Technical Report No. 3

NorthSouthRailLink
PROJECT

Schematic Design Report

NorthSouth**RailLink**
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Introduction

This Schematic Design Report is one of a series of technical reports prepared in support of the alternatives analysis for the North-South Rail Link study. The information presented in this report will serve as a basis for the environmental, operational, and financial analysis aspects of the overall study, which provides an evaluation of alternatives for improving the Boston metropolitan region's rail system by connecting North and South stations in downtown Boston. The Build Alternative for the North-South Rail Link study is a rail link tunnel between the two stations. This report focuses on the design and construction of this alternative.

Rail Link Tunnel

The rail link tunnel would generally follow the path of the Central Artery/Tunnel highway project. It would involve the construction of at least two tunnel bores, associated portals, and at least two new underground stations (North Station and South Station). Design options evaluated during the schematic design process included a two-station scenario (no Central Station), as well as a two-track tunnel scenario. Additionally, several different design variables were considered, including the specific tunnel alignment, the number of platforms provided, and the number of tunnel bores constructed. In areas of general discussion, the four-track, three-station option with two tunnel bores and three station platforms along the Dorchester Avenue alignment is considered the base case scenario.

Design Assumptions

To initiate the schematic design process, a series of assumptions were developed for the design and construction of a rail link tunnel based on current MBTA standards and practices. The maximum horizontal curvature used was 8 degrees, and the maximum vertical grade was 3 percent on tangent.

Alignment

As shown in Figure EX-1, much of the rail link tunnel alignment between South Station and North Station would be within the Central Artery/Tunnel (CA/T) project corridor. South of South Station the study area would extend west to Back Bay and south to the South Bay railroad maintenance facility and yard. From North Station, the study area extends northerly to the area of the Boston Engine Terminal. The overall length of the alignment along the main line from Back Bay to the north side is approximately 14,725 feet.

A total of five tunnel portals are proposed: three on the south side and two on the north side. These portals include:

- South Bay Portals - located in the South Bay service facility in the general vicinity of the Southampton Street overpass and the MBTA commuter rail service and inspection (S&I) building. The MBTA's Old Colony Lines (Middleborough/Lakeville, Kingston/ Plymouth, and Greenbush) would be serviced by one portal and the Fairmount Line (Dorchester Branch) would be serviced by another.
- Back Bay Portal - located approximately 100 feet east of the Washington Street overpass. It would connect the three Northeast Corridor tracks that service Providence and points south (Stoughton, Franklin and Needham lines and the proposed Fall River/New Bedford line) and the Conrail mainline tracks to Albany, New York, also servicing the MBTA's Worcester service.
- North Portals - located to the north of the Gilmore Bridge and west of the I-93 viaduct in Somerville. The first portal on the north side would service the majority of the northside MBTA rail lines (the Lowell, Reading, Haverhill, Beverly, Newburyport, and Rockport lines) as well as the extension of NEC intercity rail service to Woburn. The second portal would service the MBTA's Fitchburg Line and the MBTA's new Boston Engine Terminal.

Several different alignments are being investigated in the vicinity of South Station based on the location of the proposed rail link South Station. Two potential general locations include:

- Dorchester Avenue Alignment - with this option, the proposed South Station would be located to the northeast of the existing facility, adjacent to the Fort Point Channel. It could also be shifted as far north as Russia Wharf and may be shifted as far east as to locate it completely beneath the Fort Point Channel.
- Central Artery/Tunnel Alignment - with this option, the proposed South Station would be located directly below the existing tracks and would extend from the Federal Reserve tower to the South Station Transportation Center.

Subsurface Conditions

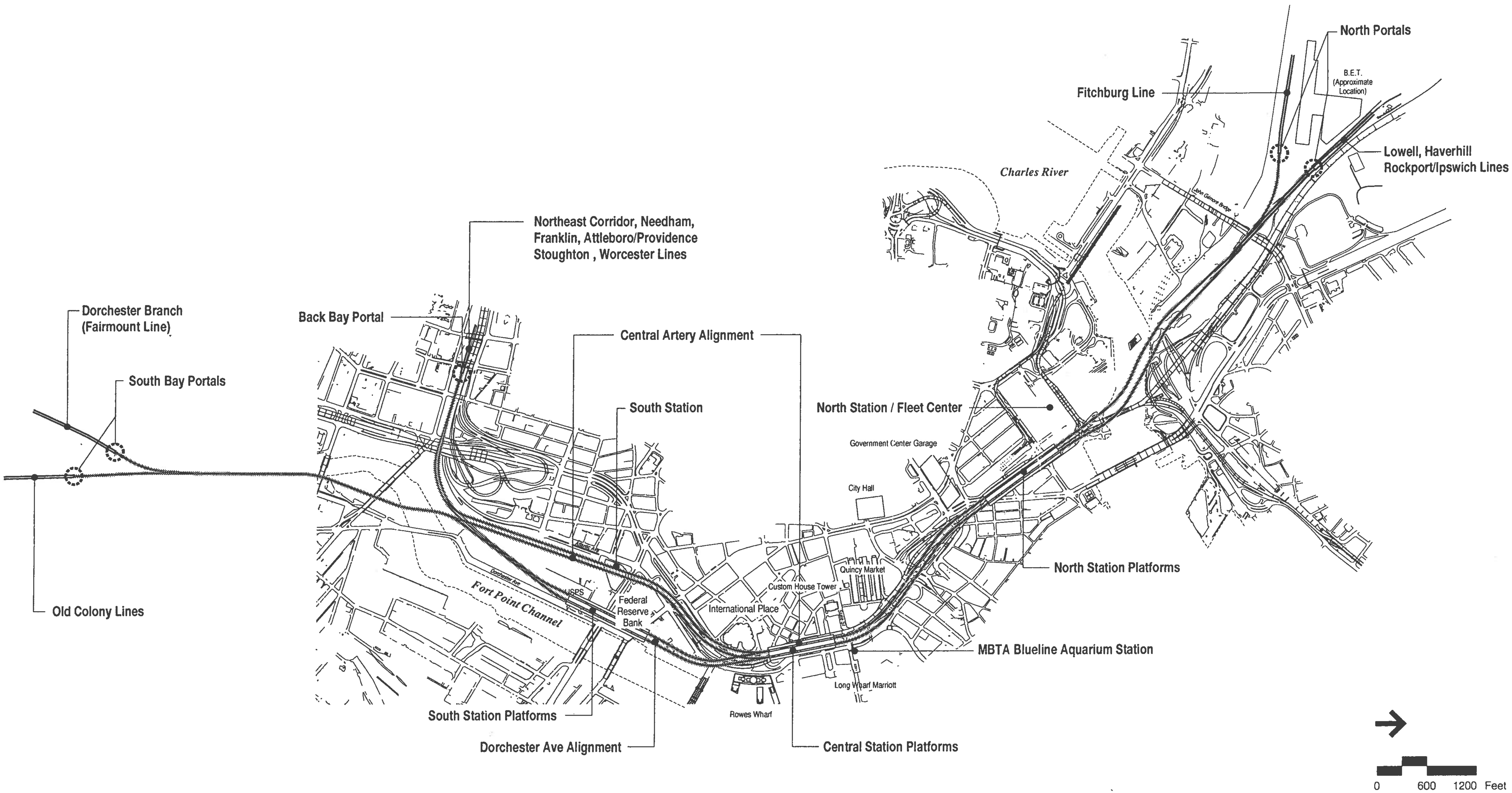
Geotechnical data and engineering reports for design sections of the Central Artery/Tunnel highway project were reviewed to determine the geology found within the study area. No additional borings were done for this phase of the rail link study. In general, the rail tunnel would be excavated through the geologic materials of the Boston Basin, which is part of the New England Physiographic Province of the Appalachian Highlands. The subsurface materials in the area from the ground surface downward generally consist of fill, organics, clay, glaciomarine deposits, till, sand, and bedrock.

Virtually all of the rail link alignment would be constructed below the natural groundwater table. Therefore, management of groundwater tables and infiltration will be an important issue during construction of the project and its permanent facilities.

The rail link would require underground construction activities which would cause the displacement of millions of cubic yards of material. Once excavated, the materials could be removed via the bored tunnels through the north portals to the construction staging area, where they could be transported by rail to its final disposal site, eliminating the need to transport excavate via trucks on city streets. An alternative to this plan could be to transport excavate from North and South Station construction access shafts via barges on the Charles River and Fort Point Channel respectively. Selection of the best means of transporting excavate will take place during preliminary engineering and will be reported in the Final EIS.

Tunnel Design

Tunnel and station clearances were developed to provide for adequate rail vehicle and inspection personnel safety requirements. These recommended horizontal and vertical clearances would be in conformance with Massachusetts Statutes,



Tunnel Alignment Figure EX-1

MBTA Design Specifications, and AREA Recommended Standard Practices, where appropriate. If a single-track tunnel is utilized, the minimum outside tunnel diameter would be 29 feet, with an inside diameter of 26 feet, assuming a 1.5 foot tunnel lining. A two-track tunnel would require a minimum outside diameter of 41 feet, and an inside diameter of 38'-0" based on the same criteria. These dimensions may be refined during preliminary engineering once the specific catenary system is designed, and the components to be carried through the tunnel are further defined.

For all of the Build Alternative options, several combinations of the number of tunnel bores utilized, and the number of platforms provided at the stations were considered. Because of the narrower station width, lower excavation costs, and operational benefits, it was determined that the two tunnel bore, three platform option should be used as the base case for conceptual engineering.

Tunnel Construction

Several different construction methodologies would be employed for the construction of a rail link tunnel. The portal areas would be constructed with a boat section and tunnel using open cut and cut-and-cover technology. The majority of the tunnel would be constructed using a tunnel boring machine, and the station and transition areas would be constructed with a combination of boring and mining techniques. Figure EX-2 presents the tunnel profile and construction methods.

One possible construction scenario involves utilizing the area west of the north portal as a construction staging area, with all excavate being removed from the tunnels to this location. With this scenario the tunnel boring machine (TBM) would be launched from the north portal and proceed through the North Station, Central Station, and South Station areas for both tunnel excavations.

An alternative approach, in which tunnel bores would be started at vertical access shafts located at the sites of North and South stations, was also considered. This approach would allow for multiple tunnel boring machines to be operating in different locations concurrently, potentially shortening the construction schedule sufficiently to compensate for the additional equipment cost. The environmental impacts, right-of-way issues, and construction impacts of both of these approaches should be investigated further in preliminary engineering.

Underpinning of Subsurface Structures and Infrastructure Elements

There are several buildings and structures located within the study corridor that may require modifications to their foundation elements due to the construction of a rail link. Each of these structures will need to be reviewed relative to the final alignment of the rail link tunnel as determined during preliminary engineering. The structures likely to be affected and the extent of rail link impacts identified within the range of the schematic design are presented in the full report. An allowance has been included in the tunneling costs for foundation modifications that may be required.

Right-of-Way Requirements

Minimal right-of-way impacts would be anticipated for a rail link tunnel because the majority of the alignment would be located in an already established transportation corridor. Temporary easements, outside of the existing transportation corridor, would be needed along the Dorchester Avenue alignment, and permanent easements may be required at all headhouse and vent shaft locations. These are generally located at or near the North, Central, and South Station locations. Additionally, it would be desirable from a construction perspective to utilize the U.S. Postal Service facility site on Dorchester Avenue to facilitate the construction of a rail link South Station. If this site was acquired, it could potentially be used for joint development. The availability of this site, however, would be subject to a negotiated agreement with the USPS.

Stations

Introduction

The rail link tunnel would require construction of at least two new underground stations (South and North Stations), and a third may be desirable (Central Station). The new South Station is proposed to be sited near the existing South Station. The station would connect to the new MBTA South Boston Piers Transitway system and to the Red Line subway. This station would also connect to the South Station Transportation Center (SSTC) terminal, which makes intercity, suburban, and Logan Airport bus connections. Several station location options are being considered. The two general locations include: 1) directly beneath the SSTC and existing South Station headhouse (CA/T alignment), and 2) beneath Dorchester Avenue adjacent to the Fort Point Channel (Dorchester Avenue alignment).

For the three-station alternatives, a Central Station is being considered. This station is proposed to be located below the underground Central Artery in the area between Broad Street and the MBTA Blue Line Aquarium Station. It is the station closest to the large number of jobs in the financial district and also the most central for tourists. It would provide a direct link to the Blue Line rapid transit connection with Logan Airport.

North Station is proposed to be located below the underground Central Artery, adjacent to the North Station Superstation (Green and Orange Lines) below the area known as the Bulfinch Triangle. It would permit a direct link to those subway lines and to the FleetCenter.

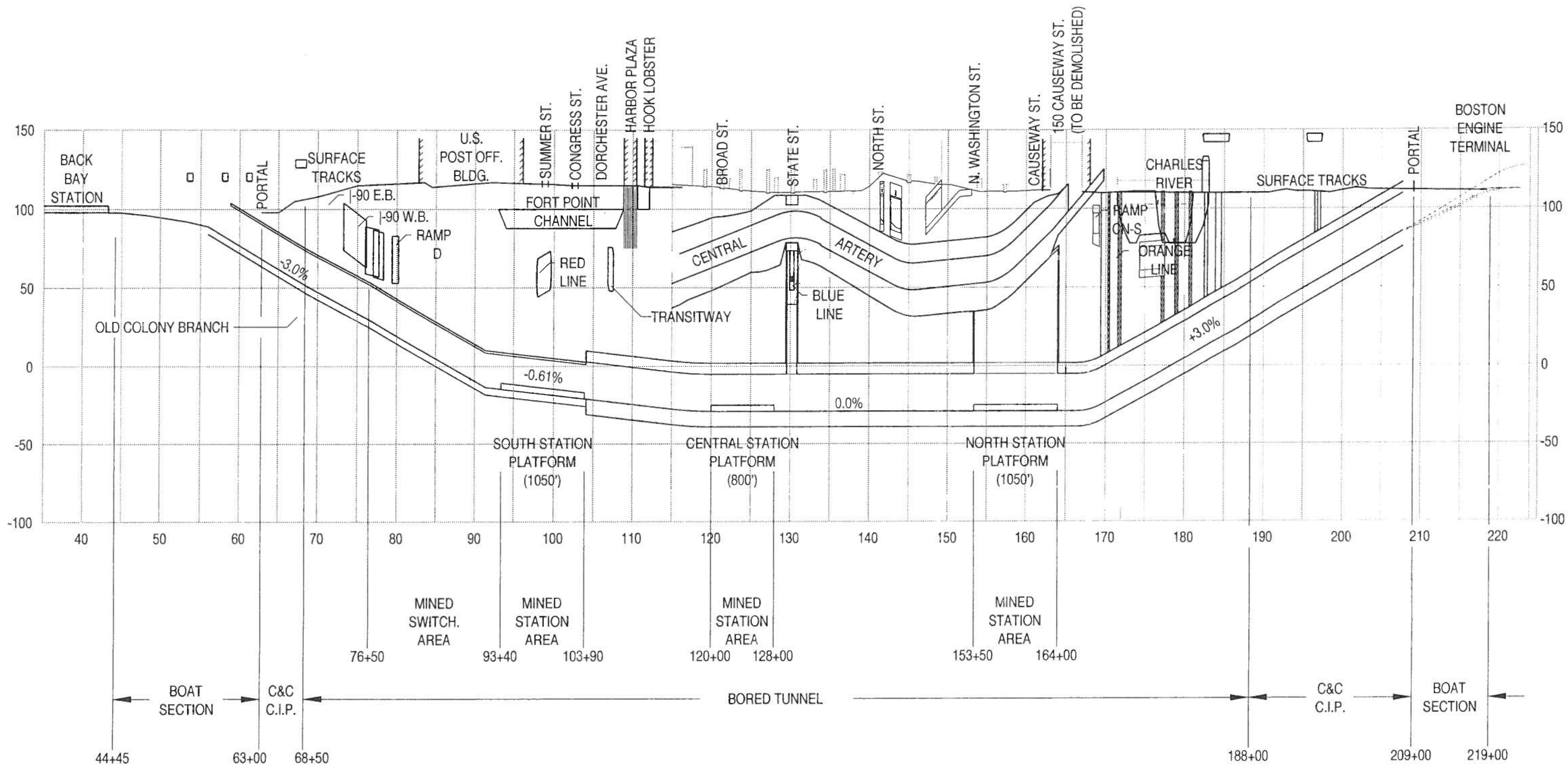
Several station design assumptions were adopted for the stations as described in the full report. At South and North stations the platforms would be 1,050 feet; at Central Station the platform length would be 800 feet. At all of the stations the outside platforms would be 30 feet wide, and the center platform would be 50 feet wide. Egress calculations were based on peak 15-minute boardings as presented in the *Ridership Forecasting and Methodology Study*.

Station Construction

Construction techniques may vary among the three rail link stations. At South Station, the CA/T alignment location would be extremely difficult to construct due to the existing pile field under the SSTC, the need to maintain all 13 surface tracks at South Station during construction, and the presence of the Federal Reserve tower above the northern portion of the proposed station. The Dorchester Avenue alignment location offers opportunities for cut and cover construction.

For Central and North Stations cut and cover construction will not be able to be utilized due to the presence of the Central Artery and other structures above the stations and the depth of the stations. In these instances, the stations may be bored with the TBM and then mined in between the bores to minimize construction impacts at the surface. This method would require underpinning of the CA/T and/or soil stabilization by grout curtains or other methods in order to prevent soil movement. Concerns with this methodology include excavation support, dewatering, the impacts of this method on the contracts and construction schedule, and the type (in terms of size) of station that could be constructed with this methodology.

Another possible station construction methodology is the "Mount Baker Ridge Method", in which many smaller diameter tunnels are bored and filled with concrete to provide a stable shell for excavation without dewatering. This method was used in the Seattle, Washington area with virtually no displacement of the materials above the excavation. Concerns with this methodology include soil stabilization and surface and environmental impacts due to the require surface access shafts. Both of these construction methodologies are recommended to be carried forward to the preliminary engineering phase until additional information, particularly more detailed geotechnical data, is available and an appropriate concept can be selected.



