2021 Triennial Inspection

METROPOLITAN HIGHWAY SYSTEM

REPORT OF CONDITIONS

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. Introduction

The Metropolitan Highway System (MHS) is a collection of assets which includes highways, roadways, tunnels, bridges and related support facilities that are owned and operated by the Massachusetts Department of Transportation (MassDOT). These assets are located in the greater Boston metropolitan area. MassDOT is responsible for the safe and efficient operation of the MHS, one of the most important elements of the Massachusetts transportation network. The MHS serves hundreds of thousands of motorists every day, including commuters traveling to work, truckers moving goods into and out of the Commonwealth, as well as tourists visiting local cultural, recreational, and historic attractions.

In accordance with the provisions of the Trust Agreement under which the MHS is financed and operated, MassDOT is required to have the MHS assets inspected by an independent consultant at least once every three fiscal years and submit a report setting forth:

(i) the independent consultant's findings as to whether the MHS has been maintained in safe and good repair, working order and condition, and
(ii) recommendations as to the proper maintenance, repair and operation of the MHS during the ensuing three fiscal years and an estimate of costs necessary for such purposes.

HNTB was retained by MassDOT to act as the independent consultant for the 2021 Triennial Inspection of the MHS assets and was tasked with the following:

- Perform a visual inspection of assets that have not been inspected since the previous triennial inspection;
- Perform an independent verification of a representative sample size of bridge assets that have been inspected or assessed within the last three years by MassDOT staff;
- Record the visual inspection condition and verification information using a customized configuration of the ESRI ArcGIS Field Maps mobile inspection application, including GIS data points (Latitude/Longitude) and digital photographs;
- Gather available information in MassDOT's possession relating to inspections, maintenance or repair activities, and new construction of MHS assets performed since the previous triennial inspection;
- Prepare estimated costs necessary to update and/or maintain the MHS assets for the next five-year and 10-year periods; and
- Prepare a summary report detailing the results of inspections and the associated projected costs necessary to maintain the MHS in a state of good repair.

Several MHS asset classes have been incorporated into MassDOT's routine inspection programs since being transferred to MassDOT's jurisdiction in 2009. Under MassDOT's ongoing comprehensive MHS bridge and tunnel inspection program, asset classes such as tunnels, bridges, and pavement are being inspected and assessed more frequently than the three-year requirement stipulated in the bond covenants.

A representative sample of bridges that were inspected by MassDOT forces received a visual audit inspection to generally validate the findings. The results of these audits substantially agreed with the data that was documented within the most recent inspection reports in MassDOT's 4D system. Therefore, the sources reviewed for this report include data exported from 4D for MHS bridges that were inspected by MassDOT forces and independent consultants between August 1, 2018 and July 31, 2021. The Inspection Responsibility Matrix in Appendix A indicates the inspecting agency and inspection date for each asset.

Pavement condition information was provided by MassDOT. The condition of Roadway pavement was reported based on Pavement Serviceability Index (PSI), whereas International Roughness Index (IRI) was used to report on pavement in Tunnels. The condition of the bridge pavement is reported on within MassDOT 4D bridge inspection database and is not included as part of this pavement assessment.

A visual inspection was performed between December 2020 and July 2021 for MHS assets that had not been inspected since the previous 2018 Triennial, including roadways, interchanges, walls, sign support structures, buildings, communication facilities, and pump stations.

This 2021 Report of Conditions was developed using a combination of data sources:

- 2021 Triennial visual inspection data;
- Inspection data exported from MassDOT's 4D system for all bridges inspected by MassDOT forces from August 2018 to July 2021;
- Inspection data exported from MassDOT's 4D system for all tunnels, boat sections, bridges, and sign structures inspected by 3rd party consultants, from August 2018 to July 2021; and
- 2020 Pavement condition information provided by MassDOT.

No representation or warranty is made with respect to any data provided by others, the completeness of any data incorporated herein, or a report prepared by another party. Each entity under contract with MassDOT to perform such inspection services shall remain solely liable to MassDOT for their services under the terms of their respective agreement(s).

1.1 Overview of the Metropolitan Highway System

The Metropolitan Highway System (MHS) is composed of transportation assets that were previously under the jurisdiction of the former Massachusetts Turnpike Authority. The MHS transportation network is a key component of both the Interstate Highway System and the regional highway network serving metropolitan Boston. MHS assets include tunnels, highways, bridges and buildings. These assets have a complex system of supporting infrastructure which includes but is not limited to: tunnel ventilation systems with heavy machinery and high-voltage electrical systems housed in several separate vent buildings and electrical substations; drainage systems, including pump stations with mechanical equipment and networks of piping; and a number of building structures that support highway operations, maintenance and State Police activities.

The MHS facilities are subject to a wide range of operating conditions. These conditions include damp, corrosive environments; vehicle exhaust which coats tunnel surfaces with a layer of carbon residue; severe winter conditions, including exposure to deicing agents, freeze/thaw cycles and snow plowing operations; vibration from heavy traffic loadings and machinery; and unanticipated events such as incidents involving over-height vehicles and vehicle collisions, all of which have impacts on the infrastructure. Constant wear with increasing traffic, harsh New England weather, and the increasing age of the MHS require that the condition of these assets be inspected regularly and that maintenance/corrective actions be undertaken to preserve their function and value.

The MHS consists of four major transportation networks: Central Artery/Tunnel, Central Artery North Area (CANA) Tunnel, Sumner/Callahan Tunnels, and Boston Extension (Weston to Boston). Table 1 provides an overview of the MHS transportation network by geographic area. Generally, the assets within each of these four areas were constructed as separate, distinct projects during various time periods.

Table 1: Metropolitan Highway System Transportation Network

MHS Network	Approximate Date Opened
Central Artery/Tunnel	Ted Williams Tunnel 1996; Central Artery 2003
Central Artery North Area (CANA) Tunnel	1980's
Sumner/Callahan Tunnels	Sumner 1930's; Callahan 1960's
Boston Extension (Weston to Boston)	1964

Figure 1 is a locus plan showing the general location of each of the four MHS networks. These transportation networks include a number of interchanges and ramps that interconnect the MHS networks with each other and provide connections to other highways and local roadways.

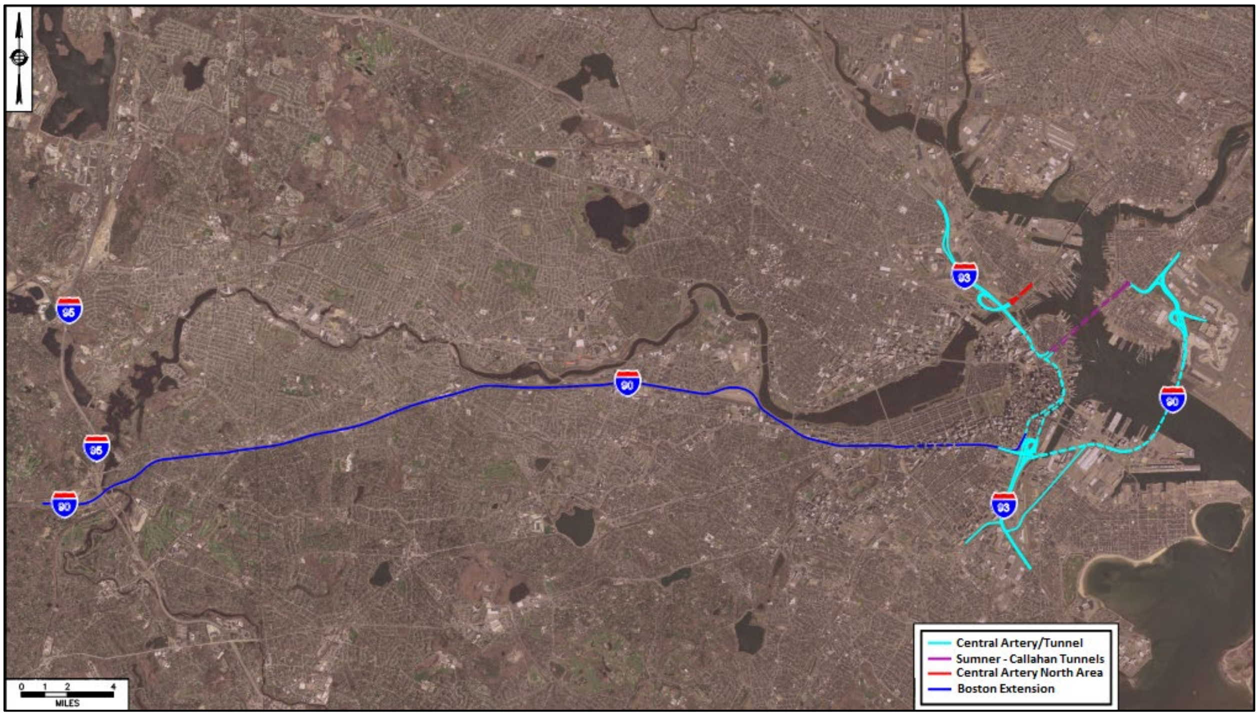

Figure 1: Metropolitan Highway System Transportation Networks

The overall MHS transportation network consists of almost 236 lane miles of roadway; approximately two-thirds of which are toll roads and one-third are non-revenue facilities. That network includes:

- 232 bridges and viaducts, including:
  - Leonard P. Zakim Bridge
  - Allston Interchange Viaduct
  - Interchange 123 (formerly Interchange 14/15)
- Seven major tunnel structures, including:
  - Three tunnels under Boston Harbor (Ted Williams Tunnel, Sumner Tunnel and Callahan Tunnel)
  - I-93 Northbound and Southbound tunnels (Thomas P. "Tip" O'Neill Tunnel) through Downtown Boston
  - I-90 Connector Tunnel under Fort Point Channel and through South Boston
  - Central Artery North Area (CANA) Tunnel beneath City Square through Charlestown
  - Prudential Tunnel
- At-grade highways and roadways, including:
  - Boston Extension

    - Air-rights associated with major developments located above the Boston Extension in the Back-Bay area are commonly referred to as the Prudential Tunnel or Prudential Passageway. Those air-rights developments include the Prudential Center complex, Hynes Convention Center and Shaw's Market; Copley Place; and the Garage at 100 Clarendon.
  - Frontage Road
  - South Boston Bypass Road
  - Massport Haul Road
  - Portions of I93 NB and SB including HOV Ramps

The All Electronic Tolling (AET) gantries on the MHS are inspected and maintained under contract by the installer and were therefore not included as part of the 2021 Triennial Inspection.

Table 2 shows the approximate average daily traffic (ADT) volumes on selected transportation networks of the MHS. Volumes were uniquely reduced due to COVID-19 impacts on travel, so average volumes for 2019 have also been included to show more typical values.

Table 2: Metropolitan Highway System Average Daily Traffic

MHS	Type	2019 Average Daily Traffic (ADT) (vehicles per day)	2020 Average Daily Traffic (ADT) (vehicles per day)
Central Artery (I-93)	Non-revenue	178,000 – 222,000	132,000-208,000
CANA Tunnel	Non-revenue	81,000	61,000
Ted Williams Tunnel	Toll	96,000	41,000
Sumner/Callahan Tunnels	Toll	72,000	56,000
Boston Extension	Toll	158,000	117,000

1.1.1 History of MHS

Until November 2009, the Massachusetts Turnpike Authority owned and operated many of the facilities that are now considered part of the MHS. The Authority was originally created in 1952 by the Commonwealth of Massachusetts to construct, maintain, repair, enlarge, improve and operate an express toll highway, which became known as the Massachusetts Turnpike (I-90).

The Initial Massachusetts Turnpike, which extends approximately 124 miles from the Massachusetts/ New York boundary in the Town of West Stockbridge to the greater Boston area, initially opened to traffic in May 1957 and terminated west of Boston at the interchange with Route 128/I-95. The 12-mile extension of the Massachusetts Turnpike from Route 128/I-95 to downtown Boston, known as the Boston Extension, opened to traffic in September 1964. The Boston Extension and the Route 128/I-95 interchange are the only portions of the legacy Turnpike roadway that are now part of the MHS.

The William H. Sumner Tunnel was constructed in the 1930's and initially served as a two-way roadway. In 1958, the Massachusetts Turnpike Authority was authorized by law to construct the Lieutenant William F. Callahan, Jr. Tunnel, to acquire and make necessary repairs to the existing Sumner Tunnel, and to operate and maintain both tunnels. These tunnels, crossing beneath Boston Harbor, served as the primary link between downtown Boston and Logan International Airport in East Boston. In the early 1990's, the Commonwealth of Massachusetts began construction of the Ted Williams Tunnel, providing a third harbor crossing. In July 1995, the Massachusetts State Legislature enacted the Ted Williams Tunnel Act, which authorized and directed the transfer of the Ted Williams Tunnel, including all responsibility for the operation and maintenance thereof, from the Commonwealth to the Massachusetts Turnpike Authority effective December 14, 1995.

In March 1997, the Commonwealth of Massachusetts enacted legislation that established two systems to be owned and operated by the Massachusetts Turnpike Authority: the Western Turnpike and the Metropolitan Highway System. The Western Turnpike is now defined as the express toll highway, designated as Interstate 90 (I-90), which extends from the Town of West Stockbridge to, but not including, the interchange of I-90 and Route 128/I-95 in the Town of Weston. The MHS network consists of the Boston Extension and the tunnels connecting downtown Boston with Logan Airport and points north.

In 2009, all Massachusetts Turnpike Authority facilities were transferred to MassDOT's jurisdiction. The Metropolitan Highway System legislation allows for the addition of highway, tunnel, and bridge components to the Metropolitan Highway System as determined by the general court and state legislature.

1.1.2 Asset Classes

The following nomenclature is used in this Report of Conditions:

- Asset Class: Primary asset type (e.g., Tunnels/Boat Sections, Bridges, Buildings, Communication Facilities, Pump Stations, Roadways, Interchanges, Pavement, Walls, Sign Supports)
- Asset: Specific facility or structure (e.g., Pump Station No. 11 or Sumner Tunnel)
- Elements and Sub-Elements: Specific parts of an asset (i.e., Buildings generally have Interior, Exterior, Roof, and Building Area elements; sub-elements can include ceilings, façade, parapets, and sidewalks)

The MHS contains the following Asset Classes:

Tunnels/Boat Sections

There is a significant network of tunnels and boat structures along the MHS carrying traffic along both mainline and ramp roadways including: the Thomas P "Tip" O'Neill Tunnel; the I90 Connector Tunnel; the CANA Tunnel; the Sumner and Callahan Tunnels; the Ted Williams Tunnel; and a section of the Boston Extension known as the Prudential Tunnel that passes under several local streets and buildings. Refer to Figure 2.

The tunnels are delineated into 40 separate structures each with an individual Tunnel Identification Number (TIN) and the associated boats into 54 separate structures each with an individual Boat Identification Numbers (BIN), as designated below.

<u>Tunnel Structures (TIN's):</u>

- Connector Tunnel: T01 to T10
- Thomas P. "Tip" O'Neill Tunnel: T11 to T26 and T45
- Ted Williams Tunnel: T27 to T32
- CANA Tunnel: T33 & T34
- Prudential Tunnel: T35, T42 & T43
- Callahan Tunnel: T36
- Sumner Tunnel: T37

Boat Structures (BIN's):

- Connector Tunnel: B01 to B15
- Thomas P. "Tip" O'Neill Tunnel: B16 to B45
- CANA Tunnel: B48 to B51
- Prudential Tunnel: B46 & B47
- Sumner Tunnel : B54
- Callahan Tunnel : B55
- Ted Williams Tunnel: B56

Tunnel Structures T38, T39, T40, T41 and T44 and Boat Structures B52 and B53 are either not part of the MHS or are not owned and maintained by MassDOT and therefore these structures are not included in the 2021 Triennial.

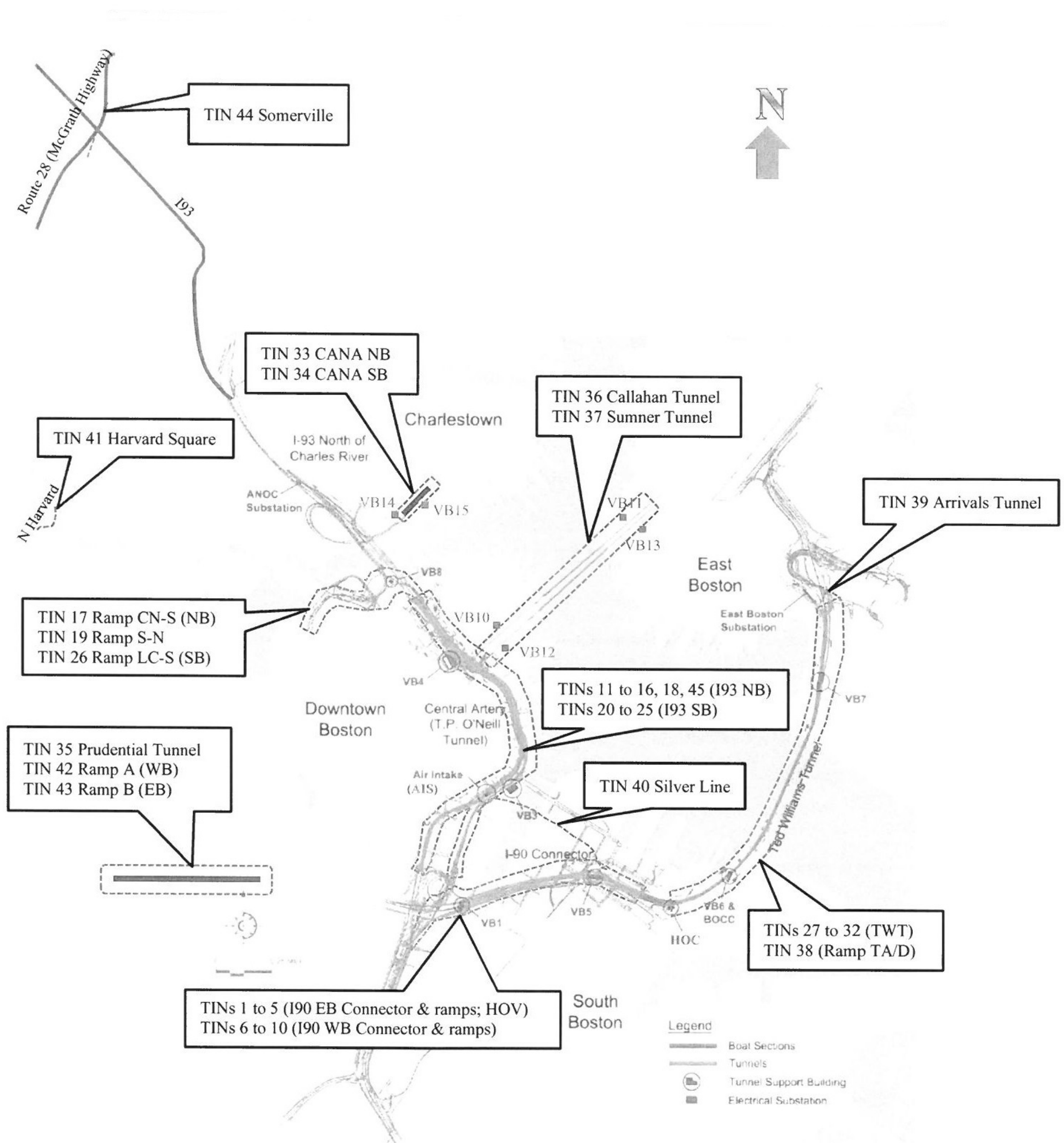

Figure 2: Metropolitan Highway System Tunnel Location Plan

Bridges/Culverts

There are 232 bridges including culverts along the MHS roadways that are incorporated into MassDOT's Bridge Inspection Program. These structures include numerous road and rail grade separated crossings over and under the I-90 and I-93 roadways; various ramp bridges along the interchanges of the Boston Extension, including the Leonard P. Zakim Memorial Bridge along with several culverts carrying roadways across aqueducts or brooks. Structure types and ages vary significantly throughout the MHS system.

Buildings

Administration/Service Buildings (8 each)

There are 8 Administration/Service Buildings which support MHS/District 6 operations.

1. Sumner/Callahan Tunnel Administration Building at 145 Harve Street (East Boston)
2. Division III Service and Garage at 145 London Street (East Boston)
3. Administration Building at Interchange 123 (formerly Interchange 14) (Weston)
4. Administration Building at Interchange 125 (formerly Interchange 16) (Newton)
5. Highway Operations and Control Center at 50 Massport Haul Road (South Boston)
6. District 6 Administration Building at 185 Kneeland Street (Boston)
7. I-90 Ted Williams Tunnel Service Building (East Boston)
8. Ramp E Ted Williams Tunnel Service Building (East Boston)

MassDOT no longer owns the administration building at 128 North Street, as this building has been recently sold. The buildings at Interchanges 123 and 125 were formerly utilized for tolling purposes but have since been repurposed into administration facilities. The two remaining toll plaza buildings at the Ted Williams Tunnel in East Boston are currently not in use. The toll plaza building associated with the Tobin Bridge has been demolished since the previous Triennial.

<u>Maintenance Facilities (5 Each)</u>

There are 5 Maintenance Buildings which support MHS/District 6 operations.

1. CA/T Satellite Maintenance Facility/Emergency Response Station ERS #10 at Bunker Hill Industrial Park (Charlestown)
2. Central Maintenance Facility at 370 D Street (South Boston)
3. Emergency Response Station ERS #4 at 480 Albany Street (Boston)
4. Maintenance Garage at I-90 Interchange 131 (formerly Interchange 18/19/20) (Allston)
5. Tobin Bridge Maintenance Building and Garage at 62 Broadway (Chelsea)

The CA/T Satellite Maintenance Facility/ERS #10 and the ERS #4 buildings no longer serve as emergency response facilities. At the CA/T Satellite Maintenance Facility/ERS #10, there is an adjacent trailer which serves as an emergency response facility for the state police. This trailer is not included as part of this report. The ERS #2 building at 100 Massport Haul Road (South Boston) is under the jurisdiction of the Massachusetts State Police and thus was not included as part of this inspection.

<u>Salt Sheds (3 Each)</u>

There are 3 Salt Sheds in the MHS which support District 6 operations.

1. Salt Shed at Bunker Hill Industrial Park (Charlestown)
2. Salt Shed at 370D Street (South Boston)

3. Salt Shed at I-90 Interchange 131 (formerly Interchange 19) (Allston)

Electrical Substations (4 Each)

There are 4 Electrical Substations in the MHS which support District 6 operations.

1. Emergency Response Station/Electrical Substation ESS #1 at 4 Harborside Drive (East Boston)
2. Electrical Substation ESS #2 at 480 Albany Street (Boston)
3. Electrical Substation ESS #3 adjacent to Bunker Hill Community College (Charlestown)
4. Mechanical/Electrical Substation at Interchange 131 (formerly Interchange 19)

The Mechanical-Electrical Substation at Interchange 131 primarily contains boiler equipment for the site.

Parking Garages (1 Each)

There is 1 Parking Garage within the Central Artery/Tunnel (CA/T) portion of the MHS, Parcel 7 Garage at 136 Blackstone Street (Boston). It serves the Faneuil Hall/North End area and sits above the Haymarket MBTA station and the Boston Public Market and is integrated with Vent Building 4.

Office/Retail Buildings (1 Each)

There is 1 Office/Retail Building within the Central Artery/Tunnel (CA/T) portion of the MHS, Parcel 7 at 136 Blackstone Street (Boston). This building which contains the Massachusetts RMV and Boston Public Market is located adjacent to the Parcel 7 parking garage and is integrated with Vent Building 4. This building was not inspected at the direction of MassDOT and therefore not included as part of this report.

Vent Buildings (13 Each)

There are 13 Vent Buildings that serve the MHS tunnels, Central Artery/Tunnels (CA/T), Sumner/Callahan Tunnels, and the Central Artery North Area Tunnels (CANA).

CA/T

1. Ventilation Building 1 at 55 Dorchester Avenue (Boston)
2. Ventilation Building 3 at 500 Atlantic Avenue (Boston)
3. Ventilation Building 4 at 136 Blackstone Street (Boston)
4. Ventilation Building 5 at Massport Haul Road (South Boston)
5. Ventilation Building 6 at 2 F.I.D. Kennedy Way (South Boston)
6. Ventilation Building 7 at 50 Harborside Drive (East Boston)
7. Ventilation Building 8 at 150 Causeway Street (Boston)

Sumner/Callahan

1. Ventilation Building 10 at 308 North Street (Boston)
2. Ventilation Building 11 at 65 Liverpool Street (East Boston)
3. Ventilation Building 12 at 201 North Street (Boston)
4. Ventilation Building 13 at 89 London Street (East Boston)

CANA

1. Ventilation Building 14 at New Rutherford Avenue (Charlestown)
2. Ventilation Building 15 at Chelsea Street (Charlestown)

Air Intake Structure (1 Each)

There is 1 Air Intake Structure within the Central Artery/Tunnel (CA/T) portion of the MHS. The Dewey Square Tunnel Air Intake Building is located at the intersection of Congress Street and Atlantic Ave in Boston.

Fan Chambers (3 Each)

There are 3 Fan Chambers located in Chinatown that support a portion of the CA/T tunnel ventilation system.

1. Beach Street Fan Chamber
2. Essex Street Fan Chamber
3. Summer Street Fan Chamber

Fan Rooms (4 Each)

There are 4 Fan Rooms located within the Prudential Passageway that support the tunnel ventilation system. These fan rooms are inspected as part of MassDOT's Tunnel Inspection Program, and as such inspection data from 4D was exported and evaluated for this report.

Communication Towers/Facilities

There are 3 Communication Towers/Facilities, all located along the Boston Extension:

1. Communication Building at Interchange 123 (formerly Interchange 15) in Weston near Riverside Road
2. Communication Tower at Interchange 125 (formerly Interchange 16) in West Newton near 186 Webster Street
3. Communication Tower at Interchange 131 (formerly Interchange 18/19/20) in Brighton

Pump Stations

Most of the pump stations within the MHS are located in the tunnels, 25 in total, and as such are incorporated into MassDOT's Tunnel Inspection Program on a maximum 2-year inspection cycle.

There are 15 pump stations that are located outside of the MHS tunnels that are not incorporated into the tunnel inspection program. Eleven of these were visually inspected as part of this report. The remaining four pump stations associated with the Sumner and Callahan Tunnels were not visually inspected at the direction of MassDOT. Refer to Section 3 for additional information.

