Town of Brookline

Massachusetts

Walnut Street
Traffic Calming Evaluation

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BETA Group, Inc.
Engineers • Scientists • Planners
315 Norwood Park South, Norwood, MA 02062 781.255.1982
email: beta@beta-inc.com

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SECTION 1 INTRODUCTION

1.1 Project Purpose

The Transportation Division of the Brookline Department of Public Works (DPW) has retained BETA Group, Inc./Bruce Campbell & Associates (BETA) to evaluate the design, construction and effectiveness of traffic calming devices which were implemented at multiple locations throughout the town of Brookline. This report summarizes the design and effectiveness of the traffic calming devices installed on Walnut Street.

1.2 Background

As indicated in the town's Traffic Calming Policy Statement, the town of Brookline is committed to improving the livability and safety of its neighborhoods by mitigating the impacts of traffic and promoting safer conditions for residents, motorists, bicyclists and pedestrians. Furthermore, as part of the town's traffic calming policy and procedures, the town is committed to ensuring that the implementation of all traffic calming plans are evaluated for their effectiveness.

This evaluation of the traffic calming devices on Walnut Street is a response to neighborhood concerns as well as the town's traffic calming policy. The town of Brookline has installed a number of traffic calming devices along Walnut Street between High Street and Warren Street. According to the DPW, the traffic calming devices were installed in various stages between January and June of 2001. The traffic calming devices were implemented to mitigate speeding and cut-through problems and ultimately improve pedestrian and vehicular safety within the neighborhood. It should be noted that a detailed intersection safety improvements study for the intersection of Walnut Street /Kennard Road / Chestnut Street was performed by BETA Group, Inc. and documented in a technical memorandum dated January 15, 2003.

1.3 Data Collection

In order to evaluate the devices on Walnut Street, the following data collection efforts were performed:

- Review traffic counts and speed studies provided by the town.

- Field investigations where roadway and traffic calming device geometry were measured.
- Compilation of intersection accident records between 2000 and 2002.
- Solicit input from the community residents and Walnut Street abutters.
- Review available construction plans and documents to determine conformance of the traffic calming devices with the original design.
- Review the Town of Brookline Traffic Calming Policy and Procedures to determine conformance with the overall traffic calming implementation process.

1.4 Evaluation Criteria

Due to the limited availability of traffic calming design manuals or criteria to aide in the design of traffic calming devices (with the exception of speed humps), the physical design elements of the traffic calming devices for this assignment were evaluated using the following documents:

- Traffic Calming State of the Practice, ITE Publications.
- Canadian Guide to Neighborhood Traffic Calming, ITE Publications.
- Guideline for the Design and Application of Speed Humps, ITE Publications
- 2001 Policy on Geometric Design of Highways, American Association of State Highway and Transportation Officials (AASHTO).
- 2000 Manual on Uniform Traffic Control Devices (MUTCD).
- Highway Design Manual, Massachusetts Highway Department.
- Construction and Traffic Standard Details, Massachusetts Highway Department.
- Traffic Calming Policy and Procedures, Town of Brookline.
- Detail for Raised Devices, City of Cambridge.

SECTION 2 EXSITING CONDITIONS

2.1 Roadway Characteristics

Walnut Street is a town-owned roadway classified in the Massachusetts Highway Department's Roadway Inventory Database as a collector. It runs parallel to Boylston Street (Route 9) in the east/west direction. Walnut Street serves as a connector between High Street, Cypress Street and Warren Street in Brookline.

Walnut Street is approximately 3640 feet (0.7 miles) long. The horizontal alignment of Walnut Street is fairly straight between High Street and Cypress Street with no sharp or reverse curves. The vertical alignment between high Street and Cypress Street ranges between 0% and 4% grade. Walnut Street has a relatively sharp curve combined with a steep grade (approximately 5% - 8% incline) beginning at Kennard Road and extending to Warren Street. Walnut Street consists of a primarily residential area with several churches and schools at various locations.

There is no posted speed limit along Walnut Street; therefore the speed limit is governed by the Prima Facie speed limit (30 miles per hour (mph)) for thickly settled districts. The roadway cross- section of Walnut Street primarily consists of travel lanes between 8.5 and 11 feet wide with one-foot shoulder provided at locations where on-street parking is prohibited. Where present, the parking lanes are approximately 6 feet wide. On-street parking along Walnut Street is limited to residents with parking permits; otherwise a two-hour limit is posted. School zone parking by permits on school day from 6:00 AM to 3:00 PM is provided on the south side of Walnut Street, located west of Walnut Path.

Locations of the existing traffic calming measures on Walnut Street are shown in Figure 1 and listed as follows:

- Neckdowns – located at Upland Road, Irving Street, Walnut Path and Oakland Road
- Raised Crosswalks – located at Walnut Path and Oakland Road
- Chicanes – located at High Street, #103 Walnut Street, #175 Walnut Street and #263 Walnut Street.

N
MEDIAN/ISLAND TREATMENT
WARREN ST
WALNUT ST
CODMAN RD
FERRIN RD
KENNARD RD
CHESTNUT ST
CUSHING RD
CLARK CT
CYPRESS ST
A
A
CHICANE (#263 WALNUT STREET)
RAISED CROSSWALK
NECKDOWN
CHICANE (#175 WALNUT STREET)
WALNUT PATH
RAISED CROSSWALK
NECKDOWN
NECKDOWN
CHICANE (#103 WALNUT STREET)
CYPRESS ST
WALNUT STREET
OAKLAND RD
WALNUT PLACE
IRVING ST
UPLAND RD
CHICANE
HIGH ST
A
A

- Island Treatment – located at eastern section of the large triangular intersection with Warren Street.

2.2 Design and Construction of Traffic Calming Devices

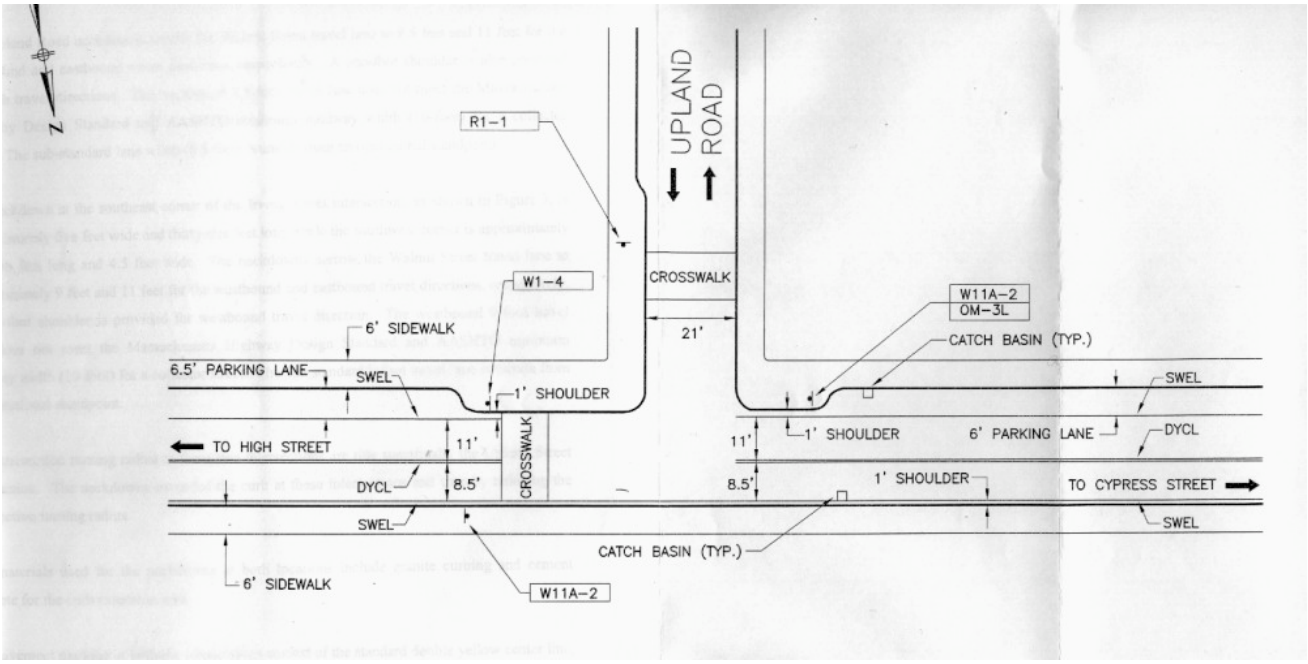
Neckdowns at Upland Road and Irving Street

