Technical Memorandum

Consideration of Tunnel Alignment Alternatives

Green Line Extension Project

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Introduction

This chapter will provide an overview of the intent of this document, as well as an overview of the various tunnel alignments proposed.

1.1 Overview

A number of suggestions for incorporating tunnel alignments into the proposed Green Line extension have been suggested by members of the Advisory Committee and the general public. The proposals offer the potential of mitigating some impacts of the extension (e.g., noise and vibration during and after construction) as well as allowing for some variations in the alignment that would be possible with a tunnel alignment.

This memorandum will summarize the proposals received, consider alternative tunnel construction methodologies, examine the feasibility of the tunnel alignment alternatives, and present order-of-magnitude construction cost comparisons.

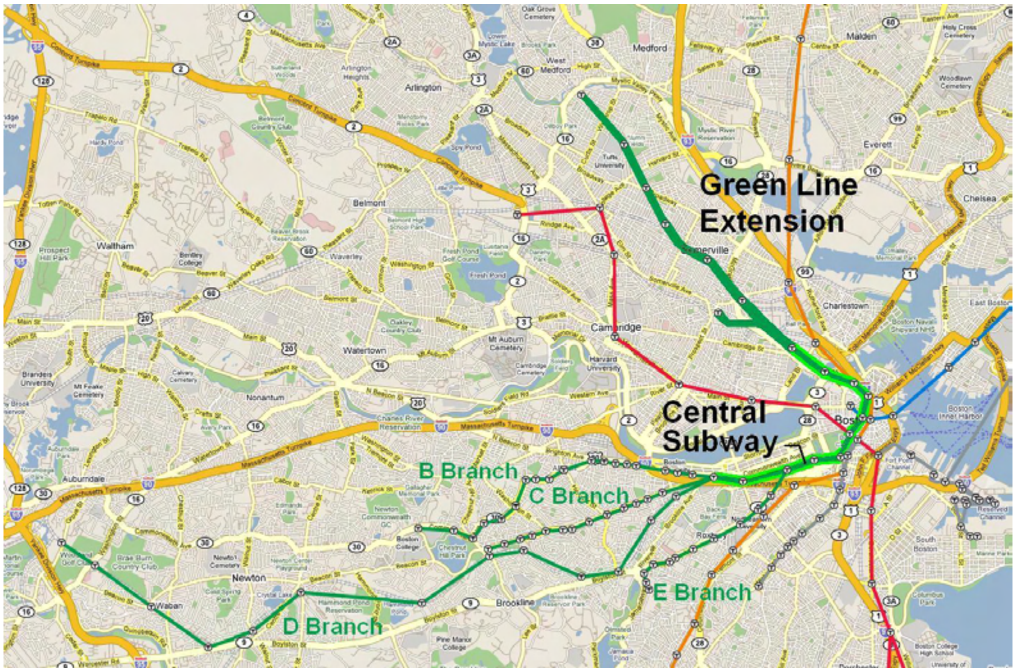
1.2 Overview of Green Line Extension Proposal

The Green Line extension is proposed to include the following elements:

- Relocated Lechmere Station
- Mainline extension along the Lowell Line to College Avenue or Mystic Valley Parkway
- Spur to Union Square

See Figure 1-1.

Figure 1-1: Existing Green Line with Proposed Extension to Somerville and Medford



1.3 Tunnel Alignment Proposals

The following tunnel alignment alternatives have been proposed:

- **Proposal T-1 – Clarendon Hill Tunnel:** Tunnel from Ball Square to Alewife Station via Powder House Square and Clarendon Hill (GLAM tunnel proposal)
- **Proposal T-2 – Medford Hillside Tunnel**: Tunnel from College Avenue to Mystic Valley Parkway/ Route 16
- **Proposal T-3 – Union Square Tunnel**: Tunnel from Prospect Street under Union Square
- **Proposal T-4 – Mainline Tunnel:** Complete tunnel alignment from Lechmere to Mystic Valley Parkway/ Route 16 with branch to Union Square

Consideration of each of these proposals is presented in Sections 2 through 5 of this report.

1.4 Tunnel Construction Technologies

This section presents an overview of typical tunnel construction technologies that are used in urban environments:

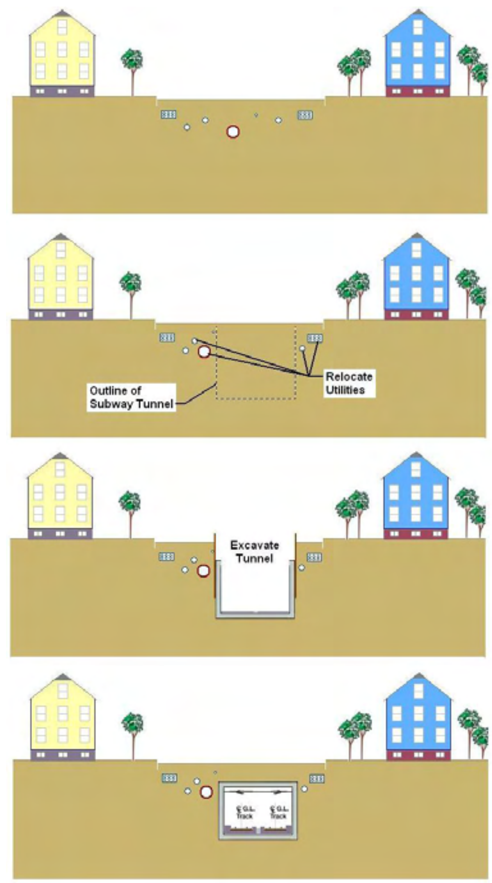
- Cut and cover tunneling
- Depressed section with decking
- Deep bore tunneling

1.4.1 Cut and cover tunneling

Cut and cover tunneling involves excavating the tunnel in an open cut. Excavation begins at the surface and extends downward. The sides of the excavation must be protected by retaining walls, which may be either temporary (e.g., sheeting) or permanent (e.g., slurry walls or traditional reinforced concrete walls). In preparation for excavation, utilities must be relocated or supported in place. Also, traffic must be detoured to create a work zone to perform the excavation.

After the excavation is completed and the permanent wall constructed, the tunnel roof (typically, reinforced concrete) is installed. Figure 1-2 illustrates the steps in constructing a cut and cover tunnel.

