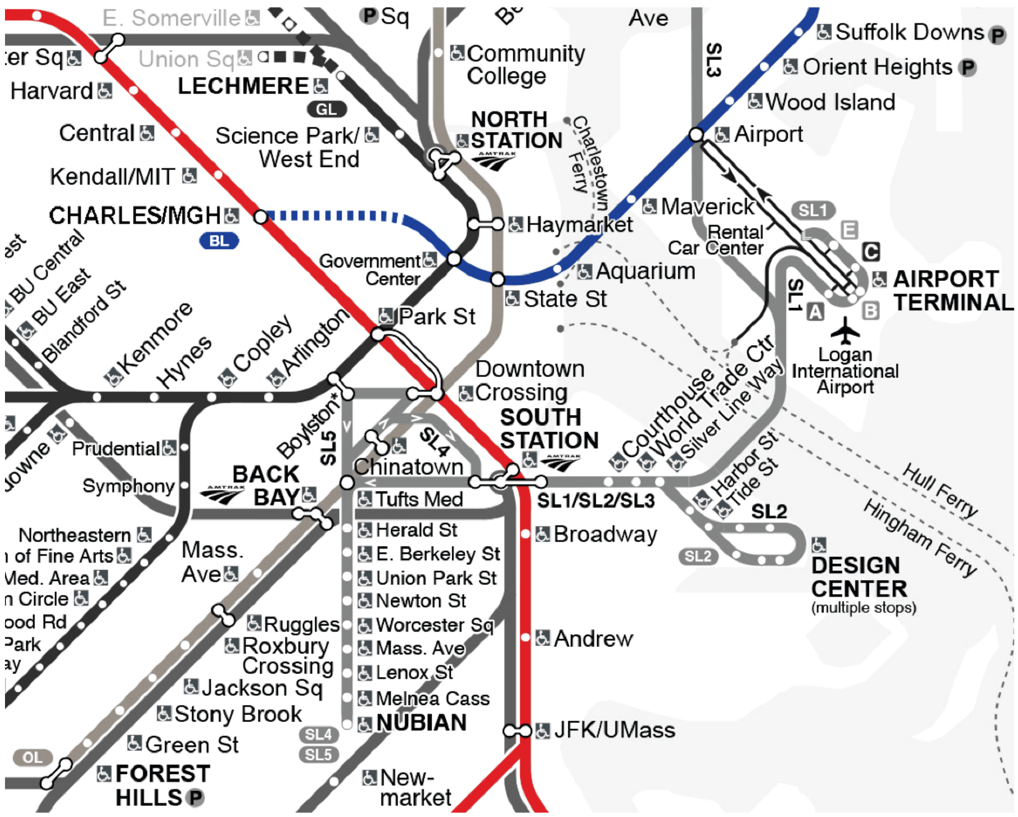
RED BLUE CONNECTOR

Concept Design Report



FINAL

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Massachusetts Bay Transportation Authority

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Table of Contents

1. Executive Summary 1-1
1.1. Project Overview 1-1
1.2. Program Summary 1-1
1.3. Major Design Issues Updated 1-2
1.4. Alternatives Considered and Recommended 1-3
1.5. Conceptual Schedule 1-4
2. Introduction 2-1
3. Context and Existing Conditions 3-1
3.1. Charles Circle and Cambridge Street 3-1
3.2. Adjacent Facilities 3-3
3.2.1. Massachusetts General Hospital (MGH) 3-3
3.2.2. Massachusetts Eye and Ear Infirmary 3-4
3.2.3. Liberty Hotel 3-4
3.3. New and Proposed Projects 3-4
4. Future Conditions 4-1
4.1. Goals and Objectives 4-1
4.2. Passenger Experience 4-1
4.3. Connectivity 4-1
5. Programmatic Requirements 5-1
5.1. Program Elements 5-1
5.1.1. Station 5-1
5.1.2. Required Ancillary Facilities 5-1
5.1.3. Tunnel 5-1
5.1.4. Storage Tracks 5-1
5.2. DEIR Alternatives for Bowdoin Station 5-4
5.3. Resiliency 5-5
6. Alternatives Considered 6-1
6.1. Station Alternatives 6-1
6.2. Tunnel Alternatives 6-10
6.2.1. 2010 Alternative 6-10
6.2.2. New Tunnel Alternatives 6-12
7. Recommendations 7-1
7.1. Station Configuration 7-1
7.2. Construction Methods 7-3
8. Preliminary Code Analysis 8-1
8.1. List of Applicable Codes, Standards and Guidelines 8-1
9. Architectural Design Approach 9-1
9.1. Station 9-1
9.1.1. Station Configuration 9-1
9.1.2. Escalators 9-2
9.1.3. Elevators 9-2
9.1.4. Materials and Finishes 9-2
9.2. Urban Design and Public Infrastructure 9-10
9.2.1. Existing Sidewalks, Crosswalks and Pedestrian Access 9-11
9.2.2. Proposed Enhancements to Streets and Curbs 9-12

9.2.3 New Blue Line Entrance at Proposed MGH Clinical and Campus Services Building ... 9-14
10. Civil Design Approach ... 10-1
10.1. Roadways and Streetscape ... 10-1
10.2. Utilities ... 10-1
10.3. Traffic Management ... 10-3
11. Structural Design Approach ... 11-1
11.1. General ... 11-1
11.2. Station/Tunnel ... 11-1
11.3. Bowdoin ... 11-1
12. Geotechnical Engineering ... 12-1
12.1. Geotechnical Design Basis ... 12-1
13. Constructability Approach ... 13-1
13.1. General ... 13-1
13.2. Traffic Management and Pedestrian Movements ... 13-2
13.3. Construction and Support of Excavation Requirements ... 13-2
13.4. Interface at Bowdoin ... 13-3
13.5. Operations During Construction ... 13-5
14. Systems ... 14-1
14.1. Signals ... 14-1
14.2. Communications ... 14-1
14.3. Traction Power ... 14-2
14.4. Mechanical / HVAC ... 14-2
14.5. Electrical ... 14-3
14.6. Plumbing ... 14-3
14.7. Safety and Security ... 14-3
14.7.1. General ... 14-3
14.8. Fire Protection, Fire Alarm and Life Safety ... 14-3
14.8.1. Scope and Purpose of NFPA 130 ... 14-3
14.8.2. Unique Characteristics of Rail Transit Stations ... 14-4
14.8.3. Use of NFPA 130 in Conjunction with the Adopted Building Code ... 14-4
14.8.4. Major Fire Life Safety Features of NFPA 130 as Applied to Stations ... 14-4
14.9. Power Feeds ... 14-5
15. Tunnel Ventilation ... 15-1
15.1. Purpose ... 15-1
15.2. Evacuation ... 15-1
15.3. Ventilation Plant Locations ... 15-1
15.4. Smoke Management Strategies ... 15-1
15.5. Engineered Approach ... 15-2
15.6. Ventilation Fan Plant ... 15-3
15.7. Multiple Tunnel Ventilation Plant Coordination ... 15-4
16. Sustainability ... 16-1
16.1. MBTA Sustainable Initiatives ... 16-1
16.2. Sustainable Design at Red Blue Connector Station ... 16-1
16.2.1. Elevators ... 16-2
16.2.2. Lighting ... 16-2
16.2.3. Station Materials ... 16-2

16.2.4. Ventilation ... 16-2
16.2.5. Recycling ... 16-2
16.2.6. Interpretive/Educational Materials ... 16-2
17. Environmental Permitting ... 17-1
18. Schedule ... 18-1
18.1. Current Schedule ... 18-1
18.2. Acceleration of Project Schedule ... 18-1
19. Cost Estimate ... 19-2
19.1. Base Costs ... 19-2
19.2. Other elements Affecting Cost ... 19-3
19.2.1. Constructability ... 19-3
19.2.2. Right of Way ... 19-3
19.2.3. Market Conditions ... 19-3
Appendix A Engineering Concepts for DEIR (2010) ... A-1
Appendix B Drawings ... A-2

Figures

Figure 2-1. MBTA System Map ... 2-1
Figure 3-1. Charles Circle Historic Aerial View, Leslie Jones, 1947 ... 3-2
Figure 3-2. Charles Circle Aerial View ... 3-2
Figure 3-3. Charles Circle and Charles/MGH Station – Existing Layout ... 3-3
Figure 3-4. MGH Property Adjacent to Charles/MGH Station ... 3-4
Figure 3-5. Site Plan with Adjacent Facilities Identified ... 3-5
Figure 5-1. Potential Storage Track West of Station ... 5-2
Figure 5-2. Potential Storage Track East of Station ... 5-3
Figure 5-3. Potential Storage Track at Bowdoin Loop ... 5-3
Figure 5-4. Bowdoin Station Location ... 5-4
Figure 5-5. DEIR Alternative 1 Profile ... 5-4
Figure 5-6. DEIR Alternative 2 Profile ... 5-5
Figure 6-1. 2010 Alternative ... 6-2
Figure 6-2. Alternative 1 ... 6-4
Figure 6-3. Alternative 2 ... 6-6
Figure 6-4. Alternative 3 ... 6-9
Figure 6-5. 2010 Alternative SEM + C&C + TBM ... 6-11
Figure 6-6. 2010 Alternative - Variation SEM + C&C + TBM ... 6-12
Figure 6-7. Alternative T1 SEM + C&C ... 6-13
Figure 6-8. Alternative T1A SEM + C&C ... 6-14
Figure 6-9. Alternative T2 SEM + C&C + TBM ... 6-14
Figure 6-10. Alternative T2A C&C + TBM ... 6-15
Figure 6-11. Alternative T3 C&C ... 6-16
Figure 7-1. Recommended Station Configuration ... 7-1
Figure 7-2. Recommended Construction Method ... 7-5
Figure 9-1. Ground Floor Layout ... 9-3
Figure 9-2. Mezzanine Level Layout ... 9-3
Figure 9-3. Platform Level Layout ... 9-4
Figure 9-4. Platform Cross Section ... 9-4
Figure 9-5. Longitudinal Part Section West ... 9-5
Figure 9-6. Longitudinal Part Section East ... 9-5
Figure 9-7. Interior View at Charles/MGH Looking from Red Line ... 9-6

Figure 9-8. Interior View 1 at Charles/MGH Looking at Blue Line Connection........................ 9-6
Figure 9-9. Interior View 2 at Charles/MGH Looking at Blue Line Connection........................ 9-7
Figure 9-10. Interior View 1 Looking at Blue Line Platform.. 9-7
Figure 9-11. Interior View 2 Looking at Blue Line Platform.. 9-8
Figure 9-12. Interior View Looking at MGH Entrance Concourse... 9-8
Figure 9-13. Interior View Looking at MGH Entrance at Grade.. 9-9
Figure 9-14. 3D Section.. 9-9
Figure 9-15. Historic District with Charles/MGH Station Shown in the Upper Left 9-10
Figure 9-16. View Looking North of Roadways and Barrier Adjacent to the Station Entrance 9-11
Figure 9-17. Existing Sidewalks, Crosswalks and Pedestrian Access.................................. 9-13
Figure 9-18. Potential Surface Access Improvements.. 9-14
Figure 9-19. Station East Entrance Layout.. 9-15
Figure 9-20. Cambridge Street Aerial.. 9-16
Figure 9-21. Station East Entrance Perspective 9-16
Figure 10-1. Existing Conditions 10-2
Figure 10-2. Utilities Concept During Construction 10-3
Figure 11-1. Bowdoin Proposed Layout... 11-2
Figure 12-1. Geotechnical Cross Section 12-2
Figure 13-1. Representative Utility Plan 13-2
Figure 13-2. Plan at Interface of New Tunnel with Bowdoin Structure................................. 13-4
Figure 13-3. Construction Staging Details 13-5
Figure 15-1. Representative Evacuation Route 15-2
Figure 15-2. A Single Tunnel Ventilation Fan Installation of Similar Type, Size and Arrangement 15-3
Figure 18-1. Schedule 18-1

Tables

Table 17-1. Possible Permits or Approvals.. 17-1
Table 19-1. Cost Estimate.. 19-2

1. Executive Summary

1.1. Project Overview

This project is intended to improve transit and access to jobs by extending the Blue Line from its current terminus at Bowdoin Station, below Cambridge Street in Downtown Boston, to Charles/MGH Station where it will connect directly to the Red Line, a distance of approximately 2,150 feet. As part of the project, the MBTA will permanently close Bowdoin Station, and Blue Line trains will travel directly from Government Center to Charles/MGH. In addition to the direct Red Line connection and access to Cambridge Street, an entrance at North Grove Street is proposed, providing access to the Massachusetts General Hospital campus.

The purpose of this report is to update the 2010 design concept, with focus on:

- Tunneling methodology
- Impacts during construction
- Station configuration
- Latest tunnel ventilation requirements
- Coordination with proposed and ongoing development projects

This report considers all aspects of the 2010 study and updates key elements, including tunneling, station configuration and connectivity, and the latest tunnel ventilation requirements and engineering approach.

1.2. Program Summary

The project includes the following key elements:

- Compliance with updated Accessibility Standards and Guidelines
- Compliance with updated Codes including NFPA 130
- Realigned tunnel structure from just east of Bowdoin Station through the existing Bowdoin Station structure
- New 2-track tunnel from Bowdoin Station to Charles/MGH Station
- New Blue Line station east of and below the Charles/MGH Station headhouse
- New connections to the existing Charles/MGH headhouse via stairs, escalators, and elevators
- New passenger connection via stairs, escalators, and elevators within Massachusetts General Hospital's future Clinical Building on Cambridge Street between North Grove Street and Blossom Street
- New fare control area at the future MGH Clinical Building entrance
- New traction power substation
- New unit substation
- New tunnel ventilation facilities

The Longfellow Approach Viaduct Rehabilitation project is currently addressing State of Good Repair and emergency egress issues at the existing Red Line Charles/MGH Station. There has been and will need an ongoing coordination by the Red Blue Connector Project with the Longfellow Approach Project. Coordination will include compatibility of scopes between the two projects.

1.3. Major Design Issues Updated

The previous design concept presented a solution and construction methodology that led to the *2010 Red Line/Blue Line Connector Project Draft Environmental Impact Report* (2010 DEIR) and the subsequent *Summary Memorandum: Tunnel Constructability Study, Update to the 2010 DEIR for the Red Line/Blue Line Connector*, published in October 2018. The current study develops and evaluates several design and construction concepts combining original work and new solutions to the range of alternatives presented in this report. Design drivers influencing the development of alternatives in the current study include:

- Connections to the existing Red Line Charles/MGH Station
- Connection within the new MGH Clinical Building
- Life Safety requirements
- NFPA 130 requirements
- Safe, accessible, and comfortable experience
- Opportunities for natural light
- Public circulation space
- Redundant elevators and escalators
- Architectural integrity of existing Charles/MGH Station
- Design coordination of the entrance within the future MGH Clinical Building
- Track grade/profile
- Track configuration – cross-over
- Support facilities requirements – traction power, station electrical, mechanical, plumbing
- Emergency ventilation requirements
    - Fan room size and location
    - Ventilation and egress structure locations
- Structural support of Red Line viaduct to facilitate new Blue Line station elements
- Property takings
- Construction methods
    - Impacts during construction
    - Maintenance of traffic
    - Construction noise and vibration
- Local construction experience
- Construction cost and schedule risk

1.4. Alternatives Considered and Recommended

The 2010 DEIR and concept design depicted a two-track tunnel with a 320-foot long center island station platform at the west end. The new Blue Line platform would be located immediately east of and below the existing Charles/MGH Station headhouse. An elevator provided connection from platform to headhouse. Stairs and two escalators provided connection from platform to headhouse via an intermediate mezzanine.

Three alternative station configurations have been developed and evaluated as part of this report. Alternative 1 utilizes a similar platform location just east of the Charles/MGH headhouse and provides access via existing Charles/MGH headhouse at the west end of the platform and via an entrance within the future MGH Clinical Building at the east end of the platform; Alternative 2 also utilizes a platform location along Cambridge Street but with new entrances on the sidewalks to the North and South of the existing headhouse and also provides access to the MGH campus from the entrance within the future MGH Clinical Building; and Alternative 3 located the new Blue Line platform to the northwest of the existing Charles/MGH headhouse.

Station Alternative 1 is the recommended alternative. This alternative locates the station platform close to the existing Charles/MGH headhouse and provides a clear travel path between Red and Blue Lines, including a single escalator run with good visual connectivity. There is also good connectivity to the MGH campus.

In addition to the tunneling method shown in the 2010 DEIR concept design, six new tunneling methodology combinations were defined and evaluated. These alternatives consisted of combinations of Cut & Cover (C&C), Tunnel Boring Machine (TBM), and Sequential Excavation Method (SEM) construction techniques.

All alternatives had significant portions of C&C construction even though other tunnel methods were included in some alternatives. C&C construction does have to be carefully planned to minimize disruption, but such planning and tried-and-true mitigations are commonplace for this type of project and can be carefully controlled.

The recommended tunneling method is C&C construction for the entire project. This tunneling method is a change from the 2010 concept design which utilized a combination of C&C, TBM, and SEM. The advantages of the recommended C&C method include:

- Least cost
- Shortest construction duration
- Most flexibility to accommodate Life Safety tunnel ventilation requirements
- Most flexibility in station design to maximize visibility and connectivity
- Comparable surface disruption in most sensitive areas
- Less project risk compared to other tunneling methods

The MBTA met with key stakeholders throughout the process to present the alternatives in this report. Their comments have been incorporated in the alternatives where applicable to produce concepts that are more functional, offer increased safety and accessibility, or provide a better experience for transit riders. Coordination with other stakeholders will continue through design.

As noted above, during the review of the future MGH Clinical Building Project, a consensus was reached to develop a concept that would accommodate an entrance to the new Blue Line Station within the future MGH Building. This ongoing concept which will facilitate and improve access to the MGH campus, is being coordinated by the MBTA, Boston Planning & Development Agency (BPDA), Boston Transportation Department (BTD), and the MGH Team.

1.5. Conceptual Schedule

Based on the assumptions that the project can move forward, final bid documents could be completed by spring 2025 with construction starting in the fall of 2025. The anticipated construction duration is estimated to be 4 ½ to 5 years, bringing completion of the project to spring 2030.

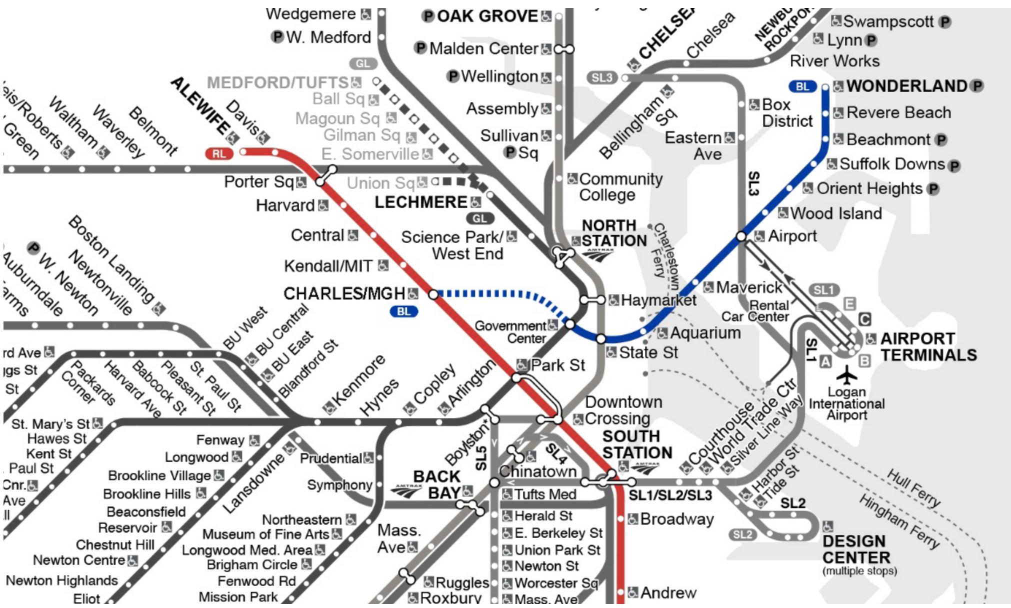
The major elements to achieve this schedule include procuring a final design team, completing the preliminary design and environmental permitting process, advancing to final design, generating construction bid documents and bid procurement, and issuing a contractor notice to proceed and the construction phase.

2. Introduction

In June 2019 the Massachusetts Bay Transportation Authority (MBTA) revised the state's vision for 2040 by identifying the design of a rail connection between the Red Line and the Blue Line as a priority. The Red Blue Connector Project is an initiative of the Massachusetts Department of Transportation (MassDOT) and the MBTA to improve air quality and increase public transit ridership and system capacity. Enhancing transit services would improve mobility and regional access for residents of East Boston and North Shore communities as well as residents of Cambridge and other communities northwest of Boston. The project will also improve access to Massachusetts General Hospital (MGH), the Massachusetts Eye and Ear Infirmary (MEEI), and other nearby medical facilities, as well as to Logan International airport, one of the region's economic engines.

According to the *2010 Red Line/Blue Line Connector Project Draft Environmental Impact Report*, a direct connection between the Blue and Red Lines would boost transit ridership, improve air quality, reduce passenger congestion in the existing downtown transfer stations, and improve mobility and access to jobs, education, and health care, in particular for Blue Line riders. Refer to the dashed blue line in Figure 2-1 depicting the proposed connection between the Red and Blue Lines.

Figure 2-1. MBTA System Map



In 2007 the MBTA began a study of the Red Blue Connector which led to the filing of a Draft Environmental Impact Report (DEIR) in 2010. The study included engineering concepts for certain project elements of the tunnel from Bowdoin Station to Charles/MGH Station, and a new below-grade Blue Line Station. An update of certain relevant sections of the DEIR was prepared in 2018, and the project is currently in a renewed conceptual engineering phase building upon the work of the previous engineering study.

3. Context and Existing Conditions

3.1. Charles Circle and Cambridge Street

Charles Circle is an urban traffic rotary connecting Cambridge Street, Charles Street, the Longfellow Bridge and ramps to and from Storrow Drive. Originally conceived as a true rotary with an infield (see Figure 3-1), Charles Circle has evolved into a complex of signalized intersections that experience heavy volumes of weekday commuter traffic composed of pedestrians, cyclists, cars, delivery trucks, and private bus shuttle service.

Anchoring Charles Circle is the recently renovated Longfellow Bridge which fully reopened in 2018 after five years of renovation. Originally opened in 1906 and replacing a timber-pile structure built in 1793, the Longfellow Bridge spans the Charles River to connect Charles Circle and Boston's Beacon Hill neighborhood with the Kendall Square area of Cambridge, Massachusetts. The bridge carries Massachusetts Route 3, US Route 3, the MBTA Red Line, bicycle and pedestrian traffic.

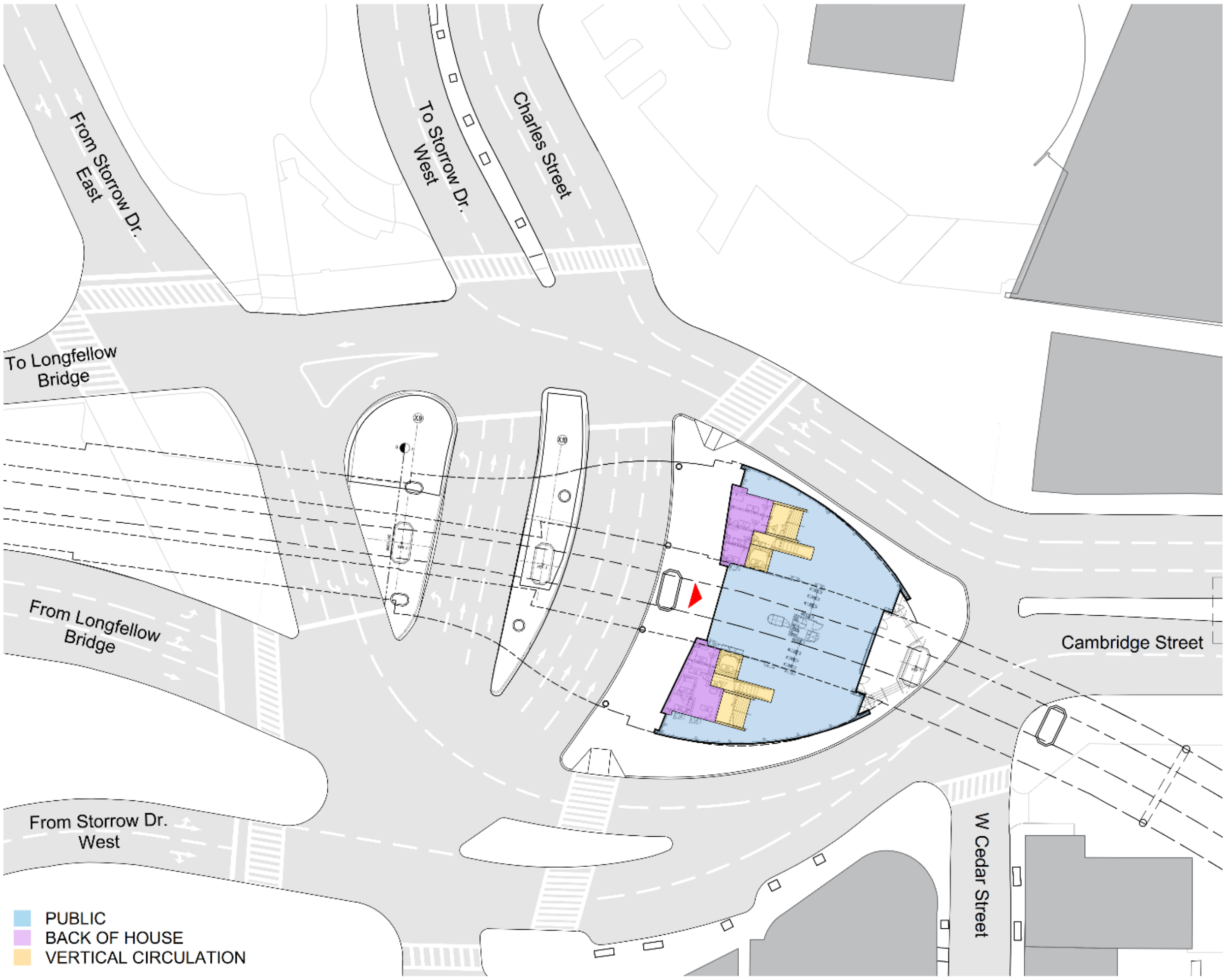
MBTA's Charles/MGH Red Line Station is located in the center of Charles Circle with elevated tracks in a viaduct section connecting the Longfellow Bridge to the Red Line tunnel under Beacon Hill. Constructed in 1931, Charles/MGH Station was designed to accommodate the Red Line elevated track, which was built in 1912, see Figure 3-1. Charles/MGH Station was renovated in 2007 allowing street level access under the alignment and making the station accessible with elevators and escalators. The station renovation was a headhouse project only and did not replace Red Line platforms or address the needed 'second means of egress' required under National Fire Protection Association (NFPA) 130 Standard. This project should continue coordination with the current Red Line Longfellow Approach Project to facilitate a second means of egress. The new two-story station building replaced the elevated pedestrian footbridges and three-story headhouse. The station currently consists of a street-level headhouse entrance and fare collection lobby located in Charles Circle, and two semi-enclosed side platforms above the lobby area. Stairs, upward escalators, and elevators allow patrons to access the platforms, see Figure 3-2 for urban context and Figure 3-3 for station diagram.

The Cambridge Street corridor running east from Charles Circle is a dense urban sector of Downtown Boston. There are approximately 560 individual properties along the corridor that are commercial/ retail and institutional, mixed-use, and residential properties bordering the corridor.

Figure 3-1. Charles Circle Historic Aerial View, Leslie Jones, 1947

Figure 3-2. Charles Circle Aerial View

Figure 3-3. Charles Circle and Charles/MGH Station – Existing Layout



3.2. Adjacent Facilities

3.2.1. Massachusetts General Hospital (MGH)

Massachusetts General Hospital (MGH) is the original and largest teaching hospital of Harvard Medical School located on a multi-building campus adjacent to Cambridge Street and Charles/MGH Station. It is the third oldest general hospital in the United States and has a capacity of 1,000 beds. With Brigham and Women's Hospital, it is one of the two founding members of Partners HealthCare, the largest healthcare provider in Massachusetts. According to the US News & World Report Magazine's article *US News Announces 2020-21 Best Hospitals*, Massachusetts General Hospital conducts the largest hospital-based research program in the world, with an annual research budget of more than $1 billion in 2019. The article further states that MGH employs over 25,000 workers and is one of the largest private employers in Boston. Its workforce includes more than 5,000 registered nurses, 4,500 allied health workers, 2,400 physicians, 2,300 research scientists and fellows, and hundreds of other employees that support daily operations. MGH offers 3 parking garages on campus: Fruit Street, Parkman Street and Charles River Plaza, and a remote lot at Yawkey Way near Kenmore Square with shuttles to the campus. Figure 3-4 illustrates MGH property as shown in the MGH's 2019 Institutional Master Plan.

3.2.2. Massachusetts Eye and Ear Infirmary

Massachusetts Eye and Ear Infirmary is a teaching partner of Harvard Medical School. The hospital's main campus is surrounded by various MGH buildings. Maps often show the entire area labeled as "Massachusetts General Hospital".

Charles/MGH is the transit stop serving Massachusetts Eye and Ear Infirmary. They offer parking at a surface lot between the main building and Storrow Drive.

Figure 3-4. MGH Property Adjacent to Charles/MGH Station

3.2.3. Liberty Hotel

Located on Cambridge Street adjacent to the Charles/MGH Station, the Liberty Hotel reuses the former Charles Street Jail, a national historic landmark built in 1851. The hotel has 298 rooms and suites, and 6,000 square feet of meetings and event space. The hotel provides valet parking and uses Charles River Plaza parking facility for vehicle storage.

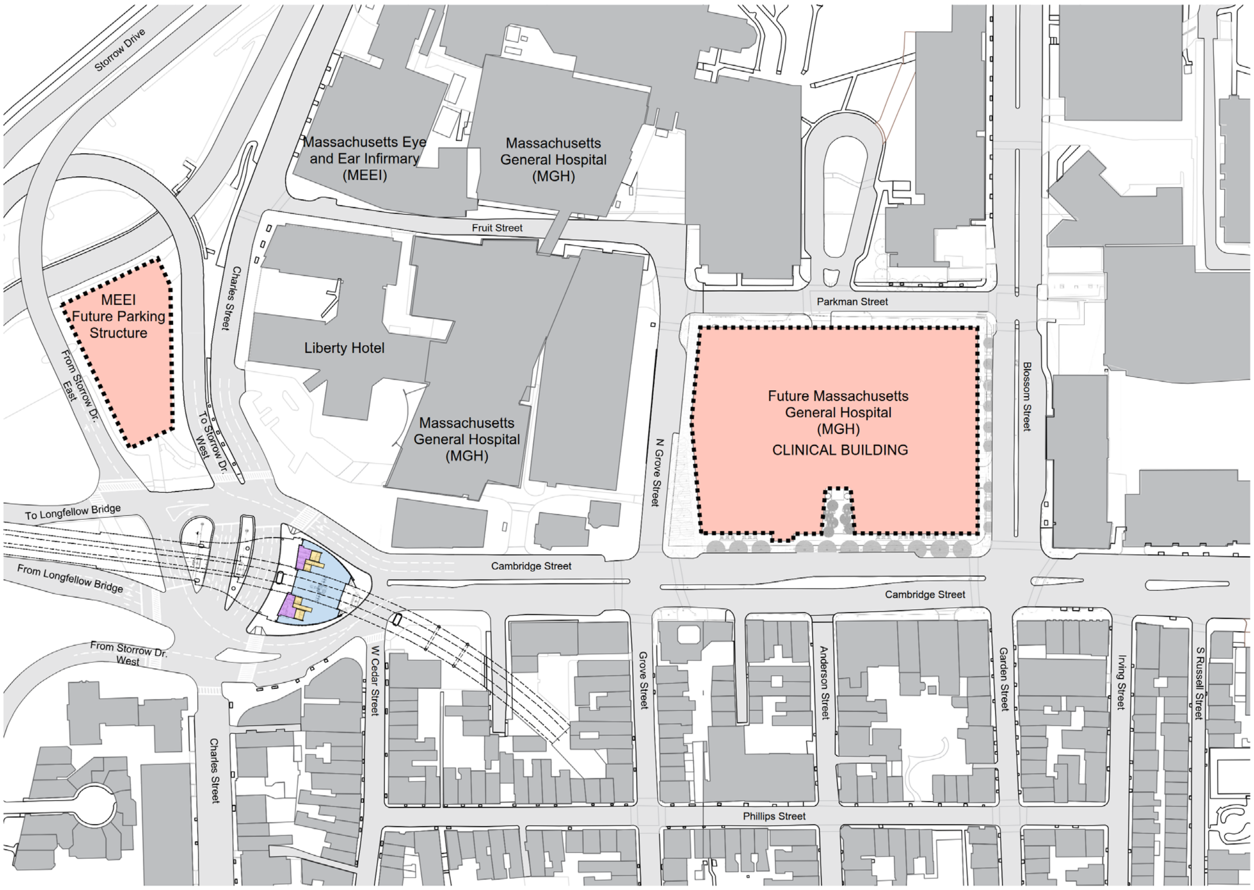
Figure 3-5 identifies the locations of these adjacent facilities.