In general, a neckdown consists of curb extensions at an intersection that narrow a street by widening the sidewalk. The primary function of a neckdown is to reduce speed. This is achieved by narrowing the width of the street and drawing attention to the constriction which automatically causes motorists to reduce speed at the curb extension area. It helps prevent vehicles from parking illegally on the street corner, thus improving the sight line for motorists and pedestrians. In addition, it encourages turning vehicles to reduce speeds as they turn at the intersection. A secondary function of a neckdown is to offer a physical barrier thereby better defining and protecting the on-street parking lane. Handicap ramps are provided at the curb extensions for wheelchair access where the neckdowns meets the on-street crosswalks.

The neckdowns on Walnut Street are located at the intersections with Upland Road and Irving Street, which approach Walnut Street from the south to form T-intersections. Upland Road and Irving Street are under Stop sign control. Due to the limited roadway width, a half neckdown (curb extension) is provided at the southern side of Walnut Street for both locations and there are no neckdown curb extensions along the northern side. Upland Road and Irving Road are both two-way street configuration.

Construction plans were available for referencing the traffic calming devices on Walnut Street. In addition, field measurements were taken and compared to the construction plans. Figure No. 2 shows the neckdown at Upland Road/Walnut Street intersection. The neckdown at the southeast corner of the Upland Road intersection is approximately forty feet long and extends five feet into the roadway from the existing sidewalk edge. The neckdown at the southwest corner is approximately twenty-three feet long and extends approximately 4.5 feet into the roadway.

The crosswalks on the Upland and Walnut Street approaches are located approximately 15 feet away from the intersection which is inconvenience for pedestrians at the sidewalks within the


N
R1-1
UPLAND ROAD
CROSSWALK
21'
W1-4
W11A-2
OM-3L
CATCH BASIN (TYP.)
6' SIDEWALK
6.5' PARKING LANE
SWEL
1' SHOULDER
SWEL
TO HIGH STREET
11'
CROSSWALK
11'
1' SHOULDER
6' PARKING LANE
DYCL
DYCL
8.5'
8.5'
1' SHOULDER
TO CYPRESS STREET
SWEL
SWEL
CATCH BASIN (TYP.)
6' SIDEWALK
W11A-2

intersection.

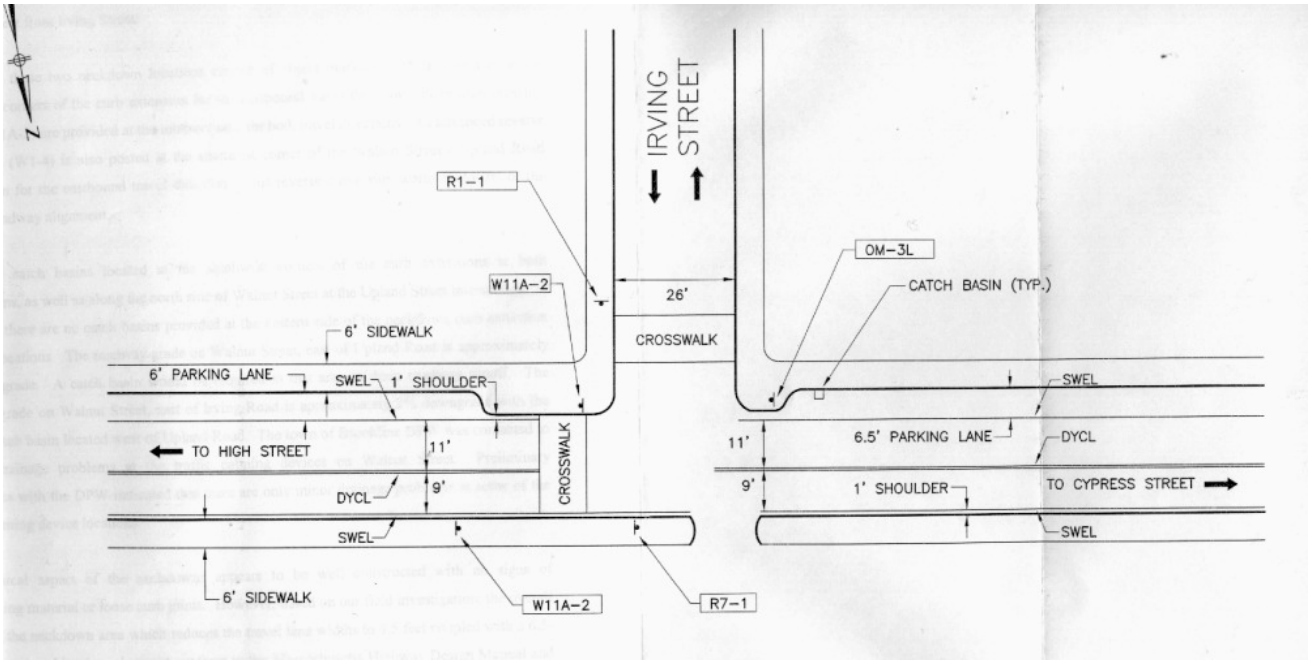
The Upland Road neckdowns narrow the Walnut Street travel lane to 8.5 feet and 11 feet for the westbound and eastbound travel directions, respectively. A one-foot shoulder is also provided for both travel directions. The westbound 8.5-foot travel lane does not meet the Massachusetts Highway Design Standard and AASHTO minimum roadway width (10-foot) for a collector street. The sub-standard lane width (8.5 feet) is unsafe from an operational standpoint.

The neckdown at the southeast corner of the Irving Street intersection, as shown in Figure 3, is approximately five feet wide and thirty-one feet long while the southwest corner is approximately fourteen feet long and 4.5 feet wide. The neckdowns narrow the Walnut Street travel lane to approximately 9 feet and 11 feet for the westbound and eastbound travel directions, respectively. A one-foot shoulder is provided for westbound travel direction. The westbound 9-foot travel lane does not meet the Massachusetts Highway Design Standard and AASHTO minimum roadway width (10-foot) for a collector street. The sub-standard 9-foot travel lane is unsafe from an operational standpoint.

The intersection turning radius at these two intersections are tide specifically the Upland Street intersection. The neckdowns extended the curb at these intersections and thereby reducing the intersection turning radius.

The materials used for the neckdowns at both locations include granite curbing and cement concrete for the curb extension area.

The pavement marking at both the intersections consist of the standard double yellow center line, single white edge line, parking lane line and crosswalk marking. The on-street parking lanes are provided along the southern side of Walnut Street in the vicinity of Upland Road and Irving Street. The 6.5-foot width on-street parking lane does not meet the 7-foot minimum requirement outlined in the Massachusetts Design Manual and AASHTO for collector streets. The narrow parking lane creates safety problems and will impede traffic flow along Walnut Street. At the Irving Street approach, vehicles are parked too close to Irving Street at the southwest corner of


N
IRVING STREET
R1-1
W11A-2
26'
CROSSWALK
OM-3L
CATCH BASIN (TYP.)
6' SIDEWALK
6' PARKING LANE
SWEL
1' SHOULDER
SWEL
TO HIGH STREET
11'
CROSSWALK
11'
6.5' PARKING LANE
DYCL
DYCL
9'
9'
1' SHOULDER
TO CYPRESS STREET
SWEL
SWEL
6' SIDEWALK
W11A-2
R7-1

the intersection on Walnut Street, thereby obstructing the sight distance for traffic entering onto Walnut Street from Irving Street.

