Commonwealth of Massachusetts

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

Operating Certification of the Project Ventilation System

Supplemental Application Technical Support Document

Final Report
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by
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Table of Contents

EXECUTIVE SUMMARY I

INTRODUCTION 1

PART I – VENTILATION SYSTEM – OPERATION AND EMISSION LIMITS 1–1

1 Description of Central Artery/Tunnel Project Ventilation Systems 1–1

1.1 Ventilation System Design Criteria *1–1*

1.1.1 Full-Transverse Ventilation 1–3

1.1.1.1 System Description 1–3

1.1.2 Longitudinal Ventilation 1–12

1.1.2.1 Dewey Square Tunnel 1–12

1.1.2.2 Exit Ramps with Fresh-Air Supply and/or Jet Fan Ventilation 1–12

1.2 Feasible Emission Control Technologies *1–20*

1.3 Tunnel Operating Conditions *1–21*

1.3.1 During Non emergency Operations 1–21

1.3.2 During Emergencies 1–21

1.4 Ventilation System Physical Properties *1–21*

1.4.1 Ventilation Building Dimensions and Ventilation Capacities 1–22

1.4.2 Longitudinally Ventilated Tunnels Dimensions and Ventilation Capacities 1–23

2 Determination of Emission Limits 2–26

2.1 Project Preconstruction Certification Acceptance Record *2–26*

2.2 MassDEP Regulatory Requirements for Operating Certifications *2–28*

2.3 Acceptance of Concentration–Based Emission Limits *2–29*

2.4 Acceptance of emission Limits Established in 2006 Application *2–29*

2.5 2011 Renewal of Certification Process *2–30*

2.5.1 $PM_{2.5}$ Limits 2–30

2.5.2 VOC Compliance 2–30

2.5.3 Revised CO and NO_2 Limits and Need for Supplemental Application 2–31

2.5.4 Dewey Square Tunnel Monitoring Program 2–31

2.6 Technical Approach *2–33*

2.6.1 Relevant Pollutants 2–33

2.6.2 Averaging Times for Emission Limits for CO, NO_x, and $PM_{2.5}$ 2–33

2.6.3 Predictive Model for NO_x Emission Estimates 2–33

2.6.4 NO to NO_2 Conversion 2–35

2.6.5 Representative Surface and Upper Air Meteorological Data 2–37

2.6.6 Attainment Status of Project Area 2–37

2.6.7 Background Concentration Levels 2–37

2.6.8 Volatile Organic Compounds (VOC) 2–41

2.7 Emission Limit Determination *2–42*

2.7.1 For Full Transverse Ventilation—Ventilation Buildings 2–42

2.7.1.1 Determination of Ventilation Building Emission Impacts 2–42

2.7.1.2 Modeling Methodology 2–43

2.7.1.3 $PM_{2.5}$ Analysis 2–52

2.7.1.4 CO and NO_2 Analysis 2–54

2.7.1.5 CO and NOx Input Parameters and Modeling Results 2–55

2.7.2 For Longitudinal Ventilation – Exit Ramps and DST 2-60

2.7.2.1 Modeling Procedures to Determine the Impact of Exit Portal Emissions 2-60

2.7.2.2 Use of Physical Simulation Data 2-73

2.7.2.3 CO Analysis 2-73

2.7.2.4 NO_2 Analysis 2-77

2.7.3 VOC Emission Limit Determination 2-86

2.7.3.1 Travel Demand Model 2-86

2.7.3.2 Procedures for Highway Network VOC Analysis 2-89

2.7.3.3 Procedure for Off-Model VOC Analysis 2-91

2.7.4 VOC Analysis Results 2-91

2.8 Proposed Operating Emission Limits *2-93*

2.8.1 CO, NOx and $PM_{2.5}$ 2-93
2.8.2 VOC 2-94
2.9 Operating Certification criteria *2-94*

PART II – COMPLIANCE MONITORING PROGRAM 2-97
3 Project Compliance Monitoring System 3-97
3.1 MassDEP 310 CMR 7.38(8) Regulatory Requirements *3-97*
Emissions Monitoring 3-97
Traffic Monitoring 3-97
3.2 Emissions Measurement Methodologies *3-97*
3.2.1 Applicability of 40 CFR Parts 58, 60 and 75 3-97
3.3 Continuous Emissions Monitoring Systems Description *3-97*
3.3.1 Monitoring Locations for Ventilation Buildings 3-97
3.3.2 Monitoring Locations for Longitudinal Ventilation 3-99
3.3.3 CO Monitoring System 3-99
3.3.3.1 Ventilation Buildings and Longitudinally Ventilated Exit Ramps 3-100
3.3.3.2 CEM Equipment Housing 3-100
3.3.3.3 Sample Probe / Sample Transport / Sample Conditioning 3-101
3.3.4 $PM_{2.5}$ Monitoring System 3-102
3.3.4.1 VBs and Longitudinally Ventilated Exit Ramp 3-102
3.3.4.2 Monitoring Locations and Housing 3-102
3.3.5 Data Acquisition and Handling System 3-102
3.4 Continuous Emissions Monitoring Systems Initial Certification *3-102*
3.4.1 CO Monitoring System 3-103
3.4.1.1 CO Analyzer Multi-Point Calibration Test 3-103
3.4.1.2 Cycle Time and Linearity Test 3-103
3.4.1.3 Seven-Day Calibration Drift Test 3-104
3.4.1.4 System Bias Test 3-104
3.4.2 $PM_{2.5}$ Monitoring System 3-104
3.4.2.1 K Factors 3-104
3.4.2.2 Flow 3-105
3.4.2.3 Temperature and Barometric Pressure 3-105
3.4.3 Continuous Emissions Monitoring Certification Data Submittal 3-105
3.5 Traffic Monitoring *3-105*
4 Continuous Emissions Monitoring Plan 4-105
4.1 Project-Wide Quality Assurance/Quality Control Program *4-105*
4.1.1 Quality Assurance/Quality Control – Definition and Function 4-106
4.1.2 QA/QC Goals and Objectives 4-106
4.1.3 Organization and Responsibilities 4-106
4.1.3.1 Director of Environmental Engineering 4-106
4.1.3.2 Senior Environmental Engineer 4-107
4.1.3.3 Environmental Engineers 4-108
4.1.4 Document Distribution and Control 4-108
4.2 Training *4-109*
4.2.1 General Training 4-110
4.2.2 Specialized Vendor Training 4-110
4.2.3 Monitoring Plan Review 4-110
4.2.4 Periodic Refresher and Specialized Training 4-110

PART III - RECORD KEEPING AND REPORTING 4-115
5 Data Recording and Reporting 5-115
5.1 MassDEP 310 CMR 7.38(9) Regulatory Requirements *5-115*
5.2 Continuous Emissions Monitoring Measurement Data Processing *5-116*
5.3 Traffic Data Processing *5-116*
5.4 Tunnel Ventilation System Maintenance Records *5-117*
5.5 Continuous Emissions Monitoring Data Summary Reports *5-117*
5.6 Request to Reduce CEM at Selected Ramps *5-136*

PART IV - CORRECTIVE ACTIONS 5-137
6 Contingency Plan 6-137

6.1 General Requirements (310 CMR 7.38(4)) 6-137
6.2 Compliance Status Determination for Day-to-Day Operations 6-137
6.3 Pre-emptive Actions 6-138
6.4 Corrective (Contingency) Actions 6-139
6.4.1 Emission Limit Exceedance Notification 6-139
6.4.2 Emission Limit Assessment (ELA) 6-140
6.4.3 Additional Contingency Measures 6-140
6.5 Mitigation Plan 6-140
6.6 Compliance of the Ventilation System from 2006 to 1st Quarter of 2012 6-141
6.6.1 Exceedances of Emission Limits from 2006 to 1st Quarter of 2011 6-141
6.6.2 Exceedances of Emission Limits from 2nd Quarter of 2011 to 1st Quarter 2012 6-144
6.6.3 Summary of Exceedances, Reasons and Lessons Learned 6-145

Appendices

Appendix A

Appendix A-1 MassDEP Final Acceptance of the 2006 Central Artery/Tunnel Operating Certification (December 22, 2006) – Submitted with 2011 Renewal Application

Appendix A-2 MassDEP Final Acceptance of the 2011 Central Artery/Tunnel Operating Certification (December 19, 2011)

Appendix B Air Quality Analysis Protocol for Determination of Emission Limits as Part of the Operating Certification of the Project Ventilation Systems

Appendix B-1 2006 Air Quality Analysis Protocol for the Determination of Emission Limits of the Operation Certification for the Project Ventilation System – superseded by Appendix B-3

Appendix B-2 2011 Air Quality Analysis Protocol for the Determination of $PM_{2.5}$ Emission Limits and Verification of VOC Emissions Budget for the Renewal of the Operation Certification for the Project Ventilation System– Submitted with 2011 Renewal Application

Appendix B-3 2012 Air Quality Analysis Protocol for the Determination of CO and NO_x Emission Limits for 2012 Supplemental Application for the Renewal of the Operating Certification for the Project Ventilation System

Appendix C Air Quality Impact Analysis Supporting Data

Appendix C-1 2006 Air Quality Impact Analysis Supporting Data– superseded by Appendices C-4 and C-5

Appendix C-2 2011 Air Quality Impact Analysis Supporting Data for $PM_{2.5}$ Emission Limit Demonstration– Submitted with 2011 Renewal Application

Appendix C-3 Air quality Analysis for VOC Compliance– Submitted with 2011 Renewal Application

Appendix C-4 2012 Air Quality Analysis Supporting Data for CO and NO_x Emission Limit Demonstration for VB

Appendix C-5 2012 Air Quality Analysis Supporting Data for CO and NO_x Emission Limit Demonstration for longitudinally ventilated ramps and DST

Appendix C-6 Air Quality Modeling Background Concentrations for $PM_{2.5}$, CO and NO_x

Appendix D CEM Certification Test Data (Audits, Calibration, Certification)

Appendix D-1 2006-2011, 1st quarter test data – Submitted with 2011 Renewal Application

Appendix D-2 2011-2012 test data

Appendix E CEM Data

Appendix E-1 2006-2011, 1st quarter CEM data – Submitted with 2011 Renewal Application

Appendix E-2 2011-2012 CEM data

Appendix F MassDEP Correspondence

Appendix F-1 Recertification Process – Submitted with 2011 Renewal Application

Appendix F-2 Emission Limits Exceedances and ELA Assessments

F-2a Emission Limits Exceedances and ELA Assessments (2006-2011, 1st quarter) – Submitted with 2011 Renewal Application

F-2b Emission Limits Exceedances and ELA Assessments (2011-2012)

Appendix F-3 Air Quality Analysis Protocols MassDEP approval letters

F-3a 2011 Air Quality Analysis Protocol MassDEP approval letters – Submitted with 2011 Renewal Application

F-3b 2012 Air Quality Analysis Protocol MassDEP approval letters

Appendix G Monitoring Equipment Standard Operating Procedures – Submitted with 2011 Renewal Application

Appendix H Dewey Square Tunnel NO_x Monitoring Program Description and Results

Attachment 1: CEM Air Emissions Monitoring Protocol – Submitted with 2011 Renewal Application

LIST OF FIGURES

Figure 1-1: Physical Limits of CA/T Project....1–2
Figure 1-2: Schematic of Full-Transverse Ventilation System....1–4
Figure 1-3: Ventilation Building 4 Ventilation Schematic Diagram....1–4
Figure 1-4: Location of Ventilation Buildings....1–5
Figure 1-5: Location of Ventilation Building 1....1–6
Figure 1-6: Location of Ventilation Building 3....1–7
Figure 1-7: Location of Ventilation Building 4....1–8
Figure 1-8: Location of Ventilation Building 5....1–9
Figure 1-9: Location of Ventilation Building 6....1–10
Figure 1-10: Location of Ventilation Building 7....1–11
Figure 1-11: Location of Existing and Possible Future DST Exit Portal....1–13
Figure 1-12: Location of Ramp Portals 1(L-CS) and 3 (SA-CN)....1–14
Figure 1-13: Locations of Ramp Portal 2 (CN-S)....1–15
Figure 1-14: Locations of Ramp Portals 4 (ST-CN) and 5 (ST-SA)....1–16
Figure 1-15: Locations of Ramp Portal 6 (CS-SA)....1–17
Figure 1-16: Location of Ramp Portal 7 (CS-P)....1–18
Figure 1-17: Location of Ramp Portal 8 (F)....1–19
Figure 1-18: Supply Fan at VB 7 Air Intake Floor....1–22
Figure 1-19: Jet Fan at Longitudinally Ventilation Ramp....1–24
Figure 2-1: Locations of the Three Ambient Monitors Deployed at Albany Street....2–32
Figure 2-2: CO/NOx Relationship Based on Monitored Levels at the DST from April 2011 through March 2012....2–35
Figure 2-3: Stack Configuration Ventilation Building 1....2–45
Figure 2-4: Stack Configuration Ventilation Building 3....2–46
Figure 2-5: Stack Configuration Ventilation Building 4....2–47
Figure 2-6: Stack Configuration Ventilation Building 5....2–48
Figure 2-7: Stack Configuration Ventilation Building 6....2–49
Figure 2-8: Stack Configuration Ventilation Building 7....2–50
Figure 2-9: Sensitive Receptors and Ventilation Building Locations....2–55
Figure 2-10: Ramp L-CS – Portal Location and Critical Receptor....2-62
Figure 2-11: Ramp SA-CN– Portal Location and Critical Receptor....2-63
Figure 2-12: Ramp CN-S - Portal Location and Critical Receptor....2-64
Figure 2-13: Ramp ST-SA and ST-CN- Portal Location and Critical Receptors....2-65
Figure 2-14: Ramp CS-SA- Portal Location and Critical Receptors....2-66
Figure 2-15: Ramp CS-P- Portal Location and Critical Receptors....2-67
Figure 2-16: Ramp F- Portal Location and Critical Receptors....2-68
Figure 2-17: Dewey Square Tunnel – Configuration 1....2-70
Figure 2-18: Dewey Square Tunnel – Configuration 2....2-71
Figure 2-19: Dewey Square Tunnel – Configuration 3....2-72
Figure 2-20: CTPS Modeled Area....2-87
Figure 2-21: CA/T Project Study Area....2-88
Figure 3-1: CO Ceiling Monitoring Probe at DST....3-99
Figure 3-2: CO and $PM_{2.5}$ Monitoring Units at VB 7 Exhaust....3-100
Figure 3-3: CO Monitors Longitudinally for Ventilated Tunnels....3-101
Figure 4-1: Organizational Structure for the MASSDOT-CA/T Project Continuous Air Emissions Monitoring Program....4-112
Figure 5-1: Peak and Average Daily Traffic Volumes for period 2006-2012....5-116
Figure 5-2: Peak Hourly Traffic Volumes for Period 2006-2012....5-117

LIST OF TABLES

Table EX-1: Summary of Emission Limits for 2012 to 2016 period IV
Table 1-1: Ventilation Building and Exhaust Stack Heights....1–22
Table 1-2: Ventilation Buildings Exhaust Capacity for Varying Steps....1–23
Table 1-3: Longitudinal Ventilation Tunnel Section Dimensions and Mechanical Ventilation Capacities 1–24
Table 1-4: Traffic Volumes, Speeds and Air Flow Rates for DST and Eight Longitudinally Ventilated Ramps....1–25
Table 2-1: Summary of 2006 Emission Limits 2–30
Table 2-2: Collected NOx, NO and NO_2 Concentrations (ppb) 2–32
Table 2-3: CO/NOx Relationship Based on April 2011–March 2012 Measured Data 2–34
Table 2-4: NO/NO_2 Conversion Factors Based on DST Monitoring Study....2–37
Table 2-5: Days with Valid $PM_{2.5}$ Concentrations at North Street Monitoring Site 2–38
Table 2-6: Annual $PM_{2.5}$ Levels at North End Monitoring Station....2–38
Table 2-7: Boston NO_2 Monitoring Sites 2007-2011....2–39
Table 2-8: Boston CO Monitoring Sites 2007-2011 2–41
Table 2-9: Ventilation Building Operating Scenarios....2–43
Table 2-10: Model Input Parameters for Ventilation Buildings....2–51
Table 2-11: Ventilation Building Exhaust and Stack Parameters – Step 4 Operations....2–52
Table 2-12: Ventilation Building Exhaust and Stack Parameters – Step 1 Operations....2–53
Table 2-13: Maximum 24-Hour and Annual $PM_{2.5}$ Concentrations from Individual Ventilation Buildings at Ambient Receptors for Compliance Demonstration (**µg/m^3**) based on a source level of 900 (**µg/m^3**) 2–53
Table 2-14: Maximum cumulative 24-Hour and Annual $PM_{2.5}$ Concentrations from All Ventilation Buildings for Compliance Demonstration (**µg/m^3**) based on a source level of 900 (**µg/m^3**)....2–54
Table 2-15: Modeling Input Parameters for Step 1 2–56
Table 2-16: Modeling Input Parameters for Step 4....2–56
Table 2-17: Highest 2nd High 1-Hour and 8-Hour Predicted CO Concentrations from Ventilation Buildings at Ambient Receptors for Compliance Demonstration 2–57
Table 2-18: Predicted NO_2 Design Concentrations from Ventilation Buildings at Ambient Receptors for NAAQS Compliance Demonstration 2-58
Table 2-19: Predicted NO_2 Design Concentrations from Ventilation Buildings at Ambient Receptors for MassDEP Guideline Compliance Demonstration....2-59
Table 2-20: 1- and 8-Hour CO Levels for Compliance Demonstration: Ramp LC-S (PPM) 2-74
Table 2-21: 1- and 8-Hour CO Levels for Compliance Demonstration: Ramp SA-CN (PPM)....2-74
Table 2-22: 1- and 8-Hour CO Levels for Compliance Demonstration: Ramp CN-S (PPM)....2-74
Table 2-23: 1- and 8-Hour CO Levels for Compliance Demonstration: Ramp ST-CN no Parcel 6 (PPM)....2-75
Table 2-24: 1- and 8-Hour CO Levels for Compliance Demonstration: Ramp ST-SA no Parcel 6 (PPM)....2-75
Table 2-25: 1- and 8-Hour CO Levels for Compliance Demonstration: Ramp ST-SA + Parcel 6 (PPM)....2-75
Table 2-26: 1- and 8-Hour CO Levels for Compliance Demonstration: Ramp CS-SA + Parcel 12 (PPM)....2-75
Table 2-27: 1- and 8-Hour CO Levels for Compliance Demonstration: Ramp CS-SA no Parcel 12 (PPM) 2-76
Table 2-28: 1- and 8-Hour CO Levels for Compliance Demonstration: Ramp CS-P (PPM)....2-76
Table 2-29: 1- and 8-Hour CO Levels for Compliance Demonstration: Ramp F (PPM)....2-76
Table 2-30: 1- and 8-Hour CO Levels for Compliance Demonstration – Dewey Square Tunnel: Configuration 1 (PPM)....2-76
Table 2-31: 1- and 8-Hour CO Levels for Compliance Demonstration – Dewey Square Tunnel: Configuration 2 (PPM)....2-77
Table 2-32: 1- and 8-Hour CO Levels for Compliance Demonstration – Dewey Square Tunnel: Configuration 3 (PPM)....2-77
Table 2-33: 1-Hour NO_2 Levels for Compliance Demonstration: Ramp LC-S (PPM)....2-79
Table 2-34: 1-Hour NO2 Levels for Compliance Demonstration: Ramp SA-CN (PPM)....2-79

Table 2-35: 1-Hour NO_2 Levels for Compliance Demonstration: Ramp CN-S (PPM) 2-80
Table 2-36: 1-Hour NO_2 Levels for Compliance Demonstration: Ramp ST-CN no Parcel 6 (PPM) 2-80
Table 2-37: 1-Hour NO_2 Levels for Compliance Demonstration: Ramp ST-SA no Parcel 6 (PPM)................2-81
Table 2-38: 1-Hour NO_2 Levels for Compliance Demonstration: Ramp ST-SA + Parcel 6 (PPM) 2-81
Table 2-39: 1-Hour NO_2 Levels for Compliance Demonstration: Ramp CS-SA + Parcel 12 (PPM) 2-82
Table 2-40: 1-Hour NO_2 Levels for Compliance Demonstration: Ramp CS-SA no Parcel 12 (PPM) 2-82
Table 2-41: 1-Hour NO_2 Levels for Compliance Demonstration: Ramp CS-P (PPM) 2-83
Table 2-42: 1-Hour NO_2 Levels for Compliance Demonstration: Ramp F (PPM) 2-83
Table 2-43: 1-Hour NO_2 Levels for Compliance Demonstration – Dewey Square Tunnel: Configuration 1 (PPM) 2-84
Table 2-44: 1-Hour NO_2 Levels for Compliance Demonstration – Dewey Square Tunnel: Configuration 2 (PPM) 2-84
Table 2-45: 1-Hour NO_2 Levels for Compliance Demonstration – Dewey Square Tunnel: Configuration 3 (PPM) 2-85
Table 2-46: Projects Included in the 2005 and 2010 C/A Project Build Network 2-89
Table 2-47: Network-based Daily VMT (vehicles miles traveled) and VOCs (Kg/day) 2-92
Table 2-48: MBTA Buses Daily VMT and VOCs (Kg/day) 2-92
Table 2-49: Commuter Railroad Daily VMT and VOCs (Kg/day)..2-92
Table 2-50: Ferry Daily Fuel Consumption and VOCs (Kg/day) 2-92
Table 2-51: Total Daily VOC Emissions (Kg/day)..2-92
Table 2-52: Summary of 2012-2016 Emission Limits 2-93
Table 4-1: Key Personnel and Responsibilities...4-111
Table 5-1: Summary of CO and NO_x Average and Peak Levels: Ventilation Building 1..............................5-119
Table 5-2: Summary of CO, NO_x , PM_{10} and $PM_{2.5}$ Average and Peak Levels: Ventilation Building 3........5-121
Table 5-2: Summary of CO, NO_x, PM_{10} and $PM_{2.5}$ Average and Peak Levels: Ventilation Building 3 (continued)..........5-122
Table 5-3: Summary of CO and NO_x Average and Peak Levels: Ventilation Building 4..............................5-123
Table 5-3: Summary of CO and NO_x Average and Peak Levels: Ventilation Building 4 (continued) 5-124
Table 5-4: Summary of CO and NO_x Average and Peak Levels: Ventilation Building 5..............................5-125
Table 5-4: Summary of CO, NO_x, PM_{10} and $PM_{2.5}$ Average and Peak Levels: Ventilation Building 5 (continued)..........5-126
Table 5-5: Summary of CO and NO_x Average and Peak Levels: Ventilation Building 6..............................5-127
Table 5-6: Summary of CO, NO_x, PM_{10} and $PM_{2.5}$ Average and Peak Levels: Ventilation Building 7.........5-128
Table 5-7: Summary of CO and NO_x Average and Peak Levels: Ramp LC-S 5-131
Table 5-8: Summary of CO and NO_x Average and Peak Levels: Ramp SA-CN 5-131
Table 5-9: Summary of CO and NO_x Average and Peak Levels: Ramp CN-S..5-132
Table 5-10: Summary of CO, NO_x, PM_{10} and $PM_{2.5}$ Average and Peak Levels: Ramp CS-SA.......................5-132
Table 5-11: Summary of CO and NO_x Average and Peak Levels: Ramp CS-P..5-133
Table 5-12: Summary of CO and NO_x Average and Peak Levels: Ramp F...5-133
Table 5-13: Summary of CO and NO_x Average and Peak Levels: DST I-93 5-134
Table 5-14: Summary of CO and NO_x Average and Peak Levels: DST I-90 5-134
Table 5-15: Summary of CO and NO_x Average and Peak Levels: Ramp ST-CN...5-135
Table 5-16: Summary of CO and NO_x Average and Peak Levels: Ramp ST-SA 5-135
Table 5-17: CO Emission Limits and hourly measured levels 2006-2012...5-136
Table 6-1: Summary of Emission Limits (2012-2016) 6-138
Table 6-2: Emission Action Levels (2012-2016)...6-139
Table 6-3: CEM Emission Limit Exceedances (2006 – 2011)...6-142
Table 6-4: CEM Emission Limit Exceedances (2011-2012) 6-145

LIST OF ABBREVIATIONS AND ACRONYMS

ACO	Administrative Consent Order
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 includes 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)).

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 Ambient Air Quality Standards and Massachusetts Ambient Air Quality Standards (MAAQS) for CO, nitrogen dioxide (NO_2), and PM_{10} and state 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).

MassDEP Regulation 310 CMR 7.38 requires a renewal of 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 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 new $PM_{2.5}$ 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, which are needed to demonstrate compliance with the new 1-hour NAAQS for NO_2. The 2011 CA/T Renewal Operating Certification proposed to retain the existing emission limits for NO_x and CO for all Project ventilation buildings and longitudinally ventilated ramps until the approval of the supplemental application in 2012.

Need for two-part renewal and supplemental application

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 delayed 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 new 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 conversion rates were likely lower and that 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 are also established in this supplemental application.

Conditional Acceptance of 2011 CA/T Renewal Operating Certification

MassDEP issued a conditional acceptance of the CA/T Renewal Application submitted July 1, 2011 on its letter dated December 19, 2011. The conditional acceptance includes a list of specific requirements described in the December 19, 2011 MassDEP letter, and covers the five year operating period from December 19, 2011 to December 19, 2016. The supplemental application to be submitted on July 1, 2012 augments the 2011 CA/T Renewal Operating Certification and will cover the remaining four-year period from the date of MassDEP approval of the supplemental application through December 19, 2016.

2011 CA/T Renewal Operating Certification

The 2011 CA/T Renewal Operating Certification included a Technical Support Document (TSD) divided into four parts:

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

The 2011 TSD also included several appendices and attachments:

- Appendix A: MassDEP Pre-Construction Certification Acceptance

- 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 Impact Analysis Input Data
- Appendix D: CEM Certification Test Data
- Appendix E: Initial CEM Data in Support of Operating Certification
- Appendix F: MassDEP Correspondence
- Appendix G: Monitoring Equipment Standard Operating Procedures; and

Attachment 1: CEM Air Emissions Monitoring Protocol

2012 CA/T Supplemental Application

For consistency, the supplemental application follows the format of the 2011 CA/T Renewal Operating Certification TSD, retaining the aspects that remain unchanged and replacing or adding information, as needed, to incorporate new requirements and to update summaries of data collected.

The appendices that appear in the September 30, 2011 TSD are not repeated here, but appendices relevant to the CO and NO_x emission limits, new correspondence, and CEM data are included with this supplemental application TSD.

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 exit ramps). The emission limits established for the 2006-2011 operating certification apply to day-to-day tunnel operation, except for emergency situations during a tunnel fire. The limits for CO, NO_x and PM_{10} (replaced with $PM_{2.5}$ in 2012) 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 and 2011. 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. This section is reprinted in this document in its totality from the 2011 CA/T Renewal Operating Certification TSD.

Section 2 of TSD Part I – Determination of Emission Limits – includes the established emission limits for $PM_{2.5}$, and VOC in the 2011 CA/T Renewal Operating Certification TSD, and the MassDEP acceptance of such limits, and the revised CO and NO_x emission limits which are the bases for this supplemental application.

It describes the currently used dispersion modeling process (using EPA approved air quality models and wind tunnel modeling techniques), its relationship to the data collected as part of the 2006 and 2011 modeling demonstrations; and the compliance demonstration currently performed to meet the applicable NAAQS for CO and NO_2, and state guideline values for NO_2. Table EX-1 below provides the CO and NO_x revised emission limits presented in this document. These emission limits will come into effect once MassDEP approves this supplemental application in December 2012.

This section also provides a summary of 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. It describes how data gathered from the Albany Street monitoring program were used to develop more accurate NO to NO_2 conversion factors for the new NO_x emission limits to ensure compliance with the new 1-hour NO_2 NAAQS.

Section 2 also reprints the description of the modeling methodology used to establish $PM_{2.5}$ emission limits and the results of the compliance demonstration performed as part of the 2011 CA/T Renewal Operating Certification. The modeling performed used the EPA AERMOD dispersion model, five years of meteorological data, and included daily background air quality data used to obtain a total daily (24-hour) $PM_{2.5}$ concentration at each ambient location potentially affected by emissions from the ventilation buildings. The results of the analysis indicate that a $PM_{2.5}$ emission limit of 900 µg/m^3 demonstrates compliance with the $PM_{2.5}$ annual and 24-hour NAAQS. Table EX-1 below also provides the $PM_{2.5}$ emission limits presented in the 2011 CA/T Renewal Operating Certification. These $PM_{2.5}$ emission limits came into effect in January 2012.

TABLE EX-1: SUMMARY OF EMISSION LIMITS FOR 2012 TO 2016 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	900
VB 3	70	70	6.1	900
VB 4	70	70	6.1	900
VB 5	70	70	6.1	900
VB 6	70	70	6.1	900
VB 7	70	70	6.1	900
Ramp L-CS	57	70	5.0	NA
Ramp CN-S	37	58	3.4	NA
Ramp SA-CN	70	70	6.1	NA
Ramp ST-CN	70	70	6.1	NA
Ramp ST-SA	58	70	5.5	NA
Ramp CS-SA***	38	55	3.4	35****
Ramp CS-P	41	70	3.7	NA
Ramp F	70	70	6.1	NA
Dewey Sq. Tunnel	23	30	2.2	NA

Notes: Acronyms are defined as: Leverett Circle to Central Artery Southbound (L-CS), Central Artery Northbound to Storrow Drive (C-NS), Sumner Tunnel to Central Artery Northbound (ST-CN), Surface Artery to Central Artery Northbound (SA-CN), Central Artery Southbound to Surface Artery (CS-SA), Sumner Tunnel to Surface Artery (ST-SA), Central Artery Southbound to Purchase Street (CS-P), I-90 Westbound to Congress Street (Ramp F), part per million (ppm), microgram per cubic meter (µg/m^3).

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

** $PM_{2.5}$ emission limits remain unchanged from the 2011 CA/T Renewal Operating Certification and took effect January 2012

*** 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/m3) 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 performed as part of the 2011 CA/T Renewal Application by the Central Planning Transportation Staff (CTPS) using the 2010 vehicular traffic and transit operating conditions. The analysis demonstrates that the 2010 total estimates for the CA/T area resulted in a reduction of 2,189 kilograms per day (kg/day) of VOC with respect to the VOC budget of 6,095.9 kg/day established in the 2006 operating certification. This VOC reduction is approximately 36% relative to the emissions budget and occurred despite an increase of approximately

1% in vehicle miles traveled (VMT) for the five-year period. 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 2011 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 2011-2016 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 zone prior to discharge up, and out the building stacks and at the exit portal of each longitudinally ventilated exit ramp. MassDOT monitors $PM_{2.5}$ emissions at four representative in-tunnel locations with the highest $PM_{2.5}$ levels and ambient levels the vicinity of Ramp CS-SA.

This section is reprinted in this document in its totality from the 2011 CA/T Renewal Operating Certification TSD.

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 2006-2011 conversion equation was based on data collected at the TWT, and the new revised conversion equation is based on data collected at the DST during the April 2011-March 2012 monitoring program.

In 2011, peak hour traffic volumes in vehicles per hour (VPH) using the mainline tunnels were generally in the range of 7,170 to 7,910 VPH in each direction of I-93 and in the range of 2,960 to 3,530 VPH in each direction of the TWT. The average daily volumes were in the range of 81,000 to 103,700 vehicles per day (VPD) in each direction of I-93 and in the range of 32,300 to 48,000 VPD in each direction of the TWT. 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 normal peak traffic conditions. The longitudinal DST ventilation system operates between Step 1 and Step 3 for off peak and normal peak traffic conditions, respectively.

The 2006-2012 (1st quarter) data presented in Section 5 of TSD Part III indicate that measured hourly CO concentrations for the ventilation buildings range from 0.5 to 10.1 ppm on average and as high as 31.4 ppm during peak periods for the ventilation buildings. For the DST and ramps, hourly CO concentrations were in the range of 0.5 to 5.8 ppm on average with maximum levels in the range of 12.6 to 71.9 ppm.

Measured hourly NO_x levels from the ventilation buildings ranged from 0.3 to 0.7 ppm on average with peak values ranging from 1.6 to 4.5 ppm. Measured hourly NO_x levels for the DST and Ramps ranged from 0.3 to 0.9 ppm on average with peaks ranging from 1.8 to 9.1 ppm.

Measured average daily PM_{10} concentrations between 2006 and 2011 were between 31 and 121 µg/m^3, Maximum daily PM_{10} values were in the range of 100 to 577 µg/m^3. The PM_{10} monitor outside Ramp CS-SA, which measures ambient levels, recorded between 2006 and 2011 annual averages from 19 to 21 µg/m^3, and a maximum daily level of 116 µg/m^3.

Measured average daily $PM_{2.5}$ concentrations during the first four months of 2012 were between 6.8 and 40.9 µg/m^3, Maximum daily $PM_{2.5}$ values were in the range of 23 to 88.1 µg/m^3. The $PM_{2.5}$ monitor outside Ramp CS-SA, which measures ambient levels, in the first four months of 2012 recorded concentrations from 7.6 to 25.5 µg/m^3.

At the start of the $PM_{2.5}$ monitoring, the reports will be submitted to MassDEP on a monthly basis from January through December 2012, and at a quarterly intervals thereafter.

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 CA/T Renewal Operating Certification, and will not be provided for the 2011-2016 Operating Certification period.

There were eleven episodes when emission limits were exceeded (sometimes lasting more than a relevant emission limit period) from the beginning of 2006 through the end of the first quarter of 2011. These episodes (reported in the 2011 CA/T Renewal Operating Certification, including 1st quarter of 2011) resulted in a total of 10 hours when CO measured levels were above the emission limits set for specific locations and 8 days when the measured PM_{10} levels were above the emission limits set for a ventilation building. During the one-year period (2nd quarter 2011 to 1st quarter 2012) there were two episodes when concentrations at DST exceeded the one-hour emission limits. This makes up thirteen episodes of exceeding emission limits in the six-year period.

The main reasons for the CO emission limit exceedance (eight episodes with a total of 12 hours) were the result of emissions from maintenance equipment working during nighttime tunnel closings and a lack of adequate ventilation air due to the closure of the tunnels.

The reason for the PM_{10} emission limits exceedances (five episodes with a total of 8 days) was due to the pulverization of road salt applied during winter snowstorm events by the wheels of moving traffic inside the tunnels. This salt on the roadway surface created a large source of salt crust available for vehicle pulverization and re-entrainment into the ventilation system.

CO concentrations were measured every hour at 24 VB exhaust locations and at eight locations in the longitudinally ventilated ramps and DST over the last six calendar years (2006-2011) yielding approximately 1.7 million hourly observations. The 12 hours of the CO emission limit exceedance represent an exceedingly infrequent occurrence, only about 0.0007% of the hours during this period, and shows that the ventilation system is nearly always in compliance with its CO emission limits.

Appropriate corrective measures were taken in these instances, and response procedures were modified when necessary as part of the contingency plan. As a result, the periods of CO emission limit exceedances never lasted longer than two hours, and the periods for daily PM_{10} emission limit exceedance never lasted longer than two days.

The results of the Emission Limit Assessment (ELA) performed for each of these episodes demonstrated that none of these events resulted in a violation of the applicable NAAQS or MassDEP NO_2 policy guideline. Moreover, the maximum predicted ambient values resulting from these peak measurements were 50% or less of the applicable NAAQS or MassDEP NO_2 policy guideline. This provides a good indication that the emission limits established provide a considerable margin of safety with regard to ensuring compliance with NAAQS and protection of the health of abutters and surrounding communities.

There were no exceedances of the new $PM_{2.5}$ emission limit established in 2011, which replaces the previous PM_{10} emission limit.

MassDOT Request to reduce the CEM at selected Ramps

The discussion between MassDOT and MassDEP about reducing the CEM program at certain longitudinally ventilated ramps dates back to 2008. The 2011 CA/T Renewal Operating Certification (TSD Part III, section 5.5) indicated that MassDOT will request the reduction of the CEM program to a more limited number of longitudinally ventilated ramps as part of the supplemental application.

The five ramps proposed for elimination from the CEM 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 the sidewalls for traffic congestion or emergency conditions, such as a tunnel fire.

The average hourly CO levels measured at these ramps during the past six years have been below 3.0 ppm. With the exception of two incidents at Ramps L-CS and ST-CN during nighttime tunnel closings for road maintenance operations, the maximum concentrations recorded during 2010-2012 have been below 29 ppm (see Part III, section 5.6 for details).

Since the revised CO emission limits for these ramps are between 57 and 70 ppm for one-hour and 70 ppm for the eight-hour average (see Table EX-1), it is very unlikely that these limits will be exceeded in the coming years. Today's clean motor vehicle fleet, and the short length of these tunnels open to ambient air at both ends precludes the formation of elevated CO levels during normal operating conditions.

The remaining three longitudinally ventilated ramps (CN-S, CS-SA, and CS-P), which are connected to the tunnel mainline's full transverse ventilation system, the DST, and all VBs will continue the monitoring and reporting process of the current CEM program.

The elimination of these five ramps from the CEM will result in significant labor savings for MassDOT. More importantly, the equipment that will no longer be needed at the eliminated ramps will be refurbished and used as spares for the remaining monitoring sites. As all of these instruments have been in continuous service for more than eight years, they require more frequent and extensive maintenance, so the spares will minimize lost data.

Introduction

In compliance with MassDEP Regulation 310 CMR 7.38, the CA/T Project filed an 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 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 new $PM_{2.5}$ 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 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, which reflects the emissions of the current motor-vehicle fleet in Massachusetts.

MassDEP issued a conditional acceptance of the 2011 CA/T Renewal Operating Certification Application submitted July 1, 2011 on its letter dated December 19, 2011. The conditional acceptance includes a list of specific requirements described in the December 19, 2011 MassDEP letter, and covers the five year operating period from December 19, 2011 to December 19, 2016.

This supplemental application augments the 2011 CA/T Renewal Operating Certification, and covers the remaining four-year period from the date of MassDEP approval of this supplemental application through December 19, 2016.

For consistency, this supplemental application follows the format of the 2011 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 2011. As such, this 2012 TSD document provides all the information provided in the 2011 TSD plus all the necessary updates, which form part of this supplemental application.