3.3. New and Proposed Projects

Massachusetts General Hospital is proposing a future Clinical Building facing Cambridge Street. This major addition would add 1 million square feet and 450 single-patient rooms, increasing their current 1,000 bed capacity, see Figure 3-5. The future Clinical Building will include a pair of 12-story towers with underground parking and will house a cancer center and a heart center, along with space for a variety of inpatient and outpatient services.

Massachusetts Eye and Ear Infirmary is exploring opportunities to implement a structured parking project to increase parking capacity in the area adjacent to the hospital on Charles Street where surface parking is located today, see Figure 3-5.

Figure 3-5. Site Plan with Adjacent Facilities Identified



4. Future Conditions

4.1. Goals and Objectives

The project is intended to improve access to jobs and transit connectivity. The project will connect some of the largest economic growth destinations in the entire state: jobs-rich Kendall Square, Massachusetts General Hospital, the complex at Government Center, and Logan Airport, and will also complete the inner core subway system.

The project will improve access for residents in outlying areas along the Blue Line to destinations in Cambridge and Somerville. This would provide benefits for Blue Line communities north of Boston resulting in improved access to jobs, health care and educational opportunities. These benefits would accrue to both environmental justice and non-environmental justice populations. At the same time, for residents of Cambridge and Somerville, more convenient access to Blue Line destinations in the Downtown Core and Logan Airport could result in fewer ride share trips.

Another benefit of the project is reducing Green Line transfers resulting in shorter dwell times and improved operational efficiency for the Green Line.

4.2. Passenger Experience

A focus of the project is better connectivity achieved through the reduction of complex transfers between the subway lines. Despite a comprehensive program of accessibility improvements throughout the system, some challenges still remain when connecting between transit lines. Park Street Station, for example, allows a Red Line transfer via stairs or elevator from the central platform to the Green Line where patrons can ride for one stop to Government Center to access the Blue Line. This is a difficult transfer for transit patrons unfamiliar with the system (tourists for example), persons with disabilities, or families with children. The Green Line is often at capacity during rush hour adding to the complexity and duration of the transfer. Reducing transfers would relieve congestion at other stations in Downtown Boston, and the increased connectivity of the system would accommodate increased ridership, and improve accessibility, benefitting the system and transit riders.

When the Red Blue Connector Project is completed, those passengers making a Red Line to Blue Line connection or vice versa will be guided by platform signs directing them to change levels in the combined station using stairs, escalators or elevators. Approaching Charles/MGH from the Beacon Hill neighborhood or the hospital campus, for example, transit patrons will see signs offering service to both Red Line and Blue Line destinations.

4.3. Connectivity

The Red Blue Connector Project will provide benefits to the rapid transit system as a whole - not just the Red Line and Blue Line - because the Red Blue Connector will serve as an essential link for all transit riders passing through the heart of the MBTA system in the downtown where the major line-haul transit services intersect. The Red and Blue Lines remain the only two rail rapid transit lines in the Boston transit network that do not directly intersect. The lack of a direct link forces double transfers on passengers. According to the 2010 DEIR, this transfer penalty reduces ridership and increases congestion at other Downtown Boston stations.

The Blue Line today has approximately 50% more capacity than 20 years ago due to 6-car platforms and new equipment and this increased capacity contributes in part to new transit-oriented development projects in East Boston and Revere. With Blue Line service extending to

Charles/MGH, a share of those riders previously making a double transfer will lessen creating more efficiency in the most crowded part of the system.

Suffolk Downs in East Boston and Revere, for example, is a proposed billion dollar, 161-acre multi-use redevelopment currently under review, which straddles the two communities. The Suffolk Downs project is adjacent to the Blue Line and plans to construct residences, retail, office and lab space, hotel space and accessory parking. Residences would include townhomes, apartments, condominiums and senior housing. Also near the Blue Line, Revere Beach is one of the fastest growing neighborhoods in the Boston area and recently added 400 transit-friendly residential units, with another 320 units underway, as part of a 1.3 million square feet Master Plan.

5. Programmatic Requirements

5.1. Program Elements

The following program elements will be incorporated into the proposed design:

5.1.1. Station

- The Blue Line platform is 320 feet long to accommodate 6-car trains.
- Two escalators, two elevators, and separate stairway are required at the west end of the platform for connection to Red Line and access to street.
- Two escalators, two elevators, and separate stairway are required at east end of platform for access to Cambridge Street and the MGH campus. The east entrance will be within the future MGH Clinical Building.

5.1.2. Required Ancillary Facilities

In addition to the platform and public circulation spaces, the Red Blue Connector Project includes many support facilities. These facilities provide the many functions necessary for the operation of the station and adjoining tunnel. These facilities include:

- Traction power substation
- Unit substation
- Emergency ventilation fan rooms
- Fan control room
- Mechanical (HVAC) room
- Signal room
- Electrical room
- Communications room
- Pump room
- Storage room
- Staff Toilet rooms
- Janitor closet
- Elevator control room

5.1.3. Tunnel

- Two-track tunnel with cross-over east of the station platform.

5.1.4. Storage Tracks

- The 2010 DEIR and concept design included two tail tracks for train storage, which extended west beyond the station (Figure 5-1). The storage tracks would provide train storage of two 6-car consist trains. No trains could be stored on the tracks during revenue service - for safe braking reasons. Construction of such storage tracks west of the station are problematic from a construction cost and impact perspective, and from a tunnel ventilation and emergency egress perspective.

- Potential Storage Track East of Station (Figure 5-2) provides less construction impact and greater operational flexibility.
- Potential Storage Track at Bowdoin Loop (Figure 5-3) is problematic from operations perspective.
- However, confirmation of the need for storage tracks at this location and evaluation of alternatives is needed during the next phase of design.
- If need is confirmed, three potential storage track configurations are as follows:
  - Figure 5-1 2010 DEIR concept with tracks west of the station
  - Figure 5-2 Pocket Track alternative with storage east of the station
  - Figure 5-3 Utilization of a portion of the existing Loop Track at the existing Bowdoin Station

Figure 5-1. Potential Storage Track West of Station

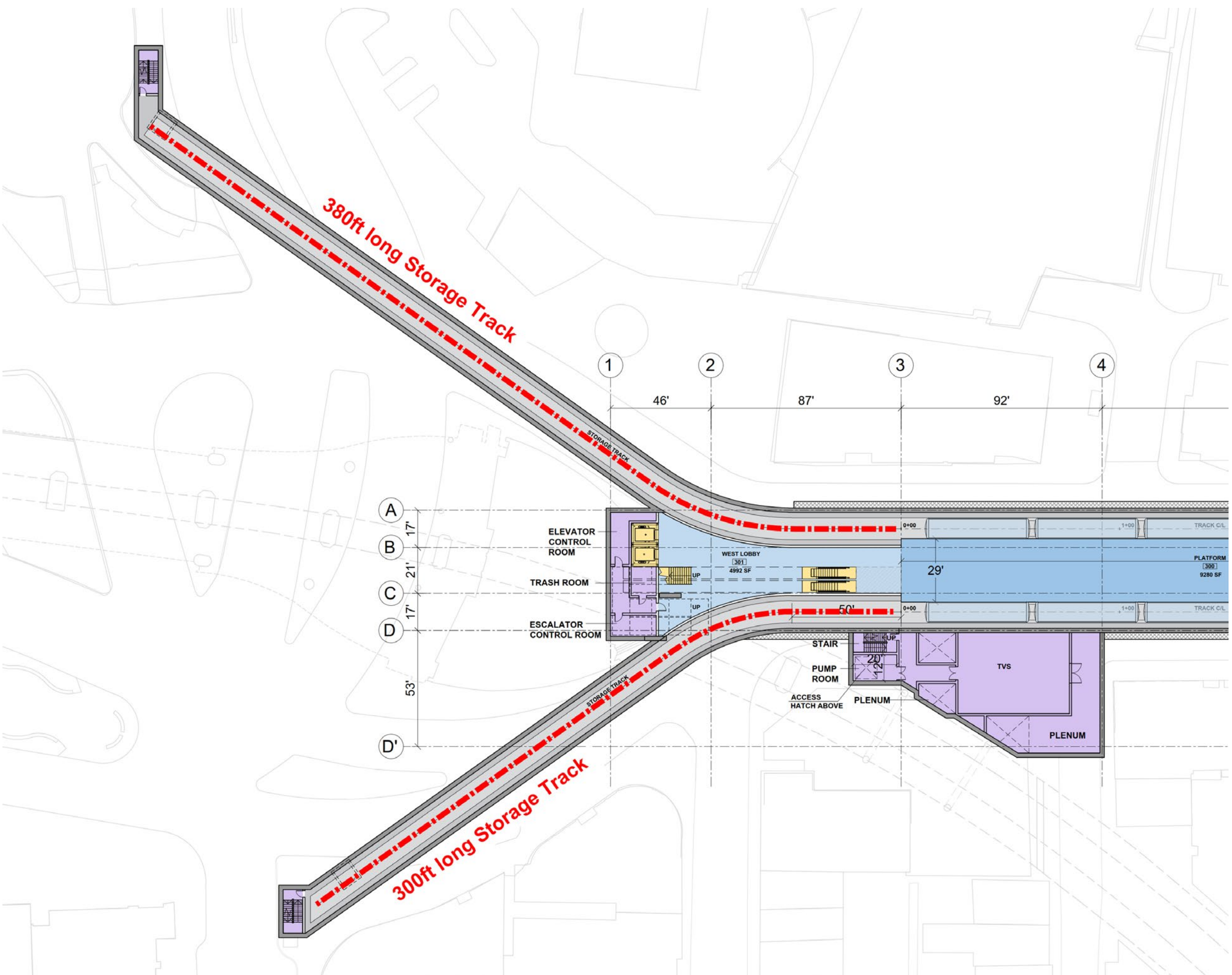


Figure 5-2. Potential Storage Track East of Station

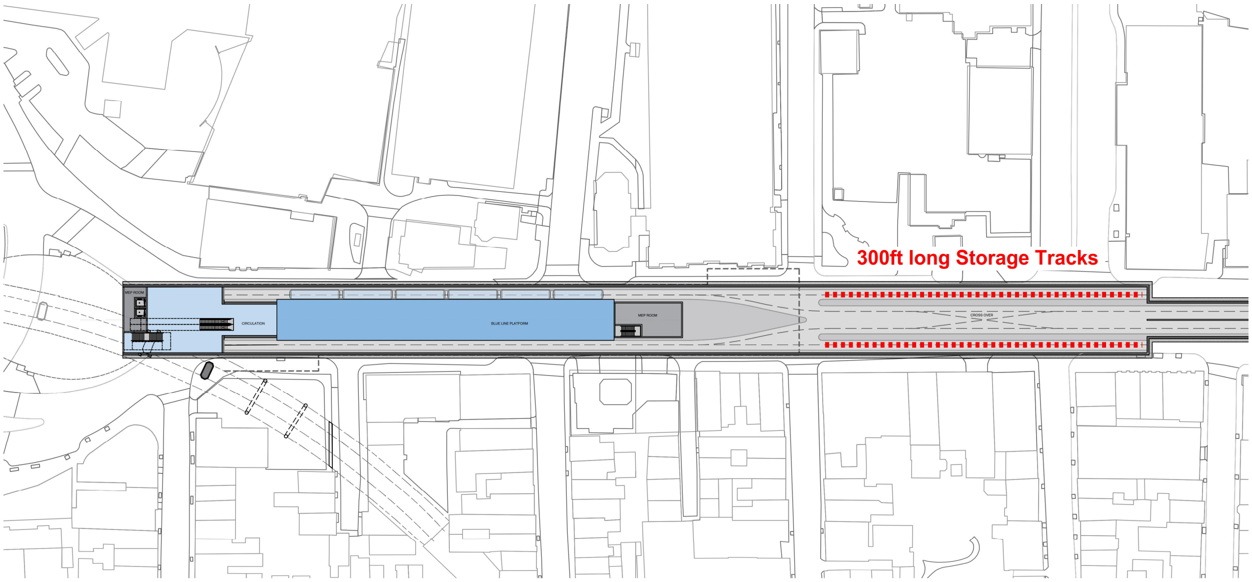
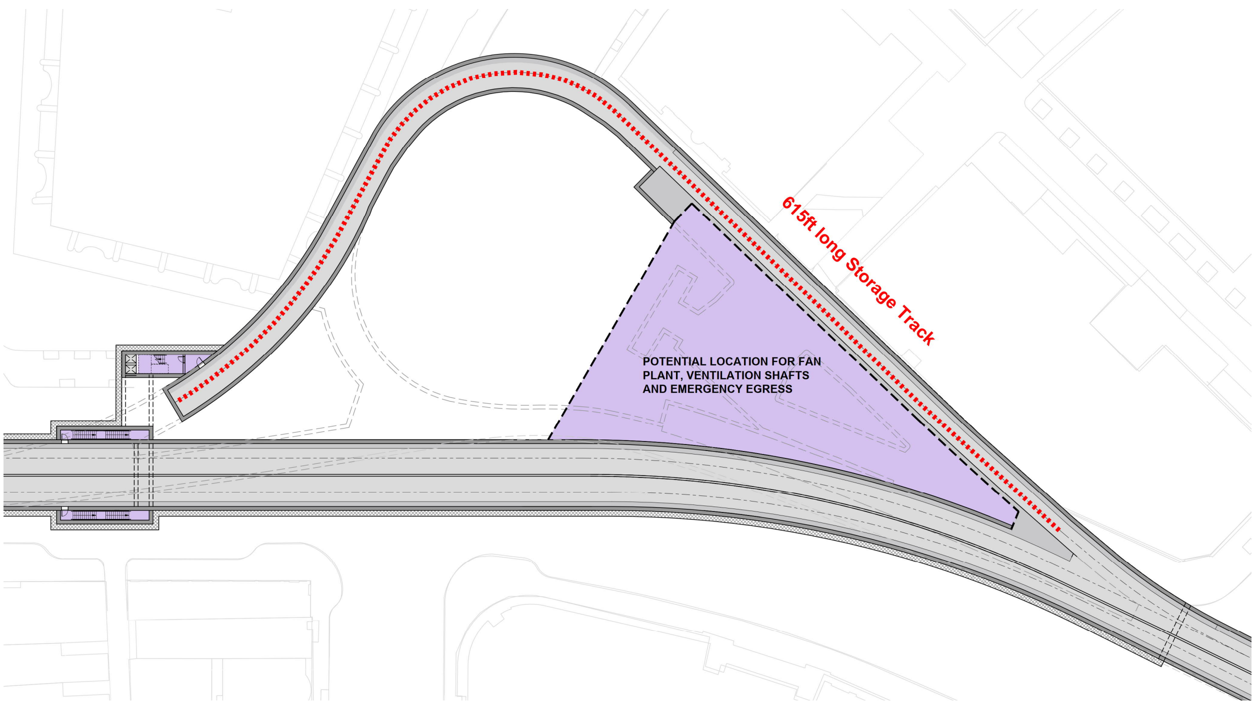


Figure 5-3. Potential Storage Track at Bowdoin Loop



5.2. DEIR Alternatives for Bowdoin Station

In the DEIR, two alternatives were considered for the Red Blue Connector Project. The primary difference in the alternatives is the future of the existing Bowdoin Station (see Figure 5-4). These two alternatives emerged from an exhaustive analysis of 32 alternatives conducted under the project's Expanded Environmental Notification Form (EENF).

Figure 5-4. Bowdoin Station Location

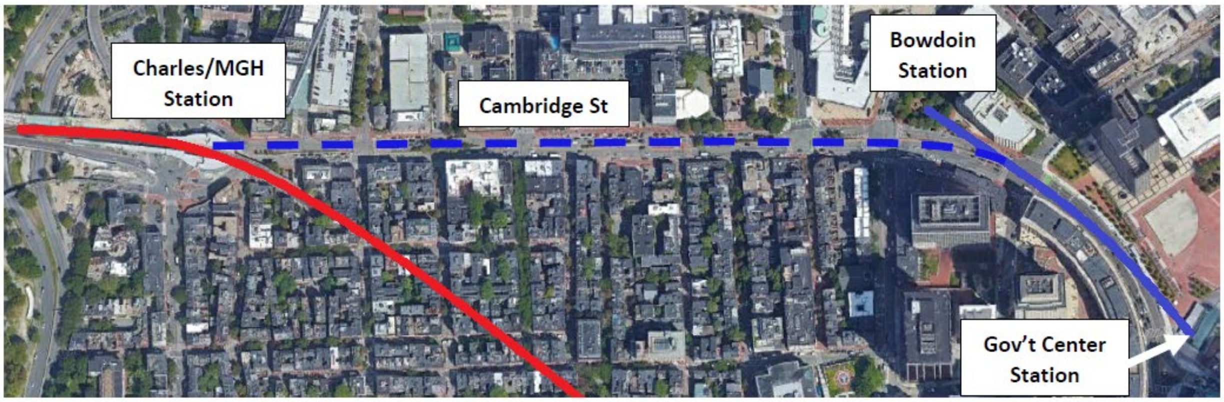
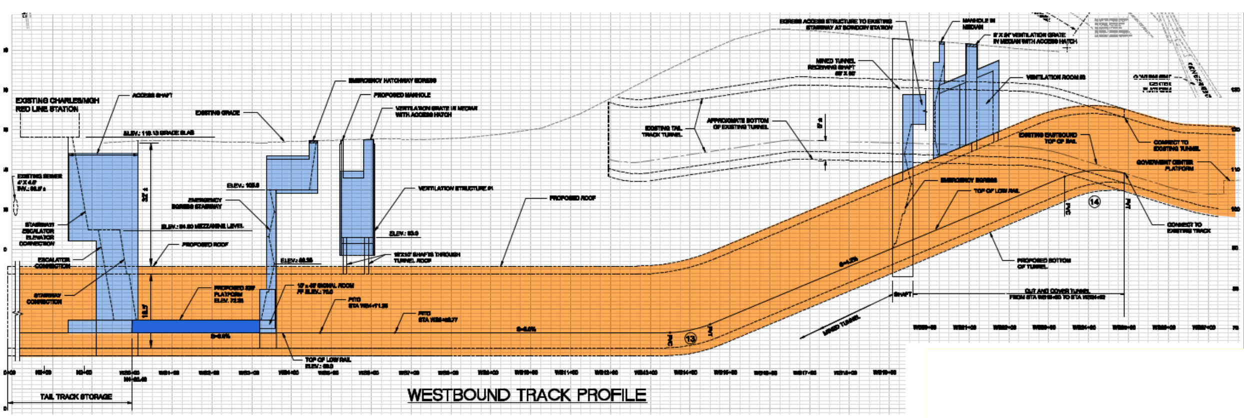


Figure 1: Aerial View of the Connector Location

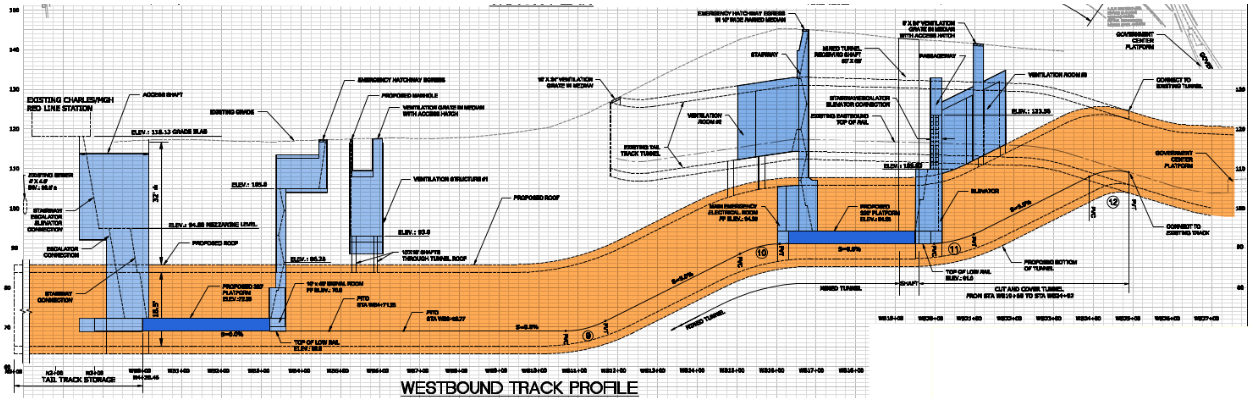
Alternative 1: Red Blue Connector with eliminated Bowdoin Station would extend the Blue Line from Bowdoin Station to Charles/MGH Station, eliminating the existing Bowdoin Station. The station would be deactivated. A new underground Blue Line platform would be constructed east of and below the existing Red Line Charles/MGH Station. The Blue Line platform at Charles/MGH Station would connect to the existing elevated Red Line platforms by stairways, escalators, and elevators (see Figure 5-5).

Figure 5-5. DEIR Alternative 1 Profile



Alternative 2: Red Blue Connector with relocated Bowdoin Station would similarly extend the Blue Line from Bowdoin Station to Charles/MGH Station, but the platform of Bowdoin Station would be relocated while maintaining the existing mezzanine and headhouse. As with Alternative 1, the loop track would be eliminated. A new underground Blue Line platform would be constructed east of and below the existing Charles/MGH Station. The Blue Line platform at Charles/MGH Station would connect to the existing elevated Red Line platforms by stairways, escalators, and elevators.

Figure 5-6. DEIR Alternative 2 Profile



Alternative 1 has been identified as the preferred alternative. This alternative provides the best balance of cost, ridership, and environmental impacts. This alternative would have more operational reliability and have a lower capital cost than Alternative 2. An excerpt from the DEIR is provided below:

> **Preferred Alternative**
>
> Alternative 1, Blue Line Extension with Eliminated Bowdoin Station, has been selected as the Preferred Alternative for the Red Line/ Blue Line Connector Project, as it provides the best balance of cost, ridership, and environmental impacts. MassDOT also believes that this alternative would help the Commonwealth achieve its goal of providing expanded transportation services and improving regional air quality. This alternative extends the Blue Line to Charles/ MGH Station under the Cambridge Street right-of-way has environmental benefits, has faster transit travel time and have a lower capital cost than Alternative 2. Alternative 1 would meet all Project goals, would be operationally practical, and would generate a high number of new system-wide transit trips.

5.3. Resiliency

For all new, repair or replacement projects, MBTA's 2019 Flood Resiliency Design Directive requires a flood resiliency design approach to:

- Minimize risk to MBTA assets from flooding events;
- Maximize the ability of a system or asset to withstand or recover from an extreme weather event;
- Minimize downtime and prevent disruptions to the traveling public; and
- Protect the safety of system users, workers, and the surrounding environment from risks associated with flood hazards.

The proposed Blue Line alignment falls outside the area covered by the Boston Harbor Flood Risk Model (BH-FRM) developed by MassDOT to determine inundation and flooding pathways for future climate change scenarios. An effort is currently underway to update the BH-FRM and create a new Massachusetts Coast Flood Risk Model (MC-FRM) that includes complete coverage of the Massachusetts coastal area. A resiliency assessment of the proposed project would include an evaluation of the stressors on the system in addition to flooding including high heat events, heavy rainfall, wind, and winter weather.

The design of the new Blue Line station and tunnel, track, signal and ventilation system connecting to existing infrastructure at Bowdoin station will adhere to the design hierarchy in the Directive:

- Protect system users and employees from flood hazards;
- Protect the MBTA's critical infrastructure from flood hazards (both coastal and inland);
- Protect the environment and downstream resources;
- Maximize the simplicity of designed systems, emphasizing ease of use and ease of maintenance; and
- Create a resilient and sustainable design that withstands decades of use and maintenance.

Resilient design strategies, including potential utilization of flood control barriers, will be considered in the next phase of development of station and tunnel designs to mitigate impacts caused by climate change.

6. Alternatives Considered

6.1. Station Alternatives

The 2010 DEIR and concept design depicted a two-track, end of line, 320-foot long center platform station. The proposed new platform for the Blue Line would be located immediately east of, and below, the existing Charles/MGH Station headhouse. An elevator would provide access to the Blue Line level. A stairway and two escalators connect the existing street level headhouse down to the Blue Line platform via an intermediate mezzanine. This concept included an emergency exit from the East end of the platform up to street level and a hatch in the median of Cambridge St. This concept is referred to below as the 2010 Alternative.

Three new alternative station configurations have been developed and evaluated as part of this report, as presented below:

- Alternative 1 utilizes a similar platform location just east of the Charles/MGH headhouse. This alternative differs from the 2010 Alternative by reconfiguring the vertical circulation for Blue Line platform to grade level headhouse and adding an East entrance within the future MGH Clinical Building.
- Alternative 2 also utilizes a platform location east of the existing headhouse, but with an intermediate mezzanine. Sidewalk entrances to the north and south of the headhouse, connecting to the new mezzanine, are key features of this alternative. This alternative also includes an entrance within the future MGH Clinical Building.
- Alternative 3 locates the new Blue Line platform to the northwest of the existing headhouse. This alternative also utilizes an underground mezzanine and sidewalk entrances. An entrance within the future MGH Clinical Building is not feasible with this alternative.

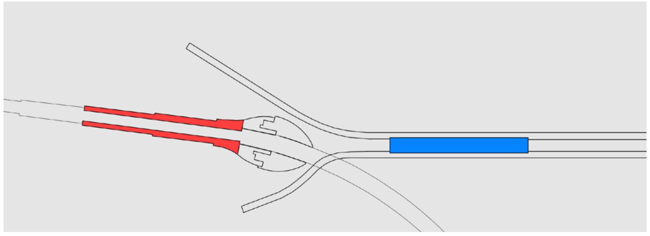
As mentioned in Alternatives 1 and 2 above, an entrance in the future MGH Clinical Building has been incorporated in the concepts. This entrance reflects ongoing coordination between MBTA, BPDA, BTD and the MGH Team to develop a Station entrance within the future MGH facility. This entrance would provide improved access to the medical center as well as long term benefits relative to open space and streetscape along this densely developed area of the City.

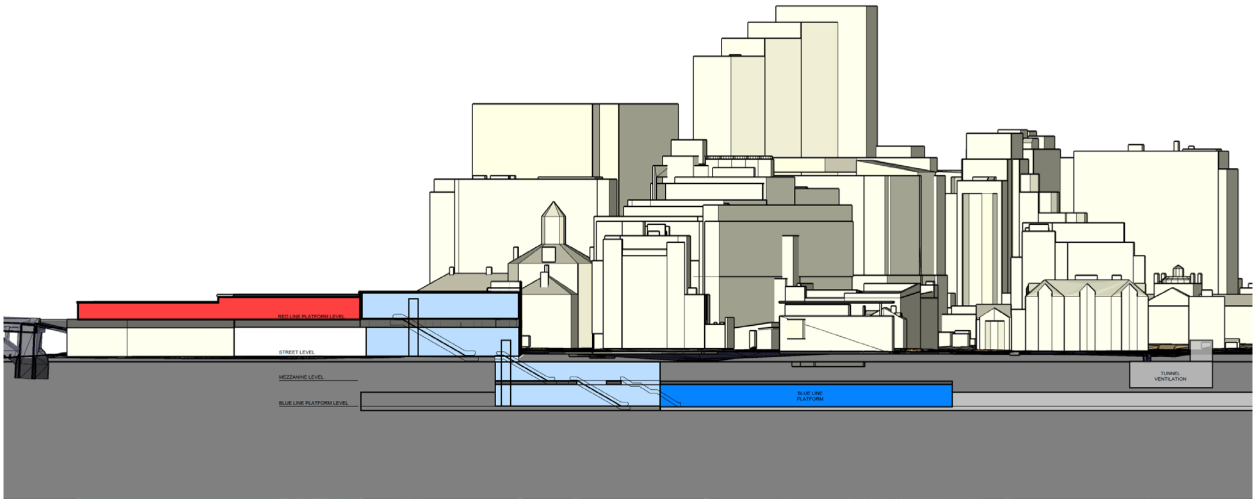
Prior to this coordination, the desirability of an entrance at the East end of the platform, convenient to the main entrance of MGH was recognized by all parties. In coordination with MGH, a range of alternatives were also explored providing an entrance outside of and adjacent to the future Clinical Building. The exterior entrance was on the Northeast corner of Cambridge and North Grove Streets. The alternatives have been included in Appendix B. Locating the East entrance within the future MGH Clinical Building is considered preferable to the exterior entrance by all parties and thus, has been incorporated in Alternatives 1 and 2.

2010 Alternative is the concept depicted in the DEIR and 2010 concept design (see Figure 6-1). From a station configuration and circulation perspective, some concerns with the 2010 Alternative include:

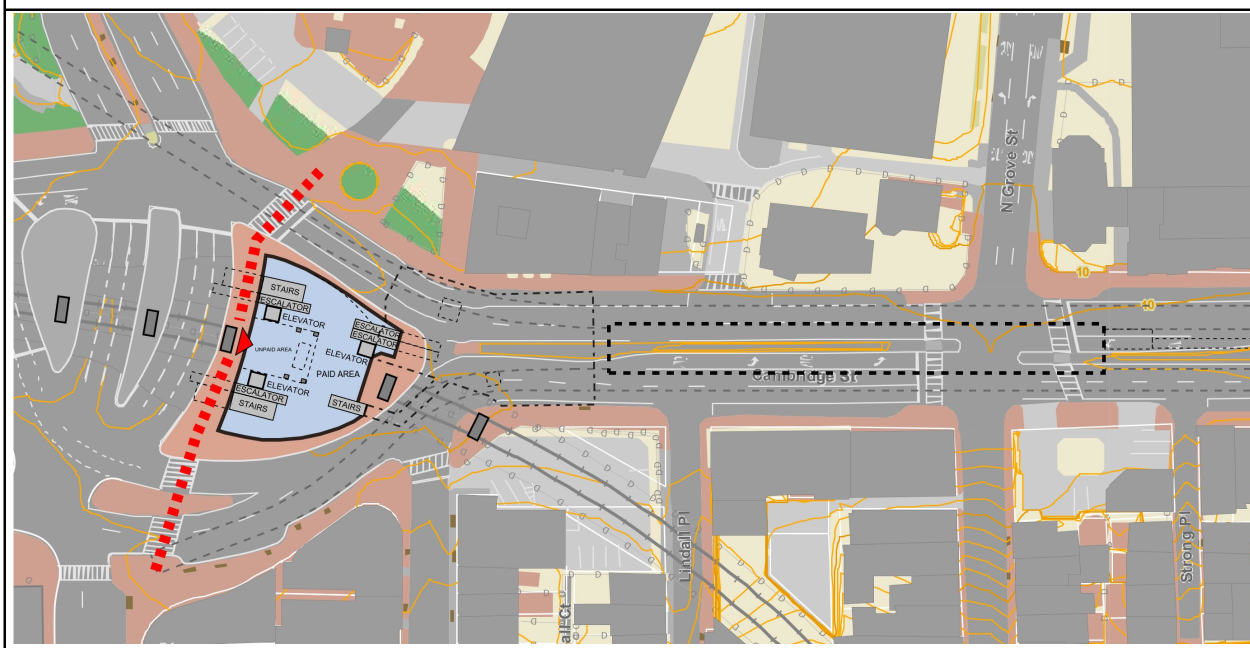
- No redundant elevator – required by MBTA under current policy;
- Circuitous and non-intuitive path to elevator;
- Circuitous and non-intuitive path to escalators; and
- Need for passengers to change escalators at mezzanine.