Signage at these two neckdown locations consist of object markers (OM-3R), located at the southwest corners of the curb extension for the eastbound travel direction. Pedestrian crossing signs (W11A-2) are provided at the intersections, for both travel directions. An advanced reverse curve sign (W1-4) is also posted at the southeast corner of the Walnut Street / Upland Road intersection for the eastbound travel direction. This reverse curve sign warns motorists of the chicane roadway alignment.

There are catch basins located at the southwest corners of the curb extensions at both intersections, as well as along the north side of Walnut Street at the Upland Street intersection. However, there are no catch basins provided at the eastern side of the neckdown curb extension for both locations. The roadway grade on Walnut Street, east of Upland Road is approximately 3% downgrade. A catch basin would be required at this area to drain roadway runoff. The roadway grade on Walnut Street, east of Irving Road is approximately 2% downgrade with the nearest catch basin located west of Upland Road. The town of Brookline DPW was contacted to discuss drainage problems at the traffic calming devices on Walnut Street. Preliminary discussions with the DPW indicated that there are only minor drainage problems at some of the traffic calming device locations.

The physical aspect of the neckdowns appears to be well constructed with no signs of deteriorating material or loose curb joints. However, based on our field investigation, the overall design of the neckdown area which reduces the travel lane widths to 8.5 feet coupled with a 6.5-foot on-street parking lane does not conform to the Massachusetts Highway Design Manual and AASHTO standards. The narrow travel and parking lanes create safety problems and impede traffic flow along Walnut Street.

Raised Crosswalk with Curb Extension at Walnut Path

Raised crosswalks are vertical traffic calming devices used for speed control and pedestrian safety. A raised crosswalk slows vehicles by acting as a speed hump. A raised crosswalk

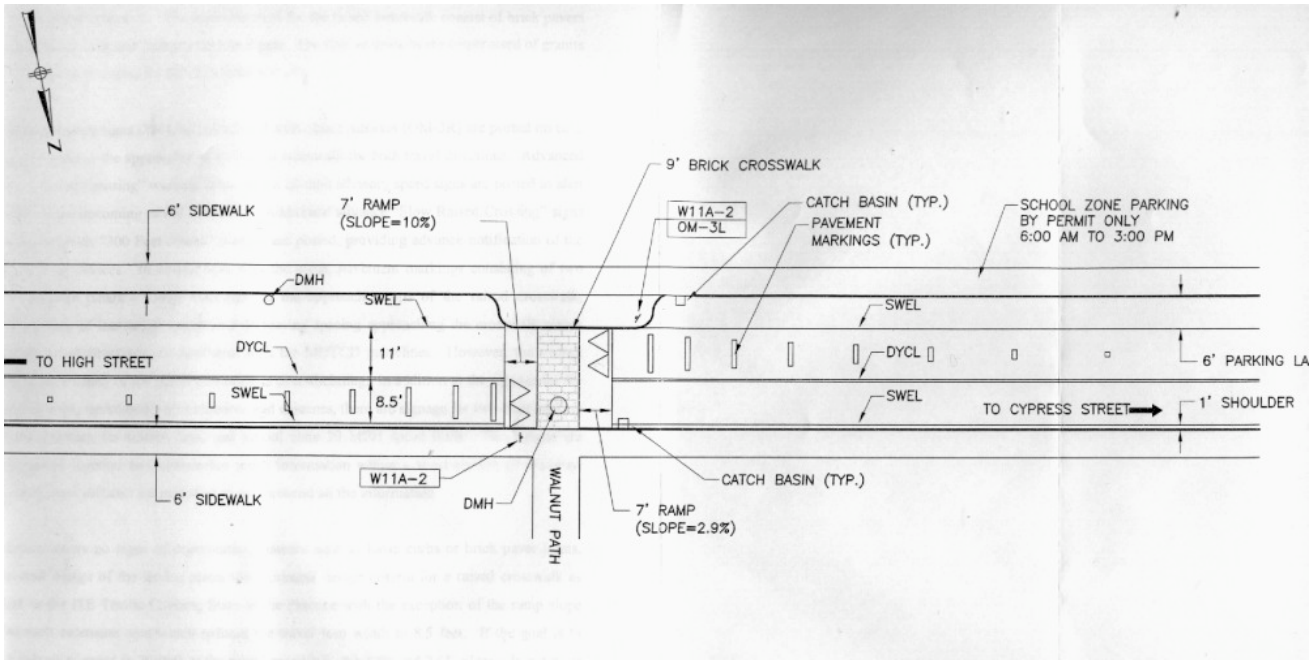
coupled with a curb extension increases pedestrian safety by reducing the length of the crosswalk and improving pedestrian visibility. It also encourages the use of the crosswalk by providing a strong visual cue to pedestrians and motorists.

The raised crosswalk is located approximately 270 feet west of Irving Street. It serves the pedestrian activity at Walnut Path. The raised crosswalk at Walnut Path extends from the northern side of Walnut Street to a curb extension on the southern side (see Figure No. 4). Walnut Path is a ten-foot wide pedestrian walkway, located at the north side of Walnut Street. The curb extension narrows the Walnut Street travel lane to 8.5 feet and 11 feet for the westbound and eastbound travel directions, respectively. The westbound 8.5-foot travel lane does not meet the Massachusetts Highway Design Manual and AASHTO design standards for a collector street. The sub-standard lane width (8.5 feet) is unsafe from an operational standpoint. A one-foot shoulder is provided on the north side of Walnut Street. On-street parking (school zone parking by permit only 6:00 AM to 3:00 PM) is provided along the southern side of Walnut Street. The 6.0-foot width on-street parking lane does not meet the 7-foot minimum requirement outlined in the Massachusetts Design Manual and AASHTO design standard for collector streets. The narrow parking lane creates safety problems and impedes traffic flow along Walnut Street.

The crosswalk is approximately nine feet wide with seven-foot ramps. The height of the raised crosswalk is approximately six inches. Field measurements utilizing the Smart Level revealed that the ramp slopes are 10.0% for the east side and 2.9% for the west side.

The curb extension on the south side of Walnut Street is approximately thirty-eight feet long. It extends seven feet from the existing sidewalk edge into the raised crosswalk and roadway. The curb extension helps prevent vehicles from parking illegally on the street corner, thus improving sight lines for motorists and pedestrians.

For drainage, there is a catch basin on the southwest side of Walnut Street adjacent to the curb extension and at the northwest corner adjacent to the raised crosswalk. There are catch basins on the west side of the raised crosswalk, to drain roadway runoff; however, there are no catch basins on the east side of the raised crosswalk. The nearest catch basin is located approximately 70 feet


N
9' BRICK CROSSWALK
6' SIDEWALK
7' RAMP
(SLOPE=10%)
W11A-2
OM-3L
CATCH BASIN (TYP.)
PAVEMENT
MARKINGS (TYP.)
SCHOOL ZONE PARKING
BY PERMIT ONLY
6:00 AM TO 3:00 PM
DMH
SWEL
SWEL
DYCL
11'
DYCL
6' PARKING LA
TO HIGH STREET
SWEL
8.5'
SWEL
TO CYPRESS STREET
1' SHOULDER
W11A-2
CATCH BASIN (TYP.)
6' SIDEWALK
DMH
WALNUT PATH
7' RAMP
(SLOPE=2.9%)

east of the raised crosswalk. The materials used for the raised crosswalk consist of brick pavers on the crosswalk area and cement concrete ramps. The curb extensions are constructed of granite curb with cement concrete for the curb extension area.

