EEA #11202

MassDOT Snow and Ice Control Program

2022 Environmental Status and Planning Report

PREPARED BY

massDOT
Massachusetts Department of Transportation

Massachusetts Department of Transportation (MassDOT)
10 Park Plaza, Suite 7130, Boston, Massachusetts 02116

December 2022

Table of Contents

Appendices

List of Tables

List of Figures

This page intentionally left blank.

Introduction/Executive Summary

Introduction

This Environmental Status and Planning Report (ESPR) describes the various tools, policies and technologies used by the Massachusetts Department of Transportation (MassDOT) Snow and Ice Control Program (SICP) to maintain reasonably safe travel conditions on state roads during winter weather while minimizing the potential for environmental impacts. The SICP operates as part of the MassDOT Highway Division's Operations and Maintenance Department.

Prior to preparing this ESPR, a Scope of Work (SOW) Plan was developed and posted in the Environmental Monitor on February 10, 2021, for public and agency review (see Appendix A). The SOW Plan outlined major topics and analyses to be included in the 2022 ESPR. The SOW Plan was discussed during a virtual meeting held on February 24, 2021, with representatives from the Massachusetts Department of Environmental Protection (MassDEP), the Natural Heritage and Endangered Species Program (NHESP), MassDOT, and the Nashua River Watershed Association.

Following this meeting, additional questions and comments were submitted by MassDEP, NHESP, the Cambridge Water District, and the WalkBoston organization via separate letters or email to the Massachusetts Executive Office of Environmental and Energy Affairs (EEA). The comments contained in these letters were summarized in the Massachusetts Environmental Policy Act (MEPA) Certificate issued by the EEA on March 19, 2021. This ESPR contains information intended to address these questions and comments. MassDOT prepared similar ESPRs in 2012 and 2017 and, in the future, it is anticipated to prepare an updated ESPR every 5 years, with supplemental Annual Reports submitted and posted in the Environmental Monitor in the intervening years.

The MEPA Certificate (#11202) issued on March 2, 2018, after the 2017 Final ESPR was completed, revised the filing process for this 2022 and future MassDOT ESPRs to a single Final ESPR format to be submitted on a 5-year cycle. The previous format involved submitting Draft and Final ESPR versions for public and agency review. This new single ESPR filing process is consistent with the Special Review Procedures used by MassPort for its ESPR filings related to its airport facilities per MEPA regulations 301 CMR 11.09.

Major Changes Since the 2017 ESPR Completion

The following represents some of the major changes to the SICP since the 2017 ESPR:

» MassDOT is now using over 75 liquid-intensive slurry-spreaders statewide, which are much more effective in preventing hardpack from forming on the pavement and limiting the number of potential repeat applications during a prolonged winter event. Five years ago, less than a dozen slurry spreaders were being used.

» MassDOT has added over 25 vehicle mounted mobile Road Weather Information Systems (RWIS) sensors to supplement the over 45 fixed stations across the state.

» Calibration contractors are now required to add visible markings on the rear of the spreader vehicles to indicate the gate opening at the time of calibration, which allows visual inspections of gate openings during the winter season.

» In the last 5 years, MassDOT has reduced its average annual statewide salt usage from 26.9 to 23.0 tons per lane-mile (ln-mi), which is approximately 30% less than the 33.4 tons per ln-mi used on an average annual basis between FY01 and FY10 under similar winter weather severity conditions.

Report Organization

Chapter 1 provides an update on the operational practices, polices, equipment, tools and technologies used to enhance the effectiveness and efficiency of SICP operations as well as an update on MassDOT's average annual material usage relative to that used prior to the adoption of various efficiency measures while accounting for differences in winter weather severity.

Chapter 1 also provides an update on MassDOT's roadway lane-miles and describes new measures to build capacity to address the snow and ice removal needs on sidewalks and pedestrian facilities as identified in the 2019 Pedestrian Transportation Plan and as requested by the WalkBoston following review of the 2022 ESPR SOW Plan.

Chapter 2 provides updates on MassDOT's Salt Remediation Program, its Reduced Salt Zone (RSZ) Program, an analysis of sodium and chloride levels in Public Water Supplies (PWSs), as well as other environmental issues. This chapter also describes MassDOT's plan to transition away from using sand in RSZs and instead rely on other more effective tools and technologies to reduce salt use. A summary of recent research that links elevated chloride levels to potential increased risks of corrosion in drinking water infrastructure is also included.

Chapter 3 provides updates on the various Best Management Practices (BMPs) currently being used in the MassDOT SICP as well as other emerging technologies.

Chapter 4 describes new research findings and data regarding the potential corrosive effects of deicing material on roadway infrastructure and vehicles.

Chapter 5 provides new information on the effect that winter weather has on vehicle accidents, mobility and the local and regional economy based on published data.

Chapter 6 describes MassDOT's planned future initiatives to further enhance salt use efficiency and improve tracking of salt usage in key environmentally sensitive areas.

Executive Summary

The following Executive Summary provides a brief synopsis of the subject matter, data analyses and general findings for the various topics covered in each Chapter. Readers are encouraged to read the complete Chapters included herein to obtain more details on MassDOT's various practices and policies as well as the data sources, methods and assumptions used in the various analyses and the studies and reports reviewed as part of the literature review.

Chapter 1: Operations

MassDOT continues to add new tools and technologies into its SICP, which include increased use of liquid deicers for pretreatment and pre-wetting, new pavement sensors, flexible plow blades, tow plows, AVL/GPS technology, to name a few. MassDOT is now using more than 75 slurry-spreaders across the state, which has been one of the more impactful pieces of equipment to improve salt use efficiency.

Vendor service agreements with hired contractors were recently revised to require contractors to have additional salt spreader gate opening markings to allow visual inspections of gate openings throughout the winter period. Hired equipment must also be calibrated by an approved, third-party calibrator and be inspected by MassDOT personnel prior to, and throughout the winter season.

Annual Training

In 2019, more than 900 contractors attended MassDOT's annual snow and ice training.

MassDOT requires its SICP employees to participate in annual training using video training modules that provide guidance on various operational aspects including equipment calibration, weather monitoring and use of liquid deicers, to name a few. MassDOT also provides separate "tailgate" training sessions at various depots in each District for both state personnel and hired contractors. Tailgate training is used to provide updates on any new MassDOT policies and reemphasize the use of current best management practices including spreader calibration, prewetting requirements, application timing, reducing spillage due to overloading spreaders and any specific practices related to environmentally sensitive areas. This training also provides an opportunity to exchange ideas and to discuss challenges and concerns with various practices, environmental stewardship, material tracking and reporting requirement.

Weather Forecast and Road Condition Monitoring

MassDOT relies on multiple sources of weather forecasting and road surface condition data to assist in deciding when to initiate SICP operations and what type and amount of equipment is needed. MassDOT contracts with a commercial weather forecasting service (DTN) to provide area-specific weather forecast information four times a day at 2 a.m., 6 a.m., 2 p.m., and 8 p.m., throughout the year. The weather data is sent to each district, headquarter personnel as well as the Highway Operations Center (HOC) located in South Boston.

MassDOT also has added 25 mobile, vehicle-mounted Road Weather Information System (RWIS) units to supplement the existing 45 stationary stations located across the state that provide pavement and dew point temperature, friction (grip) data, precipitation type, and roadway surface condition data (i.e., icy, slushy, wet) to inform the decision-making process in determining when plowing and deicing applications may be needed.

Material Application Policy

MassDOT typically applies road salt at a rate of 240 lb./lane-mile per application, in accordance with their salt application policy, which equates to approximately 4.1 lb. per 1,000 square feet or 0.4 lb per 100 square feet of area (about the size of a small room). This application rate is considered the minimum amount necessary under most weather conditions to prevent snow and ice from freezing to the pavement, especially when air and pavement temperatures are between 25°F and 32°F. As the applied material begins to dilute as snow, rain or freezing rain accumulates and melts, its effectiveness to lower freezing temperatures declines. Thus, repeat applications are often needed with number and timing of repeat applications depending on many factors including precipitation intensity, storm duration, and pavement temperatures.

Road salt's ability to lower freezing temperatures and melt snow and ice also declines dramatically as temperatures fall below 25°F and essentially becomes ineffective below 15°F. One pound of salt at 30°F can typically melt approximately 46 pounds of ice but at 20°F the same one pound of salt would only melt 8.6 pounds of ice or is approximately 80% less effective. In other words, it takes nearly 5 times as much salt to melt the same amount of ice at a temperature of 20°F compared to that at 30°F. Thus, just a 10°F difference in temperature can have a major impact in the amount of salt needed to prevent snow and ice from freezing.

In the same sense, MassDOT instructs operators to use lower application rates closer to 200 lb. per lane-mile during warmer temperatures and/or when temperatures are forecasted to rise recognizing that less salt may be needed at warmer temperatures compared to colder temperatures.

MassDOT Roadway Lane-Miles

MassDOT's road network for snow and ice control purposes has steadily increased over the years and now consists of just over 16,120 lane-miles across six different maintenance districts. MassDOT roads account for approximately 20% of the total roadway lane-miles in the Commonwealth. MassDOT also maintains approximately 726 lane-miles of Department of Conservation and Recreation (DCR)-owned roads.

Comparison of Recent and Historical Average Annual Road Salt Usage

Since 2011, when liquid deicers and other efficiency measures began in earnest, MassDOT has reduced its average annual statewide salt usage by approximately 26% on a tons per lane-mile basis. In just the last 5 years, or since the 2017 ESPR, the average annual statewide salt usage has decreased from 26.9 to 23.0 tons per lane-mile, which is approximately 30% less than the 33.4 tons per lane-mile that was used between FY01 and FY10 on an average annual basis under similar winter weather severity conditions. As a result, this reduction translates to a savings of approximately 74,150 tons of salt on an average annual basis compared to what was used prior to FY11. The differences in recent salt usage compared to the prior usage are even greater during more severe winters like in 2015, when MassDOT used approximately 125,000 tons less road salt compared to what was used in similar severe winters of 2003 and 2005 prior to the use of efficiency measures.

MassDOT Pedestrian Transportation Plan

In 2019, MassDOT developed a Pedestrian Transportation Plan[1] to identify initiatives and priorities to improve pedestrian facility access and safety throughout the Commonwealth. Maintenance of sidewalks and other pedestrian facilities is a shared responsibility between MassDOT, municipalities, and other organizations.

Like roads, MassDOT relies mostly on hired contractors to clear snow and ice on sidewalks and other pedestrian facilities. Sidewalk winter maintenance may involve different types of equipment and maintenance practices not used on roads. Since space is limited, smaller equipment and even manual shoveling may be required to clear snow from sidewalks. Since the pool of available contractors is mainly the same as those that sign up to maintain roads, the equipment and personnel needed to maintain sidewalks has been limited. In fact, MassDOT has seen the number of contractors interested in plowing roads recently decline for various reasons.

New for the 2022/23 winter, MassDOT plans to hire more "seasonal' snow and ice employees that report directly to MassDOT to help with sidewalk clearing as well as other activities. MassDOT will continue to evaluate vendor reimbursement rates and pay codes to enlist more contractors for sidewalk maintenance services and better reflect the variable snow removal efforts for large storms versus smaller storms.

Chapter 2: Environmental Protection and Remediation

Reduced Salt Zone Program Update

MassDOT plans to phase out the use of sand in Reduced Salt Zone (RSZ) areas to instead focus its efforts on expanding the use of other efficient measures currently being used statewide to increase the efficiency and effectiveness of road salt. The previous RSZ application practice of using a 50:50 sand/salt mix was often ineffective in preventing snow and ice from bonding to the pavement and keeping snow in plowable form especially at colder temperatures near and below 25°F. As a result, additional repeat applications were often necessary to compensate for the reduced effectiveness of the applied material. As such, the amount of salt used in these RSZs over the course of a season could often be as much or even more than that used on adjacent roads particularly during severe winters. Thus, the RSZ practices were not only less effective in reducing salt use or maintaining safe road conditions but also added additional annual labor and equipment costs to perform post-season cleanup of sand along the roadways. See Section 2.1 of this document for more details.

Salt Remediation Program

The Environmental Services Section of MassDOT's Highway Division administers a Salt Remediation Program, which processes and investigates complaints from private well owners and public water suppliers whose water supplies are experiencing elevated sodium concentrations. MassDOT has been spending approximately $1.5 million per year, on average, for technical services provided by the UMASS Engineering

1 https://www.mass.gov/service-details/pedestrian-plan

Department to investigate and remediate complaints as part of this program. The annual costs vary depending on the number of cases, the geographic extent of affected areas, and the type of remedial measures used to address the complaints.

In the last 5 years or since 2017, MassDOT received 76 remediation claim applications related to elevated sodium and/or chloride levels in private drinking water wells. MassDOT typically receives 12 to 15 claims per year and a total of 277 remediation claims have been received since 2000. Twenty-two cases remain open and remain under investigation or in the process of implementing remediation measures.

Overall, the Salt Remediation Program has successfully provided potable water with reduced sodium levels for over 250 private water supply complaint cases using various remedial measures. In a few instances where remediation measures were not initially successful in reducing sodium concentrations, MassDOT continues to work with the affected homeowner or PWS to identify the primary sources and potential solutions that MassDOT could implement to reduce sodium concentrations.

Sodium Concentrations in Public Water Supplies

Review of MassDEP's Public Water Supply (PWS)drinking water quality database PWSs revealed that of the 1,713 different PWSs reported sodium data, and approximately 930 PWSs have at least one water supply source within the 0.5-mile of a MassDOT roadway, and the remaining 783 PWSs had water supply sources that were estimated to be more than 0.5-mile from a MassDOT roadway. As of October 18, 2021, the data base contained 37,329 records of sodium sampling results, which is twice the amount of sodium data evaluated in the 2017 ESPR (16,345 records) based on reported prior to August 2016.

Analysis of the sodium data suggests that approximately 52% of the PWSs located within a 0.5-mile of a MassDOT road have average sodium concentrations above 20 mg/L compared to approximately 34% of the PWSs located beyond a 0.5-mile of a MassDOT road. A similar finding was reported in the previous 2017 ESPR, where 52% of the PWSs located within a 0.5 mile had average sodium concentration above 20 mg/L compared to 38% of the PWSs outside a 0.5-mile of a MassDOT road.

Approximately 28% of the PWSs located within a 0.5-mile of a MassDOT road have average sodium concentration above 40 mg/L compared to approximately 15% of the PWSs located outside of a 0.5-mile radius, a difference of 13.0 percentage points. The differences between the two groups narrows considerably when comparing average sodium concentrations above 60 mg/L. Approximately 15% of the PWSs located within a 0.5-mile of a MassDOT road have an average reported sodium concentration above 60 mg/L compared to approximately 8.4% of the PWSs located outside of a 0.5-mile radius, a difference of less than 7 percentage points.

Historical sodium data trends suggest that sodium concentrations have increased over time for both PWSs within and beyond a 0.5-mile of a MassDOT road. For PWSs located within a 0.5-mile of a MassDOT road, the percentage of PWSs with an average sodium concentration above 25 mg/L increased from approximately 25% to 50% based on data reported from1991 to 1996 and that reported from 2017 to 2021, compared to an increase of 10% to 25% for PWSs beyond a 0.5-mile of a MassDOT road in the same time periods.

Regression Analysis of Sodium Concentrations in PWSs and Distance to a MassDOT Roadway

Regression analyses of PWS sodium concentrations and distance to a MassDOT road over 5-year increments indicate a very weak correlation with a peak correlation coefficient (R2) value of 0.053. This suggests that distance to a MassDOT roadway explains only 5.3% of the differences in sodium concentration in PWSs. The fact that sodium concentrations are increasing in PWSs that are both close to and farther away from a MassDOT road is perhaps due in large part to increased urbanization and suggests a more holistic approach would likely be needed involving a broader range of sodium sources to effectively reverse or slow this trend of increasing sodium levels.

Sodium Level Trends in Municipal Water Supplies

Similarly, even though MassDOT has recently decreased its average annual road salt usage over the last decade or so, average annual sodium concentrations in at least 17 municipal PWSs appear to have increased by more than 50 mg/L in the last few decades. Based on data from both finished and raw water samples, as many as 10 municipal PWSs have average sodium concentrations at or above 100 mg/L. Municipal PWSs with some of the highest sodium levels are drinking water sources for the Towns of Auburn, Burlington, Cambridge, Millbury, N. Chelmsford, East Chelmsford, Shrewsbury, Weymouth and Woburn. These sodium increases occurred despite MassDOT having reduced their average annual salt usage over the last 12+ years, suggesting that the rise in sodium levels in many municipal PWSs may be due to other sources or influences. It is possible that the effects of the efficiency measures have not been detected in the well data, although several PWSs did see recent declines in the last 2 to 3 years.

Reported Chloride Concentrations in PWSs

Approximately 74% of the 582 PWSs with reported chloride levels in the MassDEP database have estimated average chloride concentrations that are less than100 mg/L while another 112 PWSs or 19% have average chloride levels between 100 and 250 mg/L. Together, approximately 94% of the PWSs in the data base have estimated average chloride concentrations below 250 mg/L or the Massachusetts secondary drinking water standard set to avoid issues with taste.

Reported chloride concentrations in PWSs were also analyzed as part of this 2022 ESPR. Approximately 38 PWSs that reported chloride data have average chloride concentrations above 250 mg/L including 28 PWSs with average chloride levels between 251 and 500 mg/L, six PWSs with average chloride levels between 501 and 1,000 mg/L, and three PWSs have average levels above 1,000 mg/L. Several of the PWSs with averaged chloride concentrations above 500 mg/l have been or are currently being investigated as part of the MassDOT Salt Remediation Program.

Like the sodium data, regression analyses indicate a very weak correlation between chloride concentrations in PWSs and distance to a MassDOT roadway. The highest correlation coefficient (R2) value was 0.029. Thus, only 3.0% of the variability in the chloride levels reported by PWSs might be explained by distance to a MassDOT road. Given that MassDOT roadways and densely developed commercial and residential areas often co-exist in the same area, it is difficult to quantify the relative influence of the road salt used on each of these land uses on PWS chloride concentrations.

Chloride Levels in Drinking Water and Increased Risk of Corrosion

Recent studies suggest that elevated chloride levels in drinking water along with other water quality changes could raise the risk for increased corrosion of drinking water piping and associated connectors. Researchers have indicated that water systems with chloride to sulfate mass ratios (CSMR) greater than 0.5 can lead to increased galvanic corrosion of lead pipe service lines in PWS distribution systems.

As discussed in more detail in Section 2.3.8 of the full 2022 ESPR, several PWSs were identified as potentially having estimated CSMR values above 50 based on chloride and sulfate concentration data included in MassDOT's drinking water data base. Facilities with the highest estimated CSMR values include the Assembly of God of the Southern NE District facility in the Town of Charlton and a PWS that services the Henry P. Clough School in the Town of Mendon. These PWS have estimated CSMR values above 200, however, no new data has been reported for these PWSs since 2012 and 2015, respectively, suggesting that these PWS may no longer be used for potable water. Three other facilities with estimated CSMR values above 100, include the PWS wells serving the Groton-Dunstable Regional High School, the Millstone MIT Laboratory in Westford and a PWS well used by the Peabody Water Department. The sampling details for the first two facilities indicate that the chloride concentrations represent finished water or post-treatment conditions and, thus it is unclear to what extent treatment chemicals might be affecting the chloride levels.

Specific Watershed Studies of Salt Usage near Municipal PWS

MassDOT has recently worked with several municipal PWS to evaluate the relative salt contributions from various sources and uses within the watershed or to track salt usage within the Wellhead Protection Area. The municipal PWS include the Auburn Water District, the Cambridge Water District, Dedham-Westwood Water District, and the town of Millbury. See Section 2.4 of this document for more details.

Chloride Impaired Water Bodies in Massachusetts

MassDEP's 2018/2020 (305(b)/303(d) Integrated List of Waters identifies twenty-four (24) water bodies throughout the state as being chloride impaired. This represents 11 additional water bodies that were not on the 2016 Integrated List and 18 additional water bodies that were not on the 2014 Integrated List, which was used in the 2017 ESPR. The determination of water quality impairments is primarily based on ambient water quality data collected by MassDEP. These impaired water quality assessment units are mostly located in the more urbanized areas in the central and eastern regions of the state. Recently added water bodies include Gates Brook, Scarletts Brook and two unnamed tributaries in the Boylston and West Boylston areas that drain to the Wachusett Reservoir. See Section 2.5 of this document for more details.

Areas of Critical Environmental Concern and Priority Habitat Areas

Other sensitive environmental resources including Areas of Critical Environmental Concern (ACEC) and Priority Habitats and Natural Communities, as designated by the Massachusetts Natural Heritage and Endangered Species Program (NHESP). Each of MassDOT's maintenance districts, except District 2, has at least one designated ACEC that borders or is traversed by a MassDOT roadway. Districts 1, 3, and 6 have five designated ACECs, while District 4 has 4 ACECs and District 5 has sixteen ACECs that are adjacent to or traversed by a MassDOT highway.

Kampoosa Bog, located adjacent to Interstate 90 in the Towns of Stockbridge and Lee in District 1 has been the subject of extended research relative to the potential road salt effects on vegetation. A recent 2021 study provides updated sodium (Na+) and chloride (Cl-) levels in the Kampoosa Bog. Higher Na+ and Cl- levels in groundwater were generally observed near the I-90 roadway. Recent findings suggest that existing vegetation communities can be maintained if chloride levels in the bog stay below 77 to 95 mg/L, which is higher than the previously recommended limit of 54 mg/L. MassDOT continues to provide financial support for this research on Kampoosa Bog through its agreement with NHESP.

Chapter 3: Best Management Practices for Improving Salt Use Efficiency

MassDOT has adopted a number of practices, equipment upgrades and the use of innovative technologies to improve its snow and ice control operations. The principal means of clearing snow and ice from roadways is by plowing, particularly during major snow events with colder temperatures and the snow remains in plowable form. Advancements in plow types, designs and materials in just the last 5 to 10 years have made plowing much more effective in clearing snow compared to older plow models.

Segmented Plow Blades

MassDOT currently uses Kuper Tuca SX Wave blades, which are segmented blades with excellent scraping/snow removal properties, for its own plows. Segmented blades have a series of blade sections along the plow edge that move independently and conform better to uneven road surfaces, allowing for improved snow removal that typically results in less reliance on deicers. MassDOT plans to add more segmented blades for its fleet and, in the future, will evaluate whether the added performance may warrant revising vendor agreements to require contractors to have segmented blades. Some contractors are already using these plows because of the improved operator experience and are easier to repair.

MassDOT plans to add more segmented blades for its fleet and, in the future, will evaluate whether the added performance may warrant revising vendor agreements to require contractors to have segmented blades. Some contractors are already using these plows given the improved operator experience and they are easier to repair.

Pre-Treatment of Roads

Since 2011, MassDOT has been using liquid brine to pre-treat roads. Pretreatment, also known as anti-icing, involves direct applications of brine to the road surface prior to or in the early stages of a winter storm. This initial coating or application to the pavement helps prevent snow and ice from bonding to the roadway, much like how anti-stick spray is used for cooking. Pre-treatment is performed using a tanker truck outfitted with a spreader bar and nozzles. Liquid deicer is applied via nozzles from the rear of the truck at approximately 20 to 50 gallons per lane-mile. Like most state transportation agencies, MassDOT uses salt brine at a 23% concentration of sodium chloride dissolved in water to pretreat roads.

Pre-Wetting Salt

The practice of pre-wetting salt is a key aspect of MassDOT's strategy to making road salt more effective. Pre-wetting involves coating dry granular salt with a liquid deicer that typically consists of a magnesium chloride (MgCl2) solution or brine. This coating usually takes place at the end of the spreader chute during regular salt applications, but if equipment for this process is not available, pre-wetting can also be performed by spraying the salt pile at the depot or by purchasing pre-wetted salt. The purpose of pre-wetting is two-fold. First, pre-wetting salt initiates the dissolution process and helps salt become effective sooner after application. Pre-wetted salt also adheres to the roadway better and minimizes material loss due to dry salt particles bouncing and scattering off the pavement. As a result of these benefits, pre-wetting has been reported to reduce salt use by 25 to 30%.[2]

Slurry Spreaders

MassDOT currently uses over 75 slurry spreaders mostly in Districts 2, 3, and 4 with plans to expand usage in other districts. These spreaders apply a liquid intensive salt-slurry mix with up to 50 to 90 gallons of liquid deicer per ton of granular salt. The liquid slurry distributes more evenly, is retained longer on the pavement surface, and accelerates the melting process, and thus is much more effective than granular salt.

Slurry spreaders can be used during a wider range of weather conditions compared to pretreatment and combine the benefits of pre-treatment and pre-wetting. However, given the higher liquid deicer usage, use of slurry spreaders may be limited to the availability of liquid deicer storage. One of MassDOT's planned initiatives is to increase the liquid deicer storage capacity in areas where it may be limited to support the expanded use of slurry spreaders as appropriate.

Closed-Loop Controllers

MassDOT requires hired contractors to equip their material spreaders with closed-loop controllers, which are computer-based devices that regulate the rate at which road salt is applied based on vehicle speed and auger speed sensors. The controller is programmed to a desired salt application rate, and once adequately calibrated, can adjust the salt application rate based on detected changes in vehicle and auger

2 Michigan Department of Transportation. 2012. Salt Bounce and Scatter Study. https://www.michigan.gov/documents/mdot/Final_ReportNov2012_404228_7.pdf

speed. Auger speed can change over time due to temperature fluctuations and wear of hydraulics, so the auger sensor feedback helps to ensure consistent applications of road salt as programmed. Controllers are programed to apply at a rate of 240 pounds of pre-wetted salt per lane-mile. Closed-loop controllers can also track and report material usage in terms of amount material applied, lane-miles traveled, location of dispensed material, time of application, and average application rate.

Road Weather Information Systems (RWIS)

MassDOT has expanded its use of mobile Road Weather Information System (RWIS) unit to add its more than 45 fixed RWIS stations across the state. The mobile, vehicle mounted RWIS units have become as accurate and reliable as the traditional fixed, tower-based RWIS units and are more cost-effective since they are easier to install and provide more geographic coverage. MassDOT is progressing toward using more mobile RWIS sensors, which provide a wide range of critical data (e.g., pavement temperature, moisture, wind speed, pavement grip, and deicer concentrations).

Lower Application Rates

MassDOT instructs operators to use lower application rates when appropriate weather and pavement conditions allow. This decision requires sufficient pavement and weather forecast data as well as experience to know when weather and road surface conditions can support a lower application rate without compromising vehicle safety. Having more weather and pavement surface data available helps to support the decision-making process around the appropriate timing and rates of application.

MassDOT plans to continue its use of GPS/AVL technology to track material usage in select areas. These areas include certain roads maintained by the Andover Depot, roads adjacent to Kampoosa Bog and roads in the Dedham Westwood Water District. MassDOT has recently updated its service provider and AVL/GPS equipment on certain material spreaders with a goal of eventually using this technology statewide.

Alternative Pavements

MassDOT recently partnered with the UMass Transportation Center to investigate how open grade friction course (OGFC) pavement might affect deicing material needs. The study involves a segment of Interstate-95 in Needham, which is a high traffic volume area. The study will compare stormwater runoff and pollutant loads from the OGFC test section to traditional hot-mix asphalt and will monitor deicing material needs and pavement conditions during winter events over a 3-year period.

Pretreated Salt

MassDOT is also evaluating the use of pretreated salt, which is road salt already sprayed or coated with a liquid deicer. Pretreated salt eliminates the need to store liquid deicers where space is limited or have spreaders equipped saddle tanks. However, an organic product or agricultural byproduct such as beet juice is often used as the liquid deicer to pretreat salt. Thus, this material can have a high Biological and Chemical Oxygen Demand and possibly elevated levels of nutrients such as phosphorus and nitrogen. The potential environmental effects of using this material will need to be evaluated further as these issues may pose as much, if not a greater concern, for downstream water quality in receiving waters. MassDOT plans to get more product information from suppliers and may consider initiating a pilot test where water quality data can be collected to assess the effects on receiving waters.

Chapter 4: Corrosion Effects of Deicing Materials

The corrosive effects of deicing material on roadway infrastructure and motor vehicles are widely known and studied. Various strategies and products are available to mitigate and/or prevent deicer induced corrosion on infrastructure and vehicles.

Measures to Reduce Roadway Infrastructure Corrosion

Approximately 42% of the nearly 620,000 roadway bridges that exist across the nation are estimated to be more than 50 years old, which is the typical design life for most bridges. Approximately 23% are more than 60 years old and 12% are over 80 years old. To fully address the estimated backlog of structurally deficient bridge repairs needed nationwide, the annual spending on bridge rehabilitation would need to increase by nearly 60% from $14.4 billion annually to $22.7 billion. At the current rate of investment, the necessary repairs would not be completed until 2071.

MassDOT is responsible for inspecting approximately 1,500 bridges in the state, and currently has over 30 bridge inspection teams amongst its six maintenance districts, including four underwater "dive" teams. The MassDOT Bridge Inspection Handbook; 2015 Edition provides inspection guidelines on condition assessment criteria, inspection methods, inspection waivers, and bridge inspector qualifications.

As part of an Accelerated Bridge Program (ABP) that extended from 2015 through 2018, MassDOT completed 200 bridge projects at an estimated total cost of $2.4 billion that reduced the number of bridges of classified as structurally deficient to less than 9% of the total number of bridges in the state.

MassDOT also utilizes sealants and additives in concrete mixtures to slow the rate of intrusion of chloride anions into the concrete or mortar. Common sealants such as siloxane and silane typically last only three to five years and need to be reapplied periodically. MassDOT has listed several types or brands of concrete sealer products that have been qualified for use on the state’s concrete mixtures.

Measures to Reduce Motor Vehicle Corrosion

Vehicle manufacturers have made significant progress in the last 20 to 30 years in making vehicles more corrosion resilient by changing the materials used in their design. Vehicles today are made with a variety of corrosion resistant metal alloys, plastics, and resin composites and much less steel. Where metal is still used, coatings, splash guards, and improved drainage are used to limit exposure to trapped water.

Despite these advancements, a 2016 survey conducted by AAA, estimated that U.S. drivers that live in areas affected by snow and ice, paid approximately $3 billion per year in corrosion related repairs linked to deicing chemical usage. Certain vehicle components are more vulnerable to corrosion than others, such as fuel line, brake pads and rotors, and exhaust and electrical systems primarily because of their metal alloy composition and exposure to road spray splashing on or beneath the vehicle. Exhaust systems traditionally were one of the most vulnerable and most expensive vehicle components to replace, but most are now made with rust resistant metal alloys and even stainless steel to provide greater longevity. MassDOT's corrosion protection measures for bridges and other road infrastructure include the use of epoxy-coated steel; spray applied membranes and sealants for bridge decks; as well as applying more effective metal coatings, such as galvanizing and/or metalizing the steel components; and limiting the use of un-coated weathering steel to sites where there is less salt use, such as over railroads.

Corrosion Effects on Drinking Water Supply Infrastructure

A more recent issue relates to the potential corrosion of drinking water distribution pipes and fixtures due to increased chloride levels as well as other water quality changes drinking in water supply sources. The corrosion issues involving water supply infrastructure are complex as many site-specific factors involved with source water quality and the use of chemicals for treatment and corrosion protection, as well as pipe materials, can affect the corrosion potential of distributions pipes.

Recent studies have reported that drinking water sources that have chloride to sulfate mass ratio (CSMR) above a threshold of 0.5 appear to have an increased risk of pipe corrosion. The elevated CSMR ratios can result from increased salinization of source waters as well as the use of salt-based treatment coagulants. Corrosion protection measures and frequent water quality monitoring are ever more critical as watershed areas of drinking water source become more urbanized. Drinking water sources along the coastline are also more prone to future increases CSMR ratios due to saltwater intrusion and predicted sea level rise due to climate change.

EPA banned the use of lead-based pipes and solder in new plumping systems in 1986. However, according to a 2016 MassDEP survey, more than 20,000 lead service lines (LSLs), installed prior to the 1986 ban, may still be in use statewide.[3] As part of the cost analysis for the 2021 revisions to the Lead and Copper Rule, EPA estimated that the average cost to replace LSLs was approximately $3,600 but could be as much as $10,000 or more depending on the site complexities and constraints.

The American Rescue Plan Act of 2021 provides $15 billion over the next five years for lead pipe removal. Funds from the bill will be distributed to the states and will be made available through the Drinking Water State Revolving Loan Fund to fund various investments to water and sewer infrastructure, including LSL replacements.

The Massachusetts Clean Water Trust is offering $20 million in loans and 100% loan forgiveness for all public water suppliers (PWSs) to conduct planning projects to inventory Lead Service Lines (LSLs) and to develop LSL replacement plans. PWSs can apply for loans through the State Revolving Loan Fund.

Chapter 5: Effect of Winter Weather on Public Safety and Vehicle Mobility

Public safety and maintaining vehicle mobility are the two principal drivers behind the various road maintenance activities conducted as part of the MassDOT Snow and Ice

3 2016 Massachusetts Department of Environmental Protection (MassDEP) Lead Service Line Survey https://www.mass.gov/service-details/lead-and-copper-rule-lead-service-line-survey

Control Program. Consistent with previous ESPRs, the effects of winter weather on vehicle mobility and crash rates were assessed using Massachusetts vehicle crash data and reported seasonal economic data.

Winter Weather and Vehicle Crash Rates

In Massachusetts, review of statewide crash data for the last 20 years indicates that each winter day approximately 385 vehicle crashes occur statewide, on average, compared to an average of 352 crashes on a summer day. The additional 33 vehicle crashes per day can add up to1,000 additional vehicle crashes per month and over 5,000 additional crashes over the 5-month winter season. The 2017 MassDOT Snow and Ice ESPR reported a similar finding of 36 additional vehicle crashes occurring on winter days versus summer days, based on vehicle crash data from 2006 to 2014.

The average daily crash rate between 2011 and 2021 was lower than the average daily crash rate in the pre-2011 period, despite the more recent period having a more severe average WSI value. The lower average crash rate suggests that road conditions may have improved with the use of liquid deicers as well as other efficiency practices. At the same time, the average annual salt usage during the recent 2011-2021 period was lower than that used during the 2001-2010 period.

The major traffic backup in eastern Virginia on Interstate 95 on January 3, 2022, highlights the precarious nature of how winter weather can adversely affect vehicle mobility and public safety. Virginia DOT officials were not able to pretreat the roads since the storm started as heavy rain and any applied material would have been washed away by the rain. The inability to pretreat and the buildup of water on the roads combined with a sudden drop in temperature led to icy road conditions that caused a major vehicle backup. The conditions went from bad to worse when the rain turned to snow falling at a rate of 2 inches per hour, causing a tractor-trailer truck to jackknife and block traffic. Motorists were stranded along 50 miles for over 24 hours.

State Economy and Vehicle Mobility

Maintaining safe travel conditions on the Commonwealth roadway system is vital to supporting the tourism activity and related travel as part of the state's economy. Data published in the 2020 Annual Report of the Massachusetts Office of Travel and Tourism (MOTT) indicates that nearly $25 billion was spent in the State by domestic and international visitors in 2019, an increase of 3% from 2018 and more than $3 billion more than in 2015 and $10.5 billion more than in 2009. In FY20, approximately 92% of these dollars were spent by domestic visitors, and 56.3% of all domestic trips originated in New England and other nearby northeast states. Travel disruptions and reduced vehicle mobility due to weather and poor road conditions can have a major impact on tourism, business commerce and other economic activity in the state.

A IHS Global Insight study estimated that a one-day shutdown in Massachusetts could result in economic losses of $265.1 million. Much of the impact was attributed to lost wages for hourly workers ($194 million), but also estimated losses in retail sales ($40.5 million), and lost federal, state, and local tax revenue ($30.5 million). These cost estimates assumed that nearly all businesses and government agencies would be closed due to impassable roads and the closure of other modes of transit

The Massachusetts Emergency Management Agency (MEMA) estimated that the severe winter weather of 2015 caused over $300 million in economic losses in the Boston Metro area due to lost revenue, wages and productivity as well as property damage and higher snow removal costs. The MBTA, MassPort, and the Steamship Authority also reported significant losses of approximately $22.4 million, $13.3 million, and $0.4 million, respectively, due to reduced operations and cancelled trips. MassDOT lost nearly $3 million in toll revenue. Boston area hospitals lost approximately $10.3 million in revenue. Retail sales were estimated to decline by 22% and employee payroll dropped by approximately 7%.

Shipping and trucking industries are especially vulnerable to financial impacts caused by adverse road conditions and winter weather. A 2016 U.S. Federal Highway Administration study estimated that weather events cost the freight industry approximately $3.8 million per year in lost time due to delays and decreased speeds.

Potential Economic Impact of Ecosystem Service Declines

With respect to potential economic impacts to the environment, a 2010 study predicted potential economic impact resulting diminished ecosystem services in roadside waters and forested areas due to road salt use adjacent to lakes, wetlands, and forests in the New York Adirondack region. Based on model simulations, the study suggests that the potential loss or reduction in ecosystem services due to road salt use could have an economic impact of approximately $2,320 per lane mile due to diminished water recharge, soil stabilization, nutrient cycling, and recreation activity.

Applying the estimated environmental impact rate of $2,320 per lane-mile, discussed above, to the approximately 16,100 lane-miles maintained by MassDOT would result in an estimated potential environmental impact of approximately $37 million per year related to MassDOT's road salt usage based on the study assumptions. Adjusting for inflation from 1997, the estimated impact could be nearly twice as much. However, since much of MassDOT's road network is in more urban or developed areas of the eastern half of the state, the type and extent of ecosystem services provided by directly adjacent, forested or wetland areas may be different than those along the rural roads in the Adirondack Region. Also, the potential impacts to ecosystem services will depend on the type and extent of winter maintenance chemicals and practices deployed as well as many other factors and influences.

As discussed earlier, MassDOT has been able to reduce its overall annual road salt usage by using liquid deicers as well as other technologies and equipment upgrades, which has the added benefit of reducing the potential for environmental impacts.

This page was intentionally left blank.

1 Operations, Practices and Material Usage

1.1 Overview of MassDOT SICP Operations

Consistent with the March 2021 MEPA Certificate, this chapter provides both a retrospective analysis and an update of the snow and ice control operations with a greater focus on the more recent efficiency measures that have led to an overall reduction in the average annual salt usage.

1.1.1 Pre-Season Preparation Activities

1.1.1.1 Equipment Calibration Policy

Prior to each season, state-owned and hired material spreaders are inspected and calibrated to ensure that the spreader components are functioning properly, and the controllers' settings are appropriately set to apply materials within MassDOT's application policy. The following describes the different calibration procedures for state-owned and contractor equipment.

MassDOT Equipment

District personnel typically inspect and calibrate state-owned material spreaders and plows by mid-November. The inspection results, as well as any equipment repair or part needs, are submitted to the District Foreman. Depending on available personnel, calibration teams will be used to conduct random checks of spreader gate openings on hired and state equipment during the winter months to make sure gate openings have not changed. The calibration teams typically rotate between various depots and schedule equipment checks in between winter events to avoid disrupting operations.

Hired Equipment

Hired contractors are required to have their material spreaders calibrated by an approved, third-party calibrator prior to each winter season. The calibration vendors provide a signed certificate certifying that the spreader controller is working within the manufacturer specifications and can be set to apply materials in accordance with MassDOT's application policy. MassDOT requires contractors to submit calibration certificates to the District office, the MassDOT headquarters and have a copy kept in each truck. Prior to each season, district personnel inspect hired equipment to confirm vehicles have the required safety devices, appropriate vehicle registration, and a calibration certificate as well as have the required prewetting apparatus and closed-loop controllers. As an incentive to get inspections done early, contractors are eligible for an Early Sign-up Bonus if they complete inspections by the specified early season date indicated in the SICP vendor agreement.[4]

MassDOT recently updated its contractor/vendor agreement to now require calibration vendors to apply durable reflective tape on the spreader to indicate the opening height at the time of calibration.[1]

This added requirement of marking the gate opening helps MassDOT calibration teams to visually detect if gate openings have changed during the season. On occasion, operators might increase their gate openings during the season to allow increased material output, especially if they maintain other paved areas besides MassDOT roads. The calibration team also checks spreader spinner heights to make sure they are within 16 inches (+/- 4") above ground. Higher spinner heights may lead to greater material loss off the roadway during application.

1.1.2 Annual Training

In 2019, more than 900 contractors attended MassDOT's annual snow and ice training.

MassDOT requires its SICP employees to participate in annual training using video training modules the provide guidance on various operational aspects including equipment calibration, weather monitoring and the use of liquid deicers, to name a few. The video modules are obtained from various snow and ice practitioner organizations including the Clear Roads Program (https://clearroads.org/videos/).

MassDOT also provides separate "tailgate" training sessions at various depots in each District for both state personnel and hired contractors. Tailgate training is used to provide updates on any new MassDOT policies and reemphasize the use of current best management practices including spreader calibration, prewetting requirements,

4 See MassDOT vendor agreement at: https://www.mass.gov/doc/2022-2023-snow-and-ice-control-agreement-with-attachments/download

application timing, reducing spillage due to overloading spreaders and any specific practices related to environmentally sensitive areas. This training also provides an opportunity to exchange ideas and to discuss challenges and concerns with various practices, environmental stewardship, material tracking and reporting requirements.

MassDOT offers a training stipend to hired contractors if they attend tailgate training. As indicated in **Table 1.1**, in the 2019-20 season, approximately 930 hired contractors as well as more than 700 state employees attended tailgate training, In the 2020/21 season, however, tailgate training had to be curtailed due to the COVID-19 pandemic and was limited to just a few locations for smaller groups. In 2021-22 season, which was still affected by the pandemic, 740 hired contractors attended tailgate training.

Table 1.1 MassDOT 2019-2020 Snow & Ice Training Attendance

District	Contractors	District Operators	Route Coordinator	Timekeeper
1	25	53	28	28
2	80	56	25	14
3	228	69	30	30
4	269	75	30	28
5	259	121	58	26
6	72	41	18	6
Totals	933	415	189	132
			Total	1,669

Source: MassDOT Lead Snow and Ice Engineer.

As opportunities arise and as appropriate, MassDOT is willing share information on best practices with the Baystate Roads Program for state and municipal personnel. Additional coordination is perhaps needed amongst a broad group of stakeholders to determine how best to share this information and make the most of this Program. MassDOT recently organized an Interagency Salt Working Group with representatives from MassDEP, DCR and MWRA to discuss potential approaches for training and promote greater awareness of the efficiency measures available to a larger audience. MassDOT plans to continue to meet quarterly with these agency representatives.

1.1.3 Monthly Material Use Committee Meetings

District SICP Engineers and the Lead statewide SICP Engineer typically meet monthly to discuss personnel, material and equipment needs, upcoming policy and equipment changes, recent material usage and weather conditions during the winter season.