The appendices that appear in the 2011 CA/T Renewal Operating Certification are not reprinted with this 2012 supplemental application, but appendices relevant to the CO and NO_x emission limits, new correspondence, and CEM data are included.

Following the same format as the 2011 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 2006-2010 operating levels
- Part IV – Corrective Actions – Procedures implemented during 2006-2010 operations

Part I – Ventilation System – Operation and Emission Limits

1 DESCRIPTION OF CENTRAL ARTERY/TUNNEL PROJECT VENTILATION SYSTEMS

This section remains unchanged from the 2011 CA/T Renewal Operating Certification TSD and for completeness purpose it is reprinted in this document in its totality.

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 2011 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 potentially 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 estimated average time for a vehicle traveling inside the tunnel is less than 9 minutes during PM peak hour conditions and is shorter for AM peak hour conditions.

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

From a tunnel ventilation perspective, the Project is defined as three distinct and separate road tunnel "systems": the 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 is served by a dedicated and independently controlled set of fans. This concept allows for significant operational flexibility throughout the Project and provides 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 are progressively decreasing. Therefore, the CA/T Project ventilation system is expected to provide ample ventilation to accommodate the anticipated 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 diverted up 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 & 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

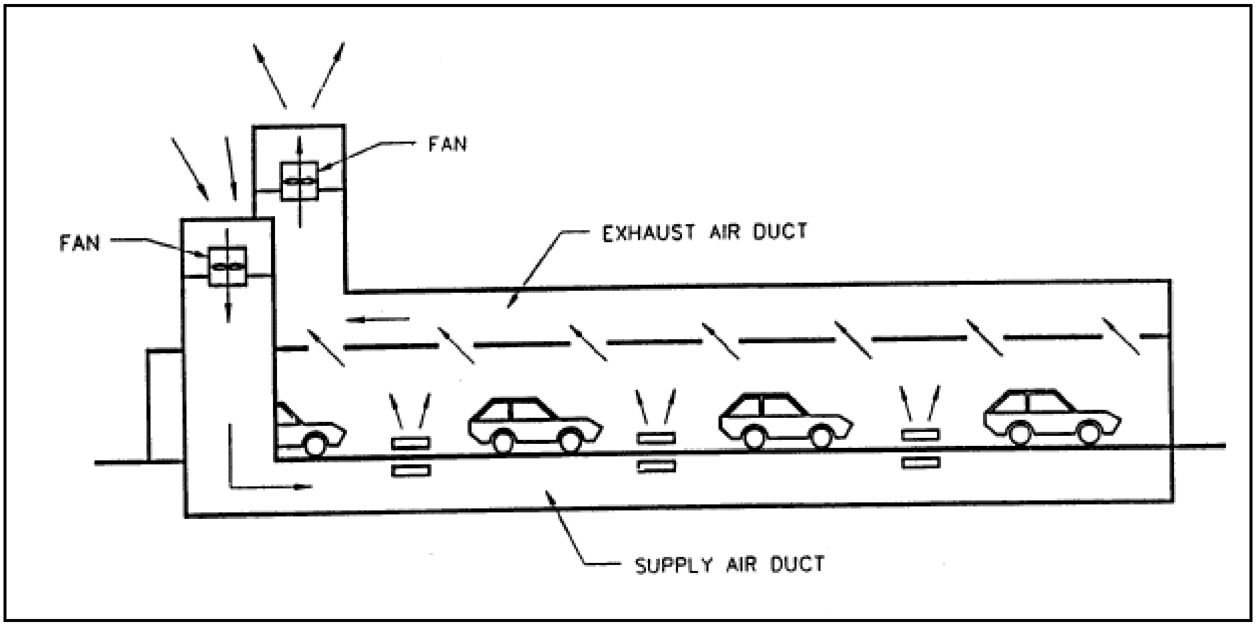


FIGURE 1-3: VENTILATION BUILDING 4 VENTILATION SCHEMATIC DIAGRAM

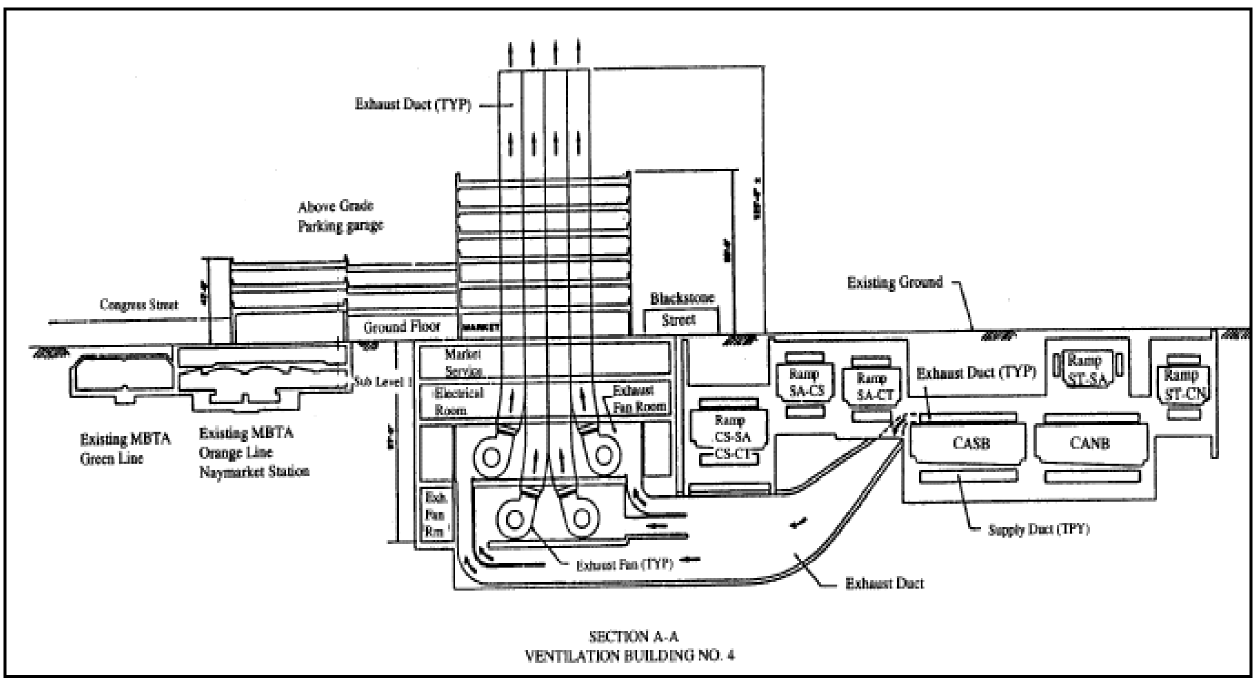


FIGURE 1-4: LOCATION OF VENTILATION BUILDINGS

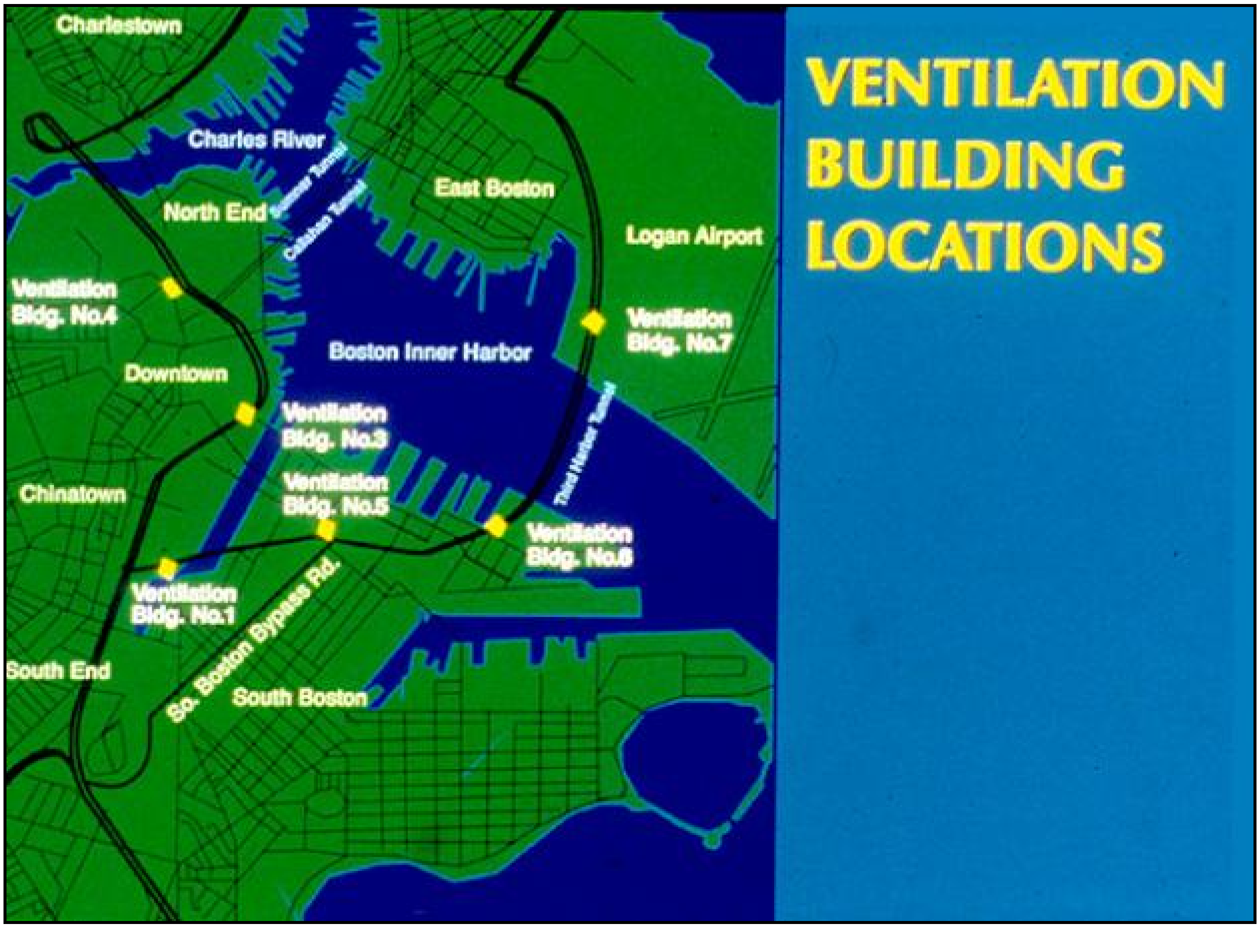


FIGURE 1-5: LOCATION OF VENTILATION BUILDING 1

FIGURE 1-6: LOCATION OF VENTILATION BUILDING 3

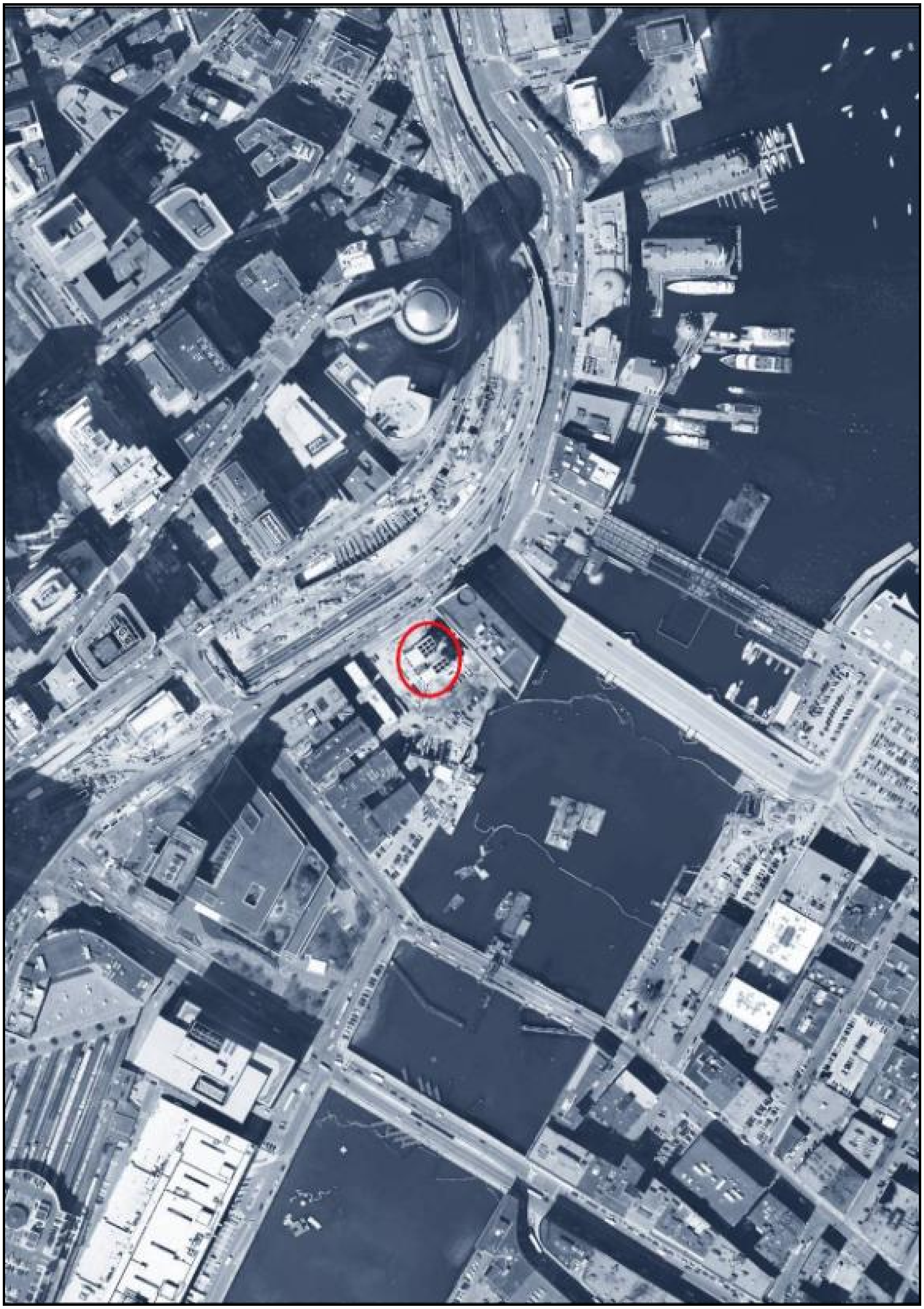


FIGURE 1-7: LOCATION OF VENTILATION BUILDING 4

FIGURE 1-8: LOCATION OF VENTILATION BUILDING 5

FIGURE 1-9: LOCATION OF VENTILATION BUILDING 6

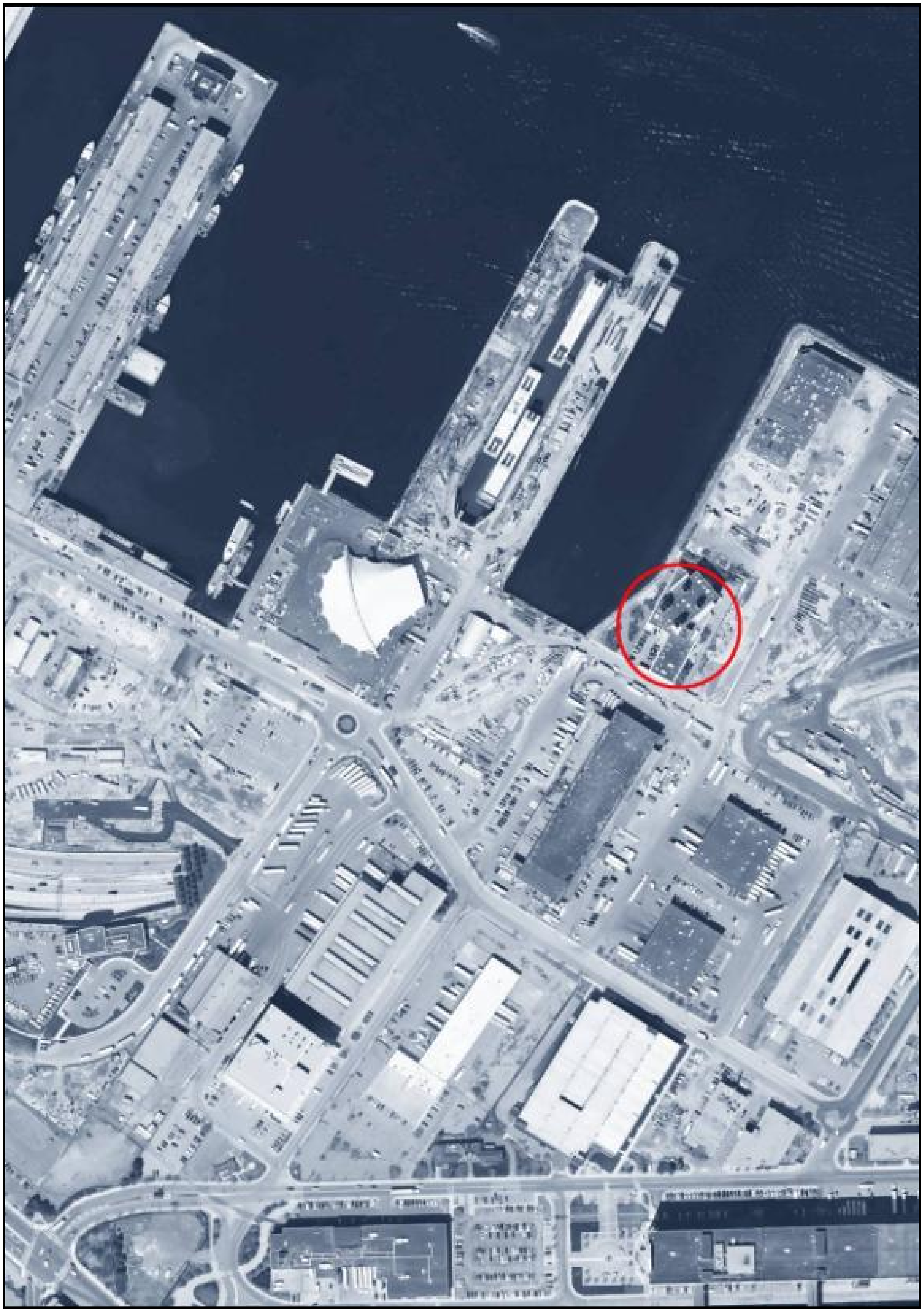


FIGURE 1-10: LOCATION OF VENTILATION BUILDING 7

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) – formerly Operations Control Center (OCC) – in South Boston and are determined by the CO levels monitored inside each ventilation zone.

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 original DST was designed and operated for approximately 50 years as a longitudinally ventilated tunnel. Under normal traffic conditions, the tunnel is ventilated by the piston effect of the vehicles traveling through the tunnel.

The reconstructed tunnel (which is connected at its northern end to the new 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 stalled traffic conditions.

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). The future location of the portal under the full commercial development scenario may be 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 three ramps 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.

Figures 1-12 to 1-17 identify the location of each ramp.

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

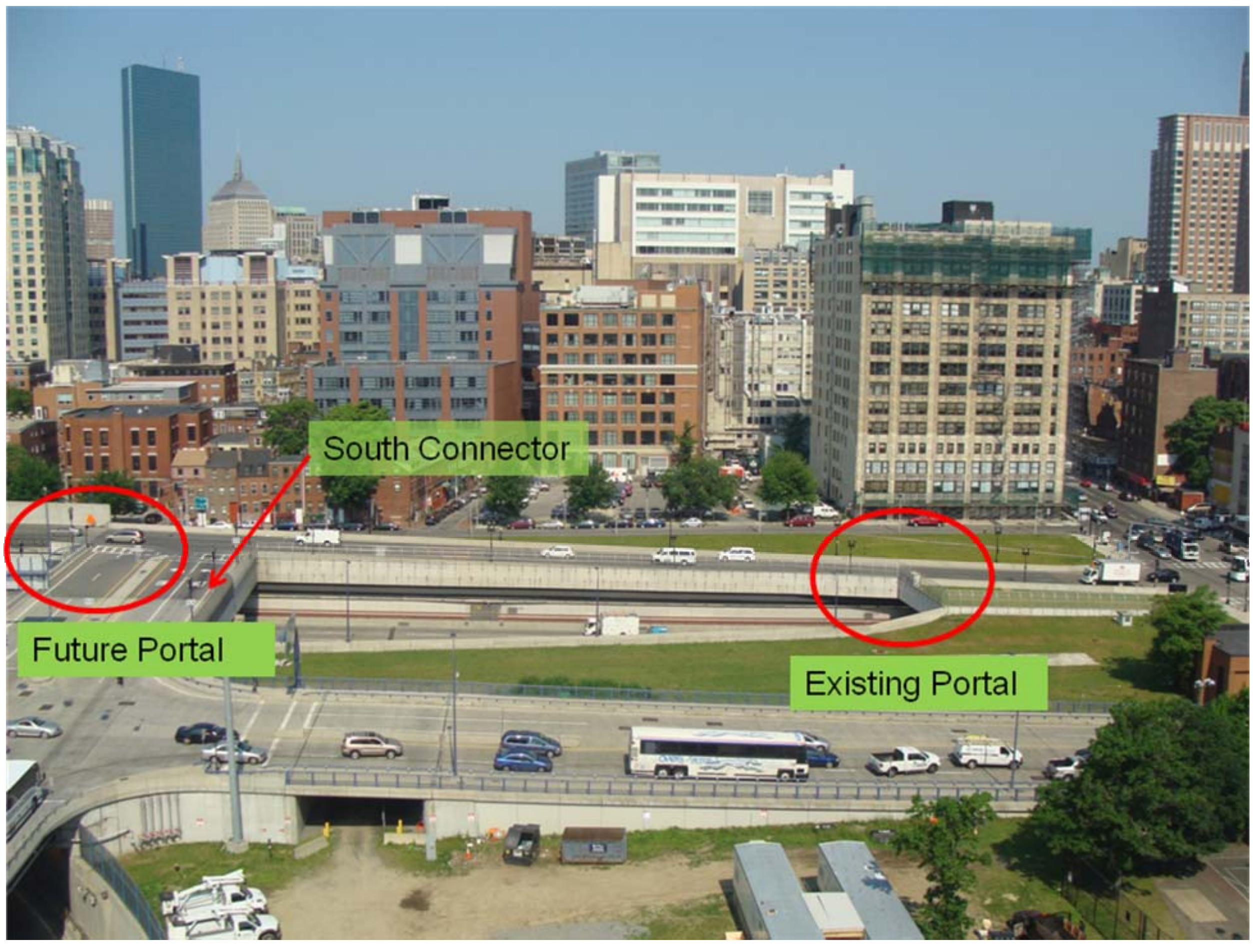


FIGURE 1-12: LOCATION OF RAMP PORTALS 1(L-CS) AND 3 (SA-CN)

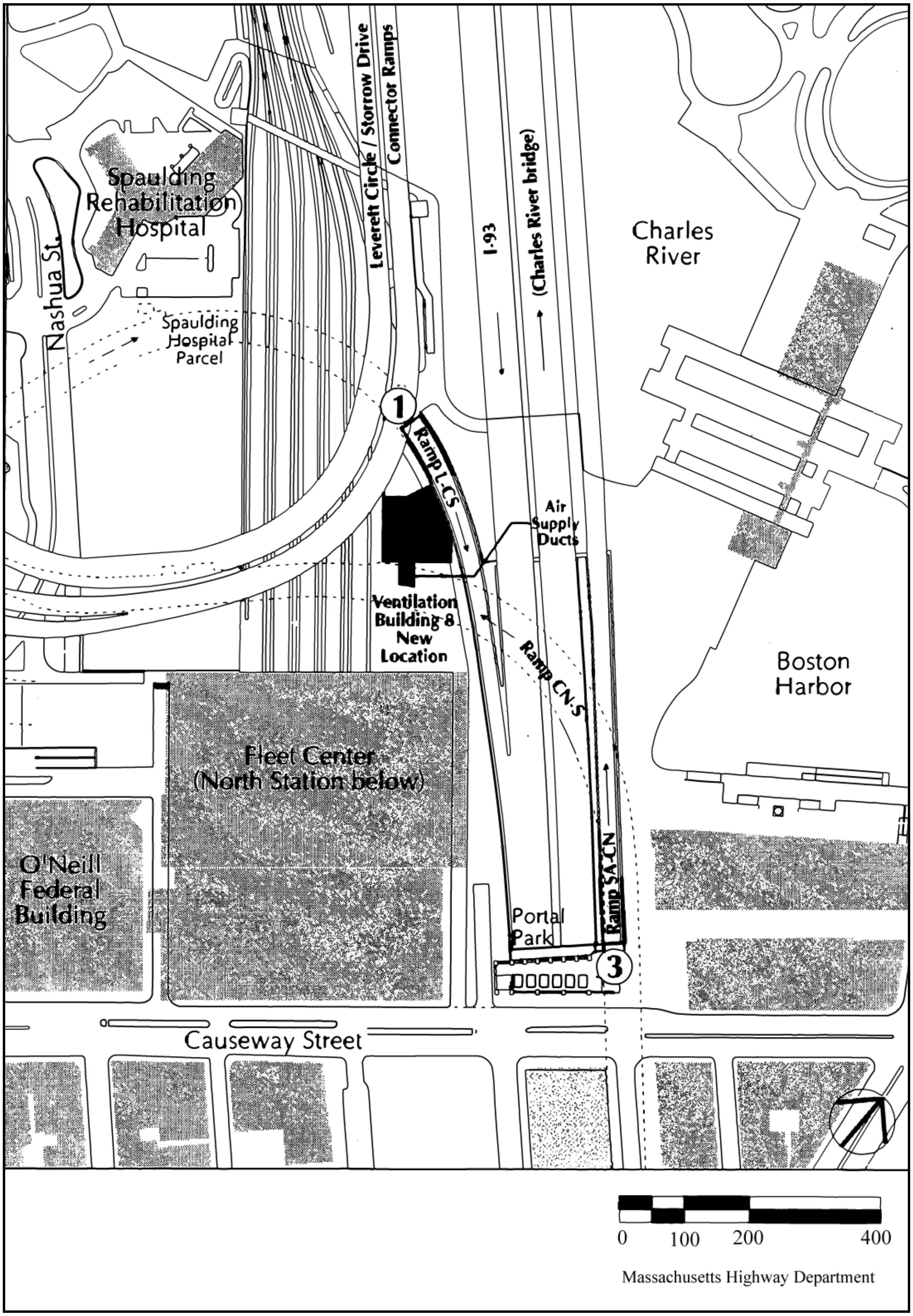


FIGURE 1-13: LOCATIONS OF RAMP PORTAL 2 (CN-S)

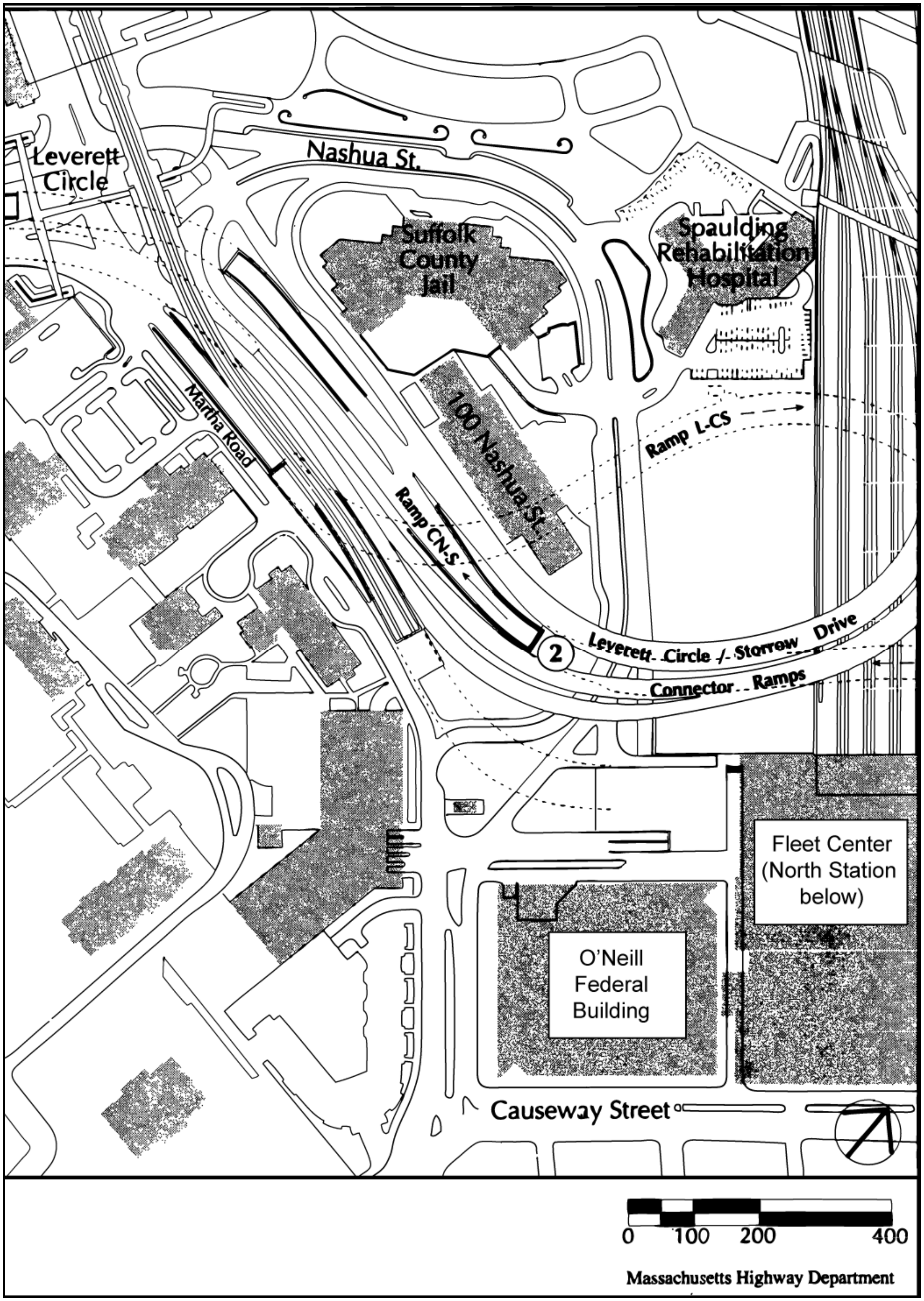


FIGURE 1-14: LOCATIONS OF RAMP PORTALS 4 (ST-CN) AND 5 (ST-SA)

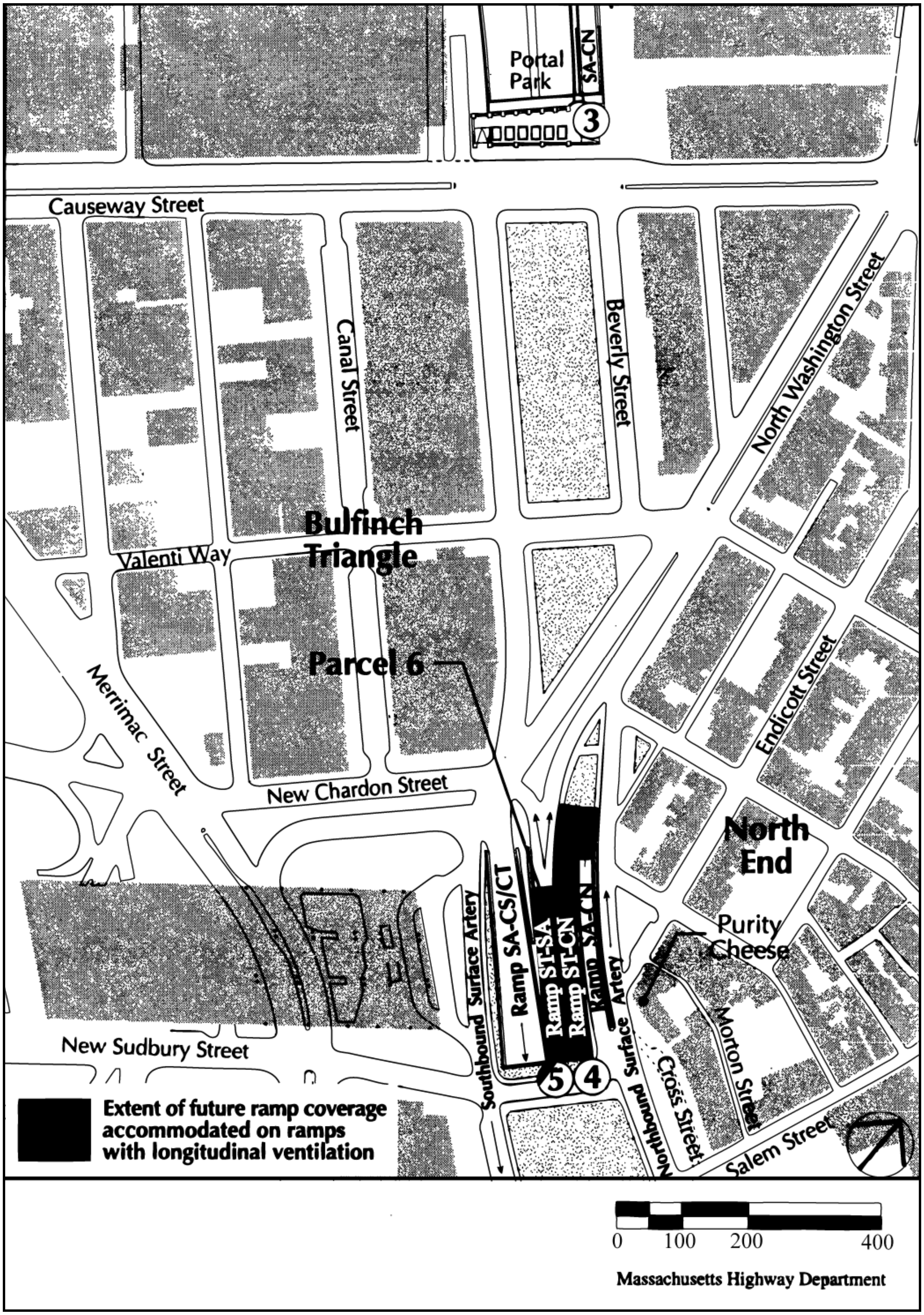


FIGURE 1-15: LOCATIONS OF RAMP PORTAL 6 (CS-SA)

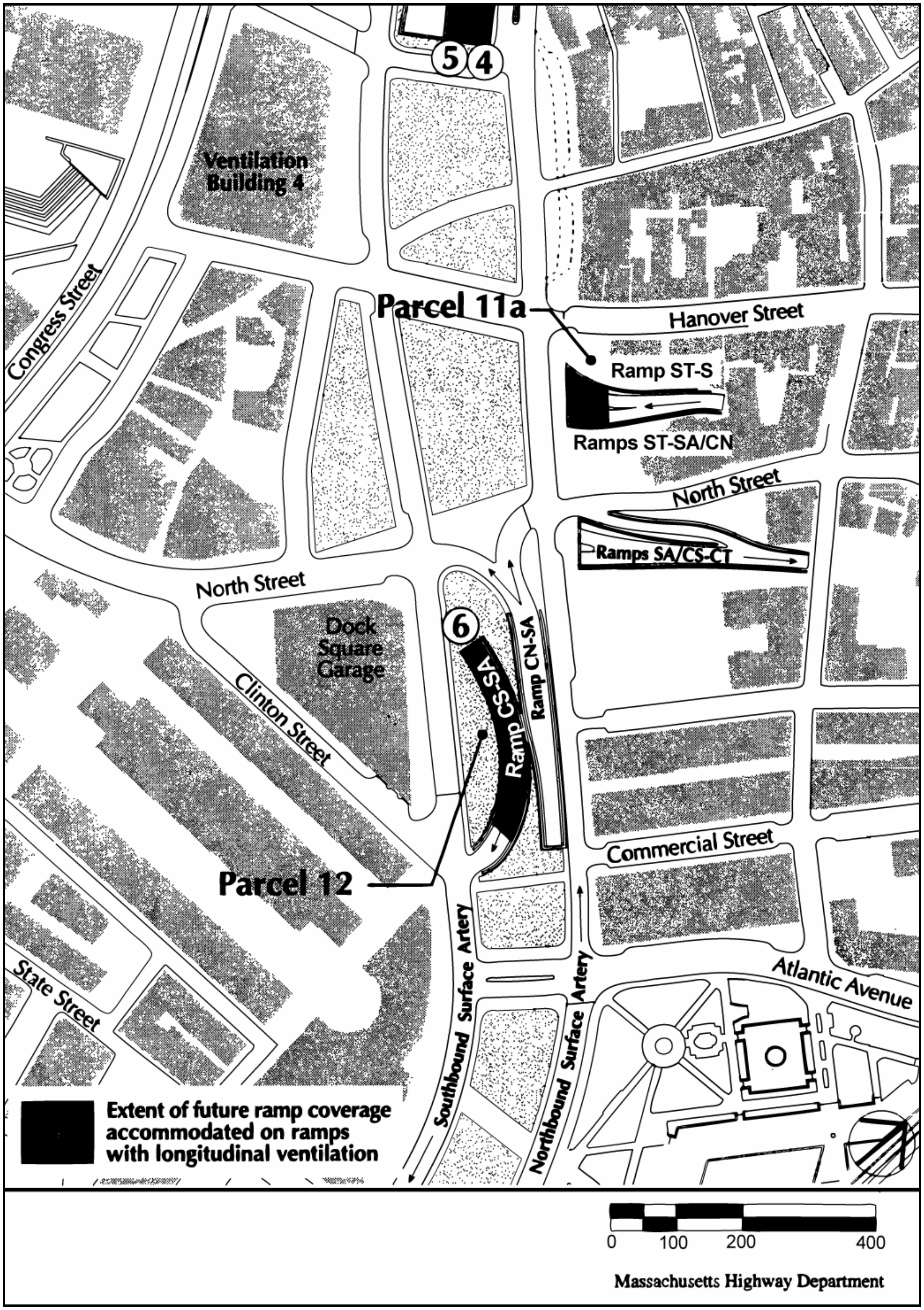


FIGURE 1-16: LOCATION OF RAMP PORTAL 7 (CS-P)