C&C : CUT AND COVER
C.I.P. : CAST IN PLACE

Tunnel Construction Methodology Figure EX-2

Construction of the rail link stations deep below the existing ground and water table creates additional parameters for station design including buoyancy and groundwater intrusion. Possible methods for counteracting the effects of buoyancy include the use of air-rights development, ballast, tie-downs, and relief-slabs. It is anticipated that the effects of buoyancy at each station will be reviewed independently during preliminary engineering and that a combination of measures may be employed.

Systems Engineering

Vehicles

The Equipment Engineering Study prepared for the North-South Rail Link study recommended the use of a dual-mode locomotive which could operate in electric-mode through the tunnel and diesel-mode outside the tunnel on the non-electrified tracks. This locomotive would eliminate the need to electrify all of the commuter rail lines from an equipment perspective. The findings of the Equipment Engineering Study also revealed that existing MBTA coach fleet could be utilized in the tunnel. However, several operational recommendations were identified, including installing high-level platforms at stations and increasing crew discipline and performance efficiency.

Traction Power Electrification System

It is assumed that the rail link tunnel and the MBTA Lowell Line to Woburn would be electrified by means of an overhead traction power system. This system would be built as an extension to the current Northeast Corridor Improvement Project, which is electrifying the Northeast Corridor between New Haven, Connecticut and Boston, Massachusetts. The limits of proposed electrification for the rail tunnel would be the Back Bay portal, east of Back Bay Station, and the vicinity of the proposed Woburn Regional Transportation Center, on the Lowell Line.

Signals and Communications System

Speeds through the proposed tunnel are anticipated to be on the order of 30 miles per hour. Therefore, the proposed tunnel signal system need not be as sophisticated as the Northeast Corridor itself. Conventional wayside automatic block and interlocking signals are proposed, supplemented by conventional four-aspect cab signals. Currently, North Station and South Station dispatching operations are completely separate from each other. The rail link tunnel would change this significantly by connecting the two existing separate systems. The need for cross communications would therefore become of major importance to a safe and successful operation through the tunnel.

The communications systems required to support a rail link tunnel would consist of radio, telephone, fire alarm and SCADA systems.

Emergency Ventilation

During fire emergencies, the ventilation system should provide a safe path of egress for the passengers involved in a fire/smoke emergency, as well as a clear access path for fire fighters. There is some concern regarding the large vertical distances passengers would need to travel to leave the rail link tunnel in an emergency situation, potentially up to 140 vertical feet. Assuming that passengers are not able to use stairs to travel such a distance, it may not be reasonable given disabled or less fit passengers. For this reason, other alternatives for egress which provide sanctuary more quickly, such as providing areas of refuge at or near track level, are recommended to be evaluated as design work progresses.

Construction Costs

Table EX-1 presents an order of magnitude infrastructure cost estimate for the North-South Rail Link Build Alternatives. The estimate includes costs for fixed facilities, including stations, trackwork, tunnel construction, structures, and utilities. In addition, the estimate includes costs associated with systemwide elements such as signal and communication systems, power and catenary, and maintenance facilities.

Contingency multipliers were applied to reflect the preliminary nature of the estimate, degree of difficulty in the work, and the uncertainty of existing conditions and the scope of work. Allowances were provided for work associated with the underpinning and/or providing foundation modifications for those structures located along the rail link corridor.

Table EX-1
North-South Rail Link Build Alternative Infrastructure Cost Estimate

	Two-Track Two-Station	Two-Track Three-Station	Four-Track Two-Station	Four-Track Three-Station
Stations	$620,000,000	$802,500,000	$870,000,000	$1,115,000,000
Trackwork	$19,000,000	$19,000,000	$33,000,000	$33,000,000
Tunnel Construction	$295,000,000	$295,000,000	$582,000,000	$582,000,000
Systemwide Elements	$29,000,000	$29,000,000	$49,000,000	$49,000,000
Total Construction	$963,000,000	$1,145,500,000	$1,534,000,000	$1,779,000,000
Design and Cont. (50%)	$481,500,000	$572,750,000	$767,000,000	$889,500,000
GRAND TOTAL	$1,444,500,000	$1,718,250,000	$2,301,000,000	$2,668,500,000

Next Steps

The technical analysis completed for the schematic design process revealed a clear set of issues to be addressed as the project advances into its next phase of design development, preliminary engineering. Some of the key outstanding issues identified thus far include:

- Refine the recommended alignment and receive concurrence from operators
- Refine the understanding of construction methods and coordinate with railroad and yard operations.
- Undertake a boring and testing program

Additionally, one of the most important issues revealed during the schematic design process was the degree to which underground physical constraints limit the alignment and construction options for a rail link tunnel. This places the project at risk of being precluded by third party actions that add additional physical or political constraints. For that reason, it is felt that is very important to quickly advance the design in order to reserve the project's right-of-way requirements and preserve a range of flexibility for alignment and construction solutions. The following recommendations are proposed, in addition to the next steps listed above:

- Immediately commence preliminary engineering activities. Any delay in the program puts the project at risk of third party construction or planning which precludes the alignment, acquisition of necessary construction or permanent access locations, or other actions which obstruct or increase the complexity of the project.
- Phase the preliminary engineering program to develop the information required for a sequential decision-making process, with each critical decision scheduled within a specific timeframe.
- Secure the approximately 40-acre area at the Fitchburg Portal to ensure adequate staging area during construction, and thus the overall viability of the project.

Introduction

1

1.1 Background

The North-South Rail Link study provides an evaluation of alternatives for improving the Boston metropolitan region's rail system by connecting North and South stations in downtown Boston. These two stations are approximately one mile apart and each serves as a terminal end for a separate regional rail system operated by the Massachusetts Bay Transportation Authority (MBTA). South Station also serves as the terminus for Amtrak's Northeast Corridor service to Washington D.C., while North Station will serve as the terminus for future intercity passenger rail service to Portland, Maine.

The transportation improvements proposed by the North-South Rail Link study require a Major Investment Study (MIS) under the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, as documented in the Federal Transit Administration (FTA)/Federal Highway Administration (FHWA) guidelines. Additionally, compliance with federal (NEPA) and state (MEPA) environmental processes is also required. The purpose of a MIS is to develop sufficient technical information to identify and evaluate alternatives that meet identified transportation needs and objectives, so that an investment decision may be made by the local metropolitan planning organization. The NEPA and MEPA processes require an objective consideration of all reasonable alternatives, full and open disclosure of environmental impacts of proposed actions, and the development of measures to mitigate adverse impacts.

In late November 1994, the Massachusetts Bay Transportation Authority (MBTA), the Executive Office of Transportation and Construction (EOTC), the Massachusetts Highway Department (MHD), and Amtrak began the planning, design, and environmental work required to prepare a MIS, as well as an Environmental Impact Statement/Report for a connection between North and South stations. This effort builds upon previous studies which examined the feasibility of constructing a rail connector, most notably the Central Artery Rail Link (CARL) Task Force study (1993), the Boston Society of Civil Engineers (BSCE) study (1994), the Central Transportation Planning Staff (CTPS) Logan Airport Connection study (1994), and the Federal Transit Administration (FTA) study (1995). (See Chapter 1.0 of the MIS/DEIS/DEIR for a more detailed discussion of these studies).

The alternatives under consideration in the MIS/DEIS/DEIR include a Build Alternative, which consists of a rail tunnel under downtown Boston connecting the two stations. Various design options for the Build Alternative, including two or three downtown stations, a two- or four-track tunnel and alignment variations were included in the evaluation. Other alternatives evaluated included Transportation Systems Management (TSM) alternatives consisting of a dedicated shuttle bus in combination with improved downtown express bus distribution or an Orange Line shuttle option, and a No-Build Alternative, which provides the basis against which the other alternatives are evaluated. The alternatives evaluation included conceptual design development, a technical analysis of operations, ridership and equipment, an assessment of environmental impacts and mitigation, the development of capital and operating costs, and a cost-benefit analysis.

1.2 Role of Schematic Design Report in MIS/DEIS/DEIR Process

As mentioned, a combined Major Investment Study/ Draft Environmental Impact Statement/ Draft Environmental Impact Report is being prepared for the North-South Rail Link study. This Schematic Design Report is one of a series of technical reports prepared in support of the alternatives analysis. The information presented in this report will serve as a basis for the environmental and operational analysis aspects of the overall study and provide the construction cost estimate for Build Alternative options.

Other technical reports include:

- Build Alternative Alignment Corridors: Screening Analysis and Evaluation
- Equipment Engineering Study
- Ridership Methodology and Forecasting Study
- Operations Study
- MBTA Commuter Rail RAILSIM Simulation Report
- Economic Briefing Paper
- Financial Feasibility Study
- Public Participation Process

1.3 Evolution of the Schematic Design Process

In February 1993, Governor Weld, through the Executive Office of Transportation and Construction, appointed a task force to assess the feasibility of building a rail tunnel that would connect North and South stations within the Central Artery highway corridor. The Central Artery Rail Link (CARL) Task Force was given four months to review the potential operational, design, and environmental impacts and benefits of the rail tunnel. The final report of the CARL Task Force, issued in May 1993, concluded that the rail tunnel could be built beneath the Central Artery highway tunnel without substantially impacting the cost or schedule of the highway project.

The rail tunnel alignment identified in the CARL Task Force final report was directly beneath the highway tunnel from the vicinity of Summer Street to Causeway Street. It included three new underground railroad stations: the first directly beneath the existing South Station terminal tracks and headhouse; a central station located directly beneath the highway tunnel and Blue Line tunnel at State Street, and a third station located beneath the highway tunnel adjacent to the MBTA SuperStation at North Station. Portals were located in the Back Bay and South Bay rail corridors on the south side and in the rail yard located north of the Charles River on the north side.

Following completion of the CARL Task Force efforts, the Massachusetts Bay Transportation Authority and Amtrak entered into an agreement to begin preliminary engineering and design for a Central Artery Rail Link. The Request For Proposals issued by the MBTA identified three immediate project objectives to be advanced in the Phase I North-South Rail Link Study: 1) refined operational design, 2) preserving the option of building a rail link tunnel within the CA/T highway corridor, and 3) the development of an environmental impact statement. Of specific interest to the schematic design process is the objective to "Preserve the Option". For this objective, the MBTA noted that "engineering designs for the highway/rail facilities to be built in the next five years must be developed now if there are to be significant cooperative cost savings for the Rail Link"[1]. The task objective outlines the expected Phase I design effort by stating "Work by others (MHD, CA/T) will be evaluating how to best provide for a Rail Link at some later date via modifications to the highway now"[2].

On November 30, 1994, the VHB/FRH Joint Venture team (JV) received full authorization to proceed with the services associated with the NSRL Project: Phase I. The immediate objectives of the team were to refine the operational analysis for the CARL Task Force alignment. At the same time, both the federal and state environmental scoping processes were being initiated. From the joint scoping process came the directive to further explore the Congress Street Rail Link alignment along with the CA/T alignment. Introduction of the Congress Street issue and the subsequent preparation of Technical Report No. 2: *Build Alternative Alignment Corridors: Screening Analysis and Evaluation* introduced an extra step into the study process, thus delaying the initiation of the schematic/conceptual design process.

Following the screening analysis, which reaffirmed the choice of the CA/T corridor, the team's efforts re-focused on the preservation of the CA/T Rail Link alignment. The CARL Task Force report had identified a construction methodology that included both shallow bore and mined tunnel construction techniques. The bored sections were to include four 18-foot diameter tunnels. The mined box segments were located directly beneath the CA/T highway tunnel incorporating extended supplementary excavation support walls. Supplemental work developed by the CA/T Project design staff incorporated the shallow bore methodology into a new deep bore alignment.

The JV team reviewed existing geotechnical information developed for the CA/T and MBTA projects in the area and, through a series of meetings and correspondence with the CA/T staff, it was decided that the deep bore tunnel construction methodology was the preferred approach for the rail tunnel. Specific geotechnical work for the rail link was to be deferred until the preliminary engineering stage of the study. The CARL Task Force report had cited significant cost benefits to the Rail Link Study by incorporating design changes into the CA/T plans for extended supplementary excavation support walls. These design changes were to be incorporated into construction packages to be let in mid-1993. Given the extended schedule as a result of the additional Congress Street evaluation, the CA/T Project was not able to incorporate the suggested design changes. Therefore, the mined construction option for the rail tunnel was eliminated. The shallow bore methodology was also eliminated based on potential disturbance to the highway tunnel during rail tunnel construction operations.

With the decisions to use the deep bore methodology, the JV team was able to initiate its efforts on preservation of the option in the Fall of 1995. Base data was assembled to assess the critical elements of locating the rail tunnel fully within the existing rail and highway corridors located between the Back Bay and South Bay areas and the north side. The clear mandate was to maximize the use of existing infrastructure and publicly held rights-of-way. Included as part of this mandate was the objective to provide large, vaulted underground spaces for the three new stations. The vision of the CARL Task Force was to create bright, open friendly stations as gateways into the city.

One of the first concerns identified by the design team was the construction of the new underground South Station directly below the existing surface tracks, platforms, and headhouse at South Station. The major obstacles included the number of piles driven to support existing and future air rights development at South Station and the ability to keep the existing South Station fully functioning while the underground station was constructed. The design team concluded that, while a station could be constructed in this location, it would be costly and require complex approaches to construction, as well as having potential impacts to existing and future surface terminal operations.

In response to this issue, the concept of a tunnel alignment to the east of the proposed CA/T Rail Link alignment was developed for the South Station area. Known as the Dorchester Avenue alignment, it traversed east of South Station under the property of the United States Post Office, Dorchester Avenue, and Russia Wharf before rejoining the CA/T alignment in the vicinity of Rowe's Wharf. This proposed alternative shifted the station to an area under Dorchester Avenue between the Federal Reserve Bank and the Fort Point Channel. It was felt by the design team that it would be much easier to construct the station in this area. This station location, however, was slightly further from the existing South Station and SSTC connections and services than suggested in the CARL Task Force report. The MBTA Project Office directed the team to fully explore both South Station options.

The schematic design/conceptual engineering effort to "preserve the option" of a rail tunnel within the CA/T corridor continued through the fall/winter of 1995/96. Concepts were developed for both the Central Station and North Station which relied on the extension of the supplementary excavation support walls as part of the CA/T Project. Other methods were also explored. The tunnel design was progressed as two 41 foot diameter deep bore tunnels completely independent of the CA/T highway tunnel. This work effort was presented in the April 1996 draft Schematic Design Report.

Through a series of design review meetings, the CA/T Project requested that both the station and tunnel elements of the Rail Link be independent of the highway tunnel. The concern focused on the large, vaulted ceilings at the Central and North stations directly below the highway tunnel. The CA/T Project also identified highway design alterations that impacted the placement of the tunnel alignment in the Charles River Crossing and South Bay areas. The design team was directed to review these areas of concern and to develop station designs at Central and North stations that would be independent of the CA/T tunnel.

As the schematic design process was nearing completion, a Constructibility Peer Review was held to review the alignment and profile and to discuss construction-related issues. This group, which met over a two week period in late January 1997 with representatives of the MBTA, CA/T, the Citizen's Advisory Committee, and the Project Team, focused on more clearly defining the construction methods proposed and identifying and defining alternate construction techniques to address specific CA/T concerns. Through a series of workshop meetings, the Peer Review group first developed an understanding of the Project Team's efforts to date. They then worked with the agency and Project Team representatives to identify alternative methodologies that could reduce certain construction impacts. The major difference between the Project Team's mandate and the Peer Review group's direction was that, because of their role as outside experts, the Peer Review group was less constrained by historic project mandates such as minimizing construction impacts to the surface and addressing environmental and right-of-way concerns. The Peer Review group's findings have been incorporated where appropriate throughout this report, and are presented in detail in Appendix A.

[1] Massachusetts Bay Transportation Authority, Request For Proposal: Planning, Conceptual Design and Environmental Analysis for the North Station-South Station Rail Link. May 5, 1994.
[2] Ibid.

The schematic design/conceptual engineering process concluded with a design for the rail link tunnel that has been carefully examined and adjusted to address many complex issues. At this time, the alignment has been refined to the extent possible based on available information. The key to the ultimate success of the rail link will be to advance this conceptual design into preliminary engineering thereby meeting the mandate of "preserving the option".

1.4 Study Area

For the Schematic Design Report, the work primarily focused on the tunnel and portal areas. The alignment corridor is approximately three miles in length and is located almost entirely within the City of Boston, although a small section of the northern portal area extends into Somerville. On its southern end, the corridor extends from Back Bay Station (Dartmouth Street) to South Station, with another leg extending from Southampton Street through the MBTA and Amtrak rail yards at South Bay to South Station. The central portion of the corridor is located in downtown Boston between South and North stations in the area roughly bounded by Congress Street and the waterfront. From North Station the corridor follows the existing rail line and terminates north of the Gilmore Bridge in the vicinity of the MBTA's Boston Engine Terminal. Figure 1.4-1 shows the Build Alternative alignment corridor.

It should be noted that for other aspects of the North-South Rail Link study, particularly the economic benefits study, the study area was broadened to include all of New England. For this Schematic Design Study the work primarily focuses on the tunnel and portal areas.