1. Pump Station No. 1: Tandem Trailer Area Interchange 131 (formerly Interchange 18/19/20), Ramp B, Station 45+40
2. Pump Station No. 2: Boston Extension I-90 WB Station 465+50 beneath Structure 111
3. Pump Station No. 4: Boston Extension I-90 EB Station 526+50 near Muddy River
4. Pump Station No. 7: Boston Extension I-90 WB Station 607+40
5. Stormwater Pump Station SWPS-03, West 6th Street and Broad Street, South Boston
6. Stormwater Pump Station SWPS-04, TWT EB Portal, South Boston
7. Stormwater Pump Station SWPS-05, Harborside Drive at E-T Toll Plaza
8. Stormwater Pump Station SWPS-09, directly behind 185 Kneeland Street
9. Stormwater Pump Station SWPS-11, 280 Southampton Street
10. Stormwater Pump Station SWPS-12, 250 Frontage Road
11. Stormwater Pump Station SWPS-18, 497 Austin Street, Charlestown

Roadways

Roadway

The I-90 EB and WB portion of the MHS was visually inspected from the Ridgeway Road Underpass at the western limit in Weston, approximately at mile-marker 122.8, to the eastern limit of the turnpike in East Boston at the Route 1A interchange, approximately to mile-marker 138.0. The I-93 NB and SB portion of the Central Artery were visually inspected from Southampton St Overpass at the southern limit, approximately at mile-marker 15.5, to the bridge joint approximately at mile-marker 16.0. These roadways were divided into 2/10th of a mile (approximately 1,000 foot) long segments for the purposes of this inspection resulting in a total of 128 segments.

The remaining roadways within the MHS that were visually inspected include I-93NB and SB HOV ramps, Ramp X and Ramp XXE; Frontage Road NB and SB; South Boston Bypass Road from just north of West Service Road Exit to Dorchester Avenue; and Massport Haul Road from Pump House Road to the South Boston Bypass Road.

Interchanges

There are 7 interchanges along the Boston Extension portion on the MHS. At the time of this inspection the interchange exit numbers along the various MHS roadways were in the process of being upgraded by MassDOT to reflect the associated roadway mile marker designations in accordance with the most recent FHWA directives. As such, the inspection data that has been documented for the interchanges reflects, where possible, the new interchange exit numbers along with the old exit number designation. The next inspection cycle of the Triennial should be able to capture any outstanding upgrades that were not captured during the current cycle.

Interchange 123 is the westernmost interchange of the MHS, connecting Interstate 95 and Route 128 with I-90, and serving as the transition between the Western Turnpike corridor and the Boston Extension. Interchange 134 is located furthest to the east; it connects the Boston Extension to I-93 and the Ted Williams Tunnel. The interchanges in between connect local roads and state routes to the Boston Extension.

1. Interchange 123 (formerly Interchange 14/15)
2. Interchange 125 (formerly Interchange 16)
3. Interchange 127 (formerly Interchange 17)
4. Interchange 131 (formerly Interchange 18/19/20)
5. Interchange 132 (formerly Interchange 21 – Massachusetts Avenue On-Ramp)
6. Interchange 133 (formerly Interchange 22)
7. Interchange 134 (formerly Interchange 24)

Interchange 133 is located within a portion of the Prudential Tunnel and as such was not visually inspected; inspection data from 4D was exported and evaluated for this report.

Walls

There are 98 walls within the limits of the MHS that are not incorporated into MassDOT's tunnel inspection program as they are located outside of the limits of the MHS tunnels. These walls are located along various open roadways of the MHS including those along the Boston Extension I-90 EB/WB and associated interchanges, Massport Haul Road, and South Boston Bypass Road.

These walls are comprised of concrete retaining walls; metal BIN retaining walls and timber or concrete noise barrier walls of varying lengths and heights.

Sign Support Structures

There are 97 sign support structures within the limits of the MHS that are not incorporated into MassDOT's Tunnel Inspection Program as they are located outside of the limits of the MHS tunnels. Some of these sign support structures are included within MassDOT's Ancillary Structures Inspection Program and as such, additional inspection data from 4D was exported and evaluated for this report. Refer to Section 3, Summary of Findings, for additional information.

The sign structures that were visually inspected are located along various open roadways of the MHS including those along the Boston Extension I-90 EB/WB and associated interchanges, and the Central Artery I-90 EB/WB, I-93 NB/SB, Rte. 1A NB/SB; Frontage Road, Massport Haul Road and South Boston Bypass Road.

These signs are comprised of full span or cantilever truss and tubular type structures that support either aluminum sign panels, variable message boards, lane signals or over-height vehicle detectors.

Parks

There is one park within the limits of the MHS that is visually inspected as part of the Triennial. London Street Park (also known as Veterans Park) is located across from Vent Building 13 between London Street and Liverpool Street. A separate area adjacent to Vent Building 13 property, with a fenced in basketball and play court, was inspected as part of Vent Building 13.

A summary of MHS assets is shown in Table 3.

Table 3: Metropolitan Highway System Assets by Class

Asset Class	Total
Bridges	232
Tunnels/Boat Sections	94
Admin/Service Building	8
Maintenance Facilities	5
Salt Sheds	3
Mechanical-Electrical Substations	4
Parking Garages	1
Vent Buildings	13
Air Intake Buildings	1
Walls	98
Sign Support Structures	97
Pump Stations	40
Fan Chambers	3
Fan Rooms	4
Communication Towers/Facilities	3
Roadway (I-90 EB/WB & I93NB/SB) (2/10th of a mile segments)	128
Interchanges	7
Parks	1

1.2 Description of MHS Networks

1.2.1 Central Artery/Tunnel

The Central Artery/Tunnel (CA/T) is a complex system of roadways, tunnels, bridges, and structures which carry portions of I-90, I-93 and US-1. It connects I-93 with I-90 and US-1 and connects to the Sumner/Callahan Tunnels. The construction of the Central Artery/Tunnel Project started in late 1991. The underground tunnel system replaced an elevated steel viaduct structure and now carries I-93 Northbound and Southbound under downtown Boston. Twenty-five associated ramps connect the I-93 and I-90 Tunnels to surface arteries and interchanges. The Central Artery/Tunnel also includes the Leonard P. Zakim Bridge, a ten-lane cable-stayed bridge crossing the Charles River constructed in 2003.

The I-90 Connector portion of the Central Artery/Tunnel system became fully functional in 2004. The I-90 Eastbound and Westbound Tunnels introduced interstate connections to South Boston and Logan Airport in East Boston. The construction of the Ted Williams Tunnel, which added a new crossing below Boston Harbor, was completed in December 1996. That tunnel was one of the first elements of the Central Artery/Tunnel Project to be incorporated into the former Massachusetts Turnpike Authority.

The Central Artery/Tunnel network consists of the following eight areas:

- South Bay – I-90/I-93 Interchange
- I-90 Connector Tunnel – I-90 between the Boston Extension and the Ted Williams Tunnel
- South Boston – Seaport Access
- Ted Williams Tunnel – I-90 beneath Boston Harbor between South Boston and Logan Airport
- East Boston – I-90 east of the Ted Williams Tunnel
- Massachusetts Avenue – I-93 Interchange with Massachusetts Avenue
- Downtown – I-93 Tunnels from South Bay to North of Causeway Street
- North of Causeway Street – I-93/US-1 Interchange to Cambridge Street

This network, shown in Figure 3, includes approximately 107 lane miles of roadway, primarily tunnels and bridges, of which approximately 35 lane miles are toll roads. The tunnels include eight ventilation buildings, three fan chambers, four fan rooms, 29 pumping stations and approximately 90 utility rooms.

Figure 3: Central Artery/Tunnel

1.2.2 Central Artery North Area (CANA) Tunnel

The Central Artery North Area (CANA), which includes a tunnel system and other structures, carries US Route 1 and connects I-93 to the Tobin Bridge in Charlestown. The Central Artery North Area Tunnel was constructed in the 1980’s by the Massachusetts Highway Department (predecessor agency to MassDOT).

Unlike the Sumner, Callahan and Ted Williams Tunnels, the CANA Tunnel was built using cut and cover construction techniques. The configuration of the CANA tunnel is different from the other tunnels in that it does not have a fresh air supply duct. Ventilation is provided solely by exhaust ducts located along the side of the tunnel. The exhaust from vehicles is drawn into the exhaust duct and moved through the exhaust vents by the fans in two ventilation buildings, Vent Building 15 for the northbound tunnel, and Vent Building 14 for the southbound tunnel. Figure 4 shows the overall limits of the CANA Tunnel.

The combined length of the CANA tunnel (northbound and southbound) is 2,440 feet. The facility includes two ventilation buildings and one stormwater pumping station.

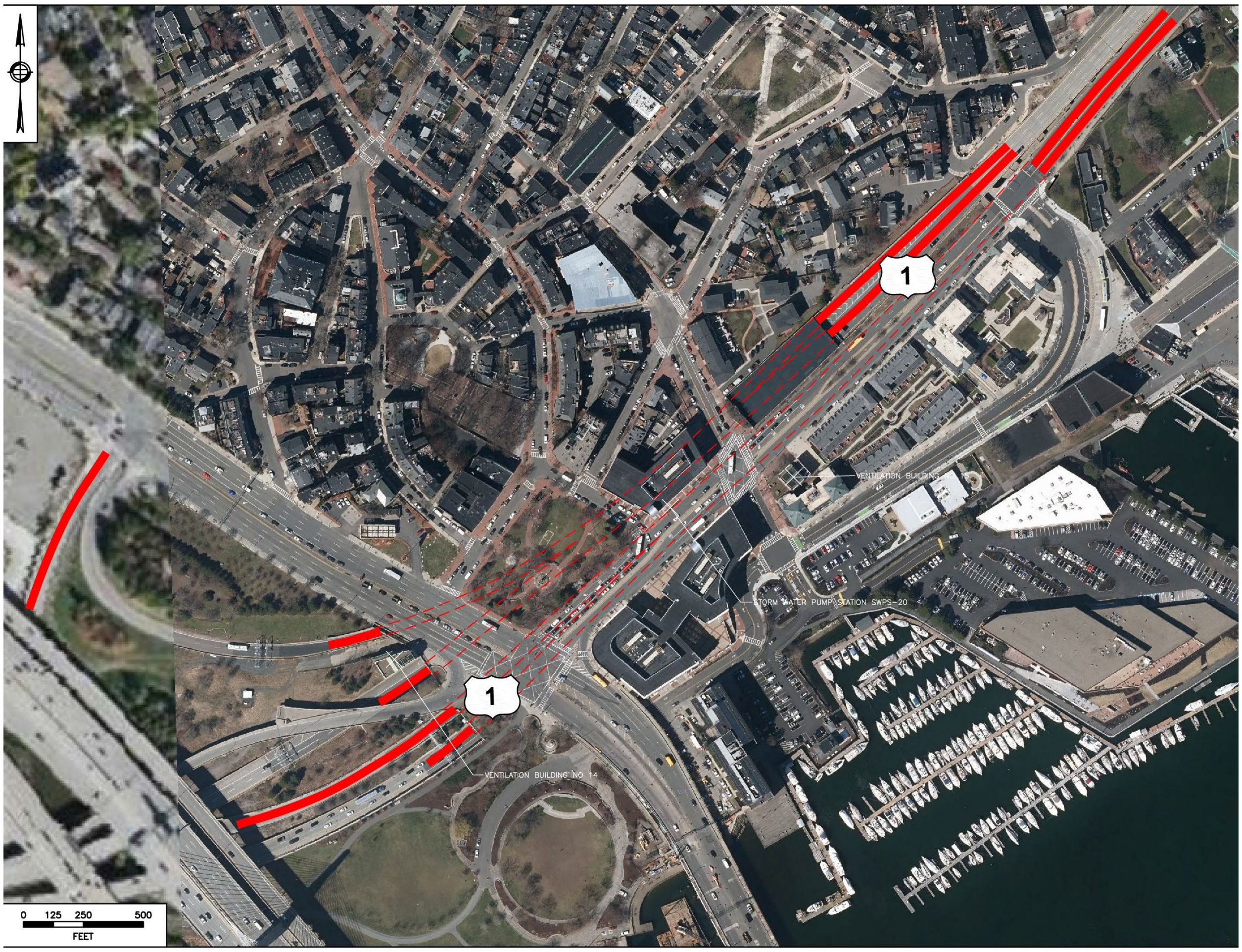

Figure 4: CANA Tunnel

1.2.3 Sumner/Callahan Tunnels

The Sumner/Callahan Tunnels, which carry State Route 1A, connect I-93 and downtown Boston to East Boston and Logan Airport. The Sumner and Callahan Tunnels are toll facilities.

The southerly ends of both tunnels connect into ramps that were constructed as part of the Central Artery/Tunnel Project. The limits of the Sumner/Callahan Tunnels are shown in Figure 5. The Sumner/Callahan Tunnels are 5,655 feet and 5,070 feet long respectively. This transportation network includes four ventilation buildings, six stormwater pumping stations and two administration buildings.

Figure 5: Sumner/Callahan Tunnels

1.2.4 Boston Extension

The Boston Extension is the portion of I-90 from Ridgeway Road, just west of the Route 128/I-95 interchange in Weston, to the South Bay interchange (reconstructed as part of the Central Artery/Tunnel project) at I-93 in Boston. It extended the Initial Turnpike, which ended at Route 128, into Boston where it connects with I-93. This segment of the Turnpike has become known as the Boston Extension. Traffic began using this new 12-mile section of the Massachusetts Turnpike toll road in September 1964.

The overall limits of the Boston Extension are shown in Figure 6. The Boston Extension is divided into the following five areas, from west to east:

1. Weston (starting at Ridgeway Road, just west of the interchange with Route 128/I-95)
2. Newton
3. Brighton (including a short section in Brookline)
4. Prudential Passageway (also referred to as the Prudential Tunnel) passes under the Prudential, Copley and Hancock private developments in the Back Bay area of Boston.
5. Boston (ending at the point where the Boston Extension connects with the I-90/I-93 South Bay Interchange completed as part of the Central Artery/Tunnel project)

The Boston Extension has approximately 80 lane miles of roadway, all of which are open toll road. This facility includes four stormwater pumping stations and four fan rooms within the Prudential Passageway.

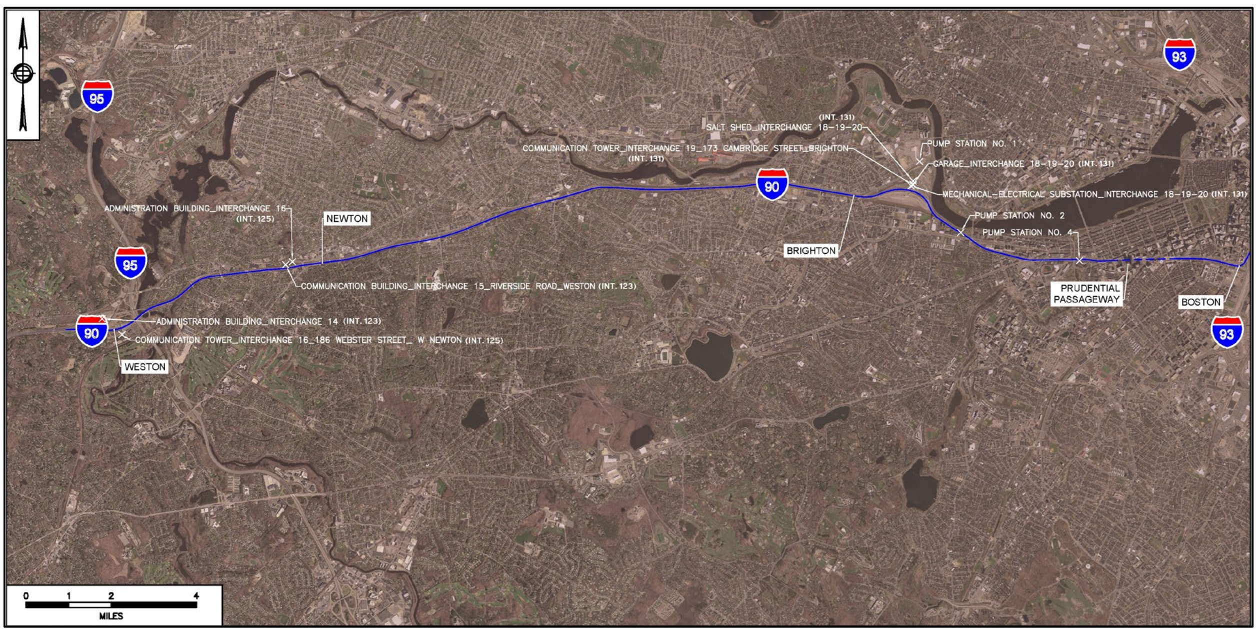

Figure 6: Boston Extension

1.2.5 MHS Supporting Infrastructure

The MHS transportation networks require a complex and extensive network of supporting infrastructure including tunnel ventilation systems, stormwater pumping systems, buildings and various other supporting infrastructure.

Mechanical, Electrical, Plumbing and Communications Systems

The supporting infrastructure includes significant mechanical, electrical, plumbing and communications (M/E/P/C) systems housed in several ventilation buildings, pump stations, electrical substations, utility rooms and other ancillary facilities located throughout the system.

This infrastructure includes 13 major tunnel ventilation buildings, three fan chambers and four fan rooms that provide ventilation to the tunnels, as shown in Table 4.

Table 4: Metropolitan Highway System Ventilation Systems

MHS Network	Ventilation
Central Artery/Tunnel	(7) Vent Buildings and (3) Fan Chambers
Central Artery North Area (CANA) Tunnel	(2) Vent Buildings
Sumner/Callahan Tunnels	(4) Vent Buildings
Boston Extension (Weston to Boston)	(4) Fan Rooms (Prudential Passageway)

Vent Building 3 is incorporated as part of a waterfront hotel, and Vent Building 4 is incorporated into a MassDOT owned office building/parking garage structure (Parcel 7). These two ventilation buildings are located adjacent to the Surface Artery and are not generally visible to the public.

The MHS support infrastructure also includes 40 stormwater pumping facilities, as shown in Table 5.

Table 5: Metropolitan Highway System Stormwater Pumping Stations

MHS Network	Stormwater Pumping
Central Artery/Tunnel	29 Pumping Stations
Central Artery North Area (CANA) Tunnel	1 Pumping Station
Sumner/Callahan Tunnels	6 Pumping Stations
Boston Extension	4 Pumping Stations

In addition, there are approximately 90 Utility Rooms and three Electrical Substations within the Central Artery/Tunnel portion of the MHS. Other MHS supporting infrastructure includes three Communication Tower facilities on the Boston Extension, and various monitoring systems and equipment.

MHS Buildings

The MHS includes the following operations/support facilities:

Central Artery/Tunnels

- District 6 Headquarters at 185 Kneeland Street Boston (10-story office structure also known as the Wang Building)
- Highway Operations Center (HOC) in South Boston
- Maintenance Garage/Facility (M-8) in South Boston
- CA/T Satellite Maintenance Facility/Emergency Response Station #10 and CA/T Salt Shed in Charlestown

- Maintenance Facility and Electrical Substation #2 at 480 Albany Street in Boston
- Emergency Response Station ERS #4 at 480 Albany Street in Boston
- Electrical Substation #3 at 497 Austin Street in Charlestown
- Salt Shed at 370D Street in South Boston
- I-90 Ted Williams Tunnel Service Building in East Boston
- Ramp E Ted Williams Tunnel Service Building in East Boston

Sumner/Callahan Tunnels

- Sumner/Callahan Tunnel Administration Building at 145 London Street in East Boston
- Division III Service and Garage at 145 Havre Street in East Boston

Boston Extension

- Administration Buildings at Interchange 125 in Newton and Interchange 123 in Weston
- Mechanical-Electrical Substation, Garage, and Salt Shed at Interchange 131 in Brighton

2. Inspection Methodology

A visual inspection was performed on MHS assets which have not been inspected since the previous 2018 Triennial Inspection, including roadways, interchanges, buildings, communication facilities, pump stations, walls, and sign support structures.

Bridges, culverts and sign support structures that are mounted to bridges along the MHS are routinely inspected either by MassDOT's own forces or under contract by third-party consultants while tunnels, boat structures and sign support structures that are contained within these tunnels and boat structures are routinely inspected under contract by third-party consultants only.

As part of the 2021 Triennial Inspection, a visual inspection audit was required to be performed by HNTB on a representative sample of bridges/culverts that were inspected by MassDOT's own forces. The audit inspections were performed to verify that the conditions documented within the most recent inspection reports and overall rating values assigned to Items 58 Deck, Item 59 Superstructure, Item 60 Substructure and Item 62 Culverts were accurate.

Although performed as part of the 2018 Triennial, visual audit of tunnel/boat section inspections was not necessary for this cycle because 3rd party consultants, not MassDOT forces, now conduct all such inspections.

Bridges, culverts, tunnels, and boat structures that were inspected by third-party consultants did not require visual audit inspections; those inspection findings were exported from MassDOT's 4D system, analyzed, and incorporated into this report.

2.1 Sample Size

A sample set of 46 bridges/culverts along the MHS that had been inspected by MassDOT forces underwent visual audit inspections over the course of the 2021 Triennial Inspection. This sample set was calculated with a 90% confidence level and a 10% margin of error, as demonstrated in Table 6.

$$Sample\ Size = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1+(\frac{z^2 \times p(1-p)}{e^2 N})}$$

Table 6: Sample Size for Audit Inspection of Bridges and Culverts

	BRIDGES AND CULVERTS
Population Size (N)	144
Margin of error (e)	0.1
Z-score (z)	1.65 (90% confidence level)
Population proportion (p)	0.5
Calculated Sample Size	46

2.2 Visual Inspection

Visual inspections were conducted of the assets of the MHS which had not been otherwise inspected since the 2018 Triennial Inspection. These visual inspections included facilities related to Buildings and Highways.

The visual inspections were limited to those items accessible to view from ground level. They did not include hands-on or in-depth inspections and no in-situ testing was performed. Visual inspections for the roadways were conducted with lane closures during the nighttime where required or with no lane closures during the day whenever possible For example, the visual inspection of portions of the Boston Extension mainline highway elements that could be inspected from the right of way (ROW) from behind the guardrail was done so during the daytime whereas portions of the roadway adjacent to MBTA and Amtrack railroad ROW were inspected utilizing a single lane closure with police details during the nighttime. Inspectors utilized binoculars as appropriate to get a better assessment of conditions beyond the closure limit since live traffic was in the adjacent lanes.

The visual inspection included mechanical, electrical, plumbing and communication infrastructure associated with the MHS facilities. Systems were not tested for operational functionality.

All inspections used to prepare this report were condition-based and did not include determination of code compliance or designs which are now obsolete.

2.3 Third Party Inspection Data

The inspection data for tunnels, bridges, culverts, sign structures and highway pavement used to generate the 2021 Report of Conditions was obtained from MassDOT, comprised of inspections conducted by various organizations. All third-party data was utilized “as-is” for incorporation into this Report of Conditions. The third-party data included the following types of inspections:

- Bridge and Culvert Inspections: Routine, Special Member, Underwater, Culvert
- Tunnel and Boat Structure Inspections: All Items, Overhead Items, Special Member
- Ancillary Structure Inspections - Sign Support Structures: Initial, Routine, Special Member
- Pavement: 2020 MassDOT Pavement Condition Assessments (PSI and IRI)

Pavement Serviceability Index (PSI)

MassDOT's Pavement Management Section of the Highway Division surveys roadway pavement conditions on a regular basis. Specialized data collection devices measure overall pavement condition (Pavement Serviceability Index, or PSI) and ride quality (International Roughness Index, or IRI). This report describes roadway pavement using PSI and tunnel pavement using IRI. Bridge pavement is not included.

PSI is a composite pavement condition index that considers the severity and extent of cracking, rutting, and raveling on surfaces as well as ride quality. It measures the conditions of the pavement from impassable to perfectly smooth. The PSI thresholds "Excellent," "Good," "Fair," and "Poor" are different for interstate highways vs non-interstate highways. The condition thresholds for interstate highways are more stringent to support the higher speeds and volumes present on those facilities. Table 7 shows the PSI ranges used to establish the thresholds.

Table 7: Pavement Serviceability Index (PSI)

	Interstate	Non-Interstate
Excellent	3.5-5.0	3.5-5.0
Good	3.0-3.5	2.8-3.5
Fair	2.5-3.0	2.3-2.8
Poor	0.0-2.5	0.0-2.3

International Roughness Index (IRI) is a measurement of ride quality based on a quantitative measurement of roadway surface conditions. Based on those measurements, ride quality is determined to be Good, Fair or Poor depending on the numerical value of the rating system (see Table 8).

Table 8: International Roughness Index (IRI)

Ride Quality	IRI
Good	<= 95 inches/mile
Fair	<= 170 inches/mile
Poor	> 170 inches/mile

2.4 Asset Condition Data Collection

Inspection data for this assignment was collected via two-person teams using tablets with a customized configuration of the ESRI Collector for ArcGIS application, inclusive of geocoordinate data points with attribute information and digital photographs.

Inspectors participated in a two-day training session which covered technology, condition ratings, inspection protocols, safety measures, and logistics, as well as an inspection calibration exercise where team members compared notes, discussed discrepancies, and corroborated methodologies after virtually reviewing inspection data from various sample assets. The inspection team met weekly to review data, discuss field activities, and monitor progress. Comments and associated photographs were reviewed by the QC Manager on an ongoing basis.

Data collection web maps were developed for each asset class that allowed inspectors to input information regarding sub-elements specific to each asset. Individual web maps were configured for inspecting Buildings (Structural, Electrical, Mechanical), Communication Facilities, Pump Stations (Structural, Electrical, Mechanical), Roadways, Interchanges, Sign Support Structures, Walls, and Parks (see Figure 7). Validation web maps were also created for Bridges and Culverts to allow inspectors to perform the inspection audits. The 2021 inspection data, along with the previous 2018 triennial data, are published to ArcGIS Online, where MassDOT staff may securely access the information.

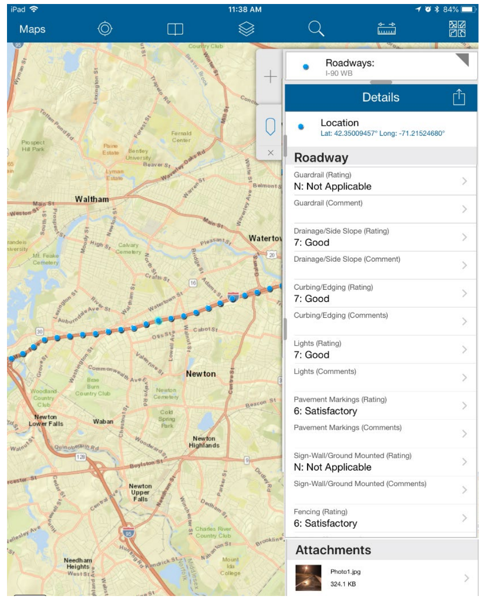

Figure 7: Sample Data Collection Web Map

2.5 Field Inspection Process

The 2021 Triennial Inspection was performed as a visual inspection of assets in order to determine the general condition of the asset. The approach to inspecting each asset class is described below.

