Transportation
Land Development
Environmental
Services

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Memorandum

To: Terrance Connolly
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Date: May 5, 2014

Project No.: 12309.05

From: Mike Regan, P.E., PTOE
Angela Dempsey, P.E.

Re: Cedar Street at Hunnewell Street/
McLean Street/Hastings Street
Wellesley, Massachusetts

INTRODUCTION

This technical memorandum has been prepared to evaluate traffic operations at the intersection of Cedar Street at Hunnewell Street/McLean Street/Hastings Street in Wellesley. This memorandum summarizes existing conditions, traffic count data, crashes, sight distance, signal warrant analysis and capacity analysis. Recommendations for the study intersection are provided. The study intersection is shown in Figure 1.

PREVIOUS STUDIES

This intersection has been evaluated in the past by other consultants. An October 1996 memorandum by McDonough & Scully, Inc. recommended the installation of a traffic signal at this location, while a January 2001 study by the Beta Group concluded a traffic signal was not warranted at that time. There was also an earlier memorandum by Bruce Campbell and Associates, Inc. in 1994 that looked at crashes and sight distance at the intersection to recommend safety improvements, but did not contain any traffic signal warrant analysis.

TRAFFIC VOLUMES

Data Collection

Traffic count data was collected by Precision Data Industries, Inc. of Berlin, Massachusetts manually and electronically. Turning movement counts (TMCs) were conducted at the study intersection, from 7:00 AM to 9:00 AM and 2:30 PM to 6:00 PM on Tuesday February 25, 2014. The data indicated that the morning peak hour occurs between 7:30 and 8:30 AM and the evening peak hour occurs between 5:00 and 6:00 PM. There is also an afternoon peak that coincides with the end of the school day at Fiske Elementary School from 3:00 to 4:00 PM.

The TMCs indicate the pedestrian volumes are quite low at this location, even given the proximity to the elementary school. A total of 17 pedestrians were recorded during the entire TMC collection hours. In April 2014, the pedestrian count was repeated to see if there was an increase in the number of students walking to school when the weather was better. Between 3:00 PM and 4:00 PM, 19 pedestrians were observed at the study intersection, 16 of those between 3:05 PM and 3:15