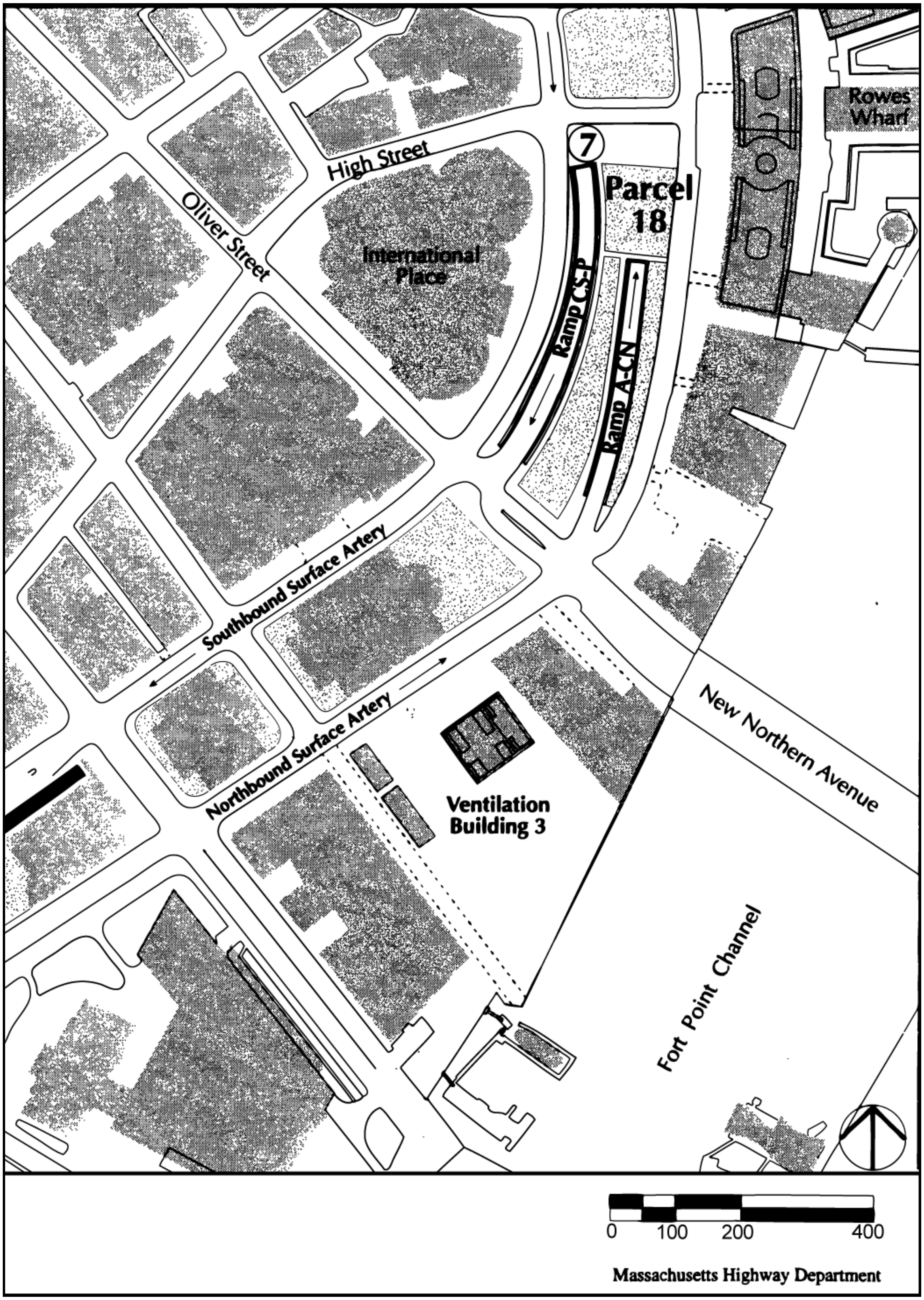
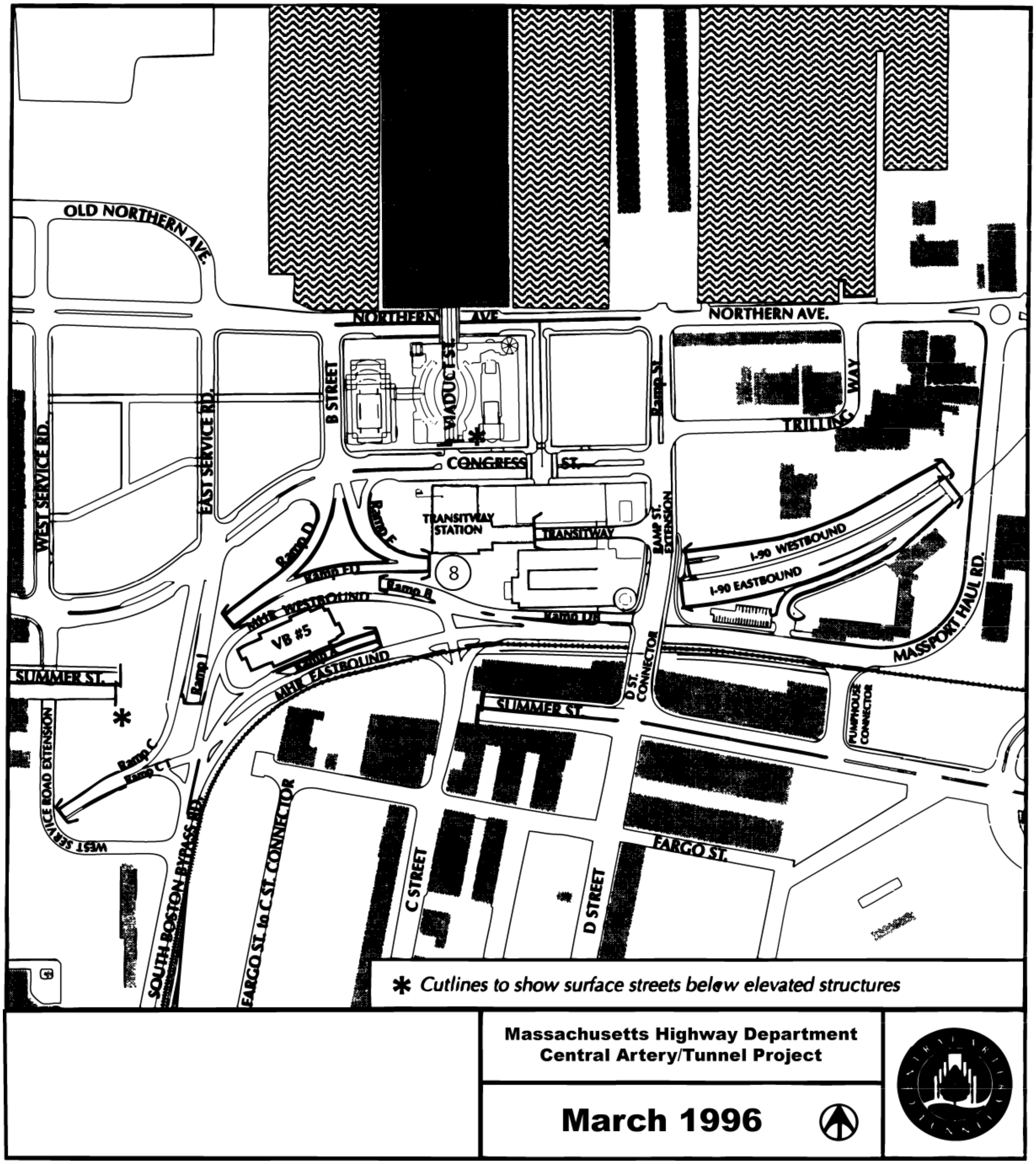


FIGURE 1-17: LOCATION OF RAMP PORTAL 8 (F)



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 and subsequently revisited and updated in 2011. 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 decade 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.

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 and catalysts 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.

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.

In addition, the emissions data collected inside the CA/T tunnel (and summarized in this report) indicate that safe in-tunnel air quality levels were maintained during the past five years. The results of the monitoring program and corrective actions indicated that despite a very few instances between 2006 and 2011 when abnormal conditions resulted in measured concentrations exceeding the established emission limits, ambient pollutant levels outside the tunnels never exceeded the applicable NAAQS and MassDEP One Hour NO_2 Policy Guideline.

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 is 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.

Based on discussions with MassDEP, MassDOT understands that 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 the 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 jets 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 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. It 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

	Heights of Ventilation Buildings and Stacks Above Grade (feet)	
VB	**Building Roof**	**Stacks**
VB1	82	121
VB3	239	278
VB4	80	131
VB5	117	178
VB6	60	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 (depending on the level of air flow delivered). 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 1-18 provides a view of a supply fan at VB7 with the CO and PM_{10} monitoring unit.

FIGURE 1-18: SUPPLY FAN AT VB 7 AIR INTAKE FLOOR

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 Logon International Airport (Terminal -Arrival/Departure)

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 dimensions, number of lanes and mechanical ventilation capacities of the DST and the eight longitudinally ventilated ramps exit portals are provided in Table 1-3. Figure 1-19 provides a view of a side-mounted jet fan.

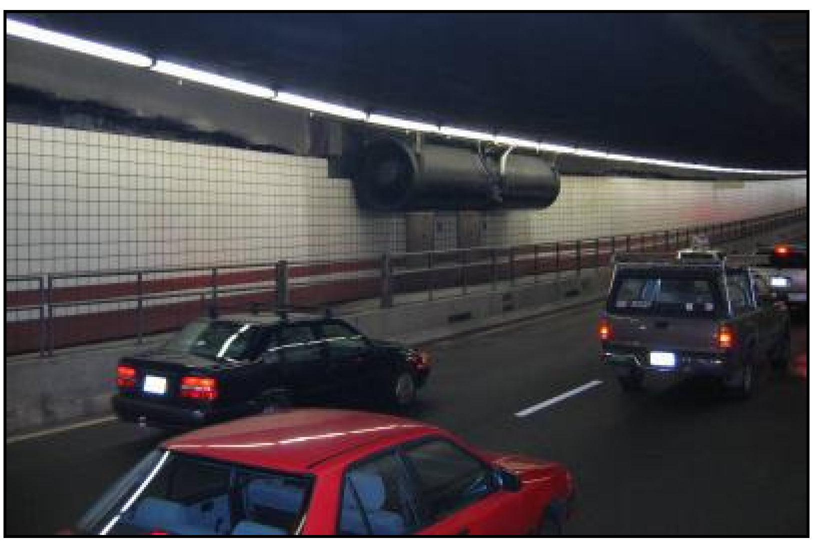
TABLE 1-3: LONGITUDINAL VENTILATION TUNNEL SECTION DIMENSIONS AND MECHANICAL VENTILATION CAPACITIES

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 1-19: JET FAN AT LONGITUDINALLY VENTILATION RAMP



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 1-4: 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 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 six years indicate that these assumptions remain valid.

2 DETERMINATION OF EMISSION LIMITS

In compliance with MassDEP Regulation 310 CMR 7.38, during 2006 the CA/T Project filed an Operating Certification for the Project's Tunnel Ventilation System in which it established emission limits for the exhaust of each ventilation building, Dewey Square tunnel and longitudinal ventilated exit ramps. MassDEP gave final acceptance to the 2006 CA/T Operating Certification on December 22, 2006.

The 2006 Operating Certification established tunnel emission limits for CO, NOx and PM_{10} to demonstrate compliance with ambient air quality standards for CO, NO_2, and PM_{10} and state guideline value for NO_2. It also established a regional emission budget for volatile organic compounds based on the 2005 CA/T build predictions, which included highway and transit components. MassDEP Regulation 310 CMR 7.38 requires a renewal of 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 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 from the 2006 submittal. The final 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 $PM_{2.5}$ and demonstrated compliance with the $PM_{2.5}$ 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. The 2011 CA/T Operating Certification also demonstrated that the VOC regional emissions for 2010 were below the VOC budget based on the 2005 CA/T build predictions that 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 NO_x that would demonstrate compliance with the new 1-hour NAAQS for NO_2. The 2011 CA/T Renewal Operating Certification proposed to retain the existing emission limits for NO_x and CO for all project ventilation buildings and longitudinally ventilated ramps until the approval of the supplemental application in 2012.

MassDEP issued a conditional acceptance of the CA/T Renewal Operating Certification submitted on July 1, 2011 in its letter dated December 19, 2011. The conditional acceptance includes a list of specific requirements and covers five-year operating period from December 19, 2011 to December 19, 2016. The supplemental application, to be submitted on July 1, 2012, augments the 2011 Operating Certification. The supplemental application will cover the remaining four-year period from the date of the MassDEP approval of the supplemental application through December 19, 2016.

2.1 PROJECT PRECONSTRUCTION CERTIFICATION ACCEPTANCE RECORD

The following section remains unchanged from the 2011 CA/T Renewal Operating Certification and is reprinted here for completeness of this document.

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 September 10, 1992, MassDOT submitted an amendment to the Pre-Construction Certification to update technical information based on design refinements to the CA/T Project and to provide a basis for MassDEP to clarify the requirements of Section VI of the 1991 Technical Support Document (that was submitted with and in support of the Pre-Construction Certification) to provide consistency with the 1991 Transit Regulations, 310 CMR 7.36, and HOV Regulations, 310 CMR 7.37, that were adopted by MassDEP in December 1991.

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 1999 Amendment to the Pre-Construction (Amended Pre-Construction Certification) superseded the 1992 amendment. Submitted with and in support of the Amended Pre-Construction Certification was a 1999 Technical Support Document that updated, but did not replace, the 1991 Technical Support Document to reflect analyses performed in connection with design changes to the CA/T Project since 1991 that had been reviewed through the Massachusetts Environmental Policy Act (MEPA) and that had then been incorporated as part of the CA/T Project design. In addition, the 1999 Technical Support Document updated Section VI, of the 1991 Technical Support Document on “Methods to Minimize Miles Traveled” to reflect the current status of the demand reduction strategies and transportation control measures included in the planning and implementation programs of the Executive Office of Transportation and Construction (EOTC), now the Executive Office of Transportation (EOT).

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. After review of the information submitted by MTA, MassDOT and EOTC and the information presented at the public hearings and during the public comment period, MassDEP accepted the Amended Pre-Construction Certification subject to certain conditions in a document dated September 1, 2000 entitled “DEP Determination on the Amended Pre-Construction Certification of the CA/T Project under 310 CMR 7.38” (MassDEP Determination). Among those conditions was an Administrative Consent Order (ACO) by and between MassDEP and EOTC, also dated September 1, 2000 that was incorporated by reference into and thereby made part of the MassDEP Determination. The ACO has been twice amended; Amendment #1 on May 23, 2002 and Amendment #2 on January 26, 2005.

The Pre-Construction Certification and the Amended Pre-Construction Certification required a number of mitigation measures designed to “ ... mitigate potential adverse air quality impacts from the CA/T Project and to meet the criteria for project certification.” To address delays in certain mitigation measures, the ACO and amendments to the ACO required additional measures to be implemented to provide reductions in VMT and emissions during the delay of the required mitigation measure.

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 $\mu g/m^3$; 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.

During the past five years, the 24-hour NAAQS for particulate matter equal to or smaller than 2.5 microns in diameter ($PM_{2.5}$) was modified, and MassDEP required that the 2011 renewal included emission limits for $PM_{2.5}$. The limits for $PM_{2.5}$ replace the limits for PM_{10}.

During the spring of 2010, MassDEP determined that the recertification should also include a demonstration of compliance with the new 1-hour NO_2 NAAQS of 188 $\mu g/m^3$ equivalent to approximately 100 ppb. The 2006 NO_x emission limits, currently in effect, 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 policy guideline for nitrogen dioxide do not apply during emergency conditions (i.e., tunnel fires).]

MassDOT is required to establish 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. Actual CA/T operating experience and measured in-tunnel pollutant concentration levels thus far are taken into consideration in determining these emission limits.

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 permanent PM_{10} monitor was installed in 2006 at outside exit Ramp CS-SA to determine if the emissions from the longitudinally ventilated ramps could cause high PM_{10} levels in the adjacent areas. In the end of 2011 all PM_{10} monitors were converted to monitor $PM_{2.5}$. NO_x levels at each CEM monitoring location were determined as a function of the hourly monitored CO levels. The monitoring results and the calculated NO_x levels were compared to their predetermined emission limits for compliance assessment.

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 2011 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 2006 APPLICATION

The following section remains unchanged from the 2011 CA/T Renewal Operating Certification and is reprinted here for completeness of this document.

The 2006 Operating Certification established tunnel emission limits for CO, NOx and PM_{10} to demonstrate compliance with ambient air quality standards for CO, NO_2, and PM_{10} and state guideline values for NO_2.

The final acceptance letter by MassDEP dated December 22, 2006 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 2006 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_{10} Emission Limit ($\mu g/m^3$)
VB 1	70	70	8.88	500
VB 3	70	70	8.88	500
VB 4	70	70	8.88	500
VB 5	70	70	8.88	500
VB 6	70	70	8.88	500
VB 7	70	70	8.88	500
Ramp L-CS	52	39	6.64	NA
Ramp CN-S	66	58	8.38	NA
Ramp SA-CN	70	70	8.88	NA
Ramp ST-CN	70	70	8.88	NA
Ramp ST-SA	70	51	8.88	NA
Ramp CS-SA	56	46	7.14	150**
Ramp CS-P	70	70	8.88	NA
Ramp F	70	70	8.88	NA
Dewey Sq. Tunnel	25	23	3.30	NA

* For VBs, location includes all ventilation zones of this VB.
** The ambient PM_{10} 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 2011 RENEWAL OF CERTIFICATION PROCESS

The 2011 CA/T Renewal Operating Certification included new emission limits for $PM_{2.5}$ and demonstrated compliance with the $PM_{2.5}$ 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. The 2011 Operating Certification 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.

2.5.1 $PM_{2.5}$ Limits

The results of the analysis in 2011 TSD indicated that a $PM_{2.5}$ emission limit of 900 $\mu g/m^3$ demonstrates compliance with the $PM_{2.5}$ annual and 24-hour NAAQS.

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.

Since the modeling methodology for the VB $PM_{2.5}$ analysis is integrated into the CO and NOx analysis for VBs, the $PM_{2.5}$ analysis and results are also described in section 2.6.

2.5.2 VOC Compliance

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

The 2011 renewal application demonstrated compliance with 310 CMR 7.38(2)(c) (non-methane hydrocarbon budget) established for the year 2005, in the original Operating Certification approved by

MassDEP in 2006 (6,095.9 kg/day). The renewal application demonstrated that the VOC emissions in 2010 were 3,906.9 kg/day, far below the budget of 6,095.9 kg/day.

The 2011 compliance demonstration calculated the 2010 VOC emissions for each area using the CTPS model area for Eastern Massachusetts including the highway, transit, and commuter rail components. The analysis and results are also described in section 2.6.

2.5.3 Revised CO and NO_2 Limits and Need for Supplemental Application

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 delayed 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 new NO_2 NAAQS requires 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 new 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. The OLM technique conservatively 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 conversion rates were likely lower and that monitoring-based approach was a more appropriate method to establish the revised emission limits for NO_x.

Since NOx 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-NOx correlation.

2.5.4 Dewey Square Tunnel Monitoring Program

A four station NO_x monitoring network was deployed by MassDOT along Albany Street and within the DST. 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 is located 258 feet from the exit portal. Monitor Number 2 is located 126 feet from the exit portal. Monitor Number 3 is located 6 feet from the exit portal. Monitor Number 4 is located inside the DST approximately 150 feet north of the exit portal, and measures concentrations within the tunnel itself. Figure 2-1 provides the location of each monitor.

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 1, 2011 and it will operate until the end of 2012. NO, NO_2 and NO_x are monitored on an hourly average basis at each monitoring location. Table 2-2 provides a summary of the data collected.

These concentrations have been reported monthly to the MassDEP. The network uses EPA certified monitoring equipment and is 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) is being used to support the modeling effort for the compliance demonstration to determine the revised NOx and CO limits at the VBs, DST, and Longitudinally ventilated Ramps.

Section 2.6 explains in more detail the use of this data for the NOx levels determine as a function of CO levels within the CEM program, and the NO to NO_2 conversion factor used in the compliance demonstration to meet the one-hour NO_2 NAAQS. Further description and results on the DST NO_x Monitoring program are provided in Appendix H.

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

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.

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 CA/T Renewal Operating Certification. Appendix B-2 provides updated models, parameters and procedures for the determination of $PM_{2.5}$ emission limits and for the VOC budget compliance analysis. The 2012 air quality analysis protocol contains procedures for the determination of CO and NO_x emission limits, as approved by MassDEP (see Appendix B-3).

The following sections briefly summarize the methodology employed.

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 Emission Limits for CO, NO_x, and $PM_{2.5}$

The averaging times associated with the 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.

2.6.3 Predictive Model for NO_x Emission Estimates

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 20,000 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 new 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. 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 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 at 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*** changes with unit change of ***X***.

The equation developed from this data was used in the modeling analysis and will estimate the hourly NO_x levels is:

NO_x = 0.2956 + 0.0829*CO

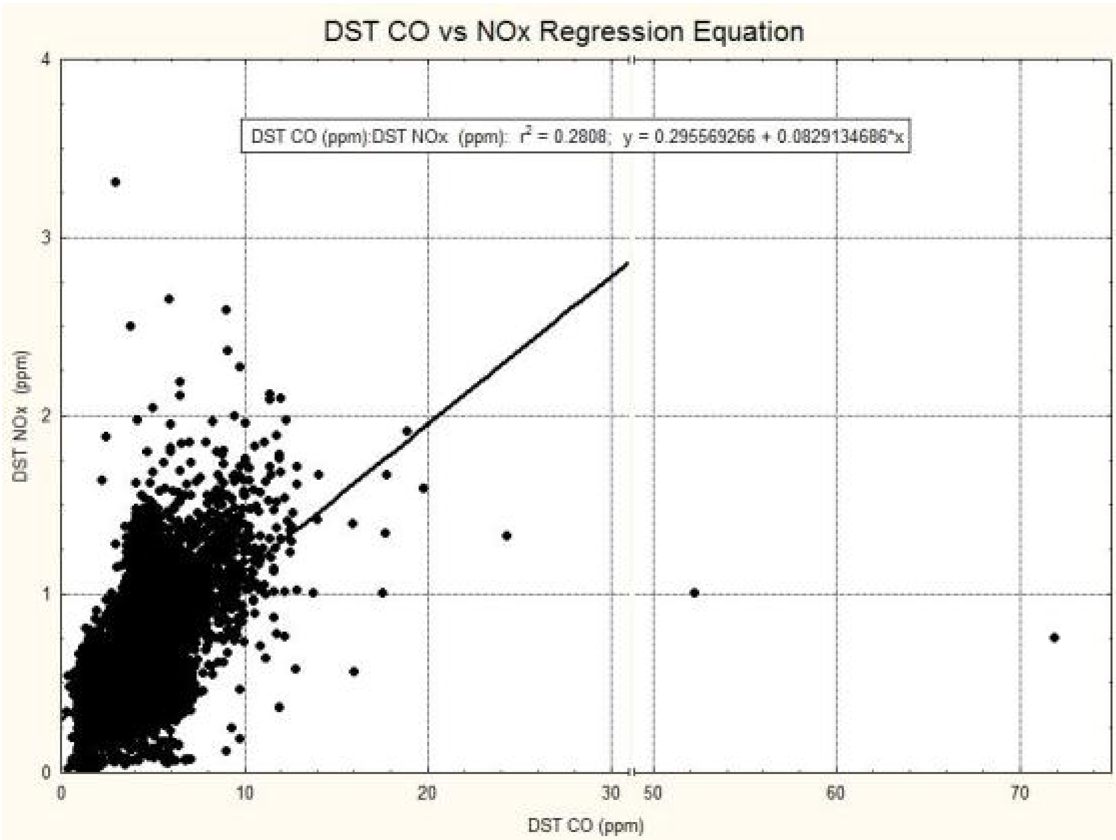
Table 2-3 presents calculated NO_x concentrations at selected CO concentrations based on the regression equation.

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

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. 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, 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.

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.

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 (DECEMBER – FEBRUARY)	AVERAGE	**0.07**	**0.07**
	STANDARD DEVIATION	0.08	0.08
FULL YEAR RESULTS	**WEIGHTED AVERAGE**	**0.082**	**0.068**
	STANDARD DEVIATION	0.08	0.09

2.6.5 Representative Surface and Upper Air Meteorological Data

The 2011 demonstration used the most recently available five years (2006–2010) 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. These data were used for $PM_{2.5}$ analysis. For this 2012 supplemental application the Logan airport surface and Gray, Maine, upper air data from 2007 through 2011 were used for the NO_2 and CO compliance demonstrations.

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 O_3 and as attainment for PM_{10} and NO_2. In addition, since the Boston area had previously been re-classified from nonattainment to attainment for CO, it was considered a maintenance area for that pollutant.

The last violation in the state of the CO NAAQS occurred in 1986. In 2000, MassDEP formally requested that the EPA re-designate the cities of Lowell, Springfield, Waltham, and Worcester as attainment for CO since the CO monitoring data for those cities had been below the standard for many years. With the re-designation of these cities to CO attainment status in April 2002, the entire state acquired attainment status and has remained in attainment ever since.

In December 2008, EPA designated Massachusetts as "Attainment/Unclassifiable" area statewide for the 2006 24-hour $PM_{2.5}$ standard based on monitoring data.

2.6.7 Background Concentration Levels

Background pollutant concentrations used in the 2011 CA/T Renewal Operating Certification ($PM_{2.5}$ levels) and this supplemental application (NO_2 and CO levels) 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.

$PM_{2.5}$ Background

The background $PM_{2.5}$ data from the two collocated $PM_{2.5}$ monitors at the North Street monitoring site served as the primary source of data for determining background air quality. The $PM_{2.5}$ data from North Street are relatively complete in recent years. There were only a small number of days (5 or less) in any year in the period (2006 – 2010) for which no valid data from North Street were available (see Table 2-5).

TABLE 2-5: DAYS WITH VALID $PM_{2.5}$ CONCENTRATIONS AT NORTH STREET MONITORING SITE

Year	POC-1	POC-2	POC-1 or POC-2
2010	361	349	361
2009	360	342	360
2008	366	353	366
2007	365	343	365
2006	359	294	361

Notes:
1. POC = Parameter Occurrence Code
2. POC-1 refers to the designated primary PM2.5 monitor.
3. POC-2 refers to the collocated PM2.5 monitor.

An annual monitoring design value for $PM_{2.5}$ was determined based on monitoring data from the North Street monitoring site for the most recent three calendar years (2008 through 2010) as follows:

- If valid data were available from both North Street monitors on a given day, then the daily averages at each monitor were averaged to obtain a background value for the day.
- If valid data were available from only one of the North Street monitors on a given day, then the valid data from that monitor were used to define a background value for the day.
- The annual average concentration was calculated for each year based on days with valid data.
- The annual average concentrations in each of the three years in the period were averaged to define the annual monitoring design value.

The annual background concentrations are summarized in Table 2-6. The average of the annual average concentrations over the last three years (10.5 $\mu g/m^3$) was selected as the annual monitoring design value and incorporated in the compliance demonstration for the annual NAAQS for $PM_{2.5}$.

TABLE 2-6: ANNUAL $PM_{2.5}$ LEVELS AT NORTH END MONITORING STATION

Year	Annual Average $PM_{2.5}$ ($\mu g/m^3$)
2010	10.1
2009	10.3
2008	11.1
(2008 – 2010) Design Value	10.5

Daily background concentrations for $PM_{2.5}$ were defined for each day in the five-year period (2006 – 2010) that was used for the compliance demonstration with the 24-hour NAAQS for $PM_{2.5}$. The following procedure was used to define background air quality for each day in the five year period:

- If valid data were available from both North Street monitors on a given day, then the daily averages at each monitor were averaged to obtain a background value for the day.
- If valid data were available from only one of the North Street monitors on a given day, then the valid data from that monitor were used to define a background value for the day.

- If no valid data were available from North Street monitors on a given day, the 24-hour average from the Harrison Avenue monitor was used if available.
- If no valid data were available from North Street or Harrison Avenue monitors for a given day, then the higher of the two background values already selected for the prior and following days was selected.

NO_2 Background

In the 2007 through 2011 time period ambient NO_2 concentrations were measured at several air quality monitoring stations in the Boston area, including four sites in Boston. MassDEP operates and maintains Federal Reference Method (FRM) monitors for NO_2 at four sites in Boston: Kenmore Square, 531 East First Street, Harrison Avenue, and Long Island.

Monitoring sites are located and established for various purposes. Table 2-7 summarizes several characteristics of the NO_2 monitoring sites and their surroundings in Boston as obtained from the EPA AirData website.

TABLE 2-7: BOSTON NO_2 MONITORING SITES 2007-2011

Parameter	Monitoring Locations			
	Kenmore Square	**531A East First Street**	**Harrison Avenue**	**Long Island**
Monitor Type	SLAMS	Industrial	SLAMS	SLAMS
Site ID	250250002	250250040	250250042	250250041
Measurement Scale	Microscale	Neighborhood	Neighborhood	Urban Scale
Dominant Source Type	Mobile	N/A	Area	N/A
Monitoring Objective	Population Exposure/ Highest Concentration	Population Exposure	Population Exposure	Population Exposure
Location Type	Commercial	N/A	Commercial	N/A
Monitoring Schedule	1 hour	1 hour	1 hour	1 hour
Number of NO2 Monitors	1	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 Harrison Avenue and Kenmore Square sites are the most representative of background concentrations of NO_2 for the Project area. Based on the mixed commercial/residential location of the Harrison Avenue site, the NO_2 monitoring data from the Harrison Avenue monitoring site are used as the primary source of data to establish NO_2 background levels representative of modeling domain. These background levels are incorporated in the analyses to demonstrate compliance with NAAQS for NO_2 for the ramp, portal, and VB NO_x emission limits.

Harrison Avenue data, with Kenmore Square data as a substitute are used as hourly background values in the VB, ramp, and portal NO_2 modeling to demonstrate compliance with the 1-hour NO_2 NAAQS. For the modeled years of 2007 through 2011, the hourly Harrison Avenue values are used. If the observation from Harrison Avenue is missing, then the hourly value from Kenmore Square is used. If there are no observations available from either monitor, the maximum value from the previous or next available hour is used. This is a conservative substitution approach as Kenmore Square typically has higher values then Harrison Avenue and when both are missing the maximum as opposed to the average values from the previous or next available hours is used. Background concentrations are presented in the Appendix C-6. The hourly values are added to the model output to obtain the hourly concentration resulting from the CA/T Ventilation System. These hourly model predicted plus monitored observed concentrations are compared to the 1-hour and annual NO_2 NAAQS, and MassDEP NO_2 Policy guideline.

CO Background

The 2007 through 2011 hourly CO background monitoring data are used to demonstrate compliance with the 1-hour and 8-hour CO NAAQS for the VB CO emission limits. Table 2-8 summarizes characteristics of the CO monitoring sites and their surroundings in Boston as obtained from the EPA AirData website.

TABLE 2-8: BOSTON CO MONITORING SITES 2007-2011

Parameter	Monitoring Locations	
	Kenmore Square	Harrison Avenue
Monitor Type	SLAMS	SLAMS
Site ID	250250002	250250042
Measurement Scale	Microscale	Neighborhood
Dominant Source Type	Mobile	Area
Monitoring Objective	Population Exposure/Highest Concentration	Population Exposure
Location Type	Commercial	Commercial
Monitoring Schedule	1 hour	1 hour
Number of CO Monitors	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

As presented in Table 2-8 the only CO monitors in Boston are Harrison Avenue and Kenmore Square. Those monitors are representative with Harrison Avenue being the primary site as discussed above for NO_2. An hourly background database was created using the same substitution scheme as discussed above for NO_2. The CO NAAQS for 1-hour and 8-hour periods are not to be exceeded more than once per calendar year. The maximum second highest 1-hour and 8-hour impact values that include the hourly CO background for the most recent complete 5-year period (2007-2011) are used for comparison to the CO NAAQS. Background concentrations are presented in the Appendix C-6.

2.6.8 Volatile Organic Compounds (VOC)

Since there are no NAAQS for VOC, concentration-based emission limits for VOC cannot be, and were not established for comparison with measurements at specific receptor locations. As such, direct measurement of VOC without a benchmark level to guide the operation of the ventilation system will not contribute to the protection of the health and welfare of the affected population. Monitoring VOC also will not resolve the aspect of how the total amount of VOC generated within the Project area can be compared to 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 2010 total VOC emissions for the study area are below the established emission budget. (2005 Build)

This process was established in the 2006 TSD application. The 2011 CA/T Renewal Operating Certification application compared regional VOC emissions from current 2010 traffic and vehicle emission factors (instead of future projections) to the 2005 VOC emission budget determined in the 2006 application. The results of the 2011 analysis are repeated in Section 2.7.3.

2.7 EMISSION LIMIT DETERMINATION

In 2011, peak hour traffic volumes in vehicles per hour (VPH) using the mainline tunnels were generally in the range of 7,170 to 7,910 VPH in each direction of I-93 and in the range of 2,960 to 3,530 VPH in each direction of the TWT. The average daily volumes were in the range of 81,000 to 103,700 vehicles per day (VPD) in each direction of I-93 and in the range of 32,300 to 48,000 VPD in each direction of the TWT. The tunnel full transverse ventilation system was operating at Step 1 (13% of exhaust capacity) for normal peak and off-peak traffic conditions.

The 2006-2012 data presented in a summary form (Tables 5-1 to 5-14) indicate the following:

- Measured CO concentrations for the Ventilation Buildings range from 0.5 to 10.1 ppm on average, with maximum 1-hour values as high as 31.4 ppm;
- Measured CO concentrations for the DST and Ramps range from 0.5 to 5.8 ppm on average, with maximum 1-hour average concentrations ranging from 12.6 to 71.9 ppm;
- Measured NO_x levels for the Ventilation Buildings range from 0.3 to 0.7 ppm on average, with maximum 1-hour values ranging from 1.6 to 4.5 ppm;
- Measured NO_x levels for the DST and Ramps range from 0.3 to 0.9 ppm on average, with maximum 1-hour values ranging from 1.8 to 9.1 ppm;
- Measured average daily PM_{10} concentrations in each year were between 31 and 121 $\mu g/m^3$, Maximum daily PM_{10} values were in the range ,of 100 to 577 $\mu g/m^3$ (2006-2011);
- The PM_{10} monitor outside Ramp CS-SA, which measures ambient levels, recorded annual averages from 19 to 21 $\mu g/m^3$, and a maximum daily level of 116 $\mu g/m^3$ (2006-2011);
- Measured $PM_{2.5}$ concentrations in the first 4 months of 2012 were between 6.8 and 40.9 $\mu g/m^3$ on average, with maximum daily values ranging from 23 to 88.1 $\mu g/m^3$;
- The $PM_{2.5}$ monitor outside Ramp CS-SA, which measures ambient levels, in the first four months of 2012, recorded concentrations from 7.6 to 25.5 $\mu g/m^3$.

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.

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 analytical models. The maximum predicted emission impacts, when added to the appropriate background pollutant concentrations were compared to the applicable ambient air quality standards or policy guideline value for compliance assessment. The entire modeling process was repeated until the maximum allowable emission limits at which ambient standards can still be attained were found. The detailed modeling procedures to determine VB emission impacts and emission limits can be found in Appendices B2 and B3 of this document.

2.7.1.2 Modeling Methodology

The modeling approach to the $PM_{2.5}$, CO and NO_x emission limit determinations was updated to incorporate current models, modeling guidance, treatment of terrain, and more recent meteorological and background data. The 2006 VB emission impact analysis was performed using the EPA's Industrial Source Complex–Prime Model (ISC-Prime, 2004) in conjunction with the then most recent background air quality data collected in the area and five years of representative hourly meteorological data (see Section 2.6.7). Sensitive receptors such as building air intakes, operable windows, pedestrian walkways and potential receptors on proposed redevelopment projects within 2000 feet of each VB were updated to reflect the existing environment and future commercial development projection.

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. Fan speeds are controlled by 8 set point steps.

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. A spectrum of four ventilation scenarios (based on fan steps 2, 3, 4 and 5) were selected to be modeled.

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

The $PM_{2.5}$, 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-2 and B-3. AERMOD was run in the urban mode using recommended regulatory default options.

The 2006 analysis initially considered four ventilation scenarios (based on fan steps listed in Table 2-9). Since 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 2011 CA/T Renewal Operating Certification was based on step 4 fan speeds, the highest ventilation rate under the normal operations, which corresponds to 42% of ventilation capacity. 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.

TABLE 2-9: 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

At each receptor location, an average of the eighth highest 24-hour concentrations including the corresponding background concentration for that day for the five modeled years was compared to the 24-hour NAAQS for $PM_{2.5}$. The annual average project impact at each receptor over five modeled years with addition of the annual background concentration based on the most recent three years of monitoring data was compared to the annual NAAQS for $PM_{2.5}$.

The highest second high 1-hour and 8-hour average CO predicted including hourly monitored background concentrations were compared the NAAQS.

The eighth highest (98th percentile) daily maximum 1-hour predicted including the corresponding hourly monitored background NO_2 concentration averaged over the 5-years at each receptor was compared to the hourly NO_2 NAAQS. The highest second high 1-hour average NO_2 predicted including hourly monitored background concentrations was compared to the MassDEP 1-hour NO_2 policy guideline concentration. The maximum predicted annual average NO_2 concentration with background was compared to the annual NAAQS.