Figure 6-1. 2010 Alternative

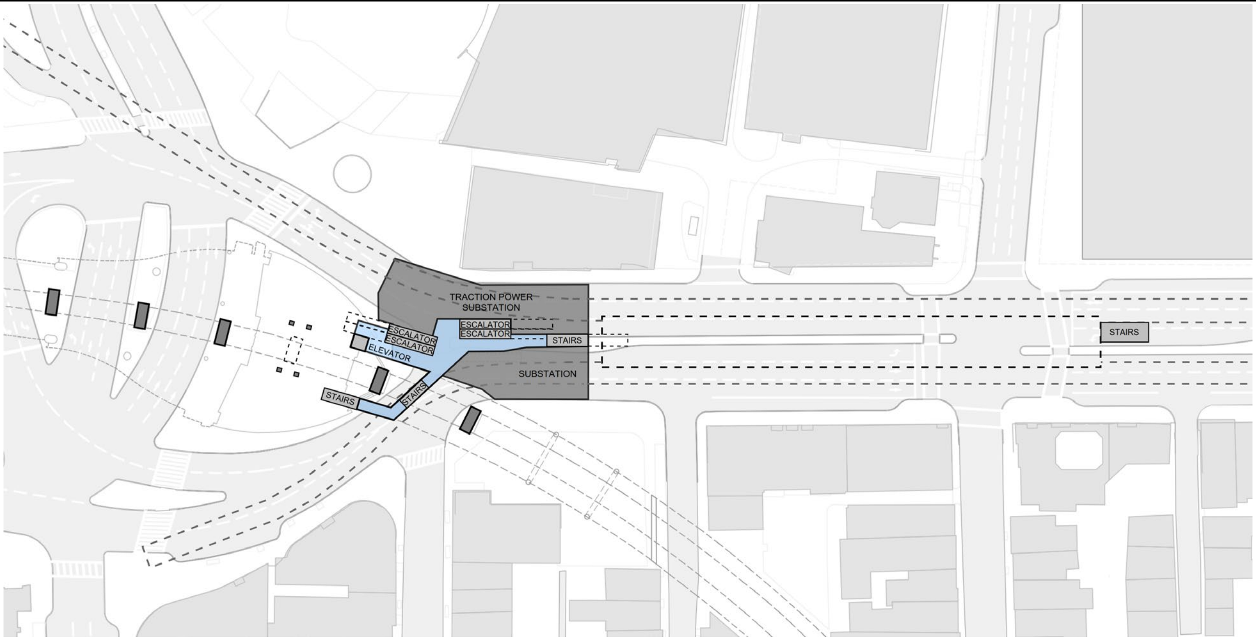




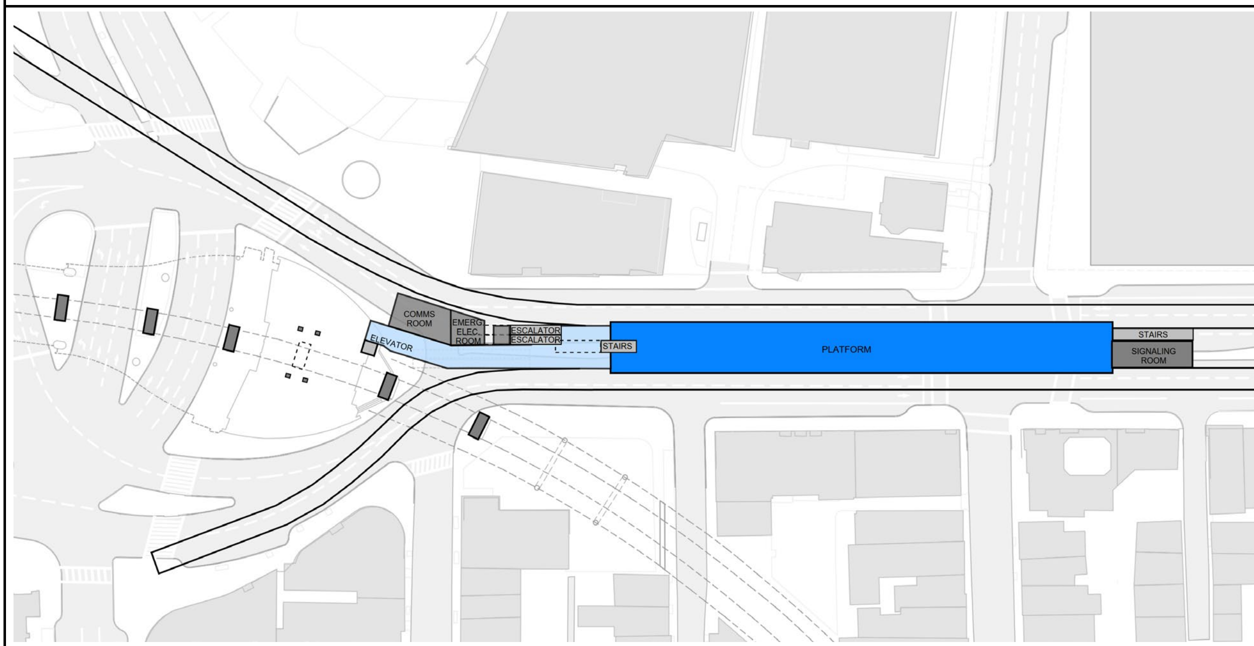
2010 Alternative / Section



2010 Alternative / Street Level Plan



2010 Alternative / Mezzanine Level Plan



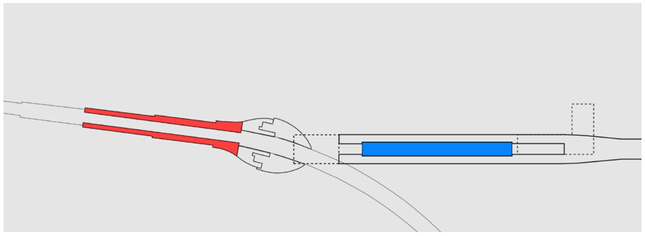
2010 Alternative / Platform Level Plan

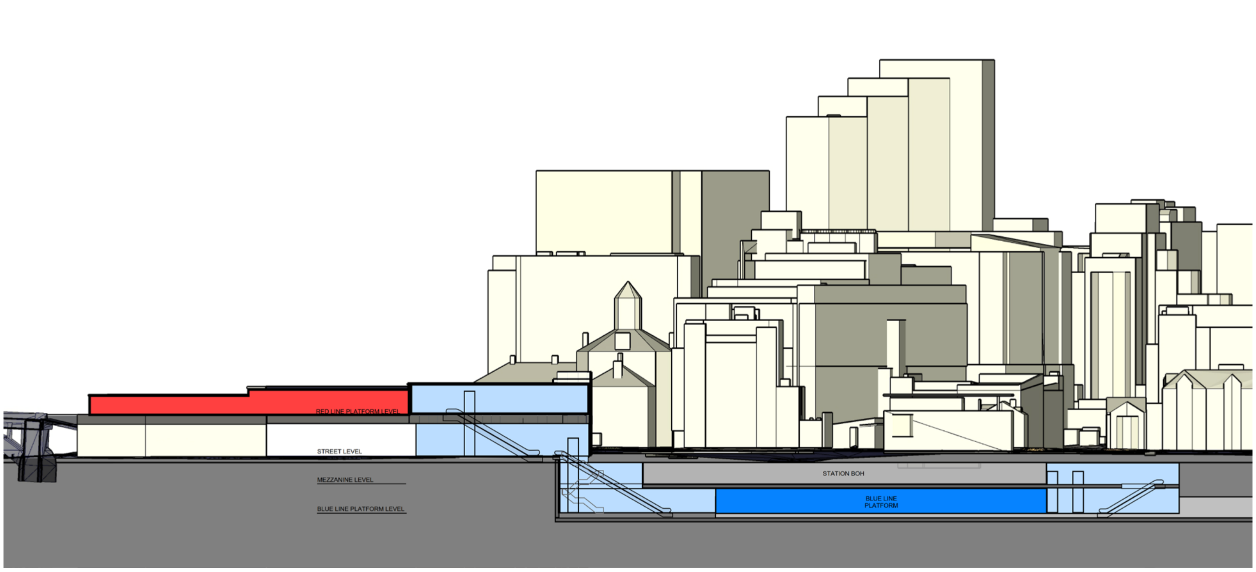
Alternative 1 is depicted in Figure 6-2. From a station configuration and circulation perspective, some key attributes of Alternative 1 include:

- Redundant elevators provided – important considering the access to adjacent hospitals;
- Path to elevators visible from platform;
- At West end of platform, direct escalator run from platform to existing headhouse – important for those making a Red Line Blue Line transfer; and

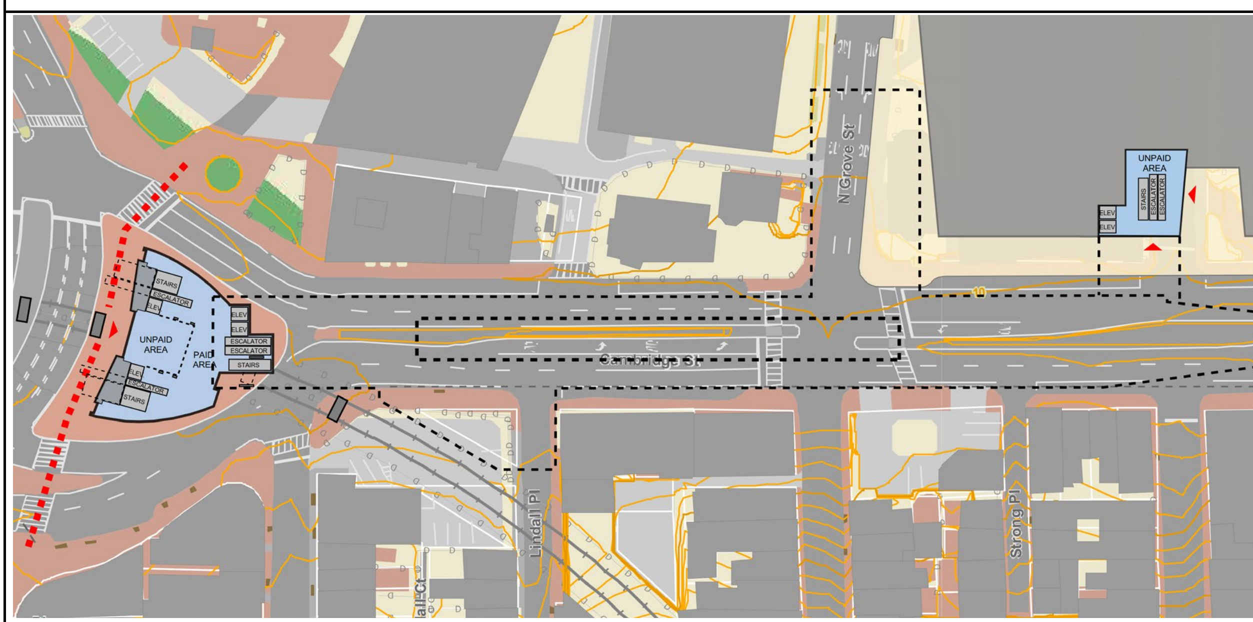
- Entrance from east end of platform to grade within future MGH Clinical Building - convenient to Massachusetts General Hospital campus.

Figure 6-2. Alternative 1

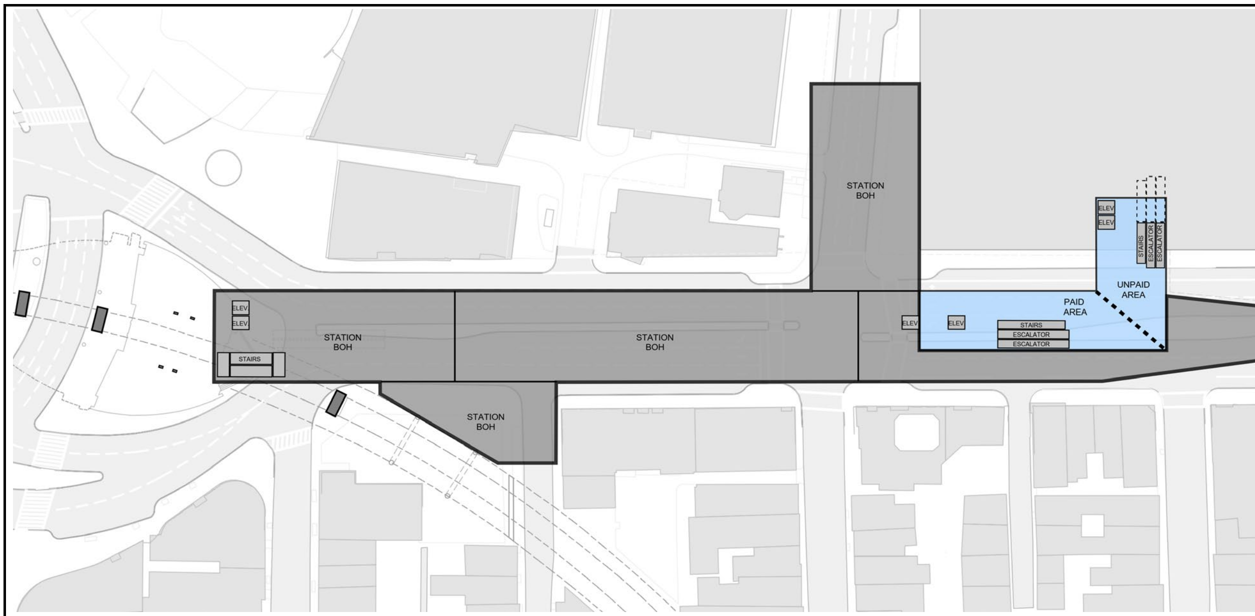




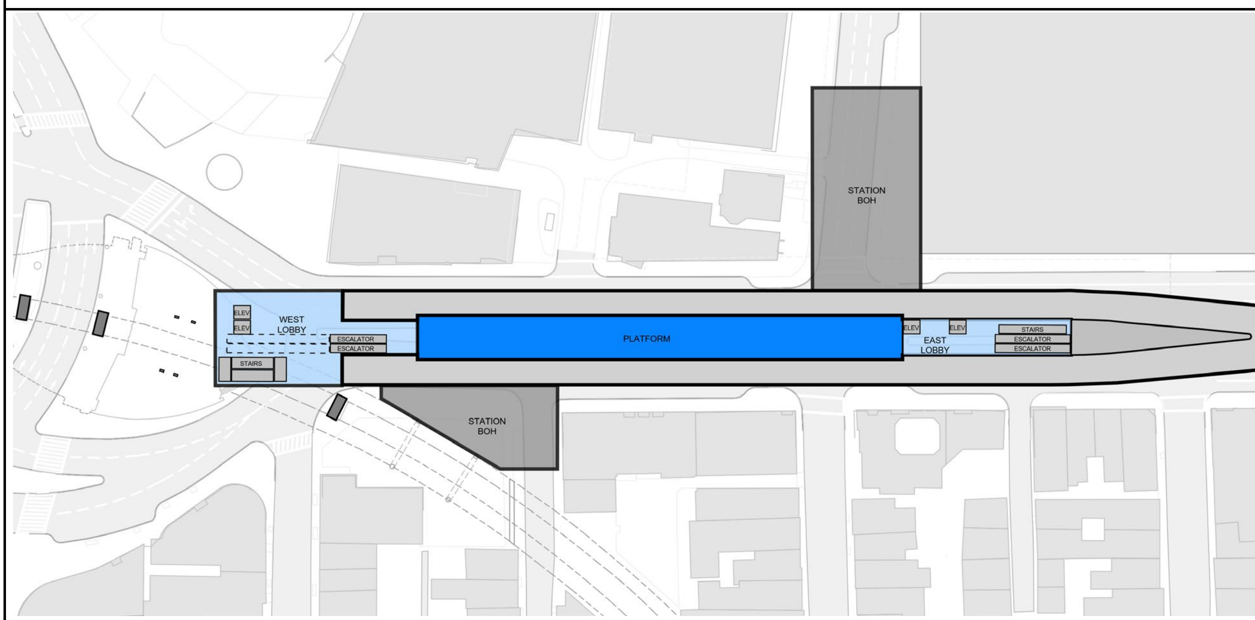
Alternative 1 / Section



Alternative 1 / Street Level Plan



Alternative 1 / Mezzanine Level Plan



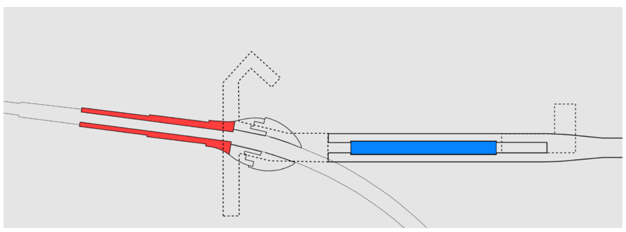
Alternative 1 / Platform Level Plan

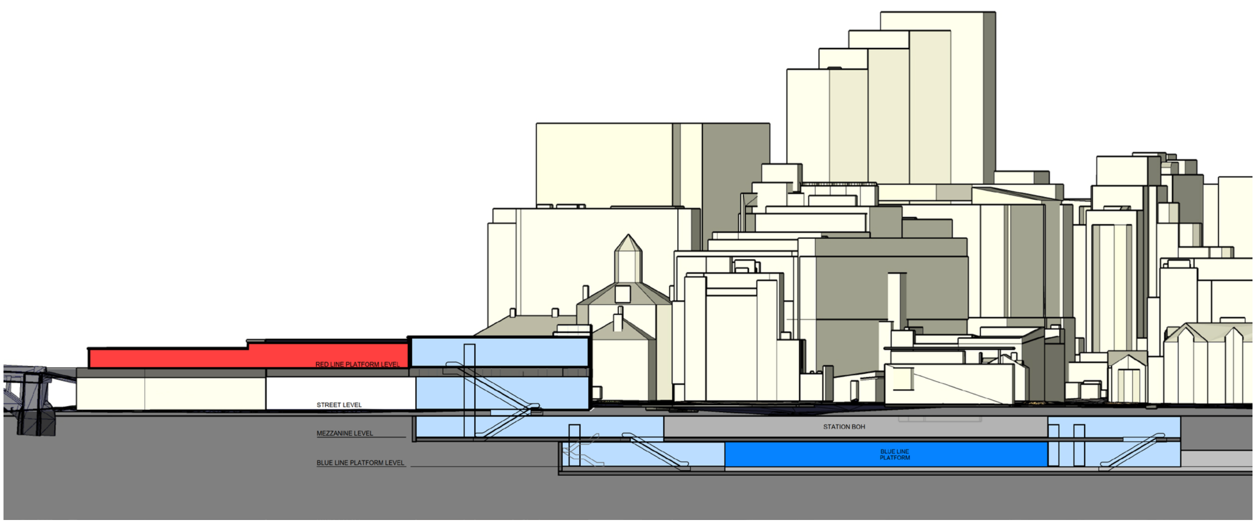
Alternative 2 is depicted in Figure 6-3. From a station configuration and circulation perspective, some key attributes of Alternative 2 include:

- Blue Line platform location similar to Alternative 1, east of the existing headhouse;
- Reconfigures the at-grade entrances to Charles/MGH to the sidewalks north and south of the existing headhouse;
- Requires a below grade mezzanine (under existing headhouse) to connect the Blue Line platform for transfer to Red Line and for sidewalk-level entrances;

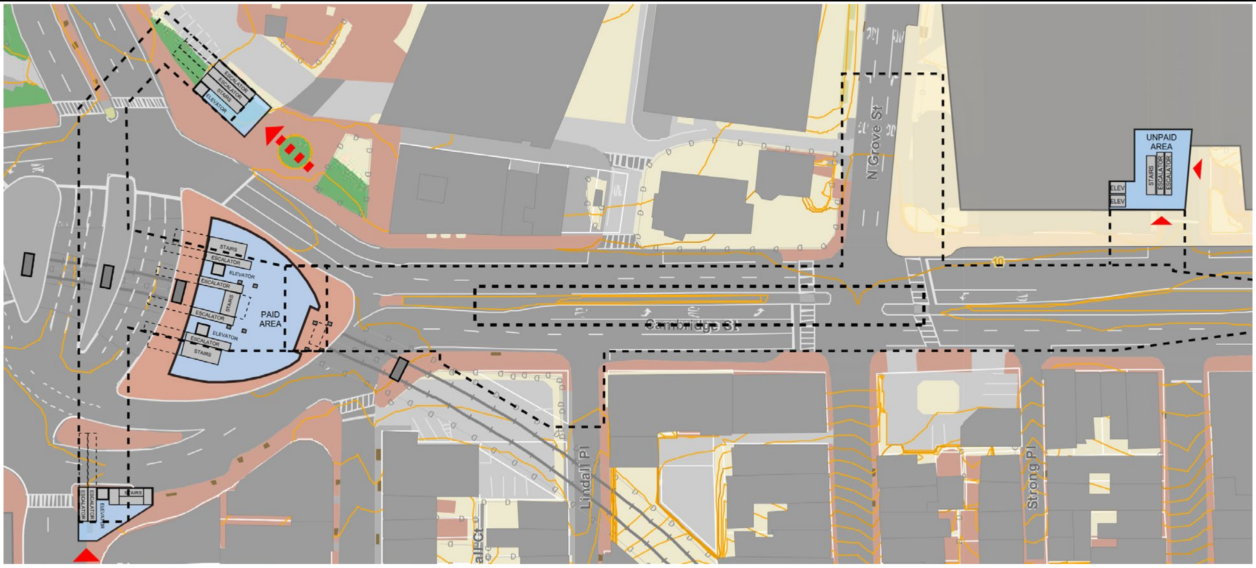
- Fare control is moved from existing at-grade headhouse to the below-grade mezzanine. It is not possible to add the vertical circulation from the mezzanine to the unpaid side of the at-grade headhouse;
- As fare control is at mezzanine level, existing at-grade entrances in center of Charles Circle would be closed. Emergency egress would need to be evaluated and configured as necessary. Controlling emergency egress locations may prove problematic;
- Red Line passengers would also have to use the new sidewalk entrances, via below grade mezzanine;
- A redundant elevator provided to Blue line platform; however, transfer at mezzanine level is required for circulation between at-grade and Blue Line platform; and
- Entrance from east end of platform to grade within future MGH Clinical Building - convenient to Massachusetts General Hospital campus.

Figure 6-3. Alternative 2

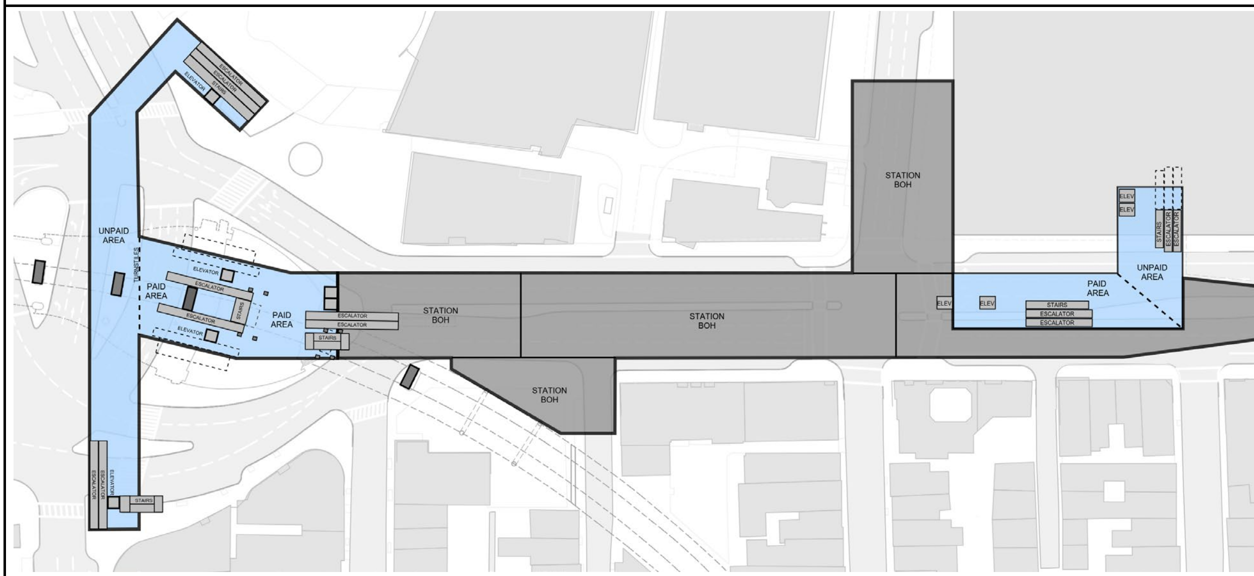




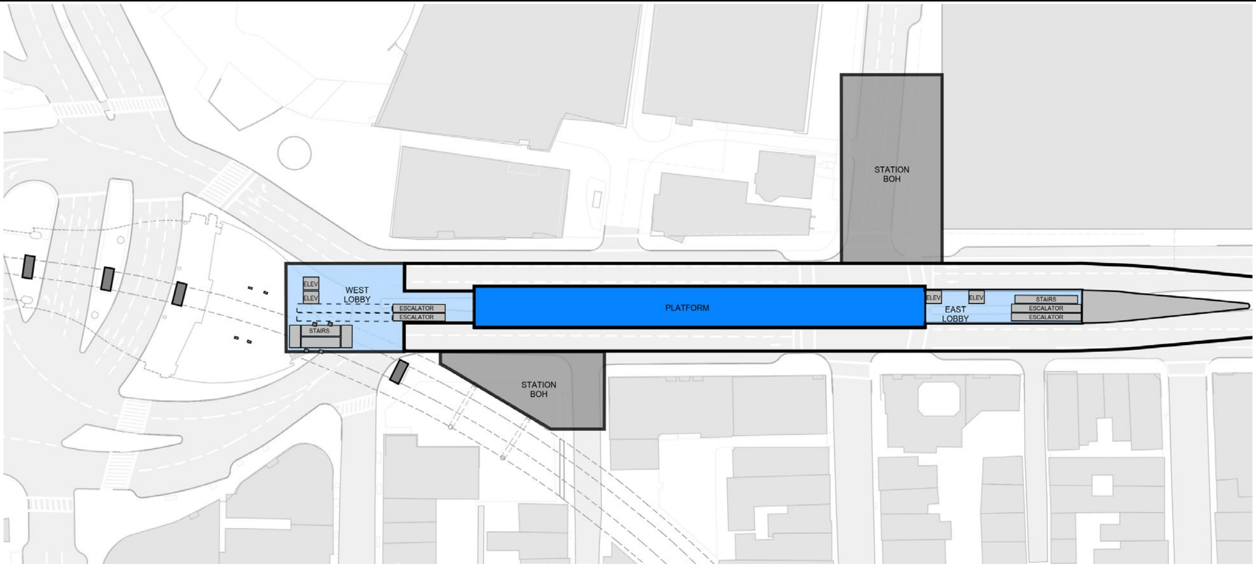
Alternative 2 / Section



Alternative 2 / Street Level Plan



Alternative 2 / Mezzanine Level Plan

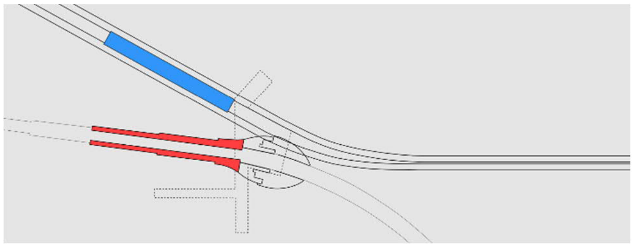


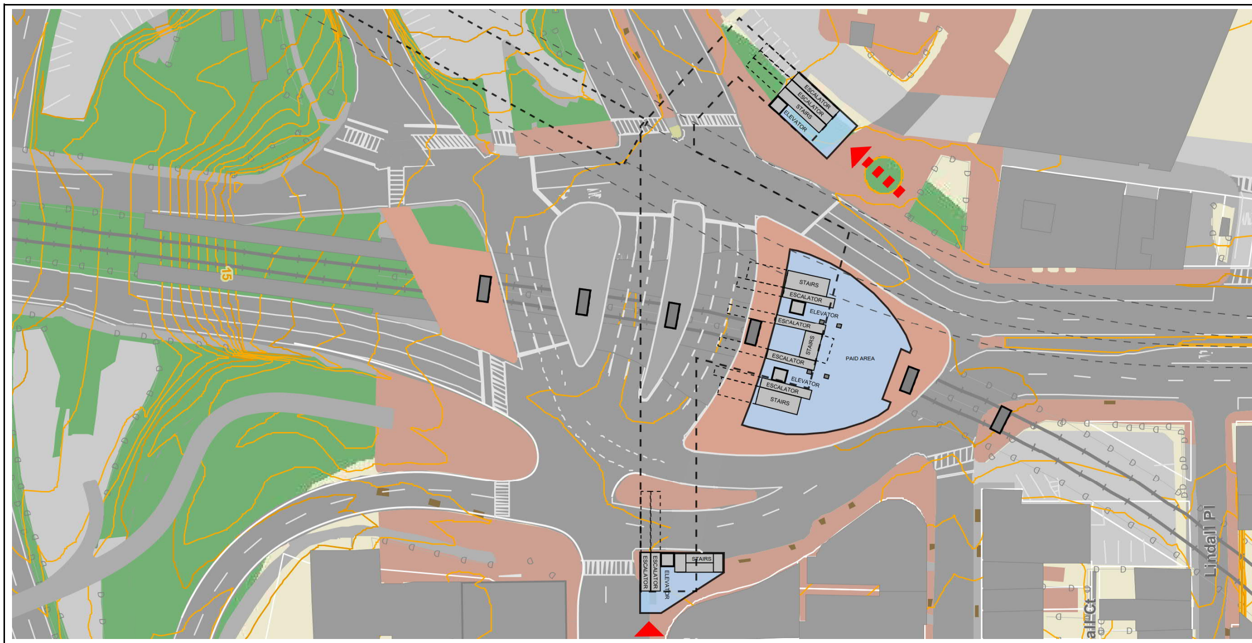
Alternative 2 / Platform Level Plan

Alternative 3 is depicted in Figure 6-4. From a station configuration and circulation perspective, some key attributes of Alternative 3 include:

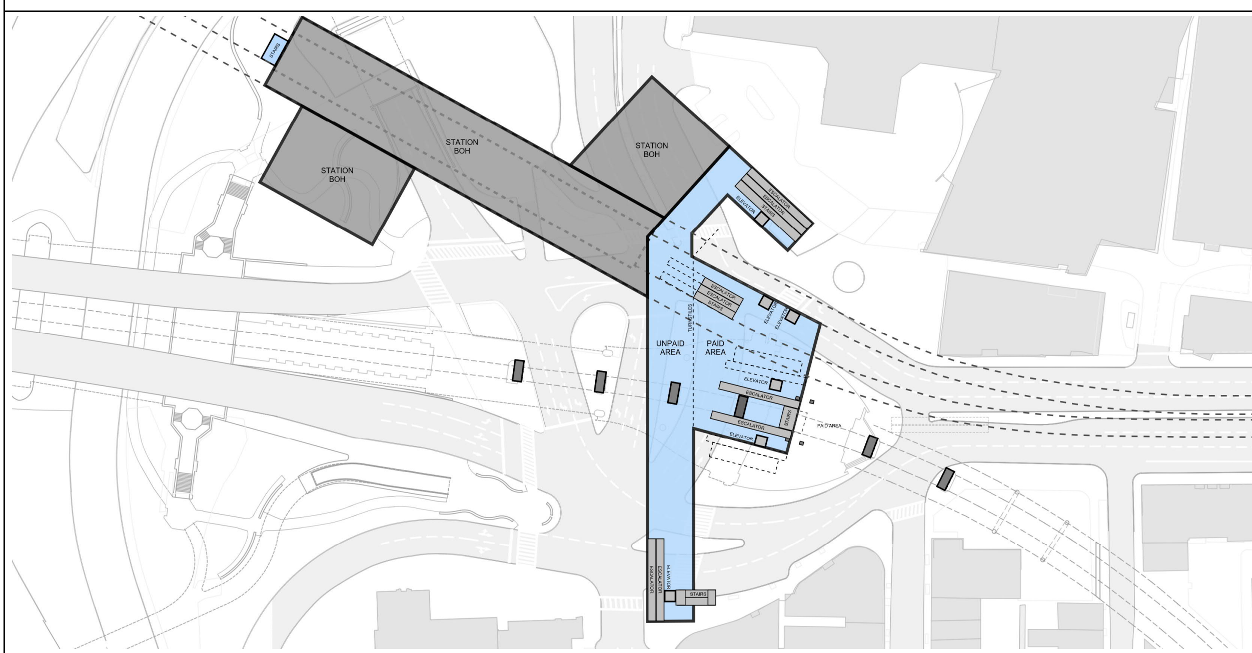
- Blue Line platform is located northwest of the existing headhouse;
- Reconfigures the at-grade entrances to Charles/MGH to the sidewalks north and south of the existing headhouse;
- Requires a below grade mezzanine (under existing headhouse) to connect the Blue Line platform for transfer to Red Line and for sidewalk-level entrances;
- Fare control is moved from at-grade to the below-grade mezzanine. It is not possible to add the vertical circulation from the mezzanine to the unpaid side of the at-grade headhouse;
- As fare control is at mezzanine level, existing at-grade entrances in center of Charles Circle would be closed. Emergency egress would need to be evaluated and configured as necessary. Controlling emergency egress locations may prove problematic;
- Red Line passengers would also have to use the new sidewalk entrances, via below grade mezzanine;
- A redundant elevator provided to Blue line platform; however, transfer at mezzanine level is required for circulation between at-grade and Blue Line platform; and
- An East end entrance within future MGH Clinical Building is not feasible for this alternative.

