2018 Triennial Inspection

REPORT OF CONDITIONS

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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 2018 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 and tunnel 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 Collector for ArcGIS 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 four-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.

Several MHS asset classes have been incorporated into MassDOT routine inspection programs since being transferred to MassDOT's jurisdiction in 2009. Under MassDOT's on-going 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. In addition, certain assets such as boat sections have been inspected by MassDOT's own forces since 2015. In recognition of these factors, a representative sample of these bridges and boat sections received a visual audit inspection to generally validate the findings of the MassDOT inspections. The results of these audits agreed substantially 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 and tunnels that were inspected by MassDOT forces and independent consultants between October 2015 and July 2018. 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. Bridge pavement was not included as part of this assessment.

A visual inspection was performed between May 2018 and August 2018 for MHS assets that had not been inspected since the previous 2015 Triennial, including roadways, interchanges, walls, sign support structures, buildings, communication facilities, and pump stations.

This 2018 Report of Conditions was developed using a combination of data sources:

- 2018 triennial visual inspection data;
- Inspection data exported from MassDOT's 4D system for all bridges and boat sections inspected by MassDOT forces from October 2015 to July 2018;
- Inspection data exported from MassDOT's 4D system for all tunnels, boat sections, bridges, and sign structures inspected by 3rd party consultants, from October 2015 to July 2018; and
- 2017 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 Metropolitan Highway System 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.

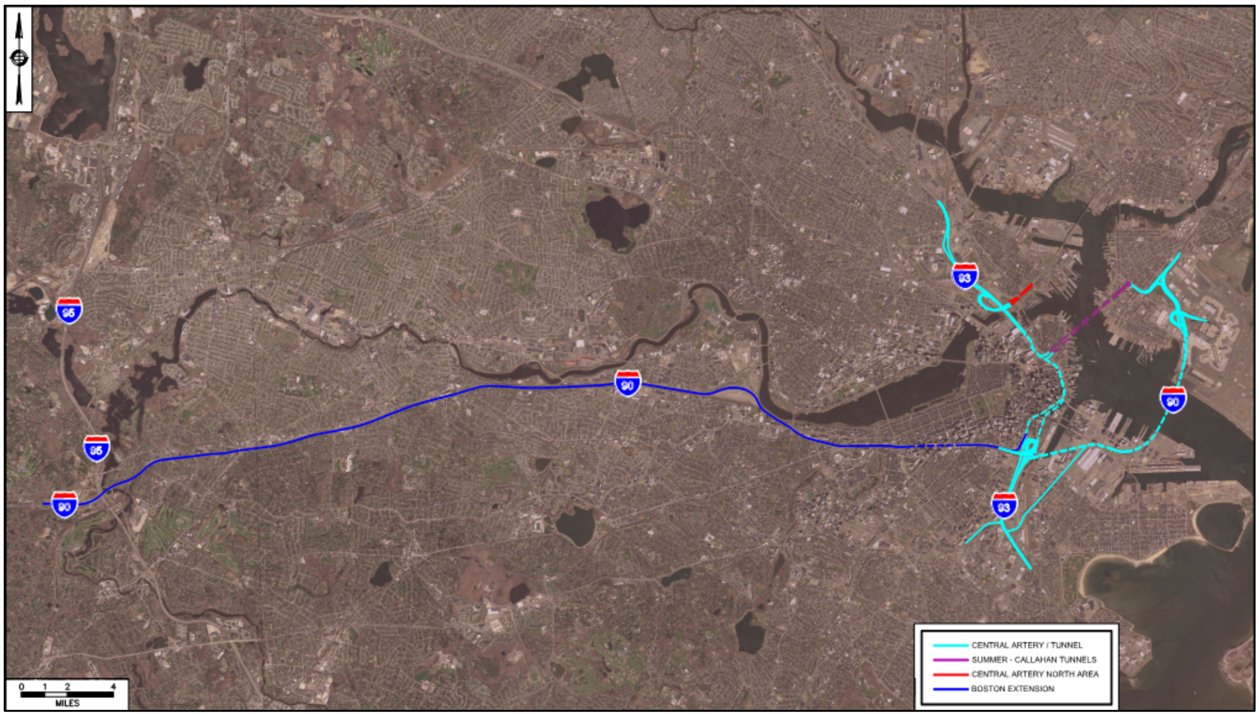

Figure 1: Metropolitan Highway System

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

- Over 237 bridges and viaducts, including:
  - Leonard P. Zakim Bridge
  - Allston Interchange Viaduct
- 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 John Hancock Garage.

- Frontage Road
- South Boston Bypass Road
- MassPort Haul Road

Toll plazas that were previously located along the MHS were replaced with All Electronic Tolling (AET) overhead gantries in October 2016, and all at-grade toll plaza structures on the MHS were demolished in 2017. The AET gantries on the MHS are inspected and maintained under contract by the installer and were therefore not included as part of the 2018 Triennial Inspection.

Table 2 shows the approximate average 2017 daily traffic (ADT) volumes on selected segments of the MHS.

Table 2: Metropolitan Highway System Average Daily Traffic

MHS	Type	Average Daily Traffic (ADT) (vehicles per day)
Central Artery (I-93)	Non-revenue	190,000 – 210,000
CANA Tunnel	Non-revenue	82,000
Ted Williams Tunnel	Toll	90,000
Sumner/Callahan Tunnels	Toll	68,000
Boston Extension	Toll	110,000 – 150,000

1.1.1 History of MHS

Until November 2009, the Massachusetts Turnpike Authority owned and operated many of the facilities that are 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).

This 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 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 three tunnels connecting downtown Boston with Logan Airport and points north.

In 2009, all Massachusetts Turnpike Authority facilities were transferred to MassDOT 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/boat sections on the MHS. These include the I-93 mainline tunnels as well as associated boat sections and ramps, the I-90 Connector, 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. These tunnels and boat sections are delineated into 228 sections with individual bridge identification numbers (BIN's), as well as 48 tunnel identification numbers (TIN's) which encompass multiple BIN's.

Bridges

There are 237 bridges along the MHS. These structures include numerous road and rail grade separated crossings over and under I-90 and I-93, several interchange ramp bridges, as well as the Zakim Bridge. Structure types and ages vary significantly throughout the system.

Building Structures

Administration/Operations Support Buildings

There are 37 administration/support buildings along the MHS, including administration buildings, maintenance facilities, emergency response stations (ERS), electrical substations (ESS), salt sheds, and State Police Barracks. The State Police Barracks is under the control of the Massachusetts State Police and was not available for inspection during the 2018 triennial.

There are 21 additional tunnel support buildings/structures (13 Ventilation Buildings, three Fan Chambers (MEP system related elements only), four Fan Rooms and one Air Intake Building) within the MHS, but they are considered integral components within tunnel structures, and are inspected and reported on as part of the MassDOT tunnel inspection program. These inspections occur at a frequency of every two years or less.

The three Fan Chamber Buildings considered integral components within tunnel structures were not structurally inspected as part of MassDOT's tunnel inspection program. HNTB suggests adding the following Fan Chamber Buildings to future Triennial structural inspections:

- Summer Street Fan Chamber
- Essex Street Fan Chamber
- Beacon Street Fan Chamber

Communication Towers/Facilities

There are three assets identified within the MHS as Communication Towers/Facilities, all located along the Boston Extension:

- Interchange 15 in Weston, at Toll Plaza 3, near Riverside Road
- Interchange 16 in West Newton, at west end, near 186 Webster Street
- Interchange 19 in Brighton

The facilities in Newton and Brighton include both a building structure and a tower. The facility in Weston includes only a building without a tower.

Pump Stations

There are eleven Pump Stations within the MHS which are inspected as part of the Triennial Inspection. Typically, these pump station are single-purpose facilities housed in individual building structures and generally supporting roadway operations. They are as follows:

- Pump Station No. 1, Tandem Trailer Area, Int. 18-19-20, Ramp B, Sta. 45+40
- Pump Station No. 2, Boston Extension, Mainline Sta. 465+50 WB, beneath Structure 111
- Pump Station No. 4, Boston Extension Mainline Sta. 526+50 EB, near Muddy River
- Pump Station No. 7, SWPS-07, Boston Extension Mainline Sta. 607+40 WB, I-90 Connector Sta. 15+00 WB
- Stormwater Pump Station SWPS-03, West 6th Street and Broad Street, South Boston
- Stormwater Pump Station SWPS-04, TWT EB Portal, South Boston
- Stormwater Pump Station SWPS-05, Harborside Drive at E-T Toll Plaza
- Stormwater Pump Station SWPS-09, directly behind 185 Kneeland Street
- Stormwater Pump Station SWPS-11, 280 Southampton Street
- Stormwater Pump Station SWPS-12, 250 Frontage Road
- Stormwater Pump Station SWPS-18, 497 Austin Street, Charlestown

In addition, an inspection of mechanical/electrical items was performed for SWPS-01 as part of the Triennial Inspection. The structural components of SWPS-01 and 28 additional pump stations within the MHS are considered integral components within tunnel roadway structures and are therefore inspected and reported on as part of the MassDOT tunnel inspection program. These inspections occur at a frequency of every two years or less.

Four of the 28 pump stations considered integral components within tunnel roadway structures were not inspected because they were not considered to be element level or they were located within a boat section. HNTB suggests adding the following pump stations to future Triennial inspections:

- Stormwater Pump Station SWPS-08, Located within Ventilation Building No. 1
- Stormwater Pump Station SWPS-15, 136 Blackstone Street, in Ventilation Building No. 4
- Portal Stormwater Pump Station SWPS-24, Sumner Tunnel, East Boston Portal (left side)
- Portal Stormwater Pump Station SWPS-25, Sumner Tunnel, Boston Portal (left side)

Roadways

Roadway

The MHS roadway facilities have been organized into 2/10th of a mile (approximately 1,000 foot) long sections, resulting in 130 data points. The roadway asset class encompasses all roadway and roadside elements including guardrails, drop inlets, light standards, fencing, side slopes, edging, roadway signs, and median barriers. Eight additional lengths of roadway are located within the Prudential Tunnel, which is inspected as part of as part of MassDOT's tunnel inspection program. This section of roadway was not inspected as part of the 2018 triennial, but the relevant inspection data was exported from MassDOT's 4D database for review.

Interchanges

There are eight interchanges on the MHS. The interchanges are along I-90 on the Boston Extension. Interchanges 14 and 15 are the westernmost interchanges 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 24 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.

Walls

There are 116 walls identified within the MHS, including reinforced concrete retaining walls and metal bin retaining walls located at Interchanges 14, 20 and 22. Nine of these walls had been previously inspected as part of MassDOT's All Item Tunnel inspections for BIN B86. These walls were not inspected as part of the 2018 triennial, but the relevant inspection data was exported from MassDOT's 4D database for review.

Sign Support Structures

There are 90 sign support structures within the MHS and they are comprised of both overhead truss and cantilevered structures. Six of these sign support structures had been previously inspected as part of MassDOT's tunnel inspection program. These signs were not inspected as part of the 2018 triennial, but the relevant inspection data was exported from MassDOT's 4D database for review.

Parks

There is one park within the MHS jurisdiction. London Street Park (also known as Veterans Park) is located across from Vent Building No. 13 between London Street and Liverpool Street. A separate area adjacent to Vent Building No. 13 property, with a fenced in basketball and play court, was inspected as part of Vent Building No. 13.

A summary of MHS assets is shown in Table 3.

Table 3: MHS Assets by Class

Asset Class	Total
Bridges	237
Tunnels/Boat Sections	228
Prudential Passageway (2/10th of a mile sections)	8
Admin/Service Building	7
State Police Barracks	1
Maintenance Facilities	4
Salt Sheds	3
Electrical Substations	3
Mechanical-Electrical Substation	1
Parking Garages	1
Office/Retail Buildings	1
Toll Plazas (to be decommissioned)	2
Vent Buildings	13
Air Intake Buildings	1
Walls	116
Sign Support Structures	90
Pump Stations	40
Fan Chambers	3
Fan Rooms	4
Communication Towers/Facilities	3
Roadway Assets (2/10th of a mile sections)	130
Interchanges	8
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 facility 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 2, 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, 29 pumping stations and approximately 90 utility rooms.

Figure 2: 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 3 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.

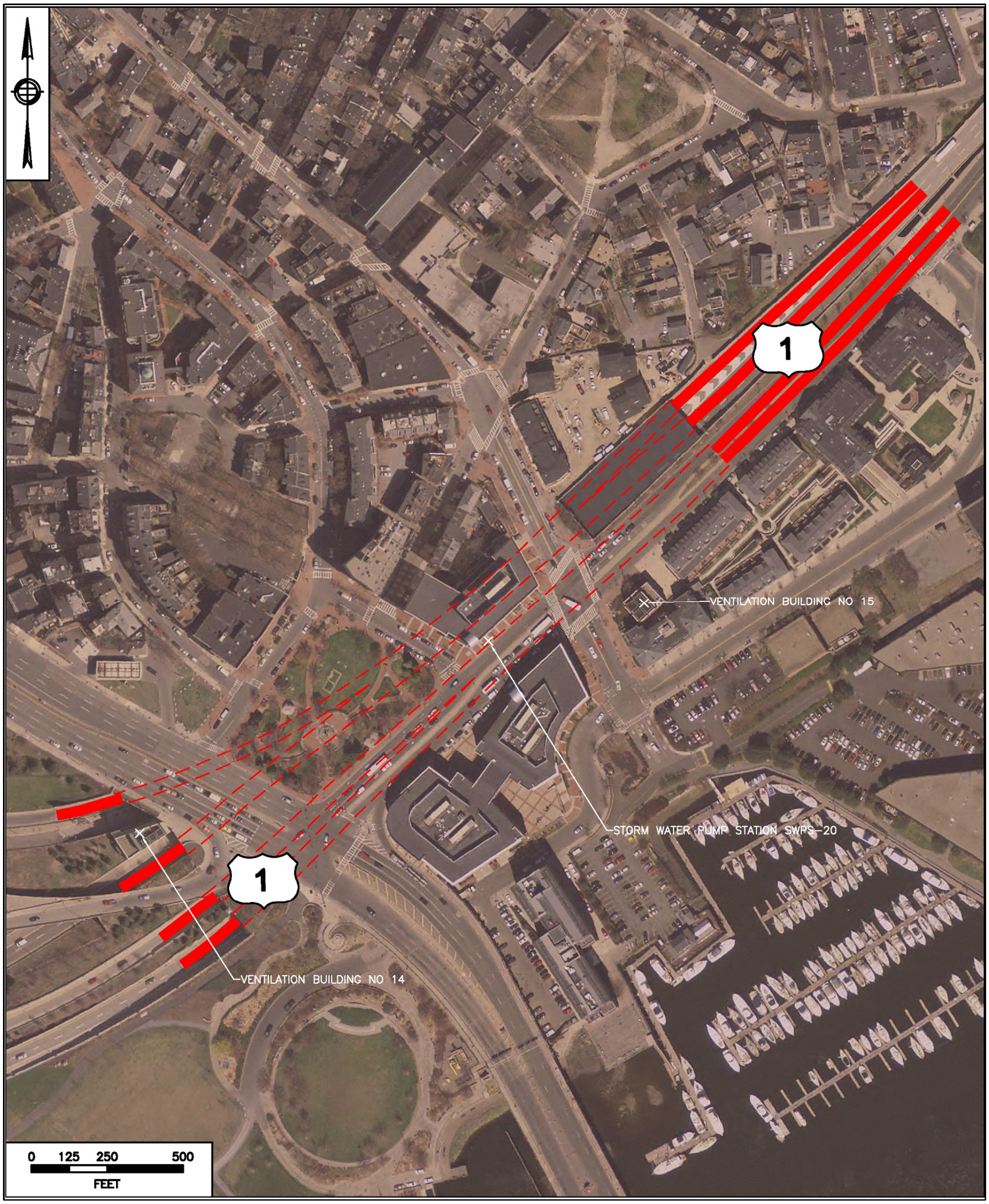

Figure 3: CANA Tunnel

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 4. The Sumner/Callahan Tunnels are 5,600 feet and 5,900 feet long respectively. This transportation network includes four ventilation buildings, six stormwater pumping stations and three administration buildings.