Figure 1-2: Cut and Cover Tunneling

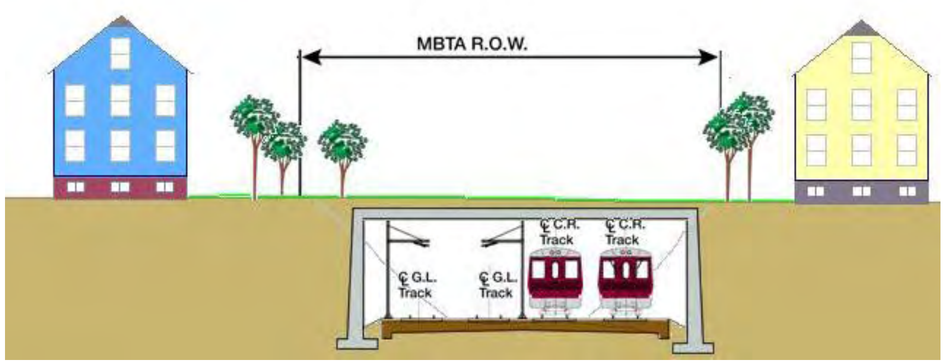


1.4.2 Depressed section with decking

Much of the Green Line extension along the Lowell Line is in a depression or cut section, where the trackbed is about 15 to 20 feet below street level. This provides the opportunity for decking over the tracks, creating sections of tunnel. This approach is used throughout the MBTA's Southwest Corridor.

For the section north of College Avenue, the option of decking over the tracks creates a tunnel section at a lower incremental cost than other methods. Typically, the walls would be required to retain the embankment and widen the trackbed from the existing two tracks to four tracks. Thus, the incremental cost is the decking[1].

Figure 1-3: Depressed Section with Decking – Green Line and Commuter Rail



The decking can provide a visual and noise buffer between the tracks and adjacent residences. The decking can also be landscaped to restore lost vegetative cover due to widening of the trackbed.

1.4.3 Deep bore tunneling

Deep bore tunneling is a mining technique that uses a tunnel boring machine (TBM) operating well below the ground surface. The TBM bores horizontally, creating a circular tunnel. The TBM can drill through rock or any kind of soil. However, the type of TBM used for rock differs from the type used for soil.

The diameter of a tunnel boring can vary from as little as 3 feet to as much as 60 feet. In earth, tunnels are typically about 2 diameters below the surface. For a 20-foot bore, the top of the tunnel would be about 40 feet down or deeper.

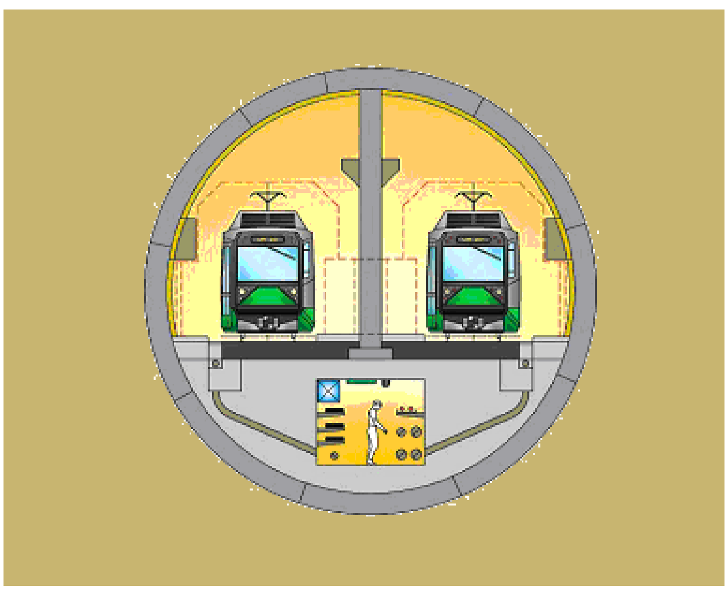
Subway deep bore tunnels are often accomplished as twin bores – one tunnel for each track. This method was used for the Red Line from Harvard Square to Davis Square. See Figure 1-4. For the Green Line, each bore would be about 24 feet, outside diameter.

An alternative approach would be a single larger bore with both tracks in one tunnel. See Figure 1-5. The larger cross section would cost considerably more due to the size of the boring machine required.

[1] The decking also braces the tops of the retaining walls, thus reducing the moment load in the walls. Therefore, even though the walls must carry the additional load of the deck itself, the net benefit of horizontal bracing creates a more efficient wall section.

Figure 1-4: Deep Bore Section below City Street (Twin Bore Configuration)

Figure 1-5: Single Bore Tunnel for Green Line



Source: EOTPW Draft Environmental Impact Report for Urban Ring (Figure 2-20)

2

T-1 – Clarendon Hill Tunnel: Tunnel from Ball Square to Alewife Station via Powder House Square and Clarendon Hill

At the October 25, 2007 Advisory Group meeting, the Green Line Advisory Group for Medford (GLAM) officially submitted a proposal for an Alternative Study for the Green Line Extension project. The request is to perform an additional analysis on this alternative route as an addendum to the current Green Line Extension Draft Environmental Impact Report (DEIR) study.