1.5 Purpose and Scope of the Schematic Design Report

1.5.1 Study Goal and Purpose

As discussed in the MIS/DEIS/DEIR, several previous reports were prepared documenting possible rail connections between North and South stations. Two of these studies, the Central Artery Rail Link (CARL) Task Force and Federal Transit Administration (FTA) reports, examined potential alignments for a rail link tunnel. A preliminary routing and profile with approximate portal locations and surface track connections was identified in these reports. The starting point of this report is the work of the CARL Task Force, and the goal of this report is to develop a schematic design of the preferred Build Alternative

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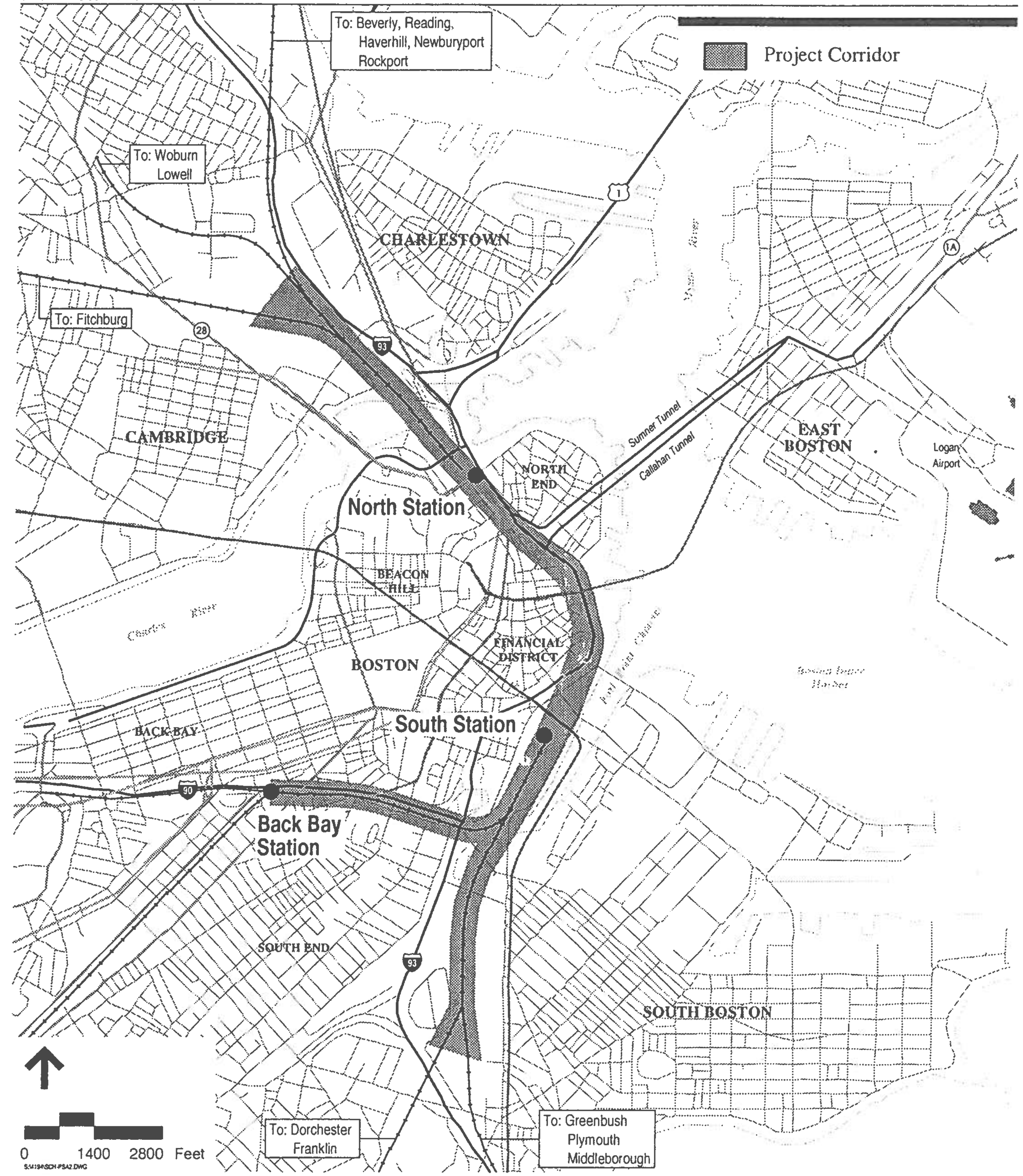


NorthSouth**RailLink**• PROJECT *VHB/FRH, A JOINT VENTURE*

Study Corridor Figure 1.4-1

option(s) to a level that allows for sufficient comparison of the alternatives, leading to an investment decision.

The purpose of this Schematic Design Report is to document and communicate the design assumptions for the Build Alternatives considered in the MIS/DEIS/DEIR. The level of engineering design required for an MIS/DEIS/DEIR must be sufficient to demonstrate that the project is feasible, and to develop an order-of-magnitude cost estimate by which to compare alternatives. However, the MIS/DEIS/DEIR design is generally conservative and broad in nature, describing what is possible while also encompassing a range of alternatives that may develop in the preliminary engineering effort to follow. At such a level of engineering design it is generally premature to consider optimizing cost and schedule because of the unknown technical variables that may later lead to changes in the project concept. Generally, as the design advances from the MIS/DEIS stage to preliminary engineering and publication of an FEIS, additional engineering analysis leads to many refinements in alignment and construction methods. At that level, optimization of cost and schedule will begin to be addressed.

1.5.2 Design Objectives

There were several specific design objectives to be accomplished as part of this schematic design study:

- the updating and refinement of the plan, profile and cross-section information developed previously in the CARL Task Force report,
- identification of locations within the tunnel and on the surface approaches to the tunnel for track interlockings, in order to maximize operational flexibility,
- refinement of schematic station and platform layouts to minimize dwell times and promote efficient passenger flows and egress,
- refinement of tunnel portal locations based on the location of adjacent structures, track layout, interlocking requirements and geometric design criteria,
- definition of the surface rail traffic and subway connections, and
- review and refinement of construction methodologies.

1.5.3 Study Methodology

the schematic design process can be divided into three phases. In the first phase, the basic design criteria and the plan and profile work developed as part of prior efforts were compiled. Design criteria include track geometric requirements, determination of maximum acceptable grades through station platforms, passenger flow design criteria (platform widths, escalator/elevator locations and numbers), and general ventilation criteria. The compilation of these guidelines and the previously developed alignment information provided the basis for development of a refined tunnel alignment and station requirements.

The second phase combined the results of the initial effort with the preliminary findings of the other technical analyses, including the *Equipment Engineering Study*, *Ridership Methodology and Forecasting Study*, and *Operations Study*. The purpose of this effort was to test various geometric constraints with operational requirements to begin the formation of a systems operation plan. After each round of interactive analysis, the findings from the initial phase were reviewed and certain criteria were modified as necessary.

The third phase of this effort identified a schematic design(s) for the Build Alternative options. As part of this phase, the identified schematic design(s) were confirmed by a peer review, in which a group of tunneling and underground construction experts reviewed the schematic design alternatives focusing on issues of constructibility. The group, known as the Constructibility Peer Review Committee, or CPRC, met over a two-week period in late January 1997 to review the schematic design materials. Their findings, which are incorporated throughout this report as appropriate, are fully contained in Appendix A.

2 Description of Corridor Land Uses

2.1 Introduction

As shown previously in Figure 1.4-1, the study area corridor is generally located within the City of Boston between South and North stations and Back Bay Station. On the southern end, the corridor extends from South Station to Southampton Street through the MBTA and Amtrak railyards at South Bay. On the northern end, the corridor extends from North Station to north of the Gilmore Bridge in the vicinity of the MBTA's Boston Engine Terminal. This chapter describes the existing and planned land uses within the study corridor.

2.2 Existing Land Use

The rail link tunnel would generally follow the path of the Central Artery/Tunnel highway project. It would pass under several established neighborhoods in Boston, including the waterfront, financial/retail districts, Government Center/Quincy Market area, several Central Artery parcels, the North End, and East Cambridge/Charlestown. The predominant land uses existing along the tunnel corridor are commercial, transportation, and institutional, although a few areas have residential populations. Based on demographic mapping provided by the Central Transportation Planning Staff (CTPS), the highest employment density and the majority of tourist activities are in the area of the proposed Central Station.

Several of the existing neighborhoods in the study area are described in more detail below.

- Waterfront: The proposed tunnel follows this district from South Station to the north end of the proposed Central Station, near the Aquarium. Land uses in this area include commercial, residential, maritime and institutional. A primary Boston Redevelopment Authority (BRA) planning goal for this area is to increase public waterfront access, and to make walkway system improvements along the waterfront itself.
- Financial District: This area includes Dewey Square, Fort Hill, Post Office Square, Broad Street, State Street, and Downtown Crossing. Land uses in this area consist of commercial, including office functions on upper floors of nearly all buildings, and retail on the ground floor of most buildings. Retail activities range from large department stores at Downtown Crossing to small lunch shops throughout the Financial District.
- Government Center: This area extends from the State House down Beacon Hill in a triangular area including the current Suffolk County Courthouse, the McCormack and Leverett Saltonstall Office buildings, and Boston City Hall, the John F. Kennedy Federal Building, and Lindeman Mental Health Center/ State Division of Employment and Training Building. A large number of the commuter rail passengers work in this area.
- Quincy Market: This area extends from Faneuil Hall through Quincy Market to the waterfront. It also includes such tourist attractions as the Blackstone Block, the Union Oyster House and the new Holocaust Memorial. This area is adjacent to the north end of the proposed Central Station and is a destination for many tourists.
- North End: This is a residential neighborhood which borders both the proposed North Station and Central stations. In addition to residential use, this area is known in the metropolitan Boston area as a focal point for fine Italian restaurants and markets, highly popular with both locals and tourists.
- North Station/Bulfinch Triangle: This area includes government offices (the Thomas P. O'Neill Federal Office Building), mixed-use offices over retail in the Bulfinch Triangle, and the FleetCenter sports arena. A primary transportation concern in this area is peak ridership demands generated by patrons attending sports, entertainment, and concert events at the FleetCenter.

The existing land uses within the portal areas (the area where the tunnel reaches the surface) are discussed in detail in Chapter 3 of the MIS/DEIS/DEIR and are summarized below:

- The Back Bay portal area is proposed to be located within an existing open-cut, depressed rail corridor adjacent to the Massachusetts Turnpike (I-90). The properties abutting the Back Bay portal site to the south support commercial, manufacturing, and residential uses.
- The South Bay portals are proposed to be located within the existing railroad right-of-way in Southampton Street Yard. This area contains extensive railroad tracks, storage and maintenance activities for both MBTA and Amtrak, and also houses several food service facilities. The Southeast Expressway (I-93) is just west of this area. The predominant uses in the area are industrial, transportation, manufacturing, and retail/business.
- The north portals are proposed to be located in an existing railroad right-of-way across the Charles River from North Station, north of the Gilmore Bridge. This area was formerly the Miller River estuary and tidal basin, which was filled to allow for expansion of railroad facilities. The north portal site is bordered by the MBTA Orange Line surface rails and the elevated I-93 superstructure to the east, and extensive railyard facilities to the west. The predominant land uses in the area are industrial, commercial, and transportation/ communications/ utilities.

2.3 Planned/Programmed Corridor Land Use and Transportation Facilities

2.3.1 The New Central Artery

The new Central Artery, now under construction, will replace the existing elevated Artery, built in 1954, with a highway tunnel. The elevated Artery formed a barrier between the waterfront and the Financial District, as well as the western boundary of the

North End. With the removal of this structure, approximately forty acres of downtown land becomes available for planning and reuse.

2.3.2 Boston 2000

The City of Boston has published Boston 2000, "A Plan for the Central Artery", which sets out Boston Redevelopment Authority (BRA) urban design and planning guidelines for the reuse and development of the land above the new CA/T. As outlined in the plan, the depression of the artery will permit the re-establishment of a network of cross streets, making improved pedestrian connections to, and from, the Boston Waterfront. The new roadway network will in turn frame a series of development parcels totaling approximately 27 acres. About 22 acres or 75% of the parcels will be reserved as open space, allowing for the creation of a new park system with a combination of city-wide and neighborhood parks, including a botanical garden and a skating rink. The plan identifies locations for creating active open spaces and extending the tourist areas, and also calls for tree-lined boulevards and expanded water transit. Additionally, this plan calls for the development of new housing in Chinatown, the North End, and in the Bulfinch Triangle, together with restoration of a cross street pattern in the Triangle similar to the historic pattern.

To quote from the plan:

"This blueprint reflects the vision of the City-as-community expressed through three principles: (1) that the economic success of the downtown is significantly dependent on its attractiveness as a place to work; (2) that the natural environment - green spaces, sunlight, clean air - is as vital to the City as its streets and buildings; and (3) that the City provides a common ground for its citizens to come together socially, politically, and culturally."

The proposed rail link tunnel, as described in the introduction, supports the larger vision of Boston 2000 with improved transportation both locally and regionally. The construction of the tunnel and associated components would be compatible with the general urban design guidelines of the plan.

2.3.3 Urban Ring Interface

A Major Investment Study is currently underway for another transportation project in Boston and the surrounding communities of Brookline, Cambridge, Chelsea, Everett, Malden, Revere, Somerville, Watertown, and Winthrop. This study, referred to as the "Urban Ring", was undertaken to examine short and long-term transportation access improvements for destinations outside the regional core and to relieve congestion in downtown Boston on the radial rapid transit system.

This project as proposed would be a circumferential transit route with service provided by light rail or bus; the specific alignment and mode has not been determined to date. Potential stations for the urban ring within the vicinity of the rail link tunnel alignment could include Lechmere Station or Bunker Hill. The ridership estimates prepared for the Rail Link study included a sensitivity analysis with and without interfaces with the Urban Ring, as discussed in the *Ridership Forecasting and Methodology Report*. The schematic design presented in this report for the rail link tunnel does not preclude connections to the Urban Ring or the construction of proposed Urban Ring stations, based on information developed to date.

3 Rail Link Tunnel

3.1 Introduction

A rail link tunnel connecting South and North stations would involve the construction of tunnel bore(s) and associated portals. This chapter describes the design assumptions, the alignment corridor, the tunnel design and construction, and the right-of-way requirements for the tunnel.

3.2 Design Assumptions

To initiate the schematic design process, a series of assumptions were developed for the design and construction of a rail link tunnel. These assumptions were based on current MBTA standards and practices, and were reviewed with the MBTA Technical Committee prior to the preparation of this report. These assumptions are also recommended for preliminary engineering, if the Build Alternative is selected. A list of design references is included in Appendix B.

Horizontal Alignment

- Maximum curvature: 8 degrees (R = 717 feet +/-)
- Preferred maximum curvature: 5 degrees (R = 1,146 feet +/-)
- Maximum curvature in stations: 1 degree (R = 5,730 feet +/-)
- Spiral transitions at curves
- Maximum superelevation: 6 inches
- Maximum unbalance: 2-3/4 inches
- Preferred maximum unbalance: 1-1/2 inches

Vertical Alignment (Profiles)

- Maximum grade: 3% on tangent, reduced on curves
- Compensation of grade for curvature: 1 degree of horizontal curvature is equivalent to 0.04% of vertical grade (i.e., number of degrees x 0.04 is deducted from the maximum tangent grade to obtain the equivalent maximum grade on a curve)
- Preferred maximum grade: 2%
- Maximum grade in stations: 1%
- Preferred maximum grade in stations: 0.5%
- Maximum rate of change on vertical curves: 1% per 100 feet
- Preferred maximum rate of change on vertical curves: 0.5% per 100 feet
- Preferred maximum lateral force of 0.02g and absolute maximum of 0.03g

Rail Tunnel Box Dimensions

- Horizontal dimensions:
  - Two-track tunnel
    - 41 foot exterior width of box
    - 38 foot interior width wall to wall
    - 1.5 foot wall thickness
    - 8.5 foot offset from track centerline to wall (on tangent)
    - 5.1 foot offset from track centerline to catwalk (4 feet wide)
  - Single-track tunnel
    - 29 foot exterior width of box
    - 26 foot interior width wall to wall
    - 1.5 foot wall thickness
    - 8.5 foot offset from track centerline to wall (on tangent)
    - 5.1 foot offset from track centerline to catwalk (4 feet wide)
- Track spacing:
  - 13 feet minimum centerline to centerline, plus curve compensation
  - 8.5 feet minimum centerline to edge of structure, plus curve compensation
- Vertical dimensions:
  - 19'-6" minimum top of rail to low point of catenary system or any obstruction within 7 feet of centerline (Northeast Corridor standards)
  - minimum 2.5 feet top of vehicle dynamic clearance envelope to underside of tunnel (for catenary system)

Study Datum

- Standard study datum equals Central Artery/Tunnel project datum. Datum is established at 100 feet below the National Geodetic Vertical Datum (NGVD) of 1929, formerly USC & GS mean sea level datum of 1929. NGVD elevation 0.00 equals CA/T and North-South Rail Link study datum elevation 100.00.

Rail

- New 132 lb. RE rail (continuous welded) in accordance with MBTA standards for main line track construction (M/W-1)
- Heat-treated rail should be used on curves over two-degrees, 30 minutes

Ties

- Wooden ties everywhere but tunnel
- Concrete ties or direct fixation to tunnel slab in tunnel

Resilient Fastening System

- Resilient fastening system and insulators per MBTA standards

Track Spikes

- Spikes will be MBTA standard lock spikes

Ballast

- To meet American Railway Engineering Association (AREA) specification for 1-1/2 inch crushed granite (AREA No. 4)

Turnouts

- 132 lb. new turnouts as per MBTA Book of Standard Plans
- Switch timber African hardwood with screw type fasteners

Drafting Standards

- Project CADD Guidelines

3.3 Overview of Alignment Corridor

3.3.1 Introduction

As discussed in Section 1.3, at the start of this phase of the study, only one Build Alternative option based upon the CARL Task Force effort was being evaluated. This option consisted of a four-track rail tunnel along the Central Artery/Tunnel corridor alignment with three stations (North Station, Central Station, and South Station).

The CARL Task Force report had identified a construction methodology that included both shallow bore and mined tunnel technology. The mined segments were located directly beneath the CA/T highway tunnel incorporating extended supplementary excavation support walls. As the CARL Task Force study developed, new construction methods were also conceived. Supplemental work by the CA/T project design staff incorporated the shallow bore alignment. The CA/T project staff also developed a methodology using four single-track deep bore tunnels each of which was 18 feet in diameter. Later, following a series of meetings between the JV and CA/T staff, it was decided that the deep bore tunnel construction methodology was the preferred approach for the rail tunnel. The necessary design changes for extended supplementary excavation walls were not able to be incorporated by the CA/T project, thus eliminating the shallow bore and mined alternatives. Therefore, this study evaluated a deep bore construction methodology using a tunnel boring machine (TBM).

In addition to the construction methodology, other design options also arose in the development of the Build Alternative. These options include a two-station scenario (no Central Station), as well as a two-track tunnel scenario. Additionally, several different design variables were considered, including the specific tunnel alignment, the number of platforms provided, and the number of tunnel bores constructed. All of these combinations of Build Alternative options and design variables are described below. In areas of general discussion, the four-track, three-station option with two tunnel bores and three station platforms along the Dorchester Avenue alignment is considered the base case scenario.

