Commonwealth of Massachusetts

Central Artery (I-93)/ Tunnel (I-90) Project

Renewal of the Operating Certification of the Project Ventilation System

Technical Support Document

Final Report
September 14, 2021

Prepared For
Massachusetts Department of Transportation

by
VHB/TRC Companies

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AIS	Air Intake Structure
CA/T	Central Artery/Tunnel
CEM	Continuous Emissions Monitoring
CFM	Cubic Feet Per Minute
CFR	Code of Federal Regulations
CMR	Code of Massachusetts Regulations
CO	Carbon Monoxide
CTPS	Central Transportation Planning Staff
DAHS	Data Acquisition Handling System
DST	Dewey Square Tunnel
ELA	Emission Limit Assessment
EPA	US Environmental Protection Agency
FHWA	Federal Highway Administration
FSEIS/R	Final Supplemental Environmental Impact Statement/Report
g/s	Grams per Second
hp	Horsepower
HOC	Highway Operations Center
MassDEP	Massachusetts Department of Environmental Protection
MBTA	Massachusetts Bay Transportation Authority
MassDOT	Massachusetts Department of Transportation
$\mu g/m^3$	Micrograms Per Cubic Meter
MMIS	Maintenance Management Information System
MPH	Miles Per Hour
MPO	Metropolitan Planning Organization
NAAQS	National Ambient Air Quality Standard
NEMA	National Electric Manufacturers Association
NIST	National Institute of Standards and Technology
NMHC	Non-Methane Hydrocarbon
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxide
NPC	Notice of Project Change
OLM	Ozone Limiting Method
PM	Particulate Matter
PM_{10}	Particulate Matter - 10 micron
$PM_{2.5}$	Particulate Matter – 2.5 micron
ppm	Parts Per Million
ppb	Parts Per Billion
QA/QC	Quality Assurance/Quality Control
Ramps	LC-S (Leverett Circle to Central Artery SB); SA-CN (Surface Artery to Central Artery NB); CN-S (Central Artery NB to Storrow Drive); ST-CN (Sumner Tunnel to Central Artery NB); ST-SA (Sumner Tunnel to Surface Artery); CS-SA (Central Artery SB to Surface Artery); CS-P (Central Artery to Purchase Street); F (I-90 WB to Congress Street)
SIP	State Implementation Plan
SOPs	Standard Operating Procedures
TEOM® monitor	Tapered-element oscillating microbalance sensing technology monitor
THC	Total Hydrocarbons
TSD	Technical Support Document
TWT	Ted Williams Tunnel
VB	Ventilation Building
VMT	Vehicle Miles Traveled
VOC	Volatile Organic Compound
VPH	Vehicles Per Hour

Executive Summary

The Central Artery/Tunnel (CA/T) Project depressed and widened I-93 through downtown Boston to Charlestown and constructed (as an extension of I-90) a Seaport Access Highway through South Boston connecting to the Ted Williams Tunnel (TWT) under Boston Harbor to Logan Airport. The Project included approximately 80 lane-miles of tunnels within a 7.5-mile urban corridor. Commercial traffic started flowing through the TWT in 1996, and the remainder of the Project opened to general traffic in March 2005.

The CA/T's ventilation system utilizes a mixture of full transverse and longitudinal ventilation. Most of the tunnels operate with the full-transverse ventilation system in which fresh air enters the tunnels under the roadway and the exhaust air exits through openings in the tunnel ceilings to plenums located above the ceiling. The ventilation fans and auxiliary equipment that provide fresh air and exhaust air are located in six ventilation buildings (VB) designated as VB1, VB3, VB4, VB5, VB6, and VB7. The portion of I-93 called the Dewey Square Tunnel (DST) and eight exit ramps are longitudinally ventilated. In the longitudinally ventilated tunnels, exhaust air moves in the direction of the traffic flow and it is exhausted through the exit portals. Some longitudinally ventilated tunnels include supply air and/or jet fans mounted in the tunnel ceilings or walls. Two additional VBs provide fresh air to two longitudinally ventilated tunnel sections (VB8, and the DST Air Intake Structure (AIS)).

MASSDEP REGULATION 310 CMR 7.38, AND ITS FIVE-YEAR RENEWAL REQUIREMENTS FOR THE OPERATING CERTIFICATION

The CA/T Project's tunnel ventilation system is subject to the regulations set forth by the Massachusetts Department of Environmental Protection (MassDEP) in the Code of Massachusetts Regulations (CMR) at 310 CMR 7.38 entitled "Certification of Tunnel Ventilation Systems in the Metropolitan Boston Air Pollution Control District." Pursuant to 310 CMR 7.38(2), no person shall construct a tunnel ventilation system and project roadway subject to 310 CMR 7.00 without first certifying to MassDEP (and receiving MassDEP written acceptance of that certification) that the operation of any tunnel ventilation system, project roadway, and roadway networks will not cause or exacerbate a violation of certain specified ambient air quality standards, guidelines, and other criteria specified in 310 CMR 7.38.

In compliance with MassDEP Regulation 310 CMR 7.38, the CA/T Project submitted to MassDEP in 2006 an Operating Certification Application for the CA/T Tunnel Ventilation System, which established emission limits for all VBs, the DST, and each longitudinally ventilated exit ramp. The 2006 Operating Certification Application established tunnel emission limits for carbon monoxide (CO), nitrogen oxides (NO_x) and particulate matter equal to or smaller than 10 microns in diameter (PM_{10}). It demonstrated that these emission limits would ensure compliance with National and State Ambient Air Quality Standards (NAAQS) for CO, nitrogen dioxide (NO_2), and PM_{10} and MassDEP guideline values for NO_2. It also established a regional emissions budget for volatile organic compounds (VOC) based on the 2005 CA/T build predictions, which included highway and transit components. MassDEP gave final acceptance to the 2006 CA/T Operating Certification on December 22, 2006 (hereafter referred to as the 2006 CA/T Operating Certification).

On July 1, 2011, MassDOT submitted to MassDEP the Renewal Application for the Operating Certification for the CA/T Tunnel Ventilation System. The renewal application included an air quality compliance demonstration, summaries of air quality and traffic monitoring data, a review of feasible emission control technologies, and updates since the 2006 submittal. The Final document (hereafter referred to as the 2011 CA/T Renewal Operating Certification), which addressed all MassDEP comments, was submitted on September 30, 2011.

The 2011 CA/T Renewal Operating Certification included new emission limits for particulate matter equal to or smaller than 2.5 microns in diameter ($PM_{2.5}$) and demonstrated compliance with the updated $PM_{2.5}$ NAAQS. The new $PM_{2.5}$ emission limits replaced the PM_{10} emission limits established as part of the original operation certification approved in 2006. It also demonstrated that the VOC regional emissions for 2010 were below the VOC budget based on the 2005 CA/T build predictions, which included highway and transit components. In addition, it requested submission of a supplemental application to MassDEP on July 1, 2012 to establish revised emission limits for CO and NOx, which were needed to demonstrate compliance with the 1-hour NAAQS for NO_2.

MassDEP approved the two-part renewal certification approach on May 12, 2011. The need for the two-part certification approach was driven by the US Environmental Protection Agency (EPA) adoption of a new and more stringent one-hour NAAQS for NO_2 effective April 12, 2010. The supplemental application allowed MassDOT to collect a full year of nitric oxide (NO), NO_2 and NO_x data at the DST portal and at the Albany Street sidewalk locations. The purpose of this monitoring was to develop a method for estimating new emission limits for NO_x at all ventilation buildings and longitudinally ventilated tunnels and ramps.

The site-specific monitoring-based methodology replaced the ozone limiting method (OLM) used to demonstrate compliance with MassDEP one-hour NO_2 Policy Guideline. The OLM technique assumes the instantaneous conversion of emitted NO to NO_2 and, in addition, allows this conversion process to continue as long as ambient ozone (O_3) is available in the atmosphere. MassDEP and MassDOT concurred that actual short-distance conversion rates were likely lower, and that a site-specific monitoring-based approach was a more appropriate method to establish the new emission limits for NO_x.

Since NO_x levels were estimated as a function of in-tunnel CO levels in the original 2006 CA/T Operating Certification, the analysis of one full year of NO, NO_2, NO_x and CO data at the DST was used to determine a more appropriate CO-NO_x correlation. Additionally, new emission limits for CO were also established in this supplemental application.

MassDOT submitted the Final Supplemental Application for the CA/T Renewal Operating Certification on August 1, 2012. MassDEP issued a Final acceptance of the 2012 CA/T Renewal Operating Certification Application submitted August 1, 2012 in its letter dated February 14, 2013. The acceptance includes a list of specific requirements and covers the remainder four year operating period from December 19, 2012 to December 19, 2016.

ACCEPTANCE OF 2016 CA/T RENEWAL OPERATING CERTIFICATION

MassDOT submitted the Final Application for the CA/T Renewal Operating Certification on September 12, 2016.

MassDEP issued a Final acceptance of the 2016 CA/T Renewal Operating Certification Application in its letter dated February 28, 2018. The acceptance includes a list of specific requirements and covers the remainder of the operating period from December 19, 2016 to December 19, 2021. The most significant changes for the 2016-2021 period accepted by MassDEP include:

- The reduction in the total number of CO monitors from 25 to 7 (one per ventilation building and two in ventilation building #7) to allow MassDOT to better maintain the current CO monitors by using the monitors removed from service for spare parts and thus extending their useful life in the CEM system. This will also make more feasible a full upgrade in the future.
- The CO monitors at Dewey Square Tunnel (I-93 and I-90 collector) and three longitudinally ventilated ramps (CN-S, CS-SA and CS-P) continued in accordance with the current CEM program.

- The four $PM_{2.5}$ monitors installed in three VBs, and one outside Ramp CS-SA continued their operation in the 2016-2021 period. In addition, a NO_x monitor inside the DST I-93 longitudinally ventilated ramp was installed and started operating after the approval of the 2016-2021 certification period.

- The $PM_{2.5}$ monitor at the air intake in ventilation building #7 that was intended to monitor background conditions at the ventilation building air intake structure in Logan airport, has served its purpose and was no longer needed. It was eliminated along with CO monitors at the same ventilation building.

2021 CA/T Renewal Operating Certification

This renewal application covers the five-year period from December 19, 2021 through December 19, 2026.

For consistency, this 2021 document follows the format of the 2016 CA/T Renewal Operating Certification TSD, retaining the aspects that remain unchanged and replacing or adding information, as needed. It incorporates new changes, updates the CO, NOx and $PM_{2.5}$ emission limits with their corresponding compliance requirements, and provides updates to the summaries of data collected since 2016. As such, this 2021 TSD document provides most of the information included in the 2016 TSD and all the necessary updates, which form part of this application.

Information contained in the versions prior to the 2016 TSD is NOT repeated in this document unless necessary to provide context and/or inputs for the emission limits compliance demonstration.

The 2021 CA/T Renewal Operating Certification includes a Technical Support Document (TSD) divided into four parts:

- Part I – Ventilation System – Operation and Determination of Emission Limits
- Part II – Compliance Monitoring Program
- Part III – Record Keeping and Reporting
- Part IV – Corrective Actions

The 2021 TSD also includes several appendices and attachments:

- Appendix A: MassDEP Certification Acceptance Letters (2006, 2011/12 and 2016)
- Appendix B: Air Quality Analysis Protocol for Determination of Emission Limits as Part of the Operating Certification of the Project Ventilation Systems
- Appendix C: Air Quality 2021 Impact Analysis Supporting Modeling Data (VBs, DST, and Ramps)
- Appendix D: CEM 2016-2021 Certification Test Data
- Appendix E: CEM 2016-2021 Data
- Appendix F: MassDEP Correspondence (2016 Certification approval, ELA assessments, AQ Protocol approval letters and other important correspondence)
- Appendix G: Monitoring Equipment Standard Operating Procedures (SOPs); and
- Attachment I: CEM 2021 Air Emissions Monitoring Protocol

TSD Part I describes in detail the CA/T's ventilation system, and the air quality emission limits established for the exhaust from the ventilation buildings and the longitudinally ventilated tunnel sections (DST and three exit ramps). Emission limits established for the 2016-2021 operating certification period apply to day-to-day tunnel operation, except for emergency situations during a tunnel fire. The limits for CO, NO_x and

$PM_{2.5}$ were determined as concentration-based emission limits (i.e., measured levels in parts per million [ppm] or micrograms per cubic meter [$\mu g/m^3$] inside the tunnels).

Section 1 of TSD Part I covers the description of the CA/T ventilation system, its physical properties, feasible emission control technologies, and expected operating conditions. Ventilation building emissions control technology reviews were performed in 1991, 1995, 2004, 2011, 2016 and are updated in this document. An extensive investigation, conducted as part of these reviews, revealed that ventilation was the predominant method of tunnel (inside and outside) air quality control employed in the United States and around the world. All reviews concluded that there are no feasible and effective control techniques available that would result in a net reduction of the tunnel exhaust emissions.

The emissions data collected inside the CA/T tunnel indicate that safe in-tunnel air quality levels were maintained during the past fifteen years. The results of the monitoring program and corrective actions indicated that despite a very few instances between 2006 and 2020 (when abnormal conditions resulted in measured concentrations exceeding the established emission limits), ambient pollutant levels outside the tunnels have been well below the applicable NAAQS and MassDEP One Hour NO_2 Policy Guideline. The Boston metropolitan area is in attainment with all NAAQS except 1997 ozone standard for which it is considered an "orphan maintenance area"[1].

Section 2 of TSD Part I – Determination of Emission Limits – includes the procedures for determining the revised emission limits for CO, NO_x, $PM_{2.5}$, and compliance with regional emission budget for VOC.

Section 2 updates the compliance demonstration following the same technical modeling approach used in the 2016 TSD to determine in-tunnel NO_x levels as a function of CO levels at every monitoring location except at the Dewey Square Tunnel where NO_x levels are monitored directly. The section describes the NO to NO_2 conversion factors based on the results of the 2011-2012 DST Monitoring Program.

The monitoring program that collected one year of CO, NO_x, NO, and NO_2 data inside the DST exit portal and along the Albany Street sidewalk locations in 2011-2012 is summarized in this section.

The compliance modeling analysis for the ventilation buildings described in this section incorporates the most current background levels, 2016-2020 meteorological data, and receptor locations based on current buildings configuration in each VB surrounding area.

The VB emission impacts were evaluated using the EPA's AERMOD air quality dispersion model. The maximum predicted emission impacts, when added to the appropriate background pollutant concentrations were compared to the applicable NAAQS and MassDEP policy guideline value for compliance assessment. The entire modeling process was repeated to establish the allowable emission limits at which ambient standards will be attained. The detailed modeling procedures to determine VB emission impacts and emission limits can be found in section 2.7.1.

The air quality dispersion modeling analyses to determine emission limits for DST and the three longitudinally ventilated ramps (CN-S, CS-SA and CS-P) are based on the dilution coefficients obtained through the 1996 physical simulation study for the longitudinally ventilated ramps and through the 2005 DST physical simulation study described in section 2.7.2. The current DST configuration in this modeling is based on Configuration #2 which includes development of Parcel 24 already built. NO to NO_2 conversion factors based on the 2011-2012 results of the DST Monitoring Program are applied to the VB, DST and ramps evaluation process.

[1] EPA defines areas that had been in non-attainment for the 1997 ozone standard at the time when this standard was revoked, see https://www.epa.gov/sites/default/files/2018-11/documents/ozone_1997_naaqs_lmp_resource_document_nov_20_2018.pdf

This section also includes a brief discussion of the status of the evaluation of the future emission limits related to the ongoing MEPA process for the creation of additional parkland features over Parcels 6 and 12, which was envisioned to cover ramps ST-SA/CN and CS-SA/CN-SA.

Table ES-1 provides the CO and NO_x revised emission limits presented in this document. These emission limits will come into effect in December 2021 and will be valid till 2026.

Section 2 updates the $PM_{2.5}$ compliance demonstration for the VBs following the technical modeling approach used in the 2016 TSD, and explained in more detail in section 2.6, with the incorporation of the most current background levels from MassDEP monitoring stations, the 2016 to 2020 local meteorological data, and receptor locations based on current buildings configuration in each VB surrounding area. The results of this analysis indicate that a revised $PM_{2.5}$ emission limit of 700 µg/m^3 demonstrates compliance with the current $PM_{2.5}$ annual and 24-hour NAAQS.

TABLE ES-1: SUMMARY OF EMISSION LIMITS FOR 2021 TO 2026 PERIOD

Location*	1-Hour CO Emission Limit (ppm)	8-Hour CO Emission Limit (ppm)	1-Hour NO_X Emission Limit (ppm)	24-Hour $PM_{2.5}$ Emission Limit (µg/m^3)
VB 1	70	70	6.1	700
VB 3	70	70	6.1	700
VB 4	70	70	6.1	700
VB 5	70	70	6.1	700
VB 6	70	70	6.1	700
VB 7	70	70	6.1	700
Ramp CN-S	40	62	3.6	NA
Ramp CS-SA**	41	63	3.7	35***
Ramp CS-P	43	70	3.9	NA
Dewey Sq. Tunnel	70	28	2.0	NA

Notes: Acronyms are defined as: Central Artery Northbound to Storrow Drive (C-NS), Central Artery Southbound to Surface Artery (CS-SA), Central Artery Southbound to Purchase Street (CS-P), part per million (ppm), microgram per cubic meter (µg/m^3).

* For each ventilation building, location includes all associated ventilation zones.

** The ambient $PM_{2.5}$ monitor is located outside ramp CS-SA.

*** Compliance with the 24-hour $PM_{2.5}$ NAAQS is based on the monitoring design value, which is given by the 3-year average of the annual 98th percentile value of daily average concentrations. The form of the standard allows, on average, for the numerical value of the standard (35 µg/m^3) to be exceeded on seven calendar days per calendar year without triggering a violation of the NAAQS.

Lastly, Section 2 provides a summary of the VOC regional analysis. The 2016 Operating Certification demonstrated that the VOC regional emissions for 2016 were approximately one third of the VOC budget based on the 2005 CA/T Build Alternative predictions, which included highway and transit components. Based on the significant decreases in VOC motor vehicle emissions and the attainment status of the Boston Metro area to the current O_3 standard, the 2021 CA/T renewal certification follows the simplified approach to estimate the reductions in the regional VOC levels used in the 2016 CA/T renewal certification. This approach uses MOVES3 (EPA s' Motor Vehicle Emission Simulator) VOC emission factors and anticipated traffic increases based on current traffic growth factors.

The result of the 2021 VOC regional emissions approach (described in section 2.6.8) indicated that VOC emissions for the CA/T area would be in the range of 1,300 kg/day, which is close to one fifth of the 2005 VOC emission budget of 6,095.9 kg/day. The reduction is attributable to fleet turnover and cleaner vehicles and fuels mandated by Federal and State regulations over the past decade.

TSD Part II describes the CA/T's compliance monitoring program, including the Continuous Emissions Monitoring (CEM) system designed, constructed, and installed to demonstrate compliance with established emission limits and used to aid the operators to maintain safe air quality and visibility within the tunnels under normal operations.

The CEM system is a hybrid type of monitoring system. The CEM system incorporates appropriate elements of federal regulations 40 CFR Part 58, 60, and 75 for the ambient air quality monitoring systems and the continuous emission monitoring at power plants. Equipment certification and operations are specifically tailored for use in the CA/T's emission monitoring program. The 2021 CA/T Renewal Operating Certification TSD Attachment 1 (CEM Air Emissions Monitoring Protocol) provides specific information regarding CEM equipment that has been installed and/or revised for the 2021-2026 operating certification at each VB and longitudinally ventilated exit ramp as well as the operational protocol for the CEM equipment.

MassDOT monitors vehicular emissions of CO in the exhaust plenum of each ventilation building prior to discharge up and out the building stacks, and at the exit portal of DST and three longitudinally ventilated exit ramps. MassDOT monitors $PM_{2.5}$ emissions at four representative in-tunnel locations with the highest $PM_{2.5}$ levels and ambient levels in the vicinity of Ramp CS-SA. Starting in April of 2018, a NO_x monitor measured hourly levels inside the DST (I-93 portal).

TSD Part III describes the record keeping and reporting aspects of the CA/T's Operating Certification, MassDOT process to record CO and $PM_{2.5}$ data continuously at each CEM location and the procedures to download data to a central computer location. MassDOT reviewed the data and generated daily data summaries for each month. Using the daily summaries, MassDOT developed NO_x emission concentrations using a Project-specific CO to NO_x conversion ratio based on the statistical analysis of several thousand hours of monitored data for both pollutants. The conversion equation is based on data collected at the DST during the April 2011-March 2012 monitoring program.

Traffic monitoring loop detectors failed in 2018. The I-93 (North/South) traffic reporting system was intended to be replaced by cameras, but that project was delayed. The I-90 (East/West) traffic reporting from the last quarter of 2018 has been based on the electronic tolling system.

Traffic estimates reported in this document include conditions during 2020-2021, a very unusual year with significant changes to travel patterns due to the COVID19 pandemic. Estimated peak hour traffic volumes in vehicles per hour (VPH) using the mainline tunnels were generally in the range of 5,780 to 7,280 VPH in each direction of I-93 and in the range of 3,210 to 3,330 VPH in each direction of the I-90. The average daily volumes were in the range of 76,500 to 108,100 vehicles per day (VPD) in each direction of I-93 and in the range of 37,200 to 62,540 VPD in each direction of the I-90. These traffic levels are still below the 2010 project design projections published in the 1990 FSEIS/R.

The tunnel full transverse ventilation system currently operates at Step 1 (13% of exhaust capacity) for off-peak and Step 3 (32% of exhaust capacity) under peak traffic conditions.

The 2016-2021 (1st quarter) data presented in Section 5 of TSD Part III indicate that measured hourly CO concentrations for the ventilation buildings range from 0.9 to 3.0 ppm on average and as high as 26.2 ppm during peak periods for the ventilation buildings. For the DST and ramps, hourly CO concentrations were in the range of 0.9 to 3.5 ppm on average with maximum levels in the range of 10.5 to 27.0 ppm.

Hourly NO_x levels (based on CO measured results) from the ventilation buildings ranged from 0.4 to 0.5 ppm on average with peak values ranging from 0.9 to 2.5 ppm. Hourly NO_x levels for the ramps ranged from 0.3 to 0.6 ppm on average with peaks ranging from 1.2 to 2.5 ppm.

Measured NO_x (NO and NO_2) levels at the DST I-93 portal, for the 2018-2021 1st quarter period ranged from 0.3 to 0.4 ppm on average with peak values ranging from 0.9 to 2.3 ppm.

Measured average daily $PM_{2.5}$ concentrations between 2016 and 2021 were between 12 and 36.4 $\mu g/m^3$, Maximum daily $PM_{2.5}$ values were in the range of 57.0 to 140.9 $\mu g/m^3$. The $PM_{2.5}$ monitor outside Ramp CS-SA, which measures ambient levels, recorded between 2016 and 2021 annual averages from 5.9 to 9.0 $\mu g/m^3$, and a maximum 24-hour daily level of 26.1 $\mu g/m^3$.

TSD Part IV describes the procedures and actions that MassDOT implemented in the event of an exceedance of the established emissions limits due to non-emergency traffic conditions. Part IV also describes the notification process; including MassDOT written notification to MassDEP for emission limits exceedances and actions undertaken by MassDOT to restore compliance with limits.

To help ensure compliance with the emission limits at any location, MassDOT established CEM emission action levels generally in the range of 75% to 80% of the emission limit for each of the monitoring locations. Based on operating experience, MassDOT can effectively maintain acceptable in-tunnel CO concentrations by small, step-by-step increases in the ventilation rate.

Based on the Project's abundant ventilation capacity and well-established procedures, the operation of the system has worked well within the established emission limits. Therefore, specific information regarding a long-term mitigation plan was not included as part of the 2006 Operating Certification, 2011 or 2016 CA/T Renewals of the Operating Certification and will not be provided for the 2021-2026 Operating Certification period.

There were two episodes during the five period from the beginning of 2016 through the end of the first quarter of 2021 when emission limits were exceeded. These episodes resulted in a total of 3 hours when NO_x measured levels at the DST exceeded the corresponding emission limit of 2.1 ppm hourly. There were no emission limit exceedances for CO or $PM_{2.5}$ during the five-year period.

For these two cases when NO_x limit was exceeded, the I-93 southbound tunnel ventilation system was operating at Step 1 (13% capacity). In both instances when the I-93 SB ventilation system was increased to Step 3 (32% capacity) the NO_x levels within the DST were reduced below the action levels within an hour.

To put these events in perspective, CO concentrations were measured every hour at 7 VB exhaust locations and at five locations in the DST and ramps over the last five calendar years (2016-2021) and during the first quarter of 2021, yielding approximately 525,000 observations. No CO exceedances on the emission limits were recorded during this operating period. The two exceedances (3 hours) of the NO_x emission limit for the DST tunnel represent only 0.017% of the direct NO_x measurements at DST.

It is also important to note that none of the episodes when an emission limit was exceeded resulted in a violation of the applicable NAAQS or MassDEP NO_2 Policy guideline. The results of each ELA indicated that the maximum predicted ambient values for NO_2 were 44 and 68% of the applicable NAAQS for NO_2. This shows that the emission limits were established with a considerable margin of safety with regard to the health-related NAAQS.

Introduction

In compliance with MassDEP Regulation 310 CMR 7.38, the CA/T Project filed an application for Operating Certification for the Project's Tunnel Ventilation System during 2006 in which it established emission limits for the exhaust of each Ventilation Building, Dewey Square tunnel, and longitudinally ventilated exit ramps. The 2006 Operating Certification established tunnel emission limits for CO, NO_x and PM_{10} that allowed the tunnel ventilation system to demonstrate compliance with ambient air quality standards for CO, NO_2, and PM_{10} and Massachusetts one-hour Policy Guideline for NO_2. It also established that the CA/T Project was within the regional emissions budget for volatile organic compounds based on the 2005 CA/T build predictions, which included highway and transit components. The 2006 Operating Certification also included: a compliance monitoring program for CO and $PM_{10,}$ record keeping and reporting requirements and procedures, and corrective actions that would be required if any of the established emission limits were exceeded. MassDEP gave final acceptance to the 2006 CA/T Operating Certification in December 22, 2006.

MassDEP Regulation 310 CMR 7.38 requires MassDOT to renew the Operating Certification every five years. On July 1, 2011, MassDOT submitted to MassDEP the Renewal Application for the Operating Certification for the CA/T Tunnel Ventilation System.

The 2011 CA/T Renewal Operating Certification included new emission limits for particulate matter equal to or smaller than 2.5 microns in diameter ($PM_{2.5}$) and demonstrated compliance with the 2006 $PM_{2.5}$ NAAQS. The new $PM_{2.5}$ emission limits replaced the PM_{10} emission limits established as part of the original operation certification approved in 2006. It also demonstrated that the VOC regional emissions for 2010 were below the VOC budget based on the 2005 CA/T build predictions, which included highway and transit components. In addition, it requested to submit a supplemental application to MassDEP on July 1, 2012 to establish revised emission limits for CO and NOx.

The need for the two-part certification approach (2011/12) was driven by the US EPA adoption of a new and more stringent one-hour NAAQS for NO_2 effective April 12, 2010. The delayed supplemental application allowed MassDOT to collect a full year of NO, NO_2 and NO_x data at the DST portal and at the Albany Street sidewalk locations. The purpose of this monitoring was to develop a data-based method for estimating new emission limits for NO_x at all ventilation buildings and longitudinally ventilated tunnels and ramps. MassDEP and MassDOT concurred that a monitoring-based approach was a more appropriate method to establish the new emission limits for NO_x.

Since NO_x levels were estimated as a function of in-tunnel CO levels in the 2006 CA/T Operating Certification, the analysis of one full year of NO, NO_2, NO_x and CO data at the DST was also used to determine a more appropriate CO-NOx correlation that reflected emissions of the motor-vehicle fleet in Massachusetts during the 2012 CA/T Renewal time frame.

MassDOT submitted the Final Supplemental Application for the CA/T Renewal Operating Certification on August 1, 2012.

MassDEP issued a Final acceptance of the 2012 CA/T Renewal Operating Certification Application submitted August 1, 2012 on its letter dated February 14, 2013. The acceptance includes a list of specific requirements described in the February 14, 2013 MassDEP letter, and covers the remaining four-year operating period from December 19, 2012 to December 19, 2016.

MassDOT submitted the Final Application for the CA/T Renewal Operating Certification on September 12, 2016. MassDEP issued a Final acceptance of the 2016 CA/T Renewal Operating Certification Application submitted September 12, 2016 in its letter dated February 28, 2018. The acceptance included a list of specific requirements and covers the remainder of the operating period from December 19, 2016 to December 19, 2021. The most significant changes for the 2016-2021 period accepted by MassDEP included:

- The reduction in the total number of CO monitors from 25 to 7 (one per ventilation building and two in ventilation building #7) will allow MassDOT to better maintain the current CO monitors by using the monitors removed from service for spare parts and thus extending their useful life in the CEM system and make more feasible a full upgrade in the future.

- The CO monitors at Dewey Square Tunnel (I-93 and I-90 collector) and three longitudinally ventilated ramps (CN-S, CS-SA and CS-P) continued in accordance with the current CEM program. There were 12 CO monitors in the CEM system from 2017.

- The four $PM_{2.5}$ monitors installed in three VBs, and one outside Ramp CS-SA continued their operation in the 2016-2021 period.

- In addition, a NO_x monitor inside the DST I-93 longitudinally ventilated ramp was installed and started operating during 2018 after the approval of the 2016-2021 certification period.

This renewal application covers the five-year period from December 19, 2021 to December 19, 2026.

For consistency, this application follows the format of the 2016 CA/T Renewal Operating Certification TSD, retaining the aspects that remain unchanged and replacing or adding information, as needed, to incorporate new compliance requirements and to update summaries of data collected since 2016. As such, this 2021 TSD document provides most of the information included in the 2016 TSD plus all the necessary updates, which form part of this application.

Information contained in the versions prior to the 2016 Approved TSD is NOT repeated in this document, unless necessary to provide context and/or inputs for the emission limits compliance demonstration.

The appendices that appear in this 2021 CA/T Renewal Operating Certification are included as supplements to the electronic files.

Following the same format as the 2016 CA/T Renewal Operating Certification TSD, this document is divided into four parts and several appendices:

- Part I – Ventilation System – Operation and Emission Limits
- Part II – Compliance Monitoring Program
- Part III – Record Keeping and Reporting of 2016-2021 operating levels
- Part IV – Corrective Actions – Procedures implemented during 2016-2021 operations

And several Appendices:

- Appendix A: MassDEP Certification Acceptance Letters (2006, 2011/12 and 2016)
- Appendix B: Air Quality Analysis Protocol for Determination of Emission Limits as Part of the Operating Certification of the Project Ventilation Systems
- Appendix C: Air Quality 2021 Impact Analysis Supporting Modeling Data (VBs, DST, and Ramps, VOC)
- Appendix D: CEM 2016-2021 Certification Test Data

- Appendix E: CEM 2016-2021 Data
- Appendix F: MassDEP Correspondence (2016 Certification approval, ELA assessments, AQ Protocol approval letters and other important correspondence)
- Appendix G: Monitoring Equipment Standard Operating Procedures (SOPs)

Part I – Ventilation System – Operation and Emission Limits

1 DESCRIPTION OF CENTRAL ARTERY/TUNNEL PROJECT VENTILATION SYSTEMS

The Central Artery/Tunnel (CA/T) Project was designed and built to reduce traffic congestion, accidents, and air pollution in the Boston area by replacing the old elevated Central Artery with new aboveground and underground roadways. Figure 1-1 provides the physical limits indicating the above and underground portions of the Project

Approximately 80 lane miles of these new roadways are underground tunnels, including the 7,900-foot-long, four-lane Ted Williams Tunnel (TWT) under the Boston Harbor that connects East Boston to South Boston, the eight to ten lane underground Southeast Expressway (I-93), and the underground portions of the Massachusetts Turnpike (I-90). The TWT opened to commercial and other authorized vehicles on December 15, 1995, and the entire Project was fully operational in March 2005.

As described in the 2016 Renewal of the 2006 TSD of the Operating Certification, in the 1991 Project-wide Final Supplemental Environmental Impact Statement/Report (FSEIS/R), and in the Preferred Alternative in the 1994 FSEIS/R for the Charles River Crossing, the CA/T Project utilizes a full-transverse ventilation system to maintain acceptable in-tunnel air quality set forth by the Federal Highway Administration (FHWA) for motorists traveling in the tunnels.

In response to authorization from the FHWA in November 1995 regarding the use of the longitudinal ventilation system, the Massachusetts Department of Transportation (MassDOT) implemented design refinements to the Project's tunnel ventilation system by using jet fans as a viable alternative for maintaining adequate ventilation. Specifically, the refinements included the replacement of the full-transverse ventilation systems with longitudinal ventilation at the Dewey Square Tunnel (DST) section of I-93 Southbound, and at eight tunnel exit ramps.

1.1 VENTILATION SYSTEM DESIGN CRITERIA

Tunnel ventilation systems servicing the CA/T Project have been designed to provide adequate ventilation capacity during both normal traffic operation and emergency/fire conditions. The urban setting of the Project also imposed significant demands on the tunnel ventilation system design and its allowable impact to the surrounding community. Sensitivity to land use and ambient environmental issues such as noise and air quality weighed heavily in determining the allowable size and locations of the necessary ventilation facilities. Full transverse and longitudinal type ventilation systems were therefore utilized to meet the functional demand of the various road tunnel configurations and the local environmental challenges in the most cost effective and efficient manner.

The design followed the FHWA-Environmental Protection Agency (EPA) in-tunnel air quality criteria, which were established, based on time exposure of the motorists traveling inside the tunnel. Based on these criteria the tunnel operator is required to maintain CO levels below 120 part per million, when the time exposure does not exceed 15 minutes during peak rush hour traffic, 65 ppm for the exposure between 15 and 30 minutes; below 45 ppm for exposure between 30 and 45 minutes; and below 35 ppm when motorists remain inside the tunnels for 60 minutes. The two and half million plus hourly CO concentrations measured during 14 years at the ventilation building (VB) zones ranged from 0.5 to 10.1 ppm on average and reached the highest level of 34.4 ppm at VB7, which is below 50% of the emission limit.

FIGURE 1-1: PHYSICAL LIMITS OF CA/T PROJECT

From a tunnel ventilation perspective, the Project was defined as three distinct and separate road tunnel "systems": Ted Williams Tunnel, the I-90 Tunnel Extension, and the I-93 Central Artery Tunnel. Each of these tunnel systems was divided into multiple "ventilation zones." Each ventilation zone was served by a dedicated and independently controlled set of fans. This concept allowed for significant operational flexibility throughout the Project and provided the means for establishing the most efficient system operation under normal conditions and the most effective system operation in the case of a traffic incident or fire emergency.

The tunnel ventilation system was designed with a supply air capacity of 65 cubic feet per minute (cfm) per lane-foot of tunnel, and an exhaust capacity of 100 cfm per lane-foot of tunnel. The total supply capacity for the full transverse ventilation system (including all six ventilation buildings [VBs]) is approximately 11.4 million cfm serving the 22 ventilation zones. This ventilation system was designed to maintain in-tunnel CO levels between 20 and 60 ppm, and NO_x levels between 1 and 5 ppm, during normal peak hour traffic conditions. Due to advances in motor-vehicle emission control technology and the public's demand for cleaner air, new car emissions have been progressively decreasing. The CO data collected during the first 10 years of operation indicates a significant decrease in tunnel CO levels. Therefore, the CA/T Project ventilation system is expected to provide ample ventilation capacity to accommodate any potential traffic growth.

1.1.1 Full-Transverse Ventilation

In the full-transverse ventilation system, fresh air supply is introduced to the tunnels from under the roadway, and the mixture of vehicle exhaust is extracted through openings in the tunnel ceilings to plenums located above the ceiling before being ducted through the VB's exhaust stacks. Figure 1-2 provides a schematic of the full transverse ventilation system.

1.1.1.1 System Description

The full transverse ventilation system includes six ventilation buildings (VB1, VB3, VB4, VB5, VB6, and VB7) serving 22 ventilation zones with their supply and exhaust fans. The system includes a total of 73 exhaust stacks, each of which is connected to an exhaust fan. The system also includes VB8, which provides only supply air to Ramp CN-S. Figure 1-3 provides a typical cross section for VB4. Figure 1-4 provides the locations of the ventilation buildings.

The sections of the Project served by each VB are as follows:

- VB 1 serves a section of I-90 Westbound / Eastbound, and Ramps D and L. It has four ventilation zones, 11 exhaust stacks, and a supply capacity of 1.66 million cfm.
- VB 3 serves a section of I-93 Northbound / Southbound. It has three ventilation zones, 14 exhaust stacks, and a supply capacity of 2.44 million cfm.
- VB 4 serves a section of I-93 Northbound / Southbound. It has four ventilation zones, 16 exhaust stacks, and a supply capacity of 2.48 million cfm.
- VB 5 serves a section of I-90 Westbound / Eastbound. It has four ventilation zones, 12 exhaust stacks, and a supply capacity of 1.98 million cfm.
- VB 6 serves a section of the TWT Westbound / Eastbound. It has two ventilation zones, 6 exhaust stacks, and a supply capacity of 1.16 million cfm.
- VB 7 serves a section of the TWT Westbound / Eastbound, and Ramp T-AD. It has five ventilation zones, 14 exhaust stacks, and a supply capacity of 1.68 million cfm.

Figures 1-5 to 1-10 provide the location of each VB.