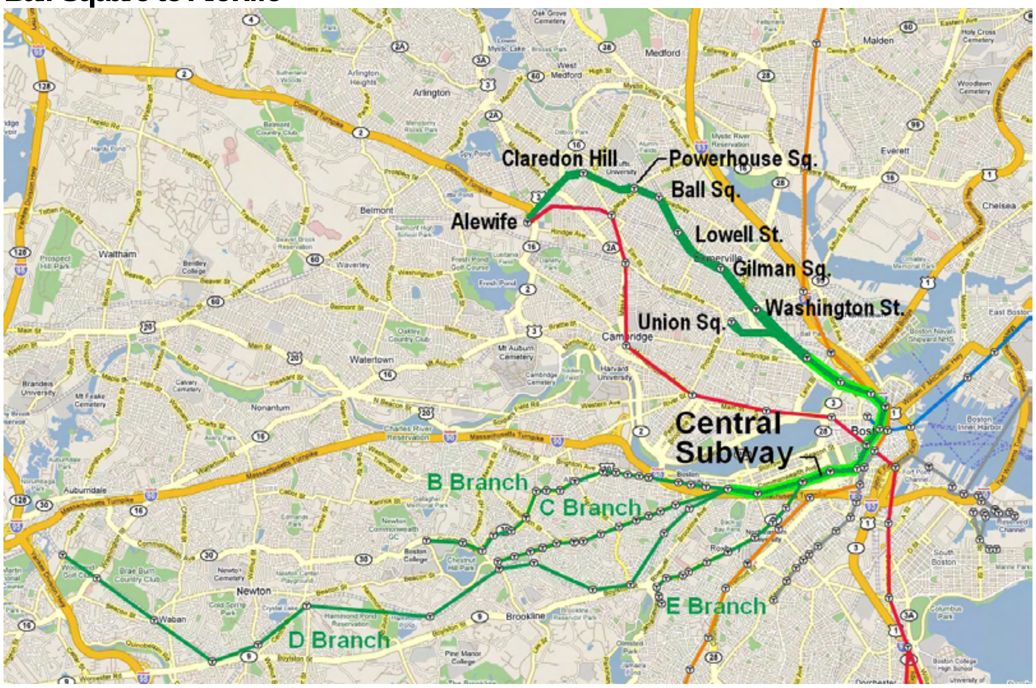
2.1 Description of Proposal

The alignment proposed by GLAM in an October 25, 2007 letter would redirect the current proposed Green Line alignment beginning at Ball Square. Rather than follow the currently proposed alignment along the Lowell Line, the GLAM proposal proposes an alternative alignment that would have it generally follow Broadway in Somerville through Teele Square/ Clarendon Hills until reaching Route 16/ Alewife Brook Parkway. At this point, the proposal suggest the alignment should follow Route 16/ Alewife Brook Parkway until ending at the MBTA's Alewife Station, where it would be co-terminating with the existing Red Line and share the existing parking garage located at the junction of Route 2.

Due to the lack of an existing surface right-of-way (ROW), GLAM has proposed putting the service underground for the majority of its deviation from the currently proposed Green Line alignment. The GLAM proposal suggests stations at Ball Square, Powder House Boulevard, and Clarendon Hill, as well as at the existing Alewife Station. See Figure 2-1 for a map of this proposed alignment.

Additional capacity improvements advocated in the GLAM alternative include expansion of the garage at Alewife to accommodate more riders and the development of a commuter rail/ Green Line intermodal station at Ball Square.

Figure 2-1: T-1 Clarendon Hill Tunnel: Green Line Extension with Tunnel from Ball Square to Alewife



Note: Tunnel segment is from Ball Square to Alewife

2.1.1 Stations Locations and Spacing

Beginning with the diversion from the presently proposed route at Ball Square, stations would be located at intervals of approximately 0.4 to 1.1 miles, as indicated in Table 2-1.

Table 2-1 Station Spacing between Ball Square and Alewife

Segment	Length (Miles)	Route
Ball Sq. to Powder House Sq.	0.4	Broadway
Powder House Sq. to Clarendon Hill	0.8	Broadway
Clarendon Hill to Alewife	1.1	Rt. 16/Alewife Brook Parkway
Tail tracks (600 feet includes switches)	0.1	
TOTAL LENGTH	**2.4**	

Ball Square Station

The alignment approaching Ball Square is along the west side of the Lowell Line right-of-way. At Ball Square, the alignment would curve westward to follow Broadway heading towards Powder House Square.

To transition vertically to the depth of a tunnel, the tracks would need to descend prior to Ball Square, thus making Ball Square an underground station. A likely location for the station might be under Broadway, just west of Boston Avenue. See Figure 2-2.

Figure 2-2: Tunnel T-1 at Ball Square

Powder House Station

The alignment would follow Broadway from Ball Square to Powder House Square in Somerville.

The proposal envisions an underground station at Powder House Square. This station would accommodate Tufts University and the surrounding Somerville neighborhoods. Portions of Medford would also be within walking distance.

The Powder House Station would be about 0.5 miles from the existing Davis Square station, providing some overlap of the catchment areas, but also providing two transit line alternatives for riders in neighborhoods between the stations.

Clarendon Hill Station

The alignment would continue to follow Broadway from Powder House Square past Teele Square to Clarendon Hill.

The proposed station would be located near the MBTA Clarendon Hill bus turn-around. This location is the site of the former streetcar yard. Currently the MBTA owns a small parcel of land that serves as the off-street terminus of bus routes 87 and 88. The proposed station would serve as an intermodal transfer point with these bus lines.

This station would serve the immediate neighborhood and would be within walking distance of Teele Square. It is also within walking distances of residential neighborhoods in Arlington, Somerville and Medford. The site is adjacent to existing high-density housing, an elderly housing project, and low income housing located between Broadway and Powder House Boulevard. This station would also be about 0.5 miles from the existing Davis Square station, providing some overlap coverage and two options for riders who live in between.

Alewife Station

From Clarendon Hill, the alignment would continue west along Broadway to Alewife Brook Parkway. The alignment would turn south and follow the Parkway to the existing Alewife station.

This proposal suggests that the Green Line be co-terminal with the Red Line at the existing Alewife station complex. This would provide a connection between the Red and Green Lines outside the downtown core of the subway system. The Green and Red Lines would share a common garage. The proposal envisions an expansion of the capacity of the garage.

Located at the eastern end of the Route 2 expressway, the station's capture area includes Arlington, Lexington, and other communities in the Route 2 corridor as well as towns along the I-95/ Route 128 corridor.

The Green Line tunnel would need to pass under the Red Line tunnel, which is fairly shallow. A series of interconnecting stairs, escalators and elevators would provide access between the two station platforms and the station fare collection and entrance areas.

Tail Tracks

Typical of all terminal stations on the MBTA subway system, tail tracks would be provided after the platforms at Alewife Station. This allows for temporary storage of an extra train during operating hours as well as a place to temporarily park a disabled train until it can be moved to the maintenance facility. A typical configuration would be 2 or 3 tracks, with turnouts (switches) which connect each tail track with each station track.

2.1.2 Advantages of the Alignment

According to GLAM, benefits of this underground Green Line extension would include:

- The alignment would serve an Environmental Justice (EJ) community near Clarendon Hill/ Teele Square in Somerville
- The underground construction would lessen airborne contaminants for the local community compared to an above ground construction and operation
- There are no environmentally hazardous sites along the proposed alignment whereas there are some sites adjacent to Lowell Line
- Underground construction "lessens the risk of eminent domain" takings

2.2 Consideration of Tunnel Methodology

This alignment deviates from the existing MBTA commuter rail right-of-way and runs under city streets and other roadways. Two tunnels methodologies could be employed:

- Cut and cover
- Deep bore

2.2.1 Cut and Cover Tunnel

Section 1.4.1 and Figure 1-2 present an overview of the cut and cover tunnel construction methodology.