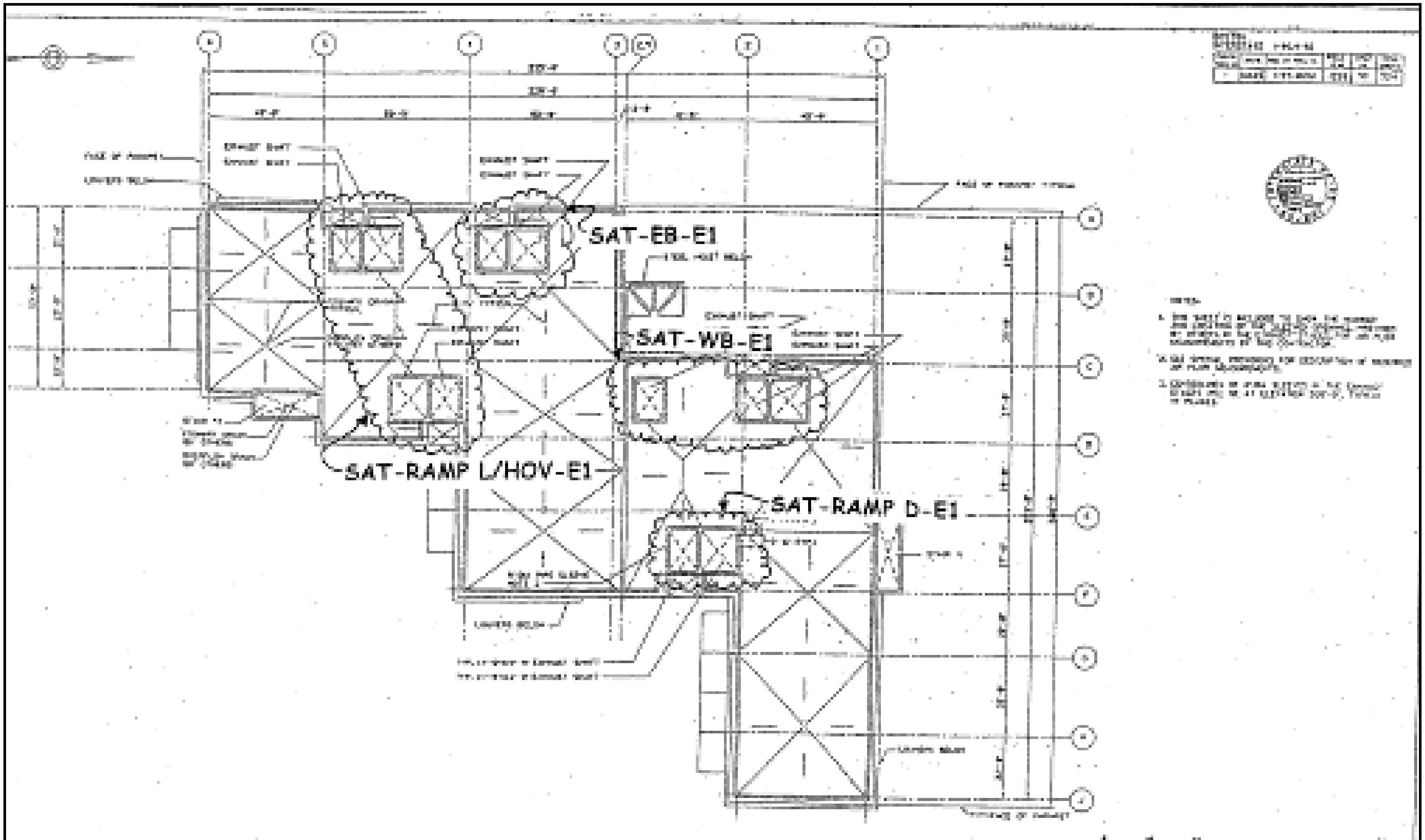
The maximum hourly allowable emission limits (in ppm for gaseous pollutants and $\mu g/m^3$ for particulates) for all VBs are identified using an iterative modeling process by increasing or decreasing the exhaust concentration in a specified interval.

To facilitate the selection of an initial exhaust concentration level to begin the iterative process, computer test runs were made to compare the resulting impacts of different ventilation scenarios (i.e., at fan steps 1, 2, 3 and 4). Modeling results indicate that for a given exhaust concentration level the higher the exhaust rate becomes, the worst the impact gets. Therefore, the worse impact would be associated with the highest ventilation scenario.

Initially a spectrum of four ventilation scenarios (based on fan steps 2, 3, 4 and 5) were selected to be modeled. Based on past CA/T Project-specific operating experience, operating the tunnel at in-tunnel CO level of 70 ppm in combination with fan speed at Step 5 is a very unlikely event. Therefore, a detailed impact assessment associated with such an operating scenario was not considered.

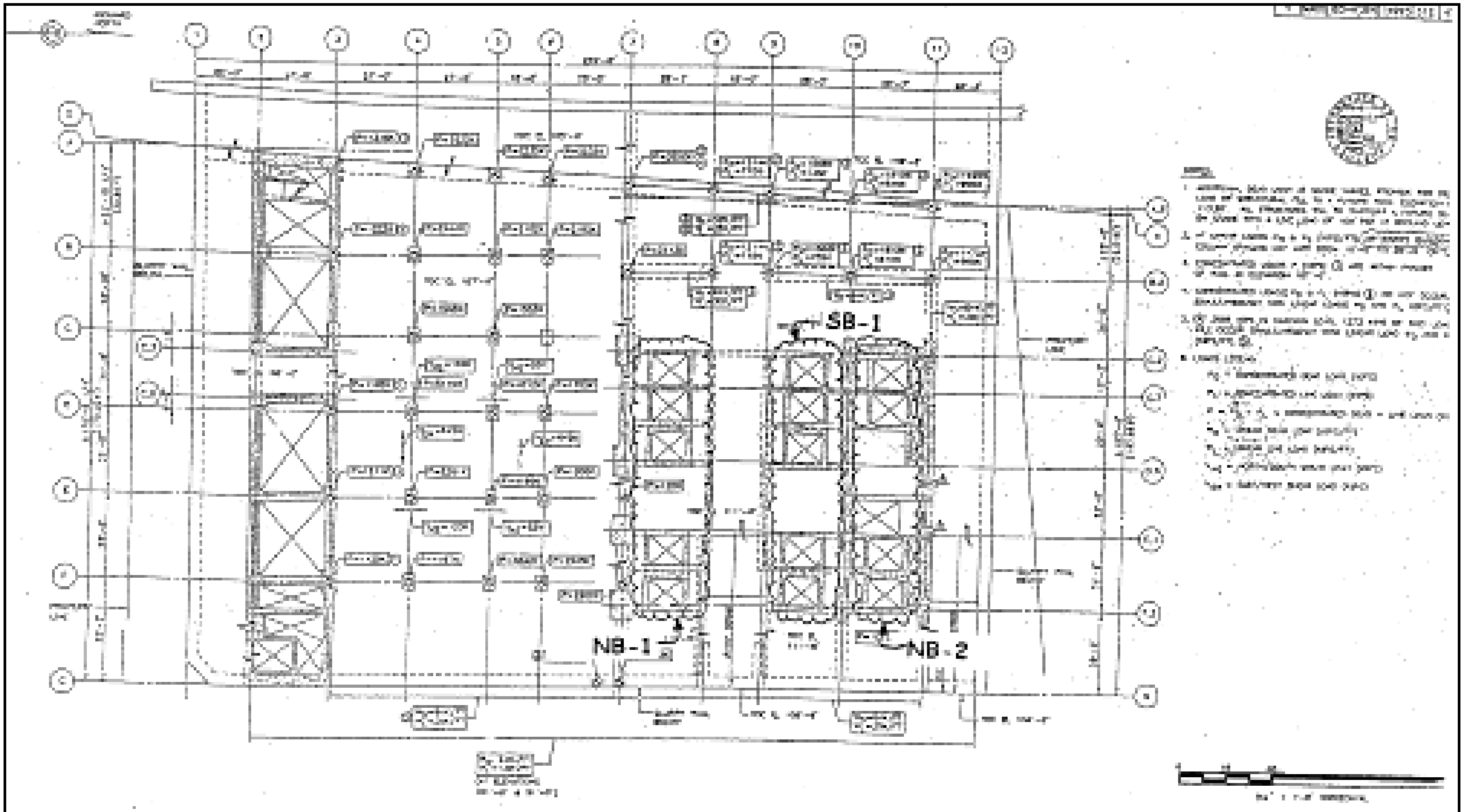
The 2006 model input data, including emission rates, exhaust flow rates, exhaust temperature, and number of fans by ventilation zone are presented in Table 2-10. The stack locations and configurations for all VBs are shown on Figures 2-3 through 2-8. Representative stack locations and sensitive receptors used in the modeling analysis are presented in Appendix B-2 and B-3 in the 2011 and 2012 Air Quality Analysis protocols in sections 5-4 and 5-5 for 2011 and 11-5 and 11-6 for 2012 analysis. They sensitive receptors are also presented at Figure 2-9. The 2011 and 2012 VB modeling analysis input and output data are in Appendix C-2 and C-4, respectively. Background levels used in this analysis are described in Section 2.6.7.

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

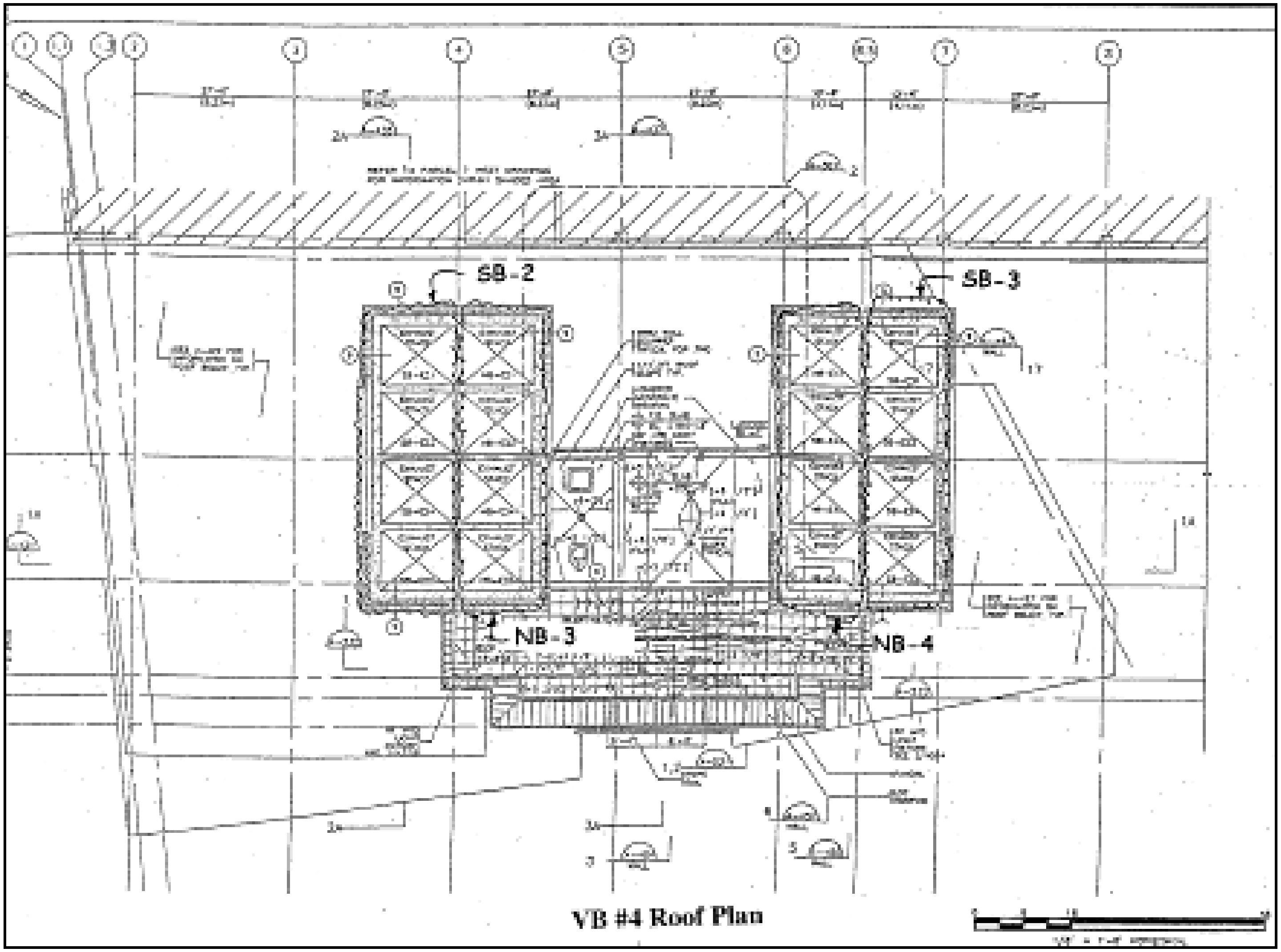
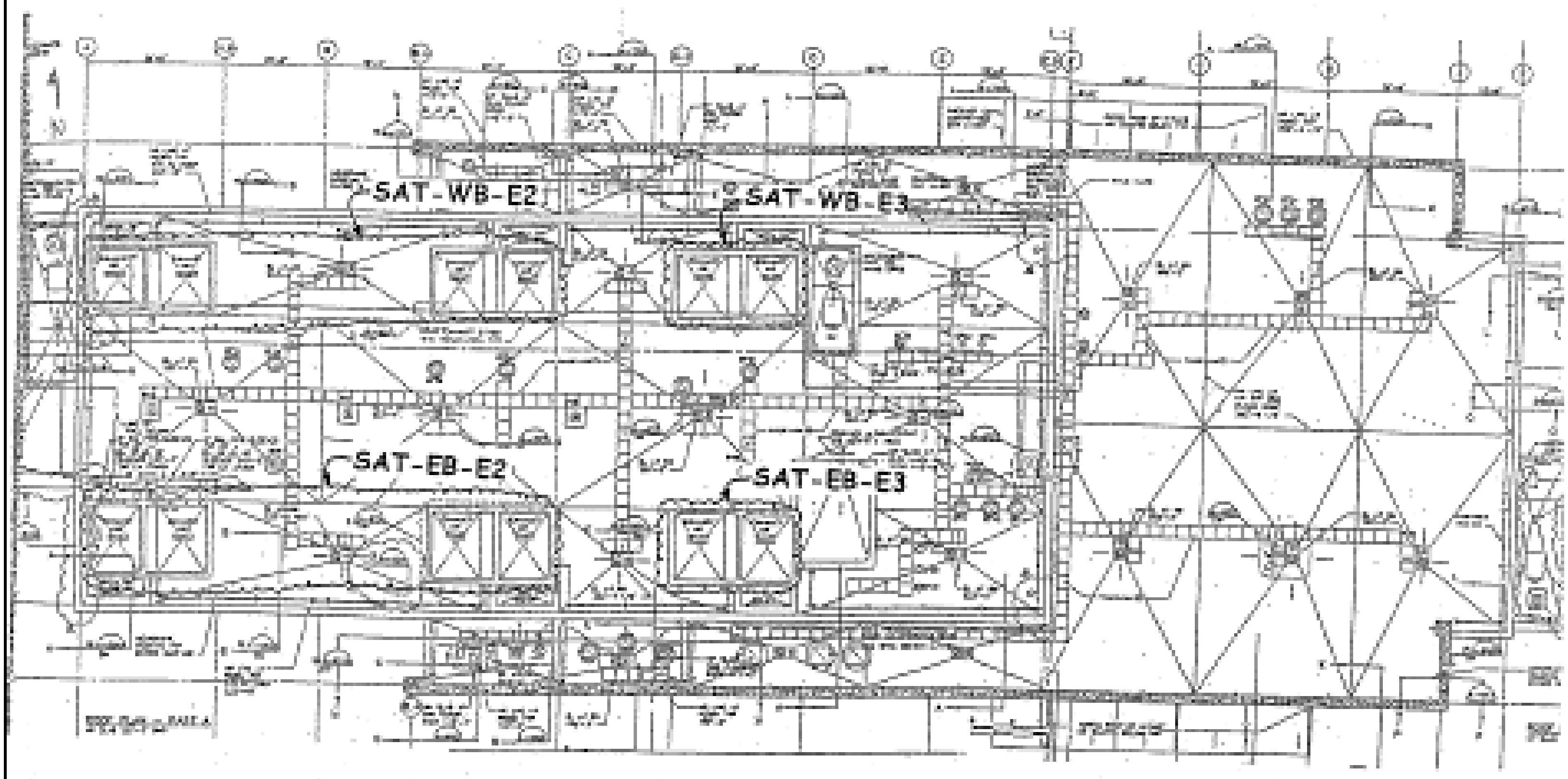
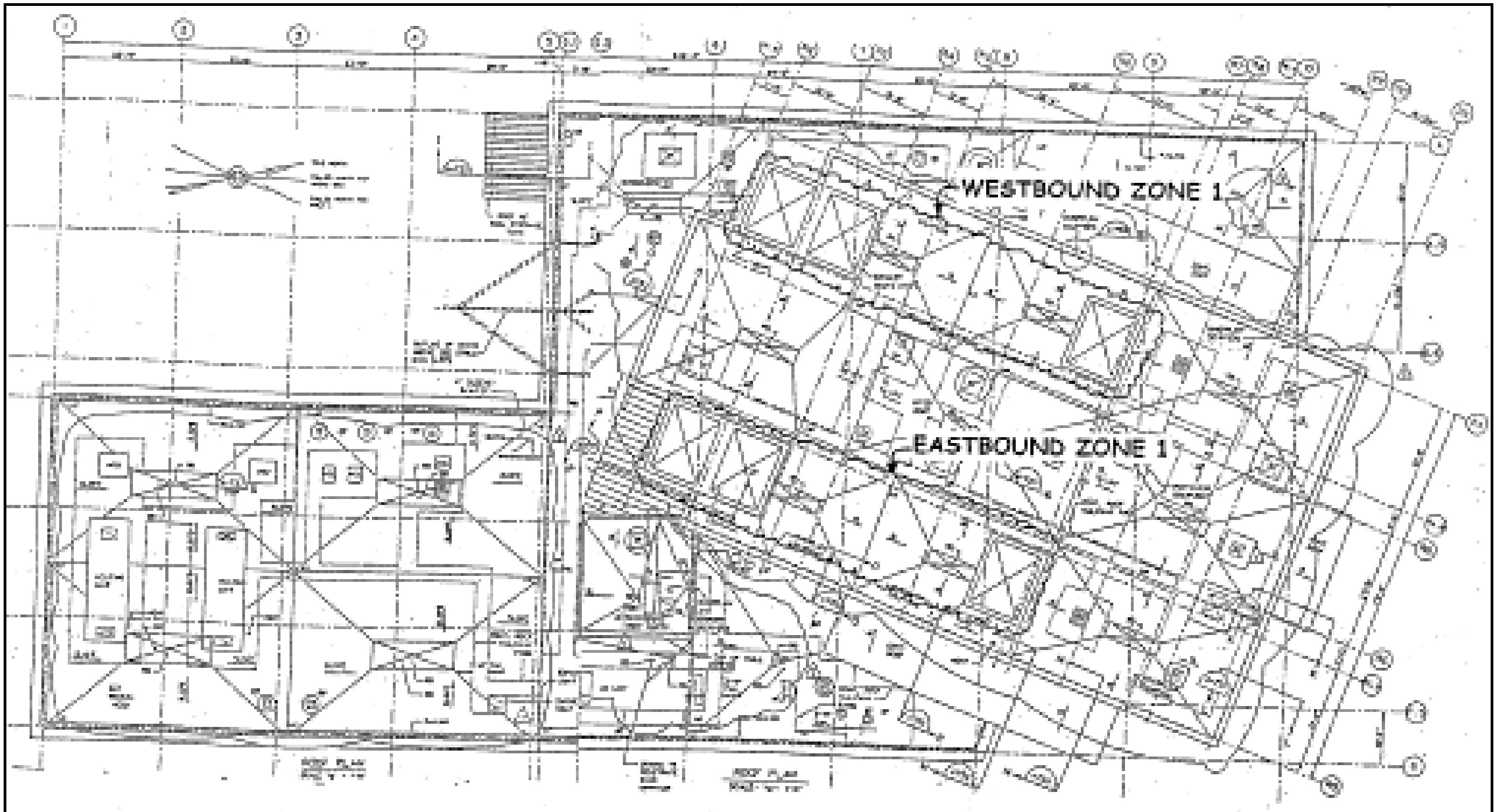


FIGURE 2-6: STACK CONFIGURATION VENTILATION BUILDING 5



VB #5 Roof Plan

FIGURE 2-7: STACK CONFIGURATION VENTILATION BUILDING 6



VB #6 Roof Plan

FIGURE 2-8: STACK CONFIGURATION VENTILATION BUILDING 7

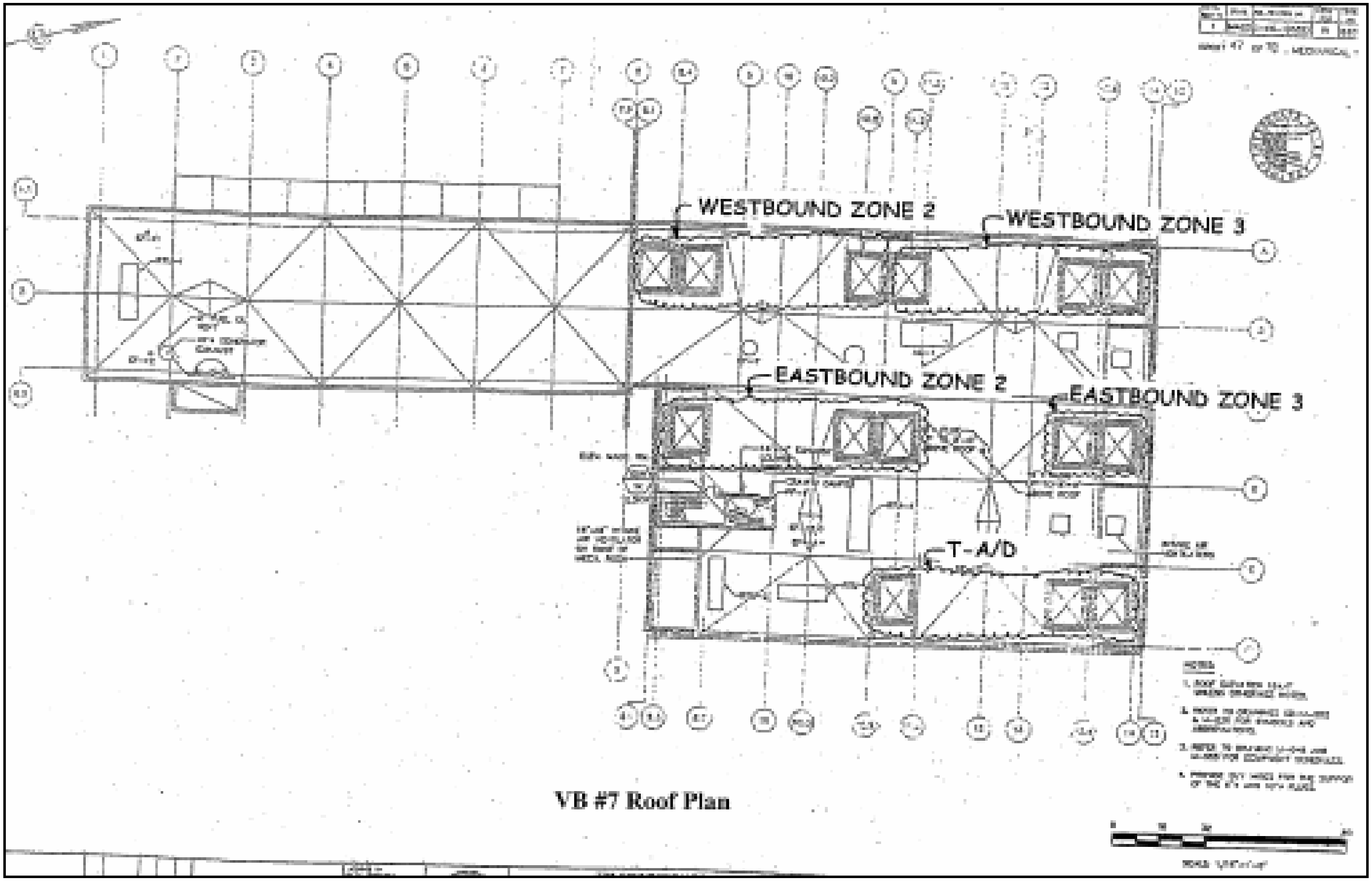


TABLE 2-10: MODEL INPUT PARAMETERS FOR VENTILATION BUILDINGS

Vent Building 3 (I-93 Tunnel)			Temperature	70	°F			Assumed								ISC Input		1 ppm of NOx =		1259.72	ug/m3
Vent Bldg	**Zone**	**# of Fans**	**Capacity/ Fan (CFM)**	**Exhaust Capacity (CFM)**	**Step Used**	**% Capacity Used**	**Flow Rate (CFM)**	**PPM CO**	**Molecular Weigt CO**	**CO Density (lb/ft^3)**	**CFM CO**	**Total Mass Flow CO (g/sec)**	**Mass Flow CO/Stack (g/sec)**	**Area of a single cell (ft^2)**	**Total Exit Area (ft^2)**	**Exit Vel. (m/s)**	**Equ. Dia. (m)**	**NOx Conc. (ppm)***	**NOx Molecul ar Wt****	**NOx Conc. (ug/m3)**	**NOx Emis. (g/s)**
3	SB-1	5	214000	1070000	4	0.42	449400	70	28	0.07238	31.46	17.21	3.44	106.6	533	4.28	7.94	8.876	30.8	11181.3	2.37
3	NB-1	5	251630	1258150	4	0.42	528423	70	28	0.07238	36.99	20.24	4.05	106.6	533	5.04	7.94	8.876	30.8	11181.3	2.79
3	NB-2	4	284750	1139000	4	0.42	478380	70	28	0.07238	33.49	18.32	4.58	106.6	426.4	5.70	7.10	8.876	30.8	11181.3	2.52

Vent Building 4

Vent Bldg	Zone	# of Fans	Capacity/ Fan (CFM)	Exhaust Capacity (CFM)	Step Used	% Capacity Used	Flow Rate (CFM)	PPM CO	Molecular Weigt CO	CO Density (lb/ft^3)	CFM CO	Total Mass Flow CO (g/sec)	Mass Flow CO/Stack (g/sec)	Area of a single cell (ft^2)	Total Exit Area (ft^2)	Exit Vel. (m/s)	Equ. Dia. (m)	NOx Conc. (ppm)*	NOx Molecul ar Wt**	NOx Conc. (ug/m3)	NOx Emis. (g/s)
4	SB-2	4	237250	949000	4	0.42	398580	70	28	0.07238	27.90	15.27	3.82	106.6	426.4	4.75	7.10	8.876	30.8	11181.3	2.10
4	SB-3	4	282625	1130500	4	0.42	474810	70	28	0.07238	33.24	18.19	4.55	106.6	426.4	5.66	7.10	8.876	30.8	11181.3	2.50
4	NB-3	4	221250	885000	4	0.42	371700	70	28	0.07238	26.02	14.24	3.56	106.6	426.4	4.43	7.10	8.876	30.8	11181.3	1.96
4	NB-4	4	202250	809000	4	0.42	339780	70	28	0.07238	23.78	13.01	3.25	106.6	426.4	4.05	7.10	8.876	30.8	11181.3	1.79

Vent Building 1 (I-90 Tunnel)

Vent Bldg	Zone	# of Fans	Capacity/ Fan (CFM)	Exhaust Capacity (CFM)	Step Used	% Capacity Used	Flow Rate (CFM)	PPM CO	Molecular Weigt CO	CO Density (lb/ft^3)	CFM CO	Total Mass Flow CO (g/sec)	Mass Flow CO/Stack (g/sec)	Area of a single cell (ft^2)	Total Exit Area (ft^2)	Exit Vel. (m/s)	Equ. Dia. (m)	NOx Conc. (ppm)*	NOx Molecul ar Wt**	NOx Conc. (ug/m3)	NOx Emis. (g/s)
1	SAT-Ramp D-E1	2	171500	343000	4	0.42	144060	70	28	0.07238	10.08	5.52	2.76	106.6	213.2	3.43	5.02	8.876	30.8	11181.3	0.76
1	SAT-WB-E1	3	230400	691200	4	0.42	290304	70	28	0.07238	20.32	11.12	3.71	106.6	319.8	4.61	6.15	8.876	30.8	11181.3	1.53
1	SAT-EB-E1	2	281820	563640	4	0.42	236729	70	28	0.07238	16.57	9.07	4.53	106.6	213.2	5.64	5.02	8.876	30.8	11181.3	1.25
1	SAT-Ramp L/HOV-E1	4	235250	941000	4	0.42	395220	70	28	0.07238	27.67	15.14	3.78	106.6	426.4	4.71	7.10	8.876	30.8	11181.3	2.08

Vent Building 5

Vent Bldg	Zone	# of Fans	Capacity/ Fan (CFM)	Exhaust Capacity (CFM)	Step Used	% Capacity Used	Flow Rate (CFM)	PPM CO	Molecular Weigt CO	CO Density (lb/ft^3)	CFM CO	Total Mass Flow CO (g/sec)	Mass Flow CO/Stack (g/sec)	Area of a single cell (ft^2)	Total Exit Area (ft^2)	Exit Vel. (m/s)	Equ. Dia. (m)	NOx Conc. (ppm)*	NOx Molecul ar Wt**	NOx Conc. (ug/m3)	NOx Emis. (g/s)
5	SAT-WB-E2	4	260000	1040000	4	0.42	436800	70	28	0.07238	30.58	16.73	4.18	106.6	426.4	5.20	7.10	8.876	30.8	11181.3	2.30
5	SAT-WB-E3	2	196500	393000	4	0.42	165060	70	28	0.07238	11.55	6.32	3.16	106.6	213.2	3.93	5.02	8.876	30.8	11181.3	0.87
5	SAT-EB-E2	4	278000	1112000	4	0.42	467040	70	28	0.07238	32.69	17.89	4.47	106.6	426.4	5.56	7.10	8.876	30.8	11181.3	2.46
5	SAT-EB-E3	2	279000	558000	4	0.42	234360	70	28	0.07238	16.41	8.98	4.49	106.6	213.2	5.58	5.02	8.876	30.8	11181.3	1.24

Vent Building 6 (Ted Wiliam Tunnel)

Vent Bldg	Zone	# of Fans	Capacity/ Fan (CFM)	Exhaust Capacity (CFM)	Step Used	% Capacity Used	Flow Rate (CFM)	PPM CO	Molecular Weigt CO	CO Density (lb/ft^3)	CFM CO	Total Mass Flow CO (g/sec)	Mass Flow CO/Stack (g/sec)	Area of a single cell (ft^2)	Total Exit Area (ft^2)	Exit Vel. (m/s)	Equ. Dia. (m)	NOx Conc. (ppm)*	NOx Molecul ar Wt**	NOx Conc. (ug/m3)	NOx Emis. (g/s)
6	Eastbound Zone 1	3	300000	900000	4	0.42	378000	70	28	0.07238	26.46	14.48	4.83	106.6	319.8	6.00	6.15	8.876	30.8	11181.3	1.99
6	Westbound Zone 1	3	300000	900000	4	0.42	378000	70	28	0.07238	26.46	14.48	4.83	106.6	319.8	6.00	6.15	8.876	30.8	11181.3	1.99

Vent Building 7

Vent Bldg	Zone	# of Fans	Capacity/ Fan (CFM)	Exhaust Capacity (CFM)	Step Used	% Capacity Used	Flow Rate (CFM)	PPM CO	Molecular Weigt CO	CO Density (lb/ft^3)	CFM CO	Total Mass Flow CO (g/sec)	Mass Flow CO/Stack (g/sec)	Area of a single cell (ft^2)	Total Exit Area (ft^2)	Exit Vel. (m/s)	Equ. Dia. (m)	NOx Conc. (ppm)*	NOx Molecul ar Wt**	NOx Conc. (ug/m3)	NOx Emis. (g/s)
7	Eastbound Zone 2	3	274000	822000	4	0.42	345240	70	28	0.07238	24.17	13.22	4.41	106.6	319.8	5.48	6.15	8.876	30.8	11181.3	1.82
7	Westbound Zone 2	3	231000	693000	4	0.42	291060	70	28	0.07238	20.37	11.15	3.72	106.6	319.8	4.62	6.15	8.876	30.8	11181.3	1.54
7	Eastbound Zone 3	2	226000	452000	4	0.42	189840	70	28	0.07238	13.29	7.27	3.64	106.6	213.2	4.52	5.02	8.876	30.8	11181.3	1.00
7	Westbound Zone 3	3	203000	609000	4	0.42	255780	70	28	0.07238	17.90	9.80	3.27	106.6	319.8	4.06	6.15	8.876	30.8	11181.3	1.35
7	T-A/D	3	194333	583000	4	0.42	244860	70	28	0.07238	17.14	9.38	3.13	106.6	319.8	3.89	6.15	8.876	30.8	11181.3	1.29

Notes:
1. Assumes all fans in a given zone are operating simultaneously.
2. Higher bound assumed conditions represent 70 ppm CO and Step 4 (a high ventilation rate for modeling purpose).
* NOx (ppm) = 0.196 + 0.124CO (ppm)
** NO_x molecular weight assumed for 95% NO and 5% NO_2

2.7.1.3 $PM_{2.5}$ Analysis

This analysis was performed as part of the 2011 CA/T Renewal Operating Certification, which established an emission limit of 900 ug/m^3. For completeness the description is repeated here.

The $PM_{2.5}$ emission limits for the VBs were identified by starting the modeling process at an assumed concentration of 1,000 µg/m^3 for each stack in each VB. The modeling was performed using five years of meteorological data (2006 through 2010, 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 2011 model input data are in Tables 2-11 and 2-12. 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 levels 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 and adding the annual monitoring design value based on the most recent three years of monitoring. The annual design value was then compared to the annual NAAQS for $PM_{2.5}$. If results showed that an NAAQS was exceeded, the prospective $PM_{2.5}$ emission limit was decreased in intervals of 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 (Table 2-13) operating conditions and then repeated to verify that the same emission limit showed compliance with the NAAQS for Step 1 (Table 2-14) operating conditions.

TABLE 2-11: VENTILATION BUILDING EXHAUST AND STACK PARAMETERS – STEP 4 OPERATIONS

Ventilation Building	Number of Fans	Zone	Flow Rate (cfm)	Total Exit Area (ft^2)	Exit Velocity (m/s)	Equivalent Diameter (m)
1	2	SAT-Ramp D-E1	144,060	213.2	3.43	5.02
1	3	SAT-WB-E1	290,304	319.8	4.61	6.15
1	2	SAT-EB-E1	236,729	213.2	5.64	5.02
1	4	SAT-Ramp L/HOV-E1	395,220	426.4	4.71	7.10
3	5	SB-1	449,400	533	4.28	7.94
3	5	NB-1	528,423	533	5.04	7.94
3	4	NB-2	478,380	426.4	5.70	7.10
4	4	SB-2	398,580	426.4	4.75	7.10
4	4	SB-3	474,810	426.4	5.66	7.10
4	4	NB-3	371,700	426.4	4.43	7.10
4	4	NB-4	339,780	426.4	4.05	7.10
5	4	SAT-WB-E2	436,800	426.4	5.20	7.10
5	2	SAT-WB-E3	165,060	213.2	3.93	5.02
5	4	SAT-EB-E2	467,040	426.4	5.56	7.10
5	2	SAT-EB-E3	234,360	213.2	5.58	5.02
6	3	EB Zone 1	378,000	319.8	6.00	6.15
6	3	WB Zone 1	378,000	319.8	6.00	6.15
7	3	EB Zone 2	345,240	319.8	5.48	6.15
7	3	WB Zone 2	291,060	319.8	4.62	6.15
7	2	EB Zone 3	189,840	213.2	4.52	5.02
7	3	WB Zone 3	255,780	319.8	4.06	6.15
7	3	T-A/D	244,860	319.8	3.89	6.15

TABLE 2-12: VENTILATION BUILDING EXHAUST AND STACK PARAMETERS – STEP 1 OPERATIONS

Ventilation Building	Number of Fans	Zone	Flow Rate (cfm)	Total Exit Area (ft^2)	Exit Velocity (m/s)	Equivalent Diameter (m)
1	2	SAT-Ramp D-E1	44,590	213.2	1.06	5.02
1	3	SAT-WB-E1	89,856	319.8	1.43	6.15
1	2	SAT-EB-E1	73,273	213.2	1.75	5.02
1	4	SAT-Ramp L/HOV-E1	122,330	426.4	1.46	7.10
3	5	SB-1	139,100	533	1.33	7.94
3	5	NB-1	163,560	533	1.56	7.94
3	4	NB-2	148,070	426.4	1.76	7.10
4	4	SB-2	123,370	426.4	1.47	7.10
4	4	SB-3	146,965	426.4	1.75	7.10
4	4	NB-3	115,050	426.4	1.37	7.10
4	4	NB-4	105,170	426.4	1.25	7.10
5	4	SAT-WB-E2	135,200	426.4	1.61	7.10
5	2	SAT-WB-E3	51,090	213.2	1.22	5.02
5	4	SAT-EB-E2	144,560	426.4	1.72	7.10
5	2	SAT-EB-E3	72,540	213.2	1.73	5.02
6	3	EB Zone 1	117,000	319.8	1.86	6.15
6	3	WB Zone 1	117,000	319.8	1.86	6.15
7	3	EB Zone 2	106,860	319.8	1.70	6.15
7	3	WB Zone 2	90,090	319.8	1.43	6.15
7	2	EB Zone 3	58,760	213.2	1.40	5.02
7	3	WB Zone 3	79,170	319.8	1.26	6.15
7	3	T-A/D	75,790	319.8	1.20	6.15

The 24-hour and annual modeling results for each VB and for the cumulative impact from all are presented in Tables 2-13 and 2-14, respectively. In the cumulative analysis the receptor with the maximum 8^{th} highest 24-hour concentration averaged over five years for Step 4 was located on the U. S. Post Office Building near VB1 at a height of 33 meters above ground level. The controlling concentration (33.6 $\mu g/m^3$) was due entirely to impacts from VB1 and background. The impacts from Step 4 were higher than those for Step 1, the level at which the Project ventilation system normally operates. The receptor with the maximum annual Project impact averaged over five years for Step 4 (4.3 $\mu g/m^3$) in the cumulative analysis was a rectangular grid receptor located at ground level immediately adjacent to VB7. Most (approximately 96%) of the controlling impact predicted at this receptor was attributable to emissions from VB7.