During the winter season, material usage is tracked at each District through material use and road weather information reports submitted on a biweekly basis via the Snow Information Management System (SIMS).

These SIMS reports include information on road conditions, snowfall amounts, storm begin and end times, and the amount and type of equipment deployed. These meetings provide an opportunity to discuss operational aspects and challenges encountered in recent winter events and adjustments that may be needed to increase the availability of equipment or other efficiency measures at the district level.

1.1.4 Plow Route Review and Optimization

Plow and spreader routes are periodically reviewed and adjusted as new roadway improvements are completed or perhaps due to changes in personnel, contractor or equipment availability, or upgrades. The starting and ending points of spreader routes may be adjusted to improve efficiencies and/or to eliminate potential overlaps between adjacent service areas of other depots or municipalities. Adjustments may also be made to address specific issues related to environmentally sensitive areas, which may involve reassigning equipment or vehicle operators. More experienced operators or certain material spreaders such as slurry spreaders or those with vehicle and material use tracking equipment are typically designated for environmentally sensitive areas to allow better tracking of material applications and usage.

As discussed more in **Chapter 3**, route optimization software has been reported to reduce travel time and related fuel and operator labor, however, it is unclear whether this potential time and fuel savings translates into a reduction in material usage as well. Material spreading is not always occurring during vehicle travel to and from the designated route. MassDOT will continue to monitor the growing research on the use of this software and may pilot test its use, especially if additional data confirms that use of the software leads to a potential savings in material as well as fuel and labor.

1.1.5 Contractor Agreements and Equipment Specifications

MassDOT annually updates its contractor service agreements to add or modify equipment requirements for hired equipment to be called into service and to help increase efficient use of materials.

Since 2011, MassDOT requires hired contractors to equip their spreader trucks with closed-loop controllers and pre-wetting equipment before being called into service.

MassDOT has adjusted the reimbursement rates in the vendor agreements to compensate contractors for the added expense of installing additional equipment such as closed-loop controllers and saddle tanks to pre-wet road salt. Starting in FY22, contractors are also required to have GPS units in their vehicles, supplied by MassDOT, primarily for monitoring vehicle miles traveled and location.

MassDOT has also added a stipend to compensate contractors to attend “tailgate” training sessions, which allows MassDOT personnel and contractors to exchange ideas and gain a better understanding of the overall program goals which include environmental stewardship, highway and personnel safety, and operational efficiency.

1.2 Weather Forecast and Road Condition Monitoring

MassDOT relies on multiple sources of weather forecasting and road surface condition data to assist in deciding when to initiate SICP operations and what type and amount of equipment is needed. MassDOT contracts with a commercial weather forecasting service (DTN) to provide area-specific weather forecast information four times a day at 2 a.m., 6 a.m., 2 p.m., and 8 p.m., throughout the year. The weather data is sent to each district, headquarter personnel as well as the Highway Operations Center (HOC) located in South Boston.

The HOC also monitors other weather, road and traffic volume data, including live information from DTN or the National Weather Service www.weather.gov. When a winter storm is forecasted to occur in the next 12 hours, the HOC transmits the report to the Snow and Ice Program Director. Outside normal working hours, the weather forecasts are relayed to the District Snow and Ice Engineers, using dedicated phone numbers established before the season.

In addition to the contractor provided forecast information, MassDOT has access to and monitors real-time weather data available from the following:

45

fixed Roadway Weather Information Stations (RWIS) located throughout the state of Massachusetts.

25

mobile, vehicle-mounted, or handheld RWIS units that provide weather and pavement condition data.

The RWIS units provide pavement temperature and friction (grip) data, wind speed and direction, air and dew point temperatures, precipitation type as well as roadway surface condition data (i.e., icy, slushy, wet) which can inform staff about actual roadway characteristics, which can be difficult to distinguish, especially during the evening. (See **Chapter 3** for additional details on RWIS and road surface monitoring).

1.3 SICP Coordination & Communication

1.3.1 MassDOT SICP Roles and Responsibilities

Coordinating winter maintenance operations is a shared responsibility between Highway Operations personnel at MassDOT Headquarters, the District SICP Engineers in each of the six Maintenance Districts, and the Highway Operations Center (HOC). Most of MassDOT's senior management and operations personnel have years, if not decades, of experience, which is critical in terms of understanding how various weather-related and site-specific factors affect road conditions.

Table 1.2 defines the roles and responsibilities of various MassDOT personnel in the SICP organizational structure. This list of responsibilities is by no means a comprehensive list of the activities performed by these positions or under the SICP.

Table 1.2 Primary MassDOT SICP Personnel Roles and Responsibilities

MassDOT Role	Snow and Ice Program Responsibilities
Lead Snow and Ice Engineer	» Develop and update SICP Operations policies and procedures » Coordinate with District Engineers on spreader routes and equipment needs » Review/approve equipment purchase requests » Coordinate/approve contractor agreements for hired equipment » Monitor weather forecasts & coordinate statewide readiness/response to storm events
District Maintenance/ Operations Engineer	» Review and approve spreader and plow routes on an annual basis » Coordinate with District SICP Engineer on reviewing contractor equipment needs » Review and approve state personnel assignments » Review and approve materials and contractor equipment expenditures » Coordinate emergency operations for roadway incidents » Assess salt storage infrastructure conditions and general housekeeping measures
District Snow and Ice Control Engineer	» Coordinate the district personnel training with the Lead Snow and Ice Engineer » Review and recommend updates to spreader and plow routes prior to each season » Coordinate material requests with Area supervisors and schedule material deliveries » Recommend contractor selection based on equipment type and quantity needs » Determine equipment mobilization start and end times based on weather/RWIS data » Review & track deicing material usage/ inventory via SIMS reports » Coordinate with road patrols and operations with the HOC and Area Supervisors
Depot Area Supervisor	» Coordinate with each Depot Foremen (approximately 7 to 11 depots per Area) » Patrol roadways and report on road/weather conditions to District SICP Engineer » Respond to emergency operations and roadway incidents » Assist in determining start and end times for hired equipment on specific routes
Depot Foreman	» Coordinate route assignments, vendor agreements, and coordinate equipment repairs » Perform callouts for state personnel and contractors at the beginning of an event » Assign/adjust plow routes for each event based on operational needs » Coordinate with Route Coordinators on road conditions and material needs » Conduct periodic checks of spreader equipment calibration throughout the season
Plow Supervisor/ Route Coordinator	» Patrol roadways and communicate road/ weather conditions to Depot Foreman » Consult with Depot Foreman on event operations based on road & weather information » Organize/synchronize plows and spreaders to ensure effective operations

Note: This is not intended to represent an all-inclusive list of the various roles and responsibilities performed by MassDOT SICP personnel.

1.3.2 Highway Operations Center

The primary role of the Highway Operations Center (HOC), located in South Boston, is to monitor traffic volumes, road surface conditions, congestion, vehicle accidents and to coordinate responses to traffic flow disruptions and other vehicle incidents. The HOC is staffed 24 hours a day, seven days a week. This role intensifies during winter maintenance operations and storm events when travel conditions worsen. The HOC monitors over 100 closed-circuit video cameras (CCTVs) as well as Road Weather Information Stations (RWISs) located throughout the state.

The HOC closely coordinates and relays relevant weather, road condition, and trouble spot data with the Lead Snow and Ice Engineer in Boston, as well as District personnel during winter weather events. Each District has a dedicated “Radio Room or Desk” to coordinate directly with HOC personnel as winter weather develops and persists. This information is used to initiate and coordinate SICP operations throughout the state. The HOC also receives road condition reports from state police, the “511” reporting system, as well as social media such as Twitter which is then relayed to appropriate district personnel. The HOC manages public messaging on the variable messaging signs located throughout the state.

1.3.3 Use of Variable Message Signs to Alert Motorists

MassDOT has greatly expanded its use of electronic variable message signs to warn motorists of pending inclement weather conditions, roadway conditions, traffic delays, and reduced speed limits. MassDOT currently has over 60 variable messaging signs located throughout the state that are connected to its “SMART” Intelligent Traffic Management Systems, which integrate data from a variety of weather, road surface and traffic monitoring sources. The messaging is monitored by the HOC and focuses on providing up to the minute local and regional roadway, traffic, and weather information. District personnel have anecdotally observed that proactive messaging appears to have had a positive effect on modifying driver behavior and reducing traffic congestion as motorists adjust to traffic speeds, seek alternative routes, or stay at home to telecommute during inclement winter weather.

MassDOT also utilizes Twitter, other social media and the Mass511.com web site to inform motorists on current and pending traffic, roadway, and weather conditions.

1.4 Field Operations

1.4.1 Plowing as the First Line of Defense

Plowing remains the principal means of snow removal and depending on weather conditions typically removes as much as 90% of the accumulated snow and ice. Plow trucks typically account for the biggest component of the equipment fleet for most winter weather events. Plowing operations are coordinated with material use operations such as pretreatment of roads depending on weather conditions to achieve the most efficient snow/ice removal. Plowing is obviously not effective during freezing rain or when black ice formation is the primary threat.

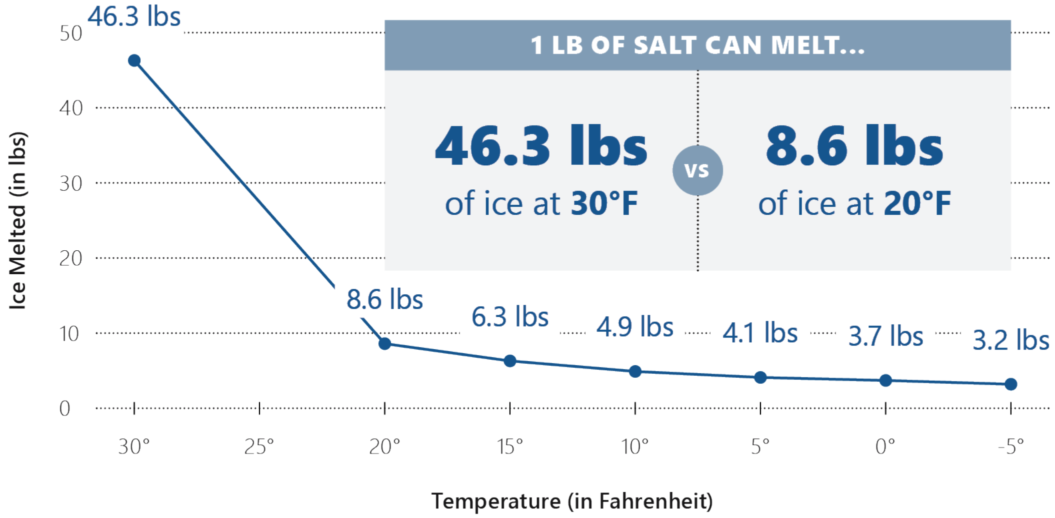
As discussed more in **Chapter 3**, MassDOT has been using segmented blades, which consist of a series of sections along the "cutting" edge of the plow blade that allows for better contact with the pavement relative to a standard straight blade. These plow blades are more effective in lifting and removing snow than traditional single piece blades. Increased blade performance generally translates to less salt applied and fewer repeat applications, as well as better road surface conditions.

1.4.2 Material Application Policy

MassDOT typically applies road salt at a rate of 240 lb./lane-mile per application, in accordance with their salt application policy, which equates to approximately 4.1 lb. per 1,000 square feet or 0.4 lb per 100 square feet of area (about the size of a small bedroom). This application rate is considered the minimum amount necessary under most weather conditions to prevent snow and ice from freezing to the pavement, especially when air and pavement temperatures are between 25°F and 32°F. As the applied material begins to dilute as snow, rain or freezing rain accumulates and melts, its effectiveness to lower freezing temperatures declines. Thus, repeat applications are often needed with number and timing of repeat applications depending on many factors including precipitation intensity, storm duration, and pavement temperatures.

Road salt's ability to lower freezing temperatures and melt snow and ice declines dramatically as temperatures fall below 25°F and essentially becomes ineffective below 15°F. As shown in **Figure 1.1**, at 30°F, one pound of salt can typically melt approximately 46 pounds of ice but at 20°F the same one pound of salt would only melt 8.6 lb of ice or is approximately 80% less effective. In other words, it takes nearly 5 times as much salt to melt the same amount of ice at a temperature of 20°F compared to that at 30°F. Thus, just a 10°F difference in temperature can have a major impact in the amount of salt needed to prevent snow and ice from freezing.

Figure 1.1 Effect of Temperature on Road Salt Melting Capacity



Source: S. J. Druschel, Salt Brine Blending to Optimize Deicing and Anti-Icing Performance and Cost Effectiveness: Phase III. Minnesota Department of Transportation, http://mndot.gov/research/reports/2017/201745B.pdf

As discussed more in Section 1.4.4 below, the reduced effectiveness of road salt at colder temperatures represents a major challenge for district personnel in Reduced Salt Zones (RSZs) where salt application rates were typically cut in half and supplemented with sand. District personnel have found the "reduced" applications often led to making more repeat applications to maintain the same reasonably safe road surface conditions as adjacent roadways, especially during cold temperatures. As a result, the total salt usage in a RSZ over the course of a season is often very similar, if not more than that used on conventionally treated roads with an application rate of 240 lb per lane mile. As discussed more below, the use of liquid deicers to pretreat roads and a MgCl2 solution to pre-wet road salt has been much more effective in reducing the amount of road salt needed, especially at colder temperatures. A more detailed discussion on the Reduced Salt Zone Policy is included in **Chapter 2**.

In the same sense, MassDOT also instructs operators to use lower application rates closer to 200 lb. per lane-mile when appropriate during warmer temperatures and/or when temperatures are rising recognizing that less salt may be needed at warmer temperatures compared to colder temperatures. The effect of these practices on annual salt use is discussed in greater detail in Section 1.8 below and **Chapter 3**.

1.4.3 Liquid Deicers for Pre-Treatment and Pre-Wetting

Since 2011, MassDOT has steadily increased its use of liquid deicers for pre-treatment of roads (a.k.a. "anti-icing") and pre-wetting of road salt. Liquid deicers have increased the effectiveness of road salt, which has resulted in substantial reductions in road salt usage over the last 10+ years. As shown in **Table 1.3**, MassDOT has used approximately 1.5 million gallons of liquid magnesium chloride (MgCl2) per season on average for pre-wetting purposes. MassDOT also uses a blended brine solution to pretreat roads when appropriate weather and pavement conditions allow. The brine solution costs less than liquid MgCl2 but is not as effective at lower temperatures.

Table 1.3 Summary of Liquid Deicer and Other Snow and Ice Control Materials Used by MassDOT Over the Last 5 Years

Fiscal Year	Liquid MgCl2 (gals)	Blended Salt Brine (gals)	Pre mix (tons)1	Sand (tons)
2017	1,596,890	171,796	601	15,573
2018	1,672,425	108,800	340	17,495
2019	1,712,687	56,200	858	11,948
2020	1,275,079	224,300	814	9,229
2021	1,256,778	243,065	101	12,234
Average	1,454,859	117,832	543	13,296

Notes: 1 Premix was not used in used in District 6. D5 accounts for approximately 80% of the sand use.

As discussed more in **Chapter 3**, pretreatment or "anti-icing" involves applying a brine solution directly to the road surface prior to or at onset of a winter precipitation event. The brine solution is generally applied at a rate of 20 to 30 gallons per lane-mile using tanker trucks outfitted with spray nozzles. This initial application provides a deicer layer to reduce the freeze temperature and prevent ice and snow from bonding to the pavement in the early stages of a storm. However, because brine solutions have a relatively low concentration of sodium chloride (e.g., 23% by weight), direct applications can be only done during a relatively narrow range of temperature and precipitation conditions without risk of freezing, especially if temperatures drop. Brine applications are also not appropriate when the threat of rain will dilute the solution even further. Eventually, the applied material will become ineffective due to dilution from melting and/or precipitation.

The MgCl2 brine solution used for prewetting purposes has a concentration of 28% MgCl2 and 70% water. Given the diluted salt concentration in liquid brine solutions compared to granular road salt, the amount of deicing material applied in a pretreatment application is generally in the range of 50 to 75 pounds (lb) per lane mile or much lower than the 240 lb per lane mile when applied in a granular form.

Pre-wetting salt boosts the effectiveness of road salt because the salt is applied in an activated or in semi-liquid state, which allows the salt to adhere to the pavement. Pre-wetting also reduces the amount of material lost due to bounce and scatter of salt particles off the pavement. A Michigan study found that when regular dry salt is applied to dry pavement, as much as 30% of the salt can be lost off the pavement due to bounce and scatter of salt particles as it hits the pavement.[5]

MassDOT is also currently using as many as 75 "Slurry-Spreaders" mostly in Districts 2 (17), District 3 (24) and District 4 (25) to apply a more "liquified" slurry of road salt, which has been found to be much more effective in preventing snow and ice from bonding to the pavement. Slurry spreaders combine the benefits of pretreatment and prewetting and can be used under a wider range of weather conditions than pretreatment alone. District 3 conducted a side-by-side comparison on Route 2 and found the slurry mixture in the test section improved road surface conditions by keeping snow plowable, which resulted in more bare or clear pavement compared to the adjacent conventionally treated road. As a result, slurry spreaders can delay and possibly avoid the need for subsequent applications.

1.4.4 Reduced Salt Zone (RSZ) Policy

MassDOT currently has over sixty (60) Reduced Salt Zones (RSZs) in various locations throughout the Commonwealth as part of a legacy program established back in the 1980's. Most of the RSZs are in Districts 4 and 5 along road segments next to major public water supply wells and surface water supplies. No new RSZs have been established in the last 20 years.

As discussed more in Section 2.1, MassDOT plans to transition away from the use of sand as one of the early practices used in RSZs and instead build on the more recent use of liquid deicers and other more effective technologies and equipment that have successfully reduced road salt on a statewide basis.

5 Michigan Department of Transportation. 2012. Salt Bounce and Scatter Study: Project Summary Report. Michigan DOT Field Operations Division. Final Report November 2012

1.4.5 Material Use Tracking in Environmentally Sensitive Areas

MassDOT has begun using AVL/GPS technology on material spreaders to improve tracking and accounting of salt usage in select environmentally sensitive areas including the Dedham-Westwood Watershed area, Kampoosa Bog, and Andover's River Road area. The initial roll-out has had several technological challenges primarily due to the different controllers used by contractors making signal connectivity and compatibility inconsistent at best. The initial units also relied on older 3G satellite communication technology that was prone to frequent connection losses. MassDOT is now replacing these units with newer 4G communication technology that will provide better signal connectivity and functionality with a "smart cable/modem" connected to the GPS tracker and the spreader's closed loop controller.

MassDOT plans to install these newer generation GPS/AVL units on salt spreaders used in the Dedham depot, as well as the Andover area, and the Wachusett Reservoir watershed in District 3. New units will also be installed on state spreaders in the Lee Depot that treat the I-90 roadway section as well as contracted equipment treating State Route 7 adjacent to the Kampoosa Bog. MassDOT plans to continue to install the wireless equipment in patrol sheds to acquire material usage from spreader operators using GPS/AVL equipment. Additional training will be provided to ensure operators pass utilize wireless stations after completing an event or route to upload data. Additional details are discussed in **Chapter 3**.

1.5 Comparison of Recent and Historical Average Annual Road Salt Usage

Table 1.4 compares the average annual salt usage (tons per ln-mi) between FY11 and FY22 to that used in the previous 10 years (FY01-FY10) for each district and on a statewide basis. The data from the FY01-FY10 period represents a baseline of the average salt usage prior to the adoption of various efficiency measures that began in FY11 from which to compare to future changes. The district averages are based on the reported data from each district while the statewide averages are based on the total statewide usage divided by the total lane-miles. Section 1.7 describes the WSI methods used to normalize the salt use data between the two periods.

Overall, MassDOT's average annual statewide salt usage in the last 12 years is approximately 15% or 74,150 tons less than that used in the FY01-FY10 period, while accounting for differences in the average winter severity index (WSI) values between the two periods. This reduction in annual salt usage relative to the past usage is mainly due to the increased effectiveness of the more recent application methods including use of liquid deicers as well as other efficiency measures adopted since 2011. At the same time, MassDOT's lane-mileage increased by approximately 15% following the merger with the Massachusetts Turnpike Authority. On a district-by-district basis, the differences in the average annual road salt usage between the two periods vary largely because of differences in the timing of equipment upgrades, availability of liquid deicers and other related factors.

Table 1.4 Comparison of Recent Annual Salt Usage (tons per lane mile) in Each District Between FY11 and FY22 to that Previously Used in the Winter of FY01-FY10

Fiscal Year	District						Statewide Average1
	1	2	3	4	5	6	
	Tons per Lane Mile						
2011	41.7	27.8	39.1	35.2	31.0	40.3	34.8
2012	20.4	9.7	15.2	10.9	15.9	10.6	13.7
2013	29.4	24.2	38.3	23.1	26.1	34.6	28.8
2014	41.5	35.5	43.3	25.7	31.9	56.2	36.6
2015	43.2	37.8	40.6	25.8	36.4	63.5	38.4
2016	17.1	18.8	30.0	16.2	21.1	39.7	23.1
2017	45.3	34.4	43.3	23.5	24.7	36.9	32.3
2018	43.9	28.7	34.7	17.8	25.5	36.1	28.5
2019	50.8	27.5	30.4	15.4	20.5	29.4	25.1
2020	37.7	25.3	21.7	12.8	12.4	12.5	17.8
2021	46.2	24.9	23.0	13.5	17.4	24.1	20.7
2022	36.4	26.5	26.5	15.7	19.3	24.0	23.0
2001-10 Avg2	49.8	28.3	44.1	34.3	32.4	34.23	36.4
2011-22 Avg	37.8	26.4	32.3	19.6	23.5	34.0	26.9
Difference	-12.0	-1.6	-11.9	-14.6	-8.9	-0.2	9.5
% Difference	-24.1%	-5.6%	-27%	-42.7%	-27.5%	-0.4%	26%

1 The statewide average is calculated independently from the districts and is based on the total statewide usage divided by total ln-miles
2 The 2001-10 average annual usage was adjusted to reflect the WSI values were milder during 2011-2022 period vs. 2001 to 2010.
3 The District 6 baseline average usage was based on District 4's average annual usage on a per lane-mile basis for the 10-year period.

In the last 5 years, or since 2017, MassDOT's average annual salt usage rate on a statewide basis declined even lower to 23.0 tons per lane-mile compared to the 12-year average and is approximately 30% lower than the average annual usage rate of 33.4 tons per lane mile used in the FY01 and FY10 baseline period. This average annual rate for the FY01 to FY10 period was adjusted from the 36.4 tons per lane mile annual usage rate to reflect the lower average annual WSI values in the last 5 years.

1.6 MassDOT Roadway Lane-Miles

Table 1.5 summarizes the total lane mileage and interstate lane miles maintained by MassDOT districts for snow and ice control purposes in each District based on the 2020 Statewide Road Inventory. All totaled, MassDOT maintains approximately 16,120 lane-miles for winter maintenance purposes, which represents approximately 20% of the total 82,400+/- roadway lane-miles across the Commonwealth. The remaining 80% of roadway lane miles are maintained by various municipalities, private landowners, or federal and other state agencies. MassDOT's total lane-mileage has increased somewhat over the last decade, with the last major change occurring in 2010 when MassDOT merged with the Massachusetts Turnpike Authority adding approximately 15% more lane miles. MassDOT also maintains the Tobin Bridge and associated connector roads previously maintained by MassPort, and approximately 726 lane-miles of DCR-owned roads.

Table 1.5 Total and Interstate Roadway Lane-Miles1 Maintained in Each District

District	Total Roadway Lane Miles1	Interstate Roadway Lane Miles	Interstate Roadway (%)
1	1,067	251	24%
2	2,117	763	36%
3	3,400	1,378	41%
4	3,351	1,168	35%
5	4,329	936	22%
6	1,856	522	28%
Total	16,120	5,018	31%

1 Lane miles estimates are based on 2020 Road Inventory. Lane-miles were determined based on the total pavement width divided by 11-foot travel lanes multiplied by the linear length of road for all roadways identified as being under MassDOT jurisdiction.

Approximately 31% of MassDOT's road network consists of multi-lane interstate roads with District 3 having the highest percentage. The equipment and material needed to maintain interstate roads is much greater than typical two-lane roads because of the number of travel lanes and larger pavement area per mile. Interstate roads are often located in urban areas to convey the larger traffic volumes that can reach 10,000 to 20,000 vehicles per hour during peak commuting hour. Even a small decrease in vehicle mobility on these roads can lead to major traffic congestion. Thus, the higher traffic volumes can make the timing of SICP operations is even more critical and often requires SICP operations be conducted on a 24-hour, 7-day week basis. This added timeframe and low margin for error can lead to greater material and equipment usage and costs compared to rural areas with secondary roads, where operations can often be delayed, done less frequently, and even suspended during the late overnight hours.

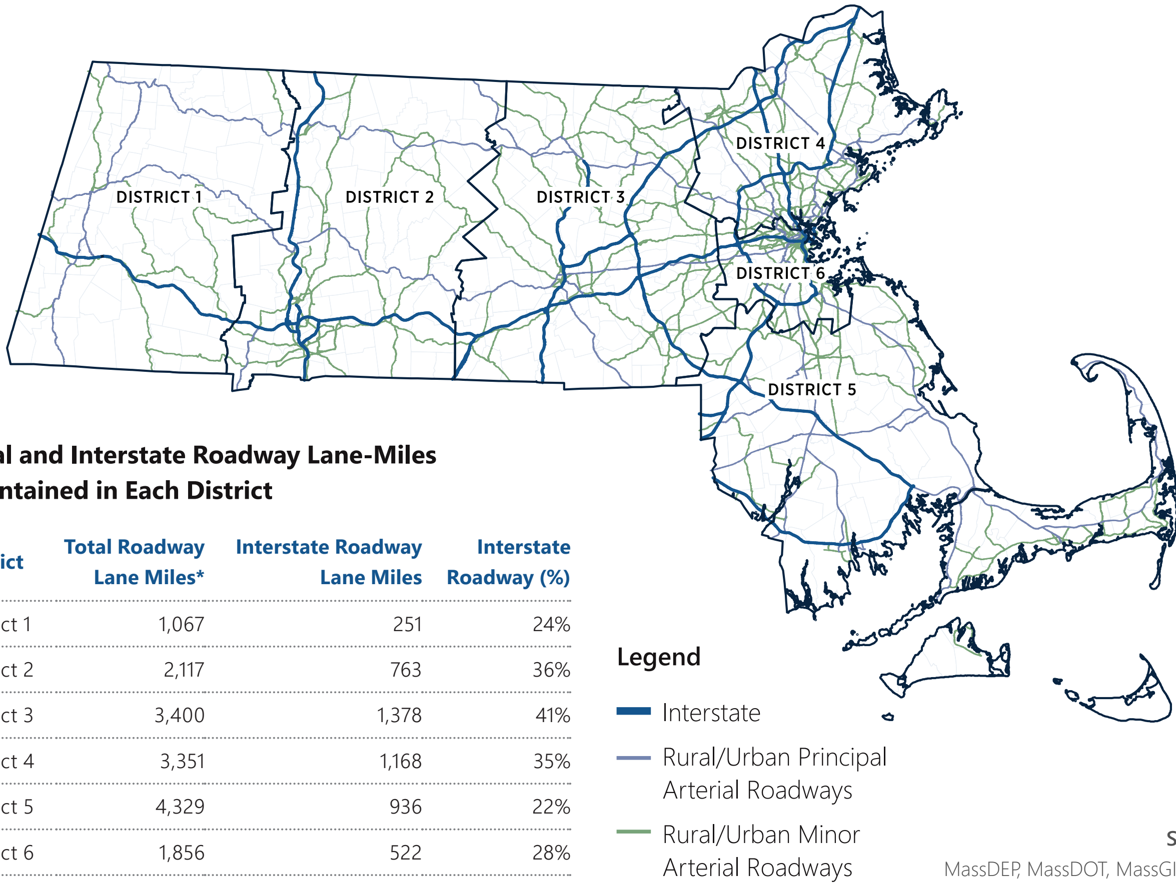
In addition to a higher percentage of interstate road miles, MassDOT's roadway density and daily traffic volumes are generally much higher than in many neighboring New England states, which can influence SICP operations. MassDOT maintains approximately 16,120 lane-miles, which is at least 50% higher than any other New England state. Connecticut has the next highest lane-mile total at 10,800 lane-miles while the total lane-mileage for other state transportation agencies in Rhode Island, Vermont, New Hampshire, and Maine range from 3,300 to 8,500 lane-miles, which is considerably less than MassDOT's lane-mileage.

In addition, the average annual vehicle miles traveled (VMT) in Massachusetts in 2019 was estimated to be approximately 64 billion miles, which is 2 to 3 times higher than any other New England state and is indicative of the higher vehicle usage and travel demands on the state roadway system.[6]

Figure 1.2 shows the boundaries of the six (6) maintenance districts as well as a summary of the total and interstate lane-miles maintained in each district.

6 Mahoney, J., E. Jackson, D. Larsen, T. Vadas, K. Wille, and S. Zinke. 2015. Winter Highway Maintenance Operations: Connecticut Executive Summary. Connecticut Academy of Science and Engineering. Prepared for the Connecticut Department of Transportation. Report no. CT-2289-F-15-1. July 2015.

Figure 1.2 MassDOT Total and Interstate Lane Miles by District and District Boundaries



Source: MassDEP, MassDOT, MassGIS, VHB

Total and Interstate Roadway Lane-Miles Maintained in Each District

District	Total Roadway Lane Miles*	Interstate Roadway Lane Miles	Interstate Roadway (%)
District 1	1,067	251	24%
District 2	2,117	763	36%
District 3	3,400	1,378	41%
District 4	3,351	1,168	35%
District 5	4,329	936	22%
District 6	1,856	522	28%
Total	**16,120**	**5,018**	**31%**

*Lane miles estimates are based on 2020 Road Inventory. Lane-miles were determined based on the total pavement width divided by 11-foot travel lanes multiplied by the linear length of road for all roadways identified as being under MassDOT jurisdiction.

1.6.1 Other Jurisdictional Roadways

Through a Memorandum of Agreement (MOA), MassDOT performs winter road maintenance on approximately 726 lane-miles of roads under the Department of Conservation and Resources (DCR) jurisdiction. This includes approximately 60% of DCR's Urban Parkways in the Boston area. DCR, however, still retains responsibility for maintaining the sidewalks and other pedestrian areas along these urban parkways[7]

DCR has its own snow removal equipment and material storage facilities as well as a Statewide Storm Center, which coordinates and monitors its SICP removal operations during winter storm events. DCR operations are monitored by the MassParks Storm Center, as outlined in DCR's Standard Operating Guide for Winter Weather Events. MassDOT and DCR share salt storage facilities in Nahant, Milton, and Stoneham.

MBTA is responsible for providing winter maintenance for the commuter rail, subway, and bus station as well as boat transportation services throughout the Commonwealth. MBTA has prepared its own Snow & Ice Operations Plan and operates their own SICP independent of the MassDOT roadway program.

1.6.2 MassDOT Pedestrian Transportation Plan

In 2019, MassDOT developed a Pedestrian Transportation Plan[8] to identify initiatives and priorities to improve pedestrian facility access and safety throughout the Commonwealth. The Plan was developed through an extensive stakeholder process and continues to be updated through monthly stakeholder meetings. These meetings provide a forum to review action item updates, identify future initiatives, and exchange comments/ideas from individuals or towns involved with the Plan. Maintenance of sidewalks and other pedestrian facilities is a shared responsibility between MassDOT, municipalities, and other organizations depending on jurisdiction, funding sources, and maintenance agreements. The number of sidewalk miles and separate bicycle facilities has increased considerably over the last decade or so.

Approximately 43% of MassDOT roads have adjacent sidewalks amounting to approximately 1,300 miles of sidewalks located mostly in the central village and downtown areas of various communities.

Like roads, MassDOT relies mostly on hired contractors to clear snow and ice on sidewalks and other pedestrian facilities. Sidewalk winter maintenance may involve different types of equipment and maintenance practices not used on roads. Since space is limited, smaller equipment and even manual shoveling may be required to clear snow from sidewalks. MassDOT has solicited bids from contractors to provide

7 https://mass-eoeea.maps.arcgis.com/apps/SimpleViewer/index.html?appid=7095a112850d4418b700c1888e05e5a5

8 https://www.mass.gov/service-details/pedestrian-plan

winter sidewalk maintenance. However, given that the pool of available contractors is mainly the same as those that sign up to maintain roads, the additional equipment and personnel needed to maintain sidewalks has been limited. In fact, MassDOT has seen a recent decline in contractors interested in plowing roads for various reasons.

New for the 2022/23 winter, MassDOT plans to hire more "seasonal' snow and ice employees that report directly to MassDOT to help with sidewalk clearing as well as other activities. MassDOT will also continue to evaluate vendor reimbursement rates and pay codes to enlist more contractors for sidewalk maintenance services including possible variable pay rates based on snowfall depth rather than by event to reflect the greater effort involved with snow removal for large storms versus smaller storms.

MassDOT provides grant funding of up to $50,000 to help municipalities purchase snow removal equipment for pedestrian and bicyclist facilities through its Shared Streets and Spaces Grant Program. Details on eligible projects can be found at the following link: https://www.mass.gov/shared-streets-and-spaces-grant-program

1.6.3 Winter Maintenance for Non-Roadway Facilities

MassDOT also has various Park and Ride lots and Service/Rest Areas throughout the Commonwealth (see **Table 1.6** and **Table 1.7** below). Winter maintenance activities in these areas are also mostly performed by contractors and at times by MassDOT personnel, as time and resources allow. Plowing represents the primary snow removal activity and chemical treatment is done more sparingly as these lots do not require the same level of service as the main roadways. Many Service Areas are also leased to commercial entities who have responsibility for snow and ice control.

Table 1.6 MassDOT Park & Ride Lots

District	Town	Location	Number of Spaces	Managing Agency
1	Charlemont	Route 2, West of Route 112	75	MassDOT[1]
2	Greenfield	18 Miner Street	64	MassDOT
	Ludlow	Route 21 at I-90, Exit 7	43	MassDOT
	Northampton	Route 9, Bridge Street & Old Ferry Road	81	PVTA2
	Northampton	VA Medical Center	Unknown	Unknown
	Whatley	Route 5/10 at I-91, Exit 24	25	MassDOT
3	Auburn	Midstate Drive at I-90, Exit 10	135	MassDOT
	Berlin	Route 62 at I-495, Exit 26	45	MassDOT
	Framingham	Route 9 at I-90, Exit 12	120	MassDOT
	Millbury	Route 20 at I-90, Exit 10A	446	MassDOT
	Millbury	1504 Grafton Road	120	MassDOT
	Sturbridge	Route 131 at I-84, Exit 3 (Bethlehem Church)	50	MassDOT
4	Andover	Shawsheen Square (Route 28 and Route 133)	34	Other
	Andover	Dascomb Road at I-93, Exit 42	154	MassDOT
	Andover	Faith Church (Route 28 and Ballardvale Street)	60	MRTA3
	Boxford	Middleton Road (rear of Firehouse)	15	Other

District	Town	Location	Number of Spaces	Managing Agency
	Georgetown	27 E. Main Street, Route 133, E. Georgetown Sq	110	Other
	Methuen	Pelham Street at I-93, Exit 47	189	City of Methuen
	Newburyport	Route 113 at I-95, Exit 57	605	C&J Trailways
	Peabody	Route 1	150	MassPort4
	Peabody	McVann Arena, Lowell Street	100	Other
	Topsfield	Park Street (Municipal Lot)	60	Other
	Tyngsborough	Route 113 at Route 3, Exit 35	250	MassDOT
	Woburn	Off I-93, Exit 37C ARTC	375	MassPort4
	Woburn	Hill Street	70	MassDOT
5	Barnstable	Route 132 at Route 6, Exit 6	365	MassDOT
	Barnstable	Ridgewood Avenue (Hyannis)	182	CCRTA5, P&B6
	Bourne	Meetinghouse Land at Routes 6 & 3, Exit 1	377	MassDOT
	Bridgewater	Route 104 at Route 24, Exit 15	60	MassDOT
	Falmouth	Depot Ave	51	Other
	Freetown	Gramp Dean Rd at N. Main St. Route 24, Exit 10	33	MassDOT
	Harwich	Route 124 at Route 6, Exit 10	75	MassDOT
	Kingston	Route 3A at Route 3, Exit 10	100	P&B6
	Mattapoisett	North Street at I-195, Exit 19	80	MassDOT
	Middleborough	Town Hall (Union Street off Route 105)	100	Other
	New Bedford	Mt. Pleasant Street at Route 140, Exit 4	201	MassDOT
	Plymouth	Travel Plaza at Route 3, Exit 5 (Long Pond Rd)	200	MassDOT
	Raynham	Route 138 at I-495, Exit 8	79	Other
	Raynham	Route 138 at I-495, Exit 8 (Raynham Dog Track)	150	Bloom7
	Rockland	Route 228 at Route 3, Exit 14	440	MassDOT
	Somerset	Route 6 at Route 138	80	Other
	Somerset	Route 103 at I-95, Exit 4	68	MassDOT
	Taunton	Silver City Galleria at Route 24, Exit 12	187	MassDOT
	Taunton	Oak Street (Bloom Terminal)	160	Other
	Wareham	Route 6/28 at Route 25, Exit 2	122	MassDOT
	W. Bridgewater	Route 106 at Route 24, Exit 16	185	MassDOT
6	Braintree	Off I-93 at Exit 6, Route 37, Forbes Road	975	MassPort4
	Canton	Route 138 North of Blue Hill River Road	120	MassDOT
	Milton	Granite Ave at I-93, Exit 11	200	MassDOT
	Weston	Route 30 at South Avenue	100	MassDOT

1 MassDOT = Massachusetts Department of Transportation; 2PVTA = Pioneer Valley Transit Authority; 3MRTA = Merrimack Valley Regional Transit Authority; 4MassPort = Massachusetts Port Authority; 5CCRTA = Cape Cod Regional Transit Authority; 6P&B = Plymouth & Brocton Street Railway Company; 7Bloom = Bloom Charter Service.

Table 1.7 MassDOT Travel Service Plazas and Rest Areas

District	Town	Route and Direction	Services	Seasonal
1	Blandford	I-90 Eastbound	Service Plaza	No
	Lee	I-90 Westbound	Service Plaza	No
	Lee	I-90 Eastbound	Service Plaza	No
2	Greenfield	I-91 Northbound/Southbound (Exit 26)	Tourist Information Center, RMV	Yes
	Ludlow	I-90 Eastbound	Service Plaza	No
	Ludlow	I-90 Westbound	Service Plaza	No
3	Charlton	I-90 Eastbound	Service Plaza	No
	Charlton	I-90 Westbound	Service Plaza	No
	Framingham	I-90 Westbound	Service Plaza	No
	Lancaster	Route 2 Westbound	Tourist Information Center	No
	Natick	I-90 Eastbound	Service Plaza	No
	Westborough	I-90 Westbound	Service Plaza	No
4	Beverly	Route 128 Northbound	Service Plaza	No
	Chelmsford	I-495 Northbound	Tourist Information Center	No
	Chelmsford	I-495 Southbound	Rest Area	No
	Lexington	I-95 Northbound, Route 128/I-95	Service Plaza	No
	Merrimac	I-495 Southbound	Rest Area	No
	Salisbury	I-95 Southbound	Tourist Information Center	No
5	Barnstable	Route 6 Eastbound/Westbound (Exit 6)	Service Plaza	No
	Bridgewater	Route 24 Northbound	Service Plaza	No
	Mansfield	I-95 Northbound	Tourist Information Center	No
	Plymouth	Route 3 Northbound/Southbound (Exit 5)	Tourist Center/Service Plaza	No
	Plymouth	Route 25	Tourist Information Center	Yes
	Sagamore	Route 3 Northbound/Southbound (Exit 1A)	Tourist Information Center	No
	Wareham	I-195 Eastbound	Tourist Information Center	Yes
	Yarmouth	Route 6 Eastbound	Tourist Information Center	Yes
6	Blandford	I-90 Westbound	Service Plaza	No
	Newton	I-95 Southbound, Route 128/I-95	Service Plaza	No
	Westwood	I-95 Southbound, Route 128/I-95	Rest Area	No

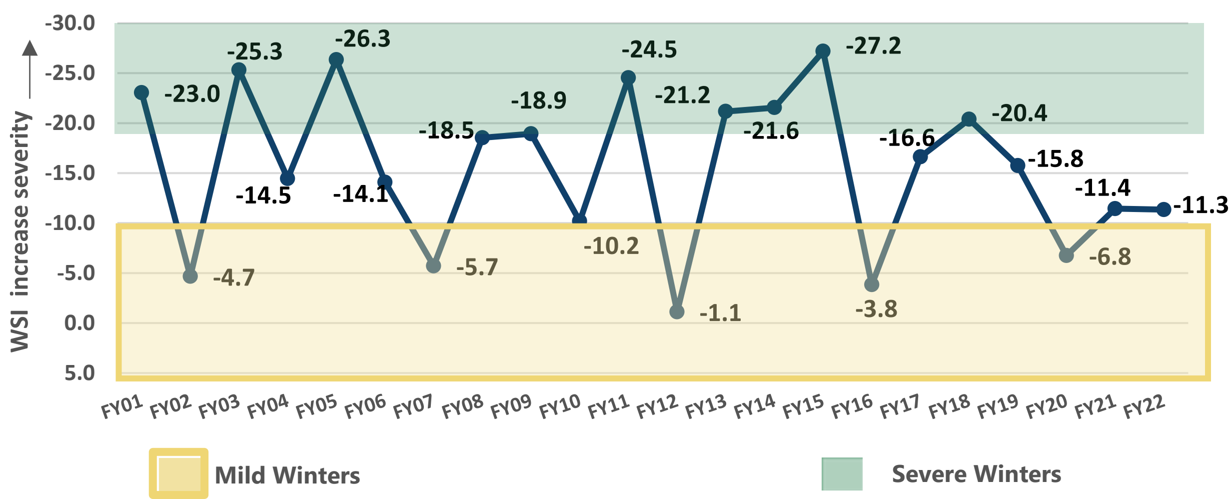
1.7 Winter Severity Index to Assess Annual Changes in Road Salt Usage

MassDOT has been using a seasonal Winter Severity Index (WSI) to assess the effect that winter weather severity has on annual road salt usage. The WSI methodology was initially developed in the early 1990's as part of a Strategic Highway Research

Project.[9] The WSI is calculated for each month based on daily snowfall, minimum and maximum temperatures, and the number of days with frost potential and then averaged over a 5-month winter period (Nov.-March) to provide a seasonal average. The WSI formula was devised in such a way that more severe winters are represented by a larger negative number or lower value.