The tunnel alignment is described below; the stations are discussed in detail in Chapter 4.

3.3.2 Portal Locations

The proposed portal locations are the same for all Build Alternative options. As shown in Figures 3.3-1 through 3.3-3 schematically, and in detail in Appendix C, a total of five portals are proposed: three on the south side and two on the north side. These portals include:

- South Bay Portals (Figure 3.3-1) - These two portals would be located in the South Bay service facility in the general vicinity of the Southampton Street overpass and the MBTA commuter rail service and inspection (S&I) building. The MBTA's Old Colony Lines (Middleborough/Lakeville, Kingston/ Plymouth, and Greenbush) would be serviced by one portal and the Fairmount Line (Dorchester Branch) would be serviced by another.
- Back Bay Portal (Figure 3.3-2) - This portal would be located approximately 100 feet east of the Washington Street overpass. It would connect the three Northeast Corridor tracks that service Providence and points south (Stoughton, Franklin and Needham lines and the proposed Fall River/New Bedford line) and the Conrail mainline tracks to Albany, New York, also servicing the MBTA's Worcester service. In the final configuration, seven tracks would be operational in the area of the portal; five at-grade tracks joined by two emerging from the rail link portal.
- North Portals (Figure 3.3-3) - These two portals would be located to the north of the Gilmore Bridge and west of the I-93 viaduct in Somerville. The first portal on the north side would service the majority of the northside MBTA rail lines (the Lowell, Reading, Haverhill, Beverly, Newburyport, and Rockport lines) as well as the extension of NEC intercity rail service to Woburn. The second portal would service the MBTA's Fitchburg Line and the MBTA's new Boston Engine Terminal.

3.3.3 Alignment Geometrics

Much of the rail link tunnel alignment between South Station and North Station would be within the Central Artery/Tunnel (CA/T) project corridor. South of South Station the study area would extend west to Back Bay and south to the South Bay railroad maintenance facility and yard. From North Station, the study area extends northerly to the area of the Boston Engine Terminal. The overall length of the alignment along the main line from Back Bay to the north side is approximately 14,725 feet.

Several different alignments are being investigated in the vicinity of South Station based on the location of the proposed rail link South Station. Two potential general locations include:

- Dorchester Avenue - with this option, the proposed South Station would be located to the northeast of the existing facility. The proposed station would be located adjacent to the Fort Point Channel, and could be shifted as far north as Russia Wharf. As shown in Figure 3.3-4, this location also has a range of flexibility in its east-west location, and may be shifted as far east as to locate it completely beneath the Fort Point Channel. The alignment associated with this location will be referred to as the "Dorchester Avenue alignment" throughout this document.
- Central Artery/Tunnel (Atlantic Avenue) - with this option, the proposed South Station would be located directly below the existing tracks and would extend from the existing South Station headhouse to the rear of the South Station Transportation Center. The alignment associated with this location will be referred to as the "Central Artery/Tunnel alignment" throughout this document.

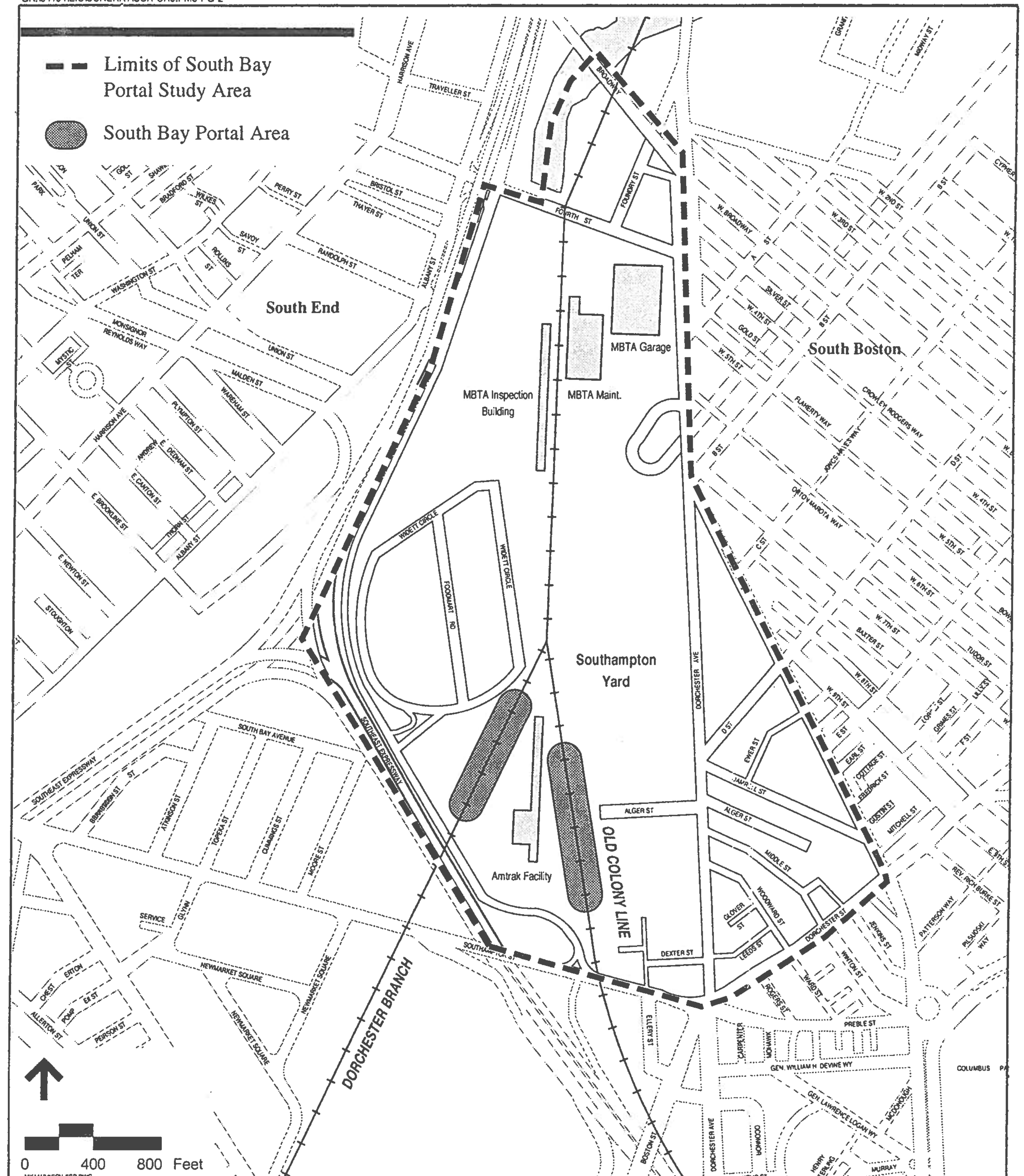
Both of these alignments are shown schematically in Figure 3.3-5. The following section provides a detailed description of the Dorchester Avenue alignment, and a summary of differences for the Central Artery/Tunnel alignment. The alignment plan and schematic track layout and profile are included in Appendix C. A three-station alternative is assumed in the descriptions below. If a two-station alternative is chosen, the alignment would be the same as presented but without the Central Station.

Dorchester Avenue Alignment

Back Bay Portal to South Station

This alignment begins east of Back Bay Station, which serves the MBTA's Framingham, Needham, Franklin, Stoughton, Providence and New Bedford/Fall River lines, as well as the Northeast Corridor.

From Back Bay Station, two tracks would diverge from the surface tracks and enter a portal just east of the station and the Orange Line Tunnel portal. The track configuration would allow a train on any of the five Back Bay Station tracks to access either the northbound or southbound track in the two-track tunnel

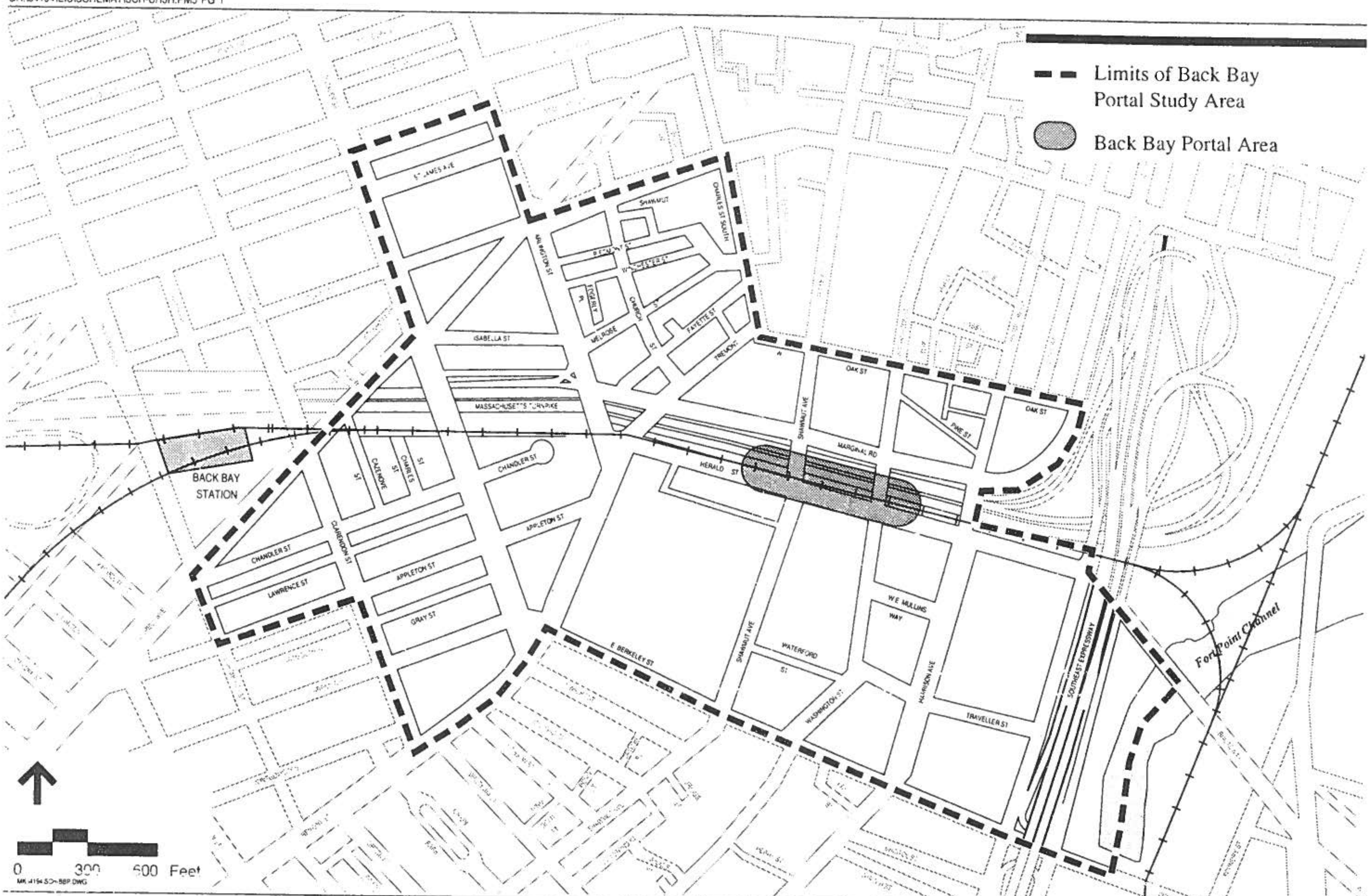


NorthSouthRailLink PROJECT • VHB/FRH, A JOINT VENTURE

South Bay Portal Location Figure 3.3-1

Source: CTPS, 1995.

GR:\04194\EIS\SCHEMAT\SCH-CH3H.PM5 PG 1



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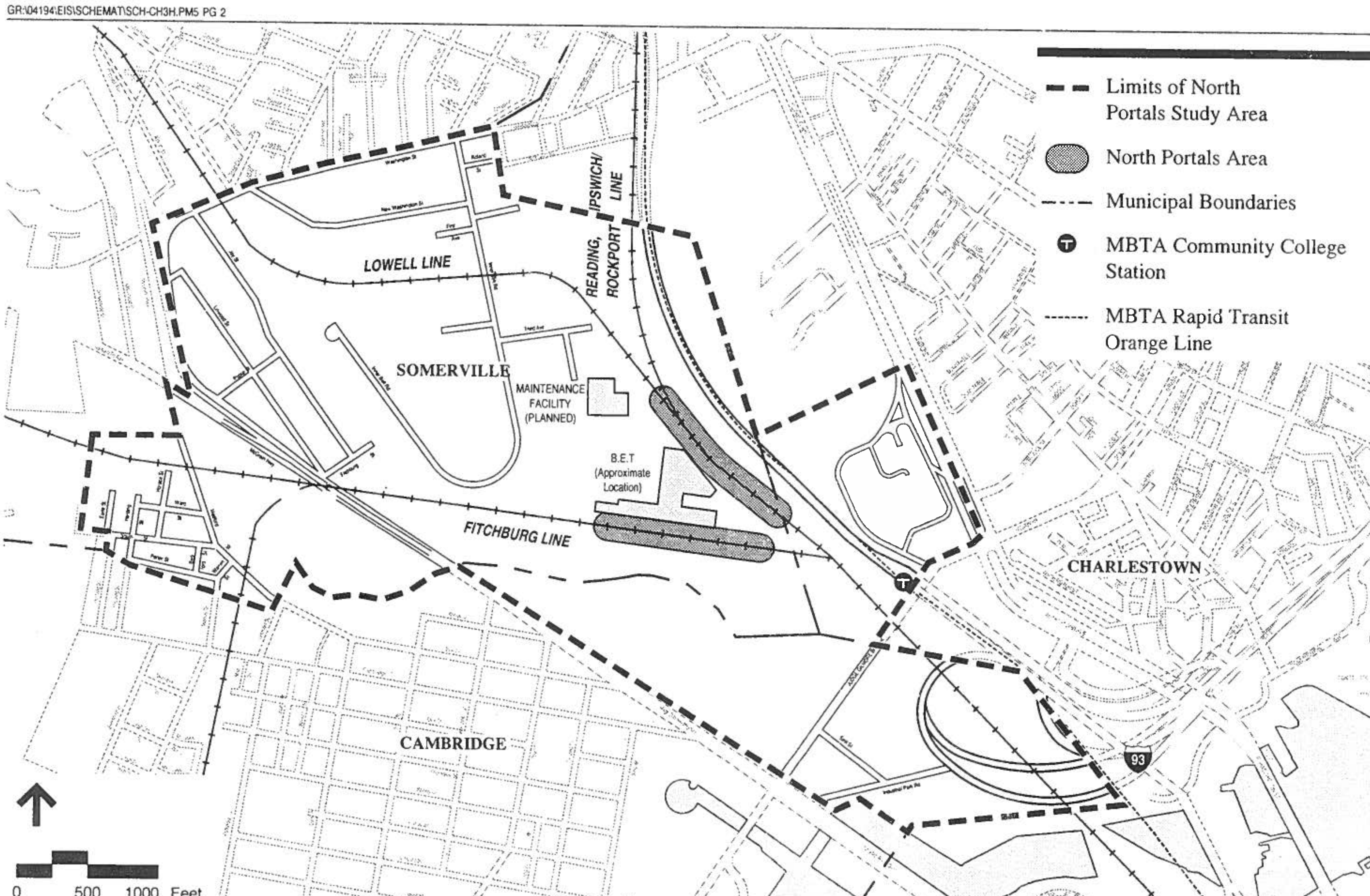
Back Bay Portal Location

Figure 3.3-2

Sources: CTPS, 1995; Boston Parks and Recreation, 1993; Boston School Committee, 1995; Boston Public Facilities Department; BRA.