TABLE 2-13: MAXIMUM 24-HOUR AND ANNUAL $PM_{2.5}$ CONCENTRATIONS FROM INDIVIDUAL VENTILATION BUILDINGS AT AMBIENT RECEPTORS FOR COMPLIANCE DEMONSTRATION ($\mu G/M^3$) BASED ON A SOURCE LEVEL OF 900 ($\mu G/M^3$)

VB	Predicted 24 hour Design Value	Predicted Annual Design Value
VB 1	33.5	13.1
VB 3	29.2	11.8
VB 4	29.3	11.5
VB 5	30.9	13.1
VB 6	27.2	11.2
VB 7	32.6	14.6

Notes: $PM_{2.5}$ NAAQS: 24-Hour - 35 $\mu g/m^3$; Annual - 15 $\mu g/m^3$
Annual $PM_{2.5}$ background level - 10.5 $\mu g/m^3$

TABLE 2-14: MAXIMUM CUMULATIVE 24-HOUR AND ANNUAL $PM_{2.5}$ CONCENTRATIONS FROM ALL VENTILATION BUILDINGS FOR COMPLIANCE DEMONSTRATION ($\mu G/M^3$) BASED ON A SOURCE LEVEL OF 900 ($\mu G/M^3$)

All VB	Predicted 24 hour Design Value	Predicted Annual Design Value
	33.6	14.8

Notes: $PM_{2.5}$ NAAQS: 24-Hour - 35 $\mu g/m^3$; Annual - 15 $\mu g/m^3$
Annual $PM_{2.5}$ background level - 10.5 $\mu g/m^3$

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 (2007 through 2011, 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 an 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.

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 2007 to 2011 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.

The overall highest second high concentration from all five modeling years was compared to the Massachusetts 1-Hour NO_2 Guideline value. Finally, the highest annual average NO_2 concentration from all five modeling years was compared to the annual NO_2 NAAQS.

2.7.1.5 CO and NOx Input Parameters and Modeling Results

Figure 2-9 presents the sensitive receptor locations analyzed during the modeling compliance analysis for all the VBs.

Table 2-15 and 2-16 present the modeling input parameters with the CO and NO_x emission rates for each VB source for Step 1 and Step 4, respectively. These modeling parameters were input into the AERMOD model and resulted in a demonstration of compliance.

Presented in Table 2-17 are the NAAQS comparable predicted concentrations for CO based on a source level of 70 ppm. All VBs meet the CO NAAQS at a 70 ppm source level.

Table 2-18 presents the predicted NO_2 concentrations from the VBs comparable to the NAAQS. Table 2-19 presents the predicted concentrations comparable to the MassDEP 1-hr NO_2 Guideline. The model predicted concentrations plus the concurrent background concentrations at a source level of 6.1 ppm NOx (equivalent of 70 ppm CO) meet the NO_2 NAAQS and the MassDEP 1-hr NO_2 Guideline.

FIGURE 2-9: SENSITIVE RECEPTORS AND VENTILATION BUILDING LOCATIONS

TABLE 2-15: MODELING INPUT PARAMETERS FOR STEP 1

VB	Zone (TSD Table 2-7)	Zone 2006 Modeling	Zone 2011/2012 Modeling	# of Fans	Fan Capacity (cfm)	Zone capacity (cfm)	Step 1 cfm	Fan area (ft^2)	Exit area (ft^2)	Height (m)	vs (ft/sec)	vs (m/s)	Equiv. D (m)	CO Emission Limit (ppm)	CO Emissions (g/s)	NOx Emission Limit (ppm)	NOx Emissions (g/s)
1	SAT-Ramp D-E1	RampD	B1_RampD	2	171,500	343,000	44,590	106.6	213.2	36.9	3.49	1.06	5.02	70.00	1.69	6.10	0.162
1	SAT-WB-E1	WestB	B1_WestB	3	230,400	691,200	89,856	106.6	319.8	36.9	4.68	1.43	6.15	70.00	3.40	6.10	0.327
1	SAT-EB-E1	EastB	B1_EastB	2	281,820	563,640	73,273	106.6	213.2	36.9	5.73	1.75	5.02	70.00	2.77	6.10	0.266
1	SAT-Ramp L/HOV-E1	RampL	B1_RampL	4	235,250	941,000	122,330	106.6	426.4	36.9	4.78	1.46	7.10	70.00	4.63	6.10	0.445
3	SB-1	Vent2	B3_SB1	5	214,000	1,070,000	139,100	106.6	533.0	84.6	4.35	1.33	7.94	70.00	5.26	6.10	0.506
3	NB-1	Vent1	B3_NB1	5	251,630	1,258,150	163,560	106.6	533.0	84.6	5.11	1.56	7.94	70.00	6.19	6.10	0.595
3	NB-2	Vent3	B3_NB2	4	284,750	1,139,000	148,070	106.6	426.4	84.6	5.79	1.76	7.10	70.00	5.60	6.10	0.538
4	SB-2	SB2	B4_SB2	4	237,250	949,000	123,370	106.6	426.4	39.9	4.82	1.47	7.10	70.00	4.67	6.10	0.449
4	SB-3	SB3	B4_SB3	4	282,625	1,130,500	146,965	106.6	426.4	39.9	5.74	1.75	7.10	70.00	5.56	6.10	0.534
4	NB-3	NB3	B4_NB3	4	221,250	885,000	115,050	106.6	426.4	39.9	4.50	1.37	7.10	70.00	4.35	6.10	0.418
4	NB-4	NB4	B4_NB4	4	202,250	809,000	105,170	106.6	426.4	39.9	4.11	1.25	7.10	70.00	3.98	6.10	0.382
5	SAT-WB-E2	WBE2	B5_WBE2	4	260,000	1,040,000	135,200	106.6	426.4	54.3	5.28	1.61	7.10	70.00	5.11	6.10	0.492
5	SAT-WB-E3	WBE3	B5_WBE3	2	196,500	393,000	51,090	106.6	213.2	54.3	3.99	1.22	5.02	70.00	1.93	6.10	0.186
5	SAT-EB-E2	EBE2	B5_EBE2	4	278,000	1,112,000	144,560	106.6	426.4	54.3	5.65	1.72	7.10	70.00	5.47	6.10	0.526
5	SAT-EB-E3	EBE3	B5_EBE3	2	279,000	558,000	72,540	106.6	213.2	54.3	5.67	1.73	5.02	70.00	2.74	6.10	0.264
6	Eastbound Zone 1	WBZ1	B6_WBZ1	3	300,000	900,000	117,000	106.6	319.8	27.6	6.10	1.86	6.15	70.00	4.43	6.10	0.425
6	Westbound Zone 1	EBZ1	B6_EBZ1	3	300,000	900,000	117,000	106.6	319.8	27.6	6.10	1.86	6.15	70.00	4.43	6.10	0.425
7	Eastbound Zone 2	EB2	B7_EB2	3	274,000	822,000	106,860	106.6	319.8	32.9	5.57	1.70	6.15	70.00	4.04	6.10	0.389
7	Westbound Zone 2	WB2	B7_WB2	3	231,000	693,000	90,090	106.6	319.8	32.9	4.70	1.43	6.15	70.00	3.41	6.10	0.328
7	Eastbound Zone 3	EB3	B7_EB3	2	226,000	452,000	58,760	106.6	213.2	32.9	4.59	1.40	5.02	70.00	2.22	6.10	0.214
7	Westbound Zone 3	WB3	B7_WB3	3	203,000	609,000	79,170	106.6	319.8	32.9	4.13	1.26	6.15	70.00	3.00	6.10	0.288
7	T-A/D	TAD	B7_TAD	3	194,333	582,999	75,790	106.6	319.8	32.9	3.95	1.20	6.15	70.00	2.87	6.10	0.276

TABLE 2-16: MODELING INPUT PARAMETERS FOR STEP 4

VB	Zone (TSD Table 2-7)	Zone 2006 Modeling	Zone 2011/2012 Modeling	# of Fans	Fan Capacity (cfm)	Zone capacity (cfm)	Step 4 cfm	Fan area (ft^2)	Exit area (ft^2)	Height (m)	vs (ft/sec)	vs (m/s)	Equiv. D (m)	CO Emission Limit (ppm)	CO Emissions (g/s)	NOx Emission Limit (ppm)	NOx Emissions (g/s)
1	SAT-Ramp D-E1	RampD	B1_RampD	2	171,500	343,000	144,060	106.6	213.2	36.9	11.26	3.43	5.02	70.00	5.45	6.10	0.524
1	SAT-WB-E1	WestB	B1_WestB	3	230,400	691,200	290,304	106.6	319.8	36.9	15.13	4.61	6.15	70.00	10.98	6.10	1.056
1	SAT-EB-E1	EastB	B1_EastB	2	281,820	563,640	236,729	106.6	213.2	36.9	18.51	5.64	5.02	70.00	8.96	6.10	0.861
1	SAT-Ramp L/HOV-E1	RampL	B1_RampL	4	235,250	941,000	395,220	106.6	426.4	36.9	15.45	4.71	7.10	70.00	14.95	6.10	1.437
3	SB-1	Vent2	B3_SB1	5	214,000	1,070,000	449,400	106.6	533.0	84.6	14.05	4.28	7.94	70.00	17.00	6.10	1.634
3	NB-1	Vent1	B3_NB1	5	251,630	1,258,150	528,423	106.6	533.0	84.6	16.52	5.04	7.94	70.00	19.99	6.10	1.921
3	NB-2	Vent3	B3_NB2	4	284,750	1,139,000	478,380	106.6	426.4	84.6	18.70	5.70	7.10	70.00	18.10	6.10	1.739
4	SB-2	SB2	B4_SB2	4	237,250	949,000	398,580	106.6	426.4	39.9	15.58	4.75	7.10	70.00	15.08	6.10	1.449
4	SB-3	SB3	B4_SB3	4	282,625	1,130,500	474,810	106.6	426.4	39.9	18.56	5.66	7.10	70.00	17.96	6.10	1.726
4	NB-3	NB3	B4_NB3	4	221,250	885,000	371,700	106.6	426.4	39.9	14.53	4.43	7.10	70.00	14.06	6.10	1.352
4	NB-4	NB4	B4_NB4	4	202,250	809,000	339,780	106.6	426.4	39.9	13.28	4.05	7.10	70.00	12.85	6.10	1.235
5	SAT-WB-E2	WBE2	B5_WBE2	4	260,000	1,040,000	436,800	106.6	426.4	54.3	17.07	5.20	7.10	70.00	16.53	6.10	1.588
5	SAT-WB-E3	WBE3	B5_WBE3	2	196,500	393,000	165,060	106.6	213.2	54.3	12.90	3.93	5.02	70.00	6.24	6.10	0.600
5	SAT-EB-E2	EBE2	B5_EBE2	4	278,000	1,112,000	467,040	106.6	426.4	54.3	18.26	5.56	7.10	70.00	17.67	6.10	1.698
5	SAT-EB-E3	EBE3	B5_EBE3	2	279,000	558,000	234,360	106.6	213.2	54.3	18.32	5.58	5.02	70.00	8.87	6.10	0.852
6	Eastbound Zone 1	WBZ1	B6_WBZ1	3	300,000	900,000	378,000	106.6	319.8	27.6	19.70	6.00	6.15	70.00	14.30	6.10	1.374
6	Westbound Zone 1	EBZ1	B6_EBZ1	3	300,000	900,000	378,000	106.6	319.8	27.6	19.70	6.00	6.15	70.00	14.30	6.10	1.374
7	Eastbound Zone 2	EB2	B7_EB2	3	274,000	822,000	345,240	106.6	319.8	32.9	17.99	5.48	6.15	70.00	13.06	6.10	1.255
7	Westbound Zone 2	WB2	B7_WB2	3	231,000	693,000	291,060	106.6	319.8	32.9	15.17	4.62	6.15	70.00	11.01	6.10	1.058
7	Eastbound Zone 3	EB3	B7_EB3	2	226,000	452,000	189,840	106.6	213.2	32.9	14.84	4.52	5.02	70.00	7.18	6.10	0.690
7	Westbound Zone 3	WB3	B7_WB3	3	203,000	609,000	255,780	106.6	319.8	32.9	13.33	4.06	6.15	70.00	9.68	6.10	0.930
7	T-A/D	TAD	B7_TAD	3	194,333	582,999	244,860	106.6	319.8	32.9	12.76	3.89	6.15	70.00	9.26	6.10	0.890

TABLE 2-17: HIGHEST 2ND HIGH 1-HOUR AND 8-HOUR PREDICTED CO CONCENTRATIONS FROM VENTILATION BUILDINGS AT AMBIENT RECEPTORS FOR COMPLIANCE DEMONSTRATION

AERMOD Predicted CO Impacts (ppm)
2nd Highest Value including Hourly Background for Comparison to NAAQS
70 ppm Source concentration of CO

Source Description	1-hour Average (ppm)					8-hour Average (ppm)				
	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
Ventilation Step 1										
VB 1	4.07	4.41	5.07	4.88	6.38	1.75	1.64	1.73	2.03	1.82
VB 3	6.90	5.96	6.91	8.14	6.92	1.72	1.92	2.35	2.85	2.40
VB 4	9.50	9.03	7.97	10.04	8.27	2.68	1.45	2.58	1.97	2.10
VB 5	3.76	2.57	3.01	3.58	2.58	1.49	1.08	1.72	2.08	1.61
VB 6	2.21	1.79	2.66	2.95	2.83	1.43	1.03	1.70	2.00	1.61
VB 7	3.33	3.53	3.95	3.05	3.42	1.99	1.49	1.87	2.08	1.91
All VB combined	**9.50**	**9.04**	**7.97**	**10.04**	**8.27**	**2.70**	**1.93**	**2.59**	**2.86**	**2.40**
Ventilation Step 4										
VB 1	16.65	14.63	14.15	16.03	19.20	4.17	3.56	3.82	4.00	5.03
VB 3	14.38	25.84	11.87	21.05	17.11	4.27	3.39	3.28	6.69	3.86
VB 4	17.21	19.07	13.94	15.91	19.65	4.85	2.92	2.69	4.76	4.15
VB 5	3.51	2.88	3.28	3.17	2.97	1.72	1.63	1.91	2.26	1.66
VB 6	3.80	3.26	2.67	3.71	3.28	1.32	1.07	1.63	1.96	1.65
VB 7	3.90	8.85	3.75	4.39	4.22	3.06	2.16	2.54	2.35	2.39
All VB combined	**17.46**	**25.86**	**14.16**	**21.05**	**19.66**	**4.92**	**3.56**	**3.82**	**6.71**	**5.03**
Maximum VB Plus Background Impact	**17.46**	**25.86**	**14.16**	**21.05**	**19.66**	**4.92**	**3.56**	**3.82**	**6.71**	**5.03**
NAAQS	**35**					**9**				

TABLE 2-18: PREDICTED NO_2 DESIGN CONCENTRATIONS FROM VENTILATION BUILDINGS AT AMBIENT RECEPTORS FOR NAAQS COMPLIANCE DEMONSTRATION

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	**Period**	
	1-hr	**Annual**
Ventilation Step 1		
VB 1	0.0573	0.0210
VB 3	0.0605	0.0204
VB 4	0.0591	0.0203
VB 5	0.0546	0.0207
VB 6	0.0552	0.0206
VB 7	0.0567	0.0217
All VB combined	**0.0606**	**0.0218**
Ventilation Step 4		
VB 1	0.0817	0.0216
VB 3	0.0773	0.0209
VB 4	0.0632	0.0206
VB 5	0.0556	0.0218
VB 6	0.0542	0.0203
VB 7	0.0600	0.0229
All VB combined	**0.0817**	**0.0230**
Maximum VB Plus Background Impact	**0.0817**	**0.0230**
NAAQS	**0.100**	**0.053**

* The maximum 5-year average of the 98th percentile (8th Highest) of the daily maximum 1-hour average

TABLE 2-19: PREDICTED NO_2 DESIGN CONCENTRATIONS FROM VENTILATION BUILDINGS AT AMBIENT RECEPTORS FOR MASSDEP GUIDELINE COMPLIANCE DEMONSTRATION

AERMOD Predicted 1-hr NO_2 Impacts (ppm)
2nd Highest Value including Background Comparison to MassDEP 1-hr Standard
6.1 ppm Source concentration of NO_x

	1-hour Average				
Source Description	**2007**	**2008**	**2009**	**2010**	**2011**
Ventilation Step 1					
VB 1	0.0748	0.0666	0.0609	0.0706	0.0740
VB 3	0.0733	0.0783	0.0711	0.0746	0.0730
VB 4	0.0813	0.0753	0.0739	0.0853	0.0741
VB 5	0.0750	0.0649	0.0613	0.0633	0.0740
VB 6	0.0768	0.0635	0.0591	0.0633	0.0707
VB 7	0.0772	0.0665	0.0605	0.0661	0.0740
All VB combined	**0.0813**	**0.0788**	**0.0739**	**0.0866**	**0.0741**
Ventilation Step 4					
VB 1	0.136	0.122	0.118	0.116	0.147
VB 3	0.109	0.113	0.092	0.142	0.145
VB 4	0.129	0.155	0.109	0.128	0.135
VB 5	0.074	0.066	0.062	0.065	0.073
VB 6	0.074	0.070	0.058	0.062	0.074
VB 7	0.081	0.070	0.062	0.068	0.074
All VB combined	**0.136**	**0.155**	**0.118**	**0.142**	**0.147**
Maximum VB Plus Background Impact	**0.136**	**0.155**	**0.118**	**0.142**	**0.147**
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

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.

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 reproduce the full scale values precisely.

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 2-16 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.

FIGURE 2-10: RAMP L-CS – PORTAL LOCATION AND CRITICAL RECEPTOR

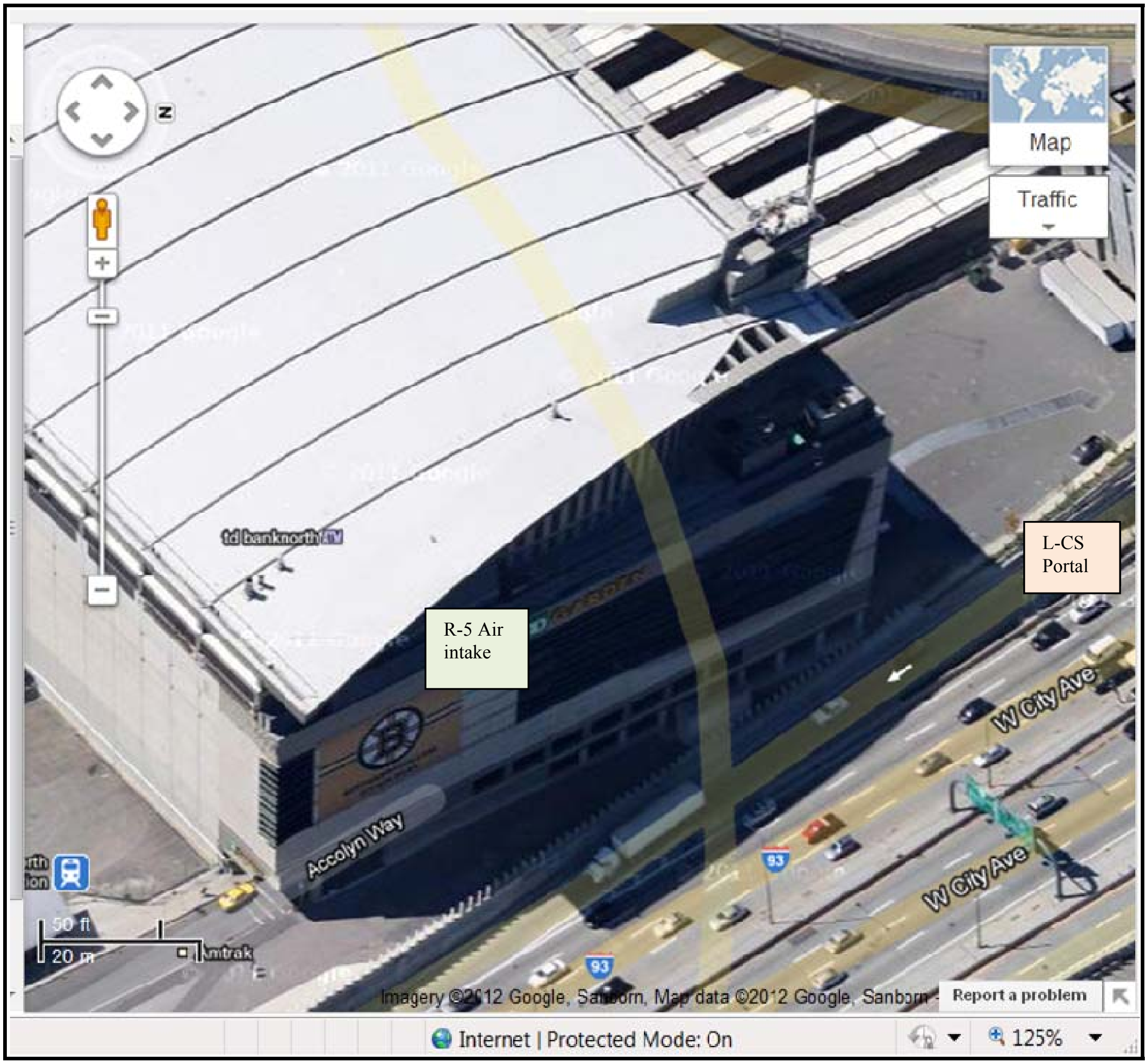


FIGURE 2-11: RAMP SA-CN– PORTAL LOCATION AND CRITICAL RECEPTOR

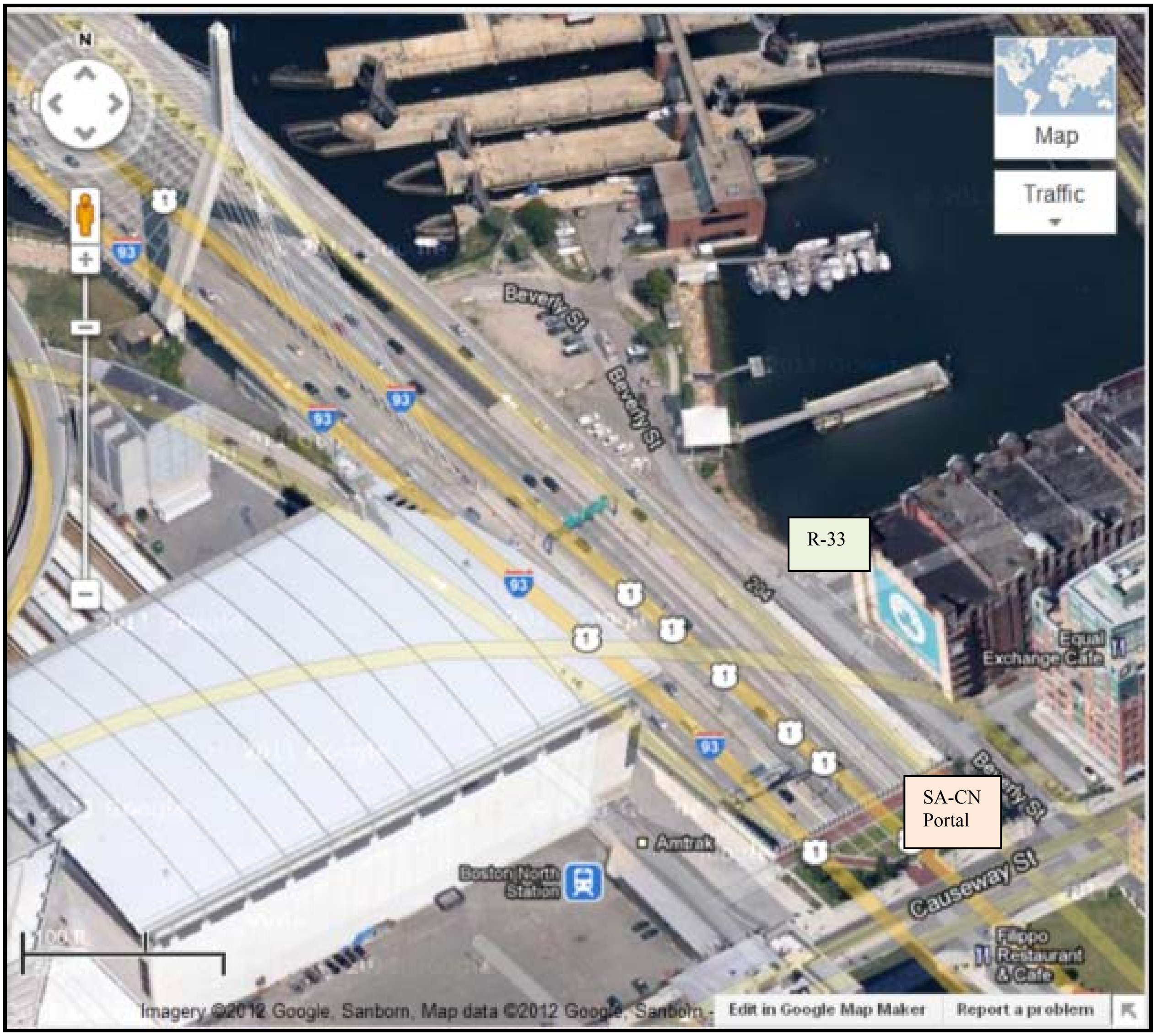


FIGURE 2-12: RAMP CN-S - PORTAL LOCATION AND CRITICAL RECEPTOR

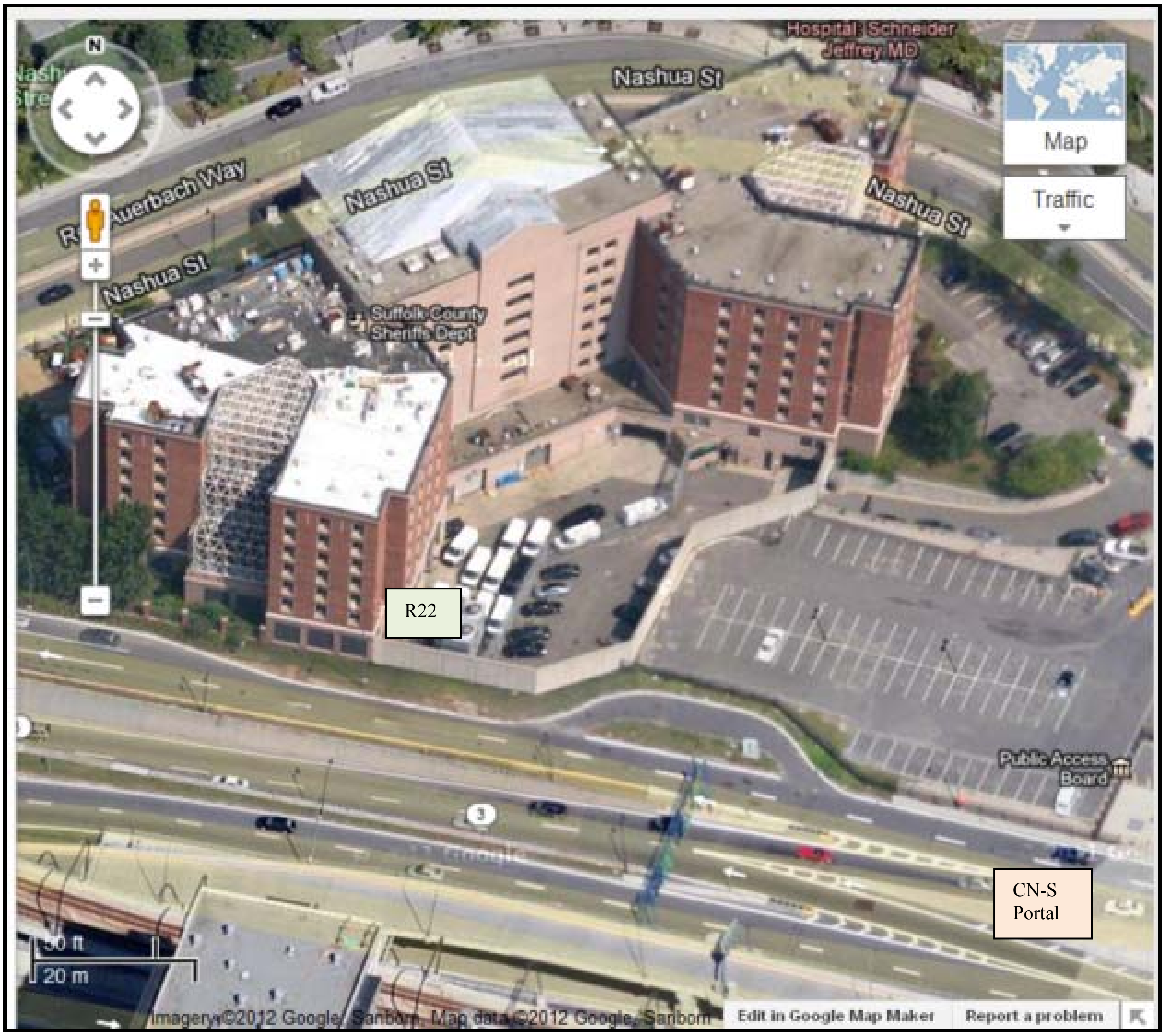


FIGURE 2-13: RAMP ST-SA AND ST-CN- PORTAL LOCATION AND CRITICAL RECEPTORS

FIGURE 2-14: RAMP CS-SA- PORTAL LOCATION AND CRITICAL RECEPTORS

FIGURE 2-15: RAMP CS-P- PORTAL LOCATION AND CRITICAL RECEPTORS

FIGURE 2-16: RAMP F- 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 2-17)
- Configuration 2 – the existing CASB portal location with development at Parcels 24 and 26a and low existing retaining wall (Figure 2-18)
- Configuration 3 – the existing "No-Build" condition without any development on Parcels 24, 25 and 26a (Figure 2-19)

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-3 ("Air Quality Analysis Protocol for Determination of CO and NOx Emission Limits- 2012 Supplemental Application for the Renewal of the Operating Certification of the Project Ventilation Systems") of this document.

FIGURE 2-17: DEWEY SQUARE TUNNEL – CONFIGURATION 1

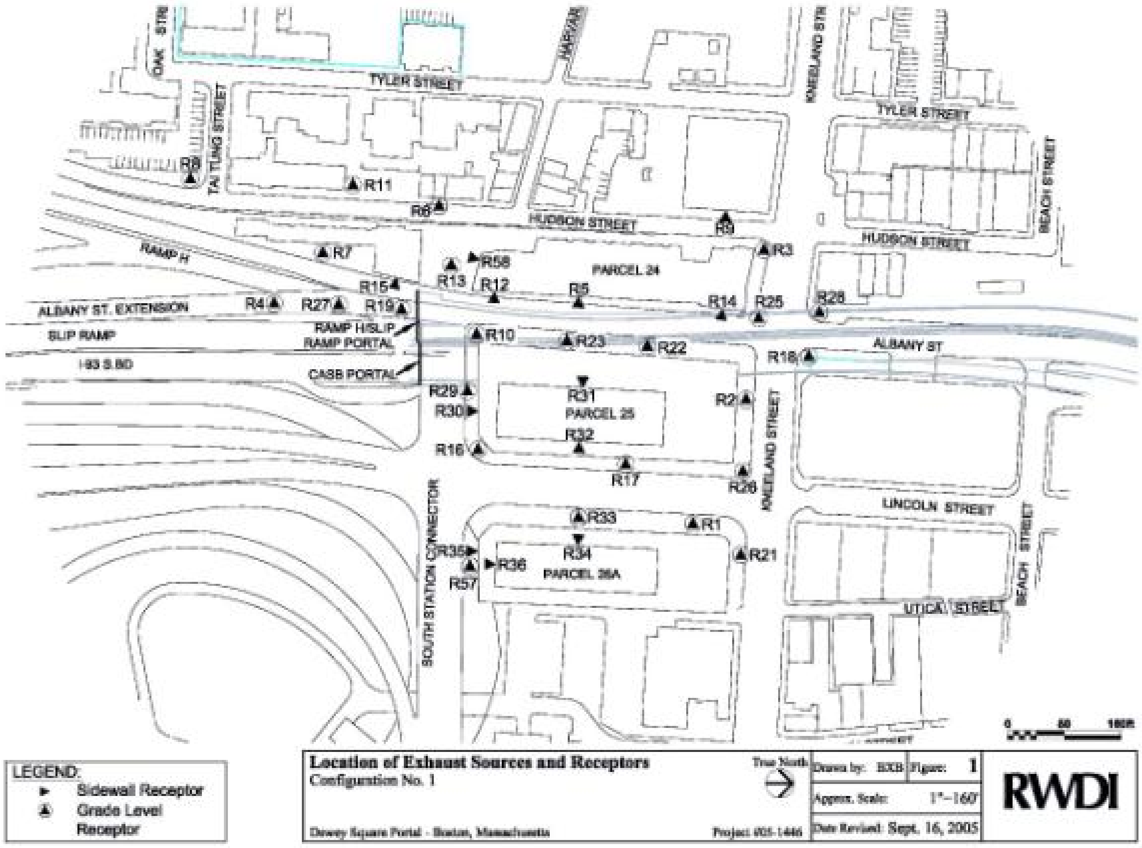


FIGURE 2-18: DEWEY SQUARE TUNNEL – CONFIGURATION 2

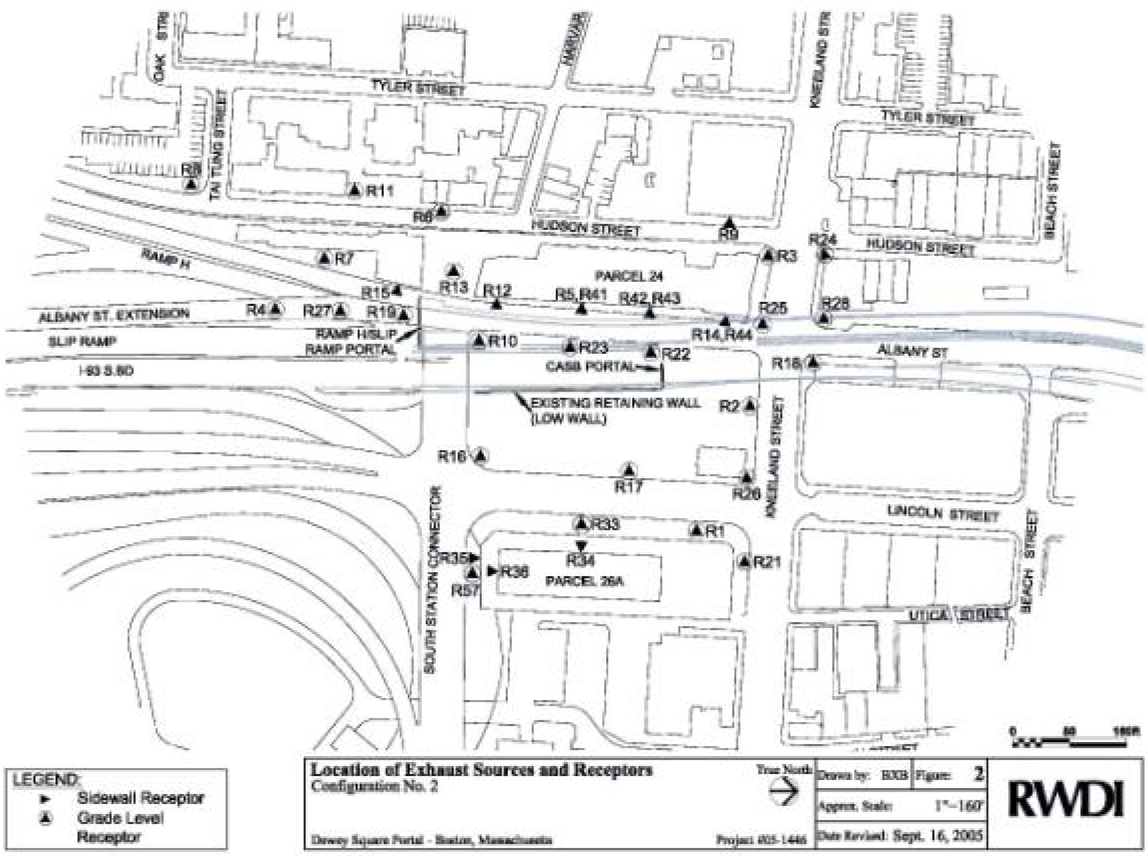
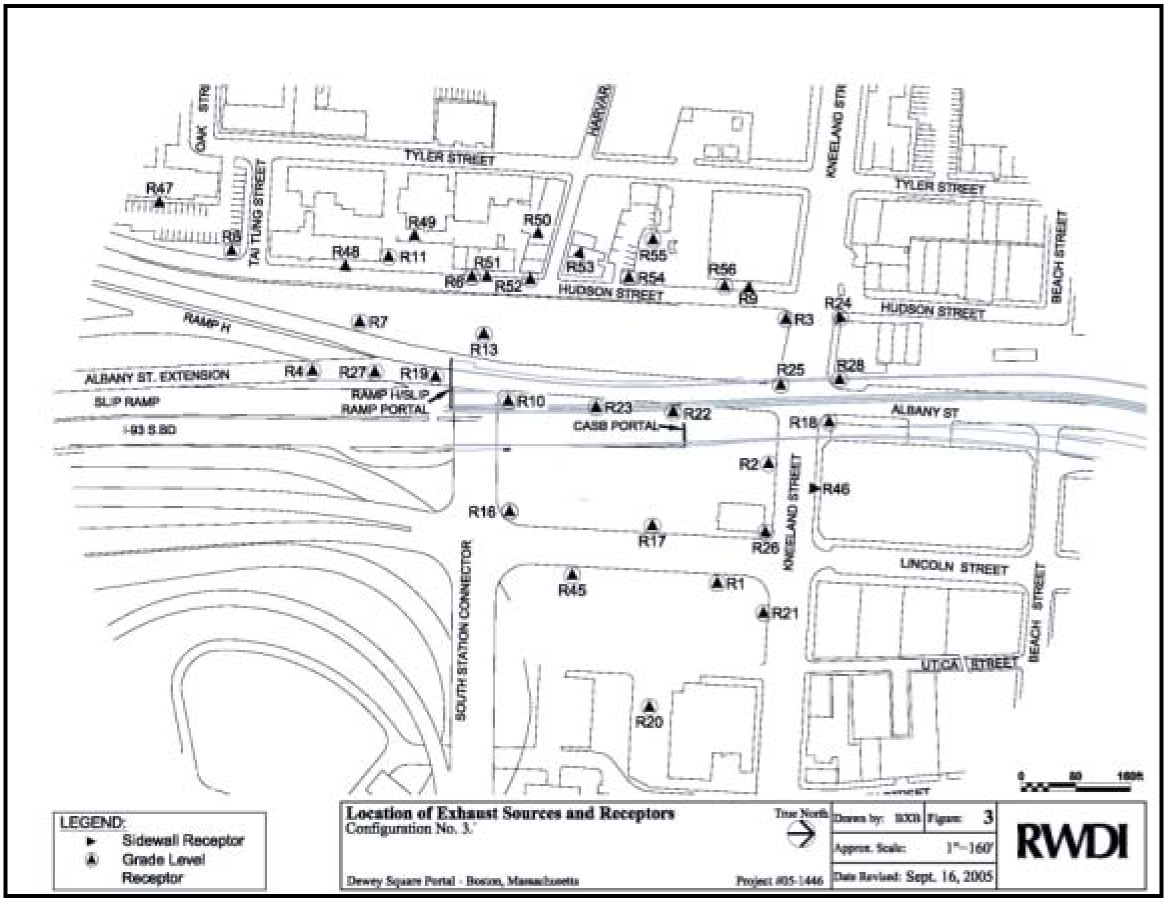


FIGURE 2-19: DEWEY SQUARE TUNNEL – CONFIGURATION 3



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 (2007–2011) of meteorological data from Logan Airport in order to obtain pollutant levels corresponding to the NAAQS and MassDEP 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 2-16.