FIGURE 1-2: SCHEMATIC OF FULL-TRANSVERSE VENTILATION SYSTEM

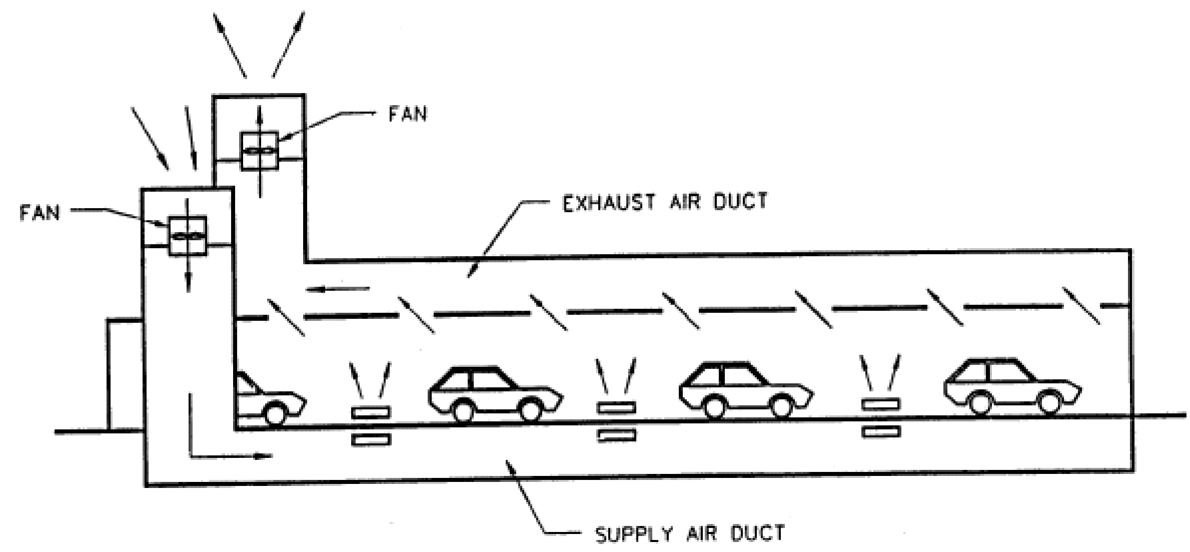


FIGURE 1-3: VENTILATION BUILDING 4 VENTILATION SCHEMATIC DIAGRAM

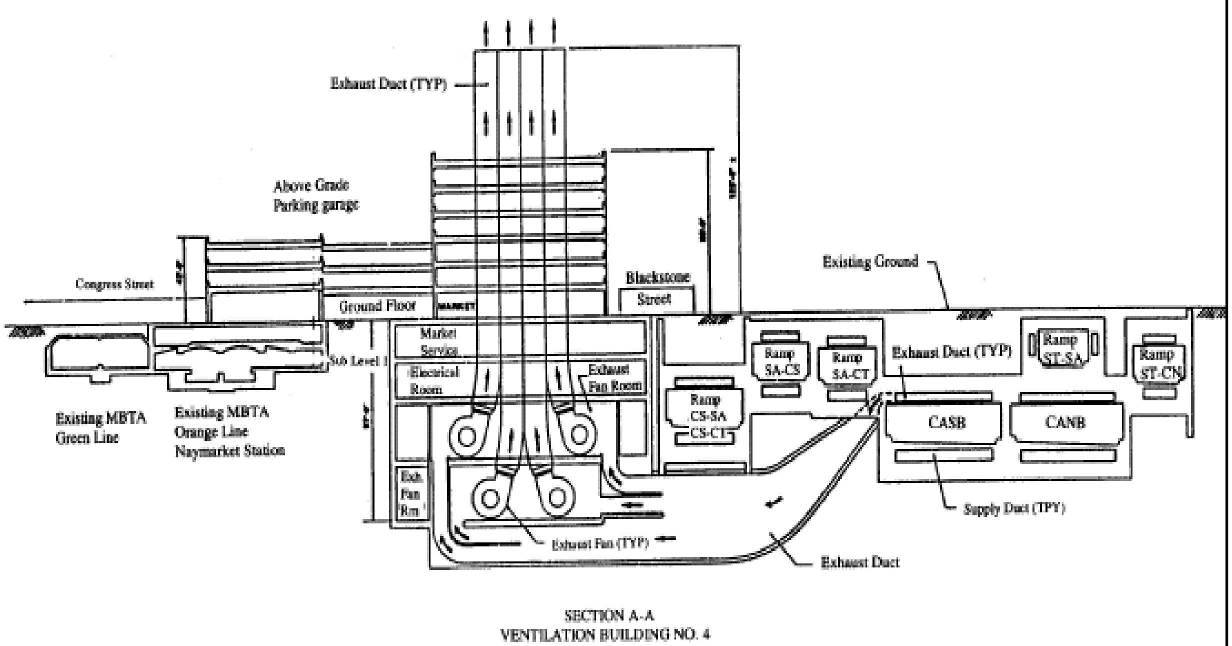


FIGURE 1-4: LOCATION OF VENTILATION BUILDINGS

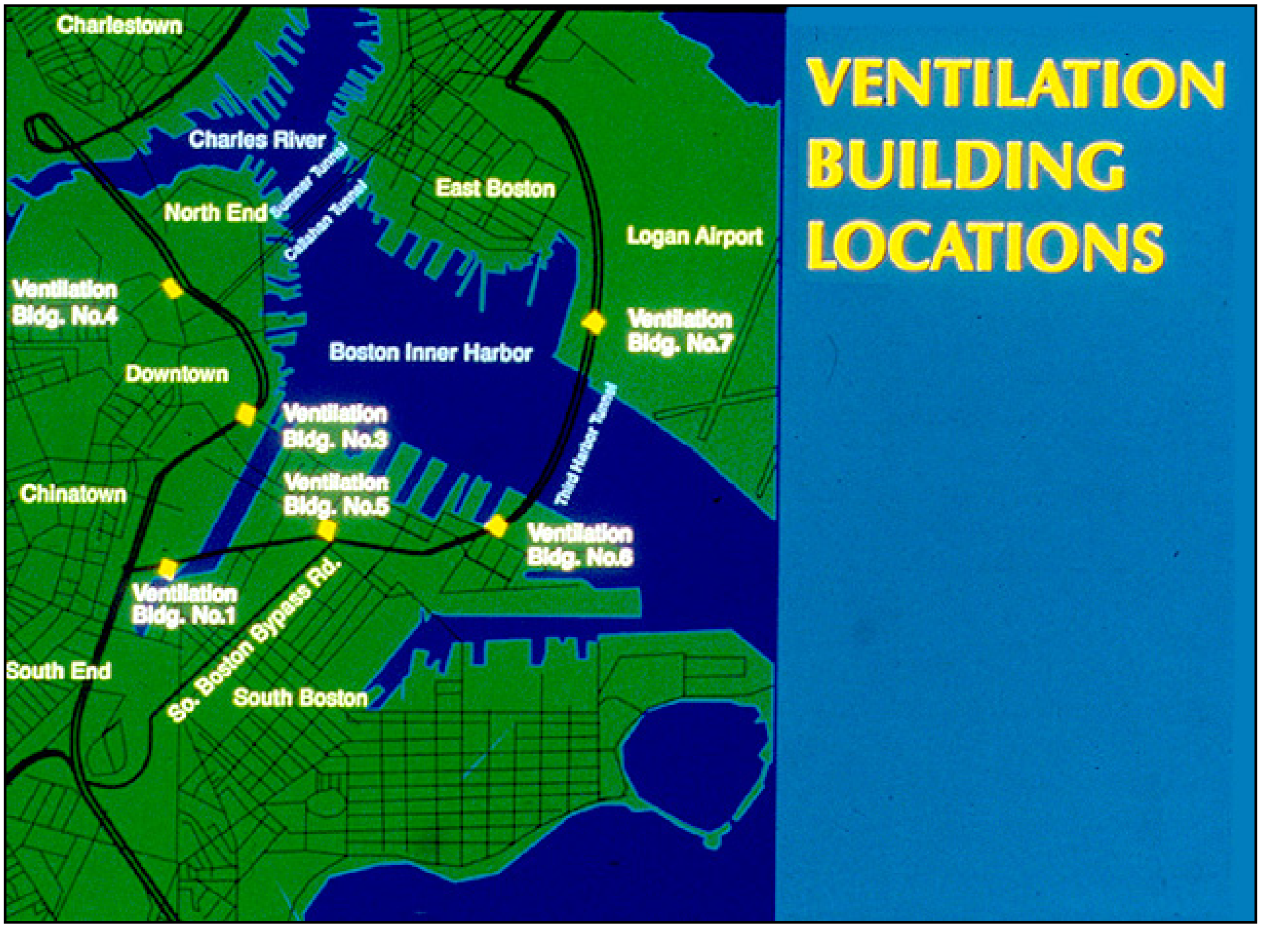


FIGURE 1-5: LOCATION OF VENTILATION BUILDING 1

FIGURE 1-6: LOCATION OF VENTILATION BUILDING 3

FIGURE 1-7: LOCATION OF VENTILATION BUILDING 4

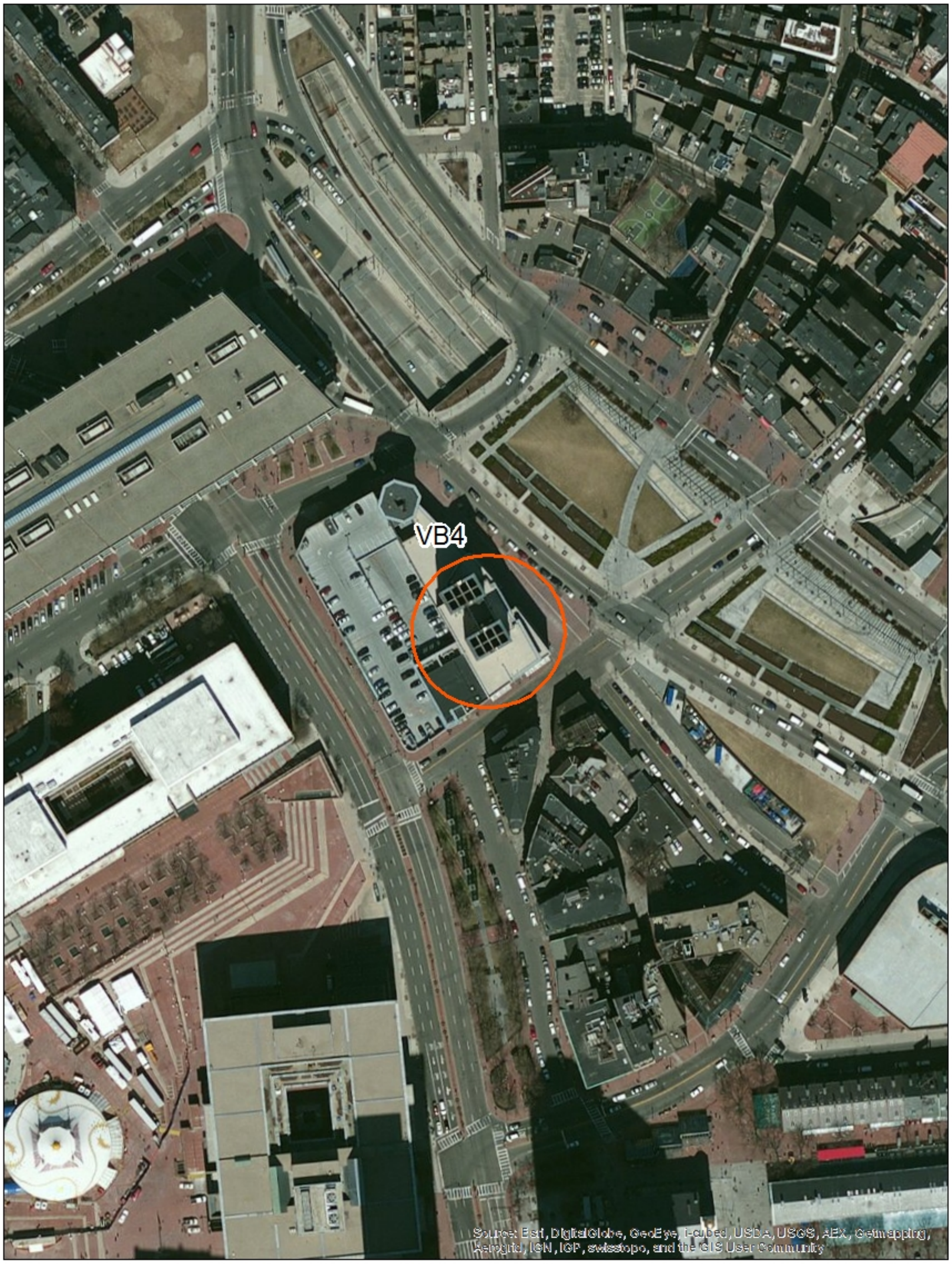
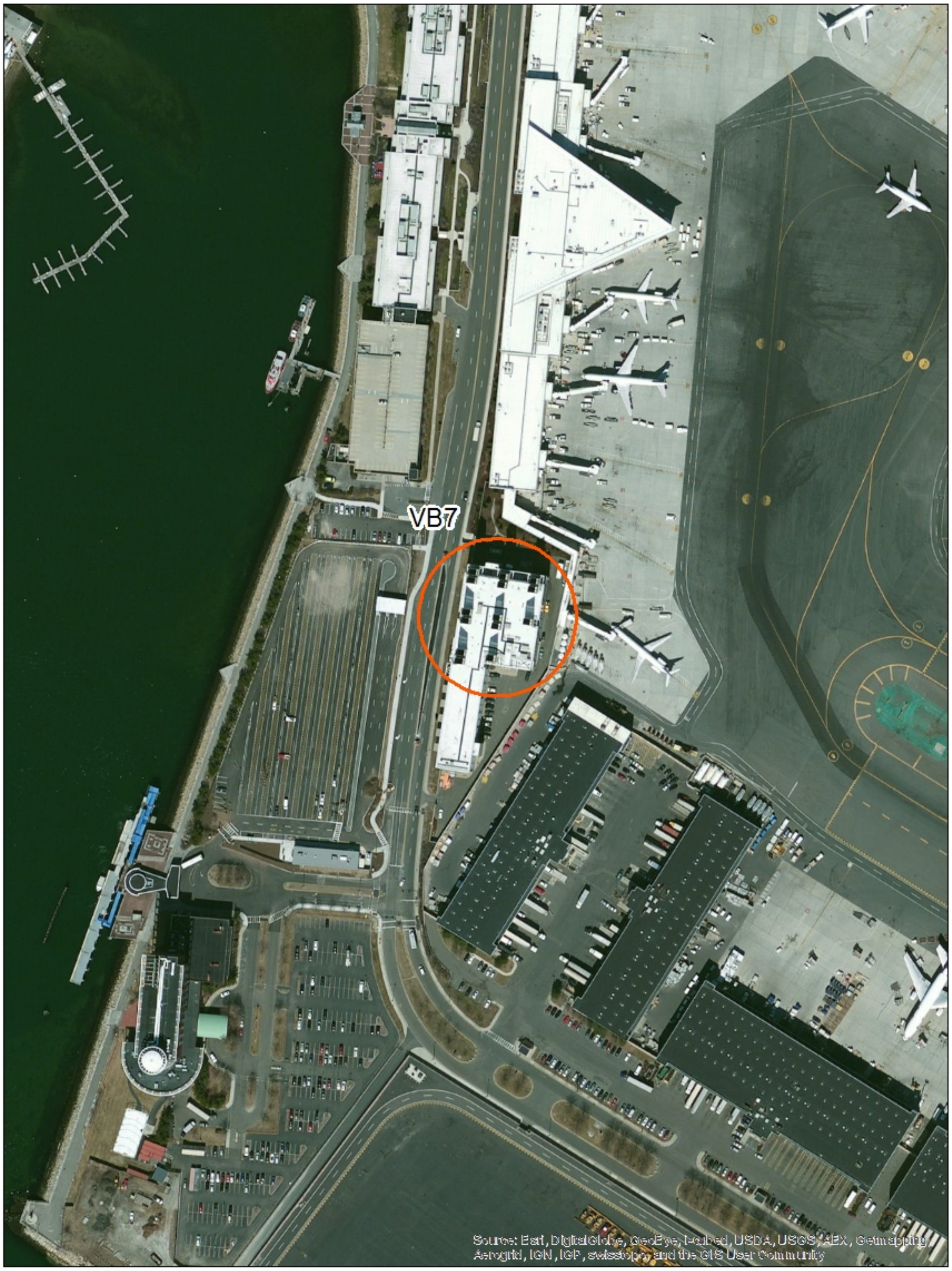


FIGURE 1-8: LOCATION OF VENTILATION BUILDING 5

FIGURE 1-9: LOCATION OF VENTILATION BUILDING 6

FIGURE 1-10: LOCATION OF VENTILATION BUILDING 7



The airflows for the full-transverse system are controlled by the many supply and exhaust fans. Airflows are set from the ventilation control system located in the CA/T Project's Highway Operations Center (HOC) in South Boston; and are determined by the CO levels monitored inside each ventilation zone based on a 15-minute average for each ventilation zone. When the CO level reaches the action level for a specific ventilation zone the system, the system warns the operator that the ventilation level is to be increased based on a preprogramed sequence.

1.1.2 Longitudinal Ventilation

In the longitudinally ventilated tunnels, the exhaust air moves in the direction of the traffic flow, and it is pushed through the exit portals by the piston action effect created by the moving vehicles. Longitudinal ventilation applies to the DST section of I-93 Southbound, and at eight tunnel exit ramps.

Some of these tunnel exit ramps are connected to the supply air from the ventilation buildings, and others have supply air in the form of jet fans mounted inside the tunnel ceilings and walls. In all cases, these tunnels are self-ventilated when the traffic flow moves at a speed that ranges from 20 to 45 miles per hour (MPH) (i.e., the traffic movement provides the majority or totality of the ventilation air). In the cases of traffic congestion, stalled conditions or other incidents, the mechanical ventilation (supply air and/or jet fans) supplements and/or replaces the natural self-ventilation system.

The fans that assist the longitudinal ventilation airflows are also controlled from the CA/T Project's HOC in South Boston and they are manually operated according to the CO levels monitored inside each section of these tunnels.

1.1.2.1 Dewey Square Tunnel

The tunnel (which is connected at its northern end to the CA/T I-93 southbound tunnel) includes an Air Intake Structure (AIS) housing two centrifugal fans (300 horsepower (hp) and 300,000 cfm each). The AIS located above the DST alignment slightly south of Congress Street is designed to provide supply air in cases of roadway accidents or congested traffic conditions. These centrifugal fans are automatically set to Step 3 during the peak morning (6-10 AM) and peak afternoon (2-8 PM) hours every weekday.

In addition, to provide operator flexibility with respect to air flow management for normal and emergency operations, three of the four existing DST fan chambers and shafts were retained and rehabilitated with reversible axial fans which typically operate in the supply mode. In the instance of a fire condition, these eight reversible fans (100 hp and 100,000 cfm each) will be operated in exhaust mode to prevent "back layering" (movement of the hot air and combustion gases counter to the desired direction of flow) of the smoke, protecting vehicles and passengers stopped behind the incident location.

The current DST exit portal is located 100 feet south of Kneeland Street (Figure 1-11). When and if MassDOT is able to implement the full commercial development scenario of Parcel 25 (development above the DST boat section south of Kneeland Street), the exit portal may be moved an additional 300 feet further south, on the South side of the South Station Connector (also identified in Figure 1-11).

1.1.2.2 Exit Ramps with Fresh-Air Supply and/or Jet Fan Ventilation

There are eight longitudinally ventilated ramps. Three of these ramps include supply air and jet fan ventilation, while the other five (which are not connected to the mainline tunnels) only include jet fans.

The longitudinally ventilated ramps are as follows:

- Ramp LC-S (Leverett Circle to Central Artery southbound (SB))
- Ramp SA-CN (Surface Artery to Central Artery northbound (NB))
- Ramp CN-S (Central Artery NB to Storrow Drive)

- Ramp ST-CN (Sumner Tunnel to Central Artery NB)
- Ramp ST-SA (Sumner Tunnel to Surface Artery)
- Ramp CS-SA (Central Artery SB to Surface Artery)
- Ramp CS-P (Central Artery to Purchase Street)
- Ramp F (I-90 westbound (WB) to Congress Street)

The five ramps eliminated from the CEM in the 2012 Renewal Application include: Ramps F, L-CS, SA-CN, ST-CN, and ST-SA.

These five ramps constitute relatively short tunnels (less than 1,200 feet each) that are not connected to the mainline tunnel ventilation system. They are ventilated by the piston action generated by the moving vehicles. All of them have jet fans installed on sidewalls for traffic congestion and emergency situations such as tunnel fire. The average hourly CO levels measured at these ramps during the time when they were part of the CEM system were below 3.0 ppm. Emission limits for these ramps were between 57 and 70 ppm for one hour and 70 ppm for eight hours. It was very unlikely that these limits would be ever exceeded.

The three remaining ramps subject to CEM compliance connected to supply air include:

- Ramp CN-S which has supply air provided by two fans (280,000 cfm) located inside VB 8.
- Ramp CS-SA which is connected to I-93 SB and has supply air from VB 4.
- Ramp CS-P which is also connected to I-93 SB and has supply air from VB 3.

The 2016 Renewal Application included an assessment of how the possible future development of a park features above Parcels 6 and 12 could affect emission limits for ramps CS-SA and ST-SA. Since the plans to cover these parcels have been suspended, this renewal application does not replicate such assessment. MassDOT has last informed MassDEP of the current situation of these two parcels in a letter dated January 27, 2021.

Figures 1-11 to 1-14 identify the location of DST and of each of the three ramps that are still part of the CEM program.

FIGURE 1-11: LOCATION OF EXISTING AND POSSIBLE FUTURE DST EXIT PORTAL

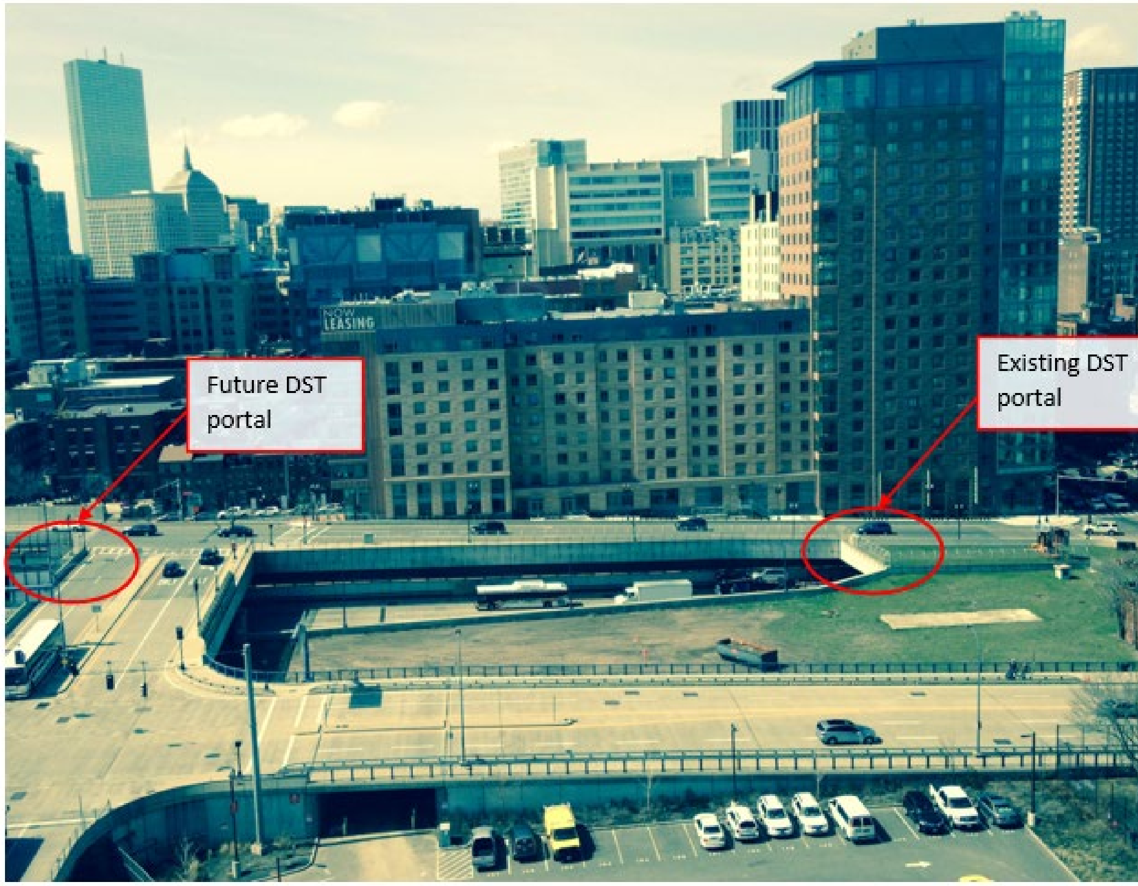


FIGURE 1-12: LOCATIONS OF RAMP PORTAL 2 (CN-S)

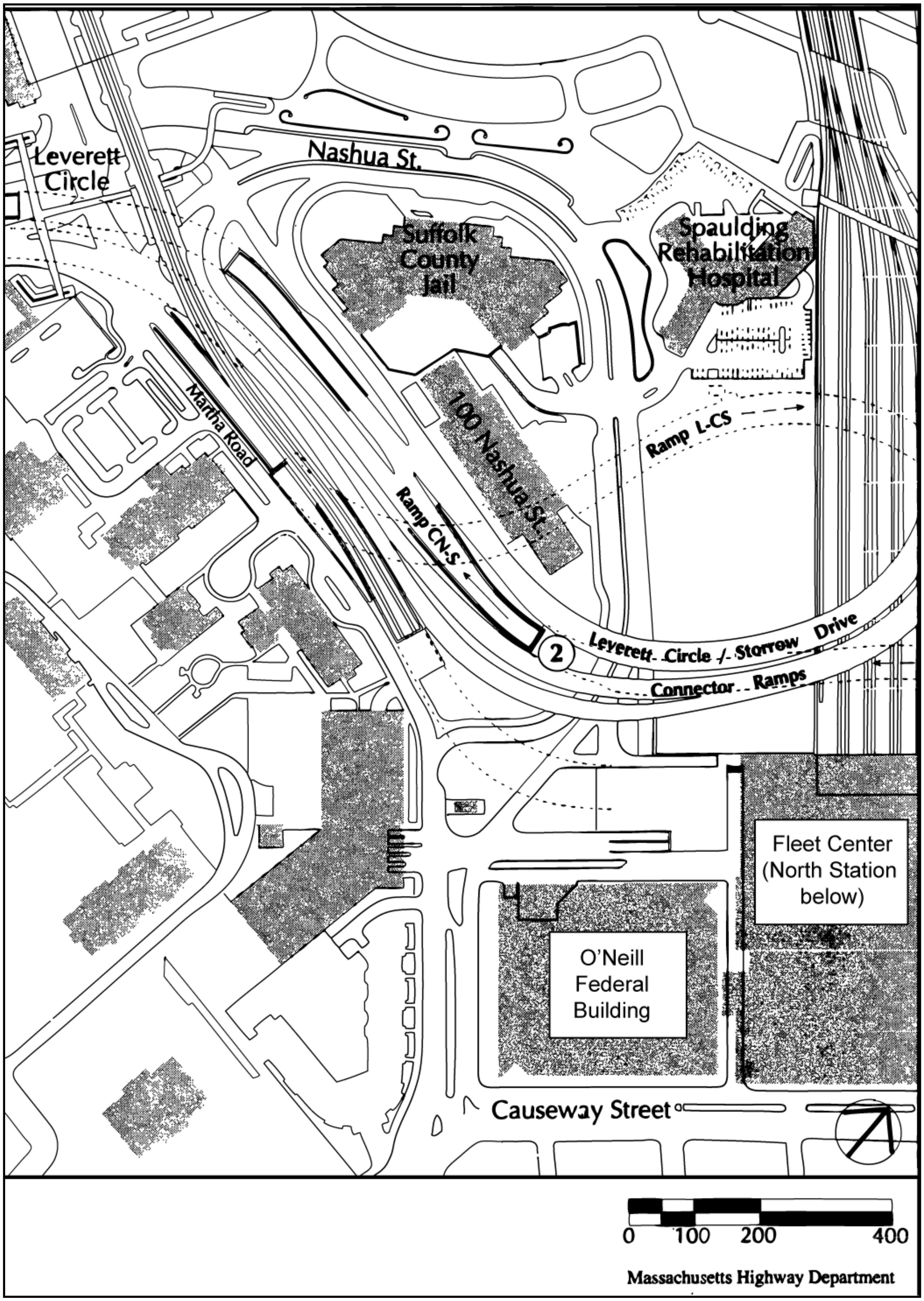


FIGURE 1-13: LOCATIONS OF RAMP PORTAL 6 (CS-SA)

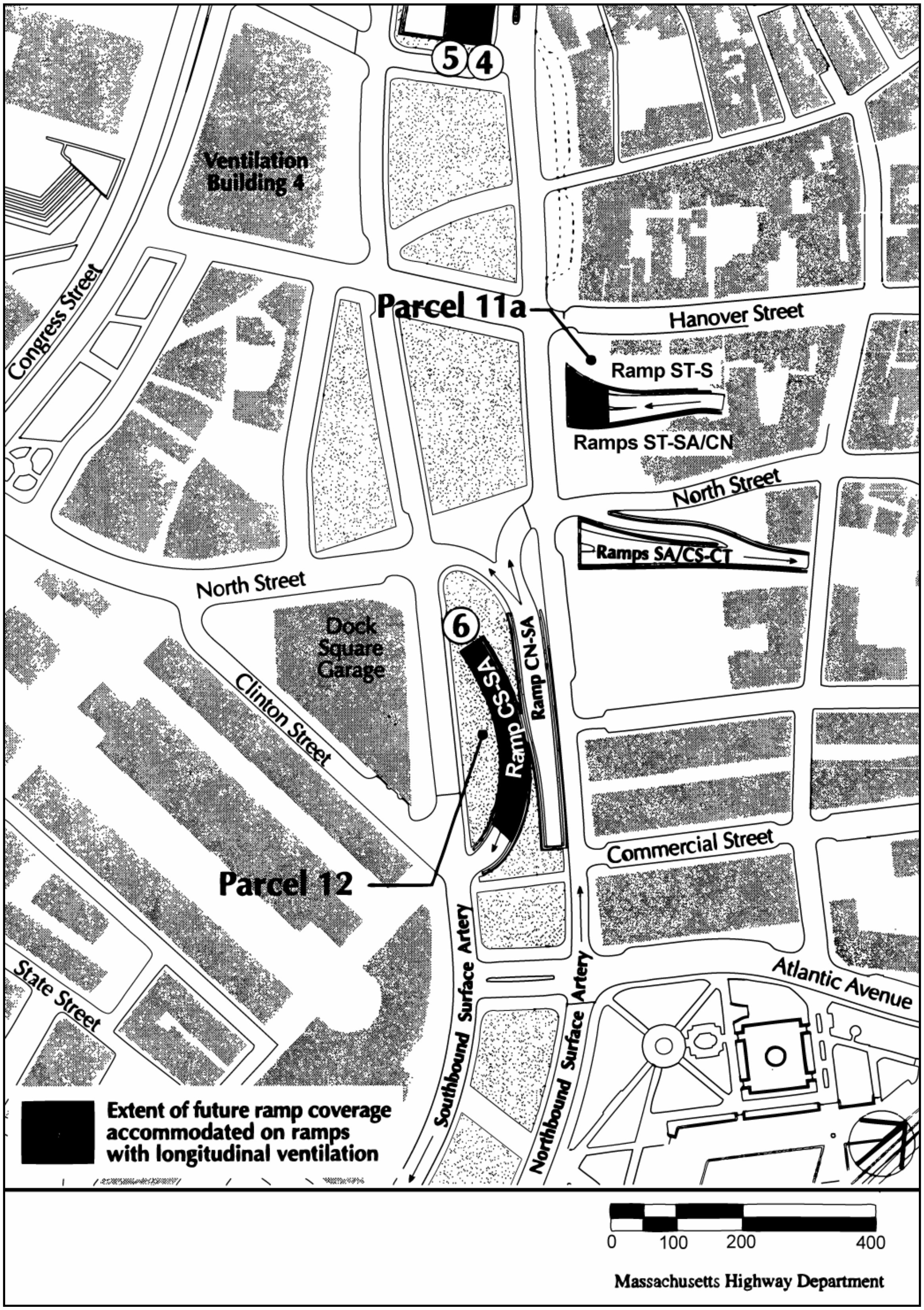
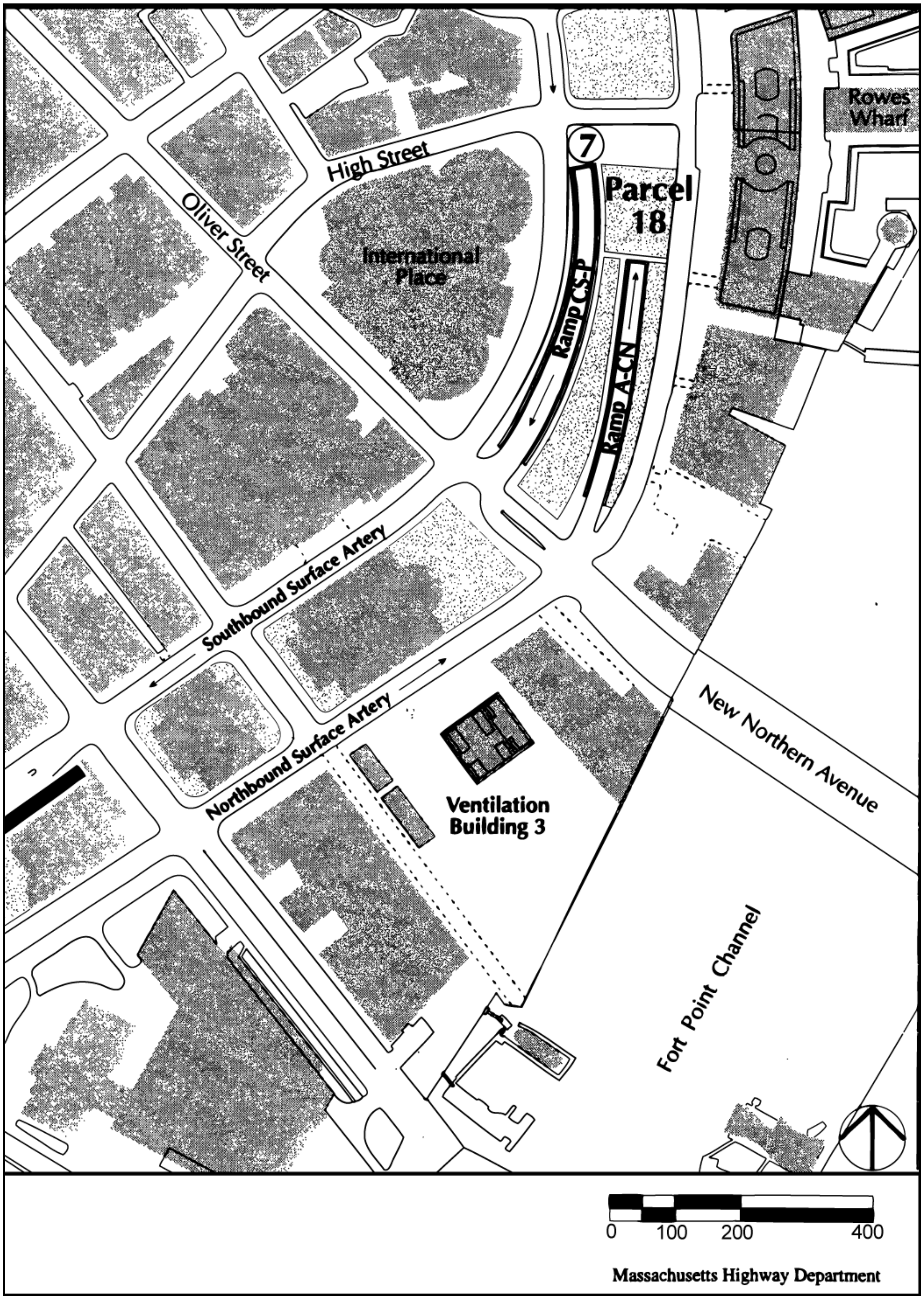


FIGURE 1-14: LOCATION OF RAMP PORTAL 7 (CS-P)



1.2 FEASIBLE EMISSION CONTROL TECHNOLOGIES

The tunnel exhaust air contains pollutants from motor vehicles including carbon monoxide (CO), nitrogen oxides (NO_x), non-methane hydrocarbons (NMHC) and particulate matter (PM).

NMHC refers to any hydrocarbon species other than methane and is used interchangeably with volatile organic compounds (VOC) and non-methane organic gases (NMOG). The term VOC is used in this document.

The tunnel ventilation systems introduce and circulate fresh ambient air into the tunnels and remove the mixture of vehicular exhaust and intake air from the tunnels through the exhaust stacks.

Ventilation building emissions control technology reviews were performed in 1991, 1995, 2004, 2011 and subsequently revisited and updated in this document. An extensive investigation, conducted as part of these reviews, revealed that ventilation was the predominant method of tunnel (inside and outside) air quality control employed in the United States and around the world. All reviews concluded that there were no feasible control techniques available that would result in a net reduction of the tunnel exhaust emissions.

The use of electrostatic precipitator (ESPs) systems has been an effective method for controlling particulate emissions for long tunnels that have relatively high in-tunnel particulate concentrations. Roadway tunnels equipped with ESPs systems in Europe and Japan are mostly those that are much longer than the CA/T and have poor in-tunnel visibility caused by heavy-duty diesel truck traffic (i.e., large PM emission sources). In addition, over the last two decades there has been an increased use of ESPs in tunnels for external environmental purposes in Japan. By comparison, the CA/T tunnels are relatively short and have a lower volume of diesel truck traffic. Therefore, the installation of ESPs systems for the CA/T Project would not result in any significant decreases in PM concentrations in the tunnel exhaust air.

Technology for the removal of NO_x from the airstream has been developed and deployed in several tunnels in Japan in recent years. However, it seems that in Japan, the decision to employ air purification for ambient purposes are determined by the politics surrounding the project, and not the technical effectiveness of the systems.

Several methods of controlling gaseous emissions from tunnel exhausts are in various stages of development. However, these methods have not yet been tested or applied to situations with very low concentration levels such as those in the exhaust air of the CA/T tunnels. The extremely high flow and the very low concentration levels of pollutants in the exhaust air have been the greatest impediments to the practical application of these control techniques. Low concentrations and large flow rates would have necessitated unreasonably large control equipment sizes, long treatment times, and the use of large quantities of reagents, catalysts and energy with the consequent generation of large amounts of waste and the need for their disposal. More importantly, the energy (heat and power) requirements of the control techniques would have resulted in fuel combustion and additional emissions of criteria pollutants (e.g., CO, NO_x, PM, SO_2) and non-criteria pollutants (e.g., SO_3 and greenhouse gases such as CO_2) that far exceed the original uncontrolled emission rates due to vehicle exhausts alone.

The 2016-2021 (1st quarter) data presented in Section 5 of TSD Part III indicate that measured hourly CO concentrations for the ventilation buildings range from 0.9 to 3.0 ppm on average and as high as 26.2 ppm during peak periods. For the DST and ramps, hourly CO concentrations were in the range of 0.9 to 3.5 ppm on average with maximum levels in the range of 10.5 to 27.0 ppm.

Hourly NO_x levels (based on CO measurements) in the ventilation buildings ranged from 0.4 to 0.5 ppm on average with peak values ranging from 0.9 to 2.5 ppm. Measured hourly NO_x levels for the DST and Ramps ranged from 0.3 to 0.6 ppm on average with peaks ranging from 1.2 to 2.5 ppm.

Measured NO_x (NO and NO_2) levels at the DST I-93 portal ranged from 0.3 to 0.6 ppm on average with peak values ranging from 0.9 to 2.3 ppm.

The 2016-2021 (1st quarter) measured average daily $PM_{2.5}$ concentrations in the ventilation buildings were between 12 and 36.4 $\mu g/m^3$, Maximum daily $PM_{2.5}$ values in VB were in the range of 57.0 to 140.9 $\mu g/m^3$. The $PM_{2.5}$ monitor outside Ramp CS-SA, which measures ambient levels, recorded average annual concentrations from 5.9 to 9.0 $\mu g/m^3$ and a maximum 24-hour average concentration of 26.1 $\mu g/m^3$.

Emissions data collected inside the CA/T tunnel indicate that safe in-tunnel air quality levels were maintained during the past certification period and since the CA/T opening. The results of the monitoring program and corrective actions indicated that despite a very few instances between 2006 and 2021 when abnormal conditions resulted in measured concentrations exceeding the established emission limits, ambient pollutant levels outside the tunnels have been well below the applicable NAAQS and MassDEP One Hour NO_2 Policy Guideline.

These results indicate that the proper programming of the existing ventilation zones to maintain the pollutant levels inside the tunnel within the emission limits is the most effective way to manage motor vehicle emissions within the tunnel ventilation system.

1.3 Tunnel Operating Conditions

The CA/T Project's tunnel ventilation systems are controlled and monitored at the MassDOT HOC in South Boston. From this facility, tunnel operators are assigned geographical areas of responsibility for oversight of all traffic management and support systems operation. Ventilation system control from this location may be either manual—allowing the operator to make specific adjustments—or automatic via a central computer-based tunnel air quality algorithm or time-of-day histogram. In addition, each of the tunnel ventilation systems can be controlled from the local ventilation facility.

The system at each ventilation zone is normally operated in what is called a balanced mode; in which equal amount of supply and exhaust air are used to keep the system in a neutral pressure state. Only in the case of emergencies will the system be operated in an unbalanced condition (i.e., over exhaust mode).

1.3.1 During Non-emergency Operations

During normal daily traffic operating conditions, the tunnel ventilation system is operated to maintain safe air quality and visibility within the tunnels. CO levels resulting from vehicle emissions are continuously monitored throughout all Project tunnels.

Real time values from each CO monitor are averaged by the HOC central computer system and reported on a per ventilation zone basis. Any exceedance of preset alert levels within a ventilation zone triggers an audible alarm to the operator. A banner display on the monitoring console provides specific data regarding actual concentrations, trends and location. The operator is then able to make any necessary adjustments to the ventilation zones in that particular tunnel area in order to restore safe air quality to the tunnel.

1.3.2 During Emergencies

The tunnel ventilation system was pre-programmed to operate in the most effective mode for controlling smoke and heat in the case of a vehicle fire. The programming is based on system simulation modeling of severe fire conditions to determine the most effective way to achieve critical air velocity for smoke dissipation at all locations. If a fire occurs within any of the CA/T tunnels, the HOC operator would bring up the ventilation system emergency operating matrix on his monitor and simply "click" on the column titled "fire location." The central computer will then operate all necessary ventilation systems in their proper modes for securing as safe an environment as possible at the site of the fire.

The criteria specified at 310 CMR 7.38(2)(a) and (b) do not apply during fire emergency situations. The protection of public safety would be the priority during emergencies.

1.4 VENTILATION SYSTEM PHYSICAL PROPERTIES

The Central Artery tunnel ventilation system includes:

- A very large and complex network of supply air ducts located underneath the roadway pavement (or on the side walls in some downtown tunnel sections) to deliver supply air from the supply fans to each segment of the tunnel network.
- Exhaust plenums located over the tunnel ceiling (or on the side walls in some downtown tunnel sections) to extract the exhaust air to exhaust fans located in the VBs.
- The supply and exhaust fans of each VB, the DST air intake structure and two reversible fan chambers.
- The jet fans on each longitudinally ventilated ramp.
- The HOC building, and extensive ancillary equipment, which provides power and controls to the entire ventilation system.
- The backup power system.

1.4.1 Ventilation Building Dimensions and Transverse Ventilation Capacities

The locations of the VBs are provided in Figures 1-5 through 1-10. Each VB is a large structure with its largest part located underground. Each includes a group of stacks at a uniform height. Table 1-1 provides the VB and exhaust stack heights above grade.

TABLE 1-1: VENTILATION BUILDING AND EXHAUST STACK HEIGHTS

VB	Heights of Ventilation Buildings and Stacks Above Grade (feet)	
	Building Roof	**Stacks**
VB1	82	121
VB3	239	278
VB4	71	131
VB5	117	178
VB6	65	91
VB7	72	108

As stated in Section 1.2, the tunnel ventilation system was designed with a supply air capacity of 65 cfm per lane-foot of tunnel and an exhaust capacity of 100 cfm per lane-foot of tunnel. The variable speed fans can be operated at different steps controlling both the supply and exhaust air flow rates. The supply fans vary from step 1 to 6, and the exhaust fans vary from step 1 to 8. Only steps 1 to 6 are required to operate the system in a balanced mode (supply equals exhaust), while steps 7 and 8 are used in cases of emergency and fire conditions. Table 1-2 provides the total exhaust capacity of each ventilation zone and the corresponding capacity at each operating step. Figure 1-15 provides a view of a supply fan at VB7 with the CO and $PM_{2.5}$ monitoring unit.

TABLE 1-2: VENTILATION BUILDINGS EXHAUST CAPACITY FOR VARYING STEPS

Ventilation Building	Ventilation Zone	Total Exhaust Capacity (CFM)	Exhaust Capacity Step 1 (CFM)	Exhaust Capacity Step 2 (CFM)	Exhaust Capacity Step 3 (CFM)	Exhaust Capacity Step 4 (CFM)	Exhaust Capacity Step 5 (CFM)	Exhaust Capacity Step 6 (CFM)
3	SB-1	1,070,000	139,100	246,100	342,400	449,400	556,400	695,500
3	NB-1	1,258,150	163,560	289,375	402,608	528,423	654,238	817,798
3	NB-2	1,139,000	148,070	261,970	364,480	478,380	592,280	740,350
4	SB-2	949,000	123,370	218,270	303,680	398,580	493,480	616,850
4	SB-3	1,130,500	146,965	260,015	361,760	474,810	587,860	734,825
4	NB-3	885,000	115,050	203,550	283,200	371,700	460,200	575,250
4	NB-4	809,000	105,170	186,070	258,880	339,780	420,680	525,850
1	SAT-Ramp D-E1	343,000	44,590	78,890	109,760	144,060	178,360	222,950
1	SAT-WB-E1	691,200	89,856	158,976	221,184	290,304	359,424	449,280
1	SAT-EB-E1	563,640	73,273	129,637	180,365	236,729	293,093	366,366
1	SAT-Ramp L/HOV-E1	941,000	122,330	216,430	301,120	395,220	489,320	611,650
5	SAT-WB-E2	1,040,000	135,200	239,200	332,800	436,800	540,800	676,000
5	SAT-WB-E3	393,000	51,090	90,390	125,760	165,060	204,360	255,450
5	SAT-EB-E2	1,112,000	144,560	255,760	355,840	467,040	578,240	722,800
5	SAT-EB-E3	558,000	72,540	128,340	178,560	234,360	290,160	362,700
6	Eastbound Zone 1	900,000	117,000	207,000	288,000	378,000	468,000	585,000
6	Westbound Zone 1	900,000	117,000	207,000	288,000	378,000	468,000	585,000
7	Eastbound Zone 2	822,000	106,860	189,060	263,040	345,240	427,440	534,300
7	Westbound Zone 2	693,000	90,090	159,390	221,760	291,060	360,360	450,450
7	Eastbound Zone 3	452,000	58,760	103,960	144,640	189,840	235,040	293,800
7	Westbound Zone 3	609,000	79,170	140,070	194,880	255,780	316,680	395,850
7	T-A/D	583,000	75,790	134,090	186,560	244,860	303,160	378,950

Notes:
Step 1 = 13% of Exhaust Capacity
Step 2 = 23% of Exhaust Capacity
Step 3 = 32% of Exhaust Capacity
Step 4 = 42% of Exhaust Capacity
Step 5 = 52% of Exhaust Capacity
Step 6 = 65% of Exhaust Capacity
Step 6 is the highest level for supply-exhaust in a balanced mode.
T-A/D - I-90 to Logan International Airport (Terminal -Arrival/Departure)

FIGURE 1-15: SUPPLY FAN AT VB 7 AIR INTAKE FLOOR

1.4.2 Longitudinally Ventilated Tunnels Dimensions and Ventilation Capacities

The plume of exhaust air that comes out of an exit portal in the wake of exiting vehicles maintains its integrity for a distance downstream of the exit portal due to the momentum created by the moving cars. This distance depends on the geometry of the roadway after the tunnel exit, the traffic flow characteristics, such as speed and density, meteorological conditions (wind direction), and other factors affecting the turbulence of the plume.