Figure 1.3 illustrates the wide variability in the average annual statewide WSI values from year-to-year over the last 22 years. In several instances, the most severe winters often followed the mildest winters or vice versa as was the case with FY01 and FY02, FY11 and FY12, and FY15 and FY16. The FY15 winter was the most severe in this recent history with a WSI value of -27.2 with more than 100 inches of snowfall and prolonged cold temperatures. In the last 22 years, there were as many severe winters with WSI values between -20.0 and -30.0 as there were mild winters with WSI values between 0 and -10.0, and the other winters were somewhere in between. The last two winters of FY21 and FY22 were relatively mild and essentially had similar WSI values.

Figure 1.3 Average Statewide Winter Severity Index (WSI) Values for FY01 – FY22



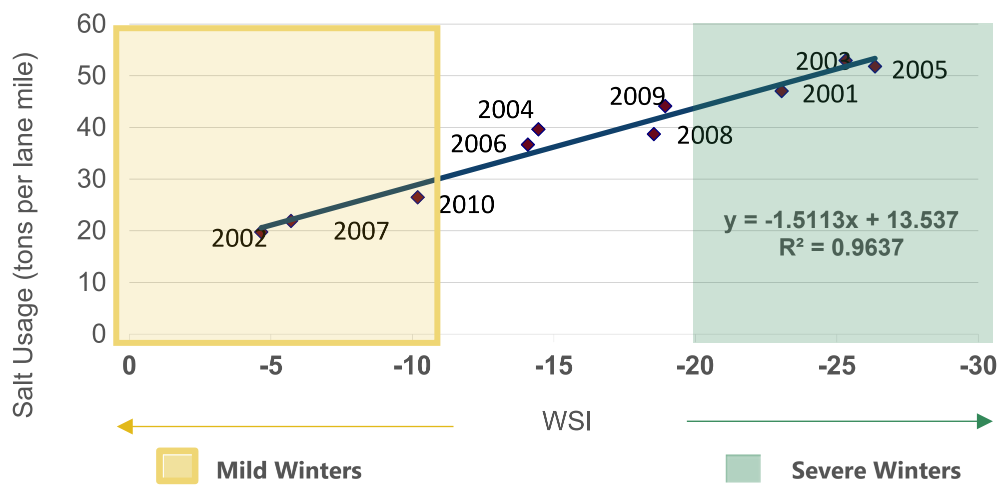
Note: The winter period for each FY extends from November to end of March. Areas shaded in light brown indicates mild winters while green shaded area to the right indicate severe winters

Figure 1.4 presents a linear regression line that depicts the relationship between annual salt usage and annual WSI values for the FY01 to FY10 baseline period. A correlation coefficient (R2) of 0.96 indicates a strong correlation and essentially 96% of the year-to-year variability in annual salt usage can be explained by changes in the annual WSI values, assuming the same operational policies and application methods are used each year, which was the case for 2001 to 2010. During this period, MassDOT's average annual salt usage ranged from 50 tons per lane-mile (ln-mi)

9 Bosely, S. Edward III, John E. Thornes, Cyrus Ulberg, and Donald D. Ernst, Road Weather Information Systems – Volume 1: Research Report, Report SHRP-H-350, Strategic Highway Research Program, National Research Council, Washington [DC] (1993)

during the severe winters of FY03 and FY05 to approximately 20 tons per ln-mi during the mild winters of FY02 and FY07.

Figure 1.4 Annual Salt Use vs. WSI Values in the Baseline Period (FY01 to FY10)



Notes: Areas shaded in light brown indicates mild winters while green shaded area to the right indicate severe winters

Given the close correlation between annual salt use and WSI values for the baseline period, MassDOT can use this relationship to assess how more recent equipment upgrades and other measures implemented since 2011 have affected annual salt usage while accounting for differences in WSI values relative to the baseline period. In other words, the regression equation is used to predict what the annual salt usage would have been under the old application practices based on the WSI value for the current year and if the actual salt use is lower than the predicted usage, then the difference is most likely attributed to the effects of the recent application practices.

If the actual usage is greater than that predicted using the baseline equation, then this could be due to any number of factors. The more likely reason is that the WSI methodology and WSI value for the current winter did not adequately reflect the deicing material demands that were the linked to freezing rain events or other weather conditions other snow or cold temperatures. This has occurred during the unusual mild winter of 2016 when several freezing rain events had caused the actual usage to be slightly more than the predicted usage. As discussed more in the next section, MassDOT now has 12 years of annual salt use data to compare with the predicted usage using the baseline regression equation and the longer the period of record extends, the more certainty is gained in comparing the actual annual salt use with the predicted usage using the WSI methodology and baseline regression equation on a long-term basis.

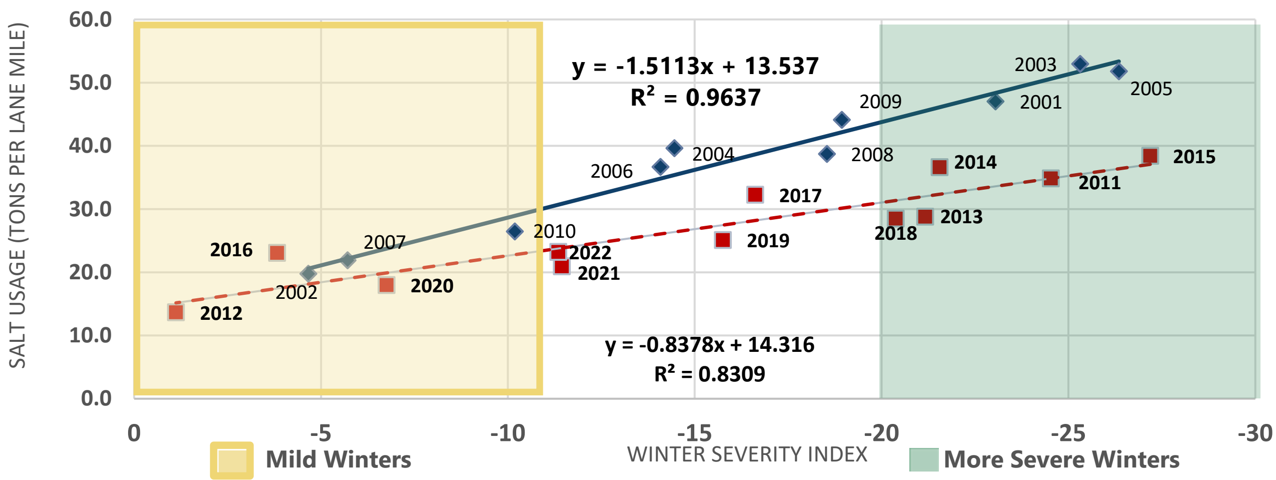
1.7.1 Annual Salt Use in the Post 2011 Period

As discussed more in Chapter 3, MassDOT has implemented a variety of equipment upgrades and other measures starting in 2011. These measures include increased use of liquid deicers for pretreatment of roads and prewetting of salt, more effective plow blades, use of closed-loop controllers as well as additional road condition and weather monitoring tools. To understand the impact of these upgrades on salt usage, MassDOT has compared annual usage during the post implementation years to the pre-implementation years while accounting for differences in WSI values.

Figure 1.5 shows the annual salt use (tons per lane-mile) relative to the WSI value from 2011 to 2022 (shown as red squares) in comparison to the annual salt usage and the WSI from 2001 to 2010 (blue diamonds) and the corresponding regression line.

In the last 12 years, except in 2016, MassDOT used less salt statewide, on an average annual basis than that used during the 2001 to 2010 baseline period under similar winter severity conditions as indicated by the red squares (2011-22 data) being below the regression line. The regression line represents the salt usage vs. WSI value for the 2001-10 baseline period (blue diamonds). For example, the annual salt usage in 2011 and 2015, which had very similar WSI values as those in 2001, 2003, and 2005, was approximately 11 to 15 tons per lane mile less than that used in the winters of 2001, 2003 and 2005. Similar reductions can be seen in comparing the annual salt usage in 2017 and 2019 with that in 2004 and 2006 or the salt used in 2013 or 2018 compared to 2008 and 2009. This lower usage under similar winter weather severity conditions is attributable to the various efficiencies gained with the updated equipment, revised application policies and pavement monitoring techniques implemented after 2011.

Figure 1.5 Annual Salt Usage (tons per ln-mi) during Baseline and Post-Implementation Periods



Note: Values indicated by blue diamonds and blue solid regression line represent annual salt usage (tons/ ln-mi) vs. WSI value during the baseline period whereas the red squares and red dashed regression line represent annual salt usage vs. WSI value during the post-implementation period (2011-22).

The effect of the recent equipment upgrades can be assessed even further by comparing the relative ranking of the annual statewide salt usage and WSI value for each year against each other over the last 22 years. Years with the most severe to least severe WSI values were ranked from 1 to 22 and years with the highest and least amount of salt use were also ranked 1 to 22. The last column presents the difference between the WSI and salt usage ranking in each year. In years where the WSI value was ranked higher or more severe than the annual salt usage suggests that less salt was used relative to that predicted (shaded in **green**). In other words, road salt was used more efficiently than that expected given the severity of winter weather. In years where the WSI value and salt use are ranked essentially the same, suggests that the salt usage was in line or what might be expected given the WSI value. Conversely, in years where the WSI value was ranked lower or less severe than the annual salt use (shaded in **yellow**), this suggests that more salt was used relative to the WSI value.

As shown in **Table 1.8**, 7 of the last 12 years or nearly 60% of the post-2011 years are shaded green indicating less road salt was used relative to that predicted by the WSI value while this occurred only once or 10% of the years in the baseline period.

Table 1.8 Summary and Ranking of the Annual Statewide WSI Value Over Last 22 Years

	Fiscal Year	WSI	Salt Usage (tons)	WSI Rank (1 Most Severe)	Salt Use Rank (1 Most Tons)	WSI Rank Minus Salt Usage Rank
Pre-BMP Implementation	2001	-23	625,855	5	3	2*
	2002	-4.7	303,606	20	21	-1**
	2003	-25.3	734,072	3	1	2*
	2004	-14.5	474,974	13	8	5*
	2005	-26.3	726,086	2	2	0
	2006	-14.1	413,095	14	11	3*
	2007	-5.7	310,390	19	19	0
	2008	-18.5	535,159	10	9	1*
	2009	-18.9	606,587	9	5	4*
	2010	-10.2	342,520	17	17	0
Post-BMP Implementation	2011	-24.5	556,839	4	7	-3**
	2012	-1.1	218,244	22	22	0
	2013	-21.2	460,183	7	12	-5**
	2014	-21.6	585,201	6	6	0
	2015	-27.2	613,765	1	4	-3**
	2016	-3.8	368,608	21	16	5*
	2017	-16.6	515,621	11	10	1*
	2018	-20.4	455,447	8	13	-5**
	2019	-15.8	401,092	12	14	-2**
	2020	-6.8	287,332	18	20	-2**
	2021	-11.4	334,419	15	18	-3**
	2022	-11.3	370,998	16	15	1*
Pre-BMP Implementation Avg		-16.1	504,800	Difference	% Difference	
Post BMP Implementation Avg		-15.1	430,646	74,154	14.7%	

Note: ***Yellow shaded** cells indicate that the salt use is ranked higher or more severe than the WSI value suggesting that more road salt was used relative to the winter severity value for that year.
****Green shaded** cells indicate that the WSI value is ranked higher or more severe than the salt use suggesting less salt was used relative to the winter severity value for that year.

Over the last 12 years, MassDOT has reduced its average annual salt usage by approximately 74,100 tons on a statewide basis, compared to what was used in the FY01-FY10 period while accounting for differences in the average annual

The reductions in overall average annual salt use in recent years occurred even as the number of lane-miles maintained by MassDOT has increased by approximately 15%. This reduction results in an estimated material cost savings of approximately $4.5 million on an average annual basis using a per unit cost of $60 per ton for road salt. Differences in average annual salt usage between the pre- and post-implementation periods appear to be greatest in the more severe winters. For example, the average annual salt use in the more severe winters of FY11 and FY15 was approximately 130,000 tons of road salt less than that used in the winters of FY03 and FY05, which had very similar WSI values. The FY15 winter was the most severe winter in recent history and had the most severe WSI value but was only ranked the #4 highest in statewide annual salt usage, meaning that 3 other years, all within the 2001-2010 period, had higher average annual salt usage.

The data indicates that the annual salt usage a per lane mile basis and overall statewide volume basis since 2011 was generally less than used in the previous 10 years and this reduction is mainly attributed to the various equipment upgrades, use of liquid deicers, revised application policies and pavement monitoring technologies.

1.7.2 Future Use of the WSI Methodology

MassDOT will continue using the WSI methodology to assess performance and effectiveness of the various equipment and technology updates designed to improve the efficiency on annual salt usage relative to the baseline period. Although the WSI methodology may not fully account for other weather-related factors that may influence deicing material usage, such as freezing rain events, this approach provides a reasonable basis to assess trends in average annual salt usage in comparison to historical usage while accounting for differences in the winter weather severity.

Other WSI methods developed in other states include other weather-related variables (e.g., freezing rain events, storm duration, or wind speeds) but these other methods may not improve MassDOT's ability to compare differences in the historical and recent annual salt usage. Other weather data may not be readily or consistently available across the state. Freezing rain is not typically recorded at most National Weather Service weather stations. MassDOT will continue to evaluate if other data or methods may improve the prediction or comparison of road salt usage to recorded weather data and WSI values. However, any changes in methodology will be difficult to apply retroactively to the baseline period to reflect how varying weather conditions affected road salt use prior to use of various efficiency measures.

1.8 Snow & Ice Control Program Costs

As shown in Table 1.9, the average annual program cost over the last 5 years was approximately $96.5 million but can fluctuate by as much 50% or more depending on various weather-related factors. The amount of snowfall, storm duration, and number of winter storms, as well as temperature variability over the course of a winter season, impact the operating costs. During the unusually mild winter of FY12, the annual program costs were approximately $41.5 million, whereas in an unusually severe winter duringFY17 the SICP costs were approximately $133 million.

The operating SICP budget typically includes the following three components:

» Purchasing deicing materials (approximately 20 to 25%)

» Hired equipment (55 to 65%)

» MassDOT personnel costs (10 to 15%)

The budget does not include:

» Equipment purchases and other capital costs associated with facility improvements

» Maintenance costs associated with post-winter sand cleanup, shed repairs, or other infrastructure maintenance such as bridge washing

» Monitoring, assessment, and remedial activities relative to drinking water or other resources (these activities are performed by MassDOT's Environmental Services within the Highway Division)

Table 1.9 Annual SICP Operating Costs ($ Millions) Over Last 5 Years

FY	Materials	Hired Equipment	State Personnel	Total Cost
17	$37.5	$81.9	$13.4	$132.8
18	$31.4	$72.8	$12.3	$116.3
19	$21.4	$55.0	$10.6	$87.1
20	$15.9	$45.9	$8.4	$70.0
21	$18.1	$49.6	$8.1	$75.9
Average	$26.5	$61.1	$10.6	$96.5

Notes: Data provided by the MassDOT SICP Lead Engineer and the annual Clear Roads agency surveys.

Based on this information, MassDOT spends approximately $6,000 per lane mile on an average annual basis to conduct snow and ice control activities on approximately 16,000 lane-miles. These expenditures are comparable with average annual per lane costs reported in nearby states:

» New York: $8,400/lane-mile

» New Hampshire: $5,800/lane-mile

» Maine: $4,900/lane-mile

The average annual per lane-mile cost estimates for these states are based on data presented in the 5-year annual operations surveys conducted by Clear Roads and are posted on their website at https://clearroads.org/winter-maintenance-survey/.

2 Environmental Protection and Remediation

This Chapter provides an update on operational practices, policies, and equipment used to minimize and/or remediate any effects of MassDOT's Snow and Ice Control Program on environmental resources including a description of its Salt Remediation Program and Reduced Salt Zone (RSZ) Policy.

This chapter also includes an analysis of sodium and chloride levels in public water supply (PWS) wells and surface waters located within and beyond a 0.5-mile radius of a MassDOT roadway based on reported sampling data included in MassDEP's database. This same analysis was provided in the previous 2012 and 2017 MassDOT ESPRs.

This chapter also includes updated information pertaining to other environmental data requested by MassDEP and others following review of the previous 2017 SICP ESPR, as well as in response to review of the 2022 ESPR Scope of Work (SOW) Plan that was posted in the Environmental Monitor in February 2021 and summarized in the March 21, 2021, MEPA Certificate. The environmental concerns and data requests are listed below in various categories:

1. **Salt Use Efficiency BMPs and Technology**
    a. Provide an update on the Reduced Salt Zone (RSZ) Program and the success in reducing salt use in environmentally sensitive areas (see Section 2.1 below).
    b. Provide an update on the Salt Remediation Program and the number of complaints and the successful remediation cases in addressing the complaints (See Section 2.2 below).
    c. Evaluate technology implementation and other alternatives (i.e., Best Management Practices) in select locations with a goal of reducing overall material usage as measured by the WSI (see Chapter 1)
    d. An update of annual salt usage in comparison to the Winter Severity Index (WSI) statewide and by District. (See Chapter 1)

2. **Public Water Supplies**
   a. Provide an update on sodium concentrations in Public Water Supplies (PWSs) using data reported to MassDEP and a comparison of the percentage of PWSs that exceed certain concentration thresholds for PWS' located within and outside of a 0.5-mile radius of a MassDOT road (see Section 2.3).
   b. Provide an update on salt usage in specific sensitive areas such as in the Dedham-Westwood Water District (DWWD) watershed using the recently installed AVL/GPS equipment (See Section 2.4).
   c. Collaborate with MassDEP and other State or municipal agencies, as applicable, to develop a work scope to conduct a watershed study in the Cambridge Water District to update the 1985 study and estimate the relative sodium and chloride contributions from various sources (See Section 2.4).
   d. Conduct a limited desktop study for the DWWD WHPA to update sodium and chloride contributions related to increased development in the watershed (Section 2.4).
   e. Work with the Auburn Water District to study the impacts of snow and ice operations on the surrounding watershed, specifically the recharge sources for their supply wells (see Section 2.4).
   f. MassDEP wishes to collaborate with MassDOT on identifying target locations for expanded use of AVL/GPS equipment like that currently underway in the Dedham-Westwood Water District (DWWD) along with subject municipalities.
   g. The Cambridge Water District requested MassDOT include an assessment of potential costs of increased corrosion in drinking water supplies related to chloride (See Sec. 2.3.8).

      Also, CWD requested the Cambridge water supply watershed be a priority when implementing new measures aimed at reducing salt use (see Section 2.4).
3. **Surface Water Quality**
   a. A summary of observed chloride concentrations in water bodies based on data collected primarily by MassDEP and others. The summary will include an update on water bodies categorized as being chloride impaired based on MassDEP's 305(b)/303(d) integrated report (see Section 2.5).
   b. Continue to study the impacts of road salt in the Kampoosa Bog with the Natural Heritage and Endangered Species Program (see Section 2.6.2).
   c. MassDOT's proposed assessment of Best Management Practices should focus on stormwater outfalls that are near Outstanding Resource Waters, public water supplies and other sensitive water resources, especially impaired waters or where a TMDL had identified impacts associated with roadway runoff.
   d. MassDOT should conduct additional watershed-based studies in a few select areas. MassDOT should select and evaluate these added sites in partnership with MassDEP, and with municipalities, watershed protection groups, academia, and other interested parties. MassDOT should also work with these parties to identify possible funding sources and study priorities (See Sec. 2.7).

4. **Public Educational Outreach and Operator Training**
   a. Collaborate with MassDEP in developing appropriate outreach and training materials to educate the public, commercial applicators and other road salt users on various salt reduction or efficiency measures (See Sec, 2.7).
   b. Prior to the development of the outreach and training materials, MassDOT should engage with MassDEP to develop a working partnership between the agencies and municipalities, watershed protection groups, academia, and other interested parties. MassDOT should also utilize this partnership to consider how to promote acquisition and use of new de-icing/snow removal technology to both track and reduce salt and chemical usage (See Sec. 2.7).

These concerns and data requests are discussed in the following sections of this chapter or as referenced above.

2.1 Reduced Salt Zone Program Update

As part of a legacy program established many years ago, MassDOT had designated sixty-two (62) road segments as Reduced Salt Zone (RSZ) areas throughout the state. These RSZs are primarily located in Zone II Wellhead Protection Areas of major Public Water Supply (PWS) wells, although a few RSZs are located near private wells with elevated sodium and/or chloride levels.

Table 2.1 summarizes the route numbers, roadway mileage, and lane-mileage for the RSZ areas within each District. The beginning and end points for each of these roadway segments and materials used in each RSZ are detailed in MassDOT's Reduced Salt Zone Policy (HMD-01-01-1-000). These designated RSZs comprise approximately 624 miles or 1,752 lane-miles of roadway, which represent slightly more than 11% of the total lane-mileage maintained by MassDOT.

Table 2.1 Summary of Existing MassDOT Reduced Salt Zones by District

District	Number of RSZs	Routes	Total Roadway Miles	Total Lane Miles
1	4	Routes 8, 9, 112	4.7	18.1
2	8	Routes 2, 9, 63, 202	27.2	99.2
3	8	Routes 12, 20, 70, 110	25.3	133.1
4	17	Routes 2, 2A, 3, 3A, 4, 95, 110, 128, 129, I-93, I-95, I-495, Route 1/95 Interchange, Lowell Connector	193.4	404.5
5	23	Routes 1, 6, 6A, 18, 25, 28, 130, 140, I--495, I-295	359.0	1,002.6
6	2	Routes 20, 128	14.2	94.5
Total	63		623.9	1,752.0

Source: MassDOT Environmental SOP HMD-01-01-1-000

District 5 has over 1,000 lane-miles or nearly 60% of the total statewide RSZ lane-miles mainly because of EPA designating the entire Cape Cod region as a sole-source aquifer several decades ago. Approximately 803 lane-miles of MassDOT roads in the Cape Cod region are designated as RSZs and include portions of Routes 6, 6A, 28, and 28A.

However, as discussed later in Section 2.4. very few, if any, Public Water Supply (PWS) wells in the Cape Cod region have reported issues with elevated sodium or chloride concentrations as part of the MassDOT Salt Remediation Program.

Other District 5 RSZs include a section of I-495 in the Town of Middleboro between Exits 8 and 15 (approximately 43.9 lane-miles) and a parallel section of Route 28 (approximately 21.3 lane miles), which are in the vicinity of the Middleboro water supply wells. Portions of Routes 1, I-95, and I-295 in Attleboro and North Attleboro are also designated as RSZs, as well as portions of Routes 18, 28, and 140 in Avon, Freetown, Lakeville, and Taunton.

District 4 has the second highest RSZ lane mile total, which includes approximately 104 lane-miles of Route 128/I-95 that are in the watershed of the Cambridge water supply reservoir. Approximately 73 lane-miles of I-95 in Boxford and Georgetown are also designated as an RSZ due to elevated sodium levels in private wells located near I-95. Another 50.4 lane-miles of Routes 3 and 3A in Chelmsford and North Chelmsford were designated as RSZ due to elevated sodium levels in nearby municipal wells serving these communities. The northerly section of Route 128/I-95 in the Lynnfield/Peabody area (63.2 lane-miles) was established to protect the water supply for an industrial facility, which, at least at one time, required ultrapure water for manufacturing.

2.1.1 Future of the Reduced Salt Zone Program

MassDOT is transitioning away from using sand as part of the RSZ application practices and instead will focus their efforts on expanding the use of other efficiency measures currently being used statewide, which involve pretreating roads and prewetting salt with liquid deicers. These measures have reduced MassDOT's average annual salt usage by approximately 26% statewide over the last 12+ years on a tons per lane-mile basis compared to what was previously used prior to these measures while adjusting for differences in winter weather severity conditions. The salt reduction achieved with the other efficiency measures is far better than that achieved by previous RSZ practices and reflects the added effectiveness of liquid deicers to pretreat roads and prewet salt.

The previous RSZ application practice of using a 50:50 sand/salt mix was not only less effective in reducing salt use as well as maintaining safe road conditions but also added additional annual labor and equipment costs to perform post-season cleanup of sand along the roadways. As a result of this added cost, MassDOT was spending an additional money each year to cleanup excess sand along 1,750 RSZ lane miles statewide without any meaningful safety or environment benefits and in fact the use of sand likely posed other environmental impacts with respect to sediment and phosphorus loading in lakes and ponds. See Section 2.7 for additional discussion on the environmental effects of the use of winter sand.

MassDOT recognizes that the designated RSZs are still environmentally sensitive areas and plans to transition into a new approach by expanding the use of other efficiency measures such as slurry spreaders as well as the use of AVL/GPS equipment to better track salt use in these areas, which will allow for a more direct assessment of salt use.

2.2 Salt Remediation Program

The Environmental Services Section of MassDOT's Highway Division administers a Salt Remediation Program, which processes and investigates complaints from private well owners and public water suppliers whose water supplies are experiencing elevated sodium concentrations. MassDOT has been spending approximately $1.5 million per year, on average, for technical services provided by the UMASS Engineering Department to investigate and remediate complaints as part of this program. The annual costs vary depending on the number of cases, the geographic extent of affected areas, and the type of remedial measures used to address the complaints.

These annual costs do not include the costs of various remediation activities such as extending or installing new municipal water service lines to affected areas. A recent example includes the estimated construction cost of $1.5 million to install a municipal service line in the Town of Wrentham.

Remediation measures typically include replacement or rehabilitation of an existing well, connecting the property to a PWS system, or, as a last resort, installing a reverse osmosis (RO) treatment system. Installing a whole house RO system requires more space and operations and maintenance on the part of the homeowner and are much more expensive. Connecting homes or businesses to a municipal water supply is generally the preferred long-term solution when it can be done cost effectively within a reasonable distance and without major disruptions. However, this option is subject to available supply, system capacity, and the discretion of the water supply utility.

As outlined in MassDOT's Environmental Standard Operating Procedure ENV-01-30-1-000, remediation complaints are initiated through the submittal of a completed salt remediation claim application along with water quality data to the jurisdictional District Highway Director. MassDOT has posted various informational materials regarding its Salt Remediation Program on its website including application forms and contact information. More information can be found online at: https://www.mass.gov/massdot-highway-salt-remediation-program

To initiate a field investigation, a well owner must have one of the following conditions:

» A resident is on a documented sodium restricted diet of less than 1,000 mg/day and the sodium concentration in the water supply exceeds 20 mg/L, or

» A resident is on a documented sodium restricted diet of less than 2,000 mg/day and the sodium concentration in the water supply exceeds 40 mg/L, or

» The chloride concentration in a domestic supply well exceeds 250 mg/L.

For residents on a physician prescribed sodium restricted diet, or if chloride concentrations exceed 500 mg/L, MassDOT will provide bottled water as an interim measure during the investigation.

In the last 5 years or since 2017, MassDOT received 76 remediation claim applications related to elevated sodium and/or chloride levels in drinking water supplies. Following initial review, the Environmental Services Section will schedule an initial site visit to assess whether further investigations are warranted. Since 2004, the UMASS Engineering Department, through an Interagency Service Agreement with MassDOT, has performed field investigations and hydro-geological analyses to assess the potential source(s) and remediation solutions to address elevated salt concentration complaint. If MassDOT's road salt use appears to be a potential source, additional sampling will be conducted to confirm elevated levels of sodium and chloride. In most cases, MassDOT will collect water samples for up to 12 months and evaluate local salt application data to assess whether MassDOT's operations are the likely significant source of elevated salt concentrations in the water supply.

Table 2.2 summarizes the number of salt remediation cases received, investigated, and remediated in each District since 2000. Data provided by MassDOT indicates that a total of 277 remediation claims were received during this period including 76 claims in the last 5 years. As of November 2021, twenty-two complaint cases remain under investigation or in the process of implementing remediation measures.

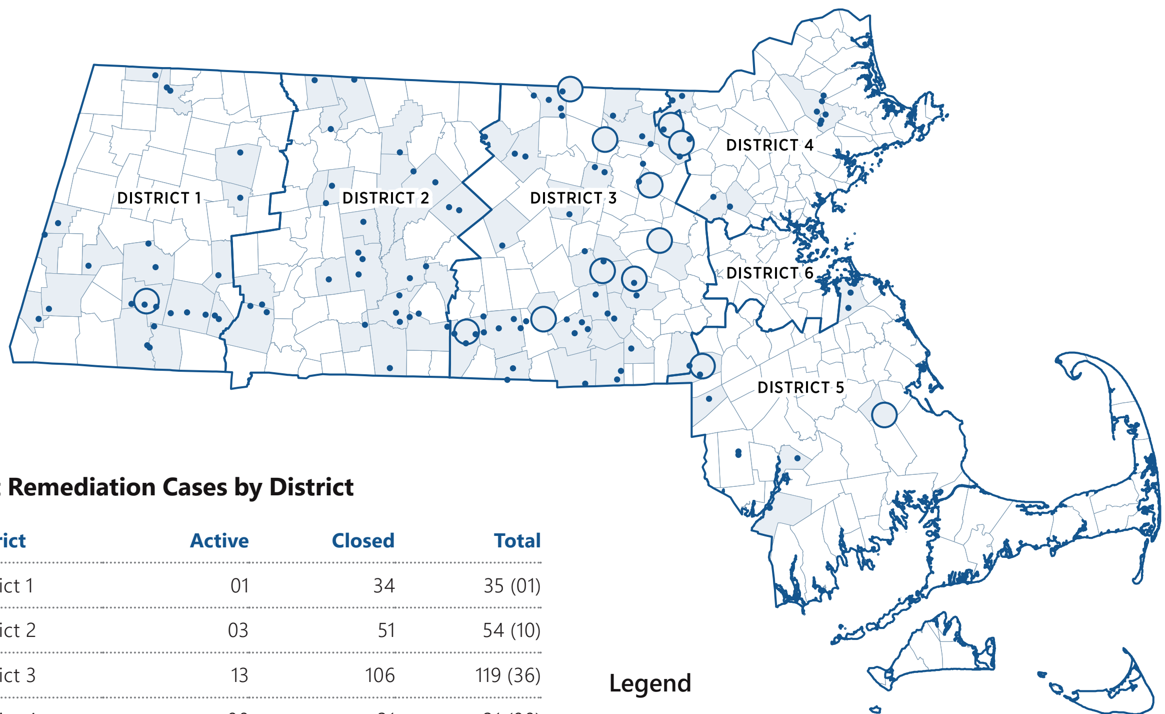
Table 2.2 Summary of Salt Remediation Cases by District

District	Total Cases[1]	Open Cases[2]	Closed Cases	Type of Wells in Program	Towns with Open Cases[2]
1	35 (1)	1	34	Private	Otis
2	54 (10)	3	51	Private	Bernardston, Brimfield, Palmer
3	119 (36)	13	106	Private/ Public	Ashby, Auburn, Boxboro, Charlton, Framingham, Franklin, Hopkinton, Northborough, Sturbridge, Westford
4	31 (0)	0	31	N/A	N/A[3]
5	38 (29)	5	33	Private	Berkley, Pepperell, Plympton, Wrentham
6	0	0	0	N/A	N/A[3]
Total	277 (76)	22 (22)	255		

1 Numbers in parentheses represent the number of cases within the last 5 years
2 Towns listed pertain to the open cases only
3 No current/open cases in database

Figure 2.1 shows the general locations and status of salt remediation cases. Many are in Districts 1, 2 and 3 since most homes and businesses are served by private wells in these areas.

Figure 2.1 Salt Remediation Case Locations



Salt Remediation Cases by District

District	Active	Closed	Total
District 1	01	34	35 (01)
District 2	03	51	54 (10)
District 3	13	106	119 (36)
District 4	00	31	31 (00)
District 5	05	33	38 (29)
District 6	00	00	00
Total	**22 (22)**	**255**	**277 (76)**

Overall, the Salt Remediation Program has successfully provided potable water with reduced sodium levels for over 250 private water supply complaint cases using various remedial measures. In a few instances where remediation measures were not initially successful in reducing sodium concentrations, MassDOT continues to work with the affected homeowner or PWS to identify the primary sources and potential solutions that MassDOT could implement to reduce sodium concentrations.

MassDOT is currently working with MassDEP and representatives from the town of Boxborough and the Littleton Light and Water Department to evaluate the feasibility of extending municipal water service to an area in Boxborough where several PWSs and private wells have elevated chloride levels as well as other water quality issues.

2.3 Sodium Concentrations in Public Water Supplies

In response to MassDEP comments on the 2022 ESPR SOW Plan, outlined in the MEPA Certificate issued on March 19, 2021, MassDOT compiled and compared reported sodium and chloride data in Public Water Supplies (PWSs) located within a 0.5-mile of a MassDOT road to that reported by PWSs located beyond a 0.5-mile of a MassDOT road. The 2017 ESPR conducted a similar evaluation for community and non-community PWSs. The evaluation analyzed the percentage of PWSs in both groups with sodium levels above MassDEP's drinking water health guideline level of 20 mg/L and the EPA health guidance level of 60 mg/L, based on reported data contained in MassDEP's database through October 18, 2021. Regression analyses were also conducted to assess the relationship or correlation between PWS sodium levels and distance to a MassDOT roadway. In addition, a time series graphs of sodium levels in various municipal water supplies is also presented in Appendix B. The potential effect of increased chloride levels on corrosion risks in water supply infrastructure is also discussed in Sections 2.3.8 and 4.3 of this ESPR.

MassDEP set a health guidance level of 20 mg/L for sodium (see MassDEP Drinking Water Regulations, 310 CMR 22.16A), which is an advisory level for individuals on a physician prescribed "low-salt" diet of no more than 500 mg sodium per day. This health guidance level was based on EPA's original guidance of 20 mg/L established in 1980, however, in 1988, EPA removed sodium from the list of contaminants to be regulated under the National Drinking Water Regulations.[10] In 2003, EPA updated the health guidance level for sodium in drinking water in recognition that the daily sodium intake from food consumption is typically much higher than that from water consumption. The revised guidance recommended a higher sodium limit of 60 mg/L in drinking water to avoid aesthetic taste effects. Drinking water with 60 mg/l would comprise 5% of the recommended dietary goal of no more than 2,400 mg of sodium per day if two liters of water were consumed each day. The Food and Drug Administration reported that most Americans consume between 4,000 and 6,000 mg of sodium per day with most of this coming from food consumption.[11]

In 2019, the National Academies of Sciences released new dietary intake guidance for sodium. This new dietary guidance, referred to as a Chronic Disease Risk Reduction Intake (CDRR) level, suggests an average daily sodium intake limit of 1,000 mg/day for individuals ages 1 to 3; 1,500 mg/day for ages 4 to 8; 1,800 mg/day for ages 9 to 13; and 2,300 mg/day for all other age groups.[12] In other words, a healthy adult may reduce their risk of chronic disease if they limit their daily sodium intake to no more

10 U.S. Environmental Protection Agency. Sodium Requirements for Public Water Supplies. https://nepis.epa.gov/

11 U.S. Environmental Protection Agency. "Drinking Water Advisory: Consumer Acceptability Advice and Health Effects Analysis on Sodium." Office of Water, Health and Ecological Criteria Division EPA 822-R-03-006. (2003).

12 National Academies of Sciences, Engineering, and Medicine. 2019. Dietary Reference Intakes for sodium and potassium. Washington, DC: The National Academies Press. https://doi.org/10.17226/25353.

than 2,300 mg/day. This guidance is now included in the USDA and USDHHS Dietary Guidelines for Americans, 2020 – 2025, released in December 2020.[13]

2.3.1 MassDEP Public Water Supply Testing Requirements

Per MassDEP Drinking Water Regulations (310 CMR 22.00), a PWS is defined as a water supply system that has 15 or more connections or serves at least 25 individuals, on a daily basis for at least 60 days out of the year. There are three categories of PWSs depending on the population served:

- **Community (COM)** wells generally serve the same people each day typically in a residential setting (e.g., municipal systems, condominiums, or homeowner associations).
- **Non-transient, non-community (NTNC)** wells typically serve the same population each day but in a non-residential setting (e.g., schools, businesses, office complexes, day care, etc.); and
- **Transient, non-community (NC)** wells generally serve a transient population of usually different people each day (e.g., restaurants, retail stores, golf courses, etc.).

75% of the PWS water supply sources are estimated to be within 1.4 miles of a MassDOT roadway

The Massachusetts Drinking Water Regulations Title 310 §22.06A require Public Water Supply systems with either ground or surface water sources to collect and report sodium concentration data beginning on January 1, 1993.[14] For PWSs using groundwater, the required sampling frequency is once every three years, while those using surface water sources (including PWSs with combined sources of surface water and groundwater) are required to sample and report sodium levels annually.

MassDEP also maintains a secondary drinking water standard for chloride at 250 mg/L to avoid issues with aesthetics and taste. Testing for chloride is not required but generally recommended, especially if sodium levels are elevated.

2.3.2 Analysis of Sodium Data in Public Water Supplies

Statewide sodium data provided by MassDEP through October 18, 2021, includes 37,329 records of reported sodium sampling results for 1,713 different PWS systems. The number of sodium results reported each year ranges from four samples in 1991 to 2,460 results reported in 2018. This recent analysis includes an additional 20,984 records of sodium sampling results, or more than twice the 16,345 records of sodium data between 1993 and August 2016 included in the 2017 ESPR. MassDEP also provided latitude and longitude coordinate data to locate each of the PWS water sources contained in the database where records exist.

The distance between each PWS source location and the nearest MassDOT roadway was estimated using the right-of-way limits of state-owned roadways and the PWS

13 U.S. Department of Agriculture and U.S. Department of Health and Human Services. Dietary Guidelines for Americans, 2020-2025. 9th Edition. December 2020. Available at DietaryGuidelines.gov.

14 Massachusetts Department of Environmental Protection. Code of Massachusetts Regulations Title 310 §22.06A. https://www.mass.gov/doc/310-cmr-2200-the-massachusetts-drinking-water-regulations/download

source coordinate data to identify PWS sources that are within 0.5-mile of a MassDOT road. Distance to a MassDOT roadway for the various PWSs ranged from less than 10 feet for a restaurant in Wellfleet on Route 6 to over several miles. Despite the wide range of distances, the median distance from a MassDOT roadway is estimated to be only 0.6 miles and the mean distance is just under 1.0 mile.

Table 2.3 presents the estimated number and percentage of PWSs that are within and beyond a 0.5-mile of MassDOT roadway that have average and maximum reported sodium concentrations below specified levels. The total number of PWSs identified in these two groups are listed below:

» 930 PWSs that had at least one water supply source within the 0.5-mile radius of a MassDOT roadway, and

» 783 PWSs with sources that were outside of the 0.5-mile radius.

Although distance to a MassDOT road was the only factor evaluated here with respect to PWS sodium levels, it is important to note that other factors and road salt sources are likely to influence sodium levels in these PWSs as discussed further below.

Table 2.3 Average and Maximum Reported Sodium Concentrations in Public Water Supplies Located Within and Beyond a 0.5-mile Radius of a MassDOT Roadway

Sodium Concentration (mg/L)	Average Reported Concentration1				Maximum Reported Concentration			
	PWSs within 0.5 mile2		PWSs outside 0.5 mile		PWSs within 0.5 mile2		PWSs outside 0.5 mile	
	Number	% of Total	Number	% of Total	Number	% of Total	Number	% of Total
<= 20	446	48%	518	66%	323	35%	394	50%
> 20	484	52%	265	34%	607	65%	389	50%
> 40	256	28%	114	15%	442	48%	236	30%
> 60	143	15%	66	8.4%	338	36%	157	20%
> 80	92	10%	39	5.0%	255	27%	115	15%
> 100	62	6.7%	27	3.4%	199	21%	81	10%
> 120	47	5.1%	22	2.8%	163	18%	65	8.3%
> 150	29	3.1%	12	1.5%	118	13%	44	5.6%
> 200	13	1.4%	7	0.9%	79	8.5%	33	4.2%
> 300	5	0.5%	4	0.5%	38	4.1%	20	2.6%
> 500	3	0.3%	1	0.1%	19	2.0%	6	0.8%
> 1,000	1	0.1%	1	0.1%	7	0.8%	3	0.4%
> 1,500	1	0.1%	--	--	3	0.3%	3	0.4%
> 2,500	--	--	--	--	1	0.1%	3	0.4%
> 5,000	--	--	--	--	--	--	2	0.3%
Total PWS	930	--	783	--	930	--	783	--

1 Average sodium (Na) concentrations represent an average for the period of record for each PWS reported between 1993 and 2021
2 Includes PWSs that have at least one source within a 0.5 mile of a MassDOT road based on 2020 Road Inventory

Based on this analysis, approximately 52% of the PWSs located within a 0.5-mile of a MassDOT road have estimated average sodium concentrations above 20 mg/L compared to approximately 34% of the PWSs located beyond a 0.5-mile from a MassDOT road. Similar findings were reported in the previous 2017 ESPR, where 52% of the PWSs within a 0.5 mile had average sodium concentration above 20 mg/L compared to 38% of the PWSs outside a 0.5-mile of a MassDOT road.

Approximately 28% of the PWSs within a 0.5-mile of a MassDOT road have an estimated average sodium concentration above 40 mg/L compared to approximately 15% of the PWSs located outside of a 0.5-mile radius, a difference of 13.0 percentage points. The differences between the two groups narrow considerably when comparing average sodium concentrations above 60 mg/L. Approximately 15% of the PWSs within a 0.5-mile of a MassDOT road have an average reported sodium concentration above 60 mg/L compared to approximately 8.4% of the PWSs located outside of a 0.5-mile radius, a difference of less than 7 percentage points.

Sixty-two (62) PWSs or just under 7% of the PWSs that are within a 0.5 mile of a MassDOT road have an estimated average sodium concentration above 100 mg/L compared to 27 PWSs or approximately 3.5% of the PWSs located outside of a 0.5-mile radius, a difference of 35 additional PWS.

With respect to maximum sodium concentrations, approximately 35% of the PWSs within of a 0.5-mile radius have reported maximum reported sodium concentrations below 20 mg/L compared to 50% of the PWSs located outside a 0.5-mile radius. The median reported sodium concentration for PWS sources inside a 0.5-mile radius was 28.2 mg/L compared to 12.7 mg/L for PWSs with any sources outside this radius.

Table 2.4 presents the same analysis but using data for each individual source within the Public Water Supply rather than averaging across multiple sources for a particular PWS. This comparison presents a more focused worst-case analysis by focusing on sodium concentrations in individual sources within a 0.5 mile of a MassDOT road. Approximately 1,609 water supply sources were identified as being within 0.5-mile of a MassDOT road and another 2,000 sources were located outside of the 0.5-mile radius.