2.5.1 Inspection Approach by Asset Class

Bridges and Culverts

Inspection reports were obtained from MassDOT's 4D system for bridges and culverts that were inspected by MassDOT forces between August 2018 and July 2021. Inspection teams visually verified the condition data for a sample set of these assets by visiting 46 bridges and reviewing the previous inspection report to validate the inspection process.

Building Structures

Visual inspections were conducted on 49 buildings, including administration buildings, maintenance facilities, vent buildings, substations, communication facilities, pump stations, parking garages, air intake structures and fan chambers. A condition rating (0 – 9) was assigned for each structural, mechanical, and electrical sub-element based on the visual inspection of each accessible room within the facility. Building exteriors were inspected from the ground level. Building roofs were accessed by stairs or fixed ladders where available. No testing of the mechanical and electrical systems was performed as part of this inspection effort.

Roadway

Assets along the MHS right-of-way were inspected visually. Crews inspected elements within each section of roadway in increments of approximately 1,000 feet along the Boston Extension and along portions of I93NB/SB. The remaining roadways consisting of Ramp X and Ramp XXE along I93; Frontage Road NB/SB; South Boston Bypass Road; and Massport Haul Road were inspected in their entirety. An overall condition rating (0 – 9) was assigned to each sub-element along the roadway right-of-way. Examples of sub-elements along the roadway include but are not limited to pavement markings, guardrail, curbing, side slopes, delineators, signs, fencing, and drop inlets.

Interchanges

Six of the seven Interchanges were visually inspected, as Interchange 133 is part of the Prudential Tunnel, and as such 4D data was reviewed for this one interchange. A condition rating (0 – 9) was assigned to each sub-element in the interchanges, which typically encompassed ramps and areas for maintenance, trailers, and parking. Examples of sub-elements include but are not limited to pavement, curbing, guardrail, side slopes, drainage, lights, and traffic barriers.

Walls

95 of the 98 walls comprised of concrete retaining walls, metal bin walls, and noise barrier walls were inspected. Three walls were not able to be visually inspected as they were located within an active construction zone at the time of this inspection. An overall condition rating (0 – 9) was assigned to each sub-element associated with the walls. Examples of sub-elements include but are not limited to include cracks, spalls, settlement, joints, posts, ribs, planks and fence.

Sign Support Structures

97 sign support structures comprised of full span or cantilever truss and tubular type structures were inspected. An overall condition rating (1- 4) was assigned to each of the 4 elements comprised of sign foundation, sign panels, sign structure and sign traffic and similarly to each sub-element associated with the four sign elements. Examples of sub-elements include but are not limited to concrete, grout pad, anchor rods, sign reflectivity, sign connect framing, posts, truss members and traffic safety elements.

2.6 Condition Coding Scale

A modified version of the National Bridge Inspection Standards (NBIS) condition coding guide was used for the 2021 Triennial Inspection, with a rating scale of 0 for Failed through 9 for Excellent, for all visually inspected assets except for Tunnels/Boats (refer to Table 9) and Sign Support Structures (refer to Table 10). Inspection data for Sign Support Structures are incorporated into MassDOT's 4D database; therefore, a rating scale of 1 (Good) through 4 (Critical Condition) was used exclusively for the sign support structure inspections (refer to Table 11).

The visual inspections included elements of assets such as electrical, mechanical, and plumbing, but did not include hands-on inspections or compliance verification with current codes or design.

Table 9: Condition States (1 to 4) – Tunnels and Boats

CONDITION STATE	CONDITION
CS1	Good
CS2	Fair
CS3	Poor
CS4	Critical

Table 10: Condition Rating (0 through 9) for Visually Inspected Assets

CODE	CONDITION	DESCRIPTION
R	Removed	
N	Not Applicable	
H	Hidden/Inaccessible	
UR	Under Repair	
X	Unknown	
9	Excellent Condition	Newly constructed
8	Very Good Condition	No problems noted
7	Good Condition	Minor problems noted such as hairline cracks in grout pads or temperature and shrinkage cracks in concrete; small and isolated areas of chipped thermoplastic pavement markings; small chips in painted surfaces; an isolated reflector missing from a section of guardrail; minor chips along concrete edging; a push bar on an entry door that occasionally gets stuck; a window that is difficult to open.
6	Satisfactory Condition	Minor defects noted such as fading of thermoplastic pavement markings; shallow spalls, rust staining and/or structural cracks less than 1/16” wide in concrete surfaces; corrosion in steel surfaces without section loss; partially clogged drainage grates; loss of reflectivity or some lettering on sign panels; loss of grout in brick facades; stained ceiling tiles; isolated cracks in glass panels; small accumulation of grease on bearings; slight noise from belts/motor.
5	Fair Condition	Advanced defects cause the element to no longer be in a state of good repair such as minor to moderate section loss to steel elements; notable service load cracks at high stress regions of an element; spalls beyond the first layer of reinforcing steel with section loss; extensive loss of reflectivity to sign panels; extensive traffic impact damage to sections of guardrail, noticeable discharge of lubricant from a pump; tears in belts; instances of 100% section loss to the ribs of metal BIN walls with retained earth exposed to view.
4	Poor Condition	Advanced defects may affect the serviceability of the element such as heavy loss to the web of a steel beam at the supports; deep spalls beyond the first layer with exposed, de-bonded and heavily corroded reinforcing steel in regions of high stress; extensive traffic impact damage to guardrail, attenuators, overhead signs; Doors with missing or seized lock sets; lights not functioning within an egress; electrical breakers tripped; drainage grates fully clogged; visible settlement or deflections.
3	Serious Condition	Advanced deterioration has seriously affected primary structural components with the possibility of local failures such as fatigue cracks in steel, shear cracks in concrete, advanced water seepage through walls, expended attenuators or sections of guardrail; loss of legibility or reflectiveness of sign panels; doors that do not open; broken belts; excessive loss of lubricant on motors; excessive water damage to ceiling tiles.
2	Critical Condition	Advanced deterioration of primary structural elements. The need for rehabilitation is urgent. The facility should be closed until indicated repair is completed.

CODE	CONDITION	DESCRIPTION
1	"Imminent" Failure Condition	Major deterioration or section loss is present in critical structural components or obvious vertical or horizontal movement is affecting stability. Facility is closed but corrective action may put it back in limited service. Study should be conducted to determine the feasibility for rehabilitation.
0	Failed Condition	Facility is closed and out of service. Facility is beyond corrective action.

Table 11: Condition Ratings (1 to 4) – Sign Support Structures

ELEMENT RATING	CONDITION	DESCRIPTION
1	Good	Element performs intended function with high degree of reliability.
2	Fair	Element performs intended function with small reduction in reliability.
3	Poor	Element performs intended function with significant reduction in reliability.
4	Critical	Element does not perform intended function with any degree of reliability.

3. Summary of Findings

The opinions, statements, and recommendations made herein were based solely on conditions revealed by the 2021 Triennial Inspection and by review of the third-party inspection reports exported from MassDOT's 4D system. The following is a summary of findings for each of asset class. See Appendix B and/or the MassDOT 4D Inspection Database for more detailed information regarding specific deficiencies.

The section below describes conditions at the time of the inspection. Refer to Section 5 for MassDOT projects that address several of the conditions noted. In addition, MassDOT has a program of ongoing special inspections to monitor specific conditions of concern.

3.1 Tunnels/Boat Sections

The condition of the 40 tunnel structures and 54 boat structures within the MHS is captured within MassDOT's Tunnel Inspection Program which entails third party contractor's performing routine inspections of each structure at a maximum cycle of two years. As such a visual inspection of each of these structures was not required to be performed as part of the 2021 Triennial Inspection. In lieu of visual inspections, HNTB utilized the information documented within the Tunnel inspection Reports contained within MassDOT's 4D database as well as supplemental inspection documentation contained within MassDOT's SharePoint Website for the 2021 Triennial.

3.1.1 Civil/Structural/MEP

Some defects are commonly found throughout all tunnels/boat sections, to varying degrees, and some are specific to the respective tunnel/boat section. Defects that are generally common to all MHS tunnels include:

- Cracked, delaminated and/or spalled concrete;
- Water intrusion/leakage and the resultant deterioration of surrounding elements;
- Missing or deteriorated fireproofing material;
- Varying degrees of corrosion to structural and MEP elements;
- Clogged roadway drainage grates, inlets and barrier drainage troughs;
- Cracked, spalled and fractured concrete wearing surfaces;
- Cracked, chipped, fractured or missing wall tiles;
- Manhole covers missing connection bolts and covers that are unstable and/or deteriorated encasements;
- Potholes, raveling, distressed areas of bituminous concrete pavement;
- Cross passage and emergency egress doors that are not able to be opened throughout the tunnels;
- Non-operational CCTV cameras; and
- Reduced operational capacity of fans and pumps.

Typical defects associated with the MEP Systems throughout all tunnels include:

- Emergency Generator System with varying degrees of corrosion to components;
- Electrical Distribution System with moderate to heavy corrosion with instances of section loss along the conduits and junction boxes;
- Emergency Distribution System moderate to heavy corrosion with instances of section loss to the wireways and open wireways with exposed wiring not contained within the wireway;

- Emergency Lighting System with non-functioning lights, corroded components; degraded enclosures;
- Fire Detection System with non-functional CCTV cameras and/or heat trace wire system;
- Ventilation System with inoperable axial fans at the time of testing, and dampers on multiple fans which were not in the proper position during operation which can affect airflow and proper operation of the system;
- Drainage and Pumping System with clogged trench drains and drain inlet boxes and inoperable pumps resulting in a reduced capability of the system to remove water from the roadways;
- Tunnel Operations and Security System with inoperable CCTV cameras;
- Fire Protection System with missing or damaged fireproofing materials; and
- Emergency Communication System with limited FM and AM stations that are audible within the tunnel.

The roadway light fixtures are in Poor to Critical condition (CS4) throughout the CA/T tunnels with advanced deterioration to aluminum components directly at support hardware, cracked spring nuts, fractured wireway compression seal ears, and long-term creep of epoxy anchors. The roadway light fixtures are similarly in Poor condition throughout the Sumner, Callahan, CANA and Prudential Tunnels mainly due to the age of these fixtures.

The oldest tunnels within the MHS are the Sumner, Callahan, CANA, and Prudential. Many of the structural, civil, and MEP elements that comprise these tunnels are in Fair (CS2), Poor (CS3) and/or Critical (CS4) condition. In many instances, the quantity of the Element in these condition states is substantial. Other civil/structural/MEP elements have varying degrees of defects that are in Fair to Critical condition but the quantity of defects account for only a small percentage of the total quantity of the element Notable elements with a substantial quantity of defects within these tunnels include:

Callahan Tunnel (T36)

- Steel hangers and anchorages mainly due to corrosion, creep, bowing and elongation along with various defects to the anchorages;
- manhole covers due to instability, and deficient connections/encasements;
- centrifugal exhaust fans and pumps due to reduced operational capacities;
- supply plenum sump pump due to non-operation;
- CCTV cameras due to component degradation and non-functioning videos; and
- facilities consisting of the mid-river pump station due to the ineffectiveness of the pumps to expel standing water within.

Most of the MEP systems are in Poor to Critical condition including ventilation, tunnel lighting and emergency lighting, fire detection, fire protection, emergency communication, and the tunnel operations and security system.

Sumner Tunnel (T37)

- concrete ceiling slab due to extensive spalls with exposed and rusted reinforcing steel, and cracking with efflorescence and rust staining;
- steel ceiling girders dues to varying degrees of corrosion, some with section loss;
- steel hangers mainly due to corrosion, creep, bowing and elongation along with various defects to the anchorages;
- concrete invert slab due to extensive deep delamination and spalls with exposed and rusted reinforcing, and cracking with efflorescence and rust staining;

- manhole covers due to instability and deficient connections/encasements;
- drain inlet boxes due to accumulation of debris within and fractured grates;
- wall panels due to instability of support framing; and
- supply plenum air flues that are completely blocked by debris preventing proper circulation of air flow.

Most of the MEP systems are in Poor to Critical condition including ventilation, drainage and pumping, electrical distribution, fire protection, emergency communication, and the tunnel operations and security system.

CANA Tunnel - T33 (NB) and T34 (SB)

- concrete ceiling slab due to extensive spalls with exposed and rusted reinforcing steel, and cracking with efflorescence and rust staining;
- ceiling panels with advanced deterioration throughout;
- trench drains due to their ineffectiveness as most are completely clogged with debris;
- manhole covers due to missing connection bolts to the frame;
- facilities (utility room) due to high atmospheric humidity causing advanced corrosion to equipment;
- tunnel egresses, as most are impassible;
- axial fans due to remote testing not being able to be performed by the HOC and high exhaust alarms being activated on some fans when tested;
- pumps due to heavy surface corrosion with evidence of leakage; and
- CCTV cameras due to the absence of video.

Most of the MEP systems are in Poor to Critical condition including ventilation, drainage and pumping, emergency generator, electrical distribution, emergency distribution, emergency lighting, fire protection, fire detection, emergency communication, and the tunnel operations and security system.

Prudential Tunnel (T35)

- steel corrosion protective coating due to ineffectiveness;
- concrete columns/piles due to spalls and cracking with efflorescence and rust staining;
- strip seal expansion joints due to extensive seal damage;
- manhole covers due to frame defects;
- drain inlet boxes due to advanced corrosion and fully clogged drains;
- barrier drainage troughs due to a heavy accumulation of debris within;
- roadway overhead utilities due to varying degrees of corrosion, missing fasteners, and deteriorated supports angles at the hangers;
- supply plenum air flues due to spalls at the supports and heavily deteriorated concrete with deformed and twisted steel supports;
- centrifugal supply fans and axial fans due to flow chart issues;
- CCTV cameras due to inadequate camera operation;
- tunnel egresses that are impassible due to obstructions; and
- overhead supply plenum air flues with varying degrees of delamination and spalls.

The MEP Systems throughout the Prudential Tunnel are generally in Good condition except for the fire protection system and the emergency communication system, both of which are in Critical condition, as there is no fire protection system currently present and most of the broadcasting stations could not be received within the tunnel at the time of the most recent inspection.

Notable elements with a substantial quantity of defects within the Central Artery tunnels include:

Ted Williams Tunnel (T27 to T32)

- concrete tunnel roof girders due to concrete delamination and spalls;
- roadway joints due to extensive spalled and cracked concrete headers;
- manhole covers due to instability and deficient connections and encasements;
- drain inlet boxes due to an accumulation of debris, corrosion and fractured grates;
- centrifugal exhaust and supply fans due to varying degrees of degradation and reduced operational capacities;
- vent duct floor drains due to missing grates with a heavy accumulation of debris;
- tunnel egress due to poor illumination;
- supply plenum sump pumps due to non-operational capacity;
- hangers and hanger anchorages experiencing long-term creep; and
- CCTV cameras due degraded components and some with non-functioning videos.

Some of the MEP systems are in Poor to Critical condition including ventilation, fire protection, fire detection, emergency communication, and the tunnel operations and security system.

I-90 Connector Tunnel (T01 to T10)

- compression joint seals and pourable joint seals due to ineffective seal adhesion;
- other joint (ITT) due to leakage and degradation of the concrete header;
- manhole covers due to instability and deficient connections and encasements;
- drain inlet boxes due to an accumulation of debris, corrosion and fractured grates;
- roadway overhead utilities due to electrical covers missing fasteners, missing covers and varying degrees of corrosion to conduits;
- jet fans due to reduced operational capacities;
- vent duct floor drains due to missing grates with a heavy accumulation of debris;
- tunnel egress due to poor illumination;
- facilities (utility rooms and pump rooms) due to general degradation of elements throughout;
- supply plenum sump pumps due to non- operational capacity;
- VMS signs and egress signs due to non-functioning components;
- traffic signs due to degraded supports; and
- CCTV cameras due degraded components and some non-functioning videos.

Some of the MEP systems are in Poor to Critical condition including ventilation, fire protection, fire detection, emergency communication, and the tunnel operations and security system.

Thomas P "Tip" O'Neill Jr. Memorial Tunnel (T11 to T26 & T45)

- steel ceiling panels due to varying degrees of corrosion;
- manhole covers due to instability and deficient connections and encasements;
- drain inlet boxes due to an accumulation of debris, corrosion, and fractured grates;
- roadway overhead utilities due to electrical covers missing fasteners, missing covers, and varying degrees of corrosion to conduits;
- jet fans due to flow chart inadequacies;
- vent duct floor drains due to missing grates with a heavy accumulation of debris;
- tunnel egress due to poor illumination;
- facilities (utility rooms and pump rooms) due to general degradation of elements throughout; and

- supply plenum sump pumps due to non-operational capacity.

Some of the MEP systems are in Poor to Critical condition including ventilation, drainage and pumping; fire protection, fire detection, emergency communication, and the tunnel operations and security system. Various rehabilitation projects are currently programed and/or funded by MassDOT, some of which address defects described above. Refer to Sections 5 and 6 for additional information.

3.2 Bridges/Culverts

A visual audit inspection was performed by HNTB on a representative sample of bridges and culverts that were inspected by MassDOT's own forces as part of the 2021 Triennial. The audit inspections resulted in the documentation of both improved (e.g., new overlay of previously documented deteriorated wearing surface; newly patched areas of the concrete deck) as well as deteriorated (e.g., additional potholes, rutting and depressions along the wearing surface; spalls along the underside of the deck and bridge deck joints with expanded areas of wear and tear) conditions to various elements that comprise the bridges. However, HNTB ultimately agreed with the overall condition ratings that were assigned to the Deck (Item 58), Superstructure (Item 59), Substructure (Item 60), and Culverts (Item 62) within the most recent inspection reports.

Box culverts 9YV and 9YW did not have a recent inspection report within the past 3 years in the 4D database. The span lengths of these structures are less than 10 feet, so in accordance with current MassDOT policy they are not required to be inspected at a maximum frequency of 2 years, as is the usual schedule for longer spans. The most recent inspection of BIN 9YW was in 2016 and that of 9YV was 2010. As such a visual inspection of these structures was also performed as part of the 2021 Triennial.

A visual inspection of BIN 9YU was previously performed as part of the 2018 Triennial; however, the structure is presently being inspected regularly by MassDOT under BIN 2MA. BIN 9YU is currently coded as a removed structure within the 4D database. Based upon discussions with the MassDOT District 6 Area Bridge Inspection Engineer and a review of the 1961 construction plans for the Boston Extension, BIN 9YU has been removed from the bridge inventory.

HNTB reviewed the data for 232 bridges and culverts within the MHS and evaluated the four primary items pertaining to the inspection reports: Deck (Item 58), Superstructure (Item 59), Substructure (Item 60), and Culverts (Item 62). Based on this review it was determined that 18 bridges have at least one of the four primary items with a minimum rating of 4 (Poor), 73 bridges have a minimum rating of 5 (Fair), and the remaining bridges have a minimum rating greater than or equal to 6 (Satisfactory/Good/Excellent).

One bridge remains weight posted, BIN 4QY that carries Highland Street over I90 EB/WB. This bridge has a minimum rating of 5 for both Items 59 and 60 and is posted for 7, 8 and 12 tons for the Type H, 3 and 3S2 truck loadings respectively.

Table 12 shows a breakdown of the bridges' minimum ratings described above based on their geographical location along the MHS.

Table 12: Summary of Minimum Condition Ratings for Bridges

MHS Location	Poor Condition (Rating = 4)	Fair Condition (Rating = 5)	Satisfactory to Excellent Condition (Rating: ≥ 6)
Boston Extension *(excluding Allston Viaduct and Interchange 123, formerly Int. 14/15)*	13	52	14
Allston Viaduct	3	2	0
Interchange 123 (formerly Int. 14/15)	2	5	1
Central Artery	0	14	126
MHS TOTAL	**18**	**73**	**141**

There are 18 bridges that are structurally deficient, as shown in Table 13. This number remains unchanged from the previous Triennial Inspection. Twelve of these bridges are in Poor condition for Deck (Item 58), three are in Poor condition for Superstructure (Item 59), and eight are in Poor condition for Substructure (Item 60).

Table 13: Structurally Deficient Bridges

Location	BIN	Deck (Item 58)	Superstructure (Item 59)	Substructure (Item 60)
Allston Viaduct, Cambridge	4RY	4	5	4
Allston Viaduct, Cambridge	4RX	4	5	4
Allston Viaduct, Cambridge	4RT	4	5	4
Interchange 123, Weston	4QE	5	4	5
Interchange 123, Weston	4QL	4	5	5
Interchange 125, Watertown	4QW	4	5	5
Interchange 125, Watertown	4QX	7	4	5
Interchange 127, Newton	4R7	7	6	4
Interchange 127, Newton	4R9	6	6	4
Cambridge Street Boston	4RE	4	5	5
Mass. Avenue, Boston	4T5	4	5	5
Tremont Street, Boston	4TF	4	5	5
Beacon Street, Boston	4T2	4	4	4
Arlington Street, Boston	4TE	5	6	4
St. Mary's, Boston	4T1	4	6	5
Shawmut Street, Boston	4RQ	4	6	5
Interchange 131, Boston	B8F	4	7	8
Boylston Street, Boston	4T6	6	6	4

The structurally deficient bridges shown in Table 13 and Figure 8 are all located along the Boston Extension.

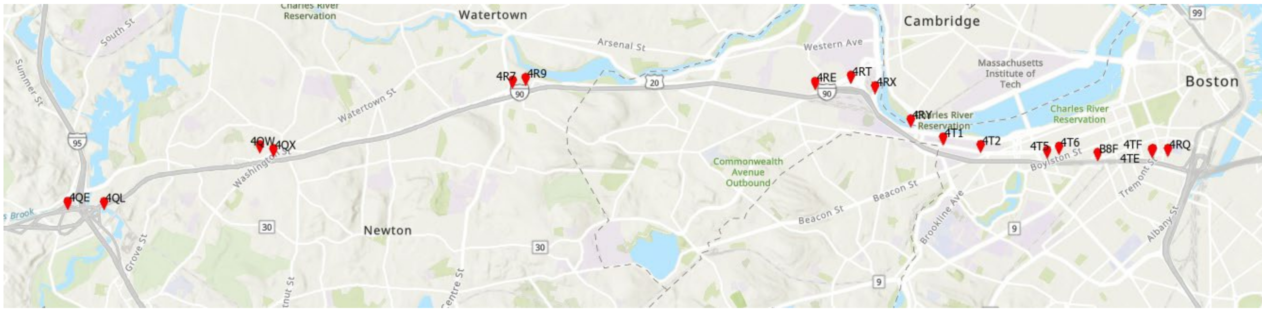

Figure 8: Location of Structurally Deficient Bridges on MHS

The following are typical deficiencies documented in the 4D inspection reports during the past three years for bridge structures:

Deck (Item 58)

- Deterioration of the wearing surface including cracks, potholes, distressed areas, ruts, and settlement, particularly along the approaches;
- Deterioration of the deck including cracks, some with efflorescence and/or rust staining; areas of hollow sounding concrete, incipient spalls, and spalls with exposed and rusted reinforcement;
- Drainage systems that are clogged; pipes that are detached;
- Expansion joints with torn or missing seals or that are clogged;
- Traffic impact damage to curbs, parapets, safety walks and impact attenuators;
- Safety railing sections that are missing, deteriorated, or damaged or safety railing sections that are substandard; and
- Signs with impact damage, that are missing or are illegible.

Superstructure (Item 59)

- Varying degrees of corrosion with instances of section loss to girders, floor beams, truss members and associated lateral bracing members and gusset plates;
- Bearing assemblies that are overextended or have broken and corroded keeper plates; and
- Protective steel coatings that are generally failed throughout.

Substructure (Item 60)

- Deteriorated bridge seats, abutments, pier caps, columns and footings including extensive cracks, areas of unsound concrete, incipient spalls, and spalls with exposed and rusted reinforcement; and
- Slope paving embankments that are settled, fractured and deteriorated.

Culverts (Item 62)

- Headwall delamination with edge spalls and punky concrete;
- Delamination along the underside of the roof slab with areas of hollow concrete, and hairline transverse, longitudinal and map cracks; and
- Leakage through wall joints with random rust staining, efflorescence staining, hairline and light cracking and minor spalling with some delamination.

3.3 Building Structures

Visual inspection of MHS buildings included Service/Administration Buildings, Maintenance Facilities, Ventilation Buildings, Electrical Substations and Communication Facilities. MassDOT 4D data was also reviewed pertaining to the three Fan Chambers and four Fan Rooms that are incorporated within tunnels and were therefore previously inspected as part of MassDOT's tunnel inspection program between August 2018 through July 2021.

The structural/architectural inspection included various building elements such as structural steel and concrete beams and columns, ceilings, walls, lintels, doors, floors, stairways, and other miscellaneous items. The electrical and mechanical inspections included the physical condition of fire protection systems, building HVAC systems, CO monitoring systems, and power supply systems, conduits and wiring, lighting and other associated items. Any mechanical, electrical, or plumbing element/system that directly supports the operation of the tunnels was not visually inspected as these elements/systems were previously inspected as part of MassDOT's tunnel inspection program between August 2018 and July 2021.

A hands-on inspection of the façade of two Ventilation Buildings, VB1 and VB5, was performed by a third-party consultant in 2020. This special member inspection included the architectural façade panels, air intake vents and exposed concrete on the vent buildings to determine the overall condition and identify any potential danger to the traveling public or maintenance personnel. Refer to Buildings Structural/Architectural section for additional information.

3.3.1 Buildings

Structural/Architectural

The hands-on inspection of the façade elements of VB1 resulted in 3 minor architectural elements that were found to be in imminent danger of failure which were immediately removed by the inspectors. The results of the inspection of the façade of VB5 found deteriorated and missing mortar below parapet capstones, which may become a serious issue in the future, along with scattered minor defects to the architectural elements and the concrete and brick façade.

Based on HNTB's visual inspection, the conditions varied substantially throughout these buildings. The older buildings which have not undergone major capital upgrades are generally in need of substantial repair, while the newer buildings require various levels of routine maintenance. Typical structural/architectural deficiencies observed included the following:

Building Roof

- Inoperable roof access hatches;
- Tears in expansion joint and membrane materials; and
- Missing and cracked mortar in roof parapets.