For this methodology to be feasible, the alignment must follow either existing roadways or other undeveloped land where surface construction is possible. As this alignment generally follows both Broadway and Alewife Brook Parkway, it would be possible to construct a cut and cover tunnel.

A second important consideration for this methodology is traffic interruption. As Figure 1-2 illustrates, during the tunnel construction, the roadway would be greatly reduced in width or possibly closed to traffic. This would be difficult, due to the high traffic volumes along both Broadway and especially Alewife Brook Parkway.

The parkway corridor also includes both wetlands associated with Alewife Brook itself and the DCR park reservation. Construction would also impact both these wetland resource areas and the parklands along the corridor.

Other impacts during construction would include noise, vibrations, dust, construction vehicle traffic, and temporary disruptions/ inconveniences to access to businesses and residences.

2.2.2 Deep Bore Tunnel

Section 1.4.3 and Figures 1-4/ 1-5 present an overview of the deep bore tunnel construction methodology.

While the tunnel could be bored from either end, for the purposes of this conceptual analysis, it is assumed that it would be bored from the Ball Square end. A mining shaft would be built near Ball Square to the depth of the tunnel. The tunnel boring machine (TBM) would be lowered in the shaft and tunnel boring would commence.

Though the main tunnel would be bored from underground, surface construction would be required at stations, ventilation shafts and access shafts. For safety during construction, periodic access shafts (about 5,000 feet apart) would be needed for emergency access and evacuation. At these surface construction locations, the impacts would be similar to that of cut-and-cover tunneling.

2.2.3 Conclusions

Based on a preliminary consideration of each method, the use of deep bore tunneling would have less surface impacts along a corridor that includes dense urban development as well as parklands and wetlands.

2.3 Order of Magnitude Additional Cost

An order-of-magnitude estimate was made of the additional cost of this tunnel alternative. The "additional cost" represents the difference between the preferred at-grade alignment along the Lowell Line right-of-way and this tunnel alignment. As such, the costs common to any alternative (e.g., track, power and signals) are not included. Also, no estimate was made of the real estate costs for property takings and easements for the tunnel, stations, shafts and other support facilities including power substations.

Included	Not Included
Tunnel construction	Trackwork
Additional cost of underground stations	Traction power
Tunnel ventilation including ventilation shafts	Signals and communications
Access shafts	
Tunnel lighting	Real estate costs
Tunnel fire protection (dry standpipes)	
Tunnel drainage	

Table 2-2 includes the estimated quantities of work and the additional cost for either a single or double bore tunnel.

Table 2-2 T-1 – Clarendon Hill Tunnel Additional Construction Costs

Item	Quantity	Double Bore	Single Bore
Tunnel Construction	2.4 miles		
Number of Underground Stations	4		
Ventilation Shafts	7		
Access Shafts	3		
Tail Tracks	600 feet		
Tunnel Lighting	2.4 miles		
Tunnel fire protection	2.4 miles		
Tunnel drainage	2.4 miles		
TOTAL LENGTH	**2.4 miles**	**$1.54 billion**	**$2.13 billion**

3

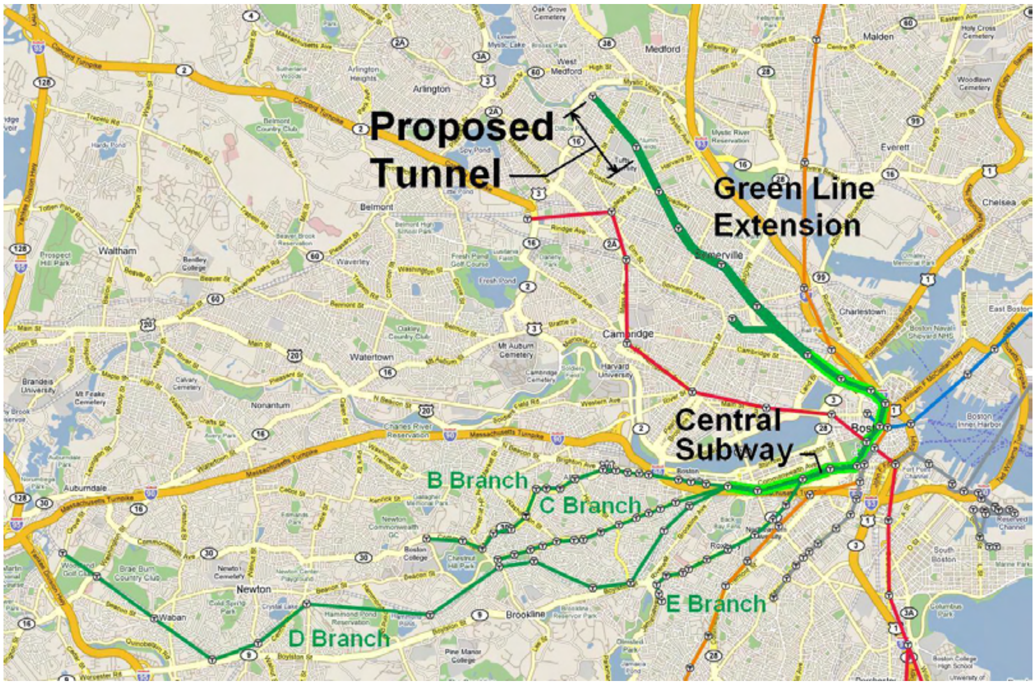
T-2 – Medford Hillside Tunnel: Tunnel along Lowell Line from College Avenue to Mystic Valley Parkway/Route 16

At various Advisory Group meetings, proposals to consider a tunnel alignment within Medford were put forth. The overall alignment would be the same, with stations at College Avenue and Mystic Valley Parkway/ Route 16. However, instead of widening the track bed and relocating the commuter rail tracks, this proposal would have the Green Line run below the ground, thus, minimizing the temporary construction and permanent impacts on the community.

3.1 Description of Proposal

The proposal is to substitute a tunnel alignment in place of the proposed alignment that would locate the Green Line and commuter rail tracks side-by-side in the existing railroad right-of–way. See Figure 3-1.

