisfied, it is unlikely MassHighway would approve signalization at this location. However, geometric improvements might be warranted in the future and this intersection may be a candidate for traffic monitoring.

3.2 Geometric and Pedestrian Accommodations

Accident data indicates some pedestrian and bicycle accidents occurred with motor vehicles and some measures will be identified in the next section to enhance pedestrian and bicycle safety, as well as improve traffic operations at area intersections. Since Massachusetts Avenue has an expansive width and is not very pedestrian-friendly today, maintaining controlled areas for pedestrian crossings via signals or designated areas such as bump outs is critical to reducing pedestrian crossing times. In addition, at selected locations along the corridor, some geometric modifications are warranted. These will be discussed in the next section.

3.3 Travel Lane Requirements

The geometric conditions and description of the corridor are noted in a previous section of this report. Essentially two travel lanes exist on Massachusetts Avenue in each direction. Historically the corridor used to accommodate trolley tracks and automobiles as well as pedestrians. With the east-west travel being the primary travel route, the 68-80 foot curb-to-curb width of the roadway was necessary to service this historic mixed-use demand. With the removal of the trolley tracks, the road was simply paved over curb-to-curb. Traffic analysis was conducted for the urban arterial corridor for the 2008 existing and 2012 future conditions using procedures outlined in the Highway Capacity Manual (HCM)[1], and as adopted by MassHighway. Review of the corridor intersection layout, field observations and traffic analysis indicate that the present 4-lane arterial is not necessary along the entire 1-mile section of the project. Traffic projections for the 2018 horizon year and respective traffic analysis indicate this as well. Reference is made to Table 10-7 – Example Service Volumes for Urban Streets of the HCM, and the reference to saturation flow rates. Saturation flow rate is defined as the equivalent hourly rate

[1] *Highway Capacity Manual;* Transportation Research Board; 2000

at which previously queued vehicles can traverse an intersection under prevailing conditions assuming the green signal is available at all time. Adjustments are made to the saturation flow to account for bicycles, pedestrians, bus activity, lane widths, left and right turns, parking maneuvers, corridor speeds, spacing of traffic signals, use of travel lanes and other such factors affecting roadway and intersection operations.

Current peak hour volumes along Massachusetts Avenue indicate that morning eastbound traffic volumes are in the range of 900-1,100 vehicles per hour (vph) indicating one lane is sufficient except at key area intersections. Total peak hour volumes are recorded to be 1,575-1,785 vehicles per hour in two directions. For future conditions these respective peak hour volumes are 1,055-1,170 vph in the eastbound direction and a total (two directions) of 1,686-1,935 vph at key intersections where turn lanes will be provided. Thus, for selected locations, one through lane is proposed along the corridor, while two lanes eastbound are proposed from Lake Street to Alewife Brook Parkway.

4.0 RECOMMENDATIONS

As previously noted, there are some significant delays at area signalized and unsignalized intersections. The existing traffic signals are operating inefficiently with improper timing and phasing, lane capacity, and configuration. The proposed design calls for reducing the Massachusetts Avenue cross-section where appropriate and providing turn lanes at intersections with side streets to enhance safety. In addition, there are unsignalized locations that are also candidates for improvement. Noted below are our recommendations for the corridor.

4.1 Massachusetts Avenue/Linwood Street/Foster Street and Massachusetts Avenue/Bates Road/Marion Road

In meetings with the public and MassHighway, it was determined that the Linwood/Foster intersection will stay under signal control. Since the current phasing and timing is inefficient for the Massachusetts Avenue corridor, changes will be made to the timings and phasing of the Foster/Linwood signal and it will be interconnected with the proposed new signal at Bates Road/Marion Road. The Bates/Marion location will include split phasing for the side streets and improvements will include exclusive turn lanes on Massachusetts Avenue, and separate left and right turn lanes on Bates Road. The 2018 Build analysis results of these two locations are shown in Table 15.

4.2 Massachusetts Avenue/Orvis Road/Grafton Street

The recommendation for this location is for the intersection to remain as an unsignalized intersection, but improve the lane configuration on Massachusetts Avenue to better accommodate added traffic volumes on Massachusetts Avenue at this location. The addition of an exclusive right turn on Massachusetts Avenue leading to Orvis Road is recommended. The Orvis Road approach would remain unchanged with parking on the south (east) side on Orvis Road also remaining. The peak hour analysis results are shown in Table 16.