Table 2.4 Average and Maximum Reported Sodium Concentrations in Individual Public Water Supply Sources Located Within and Beyond a 0.5-mile Radius of a MassDOT Road

Sodium Concentration (mg/L)	Average Reported Concentration1				Maximum Reported Concentration			
	Source within 0.5 mile		Source outside 0.5 mile		Source within 0.5 mile		Source outside 0.5 mile	
	Number	% of Total	Number	% of Total	Number	% of Total	Number	% of Total
<= 20	693	43%	1,212	61%	516	32%	961	48%
> 20	916	57%	788	39%	1,093	68%	1,039	52%
> 40	530	33%	339	17%	790	49%	674	34%
> 60	283	18%	143	7.2%	578	36%	399	20%
> 80	172	11%	61	3.1%	397	25%	243	12%
> 100	100	6.2%	36	1.8%	286	18%	147	7.4%
> 120	73	4.5%	28	1.4%	218	14%	115	5.8%
> 150	50	3.1%	15	0.8%	156	10%	64	3.2%
> 200	16	1.0%	9	0.5%	100	6.2%	48	2.4%
> 300	6	0.4%	5	0.3%	44	2.7%	26	1.3%
> 500	3	0.2%	2	0.1%	20	1.2%	7	0.4%
> 1,000	1	0.1%	2	0.1%	7	0.4%	4	0.2%
> 1,500	1	0.1%	--	--	3	0.2%	4	0.2%
> 2,500	--	--	--	--	1	0.1%	4	0.2%
> 5,000	--	--	--	--	--	--	2	0.1%
Total		--	2,000	--	1,609	--	2,000	--

1 The average concentration based on reported data for entire period of record for each source

The percent differences between the sources within a 0.5-mile of a MassDOT road and those outside of that area were very similar to that presented above for each of the individual PWSs suggesting that source location does not provide any better indication of the potential effects of MassDOT operations on sodium levels in PWSs.

2.3.3 PWSs with the Highest Sodium Concentrations

The highest reported sodium concentrations PWSs are linked to the Harvard Ridge Condominium (HRC) complex and the Boxboro Executive Center. The HRC complex, in the Town of Harvard, reported a sodium concentration of 1,050 mg/L in June 2021 and is by far its highest reading reported during this period. The second highest levels were reported by the Boxboro Executive Center, which had five readings above 1,000 mg/L, ranging from 1,120 mg/L in April 2018 to 1,011 mg/L in March 2021. In 38 distinct samples taken during this period, results at this well have ranged from 169 mg/L to 1,120 mg/L. Although both these PWSs are within 0.5-mile of a MassDOT road, both systems are also treated with salts for water softening purposes, which may have more influence on sodium levels than the road salt used on the MassDOT roadway. Similar elevated sodium concentrations have not been recorded in other PWSs in the area that are as close or even closer to a MassDOT road. MassDOT and MassDEP, in cooperation with the town of Boxboro and the Littleton Light and Water Department, are currently evaluating the possibility of extending municipal water service to these facilities.

The analysis did not evaluate the effect of other sodium inputs on PWS sodium levels such as salt used for water softening purposes or that used on adjacent commercial parking lots or municipal roads. Often, various commercial properties such as office, retail, industrial, and even multifamily residential complexes are developed along major roadways to take advantage of the greater accessibility and traffic volumes. Given this co-dependence or co-existence of commercial developments with major roadways, it is often difficult to isolate the relative influence of deicing material used by each of these sources without more detailed investigations of the actual road salt usage by each source and hydrogeological conditions surrounding each PWS. Proximity to saline or brackish ground or surface waters, especially in the Cape Cod region, can also have a major influence on sodium and chloride levels in nearby PWS wells.

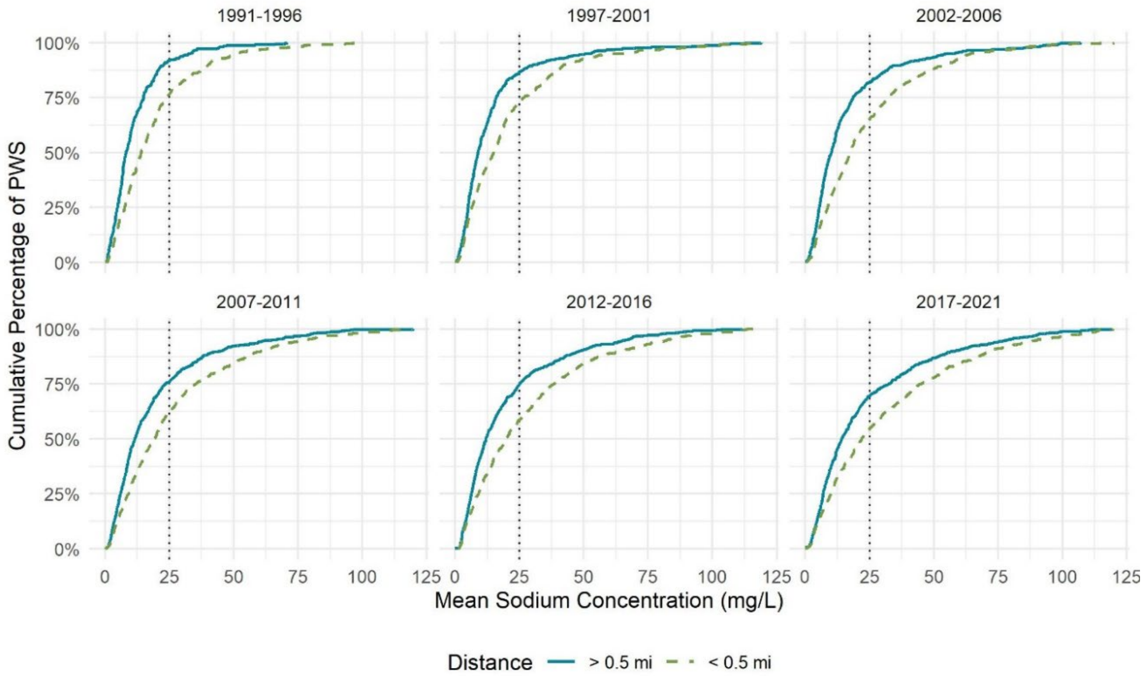
As discussed further in Section 2.5, relative road salt contributions from paved areas were recent evaluated in the Hobbs Brook watershed, a major surface water source for the Cambridge Water District. The evaluation indicated that more than 50% of the estimated average annual road salt usage in the watershed was related to winter maintenance operations on municipal roads, private roads, and parking lots.

2.3.4 Cumulative Frequency Distribution Curves of Reported Sodium Levels

To assess changes over time, **Figure 2.2** compares the cumulative percentage of PWSs located within and outside of 0.5 mile of a MassDOT road with estimated average sodium (Na) levels at or below certain thresholds over 5-year intervals. Differences in the cumulative percentage curves for PWSs within 0.5 mile of a MassDOT road (**dashed green line**) and those located outside of 0.5-mile of a MassDOT road (**blue line**) are greatest between 10 and 50 mg/L and peak at around 25 mg/L. Between 2017 and 2021, approximately 50% of the PWSs within a 0.5-mile of MassDOT road had average Na levels below 25 mg/L compared to slightly less than 75% of the PWSs located beyond a 0.5-mile of a MassDOT road. The percentage of PWSs with reported Na concentrations of less than 10 mg/l or above 100 mg/l are essentially the same for PWSs within or beyond 0.5 mile of a MassDOT road.

Over time, the percentage of PWSs with average Na concentrations above 25 mg/L increased for both groups of PWS. As mentioned above, the percentage of PWSs within a 0.5-mile of a MassDOT road that have average Na concentrations above 25 mg/L increased from approximately 25% to 50% between the periods of 1991 to 1996 and 2017 to 2021, or roughly a 30-year period. A similar but less dramatic trend was observed for PWSs located outside of 0.5 mile, where in 1991 to 1996, 10% of the PWSs had average concentrations above 25 mg/L compared to slightly more than 25% of the PWSs between 2017 and 2021. Again, this trend of increasing sodium levels in both PWS groups, regardless of distance to a MassDOT road, suggests that the rising Na concentrations are due to multiple sources of sodium and to have a meaningful impact in reversing this trend, a more holistic approach will be required to reduce inputs from these various sodium sources.

Figure 2.2 Cumulative Distribution of PWS Mean Sodium Concentrations

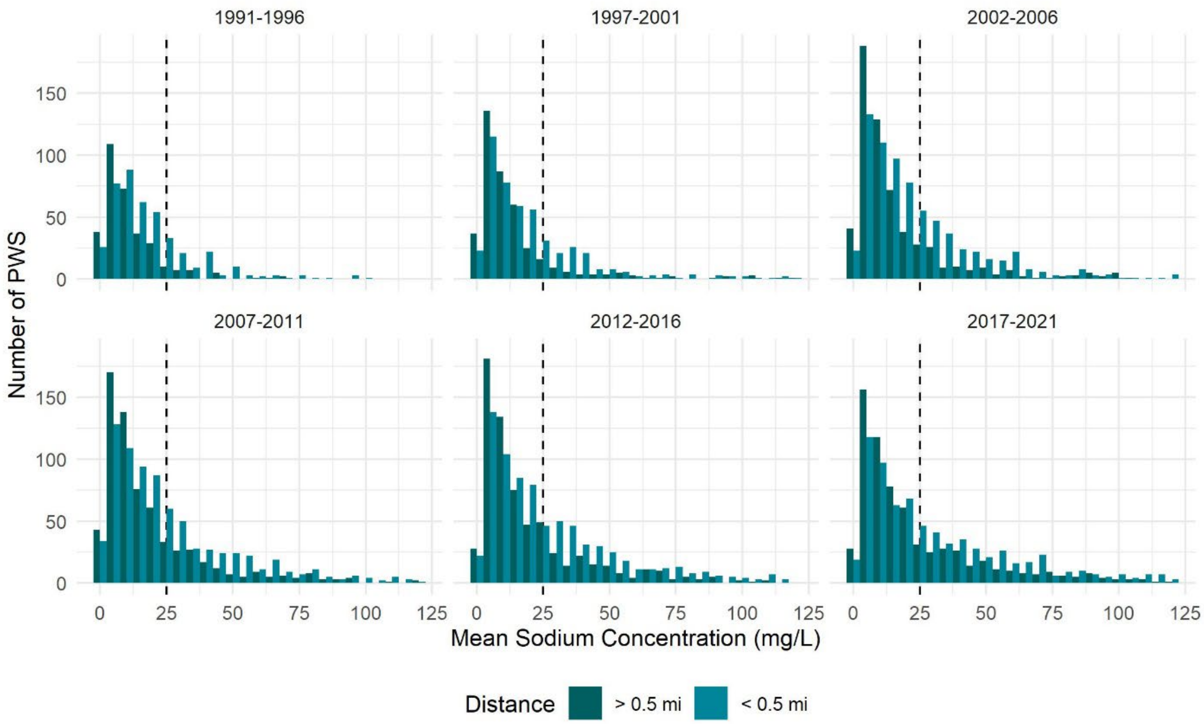


Source: MassDEP drinking water quality database of reported sodium concentrations in PWS.
Blue line shows the cumulative percentage of PWSs located beyond a 0.5 mile of a MassDOT road with a mean sodium level below or at a certain sodium concentration (mg/L) and the green dashed line shows the cumulative percentage of PWSs located within a 0.5 mile of a MassDOT road with a mean sodium level below or at a certain sodium concentration.

Figure 2.3 presents the same data as above but in a series of histograms using data in 5-year intervals to illustrate changes in the number of PWSs with average sodium concentrations below specified Na concentration thresholds. Like above, the **lighter green bars** represent PWSs within the 0.5-mile radius and the **dark blue bars** represent PWSs that are outside a 0.5-mile radius of a MassDOT road. Higher bars indicate a greater number of PWSs with average concentrations below the specified threshold. The vertical dashed line denotes the 25 mg/L concentration threshold.

Over time, perhaps the biggest apparent change is that fewer PWSs have reported average Na concentrations below 10 or 20 mg/L for both PWS categories, and more PWS appear to have average Na concentrations above 25 mg/L. Relatively few PWSs appear to have average Na concentrations above 80 mg/L.

Figure 2.3 Distribution of PWS with Average Sodium Concentrations Above Specified Levels



Source: MassDEP drinking water quality database of reported sodium concentrations in PWSs.
Notes: Dark blue bars show the number of PWSs located beyond a 0.5 mile of a MassDOT roadway with a mean sodium concentration below or at a certain sodium concentration (mg/L) and the lighter blue bars show the number of PWSs located within a 0.5 mile of a MassDOT roadway with a mean sodium concentration below or at a certain sodium concentration (mg/L).

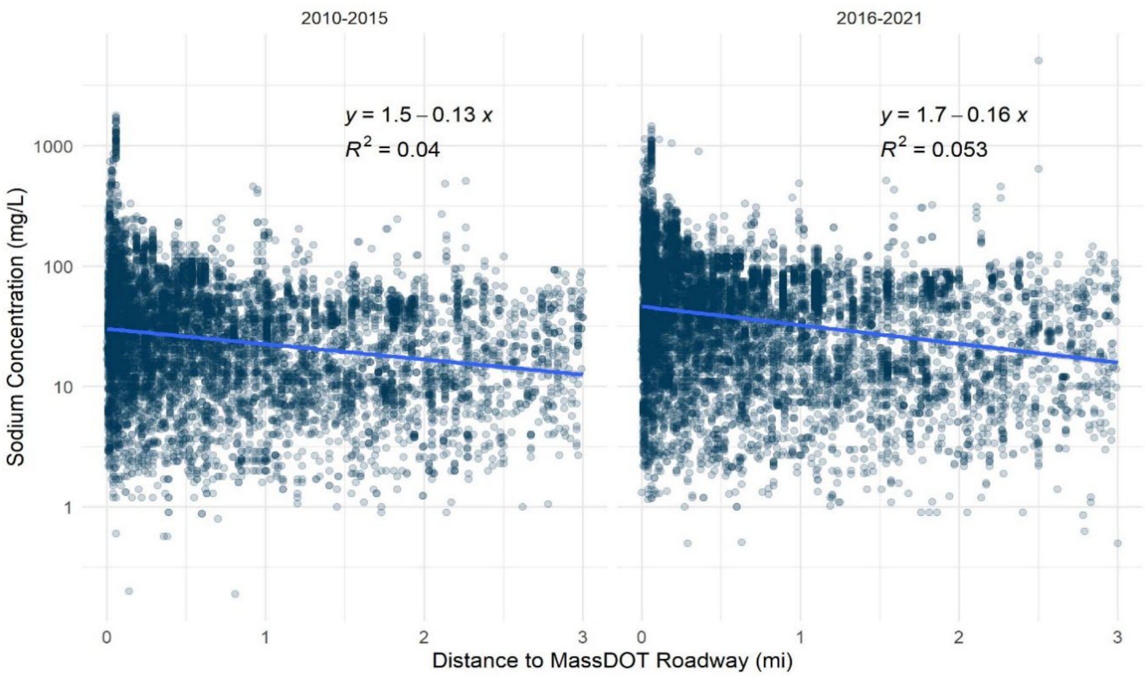
2.3.5 Regression Analysis of Sodium Concentrations in PWSs and Distance to a MassDOT Roadway

Regression analyses were performed to assess the relationship between sodium levels in PWS sources and proximity to a MassDOT roadway. To perform a more direct analysis of how PWS sodium levels may correlate to distance to a MassDOT road, only PWS sources that were within 3.0 miles of a MassDOT roadway were included. More distant PWSs are highly unlikely to be affected by MassDOT operations and inclusion of this data would seem to only negatively bias or dilute any correlation between these two factors, especially if the more distant PWS have low concentrations. Secondly, only more recent data post-2010 was used in the analysis to eliminate any bias from PWS that are no longer active. Active PWSs required to report sodium data would have had at least 3 reporting cycles since 2010. The data for PWSs located > 3.0 miles from a MassDOT road represents approximately 5.2% of the post-2010 sodium data.

Finally, where possible, sodium data from individual PWS sources was used rather than treated water or blended water data. For some PWSs, however, only sodium data from the final common sampling point was available, which may represent a blend of water from several source points.

Figure 2.4 illustrates the distribution of reported PWS sodium concentrations from 2010 to 2015 and from 2016 to 2021with fitted linear regression lines. The sodium concentrations are plotted on a log -scale y-axis to better visualize the data distribution and the darker shading indicates highest frequency of concentrations.

Figure 2.4 Sodium Concentrations and Proximity to a MassDOT Roadway



Notes: MassDEP reported sodium concentration database through October 18, 2021. The darker shading denotes a relatively higher density of PWS with similar average annual sodium concentrations.

These plots reveal that Na concentrations decrease slightly with greater distance from a MassDOT road as indicated by the slight slope in the regression lines of 0.13x and 0.16x. These plots also show relatively minor changes in Na concentrations over time except for perhaps a few more PWSs with elevated Na levels in the more recent data that are located both close to and a few miles away from a MassDOT road.

The correlation coefficient (R2 value) of 0.053 indicates a relatively weak correlation between Na concentrations and distance to a MassDOT road. In other words, only 5.3% of the Na concentration variability is likely related to proximity to a MassDOT road, suggesting that distance to a MassDOT road is not a strong predicter of PWS sodium concentrations.

Based on these results, it appears that Na concentrations in PWSs are as much affected, if not more so in some locations, by other sources and road salt users as that related to MassDOT’s SICP operations. Urbanization and increasing amounts of impervious surfaces treated with road salt as well as the increased need for drinking water treatment chemicals as discussed later in this Chapter are likely affecting Na concentrations In PWSs. Determining the principal contributors of sodium for each PWS would require detailed site-specific investigations of potential salt contributions as well as the hydrogeologic conditions in the area on a case-by-case basis.

2.3.6 Sodium Level Trends in Municipal Water Supplies

Table 2.5 presents average sodium concentrations for various municipal PWS for sampling results over 5-year periods. Only municipal PWSs with more than 6 years of sodium data were included. This analysis was used to detect any discernable trends in sodium levels within some of the larger municipal PWSs located near major roads, particularly in recent years. Time series graphs of average annual sodium concentrations for these municipal PWSs are included in **Appendix B**.

Review of the municipal PWS sodium data reveal mixed results with several municipal PWS showing decreases in sodium concentrations in recent years while others show steady increases. Municipal PWSs showing recent decreases in average annual sodium concentrations of more than 10 mg/L in the last 5-years include Billerica (-33.8 mg/L), North Chelmsford (-22.8 mg/L), Salisbury (-15.6 mg/L), Webster (-18.2 mg/L), and Weymouth (-19.5 mg/L). These decreases may be in part due to certain wells be replaced and/or no longer being used.

As indicated in the shaded cells in **Table 2.5**, as many as 17 municipal PWSs have had average annual sodium concentration increases of more than 50 mg/L over the roughly 30-year period of record. This is based on sampling data from both finished and raw water sources. However, several of these municipal PWSs have had recent declines in their average annual sodium levels in the last 2-3 years, while other municipal PWSs have seen levels continue to rise, refer to the time-series graphs in **Appendix B**.

As discussed in more detail in Section 2.5, MassDOT has conducted several studies to evaluate the relative road salt contributions associated with MassDOT's snow and ice operations compared to that used on other developed land areas in in the watershed or Wellhead Protection Area based on GIS analyses of mapped impervious cover areas.

Table 2.5 Average Sodium Concentrations in Select Municipal Water Systems over 5-Year Intervals

Municipality	No. of Samples	Average Sodium Concentration (mg/L)					
		1991 1996	1997 2001	2002 2006	2007 2011	2012 2016	2017 20211
Auburn	153	N/A	122.8	183.8	168.7	187.1	202.6
Billerica	97	36.9	39.9	68.5	81.4	129.7	95.9
Burlington	292	53.2	49.0	69.4	85.0	110.5	119.6
Cambridge	104	42.3	44.8	69.2	70.2	93.8	127.3
Chelmsford	141	31.5	35.0	50.3	50.9	47.8	85.2
Concord	175	10.7	18.4	26.7	31.1	30.2	38.2
Dedham	237	32.2	36.5	53.7	67.3	72.5	90.3
E. Chelmsford	28	97.7	102.6	118.0	143.0	175.5	186.0
Franklin	142	20.0	30.9	60.1	63.1	76.3	88.3
Hamilton	57	18.3	23.2	31.7	34.0	38.9	52.4
Marlborough	18	41.5	55.6	89.4	109.4	164.0	N/A
Middleboro	123	26.4	24.3	32.2	38.1	47.5	60.3
Millbury	221	40.2	70.9	102.4	96.2	166.6	196.2
Natick	72	N/A	38.3	56.6	66.1	75.9	87.3
N. Attleboro	1,360	20.3	21.4	31.1	83.3	35.2	61.3

Municipality	No. of Samples	Average Sodium Concentration (mg/L)					
		1991 1996	1997 2001	2002 2006	2007 2011	2012 2016	2017 20211
N. Chelmsford	514	96.0	138.0	144.5	132.5	134.7	111.9
Orange	40	11.8	N/A	27.1	53.9	83.8	74.4
Oxford	85	23.8	35.6	49.2	40.8	46.4	52.6
Reading	63	62.7	52.0	62.3	N/A	N/A	N/A
Rowley	24	N/A	N/A	40.8	N/A	42.7	69.3
Salisbury	55	33.9	59.5	59.5	82.3	87.1	71.5
Shrewsbury	80	52.3	N/A	71.8	84.0	89.9	105.1
Topsfield2	44	16.6	20.1	26.2	27.9	32.7	38.5
Wakefield	24	32.0	50.2	78.8	69.0	78.9	89.9
Webster	129	12.6	12.4	17.3	81.9	82.6	64.4
Wellesley	187	37.0	45.2	59.5	55.8	76.3	98.4
Weymouth	451	29.3	52.8	84.6	67.7	144.5	143.4
Wilmington	215	52.4	46.7	58.6	73.1	93.4	101.3
Woburn	571	40.8	40.2	72.9	80.5	94.7	110.3

Note: Blue shaded rows represent municipal PWSs that have had average annual sodium concentration increases of more than 50 mg/L over the roughly 30-year period of record.

1 The period 2017 – 2021 includes only data from January 1, 2017, through October 18, 2021

2 One outlier of 2,424 mg/L was removed from the period 2002 – 2006

N/A = data not available

2.3.7 Reported Chloride Concentrations in PWSs

Chloride in drinking water is regulated as a secondary drinking water contaminant for aesthetic reasons to avoid issues with taste. MassDEP has set a secondary maximum contaminant level (SMCL) for chloride at 250 mg/L. Chloride levels above 250 mg/L may result in a salty taste but are not considered to be a direct human health risk. PWSs are not required to test for chloride levels, but it is recommended, especially where sodium levels are elevated. The MassDEP database had reported chloride levels for 582 PWSs and 1,596 different sources. The earliest reported chloride data appears to be in 2007 and, thus, very few data records are available prior to 2010.

Based on the reported chloride data, approximately 74% or 433 PWSs have estimated average chloride concentrations that are less than 100 mg/L while another 112 PWSs have estimated average concentrations between 100 – 250 mg/L. Together these represent 94% of the PWSs in the database.

Table 2.6 lists 38 PWSs that have estimated average chloride concentrations above the 250 mg/L SMCL threshold including 28 PWS with average chloride concentrations between 251 and 500 mg/L, six PWSs with average chloride concentrations between 501 and 1,000 mg/L, and three PWSs with average concentrations greater than 1,000 mg/L. Average chloride concentrations were calculated using all available data across multiple years. As discussed with the sodium data, the extent to which MassDOT's SICP operations might influence these chloride concentrations is unclear, as some PWSs are located a considerable distance from a roadway, and/or may use chloride-based chemicals for water quality treatment and a few are located near brackish waters.

Table 2.6 Summary of PWS with Average Reported Chloride Concentrations Above 250 mg/L

PWS Category	PWS Name	Average Chloride Concentration (mg/L)	No. of Sources	No. of Samples	County	Sampling Date Range
Community	Aquarion Water Company, Millbury	327	4	30	Worcester	2013-2021
	Auburn Water District	310	12	6	Worcester	2015-2021
	Brook Village Condominium	464	3	1	Middlesex	2012
	Burlington Water Dept	305	9	16	Middlesex	2011-2021
	Campion Residence & Renewal Ctr	271	1	9	Middlesex	2013-2021
	East Chelmsford Water District	410	3	1	Middlesex	2007
	Leicester Water Supply District	286	5	2	Worcester	2013-2017
	Marlborough Water Div. (MWRA)	380	1	1	Middlesex	2016
	North Chelmsford Water Dist.	265	6	55	Middlesex	2008-2021
	Pine Hill Condominium	408	1	12	Middlesex	2010-2021
	Townhouses @ Copper Lantern	318	2	4	Plymouth	2014-2019
Transient Non-Community	Ashby Market	312	1	1	Middlesex	2017
	Chappaquiddick Beach Club, Inc.	1,000	1	1	Dukes	2015
	Charlton Chinese Takeout	250	1	1	Worcester	2012
	CJs Restaurant	255	1	1	Hampden	2012
	Dads Restaurant	574	1	1	Worcester	2012
	Howlett Lumber/Flea Market	418	1	1	Worcester	2012
	McDonalds Restaurant	327	1	3	Worcester	2012-2015
	On The Trax Restaurant	317	1	5	Worcester	2013-2018
	Quarter Keg Pub*	1,210	1	1	Worcester	2020
	Sims Health and Racquet Club	340	2	1	Worcester	2011
	The Assembly of God Southern NE *	1,400	1	1	Worcester	2012
Non-Transient Non-Community	155 Swanson Rd Synqor	274	2	6	Middlesex	2008-2012
	159 Swanson Rd Setra Systems Inc	493	2	5	Middlesex	2008-2017
	60 And 70 Codman Hill Rd	517	1	16	Middlesex	2008-2021
	85 Swanson Rd LLC	498	1	31	Middlesex	2008-2021
	Boxboro Executive Center	1,693	1	7	Middlesex	2017-2018
	Dambrosio Eye Care, Inc.	304	1	1	Worcester	2019
	Henry P. Clough School	511	1	4	Worcester	2014-2018
	Heritage Professional Bldg.	517	1	4	Worcester	2014-2017
	MIT Millstone Laboratory	366	2	8	Middlesex	2008-2021
	Piconics	488	1	1	Middlesex	2015
	Pilgrim Church	264	1	2	Middlesex	2012-2013
	Pilot Travel Center	254	1	1	Worcester	2012
	Savoy Elementary School	558	1	1	Berkshire	2017
	Sutton Public Schools	444	2	1	Worcester	2012
	The Appleworks	449	1	1	Worcester	2012
	The Quabbin Retreat	288	1	3	Worcester	2019-2021

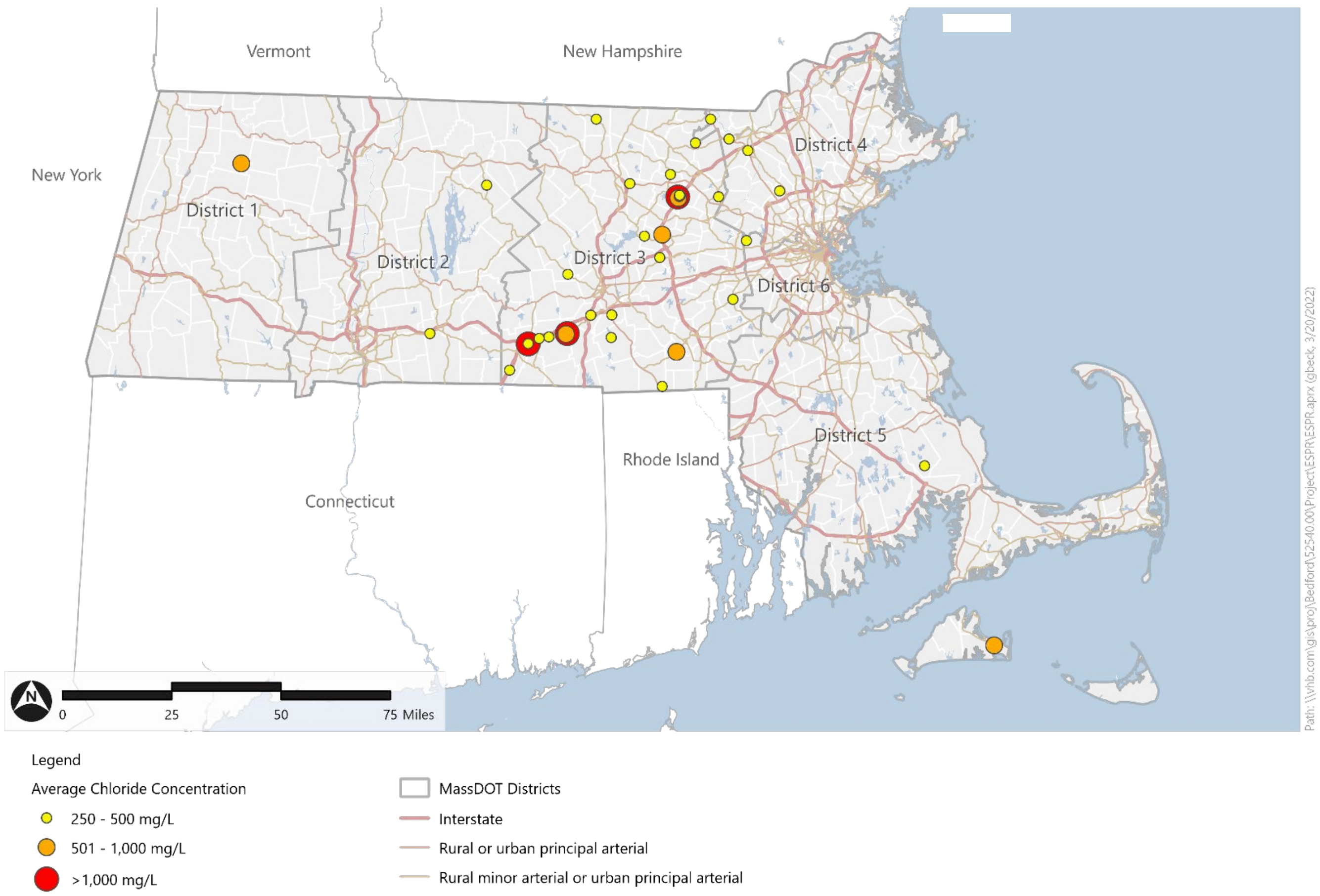
Source: MassDEP data based on reported chloride data from August 2007 – October 2021

* Indicates that this property owner either did not respond to MassDOT's request to coordinate complaints under the Salt Remediation Program or has been remediated or accepted a financial settlement with MassDOT.

** Indicates that this property is currently being investigated by MassDOT.

Figure 2.5 shows the locations of the PWS sources that have average chloride levels above the recommended SMCL level of 250 mg/L, which are mostly located in the central and eastern portions of the state. At least 9 of these PWSs have average chloride levels above 500 mg/L and may warrant more detailed investigations to try to identify the source(s) of chloride and to determine whether the elevated levels are a concern for increased corrosiveness as discussed further below.

Figure 2.5 Public Water Supplies with Average Chloride Concentrations above 250 mg/L

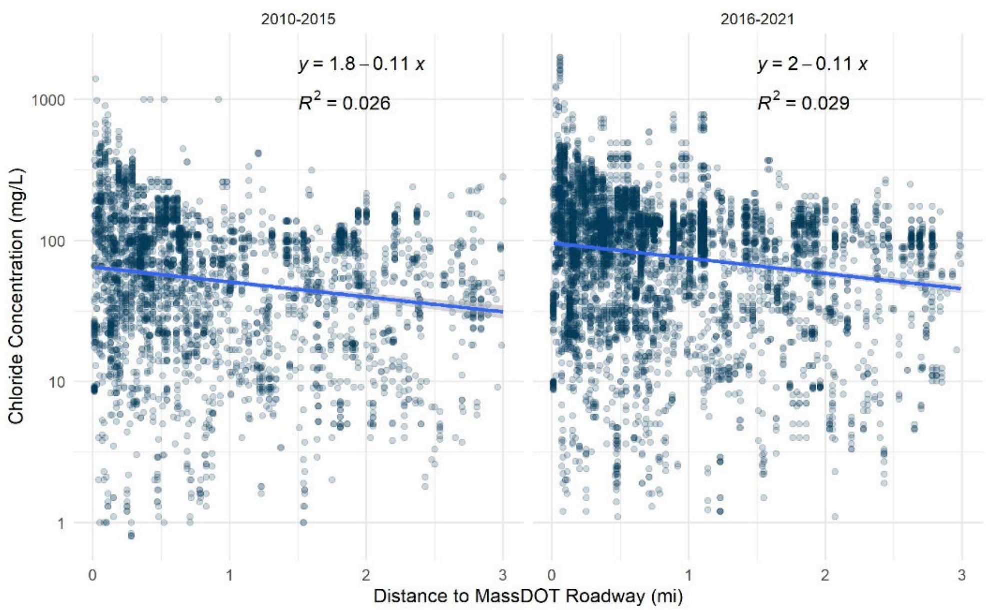


Source: MassDEP, MassDOT, MassGIS, VHB

Distance to a MassDOT roadway appears to explain only 3.0% of the variability in the chloride data in PWS.

Figure 2.6 presents a frequency distribution graph and a fitted linear regression line to illustrates the relationship between distance to a MassDOT road and chloride concentrations in PWSs for chloride data reported between 2010 to 2015 and 2016 and 2021. The correlation coefficient values (R2) of 0.026 and 0.029 from the regression equations produced for the two different periods, respectively, suggests a very weak correlation between proximity to a MassDOT roadway and chloride concentrations. These R2 values suggest that approximately 3.0% of the variability in the reported chloride levels in PWSs may be explained by distance to a MassDOT roadway. As discussed previously, given the co-existence of MassDOT roadways and commercially developed areas and municipal roads, it is often difficult to quantify the relative influence of the various road salt users on chloride concentrations levels in PWS.

Figure 2.6 Chloride Concentrations and Proximity to a MassDOT Roadway



Source: MassDEP data based on reported chloride data from August 2010 – October 2021. The dark blue shading denotes a higher density of PWS with similar average annual chloride concentrations.

2.3.8 Chloride Levels and the Potential Increased Risk of Corrosion in Drinking Water

The 2021 revisions to National Lead and Copper Rule (LCR) may require additional sampling to detect potential increased metal concentrations in drinking water due to corrosion. Additional sampling is especially required for all schools and child-care facilities and any larger PWS systems that have or had lead levels or other metals that approach or exceed action levels indicative of corrosion. Any of the larger PWS systems with lead levels that are above the threshold levels will need to implement or optimize their corrosion control strategies and technology. This would obviously add more treatment and sampling costs for affected PWS systems. Based on the revised LCR rule, EPA estimates that approximately $360M to $375M in additional annual costs for sampling, administrative and corrosion control efforts may be incurred by affected PWS, nationwide.[15] See Section 4.3.1 for additional discussion on available grant funding programs to assist with removal of existing lead service lines.

Recent studies have indicated that PWS systems with chloride to sulfate mass ratio (CSMR) in source water greater than 0.5 can lead to increased potential galvanic corrosion of lead connections in the PWS distribution system. Additionally, a Larson Ratio (LR) of greater than 0.3 may indicate the potential for iron and steel corrosion. However, additional water quality data for alkalinity would be needed to calculate the LR. The extent of water quality monitoring needed for the entire distribution system will depend greatly on whether existing lead or copper already exceed action[16]

A 2018 study found that chloride concentrations in public wells in the U.S. have in general increased from 1992 to 2012 and especially in highly developed watersheds where some of the highest chloride concentrations have been observed. Urban development and elevated chloride concentrations were found to be highly correlated to increases in CSMR levels and the Larson Ratio. This relationship between land use and surface water CSMR and the increased risk of elevated lead levels was found to be statistically significant, although levels can be highly variable and influenced by site-specific factors. Lead action levels were more often exceeded with a CSMR value that is greater than 1.0. These results underscore the fact that increased land development in the watershed can affect drinking water quality and the potential for increased corrosion in water supplies and the need to continually monitor the source water and distribution system water quality in order to maintain optimal corrosion control.

Table 2.7 lists various facilities or water suppliers with estimated CSMR values above 50 based on reported chloride and sulfate levels. Facilities with the highest estimated CSMR values include an Assembly of God of the Southern NE District facility in the Town of Charlton and a community PWS that services the Henry P. Clough School in the Town of Mendon. These PWS have estimated CSMR values above 200, however, no new data has been reported for these PWS since 2012 and 2015, respectively, and thus it is unclear whether these PWS are still being used for potable water.

Three other facilities have estimated CSMR values above 100, which include the PWS wells serving the Groton-Dunstable Regional High School, the Millstone MIT Laboratory in Westford and a PWS well used by the Peabody Water Department. The sampling details for the first two facilities indicate that the chloride concentrations represent finished water or post-treatment conditions and, thus it is unclear to what extent use of treatment chemicals might also be affecting the chloride levels. The MIT Millstone Laboratory is located at least 1.5 miles from the nearest MassDOT road in within a rural, wooded area in the Town of Westford with no adjacent development and thus the elevated chloride levels would appear to be unrelated road salt use.

15 National Primary Drinking Water Regulations: Lead and Copper Rule Revisions: 40 CFR Parts 141 and 142. Environmental Protection Agency; Federal Register Vol. 86 No. 10 January 15, 2021. https://www.govinfo.gov/content/pkg/FR-2021-01-15/pdf/2020-28691.pdf

16 E. G. Stets et al. "Increasing chloride in rivers of the conterminous U.S. and linkages to potential corrosivity and lead action level exceedances in drinking water." *Science of the Total Environment* 613-614 (2018): 1498 – 1509. https://doi.org/10.1016/j.scitotenv.2017.07.119

Table 2.7 PWS with Estimated Chloride to Sulfate Mass Ratios (CSMR) Values Above a Threshold of 50

PWS Name	Source Name	Treatment Status	Sample Date	Chloride (mg/L)	Sulfate (mg/L)	CSMR
Attleboro Water Department	West St WTP Finished	Finished	Apr 12, 2021	191.0	2.0	95.5
	West St WTP Finished	Finished	Apr 6, 2017	344.0	4.0	86.0
	Manchester Pond Finished	Finished	Jun 27, 2017	146.0	2.0	73.0
	Manchester Pond Finished	Finished	Aug 3, 2016	141.0	2.0	70.5
	Wading River Finished	Finished	Aug 3, 2016	141.0	2.0	70.5
	West St WTP Finished	Finished	Apr 3, 2014	116.0	2.0	58.0
	Wading River Finished	Finished	Jul 1, 2013	103.0	2.0	51.5
	West St WTP Finished	Finished	Jul 1, 2013	100.0	2.0	50.0
MIT Millstone Laboratory	Well #3 – Raw Water	Raw	Aug 22, 2019	475.0	3.3	143.9
	Wells #2 & #3 After Treatment	Finished	May 11, 2021	486.0	4.3	113.0
	Wells #2 & #3 After Treatment	Finished	Apr 17, 2019	451.0	4.4	102.5
	Wells #2 & #3 After Treatment	Finished	Apr 13, 2021	495.0	4.9	101.0
	Wells #2 & #3 After Treatment	Finished	Mar 15, 2020	424.0	4.4	96.4
	Raw Water Well #2	Raw	Mar 25, 2011	115.0	2.3	50.0
Peabody Water Department	Pine St. GP Well	Finished	Feb 5, 2018	246.0	1.8	135.9
	Pine St. GP Well	Finished	Jan 11, 2021	500.0	4.0	124.7
	Pine St. GP Well	Finished	Feb 3, 2020	585.0	10.2	57.4
The Assembly of God Southern NE	Well #1	Finished	Jul 19, 2012	1,400.0	3.0	466.7
Henry P. Clough School	Finished Well #1	Finished	May 12, 2015	427.0	1.8	237.2
Groton Dunstable Reg. H.S.	Well #1 (After Treatment & Storage)	Finished	May 21, 2019	144.0	1.1	130.9
	Well #1 (After Treatment & Storage)	Finished	Mar 9, 2020	134.0	1.2	111.7
Bangmas Farm Store & Dairy Bar	Well #1: Finished Water	Finished	May 11, 2015	107.0	1.6	66.9
Manchus Water District of Sutton	Well #3: Raw Water	Raw	Apr 6, 2015	370.0	5.8	63.8
Classic Pizza III	Well #1: Finished Water	Finished	Aug 11, 2020	255.0	4.4	58.0
	Well #1: Finished Water	Finished	Aug 25, 2021	270.0	4.9	55.1
Townhouses @ Copper Lantern	Well #1 & Well #2	Finished	Dec 12, 2018	370.0	6.6	56.1
	Well #1 & Well #2	Finished	Nov 28, 2017	370.0	6.9	53.6
N. Chelmsford Water District	Bomil GP Well #2 – Raw Water	Raw	Jun 4, 2019	174.0	3.3	52.7

Source: MassDEP Drinking Water Quality database as provided on Oct. 18, 2021

2.4 Specific Watershed Studies of Salt Usage near Municipal PWS

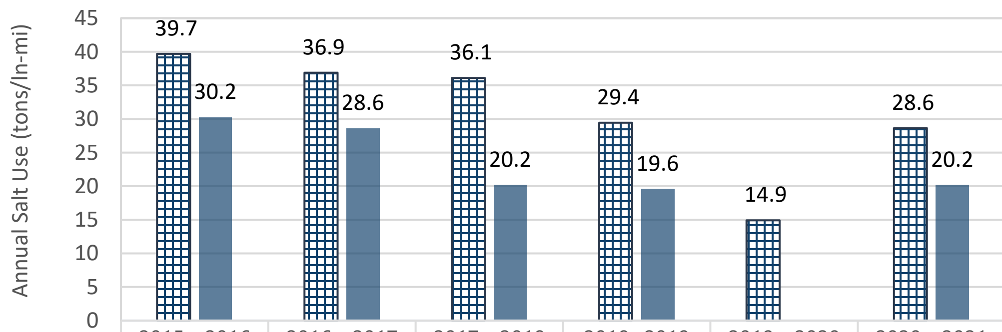
Over the last 5 to 10 years, MassDOT has coordinated with various larger municipal water suppliers who have experienced elevated sodium and chloride concentrations to conduct desk-top GIS based analyses to estimate the relative contributions of salt from major land uses and road salt users on an annual basis within the watershed or Wellhead Protection Area (WHPA). These studies often show that salt contributions are often more widely distributed amongst other users that apply salt to municipal roads, private roads, and commercial parking lots as well as MassDOT roads. Thus, each of the major road salt users would need to implement various salt efficiency measures to produce meaningful reductions in future sodium and chloride concentrations. The following section describes details of several studies recently completed in select locations involving large municipal water supplies.

2.4.1 Dedham-Westwood Water District

In response to requests from the Dedham-Westwood Water District (DWWD), MassDOT adopted additional efficiency measures to minimize road salt usage on roads and AVL/GPS technology to track salt usage within the DWWD Wellhead Protection Area.

Figure 2.7 compares the estimated annual salt usage on MassDOT roadways in the DWWD area to that used on the rest of District 6 roadways since the 2015/16 season. In the last 5 of 6 years. the annual salt usage in the DWWD WHPA was approximately 30% less than that used on other District 6 roadways, on average, due to the various efficiency measures used in the DWWD area.