Figure 3-1: T-2 Medford Hillside Tunnel: College Avenue to Mystic Valley Parkway/Route 16



This proposal was put forth because of the potential benefits of reduced impacts both during construction and thereafter:

- Less impacts during construction:
  - No construction in right-of-way (no removal of trees, no earthwork and construction of retaining walls
  - No relocation of commuter rail tracks to the east side of the right-of-way
- Less impacts after construction:
  - Little to no noise or vibrations from Green Line operations
  - Retains visual buffer of existing vegetation along right-of-way

3.2 Review of Proposal

While the initial proposal would be for a deep bore tunnel under the right-of-way, there are a number of alternative approaches to constructing this segment of the Green Line extension in a tunnel. These options include:

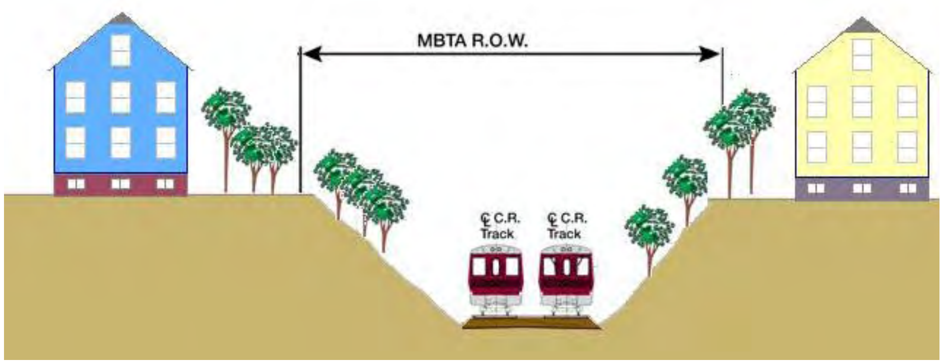
- Deep bore tunnel under MBTA right-of-way
- Deep bore tunnel under Boston Avenue.
- Decking over tracks in MBTA right-of-way

Figures 3-2 through 3-6 provide a comparison of these alternatives with existing conditions and with the proposed Green Line extension next to the commuter rail tracks in an open cut.

3.2.1 Existing Conditions

Figure 3-2 shows the existing two commuter rail tracks in a cut section with vegetated slopes on either side and residential structures near the right-of-way.

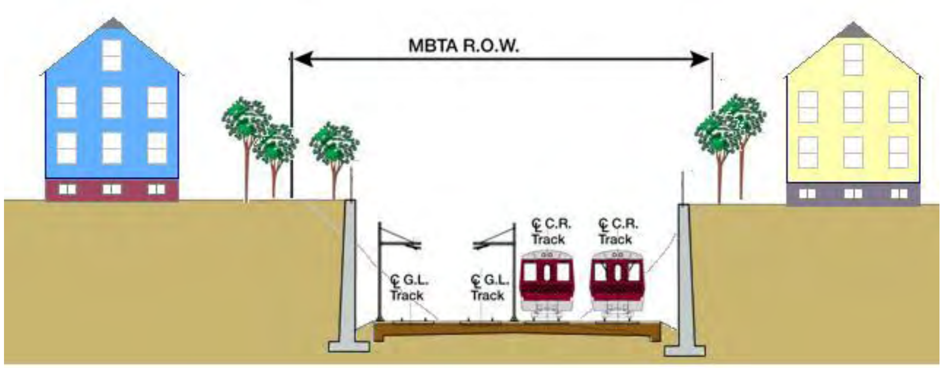
Figure 3-2: Existing Section Looking North



3.2.2 Proposed Extension in Open Cut

Figure 3-3 shows the widening of the cut by installing retaining walls on either side and excavating the slopes, resulting in a loss of the existing vegetation on the slopes. The commuter rail tracks are shifted to the east side of the widened cut. The new Green Line tracks are built along the west side.

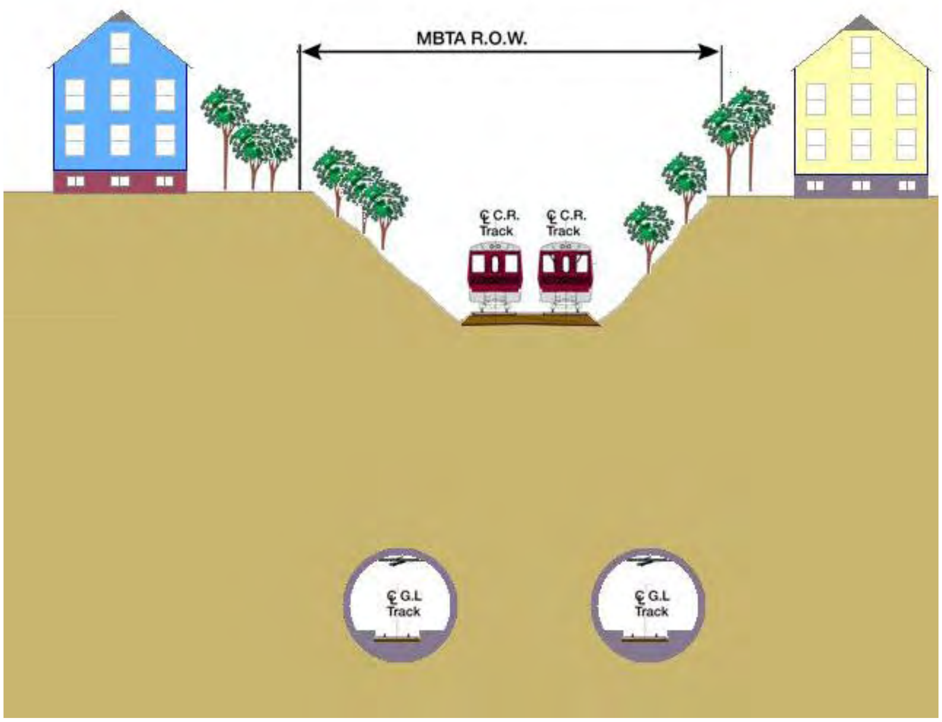
Figure 3-3: Open Cut – Green Line and Commuter Rail



3.2.3 Proposed Deep Bore Tunnel under Right-of-Way

Figure 3-4 shows the Green Line extension in a deep bore twin-tunnel under the right-of-way. To provide at least 2 diameters of cover on the tunnels, the Green Line tracks would be in the order of 60 feet below the existing track bed, or about 80 to 90 feet below street level.