GR:\04194\EIS\SCHEMAT\SCH-CH3H.PM5 PG 2



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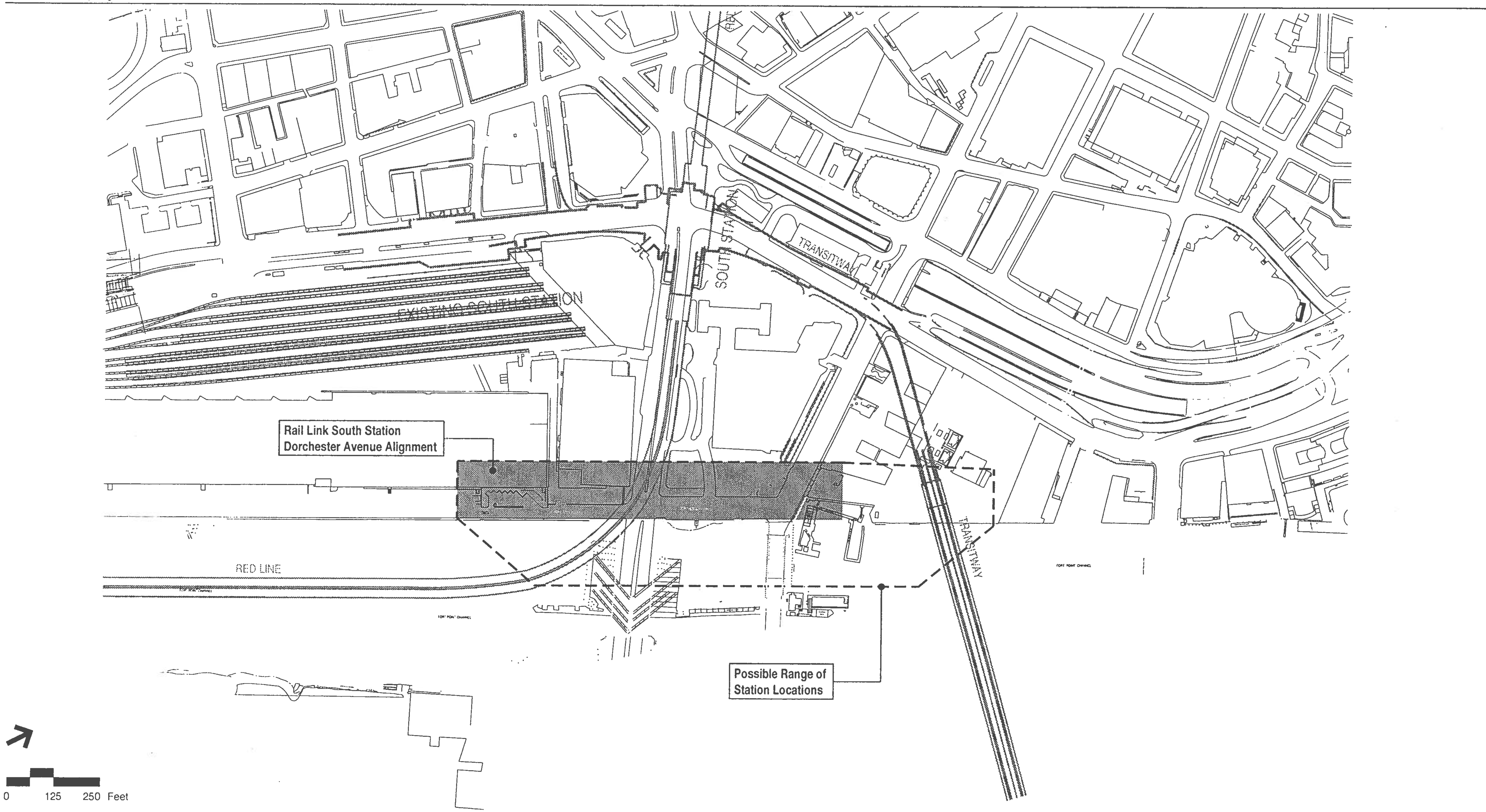
North Portal Locations

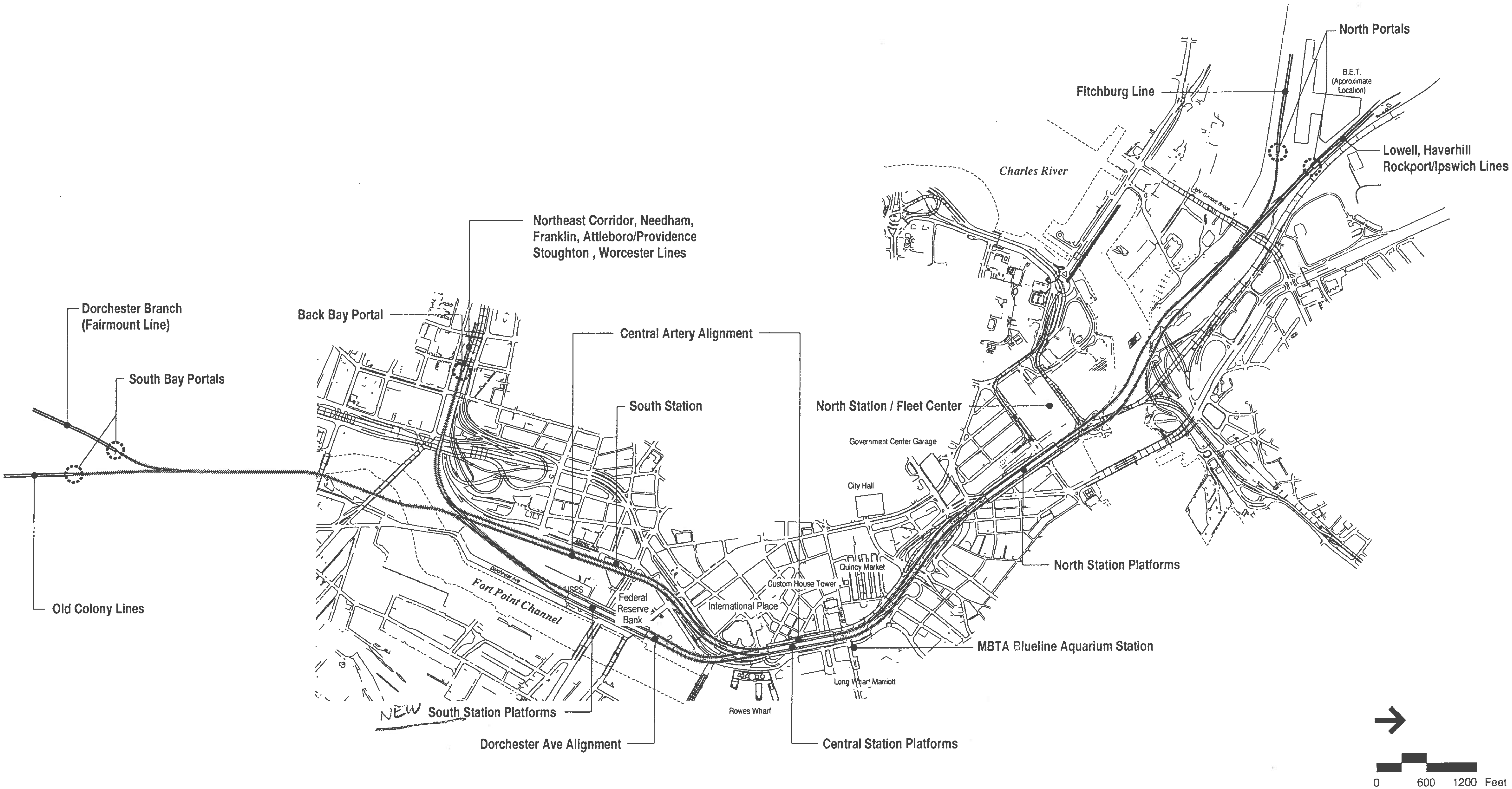
Figure 3.3-3

Sources: CTPS, 1995; MBTA



South Station
Dorchester Ave Alignment
Station Envelope

Figure 3.3-4



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Tunnel Alignment

Figure 3.3-5

approach. It should be noted that the preliminary operational analysis indicates that three tunnel tracks may be required at the Back Bay portal. This potential refinement will be addressed during development of preliminary engineering plans, if the Build Alternative is selected. Just east of the portal area the tracks would separate into two single-track tunnels. The two single-track tunnels would descend at a 3.0 percent grade, generally following the alignment of the surface tracks and passing beneath the CA/T I-90 tunnels and ramps, along tangents and horizontal curves up to eight degrees. After passing beneath the jacked highway tunnels, the tracks head northeasterly towards the Post Office building and are joined by the Old Colony and Dorchester Branch tracks. This alignment is the only possible route which avoids several physical conflicts with support structures for the new I-90/I-93 interchange.

South Bay Portals to South Station

Two other contributing lines are also part of the southern end of this study: the MBTA's Dorchester Branch and the MBTA's Old Colony Line. Both the Dorchester Branch and the Old Colony Line would have their beginnings and portals in the vicinity of Amtrak's Southampton Yard Maintenance Facility. The Old Colony Line would diverge from a single surface track and descend to a portal approximately 200 feet north of the Southampton Street Bridge. The two-track tunnel would descend at an approximately 3.0 percent grade until approximately 30 feet below the surface. The track would then descend at a 1.1 percent grade to its junction with the Dorchester Branch tunnel. This alignment runs parallel to and east of the Red Line surface track.

The Dorchester Branch tunnel tracks would diverge from the surface tracks west of I-93 and run parallel to and just south of the surface tracks. Crossovers would provide universal access between all tracks. The tunnel tracks would cross over I-93 on a separate bridge and descend at a 3 percent grade to the junction with the Old Colony tracks, passing beneath surface tracks serving MBTA and Amtrak service facilities. Some realignment of these tracks will be necessary.

The Old Colony/Dorchester Branch junction will be just north of the South Boston Bypass Road, east of the Red Line surface tracks. It will have the necessary crossovers for universal access for all tracks. From this point, the combined lines will descend in a two-track tunnel at 3 percent, running north beneath Red Line Service Facilities and Cabot Yard. At the north end of Cabot Yard, the tunnel will level off at approximately ninety feet below surface. It then passes beneath the Fort Point Channel and around I-90 structures until the tunnel is adjacent to the Back Bay tunnels and on the same profile.

At this point the four tracks become a single alignment of two 41-foot diameter, two-track tunnels at the southerly end of South Station. Crossovers placed south of the platforms would make any of the four station tracks accessible from any of the four tunnel tracks. After track crossovers, the tracks turn and run parallel to the Fort Point Channel and enter South Station, flattening to a 0.6 percent grade.

The station platforms would be aligned parallel to the Fort Point Channel and extend from the U. S. Postal Service property under Summer Street and the Red Line, beneath the open area behind the Federal Reserve Bank, and under Congress Street. The tracks at this point would be approximately 120 feet below the surface. There would be three 1,050 foot platforms at the station. The station as proposed would be located adjacent to the west edge of the Fort Point Channel and run from approximately five hundred feet south of Summer Street to Congress Street. It could also be shifted to the east under the Fort Point Channel. The location of the station would be finalized during the preliminary engineering phase.

South Station to North Station

From the north end of South Station, the tracks continue parallel to the channel, descending at a 0.6 percent slope. The alignment then turns left in an eight degree curve near Northern Avenue and passes beneath the Central Artery near Rowes Wharf and levels off approximately 140 feet below the surface. The two tunnels are now within the limits of the Central Artery slurry walls.

From this point, the two tunnels travel north beneath the Central Artery tunnels on a level grade to three 800-foot long Central Station platforms. These platforms run from Broad Street to State Street. The tracks at this point are approximately 140 feet below the surface and 60 feet below the MBTA's Aquarium Station.

From Central Station, the two tunnels travel north beneath the Central Artery on six-degree curves and on a level grade to North Station. At North Station the two tunnels are in an 1,050-foot three-platform configuration, running from North Washington Street to the FleetCenter on a level grade beneath the Central Artery tunnels. The tracks at this point are approximately 140 feet below the surface.

North Station to North Portals

At the north end of North Station, the tunnels would begin to ascend at a 3 percent grade. At the new Charles River Crossing bridge, the two tunnels would diverge. The eastern tunnel would run around the east side of the south pier and the western tunnel would go between footings of the south pier. Both tunnels would then turn westward toward the new Storrow Drive bridge. The eastern tunnel would go beneath the north span and the western tunnel would go beneath the center span. Crossing under the southern end of the CANA ramps, the northbound tunnel would be beneath the MBTA surface tracks, just north of the bascule bridges. The two tunnels converge beneath the north end of the CA/T north area ramps and Boston Sand and Gravel. Crossovers would be placed at this location allowing all four tunnel tracks to access all surface tracks. The two tunnels would then ascend together at a 3 percent grade to the north portal, east of the Boston Engine Terminal.

The Rockport/Ipswich, Haverhill/Reading, and Lowell lines would be accessed from this portal. The two western tracks would continue northward as the Lowell Line inbound and outbound tracks. The two eastern tracks would become the Haverhill/Rockport/Ipswich inbound and outbound tracks.

The two Lowell Line tracks would ascend on an approximately 3 percent grade at the portal to meet the existing Lowell Line alignment just south of the existing High Bridge that crosses over the Grand Junction Branch. The Lowell Line single surface track would converge with the Lowell Line inbound track at this point.

The two Haverhill/Rockport/Ipswich Line tracks would ascend on a 2.4 percent grade at this point. Tracks would be on a tangent and meet the existing Haverhill/Rockport/Ipswich Lines alignment approximately 2,000 feet north of the Gilmore Bridge. The single surface track would converge with the outbound track of the Haverhill/Rockport/ Ipswich Line at this point.

A double-track tunnel would diverge from the westernmost tunnel approximately 300 feet south of the Gilmore Bridge and turn west adjacent to the Boston Engine Terminal (BET) facility. At this location, the second portal would service the MBTA's Fitchburg Line and the new BET and storage yards. Crossovers would make both tracks accessible from all four tunnel tracks. These two tracks would turn west and be the Fitchburg Line inbound and outbound tracks. They would ascend on a 1.9 percent grade to the second northern portal, which would be on the existing Fitchburg Line alignment, south of the BET, approximately 1,200 feet north of the Gilmore Bridge. At this point, the tracks would become steeper to a 2.4 percent ascending grade, which would be maintained until the tracks meet the surface. The Fitchburg Line single surface track would converge with the Fitchburg Line inbound track at this point. A new right-hand crossover would be built to access the Fitchburg Line outbound track.

Central Artery/Tunnel Alignment

The Central Artery/Tunnel alignment is similar to the Dorchester Avenue alignment except in the area of South Station. The specific differences would be as follows:

- From Back Bay this route would be the same from the portal to the eight-degree curve which threads between the obstructions of the I-90/I-93 interchange. For the CA/T alignment, this curve would be extended to bring the tunnels beneath the existing South Station tracks.
- South Station would be built on a 1 percent descending grade beneath the South Station Transportation Center, the surface South Station, Summer Street, the Red Line, and the Federal Reserve tower. It should be noted that there would be many difficulties involved with constructing a station at this location due to the piles supporting the South Station Transportation Center (SSTC) and future air right developments, and the need to maintain surface rail operations during construction. If full flexibility is maintained between all four tunnel tracks south of the station, it will result in slower train operations through shorter turnouts, and involve major underpinning of the SSTC. It would also place the north end of the station beneath the Federal Reserve tower. This design would require close coordination with the Federal Reserve Bank and the development of an extensive construction mitigation program. Tunneling directly beneath the tower would present numerous issues resulting in a more complex station design. It may be possible to place the station south of the Federal Reserve building and to reduce the underpinning of the SSTC, but this would eliminate or reduce track connections south of the station.
- From the north end of the South Station platforms, the two tunnels would descend on a 3 percent grade, along tangents and eight degree curves. The alignment would pass beneath the Federal Reserve building, Congress Street, and Russia Wharf. It would meet the Dorchester Avenue alignment in the vicinity of Northern Avenue.

3.3.4 Subsurface Conditions

Geotechnical data and engineering reports for design sections D09A, D19D, D19B, D17A, D15A, D09C, and D11A of the Central Artery/Tunnel highway project were reviewed to determine the geology found within the study area. No additional borings were done for this phase of the rail link study. A summary of the geological characteristics of the study area is given below and discussed in Chapter 3 of the MIS/DEIS/DEIR.

The rail tunnel would be excavated through the geologic materials of the Boston Basin, which is part of the New England Physiographic Province of the Appalachian Highlands. The subsurface materials in the area from the ground surface downward generally consist of the following:

- ***Fill:*** Fill is the ground surface material throughout much of the Boston Basin. It generally consists of fine to coarse sand with varying amounts of silt and gravel. Localized areas contain organic silt, clay, relatively clean gravel, and miscellaneous materials such as brick, concrete, wood, construction debris, and rubbish. The thickness of the strata ranges between 8 and 20 feet, with some localized deeper pockets.
- ***Organics***: Organic soils generally underlie the fill materials. These soils were deposited in tidal marsh and estuarine environments after a period of glacial deposition. They consist primarily of dark gray organic silt and clay with a trace to little fine sands and shells, and locally have partings and thin layers or lenses of fine sand. Also, some localized areas contain deposits of peat, which is distinguishable by the remains of plant materials (roots, fibers, etc.).
- ***Clay***: Below the fill and organic materials is a deposit of marine clay and silt. This material is commonly known as Boston Blue Clay. The clay generally has moderate plasticity and is stratified with partings, lenses, and layers of silt and fine sand. It also contains occasional coarse material, ranging from coarse sand to boulders, distributed randomly throughout the deposit. The stiffness of the clay varies within the stratum from hard to soft.
- ***Glaciomarine Deposits***: Glaciomarine deposits are materials consisting of clayey silt and sand with a small gravel content and varying amounts of coarse gravel, cobbles, and boulders in localized areas. Glaciomarine deposits are usually found between the clay and till layers and have properties which are very similar to both layers. The deposits are generally more plastic and less dense than the till material, but also contain more coarse gravel, cobbles, and boulders when compared with the clay material.
- ***Till***: The till is glacial in origin and typically consists of a heterogeneous mixture of sand, silt, clay and gravel, with cobbles and boulders. The layer is located on top of the bedrock and is approximately 10 feet thick.
- ***Sand***: Sand and gravel deposits occur in localized areas within the Boston Basin. These deposits are generally in thin layers within the clay, glaciomarine, and till deposits with typical thickness of less than 10 feet. The gradation of the material ranges from fine sand with silt to widely graded sand and gravel.
- ***Bedrock***: Cambridge Argillite is the predominant rock type along the tunnel alignment. Other rock types include tuffaceous argillite and intrusive rocks such as basalt, andesite, and diabase. The argillite is a fine-grained very thinly bedded rock characterized by alternating dark and light gray beds of silt- and clay-sized particles. Regionally the rock is folded, and locally the dip of the bedding is generally high angle, although it varies from horizontal to vertical. The rock is very susceptible to weathering and may vary within the study area between rock that is completely decomposed and behaves essentially as a hard clay, to unweathered rock that is generally soft to moderately hard, moderately fractured to sound, with very close to moderately close joint spacing.

The presence of each type of subsurface material varies within the study corridor. The tunnel excavation would be expected to encounter both soil and bedrock conditions. The tunnel boring machine is expected to operate almost entirely in clay south of South Station; within a mixed interface of clay, argillite and till at South Station; till and argillite between South and Central stations; almost entirely within argillite between Central Station and the Charles River; and within a mixed interface again in the area of the north portals.

Virtually all of the rail link alignment would be constructed below the natural groundwater table. Groundwater infiltration in construction sites and permanent facilities is a maintenance issue to be considered in design and in selecting a construction process. Groundwater infiltration may also impact area groundwater tables by lowering their level, which may cause settlement in nearby buildings and structures. Management of groundwater tables and infiltration will be an important issue during construction of the project and its permanent facilities, if the Build Alternative is selected.