The length, number of lanes and mechanical ventilation capacities of the DST and the eight longitudinally ventilated ramps exit portals (included in the 2006 Operating Certification) are provided in Table 1-3. Figure 1-16 provides a view of a side-mounted jet fan.

The air flows at the exit portals are very dependent on the traffic characteristics such as vehicle classification, density and speed at any given time. Table 1-4 summarizes the air flows at each portal in order to provide an indication of the airflows generated by the traffic flows and the available mechanical ventilation that can be delivered by the air supply and jet fans. The air flows at each portal have been estimated in the *Notice of Project Change (NPC)/Environmental Reevaluation (ER) for the Implementation of Longitudinal Ventilation in the Area North of Causeway Street and Central Area, October 1996* (1996 Longitudinal Ventilation NPC/ER), and in the DST final report *Air Quality Study Dewey Square Portal Boston, Massachusetts*, prepared by RWDI, January 2006.

TABLE 1-3: LONGITUDINAL VENTILATION TUNNEL SECTION DIMENSIONS AND MECHANICAL VENTILATION CAPACITIES

Portal No	Ramps/Scenario	Ramp Length (ft)	Number of Lanes	Total Length (lane-ft)	Mechanical Airflow Rates (KCFM) Supply Air	Min Jet Fan	Max Jet Fan
DST I-93a	DST Existing Portal	2400	4	9600	400	NA	NA
DST I-93b	DST Relocated Portal	2700	4	10800	400	NA	NA
DST I-90	I-90 Collector	2700	2	5400	200	NA	NA
1	LC-S	1020	2/1	1950	NA	197	393
2	CN-S	2000	2	4000	260	NA	NA
3a	SA-CN	1130	2	2260	NA	225	318
3b	SA-CN (with parcel 6)	2000	2/1	3000	NA	359	508
4	ST-CN	600	1	600	NA	232	328
5a	ST-SA	600	1	600	NA	232	328
5b	ST-SA (with parcel 6)	1000	1	1000	NA	130	260
6a	CS-SA	480	1	480	31	NA	NA
6b	CS-SA (with parcel 12)	780	1	780	51	NA	NA
7	CS-P	740	2	1480	96	NA	NA
8	F	700	1	700	NA	130	260

Notes: The relocated DST portal extends the DST tunnel approximately 300 feet south when development of parcel 25 is built. The DST supply capacity does not include the installed ventilation capacity of the three reversible fan chambers, which operate in exhaust mode for emergency conditions.

KCFM – thousands cfm

FIGURE 1-16: JET FAN AT LONGITUDINALLY VENTILATION RAMP

TABLE 1-4: TRAFFIC VOLUMES, SPEEDS AND AIR FLOW RATES FOR DST AND EIGHT LONGITUDINALLY VENTILATED RAMPS

Portal No	Ramps/Scenario	Peak Hour			Eight Hour		
		Flow Rate	Traffic Volume	Traffic Speed	Flow Rate	Traffic Volume	Traffic Speed
		cfm	veh/hr	mph	cfm	veh/hr	mph
DST I-93a	**DST Existing Portal**	746,000	4,580	20	1,140,000	3,800	44
DST I-93b	**DST Relocated Portal**	772,000	4,580	20	1,220,000	3,800	44
DST I-90	**I-90 Collector**	592,000	3,140	27	585,000	2,650	28
1	**LC-S**	183,420	2,068	8	248,460	1,839	13
2	**CN-S**	549,440	2,997	20	610,900	2,015	26
3a	**SA-CN**	345,060	2,204	27	339,400	1,756	29
3b	**SA-CN (with parcel 6)**	382,880	2,204	27	402,500	1,756	29
4	**ST-CN**	130,380	166	30	160,920	350	29
5a	**ST-SA**	169,740	1489	20	180,150	1187	26
5b	**ST-SA (with parcel 6)**	208,730	1489	20	208,070	1187	26
6a	**CS-SA**	265,000	1,904	12	273,300	875	16
6b	**CS-SA (with parcel 12)**	241,320	1,904	12	275,700	875	16
7	**CS-P**	136,150	1,559	11	81,400	1,099	15
8	**F**	308,450	1,929	29	281,300	1,440	30

The conditions analyzed in the wind tunnel tests include the partial and full development conditions. The DST airflows provided represent a combination of traffic induced piston effect and the Air Intake Structure (AIS) operating at 50% capacity. The airflows for the ramps represent only the result of piston action. It is worth noting the differences in the airflows between the peak and eight-hour scenarios and the effect of the traffic speeds on such airflows.

The traffic levels monitored during the last ten years indicate that these assumptions remain valid.

2 DETERMINATION OF EMISSION LIMITS

MassDOT submitted the Final Application for the CA/T Renewal Operating Certification on September 12, 2016. MassDEP issued a Final acceptance of the 2016 CA/T Renewal Operating Certification Application on February 28, 2018. The acceptance covers the five year operating period from December 19, 2016 to December 19, 2021.

This renewal application covers the five-year period from December 19, 2021 to December 19, 2026.

2.1 PROJECT PRECONSTRUCTION CERTIFICATION ACCEPTANCE RECORD

MassDEP 310 CMR 7.38(2) “Pre-Construction Certification” states that no person shall construct a tunnel ventilation system and project roadway subject to 310 CMR 7.00 without first certifying to MassDEP (and receiving MassDEP’s written acceptance of that certification) that the operation of any tunnel ventilation system, project roadway, and roadway networks will not cause a violation of certain air quality standards, guidelines, and criteria specified in MassDEP Regulation 7.38.

On February 20, 1991, to comply with the provisions of 310 CMR 7.38, the Massachusetts Department of Public Works, now the MassDOT, submitted to MassDEP a Pre-Construction Certification of the Tunnel Ventilation System for the CA/T Project (Pre-Construction Certification). The Pre-Construction Certification was found to be administratively complete by MassDEP on March 27, 1991. On May 7, 1991, MassDEP conducted a public hearing on the Pre-Construction Certification to receive comments pursuant to 310 CMR 7.38(11). After review of the Pre-Construction Certification and consideration of information presented at the public hearing and during the public comment process, MassDEP accepted the Pre-Construction Certification subject to conditions set forth in the decision document dated July 8, 1991 entitled *Conditional Acceptance of Pre-Construction Certification of the Central Artery/Third Harbor Tunnel Project* (Conditional Acceptance). MassDEP determined that the mitigation measures presented in the Conditional Acceptance were necessary to mitigate potential adverse air quality impacts from the CA/T Project and to meet the criteria for project certification in 310 CMR 7.38. The mitigation measures set forth in the Conditional Acceptance included Public Transportation Measures, Measures to Increase Commuter Rail Ridership, Water Transportation Measures, Transportation Management Measures, and a High Occupancy Vehicle (HOV) Program.

On January 7, 1999, the MTA, on behalf of MassDOT, submitted to MassDEP for its review and acceptance pursuant to the 310 CMR 7.38 an amendment to the Pre-Construction Certification.

The Amended Pre-Construction Certification was found to be administratively complete by MassDEP on February 26, 1999. On March 30, 1999 MassDEP conducted a public hearing on the Amended Pre-Construction Certification to receive comments pursuant to 310 CMR 7.38(11). MassDEP issued proposed decision documents on the Amended Pre-Construction Certification on April 29, 1999 and conducted a public hearing on those proposed decisions on May 20, 1999.

A more complete description of the amendments to the Pre-Construction Certification process is detailed in the 2012 CA/T Renewal Operating Certification document and is not repeated here.

2.2 MASSDEP REGULATORY REQUIREMENTS FOR OPERATING CERTIFICATIONS

As discussed in Section 2.1, 310 CMR 7.38 required the issuance by the constructor, MassDOT, of a Pre-Construction Certification; and subsequently by the operator, MassDOT, of an Operating Certification.

As part of the Operating Certification requirements, MassDOT must demonstrate that the tunnel ventilation system when operated in accordance with its design standard operation and maintenance procedures would not:

- Cause or exacerbate a violation of any National Ambient Air Quality Standard (NAAQS), or a Massachusetts Ambient Air Quality Standard (MAAQS);
- Cause or exacerbate a violation of the MassDEP's one-hour ambient nitrogen dioxide (NO_2) guideline of 320 $\mu g/m^3$ (170 ppb) or
- Result in an actual or projected increase in the total amount of non-methane hydrocarbons (referred as VOC in this document) measured within the Project area when compared with the No-Build alternative.

The 24-hour NAAQS for particulate matter equal to or smaller than 2.5 microns in diameter ($PM_{2.5}$) was modified several times since its promulgation, and MassDEP required that the 2011 renewal included emission limits for $PM_{2.5}$. The limits for $PM_{2.5}$ replaced the limits for PM_{10}. The annual NAAQS for $PM_{2.5}$ was lowered to 12 $\mu g/m^3$ from 15 $\mu g/m^3$ in December of 2012.

During the spring of 2010, MassDEP determined that the recertification should also include a demonstration of compliance with the 1-hour NO_2 NAAQS of 188 $\mu g/m^3$ equivalent to approximately 100 ppb. The 2006 NO_x emission limits were established to comply with the MassDEP 1-hour NO_2 policy guideline of 320 $\mu g/m^3$ equivalent to approximately 170 ppb.

MassDOT is required to demonstrate that the operation of the tunnel ventilation system is in accordance with the criteria set forth in the Pre-Construction Certification accepted by MassDEP. The MassDEP Regulation 310 CMR 7.38 provides that this demonstration shall be based on actual measured emissions and traffic data. It is worth noting that that the 310 CMR 7.38(2) requirements regarding compliance with the applicable ambient air quality standards and the 1-hour NO_2 MassDEP policy guideline for nitrogen dioxide (NO_2) do not apply during emergency conditions (i.e., tunnel fires).

MassDOT is required to establish concentration-based emission limits for the tunnel ventilation system such that operation of the CA/T ventilation system below these limits would not cause or exacerbate a violation of any applicable ambient standards. The Boston metropolitan area is in attainment with all NAAQS, except for 1997 ozone NAAQS for which it is designated an orphan maintenance area[2] as part of Boston-Manchester-Portsmouth (SE) area. Such areas according to the court decision would need to submit a maintenance plan for the 1997 ozone NAAQS.

The project compliance monitoring program approved in 2006 included CO continuous emission monitoring (CEM) at the plenum of each ventilation zone and PM_{10} CEM at four ventilation zones that presented the highest potential PM_{10} levels at the mainline tunnel exhaust points. Due to the limited space available and other technical impediments inside the ramps, instead of in-tunnel monitoring, a PM_{10} monitor was installed in 2006 at outside of exit Ramp CS-SA to determine if the emissions from the longitudinally ventilated ramps could cause high PM_{10} levels in the adjacent areas. By the end of 2011 all PM_{10} monitors were converted to monitor $PM_{2.5}$. NO_x concentrations at each CEM monitoring location were determined as a function of the hourly monitored CO concentrations. The monitoring results and the calculated NO_x levels were compared to their predetermined emission limits for compliance assessment. In 2018 MassDOT installed a NO_x monitoring station at the DST exit portal (I-93) measuring hourly NO_x, NO and NO_2, since the DST has the lowest emission limits for the entire system. As such the compliance with the NO_x limit for the DST is done by direct comparison with the NO_x measurements since 2018.

[2] EPA defines areas that had been in non-attainment for the 1997 ozone standard at the time when this standard was revoked, see https://www.epa.gov/sites/default/files/2018-11/documents/ozone_1997_naaqs_lmp_resource_document_nov_20_2018.pdf

For VOC emissions, MassDOT is required to demonstrate that the tunnel ventilation system when operated in accordance with its design, standard operation and maintenance procedures would not result in an actual or projected increase in the total amount of VOC measured within the Project area compared to the No-Build alternative. The 2005 regional VOC emissions for the area affected by the CA/T Project Build scenario was used as a budget limit, not to be exceeded in future years for compliance demonstration purposes.

2.3 ACCEPTANCE OF CONCENTRATION–BASED EMISSION LIMITS

The following section remains unchanged from the 2016 CA/T Renewal Operating Certification and is reprinted here for completeness of this document.

The MassDOT-MassDEP technical working group proposed and received concurrence from MassDEP (see MassDEP letter dated April 16, 2002) that the CA/T emission limits for CO, NO_x and PM_{10} (and now, by extension, for $PM_{2.5}$) should be determined as concentration-based levels (i.e., ppm or $\mu g/m^3$) in lieu of the mass-based (e.g., grams per second (g/s) or pounds per hour (lb/hr)) limits that are usually imposed on stationary sources. The rationale for the concentration-based emission limits, which meet the requirements of 310 CMR 7.38, is briefly discussed as follows.

Vehicular emissions depend on the number, type and conditions of the vehicles and their traveling speeds. Although the MassDOT is the Owner and Operator of the CA/T tunnel ventilation system, the Project tunnels are open for general public use under normal operation conditions without exception. Therefore, the MassDOT has no control regarding the type and conditions of vehicles entering the tunnel and can only manipulate the ventilation rates of the tunnel ventilation system based on traffic conditions to provide acceptable in-tunnel air for the motorists traveling the tunnels. Thus, the emission limits to be set for all applicable pollutants will be the maximum allowable concentrations that will ensure that the applicable ambient standards are not violated.

Since there is no NAAQS for VOC, emission limits for VOC cannot be established based on concentrations measured at a specific receptor location. As such, direct measurement or monitoring of VOC without a benchmark level to guide the operation of the ventilation system may or may not contribute to the protection of the health and welfare of the affected population. A different procedure that is based on the study area VOC budget was developed by the MassDOT-MassDEP air quality working group and accepted by MassDEP on July 30, 2002. The established VOC budget for the CA/T Build condition was then be used as the emission limit, which is not to be exceeded in the future years for compliance demonstration purposes.

2.4 ACCEPTANCE OF EMISSION LIMITS ESTABLISHED IN 2016 RENEWAL APPLICATION

The 2016 Operating Certification established tunnel emission limits for CO, NOx and $PM_{2.5}$ to demonstrate compliance with ambient air quality standards for CO, NO_2, and $PM_{2.5}$ and state guideline values for NO_2.

The acceptance letter by MassDEP dated February 28, 2018 states that MassDEP issued the final acceptance of the Operation Certification (Final Acceptance) provided that: "Emission Limits shown in the Table 2-1 will ensure that all NAAQS and MassDEP guidelines will not be exceeded in the CA/T Project area."

TABLE 2-1: SUMMARY OF 2016-21 EMISSION LIMITS

Location*	1-Hour CO Emission Limit (ppm)	8-Hour CO Emission Limit (ppm)	1-Hour NO_X Emission Limit (ppm)	24-Hour $PM_{2.5}$ Emission Limit ($\mu g/m^3$)
VB 1	70	70	6.1	550
VB 3	70	70	6.1	550
VB 4	70	70	6.1	550
VB 5	70	70	6.1	550
VB 6	70	70	6.1	550
VB 7	70	70	6.1	550
Ramp CN-S	35	59	3.2	NA
Ramp CS-SA	35	54	3.2	35**
Ramp CS-P	35	70	3.2	NA
Dewey Sq. Tunnel	22	24	2.1	NA

* For VBs, location includes all ventilation zones of this VB.

** The ambient $PM_{2.5}$ monitor is located outside ramp CS-SA.

It also established a regional emission budget for volatile organic compounds (VOCs) based on the 2005 CA/T build predictions, which included highway and transit components setting a limit of 6,095.9 kg/day for the CA/T Project area.

2.5 2021 RENEWAL OF OPERATING CERTIFICATION PROCESS

The 2021 CA/T Renewal Operating Certification includes revised emission limits for CO, NOx, and $PM_{2.5}$ and demonstrated compliance with the CO, NO_2, and $PM_{2.5}$ NAAQS, and one-hour NO_2 MassDEP Policy Guideline.

The 2016 Operating Certification also demonstrated that the VOC regional emissions for 2010 were approximate 35% below the VOC budget based on the 2005 CA/T build predictions, which included highway and transit components.

Based on the significant decreases in VOC motor vehicle emissions, and the current O_3 levels in the Boston Metro area, the 2021 CA/T renewal certification presents the same simplified approach to estimate the reductions in the regional VOC levels used in 2016. This approach uses MOVES3 (EPA's Motor Vehicle Emission Simulator) VOC emission factors and anticipated traffic increases based on current traffic growth factors. This method was agreed with MassDEP at the March 23, 2016 inter-agency meeting.

2.5.1 $PM_{2.5}$ Limits

The results of the analysis in 2016 TSD indicated that a $PM_{2.5}$ emission limit of 550 $\mu g/m^3$ demonstrates compliance with the $PM_{2.5}$ annual and 24-hour NAAQS.

This 2021 document updates the compliance demonstration following the same technical modeling approach used in the 2016 TSD, and explained in more detail in section 2.6, with the incorporation of the most current background levels from MassDEP monitoring stations, the 2016 to 2020 local meteorological data, and receptor locations based on current buildings configuration in each VB surrounding area..

The $PM_{2.5}$ emission limits replaced the PM_{10} emission limits that were established as part of the original operating certification approved in 2006. The CEMs for $PM_{2.5}$ replaced the CEMs for PM_{10} that are located in Vent Buildings 3, 5 and 7 and at the portal area of Ramp CS-SA during 2011.

2.5.2 VOC Compliance

The 2006 Operating Certificate established a regional emission budget for VOC of 6,095.9 kg/day. It was based on the 2005 CA/T build predictions which included highway and transit projects completed by the Commonwealth as of the year 2005.

2.5.3 CO and NO_2 Limits

The 2012 CA/T two-part Renewal Certification approach was driven by the US Environmental Protection Agency (EPA) adoption of a new and more stringent one-hour NAAQS for NO_2 effective April 12, 2010. The 2012 Supplemental Application allowed MassDOT to collect a full year of nitric oxide (NO), NO_2 and NO_x data at the DST portal and Albany street sidewalk locations. The purpose of this monitoring data was to derive a method for estimating new emission limits for NO_x at all ventilation buildings and longitudinally ventilated tunnels and ramps. Compliance with the 2010 NO_2 NAAQS required a more refined analysis and a better understanding of how much NO produced by motor vehicle exhaust is actually converted to NO_2 in the vicinity of the tunnel exhaust points (portals and VBs).

This site-specific monitoring-based methodology replaced the ozone limiting method (OLM) used to demonstrate compliance with MassDEP one-hour NO_2 Policy Guideline in the 2006 CA/T Application.

Since NOx levels were estimated as a function of in-tunnel CO levels in the original 2006 CA/T Operating Certification; an updated analysis of NO, NO_2, NO_x and CO data from 2011 to 2013 monitoring study at the DST was used to determine a more appropriate CO-NOx correlation.

This document uses the same technical modeling approach used in the 2016 TSD determining in-tunnel NOx levels as a function of CO levels, and determining the NO to NO_2 conversion factors based on the 2011-2012 results of the Dewey Square Tunnel Monitoring Program. This analysis also incorporates the most current background levels, 2016 to 2020 meteorological data and receptor locations based on current buildings configuration in each VB surrounding area. The Dewey Square Tunnel configuration is based on Scenario #2 that includes Parcel 24 building which is already built. Emission limit demonstration for the longitudinally ventilated ramps is limited to the three ramps that remain part of the approved 2016 Renewal Application.

2.5.4 2011-2013 Dewey Square Tunnel (DST) Monitoring Program

The four station NO_x monitoring network was deployed by MassDOT along Albany Street and within the DST in the 2011-2013 monitoring program. Three of the monitoring locations were south of the DST southbound portal at Kneeland Street along a fence separating Albany Street from the depressed I-93 “boat section.” Monitor Number 1 was located 258 feet from the exit portal. Monitor Number 2 was located 126 feet from the exit portal. Monitor Number 3 was located 6 feet from the exit portal. Monitor Number 4 was located inside the DST approximately 150 feet north of the exit portal, and measured NO, NO_2 and CO concentrations within the tunnel itself. Figure 2-1 provides the location of each monitor. Note that north is at the bottom of the Figure 2-1 photograph.

The network was deployed to assess the concentrations and chemical reaction rates of NO_x associated with the CA/T Project. The network commenced operation on April 2011 and continued to operate through September 2013. NO, NO_2 and NO_x were monitored on an hourly average basis at each monitoring location.

These concentrations have been reported monthly to the MassDEP. The network used EPA certified monitoring equipment and it was subject to routine independent quality assurance (QA) audits performed by MassDEP to ensure the accuracy of the reported concentrations. The first year of data, (April 1, 2011 to March 31, 2012) was used to support the modeling effort for the 2012 compliance demonstration to determine the revised NOx and CO limits at the VBs, DST, and longitudinally ventilated Ramps. Table 2-2 provides a summary of the data collected between April 2011 and March 2012.

Section 2.6 explains in more detail the use of this data for the NOx levels determined as a function of CO levels within the CEM program, and the NO to NO_2 conversion factor used in the 2012 compliance demonstration to meet the one-hour NO_2 NAAQS. The Final Report titled "Summary and Findings of Dewey Square Tunnel and Albany Street Nitrogen Oxides (NOx – NO_2) Monitoring Data" dated June 20, 2014 is Appendix H.

Table 2-2 shows the maximum, minimum, and average for each parameter at each location for the monitoring period (April 1, 2011 to March 31, 2012). If the instrument measured a negative value, it was recorded as a zero.

FIGURE 2-1: LOCATIONS OF THE THREE AMBIENT MONITORS DEPLOYED AT ALBANY STREET

TABLE 2-2: COLLECTED NO_X, NO AND NO_2 CONCENTRATIONS (PPB)

Pollutant	Parameter	Location 1 Albany St.	Location 2 Albany St.	Location 3 Albany St.	Location 4 Inside DST
NO_x	Average	196	176	94	669

	Max	900	1541	941	6512
	Min	0	0	5.1	0
NO	Average	164	143	64.2	609
	Max	878	1470	870	5779
	Min	0	0	0	0
NO_2	Average	31.8	33.6	29.7	63.5
	Max	131	199	119	733
	Min	0	0	4.2	0
	Hours>100 ppb	1	21	5	n/a
	Days with hours>100 ppb	1	12	4	n/a

2.6 TECHNICAL APPROACH

The technical approach to determine emission limits follows the procedures established in the 2011/12 CA/T Renewal Operating Certification. The 2021 air quality analysis protocol presented in Appendix B provides description of models, parameters and procedures for the determination of CO, NO_x and $PM_{2.5}$ emission limits and for the VOC budget compliance analysis. The 2021 air quality analysis protocol was approved by MassDEP (see Appendix F-3).

The following sections briefly summarize the methodology employed, which follows the one used in the 2016 Renewal Application TSD Report.

Compliance demonstration for ventilation buildings and ramps is based on the modeling analyses at each ramp and each ventilation building. Following approaches are used based on the available data and previously conducted physical simulations (wind-tunnel studies) as described below:

Location/scenario	Approach
Ventilation Buildings	AERMOD modeling
Longitudinally-Ventilated Ramps (CS-P, CN-S, CS-SA and DST)	Modeling based on wind-tunnel results

2.6.1 Relevant Pollutants

The relevant vehicular pollutants for which emission limits are developed are those established in 310 CMR 7.38(2) along with the current updates recommended by MassDEP, namely CO, NO_x, $PM_{2.5}$, and VOC.

2.6.2 Averaging Times for Concentration-based Emission Limits for CO, NO_x, and $PM_{2.5}$

The averaging times associated with the concentration-based emission limits for CO, $PM_{2.5}$, and NO_x are determined by their respective NAAQS and MassDEP NO_2 Policy Guideline. Concentration-based emission limits currently apply for the following pollutants and averaging periods at the indicated locations:

Averaging Period	Pollutant	Locations
1-hour and 8-hour	CO	Each VB and longitudinally ventilated ramp
1-hour	NO_X	Each VB and longitudinally ventilated ramp
24-hour	$PM_{2.5}$	Four selected locations at three VBs*

* These four locations represent conditions for mainline tunnels I-93 and I-90 in both directions. The CA/T Project is also performing ambient $PM_{2.5}$ monitoring in the vicinity of Ramp CA-SA to which ambient air standards are applicable.

2.6.3 Predictive Model for NO_x Emission Estimates

For consistency and information purposes, this section is repeated from the 2016 Renewal Application.

The 2006 Operating Certification determined that in-tunnel NO_x levels can be estimated as a function of in-tunnel CO levels. This decision was based on CO and NO_x data collected in the Ted Williams Tunnel monitoring program. The TWT monitoring program measured in-tunnel CO and NO_x levels on a quarterly basis during 1997-1998 at the time when only commercial traffic was permitted inside the TWT. The program was repeated during 2004 when the tunnel was opened to general traffic use. An analysis of the measured levels, and the derived relationship between the two pollutants (based on more than 10,000 hours of collected data) proved that there was a good correlation between the two pollutants, and that NO_x levels can be predicted as a function of CO levels within the TWT.

The results of additional TWT monitoring data collected during the summer of 2010 indicated that levels of both CO and NO_x were lower than in 2004 mostly due to cleaner vehicles, and the use of full transverse ventilation. As a result, the 2010 TWT data clustered at levels closer to background (below 5 ppm CO and 1 ppm NO_x). The low levels at the TWT prompted the use the longitudinally DST 2011/12 monitoring data to better reflect the CO-NO_x relationship at higher CO levels in the 5 – 15 ppm range which are more representative of the in-tunnel CO.

As vehicle emission standards have changed and become more stringent, the relationship between NO_x and CO emissions has been changing. A full year of concurrent NO_x and CO monitoring data (April 2011 through March 2012) collected by MassDOT from the DST monitoring program were used to update the CO-NO_x regression equation to reflect the current vehicle emission profile.

The linear regression equation described below was developed based on the 6,292 pairs of CO and NO_x observations collected inside the DST during April 2011 through March 2012. Figure 2-2 provides the scatter plot of all the data points and the linear regression.

The regression model is of the form:

Y = a + b*X

Where

Y is the unknown concentration of NO_x estimated as a function of ***X*** and

X is the known concentration of CO.

The constant ***"a"*** is the intercept of the regression line and **"*b*"** is the slope, which is the rate at which ***Y*** *(NOx)* changes with unit change of ***X (CO)***.

The equation developed from this data was used in the modeling analysis and will estimate the hourly NO_x levels as a function of CO levels:

NO_x = 0.2956 + 0.0829*CO

Table 2-3 presents calculated NO_x concentrations at selected CO concentrations based on the regression equation.

TABLE 2-3: CO/NO_X RELATIONSHIP BASED ON APRIL 2011–MARCH 2012 MEASURED DATA

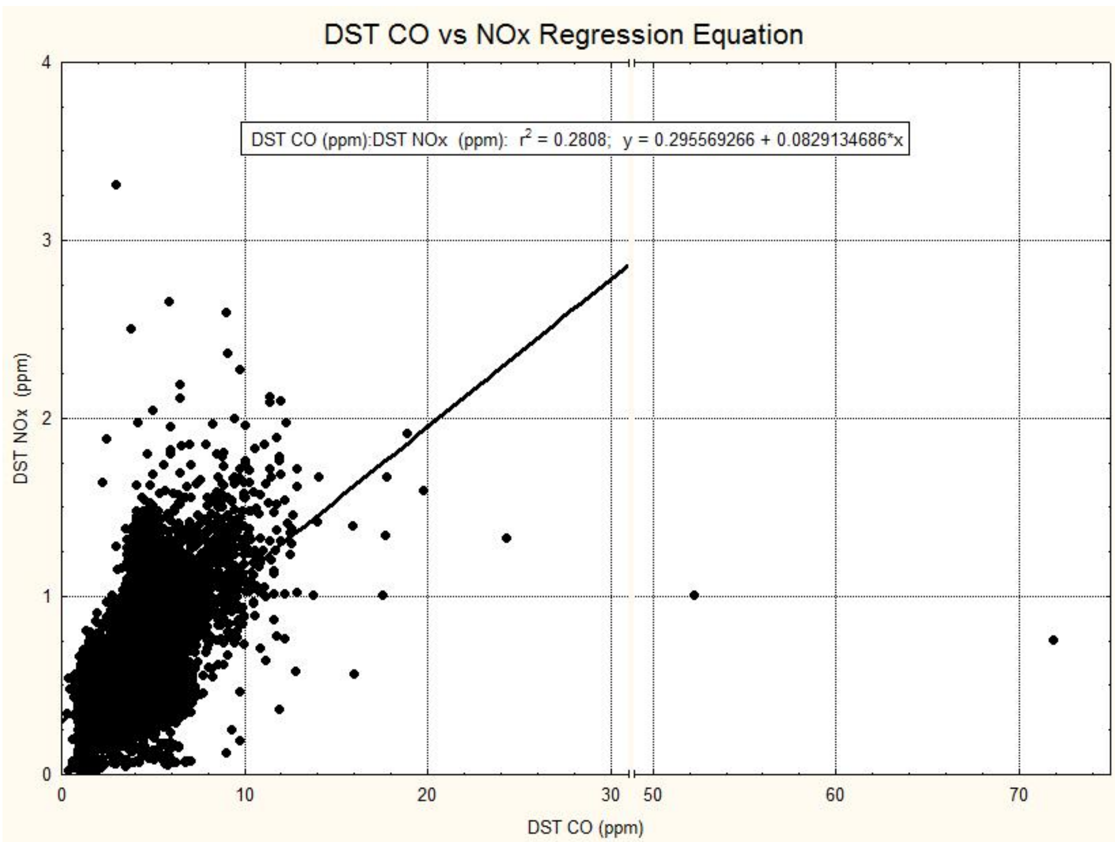
CO (ppm)	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0

NO_x (ppm)	1.12	1.54	1.95	2.37	2.78	3.20	3.61	4.03	4.44	4.86	5.27	5.68	6.10

This relationship has an r value of 0.5299 and a p-level of 0.0000, indicating that there is a strong relationship between the monitored CO and NOx concentrations in the tunnel.

Figure 2-2 presents the CO/NOx relationship that is based on monitored levels at the DST from April 2011 through March 2012.

FIGURE 2-2: CO/NOX RELATIONSHIP BASED ON MONITORED LEVELS AT THE DST FROM APRIL 2011 THROUGH MARCH 2012



2.6.4 NO to NO_2 Conversion

EPA's and MassDOT's in-tunnel monitoring programs indicated that NO_x emissions inside roadway tunnels consist predominantly of NO (85-95%) with a small fraction of NO_2 (5-15%). This finding is consistent with several monitoring programs performed at different tunnels around the world, and it was verified by the 2011-13 DST monitoring program. In general, ambient NO_2 concentrations could comprise a much higher percentage of NO_x. In the open air several reactions take place that convert NO to NO_2 and back, but the predominant reaction is the oxidation of NO with ozone in the presence of sunlight.

The amount of NO_2 present in the atmosphere within the CA/T Project that affected adjacent areas is a combination of three different sources of NO_2:

- NO_2 directly emitted from the vehicles and released into the atmosphere through the ventilation building and the exit portals. Assumed to be 5 % in 2006 CA/T Operating Certification;
- NO_2 formed from the oxidation of NO that is emitted from the vehicles and released into the atmosphere through the ventilation buildings and the exit portals; and
- NO_2 present as background in the atmosphere.

Determining background concentrations near the monitoring site is somewhat complicated. There are several sources of NO_2 in the close vicinity to the DST portal, including traffic emissions on the local streets, the South Station diesel locomotive idle emissions about 1000 feet to the northeast and the steam generation station emissions not more than 400 feet away. The closest and most representative MassDEP NO_2 background monitor is in Roxbury at Harrison Avenue a few miles away from the site. This monitor does not cover the local sources near the portals and VBs but represents only the area background concentrations.

The data collected by the DST NOx monitoring project were used to determine the effects of the NO_x emissions generated by the traffic inside the DST (and exhausted through the exit portal) at the Albany Street NOx monitors.

Conversion factors between NO and NO_2 were estimated assuming that the total NO_x exhausted out of the tunnel portal disperses downwind while part of the NO in the plume oxidizes and becomes NO_2, as follows:

$$\mathbf{NO_{x\,(rec)} - NO_{x(bkg)} = (NO_{x\,(src)} - NO_{x(bkg)})*DR}$$
$$\mathbf{NO_{2(rec)} - NO_{2\,(bkg)} = (NO_{2\,(src)} - NO_{2\,(bkg)})*DR + (NO_{(src)} - NO_{(bkg)})*DR*CF}$$

Where DR = dilution ratio
CF = conversion factor

These equations assume that the background concentrations are present in the ambient air, and in the air inside the tunnel at the same level as in the ambient air. The background concentrations were obtained from the hourly MassDEP monitor at the Harrison Avenue monitoring location.

Estimated conversion factors obtained from the monitoring data using the above equations are presented in Table 2-4. As shown in the table, the summer months, the traditional high NO_x season, confirmed the higher conversion factors. Overall, site-specific conversion from NO to NO_2 in close proximity to the source, as studied in this monitoring program, proved to be much lower than it has been reported in the literature for long distances and/or longer time-periods.

TABLE 2-4: NO/NO_2 CONVERSION FACTORS BASED ON DST MONITORING STUDY

Monitoring season	statistics by season	Albany Street Monitors	
		Monitor Number 2	Monitor Number 1
Spring (March – May)	Average	0.08	0.05
	Standard Deviation	0.06	0.06
Summer (June – August)	Average	0.12	0.10
	Standard Deviation	0.11	0.12
Fall (September – November)	Average	0.07	0.05
	Standard Deviation	0.06	0.05
Winter	Average	0.07	0.07

(December – February)	Standard Deviation	0.08	0.08
Full Year Results	Average	0.082	0.068
	Standard Deviation	0.08	0.09

The selected conversion factor for the modeling compliance demonstration is the weighted average based on approximately 4,000 hourly concentrations collected at each of the two Albany Street monitors (Monitor Numbers 1 and 2) and inside the DST at Monitor Number 4. The resulting weighted average conversion factor for the two monitors is **0.075**. The summaries of the data by month, season and yearly totals are included in the last pages of Appendix H.

This factor represents a 7.5% conversion from NO to NO_2.

This 7.5 % conversion factor is used for the compliance of all ventilation buildings, DST and longitudinally ventilated ramps**.**

2.6.5 Representative Surface and Upper Air Meteorological Data

This demonstration used the most recently available five years (2016 to 2020) of Automated Surface Observing System (ASOS) meteorological data collected at Boston Logan International Airport (BOS/KBOS) along with concurrent upper air data collected at the National Weather Station in Gray, Maine. These are the closest and most representative sources of meteorological data for the Project.

2.6.6 Attainment Status of Project Area

At the time of the 2006 application, the Boston area, inclusive of the CA/T Project, was designated as moderate nonattainment for the 8-hour NAAQS for ozone (O_3) and as attainment for PM_{10} and NO_2.

In addition, the Boston Metropolitan area, including Boston, Cambridge, Chelsea, Everett, Malden, Quincy, Medford, Revere, and Somerville was designated attainment for CO in April 2016. This ended the 20 year maintenance period designated by EPA in April 1996. The last violation in the state of the CO NAAQS occurred in 1986. With the re-designation to CO attainment status, the entire state acquired attainment status for CO, and is no longer required to demonstrate transportation conformity for CO for the Boston metropolitan area.

In December 2008, EPA designated Massachusetts as “Attainment/Unclassifiable” area statewide for the 2006 24-hour $PM_{2.5}$ standard based on monitoring data. Likewise, in May 2012 EPA designated the Boston area as “Attainment/Unclassifiable” area for the O_3 standard based on monitoring data. However, based on 2018 United States Court of Appeal for the District of Columbia decision the former nonattainment or maintenance areas for 1997 ozone NAAQS were defined as orphan maintenance areas and must make transportation conformity determinations after February 16, 2019[3].

2.6.7 Background Concentration Levels

Background pollutant concentrations for CO, NO_2 and $PM_{2.5}$ were obtained from several MassDEP air quality monitoring stations in the Boston area. Hourly measurements or the highest recorded levels were used depending on the types of analyses.

Ambient NO_2 concentrations are measured at several air quality monitoring stations in the Boston area. MassDEP operates and maintains Federal Reference Method (FRM) monitors for NO_2 at Kenmore Square, Von Hillern Street, and Dudley Square/Roxbury.

[3] https://www.ctps.org/data/pdf/plans/TIP/FFYs-2021-2025-TIP.pdf, pages 5-3 and 5-4

Monitoring sites are located and established for various purposes. Table 2-5 summarizes several characteristics of the NO_2 monitoring sites and their surroundings in Boston as obtained from the EPA AirData website.

TABLE 2-5: BOSTON NO_2 MONITORING SITES

Parameter	Kenmore Square	Von Hillern Street	Dudley Square/Roxbury
Monitor Type	SLAMS	SLAMS	SLAMS
Site ID	250250002	250250044	250250042
Measurement Scale	Microscale	Middle Scale	Neighborhood
Dominant Source Type	Mobile	Mobile	Area
Monitoring Objective	Population Exposure/ Highest Concentration	Near Road	Population Exposure
Location Type	Commercial	Highway/Commercial	Commercial
Monitoring Schedule	1 hour	1 hour	1 hour
Numberof NO_2 Monitors	1	1	1

Notes:
1. SLAMS = State and Local Air Monitoring Stations
2. Measurement scale refers to the geographic extent over which measurements are assumed to be representative.
   Microscale = 0 to 100 meters
   Middle scale = 100 to 500 meters
   Neighborhood = 500 meters to 4 kilometers
   Urban Scale = 4 kilometers to 50 kilometers

Given the measurement scale, dominant source type, and monitoring objective of the various sites, measurements at the Dudley Square/Roxbury are the most representative of background concentrations of NO_2 for the Project area. Based on the mixed commercial/residential location of the Dudley Square/Roxbury site, it is used as the primary source of data to establish NO_2 background levels representative of the overall modeling domain for the ventilation buildings analysis. For hours when Dudley Square/Roxbury NO_2 data are not available (e.g., calibrations, missing for other reasons), Kenmore Square data is substituted. The Von Hillern site is used as background data for the Dewey Square analysis because it is more representative of the open highway/viaduct environment being located close to the Southeast Expressway (Interstate Highway 93). Von Hillerns' observed concentrations are likely influenced by nearby traffic emissions. As such, the Von Hillern data are dominated by traffic using the Central Artery/Interstate Highway System and may include substantial concentration contributions from traffic emissions being modeled as described above. Thus, its observations are not used for the background at other modeled locations. If there are no observations available from either the Dudley Square/Roxbury or Kenmore Square monitor, the maximum value from the previous or next available hour at these two stations is used.

These background levels are incorporated in the analyses to demonstrate compliance with NAAQS for NO_2 for the VBs, DST and Ramps NO_x emission limits proposed for the renewal of the Operating Certification. The hourly values are added to the hourly model output to obtain the total predicted (model + background) concentration resulting from the CA/T Ventilation System. Consistent with the form of the standards, the design values are compared to the 1-hour NO_2 NAAQS, and MassDEP NO_2 Policy Guideline.

Hourly background monitoring data are also used to demonstrate compliance with the 1-hour and 8-hour CO NAAQS for the VB CO emission limits. Table 2-6 summarizes characteristics of the CO monitoring sites and their surroundings in Boston as obtained from the EPA AirData website. CO modeling for the ramps conservatively included CO design values and not the hourly concentrations.

As presented in Table 2-6, the CO monitors in Boston are Dudley Square/Roxbury and Von Hillern Street. Those monitors are representative with Dudley Square/Roxbury being the primary site as discussed above for NO_2. For the modeled years of 2016 through 2020, the hourly Dudley Square/Roxbury values are used. If the observation from Dudley Square/Roxbury is missing, then the hourly value from Von Hillern Street is used. Note that MassDEP indicates that the Von Hillern monitoring station may be moved in the future. If there are no observations available from either monitor, the maximum value from the previous or next available hour is used when only one hour is missing. If there were two or more hours missing, linear interpolation is used. The CO NAAQS for 1-hour and 8-hour periods is not to be exceeded more than once per calendar year. The highest second high 1-hour and 8-hour impact values that include the hourly CO background for the period 2016 to 2020 were found for comparison to the CO NAAQS.

TABLE 2-6: BOSTON CO MONITORING SITES

Parameter	Dudley Square/Roxbury	Von Hillern Street
Monitor Type	SLAMS	SLAMS
Site ID	250250042	250250044
Measurement Scale	Neighborhood	Middle Scale
Dominant Source Type	Area	Mobile
Monitoring Objective	Population Exposure	Near Road
Location Type	Commercial	Highway/Commercial
Monitoring Schedule	1 hour	1 hour
Numberof CO Monitors	1	1

Notes:
1. SLAMS = State and Local Air Monitoring Stations
2. Kenmore station closed 12/2014
3. Dudley Square/Roxbury and Von Hillern Street transitioned to trace CO analyzers in 2015
3. Measurement scale refers to the geographic extent over which measurements are assumed to be representative.
   Microscale = 0 to 100 meters
   Middle scale = 100 to 500 meters
   Neighborhood = 500 meters to 4 kilometers
   Urban Scale = 4 kilometers to 50 kilometers

Ambient $PM_{2.5}$ concentrations are measured at several air quality monitoring stations in the Boston area, including three sites in Boston. DEP operates and maintains Federal Reference Method (FRM) monitors for $PM_{2.5}$ at Kenmore Square, Dudley Square/Roxbury, and Von Hillern. The North End Site included two collocated $PM_{2.5}$ monitors but ceased operation in early 2018. The Von Hillern site commenced $PM_{2.5}$ monitoring in 2013.