Figure 6-4. Alternative 3

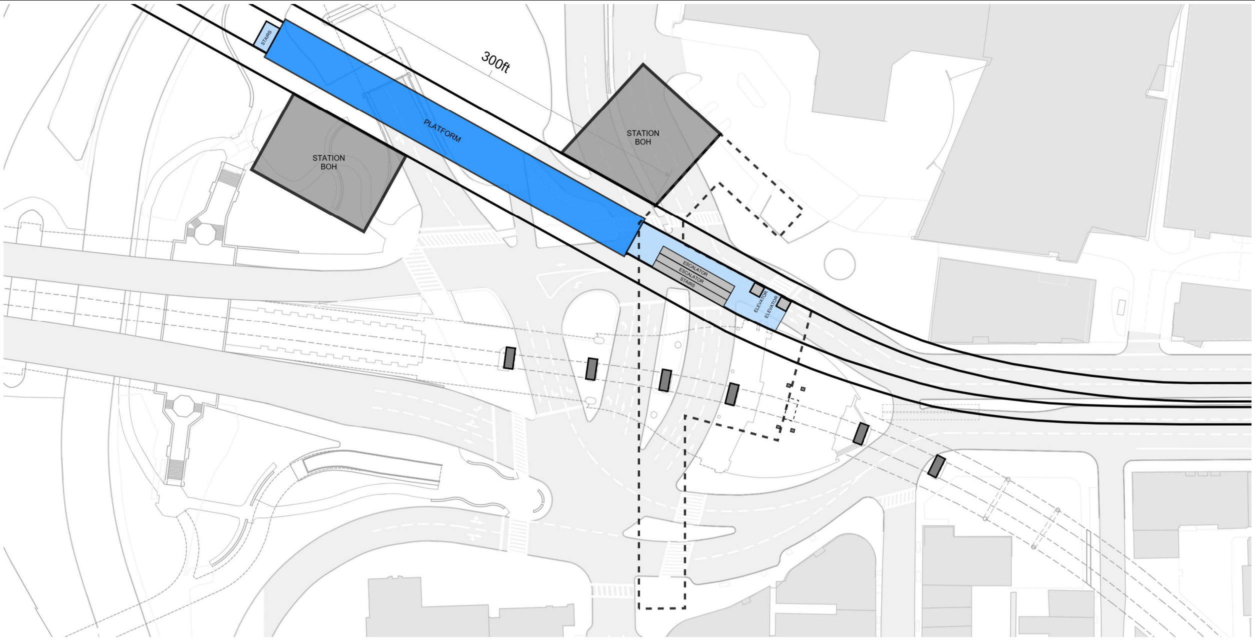




Alternative 3 / Street Level Plan



Alternative 3 / Mezzanine Level Plan



Alternative 3 / Platform Level Plan

6.2. Tunnel Alternatives

6.2.1. 2010 Alternative

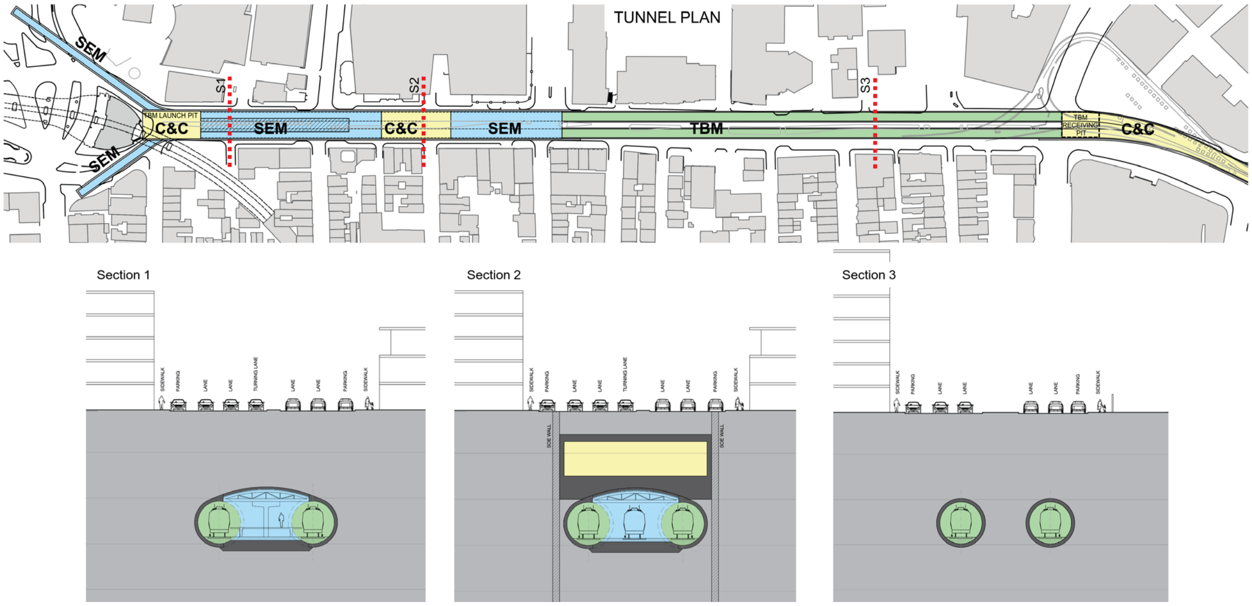
The 2010 DEIR and concept design utilized three types of tunneling methods for the project:

- Tunneling with Tunnel Boring Machine (TBM)
- Tunneling with Sequential Excavation Method (SEM)
- Tunneling with Cut-and-Cover Method (C&C)

The DEIR included a schedule with an overall duration for work of 5.75 years, which included:

- Phase 1 – Initial Utility Relocation and Other Initial Activities
- Phase 2A – Northerly Tunnel Construction
- Phase 2B – Top Down Cut-and-Cover East of Receiving Pit
- Phase 3A – Utility Relocation
- Phase 3B – Southerly Tunnel Construction

Figure 6-5. 2010 Alternative SEM + C&C + TBM



The tunneling methodology presented in the 2010 concept design consisted of segments of Tunnel Boring Machine (TBM), Sequential Excavation Method (SEM) and Cut & Cover (C&C). This alternative is presented in this report as the 2010 Alternative.

Tunneling with TBM - The use of the TBM requires the construction of a launch pit and a reception pit. The launch pit is located just east of the existing Charles/MGH Station and the reception pit will be located near the existing Bowdoin Station. The TBM will be used to tunnel from the launch pit for the northerly (outbound) track to the reception pit. Once it reaches the receiver hole it will be disassembled and transferred to the launch pit to tunnel the southern (inbound) track in the easterly direction.

Tunneling with SEM - The SEM will be used for the construction of the two storage track tunnels and also for the construction of the third arch over the new platform area and at the track cross-over area just east of the new Charles/MGH Red Line Station.

Tunneling with C&C Method – In addition to the launch pit and reception pit, the C&C method is proposed at the eastern end of the Blue Line extension between the present Bowdoin Station and the eastern terminus of the project. The walls of the temporary earth retaining structure will remain in place and will serve as permanent tunnel walls where feasible. The C&C method will also be utilized for the construction of the ventilation structure and emergency Egress structures above the new Blue Line tunnel.

Key attributes of this alternative include:

- The benefits of TBM tunneling in reducing surface disruption are offset by the need for C&C construction at the launch pits and reception pits.
- Ground improvements will be necessary in all areas that both SEM and TBM are proposed to be performed to stabilize the soils and control ground water. Ground improvement methods for the TBM and SEM in the soft ground (Boston Blue Clay) will include permeation or jet grouting. The grouting in the soft ground will require approximately 100% replacement of the existing ground to the surface and require extensive disruption and activities at the ground surface to handle the extent of spoils related to the grouting requirements. Both operations would entail drilling from the surface of the street along the tunnel alignment. This activity is expected to be underway for an extended duration prior to commencing work on tunneling. The limits of

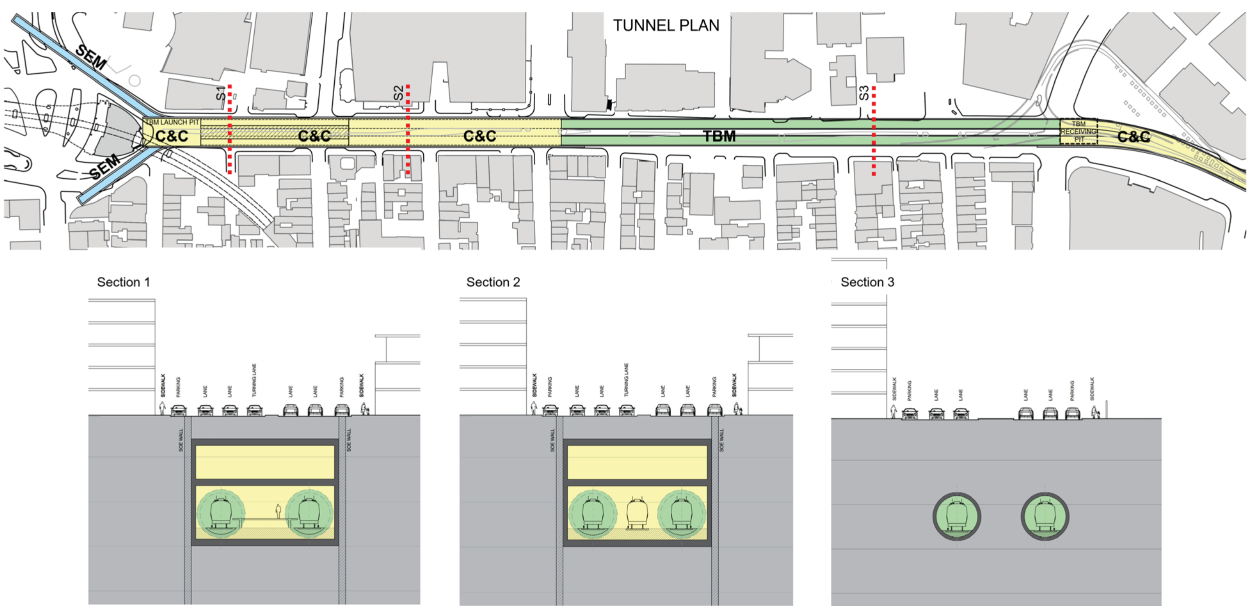
ground improvements to supplement TBM and SEM operations would include at a minimum the platform and cross-over area, storage tracks, and the area near the connection to the existing structure at Bowdoin.

- The cost of the TBM and operation for the short run, approximately 2400-2600 feet. Based on industry standards the economics to consider TBM vs. C&C construction is approximately one (1) mile minimum driving length.
- The use of TBM within the SEM station areas cannot be used as shown in the 2010 DEIR. The concrete segmental liner used in the TBM tunneling is comprised of 5-6 segments connected with dowels and bolts forming the tunnel circular lining. Stability of the lining depends on the configuration. Removing sections of the lining will require an excessive amount of internal bracing and the initial stability and final design is questionable. The method of driving the TBM through future C&C or SEM structures is occasionally used to assist in the excavation process of the final structure, but the complete TBM lining is removed and an SEM lining is constructed around the TBM lining envelop.
- The SEM construction of the platform greatly limits the size of the cavern created. This hinders the ability to provide an emergency tunnel ventilation system that meets today's standards.
- The SEM construction of the platform and cross-over areas will require significant ground improvement above the tunnel. Ground improvement will negate the desired benefits of the SEM tunneling in minimizing surface disruption.

6.2.2. New Tunnel Alternatives

Six new tunneling methodology combinations were defined and evaluated as described below.

Figure 6-6. 2010 Alternative - Variation SEM + C&C + TBM

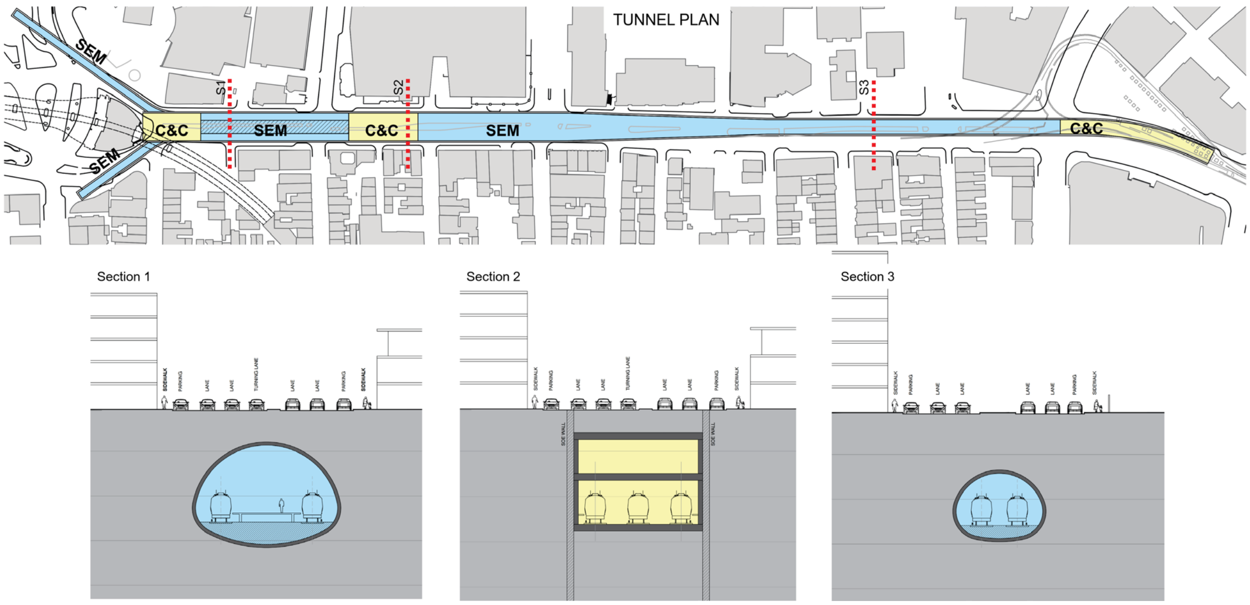


This variation is similar to the 2010 Alternative with the exception that the station and cross-over are constructed by the C&C method rather than SEM.

Key attributes of this alternative include:

- The benefits of TBM tunneling in reducing surface disruption are further offset by the need for C&C construction at the station, crossover, and receiver shafts.
- C&C construction of the platform permits flexibility in size of the cavern created. This complements the ability to provide an emergency tunnel ventilation system that meets today's standards.

Figure 6-7. Alternative T1 SEM + C&C



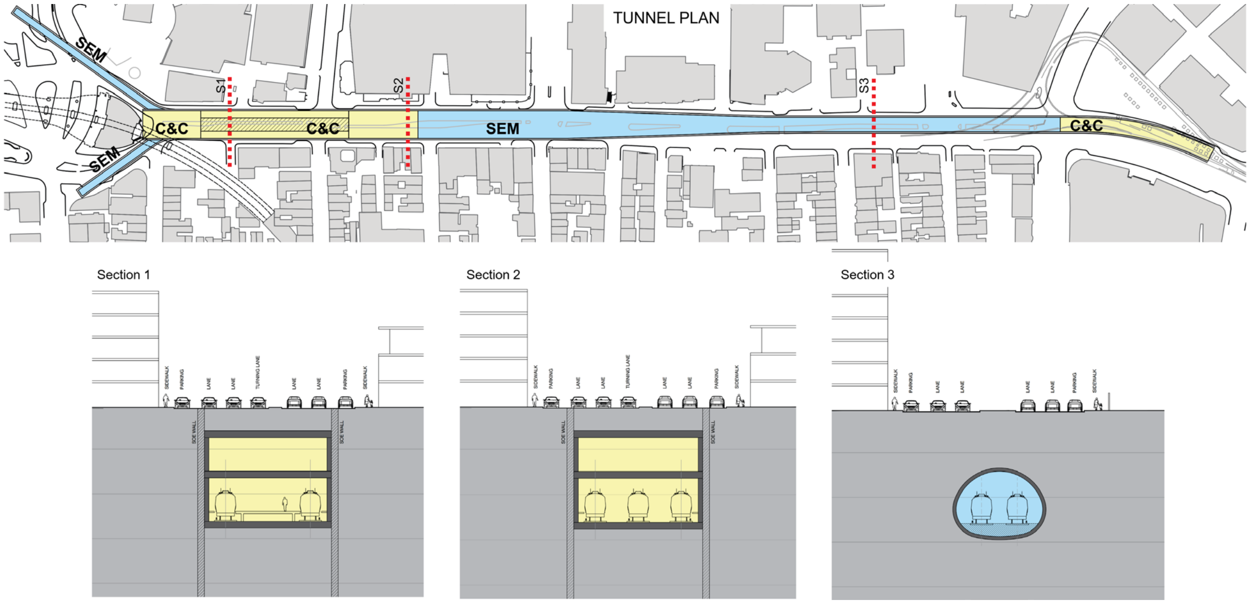
Alternative T1 will use SEM for the construction of the two storage track tunnels, the new platform and at the cross-over area.

As with the 2010 Alternative, the C&C method will be used at the eastern end of the Blue Line extension between the current Bowdoin Station and the eastern terminus of the project. The C&C method will also be utilized for the construction of the ventilation structure above the new Blue Line tunnel.

Key attributes of this alternative include:

- The benefits of SEM tunneling in reducing surface disruption are offset by the need for C&C construction at the starter and receiver shafts.
- The SEM construction of the platform greatly limits the size of the cavern created. This hinders the ability to provide an emergency tunnel ventilation system that meets today's standards.
- The SEM construction of the platform and cross-over areas will require significant ground improvement above the tunnel. Ground improvement will negate the desired benefits of the SEM tunneling in minimizing surface disruption.

Figure 6-8. Alternative T1A SEM + C&C

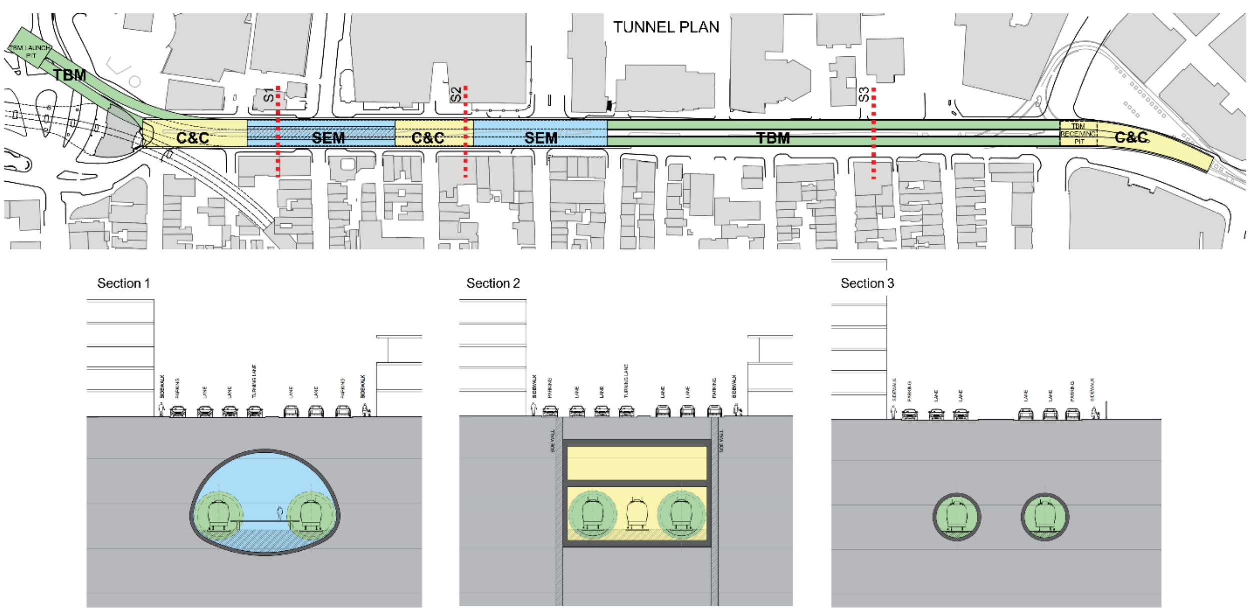


Alternative T1A is similar to Alternative T1 with the exception that the station and cross-over are constructed by the C&C method rather than SEM.

Key attributes of this alternative include:

- The benefits of SEM tunneling in reducing surface disruption are further offset by the need for C&C construction at the station, crossover, and receiver shafts.
- C&C construction of the platform permits flexibility in size of the cavern created. This complements the ability to provide an emergency tunnel ventilation system that meets today's standards.

Figure 6-9. Alternative T2 SEM + C&C + TBM



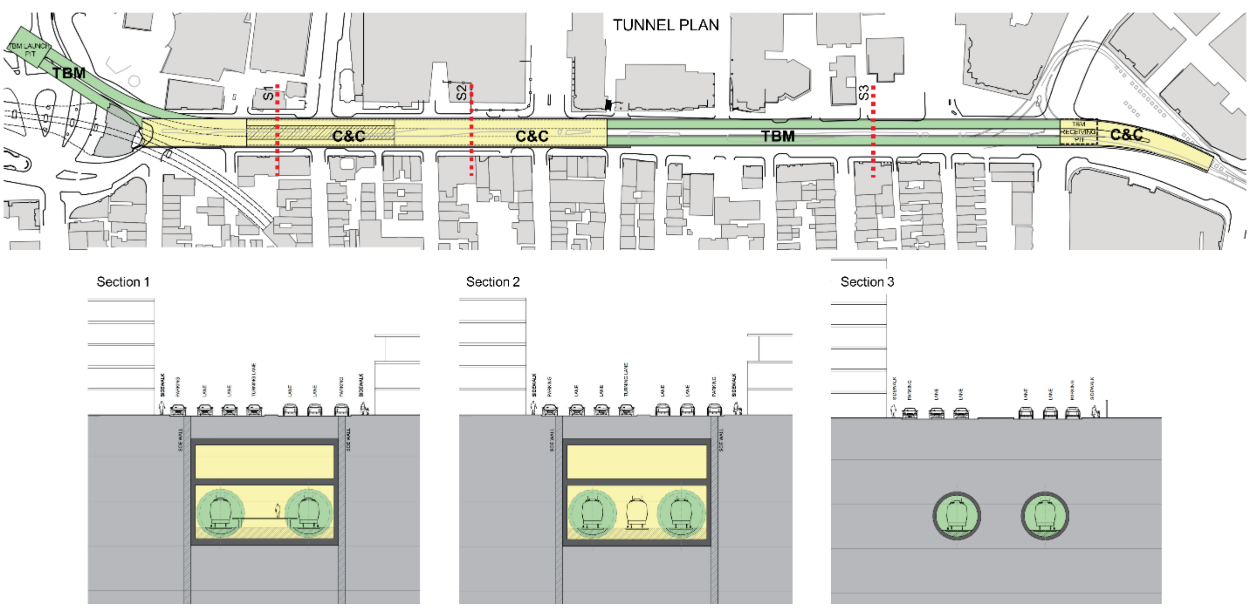
Alternative T2 maximizes the use of TBM tunneling method by constructing the two storage tracks by TBM. The TBM starter shaft is located in the existing parking lot northwest of the Charles/MGH Station. As in the 2010 Alternative the station and cross-over are constructed by

SEM. The C&C method is utilized at the eastern end of the Blue Line extension. The C&C method will also be utilized for the construction of the ventilation structure above the new Blue Line tunnel.

Key attributes of this alternative include:

- The benefits of TBM tunneling in reducing surface disruption are offset by the need for C&C construction at the vertical circulation core connecting the Blue Line platform to the at-grade headhouse and the receiver shaft.
- The SEM construction of the platform greatly limits the size of the cavern created. This hinders the ability to provide an emergency tunnel ventilation system that meets today's standards.
- The SEM construction of the platform and cross-over areas will require significant ground improvement above the tunnel. Ground improvement will negate the desired benefits of the SEM tunneling in minimizing surface disruption.
- Driving the two side-by-side TBM tunnels will require underpinning of the north wall of the existing Charles/MGH headhouse.

Figure 6-10. Alternative T2A C&C + TBM

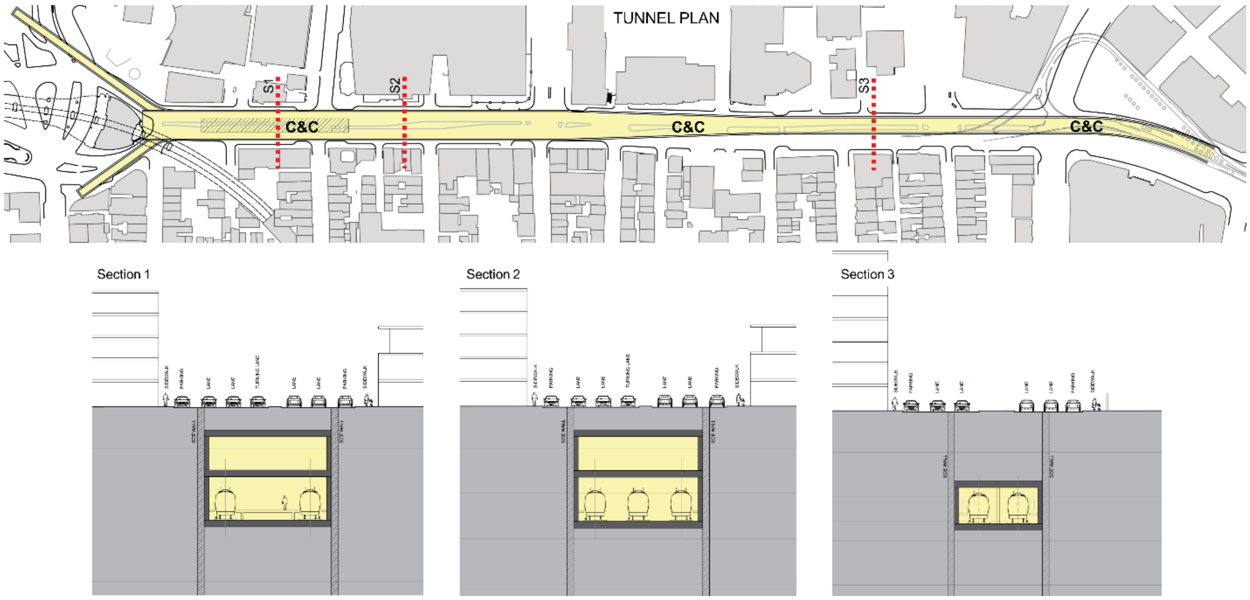


Alternative T2A is similar to Alternative T2 except the station and cross-over are constructed by C&C method. The C&C method is utilized at the eastern end of the Blue Line extension.

Key attributes of this alternative include:

- The benefits of TBM tunneling in reducing surface disruption are offset by the need for C&C construction at the station and cross-over and the receiver shaft.
- Driving the two side-by-side TBM tunnels will require underpinning of the north wall of the existing Charles/MGH headhouse.
- C&C construction of the platform permits flexibility in size of the cavern created. This complements the ability to provide an emergency tunnel ventilation system that meets today's standards.

Figure 6-11. Alternative T3 C&C



Alternative T3 propose that the entire tunnel is constructed by C&C method.

Key attributes of this alternative include:

- The C&C method is common practice for this type of tunnel.
- C&C elements for this and other alternatives require similar traffic detours and surface disruption.
- The C&C method allows for utility relocations to be performed in advance of work, potentially while design is continuing to be finalized. Providing for a shorter more compressed schedule.
- Provides shortest schedule and lowest cost.
- C&C construction of the platform permits flexibility in size of the cavern created. This complements the ability to provide an emergency tunnel ventilation system that meets today's standards.

7. Recommendations

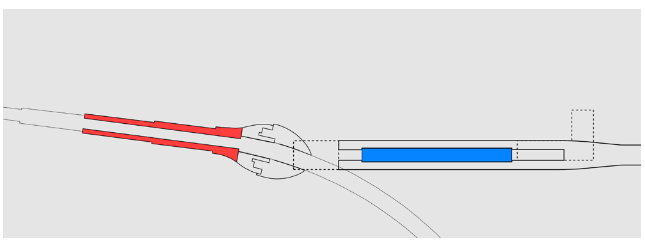
7.1. Station Configuration

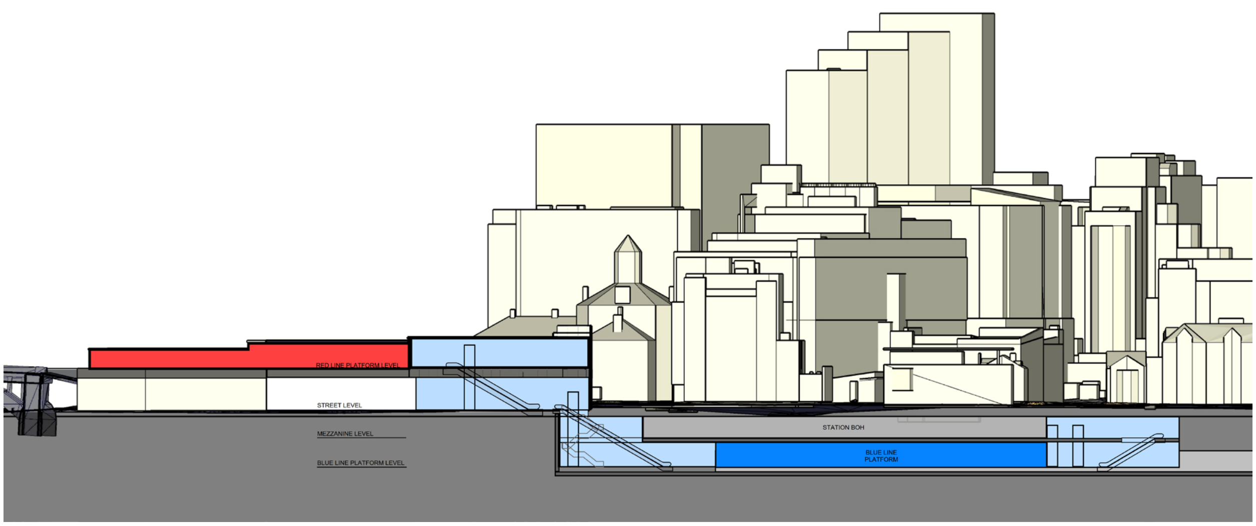
Evaluation of the alternative station configurations reveals that the following key attributes need to be considered:

- Provision for a redundant elevator
- Elevator travel path and access
- Escalator travel path and access
- Provision of an entrance within future MGH Clinical Building
- Changes to fare control
- Cost

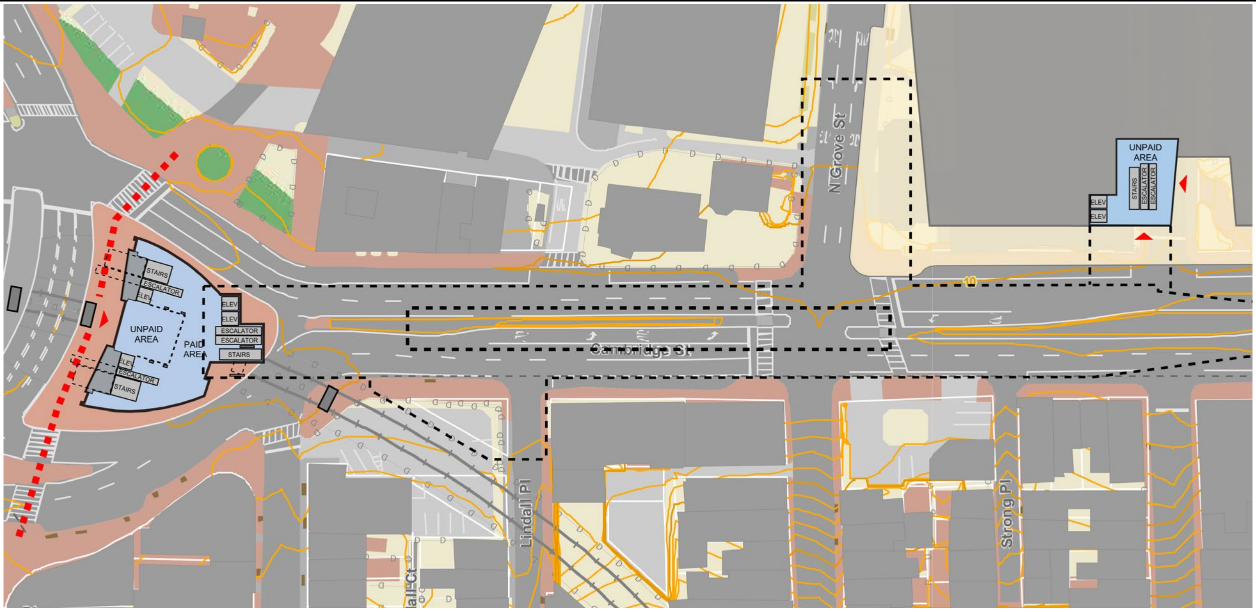
Station Alternative 1 is the recommended configuration. This alternative locates the station platform close to the existing Charles/MGH headhouse and provides a clear travel path between Red and Blue Lines, including a single escalator run with good visual connectivity. This alternative also provides an entrance within future MGH Clinical Building.