Pedestrian crossing signs (W11A-2) combined with object markers (OM-3R) are posted on each side of the street at the approaches to the raised crosswalk for both travel directions. Advanced "Caution Raised Crossing" warning signs with a 20 mph advisory speed signs are posted to alert motorists of the upcoming raised crosswalk. Additional advance "Slow Raised Crossing" signs supplemented with "300 Feet Ahead" plaques are posted, providing advance notification of the traffic calming devices. In conjunction with the signs, pavement markings consisting of two white triangular [shark's tooth] markings on the approach ramps of the raised crosswalk, transverse lines of increasing length and decreasing spacing approaching the crosswalk ramps from both travel directions are consistent with the MUTCD guidelines. However, the overall signage at the vicinity of the raised crosswalk is overwhelming. In addition to the signage for the raised crosswalk, neckdown curb extension, and chicanes, there are signage for two-hour parking restriction, parking for school days, and school zone 20 MPH speed limit. These signs are closely spaced together and contain too much information within a short section of roadway. Hence, making it difficult for motorists to comprehend all the information.

The device shows no signs of deteriorating material such as loose curbs or brick paver joints. The overall design of the device meets the minimum design criteria for a raised crosswalk as outlined in the ITE Traffic Calming State of the Practice with the exception of the ramp slope and the curb extension area which reduces the travel lane width to 8.5 feet. If the goal is to reduce vehicular speed to 20 mph at the raised crosswalk, the 10% and 2.9% slopes do not meet the ITE design standard, which calls for 8% ramp slopes.

The 10% ramp slope exceeded the industry standard for raised crosswalk of 8% ramp slope for a 20 mph travel speed. The 10% slope will create safety problem for vehicle crossing the raised crosswalk and vehicle may air borne and bottom out as they depart from the device. The 2.9% slope will allow vehicles to cross the raised crosswalk at speeds greater than the 20 mph posted advisory speed. In addition, the transition between the existing roadway and the crosswalk ramps

is abrupt due to poor vertical transition from the roadway to the crosswalk ramps. This poor vertical transition and the substandard slopes accounts for the pavement injury that exists in the area departing the raised crosswalk from both the travel directions.

Pavement damage exists on the departing side of the raised crosswalk in both travel directions. The scraped pavement indicates that vehicles are traveling at high speeds crossing the raised crosswalk and bottoming out as they depart from the device. The speeding at this raised crosswalk is a result of the steep ramp slope (10%) and the wide spacing between the traffic calming devices, which provides vehicles an opportunity to increase speed between the devices.

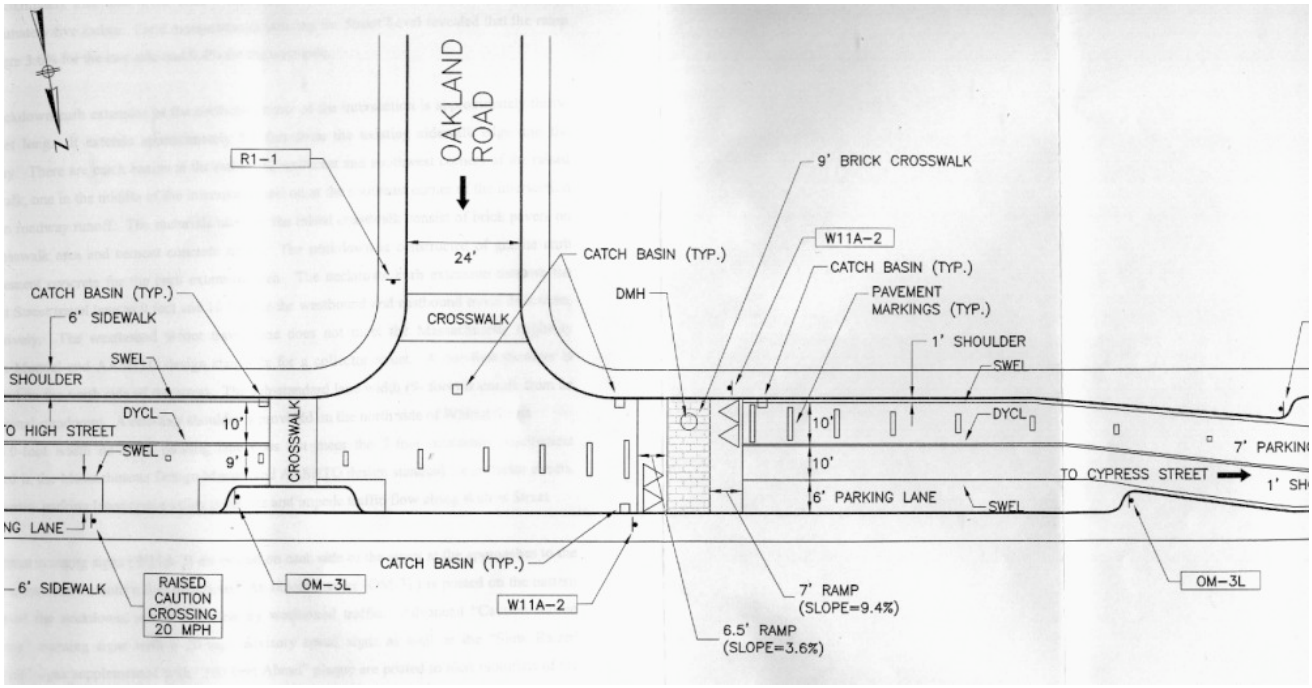
The device is well constructed with no signs of deteriorating material or loose joints and meets the minimum design criteria for a raised crosswalk as outlined in the ITE Traffic Calming State of the Practice with the exception of the ramp slopes and the narrowing of the parking lane and the westbound travel lane.

Despite the pavement scrapings made by speeding drivers, our survey of the residents and users revealed that the overall perception of the raised crosswalk is positive as it provides safety to pedestrians that utilize the crosswalk and it forces vehicles to slow down as they approach the raised crosswalk.

Raised Crosswalk and Neckdown at Oakland Road

Oakland Road approaches Walnut Street from the south to form a T-intersection. The Oakland Road approach is under Stop sign control and it is a two-way street configuration. At the intersection of Walnut Street and Oakland Road, there exists a raised crosswalk and a neckdown. The raised crosswalk at Oakland Road serves the same purpose at the Walnut Path raised crosswalk; however, the crosswalk is not coupled with curb extension. The Oakland Road intersection is approximately 410 feet east of the Cypress Street signalized intersection, and this raised crosswalk is spaced approximately 900 feet from the Walnut Path raised crosswalk.

The raised crosswalk is located across the western Walnut Street leg of the intersection, while the neckdown is located at the northeast corner of the intersection (see Figure No. 5). The crosswalk


N
OAKLAND ROAD
R1-1
24'
CROSSWALK
CATCH BASIN (TYP.)
6' SIDEWALK
SWEL
SHOULDER
DYCL
10'
9'
CROSSWALK
SWEL
CATCH BASIN (TYP.)
DMH
9' BRICK CROSSWALK
W11A-2
CATCH BASIN (TYP.)
PAVEMENT MARKINGS (TYP.)
1' SHOULDER
SWEL
DYCL
10'
10'
6' PARKING LANE
SWEL
TO CYPRESS STREET
7' PARKIN
1' SH
NG LANE
6' SIDEWALK
RAISED CAUTION CROSSING
20 MPH
OM-3L
CATCH BASIN (TYP.)
W11A-2
7' RAMP (SLOPE=9.4%)
6.5' RAMP (SLOPE=3.6%)
OM-3L

is approximately nine feet wide with 7-foot ramps. The height of the raised crosswalk is approximately five inches. Field measurements utilizing the Smart Level revealed that the ramp slopes are 3.6% for the east side and 9.4% for the west side.