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 5 years (2007 to 2011). In addition, the program adds the hourly CO background concentration for the respective hour.

The form of the equation is:

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

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

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

N-hour = each hour for the full calendar year

EPA modeling procedures described in Section 9.3.4.2 of the *USEPA Guideline on Air Quality Models (EPA-450/2-78-027R)* 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 2-20 through 2-32 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 2-20: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP LC-S (PPM)

Ramp LC - S										
	One Hour CO					Eight Hour CO				
Year	Receptor	Source CO	2nd Highest Level	Date	Hour	Receptor	Source CO	2nd Highest Level	Date	Ending Hour
2007	5	70	10.8	4/27/2007	24	5	70	5.6	8/21/2007	8
2008	5	70	10.5	11/14/2008	15	5	70	5.4	9/28/2008	10
2009	5	70	11.0	9/5/2009	19	5	70	5.9	1/27/2009	24
2010	5	70	11.2	1/19/2010	5	5	70	6.1	6/11/2010	8
2011	5	70	11.7	7/19/2011	23	5	70	6.7	1/11/2011	21

TABLE 2-21: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP SA-CN (PPM)

Ramp SA-CN										
	One Hour CO					Eight Hour CO				
Year	Receptor	Source CO	2nd Highest Level	Date	Hour	Receptor	Source CO	2nd Highest Level	Date	Ending Hour
2007	33	70	7.1	10/29/2007	11	33	70	5.7	5/1/2007	14
2008	33	70	6.8	11/20/2008	2	33	70	5.4	2/21/2008	14
2009	33	70	7.7	1/16/2009	1	33	70	5.4	3/5/2009	8
2010	33	70	7.3	4/20/2010	7	33	70	6.0	8/31/2010	11
2011	33	70	7.4	5/5/2011	1	33	70	5.9	1/20/2011	12

TABLE 2-22: 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	Ending Hour
2007	22	70	13.9	2/25/2007	21	22	59	8.95	10/3/2007	8
2008	22	70	13.8	7/19/2008	24	22	58	8.9	11/7/2008	22
2009	22	70	14.4	12/31/2009	17	22	59	8.6	1/13/2009	24
2010	22	70	14.0	5/2/2010	5	22	59	8.9	10/24/2010	17
2011	22	70	14.5	7/25/2011	23	22	58	8.9	1/1/2011	20

TABLE 2-23: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP ST-CN NO PARCEL 6 (PPM)

Ramp ST-CN no Parcel 6										
	One Hour CO					Eight Hour CO				
Year	Receptor	Source CO	2nd Highest Level	Date	Hour	Receptor	Source CO	2nd Highest Level	Date	Ending Hour
2007	12	70	8.2	4/1/2007	9	12	70	5.9	10/4/2007	24
2008	12	70	8.0	6/23/2008	21	11	70	5.7	11/7/2008	18
2009	12	70	8.8	10/24/2009	12	12	70	5.8	4/2/2009	9
2010	12	70	8.3	7/30/2010	24	11	70	6.3	10/24/2010	15
2011	12	70	8.7	6/8/2011	2	12	70	6.3	1/11/2011	21

TABLE 2-24: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP ST-SA NO PARCEL 6 (PPM)

Ramp ST-SA no Parcel 6										
	One Hour CO					Eight Hour CO				
Year	Receptor	Source CO	2nd Highest Level	Date	Hour	Receptor	Source CO	2nd Highest Level	Date	Ending Hour
2007	20	70	9.6	12/29/2007	17	20	70	6.7	11/5/2007	8
2008	20	70	9.3	11/12/2008	22	20	70	7.1	11/30/2008	10
2009	20	70	10.5	7/10/2009	3	20	70	6.5	9/7/2009	8
2010	20	70	10.1	1/14/2010	7	20	70	7.3	5/1/2010	8
2011	20	70	10.3	11/27/2011	5	20	70	7.3	12/25/2011	10

TABLE 2-25: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP ST-SA + PARCEL 6 (PPM)

Ramp ST-SA + Parcel 6										
	One Hour CO					Eight Hour CO				
Year	Receptor	Source CO	2nd Highest Level	Date	Hour	Receptor	Source CO	2nd Highest Level	Date	Ending Hour
2007	36	70	14.5	10/19/2007	3	36	55	8.7	10/19/2007	8
2008	36	70	14.3	9/19/2008	22	36	55	8.4	6/10/2008	8
2009	36	70	15.0	11/26/2009	8	36	54	8.9	6/25/2009	8
2010	36	70	14.5	7/24/2010	3	36	55	8.7	6/16/2010	10
2011	36	70	15.0	9/11/2011	4	36	54	8.9	1/11/2011	21

TABLE 2-26: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP CS-SA + PARCEL 12 (PPM)

Ramp CS-SA + Parcel 12										
	One Hour CO					Eight Hour CO				
Year	Receptor	Source CO	2nd Highest Level	Date	Hour	Receptor	Source CO	2nd Highest Level	Date	Ending Hour
2007	6	70	13.5	2/26/2007	21	6	68	8.0	11/21/2007	10
2008	6	70	12.8	11/30/2008	5	6	66	8.9	11/30/2008	10
2009	6	70	14.2	5/30/2009	4	6	68	8.0	6/25/2009	8
2010	6	70	14.1	7/10/2010	24	6	68	8.2	9/18/2010	8
2011	6	70	13.6	7/15/2011	2	6	68	8.9	12/25/2011	12

TABLE 2-27: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP CS-SA NO PARCEL 12 (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	Ending Hour
2007	34	70	15.2	12/26/2007	5	3	56	7.9	10/3/2007	9
2008	34	70	14.7	10/24/2008	8	3	56	8.3	4/18/2008	22
2009	34	70	15.9	9/8/2009	7	3	56	7.9	10/27/2009	8
2010	34	70	15.1	2/15/2010	23	3	55	8.9	10/24/2010	17
2011	34	70	15.5	10/2/2011	23	3	56	8.4	1/28/2011	18

TABLE 2-28: 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	Ending Hour
2007	19 / 20	70	14.4	10/19/2007	3	19	70	8.3	7/30/2007	24
2008	19 / 20	70	13.5	6/28/2008	4	1	70	7.2	7/23/2008	9
2009	19 / 20	70	14.1	11/26/2009	8	19	70	7.8	10/24/2009	13
2010	19 / 20	70	14.0	7/24/2010	4	19	70	8.1	10/24/2010	22
2011	19 / 20	70	13.7	10/19/2011	4	19	70	8.4	11/10/2011	19

TABLE 2-29: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP F (PPM)

Ramp F										
	One Hour CO					Eight Hour CO				
Year	Receptor	Source CO	2nd Highest Level	Date	Hour	Receptor	Source CO	2nd Highest Level	Date	Ending Hour
2007	22	70	7.5	2/2/2007	16	22	70	4.8	12/26/2007	13
2008	22	70	7.2	5/4/2008	24	22	70	4.5	8/9/2008	8
2009	22	70	8.2	2/10/2009	8	22	70	4.7	8/25/2009	8
2010	22	70	7.8	3/19/2010	5	22	70	4.6	1/8/2010	8
2011	22	70	8.2	9/11/2011	4	22	70	4.9	5/13/2011	8

TABLE 2-30: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION – DEWEY SQUARE TUNNEL: CONFIGURATION 1 (PPM)

CONFIG 1										
	One Hour CO					Eight Hour CO				
Year	Receptor	Source CO	2nd Highest Level	Date	Hour	Receptor	Source CO	2nd Highest Level	Date	Ending Hour
2007	27	70	33.1	3/20/2007	21	27	19	8.6	5/3/2007	19
2008	27	70	32.8	8/31/2008	10	27	19	8.9	3/17/2008	17
2009	27	70	33.0	2/13/2009	11	27	20	8.8	3/24/2009	8
2010	27	70	33.2	2/11/2010	6	27	18	8.6	1/9/2010	24
2011	27	70	33.3	7/30/2011	16	27	19	8.8	3/22/2011	18

TABLE 2-31: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION – DEWEY SQUARE TUNNEL: CONFIGURATION 2 (PPM)

CONFIG 2										
	One Hour CO					Eight Hour CO				
Year	Receptor	Source CO	2nd Highest Level	Date	Hour	Receptor	Source CO	2nd Highest Level	Date	Ending Hour
2007	23	70	28.8	6/13/2007	19	23	21	8.9	7/23/2007	14
2008	23	70	28.6	9/26/2008	6	23	21	8.3	3/7/2008	24
2009	23	70	29.5	9/11/2009	23	23	21	8.8	3/16/2009	12
2010	23	70	29.0	9/26/2010	18	23	20	8.7	9/26/2010	19
2011	23	70	29.2	5/16/2011	15	23	20	8.6	9/7/2011	15

TABLE 2-32: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION – DEWEY SQUARE TUNNEL: CONFIGURATION 3 (PPM)

CONFIG 3										
	One Hour CO					Eight Hour CO				
Year	Receptor	Source CO	2nd Highest Level	Date	Hour	Receptor	Source CO	2nd Highest Level	Date	Ending Hour
2007	4	70	22.4	3/9/2007	10	10	31	8.6	12/25/2007	24
2008	4	70	22.4	10/12/2008	24	10	31	8.7	12/3/2008	8
2009	4	70	22.8	11/7/2009	10	10	31	8.8	1/10/2009	17
2010	4	70	21.6	9/1/2010	10	10	30	8.8	4/18/2010	12
2011	4	70	22.0	9/25/2011	5	10	30	8.7	10/23/2011	11

2.7.2.4 NO_2 Analysis

For each ramp multiple runs were performed using a NO_x portal emission source ranging from 1.95 ppm (20 ppm CO equivalent) to 6.10 ppm (70 ppm CO equivalent) at 1 ppm CO equivalent intervals.

A similar to CO ramp analysis in-house program 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 combination of NO_2 directly emitted by motor vehicles (5% of the NO_x emitted in the tunnel was considered to be NO_2), the conversion factor of 7.5% from NO to NO_2, 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 for the five years (2007 to 2011) was used to determine emission limit.

Emission limits are set for the source concentration at which the highest receptors are below the five year average of 100 ppb (0.1 ppm) 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). 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) was demonstrated by comparing the annual average results for each year including the hourly background concentrations to the NO_2 annual NAAQS.

Tables 2-33 through 2-45 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 2-33: 1-HOUR NO_2 LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP LC-S (PPM)

Ramp LC-S																
	MassDEP One Hour Policy Guidance level						One Hour NO_2 NAAQS						Annual NO_2 NAAQS			
Year	Receptor	Source CO	Source NO_x	1st Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	8^{th} Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	Annual
2007	5	70	6.10	0.128	10/4/2007	21	5	57	5.02	0.104	10/18/2007	20	12	70	6.10	0.027
2008	5	70	6.10	0.133	3/7/2008	7	5	57	5.02	0.098	4/19/2008	7	12	70	6.10	0.027
2009	5	70	6.10	0.127	2/10/2009	3	5	57	5.02	0.099	4/2/2009	6	12	70	6.10	0.025
2010	5	70	6.10	0.128	9/19/2010	22	5	57	5.02	0.098	10/24/2010	8	12	70	6.10	0.026
2011	5	70	6.10	0.131	7/19/2011	23	5	57	5.02	0.096	1/25/2011	20	12	70	6.10	0.026
Highest				**0.133**			Average			**0.099**			Highest			**0.027**

TABLE 2-34: 1-HOUR NO2 LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP SA-CN (PPM)

Ramp SA-CN																
	MassDEP One Hour Policy Guidance level						One Hour NO_2 NAAQS						Annual NO_2 NAAQS			
Year	Receptor	Source CO	Source NO_x	1st Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	8^{th} Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	Annual
2007	35	70	6.10	0.0973	9/20/2007	17	33	70	6.10	0.088	3/23/2007	23	33	70	6.10	0.030
2008	33	70	6.10	0.0931	7/15/2008	19	33	70	6.10	0.085	3/11/2008	7	33	70	6.10	0.030
2009	33	70	6.10	0.0921	1/26/2009	7	33	70	6.10	0.086	1/16/2009	1	33	70	6.10	0.028
2010	33	70	6.10	0.0945	2/4/2010	20	33	70	6.10	0.087	5/17/2010	5	33	70	6.10	0.029
2011	35	70	6.10	0.102	2/17/2011	18	33	70	6.10	0.085	10/19/2011	7	33	70	6.10	0.029
Highest				**0.102**			Average			**0.086**			Highest			**0.030**

TABLE 2-35: 1-HOUR NO_2 LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP CN-S (PPM)

Ramp CN-S																	
	MassDEP One Hour Policy Guidance level						One Hour NO_2 NAAQS						Annual NO_2 NAAQS			
Year	Receptor	Source CO	Source NO_x	1st Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	8^{th} Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	Annual
2007	22	70	6.10	0.164	2/25/2007	21	22	37	3.36	0.100	6/1/2007	16	22	70	6.10	0.046
2008	22	69	6.02	0.169	2/26/2008	7	22	37	3.36	0.098	1/29/2008	12	22	70	6.10	0.047
2009	22	70	6.10	0.165	2/1/2009	19	22	37	3.36	0.096	4/27/2009	20	22	70	6.10	0.045
2010	22	70	6.10	0.163	2/15/2010	24	22	37	3.36	0.101	2/16/2010	1	22	70	6.10	0.042
2011	22	67	5.85	0.168	2/17/2011	17	22	37	3.36	0.103	4/4/2011	4	22	70	6.10	0.045
Highest				**0.169**			Average			**0.099**			Highest			**0.047**

TABLE 2-36: 1-HOUR NO_2 LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP ST-CN NO PARCEL 6 (PPM)

Ramp ST-CN No Parcel 6																
	MassDEP One Hour Policy Guidance level						One Hour NO_2 NAAQS						Annual NO_2 NAAQS			
Year	Receptor	Source CO	Source NO_x	1st Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	8^{th} Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	Annual
2007	12	70	6.10	0.120	9/20/2007	21	12	70	6.10	0.102	5/16/2007	7	9	70	6.10	0.031
2008	12	70	6.10	0.114	6/27/2008	20	12	70	6.10	0.102	5/2/2008	6	9	70	6.10	0.031
2009	12	70	6.10	0.111	4/27/2009	20	12	70	6.10	0.097	2/10/2009	23	9	70	6.10	0.030
2010	12	70	6.10	0.122	3/19/2010	7	12	70	6.10	0.095	9/19/2010	22	9	70	6.10	0.027
2011	36	70	6.10	0.117	2/24/2011	8	12	70	6.10	0.094	4/4/2011	3	9	70	6.10	0.030
Highest				**0.122**			Average			**0.098**			Highest			**0.031**

TABLE 2-37: 1-HOUR NO_2 LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP ST-SA NO PARCEL 6 (PPM)

Ramp ST-SA No Parcel 6																	
	MassDEP One Hour Policy Guidance level						One Hour NO_2 NAAQS						Annual NO_2 NAAQS				
Year	Receptor	Source CO	Source NO_x	1st Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	8th Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	Annual
2007	20	70	6.10	0.122	4/1/2007	5	20	58	5.10	0.095	10/5/2007	3	23	70	6.10	0.032
2008	20	70	6.10	0.122	4/16/2008	7	20	58	5.10	0.100	2/9/2008	6	23	70	6.10	0.032
2009	20	70	6.10	0.121	9/4/2009	24	20	58	5.10	0.095	2/1/2009	18	23	70	6.10	0.030
2010	20	70	6.10	0.130	3/10/2010	1	20	58	5.10	0.103	1/19/2010	4	23	70	6.10	0.030
2011	20	70	6.10	0.132	2/24/2011	8	20	58	5.10	0.101	2/17/2011	17	23	70	6.10	0.030
Highest				**0.132**			Average			**0.099**			Highest			**0.032**

TABLE 2-38: 1-HOUR NO_2 LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP ST-SA + PARCEL 6 (PPM)

Ramp ST-SA + Parcel 6																
	MassDEP One Hour Policy Guidance level						One Hour NO_2 NAAQS						Annual NO_2 NAAQS			
Year	Receptor	Source CO	Source NO_x	1st Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	8th Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	Annual
2007	36	64	5.60	0.168	10/4/2007	19	36	34	3.11	0.101	6/1/2007	16	33	70	6.10	0.035
2008	35	68	5.93	0.168	4/17/2008	8	36	34	3.11	0.102	4/18/2008	23	33	70	6.10	0.034
2009	36	66	5.77	0.169	2/10/2009	8	36	34	3.11	0.096	4/21/2009	10	33	70	6.10	0.033
2010	36	63	5.52	0.168	3/19/2010	7	36	34	3.11	0.095	2/10/2010	4	33	70	6.10	0.035
2011	35	66	5.77	0.168	2/17/2011	21	36	34	3.11	0.097	2/1/2011	3	33	70	6.10	0.032
Highest				**0.169**			Average			**0.098**			Highest			**0.035**

TABLE 2-39: 1-HOUR NO_2 LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP CS-SA + PARCEL 12 (PPM)

Ramp CS-SA + Parcel 12																	
	MassDEP One Hour Policy Guidance level						One Hour NO_2 NAAQS						Annual NO_2 NAAQS			
Year	Receptor	Source CO	Source NO_x	1st Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	8^{th} Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	Annual
2007	6 / 11	70	6.10	0.159	4/1/2007	5	6	41	3.69	0.097	6/8/2007	21	33	70	6.10	0.041
2008	10	70	6.10	0.163	4/16/2008	5	6	41	3.69	0.096	4/18/2008	5	33	70	6.10	0.041
2009	6 / 11	70	6.10	0.157	1/12/2009	21	6	41	3.69	0.098	2/2/2009	8	33	70	6.10	0.038
2010	10	70	6.10	0.161	2/15/2010	23	6	41	3.69	0.105	12/25/2010	18	33	70	6.10	0.039
2011	10	70	6.10	0.155	1/28/2011	8	6	41	3.69	0.099	6/21/2011	1	33	70	6.10	0.038
Highest				**0.163**			Average			**0.099**			Highest			**0.041**

TABLE 2-40: 1-HOUR NO_2 LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP CS-SA NO PARCEL 12 (PPM)

Ramp CS-SA No Parcel 12																
	MassDEP One Hour Policy Guidance level						One Hour NO_2 NAAQS						Annual NO_2 NAAQS			
Year	Receptor	Source CO	Source NO_x	1st Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	8^{th} Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	Annual
2007	34	70	6.10	0.167	1/1/2007	18	34	38	3.44	0.100	11/20/2007	20	33	70	6.10	0.048
2008	34	70	6.10	0.168	4/16/2008	5	34	38	3.44	0.098	1/15/2008	7	33	70	6.10	0.048
2009	34	67	5.85	0.168	11/8/2009	24	34	38	3.44	0.100	1/23/2009	7	33	70	6.10	0.046
2010	34	66	5.77	0.169	2/15/2010	23	34	38	3.44	0.102	8/19/2010	6	33	70	6.10	0.044
2011	3	69	6.02	0.168	2/18/2011	1	34	38	3.44	0.097	2/7/2011	4	33	70	6.10	0.047
Highest				**0.169**			Average			**0.099**			Highest			**0.048**

TABLE 2-41: 1-HOUR NO_2 LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP CS-P (PPM)

Ramp CS - P																	
	MassDEP One Hour Policy Guidance level						One Hour NO_2 NAAQS						Annual NO_2 NAAQS			
Year	Receptor	Source CO	Source NO_x	1st Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	8th Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	Annual
2007	19 / 20	65	5.69	0.169	10/4/2007	19	19 / 20	41	3.69	0.105	2/22/2007	7	1	70	6.10	0.031
2008	19 / 20	70	6.10	0.162	8/1/2008	22	19 / 20	41	3.69	0.104	3/19/2008	20	1 / 19	70	6.10	0.031
2009	19 / 20	70	6.10	0.152	1/6/2009	22	19 / 20	41	3.69	0.095	3/15/2009	20	1	70	6.10	0.030
2010	19 / 20	70	6.10	0.165	3/11/2010	6	19 / 20	41	3.69	0.097	1/24/2010	24	1	70	6.10	0.027
2011	19 / 20	70	6.10	0.157	6/20/2011	21	19 / 20	41	3.69	0.091	12/20/2011	20	1	70	6.10	0.031
Highest				**0.169**			Average			**0.098**			Highest			**0.031**

TABLE 2-42: 1-HOUR NO_2 LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP F (PPM)

Ramp F																
	MassDEP One Hour Policy Guidance level						One Hour NO_2 NAAQS						Annual NO_2 NAAQS			
Year	Receptor	Source CO	Source NO_x	1st Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	8th Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	Annual
2007	22	70	6.10	0.103	4/22/2007	1	22	70	6.10	0.089	2/26/2007	20	22	70	6.10	0.028
2008	22	70	6.10	0.100	1/17/2008	10	22	70	6.10	0.088	2/26/2008	4	22	70	6.10	0.028
2009	22	70	6.10	0.110	2/10/2009	8	22	70	6.10	0.087	3/15/2009	24	22	70	6.10	0.025
2010	22	70	6.10	0.106	3/19/2010	5	22	70	6.10	0.085	3/17/2010	6	22	70	6.10	0.024
2011	22	70	6.10	0.104	3/11/2011	11	22	70	6.10	0.094	2/17/2011	17	22	70	6.10	0.026
Highest				**0.110**			Average			**0.089**			Highest			**0.028**

TABLE 2-43: 1-HOUR NO_2 LEVELS FOR COMPLIANCE DEMONSTRATION – DEWEY SQUARE TUNNEL: CONFIGURATION 1 (PPM)

CONFIG 1																	
	MassDEP One Hour Policy Guidance level						One Hour NO_2 NAAQS						Annual NO_2 NAAQS			
Year	Receptor	Source CO	Source NO_x	1st Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	8^{th} Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	Annual
2007	27	31	2.86	0.165	5/13/2007	17	27	17	1.70	0.099	3/29/2007	7	4	18	1.78	0.052
2008	27	32	2.95	0.167	1/3/2008	11	27	17	1.70	0.098	11/21/2008	24	4	18	1.78	0.051
2009	27	33	3.03	0.168	2/13/2009	11	27	17	1.70	0.096	12/22/2009	19	4	19	1.87	0.052
2010	27	31	2.86	0.166	5/10/2010	7	27	17	1.70	0.096	4/12/2010	15	4	19	1.87	0.051
2011	27	32	2.95	0.167	3/22/2011	16	27	17	1.70	0.096	1/31/2011	6	4	19	1.87	0.052
Highest				**0.168**			Average			**0.097**			Highest			**0.052**

TABLE 2-44: 1-HOUR NO_2 LEVELS FOR COMPLIANCE DEMONSTRATION – DEWEY SQUARE TUNNEL: CONFIGURATION 2 (PPM)

CONFIG 2																	
	MassDEP One Hour Policy Guidance level						One Hour NO_2 NAAQS						Annual NO_2 NAAQS			
Year	Receptor	Source CO	Source NO_x	1st Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	8^{th} Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	Annual
2007	23	33	3.03	0.167	5/12/2007	8	23	18	1.78	0.098	5/16/2007	16	4	31	2.86	0.052
2008	23	37	3.36	0.169	6/10/2008	13	23	18	1.78	0.097	6/4/2008	11	4	30	2.78	0.052
2009	23	36	3.28	0.167	1/11/2009	7	23	18	1.78	0.095	3/15/2009	19	23	30	2.78	0.052
2010	23	36	3.28	0.166	2/25/2010	14	23	18	1.78	0.094	3/3/2010	8	4	34	3.11	0.052
2011	23	36	3.28	0.168	2/2/2011	7	23	18	1.78	0.097	3/11/2011	12	23	31	2.86	0.052
Highest				**0.169**			Average			**0.096**			Highest			**0.052**

TABLE 2-45: 1-HOUR NO_2 LEVELS FOR COMPLIANCE DEMONSTRATION – DEWEY SQUARE TUNNEL: CONFIGURATION 3 (PPM)

CONFIG 3																	
	MassDEP One Hour Policy Guidance level						One Hour NO_2 NAAQS						Annual NO_2 NAAQS				
Year	Receptor	Source CO	Source NO_x	1st Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	8^{th} Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	Annual
2007	10	45	4.03	0.167	5/30/2007	8	4	23	2.20	0.097	12/22/2007	18	10	23	2.20	0.052
2008	10	45	4.03	0.167	2/26/2008	3	4	23	2.20	0.100	6/10/2008	9	4	23	2.20	0.052
2009	4	44	3.94	0.167	10/30/2009	2	4	23	2.20	0.097	12/30/2009	19	10	24	2.28	0.051
2010	4	44	3.94	0.167	4/14/2010	22	4	23	2.20	0.098	12/10/2010	12	10	24	2.28	0.051
2011	4	43	3.86	0.169	12/13/2011	7	4	23	2.20	0.098	7/14/2011	22	4 / 10	24	2.28	0.051
Highest				**0.169**			Average			**0.098**			Highest			**0.052**

2.7.3 VOC Emission Limit Determination

This analysis was performed as part of the 2011 CA/T Renewal Operating Certification, which established the compliance with the VOC budget established in the 2006 CA/T operating Certification. For completeness the description is repeated here.

In order to assess the effects of the CA/T Project on VOC regional levels, transportation related (highway, transit, commuter rail and ferries) VOC emissions for 2010 were estimated for the area affected by the CA/T Project. The analysis includes a demonstration that projected VOC emissions for 2010 will not exceed the 2005 VOC emissions budget of 6,095.9 kg/day that was established as part of the 2006 Operating Certification.

2.7.3.1 Travel Demand Model

The travel model used for the CA/T Project VOC Analysis is based on procedures and data that have evolved over many years. The model set is the same type as those used in most large urban areas in North America. It is based on the traditional four-step urban transportation planning process of trip generation, trip distribution, mode choice, and trip assignment.

A description of the modeling process can be found in Appendix B-2 ("Air Quality Analysis Protocol for the Determination of $PM_{2.5}$ Emission Limits and Verification of VOC Emissions Budget for the Renewal of the Operating Certification of the Project Ventilation System") of this document.

The CTPS model area encompasses 164 cities and towns in Eastern Massachusetts, as shown in Figure 2-20. The CA/T Project area is shown in Figure 2-21. The modeled area is divided into 986 internal Traffic Analysis Zones (TAZ). There are 101 external stations around the periphery of the modeled area that allow for travel between the modeled area and adjacent areas of Massachusetts, New Hampshire and Rhode Island.

Population, employment, number of households, auto ownership, highway and transit levels of service, downtown parking costs, auto operating costs, and transit fares are some of the important inputs that are used in applying the model to a real world situation. These inputs are constantly updated, so that the model set simulates current travel patterns with reasonable accuracy. The model set simulates travel on the entire Eastern Massachusetts transit and highway system. It contains all MBTA rail and bus lines and all private express bus carriers. The model contains service frequency (i.e., how often trains and buses arrive at any given transit stop), routing, travel time, and fares for all these lines. In the highway system, all express highways and principal arterial roadways and many minor arterial and local roadways are included. Results from the computer model provide detailed information relating to transit ridership demand and highway utilization.

FIGURE 2-20: CTPS MODELED AREA

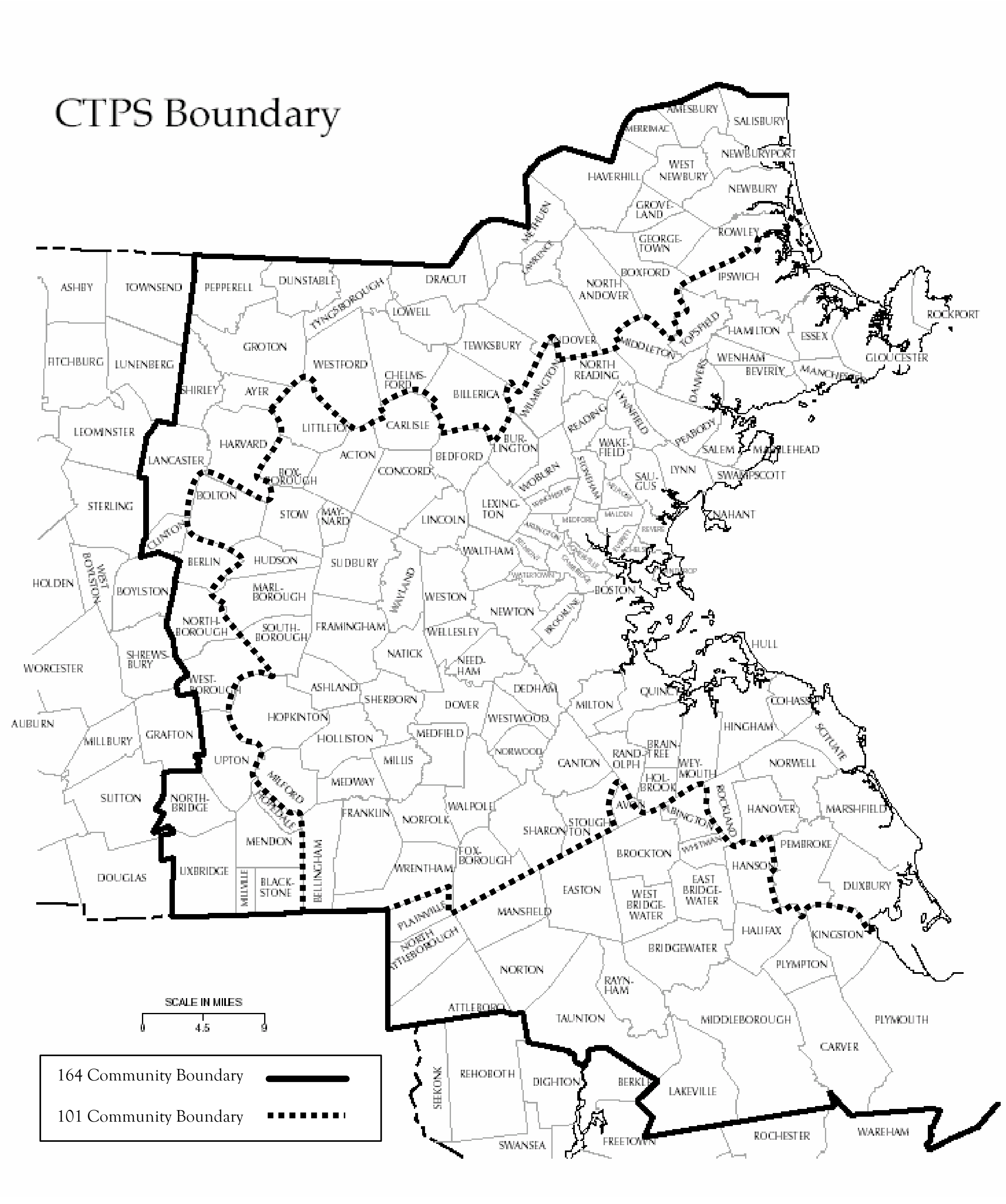


FIGURE 2-21: CA/T PROJECT STUDY AREA

2.7.3.2 Procedures for Highway Network VOC Analysis

The air quality effects of regional VOC levels of the two transportation scenarios (2005 CA/T Project Build and 2010 CA/T Project Build) were analyzed using the travel demand model previously described. From the highway assignment component of the model, traffic volumes, average highway speeds, vehicle miles, and vehicle hours traveled were estimated. The amount of VOC emitted by the highway traffic depends on the prevailing highway speeds and vehicle miles traveled on the network. The CTPS model uses MOBILE 6.2 emission factors to calculate VOC on a link-by-link basis based on the congested speed and vehicle miles of travel.

The 2010 Build network was defined by CTPS to include additional projects that were constructed between 2005 and 2010. The resulting 2010 Build network was then used to estimate VOC emissions associated with the 2010 Build scenario. VOC emissions associated with the 2010 Build network are compared to the 2005 VOC emissions budget in order to demonstrate that the Project is in compliance with the budget.

Table 2-46 provides a list of projects included in the 2005 Build and 2010 Build networks for the CA/T Project.

TABLE 2-46: PROJECTS INCLUDED IN THE 2005 AND 2010 C/A PROJECT BUILD NETWORK

Highway	Reason for inclusion
Projects Built Before 2005	
Route 53, Phase I (Hanover)	X
Blue Hill Avenue Signal Coordination	X
Brighton Avenue Signal Coordination	X
Marrett Road Signal Coordination	X
Beverly Salem Bridge	X
Route 20, Segment 1 (Marlborough)	X
Route 20, Segments 2 & 3 (Marlborough)	X
I-495 Interchange (Marlborough/Southborough)	X
I-93/Industriplex Interchange (Woburn)	X
Quincy Center Concourse, Phase I (Quincy)	X
Route 62 and Middlesex Turnpike (Burlington)	X
Route 9 (Wellesley)	X
Route 138 (Canton)	X
Bridge Street – Boston to Flint (Salem)	X
Massachusetts Avenue/Lafayette Square (Cambridge)	X
Cambridgeport Roadways	X
I-95(SB)/Dedham Street Onramp (Canton)	X
Route 140 (Franklin)	X
Route 139 (Marshfield)	X
Route 38 (Wilmington)	X
Route 1 and Associated Improvements	X
Route 3 North	X
Central Artery	X
Ted Williams Tunnel	X
South Boston Bypass Road (aka Haul Road)	X
Leverett Circle Bridge (Charlestown)	X
HOV Lane on I-93 (Mystic Avenue)	SIP
HOV Lane on Southeast Expressway	SIP

TABLE 2-46: PROJECTS INCLUDED IN THE 2005 AND 2010 C/A PROJECT BUILD NETWORK (CONTINUED)

Highway	Reason for inclusion
Projects Built Between 2005 and 2010	
Bridge Street Bypass (Salem)	X
Route 53 (Hanover)	X
Burgin Parkway (Quincy)	X
Route 53/228 (Hingham & Norwell)	X
Crosby Drive (Bedford)	X
I-93/Ballardvale Street (Wilmington) partial interchange	X
Transit	
Projects Built Before 2005	
Amtrak Northeast Corridor Electrification	X
Route 128 Amtrak Station	X
Amtrak Service to Portland, Maine	X
Mattapan Refurbishment	X
Industriplex Intermodal Center (Woburn)	X
Airport Intermodal Transmit Connector	X
Urban Ring bus service (CT1, CT2, CT3)	CAT/SIP study
Additional Park and Ride Spaces	SIP/CAT/ACO
South Station Transportation Center	SIP/CAT
Commuter Boat Service in the Inner Harbor	CAT
Newburyport Commuter Rail Service	SIP/CAT
Old Colony Commuter Rail (two lines)	SIP/CAT
Worcester Commuter Rail, full service	SIP/CAT
Worcester Commuter Rail, new stations	ACO
Silver Line – Transitway, Phase 1	SIP/CAT/ACO
Silver Line – Washington Street, Phase 2	CAT/ACO
Low Emission Buses	ACO
North Station Improvements	SIP/CAT
Bus Service Improvements to the North Shore	Substitute
Hingham Ferry	Substitute
Improved service on the Haverhill Commuter Rail Line	Substitute
New Commuter Rail Station at JFK/UMASS Station	Substitute
Projects Built Between 2005 and 2010	
Blue Line Platform Lengthening	X
Greenbush Commuter Rail Service	X
Peabody Express to Logan and Logan Express from Anderson	X
Fairmount Phase I - ACO requirements	X

Notes:
X = Also included in No Build Network
SIP = Projected included in the Transit System Improvements Regulation of the SIP
CAT = Project included in the Certification of Tunnel Ventilation System Regulation
ACO = Project included in the Administrative Consent Order
Substitute = Project approved as a substitute to the Old Colony Greenbush project
Delayed transit projects including Blue Line Platform Lengthening, Green Line extension to Medford Hillside and Union Square, Old Colony Commuter Rail extension to Greenbush, and additional Orange Line vehicles were not included in the No Build or 2005 Build Networks.

There are other transportation related components contributing to VOC emissions, which cannot be handled directly within the model. These are:

- The pollutants emitted by the Diesel Locomotives of the commuter rail system
- The pollutants emitted by the MBTA bus system
- The pollutants emitted by the commuter ferries

The pollutants from the categories above can be estimated outside of the model and included with the vehicular emissions calculated within the model. The following paragraphs describe the general off-model procedure that was used to handle these categories.

2.7.3.3 Procedure for Off-Model VOC Analysis

Commuter Rail Diesel Locomotives

The CTPS approach involved the following steps:

- Obtaining the current train-miles run by the MBTA per day.
- Estimating the number of train-miles to be run per day for 2005 on all the existing rail lines as well as on all future extensions and new services such as the Old Colony lines based on the MBTA's future service plan.

Using the emission factors developed by the EPA, and the number of train-miles, the amount of VOC emitted by the commuter rail system were estimated for 2010. The emission factors developed by EPA are based on the total diesel fuel consumption by the entire MBTA's commuter rail system. Therefore, the pollutants emitted during the long idling periods have also been figured into the calculations.

MBTA'S Diesel & CNG Buses

The bus emissions were calculated in the same way as the commuter trains but with an emission factor specific to the bus fuel type. The bus emission factors for 2010 were calculated from the MBTA's most current schedule information.

Commuter Ferries

The daily VOC emissions for the year 2005 were estimated based on fuel consumption supplied by the ferry operators, and the EPA pollutant emission factors for marine gas and diesel engines. Since there have been no significant changes in ferry operations within the CTPS modeled area; and there are no current data available on ferry fuel consumption to provide a 2010 emission estimates for actual ferry operations, the emissions reported in 2005 are reported for 2010 operations.