Figure 4: 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 5. The Boston Extension is divided into the following five areas, from west to east:

- Weston (starting at Ridgeway Road, just west of the interchange with Route 128/I-95)
- Newton
- Brighton (including a short section in Brookline)
- 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.
- 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 116 lane miles of roadway, all of which are toll road. This facility includes four stormwater pumping stations and four fan rooms within the Prudential Passageway.

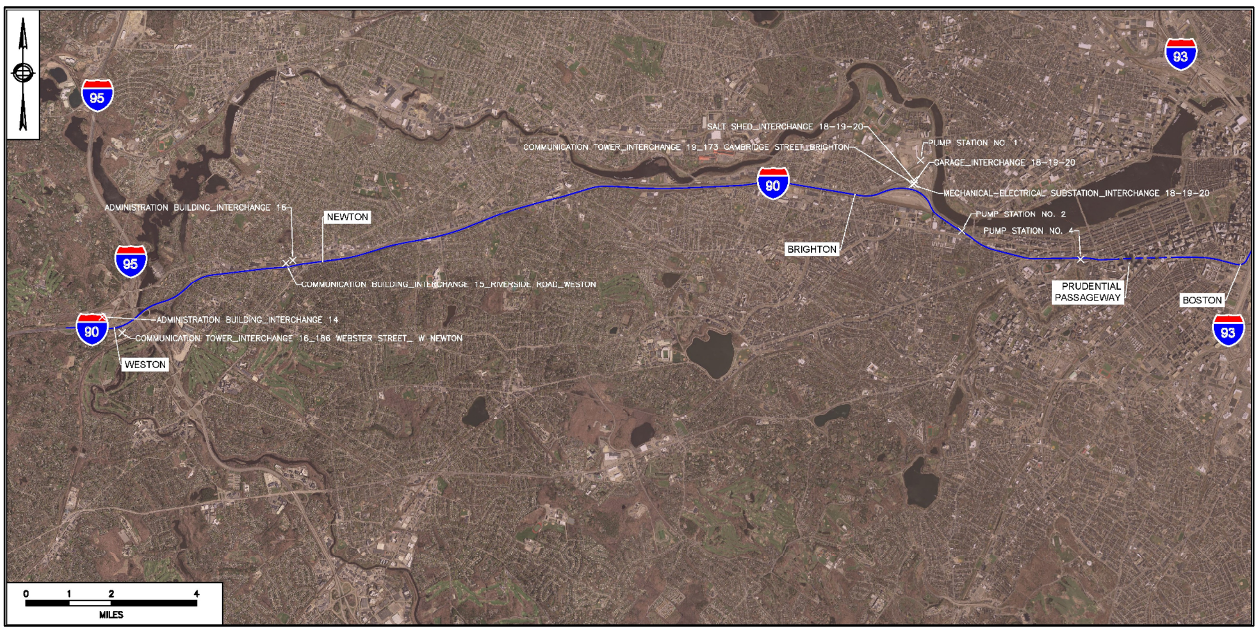

Figure 5: Boston Extension

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)

One of the buildings housing a ventilation system (Vent Building No. 3) is incorporated as part of a waterfront hotel, and another ventilation system (Vent Building No. 4) is incorporated into a MassDOT owned office building/parking garage structure (Parcel 7). Both of these are major ventilation structures adjacent to the Surface Artery and 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
- Parcel 7 Office/Retail Building & Garage at 136 Blackstone Street in 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
- Electrical Substation #3 at 497 Austin Street in Charlestown
- Salt Shed in South Boston
- State Police Barracks in South Boston (includes Emergency Response Station #2)

Sumner/Callahan Tunnels

- Sumner/Callahan Tunnel Administration Buildings: one in the North End and two in East Boston

Boston Extension

- Administration Buildings at Interchange 16 in Newton and Interchange 14 in Weston
- Mechanical-Electrical Substation, Garage, and Salt Shed at Interchange 19 in Brighton

2. Inspection Methodology

A visual inspection was performed for MHS assets which have not been inspected since the previous 2015 Triennial Inspection, including roadways, interchanges, buildings, communication facilities, pump stations, walls, and sign support structures.

Tunnels, boat sections, and bridges along the MHS are routinely inspected either by MassDOT's own forces or under contract by consultants. As part of the 2018 Triennial Inspection, a representative sample of bridges and boat sections underwent a visual inspection to audit those inspections performed by MassDOT's own forces. Bridges and boat sections 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 MHS boat sections and bridges that had been inspected by MassDOT forces underwent visual audit inspections in the course of the 2018 Triennial Inspection: 37 out of 80 boat sections and 48 out of 154 bridges were audited. This sample set was calculated with a 90% confidence level and a 10% margin of error, as demonstrated in **Table 6**.

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

Table 6: Sample Size for Audit Inspection of Boat Section and Bridge

	BOAT SECTIONS	BRIDGES
Population Size	80	154
Margin of error	0.1	0.1
Z-score	1.65 (90% confidence level)	1.65 (90% confidence level)
Population proportion	0.5	0.5
Calculated Sample Size	37	48

2.2 Visual Inspection

Visual inspections were conducted of the aspects of the Metropolitan Highway System which had not been otherwise inspected since the 2015 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 roadway facilities were generally conducted with no lane closure or only partial closure. For example, the visual inspection of the Boston Extension mainline highway elements was generally conducted within a right lane closure. 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 and highway pavement used to generate the 2018 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 Inspections: Routine, Special Member, Culvert
- Tunnel and Boat Section Inspections: All Items, Overhead Items
- Pavement: 2017 MassDOT Pavement Condition Assessments (PSI and IRI)

<u>Pavement Serviceability Index (PSI)</u>
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. The following table shows the PSI ranges used to establish the thresholds (see Table 7).

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 were 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 inspecting a sample location. 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 6). Validation web maps were also created for Bridges and Boat Sections to allow inspectors to verify previous inspection findings. The 2018 inspection data, along with the previous 2015 triennial data, are published to ArcGIS Online, where MassDOT staff may securely access the information.

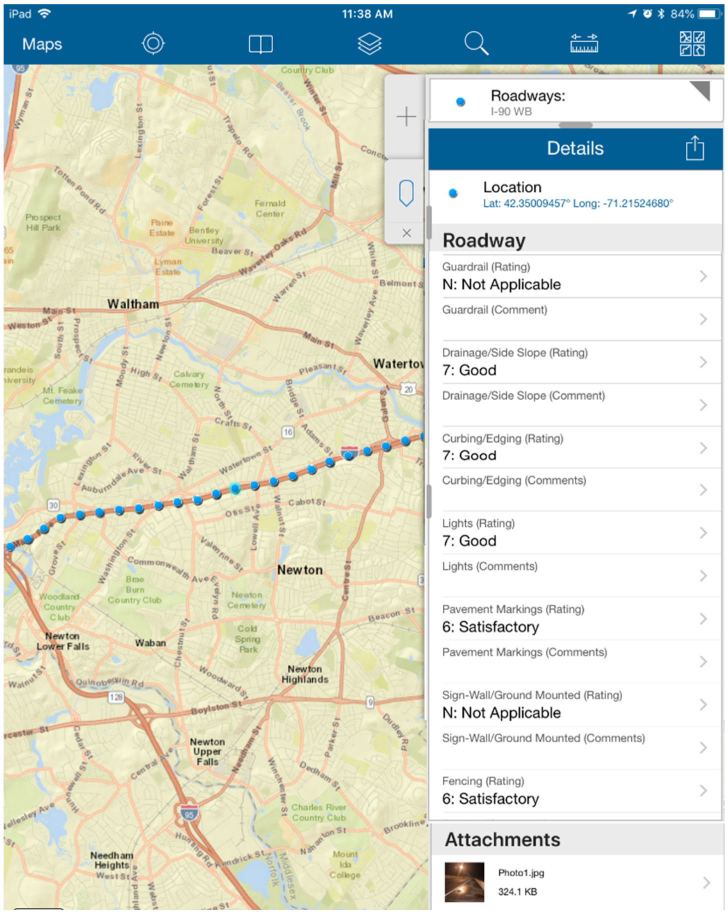

Figure 6: Sample Data Collection Web Map

2.5 Field Inspection Process

The 2018 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 Boat Sections

Inspection reports were obtained from MassDOT's 4D system for bridges and boat sections that were inspected by MassDOT forces between October 2015 and July 2018. Inspection teams visually verified the condition data for the sample set of these assets by visiting 48 bridges and 37 boat sections and reviewing the previous inspection report to validate the inspection process.

Building Structures

Visual inspections were conducted of36 administrative/support buildings, including administration buildings, maintenance facilities, vent buildings, and electrical substations; three communication facilities; and11 pump stations. An overall condition rating (0 – 9) was assigned for structural, mechanical and electrical elements based on visual inspection of each accessible room of 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. An overall condition rating (0 – 9) was assigned for each element along the roadway right-of-way. Examples of elements on the roadway are sign support structures, guardrail, curbing, side slopes, pavement markings, delineators, signs, fencing, and drop inlets.

Interchanges

Seven Interchanges were visually inspected, and 4D data was reviewed for one interchange that was included as part of a routine boat section inspection by MassDOT. An overall condition rating (0 – 9) was assigned for each element in the interchanges, which typically encompassed ramps and areas for maintenance, trailers, and parking. Inspected sub-elements included but were not limited to pavement, curbing, guardrail, side slopes, drainage, lights, and barriers.

Walls

107 noise barriers, metal bin walls, and CMU walls were inspected. Elements inspected included joints, posts, fencing, and barriers.

Sign Support Structures

84 sign support structures were inspected, including foundations, panels, structure, 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 2018 Triennial Inspection, with a rating scale of 0 for Failed through 9 for Excellent, for all inspected assets except Sign Support Structures. Inspection data for Sign Support Structures are incorporated into MassDOT's 4D database, so in order to be in line with other 4D data, a rating scale of 1 (Good) through 4 (Critical Condition) was used for Sign Support Structure inspections.

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 Ratings (0 to 9) – All Assets Except Sign Support Structures

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	Some minor problems noted. Potential exists for minor maintenance. Examples include but are not limited to replacing burnt out light bulbs, tightening loose nuts/bolts, patching pot holes, removing excessive water from drainage grates, touch up painting of surfaces, etc.

6	Satisfactory Condition	Elements show some minor deterioration. Potential exists for major maintenance. Examples include but are not limited to removing and replacing damaged section of safety rail, removing and replacing isolated areas of unsound concrete, removing deteriorated sections of fireproofing, cleaning and painting rusted portions of structural steel.
5	Fair Condition	All primary structural elements are sound but have minor section loss, notable service load cracking or spalling. Potential exists for minor rehabilitation. Examples include but are not limited to removing and replacing isolated areas of deteriorated concrete beyond the first layer of reinforcing steel, repairing cracks in concrete exceeding of 1/16" in width with epoxy crack injection, removing and replacing damaged drainage grates or guardrail, blast cleaning and painting significant areas of structural steel, etc.
4	Poor Condition	Advanced section loss to structural steel, deterioration or spalling of concrete, moderate traffic impact damage to guardrail, attenuators, overhead signs, etc. Potential exists for major rehabilitation. Examples include but are not limited to removing and replacing significant sections of deteriorated concrete and reinforcing steel, adding cover plates to structural steel exhibiting loss of section, slurry wall leak injection, removing and repaving sections of bituminous concrete pavement, removing and replacing sections of guardrail and attenuators damaged by traffic impacts, etc.
3	Serious Condition	Advanced deterioration has seriously affected primary structural components with the possibility of local failures. Repair or rehabilitation is required immediately. Examples include but are not limited to fatigue cracks in steel, shear cracks in concrete, advanced seepage of water through walls, severe traffic impact damage to sections of guardrail, attenuators, overhead signs, etc. may be present.
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.
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 10: Condition Ratings (1 to 4) – Sign Support Structures

CODE	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 2018 Triennial Inspection and review of the third-party inspection reports exported from MassDOT's 4D system. The following is a summary of typical findings for each of the asset class. See Appendix B and/or the MassDOT 4D Inspection Database for more detailed information regarding specific deficiencies.

3.1 Tunnels/Boat Sections

Inspections of MHS tunnels/boat sections are incorporated into MassDOT's inspection program, which entails performing routine inspections of each tunnel/boat section at a minimum of every two years. Therefore, MassDOT determined that a full visual inspection of each tunnel/boat section was not required as part of the 2018 Triennial Inspection. MassDOT directed HNTB to utilize the Tunnel inspection information documented within the 4D database. MassDOT also directed HNTB to conduct audit inspections of a representative number 37 of boat sections. The audit inspections were done to verify the conditions noted in the most recent Routine and Special Member reports. The audit inspections confirmed that the MassDOT inspection process and reports were valid for the sampled boat sections and that the inspection reports could be used for review of the MHS boat sections.

HNTB then reviewed inspection data from the 4D system for 48 tunnel sections and 80 boat sections and evaluated the four primary items pertaining to tunnel/boat section inspection reports: Structural (Item 62a), Roadway (Item 62b), Ceiling Overhead (Item 62c), and Air Ducts (Item 62d). Each tunnel and boat section are referred to by its Tunnel Identification Number (TIN) and Bridge Identification Number (BIN) respectively.