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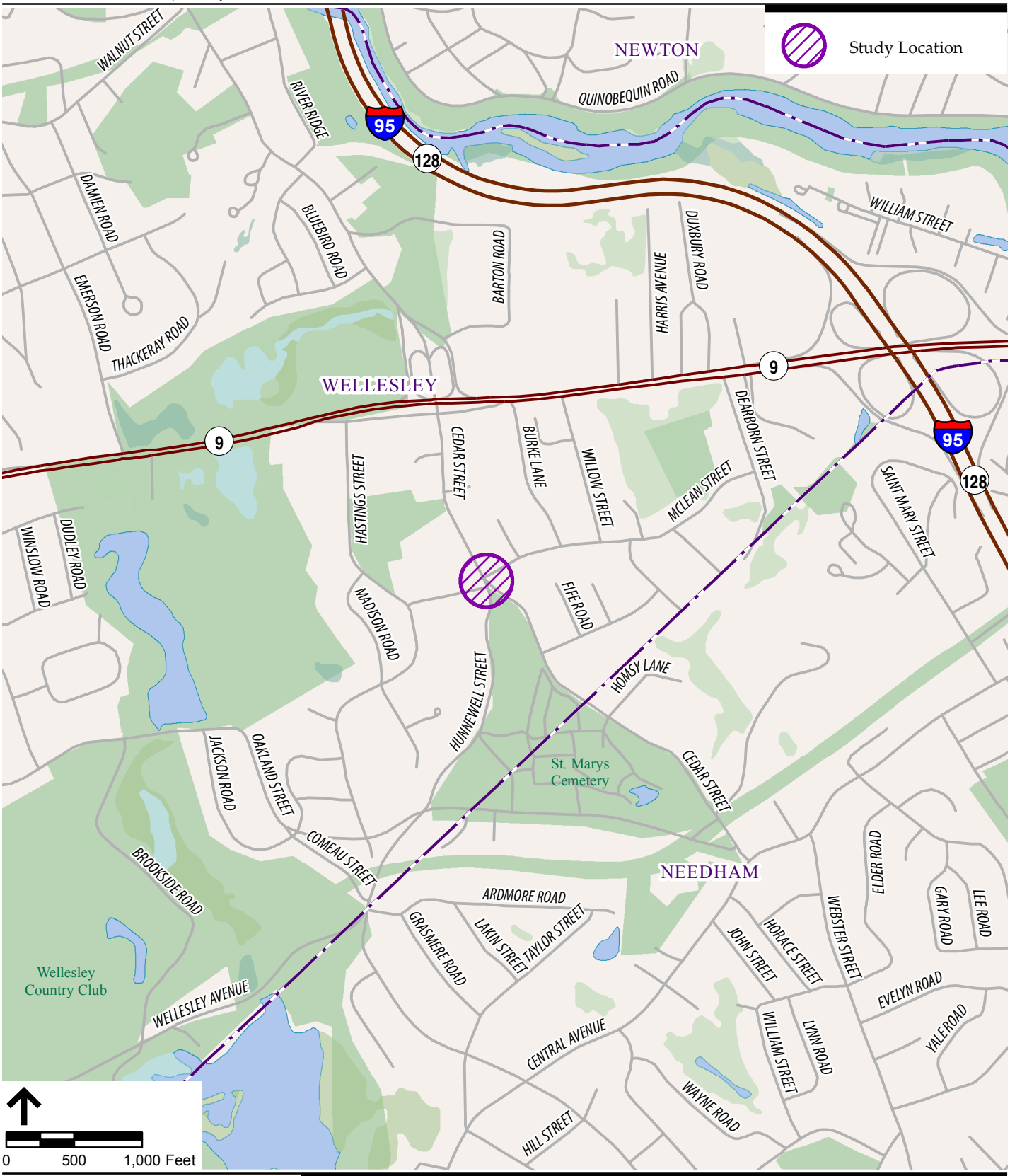

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Cedar Street at Mclean Street,
Hastings Street, and Hunnewell Street

Figure 1

Wellesley, Massachusetts

PM. However, all 19 pedestrians were only crossing McLean Street, having crossed Cedar Street at the crosswalk with a crossing guard and flashing beacons approximately 540 feet to the north. No pedestrians were observed crossing any other approach to the intersection during the observation period.

Automatic Traffic Recorders (ATRs) were placed on all the approaches of the study intersection for a minimum of 48 hours during the same week of February 2014. The ATRs collected count data, vehicle classification and speed data. The 85th percentile speed for traffic approaching the intersection ranged between 30 mph and 33 mph on Cedar Street southbound and Hunnewell Street northbound.

The traffic data collected in February 2014 was compared to the traffic data collected for the previous studies mentioned above and is summarized in Table 1. As shown in the table, there has not been a significant increase in traffic during the past twenty years. Weekday morning, afternoon and evening peak hour volumes are shown in Figure 2. In comparison to previous reports, turning movement patterns are similar with 2014 volumes not presenting as much of a pronounced north-south commuter pattern. ATRs, TMCs and the traffic volumes from previous studies of the intersection are provided in Appendix A.

Table 1
Peak Hour Traffic Volume Comparison

	Traffic Volume Count Year*			
	1994	1996	2001	2014
Morning Peak	1,928	1,837	1,412	1,707
Afternoon Peak	N/A	1,148	1,456	1,442
Evening Peak	1,601	1,627	1,617	1,679