The neckdown curb extension at the northeast corner of the intersection is approximately thirty-two feet long. It extends approximately 5.5 feet from the existing sidewalk edge into the roadway. There are catch basins at the northeast, southeast and southwest corners of the raised crosswalk, one in the middle of the intersection and on at the southeast corner of the intersection to drain roadway runoff. The materials used for the raised crosswalk consist of brick pavers on the crosswalk area and cement concrete ramps. The neckdown is constructed of granite curb with cement concrete for the curb extension area. The neckdown curb extension narrows the Walnut Street travel lane to 9 feet and 10 feet for the westbound and eastbound travel directions, respectively. The westbound 9-foot travel lane does not meet the Massachusetts Highway Design Manual and AASHTO design standards for a collector street. A one-foot shoulder is provided on the north side of the street. The sub-standard lane width (9- foot) is unsafe from an operational standpoint. A one-foot shoulder is provided on the north side of Walnut Street.
The 6.0-foot width on-street parking lane does not meet the 7-foot minimum requirement outlined in the Massachusetts Design Manual and AASHTO design standard for collector streets. The narrow parking lanes create safety problems and impede traffic flow along Walnut Street.

Pedestrian crossing signs (W11A-2) are posted on each side of the street at the approaches to the raised crosswalk for both travel directions. An object marker (OM-3L) is posted on the eastern corner of the neckdown, which is visible by westbound traffic. Advanced "Caution Raised Crossing" warning signs with a 20 mph advisory speed signs as well as the "Slow Raised Crossing" signs supplemented with "300 Feet Ahead" plaque are posted to alert motorists of the raised crosswalk. The pavement markings are similar to the Walnut Path raised crosswalk, consisting of two white triangular [shark's tooth] markings on the approach ramps of the raised crosswalk, transverse lines of increasing length and decreasing spacing approaching the ramps on either travel direction. These markings are consistent with the MUTCD guidelines.

The west side of the ramp slope (9.4%) exceeds the industry standard for raised crosswalk which

is 8% for a 20 mph travel speed. However, the east side of the slope (3.6%) is less than 8%, which allows vehicles to cross the raised crosswalk at speeds greater than the 20 mph posted advisory speed. The substandard slope accounts for the pavement injury that exists in the area departing the raised crosswalk from both the travel directions. The scraped pavement indicates that vehicles are traveling at high speeds exceeding the posted 20 mph advisory speed when crossing the raised crosswalk and bottoming out as they depart from the device. The speeding at the raised crosswalk is also due to the wide spacing between the two raised crosswalks.

The overall device is well constructed with no signs of deteriorating material or loose curb or brick paver joints. Similarly, the overall design of the device meets the minimum design criteria for a raised crosswalk as outlined in the ITE Traffic Calming State of the Practice with the exception of the raised crosswalk ramp slope and the neckdown, which reduce the travel lane width to 9 feet.

Despite the pavement scrapings made by speeding drivers, based on a survey of the residents and users, the perception of the raised crosswalk is positive for providing safety to pedestrians and forcing vehicles to slow down as they approach the raised crosswalk.

Median / Island Treatment and Curb Extension at Walnut Street / Warren Street

This intersection consists of Walnut Street running in an east/west direction and Warren Street running in a north/south direction. Walnut Street has a north and south leg which both connect with Warren Street to form a triangular intersection with a landscaped delta island in the middle, as shown in Figure 6. The southwestern portion of this three-legged intersection has Walnut Street approaching from the east and west, while Warren Street approaches from the north and south.

At the eastern point of the delta island, Walnut Street is divided into a westbound, eastbound and a northeastbound approach to form a skewed T-intersection. The northeastbound approach consists of a granite-curb median/island separating the northbound and southbound directional traffic flow. A curb extension is constructed between the northeastbound and westbound approaches to form a more perpendicular approach for the purpose of reducing vehicular speed

approaching the intersection. The raised median is approximately twenty feet long and four feet wide and is constructed of granite curbing and asphalt. A crosswalk is painted across the westbound approach lane of the intersection. This T-intersection is a two-way, stop-controlled intersection with eastbound and northbound approaches controlled by Stop signs (R1-1). The raised median is shown in Figure 6.

Figure 6
Raised Median/Island Treatment and Curb Extension at Walnut Street / Warren Street Intersection (eastern side)

The Walnut Street westbound approach to Warren Street at the northwestern point of the delta island is also under Stop control. Pedestrian sign (W11-2) are visible by motorists traveling westbound along Walnut Street, as well as along the Warren Street southbound and northbound approaches. These two points of the intersection (east and southwest of the delta island) also have painted crosswalks. At the raised median, keep right signs (R4-7), are visible by motorists approaching from both the northbound and southbound directions. Along Warren Street between the two legs of Walnut Street, a "Slow" warning sign is posted for southbound traveling vehicles. Additional roadway alignment signs (W1-10) are posted along Warren Street warning drivers of upcoming curves and intersections. The Warren Street roadway alignment consists of a 4 to 5% downgrade from the south. The Walnut Street vertical alignment within the triangular intersection is approximately 3% downgrade from the west and southwest directions. The eastern sections of Walnut Street have an approximate 3 to 7% downgrade in the eastbound direction


STOP

The overall construction of the Median/Island Treatment and Curb Extension is well constructed with no signs of deteriorating material or loose curb joints. Similarly, the overall design of the device meets the minimum design criteria for a curb extension and median/island treatment.

Although the southwestern portion of the triangular intersection is evaluated to be satisfactory from a traffic calming standpoint, we recommend continued monitoring of the overall triangular intersection locations for traffic safety operations.

Chicanes Along Walnut Street

Chicanes are curb extensions that alternate from one side of the street to the other, forming S-shaped curves. They are also referred to as *deviations*, *serpentines*, *reversing curves*, or *twists*. A well-designed chicane may still appear to permit speeding by drivers cutting straight paths across the center line or testing their skills on the curves. It should be noted that European manuals recommend shifts in alignment at least one-lane width, deflection of at least 45 degrees, and center islands to prevent drivers from taking a straight "racing line" through the feature. According to ITE, a chicane can be achieved by alternating on-street parking from one side of the street to the other. Parallel parking, angled parking, or a combination may be used. This treatment can be as simple as Restriping to delineate parking bays. Or it can include landscaped curb extensions to beautify the street, screen unsightly parking, and create protected parking bays.

The chicanes on Walnut Street begin immediately west of High Street and end at Cypress Street. This section of Walnut Street is approximately 2,450 feet long. The chicanes between High Street and #103 Walnut Street (approximately 240 feet west of High Street) shifts the horizontal roadway alignment to the south, with parking along the northern side of the roadway, and then the alignment is shifted to the north with parking on the south from this point to Walnut Place. From Walnut Place to #263 Walnut Street (approximately 120 feet west of Oakland Road), the chicane shifts the roadway alignment to the south with parking on the north. The remaining chicane ends at Cypress Street with the roadway alignment shift to the north and parking on the south side of the roadway.

There are two types of chicanes along Walnut Street, namely pavement marking bays and granite curb extensions. The chicanes vary in size according to location. The pavement-marking-chicane at #103 Walnut Street is approximately forty feet long and extends 6 feet into Walnut Street. The granite curb extension chicane at Walnut Place is approximately fifty-nine feet and eighty-four feet long on the northern and southern sides of Walnut Street, respectively, and extend five feet into the roadway. The chicanes west of Oakland Road are approximately forty feet long and sixty feet long on the northern and southern sides of Walnut Street, respectively, and extend approximately 5 feet into the roadway. The materials used for the Walnut Street curb extension chicanes include granite curbing and cement concrete for the curb extension area.