3.1.1 Structural

Some structural deficiencies were commonly found throughout all tunnels/boat sections to varying degrees, as well as some that were specific to the respective tunnel/boat section. Deficiencies typically common to all MHS tunnels included:

- Cracked, delaminated and/or spalled concrete
- Water intrusion/leakage and resultant deterioration
- Missing or deteriorated fireproofing material
- Corroded electrical junction boxes and conduit
- Missing cover plates
- Cross passage and emergency egress doors that are not able to be opened throughout the tunnels

In addition, roadway light fixtures are in Poor condition, with advanced deterioration due to dissimilar metals, as well as deficiencies to associated support hardware such as cracked spring nuts, fractured wireway compression seal ears, and long term creep of epoxy anchors. Currently, the lights have temporary straps in place to provide redundant support.

The following are documented tunnel/boat section structural deficiencies that were found to be unique to a specific tunnel/boat section location.

CANA Tunnel

- Ceiling panels are in Poor condition throughout, with numerous instances of detached and sagging framing and missing or removed panels.

Sumner Tunnel

- Concrete liner is in Poor condition, with 4" average depth spalls covering approximately 10% of liner. Hanger anchorages are in Poor condition with approximately 50% in Condition State CS3 and CS4 due to gaps, long term creep and spalls.
- Wall panels are in Fair to Poor condition. Several wall panels have been removed. Some of the remaining panels are loose due to the heavy corrosion of the steel support framing system; however, they appeared to be secure at the time of inspection. The panels themselves exhibit isolated areas of moderate water staining and corrosion holes.

Callahan Tunnel

- Ceiling panels are in Poor condition, as they were documented as being spongy when walked upon and sagging with varying degrees of traffic impact damage. The ceiling panel support stringers were documented as exhibiting varying degrees of corrosion, some with minor section loss.

Prudential Tunnel

- Supports for the overhead utilities exhibit heavy corrosion and full section loss, with instances of pipes that could be moved by hand. In some areas, supports have loss of contact with the utility pipe for 20% of its length, and some supports have pulled out of the concrete due to spalls.
- Other deficiencies noted included widespread spalls, incipient spalls and hollow sounding areas along the median walls, where there is a risk spalling material could fall into traffic lanes.

3.1.2 Mechanical / Electrical / Plumbing (MEP)

Only the tunnel pumps and system components which are directly associated with the tunnels (information gathered from 4D) are included in this section. For additional pump station deficiencies, refer to Section 3.3.3.

The conditions of the MEP elements varied substantially throughout the tunnel/boat sections. Deficiencies observed that are unique to a specific tunnel/boat section are as follows:

Central Artery Tunnels

I-93 NB and SB Tunnels MEP

- Deterioration or improper functioning of jet fans above the tunnel roadway and fans within ventilation buildings;
- Deterioration or non-functioning of egress signs, variable message boards, and lane usage signals;
- Deterioration to components of the electrical distribution system;

- Deterioration of the roadway lighting; and
- Improper function of the drainage system due to clogged drain pipes.

I-90 Connector Tunnel MEP

- Deterioration of components of fans, pumps, fire detection and fire protection systems, electrical distribution and security and operations systems.

Ted Williams Tunnel MEP

- Isolated improper function of the fire detection system;
- Scattered leaks in fire protection standpipe system;
- Deteriorated electrical conduits and junction boxes due to leakage;
- Non-functioning or deteriorated egress signs;
- Deteriorated roadway lighting systems;
- Isolated functioning issues with ventilation fans; and
- Deteriorated or not functioning lane signals above the tunnel roadway.

CANA Tunnel MEP

- Ventilation and pumping performance issues as well as deterioration of fan and pump housings and mechanical components;
- Deterioration and maintenance deficiencies causing drainage troughs to be ineffective or abandoned;
- Heavy deterioration of all lane use signal boxes causing them to be inoperable;
- Deterioration of roadway lighting; and
- General deterioration of the fire detection and fire protection systems.

Sumner Tunnel MEP

- Deterioration or functionality issues with the ventilation systems/fans and the drainage pumping systems within the vent buildings and pump stations, and damage to roadway lighting systems.

Callahan Tunnel MEP

- Deterioration or functionality issues with the ventilation systems/fans and the drainage pumping systems within the vent buildings and pump stations;
- Damage to roadway lighting systems; and
- Fire protection equipment corrosion, particularly fire extinguishers and standpipe valves.

Prudential Tunnel MEP

- Deterioration or improperly functioning components of the ventilation systems;
- Deterioration of fire detection and fire protection systems;
- Deterioration of drainage and pumping systems;
- Deterioration of security/operations systems;
- Deterioration of roadway lighting systems; and
- Deterioration of electrical distribution systems.

3.2 Bridges/Culverts

Inspections of MHS bridges are now incorporated into MassDOT's inspection program, which entails performing routine inspections of each bridge at a minimum of every two years. Therefore, MassDOT determined that a full visual inspection of each bridge was not required as part of the 2018 Triennial Inspection. MassDOT directed HNTB to conduct audit inspections of a representative number (48) of bridges. The audit inspections were done to verify the conditions noted in the most recent Routine and Special Member reports. The audit inspections confirmed that the MassDOT inspection process and reports were valid and that the inspection reports could be used for review of the MHS Bridges.

The audit inspections discovered both positive (repaving of deteriorated wearing surface) and negative (additional deterioration of bridge decks and bridge joints) changes to the condition ratings of the bridge structures as noted in the most recent inspections.

Bridge BINs 9YU and 9YV did not have a recent inspection within the 4D database (The most recent inspection was from 2010). Therefore, a visual inspection of these structures was performed.

HNTB reviewed data for 237 MHS bridges and evaluated the four primary items pertaining to bridge inspection reports: Deck (Item 58), Superstructure (Item 59), Substructure (Item 60), and Culverts (Item 62). Based on that review, 18 bridges were determined to have a minimum condition rating of 4 (Poor), 69 bridges had a minimum condition rating of 5 (Fair), and the remaining bridges had a minimum condition rating greater than or equal to 6 (Good/Excellent). In addition, there is one bridge carried over Highland Avenue in Newton that is weight posted (BIN 4QY). Table 11 shows a breakdown of bridge minimum condition ratings based on location.

Table 11: Minimum Condition Ratings for Bridges

MHS Location	Poor (Cond. Rating: 4)	Fair (Cond. Rating: 5)	Satisfactory - Excellent (Cond. Rating: ≥ 6)
Boston Extension (excluding Allston)	15	53	23
Allston Viaduct	3	2	-
Central Artery	-	14	127
MHS TOTAL	**18**	**69**	**150**

There were 18 bridge structures considered to be structurally deficient, with one or more items in Poor condition. Twelve of those structures noted Poor condition for Deck (Item 58), four structures showed Poor condition for Superstructure (Item 59), and seven structures indicated Poor condition for Substructure (Item 60), as detailed in Table 12.

Three of the 18 structurally deficient bridges (BINs 4QL, 4QE, and 9YU) are located at Interchange 14/15. The remaining BINs within Interchanges 14/15 are typically in Fair to Good condition.

Table 12: Structurally Deficient Bridges

Location	Bridge	BIN	Deck (Item 58)	Super-Structure (Item 59)	Sub-Structure (Item 60)
Boston Extension	B16054	4T2	4	4	4
Boston Extension (Allston Viaduct)	B16359	4RY	4	5	4
Boston Extension (Allston Viaduct)	B16359	4RX	4	5	4
Boston Extension (Allston Viaduct)	B16369	4RT	4	5	4
Boston Extension (Interchange 14/15)	W29057	4QE	5	4	5
Boston Extension	B16056	4RE	4	5	5
Boston Extension (Interchange 14/15)	N12065	4QL	4	5	5
Boston Extension	N12027	4QW	4	5	5
Boston Extension	B16051	4T5	4	5	5
Boston Extension	B16043	4TF	4	5	5
Boston Extension (Interchange 14/15)	W29052	9YU	N	4	4
Boston Extension	B16044	4TE	5	6	4
Boston Extension	B16216	4T1	4	6	5
Boston Extension	B16080	4RQ	4	6	5
Boston Extension	N12015	4QX	7	4	5
Boston Extension	N12069	4R7	7	6	4
Boston Extension	N12070	4R9	7	7	4
Boston Extension	B16301	B8F	4	7	8

The following are typical deficiencies observed in the bridge structures:

Deck (Item 58)

- Wearing surface deteriorated, including cracks, potholes, ruts and settlement
- Deck deteriorated, including cracks, areas of hollow sounding concrete, incipient spalls, and spalls with exposed reinforcement
- Drainage systems that are clogged
- 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 missing, deteriorated, or damaged
- Signs missing and 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
- Protective steel coating 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 reinforcement
- Slope paving embankments settled, broken and deteriorated

Culverts (Item 62)

- Headwall delamination with edge spalls and punky concrete
- Roof slab underside delamination, hollow concrete, and hairline transverse, longitudinal and map cracks
- Wall joints have water leakage 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, Communication Facilities, and Pump Stations. MassDOT 4D data was also reviewed pertaining to the seven Fan Chambers and 29 Pump Stations that are incorporated within tunnels and were therefore previously inspected as part of MassDOT's tunnel inspection program between October 2015 through July 2018.

3.3.1 Buildings

Structural

The structural/architectural inspection included various building elements such as structural steel and concrete beams and columns, ceilings, walls, doors, floors, stairways, and other miscellaneous items.

The conditions of structural/architectural elements 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
- 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
- Vent building shaft walls exhibit loose/spalled concrete with map cracking (Sumner/Callahan)
- Manholes in basement levels without appropriate covers (Vent Building 11)

- Staircases with active corrosion

Building Exterior

- Vent building louvers missing fixed blades and protective screens
- Aging windows and doors with missing weather stripping, 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
- 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
- Erosion and settlement of grounds surrounding the building footprint

Mechanical / Electrical / Plumbing (MEP)

The MEP inspection included mechanical, electrical, plumbing, communication and fire protection systems that support the operation of each facility. These systems 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 conditions generally ranged from Satisfactory to Poor. Typical MEP deficiencies observed included the following:

- Active alarm conditions
- Corrosion on piping, conduit, conduit support / hanger systems, enclosures and equipment
- Detached electric boxes and fixtures
- Detached conduit hanger / support systems
- Exposed wiring
- Lighting levels and outages
- Equipment not in service
- Not in use / abandoned equipment and systems
- Temporary unsafe power service connections

3.3.2 Communication Facilities

Generally, most items 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 partially filled abandoned manhole and a missing ladder rung. MEP inspections revealed active alarm conditions at the communication facility at Interchange 19.

3.3.3 Pump Stations

Structural

The structural/architectural visual inspection included various building elements such as structural steel and concrete beams and columns, ceilings, walls, doors, floors, stairways, and other miscellaneous items.

The conditions observed generally ranged from Satisfactory to Good. The older pump stations, such as Pump Station No. 4, 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:

- Active leaking through walls
- Minor to moderate cracking with efflorescence and active water infiltration
- Areas of ponding water on floors
- Loose stair railing (SWPS-04)
- Broken door hardware
- Corrosion of doors primarily along base of door, lower frame and threshold
- Clogged floor drains
- Heavy spalling and incipient spalling with wide cracking (Pump Station No. 4)
- Loose roll up overhead door housing (SWPS-11)

Mechanical / Electrical / Plumbing (MEP)

The MEP visual inspection included mechanical, electrical, plumbing, communication and fire protection systems that support the operation of each facility, in addition to the equipment associated with the roadway stormwater pumping activities. 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 conditions generally ranged from Satisfactory to Poor. Typical MEP deficiencies observed included the following:

- Active alarm conditions
- Corrosion on piping, conduit, enclosures and equipment
- Exposed wiring
- Lighting levels and outages
- Knox box corrosion
- Equipment not in service

3.4 Roadways

3.4.1 Roadway

The inspection of the MHS included 130 sections of roadway, each 2/10th of a mile in length, along the Boston Extension and Central Artery. The Boston Extension was inspected from the Ridgeway Road Underpass on the western limit in Weston at mile-marker 122.8, to the eastern limit of the turnpike in East Boston at the Route 1A interchange to mile-marker 138. The Central Artery was inspected from Southampton St Overpass on the southern limit at mile-marker 15.5 to the bridge joint at mile-marker 16.1. Central Artery HOV lanes within the limits as well as various network roads including Frontage Road Northbound, Frontage Road Southbound, South Boston Bypass Road, and Haul Road were also inspected.

Elements inspected along the roadway included guardrail, drop inlets, drainage, side slopes, curbing, light standards, fencing and concrete barrier.

Guardrail showed frequent areas of collision damage, with varying degrees of deformations to the rails and posts. Granite curbing and sloped edging were typically in Satisfactory to Good condition. Light standards were observed to be in Good to Very Good condition. Ground mounted, or barrier mounted signs were overall in Satisfactory condition. Right of way fencing throughout the highway system was observed to be Satisfactory. Median barriers were typically in Good to Very Good condition.

Typical deficiencies observed included the following:

Guardrail

- Punctures and tears to rails
- Misaligned and displaced posts
- Disconnected rails and posts
- Complete guardrail failure in isolated locations

Drop Inlets, Drainage, Side Slope

- Heavy debris buildup and vegetation overgrowth that clogged catch basins and swales/gutters (Boston Extension)
- Drop inlet structures exhibited settled, collapsed or spalled aprons or top courses (Boston Extension)
- Catch basins frequently exhibited heavy accumulation of sandy debris (Central Artery/Tunnel)

Curbing

- Misalignment of edging in some instances
- Minimal reveal in some places due to settlement or multiple pavement project layers burying or hiding curb faces

Light Standards

- Occasional burnt light bulbs need replacement
- Isolated cases where light standards are missing fixtures
- Two cases of light standard posts that had failed or were missing/post was detached
- Sections of roadway exhibit poor visibility where lighting was 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
- Missing or damaged hardware

Fencing

- Failed posts
- Top and bottom rails frequently disconnected from posts, causing chain link sections to collapse
- Most fencing components exhibit mild to moderate rusting

Parapet Wall

- Occasional minor collision damage
- Rail mounted barriers occasionally exhibit heavy spalling with exposed rusted reinforcing
- Rail base plates undermined
- Anchor rods exposed in isolated cases
- Rails mounted on barriers occasionally failed in isolated locations due to collision damage
- Cracked base plates

Parapet/Safety Walk

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

Roadway Miscellaneous

- Frequent missing bolts or fasteners to manhole covers
- Corrosion of utility cabinets
- Improper latching of cabinets
- Missing utility covers
- Exposed wiring
- Missing or deteriorated grout at anchor bolts for posts
- Sand accumulation and roadside debris in various areas

3.4.2 Interchanges

The inspection of interchanges included the inspection of eight interchanges on the Boston Extension. The inspected elements included pavement, curbing, guardrail, drop inlets, side slopes, lighting and concrete barriers. Tandem trailer areas at Interchange 15, on Ramp D and Ramp J, were also inspected and rated by similar elements. The toll plaza structures have been removed since the previous Triennial Inspection and have been replaced throughout the Boston Extension with numerous gantries mounted with transponder readers.