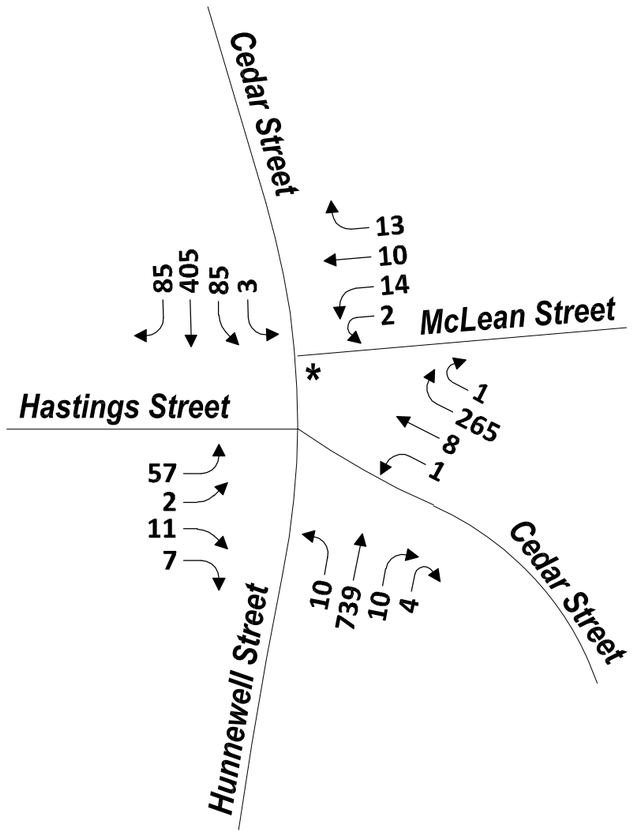
*Traffic counts were collected at various times through the year and have been adjusted to reflect average annual conditions

N/A = traffic volumes were not collected during this time of day

EXISTING INTERSECTION CONDITIONS

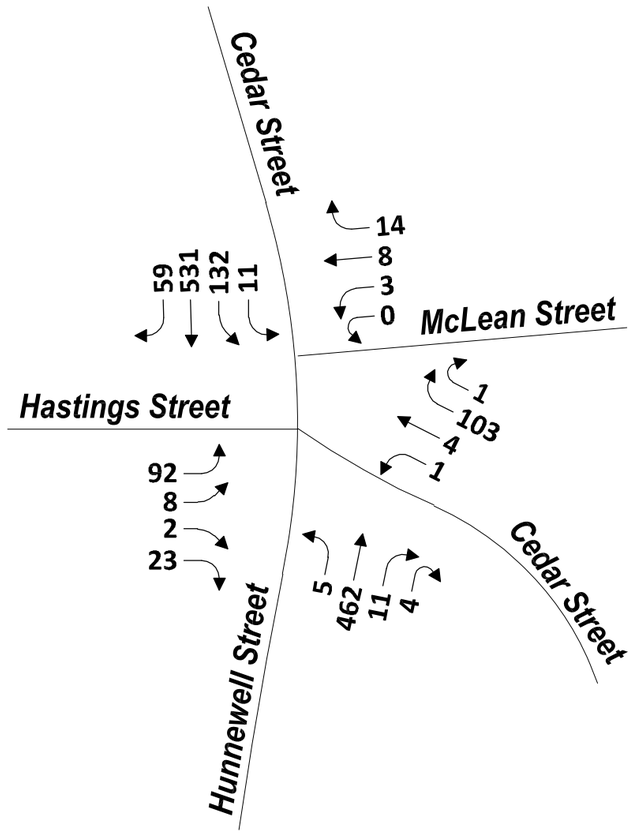
The study intersection consists of five approaches and operates unsignalized. The movements that operate free are Hunnewell Street northbound and Cedar Street southbound. Cedar Street north-westbound, Hastings Street eastbound and McLean Street westbound all operate under STOP sign control. Hastings Street and Cedar Street from the southeast intersect Hunnewell Street approximately opposite each other, though Cedar Street intersects at a tight angle. McLean Street intersects approximately 60 feet to the north of Hastings Street. Cedar Street southbound widens to provide two general purpose lanes approaching the intersection for a distance of approximately 180 feet and reduces back to one lane immediately south of the intersection. There are no markings or signs to indicate lane use, however during field observations, the additional lane functioned as a dedicated left turn lane to Cedar Street. All other approaches provide one multi-purpose approach lane. Right turns onto McLean Street are prohibited 7:30-9:00 AM Monday through Friday.