Building Interior

- Missing and water stained ceiling tiles;
- Cracks in concrete ceilings, walls, and slabs;
- Areas of concrete honeycombing, minor spalls and cracks with efflorescence and active leaking;
- Cracks in brick masonry walls;
- Roof access ladders that do not meet OSHA safety requirements;
- Doors no longer on their hinges or with non-functioning latches/locks;

- Active leaking with make-shift awnings to protect electrical/mechanical equipment;
- Sumner/Callahan vent building shaft walls exhibit loose/spalled concrete with map cracking;
- Manholes in basement levels (Vent Building 11) without appropriate covers; and
- Staircases with active corrosion.

Building Exterior

- Vent building louvers missing fixed blades and protective screens;
- Aging windows and doors with missing weather stripping and active corrosion;
- Missing and cracked caulked joints;
- Broken and boarded-up windows;
- Missing stair railings;
- Active corrosion of exposed steel members;
- Weathered brickwork with cracked and missing mortar;
- Areas of spalled and disintegrating concrete;
- Buildings/Walls requiring hands-on inspection to determine integrity of brick masonry;
- Disintegrating concrete stairs; and
- Impact damage.

Building Area

- Settled, displaced and deteriorated curbing;
- Guardrails with impact damage and/or displaced posts;
- Fencing with impact and vandalism damage and corrosion;
- Pavement with moderate cracking and breakup;
- Grounds that have become storage areas for old traffic barriers, signs and other traffic control devices;
- Concrete sidewalks with areas spalled and disintegrating concrete;
- Irrigation systems with broken/missing valve box covers and exposed polyethylene piping; and
- Erosion and settlement of grounds surrounding the building footprint.

During the inspection, there were two specific conditions that were identified as “Attention Items”, which MassDOT are addressing (refer to Section 5 for further information):

- Vent Building 3 – Louvers at the sidewalk level are missing protective screens. These screens provide fall hazard protection from outside the building into the vent shaft.
- Vent Building 7 – Three lateral bracing gusset plates (3rd floor at roof) of the HSS main braced frame are bent out of plane. Following notification, MassDOT measured the deflection at the location of the largest deformation (Column Line 10, between Lines E and F) and stated that they would be tracking the condition to determine if the level of deformation is increasing over time.

Mechanical / Electrical / Plumbing (MEP)

The MEP visual inspection included mechanical, electrical, plumbing, communication and fire protection systems that support the operation of each facility, and the equipment associated with stormwater pumping. These included water supply, sanitary and storm drainage, gas supply, HVAC, power supply, backup power, air quality monitoring, conduits and wiring, piping, lighting, fire protection and other associated items.

The condition of the MEP elements that comprise the buildings generally ranged from Satisfactory to Poor.

Typical MEP deficiencies observed included the following:

- Active alarm conditions, including heat trace, fire alarm, and power failure;
- Corrosion on piping, conduit, enclosures, and equipment;
- Exposed wiring;
- Lighting levels and outages;
- Knox box corrosion; and
- Equipment that was not in service.

3.3.2 Communication Facilities

Generally, most elements observed at the communication facilities were categorized in Good to Satisfactory condition. The communication facilities had singular deficiencies which were rated Fair or Poor, including a damaged perimeter security fence and missing covers on two electrical panels.

3.3.3 Pump Stations

Structural

The structural inspection of the 11 pump stations included a visual inspection of the buildings in which these pump stations are housed including the exterior, from the ground, and the interior. These buildings are comprised of various elements including steel and/or concrete beams and columns; concrete ceilings, walls, and floors; doors, windows, stairways, railings, and other miscellaneous appurtenances.

Pump Station Number 4 has been rehabilitated since the previous Triennial, specifically the exterior of the building including the façade and roof and the interior of Pump Rooms 1 and 3. No repairs have been performed within the Valve Pump Room of this pump station since the previous Triennial Inspection.

There are 2 pump stations located near the entrance and exit portal of both the Sumner and Callahan Tunnel (4 pump stations in total) that support drainage runoff from the associated boat sections of each tunnel (refer to Figure 5). As these pump stations do not support drainage directly from the tunnels, they are not incorporated into MassDOT's tunnel inspection program. These pump stations are listed below:

1. Portal Stormwater Pump Station SWPS-26, Callahan Tunnel @ East Boston Portal
2. Portal Stormwater Pump Station SWPS-27, Callahan Tunnel @ Boston Portal
3. Portal Stormwater Pump Station SWPS-24, Sumner Tunnel @ East Boston Portal
4. Portal Stormwater Pump Station SWPS-25, Sumner Tunnel @ Boston Portal

At the direction of MassDOT a visual inspection of these pump stations was not performed as these pump stations are scheduled for rehabilitation under MassDOT's Capital Improvement Plan (CIP) for 2021. Refer to Section 5, Recommendations, for additional information. A visual inspection of these four rehabilitated pump stations should be performed during the next Triennial.

The structural condition of the elements that comprise the buildings housing these pump stations generally ranged from Satisfactory to Good. The older pump stations, which have not undergone major capital upgrades, are generally in need of substantial repair while the newer buildings require various levels of routine maintenance.

Structural deficiencies observed included the following:

- Ceilings: hairline cracks with efflorescence, salt encrustation and minor rust staining; shallow surface spalls; heavily peeled protective coating; damaged insulation;
- Walls: hairline cracks with efflorescence; large areas of efflorescence with salt encrustation leaching from the construction joints; isolated spalls with exposed and rusted reinforcing; heavily peeled protective coatings;
- Floors: hairline cracks; ponding water near the pumps where leaks were observed; adjacent to the walls where leaching was observed or at clogged floor drains;
- Stair Railing/Ladders: isolated areas of moderate to heavy corrosion and peeled protective coatings;
- Drainage: moderate to heavy corrosion to drain grate covers; fractured covers and clogged drains;
- Doors: corrosion, particularly along the base with damaged hardware;
- Roof: concrete soffit with numerous scattered cover spalls with exposed and rusted reinforcing; separation cracks and incipient spalls (Pump Station No. 2);
- Crane Lifts: moderate to heavy corrosion to anchor bolts with failed paint and moderate corrosion on base plates and framing members;
- Fencing - Exterior: damaged/missing portions of fence around the perimeter of a transformer (Pump Station No. 2); unsecured perimeter gate, not locked (Stormwater Pump Station No. 11); and
- Grounds: isolated area of distressed bituminous concrete pavement just outside of the pump station (Pump Station No. 11).

Mechanical / Electrical / Plumbing (MEP)

The MEP visual inspection of the 11 pump stations included mechanical, electrical, plumbing, and fire protection systems that assist the operations of every pump station facility. For stormwater pumping, the equipment inspected with respect to various pump station systems included water supply, sanitary and storm drainage, gas supply, HVAC, power supply, backup power, air quality monitoring, conduits and piping, wiring, lighting, fire protection, and other associated equipment vital to the operations of the pump stations.

The condition of the MEP elements that comprise the pump stations mainly ranged from Satisfactory to Good with the older pump stations in general need of more substantial work and service to bring the pump station to a state of good repair.

MEP deficiencies noted include:

- Corrosion/rust on piping, conduit, and other equipment;
- Detached and damaged piping, conduit, and ductwork;
- Significant leakage from piping and conduits; and
- Abandoned or not in use equipment and systems.

3.4 Roadways

3.4.1 Roadway

The visual inspection of the roadways included all roadway and roadside elements, unless otherwise noted, including pavement markings, guardrail, drop inlets, light standards, fencing, side slopes, edging, roadway signs, light towers, utility cabinets, and traffic barriers.

A visual inspection of the roadway pavement was not performed, as MassDOT provides pavement condition data that is analyzed by asset class in lieu of a visual inspection. Refer to Section 4 for additional information.

Roadway elements associated with bridges and tunnels were not visually inspected, as inspection data from 4D was exported and evaluated for this report.

The condition of the elements that comprise the roadways generally vary from Poor to Very Good.

Deficiencies observed along the roadways include:

Pavement Markings

- Areas of chipped, peeled, or faded markings with occasional sections that are not visible or missing.

Guardrail

- Punctures and tears to rails;
- Misaligned and displaced posts;
- Disconnected rails and posts;
- Complete guardrail failure in isolated locations; and
- Damaged or inadequate impact attenuators.

Drop Inlets, Drainage, Side Slope

- Debris buildup and vegetation overgrowth in swales/gutters, catch basins occasionally clogged with sediment or trash (Boston Extension);
- Drop inlet structures with settled, collapsed or spalled aprons or top courses with exposed rusted reinforcement, or corroded cover plates (Boston Extension); and
- Catch basins with frequent occurrences of a heavy accumulation of sandy debris or occasional trash (Central Artery).

Curbing

- Misalignment of edging in some instances;
- Minimal reveal in some instances due to settlement or multiple pavement project layers burying or hiding curb faces; and
- Areas of damaged or split curbing.

Light Standards

- A few instances of light poles that have been removed from their foundations, by others, and are laying on the ground;
- Occasional burnt light bulbs;
- Isolated instances of missing fixtures, in some cases, with exposed wiring; and
- Isolated sections of roadway that exhibit poor visibility as lighting is not provided.

Signs

- Faded portions of sign panels (frequently on I-90 emblems);
- Signs that are misaligned or out of plumb;

- Occasional collision damage that has deformed or misaligned posts or caused hardware to fail;
- Dismounted signs including panels disconnected from posts or failure at sign supports; and
- Missing, damaged or inadequate support hardware (loose friction clamps resulting in sign panels sliding down posts).

Fencing

- Missing sections of fencing or openings in chain link fencing;
- Inadequate gates including damaged hinges, or insecure latches;
- Failed posts;
- Disconnected top and bottom rails from posts, causing chain link sections to collapse; and
- Mild to moderate rust on fencing components.

Parapet Wall

- Minor collision damage;
- Heavy spalling with exposed rusted reinforcing particularly along the rail mounted barriers adjacent to the railroad;
- Undermined rail base plates;
- Exposed and rusted anchor rods;
- Collision damage with failed sections of railing along the top of the parapet wall; and
- Cracked base plates.

Parapet/Safety Walk

- Vegetation overgrowth;
- Accumulation of sandy debris on surface; and
- Spalled, settled, heaved, or misaligned concrete caps.

Roadway Miscellaneous

- Open, collapsed, or inadequate covers to lighting utility boxes, electric manholes or communication manholes;
- Missing bolts or fasteners to manhole covers;
- Corrosion of utility cabinets;
- Improper latching of cabinets;
- Exposed wiring;
- Missing or deteriorated grout at anchor bolts for posts;
- Sand accumulation and roadside debris in various areas; and
- Overgrowth with occasional fallen trees.

3.4.2 Interchanges

The inspected elements associated with the interchanges included pavement, pavement markings, curbing, guardrail, drainage/drop inlets, side slopes, lighting, signs and concrete barriers. Tandem trailer areas at Interchange 123, on Ramp D and Ramp J, were also inspected and rated with similar elements. The condition of the elements that comprise the interchanges generally vary from Poor to Very Good.

Deficiencies noted along the interchanges include:

Pavement

- Deteriorated pavement including potholes, severe map cracking, transverse and longitudinal cracks, raveling.

Pavement Markings

- Areas of chipped, peeled, or faded markings and occasionally not visible or missing.

Signs

- Panels disconnected from posts, ineffective sign panel hardware (panels slid down on posts), damaged panels and posts, posts failed at base, faded and illegible panels.

Curbing

- Misaligned or settled resulting in low curb reveal;
- Reduced capacity to gutter line; and
- Broken or damaged curbing.

Guardrail

- Damaged posts – misaligned, disconnected from rails, deformed;
- Damaged rail sections – torn, deflected and disconnected from posts; and
- Compressed or damaged impact attenuators due to collision damage.

Drop Inlets, Drainage, Side Slopes

- Sediment and debris in catch basins and outlets;
- Eroded areas; and
- Collapsed or spalled drainage structures.

Light Standards

- Burnt out light bulbs; and
- Failed or missing light standards – typically sheared at anchor bolts.

Interchange Miscellaneous

- Open utility structures - missing utility covers, misaligned frame and cover, fractured covers, collapsed masonry under frames;
- Exposed wiring; and
- Tripping hazards on sidewalks.

3.4.3 Pavement

Roadway

Assessment of interstate and non-interstate MHS roadway pavement was made by analyzing pavement condition data provided by MassDOT. This data had been collected utilizing a vehicle equipped with a pavement scanning machine. The interstate data was collected starting in October 2020 and the non-interstate data was collected starting in May 2019. This data was forwarded to HNTB for use to analyze and incorporate into the 2021 Triennial Report of Conditions.

Each data point collected was assigned a "Heat" color and plotted along the MHS to generate a heat map. The heat map helps to identify stretches of pavement that are in Poor to Fair condition that might be suitable for rehabilitation/replacement.

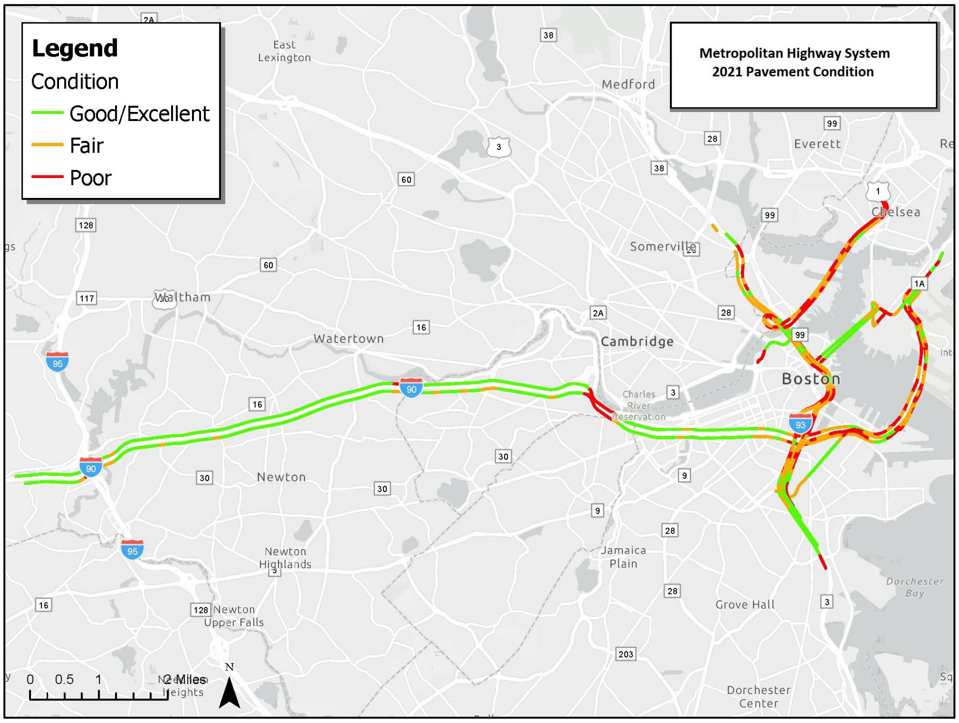

Figure 9: MHS 2020 Pavement Condition Heat Map

Roadway pavement conditions are reported based on the Pavement Serviceability Index as shown in the following tables.

Table 14: CA/T Roadway Pavement Condition PSI (Lane Miles)

	Interstate	Non-Interstate
Excellent	6.7	9.8
Good	2.4	5.5
Fair	3.9	5.0
Poor	1.2	1.8
TOTAL	**14.2**	**22.1**

Table 15: Boston Extension Roadway Pavement Condition PSI (Lane Miles)

	Interstate	Non-Interstate
Excellent	36.7	0.0
Good	17.9	0.0
Fair	7.1	0.0
Poor	1.6	0.0
TOTAL	**63.3**	**0.0**

Based on this review, 2.8 roadway lane miles of pavement in the study area (4%) are in Poor condition on the interstate portion where the PSI value was below 2.5 and 1.8 roadway lane miles (8%) are in Poor condition on the non-interstate portion where the PSI value was below 2.3.

Tunnels

Tunnel pavement conditions are reported based on the International Roughness Index, as shown in the following tables.

Table 16: CA/T Tunnel Pavement Condition IRI (Lane Miles)

	Interstate	Non-Interstate
Excellent/Good	2.3	2.5
Fair	12.2	17.0
Poor	9.2	12.3
TOTAL	**23.7**	**31.8**

Table 17: CANA Tunnel Pavement Condition IRI (Lane Miles)

	Interstate	Non-Interstate
Excellent/Good	0.000	0.0
Fair	0.000	0.4
Poor	0.000	1.1
TOTAL	**0.000**	**1.5**

Table 18: Sumner/Callahan Tunnel Pavement Condition IRI (Lane Miles)

	Interstate	Non-Interstate
Excellent/Good	0.000	1.2
Fair	0.000	1.2
Poor	0.000	1.95
TOTAL	**0.000**	**4.35**

Table 19: Prudential Tunnel Pavement Condition IRI (Lane Miles)

	Interstate	Non-Interstate
Excellent/Good	4.1	0.000
Fair	0.0	0.000
Poor	0.0	0.000
TOTAL	**4.1**	**0.000**

Based on this review, 9.2 tunnel lane miles of pavement in the study area (33%) are in Poor condition on the interstate portion and 15.4 tunnel lane miles of pavement in the study area (41%) are in Poor condition on the non-interstate portion where the IRI value was above 170.

3.4.4 Walls

The walls along the Boston Extension and Central Artery roadways that required a visual inspection are comprised of 75 concrete retaining walls, 18 metal BIN retaining walls and 5 noise barrier walls.

A visual inspection of 3 of the concrete retaining walls could not be performed as these walls were located within an active construction site:

1. Wall #201 located along I-90 EB, Boston Extension at the southwest corner of Massachusetts Avenue;
2. Wall #194 located along I-90 WB, Boston Extension just west of Brookline Avenue; and
3. The concrete retaining wall located along the south side of Massport Haul Road between the World Trade Center and Pumphouse Road.

These three walls should be inspected during the next Triennial.

Nine walls that were visually inspected during the 2018 Triennial were not visually inspected during the 2021 Triennial as these are wingwalls associated with various bridges along the Boston Extension that have been inspected within the past three years as part of MassDOT's bridge inspection program, with conditions documented within MassDOT's 4D bridge inspection database. Information pertaining to the condition of these walls has been taken from the most recent bridge inspection report contained within the MassDOT's 4D bridge inspection database and utilized for the current Triennial inspection.

Concrete Retaining Walls

Typical deficiencies include:

- Incipient spalls;
- Spalls with exposed, rusted, and/or de-bonded reinforcing;
- Wide separation cracks;
- Disintegrated sections of concrete exposing the reinforcing cage;
- Open and misaligned joints;
- Overgrown vegetation;
- Clogged weep hole drains;
- Fractured railing base plates or missing sections of railing; and
- Advanced corrosion to fencing components.

The extent of defects including cover spalls, spalls with exposed and rusted reinforcing, and incipient spalls has increased on some of the concrete walls along the Boston Extension and Haul Road since the previous Triennial Inspection. Refer to Section 5 for additional information.

Metal BIN Retaining Walls

Typical deficiencies include:

- Varying degrees of corrosion to the ribs and posts, some up to 100%, resulting in soil blowouts; and
- Heavy overgrown vegetation either through the ribs, along the front face, or along the top of the wall.

Several metal BIN walls located within Interchange 131 have substantial failed sections with soil blowouts the conditions of which have not changed from the previous Triennial. Refer to Section 5 for additional information.

Noise Barrier Walls

Deficiencies include:

- Bowed and deflected timber planks;
- Fractured and split timber planks; and
- Spalls with exposed and rusted reinforcing along the underside of precast concrete panels.

3.4.5 Sign Support Structures

97 sign support structures located along various open roadways of the MHS were visually inspected. Toll gantry structures were not inspected, at the direction of MassDOT, as these structures are owned and operated by others.

Some signs structures have been removed and not replaced; some sign structures have been removed and replaced with new structures at a nearby location; and some sign structures have been newly erected, mainly along the Boston Extension approaching various interchanges, since the 2018 Triennial Inspection.

A cantilever sign support structure located along I-90 EB at MM132.7, just west of the Prudential Tunnel entry portal, was not able to be completely inspected as the foundation elements along with components of the structure, including the base plates and anchor bolts, were located within an active construction site and could not be accessed during this inspection.

As part of MassDOT's Ancillary Structures Inspection Program, a hands-on inspection of the sign structures located along the open roadways of the MHS is scheduled to be performed on a 3-year frequency once an Initial inspection has been performed on all sign support structures. While an Initial inspection has been performed on a majority of the 97 sign support structures, only 4 have been performed within the past three years. These 4 sign structures are located along the I-93NB roadway of the MHS. All 97 sign support structures were visually inspected, and conditions documented, during the 2021 Triennial inspection. Additional information pertaining to the condition of the 4 sign structures has been extracted from MassDOT's 4D Ancillary Structures database and utilized for the 2021 Triennial inspection.

A Special Member Inspection has been performed on approximately 30 of the 97 sign support structures by third-party consultants in April of 2020 as part of MassDOT's Ancillary Structures Inspection Program. This Special Member Inspection focused solely on the condition of the vibration dampers attached to the sign structures. A review of the associated inspection reports within MassDOT's 4D database resulted in the compilation of a list of various vibration damper defects including missing or damaged dampers; loose clamps and/or loose safety chains that were often not attached directly to the damper, and taunt safety chains that prevented the dampers from properly deflecting. MassDOT confirmed that most of the sign structures documented as having deficient dampers were corrected in accordance with the manufacturer's specifications. No action has been taken to date on the structures with missing dampers as MassDOT is currently in the process of confirming whether or not a damper is required per the manufacturer's specifications.

At the time of this inspection, the panels on sign support structures along various MHS roadways were in the process of being renumbered by MassDOT to reflect the associated roadway mile marker designations in accordance with recent FHWA directives. As such, the inspection data that has been documented for these sign support structures reflects, where applicable, the old exit number designation along with the new mile marker designation. The next inspection cycle of the Triennial should be able to capture any outstanding renumbering changes that were not captured during the current cycle.

Typical deficiencies resulting from the visual inspections include:

- Concrete foundations with map cracks, efflorescence, rust staining and/or dampness;
- Fractured, spalled or missing grout pads with exposed anchor rods;
- Moderate corrosion along exposed anchor rods; under-threaded or backed off nuts and deformed anchor rods;
- Failed paint coatings with varying degrees of corrosion to posts, arms, chords, bracing members and along the chord splice plates;
- Handhole covers missing from posts;
- Minor collision damage to sign panels and/or associated traffic safety features; sign panels missing from posts;
- Moderate to heavy corrosion along the base of the VMS control cabinets; and
- Overgrown vegetation around foundations.

3.4.6 Parks

The condition of the elements that comprise the London Street Park generally vary from Satisfactory to Good with a few minor deficiencies. One park bench was found to have a missing slat, and the brick wall precast concrete capital tops were typically cracked, with a corner broken off at one location. Stamped concrete pavement was in generally Good condition, with one depressed area along a diagonal line through the paved area, causing a potential tripping hazard; a trench appears to have been cut through the paved area.

4. Performance Measures

MassDOT has established near term and long term targets for some of their assets including bridges/culverts and pavement. These targets were adopted to maintain consistency with the MAP-21 target-setting timeframe. Established performance measures applicable to the assets located within the MHS are documented in this report. Performance targets are reported as near term (5-year) and long term (10-year) metrics.

4.1 Bridges/Culverts

The bridge performance measures are based on MassDOT's Annual Performance Report "2020 Tracker".

4.1.1 Structurally Deficient Bridges weighted by Deck Area (% Poor)

This performance measure is calculated by comparing the amount of deck area that is associated with a structurally deficient bridge to the total area of bridge deck in the population of bridges evaluated.

Table 20: MHS Structurally Deficient Bridges weighted by Deck Area

Location	Current (2021)	Near Term (2026) Target MHS Total	Long Term (2031) Target MHS Total
Boston Extension (excluding Allston Viaduct and Int. 123 (14/15)	23.6%	-	-
Allston Viaduct, Cambridge	80.6%	-	-
Interchange 123 (14/15), Weston	16.5%	-	-
Central Artery	0.0%	-	-
MHS (total)	12.9%	<12%	<10%

All of the structurally deficient bridges are located along the Boston Extension, including the Allston Viaduct in Cambridge and Interchange 123 in Weston.

In order to meet the near term performance target along the Boston Extension, 37,600 square feet of structurally deficient bridge deck would need to be replaced, and in order to meet the long term target, 121,000 square feet would need to be replaced; both targets weighted by deck area would be met if the Allston Viaduct alone were replaced.

4.1.2 Minimum Bridge Rating > or = 7 weighted by Deck Area (% Good)

This performance measure is calculated by comparing the amount of deck area that is associated with a minimum bridge rating greater than or equal to 7 (% Good) to the total area of bridge deck in the population of bridges evaluated.

Table 21: MHS Structurally Good Bridges weighted by Deck Area

Location	Current (2021)	Near Term (2026) Target	Long Term (2031) Target
Boston Extension [excluding Allston Viaduct and Int. 123 (14/15)]	8.4%		
Allston Viaduct, Cambridge	0%	-	-
Interchange 123 (14/15), Weston	0%	-	-
Central Artery	32.9%	-	-
MHS (total)	23.4%	>16%	>20%

Comparing all bridge deck area along the entire MHS, the current measure more than satisfies the near term and long term performance targets.

4.1.3 Structurally Deficient Bridge Count

A bridge is rated as structurally deficient when the deck, the superstructure, or the substructure item is rated 4 or less. Structural deficiency does not necessarily imply that a bridge is unsafe. It does, however, mean that a structure is deteriorated to the point of needing repairs to prevent weight posting restrictions on the bridge. Please reference **Table 10** for further information on the rating scale.

Table 22: MHS Structurally Deficient Bridge Count

Location	Current (2021)	Near Term (2026) Target	Long Term (2031) Target
Boston Extension [excluding Allston Viaduct & Interchange 123 (14/15)]	13	-	-
Allston Viaduct, Cambridge	3	-	-
Interchange 123 (14/15), Weston	2	-	-
Central Artery	0	-	-
MHS (total)	18	Downward Trend	Downward Trend

Prioritization should be given to structures carrying interstates (I-90 and I-93) to avoid potential posting restrictions on these major truck routes. As discussed in sections 4.1.1 and 4.1.2, the metric that compares the amount of deck area associated with a structurally deficient or good bridge, can be largely met through the replacement of the Allston viaduct as well as replacement of the structurally deficient bridges at Interchange 123 in Weston however, if this approach is taken, 13 structurally deficient bridges along the Boston Extension would remain unaddressed.

4.1.4 Bridge Health Index

The Bridge Health Index provides a comprehensive overview of the condition of all bridge elements across the MHS. This measure, reported on a scale of 0 to 100, reflects element inspection data in relation to the asset value of a bridge or network of bridges. A value of zero is an indication that all of a bridge's elements are in the worst condition. This measure is calculated by comparing the amount of deck area multiplied by its' associated health index to the total area of bridge deck in the population of decks evaluated.