Elements inspected at interchanges included curbing, guardrail, drop inlets, drainage, side slopes, curbing, light standards and concrete barrier.

Concrete barriers at interchanges were documented to be in generally Very Good condition, without any notable deficiencies.

Typical deficiencies observed at interchanges included the following:

Curbing

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

Guardrail

- Damaged posts
- Damaged rail sections
- Compressed impact attenuators due to collision damage

Drop Inlets, Drainage, Side Slopes

- Sediment and debris in catch basins and outlets
- Eroded areas

Light Standards

- Burnt out light bulbs
- Failed or missing light standards

Interchange Miscellaneous

- Damaged or insufficient signs
- Missing utility covers
- Exposed wiring
- Damaged delineator posts
- Tripping hazards on sidewalks

3.4.3 Pavement

Roadway

Assessment of 232 lane miles of interstate and non-interstate MHS roadway pavement were made by analyzing data provided by MassDOT. This pavement condition data had been collected utilizing a vehicle equipped with a pavement scanning machine. The 125 lane miles of interstate data was collected starting in October 2017. The 98 lane miles of non-interstate data was collected starting in May 2016. This data was forwarded to HNTB for use to analyze and incorporate into the 2018 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.

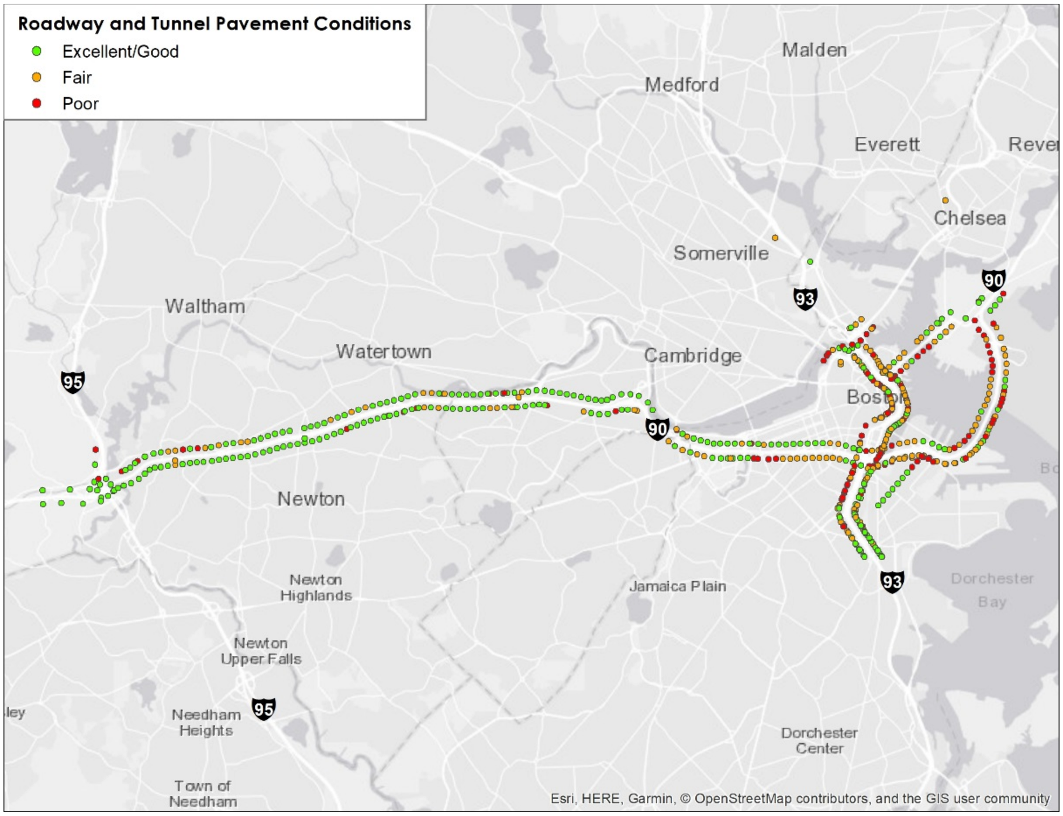

Figure 7: MHS 2017 Pavement Condition Heat Map

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

Table 13: CA/T Roadway Pavement (Lane Miles)

	Interstate	Non-Interstate
Excellent	1.400	3.771
Good	3.720	15.889
Fair	13.928	27.959
Poor	5.900	10.204
TOTAL	**24.948**	**57.823**

Table 14: Boston Extension Roadway Pavement (Lane Miles)

	Interstate	Non-Interstate
Excellent	27.186	0.000
Good	25.392	0.000
Fair	11.276	0.300
Poor	6.925	0.264
TOTAL	**70.779**	**0.564**

Based on this review, 23.3 roadway lane miles of pavement in the study area (15%) was considered deficient, where the PSI value was below 2.5 on the Interstate portions or below 2.3 on the Non-Interstate portions.

The sections of roadway and interchanges for which pavement was visually inspected as part of the 2018 Triennial exhibited typical deficiencies of potholes, map cracking, transverse cracking, longitudinal cracking as well as various areas of fractured pavement frequently adjacent to drainage structures.

Pavement Markings were typically observed to be Satisfactory. Typical deficiencies observed included a significant portion of markings on older pavement that will need to be replaced as they exhibit paint loss and moderate deterioration that reduces visibility, reflectivity and definition.

Tunnels

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

Table 15: CA/T Tunnel Pavement (Lane Miles)

	Interstate	Non-Interstate
Good	0.400	0.100
Fair	14.904	11.828
Poor	9.746	8.529
TOTAL	**25.050**	**20.457**

Table 16: CANA Tunnel Pavement (Lane Miles)

	Interstate	Non-Interstate
Good	0.000	0.044
Fair	0.000	7.058
Poor	0.000	6.813
TOTAL	**0.000**	**13.915**

Table 17: Sumner/Callahan Tunnel Pavement (Lane Miles)

	Interstate	Non-Interstate
Good	0.000	0.000
Fair	0.000	1.400
Poor	0.000	3.360
TOTAL	**0.000**	**4.760**

Table 18: Boston Extension Tunnel Pavement (Lane Miles)

	Interstate	Non-Interstate
Good	1.100	0.000
Fair	2.200	0.000
Poor	0.400	0.000
TOTAL	**3.700**	**0.000**

Based on this review, 28.8 tunnel lane miles of pavement in the study area (42%) was considered deficient, where the IRI value was above 170.

Interchanges

Pavement on interchanges was documented to be in Satisfactory to Good condition. Typical deficiencies observed included transverse and longitudinal cracking, map cracking, fractured pavement, unraveling, potholes as well as occasional rutting.

3.4.4 Walls

107 walls were inspected, comprised of 84 concrete retaining walls, 18 metal BIN retaining walls and five noise barrier walls located along various Boston Extension and Central Artery roadways. Two concrete retaining walls, CW 606 and CW 609, both located along the I-90 WB portion of the Boston Extension within the area of the former Toll Plaza at Interchange 19, have been demolished since the last Triennial Inspection.

Concrete Retaining Walls

36 concrete retaining walls, amounting to approximately 43% of all the concrete retaining walls, had one or more items with a deficiency rating of 5 (Fair) or less.

Typical deficiencies included:

- Cracks, some with efflorescence and or rust staining
- Incipient spalls
- Spalls with exposed, rusted, and/or de-bonded reinforcing
- Scaling
- Open joints with missing filler material
- Settlement
- Overgrown vegetation
- Clogged weep holes and gutters, railings with fractured base plates
- Fencing components with advanced corrosion

Metal BIN Retaining Walls

10 metal BIN retaining walls, amounting to approximately 56% of all the metal BIN retaining walls, had one or more items with a deficiency rating of 5 (Fair) or less.

Typical deficiencies included:

- Advanced corrosion, particularly to the ribs, with varying degrees of soil blow-outs
- Collision damage
- Overgrown vegetation

Noise Barrier Walls

One noise barrier wall, amounting to approximately 20% of all the noise barrier walls, had an item with a deficiency rating of 4 (Poor). The double hinged access doors associated with Noise Barrier Wall NW-3 located along the I-90 EB portion of the Boston Extension were documented to be off their hinges and laying on the ground.

Typical deficiencies included:

- Timber planks with checks, splits, warping and bowing
- Overgrown vegetation
- Corrosion of posts

3.4.5 Sign Support Structures

84 sign structures were inspected located along both the Boston Extension and Central Artery roadways. Current inspection data for an additional six sign structures was exported from MassDOT's 4D database for review, as MassDOT regularly performs inspections of sign support structures and other ancillary structures such as ITS, lights, and signals.

Ten sign structures located at various interchanges of the Boston Extension have been demolished since the last Triennial Inspection.

24 sign structures, amounting to approximately 29% of all the sign structures that were inspected, had one or more items with a deficiency rating of 2 (Fair) or higher.

Typical deficiencies included:

- Concrete foundations with map cracks, efflorescence and/or rust staining
- Incipient spalls and spalls with exposed reinforcing
- Deteriorated or missing grout pads with exposed and rusted anchor bolts
- Corrosion to posts, arms, chords and bracing members
- Faded reflective sign panels
- Collision damage to sign panels, VMS boards, or traffic safety features
- Overgrown vegetation

3.4.6 Parks

The overall condition of the London Street Park was Satisfactory, with a few minor deficiencies. One park bench was found to have a missing slat, and 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 two-year, four-year and long term targets for a variety of performance measures for their business. These time horizons 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 (four-year) and long term (10-year) metrics.

4.1 Bridges/Culverts

The bridge performance measures are based on MassDOT's Annual Performance Report "2017 Tracker".

4.1.1 Structurally Deficient Bridges based on 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 19: MHS Structurally Deficient Bridges based on Deck Area

Location	Current (2018)	Near Term (2022) Target	Long Term (2028) Target
Boston Extension (excluding Allston)	19.2%	<12%	<10%
Allston Viaduct	80.6%		
Central Artery	0.0%		
MHS (total)	11.9%		

All of the structurally deficient bridges are located within the Boston Extension, including the Allston Viaduct. To meet the near term and long term performance targets, 264,000 square feet of structurally deficient bridge deck would need to be replaced within the Allston Viaduct and 93,000 square feet within the remainder of the Boston Extension. However, if comparing all bridge deck area along the entire MHS, the current measure satisfies the near term performance target.

4.1.2 Overall Bridge Rating >=6 based on Deck Area (% Good)

This performance measure is calculated by comparing the amount of deck area that is associated with an overall bridge rating of >= 6 to the total area of bridge deck in the population of bridges evaluated.

Table 20: MHS Structurally Good Bridges based on Deck Area

Location	Current (2018)	Near Term (2022) Target	Long Term (2028) Target
Boston Extension (excluding Allston)	5.5%	>16%	>16%
Allston Viaduct	0%		
Central Artery	34.4%		
MHS (total)	24.3%		

To meet the near term and long term performance targets, 160,000 square feet of bridge structure would need to be upgraded to a condition level of Good within the Allston Viaduct and 107,000 square feet within the remainder of the Boston Extension. However, if comparing all bridge deck area along the entire MHS, the current measure satisfies the near term and long term performance target.

4.1.3 Structurally Deficient Bridge Count

A bridge is rated as structurally deficient when the deck, the superstructure, or the substructure are rated at condition 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 restrictions on the bridge.

Table 21: MHS Structurally Deficient Bridge Count

Location	Current (2018)	Near Term (2022) Target	Long Term (2028) Target
Boston Extension (excluding Allston)	15	Downward Trend	
Allston Viaduct	3		
Central Artery	0		
MHS (total)	18		

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; however, if this approach is taken, several structurally deficient bridges would remain unaddressed on the Boston Extension.

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 indicates all of a bridge's elements to be in the worst condition. This measure is calculated by comparing the amount of deck area multiplied by the associated health index to the total area of bridge deck in the MHS.

Table 22: MHS Bridge Health Index

Location	Current (2018)	Near Term (2022) Target	Long Term (2028) Target
Boston Extension (excluding Allston)	70.2%	92%	95%
Allston Viaduct	54.2%		
Central Artery	90.6%		
MHS (total)	82.3%		

Even if all 18 bridges identified as structurally deficient were to be replaced and assumed to have near perfect condition ratings, the near term performance target cannot be achieved (MHS H.I. = 87.8% & Boston Extension H.I. = 77.5%). This indicates that additional projects would be required throughout the MHS to meet this performance measure.

4.2 Pavement

The pavement performance measures are based on MassDOT's "Highway Division FHWA TAMP Update" dated April 18, 2018. These performance targets 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 in the MHS.

Table 23: Interstate Pavement (% Good/Excellent)

Location	2017	Near Term (2022) Target	Long Term (2028) Target
Central Artery/Tunnel	21%	88%	90%
Boston Extension	74%		
MHS (total)	60%		

To meet the near term and long term performance targets for interstate roadway pavement, 17.33 interstate roadway lane miles of Central Artery/Tunnel pavement and 11.12 interstate roadway lane miles of Boston Extension pavement 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 in the MHS.

Table 24: Interstate Pavement (% Poor)

Location	2017	Near Term (2022) Target	Long Term (2028) Target
Central Artery/Tunnel	24%	4%	3%
Boston Extension	10%		
MHS (total)	13%		

To meet the near term and long term performance targets for interstate roadway pavement, 5.15 interstate roadway lane miles of Central Artery/Tunnel Poor pavement and 4.8 interstate roadway lane miles of Boston Extension Poor pavement would need to be upgraded to a minimum condition level of Fair.

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 in the MHS.

Table 25: Non-Interstate Pavement (% Good/Excellent)

Location	2017	Near Term (2022) Target	Long Term (2028) Target
Central Artery/Tunnel	34%	62%	62%
Boston Extension	0%		
MHS (total)	34%		

To meet the near term and long term performance targets for non-interstate pavement, a total of 16.54 lane miles 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 in the MHS.

Table 26: Non-Interstate Pavement (% Poor)

Location	2017	Near Term (2022) Target	Long Term (2028) Target
Central Artery/Tunnel	18%	20%	12%
Boston Extension	47%		
MHS (total)	18%		

To meet the near term and long term performance targets for non-interstate roadway pavement, a total of 3.47 lane miles of non-interstate roadway pavement would need to be upgraded to a condition level of Fair 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 Condition)

This performance measure is calculated by comparing the amount of interstate tunnel lane miles that are Good to the total amount of interstate tunnel lane miles in the MHS.