Figure 3-4: Green Line in Deep Bore Tunnel in Right of Way



3.2.4 Proposed Deep Bore Tunnel under Boston Avenue

Since a deep bore alignment directly the Lowell Line right-of-way would result in very deep stations (80 to 90 feet below street level), consideration was given to a deep bore alignment under Boston Avenue. With deep bore tunneling, the alignment does not have to follow the MBTA right-of-way exactly. The tunnel would be well below utilities and building foundations, so there are more options with regard to the horizontal alignment.

By following Boston Avenue, the tunnels could theoretically be shallower. In general, Boston Avenue is about 20 feet higher than the existing Lowell Line trackbed, so the tunnel could also be about 20 feet shallower. See Figure 3-5.

Figure 3-5: Green Line in Deep Bore Tunnel under College Avenue

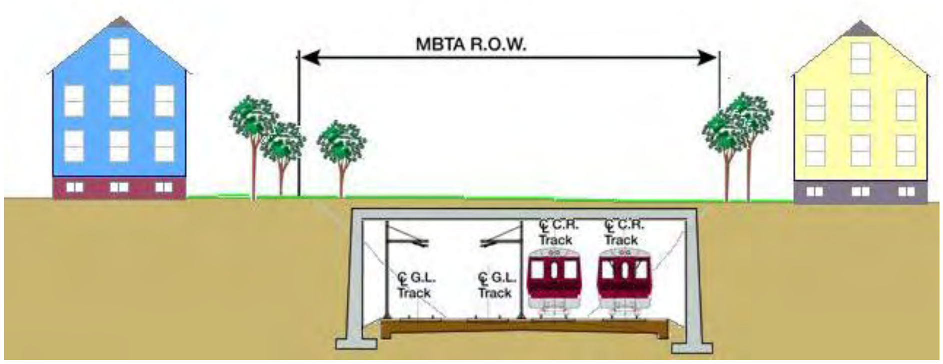
In order to make a final determination, it would be necessary to have detailed subsurface information as to soils types and the depth of bedrock. Current information is limited to some borings at the existing bridges over the tracks at College and Winthrop Avenues.

3.2.5 Alternative Tunnel: Cut & Deck Section

An alternative to deep bore tunneling would be decking over the tracks in the Lowell Line right-of-way. See Figure 3-6.

This alternative would be constructed much in the same way as the proposed extension. The existing cut is widened, the slopes are excavated, retaining walls are installed and the four tracks constructed. The difference is that a deck (or roof) is constructed over the tracks, thus, creating a tunnel.

Figure 3-6: Decking over Tracks – Green Line and Commuter Rail



As Figure 3-6 illustrates, the deck provides a number of advantages to the abutters:

- Removes the visual impact of the tracks
- Reduces noise
- Allows for landscaping over the deck

This alternative would be similar to the Southwest Corridor, where both transit and commuter rail tracks are in a depressed cut with sections of the cut covered in decking.

With this alternative, a key issue is ventilation for the commuter rail tracks, as the passenger and freight trains use diesel locomotives. One approach is to provide sections of decking alternating with sections that are open to the air. The open air sections provide the necessary ventilation.

3.3 Order of Magnitude Additional Cost

An order-of-magnitude estimate was made of the additional cost of this tunnel alternative. The "additional cost" represents the difference between the preferred at-grade alignment along the Lowell Line right-of-way and this tunnel alignment. As such, the costs common to any alternative (e.g., track, power and signals) are not included. Also, no estimate was made of the real estate costs for property takings and easements for the tunnel, stations, shafts and other support facilities including power substations.

Included	Not Included
Tunnel construction	Trackwork
Additional cost of underground stations	Traction power
Tunnel ventilation including ventilation shafts	Signals and communications
Access shafts	
Tunnel lighting	Real estate costs
Tunnel fire protection (dry standpipes)	
Tunnel drainage	

Table 3-1 includes the estimated quantities of work and the additional cost for the single or double bore tunnel, as well as for the decking option. There is no significant cost difference whether the deep bore tunnel is under the Lowell Line or under Boston Avenue.

Table 3-1 T-2– Medford Hillside Tunnel Additional Constructions Costs

Item	Quantity	Double Bore	Single Bore	Decking
Tunnel Construction	1.2 miles			
Number of Underground Stations	2			
Ventilation Shafts	3			
Access Shafts	1			
Tail Tracks	600 feet			
Tunnel Lighting	1.2 miles			
Tunnel fire protection	1.2 miles			
Tunnel drainage	1.2 miles			
TOTAL LENGTH	**1.2 miles**	**$1.02 billion**	**$0.76 billion**	**$0.40 billion**

4

T-3: Tunnel under Union Square

A number of comments were received regarding the use of a tunnel for part or the entire Union Square spur. A tunnel could allow the Union Square station to be located closer to the heart of the square, which is a comment mentioned during the public meetings.

These proposals differ from the Beyond Lechmere Study alternative that would have diverted the mainline through Union Square via the Fitchburg Line right-of-way with a tunnel under Union Square and Prospect Hill and connecting with the Lowell Line right-of-way south of Medford Street. This alternative was eliminated during the Beyond Lechmere Study.