Figure 2.7 Road Salt Usage in the DWWD Wellhead Protection Area vs. District 6 Overall



	2015 - 2016	2016 - 2017	2017 - 2018	2018 -2019	2019 - 2020	2020 - 2021
District 6	39.7	36.9	36.1	29.4	14.9	28.6
DWWD Data	30.2	28.6	20.2	19.6	N/A	20.2

Notes:
1 Salt use data was provided by MassDOT District 6 personnel and is expressed in tons per lane-mile.
2 N/A = Data for the DWWD area was not available for the 2019-20 winter

MassDOT plans to continue to track the effectiveness of various efficiency measures in the DWWD area. Despite these recent reductions, no discernable decreases in sodium and chloride levels have been observed in the DWWD wells. This may be due in part to the longer travel time associated with groundwater and/or perhaps due to the influence of other uses of road salt in the area.

2.4.2 Cambridge Water District

MassDOT recently completed a study for the Hobbs Brook watershed in the Cambridge Water District (CWD) for the purpose of updating the road salt contribution estimates from various watershed sources that were previously developed in a 1985 GEI study. The study scope was developed in consultation with CWD personnel and their drinking water consultant. This study involved both the collection of surface water and groundwater quality data and an analysis of road salt usage and treated areas to estimate the average annual salt load contributions from each of major road salt users.

Groundwater and surface water sampling was initiated in June 2019 and continued to April 2021 at over 20 surface water locations and 15 different groundwater wells. The recent study indicates that the average annual sodium concentration at the downstream reservoir outlet was estimated to be 240 mg/L or nearly 5x higher than that reported in the 1985 study. The study also suggests that overall road salt use in the watershed has increased by over 200%. MassDOT's average annual road salt usage was estimated to be 2,100 tons per year compared to 1,300 tons in the 1985 study), but its share of the overall watershed salt load was estimated to be 47% compared to 72% back in 1985. Road salt usage on municipal roads and parking lots was estimated to account for over 50% of the total watershed road salt usage. This higher usage for these sectors is largely due to updated lane-mileage and parking lot area estimates and annual application rates as compared to that estimated in the 1985 study.[17]

The study results indicate that in order to reduce future sodium concentrations in the downstream reservoir to the MassDEP sodium health advisory of 20 mg/L, road salt use would need to be eliminated on all roadways and parking lot areas. This is probably not a realistic scenario unless there was a wholesale change to using a non-chloride deicer. A potential reduction of 20% or 30% may be more realistic, but even this more moderate goal would require adoption and investment of various efficiency measures and equipment upgrades across all major road salt users.

District 4 has recently reduced its overall district-wide average annual salt usage by approximately 40% on a per lane mile basis by utilizing various efficiency measures compared to what was used between 2001and 2010. Prior to 2011, District 4 was using approximately 38.0 tons per lane mile on an average annual basis based on 10 years of data, as compared to an annual average of 20.3 tons per lane-mile since 2011 while accounting for differences in the average winter weather severity index values between the two periods. As an initial first step. MassDOT will evaluate whether the Lexington and Concord Depots have sufficient liquid deicer storage capacity to support the expanded use of slurry spreaders and the prewetting policy goals. MassDOT will continue to implement additional measures as new equipment/ technology as funding allows. The report recommends other measures as well that could initiate a more holistic approach involving other road salt users in the watershed.

17 Cambridge Water District Report, UMASS Engineering Department prepared for MassDOT, December 2022

2.4.3 Auburn Water District

Since 2016, UMASS Engineering Department personnel, through an interagency service agreement with MassDOT, have been collecting surface and groundwater quality data in Dark Brook in the Town of Auburn and in the Auburn Water District well field. The primary purpose of this study was to establish baseline surface and groundwater quality conditions in the wellfield and use the baseline data to assess the potential changes in water quality that may result from future MassDOT road salt efficiency measures. Extensive surface water and groundwater quality data has been collected and shared with the Auburn Water District.

MassDOT recently has implemented several efficiency measures in this area including the use of slurry spreaders that have been shown to be highly effective in keeping snow and ice from freezing to pavement surfaces and continues to fund the collection of additional water quality data. While MassDOT statewide has reduced its average annual road salt usage by approximately 26% on a tons per lane mile basis, District 3 has reduced its average annual salt usage by approximately 30% over the last four years compared to what was previously used under similar winter weather conditions. It is too early in the implementation phase to detect whether any discernable changes in the water quality data have occurred.

2.4.4 Town of Millbury

MassDOT also conducted a limited desktop study in the Wellhead Protection Area (WHPA) around the Town of Millbury wells to evaluate how much MassDOT roadway area and related salt use might contribute to the elevated sodium concentrations in the Towns' wells relative to other sources and treated areas in the WHPA. Two MassDOT roadways (I-295 and 146) are located within approximately 600 feet of the Town wells, however the analysis indicated that MassDOT roads account for only 33% of the overall pavement area in the WHPA when including municipal and private roads and major commercial parking lots. MassDOT's average annual usage was estimated to account for approximately 60% of the total estimated road salt usage in the WHPA, based on MassDOT's historical average annual salt use and general assumptions on average annual road salt usage on municipal roads and commercial parking lots. The study suggests that MassDOT may be one of the main contributors, but not the only source affecting sodium and chloride levels in the Town wells. Recently, District 3 has reduced its annual salt usage by at least 30% compared to what was used previously under similar winter weather conditions.

A separate USGS Study, investigating groundwater quality in the Blackstone River watershed, found that a hydrologic connection between the river bottom and the Town's main public supply well (Jacques Well) existed during low flow periods. During low flow periods, much of the river flow was found to be comprised of treated effluent from the Upper Blackstone Water Pollution Abatement District Wastewater Treatment Plant in Worcester and was a major contributor to the elevated specific conductance and chloride levels in the Blackstone River as well as the Town wells. The hydrologic connection was identified based on the detected elevated levels of boron, which is a common element found in treated wastewater but not typically abundant in the natural environment.[18] Based on this study, it appears that the sodium and chloride levels in the wells are also influenced by water quality conditions in the Blackstone River during low flow periods as well as other activities within the WHPA.

2.4.5 Wachusett Reservoir

MassDOT conducted a desktop study for the Wachusett Reservoir watershed to estimate the relative amount of treated pavement area and average annual salt usage associated with the various road salt users with the watershed. Using the latest available MassGIS impervious cover, road inventory data, and estimates of average annual road salt usage, MassDOT's operations were estimated to account for approximately 21% of the average annual road salt usage in the watershed while municipal roads and private roads combined were estimated to account for approximately 68% of the estimated salt usage in the watershed. Road salt use on major parking lots were estimated to account for approximately 12% of the overall estimated road salt use in the watershed.

MassDOT's District 3 has focused its available brine trucks for pretreatment and slurry spreaders for roads in the Wachusett Reservoir watershed. While MassDOT statewide has reduced its average annual road salt usage by approximately 26% on a tons per lane mile basis, District 3 has reduced its average annual salt usage by approximately 30% over the last four years compared to what was previously used under similar winter weather conditions.

2.5 Potential Impacts to Surface Waters and Aquatic Resources

In 1988, EPA published recommended Ambient Water Quality Criteria for chloride for the protection of aquatic life based on limited toxicity studies conducted and reported in the literature prior to 1985. The recommended water quality criterion for chronic exposure was established at 230 mg/L based on a four-day average concentration not to be exceeded more than once in a three-year period. The recommended acute water quality criterion was established at 860 mg/L based on a one-hour average concentration not to be exceeded more than once in a 3-year period. Given that these criteria are based on either four-day or one-hour average concentrations, determining if existing chloride levels exceed these thresholds will require continuous measurements at frequent intervals during peak periods to develop representative one-hour and four-day average chloride concentrations.

Secondly, the sampling needs to be done over a sufficiently long-term period to assess the return frequency of any peak concentrations observed and whether these peak concentrations would occur more than once in the specified 3-year return frequency.

In 2015, EPA began the process of researching and potentially updating these protection of aquatic life criteria. In August 2016, EPA requested nominations for

18 Izbicki, J.A. "Water Resources of the Blackstone River Basin, Massachusetts." U.S. Geological Survey Water Resources Investigations Report 93-4167. (2000).

scientific experts to provide advice to the Science Advisory Board in developing these new water quality criteria. Currently, no new criteria have been released.[19]

Recent studies have reported increasing chloride concentrations in rivers and streams throughout the northeast and other snow belt states. The U.S. Geological Survey reports that mean annual chloride concentrations in the Merrimack River increased from 2.9 mg/L in the early 1900s to 24.9 mg/L as measured in 1995.[20] A 2009 study in southeastern New Hampshire revealed that increased salinization of both surface and groundwaters closely correlates to the percentage of road and impervious areas in a watershed.[21] A 2018 study which modeled chloride concentrations in the Merrimack River watershed in New Hampshire and Massachusetts predicted that chronic chloride exceedances above 230 mg/L can be expected to occur in watersheds with only 20% impervious cover. The number of predicted exceedances per year increased linearly for watersheds with up to 60% impervious cover.[22]

A UMass study found that average chloride concentrations streams draining the Wachusett Reservoir generally increased by a factor of 2 or more over a 20-year period. The average chloride concentrations were generally highest in streams with more urbanized watersheds and were close to 300 mg/L in watersheds with 15% to 20% impervious surface coverage. Most streams with less than 10% impervious cover had average chloride concentrations below 100 mg/L.[23]

Historic data in North America show a trend of increasing salinization of freshwater ecosystems over the past 100 years.[24] This increased salinization can have various adverse effects on aquatic life and water quality. Impacts to individual species are generally not lethal but could lead to reduced growth and reproduction. At the ecosystem community level, freshwater salinization reduces biodiversity and promotes communities of primarily salt-tolerant species. In freshwater ecosystems, the increased presence of salt components may alter nutrient and energy flow.

A recent study published in the Journal of Freshwater Biology, reported that wood frogs (Rana sylvatica) living in vernal pools adjacent to roads at various sites in New England had a greater frequency and severity of oedema (bloating of the subcutaneous fluid) especially in early Spring or the breeding season. This effect was linked to

19 U.S. Environmental Protection Agency. "Aquatic Life Criteria and Methods for Toxics." Accessed January 27, 2022. https://www.epa.gov/wqc/aquatic-life-criteria-and-methods-toxics#sab

20 Robinson, K.W., J.P. Campbell, N.A. Jaworski. (2003) "Water Quality Changes in the Merrimack, Blackstone, and Connecticut Rivers During the 20th Century." U.S. Geological Survey Scientific Investigation Report 03-4012.

21 Daley, Michelle L., Jody D. Potter, & William H. McDowell. "Salinization of urbanizing New Hampshire streams and groundwater: effects of road salt and hydrologic variability." *Journal of the North American Benthological Society* 28(4). (2009) 929-940.

22 Zuidema, Shan, et al. "Controls of Chloride Loading and Impairment at the River Network Scale in New England." *Journal of Environmental Quality* (2018). doi:10.2134/jeq2017.11.0418

23 Soper, J.J. Long-term analysis of road salt loading and transport in a rural drinking water reservoir watershed. Journal of Hydrology. 2021. Long-term analysis of road salt loading and transport in a rural drinking water reservoir watershed - ScienceDirect

24 Kaushal, Sujay S. et al. "Novel 'chemical cocktails' in inland waters are a consequence of the freshwater salinization syndrome." *Philosophical Transactions Royal Society B* 374 (2019). http://dx.doi.org/10.1098/rstb.2018.0017

increased conductivity in vernal pools, which was likely due to road salt in runoff. Depending on the severity of bloating, the mobility of wood frogs and the ability to breed could be adversely affected.[25]

In lakes and ponds, increasing salinization can have varying effects on trophic levels. Salinization may increase internal nutrient loading from bottom sediments as denser saline water gathers in the hypolimnion in may limit oxygen circulation from the upper surface waters and cause oxygen depletion, which can lead to phosphorus release from lake sediments. In some lakes this has been shown to spur a trophic cascade where fewer zooplankton results in higher concentrations of phytoplankton and ultimately algae blooms. This may further contribute to algae blooms, especially under circumstances where salinization has reduced zooplankton populations.[26]

Road salts also have the potential to mobilize heavy metals from roads and surrounding soils. Many organic compounds which are typically found in upper layers of the soil horizon more readily bind to sodium, calcium, and magnesium than most heavy metals. Due to ion exchange, when these soils receive runoff with high salt ion concentration, the salt ions can displace metals such as cadmium, copper, and zinc which had previously been bound to these soils.

Chloride complexes further increase metal mobility and when metals reach mineral-based soils in lower horizons with little organic material, they can move quickly through the soil into surface or groundwaters. In aquatic systems, increased presence of metals can alter ecosystem services in many ways, including reduced diversity of macroinvertebrates, altered food-webs, and microbial respiration.[27]

A 2019 USGS study in Vermont analyzed sodium and chloride concentrations in over 4,300 private wells and found most samples had chloride concentrations below 5 mg/L and only 1% of the samples had chloride concentrations greater than 250 mg/L. The study found that the elevated chloride concentrations were generally observed near paved roads, urban land area, and higher population densities. Although higher chloride concentrations were found near urban land areas, the primary source of the elevated chloride levels was not clear. As other research has reported, surface waters and groundwater in densely populated, urban areas are more likely to have elevated chloride concentrations due to various sources, including wastewater discharge or fertilizer applications.[28]

2.5.1 MassDEP Ambient Water Quality Data

Massachusetts DEP routinely collects water quality data in various water bodies order to assess water quality conditions and identify waters that may be impaired because of

25 Brady, S.P., et. al. 2022. Salted Roads Lead to Oedema and Reduced Locomote Function in Amphibian Populations. Journal of Freshwater Biology. Vol. 67. Issue 7

26 Hintz, William D. & Rick A. Relyea. “A review of the species, community, and ecosystem impacts of road salt salinization in fresh waters.” *Freshwater Biology* 64: (2019) 1081-1097.

27 Schuler, Matthew S. & Rick A. Relyea. “A Review of the Combined Threats of Road Salts and Heavy Metals to Freshwater Systems.” *BioScience* 68: (2018) 327-335.

28 U.S. Geological Survey & State of Vermont Department of Health. “Groundwater Chloride Concentrations in Domestic Wells and Proximity to Roadways in Vermont, 2011-2018.” Open-File Report 2019-1148. April 2020.

exceedances of the state's water quality standards. In water bodies considered impaired, additional data collection or investigations may be conducted to identify the source or the extent of elevated levels.

Specific conductance (SC) is often used as a surrogate parameter for chloride as they are typically highly correlated such that chloride concentrations expressed in mg/L can often be calculated from SC expressed in µS/cm based on a linear regression equation. Based on paired SC levels and chloride data from over 240 stream and river stations, MassDEP estimates that acute and chronic chloride criteria of 860 and 230 mg/L are likely exceeded at SC readings greater than 3,193 and 904 µS/cm based on 4-day and 1-hour average SC levels, respectively. This is based on a regression equation correlating observed SC levels with chloride concentrations $Y = 0.2753X - 18.987$ ($R2 = 0.945$, $P < 0.001$), where Y = chloride concentration (mg/L) and X = observed SC level (µS/cm). MassDEP uses the SC level and chloride relationship as means to identify water bodies where chloride levels may exceed surface water quality standards and be considered water quality impaired due to elevated levels. See MassDEP's most recent list of chloride impaired waters in the next section.

Table 2.8 provides summary statistics of MassDEP's observed SC levels in various streams and rivers collected through 2017 with elevated SC levels (>800 µS/cm) based on both discrete measurements using handheld meter (attended), or continuous measurements with a deployed water quality data logger (unattended). An average SC threshold of 800 µS/cm was selected as a potential level of concern based on the SC and chloride relationship discussed above.

Table 2.8 Summary Statistics for Water Bodies with Elevated Specific Conductance Levels Based on MassDEP Data

Waterbody	Collection Method	Station ID	Year Collected	Average Specific Conductivity (µS/cm)	No. of Samples (n)
Blackstone Watershed					
Unnamed Tributary	Attended	W2062	2008	1,018.7	7
Buzzards Bay Watershed					
Acushnet River	Attended	Acush01	2005	4,220.1	7
E. Branch Westport River	Attended	EBW00	2005	3,621.0	5
Cape Cod Watershed					
Quivett Creek	Attended	W1922	2009	1,650.3	3
Charles River Watershed					
Beaver Brook	Attended	MAP2-675	2015	1,094.3	3
Beaver Brook	Attended	W1143	2007	872.8	10
Beaver Brook	Attended	W1144	2007	832.5	9
Charles River	Attended	MAP2-652	2015	842.0	3
Concord (SuAsCo) Watershed					
Beaver Brook	Attended	MA09A-107	2010	961.0	5
Cold Harbor Brook	Attended	MA09A-105	2010	801.0	6
Coles Brook	Attended	MA09A-172	2010	1,277.8	6
River Meadow Brook	Attended	MAP2-646	2015	835.0	3
River Meadow Brook	Attended	Station3	2015–2016	1,098.2	9
River Meadow Brook	Attended	Station4	2015–2016	1,071.2	9

Waterbody	Collection Method	Station ID	Year Collected	Average Specific Conductivity (µS/cm)	No. of Samples (n)
River Meadow Brook	Unattended	Station3	Oct '15–Dec '15	1,032.0	2,782
River Meadow Brook	Unattended	Station3	Dec '15–Sep '16	1,062.0	13,381
River Meadow Brook	Unattended	Station4	Oct '15–Dec '15	1,075.0	2,781
River Meadow Brook	Unattended	Station4	Dec '15–Sep '16	1,026.0	12,972
Unnamed Tributary	Attended	MA09A-154	2010	813.7	6
Unnamed Tributary	Attended	MAP2-696	2015	1,102.3	3
Mystic Watershed					
Aberjona River	Attended	Aber1	2009	937.5	6
Aberjona River	Attended	ABR006	2009	834.3	6
Aberjona River	Attended	ABR028	2009	954.0	6
Alewife Brook	Attended	ALB007	2009	1,050.8	6
Cummings Brook	Attended	Cumm1	2009	827.2	5
Mill Brook	Attended	MAP2-414	2013	828.0	3
Mill Brook	Attended	MIB001	2009	957.5	6
Mystic River	Attended	Myst3	2009	993.7	6
North Coastal Watershed					
Crane Brook	Attended	CR02	2007	826.4	9
Mill River	Attended	MR01	2007	810.3	9
Proctor Brook	Attended	MA09A-143	2010	906.3	6
Saugus River	Attended	MA09A-159	2010	906.3	6
Saugus River	Attended	MAP2-677	2015	1,062.7	3
Shute Brook	Attended	SB01	2007	863.4	9
Shawsheen Watershed					
Spring Brook	Attended	MAP2-714	2015	1,009.0	1
Unnamed Tributary	Attended	PB00	2005	834.0	4
Vine Brook	Attended	MAP2-682	2015	1,006.3	3
Westfield Watershed					
Potash Brook	Attended	West01	2016–2017	834.2	5
Potash Brook	Unattended	West01	Nov '16–Jul '17	875.0	11,082
Weymouth & Weir Watershed					
Town Brook	Attended	TB01	2009	978.6	5
Town Brook	Attended	TB02	2009	1,025.5	4

Source: MassDEP Division of Watershed Management, Watershed Planning Program. Data base on MassDEP web site includes water quality data collected through 2017. https://www.mass.gov/guides/water-quality-monitoring-program-data

2.5.2 Chloride Impaired Water Bodies in Massachusetts

As shown in **Table 2.9**, MassDEP identified 24 water bodies as being chloride-impaired throughout the state according to the Final 2018/2020 Integrated List of Waters.[29] This includes 11 additional water body segments that were not on the 2016 Integrated List and 18 additional water body segments that were not on the 2014 Integrated List,

29 Final Massachusetts Integrated List of Waters for the Clean Water Act 2018/2020 Reporting Cycle, EPA Approved in February 2022. https://www.mass.gov/doc/final-massachusetts-integrated-list-of-waters-for-the-clean-water-act-20182020-reporting-cycle/download

which was used in the 2017 ESPR. Most of these impaired water bodies are in densely populated and developed areas in the central and eastern portions of the state.

Figures 2.8 and **2.9** illustrate the locations of several chloride impaired water body segments in District 3 (Central Mass) and Districts 4 and 6, respectively. Although many of impaired segments are near major travel corridors and major MassDOT roadways, as shown on these maps, these impaired segments often originate upstream of the MassDOT road in residential and commercial land use areas indicating that other road salt users or sources are contributing to these impairments. In these cases, the designated impairment is presumably due to sampling results from both upstream and downstream locations of the nearby MassDOT roadways. More detailed watershed maps for each of the impaired water body segments can be found in **Appendix C**.

Recently added chloride impaired water bodies include Gates Brook, Scarletts Brook and two unnamed tributaries in the Boylston and West Boylston areas that drain to the Wachusett Reservoir. In the Mystic River watershed, segments of the Aberjona River, Alewife Brook, and the Little River have been added to the 2018/2020 list. These water body segments are near major MassDOT roads of I-95 and I-93. but are also in the relatively densely developed areas of Cambridge, Somerville, and Medford. In the Cambridge River watershed, Hobbs Brook is a tributary of the impaired Cambridge Reservoir. The Sawmill Brook watershed includes a section of the VFW Parkway in Newton owned by DCR, but MassDOT provides winter maintenance of the road. In the Blackstone River watershed, Dark Brook and associated unnamed tributaries are located near the Interstates 90 and 290 in Auburn.

Table 2.9 Chloride Impaired Water Bodies in Massachusetts, 2018/2020 Final 303(d) List

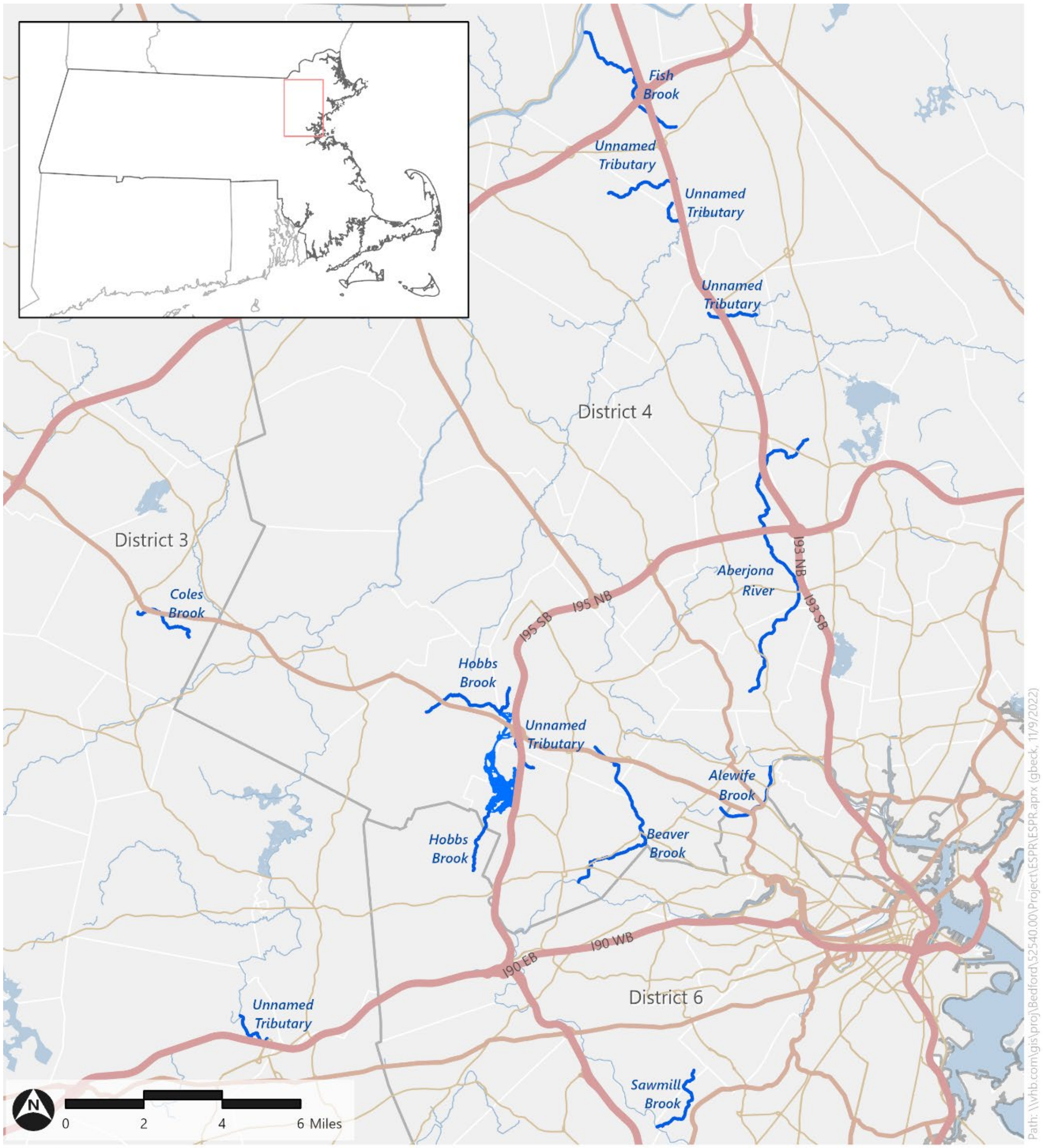
Waterbody	Assessment Unit ID	Description	Change from 2016 305b/303d Assessment
Blackstone Watershed			
Dark Brook	MA51-16	Headwaters, outlet Eddy Pond, Auburn to mouth at confluence with Kettle Brook, Auburn (MA51004).	Unchanged
Unnamed Tributary	MA51-08	(Also known as "Mill Brook") Headwaters, outlet Indian Lake in Worcester to confluence with Middle River (downstream of the railroad spur bridge west of Tobias Boland Way), Worcester	Added
Unnamed Tributary	MA51-38	Unnamed tributary to Dark Brook, near the Route 90, 290EB, 395SB, 12NB interchange, to confluence with the Dark Brook south of Water Street, Auburn (culverted).	Unchanged
Boston Harbor: Mystic Watershed			
Aberjona River	MA71-01	Just south of Birch Meadow Drive, Reading to inlet Upper Mystic Lake at Mystic Valley Parkway,	Added
Alewife Brook	MA71-20	From emergence north of Cambridge Park Drive, Cambridge to confluence with Mystic River, Arlington/Somerville: (MA71-04).	Added
Little River	MA71-21	Headwaters, outlet of Little Pond, Belmont to 150 feet upstream of the confluence with Alewife Brook, Cambridge (MA71-04).	Added

Waterbody	Assessment Unit ID	Description	Change from 2016 305b/303d Assessment
Charles River Watershed			
Beaver Brook	MA72-28	Headwaters, perennial portion north of Route 2, Lexington to confluence with the Charles River, Waltham (culverted ~2900 ft).	Added
Cambridge Reservoir	MA72014	Waltham/Lincoln/Lexington	Unchanged
Cambridge Reservoir, Upper Basin	MA72156	Lincoln/Lexington	Unchanged
Hobbs Brook	MA72-45	Headwaters west of Bedford Road, Lincoln to inlet Cambridge Reservoir, Upper Basin, Lincoln	Unchanged
Hobbs Brook	MA72-46	From outlet Cambridge Reservoir, Waltham to mouth at confluence with Stony Brook, Weston.	Unchanged
Sawmill Brook	MA72-23	Headwaters, Newton to confluence with Charles River, Boston.	Unchanged
Unnamed Tributary	MA72-47	Headwater tributary west of Forbes Road, Lexington to mouth at confluence with Hobbs Brook, Lincoln.	Unchanged
Unnamed Tributary	MA72-48	Headwater tributary northeast of the Trapelo Road/Smith Street intersection in Lexington to mouth at inlet Cambridge Reservoir,	Unchanged
Sudbury, Assabet, Concord Watershed			
Coles Brook	MA82B-22	Headwaters, east of Francine Road, Acton to mouth at confluence with Fort Pond Brook, Acton.	Added
Ipswich Watershed			
Unnamed Tributary	MA92-26	Unnamed tributary to Martins Brook, from wetland west of I-93/ Rte 125 intersection to confluence Martins Brook, Wilmington.	Unchanged
Merrimack Watershed			
Fish Brook	MA84A-40	Headwaters, east of I-93 and Greenwood Road in Andover to confluence with Merrimack River at Fish Brook Dam (MA02265),	Unchanged
Nashua Watershed			
Gates Brook	MA81-24	Headwaters west of Prospect Street, West Boylston to mouth at inlet Wachusett Reservoir (Gates Cove),	Added
Scarletts Brook	MA81-25	Headwaters west of West Boylston Street (Route 12), to mouth at confluence with Gates Brook, West Boylston	Added
Unnamed Tributary	MA81-49	Unnamed tributary from Carrolls' Pond outlet, West Boylston to mouth at inlet Wachusett Reservoir, West Boylston.	Added
Unnamed Tributary	MA81-54	Unnamed tributary, west of Route 140, West Boylston to mouth at inlet Wachusett Reservoir (Stillwater Basin), West Boylston.	Added
Shawsheen Watershed			
Unnamed Tributary	MA83-15	Also known as "Pinnacle Brook" small stream from wetland east of I-93, Andover, to confluence with Meadow Brook, Tewksbury.	Unchanged
Unnamed Tributary	MA83-20	Unnamed intermittent tributary in Tewksbury, from Dascomb Road, Andover to confluence with Shawsheen River.	Unchanged

Source: Massachusetts Integrated List of Waters for 2018/2020 Reporting Cycle, February 2022. https://www.mass.gov/doc/draft-massachusetts-integrated-list-of-waters-for-the-clean-water-act-20182020-reporting-cycle/download

Note: One Assessment Unit removed since 2016 IR (MA51-12)

Figure 2.8 MassDEP Designated Chloride Impaired Water Bodies in Districts 4 and 6

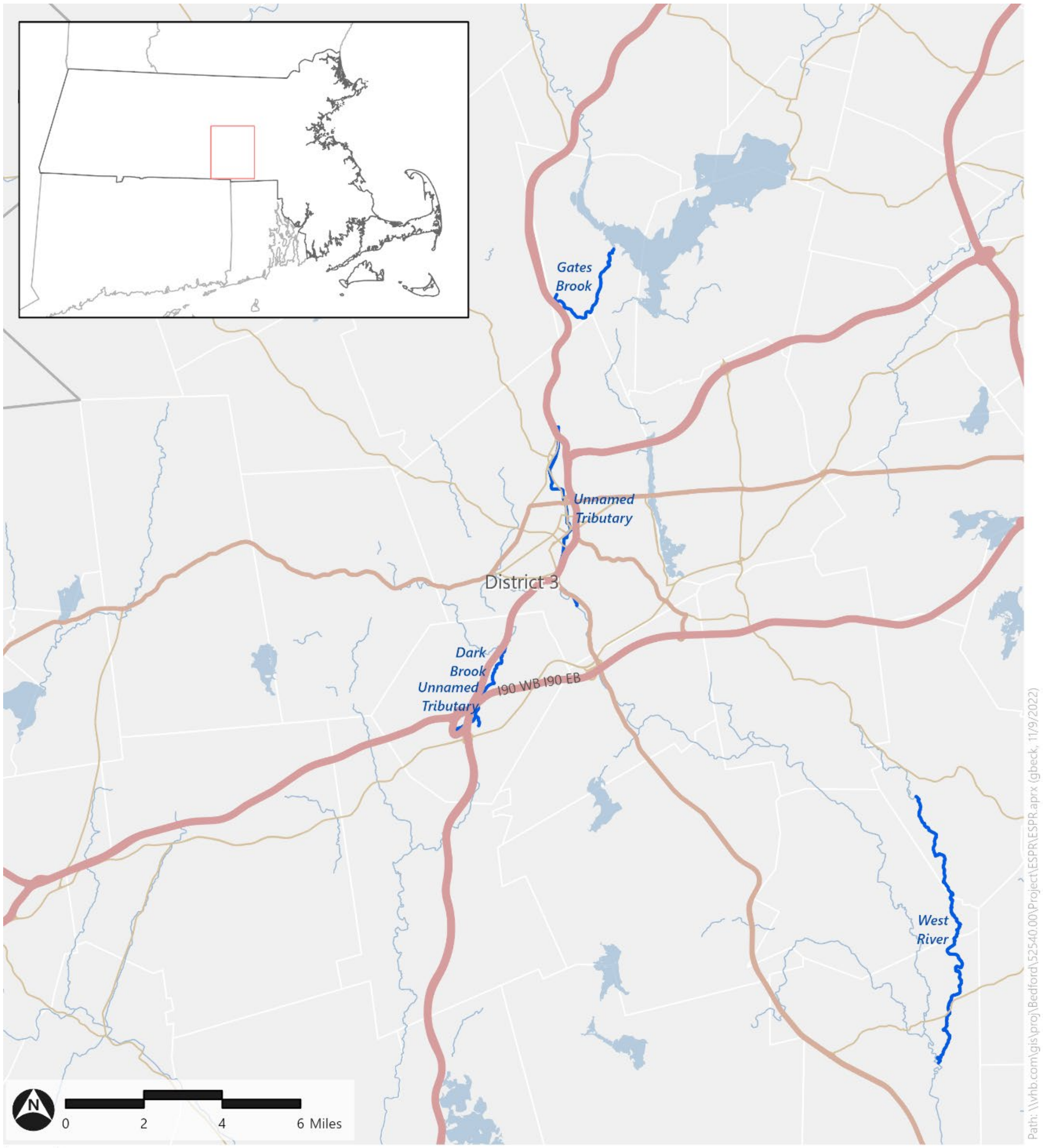


Legend

- Chloride Impaired Streams & Rivers
- Chloride Impaired Lakes
- Interstate
- Rural or urban principal arterial
- Rural minor arterial or urban principal arterial
- MassDOT Districts

Source: MassDEP, MassDOT, MassGIS, VHB

Figure 2.9 MassDEP Designated Chloride Impaired Waters in District 3



Legend

- Chloride Impaired Streams & Rivers
- MassDOT Districts
- Interstate
- Rural or urban principal arterial
- Rural minor arterial or urban principal arterial

Source: MassDEP, MassDOT, MassGIS, VHB

2.6 Potential Effects of Road Salt Use on Other Environmental Resources

The following provides a general description of other sensitive environmental resources in the Commonwealth including Areas of Critical Environmental Concern (ACEC) and Priority Habitats and Natural Communities, as designated by the Massachusetts Natural Heritage and Endangered Species Program (NHESP), a division of the Massachusetts Division of Fisheries and Wildlife. Other road salt related environmental effects discussed herein include the potential effects on roadside vegetation, cranberry bog and maple syrup production and the use of winter sand, although state or site-specific data pertaining to these issues is limited.

2.6.1 Areas of Critical Environmental Concern and Priority Habitat Areas

ACECs are designated environmental resource areas that are protected and regulated under state regulations §301 CMR 12.00 and are considered to have a unique set of natural and human resource values worthy of protection. Designating an area as an ACEC requires a five-step process including a formal nomination, a review by the Secretary of the Executive Office of Energy and Environmental Affairs (EEA), public hearings, a decision by the Secretary, and publication of notice in the Environmental Monitor. The designation process determines whether the nominated area is of regional, state, or national importance and/or contains significant ecological systems with critical interrelationships among several components. The most recent ACEC's include the Three Mile River Watershed ACEC that was added in August 2008 and the Upper Housatonic River ACEC that was added in March 2009.

Priority Habitats as identified by the Natural Heritage & Endangered Species Program (NHESP) represent another significant ecological area regulated within the state of Massachusetts. Priority Habitat is based on the known geographical extent of habitat for all state-listed rare species, both plants and animals, and is codified under the Massachusetts Endangered Species Act (MESA). Habitat alteration within Priority Habitats may result in a take of a state-listed species and is subject to regulatory review by the NHESP. Priority Habitat maps are also used to determine whether a proposed project warrants added review. There are also "Estimated Habitat Areas of Rare Wildlife," which are a subset of Priority Habitat areas and represent the geographical extent of the habitat of state-listed rare wetland wildlife and are codified under the Wetlands Protection Act. The NHESP also identifies a third key type of ecological area known as "Priority Natural Communities." These areas are identified as having natural communities that are considered uncommon and/or exemplary within the state.

As shown in Table 2.10, thirty (30) designated ACEC's have been established in the State of Massachusetts encompassing a total area of approximately 268,000 acres. The Squannassit ACEC is the largest ACEC consisting of approximately 37,420 acres in size and is in the central and northern sections of MassDOT's District 3 along the Nashua

River from Harvard and Lancaster north to New Hampshire. The Squannassit ACEC is adjacent to two other ACEC's, the Central Nashua River Valley ACEC and the Petapawag ACEC within the Nashua River Corridor. The Pocasset River ACEC, located in District 5, is the states' smallest ACEC and is comprised of 160 acres of river and estuarine habitat located on the eastern shore of Buzzards Bay and in the Town of Bourne. District 5 has more ACEC's than any other district due to the unique habitat and hydro-geologic conditions of Cape Cod and southeastern coastal region.

The NHESP GIS mapping data (as of October 2021) indicates that approximately 2,158 unique areas are designated as Priority Habitat for Rare Species locations in the Commonwealth, and 952 distinct areas designated as Natural Communities.

Table 2.10 Number of Designated Environmentally Sensitive Areas within each District

MassDOT District	ACECs	NHESP Priority Habitats	NHESP Natural Communities
1	5	504	233
2	0	356	221
3	5	295	112
4	4	205	50
5	16	780	327
6	5	41	16
Total	30	2,158	952

Table 2.11 lists the various ACECs within each District that are located directly adjacent to or traversed by a MassDOT roadway. Each District, except District 2, has at least one designated ACEC that borders or is traversed by a MassDOT roadway. Districts 1, 3, and 6 have five designated ACECs, while District 4 has 4 ACECs and District 5 has sixteen ACECs that are adjacent to or traversed by a MassDOT highway.

Table 2.11 ACECs Located Adjacent to or Traversed by a MassDOT Roadway

District	ACEC Name	MassDOT Roadways
1	Schenob Brook Drainage Basin	Routes 7, 7A, and 41
	Hinsdale Flats Watershed	Routes 8 and 143
	Karner Brook Watershed	Routes 7, 23, and 41
	Kampoosa Bog Drainage Basin	I-90, Route 7
	Upper Housatonic River	Route 7
2	None	--
3	Cedar Swamp	I-495, I-90, Route 140,135
	Central Nashua River Valley	I-190, Routes 2, 70, 110, and 117
	Miscoe, Warren, and Whitehall Watersheds	I-90, Route 140
	Petapawag	Routes 40, 111, 113, and 119/225
	Squannassit	Routes 2, 2A, 13, 31, 111, 113, 119, 225
4	Rumney Marshes	Routes 1A, 60, 107
5	Great Marsh	Routes 1, 1A, 133
	Three Mile River Watershed	I-495, Routes 44, 123, 138, and 140
	Canoe River Aquifer	I-495, Routes 24, 106, 123, and 138

District	ACEC Name	MassDOT Roadways
	Fowl Meadow and Ponkapoag Bog	I-95, Route 1
	Hockomock Swamp	I-495, Routes 24, 104, 106, 123, 138
	Weir River Estuary	Route 228
	Pleasant Bay	Route 28
	Sandy Neck Barrier Beach System	Route 6A
	Waquoit Bay	Route 28
	Herring River Watershed	Routes 3 and 6
	Ellisville Harbor	Route 3A
	Bourne Back River	Route 28
	Cranberry Brook Watershed	Route 37
6	Weymouth Back River	3A
6	Wellfleet Harbor	Route 6
6	Inner Cape Cod Bay	Route 6
6	Rumney Marshes	Routes 1A, 145
6	Neponset River Estuary	I-93, Routes 3A, 203

Of the five ACECs located in District 1, Kampoosa Bog may be the most studied with several field investigations completed in the last several years to assess the potential effect of road salt on vegetation species diversity. As discussed below, both I-90 (Massachusetts Turnpike) and Route 7 directly border the edges of the Bog. See Section 2.6.2 below for additional details.

In District 3, Cedar Swamp ACEC and the Miscoe, Warren, and Whitehall Watershed ACECs are very close to several major interstate roadways including I-495 and I-90. District 3 includes the Central Nashua River Valley ACEC that is adjacent to a segment of I-190 along its westernmost boundary. This ACEC contains approximately 20-miles of the North Nashua and Nashua Rivers. The Petapawag and Squannassit ACECs also have several state highways that traverse through them, but these ACECs are relatively large and are located within a less densely developed, rural portion of the state. The Cedar Swamp ACEC is located adjacent to the I-90/495 Interchange area.

District 4 has two ACEC areas including the Rumney Marsh and the Great Marsh ACEC that are bisected by MassDOT highways. Both these ACECs are in the coastal region of the state and in highly urbanized areas. Rumney Marsh is located within the Towns of Lynn, Revere, and Saugus, and extends south into Boston and Winthrop as part of District 6. This ACEC is bordered by Routes 1A, 107, 145, and 60. Given that both ACECs are tidally influenced, they are less likely to be affected by MassDOT SICP activities.

District 5 and portions of District 6 have several ACECs (Fowl Meadow, Ponkapoag Bog, and Neponset River Estuary) that are adjacent to segments of I-95 and/or I-93. I-495 and several other secondary state routes are located within the watersheds of the Canoe River Aquifer, the Hockomock Swamp, and the Three Mile River ACECs. These ACEC's s are in areas with relative high densities of impervious area.

The Canoe River Aquifer was designated as a Sole Source Aquifer by the EPA in 1993 based on the assumption that the watershed area supplies 50% of the drinking water consumed within the area overlying the aquifer. The aquifer currently provides drinking water for approximately 66,000 people within four towns. As stated in the EPA's 1993 Notice of Designation (58 FR 28402), the Canoe River Aquifer was considered vulnerable to elevated salt concentrations due to its geological characteristics and nearby land use activities. The Canoe River Aquifer is a stratified drift aquifer consisting of shallow sand and gravel deposits.

2.6.2 Kampoosa Bog, Stockbridge and Lee

The Kampoosa Bog, located adjacent to Interstate 90 in the Towns of Stockbridge and Lee in District 1 has been the subject of concern and research relative to the potential road salt effects on vegetation. Approximately 2 miles of I-90 directly as well as a portion of Route 7 borders the northerly and easterly limits of Kampoosa Bog maintained by MassDOT (refer to Figure 2.10).

The Kampoosa Bog is a large wetland complex, approximately 1,350 acres in size, comprised of a calcareous (calcium-rich) basin fen with red maple swamp areas and open water area that was designated as an ACEC in 1995 after being nominated by the Stockbridge Land. The bog is also one of several areas in the Commonwealth being continually monitored by several researchers.