Table 27: Tunnel Interstate Pavement (% Good)

Location	2017	Near Term (2022) Target	Long Term (2028) Target
Central Artery/Tunnel	2%	88%	90%
Boston Extension	30%		
MHS (total)	5%		

To meet the near term and long term performance targets for interstate tunnel pavement, a total of 24.37 lane miles of interstate tunnel pavement would need to be upgraded to a condition level of Good.

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 in the MHS.

Table 28: Tunnel Interstate Pavement (%Poor)

Location	2017	Near Term (2022) Target	Long Term (2028) Target
Central Artery/Tunnel	39%	4%	3%
Boston Extension	11%		
MHS (total)	35%		

To meet the near term and long term performance targets for interstate tunnel pavement, a total of 9.28 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 to the total amount of non-interstate tunnel lane miles in the MHS.

Table 29: Tunnel Non-Interstate Pavement (% Good)

Location	2017	Near Term (2022) Target	Long Term (2028) Target
Central Artery/Tunnel	0%	62%	62%
CANA	0%		
Sumner/Callahan	0%		
Boston Extension	0%		
MHS (total)	0%		

To meet the near term and long term performance targets for non-interstate tunnel pavement, a total of 24.12 lane miles 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 in the MHS.

Table 30: Non-Interstate Tunnel Pavement (%Poor)

Location	2017	Near Term (2022) Target	Long Term (2028) Target
Central Artery/Tunnel	42%	20.00%	12.00%
CANA	49%		
Sumner/Callahan	71%		
Boston Extension	0%		
MHS (total)	48%		

To meet the near term and long term performance targets for tunnel non-interstate pavement, a total of 14.01 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 is in a 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 four years (FY19-FY22). Long term recommendations include items that should be addressed within the following six years (FY23-FY28). 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, there are several deficiencies that require large capital projects to address. Due to high traffic volumes and close proximity of 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 replaced throughout the full term (to be coordinated by MassDOT).

5.1.1 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. Elements rated Condition State 2 are recommended for repair in the long term.

The following are recommendations for addressing structural deficiencies common to all MHS tunnels/boat sections:

- 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;
- Continued inspection and replacement of manhole cover deficiencies;
- Continued inspection and maintenance of deteriorated overhead utility supports; and
- Continued inspection and maintenance of deteriorated roadway lighting fixtures and hardware.

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

Central Artery Tunnels

- Remove standing water in the supply air duct in the Tip O'Neill and I-90 Connector.

CANA

- Repair or remove ceiling panels.

Sumner Tunnel

- Repair concrete liner and hanger anchorage.
- Remove or repair deficient wall panels.

Callahan Tunnel

- Repair ceiling panels, hangers, anchorages and roadway lighting.

Prudential Tunnel

- Repair or replace supports for the overhead utilities.
- Repair concrete walls.

5.1.2 Mechanical / Electrical / Plumbing (MEP)

Only the tunnel pumps and system components which are directly associated with the tunnels (information gathered from 4D) are included in this section. For additional pump station information, refer to Section 5.3.3.

Elements which are quantifiable/rated on a per item basis such as fans, pumps, 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 State 4 are recommended for replacement in the near term, Condition State 3 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 deteriorated or obsolete components, as necessary, for systems which contain defects rated Condition State 2.

The following are recommendations for addressing MEP deficiencies common to all MHS tunnels/boat sections:

- MassDOT is currently performing a detailed evaluation of ventilation systems within the MHS tunnel network. It is recommended that these ventilation issues be addressed ASAP upon completion of the evaluation.
- Repair/Replace deficient roadway lighting.
- Repair deteriorated electrical conduits, replace junction boxes, and cover plates.
- Repair egress signs and variable message boards above the tunnel roadway.
- Remediate improperly performing fire detection and protection systems, pumps, leaking standpipes, non-functioning security cameras and associated deficient electrical distribution systems.
- Replace lane usage signals above the roadway (or remove if obsolete).
- Clean clogged drainage pipes to ensure proper drainage of the tunnel.

5.1.3 Tunnel Capital Investments

MassDOT has several existing projects in various stages of design that would address several 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 31: MassDOT Capital Projects Recommended for Advancement

<table>
<tr><th>MassDOT Project #</th><th>Issue</th><th>Status</th></tr>
<tr><td>606476</td><td>Sumner – Deterioration of Concrete Liner & Hanger Anchorage</td><td>100% Design (inactive)</td></tr>
<tr><td>606859</td><td>CANA – Ventilation Performance Issues</td><td>Pre-25% Design (inactive)</td></tr>
<tr><td>609124</td><td>Prudential – Ventilation System</td><td>75% Design</td></tr>
<tr><td>608247</td><td>Callahan – Deterioration of Ceiling Panels, Hangers & Anchorages</td><td>Pre-25% Design (inactive)</td></tr>
<tr><td>609121</td><td>Ted Williams – Roadway Lighting</td><td>Pre-25% Design</td></tr>
<tr><td rowspan="4">TBD
(formerly 609122)</td><td>I-93 Mainline – Roadway Lighting</td><td rowspan="4">Pre-25% Design</td></tr>
<tr><td>I-93 Ramps – Roadway Lighting</td></tr>
<tr><td>I-90 EB and Ramps – Roadway Lighting</td></tr>
<tr><td>I-90 WB and Ramps – Roadway Lighting</td></tr>
<tr><td>606660</td><td>Sumner/Callahan – Non-Functioning Mid-River Pump Station & Electrical System Reliability</td><td>PSE</td></tr>
<tr><td>607137</td><td>General – Water Intrusion/Leakage and resultant impacts</td><td>100% Design</td></tr>
<tr><td>607878</td><td>I-90 Connector & Tip O'Neill – Standing Water in Supply Air Duct</td><td>In Construction</td></tr>
<tr><td>609122</td><td>CA/T General – Roadway Lighting</td><td>Pre-25% Design</td></tr>
<tr><td>606801</td><td>Dewey Square Vent Stack Exterior Repairs</td><td>Pre-25% Design (inactive)</td></tr>
</table>

5.2 Bridges/Culverts

For 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).

Bridges having any item with a condition rating of 4 or less were considered structurally deficient and recommended for replacement in the near term. There are 18 bridges that are currently considered to be structurally deficient, as shown in Table 12.

Bridges having ratings of five (5) or six (6) are recommended for rehabilitation of that specific low rating item (i.e. Deck / Superstructure / Substructure) in the long term. There are 139 bridges that have ratings of five (5) or six (6).

Bridges with an average condition rating greater than or equal to six (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.

5.3 Building Structures

5.3.1 Buildings

Structural

There were several buildings that appeared to be underutilized by MassDOT or may not be as relevant following the implementation of open road tolling. Consideration should be given about the needs of these buildings and the cost/benefit of continuing to maintain them versus their reconfiguration or removal. These include the following buildings/locations:

- Administration Building at 128 North Street (Boston)
- 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 16 (Newton)

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.
- Locate and repair sources of leaks in buildings throughout the MHS.

Long term

- Locate and repair sources of leaks in buildings throughout the MHS.
- 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.
- Replace missing and water stained ceiling tiles following leak repairs so repaired areas can be monitored for new leaks.
- Fix cracks in concrete ceilings, walls and slabs which are sources of active water infiltration.
- Replace doors no longer on their hinges or with non-functioning latches/locks.
- Perform 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.
- Install missing manhole covers in Vent Building 11.
- Identify areas of active corrosion on the stairs.

Long term

- Monitor cracks in brick masonry walls.
- Repair Sumner/Callahan vent buildings shaft walls.

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 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.
- 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.
- 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

<u>Near term</u>

- 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.
- Monitor erosion and settlement of grounds surrounding the building footprint and fill in areas with suitable fill material.
- Install the missing protective screens on Vent Building 3.
- Replace floor hatch at Vent Building 6.
- Inspect the lateral bracing gusset plates that are currently bent out of plane at Vent Building 7; investigate the cause of the deformation and determine if it is actively increasing; make any repairs deemed necessary by the investigation.

<u>Long term</u>

- Repave areas of pavement with moderate cracking and breakup.
- Replace areas of concrete sidewalks with areas spalled and disintegrating concrete.
- Replace irrigation systems with broken/missing valve box covers and exposed polyethylene piping.

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 in the near term and there are several items that can be remediated with general maintenance 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 MHS buildings electrical deficiencies predominantly consist of items which can be brought to a Satisfactory condition in the near time 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.

While the nature of this report focuses on making repairs to bring Poor or Fair conditions to a Satisfactory state, some of these deficiencies are of an immediate nature, typically due to safety concerns. There are longer term recommendations that some electrical equipment will need to be upgraded since their current condition is somewhat deteriorated, or that some equipment is nearing the point where it will become outdated or obsolete.

Near term and Long term recommendations are as follows:

<u>Near term</u>

- Clean and coat corroded piping, conduit, conduit support / hanger systems, enclosures and equipment.
- Secure detached electric boxes and fixtures.
- Secure detached conduit hanger / support systems.
- Repair exposed wiring.
- Repair/replace sub-standard lighting systems and outages.
- 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.
- Inspect/diagnose/rectify active alarm conditions at Vent Building 3, Vent Building 4, Vent Building 6, ERS/ESS #1, Dewey Square Air Intake Facility and Communication Building at Interchange 19.
- Re-wire power distribution at the OCC, Vent Building 7, CA/T Salt Shed and the Mechanical-Electrical Substation at Interchange 19.
- 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.
- Make lighting system functional at former Toll Plaza Administration Building, Ramp E.
- Secure fixture hanging by its conductors at Vent Building 3.
- Secure hanging pull box at Vent Building 11.
- Repair exposed wiring at CA/T Satellite Maintenance Facility and Administration Building at 145 Havre Street.

Long term

- Replace panelboards at Administration Building, Interchange 14.
- Replace backup generator at Administration Building, Interchange 16.
- Upgrade/replace power distribution equipment, fire protection system, and exterior and emergency lighting at Administration Building, 128 North Street.
- Replace exterior lighting system at CA/T Satellite Maintenance Facility.
- Replace conduit and electric boxes at ERS/ESS #1.
- Replace electric boxes and cabinets at Mech-Elec Substation, Interchange 19 .
- Replace conduit and appurtenances at Dewey Square Air Intake Structure.
- Replace overhead door motors at six fan room doors at Vent Building 1.
- Replace switchgear on first floor at Vent Building 10.
- Replace control and switchgear and replace conduit at Vent Building 11.
- Replace motor control centers, backup generator and conduit; upgrade fire protection alarm system at Vent Building 15.

5.3.2 Communication Facilities

Near term recommendations include completing the backfill of a partially filled abandoned manhole at the communication building at Interchange 15 on Riverside Road in Weston, and repair/replacement of a ladder rung support system on the tower at Interchange 19 tower in Brighton.

Recommendations to address the active alarm conditions found at the communication facility at Interchange 19 are included in the Buildings section above.

5.3.3 Pump Stations

Structural

Aging pump stations, such as Pump Station No. 4, will require substantial repairs. Newer pump stations would benefit from regular routine maintenance. Near term recommendations are shown below.

Near term

- Repair or replace aging doors with active corrosion and/or broken hardware.
- Repair loose stair railings.
- Remove and replace areas of spalled and delaminated concrete.
- Fix cracks in concrete ceilings, walls and slabs which are sources of active water infiltration.
- Fix areas of wide concrete cracking.
- Clear clogged floor drains.
- Secure roll up overhead door housing.

Mechanical / Electrical / Plumbing (MEP)

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

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, 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.

General and some specific notable near term and long term recommendations worthy of consideration are as follows.

<u>Near term</u>

- Clean and coat corroded piping, conduit, enclosures and equipment.
- Replace malfunctioning HVAC equipment.
- Repair exposed wiring.
- Replace corroded Knox boxes.
- Repair / replace sub-standard lighting systems and outages.
- Inspect / diagnose / rectify alarm conditions: Pump Station No. 2, SWPS-03 and SWPS-04.
- Re-wire power service for sump pump at SWPS-12.
- Replace and re-wire ATS at Pump Station No. 4.
- Replace sump pump at Pump Station No. 4.

<u>Long term</u>

- Rehabilitate / replace piping at SWPS-05.
- Rehabilitate / upgrade HVAC system in SWPS-05.
- Replace Pump Station No. 4.

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 exercised are also to be reset or replaced as warranted. 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 items include clearing of vegetation overgrowth in drainage swale areas or channels; removal of debris from swales or channels; clean out of all drainage basin structures of sand and other debris. Isolated areas of side slope erosion will need to be repaired to avoid impacts to pavement structure. Other 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, replacing damaged signs and replacing specific sign components including posts, mounts, foundations and hardware where structurally deficient or compromised.

Fencing

Locations where fencing is collapsed, disconnected or otherwise non-functional should be replaced as openings can welcome unwanted access to safety sensitive areas.

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 of vegetation overgrowth and removal of debris. Long term repairs include replacement of concrete caps of safety walks where significantly deteriorated.

5.4.2 Interchanges

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 replace broken or damaged curbing.

Guardrail

Maintenance items include replacing or resetting posts where warranted and replacing damaged rail sections. Impact attenuators which have been compressed due to collision are to be reset or replaced.

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 areas.

Light Standards

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

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 and patching areas of fractured or loose pavement and repainting of 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

Near term recommendations for the concrete retaining walls includes demolishing and rebuilding two walls along the I-90 WB portion of the Boston Extension, CW 194, a 300-foot-long wall west of Brookline Avenue and CW 195, a 100-foot-long wall west of Beacon Street both of which had one or more items with deficiency ratings of 4 (Poor), 3 (Serious) and/or 2 (Critical).

Additional near term recommendations include removing unsound concrete/incipient spalls; repairing spalls with exposed reinforcing steel; and removing and replacing components of fencing with advanced corrosion.

Long term recommendations for the concrete retaining walls include clearing overgrown vegetation protruding though the construction joints or accumulating behind the wall; clearing out clogged gutters and weep holes; removing and replacing fractured sections or railing; sealing cracks; joint repairs; and addressing settlement.

Metal BIN Retaining Walls

Near term recommendations for the metal BIN walls include demolishing and rebuilding four metal BIN walls along various ramps within the Interchange 18 portion of the Boston Extension, specifically M62, M62A, M63 and M65, all of which had one or more items with deficiency ratings of 4 (Poor), 3 (Serious) and/or 0 (Failed).

Additional near term recommendations include removing and replacing sections of ribs with advanced corrosion; reinforcing ribs that exhibit advanced corrosion; and repairing post to rib connections with advanced corrosion.

Long term recommendations for the metal BIN walls include clearing overgrown vegetation and removing overburden.

Noise Barrier Walls

Near term recommendations for the noise barrier walls include replacing the double hinged access doors at Wall NW-3 located along the I-90 EB portion of the Boston Extension.