Crosswalks are provided across Hastings Street and McLean Street. Sidewalks are provided along both sides of Cedar Street north of the intersection and the east side of Cedar Street south of the intersection. Sidewalks are also provided on the west side on Hunnewell Street and on the south sides of Hastings Street and McLean Street. Land use in the area is primarily residential with the Joseph Fiske Elementary School located on Hastings Street. There is a crosswalk with push-button actuated flashing beacons located approximately 540 feet to the north of the intersection. This

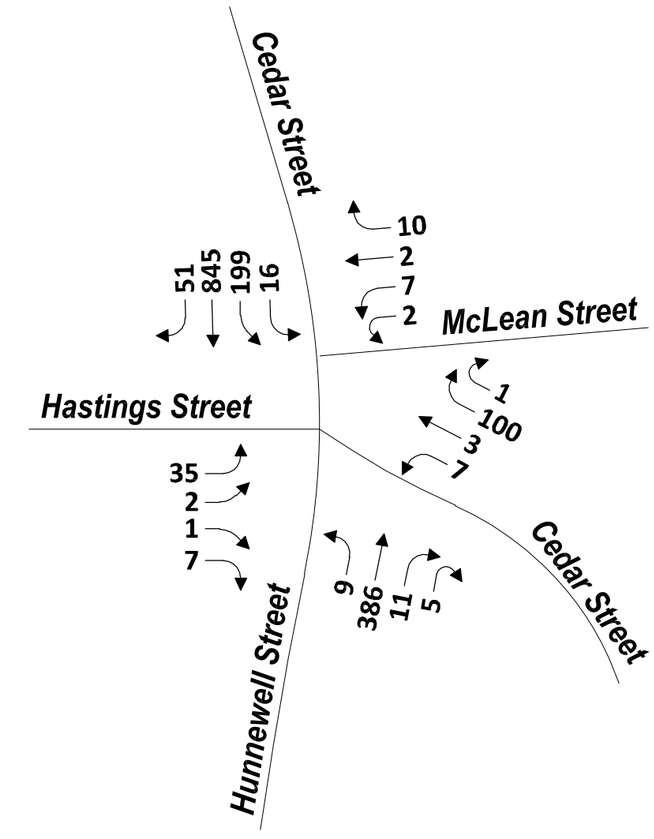


Weekday Morning

** Right turns onto McLean Street are prohibited 7:30-9:00 AM, Monday though Friday*



Weekday Afternoon



Weekday Evening

Not to Scale

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Figure 2

2014 Existing Peak Volumes
Cedar Street at Hunnewell Street/
Hastings Street/McLean Street
Wellesley, MA

crosswalk provides a connection to the Fiske Elementary School. There is a crossing guard present during school arrival and dismissal times.

There is a signalized intersection of Cedar Street and Worcester Street located approximately 1,300 feet to the north of the study location. Field observations conducted by VHB on April 9, 2014 indicate that during the morning peak hour, the northbound queue to the signalized intersection extended to the study intersection several times during the hour.

CRASHES

To identify crash trends at the study intersection, the most current crash data was obtained from Massachusetts Department of Transportation (MassDOT) for the years 2007 through 2011. Crash reports were also obtained from the Town of Wellesley Police Department. The reports from the Town included five crashes between 2008 and 2001, all of which were also included in the MassDOT data. The data from the Town included one crash each in 2012 and 2013. The data for these years is not yet available in the MassDOT database. A summary of the vehicle crash data is presented in Table 2. The crash rate calculation worksheet and the raw crash data are included in Appendix B.

The crash data indicates that the most frequent type of crash at this location is rear-end collisions (5 of 14). The occurrence of rear-end type collisions typically does not decrease with the installation of a traffic signal.

The MassDOT Statewide average crash rate for unsignalized intersection is 0.60 and the District 6 (The MassDOT district designation for Wellesley) average crash rate is 0.58 crashes per million entering vehicles. As Table 2 indicates, the crash rate of 0.32 for the study intersection is well below the MassDOT average crash rates.