Dr. Julie Richburg of the UMass Department of Natural Resources Conservation was first to document the presence and spread of Phragmites (Phragmites australis) along the Turnpike right-of-way. Phragmites is an invasive, salt tolerant plant species that is highly aggressive and opportunistic that spreads via seeds or rhizomes and can quickly colonize disturbed areas especially if they exist nearby or are brought in with new soils as fill material. Once established, Phragmites can out-compete native species causing adverse effects on habitat conditions and native plant diversity. The study results were published in a report entitled "Effects of Road Salt and Phragmites australis Invasion on the Vegetation of a Western Massachusetts Calcareous Lake-Basin Fen."[30]

Another study led by Dr. Amy Rhodes of Smith College evaluated the water chemistry in surface runoff and shallow and deep groundwater flow within the wetland. The study found that water chemistry was influenced by surface and shallow ground water flow from the I-90 area. The study also found that significant amounts of salt-was exported from the bog following large rain and snowmelt events during non-winter months. Data showed that more than half of the estimated annually applied sodium and chloride applied to I-90 was flushed out of the watershed from March to May.[31]

A subsequent study completed in 2021 provides updated sodium (Na+) and chloride (Cl-) levels in the Kampoosa Bog. Although the effect of road salt use on MassDOT roadways is still not fully understood given the various hydrologic variables, the following summarizes key findings and suggestions for continued ongoing monitoring:

30 Richburg, Julie A., William A. Patterson III, & Frank Lowenstein. "Effects of road salt and *Phragmites australis* invasion on the vegetation of a western Massachusetts calcareous lake-basin fen." *Wetlands* 21 (2001): 247-255.

31 Rhodes, Amy L. & Andrew J. Guswa. "Storage and release of road-salt contamination from a calcareous lake-basin fen, western Massachusetts, USA." *Science of the Total Environment* 545 – 546 (2016): 525 – 545. http://dx.doi.org/10.1016/j.scitotenv.2015.12.060

» Greater fluctuations and higher peak Na+ and Cl- concentrations were recently detected compared to 1990s, but average concentrations had little change

» Higher Na+ and Cl- levels in groundwater were generally near the I-90 roadway

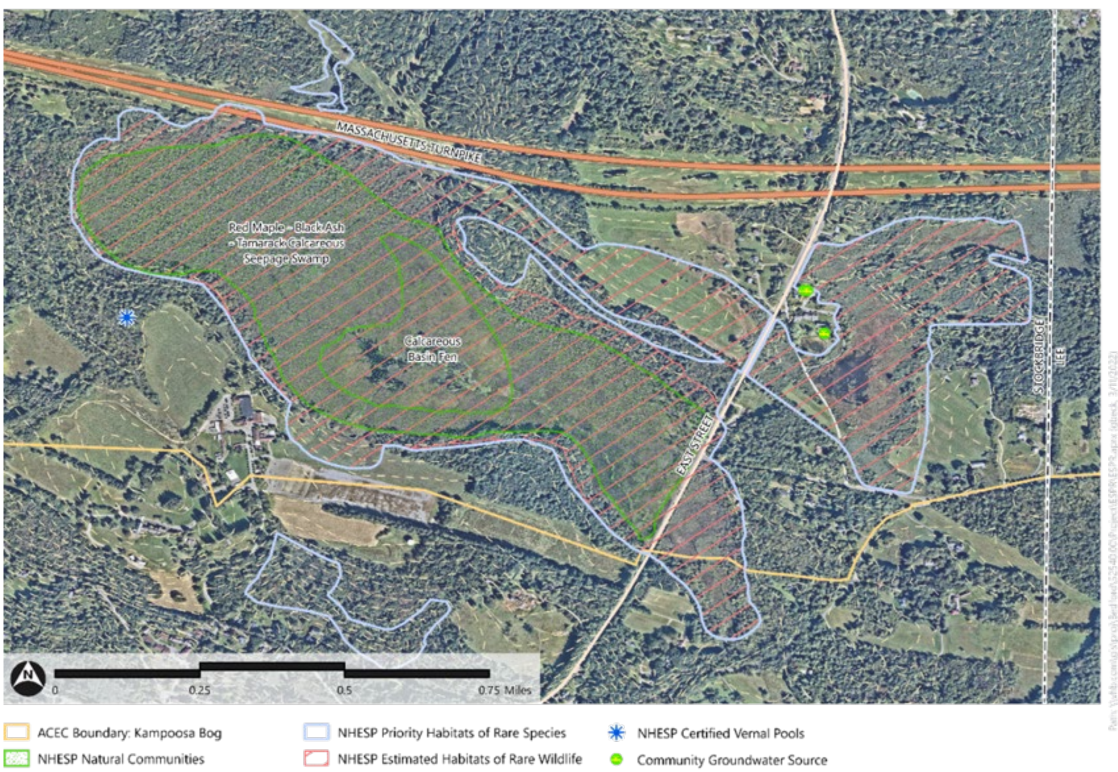
» The bog was a net exporter of Cl- in 3 out of 4 seasons, however, the entire Kampoosa Bog watershed generally retains chloride.

» The study suggests that existing vegetation communities would likely be maintained if Cl- levels in the bog were limited no more than 77 to 95 mg/L, which is higher than the previously recommended level of 54 mg/L.[32]

The study results indicate that even if future road salt applications were eliminated, elevated levels in groundwater and in the bog may continue for some time as the salt retained in the surrounding watershed are released and reach a new equilibrium.[33]

MassDOT has been using AVL/GPS technology to electronically track road salt usage along the roadway sections adjacent to the Kampoosa Bog, NHESP, as described in their comments in their March 12, 2021, letter following review of the 2022 Scope of Work (SOW) Plan, supports the use of vehicle and material tracking technology.

Figure 2.10 Kampoosa Bog



Source: Nearmap, MassGIS, MassDOT, VHB

32 Richburg, Julie A., William A. Patterson III, & Frank Lowenstein. "Effects of road salt and *Phragmites australis* invasion on the vegetation of a western Massachusetts calcareous lake-basin fen." *Wetlands* 21 (2001): 247-255.

33 Rhodes, Amy L., Paul Wetzel, & Wayne Ndlovu. "Kampoosa Bog Water Quality and Vegetation Composition Review and Analysis." Final Report. (March 31, 2021).

2.6.3 Potential Salt Impacts on Roadside Vegetation

Deicing chemicals used by MassDOT include sodium chloride, calcium chloride, and magnesium chloride in various forms during various weather conditions. Sodium and chloride are the two main ions that can negatively affect roadside vegetation. Roadside plants are potentially exposed to road salt inputs through two different avenues: 1) root absorption, i.e., the uptake of salt contained in soil and soil water, and 2) salt spray on branches and foliage due to tire splash and wind. In the winter months, salt can build up on branches and twigs of deciduous trees and invade living tissue through existing leaf scars. Although salt spray is generally considered less damaging than root absorption, since it does not usually result in outright death, it has been known to stunt bud development, flowering, and foliar growth. A 2021 Connecticut study found sodium levels in forested wetlands near roadways persisted for several months after the final winter road salt applications. High concentrations of sodium ions tended to replace other key nutrients (Mg, K) in plant tissues, although not at levels significant enough to lead to plant mortality.[34,35]

Root adsorption and salt spray can result in plant tissue damage due to a potential disruption in the ion exchange and an imbalance in the osmotic pressure across cell membranes. The excess sodium and chloride ions end up desiccating cells, leaving plant tissues in a vulnerable or weakened state.[36] This osmotic imbalance can also occur in the root zone making it difficult for plants to draw water from the soil leading to additional drought-related stress. The typical symptoms of these effects generally manifest as browning of foliage, premature defoliation, diminished flowering and shoot growth and sometimes mortality, under severe conditions. Most plant damage is confined within ten meters (~30 feet) of the road and minimal effects were generally observed beyond 30 meters (~100 feet) based upon observations and plant tissue analysis conducted along roadways in Massachusetts.[37]

Recent studies in the state of Colorado concluded that magnesium chloride may be less detrimental than sand and other road salts such as sodium chloride. The study focused on current application rates and concluded that the effects of magnesium chloride are not likely to extend beyond 60 feet from the roadway. A study by the California Department of Transportation found that magnesium chloride is less likely to affect roadside vegetation because it is applied as a liquid and at a lower concentration level as compared to straight sodium chloride when applied in solid form.[38]

34 Walker, Samantha E. et al. "Road salt inputs alter biogeochemistry but not plant community composition in exurban forested wetlands." *Ecosphere* 12(11). (2021). https://doi.org/10.1002/ecs2.3814

35 Tiwari, Athena & Joseph W. Rachlin. "A Review of Road Salt Ecological Impacts." *Northeastern Naturalist* 25(1): 123-142. (2018).

36 Berkheimer, S.F. & E. Hanson. "Deicing salts reduce cold hardiness and increase flower bud mortality of highbush blueberry." *Journal of the American Society for Horticultural Science* 131 (1). (2006): 11-16.

37 Bryson, G.M and A.V. Barker. "Sodium Accumulation in Soils and Plants along Massachusetts' Roadsides." *Communications in Soil Science and Plant Analysis* 33(1-2): 67-78. (2002).

38 American Association of State Highway and Transportation Officials (AASHTO) Standing Committee on Highways. "Revised Chapter 8, Winter Operations and Salt, Sand and Chemical Management, of the Final Report on NCHRP 25-25(04)." Revised April 2, 2013. https://sicop.transportation.org/wp-content/uploads/sites/36/2017/07/NCHRP_20-07318_Final-Report-2013.pdf

Magnesium and calcium were reported to have little to no effect on vegetation since most plants are capable of processing high amounts of these ions.[39]

Excess sodium in roadside soils can also contribute to increased vehicle collisions with wildlife, as road salt along roadways attracts wildlife which ingest salt residue from the road surface when they become salt deficient due to a lack of available food sources. When this occurs, the frequency of road kills generally increases.[40]

2.6.4 Potential Salt Impacts on Cranberry Bog Production

According to the 2017 USDA Agricultural Census, Massachusetts has a total of 13,555 acres of land in cranberry production. Cranberries account for 16% of the agricultural sales in the state, totaling $59.5 million in 2017.[41]

Cranberry bogs by their very nature can be susceptible to road salt use on roadways because they rely on surface water drainage to support the production of cranberries. As roadways are extended or widened in the southeast corner of the state such as Route 25 in Wareham, consideration must be given as to how road runoff will be directed and whether it has the potential to enter nearby cranberry bogs.

In 2005, the UMASS Cranberry Research Station located in the Town of Wareham evaluated the effects of long-term exposure of elevated levels of sodium and chloride in irrigation water had on cranberry growth and production. The study indicated that plants exposed to chloride concentrations of 100 mg/L showed minor declines in plant growth. At 250 mg/L, plant growth was inhibited, and flowering was suppressed. Cranberry growth was visibly suppressed at 500 mg/L Cl, and at higher concentrations, plants exhibited severe leaf drop and eventual death.[42]

The studies showed that chloride concentrations greater than 250 mg/L resulted in significant effects, although some recovery occurred after desorption. Irrigation water with chloride concentrations at 250 mg/L or greater would be cause for concern and levels of 500 mg/L had more definitive negative effects on growth in soil-free culture.[43]

---

39 Casey, P.C., C.W. Alwan, C.F. Kline, G.K. Landgraf, K.R. Linsenmayer. "Impacts of Using Salt and Salt Brine for Roadway Deicing." CTC & Associates LCC. Prepared for Idaho Department of Transportation Research Program, Division of Highways, Resource Center. June 2014.

40 American Association of State Highway and Transportation Officials (AASHTO) Standing Committee on Highways. "Revised Chapter 8, Winter Operations and Salt, Sand and Chemical Management, of the Final Report on NCHRP 25-25(04)." Revised April 2, 2013. https://sicop.transportation.org/wp-content/uploads/sites/36/2017/07/NCHRP_20-07318_Final-Report-2013.pdf

41 U.S. Department of Agriculture National Agricultural Statistics Service. 2017 Census of Agriculture, Massachusetts State Data. Market Value of Agricultural Products Sold , and Value-Added Products: https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_State_Level/Massachusetts/

42 University of Massachusetts Cranberry Station, College of Natural Resources and the Environment, East Wareham, MA. "Cranberry Production: A Guide for Massachusetts." December 2008. https://ag.umass.edu/sites/ag.umass.edu/files/pdf-doc-ppt/cranberry_production_guide.pdf

43 DeMoranville, C. "Salt Effects on Cranberry Soils, Plant Growth, and Productivity." Final Report. Prepared for the Executive Office of Transportation. University of Massachusetts Amherst Cranberry Station. Wareham, Massachusetts. June 30, 2005.

2.6.5 Potential Salt Impacts on Maple Sugar Production

In general, elevated salt concentrations in soils can lead to decreased water uptake which can cause tree stress similar to that observed during drought conditions. Although the maple syruping industry could be affected to some degree by road salt use roadways and parking lots, no specific data or studies were found that describes the direct impact of road salt use on maple syrup production in Massachusetts.

The 2017 USDA Agricultural Census indicates that Massachusetts has over 300 maple syrup producers generating an annual market value of $3.5 million worth of maple syrup in 2017, an increase of $1.2 million since 2012.[44] It is estimated that some 60,000 tourists spend over $1.9 million a year during the maple sugaring season for maple related products and for meals and lodging accommodations. Several studies have reported that road salt can cause decreases in tree vitality, tree growth and increased salinity in maple syrup in roadside trees.[45,46,47]

2.6.6 Potential Impacts of Winter Sand Applications

Historically, sand was primarily used in RSZs to supplant road salt. However, the applied sand is generally quickly pulverized by passing vehicles or blown off the road if applied on dry pavement and thus, provide limited and, at best, temporary traction benefits. Sand also does not prevent snow and ice from freezing and the post-season cleanup costs can be substantial. An Oregon DOT study found that as much as 50 to 90% of the applied sand accumulated on roadside edges as well as in catch basins and drainage pipes causing flow restrictions and blockages in the storm drain system.[48]

A 2010 study reported that average sediment and phosphorus concentrations in Massachusetts highway runoff from principal roadways were found to be 3 to 10 times higher in winter months compared to that in non-winter months. The increases were largely attributed to the use of winter sand on roadways.[49] In the Charles River watershed, where a phosphorus TMDL has been established, as well as other nutrient sensitive watersheds, the use of winter sand can represent a source of phosphorus.

MassDOT has steadily reduced its use of sand over the last 5 years (FY17- FY21) and has applied less than 15,000 tons per year on average statewide compared to over a

---

44 U.S. Department of Agriculture National Agricultural Statistics Service. 2017 Census of Agriculture, Massachusetts Data. Market Value of Agricultural Products, and Value-Added Products: 2017 and 2012. https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_State_Level/Massachusetts/

45 Carroll, J.E., T.A. Tatter, and P.M. Wargo. "Relationship of Root Starch to Decline of Sugar Maples." *Plant Dis. RE.* 67. (1983): 1347-1348.

46 Dyer, S.M., and D.L. Mader. 1986. "Declined Urban Sugar Maples: Growth Patterns, Nutritional Status and Site Factors." *Journal of Arboriculture* 12(1). (January 1988)

47 Herrick, G.T. "Relationship Between Soil Salinity, Sap-Sugar Concentration and Health of Declining Roadside Maples (Acer saccharum)." *The Ohio Journal of Science* 88(5). (1988): 192-194.

48 American Association of State Highway and Transportation Officials (AASHTO) Standing Committee on Highways. "Revised Chapter 8, Winter Operations and Salt, Sand and Chemical Management, of the Final Report on NCHRP 25-25(04)." Revised April 2, 2013. https://sicop.transportation.org/wp-content/uploads/sites/36/2017/07/NCHRP_20-07318_Final-Report-2013.pdf

49 Smith, K.P., and G.E. Granato. "Quality of Stormwater Runoff Discharged from Massachusetts Highways, 2005-07." *U.S. Geological Survey Scientific Investigations Report 2009-5269.* (2010): 198.

100,000 tons per year between FY11 and FY16 and over 200,000 tons per year prior to FY10. These reductions are the result of operational changes in RSZ's where more liquid deicer is being used to increase the effectiveness of salt and much less sand. Approximately 70% of the sand still currently being used is applied in District 5, which has extensive RSZ's in the Cape Cod region.

2.7 Future Considerations for Environmental Resources Areas

The following describes various future considerations and specific responses to various information requests and/or suggestions that MassDEP raised in review of either the previous 2017 ESPR and/or the 2022 ESPR Scope of Work Plan that was published the EEA Environmental Monitor in February 2021. Many of these topics were listed as initiatives in the March 19, 2021, MEPA Certificate that followed the 2022 ESPR Scope of Work document as items to be discussed in the 2022 SICP ESPR and which involve collaboration with MassDEP during the ESPR development.

2.7.1 Public Outreach and Training Materials

In their March 12, 2021, comment letter, following review of the 2022 ESPR Scope of Work Plan, MassDEP requested that "MassDOT collaborate with MassDEP and others in developing appropriate outreach materials and training materials to educate the public, commercial applicators, and other road salt users on the various salt efficiency measures, equipment, and technologies that can be used to reduce salt usage."

MassDOT has recently organized an Interagency Salt Working Group with representatives with MassDEP, the DCR Water Supply Watershed Protection and MWRA to discuss road salt issues and potential initiatives to increase awareness about various efficiency measures and promote additional training and education for a broader audience of road salt users. MassDOT plans to continue to meet quarterly with agency representatives to discuss how existing programs such as the Baystate Roads Training Program as part of the UMASS Transportation Center) can be used to provide more training for municipal and commercial operators.

Establishing a Operator Certification Program like the Green SnowPro™ Program in New Hampshire could be considered as means to raise awareness of best practices through training to a broad audience of road salt users. Developing this initiative would require participation of several stakeholder groups including possibly state legislatures to sponsor legislation to enable limited liability for winter maintenance operations to incentivize property owners to hire Certified Operators.

2.7.2 Opportunities for Technology Based BMPs

MassDOT will monitor the progress of a pending Clear Road Pooled Funding Study evaluating the feasibility of developing potential programming tools to connect closed-loop controllers with real-time road surface and weather sensor data. This would enable controllers to automatically adjust application rates based on weather (especially pavement temperatures) and road surface conditions. This concept has been tested on a very limited basis in other states. The proposed research would assess the feasibility for automated spreader systems and identify the technological approaches and challenges to connecting various equipment. This will likely involve integrating the AVL/GPS georeferencing functions, the road and weather data with the controller programing capabilities to adjust and record material usage as well as number of lane-miles traveled, number of applied miles, and average application rate.

2.7.3 Expanding the Use of AVL/GPS in Key Locations

MassDOT plans to expand the use of AVL/GPS tracking units with new a 4G LTE system prior to 2022/23 season. Targeted areas include the Dedham/Westwood area, Andover River Road, and the depots treating roadways near Kampoosa Bog.

However, depending on how operators set their controllers or utilize their spreaders, the material use data recorded by AVL units can be misleading or inaccurate. If operators inadvertently set the spreader controller to "manual" mode while applying material, then the material applications may not be recorded. In other instances, especially during extreme cold temperatures, an operator may run its spreader auger or conveyor while the spreader is empty to prevent it from freezing up. In this situation, the AVL sensor will indicate material is being applied even though the spreader is empty. As a result, the data collected will require a quality control review and validation assessment following each application event to identify and correct any anomalies in the data, which involves additional staff time and financial resources.

2.7.4 Assess Need for Future Watershed Based Studies

As discussed earlier, using the technical expertise of the UMASS Engineering Department, MassDOT has recently completed several watershed studies in municipal water supply watersheds to assess the relative contributions of sodium inputs from MassDOT roads, municipal roads and commercial parking lots. The results of these studies have generally produced similar findings in that salt usage from each of these sources or areas can account for a significant portion of the overall watershed salt load and any effort to meaningfully reduce sodium inputs in the future would require participation by all major road salt users. MassDEP had suggested that MassDOT conduct additional similar studies in other watersheds. Prior to conducting additional studies, MassDOT would be interested in discussing with MassDEP how a more holistic approach could be implemented that engages other stakeholders and road salt users to adopt similar road salt efficiency and reduction measures in key areas of concern.

This page intentionally left blank.

3 Best Management Practices for Improving Road Salt Use Efficiency

Consistent with the 2022 SICP ESPR Scope of Work Plan and comments included in the March 19, 2021, MEPA Certificate, this chapter provides an update on MassDOT's latest equipment improvements, technologies, and Best Management Practices (BMPs) used to improve the effectiveness and efficiency of road salt use. The latest measures include utilizing new plow blades, expanding storage and availability of liquid deicers for anti-icing and prewetting, use of slurry spreaders, and adding more advanced weather and pavement condition sensors to incorporate more weather and road surface condition data. These innovations have not only led to less road salt usage, but also seemingly more improved road surface conditions. In addition to current best practices (Section 3.3), other emerging practices recently developed and likely to be evaluated for possible future adoption are discussed in Section 3.4.

3.1 MassDOT's Best Management Practices

The section describes MassDOT's various best management practices currently used and their likely effect to improve road salt use efficiency and effectiveness based on a review of available literature and MassDOT's experience with each practice.

3.1.1 Plowing Technology

MassDOT's principal means of clearing snow and ice from roadways is by plowing, particularly during major snow events with cold temperatures. As such, any improvement to make plowing more effective and efficient can have a major impact on deicer material usage, as well as pavement conditions, surface wear, and lowering labor and equipment costs. Plow manufacturers have enhanced plowing using innovative plow blade materials, plow blade configurations, and plow types.

3.1.1.1 Plow Blades

The plow blade, which is the working "edge" of the snowplow that is in contact with the roadway surface, is the key component of the plowing system. Variations to plow blade material and configuration can enhance plow performance.

Plow blade material is traditionally steel, but some newer plow blades now include rubber, tungsten carbide, ceramic, and other materials. These alternative materials can make blades lighter, more flexible, and more durable than traditional steel plow blades, improve snow removal performance and operator experience because these newer blades cause less plow vibration and consequently less operator fatigue. In addition, these blades are easier to install and remove because they are lighter.

MassDOT uses segmented blades on most of its fleet and, like other DOTs, has found segmented blades to be more effective than traditional single piece blades for snow removal.

Segmented blades consist of a series of blade sections along the plow edge that move independently and conform better to uneven road surfaces, allowing for improved snow removal that typically results in less reliance on deicers. As shown in **Figure 3.1**, MassDOT currently uses Kuper Tuca SX Wave segmented blades for its own plows, have an ultrahard tungsten carbide core and vulcanized rubber/ steel cover. Segmented blades also cause less damage to roadway markings, crack sealing or other obstacles, and reduce noise and vibrations resulting in less operator and equipment fatigue. Each blade segment can be replaced individually, which saves time and money for blade replacement. Despite being more expensive than traditional and other comparable alternative blades, MassDOT has found the Kuper Tuca SX to be cost effective for its performance and durability.

MassDOT plans to add more segmented blades for its fleet and, in the future, will evaluate whether the added performance may warrant revising vendor agreements to require contractors to have segmented blades. Some contractors are already using them because of the improved operator experience, and they are easier to repair.

Figure 3.1 The JOMA 6000: Segmented Plow Blade

Source: https://www.winterequipment.com/products/joma-articulating-cutting-edge-system-by-winter/

3.1.1.2 Plow Types

In addition to front-mounted plows MassDOT also uses other types of plows such as tow plows and wing plows, which allow for more road surface to be cleared in one vehicle pass and, in the right circumstances, underbelly plows may also be used.

Tow plows, often consisting of a trailer-mounted plow towed behind a standard plow truck, allow plow operators to clear two lanes in one vehicle pass (**Figure 3.2**). MassDOT has 17 tow plows, which are primarily used on multi-lane interstate highways. The trailers are also often equipped with a spreader hopper or liquid tank for applying deicing chemicals. By eliminating an additional plow truck and operator, tow plows can reduce the number of operators, man-hours, equipment, and fuel usage. A study in Michigan also found that using tow plows on four-lane and six-lane highways can result in fewer delays for motorists, especially during moderate to larger snowfall events.[50] For these reasons, use of tow plows has become more common in recent years. A 2020 Clear Roads practitioner survey of transportation agencies reported 30 of 91 respondents using tow plows.[51]

Figure 3.2 Tow Plow

Source: https://blog.mass.gov/transportation/massdot-highway/mega-plows-ready-for-snow-ice-season/

Wing plows, attached to the side of a plow, clear a wider path than a standard front plow, reducing the number of plow vehicles needed. Wing plows are mainly used to clear snow from roadway shoulders and turning lanes. MassDOT owns 14 wing plows and finds that, much like tow plows, they reduce labor and equipment costs and allow greater flexibility.

50 Transportation Research Board. 2017. Cost–Benefit Analysis of Using the Tow Plow for Winter Maintenance. https://trid.trb.org/view/1494730

51 Clear Roads. 2020. Alternative Methods for Deicing. https://clearroads.org/wp-content/uploads/dlm_uploads/FR_CR.18-05.pdf

Occasionally, during major storm events, MassDOT also utilizes underbelly plows, or plows attached underneath the main body of the truck. This blade can stand alone or supplement a front-mounted plow blade and the added weight of the truck helps scrape hard pack snow from the roadway, providing a cleaner road surface. MassDOT almost exclusively uses underbelly plow blades with graders, which are only deployed during large and long storm events.

3.1.2 Material Application

As discussed above, although plowing remains the primary means of clearing snow from roadways, plowing alone will not prevent roads from becoming icy during winter weather events. Thus, deicing materials are used to lower the freezing point of water as precipitation accumulates on the road surface. Without deicing materials, water derived from fog, rain, freezing rain, snow, or melting snow will freeze when pavement temperatures drop below 32ºF, resulting in slippery and dangerous driving conditions. MassDOT relies on road salt in its granular form, as the principal deicing material because of its widespread availability and relatively low material cost.

3.1.2.1 Closed-Loop Automatic Spreader Control Systems

The rate at which material is applied from material spreaders is controlled by closed-loop controllers, which are computer-based devices installed in the vehicle cab that are connected to both vehicle ground speed and auger speed sensors. The controller can be programmed to a desired salt application rate, and once adequately calibrated, can adjust the salt spreader's auger speed based on detected vehicle speed and auger speed. Auger speed can change over time due to temperature fluctuations and wear of hydraulics, so the auger sensor feedback helps to ensure consistent applications of road salt as programmed. Controllers are programed to apply at rates of 240 pounds of pre-wetted salt per lane-mile.

As shown in Figure 3.3, MassDOT has installed Cirrus SpreadSmart Rx controllers for its own spreaders because of its ease of use, adaptability, and technical support. Contractors are also required to equip their own material spreaders with closed-loop controllers and have several manufacturers to choose from. Closed-loop controllers can also track and report material usage such as total amount material applied, lane-miles traveled, location of dispensed material, time of application, and average application rate.

Figure 3.3 Cirrus SpreadSmart Rx Controller

Source: https://blog.mass.gov/transportation/massdot-

The data is typically reported by operators by manually recording the data from the controller display unit on post-storm reporting forms.

Most controllers also have wireless data transfer capabilities, but this requires depots to be equipped with wireless modems and relevant computer hardware and software. It also requires on spreader drivers to pass within range of the modem to allow data transfer. Because contractors also use different types of controllers, the data transfer compatibility and connectivity to modems at each MassDOT depot can vary and be challenging. MassDOT has focused its initial rollout of wireless material usage data capabilities in select depots in environmentally sensitive areas. MassDOT plans to expand the data transfer capabilities by contracting with Geotab, a fleet management analytics company, while continuing to prioritize environmentally sensitive areas.

3.1.2.2 Pre-treatment

Since 2011, MassDOT has been using liquid brine to pre-treat roads. Pretreatment, also known as anti-icing, involves direct applications of brine to the road surface prior to or in the early stages of a winter storm. This initial coating or application to the pavement helps prevent snow and ice from bonding to the roadway, much like how anti-stick spray is used for cooking. Pre-treatment is performed using a tanker truck outfitted with a spreader bar and nozzles. Liquid deicer is applied via nozzles from the rear of the truck at approximately 20 to 50 gallons per lane-mile. Like most state transportation agencies, MassDOT uses salt brine at a 23% concentration of sodium chloride dissolved in water to pretreat roads.

Pre-treatment has played a major role in MassDOT's ability to reduce its average annual salt use and will continue to expand its pre-treatment capabilities by adding more brine production and storage facilities, A new production facility was completed in 2020 at the Deerfield Depot in District 2, which can provide 60,000 gallons of brine storage for Districts 1, 2, and 3. A similar facility was built in District 5 in 2015 and another brine generator facility is planned in the near future for the Sterling Depot in District 3. Additional brine-production capabilities are also planned for District 4.

Because brine is essentially comprised of a dilute solution of salt and water and contains much less salt by weight compared to dry granular salt, the appropriate weather conditions for pre-treatment applications can be relatively narrow and are typically only done when roadway temperatures are close to or just below 32°F and temperatures are forecasted to remain steady or rise. Brine solutions are vulnerable to freezing and have limited melting capacity at colder temperatures. Thus, pre-treatment does not replace or eliminate the need for granular road salt applications, but it can delay and potentially reduce the number of subsequent road salt applications, depending on pavement conditions and other weather factors.

MassDOT focuses its pre-treatment activity on Interstate roads and in Reduced Salt Zones as these roads stand gain the most benefit in minimizing salt applications. For any given storm and over the course of a season, the amount of roadway that is typically pre-treated will vary greatly depending on weather conditions, as discussed above. In recent years, district personnel have reported being able to treat as much as 90% of the interstate roadway lane miles, on average, and as much as 45% of the total roadway lane miles, which is up from a reported average of 35% in 2016. Interstate roads are also a priority for pretreatment because the higher traffic volumes tend to quickly convert snow to frozen hardpack due to vehicle compaction.

The Benefits and Costs of Pre-treatment

Despite the narrow range of weather conditions where pretreatment is appropriate, the use of this practice offers the following benefits:

- » **Increased roadway safety and mobility.** Pre-treatment helps prevent snow and ice from bonding to the pavement, which improves vehicle traction and mobility.
- » **Reduced environmental impacts.** By keeping snow and slush in more plowable form, roads are likely to return to bare pavement conditions sooner and potentially resulting in less salt being needed over the course of a winter event.
- » **Reduced material costs.** If roads return to bare pavement conditions sooner, then the need for additional repeat granular salt applications may be reduced.

Pre-treatment can also add the following operational needs and equipment costs:

- » **Additional equipment and storage facilities.** Pretreatment involves additional upfront costs to acquire brine generators, storage tanks, tanker trucks, as well as pavement and weather monitoring equipment.
- » **Need for additional weather and pavement data.** Access to detailed weather data is essential as pretreatment is only appropriate under certain conditions.
- » **Additional Training for Operators.** Additional staff training is needed to know the right weather conditions for pre-treatment and to execute application timing for maximum effectiveness.

3.1.2.3 Pre-Wetting of Road Salt

The practice of pre-wetting salt is a key aspect of MassDOT's strategy to making road salt more effective. Pre-wetting involves coating dry granular salt with a liquid deicer that typically consists of a magnesium chloride (MgCl2) solution or brine. This coating usually takes place at the end of the spreader chute during regular salt applications, but if equipment for this process is not available, pre-wetting can also be performed by spraying the salt pile at the depot or by purchasing pre-wetted salt. The purpose of pre-wetting is two-fold. First, pre-wetting salt initiates the dissolution process and helps salt become effective sooner after application. Pre-wetted salt also adheres to the roadway better and minimizes material loss due to dry salt particles bouncing and scattering off the pavement. As a result of these benefits, pre-wetting has been reported to reduce salt use by 25 to 30%.[52]

Since 2011, MassDOT has required all contractors to have pre-wetting equipment (i.e., saddle tanks and spray nozzles) in order to be called in to service. MassDOT has also outfitted its own trucks with pre-wetting equipment and has increased its liquid

52 Michigan Department of Transportation. 2012. Salt Bounce and Scatter Study. https://www.michigan.gov/documents/mdot/Final_ReportNov2012_404228_7.pdf

deicer storage capacity at various depots. MassDOT's preferred liquid deicer for pre-wetting is ProMelt Mag 28 INH, which consists of 28% liquid magnesium chloride in water with an amine corrosion inhibitor comprising less than 1% of the solution. MassDOT instructs operators to apply 8 to 10 gallons per ton of salt applied which is the general standard of practice for conventional spreaders.[53]

3.1.2.4 Slurry Spreaders

MassDOT has recently been using slurry spreaders for material applications. This practice represents an enhanced form of pre-wetting with up to 50 to 90 gallons of liquid deicer applied with each ton of granular salt compared to 8 to 10 gallons per ton as a typical pre-wetting rate. The application of liquid slurry distributes more evenly and is retained longer on the pavement surface. The higher liquid content accelerates the melting process and minimizes the bounce and scatter loss of salt. Slurry spreaders can be used during a wider range of weather conditions compared to pretreatment and combine the benefits of pre-treatment and pre-wetting.

MassDOT currently has over 75 slurry spreaders mostly in Districts 2, 3, and 4 with plans to expand usage in other districts. District 3 conducted a side-by-side experiment on Route 2 in Westminster during the winters of FY20 and FY21 and found that road sections treated by a slurry spreader had more exposed bare pavement and less snow cover/hard pack than adjacent sections using standard applications. Use of slurry spreaders may be limited during colder temperatures but not to the same degree as pre-treatment and are also dependent of the availability of liquid deicer. Nonetheless, slurry spreaders represent one of the more effective tools in the toolbox to maximize the efficiency of salt use.

3.1.2.5 Lower Application Rates

Under appropriate conditions, MassDOT has been instructing operators to use a lower application rate closer to 200 pounds per lane mile rather than the standard 240 pounds per lane mile. The reduced rate typically requires sufficient road monitoring and experience to know when weather and road surface conditions are appropriate and will not compromise safety. Thus, reduced application rates may involve more personnel hours and road sensor data. However, increased availability of weather forecasting and strategically placed road surface sensors can help to support decision-making around the appropriate timing and rates of application.

53 Clear Roads. 2021. Review and Summary of Pre-wet Methods and Procedures. https://clearroads.org/wp-content/uploads/dlm_uploads/FR_CR.18-04.pdf

3.1.3 Advanced Tracking of Material Usage and Road Conditions

In addition to road surface monitoring and material application improvements, MassDOT has acquired more communications and video monitoring technology as well as software systems to enable better monitoring of material usage and equipment, including Global Position System/ Automatic Vehicle Locator (GPS/AVL) equipment and Road Weather Information Systems technology.

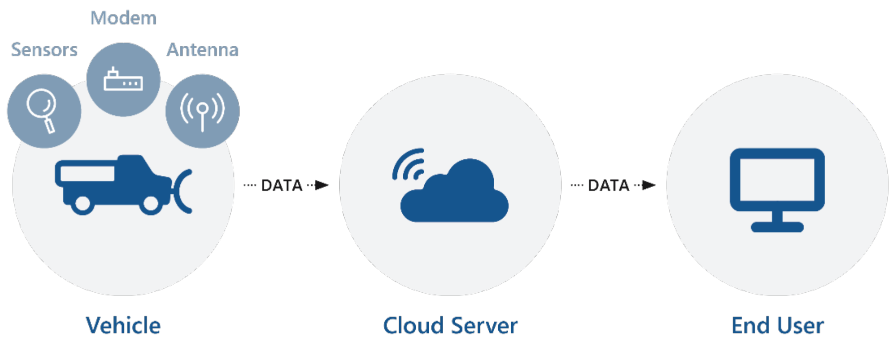
3.1.3.1 GPS/AVL Equipment

MassDOT has been pilot testing the use of GPS/AVL technology in the winter of 2016-17 at the Andover Depot, as well as on roadways located in the Dedham Westwood Water District. The pilot testing was used to assess the feasibility of using GPS/AVL tools to better track material usage in environmentally sensitive areas.

MassDOT plans to expand the use of AVL/GPS equipment on material spreaders in key environmentally sensitive areas with a goal of eventually using this technology statewide. A 2018 Clear Roads survey indicates that 26 other state transportation agencies are in the initial stages of incorporating the use of GPS/AVL technology and that on average about 35% of their vehicles are equipped with an AVL system.[54]

As shown in **Figure 3.4**, various communication components are essential to access the full functionality of GPS/AVL systems. Communication between the various equipment depends on signal connectivity, operator activation and compatibility amongst hardware manufacturers and data management software.

Figure 3.4 GPS/AVL Schematic



MassDOT supplies GPS units to its operators to collect location information on fleet vehicles. However, the added AVL component is needed to track material usage by recording when certain equipment is being used through activation sensors mounted to the-vehicle control unit. Connectivity to equipment sensors requires additional wiring and installation efforts typically provided by a 3rd party contractor. The

54 Clear Roads. 2018. Utilization of GPS/AVL Technology: Case Studies. http://clearroads.org/wp-content/uploads/dlm_uploads/FR_CR.16-01_Final.pdf

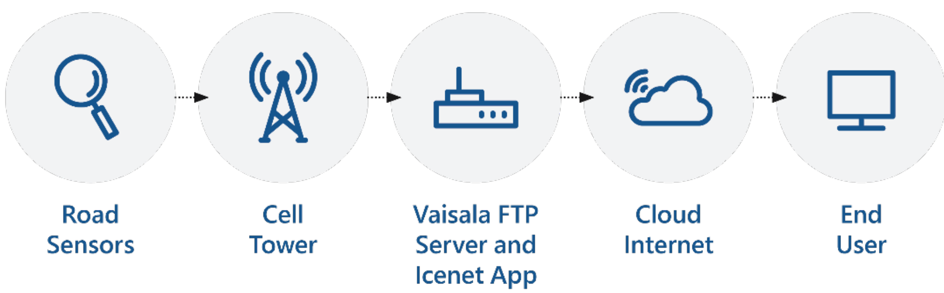
sensors indicate when material is being applied by sensing the spreader auger movement. However, at times, operators may activate the spreader augers even when material is not being applied to keep augers from binding or freezing during extremely cold temperatures. Thus, the data collected by AVL units must be closely monitored and validated to avoid inaccurate data, which can be labor intensive.

3.1.3.2 Road Weather Information Systems

MassDOT has used Road Weather Information Systems (RWISs) for several decades. RWIS stations generally include various sensors to detect air temperature, pavement temperatures, dew point temperature, relative humidity, precipitation type, precipitation intensity, wind speed, wind direction, visibility, surface friction, snow depth or water accumulation, and/or concentration of deicing chemicals on the pavement. This data is then transmitted to and processed by a central computer system via the RWIS's communication system, integrated with additional meteorological information to develop nowcasts and forecasts to inform managers of current and future roadway conditions and to help determine where and when to deploy resources. Mobile sensor information is presented directly in-cab displays so operators can monitor real-time conditions.

Figure 3.5 illustrates the flow of data collected from RWIS networks that involve various specialized equipment and computer programs to collect and process the data to support winter maintenance decision-making.

Figure 3.5 Schematic of RWIS System



Note: This graphic reflects the general concept of the data flow from road sensors to end users

Previous cost-benefit analyses have shown that the long-term benefits of RWIS generally outweigh the initial upfront costs. One study in Idaho reported a RWIS benefit-cost ratio of 22.[55] Another study in Montana found the benefits outweighed the costs even when only considering the winter maintenance benefits and not the societal benefits (e.g., fewer vehicle accidents).[56]

55 Transportation Research Board. 2014. Relationship of Winter Road Weather Monitoring to Winter Driving Crash Statistics. https://trid.trb.org/view/1336569

56 Western Transportation Institute. 2017. Assessment of Montana Road Weather Information System (RWIS). https://www.mdt.mt.gov/other/webdata/external/research/DOCS/RESEARCH_PROJ/RWIS_ASSESS/Final_Report.PDF

Benefits of RWIS to transportation agencies include reduced labor, reduced material usage, and reduced equipment mobilization hours as RWIS allows managers to more accurately time when and where crews and materials are needed, especially in the early stages of a storm. Benefits reduced crashes and reduced delays, in part due to increased level of service, but also because RWIS is often linked to electronic messaging signs that alert drivers to changing road and weather conditions.

The Benefits and Costs of RWIS

Benefits	Costs
» Reduced labor » Reduced material usage » Reduced equipment usage » Reduced crash occurrence and/or severity » Reduced travel time	» Initial Installation » Foundation and tower » Hardware (e.g., sensors) » Software » Communications and power » Operations and maintenance » Administrative (e.g., data management, reporting)

MassDOT has about 45 fixed RWIS stations throughout the state. Many of these stations monitor a wide range of parameters (e.g., temperature, moisture, wind speed) while others, known as "mini-RWIS", consist of non-invasive pavement temperature sensors only. Mini-RWIS stations, in combination with closed circuit video cameras, provide valuable information at less cost than a full RWIS station.

Since 2017, MassDOT has transitioned to using more mobile, vehicle-mounted RWIS equipment and has since acquired 25 mobile RWIS sensors, which provide greater geographic coverage. These new sensors now rely on laser technology to measure key data and thus are less susceptible to damage compared to pavement-embedded sensors and are easier to install than both pavement and pole-mounted sensors.

Figure 3.6 depicts photos of the Vaisala MD30 Mobile Detectors that detect and transmit real-time data on road temperature, pavement grip and other parameters.

Figure 3.6 The Vaisala MD30 Mobile RWIS Sensors

Note: Vaisala MD30 Mobile, Vehicle Mounted RWIS Detectors

Note: Vaisala MD30 Mobile Display

3.2 Emerging Best Management Practices

Although MassDOT already employs many best management practices to enhance salt efficiency as discussed in the previous section, MassDOT will continue to evaluate other emerging practices as their effectiveness becomes more established and as funding allows. Many of these practices have only recently emerged or are still being implemented by other transportation agencies. The following section provides a description of salt efficiency best management practices that may be feasible for future implementation.

3.2.1 Alternative Plow Designs

Plow innovations continue to emerge to enhance snow clearing efficiency. One recent innovation involves a multi-blade plow, which has two to three blades in sequence, each performing a different snow removal function. A typical configuration consists of a standard cutting-edge blade in front, with one or more specialized blades located behind the moldboard, such as a scarifying blade to break up hardpack or a squeegee blade to remove slush or light snow. Multi-blade systems combine different blade designs and materials to address variable snow and ice conditions in a single pass, saving time and improving the level of service. They also reduce wear on each individual plow blade and thus increase their effective lifespan.