Long term recommendations for the noise barrier walls include clearing overgrown vegetation.

5.4.5 Sign Supports

Near term recommendations for the sign structures include removing and replacing sign panels that exhibit poor reflectivity; repairing deteriorated grout pads and exposed anchor bolts with advanced corrosion; removing incipient spalls, repairing spalls with exposed and heavily rusted reinforcing steel, and sealing cracks with moderate to heavy efflorescence, dampness and/or rust staining along the concrete foundations and replacing traffic safety features that exhibit impact damage.

Long term recommendations for the sign structures include cleaning and painting posts, chords and bracing members; verifying vertical clearance at sign panels that exhibit impact damage and repairing or replacing these sign panels; and removing VMS boards that appear to be no longer in use.

5.4.6 Parks

Near term recommendations include replacement of park bench broken slat and monitoring of 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 of fifteen percent (15%) was added to projects to account for anticipated cost increase based on the project location (i.e. Tunnels, Fouling Railroad, Water, etc.).
- Traffic Control – A value of fifteen percent (15%) was added 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 in 4D 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 a near term (first 4 years) and long term (last 6 years) expenditures.

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 $1.86 Billion (Escalated dollars) will be needed over the next 10 years. The near term expenditure (4-year) need is approximately $750 Million (40% of total cost) while the long term expenditure (10-year) need is approximately $1.113 Billion (60% of total cost). On average approximately $186 Million is needed on an annual basis. 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 32: Total Projected MHS Expenditures – By Location – Present Day ($M)

Location	FY19-FY28
Central Artery	$745
CANA	$72
Sumner/Callahan	$201
Boston Extension (Excluding Allston)	$395
Allston Viaduct (Bridge Replacement Only)	$222
MHS TOTAL	**$1,634**

Table 33: Annualized Projected MHS Expenditures – By Location – Escalated ($M)

Location	FY19	FY20	FY21	FY22	Near Term FY19 - FY22	FY23	FY24	FY25	FY26	FY27	FY28	Long Term FY23-FY28
Central Artery	$54	$54	$57	$55	$220	$105	$106	$104	$108	$111	$114	$648
CANA	$7	$8	$8	$8	$31	$8	$8	$9	$9	$9	$9	$52
Sumner/Callahan	$20	$21	$21	$22	$83	$23	$23	$24	$25	$26	$26	$147
Boston Extension (Excluding Allston)	$52	$53	$55	$56	$216	$35	$36	$38	$39	$40	$41	$229
Allston Viaduct (Bridge Replacement Only)	$48	$49	$51	$52	$200	$6	$6	$6	$6	$6	$7	$37
MHS TOTAL	**$181**	**$184**	**$192**	**$193**	**$750**	**$177**	**$180**	**$181**	**$186**	**$192**	**$197**	**$1,113**

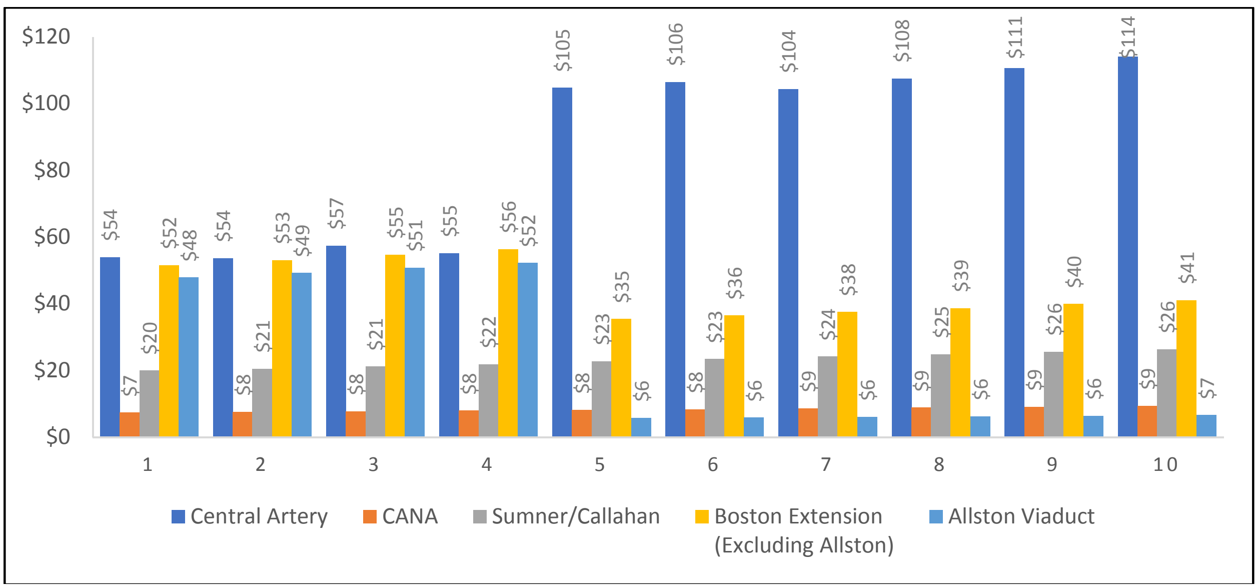

Figure 8: Annualized Projected MHS Expenditures – By Location – Escalated ($M)

Figure 9 and Figure 10 show the near and long term project expenditures respectively. Near term expenditures (FY19 – FY22) are distributed as follows, 58% is within the Boston Extension (including Allston Viaduct), 26% is within the Central Artery and the remaining 16% is shared between Sumner/Callahan/CANA tunnels. Long term expenditures (FY23 – FY28) are distributed as follows, 25% is within the Boston Extension (including Allston Viaduct), 56% is within the Central Artery and the remaining 19% is shared between Sumner/Callahan/CANA tunnels.

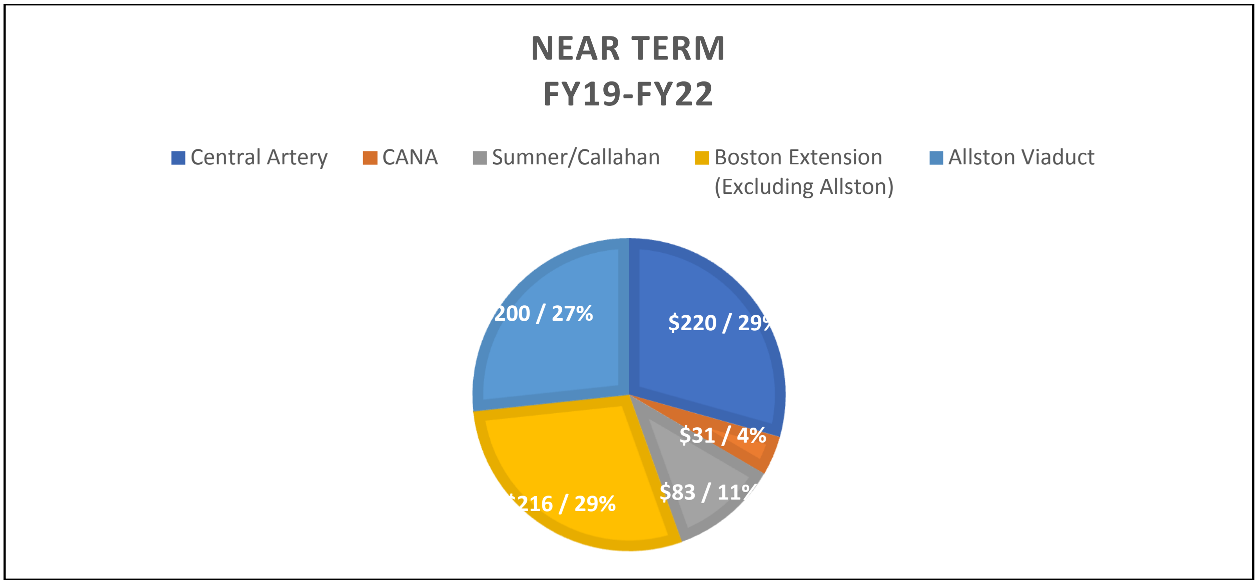

Figure 9: Projected Expenditures – By MHS Location – Near Term - Escalated ($M)

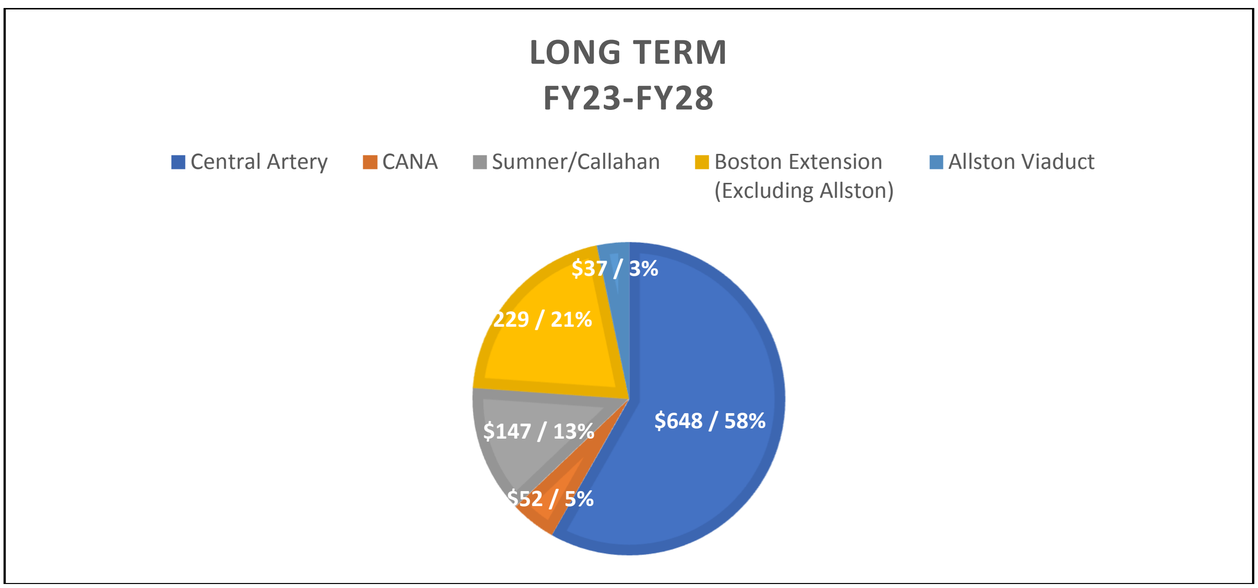

Figure 10: Projected Expenditures – By MHS Location – Long Term - Escalated ($M)

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

Table 34: Total Projected MHS Expenditures – By Asset Class - Present Day ($M)

Location	FY19-FY28
Tunnel & Boat Sections	$646
Bridges	$701
Buildings	$95
Roadway	$192
MHS TOTAL	**$1,634**

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

Location	FY19	FY20	FY21	FY22	Near Term FY19-FY22	FY23	FY24	FY25	FY26	FY27	FY28	Long Term FY23-FY28
Tunnels & Boat Sections	$64	$66	$68	$70	$269	$73	$75	$77	$80	$82	$84	$471
Bridges	$84	$87	$90	$92	$353	$68	$70	$72	$75	$77	$79	$441
Buildings	$11	$10	$12	$9	$42	$15	$14	$9	$9	$10	$10	$66
Roadway	$20	$21	$22	$22	$85	$21	$21	$22	$23	$23	$24	$134
MHS TOTAL	**$181**	**$184**	**$192**	**$193**	**$750**	**$177**	**$180**	**$181**	**$186**	**$192**	**$197**	**$1,113**

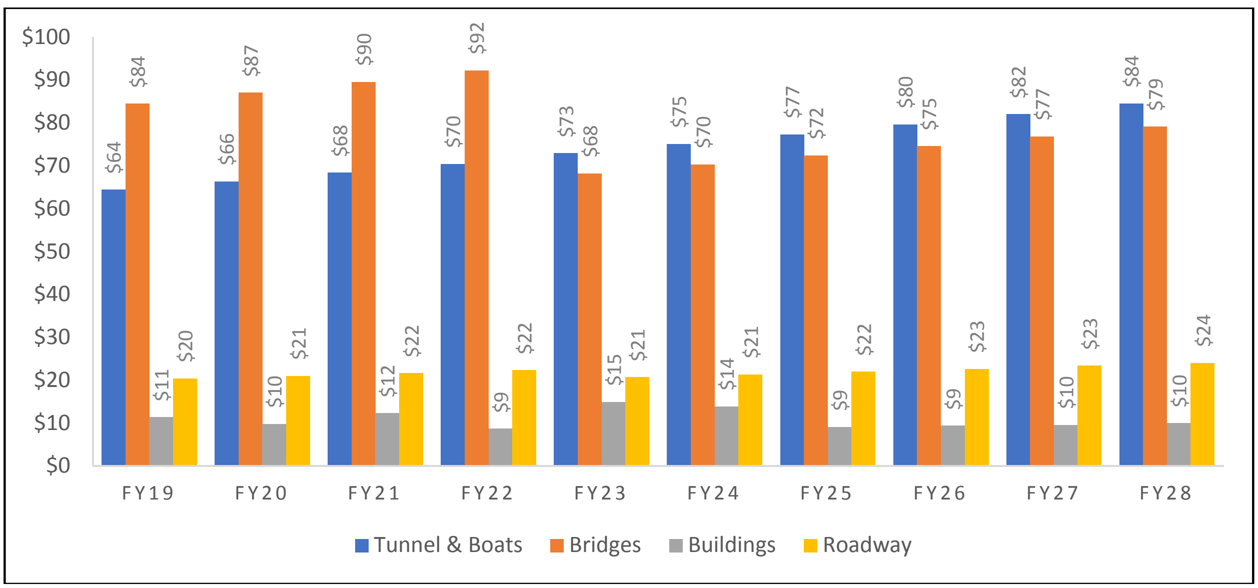

Figure 11: Annualized Projected Expenditures – All MHS Assets – Escalated ($M)

Figure 12 and Figure 13 show the near and long term project expenditures respectively. Near term expenditures (FY19 – FY22) are distributed as follows, 49% is Bridge (including Allston Viaduct), 33% is Tunnel, 12% is Roadway and 6% is Buildings. Long term expenditures (FY23 – FY28) are distributed as follows, 42% is Bridge, 39% is Tunnel, 13% is Roadway and 6% is Buildings.