Monitoring sites are located and established for various purposes. Table 2-7 summarizes several characteristics of the $PM_{2.5}$ monitoring sites and their surroundings in Boston as obtained from the EPA AirData website.

Daily $PM_{2.5}$ data from EPA's AirData website are used for these analyses. Given the measurement scale, dominant source type, and monitoring objective of the various sites, measurements at the Kenmore Square and Dudley Square/Roxbury sites are the most representative of background levels of $PM_{2.5}$ for the Project area. Based on the mixed commercial and residential character of its setting, the Dudley Square/Roxbury site is the primary $PM_{2.5}$ monitoring data used to establish $PM_{2.5}$ background levels. If the observation from Dudley Square/Roxbury is missing, then the data from Kenmore Square are used. If data from both Kenmore and Dudley Square/Roxbury are missing, then data from the North End or Von Hillern Street are used. If there are still 24-hour block average concentration values missing after substitution then the annual design value data from the Dudley Square/Roxbury site are used to calculate an annual monitoring design value based on the most recent available three years of data (2018-2020) consistent with the form of the NAAQS and that design value is used.

TABLE 2-7: BOSTON $PM_{2.5}$ MONITORING SITES

Parameter	Kenmore Square	Von Hillern	Dudley Square/Roxbury
Monitor Type	SLAMS	SLAMS	SLAMS
Site ID	250250002	250250044	250250042
Measurement Scale	Microscale	Middle Scale	Neighborhood
Dominant Source Type	Mobile	Mobile	Area
Monitoring Objective	Population Exposure/Highest Concentration	Near Road	Population Exposure
Location Type	Commercial	Highway/Commercial	Commercial
Monitoring Schedule	1-in-3 days, hourly	1-in-6 days, hourly	1-in-3 days, hourly
Number of $PM_{2.5}$ Monitors	1	1	1

Notes:
1. SLAMS = State and Local Air Monitoring Stations
2. Measurement scale refers to the geographic extent over which measurements are assumed to be representative.
   Microscale = 0 to 100 meters
   Middle scale = 100 to 500 meters
   Neighborhood = 500 meters to 4 kilometers

2.6.8 Volatile Organic Compounds (VOC)

Since there are no NAAQS for VOC, concentration-based emission limits for VOC were not established for comparison with measurements at specific receptor locations. Monitoring VOC could not address comparison of total amount of VOC generated within the Project area to the amount of VOC generated under the no-build alternative.

Therefore, the following procedure to address the VOC requirements of 310 CMR 7.38 (4) and (2)(c) was developed by the MassDOT-MassDEP air quality working group and accepted by MassDEP on July 30, 2002.

- Prepare an updated emission estimate, which compares the total amount of VOC generated by motor vehicle activity within the Project area for two scenarios including the full operation of the CA/T Project (post opening – year 2005) and a No-Build condition for the same year 2005.
- Establish an emission budget for the Project study area based on the results of the VOC evaluation for year 2005.
- Verify that future total VOC emissions for the study area are below the established emission budget. (2005 Build)

Based on the significant decreases in VOC motor vehicle emissions and the current O_3 attainment status of the Boston Metro area for the 2015 ozone NAAQS, MassDEP concurred with MassDOT at the February 16 and March 23, 2016 technical meetings, that the 2016 CA/T renewal certification would present a simplified approach to estimate reductions in regional VOC levels. The 2016 approach is repeated in this 2021 Renewal Application analysis.

The 2021 approach includes:

- A discussion of the previous approach to the VOC Emission Limit assessment and the reasons why it was changed to semi-quantitative.

- A presentation of historical CTPS's travel demand model VOC emission budget for the CA/T and its comparison with the 2005 baseline VOC budget.
- A discussion of Boston's previous nonattainment status for the ozone NAAQS, EPA's designation of Boston as an attainment area for 2015 NAAQS and the court decision regarding former 1997 nonattainment areas.
- Measured ozone concentration trends in Suffolk County
- Trend data for nearest non-methane hydrocarbon monitoring station located in Lynn, MA
- Estimate of vehicular VOC emission factors based in MOVES3 for the Suffolk County fleet based on input parameters obtained from MassDEP.
- MOVES3 runs for VOC in emission factor mode for years 2010, 2016, 2021 (Current Op Cert Renewal) and 2026 (to examine the future trend during the five year certification period).
- A description of CA/T average and peak traffic volumes covering the period 2006-2021, with projected increases for the future.
- An evaluation of VOC emission factors from 2010 to 2016, 2021, and 2026, which will provide the supporting evidence to demonstrate the VOC reductions when compared to the 2005 baseline emission budget.
- A semi-quantitative assessment of the 2021 and 2026 VOC emission budgets and comparison with the baseline year (2005).

The results of the 2021 VOC analysis are presented in Section 2.7.4.

2.7 EMISSION LIMIT DETERMINATION

The maximum hourly allowable emission limits (in ppm) for the VBs, DST and the specified exit ramps were determined using an iterative modeling process by increasing or decreasing the exhaust concentration in a prescribed interval as described below.

2.7.1 For Full Transverse Ventilation—Ventilation Buildings

2.7.1.1 Determination of Ventilation Building Emission Impacts

The VB emission impacts were evaluated using the EPA's AERMOD dispersion model. The model predicted emission impacts, when added to the representative background pollutant concentrations, were compared to the applicable ambient air quality standards (NAAQS) and MassDEP policy guideline value for compliance assessment. The modeling process was repeated at iterative emission concentrations until the maximum allowable emission limits at which ambient standards are attained were established. The detailed modeling procedures to determine VB emission impacts and emission limits can be found in Appendix B of this document.

2.7.1.2 Modeling Methodology

The modeling to determine the $PM_{2.5}$, CO and NO_x emission limits was updated from the previous certification to incorporate changes to models, modeling guidance, and more recent meteorological and background data. Sensitive receptors such as building air intakes, operable windows, and pedestrian walkways were updated to reflect the existing environment.

As discussed in Section 1, there are 22 ventilation zones in the CA/T ventilation system. In general, each of these ventilation zones is equipped with more than one exhaust stack and each stack is dedicated to serving one exhaust fan. In the modeling, all stacks serving one ventilation zone are grouped together and treated as an individual emission point. The physical center of the stacks serving the same ventilation zone is treated as the center of the source in the modeling runs. The total stack exit area is used in calculation of the equivalent stack diameter. The total flow rate is divided by the total stack exit area to obtain the equivalent stack exit velocity.

The predicted pollutant concentration consistent with the form of each air quality standard was added to the appropriate background concentration to determine their combined impact and to compare to the applicable short or long-term air quality standard.

Consistent with the current analysis, the 2011/12 and 2016 $PM_{2.5}$, CO and NOx ventilation building analyses were performed using AERMOD, the currently recommended EPA air quality model. AERMOD is recommended for analyses where building downwash may be an important consideration. AERSURFACE, AERMET, AERMINUTE, AERMAP and the Building Profile Input Program for PRIME (BPIPPRM) were used to process meteorological, terrain information and information relating to building dimensions. These associated preprocessors are discussed in Appendix B in the Air Quality Analysis Protocol for the Determination of CO, NOx and PM Emission Limits2021 Application for the Renewal of the Operating Certification for the Project Ventilation System. AERMOD was run in the urban mode using recommended regulatory default options.

The current analysis was performed using AERMOD version 19191 and its pre-processors. Detailed discussion of inputs (meteorological, terrain, building configurations, emission variables, etc.) for AERMOD and its preprocessors are presented in Appendix B.

The 2006 analysis considered normal operation ventilation steps 1 through 4 (based on fan steps listed in Table 2-8). Emission rates increase linearly with the increase in the exhaust flow rate, and ventilation rates at step 5 or above would only occur in cases of emergency (fire or smoke dissipation).

The VB analysis for the 20116 CA/T Renewal Operating Certification was based on step 4 fan speeds, the highest ventilation rate and potential emission rate under the normal operations, which corresponds to 42% of ventilation capacity, see Table 2-89. Step 1 of the tunnel ventilation system, corresponding to the 13% of exhaust capacity, was also selected for modeling in order to analyze the low ventilation flows under the normal peak and off-peak traffic conditions. Those same ventilations steps were modeled for the current 2021 analysis bracketing the normal, non-emergency operating scenarios.

TABLE 2-8: VENTILATION BUILDING OPERATING SCENARIOS

Scenario	Zone Step 1	Zone Step 2	Zone Step 3	Zone Step 4	Zone Step 5
Ventilation Rate (% of total exhaust capacity)	13	23	32	42	52

The maximum hourly allowable in-tunnel emission limits (in ppm for gaseous pollutants and $\mu g/m^3$ for particulates) for all VBs were identified using an iterative modeling process by increasing or decreasing the exhaust concentration in specified intervals.

The 2021 model input data, including VB number, exhaust zone, zone modeling identifier, stack height, exhaust exit velocity, equivalent stack diameter, pollutant in-tunnel concentration limit, and stack emission rates are presented in Tables 2-9 and 2-10. All stacks were modeled at a nominal 20-degree Celsius exhaust temperature. The NOx in-tunnel limit is calculated from the CO in-tunnel limit using the regression equation previously discussed. The stack locations and configurations for all VBs are shown on Figures 2-

3 through 2-8. Representative stack locations and sensitive receptors used in the modeling analysis are presented in Figure 2-9.

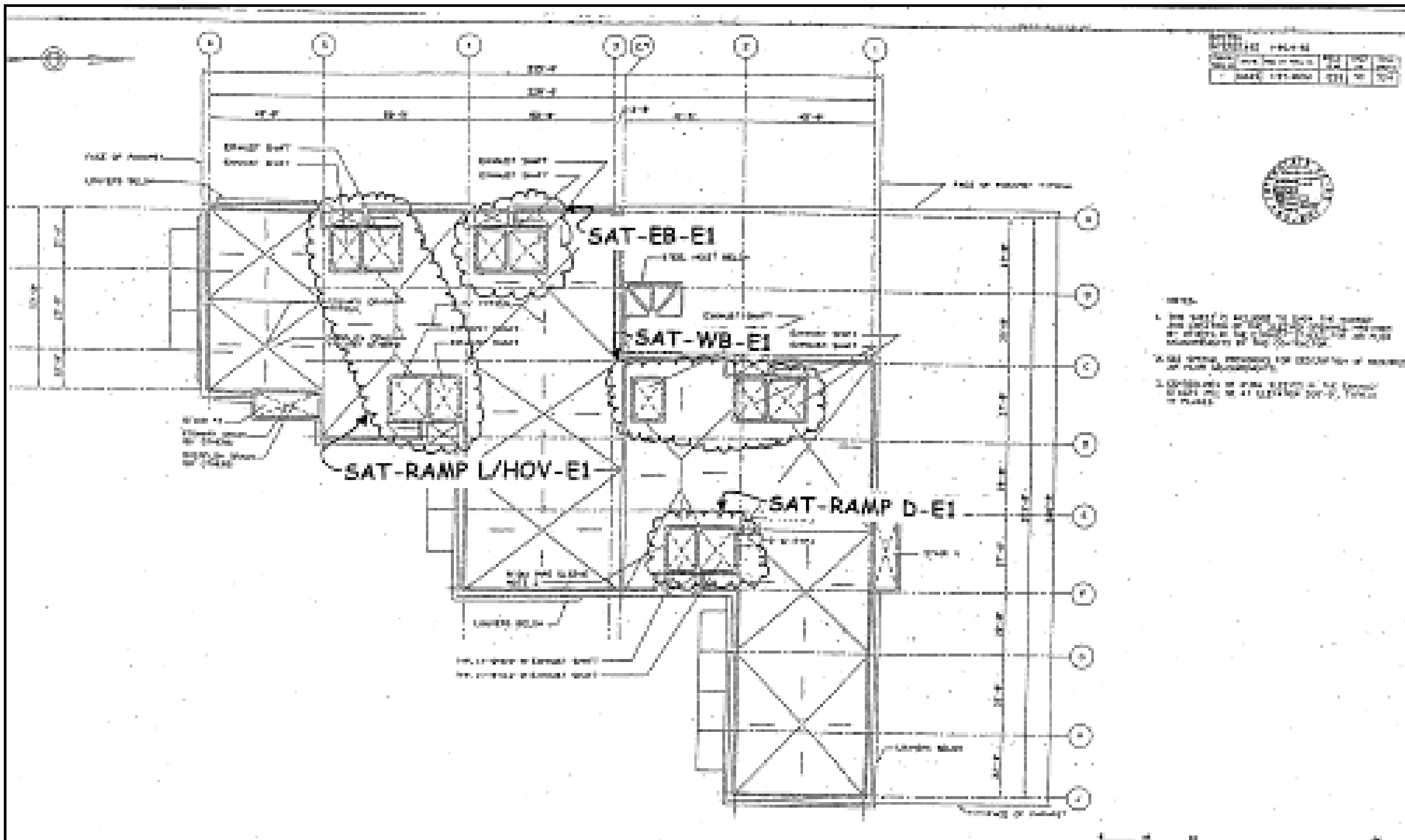
TABLE 2-9: VENTILATION BUILDING EXHAUST STEP 4 MODELING INPUT

VB	Zone (TSD Table 2-7)	Zone Modeling ID	Height (m)	vs (ft/sec)	vs (m/s)	Equiv. D (m)	CO In-Tunnel Limit (ppm)	CO In-Tunnel Limit (g/m^3)	CO Emissions (g/s)	NOx In-Tunnel Limit (ppm)	NOx Emissions (g/s)	$PM_{2.5}$ In-Tunnel Limit (ug/m^3)	$PM_{2.5}$ Emissions (g/s)
1	SAT-Ramp D-E1	B1_RampD	36.9	11.26	3.43	5.02	70.00	0.0802	5.45	6.10	0.524	700	0.0476
1	SAT-WB-E1	B1_WestB	36.9	15.13	4.61	6.15	70.00	0.0802	10.98	6.10	1.056	700	0.0959
1	SAT-EB-E1	B1_EastB	36.9	18.51	5.64	5.02	70.00	0.0802	8.96	6.10	0.861	700	0.0782
1	SAT-Ramp L/HOV-E1	B1_RampL	36.9	15.45	4.71	7.10	70.00	0.0802	14.95	6.10	1.437	700	0.1306
3	SB-1	B3_SB1	84.6	14.05	4.28	7.94	70.00	0.0802	17.00	6.10	1.634	700	0.1485
3	NB-1	B3_NB1	84.6	16.52	5.04	7.94	70.00	0.0802	19.99	6.10	1.921	700	0.1746
3	NB-2	B3_NB2	84.6	18.70	5.70	7.10	70.00	0.0802	18.10	6.10	1.739	700	0.1580
4	SB-2	B4_SB2	39.9	15.58	4.75	7.10	70.00	0.0802	15.08	6.10	1.449	700	0.1317
4	SB-3	B4_SB3	39.9	18.56	5.66	7.10	70.00	0.0802	17.96	6.10	1.726	700	0.1569
4	NB-3	B4_NB3	39.9	14.53	4.43	7.10	70.00	0.0802	14.06	6.10	1.352	700	0.1228
4	NB-4	B4_NB4	39.9	13.28	4.05	7.10	70.00	0.0802	12.85	6.10	1.235	700	0.1123
5	SAT-WB-E2	B5_WBE2	54.3	17.07	5.20	7.10	70.00	0.0802	16.53	6.10	1.588	700	0.1443
5	SAT-WB-E3	B5_WBE3	54.3	12.90	3.93	5.02	70.00	0.0802	6.24	6.10	0.600	700	0.0545
5	SAT-EB-E2	B5_EBE2	54.3	18.26	5.56	7.10	70.00	0.0802	17.67	6.10	1.698	700	0.1543
5	SAT-EB-E3	B5_EBE3	54.3	18.32	5.58	5.02	70.00	0.0802	8.87	6.10	0.852	700	0.0774
6	Eastbound Zone 1	B6_WBZ1	27.6	19.70	6.00	6.15	70.00	0.0802	14.30	6.10	1.374	700	0.1249
6	Westbound Zone 1	B6_EBZ1	27.6	19.70	6.00	6.15	70.00	0.0802	14.30	6.10	1.374	700	0.1249
7	Eastbound Zone 2	B7_EB2	32.9	17.99	5.48	6.15	70.00	0.0802	13.06	6.10	1.255	700	0.1141
7	Westbound Zone 2	B7_WB2	32.9	15.17	4.62	6.15	70.00	0.0802	11.01	6.10	1.058	700	0.0962
7	Eastbound Zone 3	B7_EB3	32.9	14.84	4.52	5.02	70.00	0.0802	7.18	6.10	0.690	700	0.0627
7	Westbound Zone 3	B7_WB3	32.9	13.33	4.06	6.15	70.00	0.0802	9.68	6.10	0.930	700	0.0845
7	T-A/D	B7_TAD	32.9	12.76	3.89	6.15	70.00	0.0802	9.26	6.10	0.890	700	0.0809

TABLE 2-10: VENTILATION BUILDING EXHAUST STEP 1 MODELING INPUT

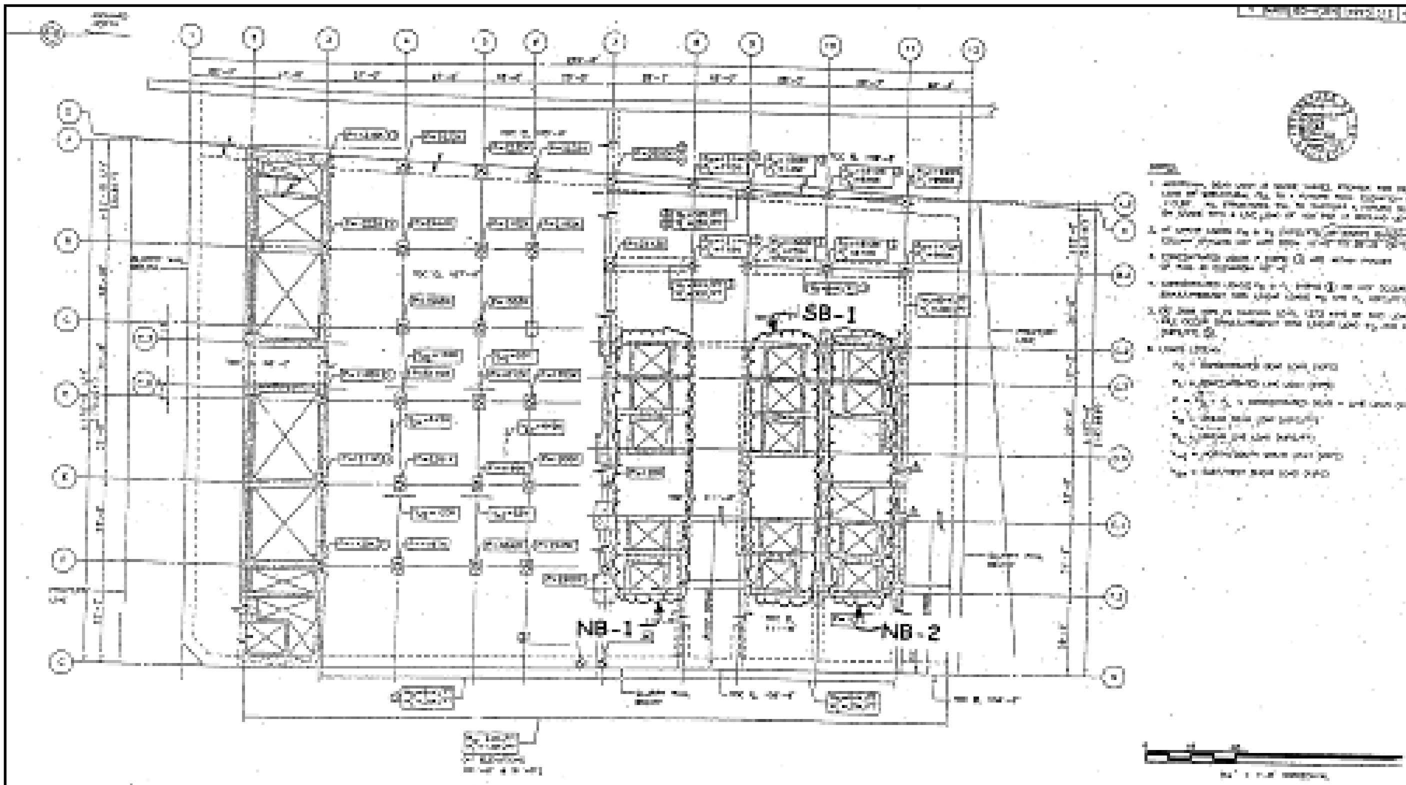
VB	Zone (TSD Table 2-7)	Zone Modeling ID	Height (m)	vs (m/s)	Equiv. D (m)	CO In-Tunnel Limit (ppm)	CO In-Tunnel Limit (g/m^3)	CO Emissions (g/s)	NOx In-Tunnel Limit (ppm)	NOx Emissions (g/s)	$PM_{2.5}$ In-Tunnel Limit (ug/m^3)	$PM_{2.5}$ Emissions (g/s)
1	SAT-Ramp D-E1	B1_RampD	36.9	1.06	5.02	70.00	0.0802	1.69	6.10	0.162	700	0.01473
1	SAT-WB-E1	B1_WestB	36.9	1.43	6.15	70.00	0.0802	3.40	6.10	0.327	700	0.02969
1	SAT-EB-E1	B1_EastB	36.9	1.75	5.02	70.00	0.0802	2.77	6.10	0.266	700	0.02421
1	SAT-Ramp L/HOV-E1	B1_RampL	36.9	1.46	7.10	70.00	0.0802	4.63	6.10	0.445	700	0.04041
3	SB-1	B3_SB1	84.6	1.33	7.94	70.00	0.0802	5.26	6.10	0.506	700	0.04595
3	NB-1	B3_NB1	84.6	1.56	7.94	70.00	0.0802	6.19	6.10	0.595	700	0.05403
3	NB-2	B3_NB2	84.6	1.76	7.10	70.00	0.0802	5.60	6.10	0.538	700	0.04892
4	SB-2	B4_SB2	39.9	1.47	7.10	70.00	0.0802	4.67	6.10	0.449	700	0.04076
4	SB-3	B4_SB3	39.9	1.75	7.10	70.00	0.0802	5.56	6.10	0.534	700	0.04855
4	NB-3	B4_NB3	39.9	1.37	7.10	70.00	0.0802	4.35	6.10	0.418	700	0.03801
4	NB-4	B4_NB4	39.9	1.25	7.10	70.00	0.0802	3.98	6.10	0.382	700	0.03474
5	SAT-WB-E2	B5_WBE2	54.3	1.61	7.10	70.00	0.0802	5.11	6.10	0.492	700	0.04467
5	SAT-WB-E3	B5_WBE3	54.3	1.22	5.02	70.00	0.0802	1.93	6.10	0.186	700	0.01688
5	SAT-EB-E2	B5_EBE2	54.3	1.72	7.10	70.00	0.0802	5.47	6.10	0.526	700	0.04776
5	SAT-EB-E3	B5_EBE3	54.3	1.73	5.02	70.00	0.0802	2.74	6.10	0.264	700	0.02396
6	Eastbound Zone 1	B6_WBZ1	27.6	1.86	6.15	70.00	0.0802	4.43	6.10	0.425	700	0.03865
6	Westbound Zone 1	B6_EBZ1	27.6	1.86	6.15	70.00	0.0802	4.43	6.10	0.425	700	0.03865
7	Eastbound Zone 2	B7_EB2	32.9	1.70	6.15	70.00	0.0802	4.04	6.10	0.389	700	0.03530
7	Westbound Zone 2	B7_WB2	32.9	1.43	6.15	70.00	0.0802	3.41	6.10	0.328	700	0.02976
7	Eastbound Zone 3	B7_EB3	32.9	1.40	5.02	70.00	0.0802	2.22	6.10	0.214	700	0.01941
7	Westbound Zone 3	B7_WB3	32.9	1.26	6.15	70.00	0.0802	3.00	6.10	0.288	700	0.02615
7	T-A/D	B7_TAD	32.9	1.20	6.15	70.00	0.0802	2.87	6.10	0.276	700	0.02504

FIGURE 2-3: STACK CONFIGURATION VENTILATION BUILDING 1



VB #1 Roof Plan

FIGURE 2-4: STACK CONFIGURATION VENTILATION BUILDING 3



VB #3 Roof Plan

FIGURE 2-5: STACK CONFIGURATION VENTILATION BUILDING 4

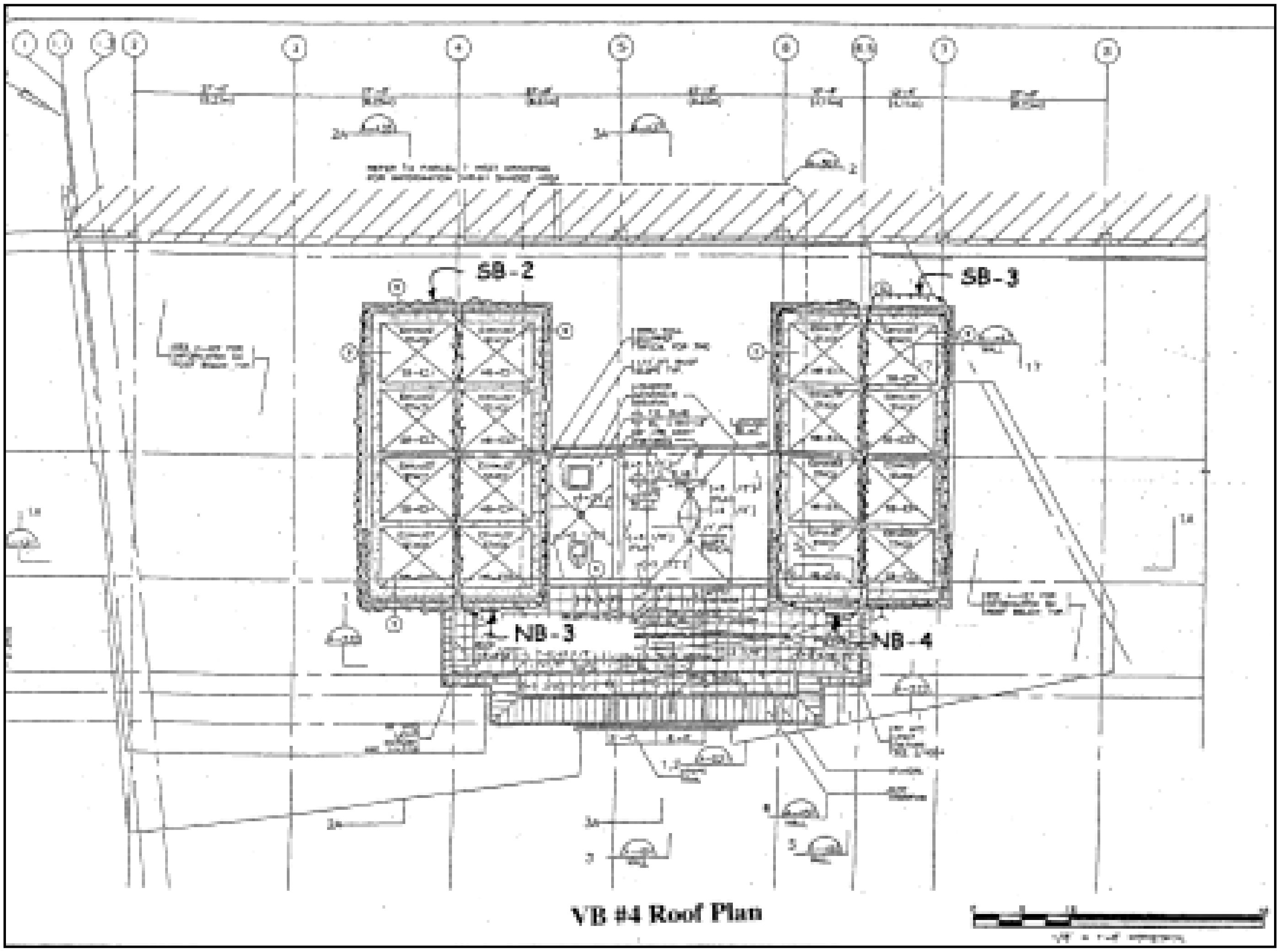
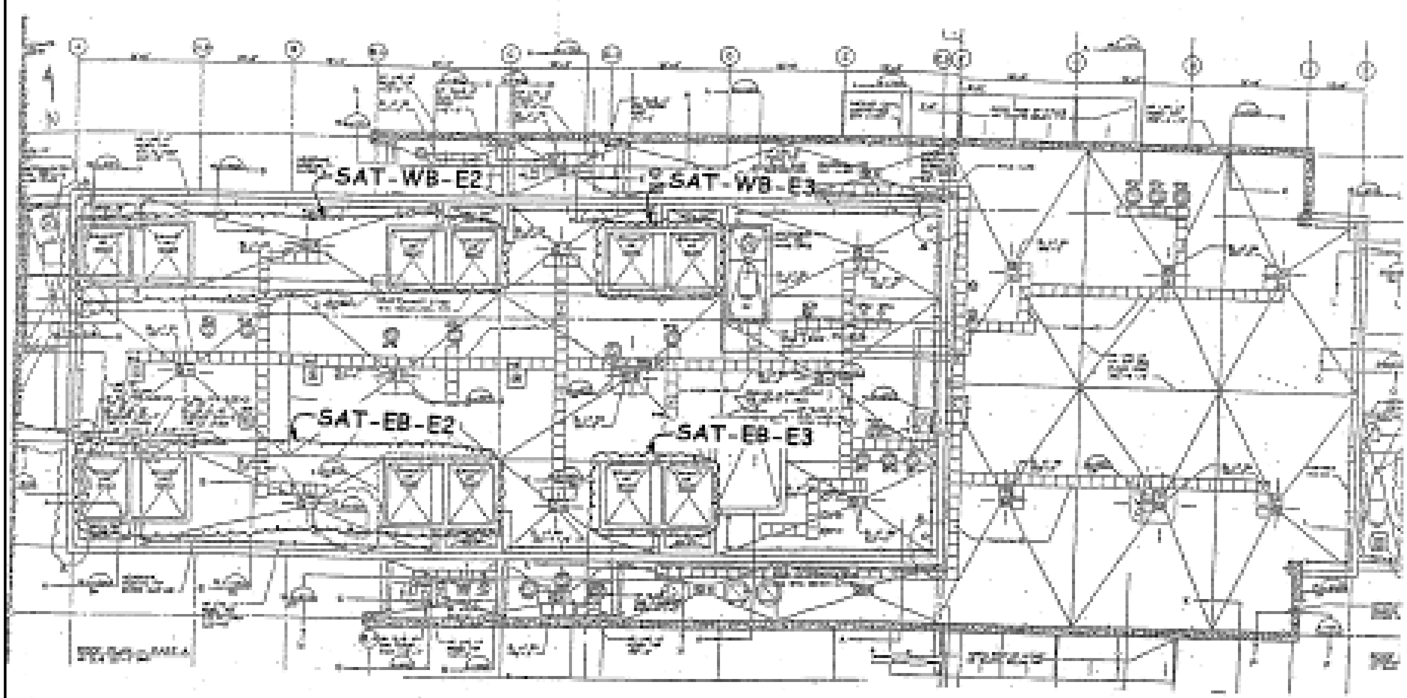
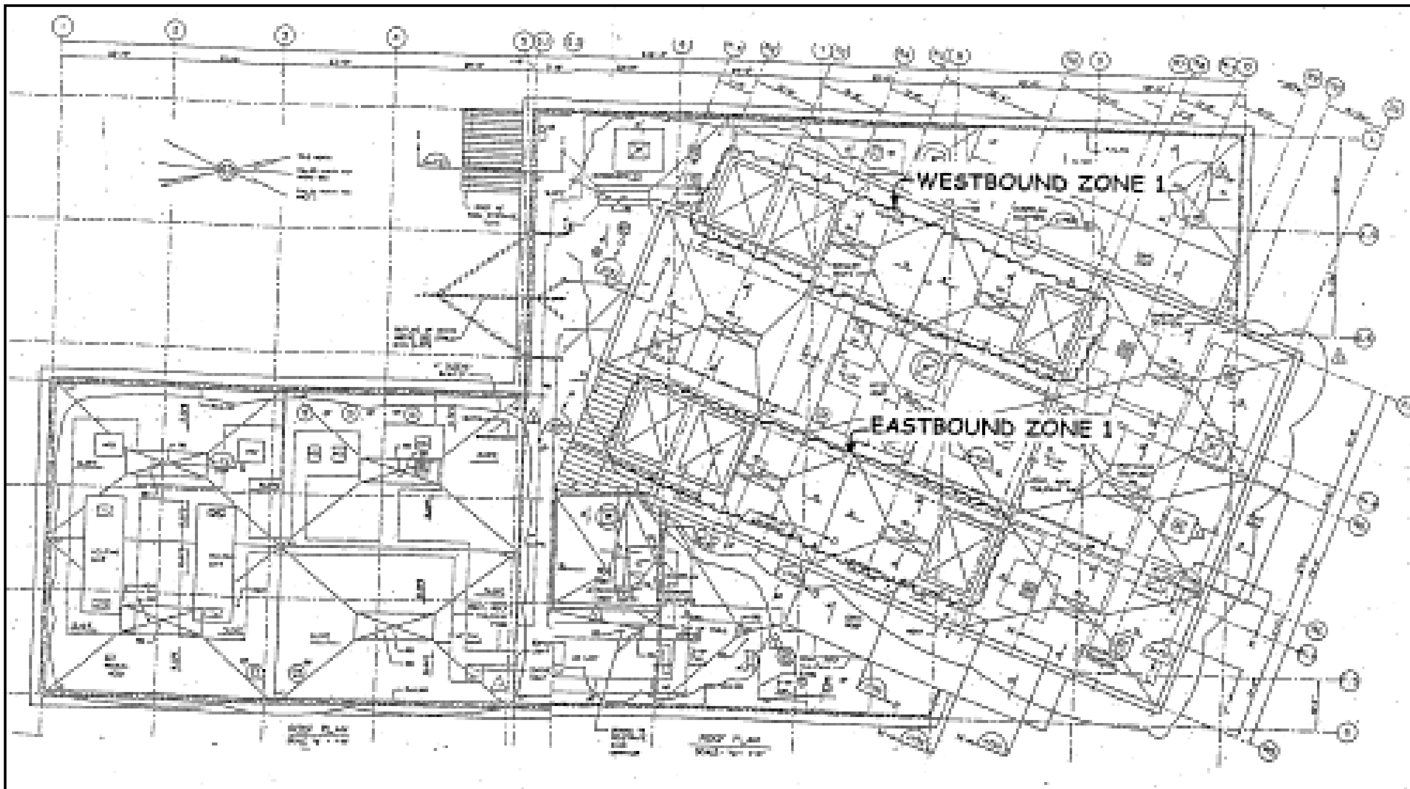


FIGURE 2-6: STACK CONFIGURATION VENTILATION BUILDING 5



VB #5 Roof Plan

FIGURE 2-7: STACK CONFIGURATION VENTILATION BUILDING 6



VB #6 Roof Plan

FIGURE 2-8: STACK CONFIGURATION VENTILATION BUILDING 7

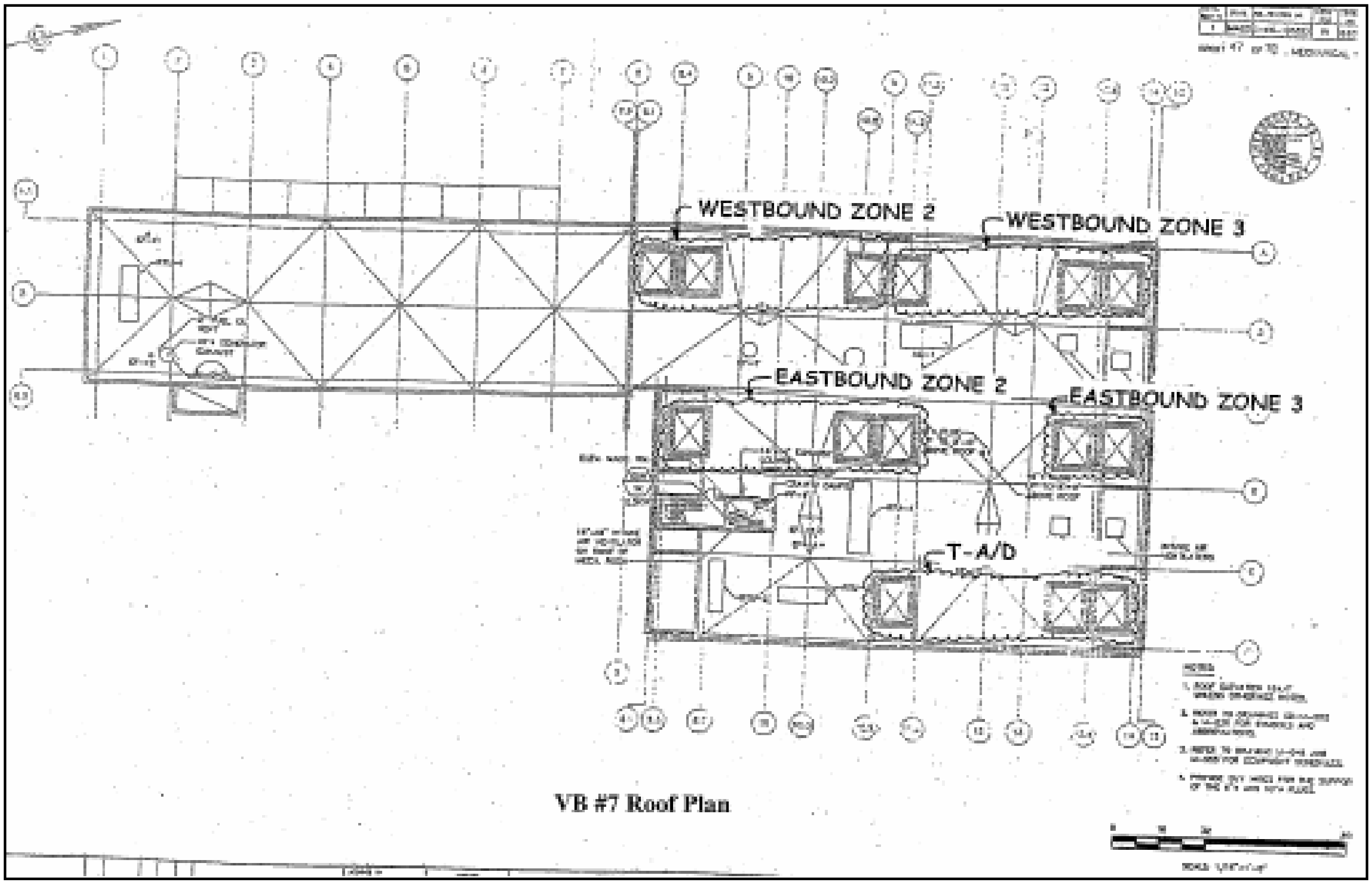
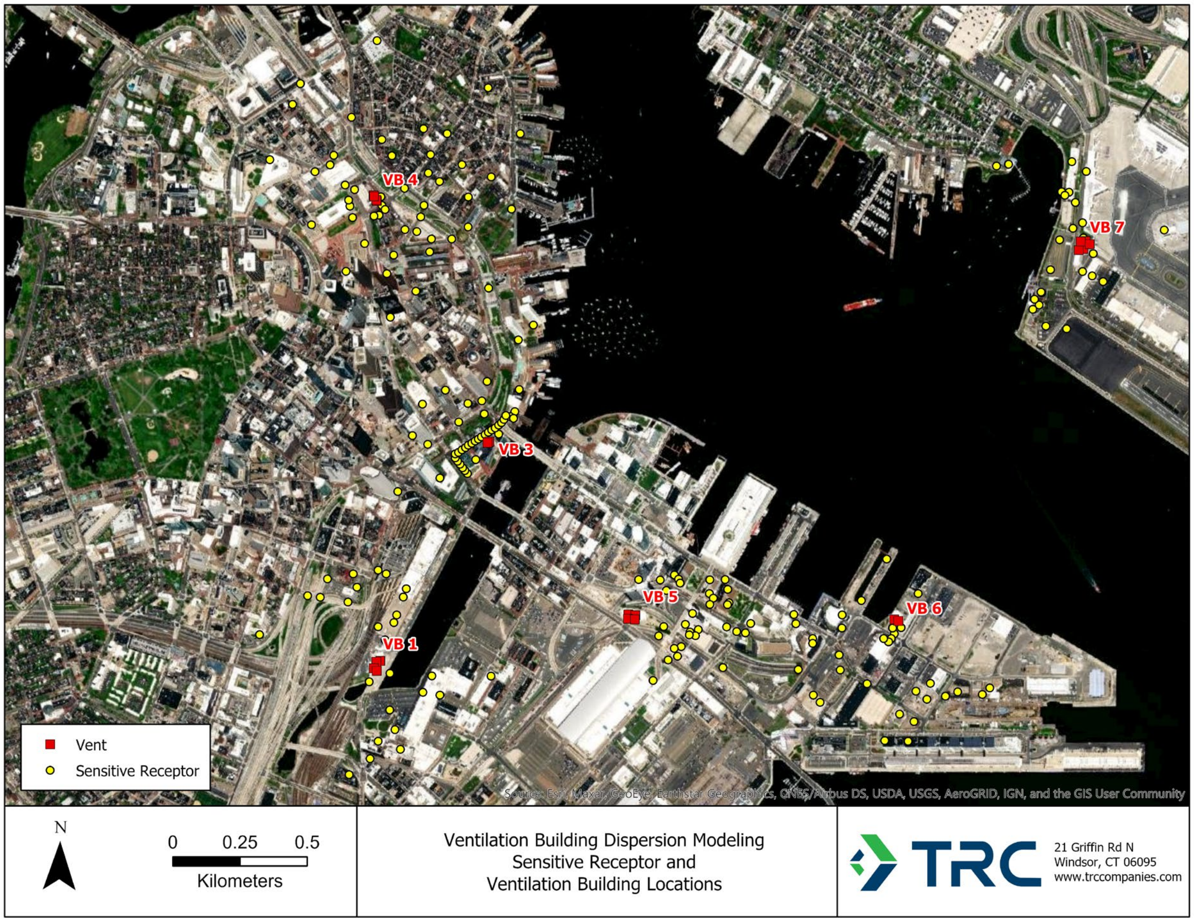


FIGURE 2-9: SENSITIVE RECEPTORS AND VENTILATION BUILDING LOCATIONS



2.7.1.3 $PM_{2.5}$ Analysis

The $PM_{2.5}$ emission limits for the VBs were identified by starting the modeling process at an assumed concentration of 550 µg/m^3 for each stack in each VB. The modeling was performed using five years of meteorological data (2016 through 2020, described in section 2.6.5) and included daily background air quality data to obtain a total daily (24-hour) $PM_{2.5}$ concentration at each receptor. The 98th percentile daily value (i.e., the 8th highest 24-hour concentration) was determined for each year and at each receptor and these five concentrations at each receptor were averaged to obtain the 24-hour design value to be compared to the 24-hour NAAQS for $PM_{2.5}$. The annual design value was determined by averaging the annual modeled concentrations at each receptor over five modeled years including the daily background. The annual design value was then compared to the annual NAAQS for $PM_{2.5}$. In-tunnel concentrations were increased until the results showed that a NAAQS was exceeded, then the prospective $PM_{2.5}$ emission limit was decreased in intervals of 50 or 100 µg/m^3 and the modeling was repeated until both the 24-hour and annual NAAQS for $PM_{2.5}$ were met. This process was conducted for Step 4 operating conditions and then repeated to verify that the same emission limit showed compliance with the NAAQS for Step 1 operating conditions.