2.7.4 VOC Analysis Results

The results of the VOC regional analyses are presented for three different scales: Eastern Massachusetts Regional Planning Area (EMRPA) 164 community boundary, the MPO 101 community boundary, and the CA/T Project area.

Tables 2-47 to 2-51 provide the daily VMT and VOCs for the vehicular network and the off-network MBTA buses, commuter railroad, and ferries.

TABLE 2-47: NETWORK-BASED DAILY VMT (VEHICLES MILES TRAVELED) AND VOCS (KG/DAY)

Region	2005 CA/T Build		2010		Changes	
	VMT	VOC	VMT	VOC	VMT	VOC
EMRPA	121,016,208	81,734	122,226,370	50,990	1,210,162	-30,744
MPO	86,877,467	59,499	87,746,242	37,460	868,775	-22,039
CA/T	7,767,266	5,909	7,844,939	3,720	77,673	-2,189

TABLE 2-48: MBTA BUSES DAILY VMT AND VOCS (KG/DAY)

Region	2005 CA/T Build		2010		Changes	
	VMT	VOC	VMT	VOC	VMT	VOC
EMRPA	88,628	52.1	91,102	53.6	2,474	1.5
MPO	88,588	52.1	91,062	53.6	2,474	1.5
CA/T	10,001	8.2	10,280	8.4	279	0.2

TABLE 2-49: COMMUTER RAILROAD DAILY VMT AND VOCS (KG/DAY)

Region	2005 CA/T Build		2010		Changes	
	VMT	VOC	VMT	VOC	VMT	VOC
EMRPA	15,509	597	15,457	595	-52.0	-2.0
MPO	11,560	445	11,521	443	-39.0	-1.5
CA/T	1,258	48	1,254	47.8	-4.0	-0.2

TABLE 2-50: FERRY DAILY FUEL CONSUMPTION AND VOCS (KG/DAY)

Region	2005 CA/T Build		2010*		Changes	
	Fuel (gallons)	VOC	Fuel (gallons)	VOC	Fuel (gallons)	VOC
EMRPA	4,793	392.2	4,793	392.2	0	0
MPO	4,793	392.2	4,793	392.2	0	0
CA/T	1,598	130.7	1,598	130.7	0	0

* 2010 emission data unavailable; 2005 data reported.

Table 2-48 provides the total cumulative (motor vehicle and transit) VMT and VOC, which results in a net reduction of VOC with the CA/T Project and transit commitments.

TABLE 2-51: TOTAL DAILY VOC EMISSIONS (KG/DAY)

Region	2005 CA/T Build	2010	Changes
EMRPA	82,775.3	52,030.8	-30,744.5
MPO	60,388.3	38,349.3	-22,039.0
CA/T	6,095.9	3,906.9	-2,189.0

The results (provided in Table 2-51) demonstrate that the 2010 total estimates for the CA/T area result in a reduction 2,189 kg/day of VOC with respect of the 2006 established VOC budget of 6,095.9 kg/day.

This reduction of approximate 36 % remains very similar for all three regional scales evaluated, despite an increase of approximately 1% in VMT for the five year period.

The emission reductions are the result of cleaner vehicles and fuels mandated by Federal and state regulations over the past decade. As older vehicles are retired and become a smaller contributor to the overall driving and VMT, newer and cleaner vehicles with better emissions control technologies account for a larger share of the VMT and result in reduced regional VOC emissions.

2.8 PROPOSED 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 2-52: SUMMARY OF 2012-2016 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 ($\mu g/m^3$)**
VB 1	70	70	6.1	900
VB 3	70	70	6.1	900
VB 4	70	70	6.1	900
VB 5	70	70	6.1	900
VB 6	70	70	6.1	900
VB 7	70	70	6.1	900
Ramp L-CS	57	70	5.0	NA
Ramp CN-S	37	58	3.4	NA
Ramp SA-CN	70	70	6.1	NA
Ramp ST-CN	70	70	6.1	NA
Ramp ST-SA	58	70	5.1	NA
Ramp CS-SA***	38	55	3.4	35****
Ramp CS-P	41	70	3.7	NA
Ramp F	70	70	6.1	NA
Dewey Sq. Tunnel	23	30	2.2	NA

Notes: Acronyms are defined as: Leverett Circle to Central Artery Southbound (L-CS), Central Artery Northbound to Storrow Drive (C-NS), Sumner Tunnel to Central Artery Northbound (ST-CN), Surface Artery to Central Artery Northbound (SA-CN), Central Artery Southbound to Surface Artery (CS-SA), Sumner Tunnel to Surface Artery (ST-SA), Central Artery Southbound to Purchase Street (CS-P), I-90 Westbound to Congress Street (Ramp F), 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 remain unchanged from the 2011 CA/T Renewal Operating Certification and took effect January 2012

*** 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 $\mu g/m^3$) 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 modeling demonstrate that the 2010 CA/T Project emissions of 3,906.9 kg/day 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) levels of pollutants, pollutant emission levels 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.

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 diverted 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.

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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_{10} monitoring system is also deployed just outside the east portal of longitudinally ventilated exit ramp CS-SA. This monitor measured ambient PM_{10} concentrations in the vicinity of ramp CS-SA, and $PM_{2.5}$ levels as a pilot program during several months of 2009-2010 It is being deployed as a permanent monitor to measure $PM_{2.5}$ ambient levels.

3.3.3 CO Monitoring System

The CEM equipment used to measure and/or record CO levels is described below. The tunnel ventilation CO monitoring system is independent of the CEM monitoring system. 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 L-CS, CN-S, SA-CN, CS-SA, ST-SA/ST-CN, CS-P, DST-I93, DST-I-90 and F, 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.

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 diverted 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 diverted 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 to the top of the ramps boat-wall section. This location is representative of the ambient $PM_{2.5}$ conditions close to the traffic emerging from the I-93 southbound 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 was 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 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 L-CS, CN-S, SA-CN, CS-SA, ST-SA/ST-CN, CS-P, DST-I93, DST-I-90 and F, is recorded using a System Controller/Data Logger (data logger) at each location. The data loggers constitute the Data Acquisition Handling System (DAHS) for each CEM location. The data loggers control the calibration routines for the CO analyzers and records 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, were 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 were: 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 was injected directly into each CO analyzer. The instruments were adjusted first at the zero level and then at the high value. After each instrument was adjusted at the high value, the zero level was injected again. If the zero level required re-adjustment, then the high level concentration was injected again. If necessary, several iterations between the zero and high level concentrations were performed to ensure that an analyzer was calibrated. The calibration specification for acceptability was ±1.0 ppm for zero and ±5% of the input concentration for the high level point. All remaining concentrations levels were injected without any further analyzer adjustments. The average Δ% for calibration points were 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 were 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 were input through the entire monitoring system for 30 minutes, or until a stable response was achieved. At the end of the period, a high-level calibration gas with a value of 80 to 90 ppm was 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 was determined. The cycle time test was successful was the response time achieved was less than 15 minutes.

The linearity of the monitoring system to the low and high scale calibration gases was also tested during the cycle time test. To pass the linearity test, the monitoring system response had to be within ±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 was 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 was 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 was performed. The high-level calibration concentration was injected through the entire emission monitoring system. The acceptable system bias was ±5% according to the equation:

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

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 will be performed on each $PM_{2.5}$ unit located at VBs and outside longitudinally ventilated exit Ramp CS-SA and will 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 will be conducted by using five pre-weighed filters. [The $PM_{2.5}$ monitoring units will become operational after December 22, 2011 when the Operating Certification is renewed.]

In all cases, the manufacturer recommended procedures specified in the $PM_{2.5}$ unit's operating manuals were applied for all certifications tests. Reference standards used were 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 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 are four locations where hourly traffic volumes are recorded, as follows:

- I-93 southbound in the vicinity of Causeway Street
- I-93 northbound in the vicinity of South Station
- I-90 westbound in East Boston
- I-90 eastbound in the vicinity of Fort Point Channel

These locations represent the tunnel sections that account for the vast majority of the Project's traffic volumes, and as such, they provide MassDEP with a very good indication of the peak hourly and daily traffic volumes passing thru the CA/T tunnels.

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 or 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, 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 to be 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 return an out-of-control system or component back to 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.

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 within.

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 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;
- 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 by the DAHS;
- Ensuring that routine and periodic QC inspections, instrument response checks, calibrations and adjustments are 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 monthly (first year of full operations only) and quarterly (thereafter) reports of CEMS data and QC check results;
- Supporting periodic independent and third-party QA Performance and Systems Audits in coordination with QA Management, regulatory agencies (as applicable), and any subcontractor(s) that may conduct such work;
- Review and timely submittal 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 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 Performance Audits;
- Preparation of monthly (first year of full operations only) or quarterly (thereafter) reports of CEMS data, QC check results, and excess emissions (if any) 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_{10} 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.

If necessary, Data Management responsibilities may be integrated with the responsibilities of the Senior Environmental Engineer and/or his designee (e.g., Environmental Engineer, Environmental Technicians).

4.1.3.3 Environmental Engineers

The Environmental Engineer(s), working with direction from the Senior Environmental Engineer, are responsible for routine operation, maintenance and calibration 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, alarms appearing on instrumentation or generated by the DAHS, 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 Management responsibilities if so assigned 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)

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 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 and QA Management 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 was 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 related systems (e.g., the DAHS), 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.

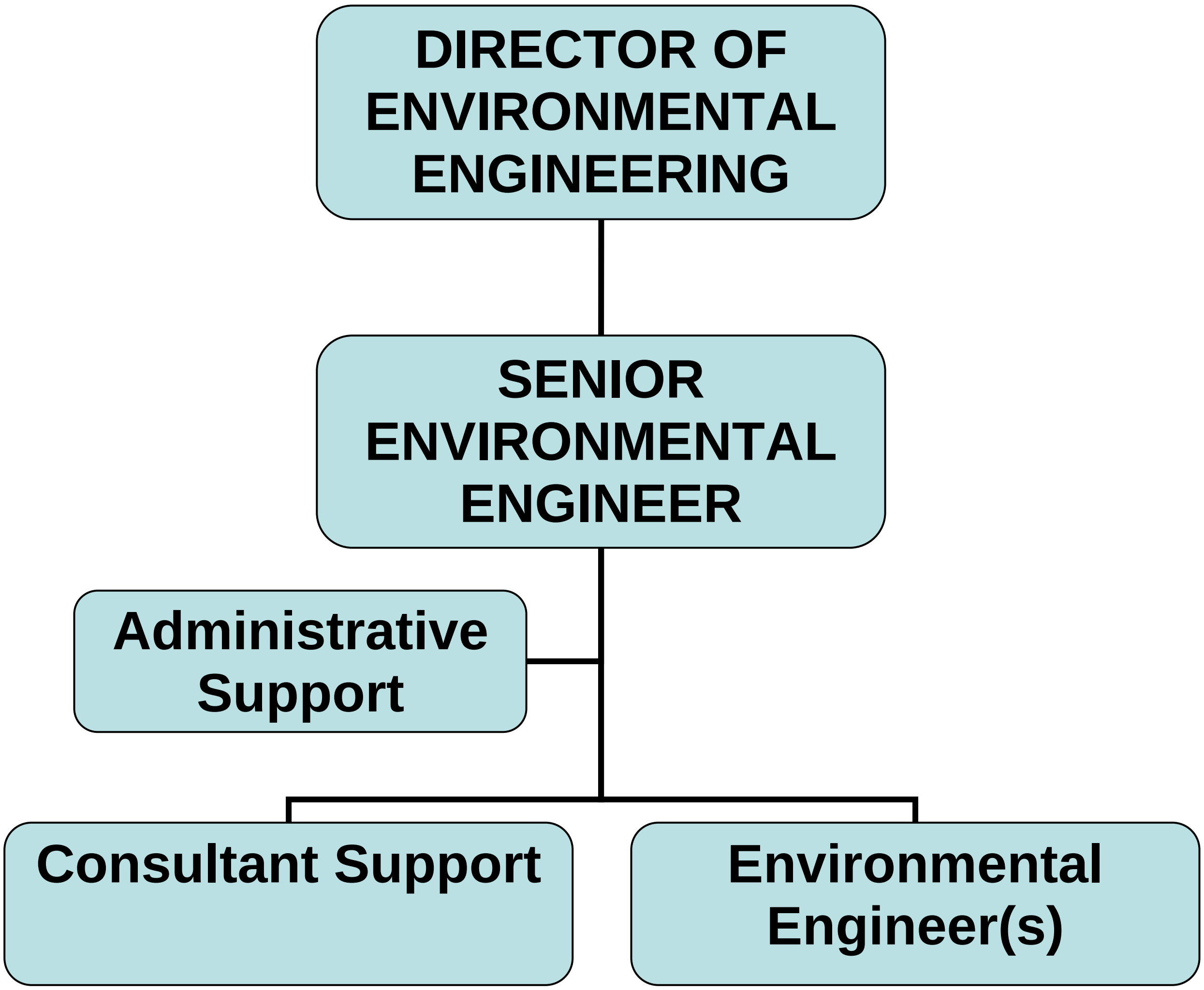
Finally, when system components change (e.g., the replacement of a pollutant monitor with an instrument that bases its measurements on a different analytical method – as opposed to the repair or replacement of a failed part) or software upgrades to the DAHS are made, specialized vendor training takes 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/submittal • QA Performance Audit report review/submittal • 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-Fri).
2 -- Each site to be visited 2 times, nominally, per regular work week (Mon-Fri).

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



MASSDOT-ENV-FORM01
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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 edited as necessary and daily data summaries for each month are generated. Using the edited daily summaries, NO_2 emission concentrations are developed using the CO to NO_2 conversion ratio described in Section 2.4.5. At the start of the $PM_{2.5}$ monitoring, the reports will be submitted to MassDEP on a monthly basis from January through December 2012 and at a quarterly intervals thereafter.

5.3 TRAFFIC DATA PROCESSING

The HOC will record hourly volumes at the following locations:

- I-93 southbound in the vicinity of Causeway Street
- I-93 northbound in the vicinity of South Station
- I-90 westbound in East Boston
- I-90 eastbound in the vicinity of Fort Point Channel

Peak hourly and average daily traffic volumes at each of the four 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 July 2006 to December 2010. Figure 5-2 presents the peak hourly volumes for the same locations and time periods.

FIGURE 5-1: PEAK AND AVERAGE DAILY TRAFFIC VOLUMES FOR PERIOD 2006-2012

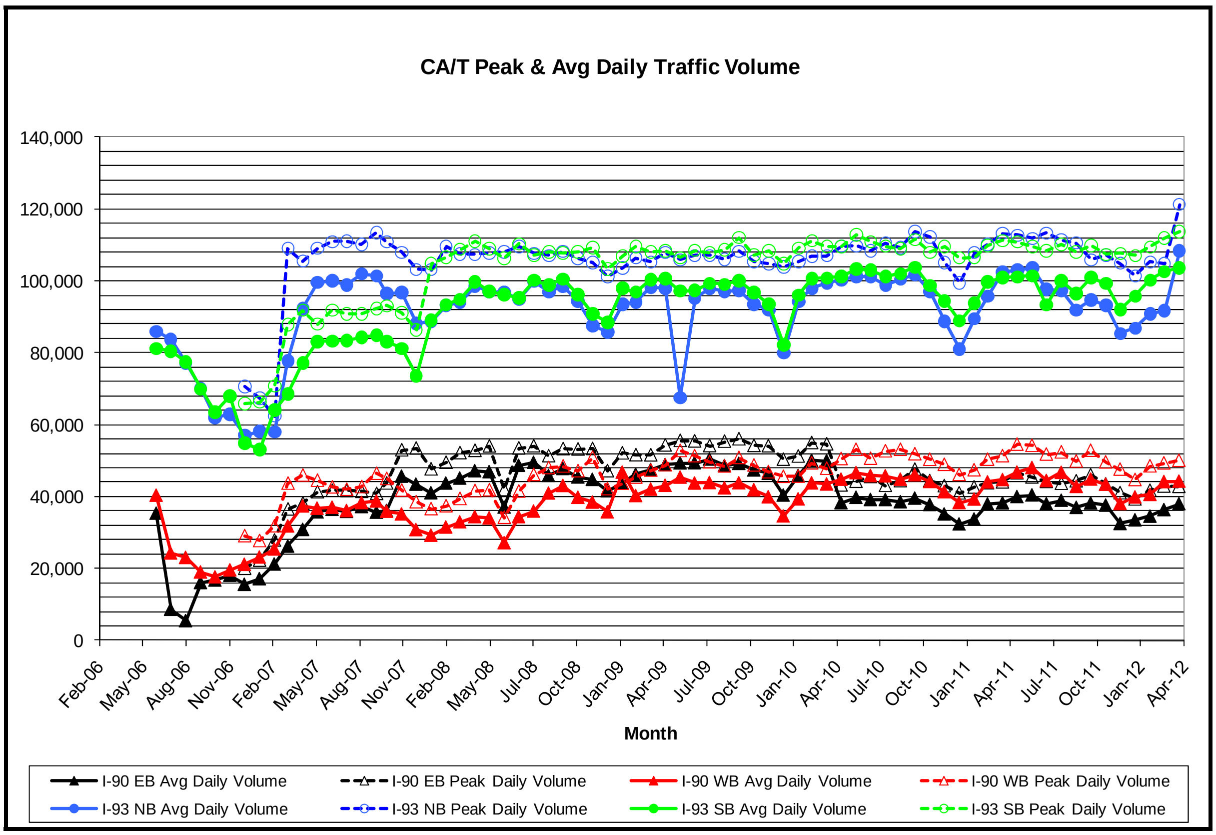
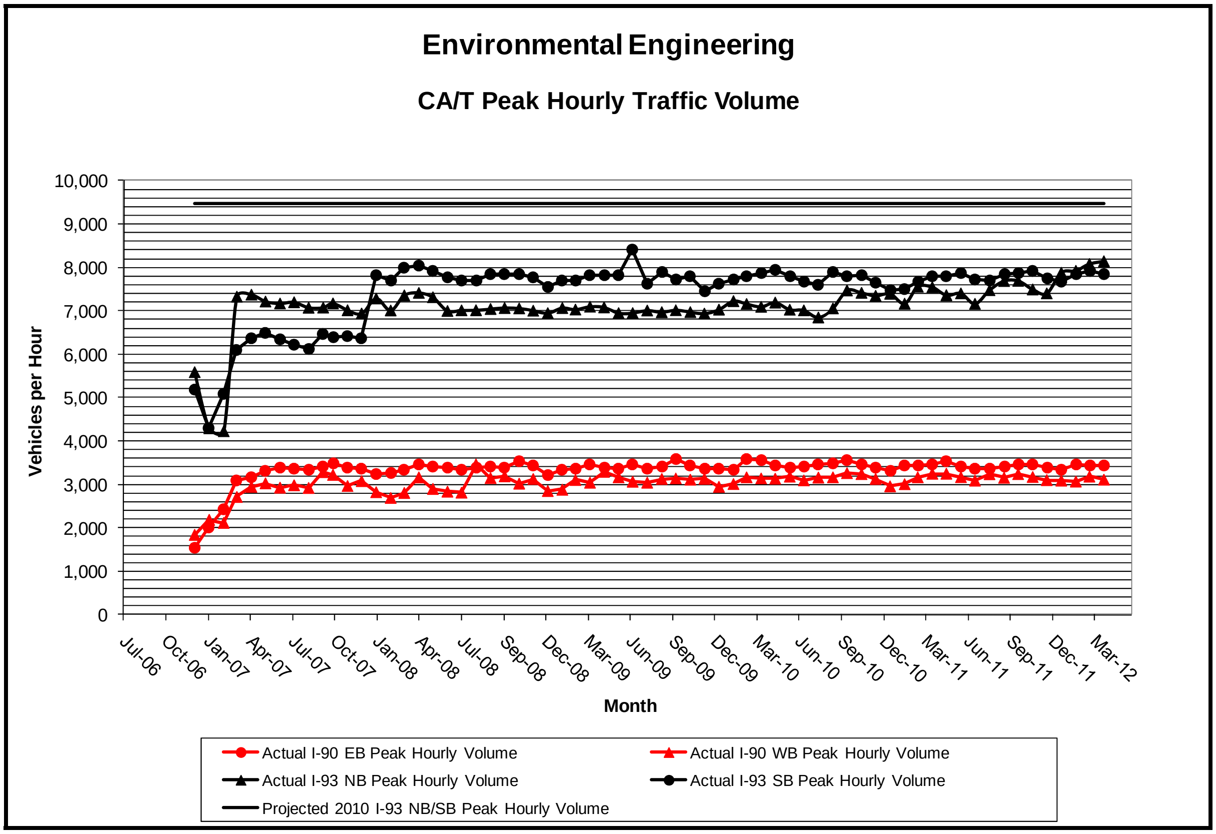


FIGURE 5-2: PEAK HOURLY TRAFFIC VOLUMES FOR PERIOD 2006-2012



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 monthly basis for the first year of 2011 Operating Certification and on a quarterly basis thereafter.

5.5 CONTINUOUS EMISSIONS MONITORING DATA SUMMARY REPORTS

Annual summaries of the CO, NO_x and PM_{10} average and peak levels for each VB (Tables 5-1 to 5-6) and longitudinally ventilated section collected between 2006 and first four months of 2012 are provided in Tables 5-1 to 5-16. The applicable emission limits for CO, NO_x, PM_{10}, and $PM_{2.5}$ are also set forth in these tables.

As described in Section 2, the PM_{10} emission limit was replaced by the $PM_{2.5}$ limit in 2012, and the five PM_{10} monitoring stations were converted to $PM_{2.5}$ in the end of 2011. Starting in January 2012, the $PM_{2.5}$ data were compiled and submitted to the MassDEP on a monthly basis for the period January 2012 through December 2012, and on a quarterly basis thereafter. The proposed CO and NO_x emission limits after they are approved will come into effect from January 2013. Starting January 2013 and through

December 2013 the CO and NO_x monitoring data will be submitted to MassDEP on a monthly basis. This data will be submitted to MassDEP on a quarterly basis thereafter.

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

- Measured CO concentrations for the Ventilation Buildings range from 0.5 to 10.1 ppm on average, with maximum 1-hour values as high as 31.4 ppm;
- Measured CO concentrations for the DST and Ramps range from 0.5 to 5.8 ppm on average, with maximum 1-hour average concentrations ranging from 12.6 to 71.9 ppm;
- Measured NO_x levels for the Ventilation Buildings range from 0.3 to 0.7 ppm on average, with maximum 1-hour values ranging from 1.6 to 4.5 ppm;
- Measured NO_x levels for the DST and Ramps range from 0.3 to 0.9 ppm on average, with maximum 1-hour values ranging from 1.8 to 9.1 ppm;
- Measured PM_{10} concentrations (2006-2011) were between 31 and 121 $\mu g/m^3$ on average, with maximum daily values ranging from 100 to 577 $\mu g/m^3$;
- Measured PM2.5 concentrations in the first 4 months of 2012 were between 6.8 and 40.9 $\mu g/m^3$ on average, with maximum daily values ranging from 23 to 88.1 $\mu g/m^3$;
- The PM_{10} monitor outside Ramp CS-SA, which measures ambient levels, recorded annual averages from 19 to 21 $\mu g/m^3$, and a maximum daily level of 116 $\mu g/m^3$. This monitor (which was converted to PM2.5 in 2011) recorded concentrations from 7.6 to 25.5 $\mu g/m^3$.

The data indicate that the pollutant levels inside the tunnels are generally much lower than anticipated, with CO levels decreasing in the latter years. However, as described in detail in Section 6, there were a very few episodes when emission limits for CO or PM_{10} were exceeded. Episodes when emission limits were exceeded were the result of abnormal conditions related to night-time tunnel closures due to maintenance, system malfunction, and of road salt application during snowstorms.

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

Monitor Location: *VB1 Exhaust Ducts 1 & 2 (Ramp L/HOV for I-90 EB)*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2006	2007	2008	2009	2010	2011	2012: Jan-Apr
CO	1 Hour	70 ppm	Maximum	ppm	8.7	27.8	8.8	7.2	7.5	6.2	3.2
			Average	ppm	1.2	1.3	1.3	1.2	1.1	1.0	0.9
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	5.1	5.1	3.5	3.2	3.5	2.6	2.0
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	1.60	3.60	1.30	1.10	1.10	1.00	0.60
			Average	ppm	0.33	0.37	0.33	0.37	0.32	0.33	0.30
			Hours exceed EL								
			Hours exceed 80% EL								

Monitor Location: *VB1 Exhaust Ducts 8 & 9 (Ramp L/HOV for I-90 EB)*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2006	2007	2008	2009	2010	2011	2012: Jan-Apr
CO	1 Hour	70 ppm	Maximum	ppm	12.2	28.6	7.8	7.2	6.6	6.0	3.4
			Average	ppm	1.1	1.3	1.1	1.1	1.0	1.0	0.8
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	5.6	6.5	3.5	3.2	3.2	3.4	1.8
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	1.70	3.70	1.20	1.10	1.00	0.90	0.60
			Average	ppm	0.31	0.36	0.33	0.33	0.32	0.32	0.30
			Hours exceed EL								
			Hours exceed 80% EL								

Monitor Location: *VB1 Exhaust Ducts 3 & 4 (I-90 EB)*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2006	2007	2008	2009	2010	2011	2012: Jan-Apr
CO	1 Hour	70 ppm	Maximum	ppm	12.8	26.6	12.1	3.7	3.2	3.9	2.1
			Average	ppm	1.1	1.0	0.9	0.9	0.8	0.9	0.7
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	5.4	4.6	5.6	2.0	2.1	2.4	1.8
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	1.80	3.50	1.70	0.80	0.60	0.70	0.50
			Average	ppm	0.36	0.33	0.31	0.31	0.30	0.32	0.30
			Hours exceed EL								
			Hours exceed 80% EL								

Note: EL = Emission Limit

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

Monitor Location: *VB1 Exhaust Ducts 7 (I-90 WB)*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2006	2007	2008	2009	2010	2011	2012: Jan-Apr
CO	1 Hour	70 ppm	Maximum	ppm	9.2	34.4	5.9	4.5	2.6	5.3	2.4
			Average	ppm	1.0	1.1	0.8	1.0	0.9	0.9	0.8
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	7.9	5.3	2.7	2.2	2.2	2.3	1.9
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	1.30	4.50	0.90	0.80	0.50	0.90	0.50
			Average	ppm	0.31	0.33	0.33	0.32	0.31	0.30	0.30
			Hours exceed EL								
			Hours exceed 80% EL								

Monitor Location: *VB1 Exhaust Ducts 5 & 6 (I-90 WB)*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2006	2007	2008	2009	2010	2011	2012: Jan-Apr
CO	1 Hour	70 ppm	Maximum	ppm	8.6	21.1	9.5	4.9	2.9	4.9	3.1
			Average	ppm	1.2	1.2	1.1	1.0	1.0	1.1	0.8
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	7.4	3.8	2.6	2.9	2.5	2.7	2.6
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	1.30	2.80	0.90	0.80	0.80	0.80	0.60
			Average	ppm	0.34	0.35	0.33	0.33	0.32	0.33	0.30
			Hours exceed EL								
			Hours exceed 80% EL								

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

Pollutant	Time Period	Emission Limits	Parameter	Unit	2006	2007	2008	2009	2010	2011	2012: Jan-Apr
CO	1 Hour	70 ppm	Maximum	ppm	29.9	23.2	11.1	6.0	7.4	6.8	7.7
			Average	ppm	1.6	1.7	1.5	1.4	1.4	1.5	1.1
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	10.1	5.6	3.7	3.2	3.5	3.8	2.9
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	3.90	3.10	1.60	0.90	1.10	1.00	1.20
			Average	ppm	0.40	0.40	0.40	0.38	0.37	0.36	0.30
			Hours exceed EL								
			Hours exceed 80% EL								

Note: EL = Emission Limit

TABLE 5-2: SUMMARY OF CO, NO_X, PM_{10} AND $PM_{2.5}$ AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 3

Monitor Location: VB3 NB-1

Pollutant	Time Period	Emission Limits	Parameter	Unit	2006	2007	2008	2009	2010	2011	2012: Jan-Apr
CO	1 Hour	70 ppm	Maximum	ppm	8.1	9.0	5.4	9.9	5.7	11.4	5.7
			Average	ppm	1.9	1.6	1.4	1.2	1.4	1.4	1.4
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	5.4	6.8	4.2	4.6	4.5	3.80	2.3
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	1.20	1.30	0.90	1.40	1.30	1.60	0.90
			Average	ppm	0.43	0.40	0.00	0.59	0.38	0.38	0.38
			Hours exceed EL								
			Hours exceed 80% EL								
PM_{10}	24 Hour	500 $\mu g/m^3$	Maximum	$\mu g/m^3$	176.4	328.3	270.6	375.1	312.5	302.4	NA
			Average	$\mu g/m^3$	63.3	70.7	71.1	108.2	73.7	72.5	NA
			Days exceed EL								
			Days exceed 80% EL								
$PM_{2.5}$	24 Hour	900 $\mu g/m^3$	Maximum	$\mu g/m^3$	NA	NA	NA	NA	NA	NA	60.0
			Average	$\mu g/m^3$	NA	NA	NA	NA	NA	NA	26.3
			Days exceed EL								
			Days exceed 80% EL								

Monitor Location: VB3 NB-2

Pollutant	Time Period	Emission Limits	Parameter	Unit	2006	2007	2008	2009	2010	2011	2012: Jan-Apr
CO	1 Hour	70 ppm	Maximum	ppm	9.6	25..3	10.5	11.8	9.3	11.1	5.9
			Average	ppm	1.7	1.6	1.5	1.2	1.8	1.8	1.7
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	6.9	7.6	4.1	4.4	4.7	6.6	3.1
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	1.90	3.30	1.50	1.70	1.30	1.60	0.90
			Average	ppm	0.40	0.40	0.40	0.41	0.42	0.43	0.40
			Hours exceed EL								
			Hours exceed 80% EL								

Note: EL = Emission Limit

TABLE 5-2: SUMMARY OF CO, NO_X, PM_{10} AND $PM_{2.5}$ AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 3 (CONTINUED)

Monitor Location: *VB3 SB-1*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2006	2007	2008	2009	2010	2011	2012: Jan-Apr
CO	1 Hour	70 ppm	Maximum	ppm	13.7	13.2	10.7	16.1	12.5	9.7	7.4
			Average	ppm	3.9	3.6	3.1	3.1	3.0	2.9	2.4
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	9.1	9.0	8.3	7.6	8.2	7.5	5.0
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	1.90	1.80	1.50	2.20	1.70	1.40	1.10
			Average	ppm	0.67	0.63	0.59	0.58	0.57	0.54	0.50
			Hours exceed EL								
			Hours exceed 80% EL								
PM_{10}	24 Hour	500 $\mu g/m^3$	Maximum	$\mu g/m^3$	166.1	541.6	304.2	545.8	411.9	542.0	NA
			Average	$\mu g/m^3$	77.8	109.0	82.9	107.8	92.6	95.7	NA
			Days exceed EL					3.0			
$PM_{2.5}$	24 Hour	900 $\mu g/m^3$	Maximum	$\mu g/m^3$	NA	NA	NA	88.1	87.5	NA	66.3
			Average	$\mu g/m^3$	NA	NA	NA	40.7	40.9	NA	35.6
			Days exceed EL								
			Days exceed 80% EL								

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.

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

Monitor Location: VB4 NB3

Pollutant	*Time Period*	*Emission Limits*	*Parameter*	*Unit*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012: Jan-Apr*
CO	1 Hour	70 ppm	Maximum	ppm	11.3	15.6	10.9	13.1	10.4	9.9	5.9
			Average	ppm	3.4	2.7	2.5	2.3	2.4	2.2	1.8
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	9.3	9.4	6.5	6.3	6.5	5.8	4.8
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	1.60	2.10	1.50	1.80	1.50	1.40	0.90
			Average	ppm	0.63	0.54	0.53	0.48	0.48	0.46	0.40
			Hours exceed EL								
			Hours exceed 80% EL								

Monitor Location: VB4 NB4

Pollutant	*Time Period*	*Emission Limits*	*Parameter*	*Unit*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012: Jan-Apr*
CO	1 Hour	70 ppm	Maximum	ppm	14.9	14.2	11.5	12.4	11.6	10.7	6.6
			Average	ppm						2.7	2.3
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	13.6	9.6	6.4	6.5	6.9	6.4	5.0
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	2.00	2.00	1.60	1.70	1.60	1.50	1.00
			Average	ppm	0.69	0.58	0.57	0.54	0.54	0.54	0.50
			Hours exceed EL								
			Hours exceed 80% EL								

Note: EL = Emission Limit

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

Monitor Location: *VB4 SB2*

Pollutant	*Time Period*	*Emission Limits*	*Parameter*	*Unit*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012: Jan-Apr*
CO	1 Hour	70 ppm	Maximum	ppm	17.9	11.2	6.8	6.8	8.7	7.5	5.3
			Average	ppm	2.5	1.9	1.9	1.5	1.5	1.5	1.1
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	6.2	6.7	4.7	4.8	5.3	5.6	3.7
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	2.40	1.60	1.00	1.00	1.30	1.10	0.90
			Average	ppm	0.46	0.44	0.43	0.39	0.39	0.38	0.35
			Hours exceed EL								
			Hours exceed 80% EL								

Monitor Location: *VB4 SB3*

Pollutant	*Time Period*	*Emission Limits*	*Parameter*	*Unit*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012: Jan-Apr*
CO	1 Hour	70 ppm	Maximum	ppm	12.2	11.4	7.4	5.5	6.6	6.2	3.7
			Average	ppm	2.2	2.1	1.8	1.7	1.7	1.7	1.3
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	10.3	5.4	4.4	4.1	4.7	4.6	2.7
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	1.70	1.60	1.10	0.90	0.80	1.00	0.70
			Average	ppm	0.49	0.45	0.43	0.43	0.43	0.43	0.40
			Hours exceed EL								
			Hours exceed 80% EL								

Note: EL = Emission Limit

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

Monitor Location: *VB5 EB2*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2006	2007	2008	2009	2010	2011	2012: Jan-Apr
CO	1 Hour	70 ppm	Maximum	ppm	18.4	11.1	7.3	5.9	6.6	4.4	4.4
			Average	ppm	1.5	1.5	1.4	1.3	1.5	1.4	1.1
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	7.8	5.8	3.2	3.8	3.5	3.0	2.2
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	2.50	1.60	1.10	0.90	1.00	0.70	0.70
			Average	ppm	0.37	0.38	0.39	0.34	0.37	0.36	0.30
			Hours exceed EL								
			Hours exceed 80% EL								

Monitor Location: *VB5 EB3*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2006	2007	2008	2009	2010	2011	2012: Jan-Apr
CO	1 Hour	70 ppm	Maximum	ppm	20.7	8.7	7.9	5.0	4.1	4.3	3.3
			Average	ppm	1.4	1.2	1.0	0.9	1.7	1.2	1.0
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	9.2	7.4	3.2	2.9	3.3	3.1	2.4
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	2.80	1.70	1.20	0.80	0.70	0.70	0.60
			Average	ppm	0.37	0.31	0.31	0.31	0.34	0.34	0.30
			Hours exceed EL								
			Hours exceed 80% EL								

Note: EL = Emission Limit

TABLE 5-4: SUMMARY OF CO, NO_X, PM_{10} AND $PM_{2.5}$ AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 5 (CONTINUED)

Monitor Location: VB5 WB2

Pollutant	*Time Period*	*Emission Limits*	*Parameter*	*Unit*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012: Jan-Apr*
CO	**1 Hour**	**70 ppm**	**Maximum**	**ppm**	16.5	10.0	8.5	3.5	2.9	11.2	2.5
			Average	**ppm**	1.4	1.2	1.2	1.1	1.1	1.2	1.2
			Hours exceed EL								
	8 Hour	**70 ppm**	**Maximum**	**ppm**	7.6	3.6	7.1	2.7	2.6	3.8	2.1
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	**1 Hour**	**8.88 ppm**	**Maximum**	**ppm**	2.20	1.40	1.30	0.60	0.60	1.60	0.50
			Average	**ppm**	0.37	0.35	0.34	0.33	0.33	0.33	0.35
			Hours exceed EL								
			Hours exceed 80% EL								
PM_{10}	**24 Hour**	**500 $\mu g/m^3$**	**Maximum**	**$\mu g/m^3$**	139.7	128.8	103.3	248.2	159.7	279.8	NA
			Average	**$\mu g/m^3$**	46.8	38.8	36.9	44.8	32.0	41.3	NA
			Days exceed EL								
			Days exceed 80% EL								
$PM_{2.5}$	**24 Hour**	**900 $\mu g/m^3$**	**Maximum**	**$\mu g/m^3$**	NA	NA	NA	NA	NA	NA	38.8
			Average	**$\mu g/m^3$**	NA	NA	NA	NA	NA	NA	18.6
			Days exceed EL								
			Days exceed 80% EL								

Monitor Location: VB5 WB3

Pollutant	*Time Period*	*Emission Limits*	*Parameter*	*Unit*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012: Jan-Apr*
CO	**1 Hour**	**70 ppm**	**Maximum**	**ppm**	13.3	4.7	6.4	2.7	2.8	3.2	2.2
			Average	**ppm**	1.4	1.1	1.1	0.9	0.9	1.0	1.0
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	**70 ppm**	**Maximum**	**ppm**	10.0	2.8	6.2	1.9	2.1	2.1	1.8
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	**1 Hour**	**8.88 ppm**	**Maximum**	**ppm**	1.80	0.80	1.00	0.50	0.50	0.60	0.50
			Average	**ppm**	0.37	0.33	0.33	0.32	0.32	0.33	0.30
			Hours exceed EL								
			Hours exceed 80% EL								

Note: EL = Emission Limit

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

Monitor Location: VB6 EB

Pollutant	Time Period	Emission Limits	Parameter	Unit	2006	2007	2008	2009	2010	2011	2012: Jan-Apr
CO	1 Hour	70 ppm	Maximum	ppm	11.1	8.4	4.4	4.2	3.0	2.7	2.3
			Average	ppm	10.1	1.2	1.1	1.1	0.9	0.9	0.7
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	4.2	3.4	2.6	2.2	1.9	2.2	1.7
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	1.60	1.20	0.70	0.70	0.60	0.50	0.50
			Average	ppm	0.33	0.33	0.33	0.31	0.31	0.31	0.30
			Hours exceed EL								
			Hours exceed 80% EL								