Similar to the CA/T, the rail link would require underground construction activities which would cause the displacement of millions of cubic yards of material. Estimates of the total quantity of solid waste generated by the rail link range from 2.5 million to 4.3 million cubic yards, depending on the option selected. By way of comparison, it is estimated that the CA/T will generate a total of approximately 14 million cy of dredged and excavated soil or material[3]. Estimated quantities of rail excavate are presented in Tables 3.3-1 through 3.3-

Table 3.3-1
Tunnel Bore Excavated Materials

Type of Material	Quantity (cubic yards)
4-Track, 2-Bore Option	
Clay	413,000
Till	216,000
Bedrock	1,141,000
Total	**1,777,000**
2-Track, 1-Bore Option	
Clay	207,000
Till	108,000
Bedrock	571,000
Total	**886,000**

Table 3.3-2
Portal Excavated Materials (Cut and Cover and Boat Section)

Material	Cubic Yards
Back Bay Portal	
Fill	9,000
Organics	3,000
Clay	60,000
Sub-Total	72,000
+ 30% Swell	21,600
Total	**93,600**
South Bay Portals	
Fill	109,000
Clay	29,000
Sub-Total	138,000
+ 30% Swell	41,400
Total	**179,400**
North Portals	
Fill	92,000
Organics	38,000
Sand	5,000
Clay	58,000
Glaciomarine	42,000
Till	11,000
Bedrock	2,400
Sub-Total	248,000
+ 30% Swell	74,400
Total	**322,400**
Total for All Portals	**595,400**

[3] Massachusetts Highway Department, January 31, 1996, Materials Disposal Program Notice of Project Change.

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Table 3.3-3
Station Excavated Materials

Material	Quantity (Cubic Yards)
South Station Under SSTC	
Fill	181,000
Organics	4,000
Clay	416,000
Till	257,000
Sand	5,000
Bedrock	104,000
Sub-Total	**967,000**
+ Contingency	**1,100,000**
South Station Under Dorchester Avenue	
Fill	138,000
Organics	4,000
Clay	336,000
Till	163,000
Sand	6,000
Bedrock	38,000
Sub-Total	685,000
+ 30% Swell	205,500
Total	**890,500**
Central Station	
Fill	5,900
Organics	3,000
Clay	99,900
Glaciomarine	0
Till	142,000
Bedrock	222,100
Sub-Total	473,000
+ 30% Swell	141,900
Total	**614,900**
North Station	
Fill*	4,000
Organics (4,500*)	17,000
Clay	30,000
Glaciomarine	0
Till	84,000
Bedrock	371,000
Sub-Total	506,000
+ 30% Swell	151,800
Total	**657,800**

* Estimated for kiosks and vents only

Once excavated, the materials from the tunnel boring and station excavation operations would be removed via the bored tunnels through the north portals to the construction staging area (see Section 3.4.2). There the material could be transported by rail to its final disposal site, eliminating the need to transport excavate via trucks on city streets. An alternative to this plan could be to transport excavate from North and South Station construction access shafts via barges on the Charles River and Fort Point Channel respectively. This alternative raises issues of environmental impact and mitigation. Selection of the best means of transporting excavate will take place during preliminary engineering and will be reported in the Final EIS.

There are a number of options available for disposal, ranging from using the excavate as fill for development sites or mine reclamation to developing a project disposal site. Hazardous materials must be transported to a licensed disposal facility. The MIS/DEIS/DEIR includes a more detailed discussion of this issue.

3.4 Tunnel Design and Construction

3.4.1 Tunnel Cross-Section

Clearances

Tunnel and station clearances have been developed to provide for adequate rail vehicle and inspection personnel safety requirements. These recommended horizontal and vertical clearances would be in conformance with Massachusetts Statutes, MBTA Design Specifications, and AREA Recommended Standard Practices, where appropriate.

Clearances were investigated for both single-track and two-track tunnels. If a single-track tunnel is utilized, the minimum outside tunnel diameter would be 29 feet, with an inside diameter of 26 feet, assuming a 1.5 foot tunnel lining. This diameter would provide a clearance envelope which meets the MBTA minimum acceptable clearances for new construction on the Northeast Corridor. Specific dimensions include 8'-6" for side clearance and 19'-6" vertical clearance (7'-0" each side of the centerline of track). All clearances accommodate a maximum 8°-00' curvature and necessary superelevation. Approximately 2'-6" remains for catenary wire and supports. A two-track tunnel would require a minimum outside diameter of 41 feet, and an inside diameter of 38'-0" based on the same criteria, with 6'-0" remaining for the catenary wire and supports.

The above criteria for single-track and two-track tunnels accommodate a safety walk beside the track, and various equipment such as signal and communication systems outside the clearance envelope. These dimensions may be refined during preliminary engineering once the specific catenary system is designed, and the components to be carried through the tunnel are further defined. Figure 3.4-1 illustrates the typical tunnel cross-section and clearances for a single-track and two-track tunnel.

Tunnel Bore/Platform Design Options

For all of the Build Alternative options, several combinations of the number of tunnel bores utilized, and the number of platforms provided at the stations were considered. Two, three and four tunnel bores were evaluated, as well as two, three, four, and five platforms. Figures 3.4-2 through 3.4-4 illustrate the combinations of tunnel bores and platforms, and Table 3.4-1 summarizes the key components of these options.

Table 3.4-1
Design Options: Number of Tunnel Bores and Platforms

No. of Bores	No. of Platforms	Tunnel Diameter	Platform Widths	Corridor Width	Station Width	Transition Zone
2	2	2-41 ft.	2-50 ft	110 ft.	165 ft	800 ft
2	3	2-41 ft.	30/50/30 ft.	110 ft	160 ft	0 ft
2	4	2-41 ft.	4-30 ft.	135 ft	180 ft	0 ft
2	5	2-41 ft.	5-30 ft.	110 ft	195 ft	800 ft
3	2	29/41/29 ft.	2-50 ft	165 ft	165 ft	0 ft
3	3	29/41/29 ft.	30/50/30 ft.	155 ft	160 ft	800 ft
3	4	29/41/29 ft.	4-30 ft.	155 ft	180 ft	800 ft
3	5	29/41/29 ft.	5-30 ft.	155 ft	195 ft	800 ft
4	2	4-29 ft.	2-50 ft	225 ft	225 ft	0 ft
4	3	4-29 ft.	30/50/30 ft.	175 ft	160 ft	800 ft
4	4	4-29 ft.	4-30 ft.	175 ft	180 ft	800 ft
4	5	4-29 ft.	5-30 ft.	175 ft	215 ft	0 ft

As can be seen, several of the combinations are not efficient because they require a wider tunnel corridor, a wider station, or they require transition zones at each end of the platform, thus necessitating additional mining, to bring the tracks into and out of the stations.

Figure 3.4-5 illustrates the summary of the "reasonable" options and Table 3.4-2 summarizes the components and incremental tunneling cost of these options.

Table 3.4-2
Summary of "Reasonable" Construction Options

No. of Bores	No. of Plat.	Corridor Width	Station Width	Trans. Zone (ft.)	Excavate* (mil. cu/yd)	Incremental Cost (mil)**
2	2	110 ft	165 ft	800 ft	2 - 2.16	$150 - 250
2	3	110 ft	160 ft	0 ft	1.77	***
3	2	165 ft	165 ft	0 ft	1.88	$85 - 150
4	2	225 ft	225 ft	0 ft	1.96	$250 - 300

* does not include material excavated for station construction or portal areas
** the incremental cost reflects tunneling, mining, and excavate costs only
*** base case option; the base tunneling cost is approx. $280 million

The two tunnel bores, two platform option has the narrowest corridor and station width, however, it would require transition zones at both ends of the platforms. The CARL Task Force option (four tunnel bores, two platforms), when applied with the dynamic envelope and cross-section constraints developed in this study, would require the widest corridor and station widths. As indicated in the table, the tunneling, mining, and excavate costs range from approximately 40 percent to 100 percent higher than the base case option (two tunnel bores, three platform), which has a base tunneling cost of approximately $280 million.

Because of the narrower station width, lower excavation costs, and operational benefits, it was determined that the two tunnel bore, three platform option should be used as the base case for conceptual engineering, and is recommended for further refinement during preliminary engineering. Figures 3.4-6 illustrates the cross section of the tunnel/platform interface for this option.

3.4.2 Tunnel Construction

Several different construction methodologies would be employed for the construction of a rail link tunnel. As shown in Figure 3.4-7, the portal areas would be constructed with a boat section and tunnel using open cut and cut-and-cover technology, the majority of the tunnel would be constructed using a tunnel boring machine, and the station and transition areas would be constructed with a combination of boring and mining techniques. The following section describes the tunnel boring process in more detail. The station construction is discussed in Chapter 4.

For the tunnel boring it is proposed that tunnel construction begin at the north portal in the Boston Engine Terminal (BET) following track relocations, the set up of a construction support and staging areas, and the excavation and construction of the portal itself. The construction staging area is shown in Figure 3.4-8.

A pressurized-face, earth balanced, soft-ground/rock tunnel boring machine (TBM) would most likely be utilized for construction of a rail link tunnel. At this stage of the study, it is proposed that the TBM would be assembled and launched from the north portal, traveling through the North Station, Central Station, and South Station areas before resurfacing at a southern portal in the Southampton rail yards previously excavated in anticipation of the TBM arrival. The TBM would be equipped to handle soils and rock ranging from soft to stiff clays, glacial tills, to weathered Cambridge Argillite. Excavated material would be conveyed to the north portal for handling and disposal, with rail transportation available to transport materials as necessary. The pressurized face capabilities of the TBM would permit handling of groundwater infiltration without loss of ground, settlements, and/or damage to existing buildings, structures, and utilities. A tunnel lining of precast concrete segments would be installed as the boring progresses to support the tunnel excavation. These segments would be bolted and gasketed to virtually eliminate water infiltration into the tunnel.

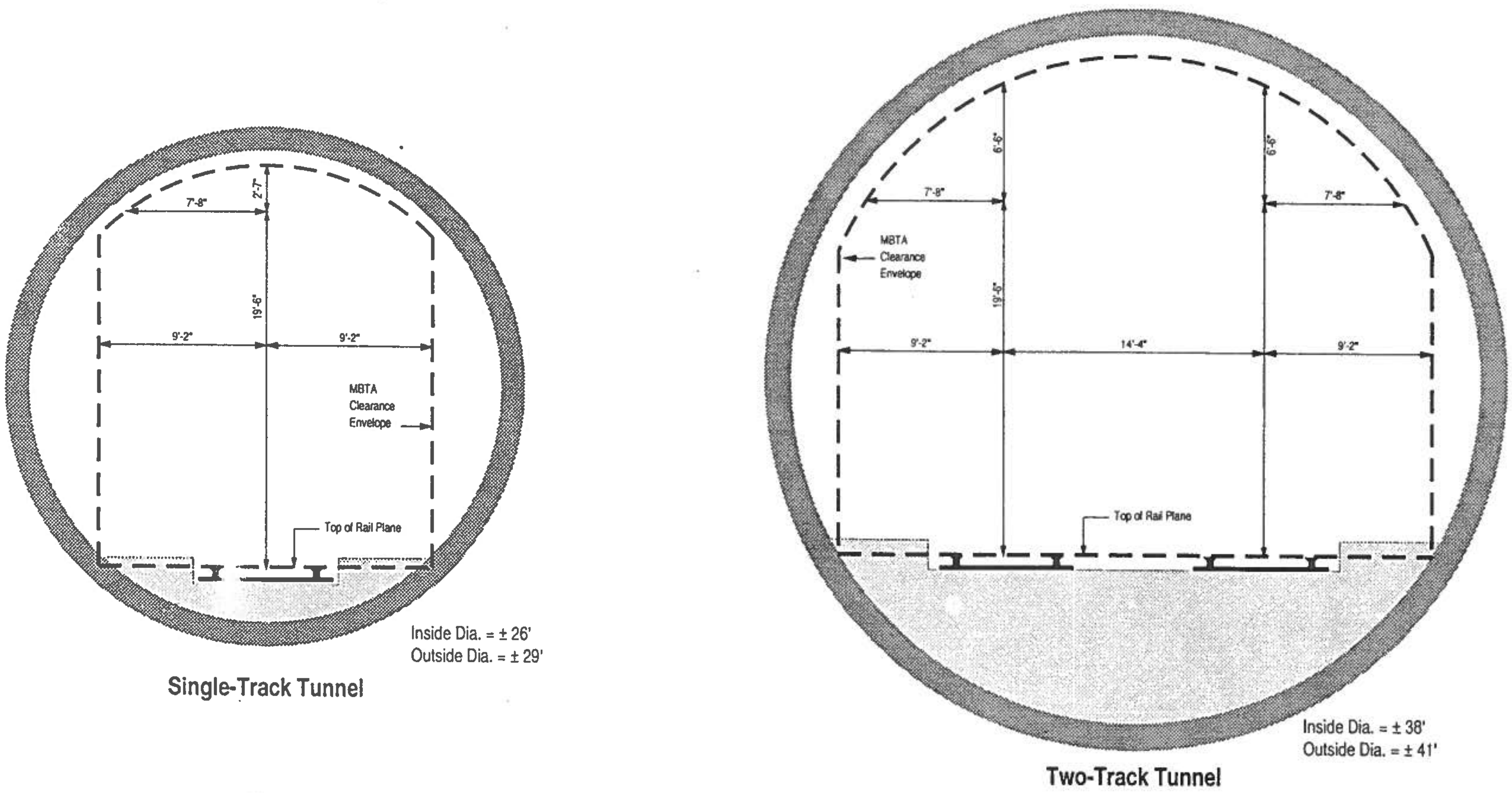
Once the TBM reaches the south portal, it would be disassembled and receive a maintenance overhaul before beginning boring operations for the second tunnel. The second tunneling operation would also begin from the north portal area, again with the TBM proceeding through the North Station, Central Station, and South Station areas before turning west and surfacing at an awaiting portal near Back Bay Station. With the tunneling operation completed, the TBM would be disassembled and transported from the portal area via rail. The construction staging and excavate handling area at the north portal would support tunneling operations for the second tunnel while also supporting tunnel finish work and station construction through the first tunnel.

An alternative approach, in which tunnel bores would be started at vertical access shafts located at the sites of North and South stations, was also considered. This approach would allow for multiple tunnel boring machines to be operating in different locations concurrently, potentially shortening the construction schedule sufficiently to compensate for the additional equipment cost. As much as practicable, these shafts would be located in positions that would eventually become access points for stations and emergency access and egress shafts along the tunnel alignment. It is anticipated that slurry wall construction would be utilized for portal and shaft structures since these provide both the strength and watertight requirements needed for these deep structures. Groundwater impacts would be eliminated by use of the slurry walls as cut-offs to groundwater flow into the excavated areas. Shallower excavations in the portal areas may utilize steel sheet piling, driven to an adequate depth to prevent groundwater flow and drawdown.

The environmental impacts, right-of-way issues, and construction impacts of both of these approaches should be investigated further in preliminary engineering. For the MIS/DEIS/DEIR, the first approach is analyzed as it minimizes surface impacts and right-of-way issues. The second approach, while offering benefits from a construction staging/scheduling viewpoint, needs further investigation into community and environmental impacts before the construction approach can be selected.

3.4.3 Underpinning of Subsurface Structures and Infrastructure Elements

There are several buildings and structures located within the study corridor that may require modifications to their foundation



Note: Clearance envelope shown is for 8° 00' curve with 2 1/4" superelevation.

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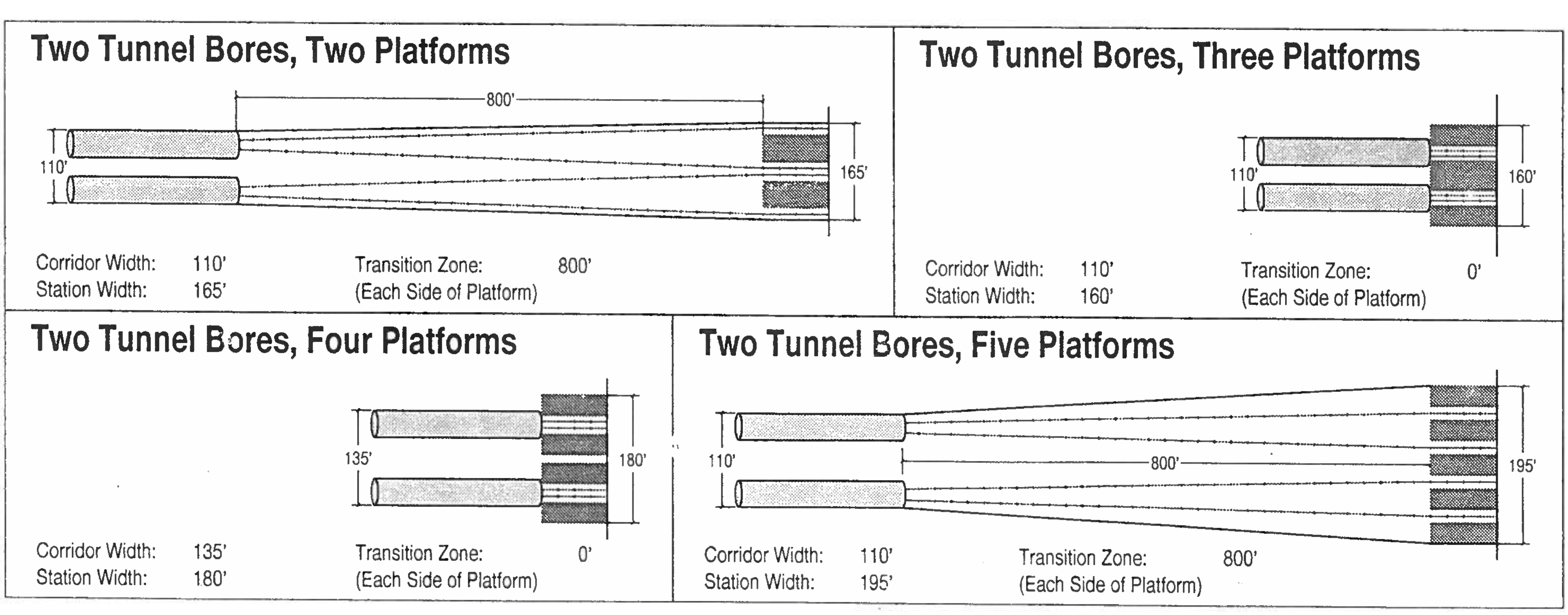
Tunnel Cross-Section — Figure 3.4-1