Figure 7-1. Recommended Station Configuration

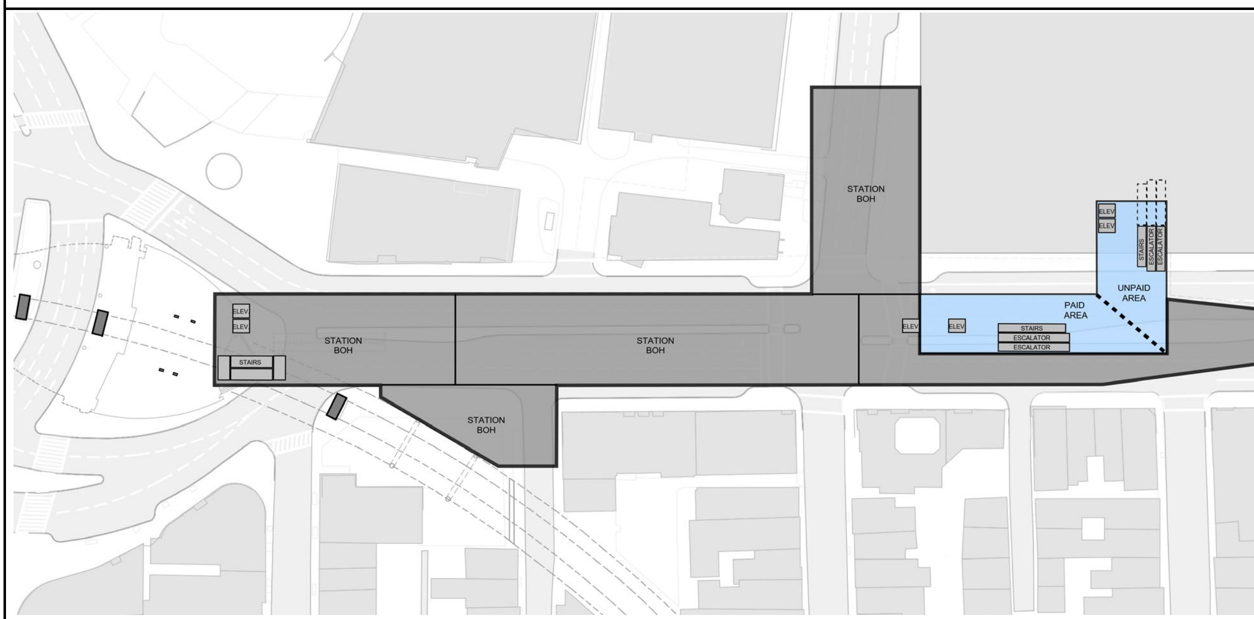




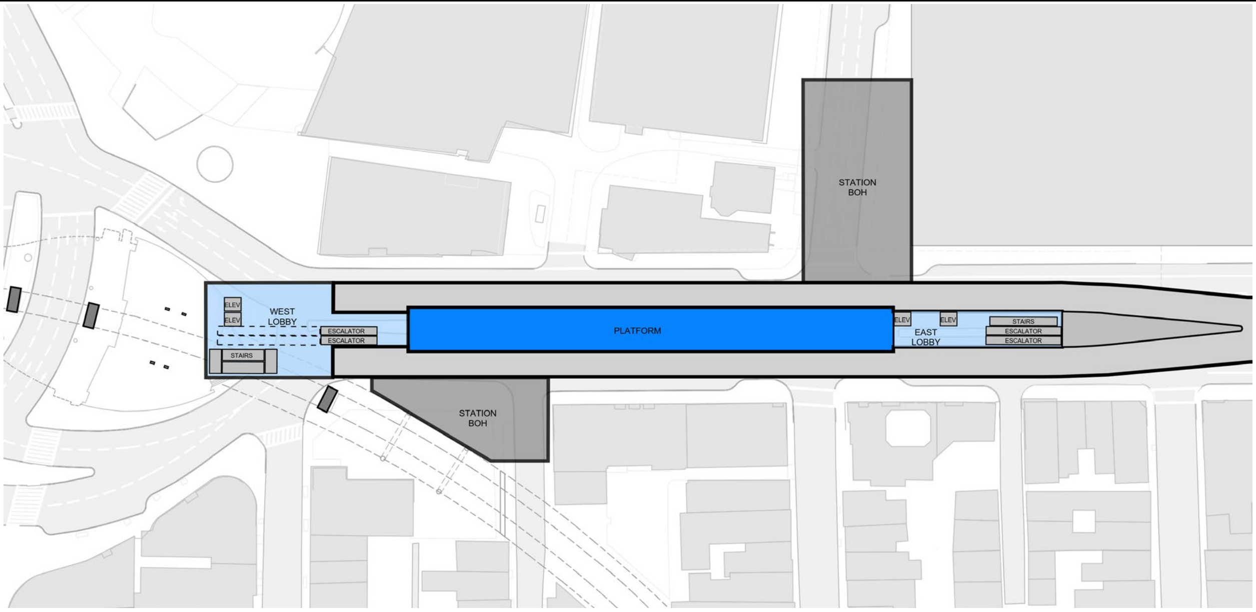
Alternative 1 / Section



Alternative 1 / Street Level Plan



Alternative 1 / Mezzanine Level Plan



Alternative 1 / Platform Level Plan

7.2. Construction Methods

Evaluation of the alternative construction methods reveals the following key attributes:

Tunnel Boring Machine (TBM) and Sequential Excavation Method (SEM)

Typically, the construction firms in the Boston area are not firms that would self-perform a TBM or SEM operation. Also, MBTA has limited experience in TBM and SEM construction vs. C&C experience.

The short distance of the tunnel does not support the use of TBM. The TBM would be utilized on this project for approximately 2,400 linear feet (1,200 ft. each tunnel x 2 twin tunnels). The economics of implementing a TBM is generally for a tunnel that is a minimum of one mile.

Construction of SEM through the station area is problematic and the use of TBM with SEM method has a high risk. The TBM tunnel is constructed using segmental concrete precast segments approximately 4-5 feet in length and 5-6 segments to complete the circular liner and remain structurally sound. The segments are connected using dowels and single bolts to form the circular tunnel and then an SEM tunneling is constructed by dismantling segments of the tunnel circle using several levels of internal bracing to support the unconnected pieces of TBM tunnel liner. Typically, but rarely, when a SEM cavern is created after driving a TBM tunnel, the entire TBM lining is removed and an independent SEM is constructed beyond the limits of the TBM. This type of construction has been rarely used and creates a significant risk of construction.

Based upon the soft soil ground conditions of Marine Clays and Marine sands, extensive soil stabilization will be required most of which will be applied from the street level causing continued surface disruption and local congestion. The extent of jet grouting required will approach 100% of soft ground replacement, e.g., spoils will approach 100% for ground replaced.

Cut-and-Cover Method (C&C)

Local Contractors as well as the MBTA are very familiar with Cut & Cover construction. Construction practice and mitigations have been developed over many years.

Construction methods have been tested on many projects and provide less risk that other tunneling methods.

Surface disruption will be required for utility relocations and installation of support-of-excavation (SOE) walls. Mitigation approaches and local traffic management techniques have been utilized on many projects to maintain access to adjacent properties and provide pedestrian and vehicular movement. Once street decking has been installed, construction takes place below and disruption at the surface is minimal.

Evaluation

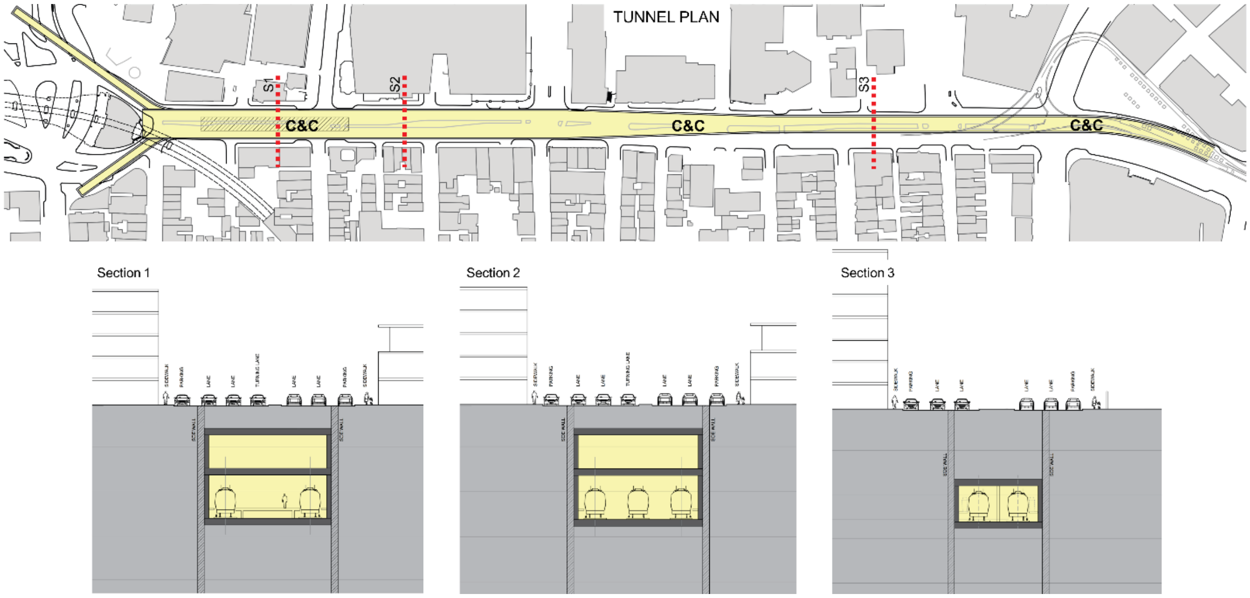
While at first it would appear that C&C would have more disruption to adjoining properties and stakeholders, upon further consideration all other methods have significant portions of C&C construction without the advantages of using a single approach for the extension. C&C construction does have to be carefully planned to minimize disruption, but such planning and tried-and-true mitigations are commonplace for this type of project and can be carefully controlled.

The advantages of using C&C method for the entire project include:

- Least cost
- Shortest construction duration
- Ability to relocate utilities in advance of C&C operation
- Most flexibility in station design to accommodate Life Safety tunnel ventilation requirements
- Most flexibility in station design to maximize visibility and connectivity
- Less project risk compared to other tunneling methods

For the reasons above, C&C appears to be the preferred excavation method (see Figure 7-2). An evaluation of the exact construction methodology of either “top-down” or “bottom-up” construction will be included in the next phase of design.

Figure 7-2. Recommended Construction Method



8. Preliminary Code Analysis

8.1. List of Applicable Codes, Standards and Guidelines

Codes (most current editions):

- Massachusetts State Building Code 780 CMR, Ninth Edition
- Massachusetts State Elevator Code 524 CMR, 2018
- 49 CFR Parts 37 and 38
- OCE Directives
- NFPA 101 Life Safety Code, 2018
- NFPA 70 National Electrical Codes
- NFPA 130 Fixed Guide way Transit and Passenger Rail Systems, 2020
- NFPA 5000 Building Construction and Safety Code
- Massachusetts Architectural Access Board 521 CMR, 2018
- ASME A17.1 Safety Code for Elevators and Escalators, 2019

Standards (most current editions):

- American National Standards Institute (ANSI)
- American Society of Civil Engineers (ASCE)
- American Society of Mechanical Engineers (ASME)
- American Society for Testing and Materials (ASTM)
- Electronic Industries Association (EIA)
- Insulated Cable Engineers Association (ICEA)
- Institute of Electrical and Electronics Engineers (IEEE)
- National Electrical Manufacturers Association (NEMA)
- National Fire Protection Association (NFPA)
- Occupational Safety and Health Administration (OSHA)
- Underwriters Laboratories, Inc. (UL)
- U.S. Department of Transportation (DOT/FTA)

Applicable Guidelines (most current editions):

- Accessibility Guidelines for Buildings and Facilities (ADAAG)
- Guide for Emergency Evacuation of Elevators (ASME A17.4)
- American Public Transportation Association (APTA)
- MBTA Guidelines & Standards, 1977
- MBTA Guide to Access, (Current Edition)
- Transit Capacity and Quality of Service Manual, Transit Cooperative Research Program (TCRP) Report 100

- Pedestrian Planning and Design, Dr. John Fruin, Second Edition 1987, supplemented with the works of Jan Gehl
- NATCO Guidelines
- BCIL Agreement
- Crime Prevention Through Environmental Design: Applications of Architectural Design and Space Management Concepts (2nd ed.) by Timothy D. Crowe, published by Butterworth, Boston 2000

9. Architectural Design Approach

9.1. Station

9.1.1. Station Configuration

The Blue Line station at Charles/MGH will consist of three floor levels: the Street Level, Mezzanine Level, and Platform Station Level. The Blue Line station itself will reside under the center portion of Cambridge Street.

The point of transfer between the Red Line and new Blue Line station will be at ground level of the existing Red Line Charles/MGH headhouse. The existing headhouse will also remain a key access point for the surrounding neighborhood. This entrance consolidates the entry point to both the Red Line and Blue Line stations within the existing Charles/MGH Station. Figure 9-1 illustrates ground floor layout and Figure 9-7 through Figure 9-9 illustrate interior perspectives of the Blue Line headhouse connection. Final design will need to consider reconfiguring of the fare array to accommodate increased throughput of exiting Red Line passengers and new Blue Line passengers, to minimize cross-traffic and accommodate escalator run-off and elevator queuing.

An important second entrance within the future MGH Clinical Building will serve the east end of the Blue Line platform. This entrance will be a more direct connection to MGH and a secondary means of emergency egress with a full-service entrance including fare vending machines, fare collection and elevator and escalator service connecting the platform to street level (see Figure 9-2).

The Mezzanine Level at the west end of the station will not be accessible to the public, but rather serve as a mechanical, electrical, utility and signaling equipment space with direct adjacency to the station for which it serves. By placing this utility space directly above the station, it optimizes the excavation and construction effort, allows for direct adjacency of all utilities that serve the station, and direct distribution of services to functions below. There is employee access to adjacent Mechanical, Electrical and Emergency Ventilation spaces to the south of the mezzanine. See Figure 9-2 for Mezzanine Level layout.

The Mezzanine Level at the east end of the station will be utilized by the public in transitioning from the platform to the vertical circulation within the future MGH Clinical Building. Fare collection line will be on this east end mezzanine level. This mezzanine also provides access to the adjacent Mechanical, Electrical and Emergency Ventilation spaces to the north under North Grove St. See Figure 9-2 for Mezzanine Level layout.

The station platform itself, located at the lowest level of the excavation, is planned as a center platform with incoming and outgoing service on either side of the platform. The platform will have two elevators, two escalators, and stairways, at both ends of the platform, meeting all minimum clearances, codes, accessibility and service requirements. The intent is to provide a column free platform, allowing for the greatest flexibility of seating and signage configurations, and safe visibility throughout the station platform. Figure 9-3 illustrates platform level layout and Figure 9-10 and Figure 9-11 illustrate platform perspectives.

The journey to the platform includes horizontal and vertical circulation elements located in the public spaces of the station. Each of the circulation elements is defined by a set of operational requirements: (a) function per pedestrian Level of Service (LOS) standards as defined in TCRP-100, (b) emergency egress and (c) accessibility.

The design of the platform shall support two functions: queuing areas for passengers waiting to board a train; and circulation area for departing and arriving passengers.

The center platform provides for a single pedestrian route and destination for system users and, consequently, improves passenger wayfinding and reduces the amount of vertical circulation and signage required. Both these conditions allow for a more intuitive understanding of the station configuration. Because circulation is simplified, emergency egress is also simplified.

The platform shall have the following requirements:

- End-loaded platform
- Platform length is 320 feet
- For width clearances, a 6-foot minimum clearance is required from platform edge to obstructions (i.e. columns and station amenities) along the platform (MBTA guideline)
- Platform is column free to the maximum extent feasible
- Station design will incorporate MBTA initiatives for artwork

9.1.2. Escalators

A standard specification shall include a nominal 48-inch wide (unless noted otherwise) (40-inch clear step) heavy-duty transit escalator with internal drive configurations. All escalators shall be based on APTA standards.

During design the addition of a third escalator at the west end of the platform should be further investigated. A third escalator would provide an added level of redundancy for both transferring passengers and passengers exiting to the street.

9.1.3. Elevators

Passenger transfers and surface connections must be able to occur by use of an elevator. Redundant elevators are provided at both ends of the new Blue Line platform.

Currently there are single elevators (non-redundant) providing access between each of the Red Line platforms and grade level. The proposed Blue Line Station incorporates redundant elevators for access between grade and platform level. Transferring passengers utilizing an elevator have a non-redundant elevator from the Red Line to reach grade level and then move across the existing lobby to a redundant pair of elevators to reach the Blue Line platform. The opportunity to provide a direct elevator connection between the Blue Line and Red Line platforms should be considered as design moves into the phase. This would have to be coordinated with near-term and long-range upgrades on the Red Line.

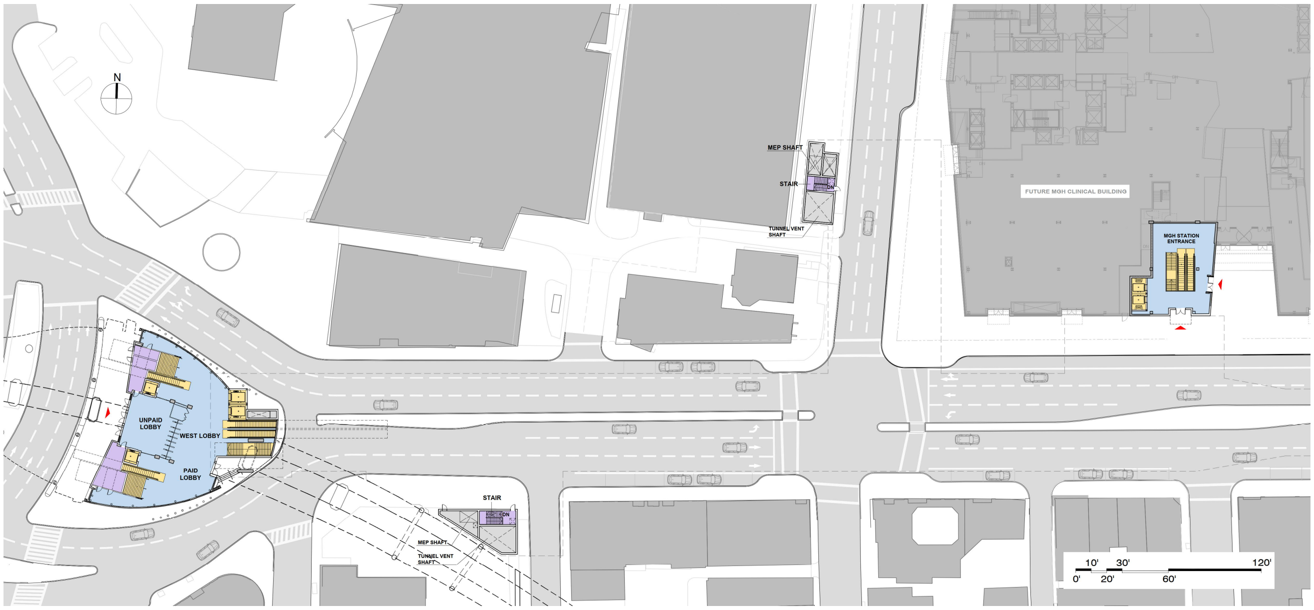
The Boston Center for Independent Living (BCIL) settlement agreement with the MBTA includes several provisions for the design of accessible elevators including the elevator shaft, elevator cab and the performance of the equipment. Representative provisions include:

- Type of elevator will be heavy duty
- Queuing/discharge space should be located to not interfere with the flow of passengers
- Hoistway and car design to promote transparency and maximum visibility
- Emergency Medical Service gurney to be accommodated in the minimum cab size

9.1.4. Materials and Finishes

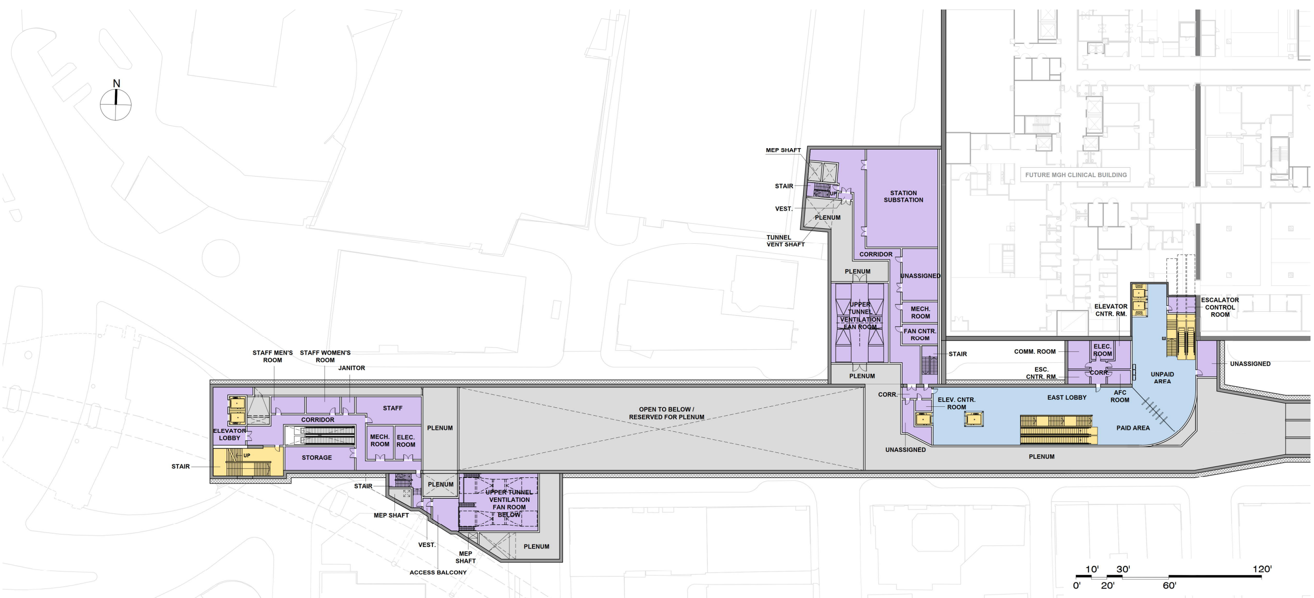
Materials should be durable, easily maintained and well designed, employing the following guidelines. Special attention should be directed to strategies to avoid exterior rusting, detrimental contact of dissimilar materials, deleterious reaction to contact with salt, and use of field welded details.

Figure 9-1. Ground Floor Layout



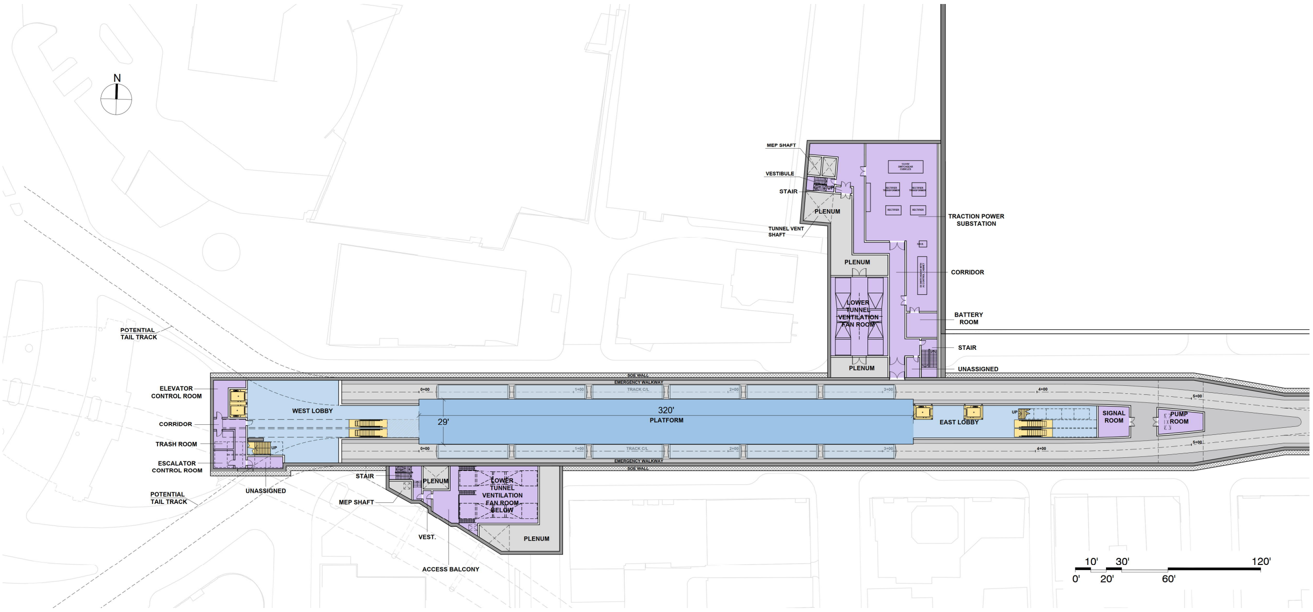
PUBLIC
MECHANICAL-ELECTRICAL-VENTILATION
VERTICAL CIRCULATION

Figure 9-2. Mezzanine Level Layout



PUBLIC
MECHANICAL-ELECTRICAL-VENTILATION
VERTICAL CIRCULATION

Figure 9-3. Platform Level Layout



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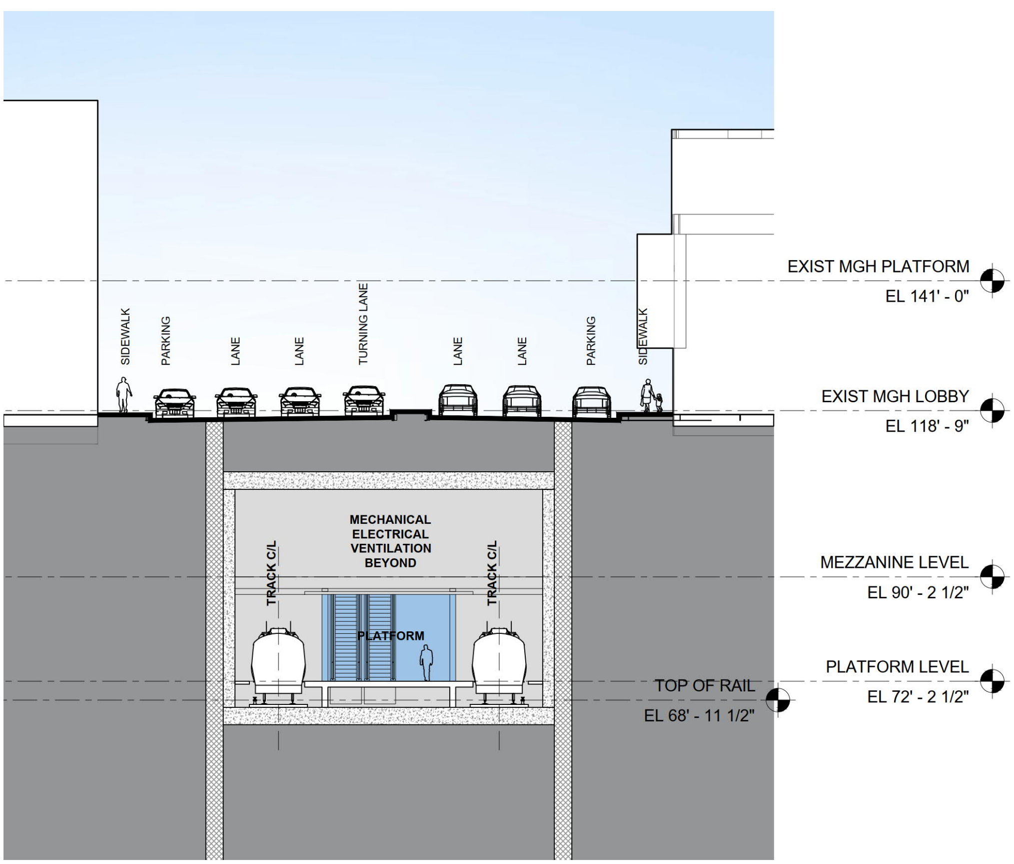
MECHANICAL-ELECTRICAL-VENTILATION
VERTICAL CIRCULATION