Table 2
Vehicular Crash Summary (2007-2011)

	Cedar Street at Hunnewell Street/McLean Street/Hastings Street
Year	
2007	5
2008	2
2009	2
2010	1
2011	2
2012*	1
2013*	1
Total	14
Collision Type	
Angle	3
Head-on	2
Rear-end	5
Sideswipe, opposite direction	1
Sideswipe, same direction	1
Single vehicle crash	1
Not reported	1
Total	14
Crash Severity	
Fatal injury	0
Non-fatal injury	3
Property damage only (none injured)	11
Total	14
Time of Day	
Weekday, 7:00 AM - 9:00 AM	4
Weekday, 4:00 PM - 6:00 PM	5
Weekday, other time	4
Saturday, 11:00 AM – 2:00 PM	0
Saturday, other time	1
Total	14
Pavement Conditions	
Dry	9
Wet	2
Snow	3
Total	14
Non Motorist (Bike, Pedestrian)	
Total	0
MassDOT Crash Rates	0.32

* 2012 and 2013 data from the Town of Wellesley Police Department.
All other data from the MassDOT database.

SIGHT DISTANCE

Sight distance analysis, in conformance with guidelines of the American Association of State Highway and Transportation Officials (AASHTO)[1], was reviewed for the study intersection. Sight distance considerations are generally divided into two categories: Stopping Sight Distance (SSD) and Intersection Sight Distance (ISD). Essentially, SSD is the minimum distance needed to avoid collisions, and ISD is the minimum distance needed so that mainline motorists will not have to reduce their speed substantially due to turning vehicles. Both are described in greater detail below.

Stopping Sight Distance (SSD) is the distance required for a vehicle approaching an intersection from either direction to perceive, react and come to a complete stop before colliding with an object in the road, in this case a vehicle departing any of the minor approaches. In this respect, SSD can be considered as the minimum visibility criterion for the safe operation of an unsignalized intersection. The calculated sight distance shown for Cedar Street southbound is based on the relatively flat approach grade. The calculated sight distance Hunnewell Street northbound is based on a 6% downgrade approaching the intersection as it takes longer to stop on a downhill approach.

Intersection Sight Distance (ISD) is based on the time required for perception, reaction and completion of the desired critical exiting maneuver once the driver on a minor street approach decides to execute the maneuver. Calculation for the critical ISD includes the time to (1) turn left, and to clear the half of the intersection without conflicting with the vehicles approaching from the left; and (2) accelerate to the operating speed of the roadway without causing approaching vehicles to unduly reduce their speed. In this context, ISD can be considered as a desirable visibility criterion for the safe operation of an unsignalized intersection. The intersection sight distance for Hastings Street and Cedar Street are based on a relatively flat approach grade. The intersection sight distance of McLean Street is greater to account for the approximately 4% uphill grade of that approach and the additional time it would take a vehicle to accelerate.

The ATR data indicated 85th percentile speeds on Cedar Street southbound and Hunnewell Street northbound approaching the intersection range between 32 and 33 miles per hour. To calculate the required stopping sight distance (SSD) and intersection sight distance (ISD) at the study intersection, a speed of 35 miles per hour was used to provide a conservative analysis. Table 3 summarizes the sight distance analysis results.

Table 3
Sight Distance Analysis Summary

	Stopping Sight Distance[1]			Intersection Sight Distance[2]		
Minor Approach	Traveling	Calculated[3]	Measured	Looking	Calculated[3]	Measured
Hastings Street	Northbound	271’	175’	Left	386’	270’
	Southbound	246’	600’	Right	386’	215’
McLean Street	Northbound	271’	335’	Left	427’	315’
	Southbound	246’	280’	Right	427’	510’
Cedar Street	Northbound	271’	235’	Left	386’	220’
	Southbound	246’	370’	Right	386’	600’

1 Traveling on Cedar Street southbound /Hunnewell Street northbound.
2 On the minor approach looking to see vehicles on the major approaches.
3 Calculated sight distance expressed in feet, based on an approximate 85th percentile speed of 35 mph.