The Iowa DOT found that a multi-blade system consisting of a traditional carbide blade, a scarifying blade, and a squeegee blade removed 20 to 25% more snow and ice than a traditional blade.[57] In one event-based test, South Dakota DOT estimated that use of squeegee blades on six plows cut salt application rates by approximately 50 percent. These squeegee blades were primarily used on asphalt with a high friction overlay and, when mounted all season (October 1 to May 1), typically lasted about one season, according to one of the districts.[58]

3.2.2 Alternative Deicing Materials

MassDOT has experimented with several non-chloride deicers and other organic based deicing materials continue to become available. These organic-based compounds are typically derived from agriculture or food processing byproducts such as acetates, glycols, succinates, or urea. Non-chloride deicers are less corrosive than chloride-based deicers and some may be more effective at lower temperatures. However, non-chloride-based deicers are generally much more expensive, not as available in large quantities and can pose other environmental concerns. Organic-based deicers are generally considered less toxic to aquatic life, roadside vegetation, and human health, but they can have a high biological oxygen demand by stimulating microorganism growth, which can lead to oxygen depletion in receiving waters and soils that can be harmful to aquatic life. Organic based deicers also have a

57 Clear Roads. 2020. Alternative Methods for Deicing. https://clearroads.org/wp-content/uploads/dlm_uploads/FR_CR.18-05.pdf

58 Ibid.

high nutrient content which can stimulate algal productivity in receiving waters and must be weighed against the potential ecological concerns posed by road salt.

Calcium magnesium acetate (CMA) is a rarely used granular organic-based deicer, typically reserved for highest sensitive areas where corrosion or environmental impacts must be reduced, such as major bridges or roads near sensitive waterbodies. Based on a 2019-20 online survey of 35 state transportation agencies, Michigan reported using the highest amount of CMA, which was only 50 tons per season.[59]

In the late 1980s, MassDOT piloted the use of CMA on a one-mile section of Route 25 in Plymouth and found that compared to road salt, CMA took more time to react, was less effective at colder temperatures, and cost approximately 20 times more than road salt. A Wisconsin DOT study found that the CMA application rates needed to be 1.2 to 1.6 times greater compared to salt to achieve the same results. The added applications resulted in 70% more miles traveled and 143% more hours[60] As a result of these findings which are similar to what MassDOT observed in addition to the considerable added cost differential, CMA is not likely to be a feasible alternative.

Pretreated Salt is a recent trend in winter maintenance involving the use of pretreated road salt or salt with liquid deicer already applied. Material suppliers have found ways to pretreat salt prior to delivery, which provides a more effective product that provides the benefits of prewetting without having to upgraded equipment or store and purchase liquid deicers. Interest in the use of pretreated salt has grown at the municipal level where Towns may not have the space or resources to add prewetting equipment and storage tanks. However, one of the potential issues or concerns with pretreated salt is that material suppliers commonly use a liquid agricultural byproduct or waste such as beet juice to pretreat salt.

As an example, one organic additive currently used is called BioMelt Ag64 (BioMelt), which is a proprietary sugar alcohol blend with beet juice. Since BioMelt is derived from agricultural products, it contains relatively high levels of carbohydrates that can exert a high Biological Oxygen Demand (BOD) during decomposition as well as nutrients, such as phosphorus. These two issues can pose serious water quality concerns to downstream receiving waters especially lakes and ponds. Pretreated salt using BioMelt or as a liquid deicer can cost anywhere from 30% to 300% more than regular road salt depending on the purchasing volume.[61]

MassDOT has been consulting with material suppliers to evaluate the extent of BOD and nutrient levels in various products and to assess whether the potential environmental concerns to nearby receiving waters, particularly in environmentally sensitive areas outweigh the potential benefits of using this product in terms of

59 Clear Roads. 2020. 2019-2020 State Winter Maintenance Data and Statistics. clearroads.org/winter-maintenance-survey. Accessed August 3, 2021.

60 Smith R.L., JR. 1988. Field Deicing Comparison of Calcium Magnesium Acetate and Salt in Wisconsin. Transportation Research Record 1246

61 Lammers, E. 2021. Evaluation of Liquid Deicing Materials for Winter Maintenance Applications. Kentucky Transportation Center. Report # KTC-211-21/SPR18-566-1F

enhancing the effectiveness of road salt. MassDOT is considering a limited pilot study to analyze the BOD and nutrient levels in a controlled but real-world environment.

3.2.3 Alternative Pavements

Various innovative pavement types have been tested for the purpose of increasing pavement friction and tire grip and to reduce salt use as well as vehicle crash rates in certain road segments. Permeable and porous pavements, which have been shown to make roads quieter and improve visibility during rain events,[62] may also have some potential for reducing deicing demands under certain conditions. Porous asphalt overlays, or open grade friction course (OGFC) pavement, can potentially trap and lower pollutants concentrations in runoff compared to conventional pavement.[63]

MassDOT has partnered with the U.S. Geological Survey (USGS) to investigate the deicing material needs on open grade friction course pavement compared to traditional hot mix asphalt. The study will be done on a segment of Interstate-95 in Needham, which is a high traffic volume area. The study's objective is to evaluate any differences in road surface conditions with respect to pavement grip, potential ice buildup and deicing material needs in the OGFC test sections in comparison to the traditional hot-mix asphalt sections over a three-year period. Although OGFC pavement overlays have been around for a while and provide the benefit of less tire noise and road spray, it is still unclear how well they perform with respect to snow and ice operations and deicing material usage. Pavement conditions and deicing material usage will be closely monitored in side-by-side OGFC and hot-mix asphalt pavement sections to gain better insight on deicing material needs and usage on the two pavement types.

3.2.4 Automated Spreader Systems

The Clear Roads™ pooled funding research collaborative, comprised of various state transportation agency snow and ice practitioners, has initiated a proposed study to evaluate the feasibility of developing programming tools to connect and automate onboard spreader controllers based on real-time road condition friction or grip data. This technology could lead to automatically adjusting material applications to use just right amount of material needed based on real-time weather and road condition data. Using more data-driven methods for determining deicing material needs has the potential to optimize the deicing operations with improved performance and greater certainty. However, given all the factors and data inputs that must be considered whether human judgement with extensive experience can be replaced with automated systems will remain to be seen. MassDOT will closely monitor the results of this proposed study.

62 Washington Department of Transportation. 2013. Summary Report on the Performance of Open-Graded Friction Course Quieter Pavements. https://www.wsdot.wa.gov/research/reports/ full reports/817.1.pdf

63 Center for Transportation Research. 2010. Investigation of Stormwater Quality Improvements Utilizing Permeable Friction Course (PFC). https://rosap.ntl.bts.gov/view/dot/22650

3.2.5 Route Optimization

Route optimization involves optimizing snowplow and spreader routes to minimize travel times and maximize efficiency to minimize labor and equipment costs. Routes can be evaluated and altered using visual observations or with specialized fleet management software to identify the optimal length and turning points that minimize vehicle mileage and overlaps while maintaining the same level of service. Defining spreader routes not only must account for travel time, but vehicle salt and liquid storage capacity, salt shed locations, depot and other jurisdictional boundaries, as well as transition areas and route overlaps. According to a Clear Roads report, the route optimization process can be divided into four steps:

1. **Selection of project team and project tools**
2. **Preparation of input data**
3. **Utilization of optimization tool**
4. **Review and revision of routes**

Various state transportation agencies and municipalities have reported successful outcomes with route optimization efforts. Route optimization generally results in route length reductions in the range of 5 to 10%, with one case reporting reductions as high as 50%.[64] In one example, the Ohio DOT was able to decrease the number of vehicles needed by 29 trucks while still providing the desired level of service. The reduction in trucks was largely due to the expansion or modification of boundaries beyond maintenance jurisdictions.[65]

With multiples salt shed locations and the institutional knowledge of travel times and spreader capacity, MassDOT has historically been able to determine appropriate routes without software assistance. However, MassDOT may consider the use of route optimization software in the future, particularly as the use of GPS/AVL becomes more prevalent.

3.3 Other Potential BMPs

Over the last 12 years, MassDOT’s recent equipment upgrades, use of liquid deicers, slurry spreaders and pavement monitoring technologies have enabled MassDOT to reduce its average annual statewide salt usage by 26% on a per lane-mile basis compared to what was used in the previous 10 years while adjusting for differences in winter severity. To expand on this success, MassDOT plans to increase brine production capabilities and storage facilities as well as expand the use of other emerging technologies.

64 Clear Roads. 2016. Identifying Best Practices for Snowplow Route Optimization. https://www.uvm.edu/sites/default/files/Transportation-Research-Center/Reports/2016/FR_CR.14-07_Final.pdf

65 Transportation Research Board. 2018. Role of Route Optimization in Benefiting Winter Maintenance Operations. https://journals.sagepub.com/doi/pdf/10.1177/0361198118796354?

MassDOT plans to build on its initial efforts to use of AVL/GPS equipment to assist in tracking salt usage on key road segments in environmentally sensitive areas. MassDOT recently executed a new contract with a service provider to install newer generation AVL/GPS devices in select areas. In addition, MassDOT will continue to expand its mobile RWIS sensor and camera network where needed.

MassDOT will continue to participate in the Clear Roads Pooled Fund Research Program to evaluate other emerging technologies that may show potential to use deicing materials more effectively and balance environmental stewardship with safety and fiscal responsibility.

See list of Future Initiatives described in the Chapter 6.

4 Corrosion Effects of Deicing Materials

The corrosive effects of deicing material on roadway infrastructure, especially bridges, and motor vehicles are ongoing issues and continue to be studied. This chapter summarizes recent literature findings on the magnitude of these issues, both on a national and state level, and the various strategies used to mitigate or prevent deicer induced corrosion on roadway infrastructure and vehicles. As discussed below, a more recent corrosion issue relates to the potential increased corrosion of drinking water infrastructure and fixtures associated with increased chloride levels.

The issues of corrosion involved with water supply infrastructure are complex as many site-specific factors involved with source water quality and the use of chemicals for treatment and corrosion protection, as well as pipe materials, can affect the corrosion potential of distributions pipes. This was a major issue in the Flint, Michigan water crisis and really brought to light how changes in raw water source(s) and/or treatment processes can affect pipe and plumbing fixture corrosion causing a major public health crisis. The crisis also revealed how extensive lead-based pipes still exist in many water supply systems. This chapter provides a general overview of the factors involved with pipe corrosion and the current programs and funding sources available to replace lead-based pipes, since identifying the actual causes and corrective actions needed to address any water supply corrosion issues requires detailed field and sampling investigations at the local level.

4.1 Corrosion Effects on Roadway Bridges

Bridges tend to be one of the more vulnerable components of our roadway infrastructure because their steel and concrete components are two materials that are most affected by deicing chemicals. The many factors that affect the structural integrity and useful life of roadways and bridges including age, wear and tear, maintenance, and exposure to other environmental stressors make determining what portion of the annual corrosion costs is directly related to deicing chemical usage difficult but some of the impact is due to deicing chemical usage.

The following sections describe the relative corrosive effects that various deicing chemicals may have on these materials, as well as various protective measures used to prevent corrosion.

4.1.1 Effect of Chloride Deicers on Steel Structures

Corrosion of internal reinforcing steel has historically been the primary mechanism for the deterioration of bridge decks and other concrete structures. Chloride-based deicer chemicals, such as sodium chloride (NaCl), calcium chloride (CaCl2), and magnesium chloride (MgCl2), are known to have deleterious effects on steel. The embedded steel in concrete is initially protected by a passive layer of ferrous oxide that forms around the steel within the highly alkaline concrete environment.[66]

Over time, chloride ions from chloride-based deicers (e.g., sodium chloride, calcium chloride, and magnesium chloride) will penetrate the concrete and replace the hydroxide anions to form hydrochloric acid, which lowers the pH in the concrete matrix and weakens the bond strength of the cement paste. The weakened concrete matrix is susceptible to the expansive forces as water freezes during freeze-thaw cycles, resulting in more void space and increased porosity allowing for even more chloride and water penetration. The encased steel then becomes more exposed to corrosive reactions associated with oxidation and acidification.

Data reported in literature suggests calcium chloride, especially in liquid form, is most corrosive to steel while calcium magnesium acetate (CMA) is the least corrosive. Sodium chloride is considered slightly less corrosive than calcium chloride but more corrosive than magnesium chloride on a relative basis.[67] While many deicer corrosion studies are done in laboratory environments with unstressed metals and concrete, one field study in Montana exposed stainless steel, aluminum, and low-carbon steel to chloride deicing solutions. Exposure to a magnesium chloride solution for six weeks had the biggest impact on carbon steel, while aluminum experienced the greatest reduction in tensile strength. Stainless steel had the least amount of tensile strength deterioration and weight loss.[68]

Guardrails, signs, and culverts composed of galvanized steel are also susceptible to corrosion.[69]

---

66 Xiao et al. 2018. Evaluation of the Effects of Deicers on Concrete Durability. https://wisconsindot.gov/documents2/research/0092-17-03-final-report.pdf

67 Olek et al. 2013. Investigation of Anti-Icing Chemicals and Their Interactions with Pavement Concretes. https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=3041&context=jtrp

68 Shi et al. 2017. Corrosion of Metals Exposed to 25% Magnesium Chloride Solution and Tensile Stress. https://www.sciencedirect.com/science/article/pii/S221450951730030X

69 Shi et al. 2009. Corrosion of Deicers to Metals in Transportation Infrastructure: https://westerntransportationinstitute.org/wp-content/uploads/2016/08/4W1095_Intro_Developments.pdf

4.1.2 Effect of Chloride Deicers on Concrete Structures

While the research findings strongly suggest that all chloride-based deicers are uniformly corrosive to steel and other metals, the findings are mixed as to which chloride or non-chloride deicer cause more damage to concrete structures. One study reported that CMA and calcium chloride caused the greatest damage to concrete pavement, while sodium chloride caused the least.[70] The study suggested that magnesium chloride was more damaging due to a higher diffusion or penetration rate in concrete, followed by calcium chloride and sodium chloride.

A Wisconsin study reported a higher degree and rate of concrete deterioration was observed in localities that had higher application rates of NaCl, CaCl2, and MgCl2 compared to other areas. The distress started as joint spalling and led to partial or full slab replacement.[71]

In the end, selecting a deicer for the purposes of minimizing corrosion can lead to competing interests or tradeoffs in terms of trying to minimize corrosion risks to steel or concrete and achieving the most effective deicer performance.

For this reason, winter maintenance professionals are inclined to use deicer blends or hybrid solutions to balance both corrosion protection and anti-icing performance. Agricultural byproducts are often blended with liquid chloride deicers to inhibit corrosion and enhance performance by lowering the freezing temperature. These products are much more expensive than chloride-based deicers, which is why blending with other deicers presents a more cost-effective solution. However, the organic, agriculture-based deicers can pose other environmental concerns as these products tend to contain elevated levels of nutrients and can exert a relatively high biological oxygen demand in receiving waters during decomposition of the organic material. Ultimately, the selection of winter maintenance materials must consider all aspects of environmental concerns, corrosion, and costs.

As discussed later in this section, various protective measures can be used in bridge design and maintenance programs to minimize the extent and rate of corrosion in both the concrete and embedded steel. Also, drainage designs to divert water away and limit the accumulation of water on bridge decks, are common best practices.[72]

---

70 Sumsion et al, 2013. Physical and Chemical Effects of Deicers on Concrete Pavement: Literature Review. https://chainsawjournal-wpengine.netdna-ssl.com/wp-content/uploads/2019/11/Physical-And-Chemical-Effects-Of-Deicers-On-Concrete-Pavement-Literature-Review.pdf

71 Xiao et al. 2018. Evaluation of the Effects of Deicers on Concrete Durability. https://wisconsindot.gov/documents2/research/0092-17-03-final-report.pdf

72 Kogler, R. 2015. Steel Bridge Design Handbook: Corrosion Protection of Steel Bridges. https://trid.trb.org/view/1416756

4.1.3 Bridge Corrosion Costs

472 or 9% of the 5,229 bridges in MA are classified as structurally deficient.

Determining how much deicing chemical usage contributes to annual corrosion costs is difficult given the many factors that affect the structural integrity and useful life of roadways and bridges including age, wear and tear, natural decay, maintenance, and exposure to other environmental stressors. An often-cited Federal Highway Administration (FHWA) study published in 2002 provides the most comprehensive assessment of the extent and cost implications of corrosion on our nation's highway bridges. At the time, the study reported that the annual cost to mitigate and prevent bridge corrosion was approximately $8.3 billion. This includes $3.8 billion per year to replace structurally deficient bridges, another $4.0 billion per year for maintenance, and $0.5 billion for painting and recoating steel bridges. This estimate does not include the indirect costs of any loss of productivity or commerce due to traffic delays, which was estimated to be 10 times greater than the direct cost.[73] Adjusting for inflation, the estimated annual direct corrosion costs to our nation's roadway infrastructure would increase to approximately $13.5 billion in today's dollars based on an average annual inflation rate of 2.1%.

Approximately 42% of the nearly 620,000 roadway bridges that exist across the nation are estimated to be more than 50 years old, which is the typical design life for most bridges. Approximately 23% are more than 60 years old and 12% are over 80 years old. To fully address the estimated backlog of structurally deficient bridge repairs needed nationwide, the annual spending on bridge rehabilitation would need to increase by nearly 60% from $14.4 billion annually to $22.7 billion. At the current rate of investment, the necessary repairs would not be completed until 2071.[74]

State transportation agencies are required to perform bridge inspections every two years for all roadway bridges with a minimum length of 20 feet. Bridge inspection protocols are set by the bridge condition assessment guidelines and rating criteria outlined in the FHWA Bridge Inspection Reference Manual: (https://www.fhwa.dot.gov/bridge/nbis/pubs/nhi12049.pdf).

MassDOT is responsible for inspecting approximately 1,500 bridges in the state, and currently has over 30 bridge inspection teams amongst its six maintenance districts, including four underwater "dive" teams. The MassDOT Bridge Inspection Handbook; 2015 Edition provides inspection guidelines on condition assessment criteria, inspection methods, inspection waivers, and bridge inspector qualifications.

Table 4.1 provides a breakdown of the total number of bridges in Massachusetts by age or year built and the number and percentage of bridges within each age class that are classified as structurally deficient according to the 2021 National Bridge

73 Koch et. al., 2002. Corrosion Cost and Preventative Strategies in the United States. Prepared of the Federal Highway Administration. https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB2002106409.xhtml

74 ASCE Report Card. 2021. Bridges. https://infrastructurereportcard.org/cat-item/bridges/

Inventory (NBI).[75] Overall, an estimated 447 bridges or approximately 8.5% of the total are considered structurally deficient in 2021 and most of these are classified as more than 50 years old.

Table 4.1 MassDOT Inspected Structurally Deficient Bridges by Year Built and Age1

Year Built	Age	Total #	Total # Structurally Deficient	% Structurally Deficient
1997-2021	0-25	959	1	0%
1972-1996	26-50	722	37	5%
1947-1971	51-75	2,270	224	10%
1922-1946	76-100	721	116	16%
1921 and earlier	>100	584	69	12%
TOTAL		5,256	447	8.5%

Source: 1 National Bridge Inventory (NBI) database last updated in March 2020; NBI, 2021.

Table 4.2 summarizes the number and percentages of structurally deficient bridges by primary construction material type including conventional reinforced concrete, pre-stressed concrete, steel, wood, masonry, and aluminum iron. Approximately 58% of the state's bridges are constructed primarily with steel components and the second-highest category consists of pre-stressed concrete, which comprise another 21% of the total. More importantly, bridges comprised mainly of steel represent 75% of the structurally deficient rated bridges.

Table 4.2 MassDOT Inspected Structurally Deficient Bridges by Construction Material Type1

Construction Material Type	Total Number of Bridges	Structurally Deficient Bridges	Percent Deficient
Conventional Reinforced Concrete	889	47	5%
Pre-stressed Concrete	1,127	42	4%
Steel	3,013	340	11%
Wood	57	7	12%
Masonry	140	9	6%
Aluminum Iron	25	1	4%
Other	5	1	20%
Total	5,256	447	9%

Source: 1 NBI database last updated in 2021.

In 2008, MassDOT launched an Accelerated Bridge Program (ABP) that invested $3 billion over an 8-year period to accelerate the pace of repair and replacement of structurally deficient bridges. At the time, approximately 10% of the total 5,167

75 National Bridge Inventory. 2021. 2021 Massachusetts Bridge Profile. https://artbabridgereport.org/reports/state/MA.pdf

bridges located in the Commonwealth were considered structurally deficient and another 700 were projected to be added by 2016. With a goal of reducing the state's backlog of structurally deficient bridges to below 450 by September of 2016, the ABP successfully reduced the list to below 432 bridges, resulting in an overall decrease of 20%. As a result of the ABP, which officially ended in September 2018, approximately 200 bridge projects were completed at an estimated cost of $2.43 billion.[76]

4.1.4 Measures to Reduce Roadway Infrastructure Corrosion

Since the mid-1980s, MassDOT has continued to adopt a variety of corrosion prevention measures in its bridge design specifications and maintenance operations to protect steel components in bridges. These measures are designed to reduce the onset and rate of corrosion and prolong the design life for steel bridges. However, given the predominance of older bridges (i.e., pre-1980s) still in use, steel bridges still make up a high percentage of structurally deficient rated bridges until the repair/ replacement backlog of older steel bridges has mostly been completed.

The FHWA guidance manual for implementing corrosion protection measures for steel bridges identifies the following bridge design and maintenance practices to prevent or delay corrosion:[77]

» Cathodic protection (CP) systems for bridge decks (prevents corrosion in reinforced steel)

» Concrete deck repairs in conjunction with deck overlays, CP systems, or Electrochemical Chloride Extraction (ECE) treatment

» Painting/coating or overcoating of structural steel (reduces how fast steel deteriorates)

» Substructure concrete repairs in conjunction with installation of CP systems or ECE treatment

» Installation of jackets with CP systems around concrete piles

» Bridge cleaning and/or washing

Material used in bridge construction can have a major role in reducing corrosion susceptibility. While stainless steel is the most resilient of steel products, the initial investment can be cost-prohibitive. Coatings, paints, and sealants represent more cost-effective alternatives for corrosion protection of steel bridges and steel reinforced bridge decks. Using three coats of paint, rather than one or two coats, has become a standard practice for greater protection, and adding inorganic zinc primer to a three-coat paint system can provide added resilience to mitigate the effects of chloride of steel. In tests using inorganic zinc primer, the three-coat paint systems

76 MassDOT. 2018. Accelerated Bridge Program (ABP) Update. https://www.mass.gov/service-details/accelerated-bridge-program-abp-update

77 Ibid.

studied were able to tolerate chloride contamination levels of up to 60 µg/cm2, which was much higher than two-coat or one-coat systems.[78]

MassDOT's corrosion protection measures include the use of epoxy-coated steel; applying sealants and membranes to bridge decks; as well as other effective metal coatings, such as galvanizing and/or metalizing the steel components; and limiting the use of un-coated weathering steel to sites where there is less salt use, such as over railroads.[79] Metalizing and galvanizing provide more effective, long-term protection for steel than regular coatings. Metalizing refers to the process of thermally applying a sacrificial metal coating onto the steel surface. This is done by using a heat source to "melt" metal over the target steel surface and allowing it to solidify. This can be done in place or at the manufacturing facility and is more labor-intensive than painting or applying other coatings but provides a more durable coating and requires no solvents or airborne related pollutants.

MassDOT also utilizes sealants and additives in concrete mixtures which can slow the rate of corrosion by reducing the rate of intrusion of chloride anions into the concrete or mortar. Common sealants such as siloxane and silane typically last only three to five years and need to be reapplied periodically. MassDOT has listed several types or brands of concrete sealer products that have been qualified for use on the state's concrete mixtures.[80]

Adding alternative materials such as fly ash and silica fume into the concrete mix production has also been shown to reduce the permeability and chloride penetration into concrete. MassDOT has been specifying the use of silica fume for new concrete structures in locations more prone to corrosion. Both concrete quality and depth of cover over embedded reinforcing bars are important mitigating factors. Other mitigation strategies include use of more durable aggregates that are less susceptible to freeze-thaw cycles and tighter control on the air-void system (5-7% entrained air) to reduce the potential for cracks and surficial defects during the curing process.

MassDOT also maintains a bridge washing program using water from local sources to rinse any residual deicing material and sand from bridge decks and the underlying support structure. The washing is done without the use of detergents. The washing is generally done using high-pressure systems with fine mist nozzles to limit water use and generation of runoff.

78 Liu, R. and Runion, A. 2020. Coating Performance on Existing Steel Bridge Infrastructure. https://www.fhwa.dot.gov/publications/research/infrastructure/structures/bridge/20065/

79 MassDOT. 2020. LRFD Bridge Manual. https://www.mass.gov/info-details/part-i-design-guidelines

80 MassDOT. 2020. Concrete Sealers. https://www.mass.gov/service-details/concrete-sealers-m-9150

4.2 Corrosive Effects of Deicing Materials on Motor Vehicles

The corrosive effect on motor vehicles has also been a widely reported and studied consequence of on deicing chemical usage. The following provides a general overview of the economic impact of this issue and the measures used to prevent vehicle corrosion as expressed in the literature.

4.2.1 Motor Vehicle Corrosion Costs

The previously cited 2002 FHWA study estimated that the annual costs of corrosion to motor vehicles was approximately $23.4 billion based on 2002 dollars. Most of the estimated costs, however, were related to depreciation or loss of value due to age ($14.4 billion), which may not be directly related to corrosion. Annual costs for repairs and maintenance related to corrosion were estimated to be approximately $6.5 billion while the added cost of using corrosion resistant materials was estimated to be $2.5 billion annually.[81] Adjusting for inflation since 2002, the estimated annual cost of vehicle corrosion would increase to approximately $32.7 billion today, using an average annual inflation rate of 2.1%. This adjusted estimate compares favorably with the findings of another study conducted by the Western Transportation Institute, which estimated that the average nationwide deicer corrosion cost on a per vehicle basis was approximately $32 per year.[82] A 2016 survey conducted by AAA, estimated that U.S. drivers that live in areas affected by snow and ice, paid approximately $15.4 billion in repairs from 2011-2016 due to corrosion and rust damage.[83] The corrosion related repairs linked to deicing chemical usage was estimated to amount to approximately $3 billion annually. These corrosive effects and the cost of repairs will likely decline as vehicle manufacturers improve vehicle designs and the materials used for exposed components.

A recent IHS-Markit study reported that the average age of vehicles on the road in 2020 was 11.9 years, or about one month older than in 2019. This is much older than the average age of approximately 7 years in the 1970s for vehicles still in operation. The study noted that consumers may have delayed vehicle purchases because of COVID-19, which may continue to have an effect in the next few years.[84] Owners of these aging vehicles will need to contend with an increasing level of deteriorating

81 Koch et. al., 2002. Corrosion Cost and Preventative Strategies in the United States. Prepared of the Federal Highway Administration. https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB2002106409.xhtml

82 Shi et al. 2009. Corrosion of Deicers to Metals in Transportation Infrastructure: Introduction and Recent Developments. https://westerntransportationinstitute.org/wp-content/uploads/2016/08/4W1095_Intro_Developments.pdf

83 Edmonds, Ellen. 2017. Road De-Icers Cause $3 Billion Annually in Vehicle Rust Damage. https://newsroom.aaa.com/2017/02/road-de-icers-cause-3-billion-annually-vehicle-rust-damage/

84 IHS Markit. 2021. Average age of cars and light trucks in the US rises to 12.1 years, accelerated by COVID-19. https://ihsmarkit.com/research-analysis/average-age-of-cars-and-light-trucks-in-the-us-rises.html

road conditions, which adds wear and tear to motor vehicles. As of 2021, 43% of the roadway miles nationwide were classified as in poor or mediocre condition.[85]

Motor vehicle corrosion can pose safety concerns as well. The U.S. National Highway Traffic and Safety Administration (NHTSA) investigated numerous reports of sudden brake line failures in northern states that were linked to long-term exposure to road salt and other deicing chemicals in over 100 crashes.[86] Additionally, Toyota Canada recalled nearly 100,000 minivans in 2014 due to corrosion of the spare tire harness caused by deicing salt mist. Other vehicle components that may be susceptible to corrosion include the exhaust system, the frame, radiator, and suspension system.[87]

4.2.2 Measures to Reduce Motor Vehicle Corrosion

Vehicle manufacturers have made significant progress in the last 20 to 30 years in making vehicles more corrosion resilient by changing the materials used in their design. Vehicles today are made with a variety of corrosion resistant metal alloys, plastics, and resin composites and much less steel. Where metal is still used, manufacturers use different coatings, splash guards, and improved drainage to limit exposure to trapped water. With these advancements, vehicles can now be driven well beyond 10 years and even 20 years or more unlike in the 1970s and 1980s when vehicles rarely lasted beyond 10 years due to corrosion issues.

For the most part, vehicle corrosion and related maintenance have become less of an issue given the latest manufacturing improvements. The benefits of extended vehicle life and reduced corrosion related maintenance costs are likely to far outweigh the added manufacturing costs. As new materials and design modifications continue to advance in the future, vehicles should continue to become more corrosion resistant.

Certain vehicle components are more vulnerable to corrosion than others, such as fuel line, brake pads and rotors, and exhaust and electrical systems primarily because of their metal alloy composition and exposure to road spray splashing on or beneath the vehicle. Exhaust systems traditionally were one of the most vulnerable and most expensive vehicle components to replace, but most are now made with rust resistant metal alloys and even stainless steel to provide greater longevity. Wheel rims are also now mostly made with aluminum alloys which are more corrosion resistant than steel rims. Routine vehicle washing, particularly in the winter months, can help minimize the amount of accumulated deicing material causing corrosion on vehicles.[88]

85 ASCE Report Card. 2021. Roads. https://infrastructurereportcard.org/cat-item/roads/

86 NHTSA. 2011. Investigation Report. https://static.nhtsa.gov/odi/inv/2011/INOA-EA11001-1004.PDF

87 2021. The Annual Cost of Vehicle Corrosion Control. https://www.corrosioncost.com/the-annual-cost-of-vehicle-corrosion/

88 Casey et al. 2014. Impacts of Using Salt and Salt Brine for Roadway Deicing, https://rosap.ntl.bts.gov/view/dot/28516

4.3 Corrosion Effects on Drinking Water Supply Infrastructure

Corrosion of water distribution pipes and associated plumbing fixtures is a growing national concern with many Public Water Supplies (PWS) reporting higher and more frequent detection of metals in drinking water due to the corrosion of various water distribution system components including piping, valves, meters, and sealants used around pipe joints. Pipe corrosion can be caused by a variety of factors including water quality changes associated with pH, alkalinity, specific conductance, hardness, chloride, sulfate, total dissolved solids, and dissolved oxygen or chemicals used in the treatment processes or added contaminants released into the environment. The quality and type of metals inherent to the plumbing systems are also critical factors.

The Flint, Michigan water crisis highlighted the importance of monitoring water quality and how changes in water quality can affect pipe corrosion and the leaching of metals. Even though the U.S. Environmental Protection Agency (EPA) adopted the Lead and Copper Rule in 1991, which requires PWSs to control and monitor the release of lead and copper in water distribution systems, changes in water quality, and chemical interactions can lead to contamination issues related to metal releases.

Subsequent investigations of the Flint, Michigan case revealed several factors likely contributed to pipe corrosion and contamination issues. In addition to the iron and lead-based pipes that connected many homes to the supply lines, changes in water quality including a decrease in pH and alkalinity levels and an increase in chloride levels when the city switched to using the Flint River instead of treated water from the Detroit system increased the corrosivity. The higher chloride levels in Flint River raw water were further exacerbated by the addition of salt-based coagulants (e.g., aluminum sulfate or ferric sulfate) to treat the suspended solids and dissolved organics in the raw water.[89] The higher dissolved organics also interfered with the disinfection process causing higher chlorine levels to be added, which lead to a breakdown of the scale deposits in the iron pipes and a release of iron bacteria that required an even greater need for chlorination. Moreover, the Detroit water supply system was using a corrosion inhibitor (organophosphate) while Flint was not.

A 2011 study that investigated nine public water systems where lead levels were more frequently detected following a change in the treatment process or source of water, found that these systems tended to have chloride to sulfate mass ratios (CSMRs) that exceeded a threshold of 0.5.[90] Higher CSMR ratios were often linked to increased salinization of the water source but also due to changes in treatment chemicals. Using salt-based coagulants (e.g., aluminum sulfate or ferric sulfate) in the treatment

89 Olson, T. 2016. The Science Behind the Flint Water Crisis: Corrosion of Pipes, Erosion of Trust. https://theconversation.com/the-science-behind-the-flint-water-crisis-corrosion-of-pipes-erosion-of-trust-53776

90 Nguyen et al. 2011. Chloride-to-Sulfate Mass Ratio: Practical Studies in Galvanic Corrosion of Lead Solder. Journal AWWA. https://awwa.onlinelibrary.wiley.coingm/doi/abs/10.1002/j.1551-8833.2011.tb11384.x

process can cause an increase in the CSMR. In one case, a higher CSMR was caused by a chloride leak into the distribution system from a hypochlorite system used to disinfect the finished water. Other chemicals used for anion exchange to treat for hardness or arsenic can also contribute to a higher CSMR as well. Surface water sources along the coastline were also reported to have higher CSMR ratios due to saltwater intrusion and increased chloride levels in rainwater.[91]

A 2018 study in upstate New York, found that elevated chloride levels were a contributing factor to accelerating galvanic corrosion and leaching of zinc from pipe samples exposed to various levels of chloride.[92] When zinc wires, used to represent new galvanized iron pipes, were exposed to varying levels of chloride, zinc leaching increased as chloride levels also increased. These findings suggest that increased galvanic corrosion can be expected for galvanized iron pipes in the presence of road salt. This study also found that corrosion of lead solder occurred when in the presence of increased salt concentrations within the system. While copper pipes, for example, are susceptible to pitting due to increased chloride, increased sulfate ions in the water and soil can play a major contributing factor to corrosion.[93]

4.3.1 Measures to Reduce Corrosion in Drinking Water Infrastructure

Amendments to the Safe Drinking Water Act in the late 1980s emphasized the need for corrosion control strategies in PWS systems to minimize pipe corrosion and leaching of metals into drinking water especially lead and copper. Corrosion protection typically involves the addition of orthophosphate or silicate corrosion inhibitors, pH adjustment, and fluctuating alkalinity levels. The use of orthophosphate inhibitors promotes the formation of insoluble corrosion scales on the pipe walls which reduces lead leaching in the water system.[94] Scaling and re-equilibration within water pipes are two major factors that affect pipe corrosion and system performance. If not controlled or properly treated, corrosion scales can cause adsorption and accumulation of harmful substances such as arsenic and lead that result in the degradation of water quality.[95]

91 Kaushal et al. 2021. Freshwater Salinization Syndrome: From Emerging Global Problem to Managing Risks. https://link.springer.com/article/10.1007/s10533-021-00784-w

92 Pieper et al. 2018. Impact of Road Salt on Drinking Water Quality and Infrastructure Corrosion in Private Wells. https://pubs.acs.org/doi/10.1021/acs.est.8b0470

93 Kaushal et al. 2021. Freshwater Salinization Syndrome: From Emerging Global Problem to Managing Risks. https://link.springer.com/article/10.1007/s10533-021-00784-w

94 Stets et al. 2018. Increasing Chloride in Rivers of the Conterminous U.S. and Linkages to Potential Corrosivity and Lead Action Level Exceedances in Drinking Water. https://www.sciencedirect.com/science/article/pii/S0048969717318223

95 Chawla et al. 2012. Corrosion of Water Pipes: A Comprehensive Study of Deposits. https://file.scirp.org/pdf/JMMCE20120500003_15093451.pdf

EPA banned the use of lead-based pipes and solder in new plumping systems in 1986. However, according to a 2016 MassDEP survey, more than 20,000 lead service lines (LSLs), installed prior to the 1986 ban, may still be in use statewide.[96]

The most effective strategy to reducing lead levels in drinking water is to fully replace existing Lead Service Lines (LSLs lines or pipes, however, this can be challenging since most LSLs are located on private property and require property owner permission to allow construction on their property and perhaps share in the costs, even though most communities generally offer to pay the full or most of the replacement cost. Property owners are generally not aware they may have an LSL or do not consider it a high priority or are reluctant to participate in the replacement program because it requires temporary construction disturbance to their property.

As part of the cost analysis for the 2021 revisions to the Lead and Copper Rule, EPA estimated that the average cost to replace LSLs was approximately $3,600 but could be as much as $10,000 or more depending on the site complexities and constraints.[97] Perhaps the biggest challenge to replacing LSLs is that they are often located on private property closer to the home or building. Even though most communities generally offer to pay the full or partial replacement cost, property owners must be willing to participate in the replacement program, which requires coordination and temporary construction disturbance on the property.

The American Rescue Plan Act of 2021 provides $15 billion over the next five years for lead pipe removal. Funds from the bill will be distributed to the states and will be made available through the Drinking Water State Revolving Loan Fund to fund various investments to water and sewer infrastructure, including LSL replacements.[98]

As of July 2022, the Massachusetts Clean Water Trust is offering $20 million in loans with loan forgiveness to encourage public water suppliers (PWSs) to complete LSL inventories and replacement plans. The State Drinking Water Revolving Fund provides funding for LSL replacement.[99] PWSs can apply for loans through the State Revolving Loan Fund Application process that can accessed through the Program website page, https://www.mass.gov/lists/state-revolving-fund-applications-forms.

MassDEP has also set aside $1.3 million in funding to specifically assist small PWS serving less than 10,000 people to conduct similar planning projects to inventory or develop a plan to remove LSLs. A similar 100% loan forgiveness is offered for eligible projects using qualified technical providers.

---

96 2016 Massachusetts Department of Environmental Protection (MassDEP) Lead Service Line Survey https://www.mass.gov/service-details/lead-and-copper-rule-lead-service-line-survey

97 National Primary Drinking Water Regulations: Lead and Copper Rule Revisions: 40 CFR Parts 141 and 142. Environmental Protection Agency; Federal Register Vol. 86 No. 10 January 15, 2021. https://www.govinfo.gov/content/pkg/FR-2021-01-15/pdf/2020-28691.pdf

98 Association of State Drinking Water Administrators. https://www.asdwa.org/2021/08/10/senate-passes-bipartisan-infrastructure-bill-measure-heads-to-house/

99 Massachusetts Department of Environmental Protection (MassDEP). Incentivized Lead Service Line Replacement Program. https://www.mass.gov/service-details/incentivized-lead-service-line-replacement-program

The Massachusetts Water Resources Authority also has a $100 million interest-free loan program to help eligible communities fund LSL replacement projects. As of June 2019, over a dozen communities have used this program to remove and replace LSLs and gooseneck connections. Communities can pay back loans over a 10-year period with zero interest. The City of Quincy represents just one of many communities that took advantage of this program and received $1.5 million loan to fund removal of over 200 identified LSLs.[100]

The City of Boston Water and Sewer Commission also has had an incentive program in place that offers customers a credit of up to $4,000 toward the replacement of their private LSLs and five years of no interest to pay off the cost. These are just a few examples of how communities are incentivizing homeowners and businesses to replace their privately owned LSLs and lead based connectors.

The City of Springfield Water and Sewer Commission recently received a low interest loan offered through the Water Infrastructure Finance and Innovation Act (WIFIA) program and received a $250 million loan, which will be used to help replace older pipes and rehabilitate and upgrade drinking water and wastewater treatment processes. The proposed infrastructure upgrades will include 30 integrated water and wastewater projects to support system reliability and resiliency. The WIFIA funding will allow the Springfield to accelerate system updates by approximately 15 years.[101]

100 Massachusetts Water Resources Authority. Local Water System Assistance Program. Lead Pipe Replacement Program. Memo to Board of Directors; Update on the Lead Service Line Replacement Program January 2019.

101 EPA. 2021. EPA Announces $250 Million WIFIA Loan to Upgrade Aging Infrastructure, Advance Renewable Energy in Springfield, Massachusetts. https://www.epa.gov/newsreleases/epa-announces-250-million-wifia-loan-upgrade-aging-infrastructure-advance-renewable

5

Effect of Winter Weather on Public Safety and Vehicle Mobility

Consistent with previous MassDOT Snow and Ice Control Program ESPRs, this Chapter evaluates the effects of winter weather on vehicle mobility and crash rates and the potential socio-economic impacts that may result from reduced vehicle mobility such as lost wages, workplace productivity, delayed deliveries, lost sales and tax revenue, and other disruptions.

Public safety and maintaining vehicle mobility are the two principal drivers behind the various winter road maintenance activities conducted as part of the MassDOT SICP. This Chapter summarizes recent research findings that have investigated how winter weather may affect vehicle crashes and mobility. Reduced vehicle mobility can have a significant impact on vehicle crashes as well as the local and regional economy.

The benefits of plowing and deicing chemical applications to minimize the adverse effects of winter weather on public safety and vehicle mobility must be weighed against the potential adverse impacts on infrastructure and environmental resources. These impacts relate to increased corrosion, as discussed in Chapter 4, and/or lost or diminished ecosystem services provided by roadside soils, vegetated areas, and receiving waters. Ecosystem services that are typically affected by deicing chemicals and sand include drinking water quality, plant and wildlife habitat diversity, water and nutrient retention, and biomass production, among others.

5.1 Winter Weather and Public Safety

According to the Federal Highway Administration, approximately 70% of the nation's roadways and population are in regions which receive at least five inches of snow per year. Adverse weather is a major cause for increased vehicle crash rates in the United States. Although rainfall is the leading cause of weather-related crashes, winter weather is the second leading cause and the primary weather condition that can be mitigated through proactive road maintenance measures including frequent plowing and deicing material applications by state and municipal road maintenance crews.[102]

The following sections provide a review of vehicle crash rates at the national and state level as well as a summary of relevant key findings expressed in the published literature that describe how various winter weather factors influence the rate and severity of vehicle crashes and mobility.

5.1.1 Effects of Winter Weather on Vehicle Crashes at a National Level

Snowfall is estimated to cause 45,000 injury-related crashes and 150,000 property damage crashes each year in the United States.[103] The National Highway and Transportation Safety Administration (NHTSA) reports that of the 6 million motor vehicle crashes that occur each year nationally, approximately 34% are weather-related crashes occurring mainly during rain events but approximately 10% are due to winter weather which includes sleet, hail, freezing rain, and snow.[104]

Although rainfall accounts for most weather-related crashes, snowfall is reported to have a larger influence on daily or event-based crash rates. One study found that crash rates increased by 84 percent during snow days.[105] Another study reported that the average crash risk during snow events increased by a factor of 2.5 compared to a factor of 1.65 during rain events, based on a review of long-term crash records.[106]

This same research suggests that vehicle crash rates linked to snowfall tend to be highest early in the winter season and during smaller snow events. An Ontario study found that the risk of collisions involving an injury increased during small to moderate snowfall events and occurred less frequently during larger snow events.[107] A possible explanation for the lower frequency during larger events is that drivers

102 US Federal Highway Administration. "Snow and Ice." *Road Weather Management Program*. Last modified Feb. 20, 2020. https://ops.fhwa.dot.gov/Weather/weather_events/snow_ice.htm

103 Eisenberg, Daniel, & Kenneth Warner. Effects of Snowfalls on Motor Vehicle Collisions, Injuries and Fatalities. American Journal of Public Health. Vol. 95. No. 1. (January 2005).