Figure 9-4. Platform Cross Section



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MECHANICAL-ELECTRICAL-VENTILATION
VERTICAL CIRCULATION

Figure 9-5. Longitudinal Part Section West

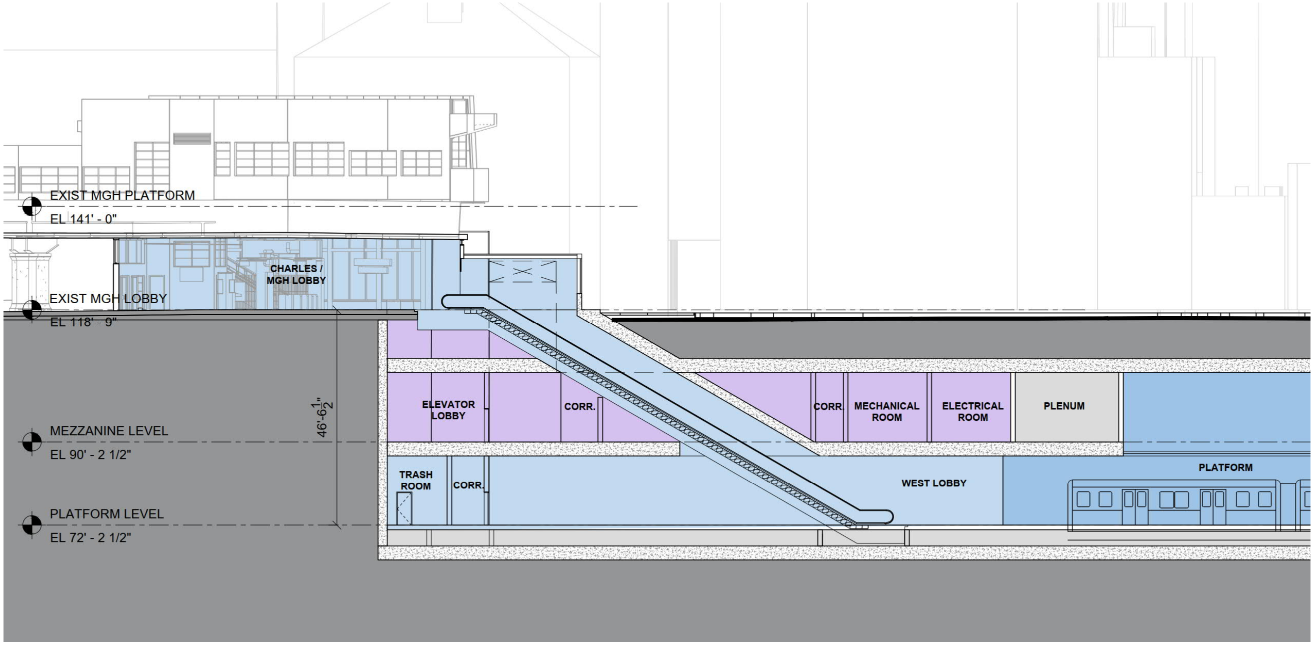


Figure 9-6. Longitudinal Part Section East

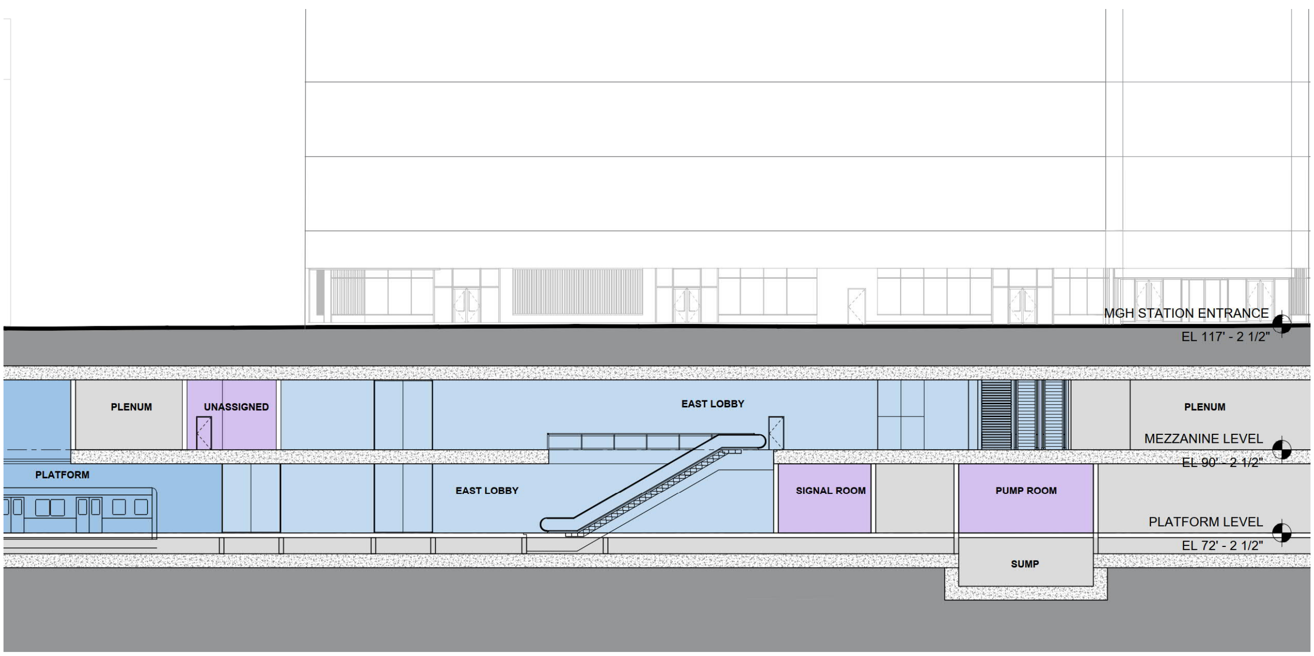


Figure 9-7. Interior View at Charles/MGH Looking from Red Line

Figure 9-8. Interior View 1 at Charles/MGH Looking at Blue Line Connection

Figure 9-9. Interior View 2 at Charles/MGH Looking at Blue Line Connection

Figure 9-10. Interior View 1 Looking at Blue Line Platform

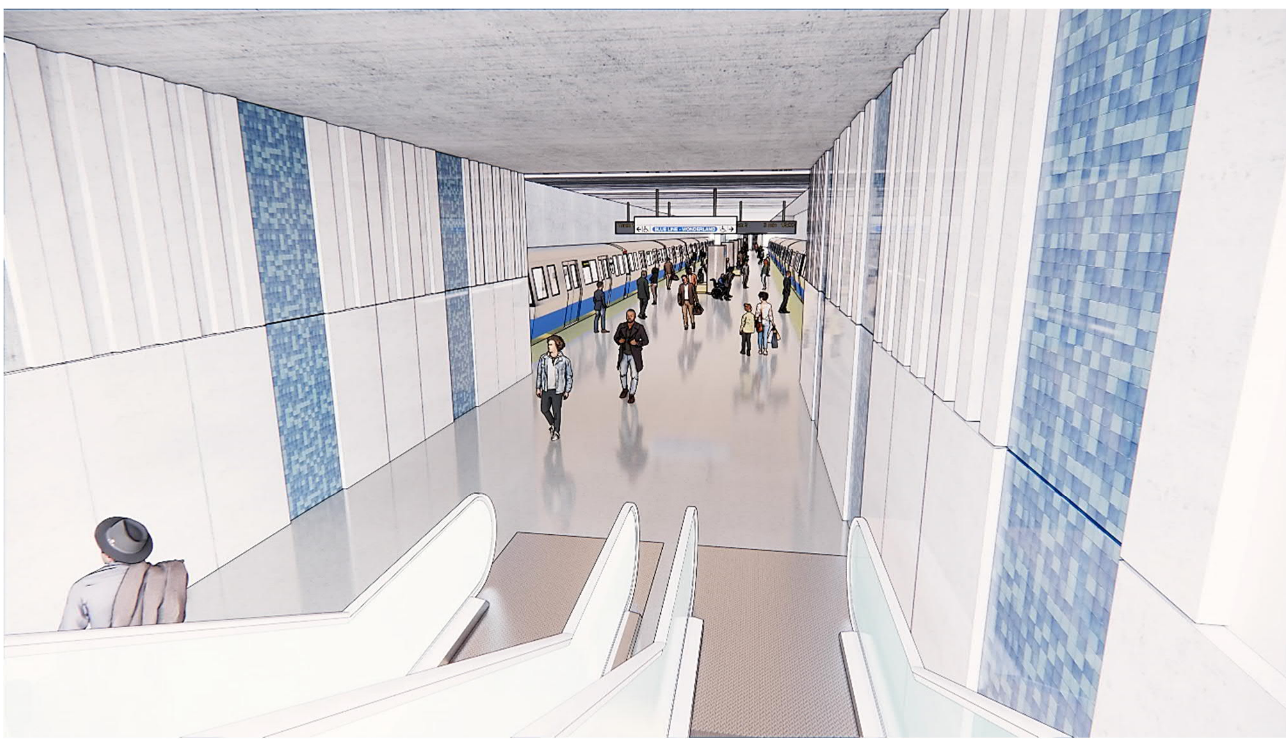
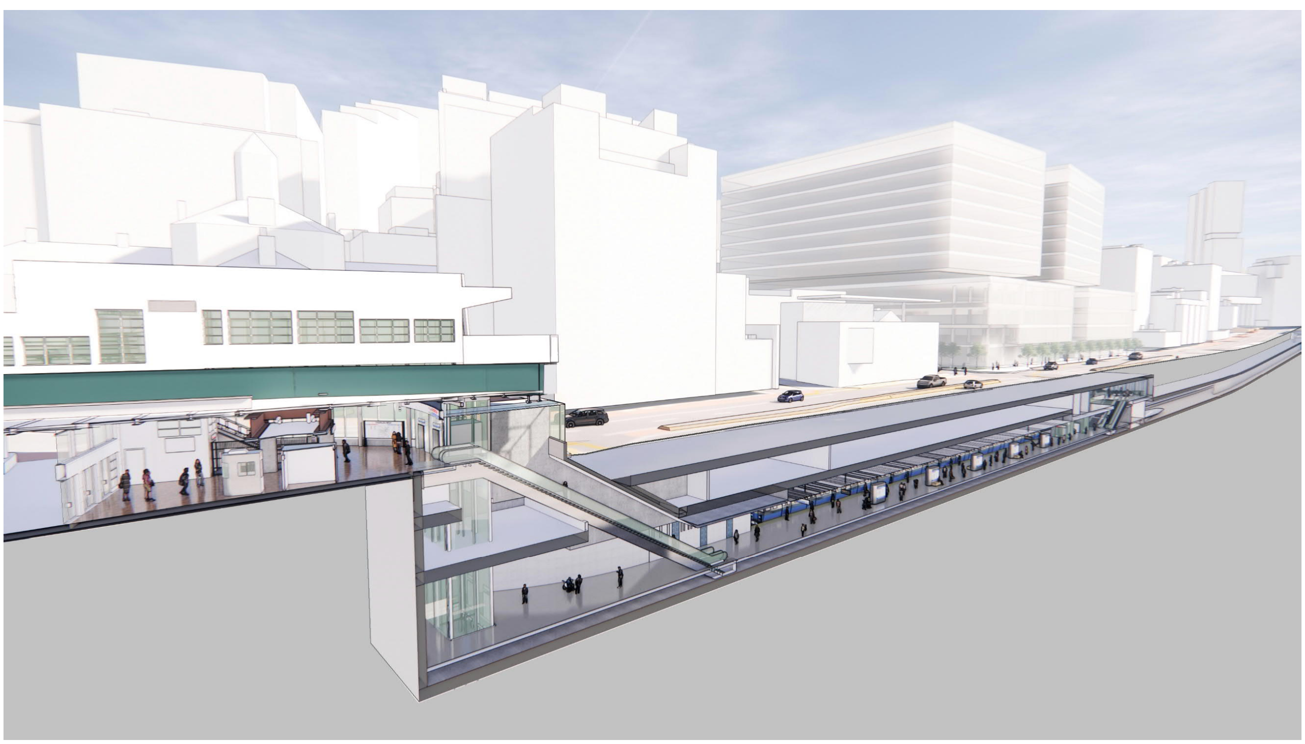


Figure 9-11. Interior View 2 Looking at Blue Line Platform

Figure 9-12. Interior View Looking at MGH Entrance Concourse

Figure 9-13. Interior View Looking at MGH Entrance at Grade

Figure 9-14. 3D Section



9.2. Urban Design and Public Infrastructure

Charles/MGH Station is located at the edge of the Historic Beacon Hill District, the oldest historic district in Massachusetts, first designated in 1955 under Chapter 616 of the Acts of 1955 and expanded in 1958 and 1963. The Act formed the Beacon Hill Architectural Commission which is charged with promoting the educational, cultural, economic and general welfare of the public through the preservation of the 'Historic Beacon Hill District', and maintaining the district as a landmark in the history of architecture and as a tangible reminder of old Boston as it existed in the early 19th century. Comprehensive architectural and historic preservation guidelines are managed by the Commission to maintain the historic integrity of this part of Boston.

Figure 9-15. Historic District with Charles/MGH Station Shown in the Upper Left

While Charles/MGH Station is technically not in the historic district, it is still a close neighbor and the station resides in the viewshed of many daily residents and users. The residents and businesses in the District contribute riders to the station, pass by the station to access the Charles River esplanade, and can be expected to participate in any public process around the project. The 2007 station renovation acknowledged the character of the original copper cladding, some of which remains with a green-tinted curtain wall that dominates the view at the head of Charles Street. Because of the station's visibility along the axes of Charles and Cambridge Street, any changes to the exterior including additions, entrances, crossings, sidewalks and signs should involve the Beacon Hill community, among others, as a key partner and stakeholder.

The primary entrance to the Charles/MGH Station is located under the guideway on Charles Street in a section of sidewalk protected from traffic by a concrete barrier running parallel to the curb for approximately 100 feet. This configuration has been in effect since 2007 when overpasses from Charles and Cambridge Streets were removed as part of the station renovation. The station today is essentially an island surrounded by busy streets and pedestrians use crosswalks to access the street level lobby during 'walk' phases on at signalized intersections.

Figure 9-16. View Looking North of Roadways and Barrier Adjacent to the Station Entrance

To accommodate the station infrastructure required for Blue Line access – elevators, escalators and stairways – some changes to the station building envelope and alignment of adjacent streets and curbs may be required. The Charles/MGH Station is a key node in the residential, commercial and institutional life of the surrounding community, and changing the appearance, function and access to the station should be carefully considered in subsequent design phases. The goal should consider respecting and maintaining the architectural appearance and character of the building envelope while improving the current street level access design by providing better and safer access for pedestrians and cyclists.

9.2.1. Existing Sidewalks, Crosswalks and Pedestrian Access

Crosswalks and signs today direct pedestrians to the lobby entrance under the viaduct on Charles Street from two crosswalks on Cambridge Street (see Figure 9-17). The emergency exit on the east end of the station lobby is used as an informal exit daily, and sometimes as an entrance to the paid lobby. While convenient for pedestrians, the location of the exit onto a non-accessible area with little sidewalk width and no cross walks creates an unsafe condition. The informal use of the emergency exit for access and egress should be studied in a future design phase. Ideally, pedestrians would be discouraged by physical controls of some type. The exit is not accessible today due to stairs and these should be replaced with an accessible ramp system in the future.

The pedestrian volumes on the south side of the station, facing Beacon Hill and Charles Street, appear lower than the MGH side, but this is a two-stage crossing covering a distance of 65 feet, and presents more opportunities for conflicts due to signal timing not meshing with pedestrian demand. The crossing from the station island to the traffic island is approximately 24 feet across two lanes of traffic, then across 17 feet of traffic island, then another 24 feet of two lanes of traffic. The travel distance and signal timing often catch people having to wait on the island until the traffic lights cycle through to the next phase.

On the north side of the station the crossing distance at the crosswalk is approximately 36 feet across three lanes of traffic. While it's a shorter crossing distance than the south side of the station, the pedestrian volumes are significantly higher, and the crosswalk width is inadequate at peak hours causing pedestrians and cyclists to cross among cars queued at the stop light. A single crossing phase is often inadequate to cross everyone at peak hour, and this creates conflicts when pedestrians continue to initiate crossing during the clearing phase.

Traffic signal timing and phasing appears to work well for most hours of the day and has been optimized. Work in future design phases should consider studying the interactions between vehicles, pedestrians and cyclists on the heavily used roadways surrounding the station. A few examples of enhancements aimed at increasing pedestrian safety and accessibility are discussed below.

9.2.2. Proposed Enhancements to Streets and Curbs

Due to heavy peak hour traffic flows on Cambridge Street coinciding with heavy peak hour transit flows, the surface design should study expanding the width of the existing crosswalks to allow more pedestrian space for added safety. Doing this, along with sidewalk widening described below, would help to guide people to the formal station entrance/exit under the viaduct and help discourage informal use of the emergency exits on the paid side of the lobby.

The Charles/MGH Station building envelope may need minimal expansion at the new vertical circulation facilities (see Figure 9-18).

- Charles Street - Charles Street at the station entrance is comprised of three through-lanes heading northbound to Leverett Circle and I-93 north and south. The current 3-lane arrangement becomes two through lanes after crossing Cambridge Street and heading toward Mass. Eye & Ear. The proposed lobby expansion may require additional sidewalk space to handle the pedestrian volume. One option is to utilize the traffic lane closest to the station entrance under the viaduct and expand sidewalk area into the lane reducing this section of Charles Street to two through lanes. Increased sidewalk area in front of the station entrance will provide for better circulation of entering and exiting passengers and may help to discourage informal use of the emergency exits in the lobby.
- Cambridge Street westbound – For safety reasons, a more spacious sidewalk is needed to provide pedestrian storage on the westbound Cambridge Street side of the station. A wider sidewalk providing more pedestrian storage will alleviate the currently high number of informal pedestrian crossings where people either cross against the light or among queued vehicles during the walk phase. The wider sidewalk design can be accommodated in the current three-lane configuration by shifting the curb line on the north side of the street to the north several feet without much impact into a large pedestrian plaza in front of the Liberty Hotel. A wider crosswalk with better pedestrian lighting should be considered in the design phase and requires relocating the vehicle stop line to accommodate the extra width. For increased accessibility and ease of use, the crosswalk could be raised to the level of the adjacent sidewalks creating a 'speed table' further promoting pedestrian safety.
- Cambridge Street eastbound – The south side of the station will undergo a slight expansion and repositioning of emergency exits needed to accommodate vertical circulation for the Blue Line. There will not be any impacts to traffic lanes. To allow for a new elevator core, stairway and escalator, the building envelope will expand to the south occupying space that is currently sidewalk. The emergency egress in this location is not accessible and existing stairs should be replaced with a ramp structure if space allows.

The long crosswalk and traffic island condition on the south side of the station would benefit from a speed table design to prioritize pedestrian movements and add safety.

Figure 9-17. Existing Sidewalks, Crosswalks and Pedestrian Access

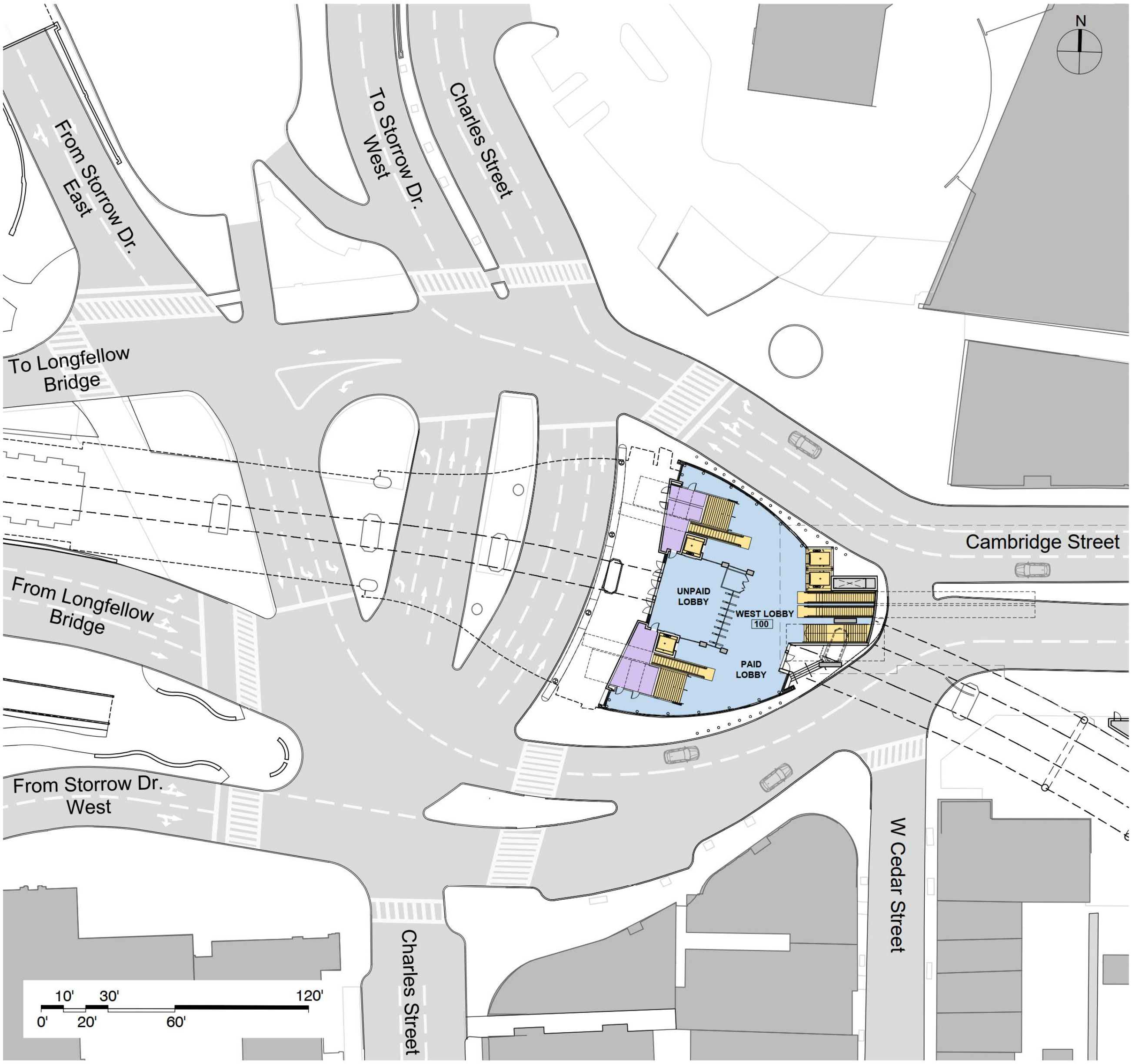
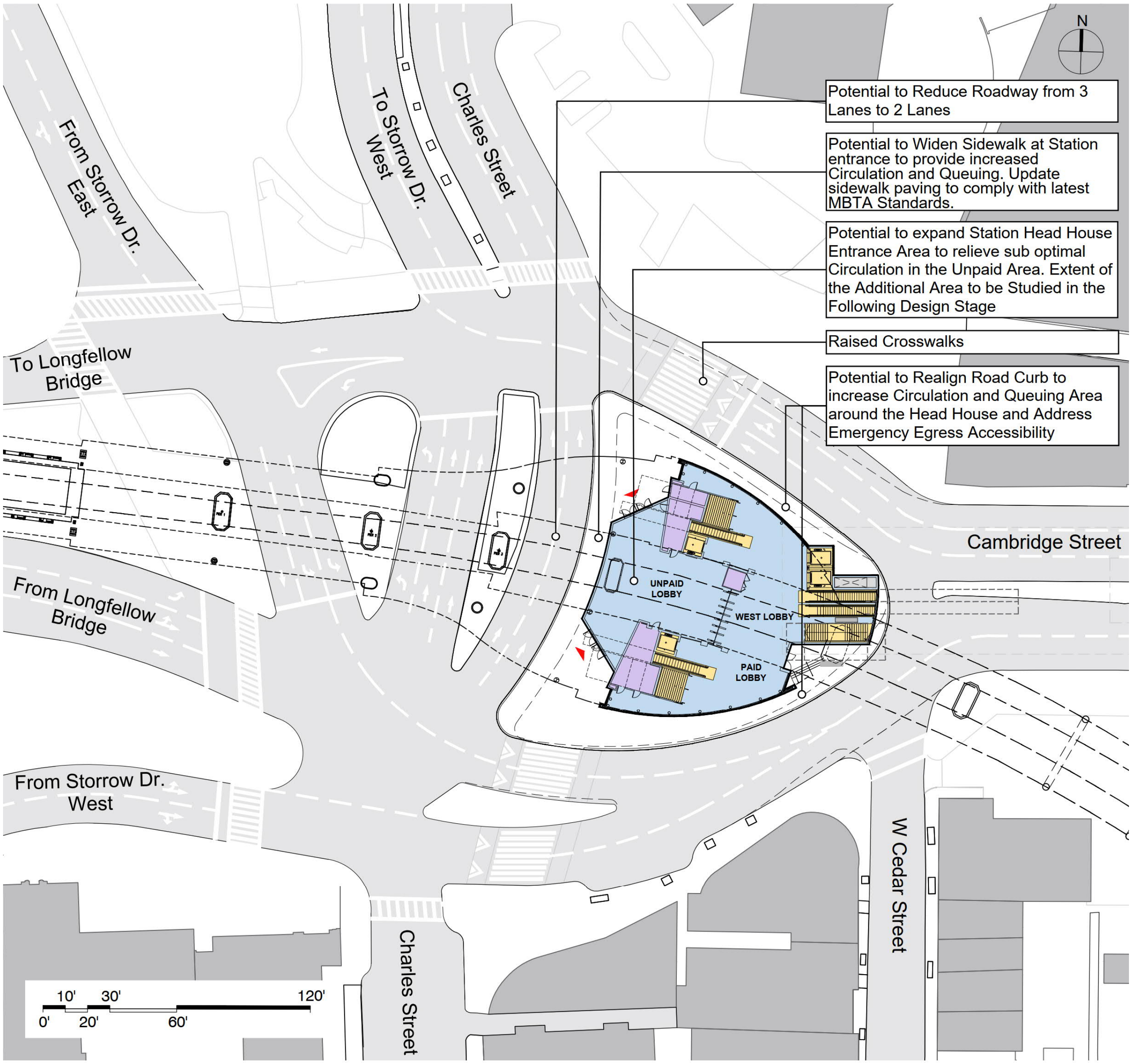


Figure 9-18. Potential Surface Access Improvements



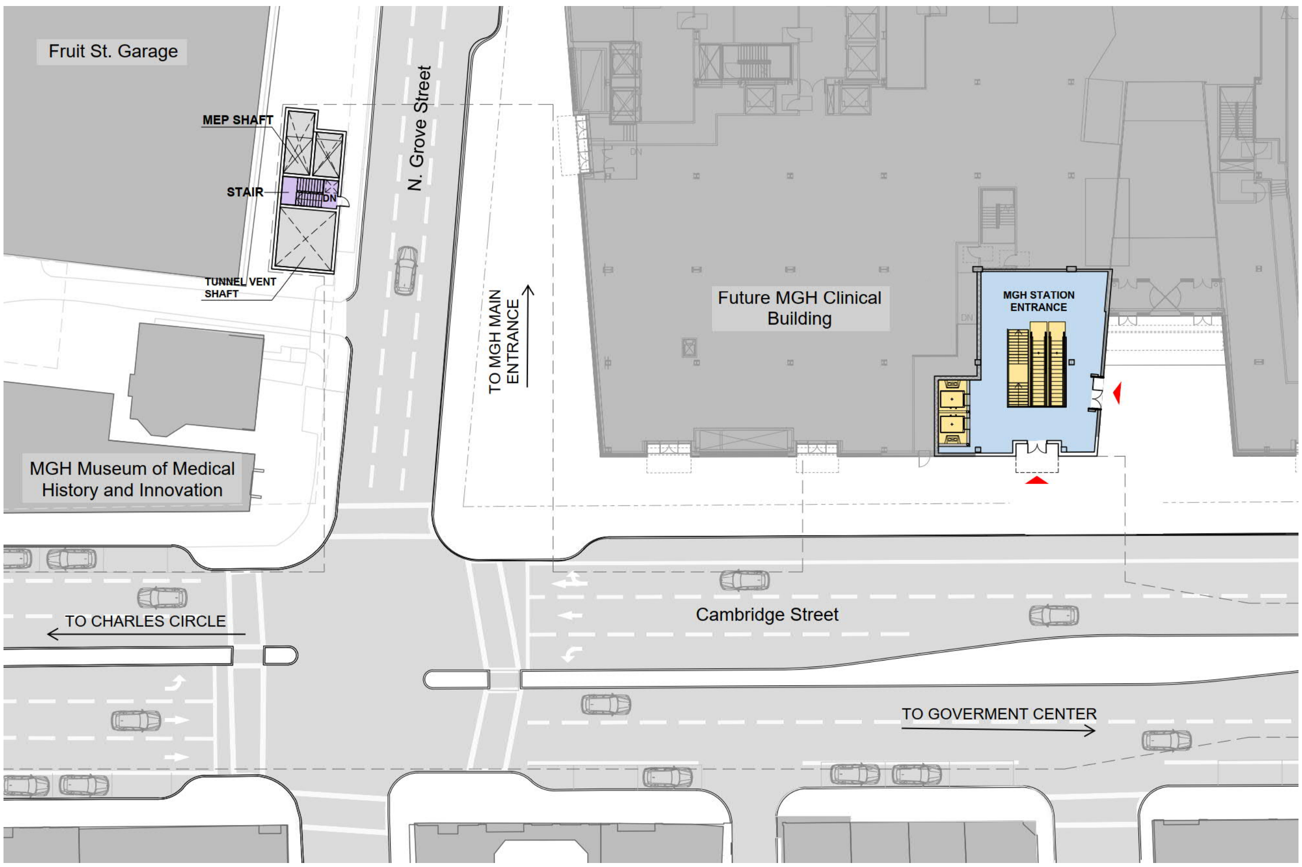
9.2.3 New Blue Line Entrance at Proposed MGH Clinical and Campus Services Building

To meet a growing demand for patient services, MGH is proposing a mid-rise clinical building located on Cambridge Street in a parcel bounded by Blossom, Parkman and North Grove Streets. The proposed Clinical Building will include approximately 1,035,000 sf of Gross Floor Area in approximately 12 above grade stories. The Clinical Building will flank both sides of North Anderson Street which will be replaced by a new internal pedestrian street.

The new building will be the future home of two important centers of excellence – cancer and cardiac care. The MGH Cancer Center and Heart Center would use the majority of inpatient bed capacity with the remainder shared amongst general medicine, thoracic surgery and vascular surgery.

As part of the agency review and approvals process for the project, the Boston Planning and Development Agency along with the Boston Traffic Department had several meetings with the development team to discuss the idea of incorporating a Blue Line entrance in the building at the lobby level. MGH supports the idea of a connection to the Blue Line that facilitates campus access for both patients and staff. The development team proposes to incorporate a Blue Line entrance into their architectural plans for the future Clinical Building (see Figures 9-19, 9-20 and 9-21).

Figure 9-19. Station East Entrance Layout



The proposed MBTA entrance is located on the Cambridge Street side of the building near the middle of the block. The entrance is signed with the standard MBTA ‘T’ logo extending perpendicularly from the building at a height of approximately 12 feet above the sidewalk. The entrance is exclusively for MBTA access and does not directly connect to the Clinical Building lobby. The sidewalk area at the Blue Line entrance will be lighted during evening hours of operation seven days a week to help passengers with wayfinding. Once inside the street-level entrance passengers have the option of accessing the mezzanine level below by using stairs, escalators or elevators.

Other street level elements located in or near the proposed Blue Line entrance include two ventilation shaft structures combined in one building envelope adjacent to the Fruit Street parking garage on the corner of North Grove and Cambridge Streets (see Figure 9-19). The structure consists of a maintenance stairway accessing the level below, a tunnel ventilation shaft and a mechanical spaces ventilation shaft. The structure is proposed between the face of the garage and the west curb of North Grove Street and aligned to allow an 8-foot wide sidewalk area for pedestrians.

Figure 9-20. Cambridge Street Aerial

Figure 9-21. Station East Entrance Perspective

10. Civil Design Approach

The major components of the civil engineering design associated with the project will be roadway reconstruction, streetscape design, utility relocation/reconstruction, and traffic management.

10.1. Roadways and Streetscape

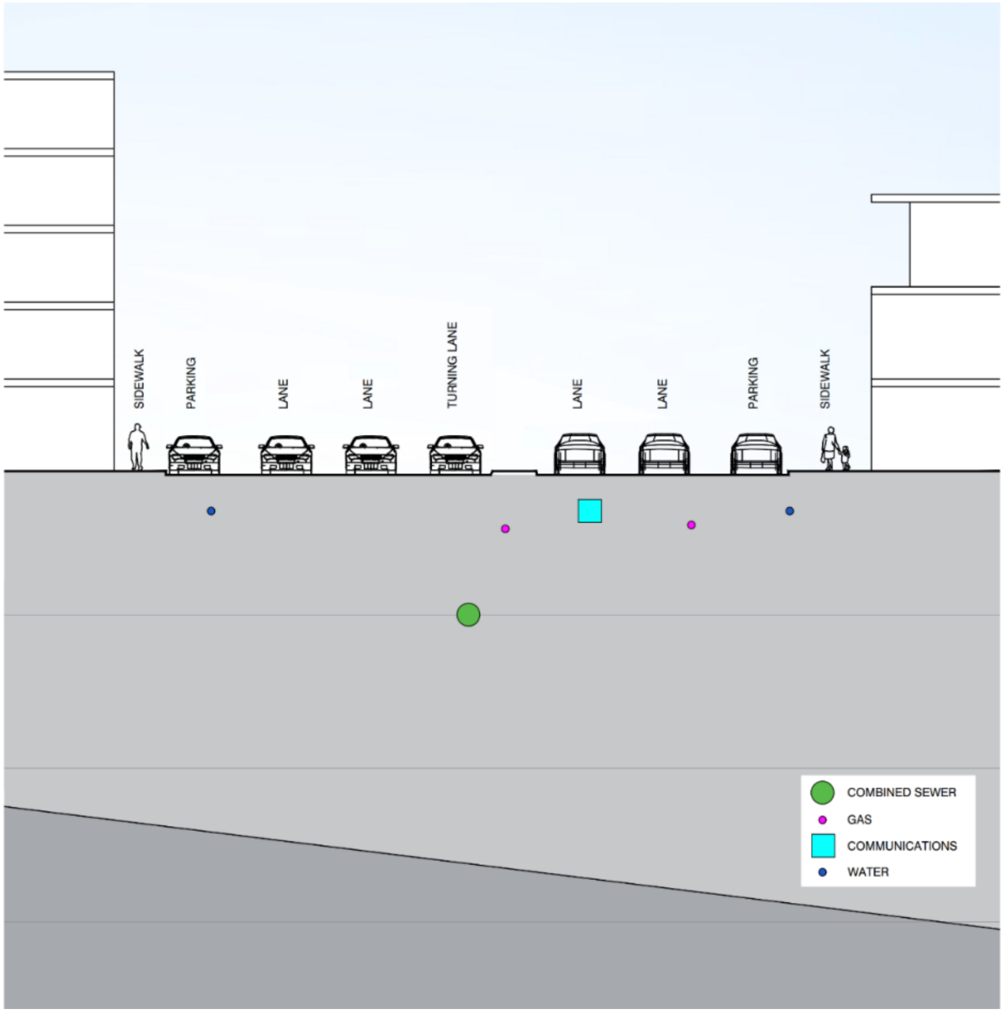
The project lies within the boundaries of Cambridge Street in Boston, from Charles Circle to Sudbury Street. Cambridge Street is generally a 100-foot wide right-of-way consisting of four travel lanes (two in each direction), turning lanes, parking lanes, sidewalks and a variable width median. All roadway elements are constructed of asphalt pavement while most of the sidewalks and medians consist of brick pavement. Granite curbing is prevalent throughout.