The standard double yellow center line pavements markings and single white edge and parking lane lines, are provided within the chicane areas delineating the shifting of the roadway alignment. Pavement markings that alternate on-street parking from one side of the street to the other are provided along Walnut Street to correspond with the chicane treatment. Parking lane widths are approximately 6 feet with the exception of the parking lane east of Cypress Street, which are 7 feet wide. The 6-foot parking lane widths do not meet AASHTO and MassHighway Design Manual standards of minimum 7-foot wide parking lane for residential area and collector road. The travel lane widths vary from 8.5 to 11 feet with one-foot shoulders where on-street parking is prohibited. The 8.5 foot travel lane does not meet MassHighway design standards or AASHTO standards which call for a minimum of 10 foot travel lanes for collector roads. Chicanes with pavement markings delineating parking bays instead of a curb extension are provided at #103 Walnut Street. There are object markers (OM-3R) posted at all the curb extension chicanes and advanced reverse curve warning signs (W1-4) informing motorists of the roadway alignment shift between chicanes. The overall signage along the Chicane treatment between High street and Cypress Street is excessive and does not conform to the MUTCD guidelines for signage placement. These signs are closely spaced together and contain too much information within a short section of roadway, making it difficult for motorists to comprehend all the information.

There are no catch basins located in the vicinity of the chicanes to drain roadway runoff, creating a potential ponding area on the high side of the neckdown where the curbline extends into the roadway.

The chicanes are well constructed with no signs of deteriorating material or loose curb joints; however, the overall design of the chicane treatment by narrowing the travel lane and parking lane to 8.5 feet and 6.0 feet respectively does not meet the minimum AASHTO and MassHighway design criteria for collector roads.

2.3 Spacing of Traffic Calming Devices

The ITE Traffic Calming State of the Practice provides specific guidelines for the spacing of vertical devices, however, guidelines for the spacing of horizontal devices such as neckdowns, and chicanes are limited.

The wide spacing (approximately 950 feet) between the two vertical devices (i.e. raised crosswalks) along Walnut Street provides vehicles with the opportunity to speed between devices. This distance greatly exceeds the ITE recommendation. It should be noted that ITE studies for spacing of vertical traffic calming devices, such as speed humps and raised crosswalks, indicate that speeds increase approximately 0.5 to 1.0 mph for every 100 feet of separation for vertical device spacing up to 1,000 feet. Furthermore, ITE indicates that on a street with desirable maximum operating speed of 30 mph, experience has shown that vertical devices should be spaced at approximately 250-foot intervals. Therefore the 250-foot interval is used as a guide for evaluating the device spacing. It is important to note that ITE also indicated that horizontal devices such as chicanes may still permit speeding by motorists cutting straight paths across the centerline of the roadway.

The spacing of the traffic calming devices from High Street to Cypress Street are as follows:

1) High Street (Chicane) to #103 Walnut Street (Chicane) - 240 feet
2) #103 Walnut Street (Chicane) to Upland Road (Neckdown) - 240 feet
3) Upland Road (Neckdown) to Irving Road (Neckdown) - 220 feet

4) Irving Road (Neckdown) to Walnut Path (Raised Crosswalk) - 280 feet
5) Walnut Path (Raised Crosswalk) to #175 Walnut Street (Chicane) - 310 feet
6) #175 Walnut Street (Chicane) to Oakland Road (Neckdown/Raised Crosswalk) - 640 feet
7) Oakland Road (Neckdown/Raised Crosswalk) to #263 Walnut Street (Chicane) -110 feet
8) #263 Walnut Street to Cypress Street (Chicane) - 340 feet

The spacing between the chicanes and neckdowns are spaced within the 250 foot intervals with the exception of the chicane at #175 Walnut Street and the raised crosswalk at Oakland Road, which is approximately 640 feet.

The wide spacing of the devices between the raised crosswalks at Oakland Road intersection and the chicane at #175 Walnut Path (approximately 640 feet apart) provides opportunity for motorists to speed between these two devices.

2.4 Maintenance of Traffic Calming Devices

There can be increased maintenance associated with traffic calming devices such as raised crosswalks with curb extensions and neckdowns due to the vertical and/or horizontal intrusion into the roadway. Damage by, or to snow plows is one example. Additional effort may be required by maintenance crews to clear debris and snow accumulated in and adjacent to the traffic calming device. Discussions with the DPW personnel and field investigations during the winter months confirmed that there was snow and debris accumulated in and adjacent to several of the traffic calming devices on Walnut Street.

There is pavement damage within the departure area adjacent to the raised crosswalk ramps in both travel directions. However, discussions with the DPW personnel indicate that no maintenance has been performed in these areas despite the pavement damage caused by vehicles bottoming out.

The traffic calming devices are well constructed with no signs of deteriorating material such as loose curb joints or brick pavers.

2.5 Safety Analysis

Accident records were compiled for the entire length of Walnut Street between High Street and Warren Street to determine the trend in accident occurrences before and after the implementation of the traffic calming devices. The data was compiled from Massachusetts Highway Department records from January 2000 to October 2000 and Brookline Police Department records from November 2000 to November 2002. Table 2-1 summarizes the total number of accidents that occurred on Walnut Street over the past three years. A breakdown of the type of accidents that occurred during the three year study period is provided in Table 2-2.

Table 2-1
Accident Data Summary

Year	Property	Injury	Fatality	Total
2000	10	9	0	18
2001	9	0	0	9
2002	7	1	0	8
Total	**26**	**10**	**0**	**36**

The trend in the total number of accidents over the past three years shows a significant decline in the number of accidents. The accident data indicates 50% decline of accidents that occurred in the year before and after implementation of the traffic calming devices. Approximately 30% (3 accidents) of the reported accidents in 2001 occurred prior to June, the month in which the final traffic calming devices were installed on Walnut Street. In addition to decline of the total number of accidents, Table 2-3 indicates that there were no accidents involving pedestrians or bicycles during 2001 and 2002.

Table 2-2
Accident Type Summary

Year	Angle	Rear-End	Head-On	Unknown	Total
2000	5	5	0	8	18
2001	1	0	0	8	9
2002	0	0	0	8	8
Total	**6**	**5**	**0**	**25**	**36**

Table 2-3
Accident Data Summary

Year	Pedestrians	Bicycles
2000	2	0
2001	0	0
2002	0	0
Total	**2**	**0**

Since there was less than two years of accident data available following installation of the traffic calming devices, the town should continue to monitor the accidents on Walnut Street and collect additional accident data in the future to further evaluate the potential effects of the traffic calming devices on pedestrian and vehicular safety.

2.6 Traffic Volumes and Speeds

As part of this evaluation traffic counts and vehicular speed records collected before and after the traffic calming devices were installed on Walnut Street were reviewed and analyzed. The data collection was performed by the town, and consisted of multi-day Automatic Traffic Recorder (ATR) counts on Walnut Street in August of 1998 and March and April of 2002. The data was collected immediately east and west of Walnut Place. The ATR data consists of directional traffic volumes and speed data. Table 2-4 and Table 2-5 below summarize the findings from the traffic data.

Table 2-4
Directional Traffic Volumes

Date of Count	Direction	ADT (vpd)
August 1998	Eastbound	1399
August 1998	Westbound	1945
March 2002	Eastbound	1743
March 2002	Westbound	1014

The traffic data revealed that the traffic volumes for the eastbound travel direction increased, whereas the westbound travel direction decreased following implementation of the traffic calming devices on Walnut Street. The eastbound average daily traffic (ADT) increased at an average annual rate of approximately 5.7% per year from 1998 to 2002, whereas the westbound

ADT decreased at an average annual rate of approximately 17.7%. The traffic volume decrease has been approximately 4.9% per year. It should be noted that according to the town's Transportation Department, the annual background growth for Brookline is approximately 1.0% per year and the background growth is included in the ADT. Based on the traffic volume data, the traffic calming devices have reduced cut-through traffic on Walnut Street in the westbound direction.