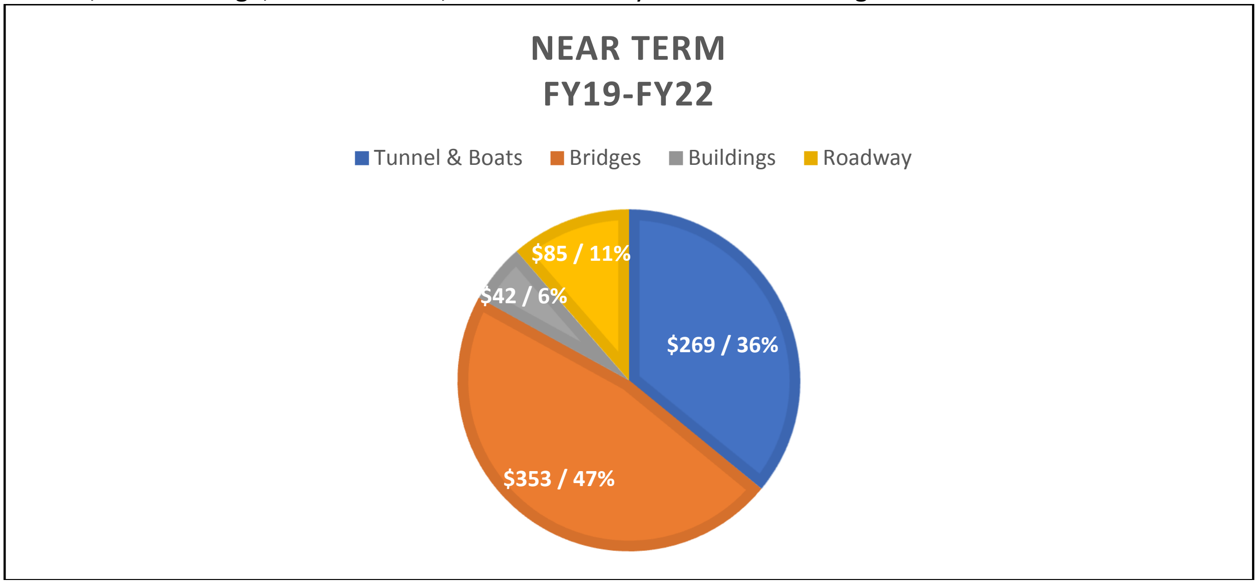

Figure 12 Projected Expenditures – By Asset – Near Term - Escalated ($M)

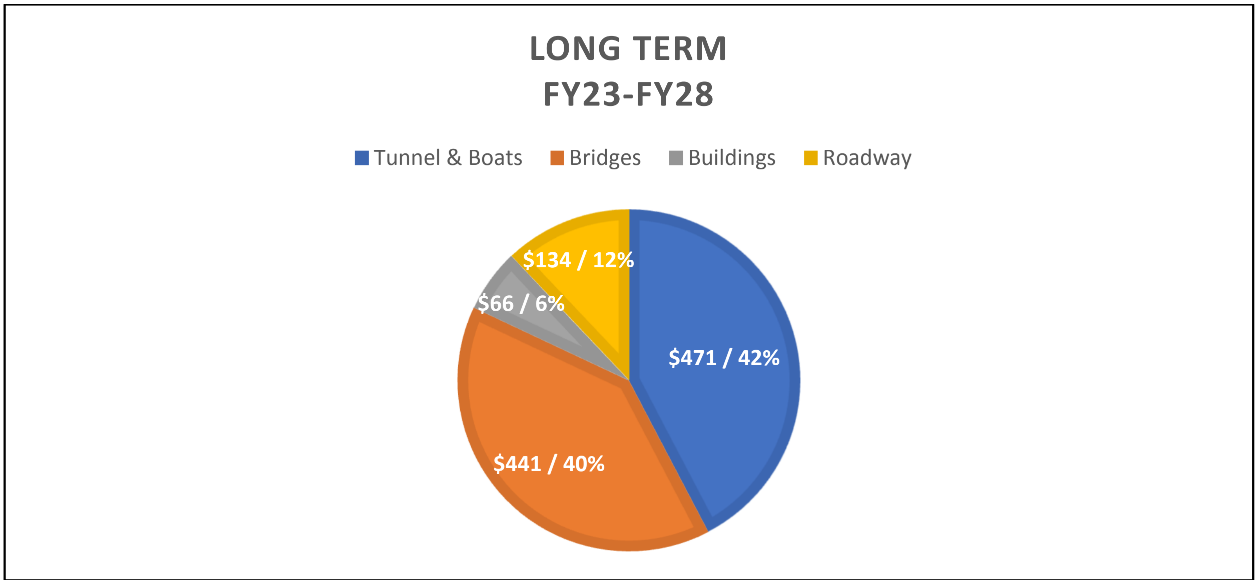

Figure 13: Projected Expenditures – By Asset – Long Term - Escalated ($M)

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 2018 dollars.

Repairs to address deficient findings as to whether the MHS has been maintained in safe and good repair, working order and condition: **$51,394,625 (Total for 10 years)**

Near Term (Assumed to occur within next 4 yrs):	$19,677,630
o Tunnel Structural Ratings of CS3 and CS4:	$1,269,258
o Boat Ratings ≤ 5:	$2,114,646
o MEP Ratings of CS4:	$16,293,727
Long Term (Assumed to occur within the last 6 yrs):	$31,716,995
o Structural Ratings of CS2:	$5,282,940
o Boat Ratings ≥ 6:	$1,310,255
o MEP Ratings of CS3:	$25,123,800

Near/Long Term Repair Types

Structural

- Small General Maintenance
- Large General Maintenance
- S mall Structural Repair
- Concrete Crack Repair
- Concrete Retaining Wall
- Partial Depth Patching
- Full Depth Patching
- Railing
- Fencing Demolition
- Catch Basin
- Vegetation Clearing

MEP

Electrical System
- Small Electrical Repair
- Large Electrical Repair

Fans/Ventilation System
- Replace Fan Components
- Replace Fan

Pumps/Drainage System
- Replace Pump Components
- Replace Pump

Signs
- Replace Sign

Full Term (Assumed to occur over the full 10 yrs): **$477,050,000 (Total for 10 years)**

Large Capital Projects (Projects are in various phases of design development; costs reflect current project estimates provided by MassDOT)

- Sumner – Deterioration of Concrete Liner & Hanger Anchorage: **$118,000,000**
- CANA – Ventilation Performance Issues: **$50,000,000**
- Prudential – Ventilation System: **$65,000,000**
- Deterioration of Ceiling Panels, Hangers & Anchorages: **$40,000,000**
- Ted Williams – Roadway Lighting: **$30,000,000**
- I-93 Mainline – Roadway Lighting: **$42,500,000**
- I-93 Ramps – Roadway Lighting: **$34,000,000**
- I-90 EB and Ramps – Roadway Lighting: **$29,750,000**
- I-90 WB and Ramps – Roadway Lighting: **$21,250,000**
- Sumner/Callahan – Non-Functioning Mid-River Pump Station & Electrical System Reliability: **$17,000,000**
- General – Water Intrusion/Leakage and resultant impacts: **$13,100,000**
- I-90 Connector & Tip O'Neill – Standing Water in Supply Air Duct: **$5,700,000**
- Dewey Square Vent Stack Exterior: **$10,750,000**

Maintenance Costs: $10M/ Year (Based on 0.15% of Tunnel Insured Value): **$10,000,000 (per year)**

- Central Artery: **$7,500,000**
- 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): **$1,750,000 (per year)**

- Central Artery: **$1,312,500**
- CANA: **$87,500**
- Sumner\Callahan: **$175,000**
- Boston Extension: **$175,000**

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

Location	FY19-FY28
Central Artery	$304.94
CANA	$60.97
Sumner\Callahan	$195.48
Boston Extension	$84.55
MHS TOTAL	**$645.94**

Table 37: Annualized Projected Expenditures – Tunnels/Boat Sections – Escalated ($M)

Location	FY19	FY20	FY21	FY22	Near Term FY19-FY22	FY23	FY24	FY25	FY26	FY27	FY28	Long Term FY23-FY28
Central Artery	$30.25	$31.16	$32.10	$33.06	$126.57	$34.50	$35.54	$36.60	$37.70	$38.83	$40.00	$223.17
CANA	$6.16	$6.35	$6.54	$6.74	$25.79	$6.81	$7.02	$7.23	$7.44	$7.67	$7.90	$44.06
Sumner\ Callahan	$19.38	$19.96	$20.56	$21.18	$81.08	$22.13	$22.79	$23.47	$24.18	$24.90	$25.65	$143.12
Boston Extension	$8.58	$8.83	$9.10	$9.37	$35.88	$9.43	$9.71	$10.00	$10.30	$10.61	$10.93	$60.97
MHS TOTAL	**$64.37**	**$66.31**	**$68.29**	**$70.34**	**$269.32**	**$72.87**	**$75.05**	**$77.30**	**$79.62**	**$82.01**	**$84.47**	**$471.33**

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 2018 dollars.

Repairs to address deficient findings as to whether the MHS has been maintained in safe and good repair, working order and condition: **$368,069,014 (Total for 10 years)**

Near Term (Assumed to occur within next 4 yrs): **$321,331,389**

- Bridge Structural Ratings ≤ 4
- Bridge Replacement = $651/SF of Bridge Deck Area

Long Term (Assumed to occur within the last 6 yrs): **$46,737,625**

- Bridge Structural Ratings = 5 or 6
- Rating = 5
  - Superstructure Repair = $20/SF of Bridge Deck Area
  - Substructure Repair = $50,000/Substructure Unit (Pier, Abutment, Culvert)
- Rating = 6 (1/2 Cost Repair)
  - Superstructure Repair = $10/SF of Bridge Deck Area
  - Substructure Repair = $25,000/Substructure Unit (Pier, Abutment, Culvert)

Maintenance Costs: **$333,267,767 (Total for 10 years)**

Annual Maintenance: **$4,088,872 (per year)**

- Asphalt Pavement Patching = $17/SF of Bridge Roadway Area
  - Assume 3" repair depth
  - Repair Quantity = 1% of Bridge Roadway Area needed per year
- Scupper/Drain Cleaning = $320 Each
  - Assume 10 scuppers per bridge cleaned per year
- Power Wash Bridge = $0.25/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: **$3,500,000/2**

Maintenance Scheduled Once every 10 yrs: **$292,379,049 (Total for 10 years)**

- Patch Concrete Deck = $214/SF of Bridge Deck Area
  - Assume 7" repair depth
  - Assume Repair Quantity = 5% of Bridge Deck Area
- Paint Bridge = $55/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 four years, and the scheduled preventative maintenance costs on a rotating 10-year basis (cost in $ millions per year).

Table 38: Total Projected Expenditures – Bridges – Present Day ($M)

Location	FY19-FY28
Central Artery	$247.90
CANA	N.A.
Sumner\Callahan	N.A.
Boston Extension (Excluding Allston)	$231.87
Allston Viaduct	$221.57
MHS TOTAL	**$701.34**

Table 39: Annualized Projected Expenditures – Bridges – Escalated ($M)

Location	FY19	FY20	FY21	FY22	Near Term FY19-FY22	FY23	FY24	FY25	FY26	FY27	FY28	Long Term FY23-FY28
Central Artery	$2.6	$2.7	$2.7	$2.8	$10.8	$44.6	$45.9	$47.3	$48.7	$50.2	$51.7	$288.3
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)	$34.0	$35.0	$36.1	$37.2	$142.3	$18.0	$18.5	$19.1	$19.6	$20.2	$20.8	$116.3
Allston Viaduct	$47.8	$49.3	$50.7	$52.3	$200.1	$5.7	$5.8	$6.0	$6.2	$6.4	$6.6	$36.7
MHS TOTAL	**$84.4**	**$87.0**	**$89.6**	**$92.2**	**$353.2**	**$68.2**	**$70.3**	**$72.4**	**$74.5**	**$76.8**	**$79.1**	**$441.2**

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 40: Projected Expenditures – Existing/Future MassDOT Bridge Projects – Estimated ($M)

Location	Bridge	BIN	MassDOT Project	Notes
Boston Extension (Allston Viaduct)	B16359	4RY	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.
	B16359	4RX		
	B16369	4RT		
Boston Extension (Interchange 14/15)	W29057	4QE	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. Interchange 15 Toll Plaza expansion.
	N12066	4QK		
	N12067	4QN		
	N12073	4QM		
	W29055	4QD		
	W29058	4QG		
	N12065	4QL	606777	**NEWTON- BRIDGE REHABILITATION ALONG I-90, N-12-065, RAMPS A & B, STRUCTURE L-50 OVER CHARLES RIVER** Replace deck, bearings, approach sidewalk, resurface approaches, repair structural steel, clean and paint superstructure, rehab substructure.
	N12064	4QJ	606790	**NEWTON- BRIDGE REHABILITATION N-12-064; I-90/I-95** Repair structural steel, clean and paint superstructure.

MassDOT's current Capital Improvement Plan (CIP) includes $8 million dollars projected for FY19 and FY20 for the Allston Viaduct project. The remaining Allston Viaduct Replacement Project cost is scheduled after FY23. The Boston Extension (Interchange 14/15) is not scheduled in the current CIP. The remaining 15 structurally deficient bridge replacements not included in the CIP add up to a cost of approximately $135 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 2018 dollars.

Repairs to address deficient findings as to whether the MHS has been maintained in safe and good repair, working order and condition.

Building overhaul costs: **$16,700,000 (Total for 10 years)**

- Ventilation Building No. 11: $11,500,000
- Ventilation Building No. 13: $1,500,000
- Admin Building (Sumner Tunnel / formerly Division III Service & Garage): $1,700,000
- Admin Building (145 Havre St, E. Boston): $500,000
- Admin Building (North Street): $1,500,000

Maintenance Costs are determined based on a percentage of the Buildings insured value: **$69,230,000 (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 overhaul of two vent buildings and three administration buildings and annual routine maintenance costs based on building condition for the remaining MHS Buildings (cost in $ millions per year).