TABLE 15 – 2018 Build Level of Service
Foster/Linwood and Bates Road/Marion Road

	AM Peak					PM Peak				
Massachusetts Avenue (NB/SB)				Queue[3]					Queue[3]	
Intersection Movement	Delay[1]	LOS	v/c[2]	50%	95%	Delay	LOS	v/c	50%	95%
Signalized Intersection										
Linwood Street / Foster Street										
Northbound Lt	0.8	A	0.13	0	0	0.5	A	0.05	0	1
Northbound Th	2.8	A	0.64	4	5	5.5	A	0.75	24	77
Southbound Th/Rt	32.0	C	1.00	406	493	6.8	A	0.78	108	225
Linwood Street Eastbound	72.3	E	0.65	16	95	76.7	E	0.69	18	91
Foster Street Westbound	563.2	F	2.01	86	177	633.5	F	2.17	93	106
OVERALL	**46.5**	**D**	**1.04**			**42.9**	**D**	**0.83**		
Bates Road/ Marion Road										
Marion Road Eastbound	48.9	D	0.39	9	11	46.1	D	0.39	13	31
Bates Road Westbound Lt	97.6	F	1.03	174	307	41.7	D	0.61	72	117
Bates Road Westbound Th/Rt	31.2	C	0.10	2	0	34.7	C	0.15	6	0
Mass Ave NB Lt	8.4	A	0.11	1	2	5.0	A	0.06	2	6
Mass Ave NB Th	18.1	B	0.80	205	524	17.7	B	0.83	331	680
Mass Ave NB Rt	5.5	A	0.07	0	8	5.1	A	0.14	10	35
Mass Ave SB Lt	6.5	A	0.22	10	16	6.1	A	0.25	14	22
Mass Ave SB Th/Rt	132.1	F	1.26	811	876	20.3	C	0.93	461	746
OVERALL	**80.9**	**F**	**1.19**			**20.4**	**C**	**0.86**		

1. Delay in seconds per vehicle.
2. Volume to capacity ratio.
3. Queue in feet per lane (25 feet per vehicle).

TABLE 16 – 2018 Build Level of Service-Orvis Road and Grafton Street

	AM Peak			PM Peak		
Massachusetts Avenue (NB/SB)						
Intersection Movement	Delay[1]	LOS	v/c[2]	Delay[1]	LOS	v/c[2]
Unsignalized Intersection						
Orvis Road/ Grafton Street						
Orvis Road Eastbound	342.1	F	-	470.7	F	-

1. Delay in seconds per vehicle.
2. Volume to capacity ratio.

4.3 Massachusetts Avenue/Lake Street/Winter Street

This intersection is to be upgraded to include the following key measures:

- An exclusive northbound left turn lane on Massachusetts Avenue to Lake Street operating under protected signal control;
- An exclusive right-turn lane southbound on Massachusetts Avenue to Lake Street;

- Elimination of the pre-timed pedestrian phase in the signal cycle and replacing it with an actuated phase, an on-call phase; and
- Placement of an exclusive left turn on Massachusetts Avenue to Winter Street, operating without signal control.

Analysis results are shown in Table 17.

TABLE 17 – 2018 Build Level of Service – Massachusetts Avenue and Lake Street

		AM Peak					PM Peak				
					Queue[3]					Queue[3]	
Intersection	Movement	Delay[1]	LOS	v/c[2]	50%	95%	Delay[1]	LOS	v/c[2]	50%	95%
Mass Ave at Lake Street											
	Eastbound Lt/Th/Rt	232.0	F	1.43	452	463	162.3	F	1.27	380	473
	Northbound Lt	20.1	C	0.68	41	92	13.5	B	0.60	48	88
	Northbound Th/Rt	22.4	C	0.80	229	444	29.4	C	0.89	293	543
	Southbound Lt	16.5	B	0.15	12	31	15.9	B	0.03	5	14
	Southbound Th	29.1	C	0.84	231	384	22.0	C	0.63	157	230
	Southbound Rt	30.2	C	0.73	134	279	17.8	B	0.26	40	87
	OVERALL	**73.8**	**E**	**1.04**			**57.4**	**E**	**1.03**		

1. Delay in seconds per vehicle.
2. Volume to capacity ratio.
3. Queue in feet per lane.

4.4 Massachusetts Avenue/Thorndike Street/Teel Street

In meetings with the public and MassHighway, it was determined that this intersection will stay under signal control. Since the current phasing runs inefficiently, changes to the timing will be made. Analysis results for the 2018 Build condition are shown in Table 18.