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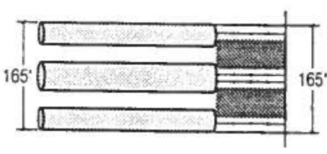
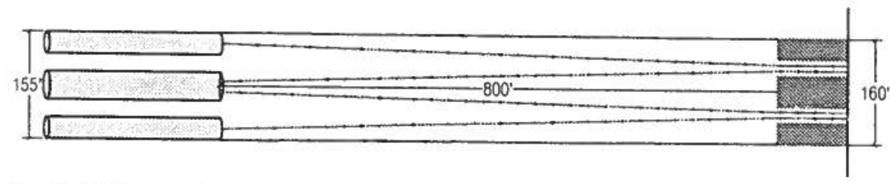
Two-Tunnel Bore Options — Figure 3.4-2

Three Tunnel Bores, Two Platforms



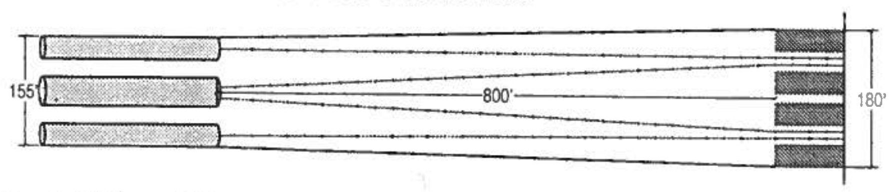
Corridor Width: 165'
Station Width: 165'
Transition Zone: 0'
(Each Side of Platform)

Three Tunnel Bores, Three Platforms



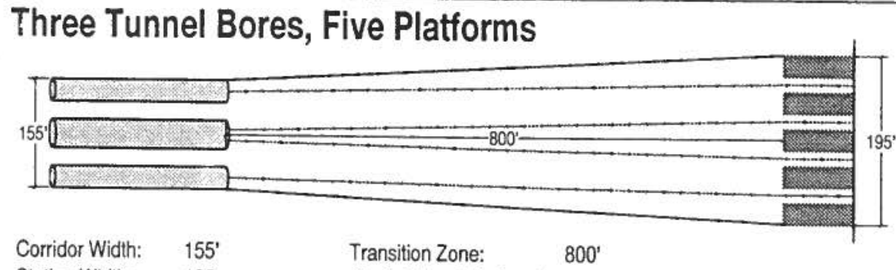
Corridor Width: 155'
Station Width: 160'
Transition Zone: 800'
(Each Side of Platform)

Three Tunnel Bores Four Platforms



Corridor Width: 155'
Station Width: 180'
Transition Zone: 800'
(Each Side of Platform)

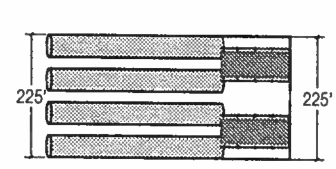
Three Tunnel Bores, Five Platforms



Corridor Width: 155'
Station Width: 195'
Transition Zone: 800'
(Each Side of Platform)

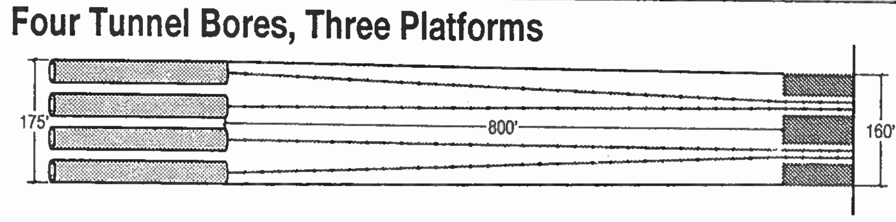
Three-Tunnel Bore Options Figure 3.4-3

Four Tunnel Bores, Two Platforms



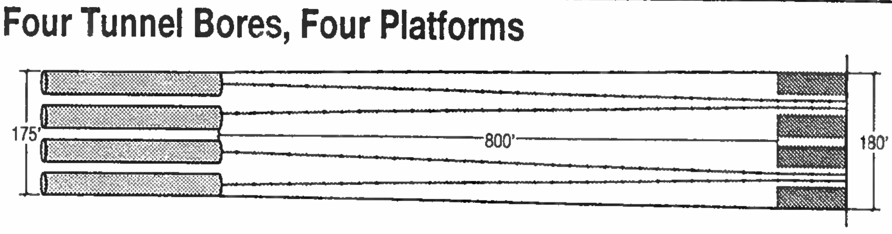
Corridor Width: 225'
Station Width: 225'
Transition Zone: 0'
(Each Side of Platform)

Four Tunnel Bores, Three Platforms



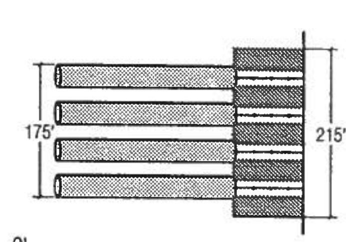
Corridor Width: 175'
Station Width: 160'
Transition Zone: 800'
(Each Side of Platform)

Four Tunnel Bores, Four Platforms



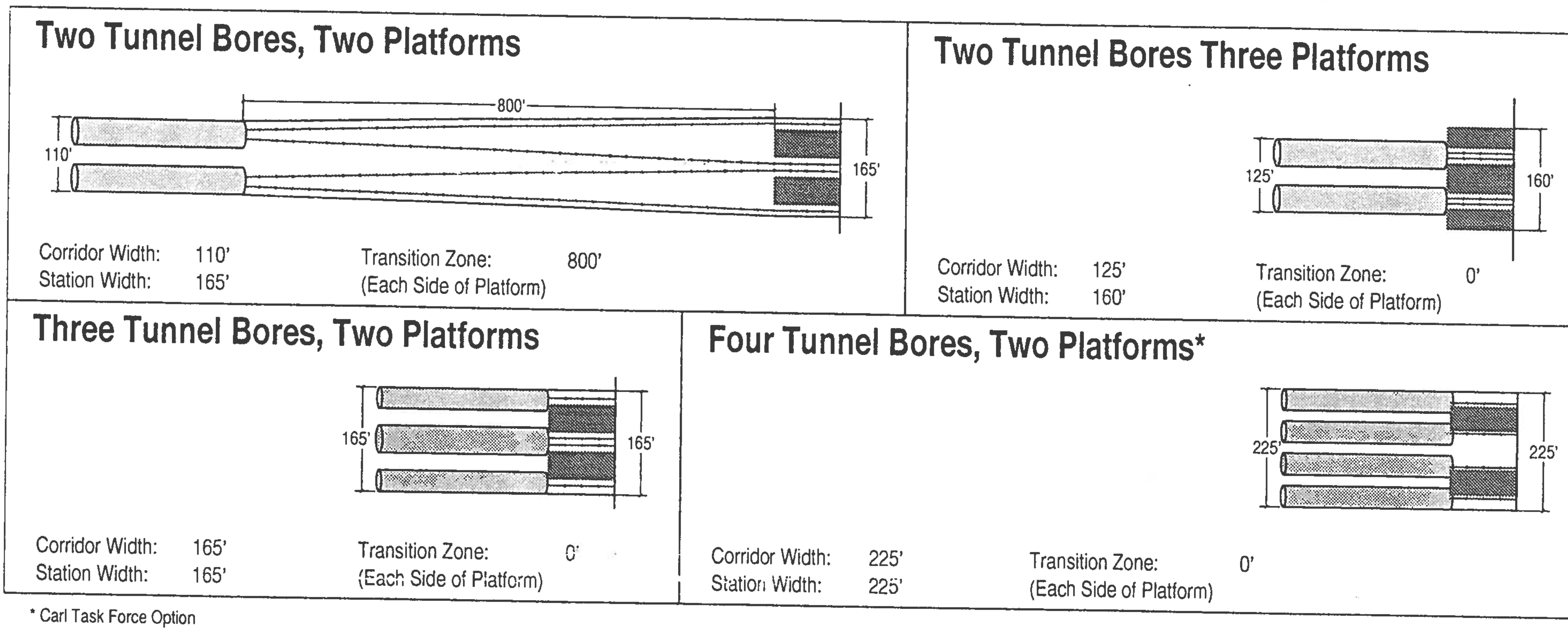
Corridor Width: 175'
Station Width: 180'
Transition Zone: 800'
(Each Side of Platform)

Four Tunnel Bores, Five Platforms



Corridor Width: 175'
Station Width: 215'
Transition Zone: 0'
(Each Side of Platform)

Four-Tunnel Bore Options Figure 3.4-4



* Carl Task Force Option

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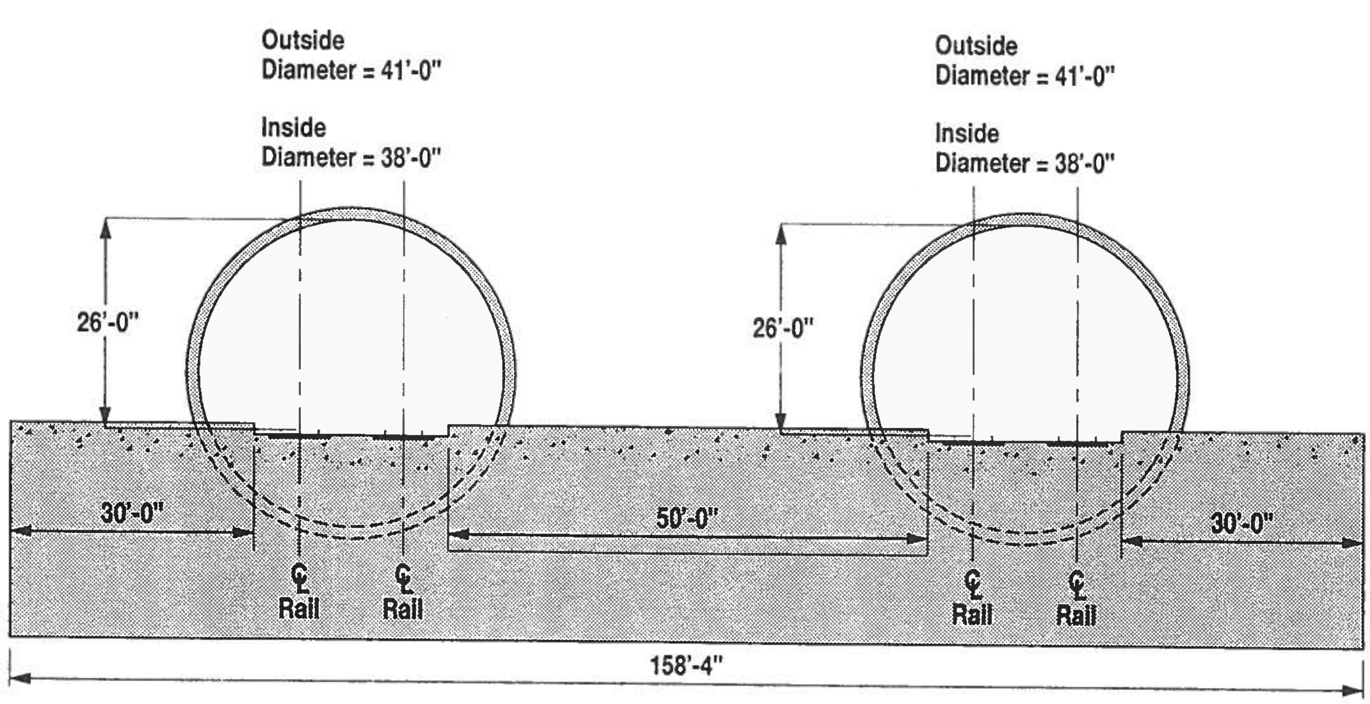
Summary of Reasonable Tunnel Bore/Platform Options

Figure 3.4-5



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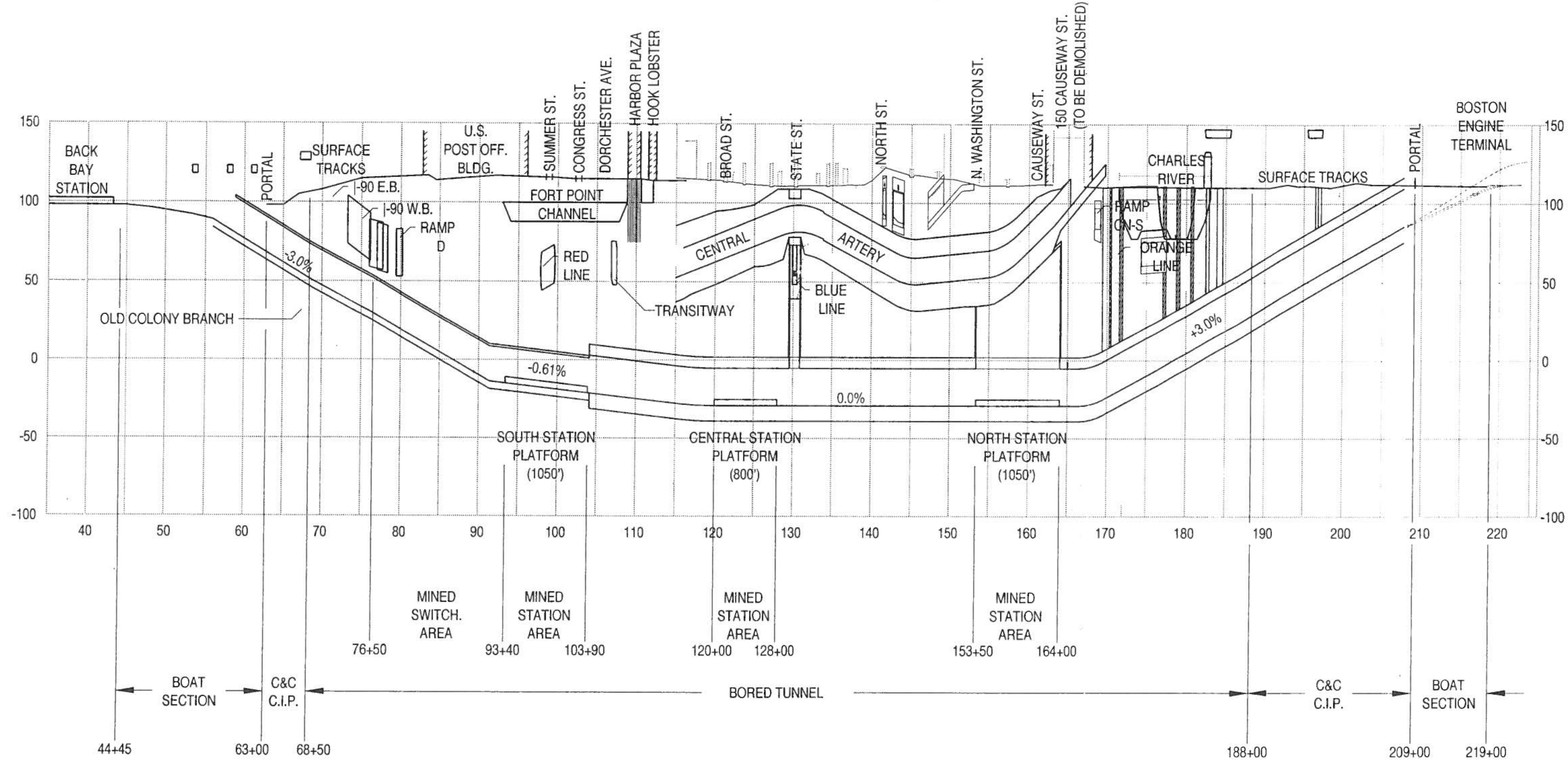
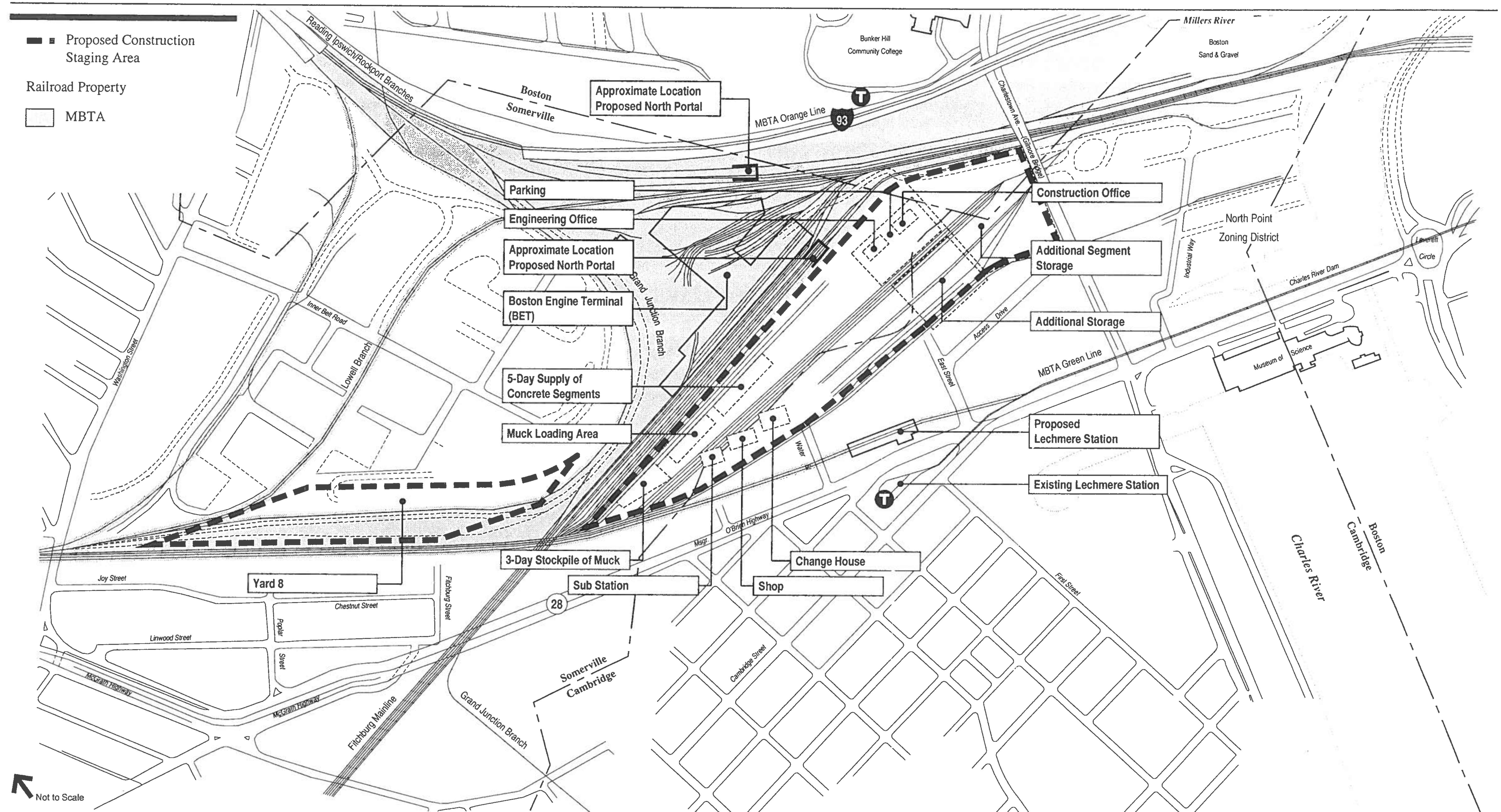
Tunnel/Platform Cross Section