Table 41: Total Projected Expenditures – Buildings – Present Day ($M)

Location	FY19-FY28
Admin/Service Building	$9.79
Maintenance Building	$2.99
Salts Sheds	$0.30
Electrical Substations	$1.94
Parking Garages	$2.26
Office/Retail Buildings	$2.70
Toll Plazas	$0.85
Vent Buildings	$63.58
Air Intake Buildings	$1.50
Misc. Buildings	$0.02
MHS TOTAL	**$85.93**

Table 42: Annualized Projected Expenditures – Buildings – Escalated ($M)

Location	FY19	FY20	FY21	FY22	Near Term FY19-FY22	FY23	FY24	FY25	FY26	FY27	FY28	Long Term FY23-FY28
Admin/Service Building	$2.88	$1.22	$1.57	$1.07	$6.74	$0.80	$0.59	$0.61	$0.63	$0.65	$0.67	$3.95
Maintenance Building	$0.53	$0.23	$0.23	$0.24	$1.23	$0.34	$0.35	$0.36	$0.37	$0.38	$0.39	$2.18
Salts Sheds	$0.03	$0.03	$0.03	$0.03	$0.13	$0.03	$0.03	$0.04	$0.04	$0.04	$0.04	$0.22
Electrical Substations	$0.20	$0.33	$0.21	$0.22	$0.96	$0.16	$0.23	$0.17	$0.25	$0.18	$0.26	$1.24
Parking Garages	$0.37	$0.38	$0.20	$0.21	$1.16	$0.21	$0.22	$0.23	$0.23	$0.24	$0.25	$1.38
Office/Retail Buildings	$0.27	$0.28	$0.29	$0.30	$1.13	$0.30	$0.31	$0.32	$0.33	$0.34	$0.35	$1.97
Toll Plazas	$0.07	$0.07	$0.07	$0.11	$0.33	$0.16	$0.09	$0.10	$0.10	$0.10	$0.10	$0.65
Vent Buildings	$6.06	$6.24	$8.63	$5.37	$26.29	$11.42	$10.61	$5.71	$5.88	$6.06	$6.24	$45.91
Air Intake Buildings	$0.15	$0.15	$0.16	$0.16	$0.63	$0.21	$0.22	$0.23	$0.23	$0.24	$0.25	$1.38
Misc. Buildings	$0.00	$0.00	$0.00	$0.00	$0.01	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.01
MHS TOTAL	**$10.56**	**$8.93**	**$11.40**	**$7.71**	**$38.60**	**$13.64**	**$12.66**	**$7.75**	**$8.06**	**$8.23**	**$8.55**	**$58.89**

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 2018 dollars.

Repairs to address deficient findings as to whether the MHS has been maintained in safe and good repair, working order and condition:

Mechanical: **$15,062 (Total for 10 years)**
- Small General Maintenance

Maintenance Costs: **$68,269 (Total for 10 years)**
- Pump Station 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 43: Total Projected Expenditures – Communication Facilities – Present Day ($M)

Location	FY19-FY28
Central Artery	N.A.
CANA	N.A.
Sumner\Callahan	N.A.
Boston Extension	$0.08
MHS TOTAL	**$0.08**

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

Location	FY19	FY20	FY21	FY22	Near Term FY19-FY22	FY23	FY24	FY25	FY26	FY27	FY28	Long Term FY23-FY28
Central Artery	0	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	$0.04	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.05
MHS TOTAL	**$0.01**	**$0.01**	**$0.01**	**$0.01**	**$0.04**	**$0.01**	**$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 2018 dollars.

Repairs to address deficient findings as to whether the MHS has been maintained in safe and good repair, working order and condition: **$2,363,870 (Total for 10 years)**

Mechanical
- Small Plumbing Repair: $32,175
- Small Mechanical Repair: $30,291
- Large Mechanical Repair: $30,297
- Small General Maintenance: $20,082
- Long Term Incidents: $900,000

Electrical
- Small Electrical Repair: $385,470
- Large Electrical Repair: $30,411
- Small General Maintenance: $35,144
- Long Term Incidents: $900,000

Maintenance Costs: **$7,034,830 (Total for 10 years)**

Pump Station maintenance costs are determined based on 0.5% percent of the Buildings insured value.
- Central Artery Tunnel: $4,656,469
- CANA: $257,786
- Sumner/Callahan: $1,123,678
- Boston Extension: $996,897

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

Table 45: Total Projected Expenditures – Pump Stations – Present Day ($M)

Location	FY19-FY28
Central Artery	$6.97
CANA	$0.26
Sumner\Callahan	$1.12
Boston Extension	$1.05
MHS TOTAL	**$9.40**

Table 46: Annualized Projected Expenditures – Pump Stations – Escalated ($M)

Location	FY19	FY20	FY21	FY22	Near Term FY19-FY22	FY23	FY24	FY25	FY26	FY27	FY28	Long Term FY23-FY28
Central Artery	$0.54	$0.56	$0.58	$0.59	$2.28	$0.90	$0.93	$0.95	$0.98	$1.01	$1.04	$5.81
CANA	$0.03	$0.03	$0.03	$0.03	$0.11	$0.03	$0.03	$0.03	$0.03	$0.03	$0.03	$0.19
Sumner\Callahan	$0.11	$0.12	$0.12	$0.12	$0.47	$0.13	$0.13	$0.13	$0.14	$0.14	$0.15	$0.82
Boston Extension	$0.11	$0.12	$0.12	$0.12	$0.47	$0.11	$0.12	$0.12	$0.12	$0.13	$0.13	$0.73
MHS TOTAL	**$0.80**	**$0.82**	**$0.84**	**$0.87**	**$3.33**	**$1.17**	**$1.20**	**$1.24**	**$1.27**	**$1.31**	**$1.35**	**$7.54**

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 2018 dollars.

Repairs to address deficient findings as to whether the MHS has been maintained in safe and good repair, working order and condition.

Near Term (Assumed to occur within next 4 yrs): **$1,426,524 (Total for 10 years)**

- Roadway Section Ratings ≤ 5
- Isolated Deficiencies

Near Term Repair Types

- Small General Maintenance
- Large General Maintenance
- Small Electrical Repair
- Full Depth Patching
- Vegetation Clearing
- Fencing
- Fencing Demolition
- Railing
- Demolish Railing
- Catch Basin
- Sign Removal (0 - 10 SF)
- Sign (24" x 24")
- Sign (30" x 30")
- Sign (12" x 18")
- Sign (18" x 24")
- Sign Post
- Impact Attenuator
- Concrete Barrier
- Temporary Barrier
- Mobilization

Annual Maintenance Costs: **$1,838,707 (per year)**

- Catch Basin Cleaning = $415/Day (Assumed work rate = 1/2 Mile per Day)
- Trash & Debris Removal = $750/Day (Assumed work rate = 2 Miles per Day)

- Washout Repairs = $2,000 Each (Assumed 2 per Mile)
- Crash Attenuator Replacement = 40,000 Each (Assume 25 replacements required for entire MHS)
- Guardrail Repairs = $35/LF (Assume 120 LF of repair per mile of roadway)
- Fence Repairs = $35/LF (Assume 1% of roadway length)
- Mowing = $600/Mile (Assume performed 2 times annually)
- Vegetation Control = $1,800/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 47: Total Projected Expenditures – Roadway – Present Day ($M)

Location	FY19-FY28
Central Artery	$10.89
CANA	$1.33
Sumner\Callahan	$0.56
Boston Extension	$7.03
MHS TOTAL	**$19.81**

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

Location	FY19	FY20	FY21	FY22	Near Term FY19-FY22	FY23	FY24	FY25	FY26	FY27	FY28	Long Term FY23-FY28
Central Artery	$1.12	$1.16	$1.19	$1.23	$4.70	$1.20	$1.24	$1.27	$1.31	$1.35	$1.39	$7.76
CANA	$0.13	$0.14	$0.14	$0.15	$0.56	$0.15	$0.15	$0.16	$0.16	$0.17	$0.17	$0.97
Sumner\Callahan	$0.06	$0.06	$0.06	$0.06	$0.23	$0.06	$0.06	$0.07	$0.07	$0.07	$0.07	$0.41
Boston Extension	$0.88	$0.91	$0.94	$0.96	$3.69	$0.66	$0.68	$0.70	$0.72	$0.74	$0.76	$4.25
MHS TOTAL	**$2.20**	**$2.26**	**$2.33**	**$2.40**	**$9.18**	**$2.07**	**$2.13**	**$2.20**	**$2.26**	**$2.33**	**$2.40**	**$13.39**

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 2018 dollars.

Repairs to address deficient findings as to whether the MHS has been maintained in safe and good repair, working order and condition.

Near Term (Assumed to occur within next 4 yrs): **$279,010 (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: **$127,459 (per year)**

- Catch Basin Cleaning = $415/Day (Assumed work rate = 1/2 Mile per Day)
- Trash & Debris Removal = $750/Day (Assumed work rate = 2 Miles per Day)
- Washout Repairs = $2,000 Each (Assumed 2 per Mile)
- Guardrail Repairs = $35/LF (Assume 120 LF of repair per mile of roadway)
- Fence Repairs = $35/LF (Assume 2% of roadway length)
- Mowing = $600/Mile (Assume performed 2 times annually)
- Vegetation Control = $1,800/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 49: Total Projected Expenditures – Interchanges – Present Day ($M)

Location	FY19-FY28
Central Artery	N.A.
CANA	N.A.
Sumner/Callahan	N.A.
Boston Extension	$1.55
MHS TOTAL	**$1.55**

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

Location	FY19	FY20	FY21	FY22	Near Term FY19-FY22	FY23	FY24	FY25	FY26	FY27	FY28	Long Term FY23-FY28
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	$0.20	$0.20	$0.21	$0.22	$0.83	$0.14	$0.15	$0.15	$0.16	$0.16	$0.17	$0.93
MHS TOTAL	**$0.20**	**$0.20**	**$0.21**	**$0.22**	**$0.83**	**$0.14**	**$0.15**	**$0.15**	**$0.16**	**$0.16**	**$0.17**	**$0.93**

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 2018 dollars.

Repairs to address deficient findings as to whether the MHS has been maintained in safe and good repair, working order and condition: **$3,275,849 (per year)**

- Pothole Repair = $12,000/Day (Assumed work rate = 3 Days per Roadway Mile)
- Pavement Crack Sealing = $12,000/Day (Assumed work rate = 2 Miles per Roadway Mile) (Annualized over 5 yrs)

Maintenance Costs (Pavement Program assumed to occur over 10 yrs): **$12,856,375 (per year)**

- Mill and Repave = $520,000/Lane Mile (Annualized over 10 years)
- Repaint Pavement Markings = $2/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 51: Total Projected Expenditures – Pavement – Present Day ($M)

Location	FY19-FY28
Central Artery	$86.57
CANA	$9.72
Sumner/Callahan	$3.48
Boston Extension	$61.55
MHS TOTAL	**$161.32**

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

Location	FY19	FY20	FY21	FY22	Near Term FY19-FY22	FY23	FY24	FY25	FY26	FY27	FY28	Long Term FY23-FY28
Central Artery	$8.66	$8.92	$9.18	$9.46	$36.22	$9.74	$10.04	$10.34	$10.65	$10.97	$11.30	$63.03
CANA	$0.97	$1.00	$1.03	$1.06	$4.07	$1.09	$1.13	$1.16	$1.20	$1.23	$1.27	$7.07
Sumner/Callahan	$0.35	$0.36	$0.37	$0.38	$1.46	$0.39	$0.40	$0.42	$0.43	$0.44	$0.45	$2.54
Boston Extension	$6.16	$6.34	$6.53	$6.73	$25.75	$6.93	$7.14	$7.35	$7.57	$7.80	$8.03	$44.81
MHS TOTAL	**$16.13**	**$16.62**	**$17.11**	**$17.63**	**$67.49**	**$18.16**	**$18.70**	**$19.26**	**$19.84**	**$20.44**	**$21.05**	**$117.45**

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 2018 dollars.

Repairs to address deficient findings as to whether the MHS has been maintained in safe and good repair, working order and condition:

Near Term (Assumed to occur within next 4 yrs): **$6,159,358 (Total for 10 years)**

- Wall Ratings ≤ 5
- Isolated Deficiencies

- Small General Maintenance
- Large General Maintenance
- Small Structural Repair
- Fabricated Structural Steel Material
- Concrete Crack Repair
- Partial Depth Patching
- Full Depth Patching
- Vegetation Clearing
- Fencing
- Fencing Demolition
- Concrete Retaining Wall (10')
- Concrete Retaining Wall (8')
- Structural Steel Repairs
- Railing
- Demolish Railing
- Joint Sealant Replacement
- Metal Wall (10')
- SOE
- Excavation
- Mobilization

Maintenance Costs: **$366,000 (Total for 10 years)**

Long Term (Assumed to occur within the last 6 yrs):

- 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 53: Total Projected Expenditures – Walls – Present Day ($M)

Location	FY19-FY28
Central Artery	$0.20
CANA	N.A.
Sumner/Callahan	N.A.
Boston Extension	$6.32
MHS TOTAL	$6.53

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

Location	FY19	FY20	FY21	FY22	Near Term FY19-FY22	FY23	FY24	FY25	FY26	FY27	FY28	Long Term FY23-FY28
Central Artery	$0.05	$0.05	$0.05	$0.05	$0.20	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.01
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	$1.49	$1.54	$1.58	$1.63	$6.24	$0.07	$0.07	$0.07	$0.07	$0.08	$0.08	$0.43
MHS TOTAL	**$1.54**	**$1.59**	**$1.63**	**$1.68**	**$6.44**	**$0.07**	**$0.07**	**$0.07**	**$0.08**	**$0.08**	**$0.08**	**$0.44**

6.6.5 Sign Support Structures

The following is the cost expenditure breakdown of the Walls Recommendations noted in Section 5.4.5. These costs are in 2018 dollars.

Repairs to address deficient findings as to whether the MHS has been maintained in safe and good repair, working order and condition: **$264,889 (Total for 10 years)**

Near Term (Assumed to occur within next 4 yrs)
- o Sign Support Structure Condition Ratings ≥ 2
- o Isolated Deficiencies

Near Term Repair Types
- o Small General Maintenance
- o Large General Maintenance
- o Concrete Repair
- o Concrete Crack Repair
- o Partial Depth Patching
- o Full Depth Patching
- o Railing
- o Paint
- o Sign Removal (0 - 10 SF)
- o Sign Removal (41 - 100 SF)
- o Sign (12" x 18")
- o Small Electrical Repair
- o Impact Attenuator
- o Backfill
- o Erosion Control Mat
- o Mobilization

Maintenance Costs: **$225,000 (per year)**
- o Bi-Annual Inspections: $5,000 Each (Annualized over 2 years)

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

Table 55: Total Projected Expenditures – Sign Support Structures – Present Day ($M)

Location	FY19-FY28
Central Artery	$1.53
CANA	N.A.
Sumner/Callahan	$0.08
Boston Extension	$0.91
MHS TOTAL	**$2.51**

Table 56: Annualized Projected Expenditures – Sign Support Structures – Escalated ($M)

Location	FY19	FY20	FY21	FY22	Near Term FY19-FY22	FY23	FY24	FY25	FY26	FY27	FY28	Long Term FY23-FY28
Central Artery	$0.18	$0.18	$0.19	$0.20	$0.75	$0.15	$0.16	$0.16	$0.17	$0.17	$0.18	$0.98
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	$0.03	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.05
Boston Extension	$0.10	$0.11	$0.11	$0.11	$0.44	$0.09	$0.10	$0.10	$0.10	$0.10	$0.11	$0.60
MHS TOTAL	**$0.29**	**$0.30**	**$0.31**	**$0.32**	**$1.22**	**$0.25**	**$0.26**	**$0.27**	**$0.28**	**$0.29**	**$0.29**	**$1.64**

6.6.6 Parks

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