Table 2-5
Speed Data

Date of Count	Direction	Vehicle Speed (mph)	
		50th Percentile	85th Percentile
August 1998	Eastbound	30	33
August 1998	Westbound	28	33
March 2002	Eastbound	25	30
March 2002	Westbound	25	29

There are no posted speed limit signs along Walnut Street with the exception of the school speed limit signs within the Lincoln Elementary School area. Therefore, the 30 mph Prima Facie speed limit governs along Walnut Street. Based on the speed study, the 85th percentile speed, the speed at or below which 85% of all vehicles are traveling, decreased by three to four miles per hour following implementation of traffic calming devices on Walnut Street. Comparing the 50th percentile speeds, which are the average or mean speeds, the eastbound speeds have decreased from 30 mph to 25 mph while the westbound speeds decreased from 28 mph to 25 mph. Therefore, based on the speed study, the traffic calming devices have a positive effect on the reduction of vehicle speeds along Walnut Street. It should be note that the speed study is based on data collected at one location in August 1998 (before installation of the traffic calming devices) and at one location in March 2002 (after installation of the traffic calming devices). Although the speed data may not be representative of the travel speeds throughout the length of the Walnut Street roadway corridor, the traffic calming devices, especially the raised crosswalks, have reduced vehicle speeds and provided safety for pedestrians. For future monitoring purposes, additional speed data should be collected at multiple locations along Walnut Street, specifically at locations where the traffic calming devices are spaced greater than 600 feet apart, to further evaluate the overall effectiveness of the traffic calming devices in reducing speed.

2.7 Community Input

Involving the public is an essential element to an effective neighborhood traffic calming plan. Because traffic calming addresses quality of life issues, it is important to consider a wide range of perspectives, observations and perceptions as well as engineering data.

In November and December, 2002 efforts were made to survey abutters on Walnut Street to solicit concerns and feedback on the effectiveness of the traffic calming devices on Walnut Street. Initially personal interviews were attempted at each residence. If no one was available to be interviewed, a pamphlet was left asking residents to call or e-mail BETA to provide their input. The survey was successful, with at least one dozen area residents responding and expressing their likes and dislikes concerning traffic calming on Walnut Street. The residents' comments are as follows:

- The residents had expressed concerns of excessive signage related to the traffic calming devices. They feel as though fewer, better-placed signs would be more effective.
- The spacing of the raised crosswalks was also noted by the residents indicating the wide spacing provides opportunity for motorists to speed between devices. A "drag strip" is created between the two raised crosswalks as vehicles speed from one raised crosswalk to the next to make up for lost time slowing down for each device.
- Sport utility vehicles and trucks drive at much higher speeds than cars over the raised crosswalks, and therefore defeat the purpose of the devices.
- Some residents indicated that a vehicle traveling at excessive speeds, while traversing the raised crosswalks, also invites opportunity for loss of vehicle control, specifically during the winter months, thereby creating safety hazards.
- On-street parking has also been an issue for residents. They feel as though the number of available on-street parking spaces has been reduced and relocated to the wrong side of the street. For instance, in the vicinity of Upland Road and Irving Street, the houses along the southern side of Walnut Street have mostly off-street parking availability (i.e. driveways), whereas the residences along the northern side rely on on-street parking, which was removed from the northern side of the street to the southern side.

- Some residents provided positive feedback on the effectiveness of the raised crosswalks in forcing vehicles to slow down and ensuring pedestrian safety.

The Lawrence School was also contacted to solicit input and concerns regarding the traffic calming devices on Walnut Street. The school indicated the effectiveness of the raised crosswalk at Walnut Path which forces vehicles to slow down at the crosswalk, thus ensuring pedestrian safety. Residents abutting this raised crosswalk also indicate that it is effective from a pedestrian safety standpoint. However, residents abutting the raised crosswalk at Oakland Road indicate that the raised crosswalk is ineffective in reducing vehicle speeds and it has created a lot of noise resulting from vehicles traversing the crosswalk and bottoming out by scraping the roadway pavement.

At the request of the Greek Apostolic Church, we met with a representative of the Church at the site location to discuss the Church's concerns related to on-street parking and traffic calming. The church is located adjacent to the Walnut Street intersection with Upland Road. The church stated the following concerns related to the implementation of the traffic calming devices:

- The on-street parking was relocated from the north side of Walnut Street to the south side, which was inappropriate due to the fact that most homes with driveways are located along the southern side of the roadway. With the on-street parking along the south side of Walnut Street forcing residents that live along the north side to cross the street, as they were not required prior to the traffic calming implementation.
- The section of Walnut Street abutting the church, adjacent to the neckdown at the southeast corner of the intersection with Upland Road, is too narrow for vehicles to safely pass. Vehicles travel too closely to pedestrians standing at the curb extension sidewalk edge waiting to cross Walnut Street. Side mirrors of vehicles often cross the plane of the curb's edge and extend over the sidewalk, which could potentially hit pedestrians.
- The church requests on-street parking abutting the church on the north side of Walnut Street and not the south side of Walnut Street.

SECTION 3 SUMMARY OF FINDINGS

3.1 Design and Construction

Neckdown at Upland Road

The design and construction of the physical neckdown is consistent with standard traffic calming design and installation practiced nationally by communities identified in the ITE Traffic Calming State of the Practice. However, the following deficiencies were discovered at this location.

- The westbound roadway width (8.5') and parking lane width (6.0') do not meet AASHTO and MassHighway design standards which call for a minimum of 10'travel lanes and 7' parking lane for collector roads.
- The crosswalks on the Upland Road and Walnut Street approach are located too far away from the intersection, approximately 15 feet south and east of the intersection respectively.
- The turning radius for vehicles turning in and out of Upland Road from Walnut Street is tight due to the neckdown curb extension.
- There are no catch basins provided at the eastern side of the neckdown curb extension.

Neckdown at Irving Road

The physical neckdown curb extension east of Irving Road is consistent with industry standards; however, the following deficiencies were discovered at this location.

- The westbound roadway width (9') and parking lane width (6.0') do not meet AASHTO and MassHighway design standards.
- Vehicles are parked too close to the southwest corner of the intersection restricting sight lines at the Irving Road approach.
- The turning radius for vehicles turning in and out of Irving Road from Walnut Street is tight due to the neckdown curb extension.
- There are no catch basins east of Irving Road.

Raised Crosswalks with Curb Extension at Walnut Path

The devices are well constructed with no signs of deteriorating material or loose brick paver joints. However, the following deficiencies were discovered:

- The raised crosswalk ramp slopes (10% and 2.9%) were not constructed to industry standards for a 20 mph design speed which calls for an 8% slope. The reduced ramp slopes permit vehicles to traverse the raised crosswalks at speeds greater than the posted 20 mph advisory speed. Thus causing vehicles to bottom out as they depart the raised crosswalk and causing pavement damage and potential safety concerns.
- The advanced "Caution Raised Crossing" warning signs are confusing. The existing pedestrian crossing sign (W11A-2) located at the raised crosswalk implies a conventional crosswalk not a raised crosswalk. The signage within the vicinity of the raised crosswalk work area is excessive with information related to
    - Raised crosswalk
    - Chicanes
    - School zones speed limits
    - Neckdowns object markers
    - Parking restrictions
- The 8.5 foot wide westbound travel lane and 6.0 foot parking lane do not meet AASHTO and MassHighway design standards.
- There are no catch basins located immediately east of the raised crosswalk.

Raised Crosswalk and Neckdown at Oakland Road

The raised crosswalk and neckdown at Oakland Road are well constructed with no signs of deteriorating material or loose joints. However, the same deficiencies concerning ramp slope and signage at the Walnut Path raised crosswalk are present at this raised crosswalk.