The 24-hour and annual modeling results for each VB are presented in Table 2-11 for both Step 1 and Step 4 at the demonstrated in-tunnel $PM_{2.5}$ compliance concentration of 700 µg/m^3. The impacts from Step 4 were higher than those for Step 1, the level at which the Project ventilation system normally operates. The stacks with the maximum annual Project impact averaged over five years for Step 4 (11.7 µg/m^3) were VB 4 and VB7. VB4 also had the highest short-term impact of 34.1 µg/m^3. The proposed in-tunnel emission limit for $PM_{2.5}$ is 700 µg/m^3 over 24-hour, midnight to midnight block averages, consistent with the form of the NAAQS.

TABLE 2-101: MODELING RESULTS FOR IN-TUNNEL $PM_{2.5}$ CONECNTRATION OF 700 µG/M^3

AERMOD Predicted $PM_{2.5}$ Impacts (µg/m^3)

24-Hour and Annual Concentrations Including Background for Comparison to NAAQS

700 µg/m^3 In-Tunnel Concentration of $PM_{2.5}$

Source Description	24-Hour Average Design Concentration	Annual Design Concentration
Ventilation Step 1		
VB 1	19.6	9.2
VB 3	18.0	8.0
VB 4	24.2	9.7
VB 5	18.4	8.4
VB 6	19.1	9.0
VB 7	19.8	10.0
Ventilation Step 4		
VB 1	24.4	10.2
VB 3	20.6	9.2
VB 4	34.1	11.7
VB 5	19.8	9.5
VB 6	18.2	8.4
VB 7	21.4	11.7
Maximum VB Plus Background Impact	**34.1**	**11.7**
NAAQS	**35**	**12**

2.7.1.4 CO and NO_2 Analysis

CO Emission Limits

CO emission limits for the VBs were identified by starting the modeling process at an assumed concentration of 70 ppm CO for each stack in each VB. The AERMOD modeling was performed using five years of meteorological data (2012 through 2016, described in section 2.6.5) and included hourly background air quality data to obtain a total CO concentration (simultaneous predicted plus monitored concentrations) at each receptor. The highest second high 1-hour and 8-hour average concentrations were determined in each year over all five modeling and monitoring years and at each receptor and the highest second high concentration design values were compared to the NAAQS for CO. If the results showed that a NAAQS was exceeded, the prospective CO emission limit would be decreased in intervals of 1 ppm and the modeling was repeated until both the 1-hour and 8-hour average NAAQS for CO were met. This process was conducted for Step 4 operating conditions and then repeated to verify that the same emission limit showed compliance with the NAAQS for Step 1 operating conditions.

Table 2-12 presents the AERMOD modeling compliance results for 70 ppm in-tunnel CO concentration emission limits. VB1 has the highest predicted CO impacts and all predicted impacts plus background comply with NAAQS. The proposed in-tunnel emission limit for CO is 70 ppm over a one-hour averaging period, consistent with form of that NAAQS.

TABLE 2-12: MODELING RESULTS FOR IN-TUNNEL CO CONCENTRATION OF 70 PPM

AERMOD Predicted CO Impacts (µg/m^3)
Modeling Period: 2016 - 2020
2nd Highest Value Including Hourly Background for Comparison to NAAQS
70 PPM Source Concentration of CO

Source Description	1-Hour Average Design Concentration	8-Hour Average Design Concentration
Ventilation Step 1		
VB 1	4,726	2,038
VB 3	4,306	1,785
VB 4	6,963	3,606
VB 5	3,028	1,640
VB 6	3,772	1,790
VB 7	3,486	2,045
Ventilation Step 4		
VB 1	17,626	7,257
VB 3	11,903	5,819
VB 4	14,989	5,518
VB 5	3,053	2,035
VB 6	4,795	2,765
VB 7	4,313	2,854
Maximum VB Plus Background Impact	**17,626**	**7,257**
NAAQS	**40,000**	**10,000**

AERMOD Predicted CO Impacts (ppm)
Modeling Period: 2016 - 2020
2nd Highest Value Including Hourly Background for Comparison to NAAQS
70 PPM Source Concentration of CO

Source Description	Design Concentration	8-Hour Average Design Concentration
Ventilation Step 1		
VB 1	4.13	1.78
VB 3	3.76	1.56
VB 4	6.08	3.15
VB 5	2.64	1.43
VB 6	3.29	1.56
VB 7	3.04	1.79
Ventilation Step 4		
VB 1	15.4	6.34
VB 3	10.4	5.08
VB 4	13.1	4.82
VB 5	2.67	1.78
VB 6	4.19	2.41
VB 7	3.77	2.49
Maximum VB Plus Background Impact	**15.4**	**6.3**
NAAQS	**35**	**9**

NO_x Emission Limits

As described in Section 2.6.3, the in-tunnel NO_x concentration can be determined from the in-tunnel CO concentration based on the presented regression equation. Thus, beginning at 70 ppm CO for the VBs, a NO_x emission rate was calculated using the regression equation. NO_x emission modeling was conducted using AERMOD with the 2016 to 2020 meteorological input data set. Based on the local, site specific NO_x conversion data from the DST air quality monitoring system, the NO_x emissions were adjusted to account for both direct NO_2 emissions in the tunnels and for the conversion of NO to NO_2 in the ambient air.

As described in Section 2.6.4, 5 percent of the NO_x in the tunnel air was determined to be NO_2 contributing to direct emissions. In addition, 7.5 percent of the NO_x emitted from the VBs and impacting the nearby receptors was modeled as NO_2 to account for NO to NO_2 conversion. Thus, a total of 12.5 percent of the NOx emitted from the VBs was modeled as NO_2.

The modeled NO_2 was combined with the concurrent hourly background NO_2 concentrations to yield the total predicted plus monitored hourly ambient NO_2 concentration at each receptor.

In each modeling year, the 98^{th} percentile (eighth highest) maximum daily 1-hour concentration, the highest second high 1-hour concentration and the annual average concentration were determined. The average of the 98^{th} percentile daily maximum 1-hour concentrations over the five modeling years found using AERMOD model output was compared to the 1-hour NAAQS for NO_2. Table 2-13 presents the AERMOD modeling NAAQS compliance demonstration results. VB1 has the highest predicted impacts and all predicted impacts plus background concentrations are below the NAAQS. The highest annual average NO_2 concentration from all five modeling was compared to the annual NAAQS. The annual AERMOD modeling results are also presented in Table 2-13. VB4 has the highest predicted impacts, and again all predicted impacts plus background concentrations are below the NAAQS.

The overall highest second high concentration from all five modeling years was compared to the Massachusetts 1-Hour NO_2 Guideline value. Table 2-14 presents the AERMOD modeling MassDEP one-hour NO_2 guideline compliance demonstration results. VB1 has the highest predicted impacts and all predicted impacts plus background concentrations are below the guideline concentration. The proposed in-tunnel emission limit for NOx is 6.1 ppm on a one-hour basis as calculated from the 70 ppm in-tunnel CO limit.

TABLE 2-113: MODELING RESULTS FOR IN-TUNNEL NO_X CONCENTRATION OF 6.1 PPM (NAAQS COMPLIANCE)

AERMOD Predicted NO_2 Impacts (μg/m^3)
One Hour and Annual Concentrations Including Background for Comparison to NAAQS
6.1 PPM Source Concentration of NO_x

Source Description	1-Hour Average Design Concentration	Annual Average Design Concentration
Ventilation Step 1		
VB 1	92.9	15.9
VB 3	94.1	14.2
VB 4	95.2	16.4
VB 5	88.0	14.7
VB 6	89.5	15.6
VB 7	92.2	16.9
Ventilation Step 4		
VB 1	170.9	17.3
VB 3	157.3	15.9
VB 4	116.4	19.0
VB 5	89.4	16.2
VB 6	87.9	14.8
VB 7	98.0	19.4
Maximum VB Plus Background Impact	**170.9**	**19.4**
NAAQS	**188**	**100**

AERMOD Predicted NO_2 Impacts (ppm)
One Hour and Annual Concentrations Including Background for Comparison to NAAQS
6.1 PPM Source Concentration of NO_x

Source Description	Design Concentration	Design Concentration
Ventilation Step 1		
VB 1	0.049	0.008
VB 3	0.050	0.008
VB 4	0.051	0.009
VB 5	0.047	0.008
VB 6	0.048	0.008
VB 7	0.049	0.009
Ventilation Step 4		
VB 1	0.091	0.009
VB 3	0.084	0.008
VB 4	0.062	0.010
VB 5	0.047	0.009
VB 6	0.047	0.008
VB 7	0.052	0.010
Maximum VB Plus Background Impact	**0.091**	**0.010**
NAAQS	**0.10**	**0.053**

TABLE 2-124: MODELING RESULTS FOR IN-TUNNEL NO_X CONCENTRATION OF 6.1 PPM (MASSDEP GUIDELINE COMPLIANCE)

AERMOD Predicted 1-hour NO_2 Impacts (µg/m^3)
2nd Highest Value Including Background - Comparison to MassDEP 1-hour Standard
6.1 PPM Source Concentration of NO_x

Source Description	1-hour Average Guideline Concentration
Ventilation Step 1	
VB 1	74.1
VB 3	85.4
VB 4	84.5
VB 5	69.1
VB 6	68.9
VB 7	76.8
Ventilation Step 4	
VB 1	232.7
VB 3	160.0
VB 4	164.4
VB 5	72.4
VB 6	70.4
VB 7	94.4
Maximum VB Plus Background Impact	**232.7**
MassDEP One-hour Policy Guideline	**320**

AERMOD Predicted 1-hour NO_2 Impacts (ppm)
2nd Highest Value Including Background - Comparison to MassDEP 1-hour Standard
6.1 PPM Source Concentration of NO_x

Source Description	Guideline Concentration
Ventilation Step 1	
VB 1	0.039
VB 3	0.045
VB 4	0.045
VB 5	0.037
VB 6	0.037
VB 7	0.041
Ventilation Step 4	
VB 1	0.124
VB 3	0.085
VB 4	0.087
VB 5	0.038
VB 6	0.037
VB 7	0.050
Maximum VB Plus Background Impact	**0.124**
MassDEP One-hour Policy Guideline	**0.170**

2.7.2 For Longitudinal Ventilation − Exit Ramps and DST

2.7.2.1 Modeling Procedures to Determine the Impact of Exit Portal Emissions

For information and historical continuity, this section is repeated from the 2016 Renewal Application.

The plume of exhaust air that comes out of an exit portal in the wake of exiting vehicles has high pollutant concentrations because of the limited dispersion of pollutants within the tunnel. This plume maintains its integrity for a distance downstream of the exit portal due to the momentum created by the moving cars. This distance depends on the geometry of the roadway after the tunnel exit, the traffic flow characteristics, such as speed and density, meteorological conditions (wind direction), and other factors affecting the turbulence and dispersion of the plume. Given the complexity of the air flow patterns and geometries of tunnel portals, physical models were used to analyze the effect of the tunnel emissions.

The air quality dispersion modeling analyses to determine emission limits for the three longitudinally ventilated ramps and the DST are based on the dilution coefficients obtained through the 1996 physical simulation study for the longitudinally ventilated ramps and through the 2005 DST physical simulation study described below.

1996 CA/T Physical Simulation Studies

Physical simulation studies (i.e., wind tunnel tests) were performed in support of the air quality evaluation for the *Notice of Project Change (NPC)/Environmental Reevaluation (ER) for the Implementation of Longitudinal Ventilation in the Area North of Causeway Street and Central Area, October 1996* (1996 Longitudinal Ventilation NPC/ER).

The changes analyzed in the 1996 Longitudinal Ventilation NPC/ER were the direct results of the emissions that previously were vented through the exhaust stacks of VB 8 (eliminated with longitudinal ventilation), and that now are exhausted through the exit portals of ramps CN-S and L-CS. Another change included a small portion of emissions that previously were vented through VB3 and VB4, and which now is vented through the exit portals of the ramps SA-CN, ST-CN, ST-SA, CS-SA and CS-P.

Another physical simulation study was performed for Ramp F as part of the air quality evaluation for the Notice of Project Change (NPC)/Environmental Reevaluation (ER) for the South Bay/South Boston Areas. In order to simplify the ducting system for VB5, the ventilation of exit ramp F was removed from VB5. Exit ramp F now is longitudinally ventilated by the piston action of the vehicles with the addition of jet fans exhausting the air through its exit portal during emergency conditions.

In order to replicate the effects of the air flows created by the moving traffic at these exit ramps, six 1:100 and 1:200 scale models were built at the RWDI wind tunnel testing facility in Guelph, Ontario.

Each model included the individual ramps, and its surrounding buildings within 800 to 1,600 feet from each portal. The scenarios with and without the development of parcels 6 and 12 were also studied. The effects of the moving vehicles were simulated using moving belts, with attached semi spheres representing the aerodynamic characteristics of the predicted traffic speed and density. Specially designed spires and roughness blocks were distributed on the floor upwind of the test section of the wind tunnel to provide a simulation of background turbulence and mean wind speed profiles in the wind flow approaching the modeled area. Urban and suburban profiles were used to simulate the upwind terrain for each area.

Several dimensionless scale parameters are important for the physical model simulation. These parameters were calculated using the full-scale information and were then reproduced on the scale model. The parameters included Reynolds numbers, velocity ratios and dimensionless vehicle drag. For the Reynolds numbers, it was necessary to ensure turbulent flow conditions, but not necessary to precisely reproduce the full-scale values.

Wind tunnel flow visualization tests were initially performed to determine the most likely locations of the highest impacts, and detailed tracer gas tests were performed at the identified high impact locations, including sensitive public areas, and air intakes of the surrounding buildings. These tests were performed for the peak hour, and the 8-hour traffic scenarios at each ramp.

Tracer gas tests were performed at the wind tunnel facility for each ramp, at each specified traffic and parcel development scenario. Monitoring of the tracer gas concentrations, at all the receptors identified during the flow visualization tests, allowed for the predictions of the concentrations at these locations under a variety of wind direction and speed conditions. The tracer gas concentration measured at each receptor location was recorded as a percentage of the gas concentration measured at the exit portal (this data provides what can be described as a dilution ratio for each location).

In order to cover a full range of meteorological conditions, three wind speeds (at low, medium, and high range) and 24 wind angles (at 15° intervals) were tested for each scenario.

A full description of the study methodology and results was prepared in the report *Physical Simulation Study for the Implementation of Longitudinal Ventilation Systems in the Area North of Causeway and Central Area*, prepared by RWDI, October 1996. The report was submitted to MassDEP as part of the 1996 Longitudinal Ventilation NPC/ER.

Figures 2-10 to 2-12 identify the location of each ramp analyzed, and the most critical receptors in terms of highest potential impacts recorded for each source scenario analyzed.

The receptor locations identified in the in the 1996 Longitudinal Ventilation RWDI report were field checked in order to include only ambient street level, operable windows and air intake locations of existing buildings. Receptor locations from 1996 for non-existent buildings, sidewalks, plazas or areas that do not represent the current condition were removed from the 2012 analysis. The same set of receptors was used for the 2016 renewal and is used for the 2021 renewal modeling.

FIGURE 2-9: RAMP CN-S - PORTAL LOCATION AND CRITICAL RECEPTOR

FIGURE 2-10: RAMP CS-SA – PORTAL LOCATION AND CRITICAL RECEPTORS

FIGURE 2-11: RAMP CS-P- PORTAL LOCATION AND CRITICAL RECEPTORS

2005 DST Physical Simulation Study

Due to the proposed commercial building development immediately downstream and adjacent to the tunnel portal, a physical simulation study was performed to evaluate the effects of tunnel motor vehicle emissions on the existing environment, the proposed building configurations and the associated sidewalks.

The objective of the 2005 exhaust dispersion study was to evaluate different Build scenarios (from No-Build to fully developed Parcels 24, 25 and 26a), and how these scenarios would affect the dispersion of exhaust from the two vehicle tunnel portals located south of Kneeland Street. These two portals carry the I-93 south-bound mainline traffic (CASB), and the I-90 collector traffic (Ramp H/Slip Ramp). The sources included in this assessment were the exhausts from the CASB and Ramp H/Slip Ramp exit portals.

Three physical configurations evaluated included:

- Configuration 1 – the relocated CASB portal (400 feet south of Kneeland Street) with development at Parcels 24, 25 and 26a (Figure 2-13). Future once Parcel 25 is developed.
- Configuration 2 – the existing CASB portal location with development at Parcels 24 and 26a and low existing retaining wall (Figure 2-14). Current 2021 configuration represents existing conditions.
- Configuration 3 – the existing "No-Build" condition without any development on Parcels 24, 25 and 26a is no longer in existence due to development of Parcel 24.

The exhaust flow from the two portals was simulated using a fan system exhausting through the modeled vehicle tunnels. The pollutants of concern for this assessment were CO, and NO_2.

Flow visualization tests were initially performed to determine the most likely location of the highest impacts, and detailed tracer gas tests were performed at the identified high impact locations, including sensitive public areas, and air intakes of the surrounding buildings.

A full description of the study methodology and results was included in the final report *Air Quality Study Dewey Square Portal Boston, Massachusetts*, prepared by RWDI, January 2006.

The detailed modeling procedures used for determination of the DST emission impacts and emission limits can be found in Appendix B ("2021 Air Quality Analysis Protocol for Determination of CO and NO_x Emission Limits for the Renewal of the Operating Certification of the Project Ventilation Systems") of this document.

FIGURE 2-12: DEWEY SQUARE TUNNEL – CONFIGURATION 1 – FUTURE WITH PARCEL 25

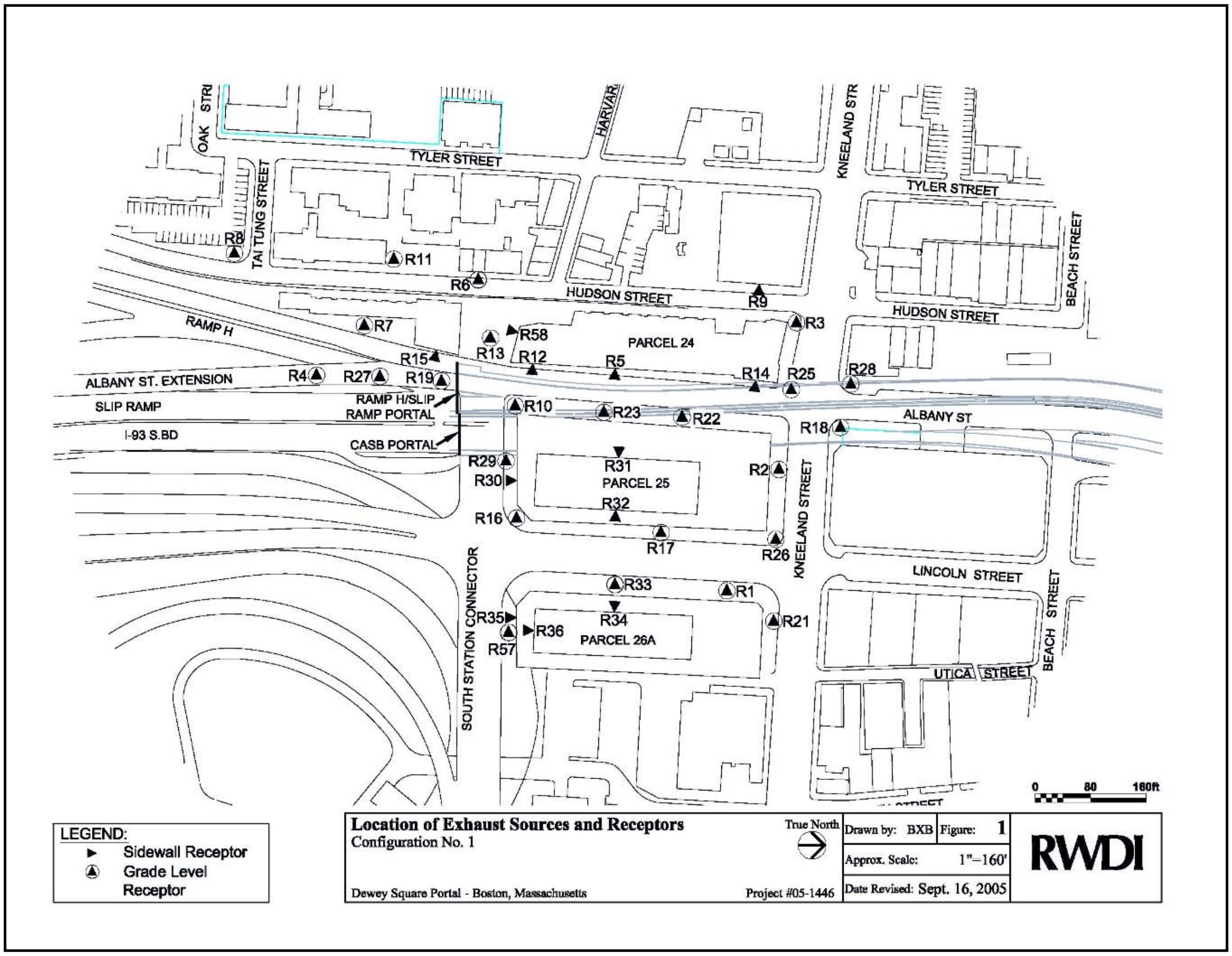
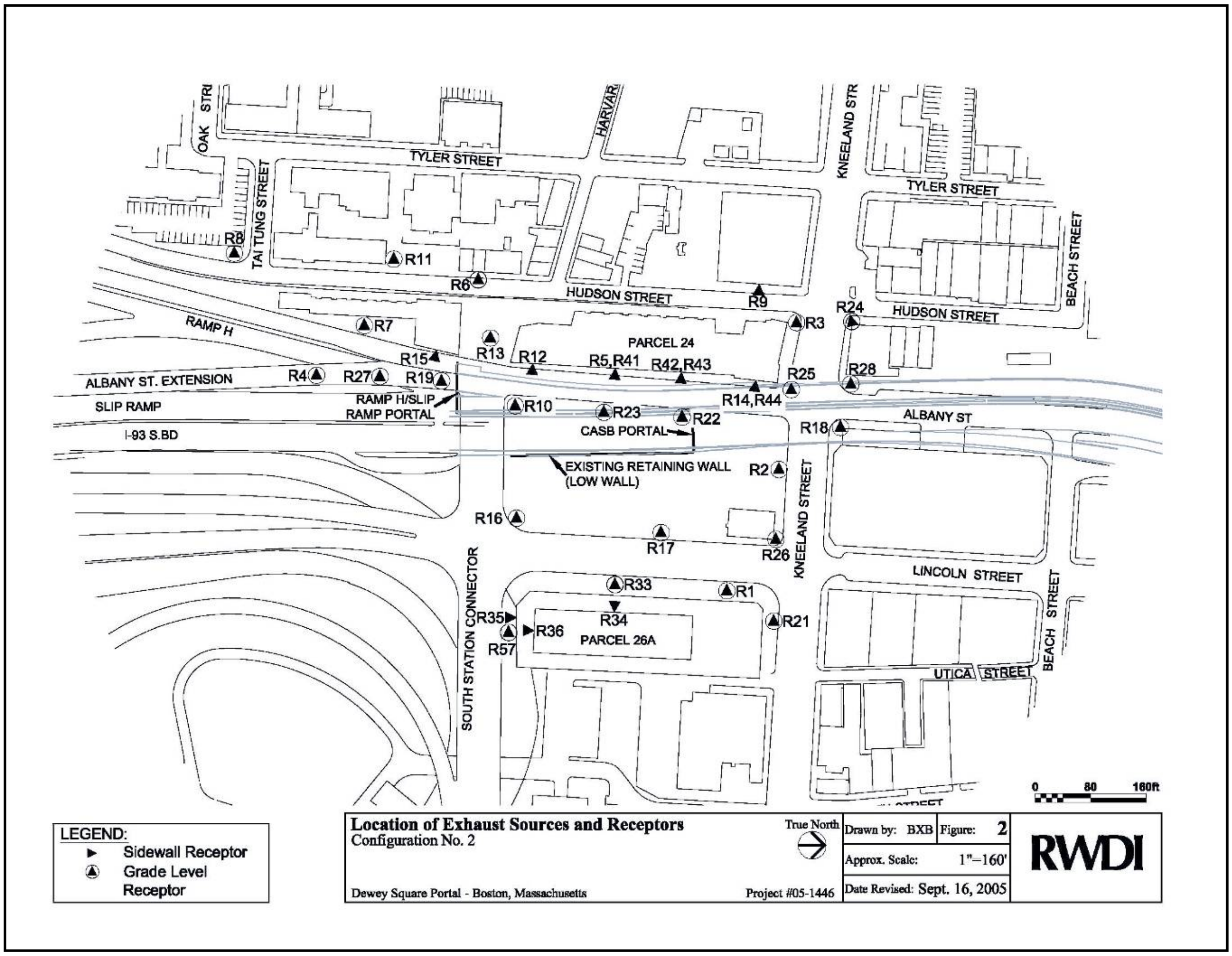


FIGURE 2-13: DEWEY SQUARE TUNNEL – CONFIGURATION 2 - EXISTING 2021



2.7.2.2 Use of Physical Simulation Data

The air quality dispersion modeling analysis to determine the emission limits for the longitudinally ventilated ramps and the DST is based on the dilution coefficients obtained through the 1996 physical simulation study for the longitudinally ventilated ramps and through the 2005 DST physical simulation study.

The dilution factors obtained for the three wind speeds and 24 wind angles for each scenario at each receptor location for the longitudinally ventilated ramps were used to create a series of matrices. These matrices provide the tracer gas concentration measured at each receptor location as a percentage of the full concentration measured at the exit portal (this is the dilution ratio).

This dilution ratio was applied to the full-scale source concentration for each pollutant analyzed, and interpolated using the five years (2016 to 2020) of meteorological data from Logan Airport in order to obtain pollutant levels corresponding to the NAAQS and MassDEP NO_2 Policy Guideline at each receptor location.

The receptor locations were the ambient locations (public access and buildings windows and/or air intake locations) used in the 1996 and 2005 physical simulation studies corrected to remove locations that do not currently exist or are not accessible to the public. The site plans and the most critical receptors for the longitudinally ventilated ramps are presented on Figures 2-10 to 2-14.

2.7.2.3 CO Analysis

The CO emission source level for the exit ramps was analyzed in the range from 20 to 70 ppm for each portal. Peak-hour flow conditions (and associated dilution factors) were used for the one-hour analysis, and 8-hour flow conditions (and associated dilution factors) were used for the 8-hour analysis. Five years of actual meteorological observations from the Logan Airport were used to determine the critical source level at which both 1-hour and 8-hour NAAQS would be potentially violated. The critical source level was identified to the nearest ppm. The one and eight-hour emission limit is established as source level 1 ppm lower than the critical level or as the highest level at which both NAAQS would not be potentially violated.

An in-house program was created to multiply the emission source level by the dilution factor (from the physical simulation study matrix). This program also applies bilinear interpolation to the ratios from the dilution matrix to account for the actual wind speed and wind direction at each hour of the year from the meteorological data set of five years (2016 to 2020). In addition, the program adds the hourly CO background concentration for the respective hour.

The form of the equation is:

$CO_{(\text{at receptor})} = CO_{(\text{at source-portal})} \times \text{Dilution Factor}_{(\text{N hour})} + CO_{(\text{background N-hour})}$

$CO_{(\text{at source-portal})}$ = from 20 to 70 ppm

Dilution Factor $_{(\text{N hour})}$ = f(Wind Speed, Wind Direction)

N-hour = each hour for the full calendar year

EPA modeling procedures described in Section 8.4. of the *USEPA Guideline on Air Quality Models (https://www.epa.gov/sites/production/files/2020-09/documents/appw_17.pdf)* were used for calm winds and missing meteorological data. In the case of missing background CO concentration, the program sets the level for that specific hour to zero. This also follows the procedures provided in the reference cited above.

The program output prints the 1st and 2nd highest levels for each source strength for the year indicating the date and hour of occurrence.

The eight-hour analysis procedure is based on the average of eight sequential one-hour results printing the 1st and 2nd non-overlapping highest levels for the year indicating date and the ending hour of the eight-hour period.

Tables 2-19 through 2-23 summarize the compliance demonstrations for the 1-hour and 8-hour NAAQS for CO for each ramp. The tables list 2nd high concentrations, consistent with the form of the CO NAAQS which allow for each short-term standard to be exceeded once per year. Concentrations are listed in units of ppm. The corresponding NAAQS for CO are 9 ppm for the 8-hour standard and 35 ppm for the 1-hour standard.

TABLE 2-15: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP CN-S (PPM)

Ramp CN-S								
	One Hour CO				Eight Hour CO			
Year	Receptor	Source CO	2nd Highest Level	Date Hour	Receptor	Source CO	2nd Highest Level	Date Hour
2016	22	70	13.68	06/25/16 02	22	64	8.93	06/25/16 08
2017	22	70	13.82	10/15/17 06	22	63	8.98	12/18/17 15
2018	22	70	13.85	07/14/18 02	22	62	8.93	01/22/18 08
2019	22	70	14.04	11/27/19 06	22	67	8.95	05/30/19 08
2020	22	70	13.76	10/02/20 05	22	68	8.97	02/01/20 10

TABLE 2-16: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP CS-SA EXISTING NO PARCEL 12 DEVELOPMENT (PPM)

Ramp CS-SA No Parcel 12								
	One Hour CO				Eight Hour CO			
Year	Receptor	Source CO	2nd Highest Level	Date Hour	Receptor	Source CO	2nd Highest Level	Date Hour
2016	34	70	14.44	01/16/16 18	3	67	8.95	08/28/16 08
2017	34	70	14.60	09/30/17 03	34	70	8.80	10/21/17 08
2018	34	70	14.84	09/13/18 21	34	68	8.95	08/24/18 10
2019	34	70	14.94	07/17/19 20	33	70	8.90	03/20/19 08
2020	34	70	15.23	11/04/20 06	34	63	8.98	07/18/20 08

TABLE 2-17: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP CS-P (PPM)

Ramp CS-P								
	One Hour CO				Eight Hour CO			
Year	Receptor	Source CO	2nd Highest Level	Date Hour	Receptor	Source CO	2nd Highest Level	Date Hour
2016	19 & 20	70	13.53	05/22/16 03	1	70	4.06	03/20/16 19
2017	19 & 20	70	14.08	01/19/17 09	19	70	4.15	10/07/17 08
2018	19 & 20	70	13.03	06/17/18 20	1	70	4.08	07/16/18 19
2019	19 & 20	70	13.02	10/30/19 23	1	70	4.08	08/06/19 17
2020	19 & 20	70	13.82	11/25/20 24	1	70	4.08	10/25/20 22

TABLE 2-13: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION – DEWEY SQUARE TUNNEL: FUTURE CONFIGURATION 1 (PPM)

DST Configuration 1								
	One Hour CO				Eight Hour CO			
Year	Receptor	Source CO	2nd Highest Level	Date Hour	Receptor	Source CO	2nd Highest Level	Date Hour
2016	27	70	22.00	01/24/16 05	27	30	8.90	01/04/16 24
2017	7 & 27	70	21.97	01/08/17 10	4	31	8.97	12/16/17 18
2018	27	70	21.97	03/31/18 05	27	29	8.79	06/19/18 15
2019	27	70	22.00	11/12/19 20	4	31	8.90	02/22/19 20
2020	19 & 27	70	22.00	08/26/20 09	27	30	8.93	09/14/20 22

TABLE 2-14: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION – DEWEY SQUARE TUNNEL: EXISTING CONFIGURATION 2 (PPM)

DST Configuration 2								
	One Hour CO				Eight Hour CO			
Year	Receptor	Source CO	2nd Highest Level	Date Hour	Receptor	Source CO	2nd Highest Level	Date Hour
2016	4 & 23	70	22.00	12/26/16 22	23	28	8.91	10/01/16 12
2017	4 & 23	70	22.00	12/18/17 07	4	28	8.97	11/07/17 20
2018	4 & 23	70	22.00	12/15/18 24	4	28	8.999	05/28/18 10
2019	4 & 23	70	22.00	12/30/19 03	4	28	8.91	11/19/19 23
2020	4 & 23	70	22.00	12/16/20 22	4	28	8.99	06/30/20 11

2.7.2.4 NO_2 Analysis

For each ramp except DST multiple runs were performed using a NO_x portal emission source ranging from 1.10 ppm (9.7 ppm CO equivalent) to 6.10 ppm (70 ppm CO equivalent) at 0.10 ppm NO_x intervals. Analysis for the Dewey Square Tunnel did not calculate CO equivalent for the in-tunnel NO_x because in tunnel NO_x is directly monitored at the DST location.

An in-house program similar to the CO ramp analysis was created to multiply the emission source by the dilution factor (a physical simulation study matrix), interpolate to the closest wind direction and speed for each hour of the year (repeating for five years), and adding the hourly NO_2 background concentrations for the respective hour.

The equations for the relationship between CO and NO_x and between NO_x and NO_2 are presented in sections 2.6.3 and 2.6.4.

The total NO_2 level at each receptor is a summation of NO_2 directly emitted by motor vehicles (5% of the NO_x emitted in the tunnel was considered to be NO_2), the converted NO_2 from in-tunnel NO (using conversion factor of 7.5%), and the background NO_2 level for the corresponding hour.

The program outputs the first 10 highest daily concentrations at each modeled receptor for each year modeled. The one-hour NO_2 average of the 8^{th} highest daily concentrations (98^{th} percentile) for the five years (2016 to 2020) was used to determine emission limit.

Emission limits are set for the lowest source concentration at which the highest receptor are below the 100 ppb (0.1 ppm or 188 $\mu g/m^3$) NO_2 NAAQS.

The highest one-hour level for each one of the five years was used for verifying that the selected emission limits complies with the MassDEP NO_2 Policy Guideline of 170 ppb (0.17 ppm or 320 $\mu g/m^3$). This is conservative, since the MassDEP Policy allows one exceedance per year.

The annual compliance with the NO_2 NAAQS of 53 ppb (0.053 ppm or 100 $\mu g/m^3$) was demonstrated by comparing the annual average results for each year including the hourly background concentrations to the NO_2 annual NAAQS.

Tables 2-24 through 2-28 provide the results of these analyses and identify the highest source level for which all receptor locations analyzed comply with the one-hour and annual NO_2 NAAQS and MassDEP NO_2 Policy Guideline.

Table 2-20: 1-Hour NO_2 Levels for Compliance Demonstration: Ramp CN-S (PPM)

Ramp CN-S																
	MassDEP One Hour Policy Guidance Level						One Hour NO2 NAAQS						Annual NO2 NAAQS			
Year	Receptor	Source CO	Source Nox	1st Highest NO2	Date	Hour	Receptor	Source CO	Source Nox	8th Highest NO2	Date	Hour	Receptor	Source CO	Source Nox	Annual
2016	22	70	6.10	0.158	12/29/2016	6	22	40	3.60	0.098	4/25/2016	10	22	70	6.10	0.038
2017	22	70	6.10	0.157	12/15/2017	18	22	40	3.60	0.0999	9/16/2017	21	22	70	6.10	0.037
2018	22	70	6.10	0.155	11/12/2018	9	22	41	3.70	0.0998	12/1/2018	23	22	70	6.10	0.037
2019	22	70	6.10	0.157	11/27/2019	6	22	41	3.70	0.099	2/14/2019	23	22	70	6.10	0.037
2020	22	70	6.10	0.154	2/1/2020	6	22	42	3.80	0.099	2/4/2020	24	22	70	6.10	0.036

Table 2-21: 1-Hour NO_2 Levels for Compliance Demonstration: Ramp CS-SA – Existing no Parcel 12 (PPM)

Ramp CS-SA No Parcel 12																
	MassDEP One Hour Policy Guidance Level						One Hour NO2 NAAQS						Annual NO2 NAAQS			
Year	Receptor	Source CO	Source Nox	1st Highest NO2	Date	Hour	Receptor	Source CO	Source Nox	8th Highest NO2	Date	Hour	Receptor	Source CO	Source Nox	Annual
2016	34	70	6.10	0.159	1/16/2016	18	34	41	3.70	0.0997	11/9/2016	7	33	70	6.10	0.041
2017	34	70	6.10	0.169	1/20/2017	10	3	42	3.80	0.099	2/11/2017	9	33	70	6.10	0.038
2018	34	70	6.10	0.165	1/3/2018	23	3	43	3.90	0.0999	12/20/2018	21	33	70	6.10	0.040
2019	34	70	6.10	0.166	1/9/2019	5	34	41	3.70	0.099	10/19/2019	22	33	70	6.10	0.038
2020	34	69	6.00	0.168	1/22/2020	5	34	39	3.50	0.099	4/24/2020	23	33	70	6.10	0.038

Table 2-15: 1-Hour NO_2 Levels for Compliance Demonstration: Ramp CS-P (PPM)

Ramp CS-P																
	MassDEP One Hour Policy Guidance Level						One Hour NO2 NAAQS						Annual NO2 NAAQS			
Year	Receptor	Source CO	Source Nox	1st Highest NO2	Date	Hour	Receptor	Source CO	Source Nox	8th Highest NO2	Date	Hour	Receptor	Source CO	Source Nox	Annual
2016	19 & 20	70	6.10	0.156	11/2/2016	18	19 & 20	43	3.90	0.098	5/27/2016	8	1	70	6.10	0.025
2017	19 & 20	70	6.10	0.156	9/15/2017	23	19 & 20	43	3.90	0.098	8/14/2017	6	1	70	6.10	0.023
2018	19 & 20	70	6.10	0.155	1/22/2018	10	19 & 20	47	4.20	0.099	6/17/2018	20	1	70	6.10	0.024
2019	19 & 20	70	6.10	0.149	1/14/2019	18	19	47	4.20	0.0997	3/10/2019	1	1	70	6.10	0.023
2020	19 & 20	70	6.10	0.161	2/13/2020	9	19 & 20	45	4.00	0.098	6/10/2020	24	1	70	6.10	0.021

TABLE 2-16: 1-HOUR NO_2 LEVELS FOR COMPLIANCE DEMONSTRATION – DST: FUTURE CONFIGURATION 1 (PPM)

Dewey Square Tunnel - Configuration 1													
	MassDEP One Hour Policy Guidance Level					One Hour NO2 NAAQS					Annual NO2 NAAQS		
Year	Receptor	Source Nox	1st Highest NO2	Date	Hour	Receptor	Source Nox	8th Highest NO2	Date	Hour	Receptor	Source Nox	Annual
2016	4	4.00	0.1697	2/2/2016	8	4	2.10	0.097	11/14/2016	18	4	2.40	0.052
2017	4	4.00	0.167	3/20/2017	23	4	2.10	0.099	3/20/2017	23	4	2.50	0.0528
2018	4	4.00	0.169	2/27/2018	7	4	2.20	0.098	1/15/2018	9	4	2.60	0.052
2019	7	3.80	0.169	2/28/2019	7	4	2.10	0.098	2/13/2019	10	4	2.40	0.052
2020	4	4.00	0.168	1/30/2020	6	4	2.20	0.098	2/29/2020	7	4	2.60	0.052

TABLE 2-17: 1-HOUR NO_2 LEVELS FOR COMPLIANCE DEMONSTRATION – DST: EXISTING CONFIGURATION 2 (PPM)

Dewey Square Tunnel - Configuration 2													
	MassDEP One Hour Policy Guidance Level					One Hour NO2 NAAQS					Annual NO2 NAAQS		
Year	Receptor	Source Nox	1st Highest NO2	Date	Hour	Receptor	Source Nox	8th Highest NO2	Date	Hour	Receptor	Source Nox	Annual
2016	4	3.70	0.167	7/24/2016	21	4	2.00	0.099	2/16/2016	1	4	2.80	0.052
2017	4	3.70	0.167	1/16/2017	6	4	2.10	0.0995	2/10/2017	20	4	2.90	0.052
2018	4	3.60	0.168	6/8/2018	22	4	2.00	0.097	10/23/2018	20	4	2.80	0.052
2019	4	3.60	0.167	3/19/2019	24	4	2.00	0.097	12/17/2019	8	4	2.80	0.052
2020	4	3.80	0.169	2/13/2020	11	4	2.00	0.0998	1/21/2020	19	4	2.90	0.052

2.7.3 Summary of Current Status and 2016 analysis for the Longitudinally Ventilated Ramps affected by the Possible Future Development of Parcels 6 and 12

Development of Parcels 6 and 12 was part of CA/T commitments during the design phase of the project. The 2016 Renewal Application included an assessment of how the possible future development of park features covering parts of Parcels 6 and 12 could affect emission limits for ramps CS-SA and ST-SA in support of a possible MEPA process.