Traveling northbound on Hunnewell Street, there is very little Stopping Sight Distance to Hastings Street and Cedar Street. This is due to the curve in the road, the crest in the road and vegetation. As

[1] A Policy on the Geometric Design of Highways and Streets, American Association of State Highway and Transportation Officials, 2011

the table indicates, most movements at the intersection do not meet the criteria for Intersection Sight Distance. In several instances, the view of oncoming traffic is obscured by vegetation, particularly on Cedar Street looking left and McLean Street looking right.

TRAFFIC SIGNAL WARRANTS ANALYSIS

Traffic signal warrants analyses were performed using the 2014 ATR data to establish the need and/or justification for traffic signal control at the study intersection. The methodology used to determine if traffic signal controls are warranted is based on the criteria set in the Manual on Uniform Traffic Control Devices (MUTCD)[2]. There are nine warrants defined in the MUTCD. A traffic signal should not be installed unless one or more of these warrants is met. Satisfaction of any one warrant does not necessarily mean that a signal should be installed at a given location, but does indicate that a signal *could* be installed.

Warrants 1, 2, and 3 are based on traffic volumes through an intersection and are most commonly used to justify the installation of a traffic signal. These warrants are described below:

- **Warrant 1 (Eight-Hour Vehicular Volume):** Warrant 1 is satisfied if either of Condition A or B is met. In addition, Warrant 1 can be satisfied by 80 percent satisfaction of both Condition A and Condition B.

  Condition A (Minimum Vehicular Volume): Satisfied when the volume of intersecting traffic (major and minor streets) exceeds MUTCD thresholds for eight or more hours.

  Condition B (Interruption of Continuous Traffic): Satisfied when the volume of major street traffic is so heavy that minor street traffic suffers excessive delay in entering or crossing the major street for eight or more hours.

- **Warrant 2 (Four-Hour Vehicular Volume):** Satisfied when volumes (major and minor streets) exceed MUTCD thresholds for four or more hours.

- **Warrant 3 (Peak Hour):** Satisfied when for the peak hour of a typical day, major and minor street traffic exceeds MUTCD thresholds and unsignalized operation at the intersection results in excessive delay for the minor street traffic.

Traffic turning right from a minor approach (i.e., Hastings Street, McLean Street or Cedar Street northwest bound) typically has less of an impact on operations than traffic turning left from the minor approach. The MUTCD leaves it to engineering judgment to determine what percentage, if any, of right turning traffic should be considered as part of the justification for a traffic signal. Cedar Street northwest bound has the highest overall volume of the minor street approaches; however turning movement counts collected for this study indicate right turns accounts for an average of 93% of the total approach volume. Since there is only one lane provided on the Cedar Street approach, a portion of the right turn volume was retained for the analysis. The traffic signal warrant analysis was completed using 60% of the total volume, approximately half of the right turn volume and all of the left/through volume.

A second analysis was completed using Hastings Street as the minor approach. Hastings Street provides one approach lane, and the majority of traffic is turning left. Therefore, the full traffic

[2] Manual on Uniform Traffic Control Devices; Part 4 – Highway Traffic Signals; U.S. Department of Transportation/Federal Highway Administration; 2009.

volume for the approach was used in the analysis. Traffic volumes on McLean Street are lower than Hastings Street.

Table 3
Traffic Signal Warrants Analysis Summary

Warrant Analysis Scenarios	Warrant 1[a] Met?	Warrant 2[b] Met?	Warrant 3[c] Met?
2014 Existing Traffic Volumes - 60% Cedar Street	No	No	No
2014 Existing Traffic Volumes - Hastings Street	No	No	No

[a] Eight-hour volume warrant
[b] Four-hour volume warrant
[c] Peak hour volume warrant

As the table indicates, the intersection does not meet Warrants 1, 2 or 3 for either of the scenarios analyzed. The traffic signal warrants analysis worksheets are located in Appendix C.