Construction of the proposed C&C tunnel will require a reconstruction of Cambridge Street. Although the general layout of the roadway will not change, the reconstruction allows opportunities for reconfiguration of the roadway elements. These reconfiguration opportunities, including future master plans of the Cambridge Street corridor will be coordinated with the City of Boston during the next phase of design.

10.2. Utilities

One of the major challenges of the Red Blue Connector Project will be the relocation of the complex system of utilities within Cambridge Street. The major existing utilities include gravity lines (storm drain, sanitary sewer and combined sewer); pressure lines (water, steam and natural gas); and power and communications lines (electrical, telephone, cable, fire alarm, etc.).

Figure 10-1. Existing Conditions



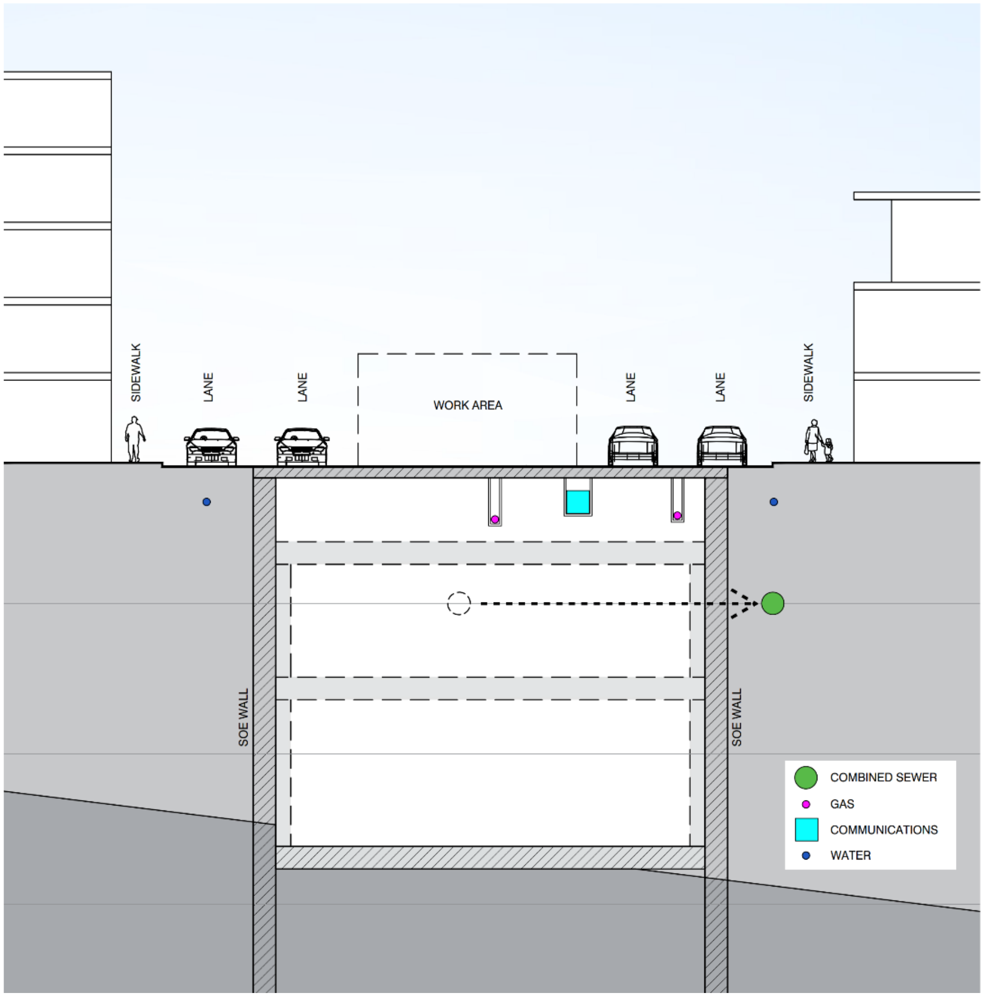
As the design progresses, all utilities within the project corridor will be examined to confirm location and depths. Meetings, discussions and coordination with the respective utility owners will occur to confirm existing facilities, and to understand future additions and replacements. Additionally, ground penetrating radar (GPR) and/or test pits may be helpful to confirm actual locations.

The major gravity lines are owned and maintained by the Boston Water and Sewer Commission (BWSC). In most cases, the major gravity lines will need to be relocated outside the limits of the proposed tunnel walls and designed in the next phase of this project. The most challenging to relocate will be the combined sewer line which crosses project area in the vicinity of the proposed Blue Line station. Coordination with BWSC will be necessary to identify the lines requiring relocation and/or restoration, and future considerations. This line could be replaced with a new line installed along the north side of the proposed tunnel.

Most of the gravity lines will need to be relocated prior to tunnel construction. A major consideration will be maintaining service connections to existing buildings. It is likely that some utilities and services to buildings may need to be relocated several times or supported in place to complete the project. This will be determined in later phases as the design is coordinated with the construction phasing of the project.

Other non-gravity line utilities may be able to be supported in place or temporarily relocated during tunnel construction. These utilities will ultimately be reinstalled along Cambridge Street within the areas created above the proposed Blue Line Tunnel. Natural gas and steam lines should be reviewed and where relocation is necessary, should be scheduled during the non-peak periods.

Figure 10-2. Utilities Concept During Construction



Utility relocations will also be required through portions of Charles Circle and along portions of North Grove Street for construction of potential ventilation shafts, alternative station access and emergency egress elements.

10.3. Traffic Management

As presented in the DEIR Certificate, four lanes of traffic will be maintained along Cambridge Street during construction, except for nights and weekends. Access for emergency vehicles (particularly to MGH) will be maintained at all times. Detailed Temporary Traffic Management Plans (TTMPs) will be developed by the final design team and the General Contractor. These plans will be subject to review and approval by the Boston Transportation Department (BTD). Additional information on traffic management during construction is described in Section 13 – Constructability Approach.

11. Structural Design Approach

11.1. General

Refer to Appendix A Engineering Concepts for DEIR (2010), Sections 6.1.48 – 6.1.57 for information of the following:

- Design criteria
- Codes
- Guidelines for general structures
- Future construction
- Loads
- Earthquake
- Temperature
- Shrinkage and creep
- Buoyance
- Hydrostatic

11.2. Station/Tunnel

Several Support of Excavation (SOE) options will be reviewed during the next phase of design, such as diaphragm slurry walls, soldier pile tremie concrete walls, and secant pile walls. These wall types have successfully been used in the past on major Boston area projects. The type of walls chosen would be required to limit groundwater intrusion during construction. Typically, these walls would be designed first as temporary SOE barriers to resist applied lateral groundwater and earth loadings, and second to act together with interior reinforced concrete walls. In this case, the SOE walls would act as a final permanent wall resisting the lateral earth loading, and the waterproofed interior cast-in-place reinforced concrete walls would be designed to resist the external lateral water pressure loading.

The SOE walls will be constructed continuously along the alignment, accommodating interferences, such as smaller utilities and other obstructions, where possible. Larger utilities and obstructions will need to be relocated or removed prior to the placement of the SOE walls.

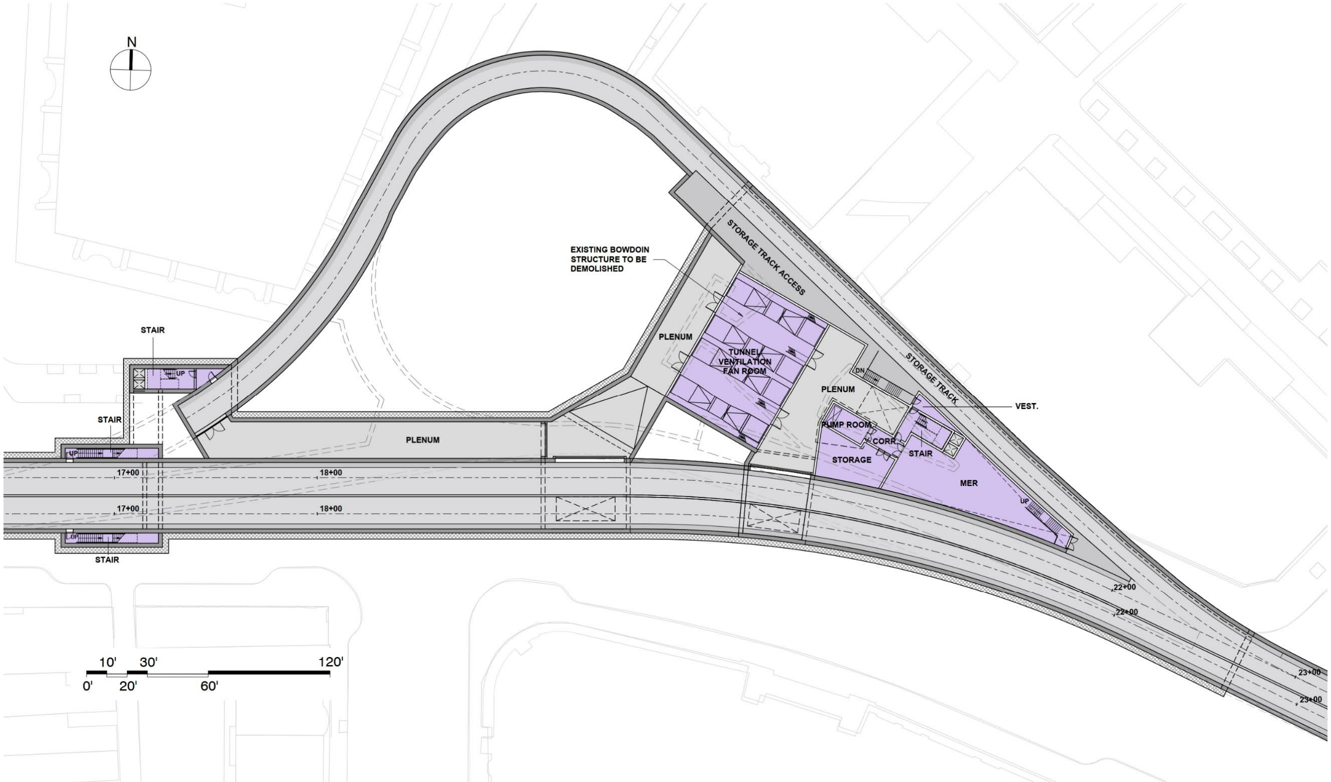
11.3. Bowdoin

Blue Line service will cease to operate at Bowdoin Station: service will stop at Government Center Station. This allows the new tunnel section to modify the alignment and connect to the existing tunnel section.

Portions of the existing station are proposed to be used for new tunnel ventilation facilities, auxiliary equipment, and emergency egress. Figure 11-1 illustrates the proposed layout at Bowdoin Station. Clearance for the tunnel ventilation equipment will require portions of the existing base slab to be lowered in some locations. SOE walls will be constructed prior to lowering and rebuilding the base slab to provide control of the potential groundwater.

Refer to Section 13.4 Interface at Bowdoin for description of one approach to structural modifications needed at Bowdoin. Further in-depth design will be included in the next phase of design.

Figure 11-1. Bowdoin Proposed Layout



12. Geotechnical Engineering

12.1. Geotechnical Design Basis

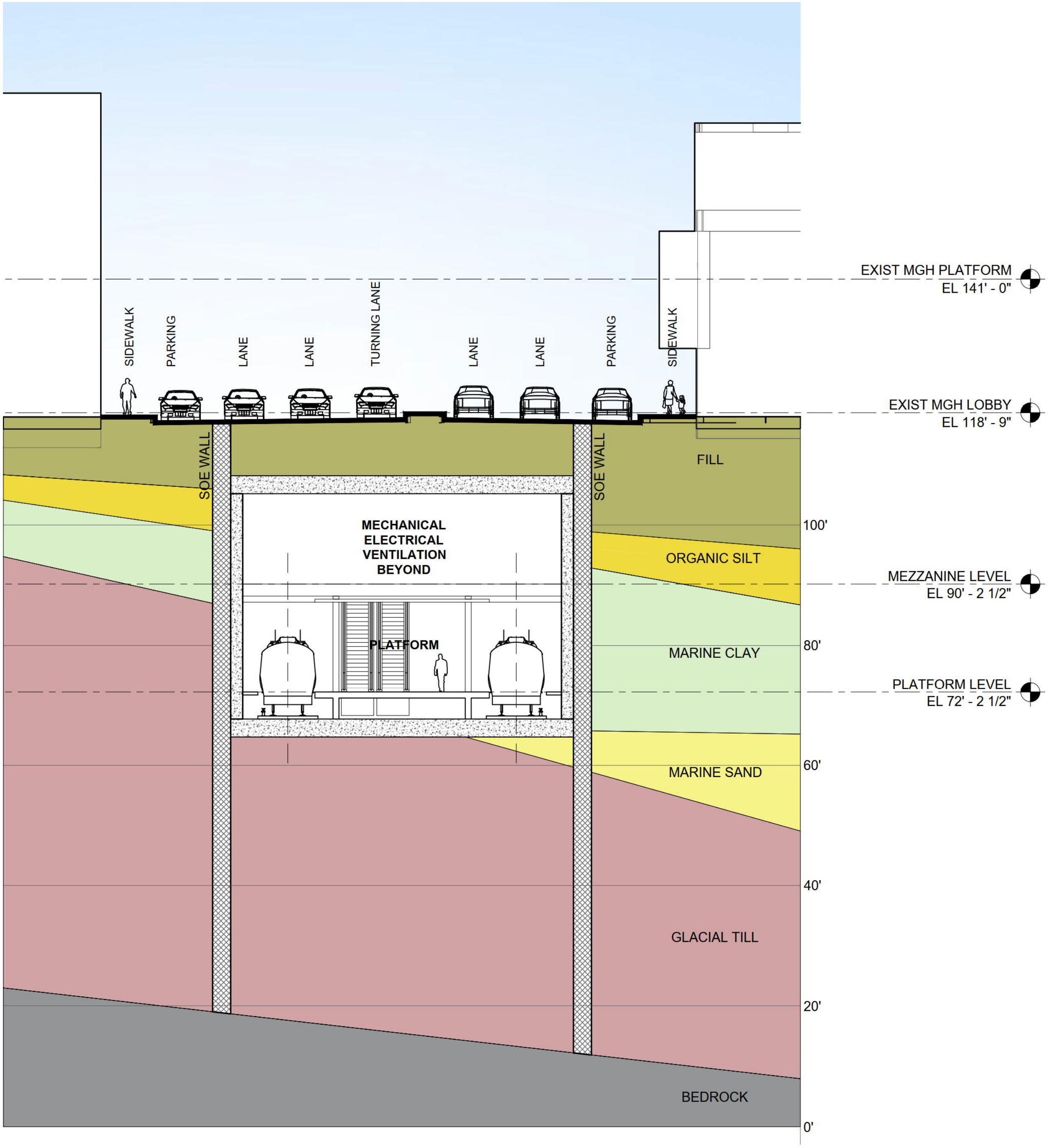
Preliminary geotechnical information developed in the Engineering Concepts for DEIR (2010) provided the following:

- Boring plans
- Boring logs
- Geotechnical profile based on the interpretation of the boring logs
- Soil layers identified below were identified in the project and not all strata are present at any given location:
  - Fill
  - Organic silt
  - Marine clay (Boston blue clay): Deposit typically includes an upper desiccated yellow silty clay layer. This layer is not present at all locations
  - Marine sand
  - Glacial till
- Occasional glacial moraine deposits
- Bedrock: Bedrock at the site is predominantly argillite and sandstone. The tunnel is expected to be above the top of bedrock; however, a few locations where top of bedrock may be encountered

A review of the above was carried out in the current study and the information is substantially complete to provide guidance at this level of design. No further exploration or testing is needed at this time; however, additional boring and testing requirements will be needed for further evaluation of the project design in subsequent design phases of the project.

Representative geotechnical conditions, at the station, is shown in Figure 12-1 Geotechnical Cross Section.

Figure 12-1. Geotechnical Cross Section



13. Constructability Approach

13.1. General

The proposed tunnel connection between Bowdoin and Charles/MGH will be beneath Cambridge Street, a major artery in the City of Boston. Maintaining vehicular and pedestrian traffic access to the businesses and residents, as well as access to MGH during construction is critical. A detailed Traffic Management Plan (TMP) will be developed in future design phases.

The constructability approach to the Red Blue Connector Project considered conditions including:

- Type of construction
- Type of construction equipment
- Traffic management and pedestrian movements
- Right of way (ROW)
- Utilities relocation and support
- Sidewalk limitation
- Business access
- Protection of adjacent structures and utilities
- Instrumentation and monitoring procedures
- Requirements to connect to the existing Bowdoin Station tunnels
- Ground water control (and preventing drawdown of adjacent areas)

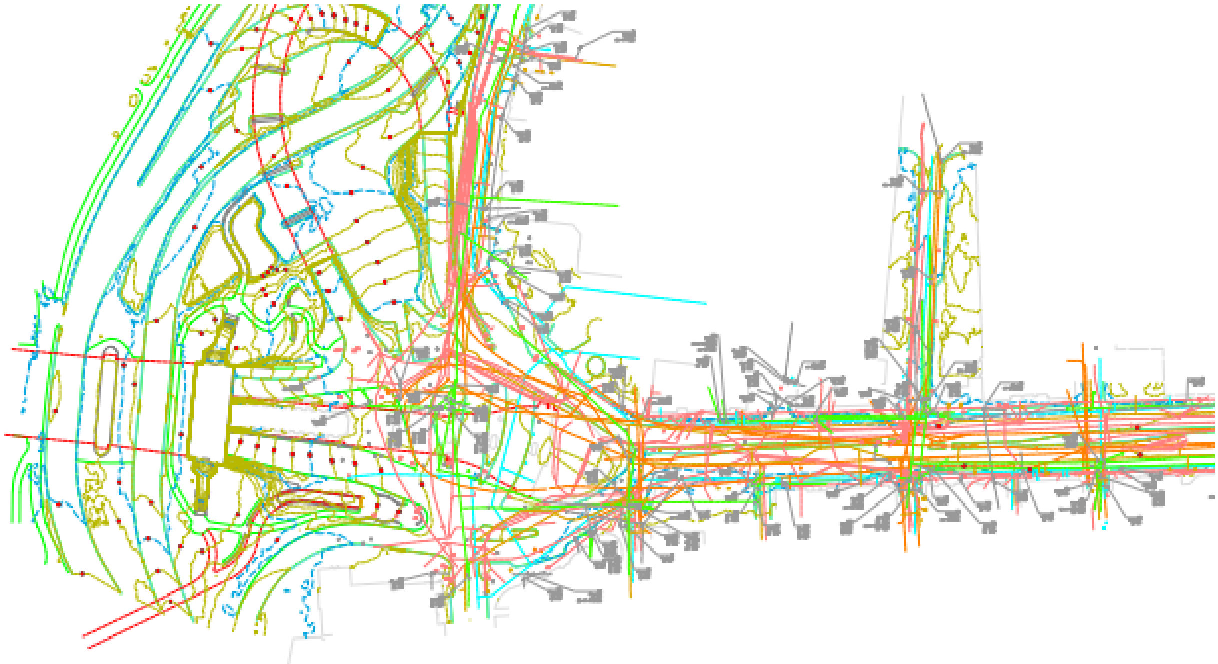
Tunneling methodology was discussed in an earlier section of this report (Section 6.2), which concluded that the other impervious type of SOE walls would best address the construction phase challenges of the project and would be the least costly.

The secant pile walls will serve as SOE as well as a water cut-off barrier to allow construction to be performed in a dry condition without drawing down the water table outside the secant pile walls, thus impacting adjacent structures and wood piles. This will be monitored daily throughout construction to ensure the water table outside the work areas is not impacting adjacent structures.

There are many utilities in Cambridge Street that the project will need to address. Currently, it is anticipated that utility coordination with the owners will occur in the next design phase. This coordination will identify the available options for relocating or supporting major utilities in place within the tunnel alignment and zone of influence. Utilities will be supported from SOE members.

A representative excerpt from the utility section contained in Appendix B is shown below for information. Complete utility information is contained in Appendix B.

Figure 13-1. Representative Utility Plan



The existing Red Line viaduct will be protected during construction operations. Construction will also be phased to maintain Red Line fare collection and station pedestrian circulation.

An instrumentation and monitoring program to monitor settlement and movement of adjacent existing structures, including Red Line viaduct, and utilities will be required prior to the start of construction.

There may be an opportunity for early enabling contracts. These contracts may include utility relocations and long-lead item procurement. Performing early utility contracts will expedite the schedule and minimize the conflicting work zones once the tunnel construction commences.

13.2. Traffic Management and Pedestrian Movements

Maintaining vehicular and pedestrian traffic along and around Cambridge Street will require establishing multiple work zones, in an orchestrated phased approach, so that work can progress simultaneously at different locations while still maintaining access. Temporary roadway decking will be required to keep the surface open to pedestrians and traffic while providing contractor works areas.

Currently Cambridge Street includes two travel lanes in each direction, two parking lanes (one each side), and turning lanes at specific intersections. Establishing contractor work zones will displace parking at times. Vehicular and pedestrian traffic will be maintained at all times. To maintain traffic flows around work areas it is likely that the median will need to be temporarily removed to allow space for temporary lane shifts.

13.3. Construction and Support of Excavation Requirements

The C&C method of construction is recommended based on a number of factors including the depth of the tunnel profile, new station, fan rooms, substation, emergency egress, the interface with the existing Blue Line tunnel at Bowdoin, and the interface with the existing Charles/MGH Station.

Prior geotechnical investigation identified the potential for a high groundwater level, and managing groundwater infiltration into the excavation is a priority issue. SOE walls such as secant pile walls are typically used to create a watertight excavation. Using secant pile walls allows for construction of the station and tunnels without drawing down the groundwater table at adjacent structures.

Several different options for SOE walls will be reviewed during the next phase of design, such as diaphragm slurry walls and soldier pile tremie concrete walls. The criteria for selection will consider that the type of walls chosen for the design must limit any groundwater intrusion during construction.

Temporary decking and framing between SOE walls will replace the existing roadway and allow construction of the station and tunnels below while maintaining vehicular and pedestrian traffic at grade. The C&C method of “bottom-up” or “top-down” construction will be evaluated in detail during the next design phase.

Existing utilities will be relocated as needed to allow for the construction of the SOE walls along the alignment. Several utilities will remain in place while the SOE walls are constructed and are anticipated to be supported in place. In some cases, independent framing may be required for support of larger utilities.

Established construction work zones will be used to progressively construct SOE walls, decking, and the tunnel. Once the alignment is decked over and excavated, construction of the tunnel and associated ventilation and emergency exit structures will proceed.

When the perimeter SOE walls are installed, conflicting utilities will be moved and the surface decking will be installed. The excavation will then progress to the base of the tunnel. Internal bracing between the SOE walls will be installed to the invert of the tunnel structure as the excavation deepens. The tunnel structure follows the top of rail and varies in depth from approximately 25 feet below the surface at Bowdoin Station to approximately 40 feet at Charles/MGH Station.

13.4. Interface at Bowdoin

At the east end of the project, where the new tunnel connects with the existing Blue Line tunnel structure, a variety of special conditions will be encountered. Portions of the existing structure will need to be removed to accommodate the profile and alignment of the new tunnel. These areas will need to be addressed early in the project as sections of the existing tunnel will be removed and the roof underpinned as necessary. Such preparatory work is necessary to install the SOE walls for the new tunnel.

An example of the approach to creating a clear construction path at the existing Bowdoin Station to support the installation of new SOE is shown on Figure 13-2 and Figure 13-3. The construction method described below is an example of how the de-construction of the existing in-ground tunnel and station will be accomplished.

1. Relocate all utilities to clear the area of the area of work
2. Install construction barriers and all traffic controls
3. Install/Construct secant pile wall from surface level outside and adjacent to the existing tunnel wall to provide a ground water cutoff and SOE. Excavation then proceeds from the surface to the top of the tunnel roof with the secant piles providing closure and creating a shaft. Secant piles within the area of future slot can be reinforced, if required, with fiberglass rebar for easy drilling through when installing the new SOE Wall

4. Construct secant pile wall from grade outside and normal to existing tunnel wall to provide an excavated closure to complete the excavated shaft from grade to top of existing roof
5. Excavate shaft from grade to existing tunnel roof within secant pile box created
6. Construct two (2) bulkhead walls within existing tunnels on each side of the invert slot as shown on sketch to strengthen existing tunnel, maintaining structural integrity of existing tunnel
7. Brace existing tunnel roof and walls, as required, for future slot construction in the existing tunnel roof, walls and invert
8. Provide jet or chemical grouting from inside existing tunnel beneath invert slab and between outside of existing tunnel secant pile walls along the future slot area to manage potential groundwater intrusion while cutting the slot across the existing tunnel invert, walls and roof
9. Construct slot through existing tunnel roof, walls and invert slab, approximately 4 feet X 40 feet to allow placement of mainline secant pile walls
10. Place flowable grout between the bulkhead walls to the top of existing tunnel roof filling the invert, walls and roof slots created for the installation of mainline secant pile walls
11. Construct tunnel SOE wall through slotted area of existing tunnel

The stages identified in Figure 13-3 are typical. Other examples involving staged construction include structural steel framed roof systems, several existing walls that pose obstructions, connections to existing Bowdoin Station walls, roof, and inverts. These situations represent slight variations in staging concept and require further study in the next phase of design.

Figure 13-2. Plan at Interface of New Tunnel with Bowdoin Structure

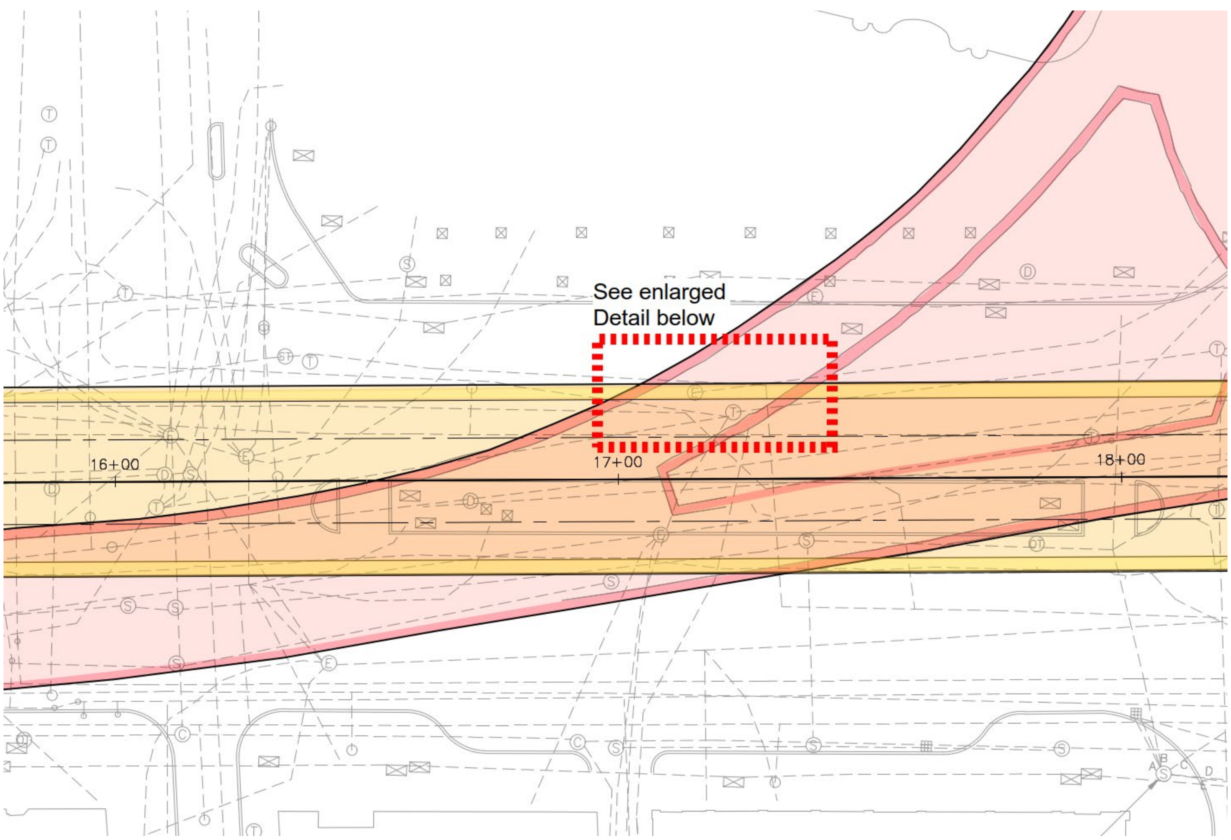
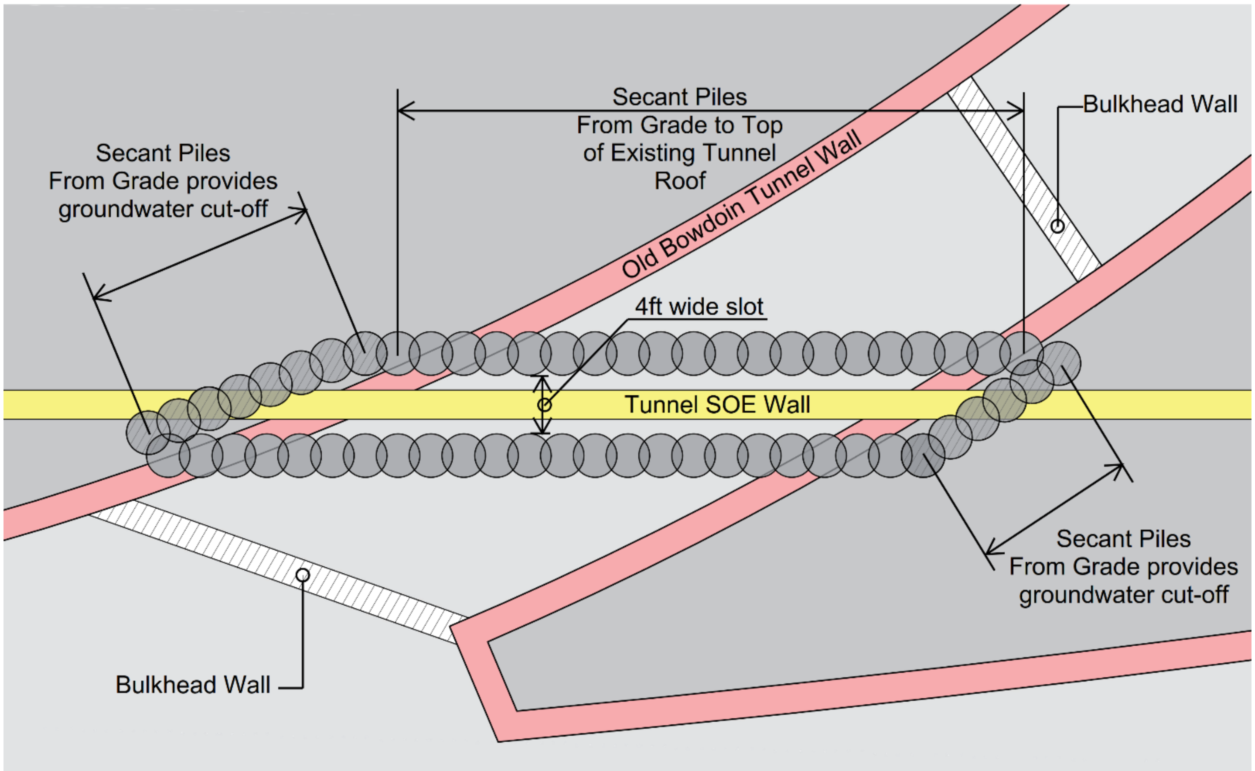


Figure 13-3. Construction Staging Details



13.5. Operations During Construction

Trains will not be able to turn back at Bowdoin Station during construction as they are able to do currently. The turnback will occur at Government Center Station. As noted in the 2010 Study the existing Number 4 interlocking at the east end of Government Center Station is problematic. This interlocking has a single crossover from the westbound platform to the eastbound track. Traffic is stopped at State Street Station while the crossover move is made.