4.1 Description of Proposal

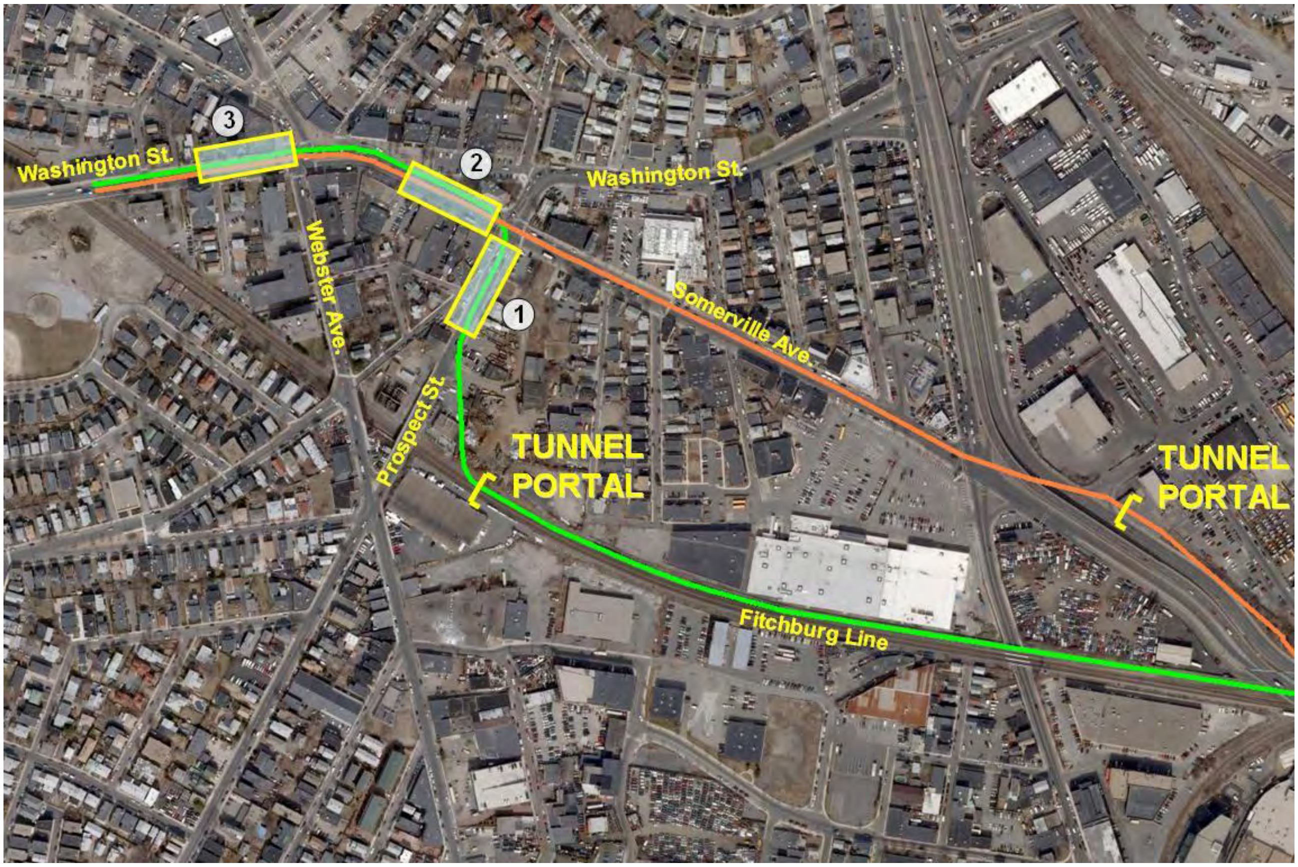
While a specific alignment was not proposed, the objective of the proposal would be to locate the new station under the heart of Union Square. To achieve this, various alignment options are possible. For the sake of this evaluation, the options include:

- Tunnel under Somerville Avenue with portal in Brickbottom area
- Tunnel under Prospect and Washington Streets with portal along the Fitchburg Line

Also, for the sake of this option, three station sites were considered (see Figure 4-1):

- 1. Vicinity of intersection of Prospect Street and Somerville Avenue (Fitchburg alignment, only)
- 2. Somerville Avenue west of Prospect Street (Somerville Ave. alignment, only)
- 3. Vicinity of intersection of Somerville Avenue, Washington Street and Webster Street (either alignment)

Figure 4-1 Options for Union Square Tunnel Alignment and Station Locations



4.2 Evaluation of Options

4.2.1 Tunnel from Fitchburg Alignment

This option would include an at grade alignment along the Fitchburg Line right-of-way. West of Medford Street, the tracks would descend to a portal just east of Prospect Street. The objective would be to minimize the tunnel length and cost by maximizing the at-grade portion of the alignment.

After the portal, the tracks would curve to the north under private property and then under Prospect Street. Option 1 for the station would be just south of the intersection of Prospect Street and Somerville Avenue. If the station is not at the Option 1 site, the tracks would curve west under Somerville Avenue and then under Washington Street. Option 3 for the station would be just beyond the intersection of Washington

Street, Webster Avenue and Somerville Avenue. Tail tracks would be included just beyond the station.

Tunnel Method

Due to the relative short length of this tunnel (about 1,500 feet), cut and cover methods were considered. However the down side of cut and cover would be the extensive impact on Union Square, coming after the current disruption for the major sewer and drain construction along Somerville Avenue.

4.2.2 Tunnel under Somerville Avenue

This option would leave the Fitchburg right-of-way just west of the Brickbottom residential building. Running parallel to McGrath Highway, it would descend into a tunnel portal before crossing under McGrath Highway and following the alignment of Somerville Avenue into Union Square. For illustrative purposes, Figure 4-1 shows the alignment turning under Washington Street just west of Union Square. However, an alignment continuing west under Somerville Avenue could be considered.

The station options include Site 2 just west of Prospect Street and Site 3 just west of Union Square itself.

Tunnel Method

Due to the congestion and heavy existing utility infrastructure, deep bore tunneling is assumed for this option.

4.2.3 Evaluation of Station Options

Figure 4-1 illustrates 3 possible locations for a Union Square subway station. Since it is a stated objective of this tunnel option to have the station in Union Square, only station option 3 provides for that. Therefore, station option 3 will be considered the preferred station location.

4.3 Order of Magnitude Additional Cost

An order-of-magnitude estimate was made of the additional cost of this tunnel alternative. The "additional cost" represents the difference between the preferred at-grade alignment along the Lowell Line right-of-way and this tunnel alignment. As such, the costs common to any alternative (e.g., track, power and signals) are not included. Also, no estimate was made of the real estate costs for property takings and easements for the tunnel, stations, shafts and other support facilities including power substations.

Included	Not Included
Tunnel construction	Trackwork
Additional cost of underground stations	Traction power
Tunnel ventilation including ventilation shafts	Signals and communications
Access Shafts	
Tunnel lighting	Real estate costs
Tunnel fire protection (dry standpipes)	
Tunnel drainage	

Tables 4-1 and 4-2 include the estimated quantities of work and the additional cost for the single or double bore tunnel for the Fitchburg and Somerville Avenue alignment options.