Of the remaining traffic signal warrants, there are three that are potentially applicable at this location. Two warrants (Warrant 6 Coordinated Signal System and Warrant 9 Grade Crossings) were not evaluated since the location did not meet the prerequisites for those warrants. The remaining three warrants were reviewed and found not to be satisfied, as described below.

- **Warrant 4 (Pedestrian Volume):** The MUTCD thresholds are based on the volume of vehicular traffic and pedestrians attempting to cross the major street, for this location Hunnewell Street northbound or Cedar Street southbound. The warrant includes criteria for four-hour pedestrian volume and peak hour pedestrian volume. The minimum pedestrian volume required to satisfy the criteria is 75 and 133 pedestrians, respectively. This far exceeds the pedestrian volume recorded for this study.

- Warrant **5 (School Crossing):** When the pedestrians are school children, the MUTCD threshold is lower and the number of gaps in traffic is taken into account. However, the minimum threshold for pedestrians is 20 during the highest hour, still far above the pedestrian volume recorded for this study.

- **Warrant 7 (Crash Experience):** To satisfy this warrant, the intersection must have experienced five or more crashes within the last year that are "correctable by signalization." This generally includes angle collisions and some head-on collisions, however rear-end crashes are not included. The intersection crashes collected from the MassDOT database or the Town of Wellesley did not trigger the warrant for crash experience.

TRAFFIC OPERATIONS ANALYSIS

Level-of-Service Criteria

Level-of-service (LOS) is the term used to denote the different operating conditions at an intersection under various traffic volume loads. It is a qualitative measure of the effect of a number of factors including roadway geometry, speed, travel delay and freedom to maneuver. Level-of-service provides an index to the operational qualities of a roadway segment or an intersection. Level-of-service designations range from A to F, with LOS A representing the best operating conditions and LOS F representing the worst operating conditions. For unsignalized intersections, the analysis considers the operation of the critical movement at an intersection, typically the left turn movement from the minor street. For signalized intersections, the analysis

considers the operation of all traffic entering the intersection and the level-of-service designation is for the overall conditions at the intersection. The signalized and unsignalized intersection criteria used to evaluate this intersection are presented in Table 4.

Table 4
Intersection Level-of-Service Criteria

	Control Delay (seconds/vehicle)	
Level of Service	**Signalized Intersections**	**Unsignalized Intersections**
A	≤ 10	0-10
B	> 10 - 20	> 10-15
C	> 20 - 35	> 15-25
D	> 35 - 55	> 25-35
E	> 55 - 80	> 35-50
F	>80	> 50

Unsignalized Capacity Analysis

As a basis to evaluate the impacts of a traffic signal at this location, VHB began by analyzing the existing operations of the unsignalized (flash mode) intersection. Critical gap is an important variable in capacity calculations at unsignalized intersections. The critical gap is the minimum time between passing vehicles on the main roadway necessary for drivers from the minor approach to enter the roadway. The analysis was initially completed using Synchro default values for the critical gap. Traffic observations were completed during the morning and afternoon peak hours in April 2014 to compare the Synchro results to actual operations at the intersection. It was found that the delay and queue calculated by Synchro were significantly greater than the observed operations. Reducing the default critical gap values by 0.5 to 1.5 seconds resulted in queue lengths comparable to the field observations, however delay time was still greater than observed. During the morning peak hour, the northbound queue from the intersection of Cedar Street and Worcester Street did have an impact on operations at the study intersection, which is not reflected in the analysis. The queue from Worcester Street backed through the intersection, causing delays on Hunnewell Street northbound.