- The raised crosswalk ramp slopes (3.6% and 9.4%) were not constructed to industry standards for a 20 mph design speed which calls for an 8% slope. The reduced ramp slopes permit vehicles to traverse the raised crosswalks at speeds greater than the posted 20 mph advisory speed. Thus causing vehicles to bottom out as they depart the raised

crosswalk and causing pavement damage and potential safety concerns.

- The advanced "Caution Raised Crossing" warning signs are confusing. The existing pedestrian crossing sign (W11A-2) located at the raised crosswalk implies a conventional crosswalk not a raised crosswalk. The signage within the vicinity of the raised crosswalk work area is excessive with information related to
    - Raised crosswalk
    - Chicanes
    - Neckdowns object markers
    - Parking restrictions

Island Treatment and Curb Extension at Warren Street

This intersection is well constructed at the eastern and northwestern corners of the large delta island. The overall device is well constructed with no signs of deteriorating material or loose curb joints. Similarly, the overall design of the device meets the minimum design criteria for a curb extension and median/island treatment.

Although the southwestern portion of the triangular intersection is evaluated to be satisfactory from a traffic calming standpoint, we recommend that the overall triangular intersection locations be monitored in the future for traffic safety operations.

Chicanes Along Walnut Street

In general, the chicanes are well constructed; however, there are some deficiencies with the overall design of the chicanes as it relates to parking and lane width configurations, and signage.

- The 6-foot parking lane widths do not meet AASHTO and MassHighway Design Manual standards of minimum 7-foot wide parking lane for residential area and collector road. The travel lane widths vary from 8.5 to 11 feet with one-foot shoulders where on-street parking is prohibited. The 8.5 foot travel lane does not meet MassHighway design standards or AASHTO standards which call for a minimum of 10 foot travel lanes for collector roads.
- The overall signage along the Chicane treatment between High street and Cypress Street is excessive. These signs are closely spaced together and contain too much information

within a short section of roadway, making it difficult for motorists to comprehend all the information.

- There are no catch basins located in the vicinity of the chicanes to drain roadway runoff, creating a potential ponding area on the high side of the neckdown where the curbline extends into the roadway.

3.2 Spacing of Devices

The vertical traffic calming devices on Walnut Street are spaced too far apart, which provides an opportunity for motorists to increase speed between the devices.

3.3 Maintenance

There is increased maintenance associated with traffic calming devices such as raised crosswalks and neckdowns due to the vertical and/or horizontal intrusion into the roadway. Additional effort may be required by maintenance crews to clear debris and snow accumulated in and adjacent to traffic calming devices.

There is pavement damage within the departure region adjacent to the raised crosswalk ramps in both travel directions. These areas will eventually require repair to eliminate potential safety problems associated with the damaged pavement.

3.4 Safety Analysis

The total number of accidents that occurred in the years immediately before and after the implementation of the traffic calming devices shows a significant decline from nineteen to nine accidents. In addition to the decline of the total number of accidents, there were no accidents involving pedestrians/bicycles in 2001 and 2002 after the implementation of the traffic calming devices. The traffic calming devices have improved the overall safety along Walnut Street.

3.5 Traffic Volumes and Speeds

The average daily traffic increased at an average annual rate of approximately 5.7% per year from 1998 to 2002 for travel in the eastbound direction, while westbound travel decreased approximately 17.4%. The overall traffic volumes have reduced approximately 4.9%. Based on

the traffic volume data, the traffic calming devices have reduced cut-through traffic on Walnut Street for westbound travel.

Based on the speed study, the 85th percentile speeds following implementation of traffic calming devices on Walnut Street reduces three and four mph for eastbound and westbound travel, respectively. Comparing the 50th percentile speeds, both travel directions' speeds reduced to 25 mph from 30 mph in the eastbound direction and 28 mph in the westbound direction. Therefore, the traffic calming devices had a positive effect in reducing vehicle speeds on Walnut Street.

SECTION 4 RECOMMENDATIONS

The following recommendations were developed based on an evaluation of the existing traffic calming devices on Walnut Street. It is recommended that the proposed modifications follow the town's Traffic Calming Policy and Procedures for conformance with the overall traffic calming implementation process.

4.1 General Recommendations

Although the evaluation revealed that the traffic calming devices have provided a positive effect on roadway vehicle speeds, accidents and cut-through traffic, we recommend that the Town continue to monitor the overall effectiveness of the traffic calming devices on Walnut Street for a period of six to twelve months. Due to the short time span between the final installation of the traffic calming devices and the traffic volume, speed and accident data collected for this study, additional monitoring will provide a better basis for determining the effectiveness and potential safety impacts of the traffic calming measures implemented on Walnut Street.

In addition, we recommend the following improvements for the traffic calming devices along Walnut Street.

4.2 Improvements

Signage Improvements

- Provide a traffic calming "Gateway" sign at each end of Walnut Street between High Street and Cypress Street. The gateway sign will consist of the message " Entering Traffic Calming Area" and will be installed at the entrance of Walnut Street from both High Street and Walnut Street. The gateway signs will be supplemented with a "Reduce Speed" or 25 mph Advisory Speed plaque mounted below the gateway signs. With the implementation of these gateway signs, we recommend removing all of the advance warning signs associated with the traffic calming devices. Hence, the existing overload of signage information resulting from the excessive signage will be improved.
- Remove existing advance warning signage for raised crosswalks and chicanes.

Neckdown at Upland Road

- Restrip travel lane width and parking lane to provide a 7 foot parking lane and 10 foot travel lane to conform with AASHTO and MassHighway design standards for parking and lane widths for collector roads.
- Consider relocating the crosswalks closer to the intersection.
- Consider improving the curb extension radius at the intersection to allow adequate vehicle turning radius from Upland Road onto walnut Street.
- Install catch basins east of the neckdown curb extension to prevent ponding of water at the curb extension.

Neckdown at Irving Road

- Restrip travel lane and parking lane widths to provide a 7 foot parking lane and 10 foot travel lane to conform with AASHTO and MassHighway design standards for travel lane and parking widths for collector roads.
- Consider improving the curb extension radius at the intersection to improve vehicle turning in and out of Irving Road.
- Restrict parking 20 feet from the curb extension at the southwest corner to improve sight lines for the Irving Road approach.
- Install catch basins east of the neckdown curb extension to prevent ponding of water at the curb extension.

Raised Crosswalk with Curb Extension at Walnut Path

- Restrip travel lane and parking lane widths to provide a 7 foot parking lane and 10 foot travel lane to conform with AASHTO and MassHighway design standards for travel lane and parking widths for collector roads.
- Improve raised crosswalk ramp slopes to meet industry standards for a 20 MPH design speed, which calls for an 8% slope.
- Install catch basins east of the raised crosswalk to prevent ponding of water at the ramp at the eastern edge of the crosswalk.
- Replace the existing pedestrian crossing sign (W11A-2) with "Raised Crossing" sign.
- Removed advance signage for raised crosswalk. Also, see signage improvements section.

Raised Crosswalk and Neckdown at Oakland Road

- Restrip travel lane and parking lane widths to provide a 7 foot parking lane and 10 foot travel lane to conform with AASHTO and MassHighway design standards for travel lane and parking widths for collector roads.
- Reconstruct raised crosswalk ramp slopes to meet industry standards for a 20 MPH design speed, which calls for an 8% slope.
- Replace the existing pedestrian crossing sign (W11A-2) with "Raised Crossing" sign.
- Removed advance signage for raised crosswalk. Also, see signage improvements section.

Chicanes along Walnut Street

- Restrip travel lane and parking lane widths to provide a 7 foot parking lane and 10 foot travel lane to conform with AASHTO and MassHighway design standards for travel lane and parking widths for collector roads. Due to the narrow roadway width (27 feet) on Walnut Street, the one foot shoulder will not be required.
- Install additional catch basins on the high side of the chicane to drain roadway runoff which may collect at the curbline extension.
- Removed advance signage for chicane. Also, see signage improvements section.