Figure 3.4-6



C&C : CUT AND COVER
C.I.P. : CAST IN PLACE

Tunnel Construction Methodology Figure 3.4-7



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Construction Staging Area Figure 3.4-8

elements due to the construction of a rail link. The extent of these modifications may range from no modifications to removal and replacement. Each of these structures will need to be reviewed relative to the final alignment of the rail link tunnel as determined during preliminary engineering. The structures likely to be affected and the extent of rail link impacts identified within the range of the schematic design are listed below:

- Tremont Street Overpass: Extent of impact will be determined by the final layout of Back Bay Portal, to be established in preliminary engineering.
- Shawmut Avenue, Washington Street, Harrison Avenue Overpasses: Will likely require complete reconstruction to eliminate the center pier between tracks and to gain sufficient clearance for seven tracks.
- Herald Street: The area beneath Herald Street was identified as a potential opportunity to increase the size of the constrained railway corridor at the Back Bay portal to accommodate seven tracks. This could be accomplished by building a deck to carry Herald Street, removing the existing retaining wall between Herald Street and the tracks, and mining beneath the roadway.
- I-93 and ramps in South Bay Interchange: The Dorchester Avenue alignment is anticipated to have limited impacts on this area. The CA/T alignment would be close to the I-93 viaduct foundations or adjacent viaduct ramp foundations (Frontage Road, Ramp LL, Ramp XX, Ramp KK, Ramp MW), but would not have direct conflict with these structures..
- I-90 and ramps (Massachusetts Turnpike): The Dorchester Avenue alignment avoids all direct interference with permanent I-90 structures and associated ramps. There are close vertical tolerances as the alignment passes below I-90 Eastbound and Westbound, and Ramp D tunnels.

  There are several potential areas of conflict in the vicinity of the CA/T alignment, including the jacking pits for the I-90 eastbound and westbound tunnels as well as the Ramp D tunnels. The walls for the jacking pits are reinforced concrete tee walls or soldier pile-tremie concrete walls. The Ramp D jacking pit is supported by a mat of 3-foot diameter drilled shafts. The CA/T alignment also is in the vicinity of the Ramp C boat section and the Ramp DN boat section, both of which are supported by 3-foot diameter drilled shafts spaced between 10 and 20 feet on center. Any load from the permanent caissons interrupted by the rail link tunnel would need to be picked up and supported by underpinning. The CA/T alignment presented in this report successfully avoids direct conflict with these and the South Bay interchange structures, however, in order to do so, the alignment has conflicts with other structures as it continues to the northeast (see SSTC and Federal Reserve Building discussion below).
- The Broadway Bridge: The Dorchester/Old Colony Lines tunnel will pass between bridge piers supported on deep foundations. While there is no direct interference, the effects of operating a tunnel boring machine in close proximity to the piers will need to be examined.
- South Station Transportation Center: The CA/T alignment and station platforms are aligned directly beneath this structure. The building is supported by a grid of pile-supported columns and pile caps. In order to construct the station beneath this building it would be necessary to support two main rows of pile caps and 13 operating railroad tracks, a difficult and complex construction challenge. The Dorchester Avenue alignment will not affect the SSTC building structure.
- The South Station Headhouse: Construction of a rail link station below this building would require significant underpinning of the existing pile foundations for the CA/T alignment. The Dorchester alignment is outside the limits of the South Station Headhouse.
- U.S. Post Office - South Postal Annex: The Dorchester Avenue alignment and station are aligned beneath this structure. The building and attached garage are founded on 16" diameter concrete-filled driven pipe piles, approximately 100' deep. Any proposed construction beneath the building would require extensive underpinning. If the building can be obtained from the USPS, the station could be constructed using a cut and cover methodology. The CA/T alignment does not impact this building.
- Stone and Webster Building (Summer Street): The Dorchester Avenue alignment may have impacts on this building. Foundation impacts will be investigated in preliminary engineering. The CA/T alignment does not impact this building.
- Federal Reserve Bank Building: South Station on the CA/T alignment as proposed would be located directly beneath the tower of this structure. The tower is founded on a mat foundation bearing at elevation 73.0. The top of the rail link tunnel in this vicinity is expected to be at approximately elevation 25.0. The Federal Reserve Bank would require a strong mitigation plan to assure this construction would have no negative impacts on the building.

  In the Dorchester Avenue alignment, the station will be constructed just to the east of the building. The construction method selected for the station will affect the degree of impact. A mined station would have little or no impact on the building while a cut-and-cover station would require mitigation measures, monitoring, and limiting the movements of nearby structures.
- Fort Point Channel Seawall: Construction of a South Station for the Dorchester Avenue alignment in the area of the seawall may require the temporary removal and rebuilding of portions of the wall, which is listed on the National Register of Historic Places. The CA/T alignment is not expected to impact the seawall.
- Summer Street Bridge: The final Dorchester Avenue alignment will determine the degree of impact to this structure. The impacts may range from negligible if the alignment and station stay inside the channel seawall, to significant, requiring underpinning of the west abutment if the final alignment passes underneath. The CA/T alignment is not expected to affect this structure.
- Congress Street Bridge: The final Dorchester Avenue alignment will determine the degree of impact to this structure. The impacts may range from negligible if the alignment and station stays south of Congress Street, to significant requiring underpinning of the west abutment if the final alignment passes underneath. The CA/T alignment is not expected to affect this structure.
- MBTA Red Line Tunnel: Both the South Station and Dorchester Avenue alignments would be close beneath the Red Line tunnel and station. Methods of protecting the structure will be developed as part of preliminary engineering.
- MBTA Transitway Tunnel: Both the South Station and Dorchester Avenue alignments would pass beneath the Transitway tunnel, but with enough clearance so as to not affect this structure.
- Russia Wharf Building: The Dorchester Avenue alignment would pass beneath the northeast corner of the Tufts Building, a structure on the National Register of Historic Places. The building was constructed about 1900 and is founded on timber piles that are believed to terminate at approximately elevation 40 to 60. The top of the tunnel boring machine would pass approximately 25 to 30 feet below the pile tip elevation. The implications of this, while expected to be minimal, will need to be evaluated in later design stages. The South Station alignment is not expected to affect this structure.
- Central Artery/Tunnel Project: Both alignments follow the Central Artery/Tunnel Project corridor to the northern limits of the project. In each case the tunnel bores would enter the tunnel corridor where CA/T slurry walls are fairly high (about elevation 30) and exit in the north near the Charles River, where the highway alignment emerges to the surface. Once within the corridor, the tunnel boring machine would follow a

path which avoids conflict with CA/T slurry walls and caissons. Additionally, the tunnel bores would be significantly deeper than the CA/T base slab and would have little impact on the structure. In the area of North and Central Stations, the rail link stations would be significantly closer to Artery structures, and its effects during construction and in the final condition must be considered. Station sections, tunnel profiles, and methods of construction that would minimize impacts on Artery structures have been explored and are discussed in further detail in Chapter 4.

- Central Artery/Tunnel Project Vent Building No. 3: Neither alignment would pass beneath the vent building foundation. The tunnel boring machine would pass nearby the mat foundation and tie-downs, but it is expected to have little impact.
- Boston Electric Company (BECO) Property (Atlantic Avenue): The Dorchester Avenue alignment would pass beneath this property. Development plans for this parcel include the Transitway tunnel, a three-story underground parking garage on the site, in addition to the reconstruction of the existing wharf as waterfront open space. The proposed slurry wall along the east edge of the garage will terminate at about elevation 40, approximately 25 to 30 feet above the proposed top of tunnel bore. The wharf is designed to be supported on 16-inch precast concrete end bearing piles with a 100-ton capacity. Estimated pile lengths of 100 feet means that the pile tips are at the same level as the upper portions of the tunnel boring machine, a possible conflict. The CA/T alignment is not expected to affect this structure.
- Harbor Plaza Building (Old Sheraton Hotel): The Dorchester Avenue alignment would pass below the property with the top of the tunnel bore at approximately elevation 10. The building is founded on bell caissons that are believed to terminate at a much higher elevation. While no direct interference would occur, it would be necessary to investigate the implications of operating a tunnel boring machine underneath the bell caissons.
- New Northern Avenue Bridge: The Dorchester Avenue alignment passes beneath the recently constructed bridge's west abutment and Pier 1. These are pile-supported structures with estimated pile-tip elevations of elevation 50 for Pier 1 and elevation 65 for the west abutment. The top of the tunnel bore for the rail link would be at approximately elevation 15 and thus would have little impact.
- J. Hook Lobster Company: The Dorchester Avenue alignment would pass below this property for which no foundation information is currently available. The impacts of tunneling below this structure would be evaluated in preliminary engineering.
- Coast Guard Building: The Dorchester Avenue alignment passes under the southwest corner of this building. No foundation information is currently available. The impacts of tunneling below this structure will be evaluated in preliminary engineering.
- Rowe's Wharf: The rail link alignment is within the CA/T corridor at this location. No impacts on the Rowe's Wharf structure are anticipated.
- Orange Line/Green Line SuperStation: While no direct impacts are anticipated due to the rail link tunneling, there is the possibility of circulation connections between the rail link's North Station and the SuperStation. These impacts will be evaluated in preliminary engineering.
- Fleet Center/Boston Garden/North Station: An entrance to the rail link's North Station will connect to the Fleet Center and may require space in any new development on the site of Boston Garden. Impacts will be evaluated as design progresses.
- CA/T (I-93) Charles River Crossing: The rail link alignment passes directly below the foundations for the Charles River Crossing at its south abutment, bents 1 and 2, and the south tower. Meetings with the CA/T have confirmed that there are no direct conflicts with the rail link tunnel in this alignment. The impacts of operating the tunnel boring machine in close proximity to deep foundations will be evaluated in preliminary engineering.
- CA/T (I-93) Ramps North of the Charles River: The rail link alignment would be in close proximity to the foundation of the connector ramps (Ramps T-C, C-T, S-T) with the possibility of direct physical impacts at one bent, requiring underpinning. The impacts will be further assessed as design progresses.
- Storrow Drive Bridge over the Charles River: The tunnel boring machine would pass near the bridge's piers founded on deep foundations. While there are no direct conflicts, the impact of operating the tunnel boring machine near the foundations will be evaluated as design progresses.
- The Charles River Dam: No direct impacts occur as a tunnel bore passes well beneath the southwest tip of the dam structure.
- Boston Sand and Gravel: The rail link alignment may pass below the Boston Sand and Gravel property in the area where tunnel boring would end and cut-and-cover construction begin. The impacts of construction on the Boston Sand and Gravel operations will be assessed as design continues.
- Orange Line Vent Building: The rail link alignment alternatives would pass below this structure, but the building is founded on till and is expected to be unaffected by the tunnel construction.
- MBTA Bascule Bridges: One alignment alternative passes near the bascule bridges which are founded on piles. Future investigation is necessary to determine whether there are any impacts on the bridge piles.
- Gilmore Bridge: The alignment does not directly conflict with the Gilmore Bridge but does pass between two bridge piers with a deep cut-and-cover excavation. The impacts of this excavation on the bridge foundation will need to be evaluated and mitigation methods determined as design progresses.
- Impacts of Stations Elements: Sites adjacent to the rail link alignment may be impacted by the location of station egresses, ventilation structures, headhouses and kiosks. As design progresses and the locations of these elements develop, the impacted structures will be identified and the impacts quantified. (See Chapter 4 for additional information on station design.)
- General Impacts: It is anticipated that, like the Central Artery/Tunnel Project, the construction impacts of the rail link tunnel on all structures adjacent to its alignment will be investigated and monitored. The Central Artery mitigation plans have established limits for construction-related vibrations, ground settlement and ground water drawdown on the adjacent buildings. Similar efforts will be undertaken for the rail link project to minimize impacts on these structures.

Costs for the anticipated impacts of station construction have been included in the estimate for each station alternative. In addition, an allowance has been included in the tunneling costs for foundation modifications that may be required to accommodate the TBM between stations (see Chapter 6.0).

3.4.4 Drainage

Surface Area Drainage

The majority of the land surface in the study area is covered by urban structures such as buildings, industrial areas, pavement, and railroad beds. Generally, most of the rainfall is impeded by the impervious land surfaces and channeled to a nearby storm drainage system to prevent flooding.

The primary impacts on drainage from a rail link tunnel would be anticipated to occur at the portals and station access points. All of the portals are proposed to be located in generally flat surface areas with slopes ranging from 0 to 5 percent. To minimize impacts, the track drainage system, including all open trackbed areas exposed to direct precipitation, would be designed to accommodate the peak flows produced by a 50-year rainfall event. All runoff would be fully contained within the drainage system; no surcharge would be allowed for undepressed catch basins and the capacity of all pipes, ditches, etc. would equal or exceed the 50-year runoff.

Any new surface and subsurface drainage requirements for the rail link tunnel and components would be handled by a system of gravity-flowing longitudinal ditches that feed into catch basins tied into the storm systems. In areas where gravity outfalls are impractical, pumps would be installed to ensure positive drainage. Any drainage work connecting to the municipal system would require a permit and would be coordinated with the MHD, MWRA, CA/T staff, the City of Boston, and other agencies as applicable.

Tunnel Drainage

The tunnel drainage would collect water from tunnel structure seepage, drippings from wet vehicles, tunnel washing operations, stormwater that bypasses the transverse drainage system at the tunnel portals, station entrances and any inflow produced from firefighting operations. Water intake from firefighting operations would be significant. Water inflow from tunnel washing operations is estimated to be approximately half this amount. The volume of water from vehicle drippings and tunnel structure seepage would be minimal.

The drainage system would consist of inlets located along the tunnel. Gravity flow would carry water from the inlets to the pumping stations located at the low points of the tunnel. Each pumping station would have a separate sump and wet well with submersible pumps, and have redundant pumping capacity. The sump would be designed to filter sand and grit before overflowing into the wet well.

3.4.5 Utilities

The rail link tunnel would be primarily located within or immediately adjacent to the Central Artery/Tunnel highway alignment between South Station and North Station. The overall alignment is being proposed at a depth of approximately 100 to 140 feet below the surface level to the top-of-rail so the impact on utilities along the tunnel is expected to be minimal. The primary utility impacts are anticipated at each end of the tunnel at the portals where boat sections would be constructed and cut-and-cover construction techniques would be used, and at headhouse locations where kiosks and vent shafts would penetrate the surface.

In general, the utilities in the study area include electric, power, steam, gas, sewer, water, discharge pipes, surface drainage lines, fiber optics, telephone lines, fire alarm, etc. A thorough investigation, which would include close coordination with the MHD, CA/T staff, City of Boston, and the utility agencies involved, would be required for the cut-and-cover sections during the preliminary design phase. Relocation of utilities in the Back Bay area, including Tremont Street, Shawmut Avenue and possibly Herald Street, the Orange Line, commuter rail, and the Southampton Rail Yard, would also require close coordination with MBTA/Amtrak and MHD.

Utilities north of North Station beneath the Charles River and the Orange Line, as well as utilities located on the east side of the Boston Engine Terminal, would also need to be addressed in design. It is anticipated that power and signal/communication lines from the rapid transit lines and commuter rail would be affected. Additional utilities running under the Charles River that could potentially be impacted include MWRA and the Boston Water and Sewer Commission's sewers and the Boston Edison Company's electrical transmission lines, which provide bulk power to downtown Boston.

Any utility located in the study area would require either close monitoring during construction and/or relocation. It should be noted that all utilities in conflict with the construction of the tunnel would be kept in service until replacement facilities are constructed and activated. The utility relocation/coordination work would occur early in the construction phase to meet construction schedule requirements.

3.5 Right-of-Way Requirements

Minimal right-of-way impacts would be anticipated for a rail link tunnel because the majority of the alignment would be located in an already established transportation corridor. As the preferred alignment is further refined, title searches and property-line surveys would be conducted to accurately identify properties and owners affected, and to confirm the right-of-way available to avoid conflicts with other projects. Easement takings could be required for temporary needs to reserve space for the below-grade portions of the tunnel and right-of-way takings could be required for permanent property needs such as headhouses, vent buildings, emergency shafts, and skylights (if incorporated in design).

Temporary easements, outside of the existing transportation corridor, would be needed along the Dorchester Avenue alignment, including parcels containing the U.S. Postal Service facility, the Stone & Webster building (Summer Street), the Federal Reserve Bank, the Russia Wharf properties, BECO development site, the Harbor Plaza building, J. Hook Lobster Company, and the Coast Guard Building.

Permanent easements may be required at all headhouse and vent shaft locations. These are generally located at or near the North, Central, and South Station locations. Schematic station concepts have identified potential headhouse locations on properties including but not limited to the Nynex Building, the Hoffmann Building, the Stop and Shop Building, Harbor Towers, the New England Aquarium, and the old Boston Garden. These locations are subject to refinement in preliminary engineering. Additionally, it would be desirable from a construction perspective to utilize the U.S. Postal Service facility site on Dorchester Avenue to facilitate the construction of a rail link South Station. This site could potentially be used for joint development, if acquired. The availability of this site, however, would be subject to a negotiated agreement with the USPS.