Table 5
Capacity Analysis – Unsignalized Condition

	2014 Existing Volumes			
	V/C[1]	**Delay[2]**	**LOS[3]**	**95th Queue[4]**
Morning Peak Hour				
Hastings Street	>1.2	>80	F	246
Cedar Street (NWB)	0.78	41.0	E	165
Afternoon Peak Hour				
Hastings Street	>1.2	>80	F	271
Cedar Street (NWB)	0.28	16.4	C	29
Evening Peak Hour				
Hastings Street	0.19	22.2	C	17
Cedar Street (NWB)	0.37	20.6	C	41

Source: Vanasse Hangen Brustlin, Inc.; based on TMC data collected in February 2014.
1 Volume-to-Capacity ratio
2 Average delay, expressed in seconds per vehicle
3 Level-of-Service
4 95th percentile queue length measured in feet

Although the traffic signal warrants were not met, VHB has performed a preliminary analysis to evaluate conditions associated signalizing the study intersection to provide a complete picture of the effects of signalization. This analysis assumes maintaining the existing single lane geometry, with the exception of Cedar Street southbound where a short left turn lane can be provided. The analysis assumes Hastings Street and Cedar Street northwest bound will operate on the same phase, with a dedicated phase for McLean Street. All minor street approaches would have vehicle detection and only be called when there is a waiting vehicle. Pedestrian accommodations are not included in this analysis. Based on the pedestrian volumes collected in February 2014 and observed in April 2014, the addition of an exclusive pedestrian phase would have very minor impacts on the intersection over the course of the hour analyzed. As the table indicates, there would be significant queues on Cedar Street and Hunnewell Street and Hastings Street would not see a significant improvement in delay.

Table 6
Signalized Intersection Capacity Analysis Summary

		2014 Volumes				
Peak Period	Intersection/Movement	v/c [a]	Delay [b]	LOS [c]	Avg Queue[d]	95th Queue[d]
Weekday Morning						
	Hastings Street EB	0.43	25.3	C	35	80
	McLean Street WB	0.43	36.6	D	14	45
	Hunnewell Street NB	0.89	27.5	C	335	#570
	Cedar Street SB Left	0.38	12.4	B	27	66
	Cedar Street SB	0.57	13.7	B	161	251
	Cedar Street NWB	0.76	33.5	D	144	#270
	Overall	0.83	24.0	C	--	--
Weekday Afternoon						
	Hastings Street EB	1.10	140.2	F	50	#186
	McLean Street WB	0.26	39.5	D	5	30
	Hunnewell Street NB	0.79	25.4	C	192	335
	Cedar Street SB Left	0.67	25.2	C	47	#164
	Cedar Street SB	0.84	28.9	C	209	#496
	Cedar Street NWB	0.21	18.9	B	34	83
	Overall	0.93	35.6	D	--	--
Weekday Evening						
	Hastings Street EB	0.40	31.0	C	13	53
	McLean Street WB	0.25	34.9	C	4	28
	Hunnewell Street NB	0.42	7.3	A	67	173
	Cedar Street SB Left	0.39	7.3	A	30	104
	Cedar Street SB	0.82	15.0	B	189	#616
	Cedar Street NWB	0.73	42.9	D	42	#120
	Overall	0.78	14.8	B	--	--

a volume to capacity ratio
b vehicle delay in seconds per vehicle
c level of service
d 50th and 95th percentile queues, measured in feet
95th percentile volume exceeds capacity, queue may be longer

CONCLUSIONS

Under 2014 conditions, the study intersection does not meet vehicular volume warrants for the installation of a traffic signal, and the capacity analysis indicates that the installation of a signal may degrade operations at the intersection. Letters from members of the community included with the previous studies of this intersection expressed concerns about safety at the intersection in terms of vehicular crashes and pedestrian safety. However, the frequency of crashes at this location is lower than the statewide and local district MassDOT crash frequencies and the number of recorded accidents at this location is not enough to meet the Crash Warrant thresholds for signal installation. The pedestrian volumes are very low, even around school arrival and dismissal times, and do not meet the warrant thresholds for the pedestrian related signal warrants.

Sight distance is an issue at this location. Some improvement can be provided by removing or trimming vegetation at the corners of some adjacent properties. There is an existing warning sign on Hunnewell Street northbound indicating the intersection is ahead. A similar sign for Cedar Street southbound is recommended to improve motorist awareness especially at night and during poor weather conditions.

The two multipurpose lanes on Cedar Street southbound could cause confusion to drivers not familiar with the area. It is recommended to formalize the lane use as a left turn lane and a shared through/right lane with the installation of appropriate signs and pavement markings.