The 2015 parcels' development proposal differs from the initial plans in the coverage area and in the plans for the development above the tunnel extensions. While the initial plans were for development of elevated structures (buildings on top of the covers), the 2015 proposal for both parcels include only the park features, paths and lookout points (see Figures 2-15 and 2-16). The wind-tunnel studies conducted for the initial plans do not properly reflect the air quality implications of the current development proposals, mostly due to different public areas adjacent to and on top of the parcels. Therefore, emission limits for the exit ramps associated with these parcels need to be determined based on the modeling of the 2015 proposed designs instead of the wind-tunnel studies done in the past.

These parcels are not covered under the existing condition. Emission limits for CO and NO_x for the ramps in the Parcel 6 area, ramps SA-CN, ST-CN and ST-SA, were determined in the first Operating Certification in 2006. Continuous Emission Monitoring (CEM), conducted inside these ramps in the period 2006-2012, demonstrated that monitored levels were well below the established limits. Based on this finding MassDEP granted MassDOTs' request during the 2012 Operating Certification to discontinue monitoring at these locations. MassDEP concurred with eliminating these ramps from the CEM monitoring system in February 2013.

The modeling analysis performed in the 2016 Renewal Application established future emission limits for CO and NOx for the longitudinally ventilated ramps in the Parcels 6 and 12 areas under the 2015 proposed condition with covers. This 2015 proposed covered condition is not expected to occur during the 2021-2026 time period. As such, the section describing the 2016 modeling scenarios is not replicated in this document. For reference purposes Figures 2-15 and 2-16 provide a visual description of the current condition of both parcels.

MassDOT has informed MassDEP of the current situation of these two parcels in the latest Parcel Status Report dated January 27, 2021 (included in Appendix F-4).

FIGURE 2-14: PARCEL 6 EXISTING CONDITION

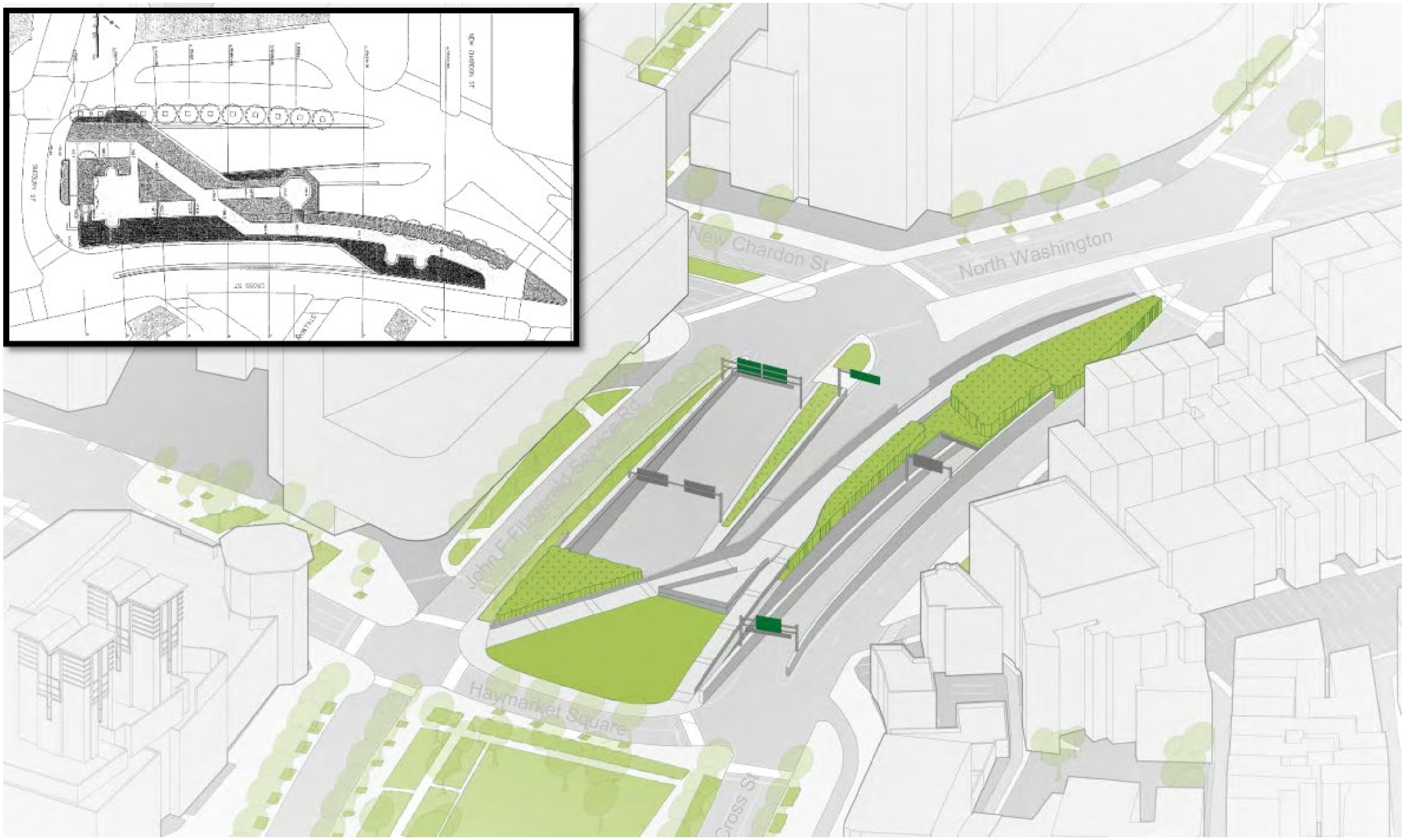


FIGURE 2-16: PARCEL 12 EXISTING CONDITION

2.7.4 VOC Emission Limit Determination

The 2016 renewal application demonstrated compliance with 310 CMR 7.38(2)(c) (non-methane hydrocarbon budget – referred to here as VOC – volatile organic compounds) established for the year 2005, in the original Operating Certification approved by MassDEP in 2006 (6,095.9 kg/day). The 2016 renewal application demonstrated that the VOC emissions in 2016 were approximately 2,000 kg/day, one third of the budget of 6,095.9 kg/day established in 2005.

Based on the significant decreases in VOC motor vehicle emissions, current monitoring levels of ozone and the current O_3 attainment status to 2015 NAAQS of the Boston Metro area, MassDEP concurred with MassDOT that the 2021 CA/T renewal certification, similar to 2016 CA/T renewal, would use a simplified approach to estimate the reductions in the regional VOC levels. Since CTPS (Boston Metro area MPO), who performed in the past the regional emission analysis as part of their planning and conformity process, was not required to conduct the conformity analysis at the time of the 2016 Renewal Application, the 2016 regional VOC demonstration was based on MOVES 2014a motor vehicle emission factors and projected percent increases in regional traffic levels. The CTPS modeling areas that were used for 2005 budget purposes are presented on Figures 2-17 and 2-18, for the overall CTPS modeling and the project-specific area.

The current 2021 renewal of the Operating Certification uses the same approach to the VOC demonstration as was used in the 2016 Operating Certification Renewal. The current version of MOVES, MOVES3, was used to estimate vehicle emission factors. MOVES3 has different underlying calculation methodologies that causes estimations of emission factors to differ from previous versions of the model. Nonetheless, MOVES3 reflects the most recent and accepted emissions modeling science and is recommended for use by the EPA. Future traffic projections were based on the available information sources.

FIGURE 2-17: CTPS MODELED AREA

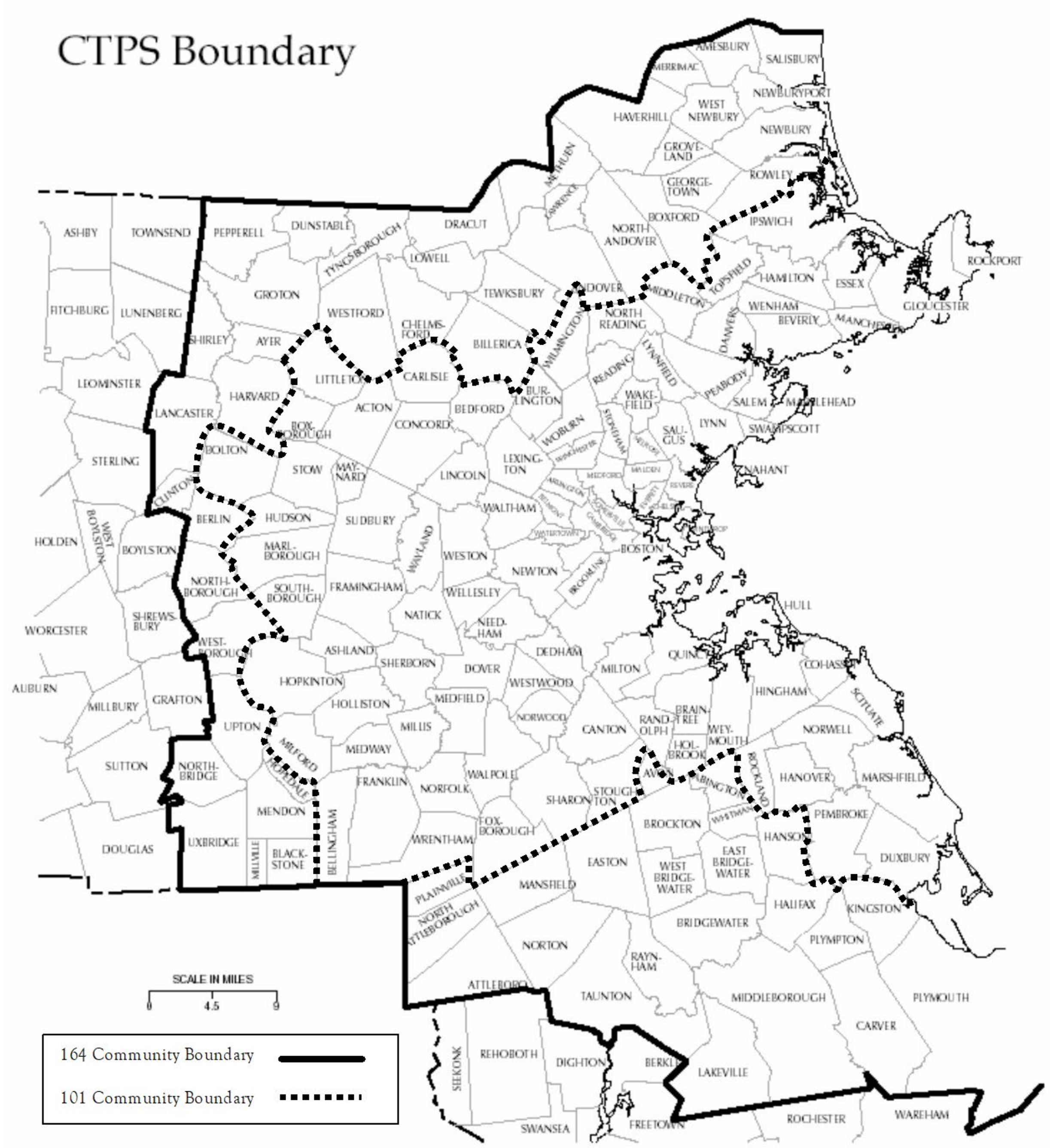


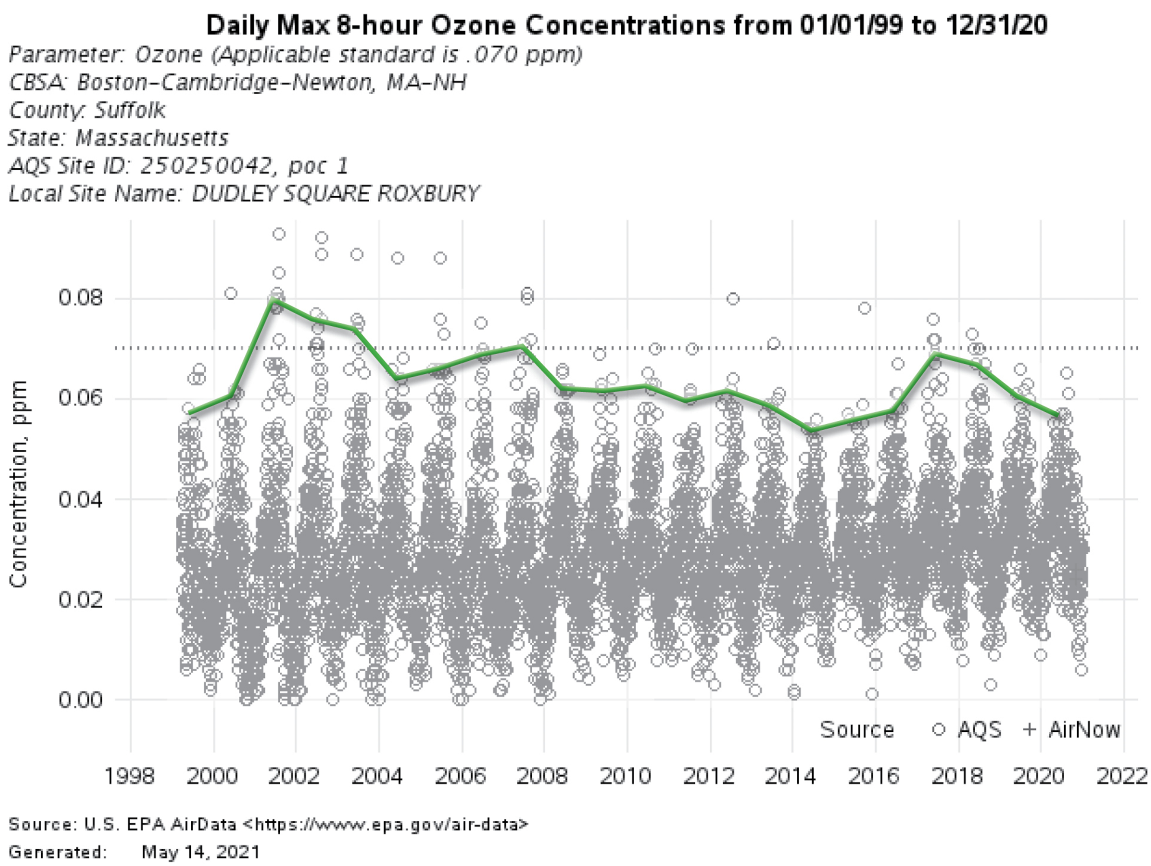
FIGURE 2-18: CA/T PROJECT STUDY AREA

2.7.4.1 Ozone (O_3) and VOC Suffolk County Historical Trends

The Boston area had been designated nonattainment for the 1997 O_3 NAAQS but EPA designated Boston area as unclassifiable/attainment for the 2008 8-hour ozone standard (0.075 ppm) in 2012. In October 2015, EPA lowered NAAQS for O_3 to 0.070 ppm for the fourth-highest daily maximum 8-hour concentration, averaged over three years. Today, Massachusetts is designated in attainment for all standards, with the exception of Dukes County. Dukes County is designated as nonattainment with 2008 ozone NAAQS (0.075 ppm). However, Dukes County currently meets 2008 ozone NAAQS and is designated as attainment with the more stringent 2015 ozone NAAQS (0.070 ppm). Based on the court decision regarding areas that were nonattainment or maintenance for 1997 ozone standard, from February 2019 Boston is part of the orphan maintenance area for that standard. Such areas are subject to the Transportation Conformity and to avoid “back-sliding” into nonattainment have to demonstrate the use of the latest planning assumptions, utilize the latest emission model and application of transportation control measures among other restrictions.

The measured ozone concentrations in Suffolk County are shown in Figure 2-19 for the period 1999 through 2020. For reference, the CA/T tunnels fully opened to traffic in early 2006, approximately the time that the monitored ozone concentrations fell below the NAAQS in Suffolk County.

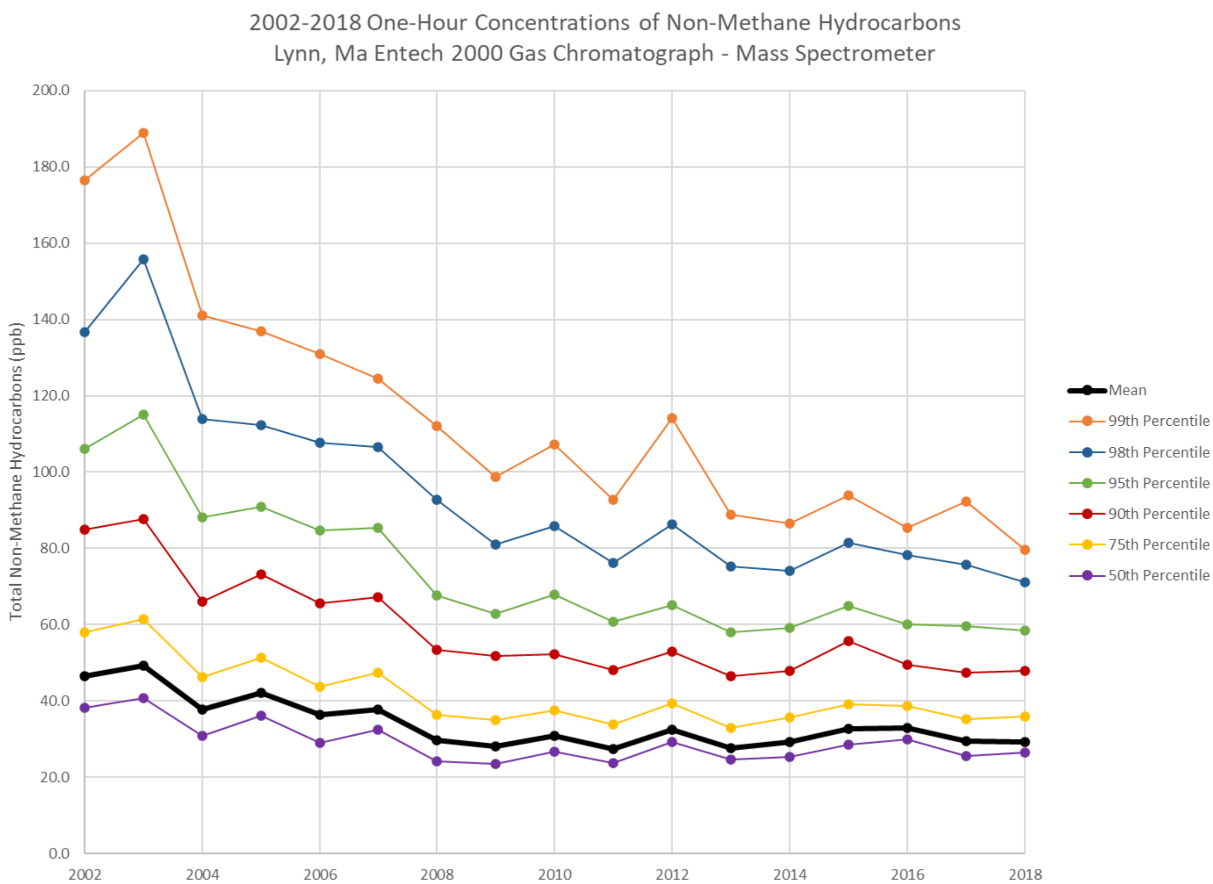
FIGURE 2-15: SUFFOLK COUNTY MEASURED 8-HOUR AVERAGE O_3 CONCENTRATION TREND



Note: Line indicating the 4th high daily maximum value has been added to original EPA figure

The nearest VOC monitoring station is located in Lynn, MA, approximately 9 miles north-northeast of the CA/T. This site monitors regional VOC concentrations. In 2002 an Entech 2000 mass spectrometer was brought on-line at that site and has recorded VOC concentrations since that time. Figure 2-20 presents the non-methane hydrocarbon/VOC one-hour concentration trend for various statistical measures recorded at Lynn from 2002 to 2018 as reported in the EPA's AIRS database. Starting in 2019, the Lynn, MA station switched to an automatic gas chromatograph and stopped reporting total non-methane hydrocarbon concentrations to EPA's AIRS database. Overall, VOC concentrations have been declining since 2002. Note that regional mean VOC concentrations have decreased approximately 40 percent during this time period. Higher percentile measures (the 95th, 98th, and 99th percentiles) have seen even larger reductions (approximately 50 percent) during this time period.

FIGURE 2-16: LYNN, MA 1-HOUR VOC CONCENTRATION TREND



Note: Starting in 2019, the Lynn, MA station switched to an automatic gas chromatograph and stopped reporting total non-methane hydrocarbon concentrations to EPA's AIRS database.

The results of the monitoring data concur with the decreasing VOC motor vehicle emission trends, which are estimated for future years using the MOVES3 (EPA Motor Vehicle Emission Simulator) in the following section.

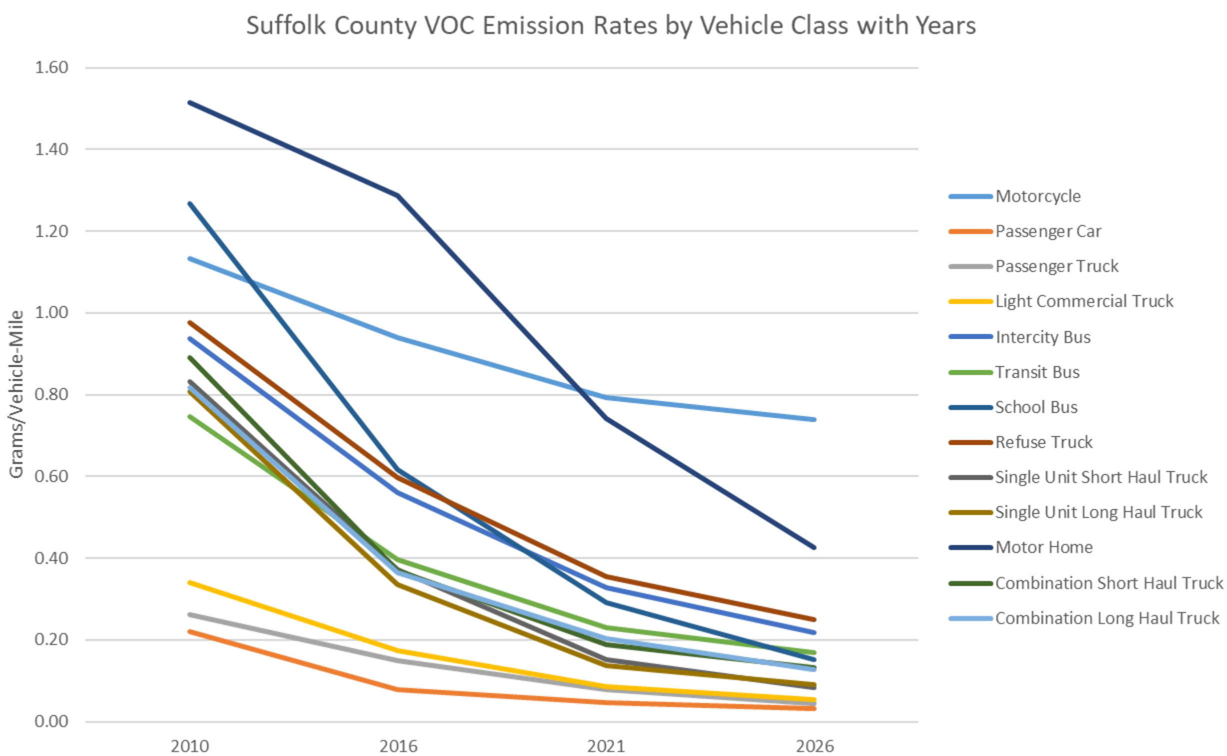
2.7.4.2 MOVES Emission Factors and Future Traffic Changes for Suffolk County Motor Vehicles

MOVES3 was run using input files obtained from MassDEP for Suffolk County. County scale runs were conducted for years 2010, 2016, 2021 and 2026 to determine VOC by vehicle class and the composite for the Suffolk county vehicle fleet. The results are presented in Table 2-25 with the percent reductions from 2010 to 2016, 2021 and 2026.

TABLE 2-18: MOVES3 EMISSION FACTORS BY YEAR AND VEHICLE CLASS (GRAM/VEHICLE-MILE)

MOVES3									
SourceTypeID	Source Description	2010	2016	2021	2026		2010->2016	2010->2021	2010->2026
11	Motorcycle	1.13	0.94	0.79	0.74		-17%	-30%	-35%
21	Passenger Car	0.22	0.08	0.05	0.03		-65%	-78%	-86%
31	Passenger Truck	0.26	0.15	0.08	0.04		-43%	-70%	-83%
32	Light Commercial Truck	0.34	0.17	0.09	0.05		-49%	-74%	-84%
41	Intercity Bus	0.94	0.56	0.33	0.22		-40%	-65%	-77%
42	Transit Bus	0.75	0.40	0.23	0.17		-47%	-69%	-77%
43	School Bus	1.27	0.62	0.29	0.15		-51%	-77%	-88%
51	Refuse Truck	0.98	0.60	0.36	0.25		-39%	-64%	-74%
52	Single Unit Short Haul Truck	0.83	0.37	0.15	0.08		-55%	-82%	-90%
53	Single Unit Long Haul Truck	0.81	0.34	0.14	0.09		-58%	-83%	-89%
54	Motor Home	1.52	1.29	0.74	0.43		-15%	-51%	-72%
61	Combination Short Haul Truck	0.89	0.37	0.19	0.13		-59%	-79%	-85%
62	Combination Long Haul Truck	0.82	0.37	0.20	0.13		-55%	-75%	-84%
	Aggregate	**0.28**	**0.13**	**0.08**	**0.05**		**-55%**	**-72%**	**-82%**

FIGURE 2-17: MOVES3 EMISSION FACTORS 2010 – 2026 BY VEHICLE CLASS



The VOC emission factor reductions from 2010 to 2016 for the Suffolk County composite vehicle fleet is in the order of 55 percent, and between 2010 and 2026 in the order of 82 percent.

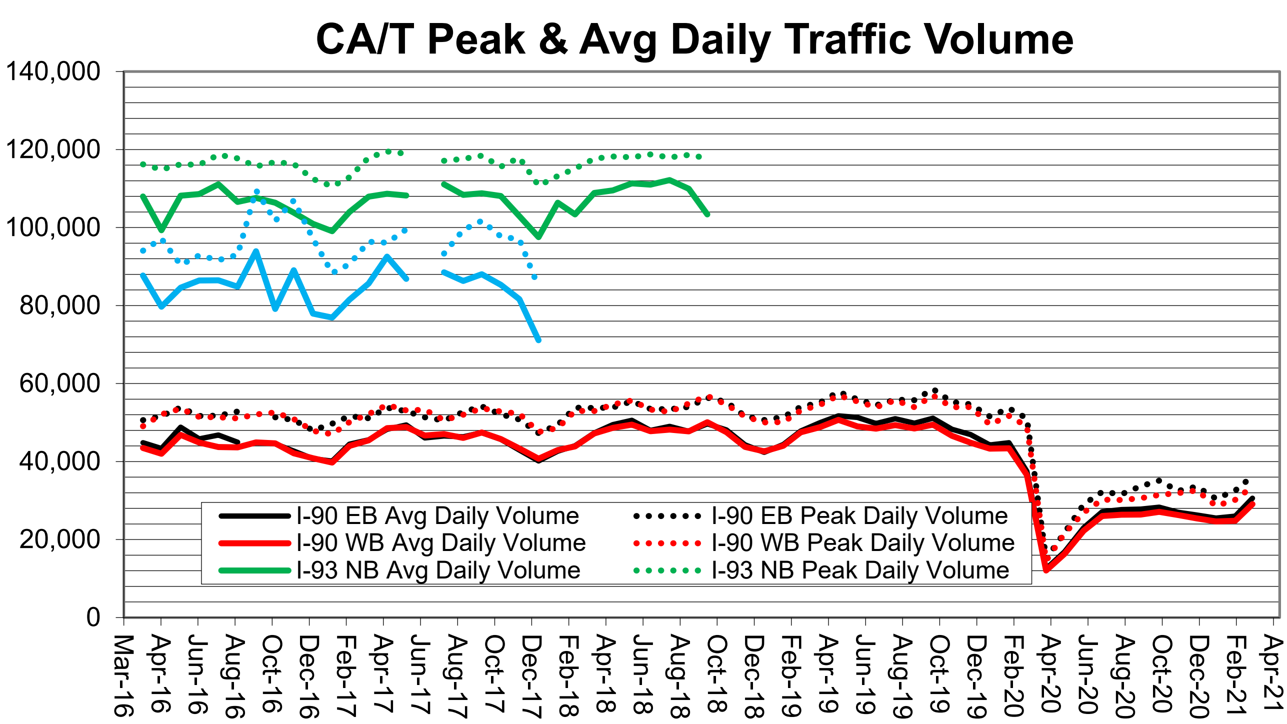
The approximate traffic VMT growth was 3% from 2010 to 2016. The CA/T estimated tunnel traffic volumes counted during the past fifteen years (provided in Figure 2-22 and Table 2-26

) indicate an even lower increase than the regional volumes. According to the data collected since the last certification before COVID, the annual growth in the Central Artery was less than 0.1 percent. During COVID year the VMT fell drastically.

TABLE 2-19: CENTRAL ARTERY/TUNNEL ANNUAL GROWTH RATE

	Annual Growth Rate		
Period	Daily Volumes	Peak Hour Volumes	
2010-2015 [1]	0.5%	0.5%	
2016-2019 [2]	0.02%	0.06%	
2019-2020 [3]	-39%	n/a	
1 - Based on CTPS annual growth projections			
2 - Average of counts on I-90 east and west of I-93 and I-93 north and south of I-90			
3 - Average of counts on I-90 east and west of I-93			

FIGURE 2-18: ESTIMATED AND MONITORED DAILY TRAFFIC IN THE CA/T TUNNELS 2006-2021



Oct-16 EB data incomplete and omitted
Oct-16 WB, Nov-16 EB, Jun-19, and Mar-20 data missing several days

2.7.5 VOC Compliance Demonstration

The MOVES3 trends for VOC described in Table 2-25 indicate a 55% reduction from 2010 to 2016 for the aggregate fleet and an 82% reduction from 2010 to 2026. The regional traffic increased approximately ½ % per year for the 2010-2016 period, and less than 0.1% a year between 2016 and 2019. Overall, the regional traffic is not expected to increase more than 5% (a very conservative estimate) from 2016 to 2026. Based on these data, it was estimated that regional VOC emissions from the region's transportation sector should decreased by about 70% between 2010 and 2021 and approximately 77% between 2010 and 2026.

As a result, the 2021 VOC regional emissions in the CA/T area will be in the range of 1,300 kg/day (about one third of the 2010 emission levels of 3,906 kg/day), which is close to one fifth of the 2005 VOC emission budget of 6,095.9 kg/day. The projected 2026 VOC regional emissions are anticipated to be in the order of 900 kg/day (23% of the 2010 emission levels). The 2010 emission budget for the project area was the last budget obtained from CTPS regional model.

2.8 PROPOSED 2016-2021 OPERATING EMISSION LIMITS

The proposed operating emission limits are based on the compliance modeling and demonstration of compliance with the applicable standards at the emission limits as described above.

2.8.1 CO, NOx and $PM_{2.5}$

The emission impact modeling results indicated that operation of the CA/T ventilation buildings below these limits would not cause or exacerbate a violation of the applicable NAAQS for CO, NO_2, or $PM_{2.5}$, or the MassDEP Policy Guideline Value for NO_2.

TABLE 2-20: SUMMARY OF 2021-2026 EMISSION LIMITS

Location*	1-Hour CO Emission Limit (ppm)	8-Hour CO Emission Limit (ppm)	1-Hour NOx Emission Limit (ppm)	24-Hour $PM_{2.5}$ Emission Limit (µg/m^3)
VB 1	70	70	6.1	700
VB 3	70	70	6.1	700
VB 4	70	70	6.1	700
VB 5	70	70	6.1	700
VB 6	70	70	6.1	700
VB 7	70	70	6.1	700
Ramp CN-S	40	62	3.6	NA
Ramp CS-SA**	41	63	3.7	35***
Ramp CS-P	43	70	3.9	NA
Dewey Sq. Tunnel Existing	70	28	2.0	NA

Notes: Acronyms are defined as: Central Artery Northbound to Storrow Drive (C-NS), Sumner Tunnel to Central Artery Northbound (ST-CN), Central Artery Southbound to Surface Artery (CS-SA), Sumner Tunnel to Surface Artery (ST-SA), Central Artery Southbound to Purchase Street (CS-P), part per million (ppm), microgram per cubic meter (µg/m^3).

* For each ventilation building, location includes all associated ventilation zones.

** The ambient $PM_{2.5}$ monitor is located outside ramp CS-SA.

*** Compliance with the 24-hour $PM_{2.5}$ NAAQS is based on the monitoring design value, which is given by the 3-year average of the annual 98th percentile value of daily average concentrations. The form of the standard allows, on average, for the numerical value of the standard (35 µg/m^3) to be exceeded on seven calendar days per calendar year without triggering a violation of the NAAQS.

2.8.2 VOC

The results of the regional analysis using MOVES3 emission factors and traffic growth demonstrate that the 2021 CA/T Project emissions would be in the range of 1,300 kg/day, which are well below the VOC Budget for the 2005 CA/T Build condition of 6,095.9 kg/day.

2.9 OPERATING CERTIFICATION CRITERIA

In summary, the data collected for the Operating Certification to-date demonstrates that the operation of the CA/T Project, as currently constructed and operated, complies with 310 CMR 7.38(2) (a)-(c) in that the CA/T project does not cause or exacerbate a violation of the applicable NAAQS for CO, NO_2 or $PM_{2.5}$ or the MassDEP Policy Guideline Value for NO_2 and does not result in an actual or projected increase in the total amount of non-methane hydrocarbons estimated within the project area when compared with the 2005 emission budget.

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Part II – Compliance Monitoring Program

3 PROJECT COMPLIANCE MONITORING SYSTEM

3.1 MassDEP 310 CMR 7.38(8) Regulatory Requirements

MassDEP Regulation 310 CMR 7.38(8) states the following requirements for vehicle emissions and vehicle traffic monitoring.

Emissions Monitoring

(a) "Any person who constructs and operates a tunnel ventilation system which is subject to the requirements of 310 CMR 7.38 shall, prior to commencing operation of the tunnel ventilation system or opening the project roadway for public use, develop and submit to the Department for review and approval an "Air Emissions Monitoring Protocol" and shall install and operate emissions monitoring and recording equipment in accordance with the approved protocol. Monitoring as approved by the Department shall be required at the exhaust stacks or exhaust plenums of VBs as well as at exit portals that utilize longitudinal ventilation. The Department will consider for approval hybrid monitoring systems that incorporate elements of the federal regulations for monitoring ambient air pollution, for monitoring stationary source emissions, and for pollutant emission trading (i.e., 40 CFR Parts 58, 60, and 75) as practicable, as well as statistical analysis, computer modeling, and innovative technologies. The "Air Emissions Monitoring Protocol" may also be modified with prior written approval of the Department."

Traffic Monitoring

(b) "Any person who constructs and operates a tunnel ventilation system which is subject to the requirements of 310 CMR 7.38 shall install, operate and maintain traffic monitoring equipment within the project area, the numbers and locations of which shall be determined in consultation with the Department."

3.2 Emissions Measurement Methodologies

3.2.1 Applicability of 40 CFR Parts 58, 60 and 75

Unlike emissions from stacks at a power plant, the emissions from the CA/T's ventilation system is unique in that the system contains multiple exhaust stacks and portal emission sources that operate at multiple exhaust flow rates that move extremely large volumes of air. In addition, unlike the emissions from a power plant which emit much higher (i.e., greater) concentrations of pollutants, pollutant emission concentrations from any CA/T VB or longitudinally ventilated exit ramp, are much lower. The CEM system described in this section, is considered a hybrid type of system, which uses elements of both ambient air quality monitoring systems and continuous emission monitoring equipment required at power plants. As such, the CA/T's CEM system incorporates various elements of the federal regulations 40 CFR Parts 58, 60, and 75 as well as statistical analysis, computer modeling, and innovative technologies.

3.3 Continuous Emissions Monitoring Systems Description

3.3.1 Monitoring Locations for Ventilation Buildings

The pollutant levels are measured at the discharge points for each ventilation zone. Since each exhaust fan has its own exhaust stack, there are more stacks than ventilation zones for each VB. In general each ventilation zone feeds two or three exhaust fans (depending on air flow to be delivered). As examples: there are six exhaust stacks at VB 6 serving two ventilation zones; and 14 stacks at VB 7 serving five ventilation zones. This duplication provides redundancy and sufficient ventilation capacity during the times when fans have to be taken out of service due to maintenance or repairs.

The number of exhaust fans in operation at a given time depends on the control of airflow to and from various section of the tunnel. This is accomplished by the ventilation control system. The amount of ventilation depends on the in-tunnel CO measurements, which are dependent on the traffic characteristics. As such, the amount of the airflow exhausted through each stack could vary from zero to full exhaust capacity depending on the number of operating fans' ventilation Step setting. Normal operation utilizes Steps 1 (13% exhaust capacity) to 4 (42% exhaust capacity).

In general, there are always some fans in stand-by mode. Therefore, it was not considered cost effective to install equipment to continuously monitor emission levels at each stack, when only some are in simultaneous operation. Instead, vehicular emissions in the tunnel are monitored in the exhaust plenums of each ventilation zone prior to being ducted up and out of the building stacks. This captures the totality of exhaust emissions before they are diverted into a particular stack.

The CO monitoring system employs a "rake probe" to gather the samples. The probe consists of a length of one-half inch Teflon or stainless steel tubing. Each of the probes had 8 equal distant holes drilled so that they allowed for sample collection along the entire width of the ventilation plenum. The probe is oriented so that the 8 holes are directed into the direction of flow of the source stream.

The $PM_{2.5}$ (PM_{10} for years 2006-2011) monitoring system also is deployed at the exhaust plenums but has a single inlet probe at the center of each exhaust plenum. The flow in the plenum is very turbulent (high Reynolds number) and the exhaust stream is expected to be well mixed. This was demonstrated by the results of tests performed during 2003/04 with multiple portable MiniVOL samplers.

There are possible mechanisms that could lead to particle size stratification, but these mechanisms are not significant in the turbulent environment of the ventilation system. PM is affected by gravity, interception (e.g., filtration), inertial separation/ impaction, electrophoresis, thermophoresis and diffusion. Each of these mechanisms could affect different sizes of PM, but as discussed below, it is very unlikely that the turbulent environment of the plenums will change the outcome of the 2003/04 test results.

- Gravitational settling will act more strongly on the heavier PM_{10} particles than on $PM_{2.5}$. if PM_{10} is uniform and well mixed across the plenum, then $PM_{2.5}$ is expected to be likewise uniform.
- Interception is more likely to deplete PM_{10} than $PM_{2.5}$; however, there are no filters or other structures in the plenum that are significant sites for interception, so this mechanism is expected to be insignificant.
- Differential inertial separation/impaction of $PM_{2.5}$ and PM_{10} could occur when there is a sharp bend in the ductwork and the heavier PM_{10} particles are preferentially carried to the outside of the bend by inertia. Since PM_{10} is uniform in the plenum, inertial separation is not occurring for particles of PM_{10} size and smaller.
- Electrophoresis and thermophoresis would affect the smaller $PM_{2.5}$ particles more than PM_{10} , but there are no strong electric fields or temperature gradients across the well mixed plenum to cause these effects.
- Diffusion in the plenum is dominated by turbulence caused by the forced movement of air. The turbulence has resulted in well mixed, uniform distribution of PM_{10} and will also result in a uniform distribution of smaller particles ($PM_{2.5}$) and gases.

3.3.2 Monitoring Locations for Longitudinal Ventilation

The plume of air that escapes from these tunnels in the wake of exiting traffic maintains its integrity for a distance downstream of the exit portal due to the momentum created by the moving cars. Due to the well mixed turbulence of this plume, the pollutant concentrations inside a cross section of these ramps are fairly uniform.

The CO monitoring system employs a similar “rake probe” with eight equal distant holes to gather the samples. Such probe is located across the roadway at the tunnel ceiling level approximately 100 feet inside each exit portal (Figure 3-1). These measurements provide an average of the in-tunnel CO levels before exiting to the atmosphere.

FIGURE 3-1: CO CEILING MONITORING PROBE AT DST

A CEM $PM_{2.5}$ monitoring system is also deployed just outside the east portal of longitudinally ventilated exit ramp CS-SA. This monitor measured ambient $PM_{2.5}$ concentrations in the vicinity of ramp CS-SA, and $PM_{2.5}$ levels as a pilot program for several months during 2009-2010. Since 2011 it has been used to monitor ambient $PM_{2.5}$ ambient levels.

MassDEP presented a request to include a NO_x monitor inside the DST at the July 10, 2015 interagency meeting. The MassDEP rationale for this additional monitor is presented in section 5.8 of this document. MassDOT agreed to include this additional NO_x monitor. This NO_x (measuring also NO and NO_2) became operational April 2018 after the MassDEP approval of the 2016 Renewal Application. The NO_x and CO analyzers will simultaneously utilize the existing CO sampling probe, currently installed inside the I-93 segment of the DST, as shown in the above figure. The NO_x data collected from this new monitor has been reported to MassDEP for compliance with the emission limit for the DST.

3.3.3 CO Monitoring System

The CEM equipment used to measure and/or record CO levels is described below. The CEM monitoring system is not typically used to control the fan step during normal operations.; this is done by Operators using independent, in-tunnel CO monitors. However, when pre-established alarm limits, determined to ensure compliance with CEM emission limits, are exceeded, control of the fans automatically shifts to the integrated project control system (IPCS) until the alarm condition is eliminated, or the system is manually overridden. The tunnel ventilation monitoring system is used to maintain safe air quality and visibility within the tunnels and to control smoke and heat in emergencies.

3.3.3.1 Ventilation Buildings and Longitudinally Ventilated Exit Ramps

The CO CEM systems located at VBs 1, 3, 4, 5, 6 and 7 and longitudinal ventilated exit Ramps CN-S, CS-SA, CS-P, DST-I93, and DST-I-90, consists of the following equipment:

- Non-Dispersive Infrared Continuous CO Gas Analyzer with a detection range of 0 parts per million to 150 parts per million,
- Multi-Gas Calibration System,
- Zero Air Generator,
- System Controller/Data Logger,
- CO Calibration Gas - RATA Class.
- There are a total of 12 CO monitors in the system. Seven in the ventilation buildings (one on each building and two in VB#7); three in the longitudinally ventilated ramps and two in the DST portals.
- MassDOT has replaced all remaining BINOS CAT-100 Infrared Continuous CO gas analyzers with Thermo Environmental Instruments units except for those at Ramps DST/I-90 and CSSA , which are in the process of being re-located (completion by end of 2021).