Table 23: MHS Bridge Health Index

Location	Current (2021)	Near Term (2026) Target	Long Term (2031) Target
Boston Extension (excluding Allston Viaduct & Interchange 123)	86.3%	-	-
Allston Viaduct, Cambridge	75.3%	-	-
Interchange 123, (14/15) Weston	72.2%	-	-
Central Artery	96.7%	-	-
MHS (total)	91.1%	92%	95%

Replacement of the structurally deficient bridges associated with the Allston Viaduct and Interchange 123 (14/15) would more than satisfy near term and long term performance targets.

4.2 Pavement

Pavement performance measures herein are based on MassDOT's "Highway Division FHWA TAMP Update" dated December 2020. These performance measures monitor the pavement conditions found along MHS roadways and tunnels and measure the percentage of pavement in "Good/Excellent" condition and "Poor" condition. Pavement for bridges and culverts is incorporated within the performance measures in Section 4.1 of this report and are not included here.

4.2.1 Roadway Pavement

MassDOT measures the overall condition of Roadway pavement using the Pavement Serviceability Index (PSI).

Interstate Roadway

PSI (% Good/Excellent Condition)

This performance measure is calculated by comparing the amount of interstate roadway lane miles that are Good/Excellent to the total amount of interstate roadway lane miles within the respective facility.

Table 24: Interstate Pavement (% Good/Excellent)

Facility	Current (2021)	Near Term (2026) Target	Long Term (2031) Target
Central Artery/Tunnel	69%	-	-
Boston Extension	86%	-	-
MHS (total)	84%	90%	90%

To meet the near term and long term performance targets for interstate roadway pavement, 5.0 interstate roadway lane miles of pavement along the MHS would need to be upgraded to a condition level of Good.

PSI (% Poor)

This performance measure is calculated by comparing the amount of interstate roadway lane miles that are Poor to the total amount of interstate roadway lane miles within the respective facility.

Table 25: Interstate Pavement (% Poor)

Facility	Current (2021)	Near Term (2026) Target	Long Term (2031) Target
Central Artery/Tunnel	1.2%	-	-
Boston Extension	1.6%	-	-
MHS (total)	2.8%	4%	4%

Both near term and long term performance targets for interstate roadway pavement are currently met.

Non-Interstate Roadway

PSI (% Good/Excellent Condition)

This performance measure is calculated by comparing the amount of non-interstate roadway lane miles that are Good/Excellent to the total amount of non-interstate roadway lane miles within the respective facility.

Table 26: Non-Interstate Pavement (% Good/Excellent)

Facility	Current (2021)	Near Term (2026) Target	Long Term (2031) Target
Central Artery/Tunnel	69%	-	-
Boston Extension	N.A.	-	-
MHS (total)	65%	70%	75%

Both near term and long term performance measures are very close to being met. To meet the near term and long term performance targets for non-interstate pavement, a total of 1.2 lane miles and 2.4 lane miles respectively of non-interstate roadway pavement would need to be upgraded to a condition level of Good within the MHS.

PSI (% Poor)

This performance measure is calculated by comparing the amount of non-interstate roadway lane miles that are Poor to the total amount of non-interstate roadway lane miles within the respective facility.

Table 27: Non-Interstate Pavement (% Poor)

Facility	Current (2021)	Near Term (2026) Target	Long Term (2031) Target
Central Artery/Tunnel	8%	-	-
Boston Extension	-	-	-
MHS (total)	11%	10%	10%

Both near term and long term performance measures are very close to being met. To meet the near term and long term performance targets for non-interstate pavement, less than one lane mile of non-interstate roadway pavement would need to be upgraded to a condition level of Good within the MHS.

4.2.2 Tunnel Pavement

MassDOT measures the condition of Tunnel pavement using the International Roughness Index (IRI).

Interstate Tunnel

IRI (% Good/Excellent Condition)

This performance measure is calculated by comparing the amount of interstate tunnel lane miles that are Good/Excellent to the total amount of interstate tunnel lane miles within the respective facility.

Table 28: Tunnel Interstate Pavement (% Good/Excellent)

Facility	Current (2021)	Near Term (2026) Target	Long Term (2031) Target
Central Artery/Tunnel	10%	-	-
Prudential Tunnel	100%	-	-
MHS (total)	23%	90%	90%

To meet the near term and long term performance targets for interstate tunnel pavement, a total of 18.6 lane miles of interstate tunnel pavement would need to be upgraded to a condition level of Good/Excellent.

IRI (% Poor)

This performance measure is calculated by comparing the amount of interstate tunnel lane miles that are Poor to the total amount of interstate tunnel lane miles within the respective facility.

Table 29: Tunnel Interstate Pavement (%Poor)

Facility	Current (2021)	Near Term (2026) Target	Long Term (2031) Target
Central Artery/Tunnel	39%	-	-
Prudential Tunnel	0%	-	-
MHS (total)	33%	4%	4%

To meet the near term and long term performance targets for interstate tunnel pavement, a total of 9.5 lane mile of interstate tunnel pavement would need to be upgraded to a minimum condition level of Fair.

Non-Interstate Tunnel

IRI (% Good Condition)

This performance measure is calculated by comparing the amount of non-interstate tunnel lane miles that are Good/Excellent to the total amount of non-interstate tunnel lane miles within the respective facility.

Table 30: Tunnel Non-Interstate Pavement (% Good/Excellent)

Facility	Current (2021)	Near Term (2026) Target	Long Term (2031) Target
Central Artery/Tunnel	8%	-	-
CANA	0%	-	-
Sumner/Callahan	28%	-	-
Prudential Tunnel	N.A.	-	-
MHS (total)	14%	70%	75%

To meet the near term and long term performance targets for non-interstate tunnel pavement, a total of 20.6 and 22.5 lane miles respectively of non-interstate tunnel pavement would need to be upgraded to a condition level of Good within the MHS.

IRI (% Poor)

This performance measure is calculated by comparing the amount of non-interstate tunnel lane miles that are Poor to the total amount of non-interstate tunnel lane miles within the respective facility.

Table 31: Non-Interstate Tunnel Pavement (%Poor)

Facility	Current (2021)	Near Term (2026) Target	Long Term (2031) Target
Central Artery/Tunnel	39%	-	-
CANA	73%	-	-
Sumner/Callahan	45%	-	-
Prudential Tunnel	N.A.	-	-
MHS (total)	42%	10%	10%

To meet the near term and long term performance targets for tunnel non-interstate pavement, a total of 11.8 lane miles of tunnel non-interstate pavement would need to be upgraded to a condition level of Fair within the MHS.

5. Recommendations

The following section presents the recommendations to ensure the MHS assets are in good working order and condition. The activities include rehabilitation, replacement, maintenance and other asset specific activities. HNTB has developed these recommendations independent of MassDOT's anticipated expenditures.

Recommendations are separated into near term and long term. Near term recommendations include items that should be addressed within the next five years (FY22-FY26). Long term recommendations include items that should be addressed within the following five years (FY27-FY31). Recommendations noted as "full term" should be addressed as soon as possible and as can be feasibly coordinated through the full 10-year planning period.

5.1 Tunnels/Boat Sections

Recommendations for repair or replacement of tunnel and boat section elements were determined based on the Condition State as reported in the 4D tunnel/boat section reports. Additionally, HNTB reviewed the scope of work associated with many of the large capital projects identified by MassDOT that are in various states of funding, design or construction. Recommendations made herein specific to the tunnels associated with these projects are intended to reflect the repair of deficiencies that are outside the scope of these projects. Due to high traffic volumes and the close proximity of the various tunnels to each other within the MHS tunnel network, these large capital projects need to be carefully coordinated. Coordination of these major projects is outside of the scope of this report and are therefore recommended to be undertaken throughout the full term (to be coordinated by MassDOT). Refer to Section 5.1.2 and Section 6 for additional information.

5.1.1 Civil/Structural

Elements which are quantifiable/rated on a per item basis were evaluated for repairs based on the reported Condition State. Structural elements rated Condition State 3 and 4 are recommended for repair in the near term while elements rated Condition State 2 are recommended for repair in the long term.

MassDOT has numerous projects in various stages of programming, funding and design that would address some of the recommendations detailed herein specific to the Sumner, Callahan, CANA and Prudential Tunnels. It is acknowledged that some portion of each project's value may have already been spent; however, it is recommended that MassDOT advance these capital projects in the near term. Refer to Section 5.1.2 for additional information.

The following recommendations are for addressing structural and civil deficiencies common to all MHS tunnels/boat sections unless included as part of an active or future programmed project:

- Boat wall concrete repairs to cracked, delaminated and/or spalled concrete;
- Boat wearing surface repairs;
- Continued inspection and maintenance of manhole cover deficiencies; and
- Continued inspection and maintenance of deteriorated sign lighting fixtures and hardware.

The following recommendations are for addressing structural and civil deficiencies unique to a specific tunnel/boat section in the full term:

Central Artery Tunnels

- Repairs to cracked, delaminated and/or spalled concrete wearing surfaces; and wide cracks and potholes in asphalt wearing surfaces;
- Concrete repairs to cracked, delaminated and/or spalled concrete focusing on overhead items;
- Repair water intrusion/leakage;
- Remove/replace missing deteriorated fireproofing material;
- Maintain cross passage and exit doors to ensure proper opening and closure;
- Clean and paint areas of steel corrosion;
- Install steel connection fasteners or replacing corroded fasteners;
- Replace broken drain inlet box grates; and
- Replace traffic markings.

Sumner Tunnel

- Concrete repairs to air supply concrete liner.

Callahan Tunnel

- Concrete repairs to portal, invert slab and air supply concrete liner.

Ted Williams Tunnel

Continue ongoing efforts of installing supplemental hangers within the tunnel at locations where deficient hangers have been documented to be undergoing long term creep, in an effort to extend the serviceability of the ceiling panel support framing system. Consider initiating a project to analyze and develop long term modifications to the ceiling panel support framing system, with consideration given to air flow analysis, associated MEP systems, and the replacement of targeted deficient ceiling panels in the long term.

5.1.2 Mechanical / Electrical / Plumbing (MEP)

Elements which are quantifiable/rated on a per item basis such as fans, pumps, CCTV, variable message boards, lane use signal boxes, and egress signs were analyzed as a replacement or a repair of that item based on the Condition State that it was rated. Systems conditions which are rated on the system as a single unit, such as electrical distribution systems, emergency generator systems, security and operations systems, fire detection systems, and fire protection systems, were summarized and interpreted such that systems rated Condition States 3 and 4 are recommended for replacement in the near term, Condition State 2 defects are recommended for replacement in the long term, and a budgetary amount is recommended to be implemented in the full term to maintain and replace components in various systems.

The following are recommendations for addressing MEP deficiencies common to all MHS tunnels/boat sections unless included as part of an active or future programmed project. Reference Table 32 in Section 5.1.3 for details on MassDOT projects that address some of the noted deficiencies.

- Continue inspection and maintenance of defects associated with the fans, including but not limited to belt adjustments; clearing out of compliance alarms; unavailable/inoperable fans during inspections; repairing areas of lubricant leakage;
- Repair defects to fan concrete pedestals;

- Repair/replace deficient roadway sign lighting;
- Repair deteriorated electrical conduits, replace junction boxes, and cover plates;
- Remediate improperly performing fire detection/protection systems and electrical distribution systems; and
- Clean clogged drainage pipes and barrier troughs to ensure proper drainage throughout the tunnel.

The following are recommendations for addressing MEP deficiencies unique to specific tunnel/boat sections in the full term:

Central Artery Tunnels

- Diagnose and repair tripped circuit breakers;
- Label, test and repair existing unit substations and switchgear;
- Diagnose and repair inoperative meters/displays, heaters and alarms related to electrical/emergency distribution systems;
- Replace battery racks past their service life;
- Test sections of standpipe as required to make the test records current; repair leaking valves; replace piping and associated supports that are heavily corroded;
- Repair/replace several inoperable/unavailable jet fans;
- Repair/replace several inoperable/unavailable fans and defects associated with dampers;
- Replace/replace several pumps at low point pump stations; and
- Repair/replace non-operational sump pumps, with a significant number of pumps in I-93 SB.

Sumner Tunnel

- Repair motor-generator units; and
- Investigate and remediate leak in ceiling over the VB10 switch-gear room ATS's.

Callahan Tunnel

- Implement a plan for addressing deficient roadway lighting fixtures; and
- Repair deficiencies related to the fire protection system, such as broken or inoperable hand wheels on isolation valves and a leak in the system.

Prudential Tunnel

- Test sections of standpipe as required to make the test records current; repair leaking valves; replace piping and associated supports that are heavily corroded; and
- Complete repairs to several inoperable/unavailable fans.

5.1.3 Tunnel Capital Investments

MassDOT has numerous existing projects in various stages of funding and design that would address some of the recommendations in sections 5.1.1 and 5.1.2. It is acknowledged that some portion of each project's value may have already been spent; however, it is recommended that MassDOT advance the following capital projects:

Table 32: MassDOT Capital Tunnel Projects Recommended for Advancement

MassDOT Project #	Tunnel/Project Description	Status	Estimated Construction Cost ($M)
607137 (Const. Cont. 106084)	General Water Intrusion, Leak Sealing, Fireproofing and Miscellaneous Repairs	Construction 76% Complete	$14.25
606476	Sumner Tunnel - Roadway, Ceiling, Arch., and Wall Reconstruction and Other Control Systems	Advertised 6/26/21	$137
606660	Sumner and Callahan Tunnel - Vent Building & Pump Station Mechanical and Electrical Improvements.	Advertised 5/25/21	$37.25
606859	CANA Tunnel - Electrical System Upgrades, PLC Control Upgrades and Facility Improvements	**Anticipated Advertisement 2022**	$61M
609124	I90 & MBTA Prudential Tunnel Rehabilitation	**Deferred**	$57
609121 (Const. Cont. 107208)	Ted Williams Tunnel - Lighting Repairs (CRC 17C & 17E)	**Construction 57% Complete**	$32.5
610894	Prudential Tunnel - Lighting Rehabilitation.	**Anticipated Bid Opening 9/8/21**	$40
608247	Callahan Tunnel - Ceiling Reconstruction, New Jet Fans, and Other Control Systems.	**Not Funded**	$20.1
609122 (Const. Cont. 107208)	I-93 Tip O'Neill Tunnel Mainline - Lighting Repairs	Began Summer 2020	$32.5
609346	I-93 Tip O'Neill Tunnel Ramps - Lighting Repairs	25% Design	$43
607079	I-93 Tip O'Neill Tunnel - Leak Sealing, Fireproofing and Miscellaneous Repairs	**Not Funded**	$0.65
609318	I-90 EB Connector Tunnel - Roadway Lighting Replacement	100% PS&E	$58
609343	I-90 WB Connector Tunnel - Roadway Lighting Replacement	75% Design	$27
606801	Vent Stack Exterior Replacement Dewey Square Tunnel Fan Chambers	Preliminary Design	$12.3
607884	I-90 EB/WB Connector Tunnels - Fire Standpipe Support Repairs.	**Not Funded**	$1.3M

Project #609124 - I90 & MBTA Prudential Tunnel Rehabilitation is currently in a deferred state. This project consists of a major rehabilitation of the Prudential Tunnel's structural, civil and MEP components, many of which are in Poor to Critical condition including overhead utilities the condition of which has not changed from the previous Triennial. However, MassDOT is advancing Project #610894 to address tunnel lighting in the Prudential Tunnel. It is recommended that MassDOT revisit this deferred project to evaluate and revise the scope of work as necessary to include elements that have fallen out of a state of good repair within this tunnel in the near term.

Project #608247 – Callahan Tunnel Ceiling Reconstruction is currently not funded. It is recommended that this project be advanced for funding in the near term and the scope of work evaluated to include elements that have fallen out of a state of good repair such as the roadway lighting fixtures.

5.2 Bridges/Culverts

For the development of the recommendations, bridges were categorized by their current condition rating, Deck condition rating (Item 58), Superstructure condition rating (Item 59), and Substructure condition rating (Item 60). It is recommended that:

- any structurally deficient bridge (i.e., a bridge with any item having a condition rating of 4 or less) with an average condition rating (between all three Items) of 5 or less be programed and funded for a full structure replacement in the near term; and
- any structurally deficient bridge with an average condition rating greater than 5 be programed and funded for targeted repairs or rehabilitation specific to the deficient Item (Deck, Superstructure or Substructure), in the near term.

As shown in Table 33, three of the eighteen structurally deficient bridges are currently programed and funded with a specific MassDOT project associated with the Allston Viaduct in Cambridge. MassDOT is pursuing options to advance a project for two bridges located at Interchange 123 (formerly Interchange 14/15) in Weston. It is recommended that:

- the programed projects for Allston Viaduct and the Weston interchange be advanced as full bridge rehabilitation/replacements;
- the remaining 13 structurally deficient bridges be funded and advanced for replacement, rehabilitation, or targeted repairs specific to the deficient Item (Deck, Superstructure or Substructure) with consideration given to bundling some of these bridges. For example,
    - 3 of the 18 structurally deficient bridges are in close proximity of each other having similar defects.
        - It is recommended that 4T2 Beacon Street undergo a full bridge replacement, bundled with a project for 4TE Arlington Street and 4T6 Boylston Street for substructure repairs/rehabilitation.
    - 2 of the 18 structurally deficient bridges are located at Interchange 127 (formerly Interchange 17) in Newton, and both have a rating of 4 for Item 60 Substructure.
        - It is recommended that 4R7 and 4R9 be bundled together for major substructure repairs.

At the completion of these projects, it is anticipated that these bridges will be removed from the structurally deficient category and that currently ongoing freeze thaw and special member inspections, both of which are on a maximum 1-year inspection cycle, will no longer be required to be performed.

The remaining bridges having ratings of 5 are recommended for rehabilitation of those specific low rating item(s) (e.g., Deck/Superstructure/Substructure) in the long term. There are 73 bridges that have ratings of 5, some of which are programed under a specific D6 project which may or may not relate to the low rating item.

Bridges with condition rating greater than or equal to 6 can be maintained in their current condition through the following activities:

- Routine maintenance. Work is required annually to prevent the onset of deterioration to bridge structural members and safety elements, consisting of the following:

- asphalt pavement crack sealing and patching;
- drain/scupper cleaning; and
- power washing superstructure and substructure areas below deck joints.

- Scheduled preventative maintenance. Work is required every 10 years to replace consumable elements which protect the bridge structure and to arrest any areas of deterioration which may exist, consisting of the following:
  - deck patching;
  - deck joint gland replacement;
  - wearing surface and membrane replacement;
  - steel superstructure cleaning and painting; and
  - concrete substructure patching, crack repair and coating.

5.2.1 Bridge Capital Investments

MassDOT has numerous existing projects in various stages of funding and design that would address some of the recommendations in section 5.2. It is recommended that MassDOT advance the programed capital projects and develop new projects to address the rest of the structurally deficient bridges on the MHS.

Table 33: Status of MassDOT Capital Bridge Projects

Location	BIN	Currently Programed (Yes/ No)	Project ID #	Currently Funded (Yes/ No)
Allston Viaduct, Cambridge	4RY 4RX 4RT	Yes	606475	Yes
	4RY 4RX	Yes	612231	Yes
Interchange 123, Weston	4QE 4QL	Yes	606783	No
Interchange 125, Watertown	4QW	Yes	606780	No
Interchange 125, Watertown	4QX	No	N.A.	No
Interchange 127, Newton	4R7 4R9	Yes	606795	No
Cambridge Street Boston	4RE	Yes	606376	No
Beacon Street, Boston Mass. Avenue, Boston	4T2 4T5	Yes	606542	No
Tremont Street, Boston Arlington Street, Boston	4TF 4TE	Yes	606543	No
St. Mary's, Boston	4T1	Yes	609325	No
Shawmut Street, Boston	4RQ	Yes	608017	No
Interchange 131, Boston	B8F	No	N.A.	No
Boylston Street, Boston	4T6	No	N.A.	No

5.3 Building Structures

5.3.1 Buildings

Structural

A strong recommendation would be to repair or replace some interior and exterior doors. Most buildings exhibit some doors in Poor condition, especially exterior metal doors showing evidence of severe corrosion at the bottom and at the hinges. Corrosion at the bottom of the exterior doors negates the purpose of a door threshold allowing rodent and moisture access into the buildings.
An additional strong recommendation would be to implement a hands-on inspection program of the exterior of the building, especially ventilation buildings.
There were several buildings that did appear to be underutilized or that may not be as relevant following the implementation of open road tolling. These include the following:

- Sumner Tunnel facility at 145 London Street (East Boston)
- Toll Plaza I-90 (Ted Williams Tunnel) (East Boston)
- Toll Plaza Ramp E (Ted Williams Tunnel) (East Boston)
- Boston Extension facility at I-90 Interchange 125 (formerly Interchange 16) (Newton)

Consideration should be given about the needs of these buildings and the cost/benefit of continuing to maintain them versus their reconfiguration or removal.

The following are recommendations for addressing deficiencies to all MHS buildings, unless location is specifically noted:

Building Roof

Near Term

- Repair inoperable roof access hatches;
- Repair tears in expansion joint and membrane materials;
- Repair missing and cracked mortar in roof parapets; and
- Locate and repair sources of leaks in buildings throughout the MHS.

Long Term

- Replace roofs as they reach their end of life.

Building Interior

Near Term

- Replace roof access ladders that do not meet OSHA safety requirements or install permanent fall protection system that will meet OSHA requirements;
- Fix cracks in concrete ceilings, walls and slabs which are sources of active water infiltration;
- Replace missing and water stained ceiling tiles following leak repairs so repaired areas can be monitored for new leaks;
- Replace doors no longer on their hinges or with non-functioning latches/locks;
- Hands on inspection of Sumner/Callahan vent buildings (Vent Buildings 10 to 13) shaft walls to understand the extents of the loose/spalled concrete with map cracking and develop a repair plan;

- Identify areas of active corrosion on the stairs;
- Investigate causes of below grade leaks in Vent Building 4 that is causing the CMU block walls to disintegrate in the B306 hallway area and develop leak repairs; and
- Investigate causes of below grade leaks in Vent Building 13 and develop leak repairs.

Long Term

- Monitor cracks in brick masonry walls;
- Repair Sumner/Callahan vent buildings shaft walls; and
- Replace CMU walls damaged by the long-term leaks in Vent Building.

Building Exterior

Near Term

- Install protective screens on Vent Building 3 to eliminate fall hazards;
- Inspect aging vent building louvers (Vent Building 11), remove any broken louver blades that may become loose, and re-install protective screens;
- Repair exterior stair threads causing potential tripping hazard (Vent Building 6);
- Repair or replace aging windows and doors with missing weather stripping and active corrosion;
- Repair missing and cracked caulked joints;
- Replace broken and boarded-up windows;
- Replace missing stair railings;
- Clean and paint areas of active corrosion of exposed steel members;
- Monitor areas of weathered brickwork with cracked and missing mortar and replace/repoint as necessary to maintain brickwork and associated masonry units;
- Remove and replace areas of spalled and disintegrating concrete;
- Replace disintegrating concrete stairs; and
- Repair areas impact damage.

Long Term

- Consideration should be made to replacing the façade louvers as part of a façade renovation of Vent Building 11 as was recently completed with Vent Buildings 12/13; and
- Consideration should be made as to the future of the Division III Service & Garage at 145 London Street (East Boston) and whether a complete building overhaul lines up with the future needs of MassDOT.

Building Area

Near Term

- Reset or replace settled, displaced, and deteriorated curbing;
- Replace guardrails with impact damage and/or displaced posts;
- Replace fencing with impact and vandalism damage and corrosion;
- Remove old traffic barriers, signs and other traffic control devices that are no longer intended to be used; and
- Monitor erosion and settlement of grounds surrounding the building footprint and fill in areas

with suitable fill material. Special attention should be directed to determining to cause of the concrete pavement settlement behind Vent Building 1, as this settlement is extensive.

Long Term

- Repair pavement that exhibits moderate cracking and breakup;
- Repair concrete sidewalks that are spalled with disintegrating concrete;
- Replace irrigation systems with broken/missing valve box covers and exposed polyethylene piping or remove system; and
- Replace the concrete pavement once the cause of settlement is determined at Vent Building 1.

Specific conditions identified and reported as “Attention Items” to MassDOT included the following:

- Vent Building 3 – Missing protective screens at the sidewalk level of Vent Building 3; and
- Vent Building 7 – Varying degrees of deformation to some of the braced frame gussets.

Per conversations with MassDOT D6, both of these issues are being monitored.

Mechanical / Electrical / Plumbing (MEP)

A predominance of the deficiencies regarding mechanical and plumbing items within MHS buildings are somewhat minor in nature and may typically be remediated with minor mechanical or general maintenance.

In several locations, mechanical parts for equipment need replacement and there are several items that can be remediated with general maintenance, both in the near term. In frequent instances, repair or replacement of portions of mechanical equipment housing will help to bring the equipment to a Satisfactory condition. In many cases, general maintenance to clean and coat mechanical equipment housing or other non-moving parts will help to lengthen the useful life of the equipment, particularly on the roof or other exposed areas. General maintenance is also necessary in the near term to unclog floor and roof drains.

There are several pieces of equipment which appear to be either out of use or abandoned, and MassDOT may want to consider whether these items should be replaced. In instances where equipment is out of order but is still intended for use, it is recommended that technicians diagnose and repair those items. In a few instances, equipment was noted to be obsolete or nearing the end of useful life; it is expected that some equipment upgrades are likely to be needed within the next 10 years.

The electrical deficiencies in MHS buildings predominantly consist of items which can be brought to a Satisfactory condition in the near term by performing minor general and electrical maintenance. Frequent instances of missing or partially detached electrical junction box or electrical panel box covers were noted, often exposing wires. Several boxes were noted to have become either fully or partially detached from their associated supports. Interior and exterior lights were often noted to be non-functional or missing. In some locations, materials and/or debris was positioned in front of electrical panels.

Most of these conditions can be remediated by reattaching covers or capping wires of unused conduits; securing loose electrical components to their support locations; replacing bulbs or entire lighting fixtures and performing general housekeeping such as debris removal. In many cases, electrical components were noted to exhibit moderate or heavy corrosion due to the presence of past or present moisture. The useful life of these components can be extended by cleaning/removing rust, coating them to keep moisture from further deteriorating the components, and removing standing water by unclogging floor drains. In several cases, abandoned/obsolete equipment or components should be removed.

Long term recommendations include upgrades to electrical equipment, including switchgear, MCCs and portions of corroded raceway systems, since their current condition is somewhat deteriorated or is nearing the point where it will become outdated or obsolete.