In 2010 it was proposed that a second crossover be added to the Number 4 Interlocking. Subject to refinement during final design, it is recommended that this added crossover be included in this concept level design.

14. Systems

14.1. Signals

A new signal system upgrade is planned by the MBTA. The Red Blue Connector Project shall be compatible with and an extension of the new system. Key elements of the signal system upgrade are as follows:

- The design will be based on a CAB Signal System using Audio Frequency (AF) track circuits
- The design will accommodate 2-minute design headways and 2:30 scheduled headways
- The design will allow for reverse running
- All Interlockings will be controlled by vital microprocessors which will also control the AF track circuits. Microprocessors will be current generation in junction with non-vital logic resident and complete event recording capability
- All communication between interlocking will be through redundant path Fiber Optic cables, as well as all communication to the Operating Control Center (OCC)
- All track circuits within interlocking will be solid state power frequency track circuits
- All signal rooms and cases will follow MBTA resiliency recommendations
- All Blue Line rail cars will have onboard cab signal equipment installed and integrated with the current onboard systems. This includes the cab signal processor, operators display, pickup coils, and interfacing to the propulsion and braking system

14.2. Communications

Refer to Appendix A Engineering Concepts for DEIR (2010), Sections 6.1.29 – 6.1.38 for information on the following. Additional information is provided below as noted in italics:

- System description
- Fiber optic communications system
- Wide area network
- *The system design shall also include all provisions to interface and extend the MBTA Secure Wide Area Network (SWAN). The SWAN shall support a critical MBTA Security and Automated Fare Collection (AFC) system*
- Wireless system
- Public address / electronic signage system (PA/ESS)
- Telephone system
- CCTV system
    - *The MBTA operates and maintains a fully integrated system-wide IP camera surveillance (CCTV) system and existing Genetec Omnicast Video Management System (VMS). All cameras are IP/PoE units which communicate with the VMS head-end located at 45 High Street over the Authority's SWAN*
    - *All CCTV data is centrally stored in Network Attached Storage (NAS) arrays located centrally in a data center at 45 High Street. Backup video storage is stored at each camera using camera-integrated SD cards*

  - *CCTV coverage requirements include all platforms, lobbies, stairs, escalators, elevators, elevator landings, fare vending equipment, passenger assistance phones, fare gates, infrastructure room entrances, signal enclosures and rail switches*
  - *The design requires PoE enabled network switches with redundant power supplies. These switches shall be hardened units when deployed outside of climate-controlled locations. They shall be contained within locked enclosures or within access controlled telecom infrastructure rooms*
  - *All cameras will utilize the H.265 compression standard for streaming data. Sufficient NAS storage arrays to support the MBTA's minimum CCTV data retention standard of 30 days at 8 frames per second for all camera inputs will be furnished and installed by the project at 45 High Street*
- Access control system
  - *ACS systems to be integrated with the existing MBTA Lenel ACS system over new SWAN infrastructure, where they will be configured for integrated monitoring and control capability on the existing Genetec Omnicast VMS. ACS to be provided for doors such as:*
    - — Mechanical, Electrical, Plumbing infrastructure spaces
    - — Elevator/escalator machine rooms
    - — Communications rooms
    - — Signals infrastructure rooms
    - — AFC infrastructure rooms
- Hub monitoring control system (HMSC)/SCADA
- Communications rooms design requirements

14.3. Traction Power

Refer to Appendix A Engineering Concepts for DEIR (2010), Sections 6.1.39 – 6.1.47 for information about the following:

- The traction power electrical needs of the extension will be met by a new double-ended traction power substation and possibly two double-ended unit substations. Power for the traction substation will be provided by the MBTA's 13.8kv network of AC cables.
- Power for the unit substations will come from four 13.8kv breakers in the new traction power substation. There will be two 480 volt, three-phase feeders coming from the unit substation to provide "house" power for the traction power substation.

14.4. Mechanical / HVAC

Refer to Appendix A Engineering Concepts for DEIR (2010), Sections 6.1.63 – 6.1.65 for information about the following:

- Station ventilation
- Heating
- Air conditioning

Please note Section 15 Tunnel Ventilation of this report covers emergency ventilation.

14.5. Electrical

Refer to Appendix A Engineering Concepts for DEIR (2010), Sections 6.1.66 – 6.1.71 for information about the following:

- Substation requirements
- Medium voltage AC distribution system
- Auxiliary power system
- AC system
- Power distribution
- Emergency power

14.6. Plumbing

Refer to Appendix A Engineering Concepts for DEIR (2010), Sections 6.1.75 – 6.1.77 for information about the following:

- The Charles/MGH Blue Line Station will be provided with one male and one female ADA compliant toilet facility. A small instantaneous hot water heater will be provided for each toilet facility. A sanitary pump system will be required.
- Hose bibs will be provided throughout the station platform area to allow for periodical wash down of the platforms.
- A dry manual standpipe system for use by the Boston Fire Department will be provided in the event of a train fire or other fire inside the tunnel. Hose outlet connections will be located every 150 feet along the tunnel. Multiple standpipe segments will make up coverage for the new tunnel section, with a fire department connection for each section visible on the sidewalk or median. The station platform will have a separate manual dry standpipe system.
- Additionally, a low point sump and pump system will be provided.

14.7. Safety and Security

14.7.1. General

Refer to Appendix A Engineering Concepts for DEIR (2010), Sections 6.1.83 for safety criteria.

Design to incorporate additional features such as:

- Customer emergency call boxes
- Single person train operations monitors

14.8. Fire Protection, Fire Alarm and Life Safety

14.8.1. Scope and Purpose of NFPA 130

NFPA 130, Standard for Fixed Guideway Transit and Passenger Rail Systems, is a nationally recognized fire life safety consensus standard for the design and operation of fixed guideway transit and passenger rail systems. The 2020 edition of NFPA 130 is the basis for this report.

The stated scope of the NFPA 130 standard is to address life safety from fire and fire protection requirements for underground, surface, and elevated fixed guideway transit and passenger rail systems, including but not limited to stations, trainways, emergency ventilation systems, vehicles, emergency procedures, communications, and control systems.

14.8.2. Unique Characteristics of Rail Transit Stations

Rail transit stations have unique characteristics that differentiate them from more conventional building types. In contrast to most buildings, transit stations typically rely on emergency exits only to augment, rather than duplicate, the carrying capacity of the egress facilities used during normal operations. In the event of an emergency, a significant portion of the occupant load typically evacuates the station by way of the facilities that they use under normal operating conditions. As a result, many emergency egress routes in stations are familiar to passengers. Transit stations further differ from conventional places of assembly in that their occupancy level is not a function of building capacity as, for instance, in theaters, but rather is determined by quantifiable patronage demand volumes. Unlike in conventional buildings, the occupancy level in transit stations may alter as a result of the emergency itself. For instance, service disruptions caused by the emergency may result in station occupancy levels that significantly exceed normal levels.

Transit stations are also characterized by interconnected spaces and levels, connected by open stairs and escalators, including station platforms, mezzanines, concourses and entrances. Passenger flows from platforms often converge onto mezzanines and concourses.

Unlike more conventional buildings, the major fire threat to a transit station is from train vehicles, which during a train fire event are intended whenever possible to be brought into a station to allow for the self-rescue of the passengers aboard the train.

Therefore, an emergency evacuation of a transit station during a train fire incident involves both passengers in the station waiting for the arrival of trains (entraining loads) and passengers on the incident train and on non-incident trains at the station (train loads).

14.8.3. Use of NFPA 130 in Conjunction with the Adopted Building Code

NFPA 130 is not a building code and is designed to be used in conjunction with the locally applicable codes for the design and construction of stations. In applying fire life safety criteria, the provisions of NFPA 130 take precedence over the corresponding applicable provisions of the locally adopted building and construction codes.

The adopted versions of the International Building Code (IBC) and other referenced International Code Council (ICC) construction codes are the statutory codes in each jurisdiction. The use of NFPA 130 in conjunction with the adopted building and construction codes modifies the adopted codes, and therefore such use requires approval by the authority having jurisdiction (AHJ) for code enforcement.

NFPA 130 §5.1.2, which was first added to NFPA 130 in the 2014 edition, directs the use of NFPA 130 in conjunction with the adopted building code.

14.8.4. Major Fire Life Safety Features of NFPA 130 as Applied to Stations

The NFPA 130 standard establishes performance-based fire life safety requirements, which address the unique characteristics of passenger stations, including timed-egress requirements and, for enclosed stations or portions of stations, requirements for emergency ventilation to provide a tenable environment along unenclosed paths of egress from a fire event.

Key features include:

- Construction type and construction protection
- Interconnected spaces and fire separations
- Means of egress
    - Occupant loads
    - Open stairs and escalators as egress components
    - Points of safety
    - Capacity and location of egress components
    - Prescriptive Platform Egress Requirements
    - Platform evacuation time
    - Evacuation time to a point of safety
- Emergency ventilation system
- Fire protection systems and fire command center
- Emergency power
- Wiring and cable requirements
- Integrity and reliability requirements

14.9. Power Feeds

Electrical power will be necessary for traction power for subway operations, station power, life safety systems and emergency ventilation.

The preferred source of electrical power is from the MBTA system, from two sources in the MBTA power grid that can be deemed reliable back-up. Should the two sources from the MBTA not be available, then the second source will be from Eversource.

15. Tunnel Ventilation

15.1. Purpose

The purpose of the tunnel ventilation system is to support operations during normal, congested, maintenance and emergency conditions in the underground tunnels or enclosed trackways and the station public areas.

For normal operations and congested operations (trains stopped for other than a fire emergency), the tunnel ventilation systems augment train-induced flows or provide air movement when trains are stopped to manage station and tunnel temperature conditions.

For emergency operations, the tunnel ventilation systems provide air movement to protect tunnel and station egress routes by managing smoke movements and smoke layer accumulations.

15.2. Evacuation

The preferred trainway location to evacuate an incident train is always at a station platform so, emergency operating procedures emphasize proceeding the incident train to the next station whenever possible. When an incident train is forced to stop in the tunnel, evacuation must then take place along the track walkway to the next station or exit shaft.

Evacuation from a station platform uses a combination of the regular routes used by passengers and additional protected egress paths (exit stairs). NFPA 130 permits physically unenclosed regular passenger routes to be used as egress routes when those routes are protected by operation of the tunnel and station emergency ventilation systems. When needed, additional physically-enclosed protected egress routes provide part of the required capacity.

15.3. Ventilation Plant Locations

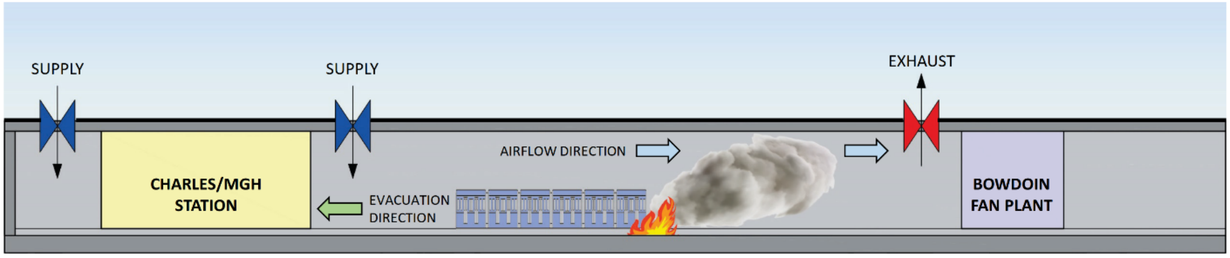
For the Red Blue Connector Project, three tunnel ventilation plants are predicted to be necessary based on best practice:

- West station plant to address station and storage track needs;
- East station plant to address station, crossover, and tunnel needs; and
- Mid-tunnel plant in the former Bowdoin Station footprint, to address the new tunnel extension.

15.4. Smoke Management Strategies

In the trainway tunnels having few egress points, the evacuation choices are typically limited to tunnel walkways in either direction along the tunnel to a station or to an exit shaft. For this project this is the walkways between the new Charles/MGH Station and an emergency exit at the east connection to the existing tunnel. The tunnel ventilation concept for this segment is longitudinal in that smoke is pushed in one direction allowing evacuation the other direction, see Figure 15-1.

Figure 15-1. Representative Evacuation Route



The large three-dimensional volumes of the new Charles/MGH Station platforms and public areas use other ventilation concepts to protect egress paths. Concepts, such as providing clear egress paths below the smoke plume and ceiling smoke layer. Recently constructed subway stations in the United States have included such smoke reservoirs above the tracks with distributed openings to capture smoke above the tracks, platforms or both. Some ventilation configurations serving high bay areas have also included end-wall ventilation openings.

The crossover east of the new Charles/MGH Station is also a special case. It is challenging to provide egress paths past a fire in the crossover section. One solution contemplated for the Red Blue Connector Project is locating a tunnel ventilation intake within the crossover to effect point extract, protecting all track walkways. Another solution is to provide supporting jet fans to allow individual longitudinal flows to be directed for each trackway.

Station back-of-house spaces are typically subject to regular building codes for egress provisions. The design of these spaces must also follow NFPA 130 requirements for separations between spaces, where more stringent.

The tunnel ventilation and smoke management concepts described above have been developed based on experience with other projects of varying geometries and train characteristics. In the next stage of design computer simulations will be required to verify performance and capacity requirements of the tunnel ventilation system. Adjustments to the design will result from additions to the input information, and from the results of the simulation efforts.

15.5. Engineered Approach

Protection of egress routes requires a coordinated design of the physical structure and architectural arrangement of passive elements and the mechanical ventilation systems. Computerized simulations predict performance for proposed space geometries and ventilation system designs, and that verification of required capacity supports selection of the ventilation equipment and sizing of the equipment spaces and air paths.

The longitudinal ventilation of tunnel trackways requires engineering analysis using network computer simulations to demonstrate desired smoke movements and protection of the egress routes. A typical application used is the Subway Environmental Simulation (SES) computer program developed for the United States Department of Transportation, Urban Mass Transportation Administration, Office of Research and Development.

For fire scenarios in the Charles/MGH Station's large open spaces, smoke management requires different modeling tools. Physically unenclosed egress routes in stations requires engineering analysis employing three-dimensional computer simulations to evaluate and demonstrate attainment of the desired smoke movements and protection of the egress routes. Computational Fluid Dynamics (CFD) computer applications are used to predict the three-dimensional behavior of smoke and heat released from a fire, and the performance of smoke management systems intended on protecting egress paths during a fire incident.

15.6. Ventilation Fan Plant

Tunnel ventilation fan plants usually are required to allow for either exhaust or supply operation. This is accomplished with reversible axial flow fans, usually with multiple parallel units sharing the air flow requirements. These fans are large heavy-duty industrial units, also requiring space for service and replacement, see Figure 15-2.

The fans are typically high-power devices and produce a significant amount of noise. Therefore, sound attenuation is usually provided on both the system (tunnel or station) and atmosphere-sides (vent shaft at grade) of the fans. Attenuators are often provided near to and serving both ends of each fan in the plant room

Figure 15-2. A Single Tunnel Ventilation Fan Installation of Similar Type, Size and Arrangement

Each ventilation plant requires a plenum on the atmosphere side that connects to the outside world for intake and exhaust. The surface terminations need to address weather and prevent flammable fluids ingress, and the locations and elevations of the outside openings need to address security considerations developed post 9/11/2001. These bidirectional vent openings must be located to minimize or prevent any recirculation into entrances and emergency exits, or mutual interference with other intakes or exhausts. Each plant also requires a plenum on the system side that connects to the station and tunnel spaces to be vented.

The tunnel ventilation mechanical and electrical equipment include large and heavy items that are not practicably disassembled and reassembled for installation. To accommodate these items, equipment access paths and doors on the horizontal and suitable slab hatches and lifting arrangements on the vertical must be provided to all levels housing them. The details to address the above requirements for each of the ventilation plants will be developed in the next project stage. It is an overarching requirement of NFPA 130 that all levels of the ancillary systems necessary to operate the emergency response must be protected from loss of the critical fire life safety function caused by the incident intended to be responded to.

15.7. Multiple Tunnel Ventilation Plant Coordination

To maximize effectiveness, economy, and redundancy, tunnel ventilation equipment is typically operated as a coordinated unit.

For longitudinal ventilation for a tunnel, the plants to either side of the fire location operate respectively in supply or exhaust to generate the required flow direction. Additional plants further away may operate in support to increase effectiveness. As design progresses, modelling will incorporate other existing MBTA vent plants.

Using multiple vent plants in support of each other assists in meeting the NFPA 130 requirement that the vent system capability include allowance for any one worst case fan to be out of service during the incident response.

16. Sustainability

16.1. MBTA Sustainable Initiatives

The Federal Transit Administration (FTA) provides financial and technical assistance to local public transit systems, including buses, subways, light rail, commuter rail, trolleys and ferries. The FTA is committed to encouraging sustainable alternative technology to reduce costs and emissions by conducting research on, developing, and deploying zero-emission transit vehicles, facilities and technologies; identifying innovative and sustainable use of transit vehicles and services through practices and technologies, and; developing partnerships with other federal agencies involved in energy and environmental research. Transit projects funded by the FTA play an important role in contributing to environmental sustainability.

The MBTA has developed environmental policy in step with FTA. The MBTA is committed to environmental sustainability and the critical role transit plays in confronting environmental challenges in the Commonwealth. Public transportation systems across the country are increasingly adopting sustainability initiatives not only to support environmental goals but also to capture operating cost savings while addressing demands of transit patrons for environmentally responsible solutions.

Public transit, by its very nature, produces environmental benefits through vehicle trip reduction and resulting greenhouse gas emissions reductions. The result is cleaner air where it matters the most, in the inner cities. Historically, transit service grew out of serving working class populations who needed access to jobs in a time before the rise of the automobile. Today, transit serves those same populations with a mobility option that addresses different circumstances of increased roadway congestion and prohibitively expensive costs for inner city parking. Transit reduces congestion and often bypasses traffic, in the case of rail transit, and offers a faster, cheaper ride to work when all costs are factored. In the MBTA service area, and in other large cities with mature transit systems, proximity to rapid transit attracts new mixed-use development further reducing the need for vehicle travel to jobs and schools.

The MBTA recognizes that providing high quality transit in a service area with several million people comes with an environmental cost as vehicles and facilities consume electricity and fossil fuels to operate. To address this impact, the MBTA is implementing sustainable strategies including procurement of more energy efficient rail vehicles and hybrid electric buses, retrofitting systems in older facilities, and requiring all new facility design to include the most current energy saving strategies.

As the Red Blue Connector project progresses through design, various project elements will be evaluated and included as part of an overall sustainability strategy.

16.2. Sustainable Design at Red Blue Connector Station

Several sustainable design strategies could be considered for implementation in the Red Blue Connector at Charles/MGH Station. Sustainable design of transit facilities covers the evaluation of a broad range of elements that comprise a facility. Elements are evaluated to develop an understanding of cost versus value of potential health effects inherent in certain materials, life cycle or replacement costs, operating costs and energy efficiency, to name a few. Sustainable design strategy could include identifying opportunities within stations to engage and educate the public on the MBTA's environmental policy initiatives and best practices, including facts about energy efficient lighting, solar and wind power generation, smart building controls, recycling or carbon reduction, and similar information that complements the public's decision to be responsible transit riders.

16.2.1. Elevators

For the new Blue Line station below Charles/MGH, elevators will provide a critical connection, not only to the Red Line, but also to street level making it easier for patients and the mobility impaired to use the Blue Line for hospital access. The design process will evaluate the use of Traction Machine Room-Less (MRL) elevators to take advantage of decreased space requirements (saves approximately 120 square feet typically required by machine rooms) and more efficient electric motors for lower energy cost. This technology locates the electric motors in the hoistway overhead and provides average speeds of 1.02-1.78 meters/second. Traditional cable driven elevators travel slightly faster at 3 meters/second but require more energy and space to operate.

16.2.2. Lighting

LED lighting is proposed on the platforms and for all paths of travel to the main lobby at street level. LED lighting maintains a constant output over the life of the fixture and represents a ten-fold decrease in energy cost while providing a significantly longer time before replacement is required.

16.2.3. Station Materials

Evaluate using recycled materials like fly ash, slag concrete or silica fume for structural concrete. Floor, wall and ceiling finishes will be selected for durability, value, recycled material content, low organic volatility, safety and esthetics. Materials will be responsibly and locally sourced where possible.

16.2.4. Ventilation

Investigate using an on-demand multi-fan ventilation system that uses 60 percent less electricity than standard systems, similar to the new Government Center Station system.

16.2.5. Recycling

Provide multiple opportunities throughout the station for 3-stream recycling containers (paper, cans, plastic).

16.2.6. Interpretive/Educational Materials

Use space in the new station to engage and educate transit patrons on sustainable policies and MBTA initiatives. This could involve messaging through digital displays or rotating themed messages around recycling, energy use, air quality and climate change.

17. Environmental Permitting

While updated engineering and analysis has occurred as recently as 2018, the most recent regulatory action was the May 28, 2010 Certificate of the Secretary of Energy and Environmental Affairs on the Draft Environmental Impact Report (DEIR). The Certificate instructed MassDOT to prepare a Final Environmental Impact Report (FEIR) based upon a limited scope of work that was included within the Certificate. Subsequent to the issuance of the Certificate, the Red Blue Connector Project was put on hold, and an FEIR was never filed.

MEPA regulations include provisions for updated filings based on lapse of time. A Notice of Project Change for Lapse in Time may be filed if more than three years have elapsed between the publication of the ENF and the publication of the notice of the availability of the single or final EIR. Unless otherwise noted by the Secretary, a new ENF for Lapse of Time would be required if more than five years have elapsed. Since the FEIR was never filed, and ten years have elapsed since the Secretary's Certificate on the DEIR, it is likely that a new ENF (or Expanded ENF) will need to be filed, and a subsequent Single EIR or Draft/Final EIR. It is recommended that a consultation with the MEPA office be conducted to determine the appropriate filings.

In the event that Federal funds will be used for the project, an associated NEPA filing would be required. MassDOT / MBTA would work with FTA (the likely lead agency) to determine the NEPA Class of Action: Categorical Exclusion (CE), Environmental Assessment (EA) or Environmental Impact Statement (EIS). It is envisioned that a combined NEPA/MEPA document would be prepared to satisfy both Federal and State processes.

In regard to Federal, State and local permits required for the project, the 2010 DEIR included the following table of possible permits or approvals, which is still applicable:

Table 17-1. Possible Permits or Approvals

Agency	Approval or Permit
Federal Transit Administration (if federal funding is used)	Finding of No Significant Impact Section 4(f) Determination Section 106 Finding Federal funding approval
U.S. Environmental Protection Agency Region I	NPDES Permit for stormwater discharges and construction period Remediation General Permit (EPA, Federal Register, September 9, 2005)
Massachusetts Department of Environmental Protection	Compliance with Massachusetts Stormwater Management Standards and Regulations Section 61 Finding
MassDOT/MBTA	State funding approval Section 61 Finding
Massachusetts Department of Conservation and Recreation	Access permits Section 61 Finding

Agency	Approval or Permit
Massachusetts Historical Commission	Approval of archaeological monitoring plan
Massachusetts Water Resource Authority	Compliance with MWRA NPDES permit No. MA0103284 for discharges through the Combined Sewer Overflow system Sewer Use Discharge Permit (issued jointly with MWRA) 8(m) permit
City of Boston	Approval for temporary road closings/detours for construction Building permits as needed for construction
Boston Conservation Commission	Order of Conditions for work in Bordering Land Subject to Flooding
Boston Water & Sewer Commission	Approval for temporary relocation of stormwater and sewer infrastructure (NPDES Permit No. MA0101192) Drainage Discharge Permit and/or Dewatering Discharge Permit Sewer Use Discharge Permit (issued jointly with MWRA)

Source: 2010 Red-Blue Connector Draft Environmental Impact Report (DEIR)

18. Schedule

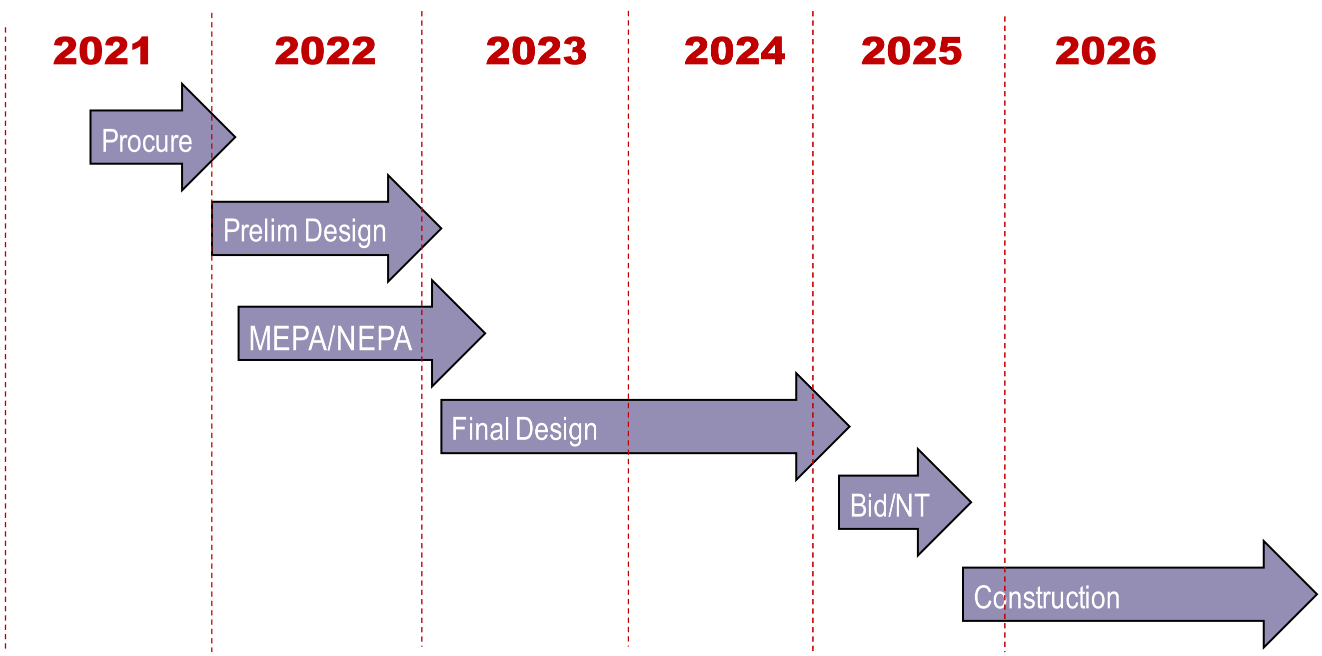
The project currently stands at a conceptual design level. Advancement to Final Design and Construction will be dependent on local support, concurrence with final project elements, environmental permitting requirements, and ultimately the availability of funding.

18.1. Current Schedule

Based on the assumptions that the project can move forward, final bid documents could be completed by spring 2025 with construction starting in the fall of 2025. The anticipated construction duration is estimated to be 4 ½ to 5 years, bringing completion of the project to spring 2030.

The major elements to achieve this schedule include procuring a final design team, completing the preliminary design and environmental permitting process, advancing to final design and generating construction bid documents, bid procurement and issuance of a contractor notice to proceed, and the construction phase. These elements are summarized in the figure below. Timeline may be adjusted depending on funding sources.

Figure 18-1. Schedule



18.2. Acceleration of Project Schedule

If the Red Blue Connector Project were to be accelerated, there would be opportunities to advance under other project delivery methods. The reasons for acceleration may be to take advantage of possible stimulus funding opportunities or may be to minimize construction impacts by coordinating with other construction projects such as the Longfellow Viaduct or MGH Expansion Projects.

Two potential alternative delivery methods for construction would be Design Build or Construction Management/General Contractor (CMGC). In both cases, the overall duration of the project could be reduced by 12 to 18 months, with potential early construction activities (such as utility relocations) starting in year 2024 and construction completed by late 2028 – early 2029.

19. Cost Estimate

Estimate of costs for the project have been developed as part of this report. The estimate developed new costs for major elements, such as tunnel structure, SOE, vertical circulation elements, new entrance to MGH, and tunnel ventilation equipment. The report also utilized cost information from the 2010 DEIR and 2018 Constructability Report, escalated to the mid-point of construction.

The cost estimate developed in this section is based on the recommended alternative of incorporating cut-and-cover (C&C) tunnel methodology as described in Sections 7 and 13 of this report.

19.1. Base Costs

The total estimated cost for the Red-Blue Connector Project is $850 million. This cost includes the following project elements:

Table 19-1. Cost Estimate

Project Element	Estimated Cost
Tunnel Structure (support walls, excavation, utility relocations)	$ 270 million
New Blue Line Station (including stairs, elevators, escalators)	$ 60 million
Secondary Station Access adjacent to future MGH Facility	$ 20 million
Track and Signals (including new crossover track)	$ 30 million
Streetscapes (including reconstruction of Cambridge Street)	$ 20 million
Ventilation Buildings and Unit Substation	$ 30 million
Storage Tracks*	$ 40 million
Contingencies (30%)	$ 140 million
Subtotal (year 2020 dollars)	$ 610 million
Escalation to mid-point of Construction (21%)	$ 130 million
Total Construction Cost	**$ 740 million**
Supplemental Project Costs	
Preliminary and Final Design Costs	$ 50 million
MBTA Administration Costs	$ 30 million
Rolling Stock	$ 30 million
Total Project Cost	**$ 850 million**

*Cost refers to Storage Tracks west of Station. Other more cost effective alternatives were explored but need further analysis to determine their feasibility (See Section 5.1.4.).

Assumptions:

- Cut-and-cover methodology to be utilized for tunnel construction.
- Streetscape reconstruction/restoration will be to a level similar to existing conditions.
- Real estate at Bowdoin Station can be used for an emergency exit and ventilation shaft.
- Real estate costs assumed to be minimal and are included in the contingencies cost.
- Previous project cost estimates utilized and adjusted for current design and escalation.
- Escalation has been calculated at an annual rate of 3% per year, with 2020/2021 being 0%.
- Mid-point of construction assumed to be fall 2027 (6.5 years).

19.2. Other elements Affecting Cost

19.2.1. Constructability

As with most construction projects, constructability will have a significant impact on the overall cost of the project. The work will need to be staged in a manner that maintains traffic along Cambridge Street and uninterrupted access to adjacent properties and businesses. During the next phases of design meetings with utility owners, City of Boston departments and other stakeholders will define and help identify requirements for traffic management and restrictions for work elements during various times (nights, weekends, peak hours, etc.). These restrictions could impact the contractor's schedule and costs.

19.2.2. Right of Way

At this early stage of the project, there do not appear to be any significant right-of-way costs. As the design progresses, it may be required or advantageous to obtain property for purposes of contractor lay-down areas, materials storage areas, etc. In addition, the project may require property acquisitions or permanent easements for construction of certain elements such as the secondary access headhouse, emergency exits, ventilation buildings and unit substations.

19.2.3. Market Conditions

Market conditions can affect construction bid prices. Factors include availability of materials, equipment and labor forces. During times of economic growth, demand for these resources typically increases resulting in a potentially significant increase in contractor bids.

Appendix A Engineering Concepts for DEIR (2010)

Appendix B Drawings