3.3.3.2 CEM Equipment Housing

All CEM equipment located at the CA/T VBs are rack mounted in NEMA certified 12 enclosures (Figure 3-2). CEM equipment located in applicable roadway utility rooms for longitudinally ventilated exit ramps are rack mounted in NEMA certified 4x enclosures (Figure 3-3).

FIGURE 3-2: CO AND $PM_{2.5}$ MONITORING UNITS AT VB 7 EXHAUST

FIGURE 3-3: CO MONITORS LONGITUDINALLY FOR VENTILATED TUNNELS

3.3.3.3 Sample Probe / Sample Transport / Sample Conditioning

The sample probe for the CO emissions monitoring system for both VBs and longitudinally ventilated exit ramps are constructed of stainless steel tubing. The sample probe is installed across each applicable VB's exhaust plenum and in the ceiling of longitudinally ventilated exit ramps in a location so that it is positioned in the stream of air being exhausted through the plenum prior to being ducted up each vent building exhaust stack or out the exit portal of a longitudinally ventilated exit ramp. The probe has eight 1/8-inch diameter holes drilled into it at equal distances along the entire length of the probe. There are no sampling holes located within 3 feet of any exhaust plenum or exit ramp wall. Each sample line is positioned in the exhaust plenum perpendicular to the direction of airflow in the plenum, which ensures that the full cross-sectional airflow within an exhaust plenum is being sampled.

The calibration system that is used to calibrate each CO analyzer uses cylinders of CO gas and a "zero" air source. The CO calibration gas used has been certified according to the EPA RATA procedures. The "zero" air source uses a zero air generator. Zero air and CO gas is diluted using a multi-gas calibration system. The calibration system is capable of controlling and mixing the CO calibration gas stream with the zero air stream to produce concentrations over the entire range of the analyzer. The calibration system supplies calibration gas through the calibration line to the sample probe at the calibration flow rates that range between 10 and 15 standard liters per minute (slpm). Calibration gases are injected through the entire sample line so that the sample line pump is constantly drawing an adequate calibration sample to the CO analyzer.

The sample/calibration bundle is comprised of two Teflon lines. The sample lines are connected to each sample probe, through a particulate filter (at the probe end of the line). The sample is drawn from the probe by a positive displacement pump that discharges to a tee. One leg of the tee is connected to an atmospheric vent and the other leg of the tee is connected to a fine particulate filter just prior to entering a CO analyzer. The sample line pump is set to operate so that the velocity in the sample line is sufficient so that sample residence time in the sample line is always less than 20 seconds. The second line in the sample/calibration bundle is a Teflon line that is connected from the calibration system to the sample probe.

3.3.4 $PM_{2.5}$ Monitoring System

$PM_{2.5}$ levels in the full-transverse ventilated section of the CA/T roadway are monitored continuously in key locations in the exhaust plenums before the exhaust air is ducted up through the VB exhaust stacks to the outside atmosphere. There are no continuous $PM_{2.5}$ CEM monitors located inside longitudinally ventilated exit ramps. At longitudinally ventilated exit ramp CS-SA, a CEM $PM_{2.5}$ monitor is located just outside the exit portal above the boat-wall section. This location is representative of the ambient $PM_{2.5}$ conditions close to the traffic emerging from the I-93 southbound tunnel and local traffic data in the CA/T surface corridor.

3.3.4.1 VBs and Longitudinally Ventilated Exit Ramp

The $PM_{2.5}$ CEM monitoring system located at VBs 3, 5 and 7 and longitudinally ventilated exit Ramp CS-SA, consists of the following equipment:

- A continuous $PM_{2.5}$ sampler with a detection range of 0 micrograms per cubic meter to 5,000 micrograms per cubic meter;
- System Controller/Data Logger.

$PM_{2.5}$ CEM equipment located at VB 3 is continuously monitoring particulate emissions from vehicles traveling on north and southbound I-93 tunnel sections. $PM_{2.5}$ equipment located at VB 5 and VB 7, continuously monitor $PM_{2.5}$ emissions from vehicles traveling on east and westbound I-90 tunnel sections.

3.3.4.2 Monitoring Locations and Housing

The $PM_{2.5}$ sensor units at VBs 3, 5 and 7 are housed in a NEMA certified 4x enclosure located in the exhaust plenums of each VB. The $PM_{2.5}$ sensor unit located at longitudinally ventilated exit ramp CS-SA samples air outside of the exit portal of the ramp itself. The intent of this monitor is to measure ambient $PM_{2.5}$ levels in the vicinity of the longitudinally ventilated exit ramp. This ramp was selected because of its close proximity to a residential community and because of the highest potential impacts predicted at the sensitive receptors in the wind-tunnel study.

3.3.5 NOx DST Monitoring System

The CEM equipment used to measure and/or record CO and $NO/NO_2/NO_X$ in-tunnel levels at the I-93 Dewey Square Tunnel Exit Portal is described and shown in a photo below:

Monitoring equipment that which collects CO and $NO\text{-}NO_2\text{-}NO_x$ concentrations inside the DST portal consists of a Model 48i Infrared (CO) Analyzer and a Model 42i Chemiluminescence $NO\text{-}NO_2\text{-}NO_x$ (NO_x) analyzer, all manufactured by Thermo Environmental Instruments, Inc. The analyzers, along with one (1) Model 146i dynamic gas calibrator, also manufactured by Thermo Environmental Instruments, Inc., is housed in an environmentally controlled shelter (i.e., enclosure), located at the top of the DST portal. Along with analyzers and gas calibrator, a data acquisition system (ESC8832) is also housed in the equipment enclosure. The 8832 controls calibration sequencing, logging of hourly NO_x concentrations, and calibration results. The 8832 is a computer-based system connected to MassDOT via modem. The system allows access to all analyzer operating status, recorded hourly NO_x data and calibration results from current MassDOT monitoring stations. Finally, calibration gas cylinders are also store in the enclosure. (See Figure 3-4 for equipment and enclosure)

FIGURE 3-4: CO-NO-NO2 DST MONITORS ENCLOSURE

3.3.6 Data Acquisition and Handling System

Data from the CO and $PM_{2.5}$ CEM systems located at VBs 1, 3, 4, 5, 6 and 7 and longitudinal ventilated exit Ramps CN-S, CS-SA, CS-P, DST-I93, and DST-I-90, are recorded using a System Controller/Data Logger (data logger) at each location. The data loggers constitute the Data Acquisition Handling System (ESC8832) for each CEM location. The data loggers control the calibration routines for the CO analyzers and record of all CO and $PM_{2.5}$ concentrations on an hourly/daily basis.

3.4 CONTINUOUS EMISSIONS MONITORING SYSTEMS INITIAL CERTIFICATION

The CA/T's ventilation system is unique in many ways. As such, the certification process performed for monitoring the emissions from the ventilation system is also unique in its application to the Project's ventilation system. Equipment certification and operations were specifically tailored for use in the Project's emissions monitoring program and reflect the unique application for which the equipment is being used.

3.4.1 CO Monitoring System

3.4.1.1 CO Analyzer Multi-Point Calibration Test

The CO analyzers that are used to monitor CO concentration in the exhaust plenum and at the longitudinally ventilated exit ramps, are calibrated using the system dilution calibration device at zero (0) concentration and at four (4) calibration points over the range of the instrument. Calibration concentrations are: a high value 100-135 ppm, a mid-range 45–75 ppm, a low-range 20–30 ppm, and a low-low-range 5-10 ppm. Calibration gas is injected directly into each CO analyzer. The instruments are adjusted first at the zero level and then at the high value. After each instrument is adjusted at the high value, the zero level is injected again. If the zero level required re-adjustment, then the high level concentration is injected again. If necessary, several iterations between the zero and high-level concentrations are performed to ensure that an analyzer is calibrated. The calibration specification for acceptability is ±1.0 ppm for zero and ±5% of the input concentration for the high-level point. All remaining concentrations levels are injected without any further analyzer adjustments. The average Δ% for calibration points are not allowed to exceed ±5% where:

$$\Delta\% = \frac{(\text{Analyzer Response} - \text{Input Concentration})}{\text{Input Concentration}} \, x\, 100$$

Where:

Analyzer Response = Concentration recorded by an analyzer

Input Concentration = Input calibration gas concentration

3.4.1.2 Cycle Time and Linearity Test

For this test, all monitoring systems are operated in their normal sampling mode, including the time sharing mode for the equipment located at VB 7.

Low-level calibration gas with a value of 40 to 50 ppm are input through the entire monitoring system for 30 minutes, or until a stable response is achieved. At the end of the period, a high-level calibration gas with a value of 80 to 90 ppm is input through the entire monitoring system for 30 minutes or until a stable response occurred.

The amount of time it took for 95% of the step change to be achieved between a stable low level and high-level calibration gas response is determined. The cycle time test was successful if the response time achieved was less than 15 minutes.

The linearity of the monitoring system to the low and high scale calibration gases is also tested during the cycle time test. To pass the linearity test, the monitoring system response must be within $\pm$5% of the low and high-level calibration gas input values using the formula:

$$\text{Linearity } \Delta\% = \frac{(\text{System Response} - \text{Input Concentration})}{\text{Input Concentration}} \, x \, 100$$

Where:

System Response = Concentration recorded by the analyzer when the calibration gas is injected through the entire system

Input Concentration = Input calibration gas concentration

3.4.1.3 Seven-Day Calibration Drift Test

The calibration drift of each monitoring system is measured once a day (approximately 24 hours apart) for seven consecutive days using zero and span gases. No manual or automatic adjustments were made to any analyzer until after recording all responses.

To pass the seven-day drift test for the zero point, each analyzer's zero drift could not be greater than $\pm$1% (1.5 ppm) of the analyzer full-scale range (150 ppm) per day. Drift for the span gas is calculated as follows:

$$\text{Calibration drift} = \frac{(\text{Analyzer Response} - \text{Input Concentration})}{\text{Input Concentration}} \, x \, 100$$

Where:

Analyzer Response = Concentration recorded by the analyzer

Input Concentration = Input span gas concentration

To pass the seven-day drift test for the span gas, each analyzer's span drift could not be greater than $\pm$5% of the span value per day.

3.4.1.4 System Bias Test

After each CO analyzer was calibrated, a system bias check is performed. The high-level calibration concentration is injected through the entire emission monitoring system. The acceptable system bias is ±5% according to the equation:

$$\text{System Bias} = \frac{\text{System Response} - \text{Direct Analyzer Response}}{\text{Direct Analyzer Response}} \quad \text{x} \quad 100$$

Where:

System Response = Concentration recorded by the analyzer when the calibration gas was injected through the entire system

Direct Analyzer Response = Concentration recorded by the analyzer when the calibration gas was injected directly into the analyzer

3.4.2 $PM_{2.5}$ Monitoring System

Tests are performed on each $PM_{2.5}$ unit located at VBs and outside longitudinally ventilated exit Ramp CS-SA and consist of calibration/certification of each particulate monitoring system, including the calibration of the main and auxiliary flow rate, the on-board temperature sensor, and the barometric pressure sensor by its referenced standard. In addition, verification of the Ko constant of each $PM_{2.5}$ unit mass transducer taper element is conducted by using five pre-weighed filters.

In all cases, the manufacturer recommended procedures specified in the $PM_{2.5}$ unit's operating manuals is applied for all certifications tests. Reference standards used are either primary standards or working standards traceable to National Institutes of Standards and Technology (NIST).

3.4.2.1 K Factors

% Error of Ko = 100 x (Average Ko – Actual Ko) /Designated Flow

The allowable Ko error ± 2.5%.

3.4.2.2 Flow

% Error of Flow = 100 x (Average Flow – Designated Ko)/Designated Flow

The allowable flow error is ± 7%.

3.4.2.3 Temperature and Barometric Pressure

Error = Display Value – Audit Value

The allowable temperature error is ± 2°C. The allowable barometric pressure error is ± 10 mm Hg.

3.4.3 Continuous Emissions Monitoring Certification Data Submittal

Results for certification tests performed on CO, NOx CEM equipment (i.e., multi-point calibration, cycle time/linearity, seven-day drift and system bias) and $PM_{2.5}$ CEM equipment (i.e., K-factor, system flow and temperature/barometric pressure), are presented in Appendix D, "CEM Certification Test Data".

3.5 TRAFFIC MONITORING

The CA/T Project has an extensive array of video cameras to monitor traffic conditions through the entire project. The main function of this centralized system, which is operated by the HOC, is to monitor real time traffic conditions to assist the HOC operations in conducting safe tunnel operation.

There were four locations where hourly traffic volumes were recorded using traffic counting loops under the tunnel pavement until these loops failed in 2018:

- I-93 southbound in the vicinity of Milk Street
- I-93 northbound in the vicinity of Milk Street
- I-90 westbound the vicinity of vent building 6 in South Boston
- I-90 eastbound under Boston Harbor in the vicinity of the South Boston Shoreline

These locations represented the tunnel sections that account for the vast majority of the Project's traffic volumes, and as such, they provided MassDEP with a very good indication of the peak hourly and daily traffic volumes passing thru the CA/T tunnels. When the loops failed, MassDOT started reporting the east-west traffic volumes using existing tolling data, while the north-south loop system was planned to be replaced with cameras. The latter project has been delayed. Currently, MassDOT continues to report east-west traffic counts on a quarterly basis.

4 CONTINUOUS EMISSIONS MONITORING PLAN

4.1 PROJECT-WIDE QUALITY ASSURANCE/QUALITY CONTROL PROGRAM

This section describes the overall quality assurance (QA) and quality control (QC) program for the continuous air emissions monitoring portion of the long-term Compliance Monitoring Program for the CA/T Project. CEM equipment currently in-place for CA/T's Operating Certification, along with specific information regarding the CEM QA/QC program, are described in Attachment 1, "CEM Air Emissions Monitoring Protocol" to this document.

The QA/QC program sets forth, among other things, the procedures to be followed and the criteria to be met, where applicable, for:

- Operating, maintaining and calibrating the CEMS equipment and related components;
- Determining the quality of the measured data; and
- Developing emissions-related parameters and directly reporting the measurement results to the MassDEP in order to demonstrate project compliance status with respect to the ambient concentration limits in 310 CMR 7.38(2)(a).

The QA/QC program has been developed through extensive technical consultation with the MassDEP taking into consideration Federal Regulations 40 CFR Parts 58, 60 and 75. The procedures to be followed also take into account equipment manufacturer's recommendations as well as good engineering practice.

4.1.1 Quality Assurance/Quality Control – Definition and Function

QA, as it relates to the continuous air emissions monitoring program for the CA/T Project, represents those planned or systematic activities, independently performed by personnel external to MassDOT, that are required to ensure that the measurements made and the data reported to regulatory authorities are representative, acceptably accurate, and supported by defendable documentation.

QC, as it is implemented for this monitoring program, represents the series of routine and periodic operational activities (based on regulatory requirements, good engineering practice, and the agreed-upon approach for this hybrid monitoring system) that are necessary for maintaining and improving data quality and the instruments and systems that produce that information.

QA checks also serve to ensure that the QC function is not only being implemented properly, but that it is adequate to the task, such that when (or even before) data accuracy or documentation becomes unacceptable, actions are taken to identify and resolve the issues or procedural steps affecting data quality until acceptable performance is once again achieved. Periodic review of implementation and documentation are typically referred to as "Systems Audits".

Corrective action encompasses both internal policies and regulatory requirements. This QA/QC program focuses primarily on the corrective actions required to maintain the system or component back in a status of compliance, but, it also acknowledges the need for periodic review of the CEM Air Emissions Monitoring Protocol and related standard operating procedures (SOPs) based on accumulated operating experience and opportunities for improvement identified as a result of Systems Audits. (**Note:** Recommendations for improvement that are generated during Systems Audits are evaluated by MassDOT staff and are implemented if deemed meritorious **and** adequate resources, e.g. manpower, funding, etc. are available.)

4.1.2 QA/QC Goals and Objectives

The goals of this QA/QC program are to collect measurement data of known and acceptable quality and quantity, and to generate and maintain the records required to demonstrate that the continued operation of the tunnel and exit ramp ventilation systems results in compliance with the air quality criteria set forth in 310 CMR 7.38(2)(a).

In order to do so, MassDOT is committed to installing, certifying, operating, maintaining and calibrating continuous emissions monitoring and related systems in accordance with applicable Commonwealth of Massachusetts regulations at 310 CMR 7.38(8) and 7.38(9), agreed-upon requirements adapted from Federal regulations conditions in the CA/T Project's Operating Certification, the QA/QC program laid out in Attachment 1, and good engineering practice.

4.1.3 Organization and Responsibilities

This section summarizes key personnel, responsibilities and organizational structure for the continuous air emissions monitoring portion of the long-term Compliance Monitoring Program for the CA/T Project which is established pursuant to 310 CMR 7.38 and implemented in accordance with the requirements of the CA/T's Operating Certification.

4.1.3.1 Director of Environmental Engineering

The director of Environmental Engineering is responsible for the overall implementation of the CEM Program described herein.

4.1.3.2 Senior Environmental Engineer

The Senior Environmental Engineer is responsible for technical oversight of the continuous air emissions monitoring program and its execution. The Senior Environmental Engineer interfaces with the Director of Environmental Engineering in carrying out the planning and administrative responsibilities of that position and with QA Management (external to MassDOT) to ensure that all program activities affecting data quality are performed and documented in accordance with the CEM Air Emissions Monitoring Protocol and the applicable SOPs. The Senior Environmental Engineer also serves as technical liaison between the MassDOT and representatives of the MassDEP and other regulatory agencies in regards to the monitoring program and the reported results.

Regarding implementation of the monitoring program, the duties of the Senior Environmental Engineer encompass:

- Procurement of equipment, related components and materials[1];
- Training and supervision of air quality staff, participating in the operation, maintenance and calibration of the CEMS equipment and related components, and interpreting CEMS output data[14];
- Ensuring that routine and periodic QC inspections, instrument response checks, calibrations and adjustments are successfully performed and documented as required;
- Verifying that measurement and QC check data are recorded and reviewed on a regular basis, and that measurement data are reduced and validated properly;
- Review, approval and timely submittal of quarterly reports of CEMS data and QC check results to MassDEP;
- Supporting periodic independent and third-party QA Equipment Performance and Systems Audits in coordination with regulatory agencies (as applicable), and any subcontractor(s) that may conduct such work;

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[4] Equiment procurement, training and limited data review responsibilities may be integrated with the responsibilities of the Senior Environmental Engineer and/or his designee(s) (e.g., Environmental Engineer, Environmental Technicians).

- Review of semi-annual QA Performance Audit and annual Systems Audit reports;
- Resolution of any issues resulting from routine operations, maintenance, QC checks or QA audits, evaluating the need for Monitoring Plan revision in coordination with QA Management and, when required, revising the CAEMP or the accompanying SOPs;
- Daily review of CO and $PM_{2.5}$ measurement data and periodic review of calculated NO_x concentrations for each monitoring location in relation to the corresponding Operating Certification limits, traffic volumes and tunnel operating conditions;
- Regular review of QC check results (i.e., daily CO analyzer response checks) versus applicable acceptance criteria and action limits;
- Routine processing and summarization of measured hourly average CO concentrations, calculated and measured (Dewey Square Tunnel only) hourly average NO_x concentrations, daily (24-hour) average $PM_{2.5}$ measurements, and daily and periodic QC check results;
- Validation of CO and $PM_{2.5}$ measurement data based on operating status of analyzers and related instrumentation, and the results of daily QC response checks (CO only), other periodic QC checks (e.g., multi-point calibrations, flow rate verifications), and periodic QA Equipment Performance Audits;
- Preparation of quarterly reports of CEMS data, QC check results, and excess emissions (if any) as they occur in accordance with 310 CMR 7.38(9)(a)(2);
- Supporting preparation of semi-annual QA Performance Audit reports and annual QA Systems Audit reports;
- Retaining all measurement data, results of periodic QC checks and QA Performance and Systems Audits, and other related documentation (e.g., records of routine and periodic inspections and preventive maintenance) for a period of at least five years in accordance with 310 CMR 7.38(9)(a)(1);
- The conduct of periodic independent QA Performance Audits - for example, semi-annual multi-point calibration response and bias checks of the CO analyzers, and semi-annual verification of $PM_{2.5}$ mass transducer calibration and flow audit response;
- The performance of annual independent QA Systems Audits of monitoring program implementation and related documentation;
- The scheduling and conduct of any third-party (i.e., regulatory agency) QA Performance or Systems Audits; and
- The preparation and review of the corresponding QA Performance and Systems Audit reports.

4.1.3.3 Environmental Engineers

The Environmental Engineer(s), working under the direction of the Senior Environmental Engineer, are responsible for routine operation, maintenance and calibration (collectively referred as QA) of the CEMS and all related components. In this regard, the duties of the Environmental Engineer and Environmental Technicians include:

- Inspection of the CEMS equipment and shelters on a regular basis (e.g., analyzer and equipment settings and readouts, calibration gas bottle pressures and inventory, general housekeeping);
- Completing periodic (e.g., weekly, monthly, semi-annual, annual) preventive maintenance items on the CEMS and related equipment;
- Maintaining an adequate inventory of spare parts and consumable items such that instrument downtime is minimized to the extent practicable;

- Conducting and/or evaluating periodic QC checks – for example, daily, quarterly, annual checks of CO analyzer response and calibration gas dilution system flow meter accuracy, and quarterly, semi-annual and annual verifications and/or calibrations of $PM_{2.5}$ monitor flow rate and related flow or measurement system components; and
- Supporting independent semi-annual QA Performance Audits and annual QA Systems Audits, or other third-party (e.g., MassDEP) audits.

As indicated at the end of the preceding subsection, the Environmental Engineer(s) may undertake some of the data review, equipment procurement and training duties if deemed qualified by the Senior Environmental Engineer.

4.1.4 Document Distribution and Control

As a matter of practicality, copies of the Continuous Air Emissions Monitoring Plan will not be placed at each continuous emissions monitoring location simply because of the number of sites in the monitoring network. Rather, distribution of the CEM Air Emissions Monitoring Protocol will be via Controlled Copy for those individuals and organizations with a need-to-know function that directly affects the successful implementation, management and/or oversight of the continuous air emissions monitoring program. Each Controlled Copy shall be sequentially numbered.

At a minimum, recipients of Controlled Copies of the CEM Air Emissions Monitoring Protocol (Attachment 1) will include:

- Director of Environmental Engineering
- Senior Environmental Engineer
- Environmental Engineer(s)
- MassDEP

Uncontrolled copies will also be distributed to individuals or organizations on an as-needed basis for informational purposes where casual familiarity with the monitoring program may be beneficial but is not essential. The Senior Environmental Engineer in coordination with the Director of Environmental Engineering shall approve such recipients.

Distribution of Controlled Copies of the CEM Air Emissions Monitoring Protocol, and revisions to it, will be documented on form MTA-ENV-FORM01. Recipients shall sign the distribution form, return the original to the Senior Environmental Engineer or designee, and retain a copy of the signed form. The signed original shall be retained by the Director of Environmental Engineering.

Distribution of Uncontrolled Copies of the CEM Air Emissions Monitoring Protocol shall be by formal transmittal letter or e-mail, as appropriate. Documentation of all such transmittals shall also be retained by the Director of Environmental Engineering.

The CEM Air Emissions Monitoring Protocol may be updated periodically as operational experience with the CEM system is gained, as the effectiveness of the SOPs and the staff's execution of them is demonstrated (as evidenced by the quality of the data and related documentation produced), and as evaluated through the results of periodic QA Equipment Performance and Systems Audits.

At a minimum, the CEM Air Emissions Monitoring Protocol will be reviewed annually by the Senior Environmental Engineer in coordination with QA Management; more frequently, if required (e.g., due to failure of multi-point calibrations or an intervening semi-annual QA Performance Audit during two consecutive calendar quarters, frequently occurring out-of-control periods).

Revisions to any requirement of the CEM Air Emissions Monitoring Protocol (e.g., the frequency of equipment and data inspections, instrument response checks, calibration checks and adjustments) or to SOPs shall be agreed upon by the Senior Environmental Engineer before incorporation. All changes to the CEM Air Emissions Monitoring Protocol shall be clearly marked on each affected page with the Revision Number, Date and Page Number updated accordingly. Controlled Copies of the affected sections (or subsections), or an individual SOP shall be re-issued by the Senior Environmental Engineer with distribution and receipt to be documented as described above. The Senior Environmental Engineer or designee shall keep a chronological log that summarizes all such revisions.

The Senior Environmental Engineer will identify all parties directly affected by such revisions and will coordinate the necessary training to implement those changes in a timely manner. The appropriate mode of training shall be at the discretion of the Senior Environmental Engineer.

4.2 TRAINING

Training represents an essential element of a successful QA/QC program by identifying the objectives to be accomplished and by providing the basic knowledge required to successfully complete a procedure or task. In this QA/QC program, training takes the form of:

- General training,
- Specialized vendor training,
- Monitoring plan review, and
- Periodic refresher and specialized training

Training and subsequent implementation can also provide a more thorough understanding (over time) of a given task or procedure that enables the individual involved to make more timely and effective decisions while executing the process or improving on the process itself. Therefore, training is the cornerstone of the framework within which activities were performed in a consistent manner regardless of who completes them.

4.2.1 General Training

General training is not intended as much to deliver detailed and specific knowledge, as it is to provide an overall understanding of the goals and objectives of the CA/T Project's continuous air emissions monitoring program within the framework of the CEM Air Emissions Monitoring Protocol. General training is provided to all individuals directly involved with the CEM program.

4.2.2 Specialized Vendor Training

Specialized training in the installation, operation, maintenance and calibration of the various monitoring systems and related components will be provided to the Senior Environmental Engineer, and to the Environmental Engineer(s), as appropriate, by the respective system vendors either at the time of or soon after initial installation of the equipment.

4.2.3 Monitoring Plan Review

All personnel involved in the routine operation, maintenance and calibration of the CEMS, related components and systems, or in the review, processing, validation and reporting of the data produced by those pollutant measurement systems will be required to review:

- The appropriate sections and/or Parts of this document (including the applicable requirements adapted from the regulations under 40 CFR Parts 58, 60 and 75), and
- The CEM Air Emissions Monitoring Protocol, SOPs and corresponding System Manuals.

4.2.4 Periodic Refresher and Specialized Training

Refresher training occurs periodically (e.g., following review of the effectiveness of the CEM Air Emissions Monitoring Protocol and accompanying SOPs).

When changes in personnel or assigned responsibilities take place, the degree of specialized training is tailored to the level of previous experience with the CA/T Project's continuous air emissions monitoring program, specific systems, and tasks to be performed. Specialized training in the operation, maintenance and calibration of the various monitoring systems and components may be conducted by the vendor or by previously trained in-house staff.

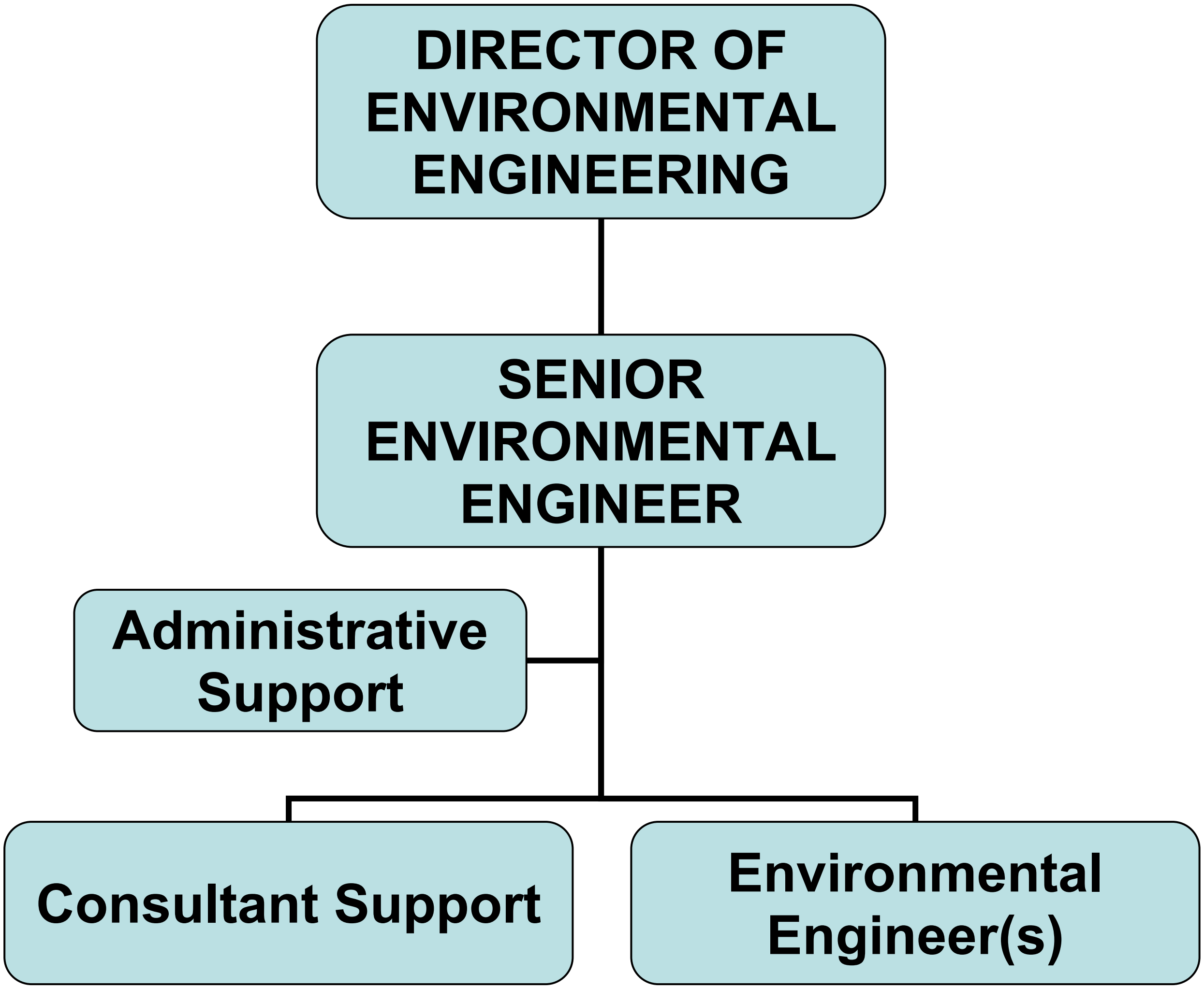
Finally, when system components change (e.g., the replacement of a pollutant monitor with an instrument that bases its measurements on a different analytical method – as opposed to the repair or replacement of a failed part) are made, specialized vendor training takes place for those personnel whose responsibilities or procedures are affected.

TABLE 4-1: KEY PERSONNEL AND RESPONSIBILITIES

Title	Responsibilities
Director of Environmental Engineering	• Overall implementation of the program
Senior Environmental Engineer	• Technical oversight of CEM program • Procure CEMS-related equipment/materials • Determine training needs of AQ staff and, as required, other program participants • Supervise Environmental Engineer and Environmental Technicians and support those responsibilities as needed • CEMS data and QC check report review • QA Performance Audit report review • QA Systems Audit report review/submittal • Revise CAEMP and SOPs (as necessary) and coordinate/conduct associated refresher training • Daily[1] data review • Data processing and validation • Prepare CEMS data and QC check reports • Support preparation of QA Performance and Systems Audit reports • Coordinate conduct of semi-annual/annual QA Performance Audits and annual QA Systems Audits • Coordinate preparation/review of Performance and Systems Audits reports
Environmental Engineer(s)	• CEMS operation, maintenance and calibration • Regular CEMS inspections[2] • Conduct quarterly, semi-annual and annual QC checks • Support independent QA Performance/Systems Audits

Notes:
1 – Data to be reviewed on a daily basis, nominally, during regular work week (Mon/Wed/Fri).
2 – Each site to be visited 2 times, nominally, per month.

FIGURE 4-1: ORGANIZATIONAL STRUCTURE FOR THE MASSDOT-CA/T PROJECT CONTINUOUS AIR EMISSIONS MONITORING PROGRAM



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Part III – Record Keeping and Reporting

5 DATA RECORDING AND REPORTING

5.1 MASSDEP 310 CMR 7.38(9) REGULATORY REQUIREMENTS

MassDEP Regulation 310 CMR 7.38(9) states the following requirements for record keeping and reporting:

“(a) Any person who constructs and operates a tunnel ventilation system on or after January 1, 1991 shall comply with the following record keeping and reporting requirements:

1. All records and data from the continuous emissions monitors, recorders and traffic monitors shall be maintained for a period of five years. The most recent two years of data shall be readily available for Department inspection.

2. Emissions Reporting. For the first year of operations monthly reports shall be filed with the Department no later than 30 days following the end of the preceding calendar month. Said monthly reports shall contain a summary of continuous monitoring data showing any excursions from allowable emission limitations contained in the Department's acceptance of the certification. In the event any of the reported data shows an excursion of the emission limitations set forth in the acceptance of certification, a written explanation of any excursion shall be included. Evidence of each calibration event on the monitoring devices shall be included in such monthly reports.

3. Traffic Reporting. For the first year of operation monthly reports shall be filed with the Department no later than 30 days following the end of the preceding calendar month. Said monthly reports shall contain a summary of average daily and peak hour counts of vehicle miles traveled as well as average daily and peak hour vehicle speeds and vehicle hours traveled as identified through the traffic monitoring network established pursuant to 310 CMR 7.38(8).

4. Tunnel Ventilation System Maintenance. For the first year of operations monthly reports shall be filed with the Department no later than 30 days following the end of the preceding calendar month. Said monthly reports shall contain a summary of routine maintenance checks performed, repairs of ventilation equipment, amount of time during which ventilation equipment was not operating in accordance with standard operating procedures and measures taken to remedy this situation.

(b) After the first year of operation, the reports required by 310 CMR 7.38(9) shall be submitted to the Department on a quarterly basis, with the first such quarterly report being due no later than 30 days after the end of the quarter and every three months thereafter.”

5.2 CONTINUOUS EMISSIONS MONITORING MEASUREMENT DATA PROCESSING

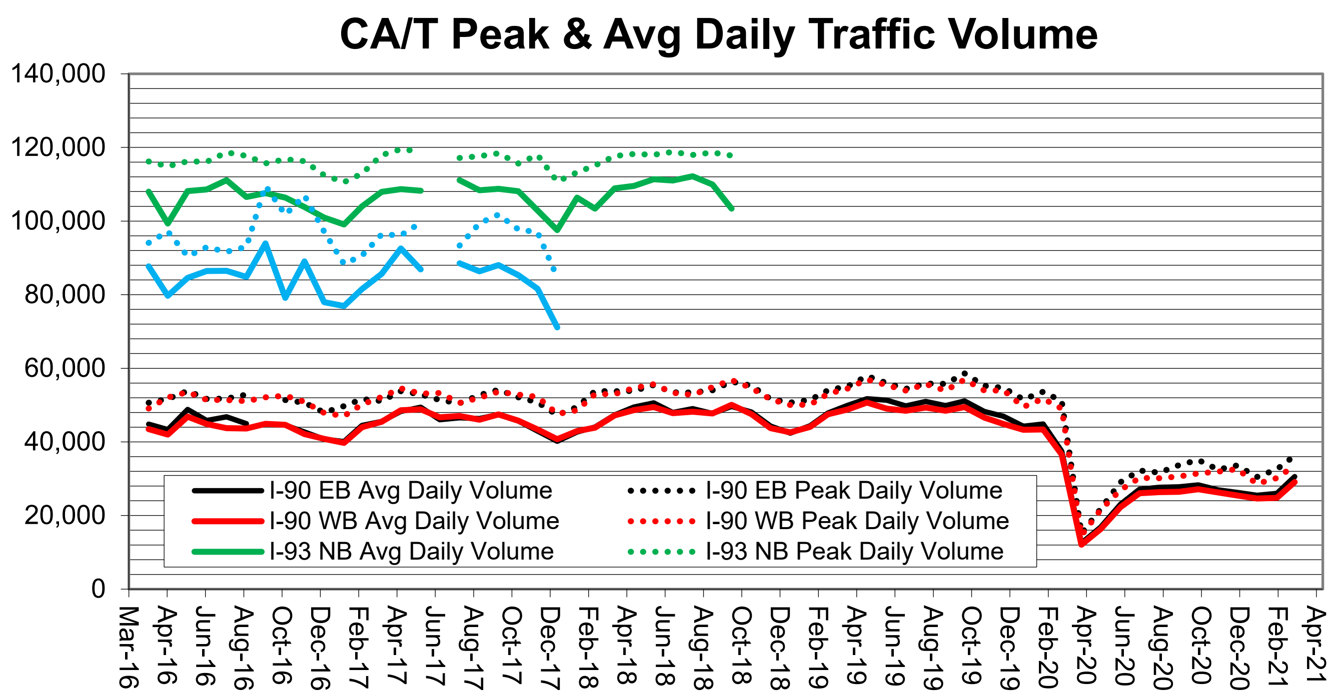
As described in Sections 3.3.3 and 3.3.4, all CO and $PM_{2.5}$ CEM data are recorded using data loggers located at each CEM location. Data from each data logger are downloaded via a modem to a central computer. All CO and $PM_{2.5}$ data are reviewed and edited as necessary and daily data summaries for each month are generated. Using the edited daily summaries, NO_x emission concentrations are developed using the CO to NO_x ratio described in Section 2.6.3. with the exception of DST, which directly measures NOx, NO and NO_2 inside the tunnel portal. The reports are submitted electronically to MassDEP at the Boston Office and the Lawrence Air Assessment Branch on a quarterly basis.

5.3 TRAFFIC DATA PROCESSING

Since CEM data reporting began, there were four locations listed below where hourly traffic volumes were recorded using traffic counting loops under the tunnel pavement. All loops failed at varying dates in 2018. As soon as the east-west loops stopped functioning, existing east-west tolling volumes were substituted for the loop data. No such data is available for I-93 NB/SB traffic counting.

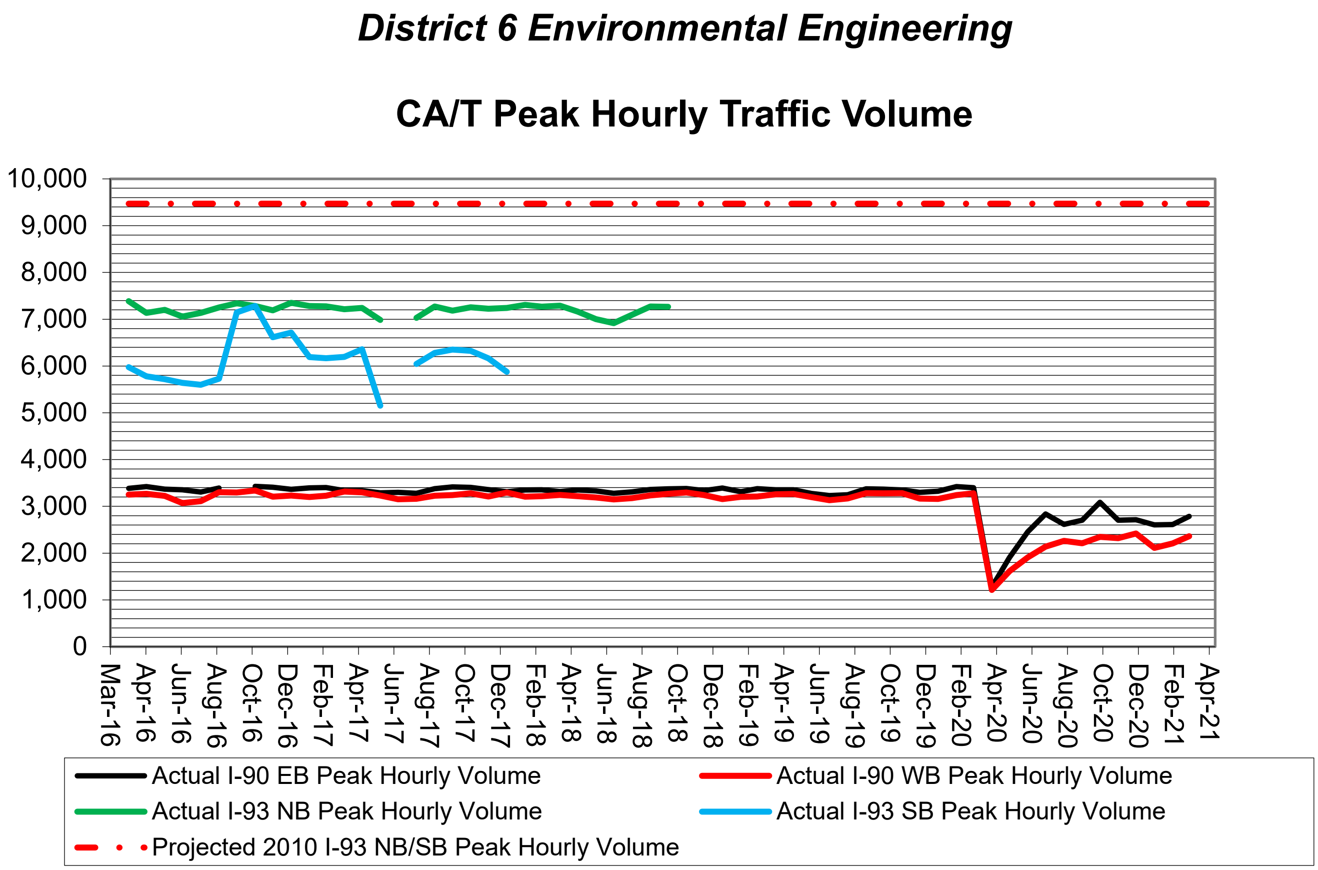
- I-93 southbound in the vicinity of Milk Street
- I-93 northbound in the vicinity of Milk Street
- I-90 westbound the vicinity of vent building 6 in South Boston
- I-90 eastbound under Boston Harbor in the vicinity of the South Boston Shoreline

FIGURE 5-1: PEAK AND AVERAGE DAILY TRAFFIC VOLUMES FOR PERIOD 2016-2021



Oct-16 EB data incomplete and omitted
Oct-16 WB, Nov-16 EB, Jun-19, and Mar-20 data missing several days

FIGURE 5-2: PEAK HOURLY TRAFFIC VOLUMES FOR PERIOD 2016-2021



Oct-16 EB data incomplete and omitted
Oct-16 WB, Nov-16 EB, Jun-19, and Mar-20 data missing several days

Peak hourly and average daily traffic volumes at each of the two locations are reported to MassDEP on a quarterly basis. The data will also provide the monthly average daily volumes for each location. Figure 5-1 presents the peak and average daily traffic volumes for I-93 and I-90 in both directions from 2016 to 2021 for the available data. For 2016-2018 the volumes at I-93 and I-90 were collected at the HOC from the loop recorders. Figure 5-2 presents the peak hourly volumes for the same locations and time periods.