Table 4-1 T-3a– Union Square via Fitchburg Line Tunnel Additional Construction Costs

Item	Quantity	Double Bore	Single Bore
Tunnel Construction	0.3 miles		
Number of Underground Stations	1		
Ventilation Shafts	2		
Access Shafts	0		
Tail Tracks	600 feet		
Tunnel Lighting	0.3 miles		
Tunnel fire protection	0.3 miles		
Tunnel drainage	0.3 miles		
TOTAL LENGTH	**0.3 miles**	**$500 million**	**$600 million**

Table 4-2 T-3b– Union Square via Somerville Ave. Tunnel Additional Construction Costs

Item	Quantity	Double Bore	Single Bore
Tunnel Construction	0.8 miles		
Number of Underground Stations	1		
Ventilation Shafts	3		
Access Shafts	0		
Tail Tracks	600 feet		
Tunnel Lighting	0.8 miles		
Tunnel fire protection	0.8 miles		
Tunnel drainage	0.8 miles		
TOTAL LENGTH	**0.8 miles**	**$620 million**	**$820 million**

5

T-4: Mainline Tunnel from Lechmere to Mystic Valley Parkway/Route 16

5.1 Description

This proposal is simply to construct the mainline extension by deep bore tunnel instead of an at-grade alignment along the Lowell Line right-of-way.

5.2 Review of Proposal

5.2.1 Horizontal Alignment

It is assumed that the alignment would generally follow the Lowell Line and that stations would be at the same locations as the at-grade proposal. Although the deep bore method does not require the alignment to follow the Lowell Line right-of-way, for evaluation purposes the alignment will be assumed to generally follow the rail line.

5.2.2 Vertical Alignment

Consideration was given to where the extension would transition into the tunnel. The relocated Lechmere station is proposed to be an elevated station. Proceeding outbound, a transition could be made prior to the Fitchburg Line crossing. The downsides of this approach would be the steep slope required to pass under the Fitchburg Line and the complexity of the junction with the Union Square spur.

A transition near Yard 8 provides for a gentler transition slope into the tunnel and retains the junction with the Union Square branch as designed.

The six mainline stations from Washington Street north would all be in the tunnel.

Tail tracks would be provided after Mystic Valley station.

5.3 Order of Magnitude Cost

An order-of-magnitude estimate was made of the additional cost of this tunnel alternative. The "additional cost" represents the difference between the preferred at-grade alignment along the Lowell Line right-of-way and this tunnel alignment. As such, the costs common to any alternative (e.g., track, power and signals) are not included. Also, no estimate was made of the real estate costs for property takings and easements for the tunnel, stations, shafts and other support facilities including power substations.

Included	Not Included
Tunnel construction	Trackwork
Additional cost of underground stations	Traction power
Tunnel ventilation including ventilation shafts	Signals and communications
Access Shafts	
Tunnel lighting	Real estate costs
Tunnel fire protection (dry standpipes)	
Tunnel drainage	

Table 5-1 includes the estimated quantities of work and the additional cost for the single or double bore tunnel.

Table 5-1 T-4 – Mainline Tunnel Additional Construction Costs

Item	Quantity	Double Bore	Single Bore
Tunnel Construction	3.7 miles		
Number of Underground Stations	6		
Ventilation Shafts	11		
Access Shafts	4		
Tail Tracks	600 feet		
Tunnel Lighting	3.7 miles		
Tunnel fire protection	3.7 miles		
Tunnel drainage	3.7 miles		
TOTAL LENGTH	**3.7 miles**	**$2.1 billion**	**$3.0 billion**

6

Conclusions

6.1 Comparison of Tunnel Alternatives

This technical memorandum considered 4 tunnel alternatives:

- **Proposal T-1 – Clarendon Hill Tunnel:** Tunnel from Ball Square to Alewife Station via Powder House Square and Clarendon Hill (GLAM tunnel proposal)
- **Proposal T-2 – Medford Hillside Tunnel**: Tunnel from College Avenue to Mystic Valley Parkway/ Route 16
- **Proposal T-3 – Union Square Tunnel**: Tunnel from Prospect Street under Union Square
- **Proposal T-4 – Mainline Tunnel:** Complete tunnel alignment from Lechmere to Mystic Valley Parkway/ Route 16 with branch to Union Square

Table 6-1 presents a summary of the alternatives and respective additional costs.

Note that the order-of-magnitude construction cost estimates represent only the additional cost of each tunnel alternative. The "additional cost" represents the difference between the preferred at-grade alignment along the Lowell Line right-of-way and the tunnel alignment. As such, the costs common to any alternative (e.g., track, power and signals) are not included. Also, no estimate was made of the real estate costs for property takings and easements for the tunnel, stations, shafts and other support facilities including power substations.

Table 6-1 Comparison of Tunnel Alternatives

Item	T-1: Clarendon Hill Tunnel	T-2: Medford Hillside Tunnel	T-3a: Union Sq. Tunnel via Fitchburg Line	T-3b: Union Sq. Tunnel via Somerville Ave.	T-4: Mainline Tunnel
	Ball Sq. to Alewife Station	Ball Sq. to Mystic Valley Parkway	Prospect St. to Union Sq.	Poplar St. to Union Sq.	Brickbottom to Mystic Valley Pkwy.
Length of Tunnel	2.4 miles	1.2 miles	0.3 miles	0.8 miles	3.7 miles
Number of Underground Stations	4	2	1	1	6
Ventilation Shafts	7	3	2	3	11
Access Shafts	3	1	0	0	4
Estimated Additional Construction Cost (Twin Bores)	1.54 billion	$1.02 billion	$500 million	$620 million	$2.1 billion
Estimated Additional Construction Cost (Single Bore)	$2.13 billion	$760 million	$600 million	$820 million	$3.0 billion
Estimated Additional Construction Cost (Decking)	N/A	$400 million	N/A	N/A	N/A

6.2 Technical Issues

6.2.1 General

All tunnel alternatives are technically feasible, in that a tunnel could be constructed along any of the alignments proposed. In all cases, the existing subsurface soils information currently available is sufficient to determine that tunneling is feasible, but not sufficient to determine other details, such as whether a bored tunnel would be in rock, soil, or mixed rock and soil conditions.

6.3 Conclusion

While the tunnel alternatives would reduce surface disruption during construction as well as post-construction noise and visual impacts, these impacts, under the surface alternative, are not expected to be significant and can be mitigated cost effectively. Therefore, the additional costs of tunnel construction are not warranted.