The following are recommendations for addressing MEP deficiencies to all MHS buildings, unless location is specifically noted:

Near Term

- Clean and coat or replace corroded piping, conduit, conduit support / hanger systems, enclosures and equipment in all buildings and ventilation buildings;
- Secure detached electric boxes, fixtures and equipment;
- Secure detached conduit hanger / support systems;
- Repair exposed or disconnected wiring;
- Repair/replace sub-standard lighting systems and outages;
- Replace exterior lighting system at Vent Building 6;
- Repair damaged intrusion detection sensors, motion sensors and cameras;
- Repair, rehabilitate or replace equipment that is malfunctioning / not in service;
- Remove or suitably terminate equipment and systems that are not in use / abandoned;
- Re-wire temporary unsafe power service connections and damaged conduit runs;
- Remove boxes/equipment blocking electrical equipment in CA/T Satellite Maintenance Facility, ERS 10, Central Maintenance Facility (M8) and Electrical Substation ESS #2;
- Protect electrical equipment in buildings subject to water ingress, including Electrical Substation ESS#2, Vent Building 4, and Toll Plaza Ramp E;
- Inspect/diagnose/rectify active heat trace, FACP, and generator alarm conditions at Administration Building at Havre Street, Vent Building 1, Vent Building 4, Vent Building 5, Vent Building 6, Vent Building 7, Vent Building 8, Vent Building 11, Vent Building 15, Garage (Int. 18-19-20), Dewey Square Air Intake Facility, Administration Building at Interchange 123 (formerly Interchange 14) and Communication Building at Interchange 123 (formerly Interchange 15);
- Implement comprehensive electric maintenance throughout Vent Building 10 and Vent Building 11;
- Implement comprehensive backup generator and appurtenances electric maintenance at Vent Building 15;
- Repairs to reinstate elevator service to Vent Building 10, Vent Building 11, Vent Building 12 and Vent Building 13;
- Repair circuits with taped circuit breakers in Vent Building 13;
- Upgrade fire alarm system at Administration Building at Havre Street, Vent Building 11, and Division III Service & Garage;
- Repair backup generator and associated cabling at Mechanical-Electrical Substation (Interchange 131, formerly Interchange 19);
- Repair gas detection system in Vent Building 3;
- Replace commercial intake vent in single location at Administration Building at Havre Street;
- Remove debris and clutter around air compressor in ERS #10; repair and seal oil leakage from the fuel oil pump, and replace front panel of the cabinet unit heater in ERS #10 and in the Toll Plaza building at I-90;
- Replace piping underneath the ceiling where oil is leaking from the fuel oil pump in ESS #2;
- Replace old baseboard heater (BB-4) in ESS #3;
- Replace electric wall heater in the men's bathroom in ERS #1 and in Vent Building 11;

- Repair trimming around the AC unit at garage (Interchange 131, formerly Interchange 18-19-20);
- Remove abandoned boiler in the basement of the Tobin Maintenance Facility;
- Remove abandoned boiler in Mechanical-Electrical Substation (Interchange 131, formerly Interchange 18-19-20);
- Remove and replace Exhaust Fan #2 at Toll Plaza Ramp E;
- Repair ductwork and pipe insulation at Toll Plaza Ramp E and Vent Building 5;
- Seal and repair air duct in Vent Building 1;
- Replace ventilation unit cover on the roof of Vent Building 1;
- Replace Standing Fire Connection on the roof of Vent Building 13;
- Seal and repair dry standpipe in Vent Building 13;
- Seal pipe in Vent Building 15 to prevent further leaking in fuel tank room;
- Seal and repair sprinkler fire pipe in stairwell of Vent Building 4; and
- Repair exhaust stack on the roof of Vent Building 6.

Long Term

- Replace panelboards at Administration Building at Havre Street and at Division III Service & Garage;
- Replace backup generator at Administration Building at Interchange 125 (formerly Interchange 16);
- Replace incoming service transformers at Administration Buildings at Interchange 123 (formerly Interchange 14) and Interchange 125 (formerly Interchange 16);
- Replace conduit and electric boxes at ERS/ESS #1;
- Replace switchgear on first floor at Vent Building 10;
- Replace control equipment and switchgear at Vent Building 11;
- Replace motor control centers, backup generator and appurtenances at Vent Building 15; and
- Repair ductwork damaged in generator room in the Administration Building at Interchange 123 (formerly Interchange 14).

5.3.2 Buildings Capital Investments

MassDOT has several projects in various stages of design or implementation that would address some of the recommendations described within Section 5.3.1. It is acknowledged that some portion of each project's value may have already been spent; however, it is recommended that MassDOT advance the following capital projects:

Project ID #606801 - Dewey Square Vent Stack Exterior Replacement: Vent Stack Exterior Replacement I-93 Fan Chambers in preliminary design.

Project ID #606477 – Sumner Tunnel Vent Building Brick Wall Replacement which is in study phase.

Project ID #611993 – Space Modernization for the Highway Operations Center (HOC) which is currently in design phase.

5.3.3 Communication Facilities

The following are recommended repairs for the communication facilities at Interchange 123 (formerly 14/15) and Interchange 131 (formerly 18/19/20).

- Interchange 123: There are three sections of chain link fence, approximately 8’ long, with damaged or missing barbed wire (three posts) totaling approximately 24 feet that should be replaced. Horizontal bracing should be installed between each set of posts.
- Interchange 131: Two electrical junction boxes should be provided with protective covers to address safety concerns.

5.3.4 Pump Stations

Structural

The pump stations in general would benefit from regular routine maintenance to prevent elements from falling into a state of disrepair. Near term and long term recommendations are described below, which are intended to bring elements back to a state of good repair and to keep elements from falling into a state of disrepair.
Near Term

- Repair spalls with exposed and rusted reinforcing at isolated locations along the interior at the stairwell walls and floor along with spalls/incipient spalls at widespread locations along the exterior of the roof soffit of Pump Station No. 2;
- Replace, in-kind, the damaged and missing chain link fence along the perimeter of the transformer pad at Pump Station No. 2;
- Remove distressed section of bituminous concrete pavement and replace in-kind at SWPS-12;
- Secure gate to perimeter fence that was observed to be unlocked at SWPS-12;
- Remove all failed protection coating from the walls and recoat in SWPS-03;
- Replace damaged insulation along the ceiling of SWPS-11;
- Clean out floor drains and remove and replace, in-kind, corroded and/or damaged sections of floor drain grates; and
- Remove efflorescence/salt encrustation from cracks in ceiling, walls and floors and seal/pressure inject as required.

Long Term

- Remove scale/corrosion from steel elements such as stairway railings, doors and components of the crane lifts, coat and repaint as required.

Mechanical / Electrical / Plumbing (MEP)

Many of the MEP systems are in need of sustained regular maintenance, and some need more substantial replacement of equipment. MassDOT’s ongoing long term repair program should consider allocation of funds and resources for repair and replacement of pump station mechanical and electrical equipment over the years to allow the pump stations to function as intended. In addition, general maintenance activities need to be considered which will remediate non-mechanical and non-electrical repairs which are necessary to continue proper function of the pump stations.

Many of the pump station mechanical and plumbing deficiencies observed consist of minor mechanical repairs, replacement of mechanical components, or replacement of floor drains in the near term. In some instances, general maintenance is required to remove debris and clean and coat mechanical components to extend the useful life of the equipment in the near term. Longer term considerations should be given to replacing pumps and related equipment as they come to the end of their useful life.

Many of the pump station electrical deficiencies observed consist of minor electrical repairs such as replacement of electrical components, or repairs to lighting in the near term. In some instances, general maintenance is required to repair doors in the near term. Longer term considerations should be given to replacing knox boxes at door entrances as well as replacement of the electrical conduits.

The following are recommendations for addressing MEP deficiencies to all MHS pump stations, unless location is specifically noted:

Near Term

- Clean and coat all three motor casings from rust and corrosion in Pump Station No. 2;
- Replace six cast iron floor drain grates in SWPS-04;
- Clean and coat stormwater pipes and valves from rust and corrosion in SWPS-04;
- Repair and seal damaged ductwork, clean and coat reduced pressure backflow preventer in SWPS-05;
- Clean and coat motor casings and replace gasket/coverplate/piping/etc. to seal up leakage from stormwater pipe. Clean and discard of mold and algae where leakage is taking place in SWPS-05;
- Replace floor drain in SWPS-11;
- Clean and coat or replace corroded piping, conduit, enclosures and equipment;
- Remove abandoned conduit, wiring and equipment;
- Replace malfunctioning HVAC equipment;
- Repair exposed wiring;
- Repair damaged receptacles, intrusion detection systems, and gas monitoring systems;
- Repair / replace sub-standard lighting systems and outages;
- Inspect / diagnose / rectify alarm conditions at SWPS-03 and SWPS-05; and
- Re-wire power service for sump pump at SWPS-12.

Long Term

- Replace corroded knox boxes and horn strobe units;
- Rehabilitate / replace piping at SWPS-05; and
- Replace corroded conduit, enclosures and equipment at SWPS-05.

5.3.5 Pump Stations Capital Investments

MassDOT has several projects in various stages of design or implementation that would address some of the recommendations described within Section 5.3.3. It is acknowledged that some portion of each project's value may have already been spent; however, it is recommended that MassDOT advance the following capital project:

Project ID #606660 - Sumner/Callahan Vent Building Upgrades: Stormwater Pump Stations SWPS-24, SWPS-25, SWPS-26 and SWPS-27, associated with the Sumner and Callahan Tunnels, are scheduled for rehabilitation in the near term.

5.4 Roadways

5.4.1 Roadway

Guardrail

Maintenance items include replacing or resetting posts where warranted and replacing damaged rail sections. Impact attenuators which have been damaged due to traffic impact should have nosing parts replaced and have cells and barrels reset or replaced as needed. Isolated locations where guardrail protection is outdated and not up to modern standards should be replaced with acceptable materials.

Drop Inlets, Drainage, Side Slope

Maintenance includes clearing vegetation overgrowth and other deleterious materials in drainage swales and channels, and cleaning out drainage basin structures of sand and other debris. Isolated instances of side slope erosion will need to be repaired to avoid impacts to pavement structure. Long term maintenance items include replacement of damaged drain grates and replacement of collapsed or deteriorated structures.

Curbing

Maintenance items include resetting curbing where misaligned or settled resulting in low curb reveal and a reduced capacity to gutter line.

Light Standards

Maintenance items include replacement of burnt out bulbs, replacement of failed light standards, and replacement or repair of missing or damaged fixtures.

Signs

Maintenance items for signs include replacing illegible signs panels; replacing damaged sign panels and replacing specific sign components including posts, mounts, foundations and hardware where structurally deficient or compromised.

Fencing

Where fencing is collapsed, disconnected or otherwise non-functional, these sections of fencing should be replaced as openings can cause unauthorized access to safety sensitive areas. Gates should also be functional and secure.

Parapet Wall

Repairs include treating exposed reinforcing bars and patching spalled areas. Rails that have been struck or otherwise have damaged components should be replaced.

Parapet/Safety Walk

Maintenance items include clearing vegetation overgrowth and removal of debris. Long term repairs include replacement of concrete caps along the safety walks that were observed to be significantly deteriorated.

Roadway Miscellaneous

Repair or install adequate frame and covers for utility boxes and manholes, replace deteriorated utility or signal cabinets, install latches or secure mechanisms to cabinets, remove roadside sedimentation and trash/debris, remove fallen trees and vegetation overgrowth

5.4.2 Interchanges

Pavement

Ramps with extensive deterioration of pavement should be repaired or milled and repaved including Interchange 123 - Ramp A and J, Interchange 125 – Ramp C and D, Interchange 131 – Ramp A and B-C, Interchange 132 – Ramp A, and Interchange 134 (Exit 134 Ramp).

Pavement Markings

Pavement markings that are barely visible or not visible should be restriped. In areas where existing pavement will remain, old markings should be eradicated. Areas include Tandem trailer areas at Interchange 123, Interchange 125 – Ramp B, C, and D, Interchange 131 – Ramp A and D, and Interchange 133 – Ramp A.

Curbing

Maintenance items include resetting curbing where misaligned or settled resulting in low curb reveal and a reduced capacity to gutter line as well as replacing broken or damaged curbing.

Guardrail

Maintenance items include replacing or resetting posts where warranted and replacing damaged rail sections. Impact attenuators which have been damaged due to traffic impact should have nosing parts replaced and have cells and barrels reset or replaced as needed.

Drop Inlets, Drainage, Side Slopes

Maintenance items with respect to drainage include removal of sediment and debris from catch basins and outlets, and repair of eroded slide slopes.

Light Standards

Maintenance items include replacement of burnt out light bulbs and replacing failed or missing light standards.

Signs

Maintenance items include replacing signposts and supports, replacing damaged or inadequate hardware, replacing deteriorated sign panels, replacing sheared anchor bolts or foundations.

Interchanges Miscellaneous

Repair trip hazards at crosswalks at interchanges, repair or install adequate frame and covers for utility boxes, structures or manholes, replace deteriorated VMS board – Interchange 133.

5.4.3 Pavement

Roadway & Interchanges

In the near term, routine maintenance shall be performed in sequence with the freeze thaw cycle to sustain a Satisfactory driving surface. These actions include repairing potholes, sealing cracks, patching areas of fractured or loose pavement, and repainting pavement markers.

In the long term, areas of older pavement will need to be resurfaced to provide a safe and reliable surface that is continuous through the roadway system. There were some interchange ramps with a level of pavement deterioration that will require full resurfacing as an action in the long term and some with isolated areas of deteriorated pavement that will need to be resurfaced.

5.4.4 Walls

Concrete Retaining Walls

The extent of defects including cover spalls, spalls with exposed and rusted reinforcing, and incipient spalls has increased on several concrete walls since the previous Triennial Inspection. Near term recommendations include implementing a rehabilitation plan for the following 13 concrete retaining walls :

- 6 concrete walls along the South Boston Bypass Road from West Broadway to Dorchester Avenue
- CW11: I90 EB Station 75+50 to 83+50 east of Woodland Road
- CW114: I90 WB Station 356+00 to 360+50 west of Market Street
- CW18: I90 WB Interchange 125 (formerly Interchange 16) left side of Ramp B
- CW197: I90 WB Station 509+50 to 523+00 Brookline Ave to Charlesgate West
- CW32: I90 EB Station 158+00 to 177+00 between Chestnut Street and Lowell Avenue
- CW37: I90 EB Station 238+60 to 246+00 west of Church Street
- CW608A: Interchange 131 (formerly Interchange 20) Ramp C Station 29+50 to 34+25

Concrete Wall CW27 at Interchange 125 (formerly Interchange 16) along the on-ramp to I90 EB was observed to be in Poor condition, as the top portion of the entire wall is disintegrated/spalled up to 16" high, exposing the reinforcing steel cages that exhibit moderate to heavy corrosion. As this wall appears to have been part of the previously demolished toll plaza and no longer functions as a retaining wall, it is recommended, in the near term, that a plan be implemented to address these defects.

Advanced corrosion with up to 100% section loss was noted to be present to components of the fencing, particularly along the base of the posts, at some concrete retaining walls. It is recommended, in the near term, that sections of fencing be removed and replaced along the following walls:

- CW117: I90 EB Station 360+50 to 364+00 east of Market Street
- CW192: West of Beacon Street on Mountfort Street
- CW35A': I90 EB Station 194+50 to 196+75 east of Market Street

- CW36: I90 EB Station 198+25 to 202+50 east of Walnut Street

Several concrete retaining walls were observed to have open construction joints with minor to moderate displacement/settlement along adjacent sections. It is recommended, in the near term, that the following walls have geotechnical monitoring instrumentation installed and monitored:

- CW 608: Interchange 131(formerly Interchange 18) Ramp C Station 33+25 to 35+00
- CW 608A: Interchange 131(formerly Interchange 20) Ramp C Station 29+50 to 34+25

Long term recommendations for the concrete retaining walls include establishing a routine maintenance program to clear overgrown vegetation protruding though the construction joints or accumulating behind the wall; clear out clogged swales and weep holes; remove and replace fractured sections or railing; and sealing cracks.

Metal BIN Retaining Walls

Near term recommendations for the metal BIN walls include implementing a rehabilitation plan for four walls, located along various ramps within the Interchange 131 (formerly Interchange 18), for demolition and replacement:

- M62: I90 EB Station 414+00 to 415+25 adjacent to CW635
- M62A: I90 EB Station 409+75 to 413+75 adjacent to M62
- M63: I90 EB Station 416+50 to 425+00 adjacent to Exit 131 (formerly Exit 18)
- M65: I90 WB Station 440+50 to 441+50

Additional near-term recommendations include reinforcing sections of ribs that exhibit 100% section loss particularly at the following walls:

- M1A: Interchange 123 (formerly Interchange 14) Ramp C Station 1+50 to 2+50
- M61: I90 WB Station 412+75 to 414+00 adjacent to Cambridge Street
- M63B: Interchange 132 (formerly Interchange 20) Ramp C Station 28+00 to 29+50
- M63C: Interchange 132 (formerly Interchange 20) Ramp C Station 26+00 to 27+00
- M86: I90 WB Station 466+00 to 466+50 Pump Station PS2 Access Drive

Long term recommendations for the metal BIN walls include establishing a routine maintenance program for clearing overgrown vegetation and removing overburden.

Noise Barrier Walls

Near term recommendations for the noise barrier walls include replacing sections of timber facing that are fractured, split, or that are excessively bowed (NW2 and NW5) and removing and repairing cracked and delaminated sections of concrete along the underside of the precast concrete panels of NW1.

- NW2: I90 EB Station 93+50 to 97+00 between Lexington Ave and Commonwealth Avenue
- NW5: I90 EB between Commonwealth Avenue and Walnut Street
- NW1: Interchange 127 (formerly Interchange 17) Ramp B I90 EB Station 272+00 to 297+00

Long term recommendations for the noise barrier walls include establishing a routine maintenance program for clearing overgrown vegetation.

5.4.5 Sign Support Structures

Near term recommendations for the sign support structures include installing sign panels that are missing or that are illegible from posts; repairing deteriorated grout pads and treating exposed anchor rods with advanced corrosion protection; sealing cracks in the foundations that exhibit moderate to heavy efflorescence, dampness and/or rust staining and repairing spalls.
Vibration dampers were noted to be missing from some of the sign structures. It is recommended that the manufacturer's specifications be reviewed to determine if the following sign structures require a vibration damper.

- B16-HS-I0090E-135-600104: Ramp I/Ramp E-C & I Congress Street Intersection
- B16-HS-I0090E-137-600111: 1st Full Span east of TWT
- B16-HS-I0090W-132-600161: 0.1 Miles west of Commonwealth Overpass
- B16-HS-I0090W-137-600-125: 2nd Full Span West of Terminal A off ramp
- B16-HS-I0090W-600-140: Ramp S-T 1st Full Span from Harborside Drive
- I90 EB Between Beacon Street and St. Mary's Overpass
- I90 WB 100' east of St. Mary's Street Overpass

A hand-on inspection of the following two sign structures is recommended, and vertical clearance measurements should be taken, as these sign panels were observed as having traffic impact damage.

- South Boston Bypass Road at New Cypher Street
- South Boston Bypass Road West of Ramp A and Haul Road split.

Non-destructive testing is recommended on the foundation (anchor rods and welds at the base plate) of the sign structure located at Interchange 123 (formerly Interchange 14) Ramp A Turnpike East/West split from 128 NB as one of the four anchor rods was noted to be deformed from apparent collision damage.

Long term recommendations for the sign structures include cleaning and painting posts, chords and bracing members that exhibit failed coatings and varying degrees of corrosion; and removing sign structures that have not been in use over several Triennial Inspection cycles.

An additional recommendation is for MassDOT to revisit the current hands-on inspection frequency for sign support structures, and to not wait until all structures have received an Initial Inspection to implement the new intended frequency, as some signs have not received hands-on inspection since 2014.

5.4.6 Parks

Near term recommendations include replacement of broken wooden slats on the park bench and monitoring the pavement and concrete capital tops for safety and repair as necessary.

Long term recommendations include replacement of concrete capital tops with material more resilient to the environment.

6. Projected Expenditures

HNTB has developed a preliminary estimate of expenditures to align with the recommendations for repair identified in Section 5 of this report.

6.1 Cost Development

The cost projections have been developed based upon the Recommendations (i.e., rehabilitation, replacement, maintenance and other asset specific activities) laid out in Section 5 as well as additional input from MassDOT regarding ongoing and upcoming project initiatives. The projected costs for each asset class were developed through an extensive data collection and analysis program. The projections were determined assuming that repairs will be contracted out as opposed to being performed by MassDOT personnel.

Additionally, project factors were added to work tasks to account for the following items:

- Location – A value was included to projects to account for anticipated cost increase based on the project location (i.e., Tunnels, Fouling Railroad, Water, etc.).
- Traffic Control – A value was included to projects that will require traffic lane closures.
- Mobilization – A value of ten percent (10%) was added to all projects.
- Engineering – A value of twenty percent (20%) was added to all projects to account for items such as program management, survey services, design, permitting, right-of-way, construction phase engineering, material testing services and construction inspections.
- Contingency – A value of twenty percent (20%) was added to all projects to account for additional scope assigned during the design phase of the project.

6.1.1 Rehabilitation Cost

Rehabilitation costs represent the cost associated with bringing deficient items to a Satisfactory condition. These costs generally do not indicate the full cost to implement more comprehensive repairs or full replacement of items. The following steps were used in determining costs:

- Identify deficient condition (i.e., Section 3 – Summary of findings)
- Determine quantity of deficiency
- Determine work tasks that correct identified deficient conditions based upon industry recommended practices (i.e., Section 5 –Recommendations)
- Recommend a frequency for each maintenance/rehabilitation work task
- Calculate the cost of each work task. The cost development came from a series of sources including RS Means data or MassDOT Weighted Average Bid Prices on a case-by-case basis with regards to which was most comprehensive or representative of the work (Appendix E).

Additional budget could be applied by MassDOT to certain repairs to upgrade the condition of other items which may not be deficient at this time, but which will continue to deteriorate over time, or which may include obsolete equipment.

6.1.2 Replacement Cost

Replacement costs represent the cost associated with replacing an item that is beyond rehabilitation. Costs were determined based on past/present MassDOT projects and unit costs.

6.1.3 Maintenance Cost

Maintenance costs represent the cost associated with maintaining the MHS at the minimum acceptable service level. This level of effort varies from extremely minimal for signs to very extensive for Bridges and Tunnels.

6.1.4 Inspection Cost

Inspection costs represent the cost associated with bi-annual inspections of bridges, boat sections, culverts, and tunnels. These costs are based on the # of crew hours noted in MassDOT's 4D system multiplied by the rate cap, OH rate, and profit rate.

6.2 Expenditure Summary

The following tables present a summary of total projected expenditures in present day dollars and annualized project expenditures escalated 3% based on a 10-year planning period. The 10-year planning period is segmented into expenditures for near term (first 5 years) and long term (last 5 years).

HNTB recognizes that it may not be feasible for all Recommendations to occur within the 10-year planning period. The annualized project expenditures could extend into later years in order to fund construction and logically sequence the work. For example, due to the high traffic volumes and lack of alternative routes it would be very challenging to complete the major rehabilitation projects needed for the Sumner, Callahan, Prudential and CANA tunnels within a 10-year timeframe. However, these challenges only underscore the need for a deliberate and earnest plan to address these critical assets, which MassDOT has recognized and this report supports.

HNTB is aware that there are multiple funding sources available for investment on specific areas of the MHS (for example, air right contributions for repairs/maintenance of the Prudential Tunnel, CARM funding for lighting projects, etc.). This report does not distinguish funding source for the expenditures included.

The following tables and figure present a summary of projected expenditures based on asset location. To accomplish the goals set forth in the Recommendations, it is estimated that $2.09 Billion (Escalated dollars) will be needed over the next 10 years. The near-term expenditure (5-year) need is approximately $1.117 Billion (53.6% of total cost) while the long-term expenditure (10-year) need is approximately $967 Million (46.4% of total cost). On average approximately $209 Million is needed on an annual basis.

Figure 10 shows a relatively even distribution for near-term project expenditures between Boston Extension, Sumner/Callahan Tunnels, Central Artery and Allston Viaduct. However, the long-term project expenditures show a dramatic spike in spending within the Central Artery network. This can be mostly attributed to prioritizing repair of deficient bridges within the Boston Extension in the near-term and deferring scheduled maintenance and rehabilitation costs within the Central Artery to long-term expenditures.

Sections 6.3 through 6.6 provide supporting data by asset class for the overall cost projection. Additional supporting information for the expenditure data can be found in Appendix E.