Monitor Location: VB6 WB

Pollutant	Time Period	Emission Limits	Parameter	Unit	2006	2007	2008	2009	2010	2011	2012: Jan-Apr
CO	1 Hour	70 ppm	Maximum	ppm	17.4	15.0	13.9	10.1	7.2	8.5	6.5
			Average	ppm	2.0	2.0	1.9	1.8	1.6	1.5	1.5
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	7.2	5.3	5.0	3.4	3.2	4.2	3.0
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	2.40	2.10	1.90	1.40	1.10	1.30	1.00
			Average	ppm	0.44	0.45	0.42	0.41	0.39	0.40	0.40
			Hours exceed EL								
			Hours exceed 80% EL								

Note: EL = Emission Limit

TABLE 5-6: SUMMARY OF CO, NO_X, PM_{10} AND $PM_{2.5}$ AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 7

Monitor Location: VB7 TA/D

Pollutant	Time Period	Emission Limits	Parameter	Unit	2006	2007	2008	2009	2010	2011	2012: Jan-Apr
CO	1 Hour	70 ppm	Maximum	ppm	30.2	12.9	13.8	13.1	14.0	22.6	5.8
			Average	ppm	2.2	2.9	2.7	2.7	2.6	2.1	1.5
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	4.8	8.4	7.6	7.1	6.8	7.7	3.4
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	3.90	1.80	1.90	1.80	1.90	3.00	0.90
			Average	ppm	0.47	0.58	0.42	0.56	0.53	0.47	0.38
			Hours exceed EL								
			Hours exceed 80% EL								

Monitor Location: VB7 Intake

Pollutant	Time Period	Emission Limits	Parameter	Unit	2006	2007	2008	2009	2010	2011	2012: Jan-Apr
CO	1 Hour	70 ppm	Maximum	ppm	6.1	2.3	2.1	2.2	6.9	2.4	2.2
			Average	ppm	1.0	0.6	0.6	0.6	0.6	0.5	0.4
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	5.1	1.8	1.8	1.6	2.3	1.7	2.0
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Average	ppm	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Hours exceed EL								
			Hours exceed 80% EL								
PM_{10}	24 Hour	500 $\mu g/m^3$	Maximum	$\mu g/m^3$	52.1	54.7	41.8	36.0	40.8	32.4	NA
			Average	$\mu g/m^3$	17.4	14.7	13.6	13.1	12.9	11.9	NA
			Days exceed EL								
			Days exceed 80% EL								
$PM_{2.5}$	24 Hour	900 $\mu g/m^3$	Maximum	$\mu g/m^3$	NA	NA	NA	NA	NA	NA	23.0
			Average	$\mu g/m^3$	NA	NA	NA	NA	NA	NA	6.8
			Days exceed EL								
			Days exceed 80% EL								

Note: EL = Emission Limit

TABLE 5-6: SUMMARY OF CO, NOX, PM_{10} AND $PM_{2.5}$ AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 7 (CONTINUED)

Monitor Location: *VB7 WB2*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2006	2007	2008	2009	2010	2011	2012: Jan-Apr
CO	1 Hour	70 ppm	Maximum	ppm	10.3	9.7	10.9	11.6	6.4	6.8	4.8
			Average	ppm	1.7	1.8	1.6	1.5	1.7	1.3	0.7
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	7.2	5.2	3.6	3.5	3.4	3.9	1.9
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	1.60	1.40	1.50	1.60	1.00	1.00	0.80
			Average	ppm	0.40	0.43	0.40	0.39	0.40	0.38	0.30
			Hours exceed EL								
			Hours exceed 80% EL								

Monitor Location: *VB7 EB2*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2006	2007	2008	2009	2010	2011	2012: Jan-Apr
CO	1 Hour	70 ppm	Maximum	ppm	10.1	22.8	9.8	10.4	8.9	27.1	6.3
			Average	ppm	1.7	2.4	2.4	2.0	2.1	1.6	1.3
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	5.9	7.9	5.8	5.5	5.6	6.3	3.0
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	1.40	2.50	1.40	1.50	1.30	3.60	1.00
			Average	ppm	0.40	0.49	0.50	0.43	0.46	0.40	0.38
			Hours exceed EL								
			Hours exceed 80% EL								
PM_{10}	24 Hour	500 $\mu g/m^3$	Maximum	$\mu g/m^3$	120.4	537.4	331.7	577.8	487.3	490.0	NA
			Average	$\mu g/m^3$	46.4	72.1	80.4	123.7	76.6	79.8	NA
			Days exceed EL					1			
			Days exceed 80% EL								
$PM_{2.5}$	24 Hour	900 $\mu g/m^3$	Maximum	$\mu g/m^3$	NA	NA	NA	NA	NA	NA	48.0
			Average	$\mu g/m^3$	NA	NA	NA	NA	NA	NA	27.8
			Days exceed EL								
			Days exceed 80% EL								

Note: EL = Emission Limit

TABLE 5-6: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 7 (CONTINUED)

Monitor Location: ***VB7 WB3***

Pollutant	*Time Period*	*Emission Limits*	*Parameter*	*Unit*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012: Jan-Apr*
CO	**1 Hour**	**70 ppm**	**Maximum**	**ppm**	10.6	7.1	7.7	8.5	4.7	4.9	2.7
			Average	**ppm**	1.3	1.3	1.1	1.1	1.3	0.9	0.5
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	**70 ppm**	**Maximum**	**ppm**	7.3	3.6	2.6	2.7	2.7	2.8	1.9
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	**1 Hour**	**8.88 ppm**	**Maximum**	**ppm**	1.50	1.10	1.20	1.30	0.80	0.80	0.50
			Average	**ppm**	0.38	0.37	0.31	0.36	0.36	0.31	0.25
			Hours exceed EL								
			Hours exceed 80% EL								

Monitor Location: ***VB7 EB3***

Pollutant	*Time Period*	*Emission Limits*	*Parameter*	*Unit*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012: Jan-Apr*
CO	**1 Hour**	**70 ppm**	**Maximum**	**ppm**	10.9	21.8	12.0	11.5	10.6	31.4	7.0
			Average	**ppm**	1.9	2.7	2.7	2.4	2.5	2.0	1.6
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	**70 ppm**	**Maximum**	**ppm**	6.7	8.9	6.5	6.4	6.7	6.0	3.6
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	**1 Hour**	**8.88 ppm**	**Maximum**	**ppm**	1.50	2.90	1.70	1.60	1.50	4.10	1.10
			Average	**ppm**	0.47	0.55	0.56	0.51	0.52	0.48	0.43
			Hours exceed EL								
			Hours exceed 80% EL								

Note: EL = Emission Limit

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

Monitor Location: *Ramp LC-S*

Pollutant	*Time Period*	*Emission Limits*	*Parameter*	*Unit*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012: Jan-Apr*
CO	**1 Hour**	**52 ppm**	**Maximum**	**ppm**	21.8	67.5	33.9	15.3	68.7	30.5	9.2
			Average	**ppm**	2.3	1.8	1.8	1.8	1.8	1.6	1.3
			Hours exceed EL			2			1		
			Hours exceed 80% EL			0			0		
	8 Hour	**39 ppm**	**Maximum**	**ppm**	7.1	16.6	9.9	5.8	18.4	6.1	4.1
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	**1 Hour**	**6.64 ppm**	**Maximum**	**ppm**	2.90	8.60	4.40	2.10	8.70	4.00	1.30
			Average	**ppm**	0.49	0.43	0.43	0.42	0.43	0.41	0.35
			Hours exceed EL			2			1		
			Hours exceed 80% EL			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.

TABLE 5-8: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: RAMP SA-CN

Monitor Location: *Ramp SA-CN*

Pollutant	*Time Period*	*Emission Limits*	*Parameter*	*Unit*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012: Jan-Apr*
CO	**1 Hour**	**70 ppm**	**Maximum**	**ppm**	12.7	50.3	28.7	11.2	14.4	22.2	5.5
			Average	**ppm**	2.0	1.6	1.5	1.5	1.5	1.5	1.3
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	**70 ppm**	**Maximum**	**ppm**	4.6	9.3	7.5	3.8	3.8	5.1	4.7
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	**1 Hour**	**8.88 ppm**	**Maximum**	**ppm**	1.80	6.40	3.80	1.60	2.00	2.90	0.90
			Average	**ppm**	0.44	0.41	0.41	0.39	0.40	0.40	0.38
			Hours exceed EL								
			Hours exceed 80% EL								

Note: EL = Emission Limit

TABLE 5-9: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: RAMP CN-S

Monitor Location:	Ramp CN-S										
Pollutant	*Time Period*	*Emission Limits*	*Parameter*	*Unit*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012: Jan-Apr*
CO	1 Hour	67 ppm	Maximum	ppm	45.8	14.5	16.3	10.4	16.5	24.7	5.5
			Average	ppm	4.5	3.7	3.3	3.0	3.1	2.8	2.4
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	58 ppm	Maximum	ppm	15.8	8.2	9.2	6.3	7.7	7.4	4.0
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.5 ppm	Maximum	ppm	4.40	1.90	2.20	1.50	2.20	3.30	0.90
			Average	ppm	0.77	0.64	0.63	0.56	0.57	0.54	0.50
			Hours exceed EL								
			Hours exceed 80% EL								

Note: EL = Emission Limit

TABLE 5-10: SUMMARY OF CO, NO_X, PM_{10} AND $PM_{2.5}$ AVERAGE AND PEAK LEVELS: RAMP CS-SA

Monitor Location:	Ramp CS-SA no Parcel 12										
Pollutant	*Time Period*	*Emission Limits*	*Parameter*	*Unit*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012: Jan-Apr*
CO	1 Hour	57 ppm	Maximum	ppm	11.2	34.4	27.0	10.4	22.1	14.1	6.6
			Average	ppm	2.6	2.3	2.0	1.9	1.9	1.7	1.4
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	46 ppm	Maximum	ppm	6.8	9.8	10.5	5.5	6.3	5	3
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	7.26 ppm	Maximum	ppm	1.60	4.50	3.50	1.50	2.90	1.90	1.00
			Average	ppm	0.54	0.49	0.43	0.43	0.43	0.41	0.40
			Hours exceed EL								
			Hours exceed 80% EL								
PM_{10}	24 Hour	150 $\mu g/m^3$	Maximum	$\mu g/m^3$	137.6	60.3	87.9	99.4	115.8	78.3	NA
			Average	$\mu g/m^3$	31.2	21.3	20.4	20.8	18.8	18.9	NA
			Days exceed NAAQS								
			Days exceed 80% NAAQS								
$PM_{2.5}$	24 Hour	35 $\mu g/m^3$	Maximum	$\mu g/m^3$	NA	NA	NA	32.9	37.1	NA	25.5
			Average	$\mu g/m^3$	NA	NA	NA	11.2	10.1	NA	7.6
			Days exceed NAAQS								
			Days exceed 80% NAAQS								

Notes: EL = Emission Limit

TABLE 5-11: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: RAMP CS-P

Monitor Location: *Ramp CS-P*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2006	2007	2008	2009	2010	2011	2012: Jan-Apr
CO	1 Hour	70 ppm	Maximum	ppm	17.0	13.3	34.9	10.0	22.7	9.5	7.7
			Average	ppm	2.7	2.5	2.1	2.0	2.0	1.9	1.4
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	8.3	7.0	13.9	5.3	9.7	6.2	3.6
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	2.30	1.80	4.50	1.40	3.00	1.40	1.20
			Average	ppm	0.54	0.51	0.43	0.44	0.45	0.43	0.40
			Hours exceed EL								
			Hours exceed 80% EL								

Note: EL = Emission Limit

TABLE 5-12: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: RAMP F

Monitor Location: *Ramp F*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2006	2007	2008	2009	2010	2011	2012: Jan-Apr
CO	1 Hour	70 ppm	Maximum	ppm	12.6	7.3	12.3	4.3	5	2.6	2.5
			Average	ppm	1.5	1.3	1.1	1.1	0.9	0.5	0.8
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	70 ppm	Maximum	ppm	5.2	4.8	4.3	2.7	2.7	1.8	2
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	8.88 ppm	Maximum	ppm	1.80	1.80	1.70	0.70	0.80	0.50	0.50
			Average	ppm	0.38	0.36	0.32	0.32	0.31	0.28	0.30
			Hours exceed EL								
			Hours exceed 80% EL								

Note: EL = Emission Limit

TABLE 5-13: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: DST I-93

Monitor Location:	Ramp DST-I-93 Existing										
Pollutant	*Time Period*	*Emission Limits*	*Parameter*	*Unit*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012: Jan-Apr*
CO	1 Hour	25 ppm	Maximum	ppm	19.1	38.2	20.3	20.8	18.4	71.9	14.7
			Average	ppm	5.8	5.2	4.6	4.6	4.4	4.3	3.6
			Hours exceed EL			2				2	
			Hours exceed 80% EL			0				3	
	8 Hour	23 ppm	Maximum	ppm	12.3	15.9	10.7	11.5	12.5	14.0	8.2
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	3.3 ppm	Maximum	ppm	2.60	4.90	2.70	2.80	4.40	9.10	2.00
			Average	ppm	0.91	0.93	0.78	0.77	0.76	0.73	0.65
			Hours exceed EL		0	2	0	0	0	2	
			Hours exceed 80% EL		10	2	12	2	2	3	

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.

TABLE 5-14: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: DST I-90

Monitor Location:	Ramp DST-I-90 Existing										
Pollutant	*Time Period*	*Emission Limits*	*Parameter*	*Unit*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012: Jan-Apr*
CO	1 Hour	25 ppm	Maximum	ppm	22.8	21.0	17.3	14.4	33.6	15.0	11.5
			Average	ppm	4.9	4.6	3.6	3.4	3.7	3.2	2.5
			Hours exceed EL						1		
			Hours exceed 80% EL						0		
	8 Hour	23 ppm	Maximum	ppm	11.7	11.5	9.4	8.7	10.6	8.8	6.3
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	1 Hour	3.3 ppm	Maximum	ppm	2.60	2.80	2.30	2.00	4.30	2.10	1.60
			Average	ppm	0.79	0.78	0.63	0.63	0.66	0.60	0.53
			Hours exceed EL		0	0	0		1		
			Hours exceed 80% EL		3	2	8		1		

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.

TABLE 5-15: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: RAMP ST-CN

Monitor Location: ***ST-CN***

Pollutant	*Time Period*	*Emission Limits*	*Parameter*	*Unit*	*2006 **	*2007*	*2008*	*2009*	*2010*	*2011*	*2012: Jan-Apr*
CO	**1 Hour**	**70**	**Maximum**	**ppm**	4.6	6.3	26.6	5.3	7.6	3.7	57.1
			Average	**ppm**	1.5	1.5	1.4	1.4	1.2	1.5	1.4
			Hours exceed EL								0
			Hours exceed 80% EL								1
	8 Hour	**70**	**Maximum**	**ppm**	3.5	3.8	7.8	3.2	3.4	3.4	8.7
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	**1 Hour**	**8.88**	**Maximum**	**ppm**	0.80	1.00	3.50	0.90	1.10	0.70	7.30
			Average	**ppm**	0.40	0.39	0.37	0.39	0.38	0.38	0.40
			Hours exceed EL								0
			Hours exceed 80% EL								1

** 2006 is only 1 month worth of data*

Note: EL = Emission Limit

TABLE 5-16: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: RAMP ST-SA

Monitor Location: ***Ramp ST-SA NO PARCEL 6***

Pollutant	*Time Period*	*Emission Limits*	*Parameter*	*Unit*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012: Jan-Apr*
CO	**1 Hour**	**70 ppm**	**Maximum**	**ppm**	No Data	12.9	5.7	8.9	4.0	3.7	2.6
			Average	**ppm**		1.0	0.9	0.8	0.9	0.9	0.6
			Hours exceed EL								
			Hours exceed 80% EL								
	8 Hour	**70 ppm**	**Maximum**	**ppm**		4.6	2.5	2.5	2.5	2.3	2.0
			Hours exceed EL								
			Hours exceed 80% EL								
NO_x	**1 Hour**	**8.88 ppm**	**Maximum**	**ppm**		1.80	0.90	1.30	0.70	0.70	0.50
			Average	**ppm**		0.33	0.32	0.32	0.32	0.32	0.30
			Hours exceed EL								
			Hours exceed 80% EL								

Note: EL = Emission Limit

5.6 REQUEST TO REDUCE CEM AT SELECTED RAMPS

Discussion between MassDOT and MassDEP about reducing the CEM program at certain longitudinally ventilated ramps dates back to 2008. The 2011 CA/T Renewal Operating Certification (TSD Part III, section 5.5) indicated that MassDOT was planning to request the reduction of the CEM program to a more limited number of longitudinally ventilated ramps as part of this Supplemental Application.

The five ramps proposed for elimination from the CEM include:

- Ramp F
- Ramp L-CS
- Ramp SA-CN
- Ramp ST-CN
- Ramp ST-SA

These five ramps constitute relatively short tunnels (less than 1,200 feet each), which 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 the sidewalls for traffic congestion or emergency conditions, such as a tunnel fire. Table 5-17 provides the revised CO emission limits compared to the average and maximum levels measured for 2006-2012 and for 2010-2012 (the latest three years).

TABLE 5-17: CO EMISSION LIMITS AND HOURLY MEASURED LEVELS 2006-2012

Location	1-Hour CO Emission Limit (ppm)	Highest Annual Average Measured 2006-2012 (ppm)	Highest Annual Average Measured 2010-2012 (ppm)	Maximum Measured CO Level 2010-2012 (ppm)
Ramp F	70	1.5	0.9	5.0
Ramp L-CS	57	2.3	2.1	68.7*
Ramp SA-CN	70	2.0	1.5	22.2
Ramp ST-CN	70	1.5	1.5	57.1**
Ramp ST-SA	58	1.0	0.9	4.0

* Midnight level on August 10, 2010 due to idling equipment under the monitor during tunnel maintenance. The next highest level was 28.2 ppm.

** Night time level on January 26, 2012 due to idling equipment under the monitor during tunnel maintenance. The next highest level was 3.0 ppm.

The average hourly CO levels measured at these ramps during the past six years have been below 3.0 ppm. With the exception of two incidents at Ramps L-CS and ST-CN during nighttime tunnel closings due to maintenance operations, the maximum concentrations recorded during 2010-2012 have been below 29 ppm. Since the revised CO emission limits for these ramps are between 57 and 70 ppm for one-hour, and 70 ppm for the eight-hour average (see Table 6-1), it is very unlikely that these limits will be exceeded in the coming years.

Today's clean motor vehicle fleet, and the short length of these tunnels open to ambient air at both ends precludes the formation of elevated CO levels during normal operating conditions.

The remaining three longitudinally ventilated ramps (CN-S, CS-SA and CS-P), which are connected to the main full transverse ventilation system, the DST and all VBs will continue the current monitoring and reporting process of the current CEM program.

The elimination of these five ramps from the CEM will result in significant labor savings for MassDOT. More importantly, the equipment that will no longer be needed at the eliminated ramps, will be refurbished and used as spares for the remaining monitoring sites. As all of these instruments have been in continuous service for more than eight years, they require more frequent and extensive maintenance, so the spares will minimize lost data.

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 separate CO and $PM_{2.5}$ CEM (continuous emission monitoring) system as described in Section 3 and Attachment 1 of this document. Data collected from the CO and $PM_{2.5}$ CEM systems is 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 collected at the DST portal. 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 should occur.

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

TABLE 6-1: SUMMARY OF EMISSION LIMITS (2012-2016)

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	900
VB 3	70	70	6.1	900
VB 4	70	70	6.1	900
VB 5	70	70	6.1	900
VB 6	70	70	6.1	900
VB 7	70	70	6.1	900
Ramp L-CS	57	70	5.0	NA
Ramp CN-S	37	58	3.4	NA
Ramp SA-CN	70	70	6.1	NA
Ramp ST-CN	70	70	6.1	NA
Ramp ST-SA	58	70	5.1	NA
Ramp CS-SA***	38	55	3.4	35****
Ramp CS-P	41	70	3.7	NA
Ramp F	70	70	6.1	NA
Dewey Sq. Tunnel	23	30	2.2	NA

Notes: Acronyms are defined as: Leverett Circle to Central Artery Southbound (L-CS), Central Artery Northbound to Storrow Drive (C-NS), Sumner Tunnel to Central Artery Northbound (ST-CN), Surface Artery to Central Artery Northbound (SA-CN), Central Artery Southbound to Surface Artery (CS-SA), Sumner Tunnel to Surface Artery (ST-SA), Central Artery Southbound to Purchase Street (CS-P), I-90 Westbound to Congress Street (Ramp F), 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 remain unchanged from the 2011 CA/T Renewal Operating Certification and took effect January 2012

******* 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 900 $\mu g/m^3$ 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.

In order to comply with the lowest emission action level (i.e., 20 ppm 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 CO emission levels from going above 20 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 900 $\mu g/m^3$ 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 900 $\mu g/m^3$ is very high, it is very unlikely that this level will ever be reached.

TABLE 6-2: EMISSION ACTION LEVELS (2012-2016)

Location*	CO Emission Action Levels (ppm)	Rolling 8-Hour $PM_{2.5}$ Emission Action Levels ($\mu g/m^3$)
VB1	60	NA**
VB3	60	900
VB4	60	NA**
VB5	60	900
VB6	60	NA**
VB7	60	900
Ramp L-CS	48	NA
Ramp CN-S	31	NA
Ramp ST_CN	60	NA
Ramp SA-CN	60	NA
Ramp ST-SA	50	NA
Ramp CS-SA	32	35***
Ramp CS-P	36	NA
Ramp F	60	NA
Dewey Square Tunnel	20	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 $\mu g/m^3$) to be exceeded on seven calendar days per calendar year without triggering a violation of the NAAQS.

6.4 CORRECTIVE (CONTINGENCY) ACTIONS

6.4.1 Emission Limit Exceedance Notification

The 2011Renewal 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 Waste Prevention, Consumer and Transportation Programs Division, Transportation Management Programs Branch, 1 Winter Street, Boston, MA 02108. MassDOT shall verbally notify Transportation Management Programs Branch by calling 617-292-5500, if unable to reach staff directly, then MassDOT shall speak with or 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 an NAAQS for CO 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 2006 TO 1ST QUARTER OF 2012

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

- Measured CO concentrations for the Ventilation Buildings range from 0.5 to 10.1 ppm on average, with maximum 1-hour values as high as 31.4 ppm;
- Measured CO concentrations for the DST and Ramps range from 0.5 to 5.8 ppm on average, with maximum 1-hour average concentrations ranging from 12.6 to 71.9 ppm;
- Measured NO_x levels for the Ventilation Buildings range from 0.3 to 0.7 ppm on average, with maximum 1-hour values ranging from 1.6 to 4.5 ppm;
- Measured NO_x levels for the DST and Ramps range from 0.3 to 0.9 ppm on average, with maximum 1-hour values ranging from 1.8 to 9.1 ppm;
- Measured average daily PM_{10} concentrations in each year were between 31 and 121 $\mu g/m^3$, Maximum daily PM_{10} values were in the range ,of 100 to 577 $\mu g/m^3$ (2006-2011).
- The PM_{10} monitor outside Ramp CS-SA, which measures ambient levels, recorded annual averages from 19 to 21 $\mu g/m^3$, and a maximum daily level of 116 $\mu g/m^3$ (2006-2011).
- Measured $PM_{2.5}$ concentrations in the first 4 months of 2012 were between 6.8 and 40.9 $\mu g/m^3$ on average, with maximum daily values ranging from 23 to 88.1 $\mu g/m^3$.
- The $PM_{2.5}$ monitor outside Ramp CS-SA, which measures ambient levels, in the first four months of 2012, recorded concentrations from 7.6 to 25.5 $\mu g/m^3$.

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 thirteen episodes recorded over the six-year period when an emission limit was exceeded. These were the result of abnormal conditions related to nighttime tunnel closures due to maintenance, system malfunction and of road salt application during severe snowstorms. 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 2006 to 1st Quarter of 2011

During the period from the beginning of 2006 through the end of the first quarter of 2011, there were eleven 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 (2006 – 2011)

No. of Incidents	Date(s)	Time	Location(s)	Pollutant(s)	No. of Hours	Highest Measured Level*	Main Reason
1	28-Jun-07	1:00 AM	DST (I-93)	CO	2	38.2	Tunnel closed for maintenance
2	12-Sep-07	midnight	DST (I-93)	CO	2	29.8	Tunnel closed for maintenance
3	2-Oct-07	11:00 PM	Ramp L-CS	CO	1	55.0	Tunnel closed for maintenance
	3-Oct-07	midnight			1	67.5	Tunnel closed for maintenance
4	11-Oct-07	3:00 PM	DST (I-93)	CO	1	33.5	Computer system malfunction
5	17-Dec-07	Daily	VB7	PM_{10}	1	537.4	Re-suspended road salt
	18-Dec-07	Daily	VB3 & VB7		2	541.6	Re-suspended road salt
6	20-Feb-09	Daily	VB3		1	545.8	Re-suspended road salt
7	4-Mar-09	Daily	VB3		1	501.4	Re-suspended road salt
8	21-Dec-09	Daily	VB7		1	521.3	Re-suspended road salt
	22-Dec-09	Daily			1	577.7	Re-suspended road salt
9	10-Aug-10	Midnight	Ramp L-CS	CO	1	68.7	Tunnel closed for maintenance
10	7-Oct-10	Midnight	DST (I-90)	CO	1	33.6	Tunnel closed for maintenance - CO monitoring equipment failure
11	4-Feb-11	Daily	VB3	PM_{10}	1	542.0	Re-suspended road salt

* Concentrations are in ppm for CO and in $\mu g/m^3$ for PM_{10}.

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

The June 28, 2007 exceedance of the CO emission limit occurred at approximately 1 AM , while the I-93 DST was closed to general traffic due to maintenance activities within the tunnel. Recorded levels exceeded the CO limit for two hours. As the MassDOT correspondence to MassDEP (July 11, 2007) indicates, that night there were multiple crews with construction equipment performing maintenance and construction activities. The HOC operators acknowledged the alarm indicating levels above the 25 ppm limit, but, since the DST was closed to traffic, the ventilation rate was not increased as expected during normal heavy traffic conditions. The high levels measured were the combined result of emissions from idling and working construction equipment and the absence of the piston action effect normally created by moving traffic which self-ventilates the DST pushing the tunnel emissions downstream of the exit portal. MassDEP acknowledged the notification, concurred with the MassDOT that the emission limit exceedance would not result in an ambient air violation of the NAAQS, and agreed that there was no need for an ELA to be prepared.

The September 12, 2007, exceedance of the CO emission limit occurred after midnight while the I-93 DST was closed to general traffic due to maintenance activities within the tunnel. As the MassDOT correspondence to MassDEP (September 13, 2007) indicates, the high measured levels were the result of idling equipment in the vicinity of the CO monitor and minimum ventilation rate due to the closing of the DST to general traffic. During this instance the MassDOT implemented corrective actions including a directive to turn off equipment while not in operation (limit idling) and to adjust the DST ventilation rate following the HOC Response Procedure 509 if the CO level approaches 25 ppm.

The exceedances of the CO emission limit on October 2 and October 3, 2007, occurred at 11 PM and midnight at Ramp-L-CS. The limit was exceeded for two consecutive hours. During this time, the Ramp was closed to general traffic due to maintenance activities within the tunnel. As the MassDOT correspondence to MassDEP (October 10, 2007) indicates, the high measured levels were the result of idling equipment in the tunnel and the lack of ventilation since the jet fans which ventilate the ramp were shut down due to the tunnel closure. Since there was no air movement inside the tunnel at the time of occurrence, MassDEP concurred with the MassDOT in the October 10, 2007 correspondence that no ambient violation of standards could occur outside the tunnel and that an ELA was not warranted.

The October 11, 2007, exceedance of the CO emission limit occurred at 3 PM at the I-93 DST. It was due to a malfunction of the computer equipment that controls the automatic ventilation system for the DST Air Intake Structure. As a result of the malfunction the DST ventilation system was not increased to step 3 as it is programmed to do between 2:00 PM and 7:00 PM. Until the problem was corrected, a manual override by the operator was implemented. The emission limit was exceeded for only one hour before the situation was corrected. An ELA was performed, and the results indicated no violation of the CO NAAQS or the NO_2 MassDEP Policy Guideline.

On January 9, 2008, MassDEP issues a NOTICE OF NONCOMPLIANCE with reference to the October 11, 2007exceedance of the CO limit at the DST. MassDEP accepted that the ELA submitted by MassDOT on October 23, 2007 concluded that the exceedance did not result in any violation of the CO NAAQS or MassDEP Policy guideline for NO_2. However, MassDEP NONCOMPLIANCE letter indicated that the OCC staff failed to properly respond to the high CO level alarms, and during the incident attempted to operate the fans at Summer, Essex and Beach streets in an exhaust mode, which were to be operated only during emergency situations. The MassDEP letter required that MassDOT respond within 21 days with a plan to correct this operational deficiency.

On January 25, 2008, MassDOT responded to the NONCOMLPIANCE letter explaining the results of the investigation, and including the proposed revisions to internal procedures RP-504 “High and HI-high Carbon Monoxide” and RP-509 “CEM Stack Zone Status”; to avoid a repetition of this type of incident.

The 24-hour PM_{10} emission limit was exceeded at VB3 on December 18, 2007 and at VB3 and VB7 on December 18, 2007, yielding three daily average concentrations above the emission limit. The cause was the pulverization of road salt applied to the tunnel and its approaches during winter snow conditions followed by a very cold and dry spell after the snowstorm. These conditions created a large source of salt crust available for vehicle pulverization and re-entrainment by the movement of vehicle tires. The results of an ELA performed for the highest levels recorded at VB3 and VB7 indicated that no violation of the PM_{10} NAAQS occurred. Furthermore, the highest predicted ambient values from the ELA, including background levels from other sources, were less than 1/3 of the NAAQS. This demonstrated that the emission limit could have been set at a much higher level (over 2,000 $\mu g/m^3$) without causing concentrations above the PM_{10} NAAQS at locations corresponding to the adjacent abutters and public. After this event, MassDEP required the MassDOT to evaluate the implementation of Best Management Practices, including street sweepers and other deicing products. The analysis concluded that these possible practices were unnecessarily costly and disruptive. Also, an increase in ventilation rate was implemented, but it exacerbated the problem by increasing the suction of road salt into the ventilation system. The conclusion of the analysis was that if PM_{10} exceedances were to re-occur due to road salting, an ELA would be performed for each instance to verify compliance with the NAAQS in areas of ambient air.

Exceedances of the 24-hour PM_{10} emission limit occurred on February 20, 2009 and on March 4, 2009 at VB3 The cause was the pulverization of road salt applied to the tunnel entrances and exits during winter snow conditions. The results of an ELA performed for the highest levels indicated that no violation of the PM_{10} NAAQS occurred. The highest ambient values, including background from other sources, predicted in the ELA were less than 1/2 of the NAAQS.

Exceedances of the 24-hour PM_{10} emission limit occurred on December 21 and December 22, 2009, at VB7. The cause was also the pulverization of road salt applied to the tunnel entrances and exits during winter snow conditions. The results of an ELA performed for the highest levels indicated that no violation of the PM_{10} NAAQS occurred. The highest ambient values, including background from other sources, predicted in the ELA were less than 1/4 of the NAAQS.

The August 10, 2010, exceedance of the CO emission limit occurred at midnight at Ramp-L-CS. The limit was exceeded for one hour. That night the Ramp was closed to general traffic due to maintenance activities within the tunnel from 10:30 PM to 4:37 AM. The high measured level was the result of idling equipment in the tunnel and no ventilation, since the jet fans, which ventilate the ramp, were shut down due to the tunnel closure. Although operating procedure RP-509 requires the operator to turn on the jet fans during this type of event, the time of occurrence (midnight) coincided with the equipment auto calibration which also produces high values. Therefore, the exceedance was not recognized as such by the operator. MassDOT subsequently modified the language for RP-509 to prevent a reoccurrence. Unfortunately, the exceedance was not discovered by the environmental engineer until the monthly data review was performed, since the technician had failed to report the incident. As a result, MassDEP was not notified until September 29, 2010.

The October 7, 2010 exceedance of the CO emission limit occurred at midnight (12:00 to 12:59 AM) while the I-90 DST Collector was closed to general traffic due to maintenance activities within the tunnel. Even though the operator followed the RP-509 procedures and increased ventilation to steps 3, 4, and then 5, the 1-hour CO concentration exceeded the emission limit. The technician failed to immediately report this event to the Environmental Engineer. Upon notification an ELA was prepared, and the results indicated that there was no violation of the CO NAAQS or the NO_2 MassDEP Policy guideline. The ELA results indicated that ambient values were 50% below the NAAQS and MassDEP Guideline.

On January 25, 2011 MassDEP issue a NOTICE OF NONCOMPLIANCE to MassDOT for the exceedances measured on August 10, 2010 and October 7, 2010. This notice states that the MassDOT was in NON COMPLIANCE with the Contingency Plan provisions due to failure of the operator to act and notify MassDEP within 24 hours. The actions required by MassDEP included a revision of procedures, a plan to train HOC operators on RP-509, and a directive to contractors to limit equipment idling.

The February 25, 2011 MassDOT correspondence acknowledged the reasons for NONCOMPLIANCE and implemented the actions described above. It also stated that the October 7, 2010 exceedance was due to instrument failure resulting from the presence of VOC during the maintenance activities. The CO monitor used at DST I-90 displays 33.6 ppm of CO in the presence of propane gas regardless of the real CO level in the inlet.

The last recorded exceedance of the PM_{10} limit occurred on February 4, 2011 at VB3. The cause was the pulverization of road salt applied to the tunnel entrances and exits during winter snow conditions. The ELA performed for the highest levels indicated that no violation of the PM_{10} NAAQS occurred. The highest ambient values including background levels from other sources predicted in the ELA were less than 1/4 of the NAAQS.

6.6.2 Exceedances of Emission Limits from 2nd Quarter of 2011 to 1st Quarter 2012

During the period from the 2nd quarter of 2011 through the end of the first quarter of 2012, there were two episodes when an emission limit was exceeded. Table 6-4 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 6-4: CEM EMISSION LIMIT EXCEEDANCES (2011-2012)

No. of Incidents	Date(s)	Time	Location(s)	Pollutant(s)	No. of Hours	Highest Measured Level (ppm)	Main Reason
1	20-Jun-11	23:00	DST (I-93)	CO	1	71.9	Tunnel maintenance-Idling equip close to CO probe
2	27-Jun-11	23:00	DST (I-93)	CO	1	52.3	Tunnel maintenance-Idling equip close to CO probe

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

The June 20 and 27, 2011during the evening hour 23:00 (11:00 PM to midnight) the CEM located at the I-93 DST recorded hourly CO levels of 71.9 and 52.3 ppm respectively. Both measurements were above the CO emission limit of 25 ppm for DST established in the 2011 CA/T renewal application. At the time of these 1-hour DST (I-93) emission exceedances, road maintenance was in progress and traffic lanes were taken. During both exceedances, supply air fans were set at step 1, the lowest value possible without being shut off. Additionally, due to the time of day, 11:00 pm to midnight, traffic volume was very light.

MassDOT notified MassDEP by phone and email, and performed an Emission Limit Assessment (ELA). The results of the ELA concluded that 1-Hour CO emission limit exceedances did **not** result in a violation of either one-hour and eight-hour CO NAAQS or the one-hour NO2 Policy Guideline Limit. The summary and supporting documentation was presented to MassDEP on the MassDOT July 7, 2011 letter.

MassDEP response by July 26, 2011 letter, concurred with the Report's modeling results and conclusion that the June 20 and 29, 2011, 1-Hour CO emission limit exceedances did **not** result in a violation of either one-hour and eight-hour CO NAAQS or the one-hour NO2 Policy Guideline Limit. MassDEP was concerned with the finding that a maintenance truck idling in very close proximity to the CO CEM rake probe, and the MassDOT "Policy Directive, Elimination of Unnecessary Idling in CA/T (I-93 & I-90) Tunnels During Maintenance & Construction Activities.

The result of further investigation of the event by MassDOT (letter September 6, 2011) concluded that the idling equipment was powering emergency lights to direct vehicular traffic away from the close lanes, and the ventilation setting at Step 1 was not sufficient to dissipate the CO levels inside the tunnel. This resulted in a small change of MassDOT SOP requiring the HOC increase to ventilation step 3 the system before and during this type of activities.

6.6.3 Summary of Exceedances, Reasons and Lessons Learned

As described in the previous sections, there were thirteen episodes during the period from the beginning of 2006 through the end of the first quarter of 2012 when emission limits were exceeded. These episodes resulted in a total of 12 hours when CO measured levels exceeded a corresponding emission limit and 8 days when the measured PM_{10} levels exceeded an emission limit.

CO concentrations were measured every hour at 24 VB exhaust locations and at eight locations in the DST over the last five calendar years (2006-2010) and during the first quarter of 2011, yielding approximately 1.7 million observations. The 12 hours for which a CO emission limit was exceeded represent an exceedingly infrequent occurrence and shows that the ventilation system nearly always was in compliance with its CO emission limits. Over 99.99% of the hourly CO concentration measurements showed compliance with CO emission limits, and the 12 hours when CO emission limits were exceeded represent only about 0.0007% of the hours during this period.

For the eight cases (totaling 12 hours) when CO limits were exceeded, the main reasons were the idling emissions of the operating maintenance equipment during tunnel closing and the lack of adequate ventilation air due to the closure of the tunnels. There was one case when equipment malfunction prevented the proper ventilation at the DST and another when the VOC fumes during maintenance caused a malfunction at the CO monitor.

For the five cases (8 days) when PM_{10} limits were exceeded, the reason was the pulverization of road salt applied during winter snowstorms, which created a large source of salt crust available for vehicle pulverization and re-entrainment.

It is important to point that corrective measures were taken and response procedures were modified when necessary as part of the contingency plan.

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 were usually 50% or less of the applicable NAAQS, and less than 80% of the MassDEP NO_2 Policy Guideline. This shows that the emission limits were established with a considerable margin of safety with regard to the health related NAAQS, due to the very conservative worst-case assumptions that went into the analysis, which supported the 2006 Operating Certification process and its 2011 Renewal Operating Certification.

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