TABLE 18 – 2018 Build Level of Service-Thorndike Street and Teel Street

		AM Peak					PM Peak				
Massachusetts Avenue (NB/SB)					Queue[3]					Queue[3]	
Intersection	Movement	Delay[1]	LOS	v/c[2]	50%	95%	Delay	LOS	v/c	50%	95%
Signalized Intersection											
Thorndike Street/Teel Street											
	Thorndike Street Eastbound	33.9	C	0.42	17	5	37.8	D	0.43	17	32
	Teel Street Westbound	31.0	C	0.12	4	25	33.8	C	0.02	0	0
	Mass Ave NB Lt/Th	5.6	A	0.63	92	297	11.5	B	0.84	202	577
	Mass Ave SB Lt/Th	3.4	A	0.51	67	130	2.3	A	0.34	37	80
	OVERALL	**6.0**	**A**	**0.60**			**8.8**	**A**	**0.80**		

1. Delay in seconds per vehicle.
2. Volume to capacity ratio.
3. Queue in feet per lane (25 feet per vehicle).

4.5 Massachusetts Avenue/Alewife Brook Parkway

This intersection is capacity constrained, so there are limited physical improvements that could be implemented. Thus working with the City, revised signal timings are proposed. The signal phasing remains unchanged. Analysis results for the 2018 Build condition are shown in Table 19.

TABLE 19 – 2018 Build Level of Service – Massachusetts Avenue/Alewife Brook Parkway

		AM Peak					PM Peak				
					Queue[3]					Queue[3]	
Intersection	Movement	Delay[1]	LOS	v/c[2]	50%	95%	Delay[1]	LOS	v/c[2]	50%	95%
Mass Ave - Alewife Brook Parkway											
	Northbound Lt	121.4	F	1.07	263	442	84.0	F	0.96	259	443
	Northbound Th/Rt	35.6	D	0.58	222	283	37.2	D	0.65	252	328
	Southbound Lt	61.8	E	0.75	139	158	59.6	E	0.65	92	156
	Southbound Th/Rt	74.5	E	1.02	419	563	57.4	E	0.88	270	373
	Parkway Eastbound Lt	169.1	F	1.07	84	182	95.3	F	0.93	155	286
	Parkway Eastbound Th/Rt	41.2	D	0.83	347	378	61.7	E	0.99	484	646
	Parkway Westbound Lt	240.0	F	1.28	129	246	118.8	F	0.96	101	171
	Parkway Westbound Th/Rt	89.8	F	1.08	596	734	45.1	D	0.84	343	407
	OVERALL	**75.9**	**E**	**1.10**			**58.3**	**E**	**0.93**		

1. Delay in seconds per vehicle.
2. Volume to capacity ratio.
3. Queue in feet per lane.

5.0 CONCLUSIONS

Based on the design plan presented with the upgraded intersections and proposed cross section, the traffic analysis indicates the improved roadway and intersection plans will reduce vehicle delays and queues at the Massachusetts/Lake Street intersection, enhance safety at this intersection as well at study area intersections, and provide improved opportunities for crossings for both pedestrians and bicycles along the corridor. In addition, bicycles will have a dedicated travel lane that is separated from vehicular traffic. At the other signalized study area intersections, enhanced operations and improved Level of Service will occur.

The proposed construction includes the reconstruction of existing cement concrete sidewalks, installation of granite curb, cold planing and overlaying the existing roadway surface, installation of new signal equipment at four intersections, new signs and pavement markings, and proposed landscape, streetscape, and pedestrian scale lighting within the East Arlington Business District. The preliminary construction cost estimate for this project is $6.1 million, which includes estimated costs for construction contingencies, inflation, police details, and MassHighway contract administration.