Table 34: Total Projected MHS Expenditures – By Location – Present Day ($M)

Location	FY22-FY31
Central Artery	$839
CANA	$68
Sumner/Callahan	$214
Boston Extension (Excluding Allston & Int. 123, formerly 14/15)	$407
Interchange 123, formerly 14/15 (Bridge Replacement Only)	$44
Allston Viaduct (Bridge Replacement Only)	$265
MHS TOTAL	**$1,838**

Table 35: Annualized Projected MHS Expenditures – By Location – Escalated ($M)

Location	FY 22	FY 23	FY 24	FY 25	FY 26	Near Term FY22-FY26	FY 27	FY 28	FY 29	FY 30	FY 31	Long Term FY27-FY31
Central Artery	$51	$53	$54	$56	$58	$272	$135	$139	$144	$148	$152	$718
CANA	$13	$13	$14	$14	$15	$69	$1	$1	$1	$1	$1	$5
Sumner/Callahan	$37	$38	$39	$40	$41	$195	$7	$7	$7	$8	$8	$37
Boston Extension (Excluding Allston & Int. 123, formerly 14/15)	$55	$56	$58	$60	$62	$291	$31	$32	$33	$34	$35	$164
Interchange 123, formerly 14/15 (Bridge Replacement Only)	$4	$4	$5	$5	$5	$23	$5	$5	$6	$6	$6	$28
Allston Viaduct (Bridge Replacement Only)	$50	$52	$53	$55	$57	$267	$3	$3	$3	$3	$3	$16
MHS TOTAL	**$210**	**$217**	**$223**	**$230**	**$237**	**$1,117**	**$182**	**$188**	**$193**	**$199**	**$205**	**$967**

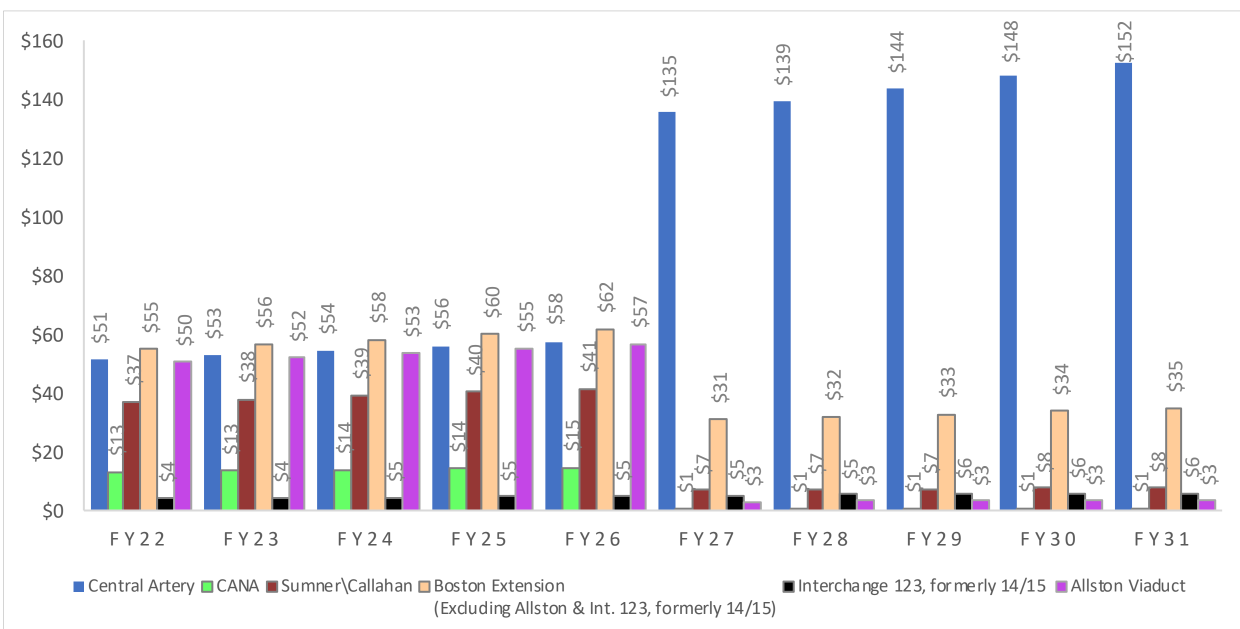

Figure 10: Annualized Projected MHS Expenditures – By Location – Escalated ($M)

Figure 11 and Figure 12 show the near and long term project expenditures respectively. Near term expenditures (FY22 – FY26) are distributed as follows, 52% is within the Boston Extension (including Allston Viaduct and Interchange 123, formerly 14/15), 24% is within the Central Artery and the remaining 24% is shared between Sumner/Callahan/CANA tunnels. Long term expenditures (FY27 – FY31) are distributed as follows, 22% is within the Boston Extension (including Allston Viaduct and Interchange 123, formerly 14/15), 74% is within the Central Artery and the remaining 4% is shared between Sumner/Callahan/CANA tunnels.

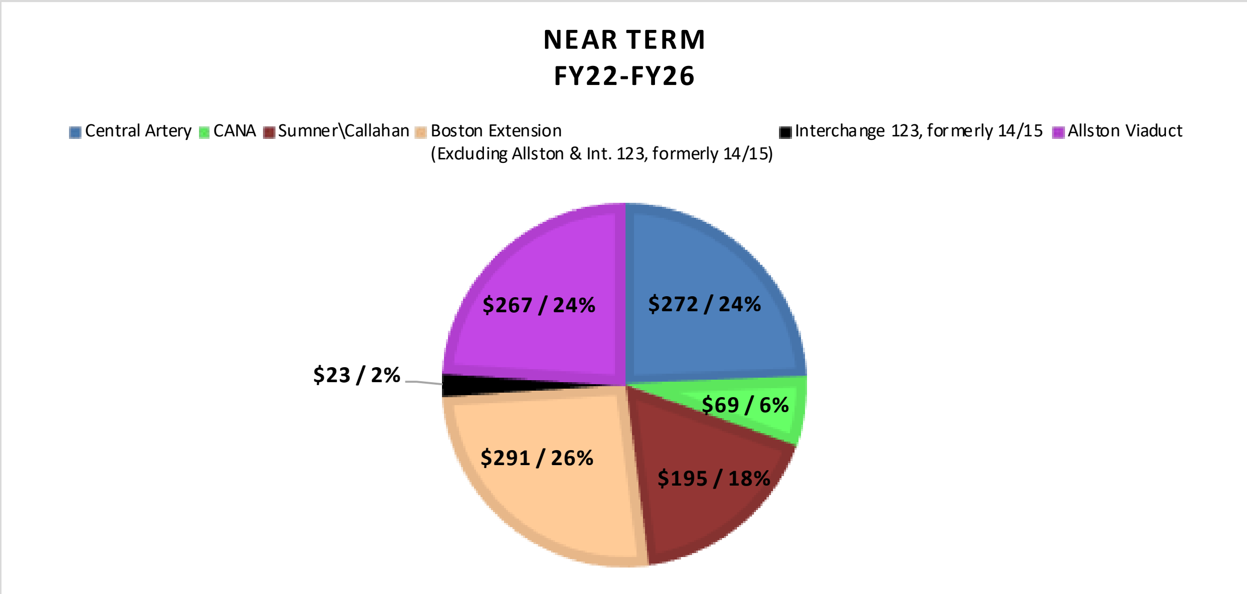

Figure 11: Projected Expenditures – By MHS Location – Near Term - Escalated ($M)

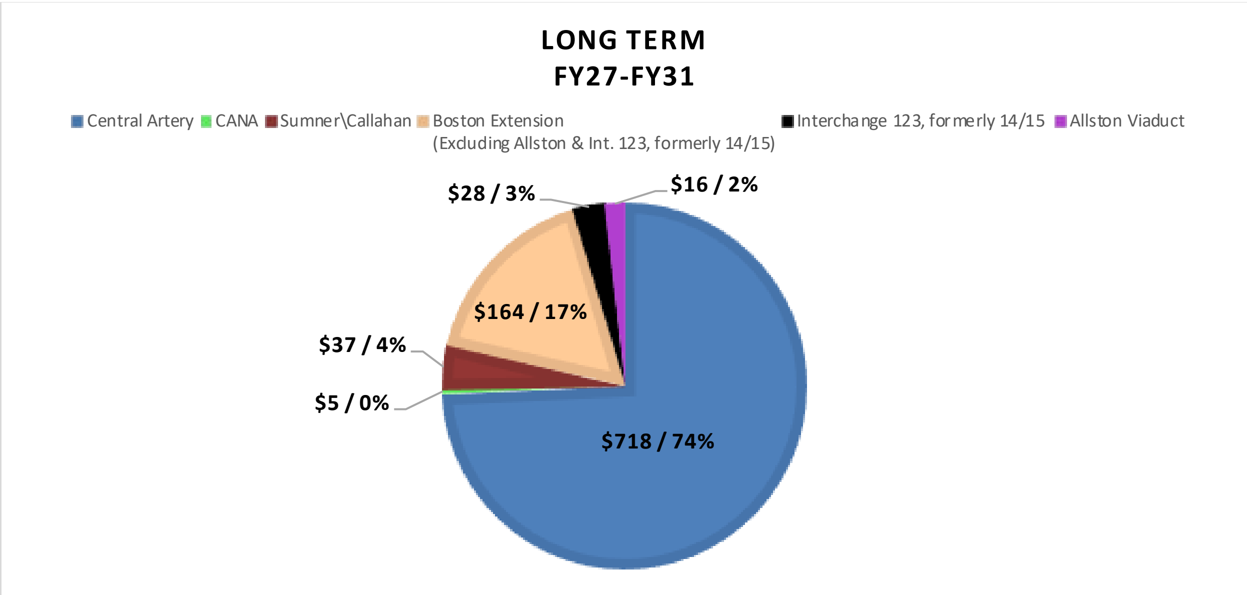

Figure 12: Projected Expenditures – By MHS Location – Long Term - Escalated ($M)

The following tables and figure present a summary of projected expenditures based on asset class.

Table 36: Total Projected MHS Expenditures – By Asset Class - Present Day ($M)

Location	FY22-FY31
Tunnel & Boat Sections	$755
Bridges	$887
Buildings	$84
Roadway	$112
MHS TOTAL	**$1,838**

Table 37: Annualized Projected MHS Expenditures – By Asset Class – Escalated ($M)

Location	FY22	FY23	FY24	FY25	FY26	Near Term FY22-FY26	FY27	FY28	FY29	FY30	FY31	Long Term FY27-FY31
Tunnel & Boats	$104	$107	$111	$114	$117	$554	$54	$56	$58	$59	$61	$288
Bridges	$86	$88	$91	$94	$96	$455	$106	$109	$113	$116	$120	$564
Buildings	$9	$9	$9	$9	$10	$46	$10	$10	$10	$10	$11	$51
Roadway	$12	$12	$13	$13	$13	$63	$12	$13	$13	$13	$14	$65
Total	**$210**	**$217**	**$223**	**$230**	**$237**	**$1,117**	**$182**	**$188**	**$193**	**$199**	**$205**	**$967**

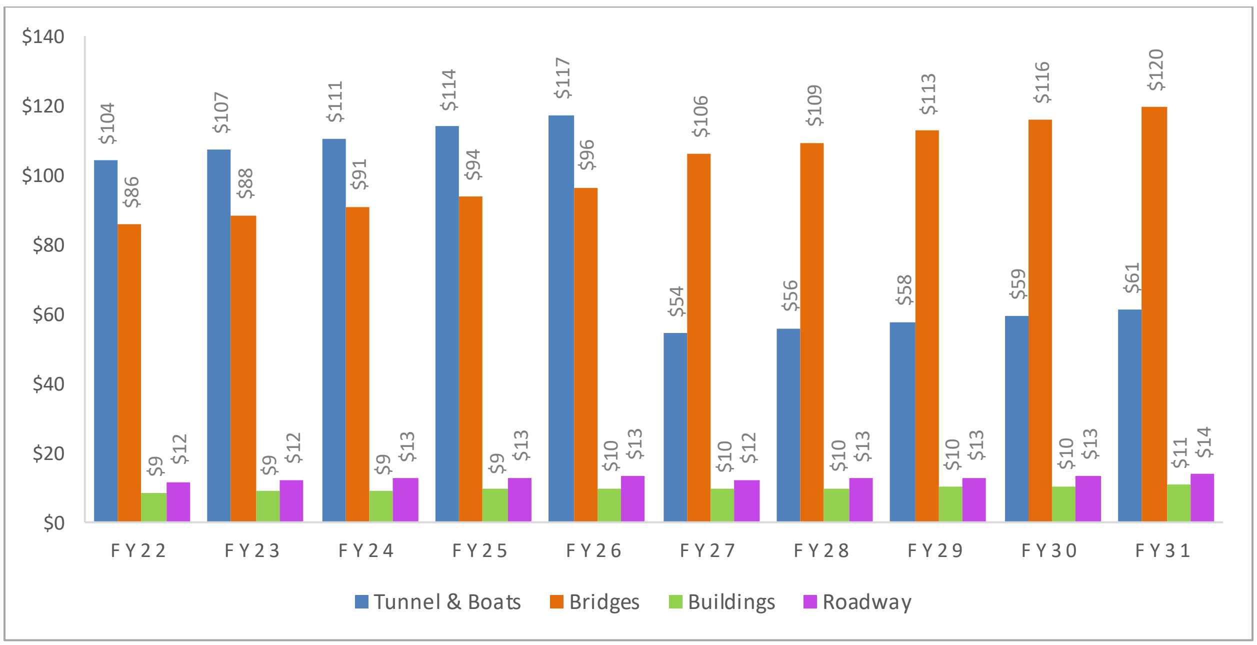

Figure 13: Annualized Projected Expenditures – All MHS Assets – Escalated ($M)

Figure 14 and Figure 15 show the near and long term project expenditures respectively. Near term expenditures (FY22 – FY26) are distributed as follows, 41% is Bridge (including Allston Viaduct), 49% is Tunnel, 6% is Roadway and 4% is Buildings. Long term expenditures (FY27 – FY31) are distributed as follows, 58% is Bridge, 30% is Tunnel, 7% is Roadway and 5% is Buildings.

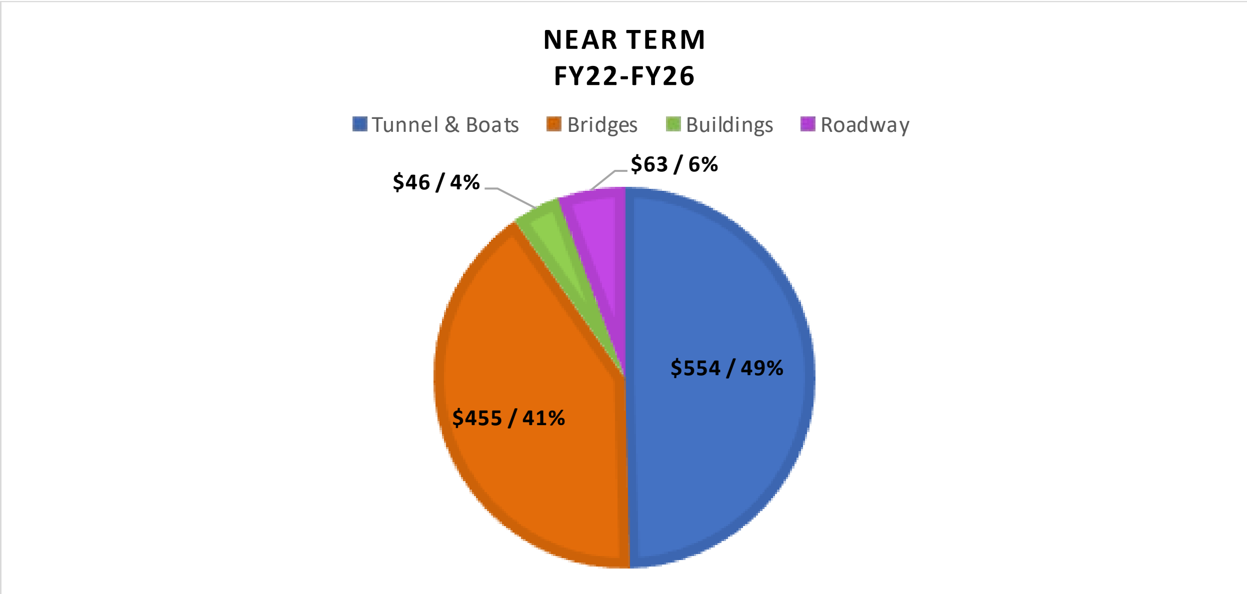

Figure 14: Projected Expenditures – By Asset – Near Term - Escalated ($M)

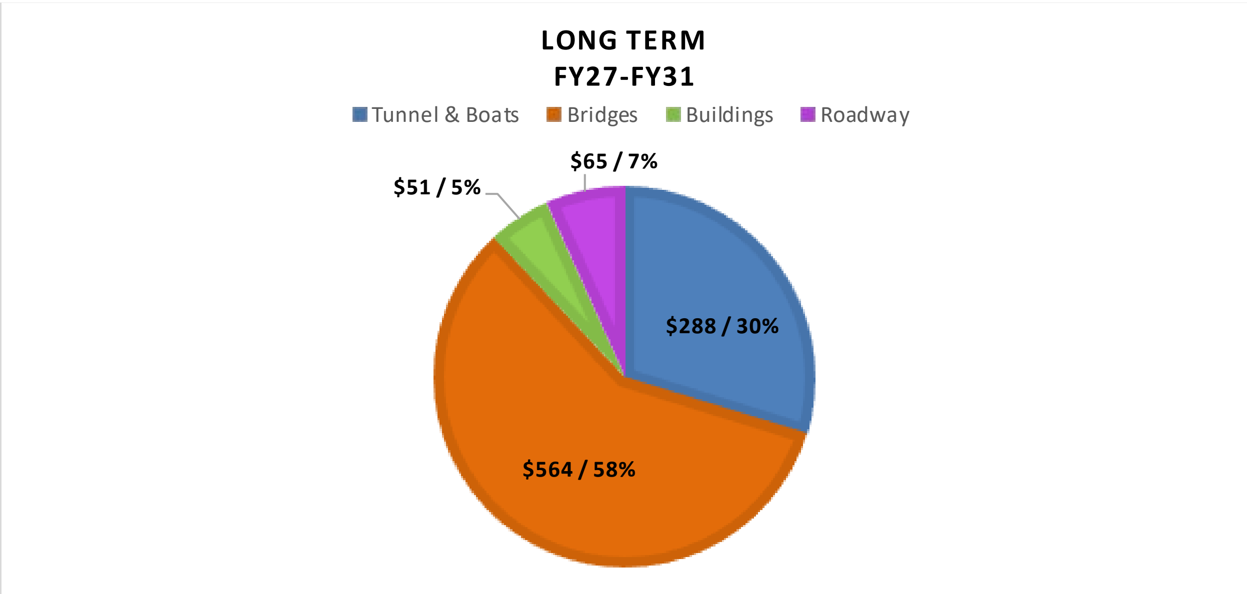

Figure 15: Projected Expenditures – By Asset – Long Term - Escalated ($M)

6.3 Tunnels/Boat Sections

The following is the cost expenditure breakdown of the Tunnel/Boat Sections Recommendations noted in Section 5.1. These costs are in 2021 dollars.

Repairs to address deficient findings in order to maintain the MHS in safe and good repair, working order and condition: **$25,686,796 (Total for 10 years)**

Near Term (Assumed to occur within next 5 years): $14,550,116

- Structural: $9,157,255
- Mechanical: $2,563,073
- Electrical: $2,829,788

Long Term (Assumed to occur within the last 5 years): $11,136,681

- Structural: $5,452,078
- Mechanical: $3,084,630
- Electrical: $2,599,973

Near/Long Term Repair Types

Structural

- Concrete Crack Repair
- Concrete Repair
- General Maintenance
- Joint Sealant
- Manhole Frame Cover
- Painting
- Small Structural Repair
- Structural Steel Repair
- Surface Repairs

Mechanical

- General Maintenance
- Mechanical Maintenance
- Replace Fan
- Access Doors Procurement
- CCTV Cameras Procurement
- Sump Pump Procurement

Electrical

- Electrical Repairs
- Replace Light Fixtures
- Wire and Conduit Removal
- Cable and Conduit Install
- Enclosure Procurement
- Junction Box Cover

Large Capital Projects

Projects are in various phases of design development and construction; costs reflect current project estimates provided by MassDOT: **$584,639,000 (Total for 10 years)**

- All Tunnels
  - Project #607137 General Water Intrusion, Leak Sealing, Fireproofing and Miscellaneous repairs at an Estimated Construction Cost of $14,2500,000. Construction is 76% completed based on MassDOT Project Info with a remaining Estimate Construction Cost of **$3,420,000**.
- Sumner Tunnel
  - Project #606476 Roadway, Ceiling, Architectural, and Wall Reconstruction and Other Control Systems. Advertised on 6/26/21 with an Estimated Construction Cost of **$137,000,000.**
  - Project #606660 (Const. Cont. 113976) Sumner and Callahan Tunnel Vent Building & Pump Station Mechanical and Electrical Improvements. Construction began Summer 2021 with an Estimated Construction Cost of **$37,249,000.**
- Callahan Tunnel
  - Project #608247 Ceiling Reconstruction, New Jet Fans, and Other Control Systems in Preliminary Design Phase with an Estimated Construction Cost of **$20,100,000**. Currently not funded. (Cost and project information were obtained from MassDOT's PINFO system, but these likely need to be reevaluated.)
- CANA Tunnel
  - Project #606859 Electrical System Upgrades, PLC Control Upgrades and Facility Improvements in 25% Design Phase with and Estimated Construction Cost of **$61,000,000.**
- Prudential Tunnel
  - Project #610894 Tunnel Lighting Rehabilitation with anticipated bid opening on 9/08/21 with and Estimated Construction Cost of **$40,000,000.**
  - Project #609124 Prudential Tunnel Ventilation System Rehabilitation project was deferred with an Estimated Construction Cost of **$57,200,000.**
- Ted Williams
  - Project #609121 Lighting Repairs which began construction in the Summer of 2019 at an Estimated Construction Cost of $32,5000,000. Construction is 57% completed based on MassDOT Project Info with a remaining Estimate Construction Cost of **$13,975,000**.
- I-93 Tip O'Neill Tunnel
  - Project #609122 Lighting Repairs along the Mainline which was advertised on 11/23/19 with an Estimated Construction Cost of $32,500,000. Construction is 18% complete based on MassDOT Project Info with a remaining Estimated Construction Cost of **$26,445,000**.
  - Project #607079 Leak Sealing, Fireproofing and Miscellaneous Repairs which in in Preliminary Design Phase with an estimated Construction Cost of **$650,000**
  - Project #609346 Lighting Repairs along the Ramps which is in 25% Design Phase with an Estimated Construction Cost of **$43,000,000**

- I-90 EB/WB Connector Tunnel
    - Project #609318 Roadway Lighting Replacement which is at PS&E Design Phase with an Estimated Construction Cost of **$58,000,000**
    - Project #607884 Fire Standpipe Support Repairs on I90 & Associated Ramps which is in Preliminary Design Phase with an Estimated Construction Cost of **$1,300,000**
    - Project #609343 Roadway Lighting Replacement which is at 75% Design Phase with an Estimated Construction Cost of **$27,000,000.**
- Dewey Square Vent Stack Exterior: Project #606801 Vent Stack Exterior Replacement I-93 Fan Chambers in preliminary design with an estimated construction cost of **$12,3000,000.**

Maintenance Costs: $11M/ Year (Based on 0.15% of Tunnel Insured Value): **$11,000,000 (per year)**

- Central Artery: **$8,500,000**
- CANA: **$500,000**
- Sumner\Callahan: **$1,000,000**
- Boston Extension: **$1,000,000**

Bi-Annual Inspections: $3.5M/Year for entire MHS (Weighted based on insured values): **$3,500,000 (per year)**

- Central Artery: **$2,704,545**
- CANA: **$159,091**
- Sumner\Callahan: **$318,182**
- Boston Extension: **$318,182**

The projected expenditures include near/long term repairs addressing structural and MEP deficiencies, large capital projects, annual routine maintenance costs and Bi-Annual Inspections for the MHS tunnels/boat sections (cost in $ millions per year).

Table 38: Total Projected Expenditures – Tunnels/Boat Sections - Present Day ($M)

Location	FY22-FY31
Central Artery	$365.40
CANA	$67.60
Sumner\Callahan	$211.02
Boston Extension	$111.31
MHS TOTAL	$755.33

Table 39: Annualized Projected Expenditures – Tunnels/Boat Sections – Escalated ($M)

Location	FY22	FY23	FY24	FY25	FY26	Near Term FY22-FY26	FY27	FY28	FY29	FY30	FY31	Long Term FY27-FY31
Central Artery	$34.1	$35.1	$36.1	$37.2	$38.3	$180.8	$45.2	$46.6	$48.0	$49.4	$50.9	$240.2
CANA	$12.9	$13.2	$13.6	$14.1	$14.5	$68.3	$0.8	$0.8	$0.8	$0.8	$0.9	$4.1
Sumner\ Callahan	$36.5	$37.6	$38.7	$39.9	$41.1	$193.8	$6.6	$6.8	$7.0	$7.2	$7.4	$35.1
Boston Extension	$20.9	$21.5	$22.1	$22.8	$23.5	$110.7	$1.6	$1.7	$1.7	$1.8	$1.8	$8.7
MHS TOTAL	**$104.3**	**$107.4**	**$110.6**	**$113.9**	**$117.4**	**$553.6**	**$54.3**	**$55.9**	**$57.6**	**$59.3**	**$61.1**	**$288.0**

6.4 Bridges/Culverts

The following is the cost expenditure breakdown of the Bridge/Culverts Recommendations noted in Section 5.2. These costs are in 2021 dollars.

Repairs to address deficient findings in order to maintain the MHS in safe and good repair, working order and condition: **$510,163,264 (Total for 10 years)**

Near Term (Assumed to occur within next 5 years): **$402,231,656**

- Bridges with Minimum Ratings ≤ 4 and Average Rating ≤ 5.0 Recommend Full Bridge Replacement
    - Bridge Replacement = $831/SF of Bridge Deck Area
- Bridges with Minimum Ratings ≤ 4 and Average Rating >5.0 Recommend Targeted Replacement/Repairs
    - Deck Replacement = $371/SF of Bridge Deck Area (for Rating = 4 or 5)
    - Deck Repair (Partial Depth) = $82/SF of Bridge Deck Area (assume 30% of deck area for Ratings = 6)
    - Steel Repairs with Cleaning and Painting = $135/SF of Bridge Deck Area (assume 50% of deck area for Ratings = 4, 30% of the deck area for Ratings = 5 and 10% of the deck area for Ratings = 6)
    - Substructure Repair = 1.5*$70,607/Substructure Unit (Pier, Abutment, Culvert) = $105,910 for Rating = 4 $70,607 for Ratings = 5 and $35,304 for Rating = 6

Long Term (Assumed to occur within the last 5 years): **$107,931,607**

- Bridge Structural Ratings = 5 or 6
- Rating = 5 (Repair Deck, Superstructure and Substructure)
    - Deck Repair (Partial Depth) = $82/SF of Bridge Deck Area (assume 50% of deck area)
    - Superstructure Repair = $135/SF of Bridge Deck Area assuming 30% of the deck area
    - Substructure Repair = $70,607/Substructure Unit (Pier, Abutment, Culvert)
- Rating = 6 (Repair Deck, Superstructure and Substructure using 1/2 Cost for Substructure Repairs
    - Deck Repair (Partial Depth) = $82/SF of Bridge Deck Area (assume 30% of deck area)
    - Superstructure Repair = $135/SF of Bridge Deck Area assuming 10% of the deck area
    - Substructure Repair = $35,304/Substructure Unit (Pier, Abutment, Culvert)

Maintenance Costs: **$376,349,130 (Total for 10 years)**

- Annual Maintenance: **$5,203,187 (per year)**
    - Asphalt Pavement Patching = $21/SF of Bridge Roadway Area
        - Assume 3" repair depth
        - Repair Quantity = 1% of Bridge Roadway Area needed per year
    - Scupper/Drain Cleaning = $282 Each
        - Assume 10 scuppers per bridge cleaned per year
    - Power Wash Bridge = $0.30/SF of Bridge Deck Area
    - Pavement Crack Sealing = $2/LF of Bridge Roadway Area
        - Assumed Repair Quantity = 1 LF for every 100 SF of Bridge Roadway Area.
    - Bi-Annual Inspections: Based upon 4D Inspection Hours x $186 /hr.