5.4 TUNNEL VENTILATION SYSTEM MAINTENANCE RECORDS

Tunnel ventilation records for both routine and non-routine maintenance activities are logged and tracked through the Project's Maintenance Management Information System (MMIS). As described in section 1.2.1 each ventilation zone has multiple exhaust fans that serve that zone. Each zone can operate with one functioning fan. If however, multiple exhaust fans within a ventilation zone are to undergo repair that results in only one operating exhaust fan, MassDOT will notify MassDEP via monthly report as to the extent of the maintenance that will be performed and the duration of the repairs. The reports, if any, will be provided on a quarterly basis.

5.5 CONTINUOUS EMISSIONS MONITORING DATA SUMMARY REPORTS

Annual summaries of the CO, NO_x and $PM_{2.5}$ average and peak levels for each VB (Tables 5-1 to 5-6) and longitudinally ventilated section collected between 2016 and first four months of 2021 are provided in Tables 5-1 to 5-16. The applicable emission limits for CO, NO_x and $PM_{2.5}$ are also set forth in these tables.

The proposed CO, NO_x and $PM_{2.5}$ emission limits after they are approved will come into effect from December 2021.

The collected 2016-2021 data presented in a summary form (Tables 5-1 to 5-16) indicates:

- Measured CO concentrations for the Ventilation Buildings range from 0.9 to 3.0 ppm on average, with maximum 1-hour values as high as 26.2 ppm;
- Measured CO concentrations for the DST and Ramps range from 0.9 to 3.5 ppm on average, with maximum 1-hour average concentrations ranging from 10.5 to 27.0 ppm;
- NO_x levels (estimated from measured CO levels) for the Ventilation Buildings range from 0.4 to 0.5 ppm on average, with maximum 1-hour values ranging from 0.9 to 2.5 ppm;
- Measured NO_x levels at the DST and estimated Ramps levels range from 0.3 to 0.6 ppm on average, with maximum 1-hour values ranging from 1.2 to 2.5 ppm;
- Measured $PM_{2.5}$ concentrations were between 12.0 and 36.4 $\mu g/m^3$ on average, with maximum daily values ranging from 57.0 to 140.9 $\mu g/m^3$;
- The $PM_{2.5}$ monitor outside Ramp CS-SA, which measures ambient levels, recorded annual averages from 5.9 to 9.0 $\mu g/m^3$, and a maximum daily level of 26.1 $\mu g/m^3$.

The data indicate that the pollutant levels inside the tunnels are generally lower than anticipated, with CO levels decreasing in the latter years. However, as described in detail in Section 6, there were two episodes (total of 3 hours) when emission limits for NO_x were exceeded at DST. These two episodes when emission limits were exceeded were outside the peak traffic hours when the tunnel ventilation system was operating at Step 1 (13% capacity). Once the ventilation system was increased to Step 3 (32% capacity) the NOx measured levels decrease below the emission limits.

TABLE 5-1: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 1

Monitor Location: *VB1 Exhaust 10&11 (Ramp D I-90 WB to I-93 NB)*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2016	2017	2018	2019	2020	Q1 2021
CO	1 Hour	70 ppm	Maximum	ppm	6.7	6.6	6.0	5.6	4.8	8.1
			Average	ppm	1.5	1.6	1.5	1.5	1.3	1.1
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
			Hours exceed AL		0.0	0.0	0.0	0.0	0.0	0.0
	8 Hour	70 ppm	Maximum	ppm	3.6	3.8	3.4	3.3	2.5	2.0
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	0.9	0.8	0.8	0.8	0.7	1.0
			Average	ppm	0.4	0.4	0.4	0.4	0.4	0.4
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0

Note: EL = Emission Limit

TABLE 5-2: SUMMARY OF CO, NO_X AND $PM_{2.5}$ AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 3

Monitor Location: *VB3 I-93 NB-1*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2016	2017	2018	2019	2020	Q1 2021
CO	1 Hour	70 ppm	Maximum	ppm	NA	NA	NA	NA	NA	NA
			Average	ppm	NA	NA	NA	NA	NA	NA
			Hours exceed EL		NA	NA	NA	NA	NA	NA
			Hours exceed AL		NA	NA	NA	NA	NA	NA
	8 Hour	70 ppm	Maximum	ppm	NA	NA	NA	NA	NA	NA
			Hours exceed EL		NA	NA	NA	NA	NA	NA
NO_x	1 Hour	6.1 ppm	Maximum	ppm	NA	NA	NA	NA	NA	NA
			Average	ppm	NA	NA	NA	NA	NA	NA
			Hours exceed EL		NA	NA	NA	NA	NA	NA
$PM_{2.5}$	24 Hour	550 $\mu g/m^3$	Maximum	$\mu g/m^3$	56.8	98.3	72.2	71.9	62.0	64.9
			Average	$\mu g/m^3$	30.0	32.9	30.6	32.8	32.7	32.0
			Days exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
			Days exceed AL		0.0	0.0	0.0	0.0	0.0	0.0

Monitor Location: *VB3 I-93 SB-1*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2016	2017	2018	2019	2020	Q1 2021
CO	1 Hour	70 ppm	Maximum	ppm	8.5	8.8	6.7	6.1	6.0	5.0
			Average	ppm	2.8	2.8	2.4	2.4	2.1	1.8
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
			Hours exceed AL		0.0	0.0	0.0	0.0	0.0	0.0
	8 Hour	70 ppm	Maximum	ppm	6.8	6.3	5.8	4.6	3.9	3.6
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	1.0	1.0	0.9	0.8	0.8	0.7
			Average	ppm	0.5	0.5	0.5	0.5	0.5	0.4
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
$PM_{2.5}$	24 Hour	550 $\mu g/m^3$	Maximum	$\mu g/m^3$	59.7	98.6	121.2	76.1	54.7	94.7
			Average	$\mu g/m^3$	32.1	33.3	31.5	30.0	24.0	27.7
			Days exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
			Days exceed AL		0.0	0.0	0.0	0.0	0.0	0.0

Note: EL = Emission Limit

TABLE 5-3: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 4

Monitor Location:	VB4 I-93 SB2									
Pollutant	Time Period	Emission Limits	Parameter	Unit	2016	2017	2018	2019	2020	Q1 2021
CO	1 Hour	70 ppm	Maximum	ppm	7.6	6.9	6.2	6.6	5.6	4.8
			Average	ppm	2.3	2.3	2.4	2.4	2.2	2.2
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
			Hours exceed AL		0.0	0.0	0.0	0.0	0.0	0.0
	8 Hour	70 ppm	Maximum	ppm	5.8	5.2	4.8	4.5	4.3	3.5
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	0.9	0.9	0.8	0.8	0.8	0.7
			Average	ppm	0.5	0.5	0.5	0.5	0.5	0.5
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0

Note: EL = Emission Limit

TABLE 5-4: SUMMARY OF CO, NO_X, AND $PM_{2.5}$ AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 5

Monitor Location: VB5 I-90 EB2

Pollutant	Time Period	Emission Limits	Parameter	Unit	2016	2017	2018	2019	2020	Q1 2021
CO	1 Hour	70 ppm	Maximum	ppm	7.2	13.8	10.1	6.7	3.1	2.2
			Average	ppm	1.2	1.2	1.2	1.3	1.1	1.0
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
			Hours exceed AL		0.0	0.0	0.0	0.0	0.0	0.0
	8 Hour	70 ppm	Maximum	ppm	4.0	4.0	8.9	4.0	2.2	1.7
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	0.9	1.4	1.1	0.9	0.6	0.5
			Average	ppm	0.4	0.4	0.4	0.4	0.4	0.4
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
$PM_{2.5}$	24 Hour	550 $\mu g/m^3$	Maximum	$\mu g/m^3$	NA	NA	NA	NA	NA	NA
			Average	$\mu g/m^3$	NA	NA	NA	NA	NA	NA
			Days exceed EL		NA	NA	NA	NA	NA	NA
			Days exceed AL		NA	NA	NA	NA	NA	NA

Monitor Location: VB5 I-90 WB2

Pollutant	Time Period	Emission Limits	Parameter	Unit	2016	2017	2018	2019	2020	Q1 2021
CO	1 Hour	70 ppm	Maximum	ppm	NA	NA	NA	NA	NA	NA
			Average	ppm	NA	NA	NA	NA	NA	NA
			Hours exceed EL		NA	NA	NA	NA	NA	NA
			Hours exceed AL		NA	NA	NA	NA	NA	NA
	8 Hour	70 ppm	Maximum	ppm	NA	NA	NA	NA	NA	NA
			Hours exceed EL		NA	NA	NA	NA	NA	NA
NO_x	1 Hour	6.1 ppm	Maximum	ppm	NA	NA	NA	NA	NA	NA
			Average	ppm	NA	NA	NA	NA	NA	NA
			Hours exceed EL		NA	NA	NA	NA	NA	NA
$PM_{2.5}$	24 Hour	550 $\mu g/m^3$	Maximum	$\mu g/m^3$	34.6	42.7	57.0	40.7	32.5	31.5
			Average	$\mu g/m^3$	16.4	18.0	18.3	15.1	13.8	12.0
			Days exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
			Days exceed AL		0.0	0.0	0.0	0.0	0.0	0.0

Note: EL = Emission Limit

TABLE 5-5: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 6

Monitor Location:	VB6 I-90 WB									
Pollutant	Time Period	Emission Limits	Parameter	Unit	2016	2017	2018	2019	2020	Q1 2021
CO	1 Hour	70 ppm	Maximum	ppm	13.1	9.9	13.2	11.9	6.5	3.0
			Average	ppm	1.9	2.0	2.1	2.2	1.4	1.4
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
			Hours exceed AL		0.0	0.0	0.0	0.0	0.0	0.0
	8 Hour	70 ppm	Maximum	ppm	5.0	5.4	5.6	7.7	3.3	2.4
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	1.4	1.1	1.4	1.3	0.8	0.5
			Average	ppm	0.5	0.5	0.5	0.5	0.4	0.4
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0

Note: EL = Emission Limit

TABLE 5-6: SUMMARY OF CO, NO_X, AND $PM_{2.5}$ AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 7

Monitor Location: *VB7 I-90 EB Ramp TA/D*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2016	2017	2018	2019	2020	Q1 2021
CO	1 Hour	70 ppm	Maximum	ppm	18.0	17.9	23.6	12.5	26.2	3.0
			Average	ppm	2.8	2.4	2.5	2.7	1.4	1.3
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
			Hours exceed AL		0.0	0.0	0.0	0.0	0.0	0.0
	8 Hour	70 ppm	Maximum	ppm	7.1	7.2	8.1	8.9	4.8	2.3
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	1.8	1.8	2.3	1.3	2.5	0.5
			Average	ppm	0.5	0.5	0.5	0.5	0.4	0.4
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
$PM_{2.5}$	24 Hour	550 $\mu g/m^3$	Maximum	$\mu g/m^3$	NA	NA	NA	NA	NA	NA
			Average	$\mu g/m^3$	NA	NA	NA	NA	NA	NA
			Days exceed EL		NA	NA	NA	NA	NA	NA
			Days exceed AL		NA	NA	NA	NA	NA	NA

Monitor Location: *VB7 I-90 EB2*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2016	2017	2018	2019	2020	Q1 2021
CO	1 Hour	70 ppm	Maximum	ppm	NA	NA	NA	NA	NA	NA
			Average	ppm	NA	NA	NA	NA	NA	NA
			Hours exceed EL		NA	NA	NA	NA	NA	NA
			Hours exceed AL		NA	NA	NA	NA	NA	NA
	8 Hour	70 ppm	Maximum	ppm	NA	NA	NA	NA	NA	NA
			Hours exceed EL		NA	NA	NA	NA	NA	NA
NO_x	1 Hour	6.1 ppm	Maximum	ppm	NA	NA	NA	NA	NA	NA
			Average	ppm	NA	NA	NA	NA	NA	NA
			Hours exceed EL		NA	NA	NA	NA	NA	NA
$PM_{2.5}$	24 Hour	550 $\mu g/m^3$	Maximum	$\mu g/m^3$	140.9	97.4	114.7	55.2	43.7	51.0
			Average	$\mu g/m^3$	32.3	29.3	28.9	27.1	21.8	25.3
			Days exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
			Days exceed AL		0.0	0.0	0.0	0.0	0.0	0.0

Note: EL = Emission Limit

TABLE 5-6: SUMMARY OF CO, NOX, AND $PM_{2.5}$ AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 7 (CONTINUED)

Monitor Location:	VB7 I-90 EB3									
Pollutant	Time Period	Emission Limits	Parameter	Unit	2016	2017	2018	2019	2020	Q1 2021
CO	1 Hour	70 ppm	Maximum	ppm	16.1	14.7	14.2	12.1	8.8	4.6
			Average	ppm	2.7	3.0	2.8	2.8	1.8	1.7
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
			Hours exceed AL		0.0	0.0	0.0	0.0	0.0	0.0
	8 Hour	70 ppm	Maximum	ppm	10.2	9.2	8.1	8.2	5.2	3.1
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	1.6	1.5	1.5	1.3	1.0	0.7
			Average	ppm	0.5	0.5	0.5	0.5	0.5	0.4
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
$PM_{2.5}$	24 Hour	550 $\mu g/m^3$	Maximum	$\mu g/m^3$	NA	NA	NA	NA	NA	NA
			Average	$\mu g/m^3$	NA	NA	NA	NA	NA	NA
			Days exceed EL		NA	NA	NA	NA	NA	NA
			Days exceed AL		NA	NA	NA	NA	NA	NA

Note: EL = Emission Limit

TABLE 5-7: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: RAMP CN-S

Monitor Location:	Ramp CNS									
Pollutant	Time Period	Emission Limits	Parameter	Unit	2016	2017	2018	2019	2020	Q1 2021
CO	1 Hour	35 ppm	Maximum	ppm	11.3	7.9	25.1	27.0	11.9	4.4
			Average	ppm	2.4	2.5	2.5	2.4	1.8	1.9
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
			Hours exceed AL		0.0	0.0	0.0	0.0	0.0	0.0
	8 Hour	59 ppm	Maximum	ppm	5.9	6.0	7.2	10.0	4.0	3.4
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
NO_x	1 Hour	3.2 ppm	Maximum	ppm	1.2	1.0	2.4	2.5	1.3	0.7
			Average	ppm	0.5	0.5	0.5	0.5	0.5	0.4
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0

Note: EL = Emission Limit

TABLE 5-8: SUMMARY OF CO, NO_X AND $PM_{2.5}$ AVERAGE AND PEAK LEVELS: RAMP CS-SA

Monitor Location: Ramp CSSA										
Pollutant	Time Period	Emission Limits	Parameter	Unit	2016	2017	2018	2019	2020	Q1 2021
CO	1 Hour	35 ppm	Maximum	ppm	7.9	6.2	10.5	8.5	4.6	3.0
			Average	ppm	1.7	1.6	1.6	1.6	1.2	0.9
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
			Hours exceed AL		0.0	0.0	0.0	0.0	0.0	0.0
	8 Hour	54 ppm	Maximum	ppm	4.3	4.0	4.3	4.7	3.6	2.3
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
NO_x	1 Hour	3.2 ppm	Maximum	ppm	1.0	0.8	1.2	1.0	0.7	0.5
			Average	ppm	0.4	0.4	0.4	0.4	0.4	0.4
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
$PM_{2.5}$	24 Hour	550 $\mu g/m^3$	Maximum	$\mu g/m^3$	26.1	20.2	25.7	21.5	19.3	24.1
			Average	$\mu g/m^3$	9.0	8.9	8.0	6.7	5.9	7.3
			Days exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
			Days exceed AL		0	0	0	0	0	0

Notes: EL = Emission Limit

TABLE 5-9: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: RAMP CS-P

Monitor Location: Ramp CSP										
Pollutant	Time Period	Emission Limits	Parameter	Unit	2016	2017	2018	2019	2020	Q1 2021
CO	1 Hour	35 ppm	Maximum	ppm	20.2	6.7	8.6	5.6	5.5	4.9
			Average	ppm	1.7	1.6	1.7	1.8	1.6	1.7
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
			Hours exceed AL		0.0	0.0	0.0	0.0	0.0	0.0
	8 Hour	70 ppm	Maximum	ppm	8.9	4.4	4.8	4.3	3.9	3.5
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0
NO_x	1 Hour	3.2 ppm	Maximum	ppm	2.0	0.9	1.0	0.8	0.8	0.7
			Average	ppm	0.4	0.4	0.4	0.5	0.4	0.4
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0	0.0

Note: EL = Emission Limit
*No valid data for November and December 2019 due to safety issues.

TABLE 5-10: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: DST I-93

Monitor Location: *Ramp DST-I-93*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2016	2017	Q1 2018
CO	1 Hour	23 ppm	Maximum	ppm	11.8	19.1	9.5
			Average	ppm	3.5	3.2	3.0
			Hours exceed EL		0.0	0.0	0.0
			Hours exceed AL		0.0	0.0	0.0
	8 Hour	30 ppm	Maximum	ppm	8.5	9.2	6.1
			Hours exceed EL		0.0	0.0	0.0
NO_x	1 Hour	2.2 ppm	Maximum	ppm	1.3	1.9	1.1
			Average	ppm	0.6	0.6	0.5
			Hours exceed EL		0.0	0.0	0.0

Monitor Location: *Ramp DSTI93*

Pollutant	Time Period	Emission Limits	Parameter	Unit	Q2 - Q4 2018	2019	2020	Q1 2021
CO	1 Hour	22 ppm	Maximum	ppm	9.9	8.7	8.3	7.4
			Average	ppm	3.2	3.2	2.7	2.5
			Hours exceed EL		0.0	0.0	0.0	0.0
			Hours exceed AL		0.0	0.0	0.0	0.0
	8 Hour	24 ppm	Maximum	ppm	6.8	6.3	5.2	4.4
			Hours exceed EL		0.0	0.0	0.0	0.0
NO_x	1 Hour	2.1 ppm	Maximum	ppm	2.2	1.7	2.3	0.9
			Average	ppm	0.4	0.4	0.3	0.3
			Hours exceed EL		2.0	0.0	1.0	0.0
			Hours exceed AL		1.0	1.0	0.0	0.0

Notes:

1. EL = Emission Limit
2. An Emission Limit Assessment (ELA) was performed following an EL exceedance. The results of the ELA enabled MassDOT and MassDEP to determine that the EL exceedances did not violate a National Ambient Air Quality Standard (NAAQS). Appendix F provides the results of the ELAs.
3. NO_x monitoring at the DST tunnel started in April 2018 after the 2016 Renewal of Operating Certification was accepted by MassDEP. In the period from 2016 through the first quarter of 2018 NO_x levels were estimated from CO levels.

TABLE 5-11: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: DST I-90

Monitor Location: *Ramp DST-I-90*							
Pollutant	**Time Period**	**Emission Limits**	**Parameter**	**Unit**	**2016**	**2017**	**Q1 2018**
CO	1 Hour	23 ppm	Maximum	ppm	17.7	13.8	9.5
			Average	ppm	3.4	3.4	3.0
			Hours exceed EL		0.0	0.0	0.0
			Hours exceed AL		0.0	0.0	0.0
	8 Hour	30 ppm	Maximum	ppm	8.1	8.8	6.1
			Hours exceed EL		0.0	0.0	0.0
NO_x	1 Hour	2.2 ppm	Maximum	ppm	1.8	1.4	1.1
			Average	ppm	0.6	0.6	0.5
			Hours exceed EL		0.0	0.0	0.0

Monitor Location: *Ramp DSTI90*								
Pollutant	**Time Period**	**Emission Limits**	**Parameter**	**Unit**	**Q2 - Q4 2018**	**2019**	**2020**	**Q1 2021**
CO	1 Hour	22 ppm	Maximum	ppm	13.5	10.7	9.6	8.3
			Average	ppm	3.5	3.4	2.7	2.4
			Hours exceed EL		0.0	0.0	0.0	0.0
			Hours exceed AL		0.0	0.0	0.0	0.0
	8 Hour	24 ppm	Maximum	ppm	8.7	8.3	6.5	5.2
			Hours exceed EL		0.0	0.0	0.0	0.0
NO_x	1 Hour	2.1 ppm	Maximum	ppm	1.4	1.2	1.1	1.0
			Average	ppm	0.6	0.6	0.5	0.5
			Hours exceed EL		0.0	0.0	0.0	0.0

Notes:
1. EL = Emission Limit
2. An Emission Limit Assessment (ELA) was performed following an EL exceedance. The results of the ELA enabled MassDOT and MassDEP to determine that the EL exceedances did not violate a National Ambient Air Quality Standard (NAAQS). Appendix F provides the results of the ELAs.
3. NO_x monitoring at the DST tunnel started in April 2018 after the 2016 Renewal of Operating Certification was accepted by MassDEP. In the period from 2016 through the first quarter of 2018 NO_x levels were estimated from CO levels.

5.6 2016-2017 Approval to Reduce the number of CEM CO and $PM_{2.5}$ Monitors

The full transverse ventilation system includes six ventilation buildings serving twenty four ventilation zones with their corresponding supply and exhaust fans. Until 2016 there were 25 CO monitors in operation: one in each ventilation zone and one in the VB7 air intake. All twenty four zones had a CO emission limit of 70 PPM and a CO action level of 60 PPM.

An analysis of the peak and average data collected since full opening of the CA/T (nine years) was presented to MassDEP in Technical Memos, dated March 20, 2015 and June 24, 2015, and discussed at the interagency meeting.

MassDOT sought to reduce the number of CO monitoring locations to one per VB, except for VB7, which would have two monitors as part of this 2016 renewal of the Operating Certification. MassDOT would achieve the objective of 310 CMR 7.38 by maintaining the CEM program and reporting compliance with CO emission limits at each VB by monitoring ventilation zones with the historically highest CO levels.

Reduction in the total number of CO monitors from twenty five to seven allowed MassDOT to better maintain the current CO monitors by using the monitors removed from service for spare parts and thus extending the their useful life in the CEM system, and to make more feasible a full upgrade in the future.

MassDEP concurred with this proposal to reduce the number of CO monitors from twenty five to seven in the Operating Certification Renewal Period from 2016 to 2021 in the MassDEP letter dated June 30, 2015.

Additional request to eliminate VB7 air intake $PM_{2.5}$ monitor that was intended to observe background concentrations at Logan airport was granted by MassDEP on March 23, 2017.

5.7 ADDITION OF NO_X – NO_2 MONITOR AT DEWEY SQUARE TUNNEL

MassDEP presented a request to add a NO_x monitor inside the DST at the July 10, 2015 interagency meeting. The MassDEP rationale for this additional monitor was based on the fact that the DST has the lowest CO emission limits that had been exceeded several times in the past, and on the margin of error in the NOx – CO regression formula that is used to predict NO_x levels based on monitored CO levels. This error can be eliminated by direct monitoring of NO_x.

MassDOT agreed to include this additional NO_x monitor, which was installed in 2016,and became operational with the approval by MassDEP of the 2016 Renewal Application in April 2018. The NO_x probe was installed inside the I-93 segment of the DST, next to the existing CO monitoring probe. MassDOT also moved the CO monitoring equipment from the utility room located inside the tunnel to the enclosure located just outside the DST exit portal, which was used in the past for the equipment measuring NO_x-NO_2 as part of the 2011-13 DST - Albany street monitoring program. This new NO_x monitor was also located in the new CO monitoring enclosure. The rationale for moving the monitoring equipment from the current utility room to the outside enclosure was solely based on the difficulty of accessing the previous room for maintenance purpose. It required a closing of a I-93 tunnel lane to walk into this room.

The NO_x data collected by this new monitor was to be directly compared to the emission limit for the DST.

All other VB zones and the longitudinally ventilated ramps continue to predict NO_x levels based on the NO_x–CO regression formula used in the 2012 TSD and described in section 2.6 of this document.

Part IV - Corrective Actions

6 CONTINGENCY PLAN

6.1 GENERAL REQUIREMENTS (310 CMR 7.38(4))

"… the operating certificate submittal shall include a contingency plan consisting of measures which could be implemented in cases of exceedance of the emission limitations in the certificate. Said contingency plan shall identify available contingency measures including, but not limited to, alternative tunnel ventilation system operations and maintenance, and transportation control measures; a commitment for implementing said measures; a schedule for implementing measures on a days-to-full effectiveness basis; and an analysis of the daily air quality impact of the measures on the emissions from the tunnel ventilation system and within the project area."

6.2 COMPLIANCE STATUS DETERMINATION FOR DAY-TO-DAY OPERATIONS

Concentration based emission limits for CO, NO_x and $PM_{2.5}$ were established as discussed in Section 2 of this document for tunnel emission exhaust locations. The limit levels that were established ensure that applicable NAAQS for CO, NO_2 and $PM_{2.5}$ and the MassDEP 1-hour NO_2 Policy Guideline Value for NO_2 will not be exceeded at any ambient (i.e., outside) receptor location.

In order to determine the compliance status of the tunnel emissions, the Project has installed a CO, $PM_{2.5}$ and NO_x CEM (continuous emission monitoring) system as described in Section 3 and Attachment 1 of this document. Data collected from the CO, $PM_{2.5}$ and NO_x CEM systems are compared to the emission limits for every emission location.

Based on discussion with MassDEP, MassDOT understands that the 310 CMR 7.38(2) requirements regarding compliance with the applicable ambient air quality standards and the State Policy Guideline for nitrogen dioxide do not apply during emergency conditions (i.e., tunnel fires).

As described in Section 2.4.3 of this document, emission limits for NO_x were established using a statistical analysis of actual CO and NO_x emission data l except for the DST where NO_x is directly monitored from 2018. The 1-hour CO emission limits listed above were established taking into account 1-hour NO_2 NAAQS and MassDEP Policy Guideline compliance. As a result, if the 1-hour CO emission levels remain below the listed emission limit, then no exceedances of the NAAQS and Massachusetts 1-hour NO_2 Policy Guideline Level occur. As mentioned above, NOx emission limits in the Dewey Square Tunnel are compared to the NO_x levels collected at this location.

The established emission limits for each location are listed in the Table 6-1.

TABLE 6-1: SUMMARY OF EMISSION LIMITS (2021-2026)

Location*	1-Hour CO Emission Limit (ppm)	8-Hour CO Emission Limit (ppm)	1-Hour NO_X Emission Limit (ppm)	24-Hour $PM_{2.5}$ Emission Limit ($\mu g/m^3$)**
VB 1	70	70	6.1	700
VB 3	70	70	6.1	700
VB 4	70	70	6.1	700
VB 5	70	70	6.1	700
VB 6	70	70	6.1	700
VB 7	70	70	6.1	700
Ramp CN-S	40	62	3.6	NA
Ramp CS-SA***	41	63	3.7	35****
Ramp CS-P	43	70	3.9	NA
Dewey Sq. Tunnel	70	28	2.0	NA

Notes: Acronyms are defined as: Central Artery Northbound to Storrow Drive (C-NS), Central Artery Southbound to Surface Artery (CS-SA), Central Artery Southbound to Purchase Street (CS-P), part per million (ppm), microgram per cubic meter ($\mu g/m^3$).

* For each ventilation building, location includes all associated ventilation zones.

** $PM_{2.5}$ emission limits are lower than in the 2011 CA/T Renewal Operating Certification due to the lowering of the $PM_{2.5}$ annual NAAQS from 15 to 12 ug/m^3.

*** The ambient $PM_{2.5}$ monitor is located outside ramp CS-SA.

**** Action level for ramp CS-SA is for 24 hours and is set to 100% of the 24-hour $PM_{2.5}$ NAAQS. Compliance with the 24-hour $PM_{2.5}$ NAAQS is based on the monitoring design value, which is given by the 3-year average of the annual 98th percentile value of daily average concentrations. The form of the standard allows, on average, for the numerical value of the standard (35 $\mu g/m^3$) to be exceeded on seven calendar days per calendar year without triggering a violation of the NAAQS.

6.3 PRE-EMPTIVE ACTIONS

In order to avoid exceedances of the emission limits and ensure compliance with the applicable air quality standards, two tiers of pre-emptive measures are applied.

First, the in-tunnel CO monitoring system that is used to control tunnel ventilation and maintain in-tunnel air quality is set to alarm at a 25 ppm CO level on an hourly basis. In response to an alarm, an HOC operator will lower the in-tunnel CO level to below 25 ppm by increasing the ventilation rate at the affected ventilation zone.

The second tier of pre-emptive measures involves the CEM system. The 1-hour CO CEM emission action levels have been established for each emission location, and actions will be taken (i.e., ventilation of the affected zone or zones increased) to lower the pollutant levels inside the tunnel when these action levels are exceeded. The action level established for each emission location falls within a range between 75% and 85% of its respective emission limit as listed below.

The $PM_{2.5}$ action level is set at 700 $\mu g/m^3$ for an eight hour rolling average, which is one third of the time (24-hour) needed to constitute an exceedance. This provides sufficient time to the operator to take corrective actions.

Real-time CO concentrations for all CO CEM monitoring locations are provided in the HOC for operator use. Procedures were established that would trigger an HOC operator response in the event when a CEM action level (presented in Table 6-2) is reached.

The one-hour CO action level for DST is set at 28 ppm which represents the 8-hour emission limit. This provides sufficient time to the operator to take corrective actions to avoid an exceedance of the 8-hour emission limit. In order to comply with the lowest emission action level (i.e., 1.6 ppm NO_x for DST), the ventilation fans for the Dewey Square Air Intake Structure along with ventilation zone SB-1 from VB 3 are set to step 3 from 6 AM to 10AM each weekday morning and from 2 PM to 8 PM each weekday afternoon. The increase in the ventilation zone settings should prevent hourly NO_x emission levels from going above 1.6 ppm for DST. If the emission action level for DST is exceeded because of a non-emergency situation, the ventilation will be stepped up to a higher setting to ensure that emission level remains below the emission action level.

CEM $PM_{2.5}$ emission levels from VB3, VB5, VB7, and ramp CS-SA are also tracked. If $PM_{2.5}$ concentrations at a VB CEM monitor exceeds action level of 700 μg/m^3 for an eight-hour rolling average, then $PM_{2.5}$ hourly concentrations will be displayed in the HOC. However, because the 8-hour $PM_{2.5}$ emission action level of 700 μg/m^3 is very high, it is very unlikely that this level will ever be reached.

TABLE 6-2: EMISSION ACTION LEVELS (2021-2026)

Location*	CO Emission Action Levels (ppm)	NOx Emission Action Levels (ppm)	Rolling 8-Hour $PM_{2.5}$ Emission Action Levels (μg/m^3)
VB1	60	NA	NA**
VB3	60	NA	700
VB4	60	NA	NA**
VB5	60	NA	700
VB6	60	NA	NA**
VB7	60	NA	700
Ramp CN-S	32	NA	NA
Ramp CS-SA	32	NA	35***
Ramp CS-P	34	NA	NA
Dewey Square Tunnel	28****	1.6*****	NA

* For each ventilation building, location includes all associated ventilation zones.

** VB1, VB4, and VB6 do not have $PM_{2.5}$ monitors. Action levels at VB3, VB5, and VB7 will be used as surrogates for these locations.

*** Action level for ramp CS-SA is for 24 hours and is set to 100% of the 24-hour $PM_{2.5}$ NAAQS. Compliance with the 24-hour $PM_{2.5}$ NAAQS is based on the monitoring design value, which is given by the 3-year average of the annual 98th percentile value of daily average concentrations. The form of the standard allows, on average, for the numerical value of the standard (35 μg/m^3) to be exceeded on seven calendar days per calendar year without triggering a violation of the NAAQS.

**** Action level for DST is for 1 hour but set to 100% of the 8-hour CO Emission Limit to avoid a violation of the 8-hour Emission Limit.

***** DST monitors CO and NOx, as such the NOx action level is directly compared to the monitored data.

6.4 CORRECTIVE (CONTINGENCY) ACTIONS

6.4.1 Emission Limit Exceedance Notification

The 2016 and this 2021 Renewal Operating Certification includes a two-step procedure whereby if an Emission Limit is exceeded, MassDOT shall verbally notify MassDEP of this exceedance within 12 hours of such an occurrence. This verbal notification shall be followed with a written notification to MassDEP within 48 hours of the Emission Limit exceedance. The written notifications shall be made to MassDEP, Bureau of Air and Waste, Transportation Management Programs Branch, 1 Winter Street, Boston, MA 02108. MassDOT shall verbally notify Transportation Management Programs Branch by calling 617-292-5762, if unable to reach staff directly, then MassDOT shall speak with the front desk at 617-292-5500, and if unable to reach a person should leave a message at MassDEP's Emergency Response phone number, 888-304-1133.

The Emission Limit Assessment shall analyze whether or not an Emission Limit exceedance may cause or contribute to a violation of the relevant NAAQS or MassDEP guideline based on the use of site-specific meteorological and background conditions at the time of the exceedance. Meteorological data collected by the National Weather Service at Boston's Logan International Airport is acceptable. The analysis shall be provided to the above MassDEP address within three business days of MassDOT receipt of background conditions data from MassDEP. If MassDEP determines that a violation of a NAAQS or MassDEP One Hour NO_2 Policy Guideline has occurred, MassDEP will post a notice of the violation on MassDEP's web site within ten business days of notification and in the MEPA Environmental Monitor as a matter of public record.

6.4.2 Emission Limit Assessment (ELA)

When an exceedance of an emission limit occurs at any of the emission locations, an Emission Limit Assessment of the causes and nature of the exceedance will be prepared and sent to MassDEP. The analysis will examine air quality impacts for each designated receptor around the VB or longitudinally ventilated exit ramp where the emission limit was exceeded. Meteorological conditions and pollutant background concentration during the exceedance time period will be used in the analysis.

6.4.3 Additional Contingency Measures

If the ELA determines that an exceedance of an emission limit resulted in an exceedance of a NAAQS for CO, NO_2, $PM_{2.5}$, or the Massachusetts 1-hour NO_2 Policy Guideline Limit, actions related to a long-term mitigation plan will be discussed with MassDEP for possible implementation. If the ELA determines that an exceedance of emission limit for $PM_{2.5}$ or NO_2 resulted in three exceedances of the level of NAAQS in a single year, MassDOT and MassDEP would meet to discuss the possible mitigation measures to avoid further exceedances.

6.5 MITIGATION PLAN

Pursuant to 310 CMR 7.38(4), the initial operating certificate submittal is not required to include a mitigation plan. Requirements related to the preparation, review, and acceptance of a mitigation plan is instead governed by 310 CMR 7.38(6).

310 CMR 7.38(6) states that if MassDEP finds—based on a review of information submitted by the operator in support of the operating certification, and such information as MassDEP has available to it—that one or more of the air quality limits specified in the regulation are being violated or are likely to be violated, then the operator of the tunnel ventilation system shall take certain identified actions. The trigger to taking those actions is a finding of a violation of air quality standards based on MassDEP review of the operating certification submittal itself.

Sections 6.2 and 6.3 already described the process in place to reduce the possibilities of exceeding emission limits. In summary: First, the tunnel ventilation system is operated to maintain CO levels at or below 25 ppm inside the tunnel which is below all hourly limits. Secondly, the CEM monitoring system warns operators if the action level (typically set in the range of 75% to 85% of the emission limit) is reached. Finally, operators will be notified by an alarm if an emission limit is exceeded. In each case, HOC operators will increase ventilation rates in order to bring emissions in the tunnel below the indicated criteria. If an emission limit is still exceeded at any location, procedures described in section 6.4 above will be followed and an assessment will be performed to analyze air quality impacts for the particular hour/day of when an emission limit was exceeded and to determine whether this caused an NAAQS or a MassDEP Policy Guideline to be exceeded or violated.

The corrective actions regarding the development of a CA/T mitigation plan are required only in the event that MassDEP finds that one or more of the 7.38 criteria are being violated. Unless and until MassDEP makes such a finding, including but not limited to an identification of the nature and severity of the violation, appropriate mitigation measures do not need to be developed.

6.6 Compliance of the Ventilation System from 2016 to 1st Quarter of 2021

The collected data presented in a summary form (Tables 5-1 to 5-11) indicate:

- Measured CO concentrations for the Ventilation Buildings range from 0.9 to 3.0 ppm on average, with maximum 1-hour values as high as 26.2 ppm;
- Measured CO concentrations for the DST and Ramps range from 0.9 to 3.5 ppm on average, with maximum 1-hour average concentrations ranging from 10.5 to 27.0 ppm;
- NO_x levels for the Ventilation Buildings range from 0.4 to 0.5 ppm on average, with maximum 1-hour values ranging from 0.9 to 2.5 ppm;
- Measured NO_x levels for the DST and Ramps range from 0.3 to 0.6 ppm on average, with maximum 1-hour values ranging from 1.2 to 2.5 ppm;
- Measured average daily $PM_{2.5}$ concentrations in each year were between 12.0 and 36.4 μg/m^3, Maximum daily $PM_{2.5}$ values were in the range, of 57.0 to 140.9 μg/m^3.
- The $PM_{2.5}$ monitor outside Ramp CS-SA, which measures ambient levels, recorded annual averages from 5.9 to 9.0 μg/m^3, and a maximum daily level of 26.1 μg/m^3.

The data indicate that the pollutant levels inside the tunnels are generally much lower than anticipated, with CO levels decreasing in the latter years.

There were two episodes recorded over the five year period when a NOx emission limit was exceeded. These were the result of low tunnel ventilation settings outside the peak hour traffic periods. They were corrected as soon as the cause was identified, and the associated ELA indicated that none of them resulted in a violation of an NAAQS or a MassDEP Policy Guideline.

6.6.1 Exceedances of Emission Limits from 2016 to 1st Quarter of 2021

During the period from the beginning of 2016 through the end of the first quarter of 2021, there were two episodes when an emission limit was exceeded. Table 6-3 provides a summary of these events in chronological order and identifies the location, the emission limit that was exceeded, the maximum level measured, and the associated conditions.

Table 6-3: CEM Emission Limit Exceedances (2016 – 2021)

No. of Incidents	Date(s)	Time	Location(s)	Pollutant(s)	No. of Hours	Highest Measured Level*	Main Reason
1	11-Apr-18	11:00 AM	DST (I-93)	NOx	2	2.20	Tunnel Ventilation System operating at Step 1 (13% capacity)
2	13-May-20	1:00 AM	DST (I-93)	NOx	1	2.28	Tunnel closed for water leak repair

* Concentrations are in ppm for NO_x. Emission limit for NOx at DST is 2.1 ppm.

An explanation of the circumstances of each episode and the actions taken to reduce concentration levels is provided below.

The April 11, 2018 exceedance of the NO_x emission limit occurred at approximately 11 AM, while the I-93 DST was open to general traffic. Recorded levels exceeded the NO_x limit of 2.1 ppm for two hours. As the MassDOT correspondence to MassDEP (April 17, 2018) indicates, the tunnel ventilation system was operating at Step 1 (13% capacity). The I-93 SB ventilation system is programed to increase to Step 3 (32% capacity) for the peak traffic hours of 6-10AM and 2-6PM).

Since the NO_x monitors had just became operational in April 2018, a week and a half prior to this event, the system, which was to be programmed to sound alarms based on 15 minutes average NO_x action levels, was still going through validation checks and operated manually. The operators took corrective action and increased ventilation to Step 3 (32% capacity) lowering the NO_x level from a peak of 2.2 ppm to 0.8 ppm after the second hour. The maximum CO level recorded during the period was 7.8 ppm which was well below the 18 ppm action level for CO.

MassDEP acknowledged the notification, concurred with the MassDOT that the emission limit exceedance did not resulted in an ambient air violation of the NAAQS.

The ELA analysis results indicated that predicted ambient levels for this exceedance were 68 ppb for NO_2 which represents 68% of the one-hour NAAQS for NO_2.

The March 13, 2020, exceedances of the NO_x emission limit occurred early morning at 1 AM for one hour with a peak level of 2.28 ppm. Upon review of video at this location, it was confirmed that tunnel water leak repair work was being conducted and that idling trucks remained in close proximity to the sampling probe in this timeframe. It was also confirmed that the appropriate fans did not ramp up automatically as they were in manual control, nor were they turned up manually per our response procedure, RP 509 until the following hour.

The maximum CO level recorded during the period was well below the action level for CO.

MassDEP was notified (March 23, 2021 letter) that the emission limit exceedance did not result in an ambient air violation of the NAAQS. The ELA analysis results indicated that predicted ambient levels for this exceedance was 44 ppb NO_2 which was 44% of the NAAQS for NO2.

6.6.2 Summary of Exceedances, Reasons, Lessons Learned, and Corrective Actions

As described above, there were two episodes during the period from the beginning of 2016 through the end of the first quarter of 2021 when emission limits were exceeded. These episodes resulted in a total of 3 hours when NO_x measured levels at the DST exceeded the corresponding NO_x hourly emission limit of 2.1 ppm. The emission limits for CO and $PM_{2.5}$ were never exceeded during the five-year period.

For these two cases when NO_x limit was exceeded, the I-93 southbound tunnel ventilation system was operating at Step 1 (13% capacity). In both instances when the I-93 SB ventilation system was increased to Step 3 (32% capacity) the NOx levels within the DST were reduced below the action levels within an hour.

To put these events in perspective, CO concentrations were measured every hour at 7 VB exhaust locations and at five locations in the DST and ramps over the last five calendar years (2016-2021) and during the first quarter of 2021, yielding approximately 525,000 observations. The two exceedances (3 hours) of the NO_x emission limit for the DST tunnel represent only 0.007% of the direct NOx measurements at DST.

It is also important to note that none of the episodes when an emission limit was exceeded resulted in a violation of the applicable NAAQS or MassDEP NO_2 Policy guideline. The results of each ELA indicated that the maximum predicted ambient values for NO_2 were 44 and 68% of the applicable NAAQS for NO_2. This shows that the emission limits were established with a considerable margin of safety with regard to the health-related NAAQS. This was due to the very conservative worst-case assumptions that went into the emission limit compliance analysis demonstration, which supported the 2006 Operating Certification process and its 2011-12, 2016, and 2021 Renewals of the Operating Certification.

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