- Maintenance Scheduled Once every 10 years: **$324,317,265 (Total for 10 years)**
    - Patch Concrete Deck = $531/SF of Bridge Deck Area
        - Assume 7" repair depth
        - Assume Repair Quantity = 5% of Bridge Deck Area

- Paint Bridge = $60/SF of Bridge Deck Area
- Wearing Surface & Membrane = $14/SF of Bridge Deck Area
  - Assume 3" wearing surface
- Deck Joint Gland Replacement = $88/LF of Bridge Deck Area
  - Assume number of joints is number of spans + 1

The projected expenditures include the routine maintenance costs for MHS bridges annually, the bridge rehabilitation/replacement costs within the next five years, and the scheduled preventative maintenance costs on a rotating 10-year basis (cost in $ millions per year).

Table 40: Total Projected Expenditures – Bridges – Present Day ($M)

Location	FY22-FY31
Central Artery	$337.32
CANA	N.A.
Sumner\Callahan	N.A.
Boston Extension (Excluding Allston & Int. 123, formerly 14/15)	$239.98
Interchange 123 (formerly 14/15)	$44.24
Allston Viaduct	$264.97
MHS TOTAL	**$886.51**

Table 41: Annualized Projected Expenditures – Bridges – Escalated ($M)

Location	FY22	FY23	FY24	FY25	FY26	Near Term FY22-FY26	FY27	FY28	FY29	FY30	FY31	Long Term FY27-FY31
Central Artery	$3.3	$3.4	$3.5	$3.6	$3.7	$17.4	$74.4	$76.6	$78.9	$81.3	$83.7	$395.0
CANA	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Sumner\ Callahan	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Boston Extension (Excluding Allston & Int. 123, formerly 14/15)	$27.7	$28.5	$29.4	$30.2	$31.2	$146.9	$23.6	$24.3	$25.0	$25.7	$26.5	$125.1
Interchange 123 (formerly 14/15)	$4.3	$4.5	$4.6	$4.7	$4.9	$23.0	$5.2	$5.4	$5.5	$5.7	$5.9	$27.7
Allston Viaduct	$50.4	$51.9	$53.4	$55.0	$56.7	$267.3	$3.1	$3.2	$3.3	$3.3	$3.4	$16.3
MHS TOTAL	**$85.6**	**$88.2**	**$90.9**	**$93.6**	**$96.4**	**$454.7**	**$106.3**	**$109.4**	**$112.7**	**$116.1**	**$119.6**	**$564.1**

Note: The dollar amount shown represents the bridge portion of the projects (replaced in kind) and may not equal the whole project value (asset expansion, improvements to adjacent roadways, Right-of-Way, etc.). For example, the cost included in this report for the Allston Viaduct includes replacement of the three structurally deficient bridges in-kind and does not include the realignment of I-90 and other infrastructure improvements currently proposed for the project.

Table 42: Projected Expenditures – Existing/Future MHS Bridge Projects – Estimated ($M)

Location	Bridge	BIN	MassDOT Project	Notes
Boston Extension (Allston Viaduct)	B16359	4RY 4RX	606475	**BOSTON- REPLACEMENT OF ALLSTON I-90 ELEVATED VIADUCT, B-16-359, INCLUDING INTERCHANGE RECONSTRUCTION BEACON PARK YARD LAYOVER & WEST STATION** The project involves the complete replacement of the elevated viaduct, realignment of I-90, reconstruction of interchange and connecting ramps, reconstruction of Cambridge Street, reconstruction of Beacon Park Yard to accommodate an MBTA commuter rail layover facility, and construction of West Station.
	B16369	4RT		
	B16359	4RY 4RX	612231	**BOSTON- BRIDGE PRESERVATION, B-16-359, I-90 (EB & WB) OVER MBTA** The project involves the rehabilitation of the elevated viaduct of I-90 over MBTA.
Boston Extension (Interchange 123, formerly 14/15)	W29057 N12066 N12067 N12073 W29055 W29058 N12065 N12064	4QE 4QK 4QN 4QM 4QD 4QG 4QL 4QJ	606783	**NEWTON- WESTON- BRIDGE REHAB, N-12-066, N-12-073, N-12-067, (STR 9, 10 & 11) I-90/I-95, CHARLES RIVER, CHARLES STREET & MBTA/CSX & N-12-078=W-29-062 & 3 RAMP G BRIDGES (DB)** Widening and deck replacement on Structure 9. Widening of Structure 10. Superstructure and deck replacement of Structure 11.

As shown in Table 42, three of the eighteen structurally deficient bridges are currently programed and funded with a specific MassDOT project associated with the Allston Viaduct in Cambridge. MassDOT is pursuing options to advance a project for two structurally deficient bridges located at Interchange 123 (formerly Interchange 14/15) in Weston. It is recommended that programed projects for Allston Viaduct and the Weston interchange be advanced as full bridge replacements. The remaining 13 structurally deficient bridges have not been allocated funds and add up to a cost of approximately $132 million dollars.

6.5 Building Structures

6.5.1 Buildings

The following is the cost expenditure breakdown of the Buildings Recommendations noted in Section 5.3.1. These costs are in 2021 dollars.

Repairs to address deficient findings in order to maintain the MHS in safe and good repair, working order and condition:

Building Near Term Repairs: **$3,559,367**

Location	Structural Repairs	Mechanical Repairs	Electrical Repairs
Admin/Service Building	$58,162	$30,177	$203,426
Maintenance Building	$111,812	$42,579	$315,610
Salts Sheds	$23,546	$13,102	$30,752
Electrical Substations	$31,374	$82,322	$74,699
Parking Garages	$9,147	N.A.	N.A.
Toll Plazas	$10,757	$59,533	$48,882
Vent Buildings	$821,441	$216,297	$1,149,839
Air Intake Buildings	$10,224	$10,966	$36,192
Misc. Buildings	$7,178	$10,414	$150,939
MHS	$1,083,641	$465,389	$2,010,338

Building Long Term Repairs: **$1,525,269**

Location	Structural Repairs	Mechanical Repairs	Electrical Repairs
Admin/Service Building	$31,357	$5,651	$214,550
Maintenance Building	$65,464	$0	$46,521
Salts Sheds	$13,500	$0	$0
Electrical Substations	$8,271	$3,448	$17,163
Parking Garages	$0	N.A.	N.A.
Toll Plazas	$33,628	$0	$2,154
Vent Buildings	$165,577	N.A.	$903,021
Air Intake Buildings	$0	$0	$0
Misc. Buildings	$14,964	$0	$0
MHS	$332,761	$9,099	$1,183,409

Maintenance Costs are determined based on a percentage of the Buildings insured value: **$71,200,000 (Total for 10 years)**

- 0.5% - Building in Good condition state
- 1.0% - Building in Fair condition state
- 2.0% - Building in Poor condition state

The projected expenditures include building structural repairs, electrical repairs, mechanical repairs and annual routine maintenance costs based on building condition for the MHS Buildings (cost in $ millions per year).

Table 43: Total Projected Expenditures – Buildings – Present Day ($M)

Location	FY22-FY31
Admin/Service Building	$9.14
Maintenance Building	$4.78
Salts Sheds	$0.78
Electrical Substations	$2.62
Parking Garages	$4.21
Toll Plazas	$0.55
Vent Buildings	$52.16
Air Intake Buildings	$1.76
Miscellaneous Buildings	$0.28
MHS TOTAL	$76.28

Table 44: Annualized Projected Expenditures – Buildings – Escalated ($M)

Location	FY22	FY23	FY24	FY25	FY26	Near Term FY22-FY26	FY27	FY28	FY29	FY30	FY31	Long Term FY27-FY31
Admin/Service Building	$0.92	$0.95	$0.97	$1.00	$1.03	$4.88	$1.06	$1.09	$1.12	$1.15	$1.19	$5.60
Maintenance Building	$0.51	$0.53	$0.55	$0.56	$0.58	$2.73	$0.51	$0.53	$0.54	$0.56	$0.58	$2.72
Salts Sheds	$0.08	$0.09	$0.09	$0.09	$0.09	$0.44	$0.08	$0.09	$0.09	$0.09	$0.09	$0.45
Electrical Substations	$0.28	$0.29	$0.29	$0.30	$0.31	$1.47	$0.28	$0.29	$0.30	$0.31	$0.32	$1.51
Parking Garages	$0.42	$0.43	$0.45	$0.46	$0.47	$2.24	$0.49	$0.50	$0.52	$0.53	$0.55	$2.58
Toll Plazas	$0.06	$0.07	$0.07	$0.07	$0.07	$0.34	$0.05	$0.06	$0.06	$0.06	$0.06	$0.29
Vent Buildings	$5.33	$5.49	$5.65	$5.82	$6.00	$28.28	$5.92	$6.09	$6.28	$6.47	$6.66	$31.41
Air Intake Buildings	$0.18	$0.19	$0.19	$0.20	$0.20	$0.96	$0.20	$0.20	$0.21	$0.22	$0.22	$1.05
Misc. Buildings	$0.04	$0.05	$0.05	$0.05	$0.05	$0.23	$0.02	$0.02	$0.02	$0.02	$0.02	$0.08
MHS TOTAL	**$7.83**	**$8.07**	**$8.31**	**$8.56**	**$8.81**	**$41.58**	**$8.61**	**$8.87**	**$9.13**	**$9.41**	**$9.69**	**$45.70**

6.5.2 Communication Facilities

The following is the cost expenditure breakdown of the Communication Facilities Recommendations noted in Section 5.3.2. These costs are in 2021 dollars.

Repairs to address deficient findings in order to maintain the MHS in safe and good repair, working order and condition:

Mechanical: **$3,635 (Total for 10 years)**
- Small General Maintenance

Electrical: **$12,909 (Total for 10 years)**
- Small General Maintenance

Maintenance Costs: **$74,599 (Total for 10 years)**
- Communication Facilities maintenance costs are determined based on 0.5% percent of the Buildings insured value.

The projected expenditures include minor general repairs and annual routine maintenance costs (cost in $ millions per year).

Table 45: Total Projected Expenditures – Communication Facilities – Present Day ($M)

Location	FY22-FY31
Central Artery	N.A.
CANA	N.A.
Sumner\Callahan	N.A.
Boston Extension	$0.09
MHS TOTAL	**$0.09**

Table 46: Annualized Projected Expenditures – Communication Facilities – Escalated ($M)

Location	FY22	FY23	FY24	FY25	FY26	Near Term FY22-FY26	FY27	FY28	FY29	FY30	FY31	Long Term FY27-FY31
Central Artery	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
CANA	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Sumner\Callahan	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Boston Extension	$0.01	$0.01	$0.01	$0.01	$0.01	$0.06	$0.01	$0.01	$0.01	$0.01	$0.01	$0.05
MHS TOTAL	**$0.01**	**$0.01**	**$0.01**	**$0.01**	**$0.01**	**$0.06**	**$0.01**	**$0.01**	**$0.01**	**$0.01**	**$0.01**	**$0.05**

6.5.3 Pump Stations

The following is the cost expenditure breakdown of the Pump Stations Recommendations noted in Section 5.3.3. These costs are in 2021 dollars.

Repairs to address deficient findings in order to maintain the MHS in safe and good repair, working order and condition: **$378,033 (Total for 10 years)**

Structural Repairs: $46,642
Mechanical Repairs: $73,197
Electrical Repairs: $258,194

Maintenance Costs: **$7,687,148 (Total for 10 years)**

Pump Station maintenance costs are determined based on 0.5% percent of the Buildings insured value.

- Central Artery Tunnel: $5,088,249
- CANA: $281,689
- Sumner/Callahan: $1,227,873
- Boston Extension: $1,089,336

The projected expenditures include repairs addressing MEP deficiencies and annual routine maintenance costs (cost in $ millions per year).

Table 47: Total Projected Expenditures – Pump Stations – Present Day ($M)

Location	FY22-FY31
Central Artery	$5.44
CANA	$0.28
Sumner\Callahan	$1.23
Boston Extension	$1.12
MHS TOTAL	**$8.07**

Table 48: Annualized Projected Expenditures – Pump Stations – Escalated ($M)

Location	FY22	FY23	FY24	FY25	FY26	Near Term FY22-FY26	FY27	FY28	FY29	FY30	FY31	Long Term FY27-FY31
Central Artery	$0.56	$0.58	$0.59	$0.61	$0.63	$2.97	$0.61	$0.63	$0.65	$0.67	$0.69	$3.25
CANA	$0.03	$0.03	$0.03	$0.03	$0.03	$0.15	$0.03	$0.03	$0.03	$0.04	$0.04	$0.17
Sumner\Callahan	$0.12	$0.13	$0.13	$0.13	$0.14	$0.65	$0.14	$0.15	$0.15	$0.16	$0.16	$0.76
Boston Extension	$0.11	$0.12	$0.12	$0.12	$0.13	$0.60	$0.13	$0.13	$0.13	$0.14	$0.14	$0.67
MHS TOTAL	**$0.82**	**$0.85**	**$0.87**	**$0.90**	**$0.93**	**$4.38**	**$0.91**	**$0.94**	**$0.97**	**$1.00**	**$1.03**	**$4.86**

6.6 Roadways

6.6.1 Roadway

The following is the cost expenditure breakdown of the Roadway Recommendations noted in Section 5.4.1. These costs are in 2021 dollars.

Repairs to address deficient findings in order to maintain the MHS in safe and good repair, working order and condition:

Near Term (Assumed to occur within next 5 years): **$626,199 (Total for 10 years)**

- Roadway Section Ratings ≤ 5
- Isolated Deficiencies

Near Term Repair Types

- Anchor Bolts
- Concrete Repair - Roadway
- Crushed Stone
- Drainage Structure Rebuilt
- Drop Inlet
- Flashing Arrows material
- Manhole Frame and Cover
- General Maintenance (With Forklift)
- General Maintenance (Without Forklift)
- Granite Curb
- Guardrail Removed and Replaced
- Guardrail TL-2
- Handhole Box
- Impact Attenuator Repairs
- Junction Box Cover
- Light or Flag Pole with Foundation
- Loam and Seed
- Nosing Section Material
- Pavement Marking Arrows
- Pavement Marking Removal
- Pavement Placement
- Pavement Standard Milling
- Remove and Replace Traffic Sign
- Roadway Light Fixture
- Sign Alum. Panel
- Sign Post - 2 Inch Steel
- Small Electrical Crew
- Superpave Surface Course
- Thermoplastic Pavement Markings
- Traffic Maintenance Crew
- Tree Removal 24" and under

Long Term (Assumed to occur within next 5 years): **$1,157,432 (Total for 10 years)**

- Roadway Section Ratings ≤ 5
- Isolated Deficiencies

Long Term Repair Types

- CIP Concrete Barrier
- Concrete Repair - Roadway
- Curb Removal and Reset
- Drop Inlet
- Gate Fence
- Granite Curb
- Guardrail TL-2
- Install New Chain Link Fence
- Light or Flag Pole with Foundation
- Manhole Frame and Cover
- Pavement Standard Milling
- Precast Concrete Barrier
- Remove Chain Link Fence
- Replace Light Fixture
- Small Electrical Crew
- Superpave Surface Course

Annual Maintenance Costs: **$2,046,896 (per year)**

- Catch Basin Cleaning = $2,472/Day (Assumed work rate = 1/2 Mile per Day)
- Trash & Debris Removal = $2,472/Day (Assumed work rate = 2 Miles per Day)
- Washout Repairs = $4,215 Each (Assumed 2 per Mile)
- Crash Attenuator Replacement = 43,200 Each (Assume 25 replacements required for entire MHS)
- Guardrail Repairs = $50/LF (Assume 120 LF of repair per mile of roadway)
- Fence Repairs = $76/LF (Assume 1% of roadway length)
- Mowing = $320/Mile (Assume performed 2 times annually)
- Vegetation Control = $640/Mile (Assume 20% of Bos. Ext. roadway)

The projected expenditures include near term repairs addressing roadway deficiencies and annual routine maintenance costs (cost in $ millions per year).

Table 49: Total Projected Expenditures – Roadway – Present Day ($M)

Location	FY22-FY31
Central Artery	$11.68
CANA	N.A.
Sumner\Callahan	N.A.
Boston Extension	$10.57
MHS TOTAL	**$22.25**

Table 50: Annualized Projected Expenditures – Roadway – Escalated ($M)

Location	FY22	FY23	FY24	FY25	FY26	Near Term FY22-FY26	FY27	FY28	FY29	FY30	FY31	Long Term FY27-FY31
Central Artery	$1.11	$1.15	$1.18	$1.22	$1.25	$5.92	$1.42	$1.46	$1.50	$1.55	$1.59	$7.52
CANA	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Sumner\Callahan	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Boston Extension	$1.06	$1.09	$1.12	$1.15	$1.19	$5.61	$1.22	$1.26	$1.30	$1.34	$1.38	$6.50
MHS Total	**$2.17**	**$2.24**	**$2.30**	**$2.37**	**$2.44**	**$11.53**	**$2.64**	**$2.72**	**$2.80**	**$2.89**	**$2.97**	**$14.02**

6.6.2 Interchanges

The following is the cost expenditure breakdown of the Interchanges Recommendations noted in Section 5.4.2. These costs are in 2021 dollars.

Repairs to address deficient findings in order to maintain the MHS in safe and good repair, working order and condition:

Near Term (Assumed to occur within next 5 years): **$781,371 (Total for 10 years)**

- Interchange Ratings ≤ 5
- Isolated Deficiencies

Near Term Repair Types

- Small General Maintenance
- Large General Maintenance
- Small Electrical Repair
- Vegetation Clearing
- Fencing
- Fencing Demolition
- Railing
- Demolish Railing
- Manhole
- Manhole Demolition
- Sign Removal (0 - 10 SF)
- Sign (30" x 30")
- Sign (12" x 18")
- Sign (18" x 24")
- Delineator
- Concrete Barrier
- Mobilization
- Gravel Borrow

Maintenance Costs: **$319,721 (per year)**

- Catch Basin Cleaning = $2,472/Day (Assumed work rate = 1/2 Mile per Day)
- Trash & Debris Removal = $2,472/Day (Assumed work rate = 2 Miles per Day)
- Washout Repairs = $4,215 Each (Assumed 2 per Mile)
- Guardrail Repairs = $50/LF (Assume 120 LF of repair per mile of roadway)
- Fence Repairs = $76/LF (Assume 2% of roadway length)
- Mowing = $320/Mile (Assume performed 2 times annually)
- Vegetation Control = $640/Mile (Assume 40% of roadway)

The projected expenditures include near term repairs addressing interchange deficiencies and annual routine maintenance costs (cost in $ millions per year).

Table 51: Total Projected Expenditures – Interchanges – Present Day ($M)

Location	FY22-FY31
Central Artery	N.A.
CANA	N.A.
Sumner/Callahan	N.A.
Boston Extension	$3.98
MHS TOTAL	**$3.98**

Table 52: Annualized Projected Expenditures – Interchanges – Escalated ($M)

Location	FY22	FY23	FY24	FY25	FY26	Near Term FY22-FY26	FY27	FY28	FY29	FY30	FY31	Long Term FY27-FY31
Central Artery	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
CANA	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Sumner/ Callahan	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Boston Extension	$0.48	$0.49	$0.50	$0.52	$0.54	$2.53	$0.37	$0.38	$0.39	$0.41	$0.42	$1.97
MHS TOTAL	**$0.48**	**$0.49**	**$0.50**	**$0.52**	**$0.54**	**$2.53**	**$0.37**	**$0.38**	**$0.39**	**$0.41**	**$0.42**	**$1.97**

6.6.3 Pavement

The following is the cost expenditure breakdown of the Pavement Recommendations noted in Section 5.4.3. These costs are in 2021 dollars.

Repairs to address deficient findings in order to maintain the MHS in safe and good repair, working order and condition: **$1,575,115 (per year)**

- Pothole Repair = $6,420/Day (Assumed work rate = 3 Days per Roadway Mile)
- Pavement Crack Sealing = $5,620/Day (Assumed work rate = 2 Miles per Roadway Mile) (Annualized over 5 years)

Maintenance Costs (Pavement Program assumed to occur over 10 years): **$6,070,169 (per year)**

- Mill and Repave = $241,710/Lane Mile (Annualized over 10 years)
- Repaint Pavement Markings = $4/Ft of Lane Mile (Annualized over 5 years)

The projected expenditures include annual routine maintenance and a pavement replacement program assumed to occur on a 10-year cycle (cost in $ millions per year).

Table 53: Total Projected Expenditures – Pavement – Present Day ($M)

Location	FY22-FY31
Central Artery	$42.10
CANA	$0.57
Sumner/Callahan	$1.66
Boston Extension	$32.12
MHS TOTAL	**$76.45**

Table 54: Annualized Projected Expenditures – Pavement – Escalated ($M)

Location	FY22	FY23	FY24	FY25	FY26	Near Term FY22-FY26	FY27	FY28	FY29	FY30	FY31	Long Term FY27-FY31
Central Artery	$4.21	$4.34	$4.47	$4.60	$4.74	$22.35	$4.88	$5.03	$5.18	$5.33	$5.49	$25.91
CANA	$0.06	$0.06	$0.06	$0.06	$0.06	$0.30	$0.07	$0.07	$0.07	$0.07	$0.07	$0.35
Sumner/Callahan	$0.17	$0.17	$0.18	$0.18	$0.19	$0.88	$0.19	$0.20	$0.20	$0.21	$0.22	$1.02
Boston Extension	$3.21	$3.31	$3.41	$3.51	$3.62	$17.05	$3.72	$3.84	$3.95	$4.07	$4.19	$19.77
MHS Total	**$7.65**	**$7.87**	**$8.11**	**$8.35**	**$8.60**	**$40.59**	**$8.86**	**$9.13**	**$9.40**	**$9.68**	**$9.98**	**$47.05**

6.6.4 Walls

The following is the cost expenditure breakdown of the Walls Recommendations noted in Section 5.4.4. These costs are in 2021 dollars.

Repairs to address deficient findings in order to maintain the MHS in safe and good repair, working order and condition:

Near Term (Assumed to occur within next 5 years): **$6,581,235 (Total for 10 years)**

- Wall Ratings ≤ 5
- Isolated Deficiencies

- Concrete Repair
- Remove/Install Chain Link Fence
- General Maintenance
- Crack Repair
- Shotcrete Repair
- Structural Steel Repairs
- Retaining Wall
- Joint Sealant Replacement
- Support of Excavation
- Excavation
- Mobilization

Maintenance Costs: **$359,000 (Total for 10 years)**

Long Term (Assumed to occur within the last 5 years):

- Vegetation Control

The projected expenditures include near term repairs addressing structural deficiencies, replacement of wall sections in Poor condition, and annual routine maintenance costs (cost in $ millions per year).

Table 55: Total Projected Expenditures – Walls – Present Day ($M)

Location	FY22-FY31
Central Artery	$0.13
CANA	N.A.
Sumner/Callahan	N.A.
Boston Extension	$6.89
MHS TOTAL	$7.03

Table 56: Annualized Projected Expenditures – Walls – Escalated ($M)

Location	FY22	FY23	FY24	FY25	FY26	Near Term FY22-FY26	FY27	FY28	FY29	FY30	FY31	Long Term FY27-FY31
Central Artery	$0.02	$0.02	$0.02	$0.03	$0.03	$0.12	$0.00	$0.00	$0.00	$0.00	$0.00	$0.02
CANA	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Sumner/Callahan	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Boston Extension	$1.29	$1.33	$1.37	$1.41	$1.46	$6.86	$0.10	$0.10	$0.11	$0.11	$0.11	$0.53
MHS TOTAL	**$1.32**	**$1.36**	**$1.40**	**$1.44**	**$1.48**	**$6.99**	**$0.10**	**$0.11**	**$0.11**	**$0.11**	**$0.12**	**$0.55**

6.6.5 Sign Support Structures

The following is the cost expenditure breakdown of the Sign Support Structures Recommendations noted in Section 5.4.5. These costs are in 2021 dollars.

Repairs to address deficient findings in order to maintain the MHS in safe and good repair, working order and condition: **$202,294 (Total for 10 years)**

Near Term (Assumed to occur within next 5 years): $119,040
- Sign Support Structure Condition Ratings ≥ 2
- Isolated Deficiencies

Long Term (Assumed to occur within next 6-10 years): $83,254
- Sign Support Structure Condition Ratings ≥ 2
- Isolated Deficiencies

Repair Types
- Backfill by hand
- Compaction, Hand Tamp
- Concrete Repair
- Crash Truck
- General Maintenance (With Scissor Lift)
- General Maintenance (Without Scissor Lift)
- General Maintenance with Crane
- Haul and Disposal
- Impact Attenuators
- Mobilization
- Seeding
- Signs Material
- Small Electrical Crew
- Steel Repairs Clean and Paint
- Testing Crew with Bucket Truck
- Weight Vibration Damper Material

Maintenance Costs: **$225,000 (per year)**
Bi-Annual Inspections: $5,000 Each (Annualized over 3 years): **$165,000 (per year)**

The projected expenditures include near term repairs addressing deficiencies and replacement of components of signs in Poor condition, and bi-annual inspection costs (cost in $ millions per year).

Table 57: Total Projected Expenditures – Sign Support Structures – Present Day ($M)

Location	FY22-FY31
Central Artery	$0.97
CANA	N.A.
Sumner/Callahan	$0.10
Boston Extension	$0.78
MHS TOTAL	$1.85

Table 58: Annualized Projected Expenditures – Sign Support Structures – Escalated ($M)

Location	FY22	FY23	FY24	FY25	FY26	Near Term FY22-FY26	FY27	FY28	FY29	FY30	FY31	Long Term FY27-FY31
Central Artery	$0.10	$0.10	$0.10	$0.11	$0.11	$0.52	$0.11	$0.12	$0.12	$0.12	$0.13	$0.60
CANA	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Sumner/Callahan	$0.01	$0.01	$0.01	$0.01	$0.01	$0.05	$0.01	$0.01	$0.01	$0.01	$0.01	$0.06
Boston Extension	$0.08	$0.08	$0.09	$0.09	$0.09	$0.43	$0.09	$0.09	$0.09	$0.09	$0.10	$0.45
MHS TOTAL	**$0.19**	**$0.19**	**$0.20**	**$0.21**	**$0.21**	**$1.00**	**$0.21**	**$0.22**	**$0.22**	**$0.23**	**$0.24**	**$1.12**

6.6.6 Parks

The projected expenditures for Parks have been absorbed with projected expenditures for Buildings.

APPENDIX A: INSPECTION RESPONSIBILITY MATRIX

APPENDIX B: INSPECTION FINDINGS

APPENDIX C: HISTORICAL TRENDS

APPENDIX D: PAVEMENT CONDITION

APPENDIX E: PROJECTED FUTURE EXPENDITURES