104 NHSTA. Fatality and Injury Reporting System Tool. Accessed September 2, 2021. https://cdan.dot.gov/query

105 Qiu, L., & Nixon, W. Effects of adverse weather on traffic crashes. Transportation Research Record: Journal of the Transportation Research Board. 2055. 139–146. (2008).

106 Andrey, J. Long-term trends in weather-related crash risks. J. of Transport Geography. 18(2), 247–258. (2010).

107 Ibid,

tend to drive at lower speeds during greater snow accumulations and intensity when visibility and traction are more severely impacted. Drivers tend to have greater confidence in their driving ability and road conditions during the smaller events. These findings in driving behavior for different sizes and timing of winter events are relevant for state and local transportation officials in their decision-making processes.

5.1.2 Impact of Winter Weather on Vehicle Crash Rates in Massachusetts

MassDOT maintains statewide vehicle crash records and statistics which are publicly accessible through the online IMPACT Crash Data Portal.[108] Crash records are uploaded at midnight daily through a web application, which allows for the analysis of vehicle crashes that have occurred on MassDOT roadways throughout the Commonwealth. The data, however, is considered preliminary and is subject to change following a subsequent MassDOT quality audit or review of these data.

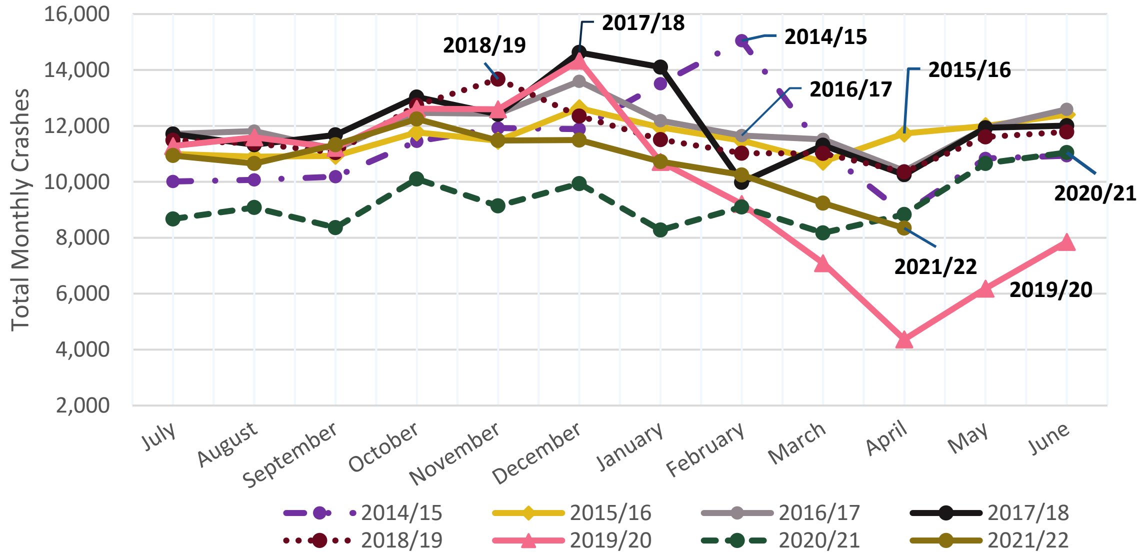
Each crash record may contain up to 120 data fields that provide relevant metadata about the event such as date, time, location, injuries, vehicles involved, and contributing circumstances. It also includes details on road surface conditions, road type, vehicle speed, traffic volume, weather, and traffic controls.

For this ESPR, vehicle crash data were extracted from the IMPACT Crash Data Portal for all crash types on MassDOT and DCR jurisdiction roadways from July 2014 through April 2022. This period of record allows for data analysis over eight winter seasons. The winter season is defined as November 1 through March 31 and crashes were classified as having occurred during either summer or winter seasons. Fields downloaded from the IMPACT Crash Data Portal include the total number of crashes during each month for the period of record.

Figure 5.1 presents a comparison of monthly statewide vehicle crash totals over the last 8 years based on crash data from July 2014 to April 2022. Review of this data suggests that monthly crash totals across the state generally range between 8,000 and 14,000 crashes except during the peak of the Covid-19 pandemic (March to June 2020) when the average monthly crash totals dipped below 6,000 crashes. In most years, the winter months of November through March had the highest monthly crash totals for the year compared to summer months and ranged between 11,500 and 15,000 crashes per month. These higher monthly crash totals are most likely due in part to winter weather as well as reduced visibility with shorter daylight hours. The monthly crash totals tended to be lower in the later winter months of February, March, and April perhaps because drivers were more acclimated to winter driving.

108 MassDOT. "IMPACT Crash Data Portal." https://apps.impact.dot.state.ma.us/cdp/home

Figure 5.1 Reported Vehicle Crashes per Month in Massachusetts, July 2014 – April 2022



Source: MassDOT IMPACT Crash Data Portal

February 2015 had the highest monthly crash total with just over 15,000 crashes and was also one of the coldest and snowiest months in recent history. Several major winter storms occurred during the month resulting in several feet of snow, following a snowy January as well. The back-to-back months of December 2017 and January 2018 also had over 14,000 vehicle crashes when several storms occurred around the Christmas and New Year's Eve holidays. December 2019 also had over 14,000 vehicle crashes and some of the highest crash totals of the 8-year period.

Figure 5.2 presents a comparison of the historical average daily statewide crash rate during the winter months (Nov. – Mar.) versus summer months (Apr. – Oct.) based on over 20 years of vehicle crash data (Jan. 2002 to Apr. 2022) downloaded from the MassDOT IMPACT crash data portal. This analysis of crash data indicates that on average approximately 385 vehicle crashes occur each winter day statewide compared to an average of 352 vehicle crashes on a summer day. This difference of 33 additional vehicle crashes per day, which can add up to over 1,000 additional vehicle crashes over the course of a month and over 5,000 additional crashes over the 5-month winter season. A similar finding of 36 additional vehicle crashes occurring on winter days versus summer days, on average was also reported in the 2017 MassDOT Snow and Ice ESPR based on vehicle crash data from 2006 to 2014. Again, some portion of this difference may also be due to the reduced daylight hours.

The previously referenced FHWA Study had estimated that the average cost per vehicle accident was approximately $45,000 with a total national economic impact of $240 billion per year based on 2010 US dollars. This same study had estimated the average cost for property-damage only (PDO) crashes was approximately $4,000 per crash again based on 2010 US dollars.[109] Using this cost information, the additional 5,000 vehicle crashes during the winter period could result in additional costs of approximately $20 million to over $200 million per year depending on the ratio of PDO crashes to the overall vehicle crash totals that involve injuries and fatalities. Converting these estimated costs in present day costs would likely be more than double the 2010-dollar value estimates when adjusting for inflation.

Figure 5.2 Average Daily Crash Rates During Winter Months vs. Summer Months

385 Average Daily Crash Rate in Winter Months (October–March)	**352** Average Daily Crash Rate in Summer Months (April–September)

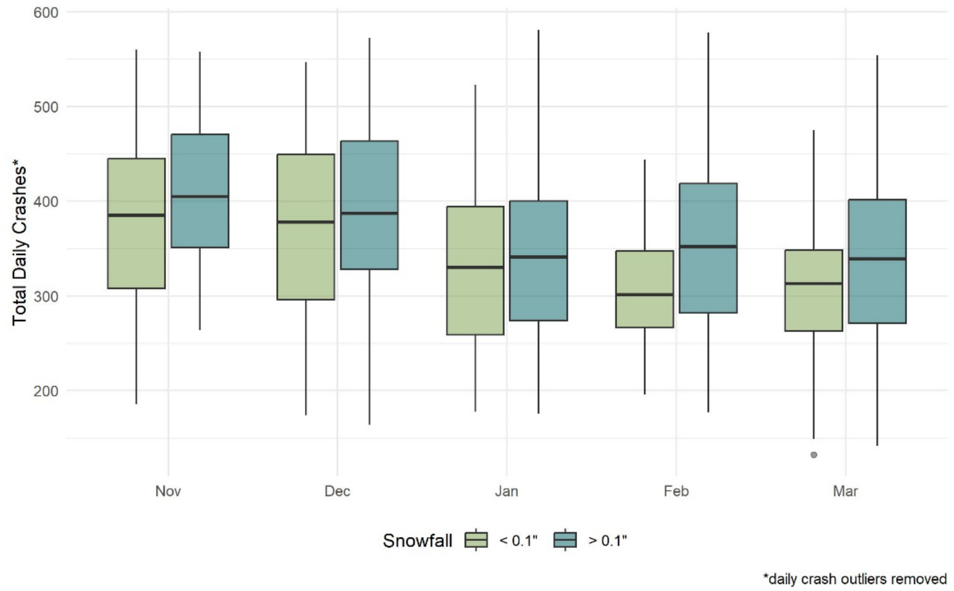
Note: Crash data from January 2002 – April 2022
Source: MassDOT IMPACT Crash Data Portal

Figure 5.3 presents a comparison of the median daily statewide crash totals from November to March on "snow days" versus "non snow days" over the last 7 years from 2015 to 2022. Snow days were identified days with at least 0.10 inch of snowfall based on daily snowfall totals averaged across the state while non snow days were days with no or less than 0.10 inch of snow. The data, presented in box-whisker plots for each winter month, provide a relative assessment of how days with snowfall may affect daily vehicle crash rates. The median daily crash values for each month, which is represented by the horizontal bar within each box, were consistently higher on the snow days with at least 0.10 inches of snow versus days without snow. February had the largest difference in median daily crash rates perhaps due to a tendency for more severe winter storms during this month.

November and December tended to have higher median crash rates for both snow and non-snow days compared to the other remaining winter months. Consistent with other research, this data suggests that the impact of winter weather on vehicle crashes tends to be greatest early in the winter season.

109 Blincoe, L., T.R. Miller, E. Zaloshnja, and B.A. Lawrence. 2015. *The Economic and Societal Impact of Motor Vehicle Crashes, 2010 (Revised)*. National Highway Transportation Safety Administration, DOT HS 812 013. May 2015.

Figure 5.3 Comparison of Daily Vehicle Crash Totals on Snow Days and Non-Snow Days During Winter Months, (2015 – 2022)

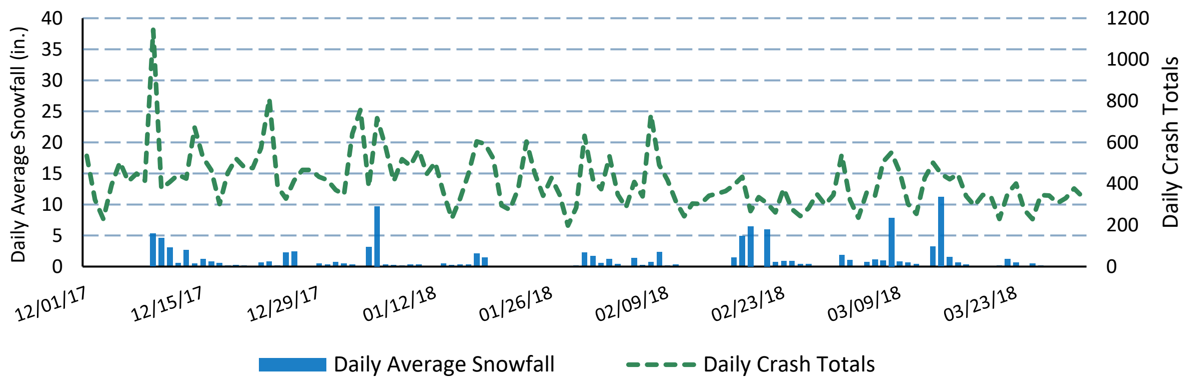


Sources: MassDOT IMPACT Crash Data Portal, NOAA National Climatic Data Center

Figure 5.4 presents statewide daily crash totals and daily snowfall totals for the 2017/2018 winter season, which was one of the more severe winters in recent years. The season had a Winter Severity Index value of -20.6, which ranks as the 8th most severe winter in the last 20 years.

The data suggests that early season snowfall events tend to have higher crash rates even with smaller snowfall totals and then the vehicle crash rates to decline in late season events. For instance, the first snow event in December had just 5 inches of snow but well over 1,100 vehicle crashes statewide. Whereas a larger storm in March that produced over 10 inches of snow had approximately 500 vehicle crashes. This may be due to drivers becoming more accustomed to driving during snowfall events as the season progresses. The snowfall timing, intensity and day of the week also are factors that likely affect daily vehicle crash rates.

Figure 5.4 Impact of Snowfall on Total Daily Crashes, Dec. 2017 – Mar. 2018

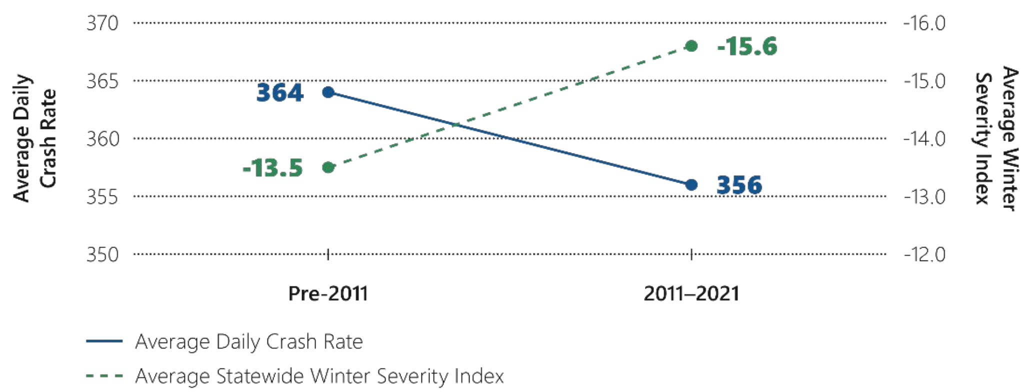


5.1.3 Anti-icing and Equipment Upgrades and the Effects on Vehicle Crash Rates

Improving road conditions through plowing and use of deicing materials can reduce the impact of winter weather on vehicle crash rates, particularly when anti-icing techniques are successfully implemented to prevent or limit snow and ice from bonding to the pavement.

Figure 5.5 presents a comparison of the average statewide daily crash rate during the winter months from 2006 to 2010 and then from 2011 to 2021 as well as the average Winter Severity Index (WSI) value for these two periods. In 2011, MassDOT began incorporating various efficiency measures and liquid deicers for anti-icing and pretreatment practices. Comparing daily crash rates and associated WSI values for the pre- and post-2011 years provides a general assessment as to whether the more recent operational changes have had a positive effect on vehicle crash rates during winter months. The average daily crash rate between 2011 and 2021 was lower than that recorded in the pre-2011 period, despite having a more severe average WSI value. The lower average crash rate suggests that road conditions may have improved because of the liquid deicers as well as other efficiency practices. At the same time, the average annual salt usage during the 2011-2021 was lower than that used during the 2001-2010 period, as discussed in greater detail in Chapter 1.

Figure 5.5 Comparison of Average Daily Crash Rate and Winter Severity Index for Pre-2011 Period vs. 2011 – 2021 Period



5.2 Economic Impacts of Winter Weather and Vehicle Mobility

Major winter storms can wreak havoc on transportation systems and inflict serious economic impacts due to loss of retail sales, income, and sales tax revenues. Winter weather has been reported to be the second leading cause of non-recurring highway congestion, accounting for approximately 15% of traffic delays nationwide.[110] Improving roadway conditions through winter road maintenance activity can have a substantial bearing on vehicle mobility and economic activity.

Shipping and trucking industries are particularly vulnerable to financial impacts caused by adverse road conditions and winter weather. A 2016 study sponsored by the US Federal Highway Administration estimated that weather events cost the freight industry approximately $3.8 million per year in lost time due to delays and decreased speeds. This impact was assessed within only 13 regions with significant truck freight corridors around the country. Although the impact is due to a variety of weather events, ice and snow events were attributable to over half of the costs.[111]

The Texas A&M Traffic Institute publishes an annual Urban Mobility Report that summarizes annual traffic congestion and travel time statistics in key urban areas across the country since 1982. In its June 2021 report summarizing data for 2020, the impacts of the COVID-19 pandemic were starkly obvious. Between 2019 and 2020, traffic congestion was reported to be substantially lower in all 100+ urban areas tracked by the report with much fewer commuter delays resulting in both reduced commuter time and total annual delay time. In the Boston MA-NH-RI urban area, the average commuter time was reduced by 36 person-hours between 2019 and 2020, from 86 hours down to 50 hours annually. However, this reduction in commuter time was partially offset in substantial truck delays. As demand for goods rapidly increased in 2020, truck delays increased anywhere from about 30-50%.[112] Winter weather can contribute to commuter and trucking delays, however, in recent years the impact of the global pandemic has been far greater than that from winter weather events.

The recent major traffic backup in eastern Virginia on January 3, 2022, highlights the precarious nature of how winter weather can adversely affect vehicle mobility and public safety. Although this may be an extreme example, motorists were stranded along 50 miles of Interstate 95 for over 24 hours. The winter weather that led to this event highlights the limited margin of error and the effect that rapidly changing weather conditions can have on road conditions. Virginia DOT officials were not able

110 Rall, J. "Weather or Not? State Liability and Road Weather Information Systems (RWIS)." Prepared for the National Conference of State Legislatures. (2010).

111 Krechmer, Daniel et al., "Regional Assessment of Weather Impacts on Freight," *U.S. Department of Transportation Federal Highway Administration*, FHWA-HOP-16-044, February 2016, https://ops.fhwa.dot.gov/publications/fhwahop16044/fhwahop16044.pdf

112 Schrank, David, Luke Albert, Bill Eisele, & Tim Lomax. "2021 Urban Mobility Report." *The Texas A&M Transportation Institute*. (2021). https://static.tti.tamu.edu/tti.tamu.edu/documents/mobility-report-2021.pdf

to pretreat the roads because the storm started as heavy rain and any applied material from pretreatment would have been washed away by the rain. The inability to pretreat and the water on the roads combined with a sudden drop in temperature led to icy road conditions that caused a major vehicle backup. The conditions went from bad to worse when the rain turned to snow falling at a rate of 2 inches per hour, causing a tractor-trailer truck to jackknife and block traffic. Eventually more vehicles became disabled, blocking travel lanes and exits until all traffic eventually stopped entirely. The Interstate could not be opened until the following morning of January 4 after hundreds of travelers spent the night in their vehicles without the ability of emergency personnel to assist with food or water.[113]

5.2.1 Economic Impact of Winter Weather and Reduced Vehicle Mobility in Massachusetts

The magnitude of economic losses from severe winter storms can be quite significant. The 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan assessed the potential risk associated with various weather-related hazards expected to be exacerbated by climate change. The report highlights potential changes in extreme weather events, specifically tropical cyclones, tornadoes, and severe winter storms. Unique winter risks include an increased occurrence of ice storms, nor'easters, heavy snow, and other severe winter conditions, all of which may become more variable and unpredictable with climate change. The report details a FEMA HAZUS property damage assessment caused by wind and storm associated with the 1978 Nor'easter, which includes both the cost to repair or replace a building and the cost of interruption to a business.

The total property damage due to wind and storm surge from the 1978 Nor'easter was estimated to be over $4.4 billion for the entire state of Massachusetts. Suffolk County alone withstood over $1.3 billion of storm damage with much of the damage related to excessive snow load and winds collapsing buildings and flooding. The Plan did not specifically identify damages or economic impacts of reduced travel and vehicle mobility due to excessive snow depths on roadways. Many businesses and schools were closed for days if not weeks, however, following the storm.[114]

A previous IHS Global Insight study had estimated that a complete snow related shutdown in Massachusetts could result in an economic impact of $250 million per day. Much of the impact was attributed to lost wages for hourly workers ($194 million), but the study also estimated losses in retail sales ($40.5 million), and lost federal, state, and local tax revenue ($30.5 million). Other predicted economic losses

113 Hedgpeth, Dana, et al. "I-95 reopens in Virginia after winter storm forced closure that stranded motorists." *The Washington Post*. Jan. 4, 2022. https://www.washingtonpost.com/transportation/2022/01/04/i-95-shutdown-virginia/

114 US Department of Homeland Security Federal Emergency Management Agency. "Hazus." https://www.fema.gov/flood-maps/products-tools/hazus

relate to lost toll and transit revenue due to impassable roads and the closure of various modes of transit as well as higher snow removal costs.[115]

This hypothetical modeled scenario became very much a reality during the unusual severe winter of 2015 when the Boston and other major metropolitan areas recorded over 100 inches of snow, mostly within a 3–4-week period in late January to February. The Massachusetts Emergency Management Agency (MEMA) conducted a post-winter assessment to estimate the economic impact of the unusual weather pattern. This assessment found that the extreme weather resulted in approximately $393 million in additional state program costs related to snow removal, property damage, and public assistance.[116]

The 2015 winter weather was estimated to cause $300 million in economic losses mostly due to lost revenue, wages and workplace productivity.

During the January 26-28th storm, the Governor issued a major disaster declaration and issued an official travel ban was established for nearly a 48-hour period. MBTA rail system was shut down for at least a day The following lists just a few of the reported economic impacts caused by this extreme winter period:

- Cities and towns spent 1.4 times more on winter maintenance than was budgeted
- MassDOT had over $90 million in snow removal and maintenance costs for this period, a 40% increase over the average annual costs
- Boston area hospitals lost approximately $10.3 million in revenue
- Storm damage and repair costs amounted to nearly $30 million to fix road systems, bridges, water control facilities, buildings, equipment, utilities, parks, etc.
- MassDOT lost just under $3 million in lost toll revenue.

Other state agencies such as the MBTA, MassPort, and the Steamship Authority also reported significant losses of approximately $22.4 million, $13.3 million, and $0.4 million, respectively, due to reduced operations and cancelled trips. Retail sales were estimated to decline by 22% and employee payroll dropped by approximately 7%. The economic impacts of winter weather were felt across the Commonwealth, with many businesses, institutions, and industries having to curtail operations either due to reduced travel mobility or added snow removal costs.

---

115 IHS Global Insight. "Economic Cost of a Disruption from Snowstorms: Sixteen-state study on the potential impact of snow-related, impassable roadways." Prepared for the American Highway Users Alliance. (2010, March). https://www.highways.org/wp-content/uploads/2014/02/economic-costs-of-snowstorms.pdf

116 Massachusetts Emergency Management Agency. "Attachment A: 2015 Severe Winter Weather Pattern Impacts – Supplemental Information." (2015, March). https://www.mass.gov/doc/severe-winter-weather-disaster-declaration-letter-attachment-a-supplemental-info/download

5.2.2 Vehicle Travel and Tourism in Massachusetts

The Commonwealth’s transportation system plays a vital role in supporting tourism activity and related travel as part of the state’s economy. Data provided by the U.S. Travel Association and summarized in the Massachusetts Office of Travel and Tourism (MOTT) 2020 Annual Report indicate that direct spending in the State by domestic and international visitors totaled $24.9 billion in 2019, an increase of 2.95% from 2018 and more than $3 billion more than in 2015 and a $10.5 billion increase from 2009. Approximately 92% of these dollars were spent by domestic visitors, and in Fiscal Year 2020, 56.3% of all domestic trips originated in New England and 21.2% from New York, New Jersey, or Pennsylvania. MOTT defines domestic visitors as those who travel over 50 miles one-way or who stay in overnight paid accommodations.

With nearly 80% of the domestic visitors originating from neighboring New England and mid-Atlantic states, roadways and safe travel conditions are important aspects to supporting to the State’s tourism industry.

In fact, travel by personal car was by far the primary mode of transportation and accounted for nearly 72% of the visits to the state. Domestic visitors spent a total of $20.9 billion in 2019 or 84% of all spending.

In 2019, money spent on public transportation accounted for the largest share of visitor spending at approximately $7.0 billion, or 28.2% of all expenditures. This was followed by lodging (~$6.4 billion) and foodservice (~$5.0 billion). Spending by visitors on public transportation supported 18,500 jobs and $1.1 million in payroll for employees in the public transportation sector. MOTT classifies public transportation sector as air, inter-city bus, rail, boat, ship, taxicab, and limousine services.[117]

117 Massachusetts Office of Travel & Tourism. “2020 Annual Report.” https://www.visitma.com/wp-content/uploads/2021/05/2020_Annual_Report-Final.pdf

5.3 Economic Impact on Ecosystem Services

An earlier study estimated the potential economic impact or lost value that road salt use may have on reduced ecosystem services provided by lakes, wetlands, and forests along roadways in the New York Adirondack region.[118] Based on model simulations, the study authors estimated a potential 1% decline in ecosystem services provided by lakes and rivers and a 5% decline in ecosystem services provided by forested areas within 100 feet of roadways. For forested areas, much of the estimated economic lost value was related to reduced nutrient recycling and lower plant vigor and growth along with a decline in soil stabilization and recreation value. For wetlands, streams, and rivers, most of the estimated lost ecological service value was related to estimated changes in water retention and nutrient cycling, followed by recreation value. The reduced ecosystem services estimates are based on many assumptions and depend on many site-specific conditions, and thus retain considerable uncertainty.

The economic value of the ecosystem services was based on an earlier 1997 study that determined the economic value of certain ecosystem services such as water cycling (e.g., infiltration, recharge), soil stabilization, nutrient cycling, and recreation activity. The economic value of ecosystem services for forested areas was estimated to be approximately $126 per acre, while for lakes, rivers and wetlands, the estimated value was approximately $7,750 per acre in 1994 dollars.[119] Based on the estimated economic value and predicted declines in ecosystem services, the study suggests that the use of road salt could result in an estimated economic impact of approximately $2,320 per lane mile due to the simulated loss of reduced ecosystem services.[120]

Applying the estimated environmental impact rate of $2,320 per lane-mile, discussed above, to the approximately 16,100 lane-miles maintained by MassDOT would result in an estimated potential environmental impact of approximately $37 million per year related to MassDOT's road salt usage based on the study assumptions. Adjusting for inflation from 1997, the estimated impact could be nearly twice as much. However, since much of MassDOT's road network is in more urban or developed areas of the eastern half of the state, the type and extent of ecosystem services provided by directly adjacent, forested or wetland areas may be different than those along the rural roads in the Adirondack Region. Also, the potential impacts to ecosystem services will depend on the type and extent of winter maintenance chemicals and practices deployed as well as many other factors and influences.

As discussed earlier, MassDOT has been able to reduce its overall annual road salt usage by using liquid deicers as well as other technologies and equipment upgrades, which has the added benefit of reducing the potential for environmental impacts.

---

118 Kelting, D. L. & C. L. Laxson. "Review of Effects and Costs of Road De-icing with Recommendations for Winter Road Management in the Adirondack Park." *Adirondack Watershed Institute, Paul Smith's College*. (2010).

119 Constanza, R. et. al., 1997. The Value of the World's Ecosystem Services and Natural Capital. published in Nature Vol. 387. p. 253-260.

120 Kelting, D. L. & C. L. Laxson. "Review of Effects and Costs of Road De-icing with Recommendations for Winter Road Management in the Adirondack Park." *Adirondack Watershed Institute, Paul Smith's College*. (2010).

6 Current and Future Planned Initiatives

Continued research on new technologies in addition to proactively updating snow and ice equipment are key aspects of the MassDOT SICP. Consistent with previous ESPRs and the 2021 MEPA Certificate following review of the 2022 ESPR Scope of Work Plan, MassDOT has identified the following current and planned initiatives to continue to make its snow and ice control more efficient and effective into the foreseeable future, as funding allows. Status updates on these initiatives will be provided in future MassDOT SICP Annual Reports that are posted in the EEA Environmental Monitor at the end of each of the intervening years between ESPRs.

Expanded Use of Slurry Spreaders: MassDOT is currently using more than 75 slurry spreaders statewide, up from less than a dozen slurry spreaders used just a few years ago. These slurry spreaders apply a more liquid-intensive salt mixture that acts as an effective anti-icing layer that prevents snow and ice from freezing to the pavement and forming a hardpack. This helps to keep snow in a plowable form, especially at colder temperatures. This enhanced effect can often delay or even eliminate the need for repeat applications during prolonged storms. MassDOT plans to expand the use of slurry spreaders as well as the availability of brine material used in slurry spreaders by acquiring additional brine production and storage facilities.

Use of Segmented Plow Blades: MassDOT has steadily increased its use of segmented plow blades to improve plowing efficiency. Segmented plow blades consist of a series of short, segmented blade sections rather than one long plow blade. The short sections allow for greater road surface contact and improved snow removal effectiveness. Better snow removal can translate to less reliance on deicer applications to keep roads clear. MassDOT has been installing these segmented blades on their own equipment and some contractors are also using them because they are easier to fix and replace, more durable and, depending on the manufacturer, dampen the plow vibrations, which reduces operator fatigue.

Expanded Use of Mobile RWIS and Road Condition Sensors: Advanced road and weather condition sensor technology developed in the last 5 to 10 years have become more cost-effective, easier to use, and with greater functionality. MassDOT now relies more on mobile, vehicle mounted Road Weather Information System (RWIS) instruments instead of fixed, tower-based RWIS systems. The mobile units allow for broader coverage and better access to real-time data while on the road. The improved user interface has made the data more readily available for such data as pavement grip or traction, available moisture, deicer concentrations, and temperature, which are critical elements. This technology allows for more data driven decisions in determining when deicing applications may be needed. MassDOT currently has over 25 mobile, vehicle-mounted RWIS units and plans to acquire additional units as funding allows in the foreseeable future.

Expanded Training Resources: In part due to the COVID pandemic, MassDOT has relied more on online training resources that cover a broad range of topics. These online resources provide greater flexibility and perhaps more effective delivery of technical knowledge through visual examples that might not otherwise be achieved via in-person, classroom instruction. MassDOT intends to expand on making online resources more available to its snow and ice program employees.

Collaboration with other State Agencies to Develop Regional Initiatives: In 2022, MassDOT has organized an Interagency Salt Working Group with representatives from MassDEP the Water Supply Protection Division of DCR and MWRA to discuss possible initiatives to increase awareness of various road salt efficiency measures to a broader audience such as municipal and commercial operators including the use of brine for pretreatment and prewetting of salt. This Working Group is intended to meet quarterly to identify ways to expand the knowledge base to a broader audience on the various technologies available to make road salt more efficient and effective.

Advance the Use of AVL/GPS on Material Spreaders in Select Locations: MassDOT plans to build on initial efforts to use AVL/GPS equipment to assist in tracking salt usage on key road segments in environmentally sensitive areas. MassDOT recently executed a new contract with a service provider to install newer generation AVL/GPS devices in select locations. These devices will initially be installed in nearly a dozen material spreaders operating out of the Dedham depot as part of a FHWA-funded study to evaluate salt usage on open-graded friction course pavement and then will be installed on spreaders servicing the Dedham-Westwood area, the Andover area, the Kampoosa Bog area, and several key areas in District 3.

Promote the Use of Lower Application Rates: MassDOT will continue to use lower application rates when weather and pavement conditions allow. Initial efforts have been positive, but further testing is needed under a variety of storm and temperature conditions to gain greater confidence in the decision process. Appropriate weather conditions that allow for lower applications can be relatively infrequent and only occur during certain types of winter storms, thus, the overall effect of lower application rates on the annual usage may be relatively small compared to other factors and measures over the course of a season. District personnel must carefully monitor potential weather changes, especially declining temperatures as well as upcoming changes in traffic volumes based on time of day as well as many other factors on a case-by-case basis.

Use of Pretreated Salt: MassDOT plans to evaluate the feasibility and potential impacts of using pretreated salt (salt with liquid deicer already applied) in key locations, especially in areas where space for brine storage is limited. Pretreated salt avoids or minimizes the need for liquid storage as well as the added equipment such as saddle tanks to prewet salt at the time of application. However, data provided by material suppliers indicate that the liquids used to pretreat salt are often agricultural byproducts such as beet juice, The organic based liquids can have a relatively high biological and chemical oxygen demand (BOD and COD) and nutrient content and thus, use of this material should consider the sensitivity of downstream receiving waters to low dissolved oxygen issues that could be exacerbated by a high oxygen demand. While the limited use of pretreated salt suggests that it is highly effective in keeping roads clear of ice and snow and perhaps minimizing the need for subsequent applications of regular road salt, further evaluation of the potential oxygen demand issues should be evaluated before committing to more widespread use.

Possible Automation of Spreader Controllers Using Real-time Data: MassDOT, as a member of the Clear Roads™ pooled funding research collaborative comprised of snow and ice practitioners working for various state agencies, will be evaluating the results of a recently initiated study to evaluate and develop programming tools to connect onboard spreader controllers with road condition friction or grip data. This technology could possibly lead to spreader controllers automatically adjusting material applications based on real-time weather and road condition data. The goal is to develop data-driven methods to use the right amount of deicing material based on real-time data being collected from the pavement and weather data sensors.

Evaluation of Open-Graded Friction Coarse Pavement: In addition, MassDOT is working with the US Geological Survey to evaluate the effects of Open-Graded Friction Coarse (OGFC) pavement on deicing material usage. This pavement type improves driver visibility with less tire spray and increases tire friction during wet weather events, but OGFC pavement’s effect on deicing material needs remains unclear compared to conventional asphalt. Anecdotal evidence suggests at times more deicing material may be used and other times less may be used depending on weather and pavement conditions.

Although OGFC open pores appear to limit the amount of water that accumulates on the pavement and available to freeze, the pores also allow cooler temperatures to penetrate deeper into the pavement compared to regular pavement potentially causing freezing to occur earlier in the event or season. MassDOT expects the study to provide better insight as to whether OGFC provides snow and ice control benefits, as well as improved driver visibility during wet weather.

This page intentionally left blank.

Appendices

A

2022 ESPR Scope of Work Plan: MEPA Certificate & Comment Letters

This page intentionally left blank.

The Commonwealth of Massachusetts
Executive Office of Energy and Environmental Affairs
100 Cambridge Street, Suite 900
Boston, MA 02114

Charles D. Baker
GOVERNOR

Karyn E. Polito
LIEUTENANT GOVERNOR

Kathleen A. Theoharides
SECRETARY

Tel: (617) 626-1000
Fax: (617) 626-1081
http://www.mass.gov/eea

March 19, 2021

CERTIFICATE OF THE SECRETARY OF ENERGY AND ENVIRONMENTAL AFFAIRS
ESTABLISHING THE SCOPE FOR THE
2022 SNOW AND ICE CONTROL PROGRAM ENVIRONMENTAL STATUS AND
PLANNING REPORT

PROJECT NAME	: 2022 Snow and Ice Control Program Environmental Status and Planning Report
PROJECT MUNICIPALITY	: Statewide
PROJECT WATERSHED	: Statewide
EOEA NUMBER	: 11202
PROJECT PROPONENT	: Massachusetts Department of Transportation
DATE NOTICED IN MONITOR	: February 20, 2021

As Secretary of Executive Office of Energy and Environmental Affairs (EEA), I hereby determine that the Draft Scope of Work (DSW) for the 2022 Environmental Status and Planning Report (ESPR) submitted on this project **adequately and properly complies** with the Massachusetts Environmental Policy Act (MEPA) (M.G.L. c. 30, ss. 61-62I) and with its implementing regulations (301 CMR 11.00).

This Certificate establishes the scope for the analysis to be presented in the 2022 Snow and Ice Control Program ESPR. The Massachusetts Department of Transportation (MassDOT) should prepare its 2022 ESPR in accordance with its DSW, the requirements of this Certificate, and the issues raised in comment letters.

Project Description

The purpose of the ESPR is to describe the methods and policies used by MassDOT to control snow and ice on roadways. It documents the environmental impacts of these practices and identifies the Best Management Practices (BMPs) to minimize these impacts while providing safe roadway driving conditions. The ESPR documents the environmental data, road safety requirements, and economic factors used by MassDOT to plan for and implement a Snow and Ice Control Program with the goal of protecting sensitive resource areas, particularly public water supplies and wetland and aquatic ecosystems. By tracking the historical changes and trends in the use of materials, equipment, storage practices, and snow and ice control practices, the ESPRs provide an opportunity to identify and prioritize aspects of the program that may be improved.

The ESPR has evolved from a largely retrospective status report on snow and ice control to a broader analysis that also provides a prospective assessment of long-range plans. The ESPR provides a "big picture" analysis of the environmental impacts of current and anticipated levels of activities, and presents an overall strategy to minimize impacts. The ESPR has become, consistent with the objectives of the MEPA regulations, part of MassDOT's long-range planning process.

History and Purpose of the ESPR

MEPA review of the MassDOT's snow and ice control procedures commenced with a series of Generic Environmental Impact Reports (GEIR) in 1978, 1995, and 2006. Revisions to the MEPA regulations in 1998 eliminated provisions for the preparation of GEIRs. In connection with the issuance of the Certificate on the GEIR in 2006, a Special Review Procedure (SRP) was established to substitute the submittal of GEIRs with ESPRs. The SRP outlined a process where ESPRs would be prepared on a five-year cycle. Each cycle would commence with MassDOT's filing of a DSW that identifies the information and analysis to be provided in a Draft ESPR (DESPR). After review of the DESPR, a Final ESPR (FESPR) would then be prepared by MassDOT to provide any necessary additional information and analysis and to address comments by State Agencies, the public, and the requirements of the MEPA Certificate on the DESPR. Reflecting changes to the review process outlined in the MEPA certificate on the most recent FESPR (issued March 2, 2018), MassDOT will prepare one Single ESPR (in place of a DESPR and FESPR) for public review and comment within 18 months of the issuance of this Certificate.

The ESPR is supplemented by Snow and Ice Control Annual Reports prepared by MassDOT that are noticed in the Environmental Monitor but not subject to a formal comment or review process. The ESPR process does not replace MEPA review of roadway projects that meet or exceed regulatory thresholds. For any project that does exceed thresholds, an Environmental Notification Form (ENF) and, if necessary, an Environmental Impact Report (EIR) would be required to analyze impacts, review alternatives, and identify measures to avoid, minimize, and mitigate impacts. The ESPR serves as a vehicle for public review of the environmental impacts associated with the MassDOT's Snow and Ice Control Program. The ESPR process is building a long-term data set which will provide the opportunity to gauge the effectiveness of efforts to minimize impacts and can serve as the basis for prioritizing future planning and implementation measures.

SCOPE

General

The DSW provided a proposed outline of the 2022 ESPR, a response to comments received on the 2017 FESPR, and preliminary responses and status updates on various topics and initiatives that were outlined in the MEPA Certificate issued on the FESPR in 2018. As stated in the DSW, MassDOT plans to meet with representatives of the Massachusetts Department of Environmental Protection (MassDEP) Drinking Water Program, the Department of Conservation and Recreation (DCR), and the Division and Fisheries and Wildlife (MassWildlife) Natural Heritage and Endangered Species Program (NHESP) prior to finalizing the Scope for the 2022 ESPR.

The 2022 ESPR should follow the general format of the 2017 DESPR/FESPR as modified by the DSW and this Certificate. The 2022 ESPR should use the base information developed for the previous ESPRs and GEIRs, update this information as necessary, include a status report on the MassDOT's policy and planning initiatives and procedures, and provide an overview of current and potential future responsibilities and jurisdictions for controlling snow and ice by the state transportation agencies. The 2022 ESPR should describe any changes in roadways and other facilities maintained by each agency since the 2017 FESPR.

The 2022 ESPR should provide a retrospective analysis of past trends in snow and ice control on state highways and the environmental impacts from these snow and ice control measures. It should present an overview of planning for and operations of snow and ice control by MassDOT. It should provide long-range projections of environmental conditions against which the effects of future snow and ice control can be compared.

The ESPR should include a response to WalkBoston's comments. To the extent it is available, the ESPR should provide basic information and data on the roadways subject to the Snow and Ice Control Program that have pedestrian and bicycle facilities and any practices or policies intended to maintain access to these facilities. As stated in the certificate on the 2017 FESPR, the 2022 ESPR should provide a summary of the findings and recommendations of the Pedestrian Transportation Plan (completed by MassDOT in 2019) pertaining to snow and ice control.[1] A description of any initiatives that will be implemented by MassDOT to provide snow and ice control on sidewalks adjacent to MassDOT roadways should be provided in the ESPR. The ESPR should also describe any such efforts already undertaken by MassDOT, including the percentage of sidewalks currently cleared by MassDOT staff or contractors and the criteria used to determine which sidewalks are selected for clearing. The ESPR should identify any additional analyses or tracking of salt use associated with pedestrian facilities, and should address any current coordination between MassDOT and communities to maintain pedestrian and bicycle facilities in the winter.

The ESPR should respond to comments submitted by MassDEP, the City of Cambridge Water Department (CWD) and NHESP. Where applicable, the responses should include revisions to the relevant portions of the DSW, including the proposed initiatives listed in Section

[1] The 2019 Massachusetts Pedestrian Transportation Plan can be accessed at: https://massdot.maps.arcgis.com/apps/MapJournal/index.html?appid=96339eb442f94ac7a5a7396a337e60c0

2.1 of the DSW and below. MassDOT should identify any additional analyses or data collection recommended by commenters that it will consider for inclusion in the ESPR anticipated to be filed in 2027.

Form and Content of the 2022 ESPR

The 2022 ESPR should include an Executive Summary summarizing the major sections of the ESPR, with supporting graphics and data tables. It should be made available as a separate document to facilitate wider distribution. The Executive Summary should be posted on MassDOT's web site. The DSW indicates MassDOT seeks to present the information included in the 2022 ESPR in a "…more concise, bulletized format using tabular summaries and data graphs and less narrative text". The information presented in the tabular summaries and graphs should be clearly identified, and any significant outliers or trends identified and/or described. Narrative text should be provided when necessary to add clarity and/or explain any complex issues or conclusions presented in the data.

As proposed in the DSW, the 2022 ESPR should provide baseline data consistent with previous ESPRs and include the following sections:

- An overview of the Snow and Ice Control Program's organization, policies, and operations, including roadway jurisdictions, historical and current use of salt, sand, and other deicing agents, materials storage and management practices, and training of employees and contractors;
- A description of the latest equipment improvements, technologies, and BMPs used by MassDOT, including, as relevant, anti-icing and pre-wetting techniques, alternative deicers, road weather information sensor (RWIS) systems, and other BMPs;
- An update on the latest environmental protection/remediation activities and related research pertaining to environmental issues concerning snow and ice control activities, including a review of the use of the Reduced Salt Zone (RSZ) designation, a discussion of sodium data from public water supplies, a review of environmental impacts of the application of sand and deicing agents, and cost of the mitigation measures;
- Updated information on the added infrastructure costs associated with the corrosion effects from deicing chemical usage;
- An assessment of the potential economic benefits of maintaining safe travel conditions on roadways during winter weather; and
- Future considerations for additional measures to improve the Snow and Ice Control Program, such as new or improved BMPs, geofencing and other uses of global positioning systems (GPS) to track spreader activity, potential measures for avoiding storage of materials in sensitive areas, changes in deicing agent application rates, new equipment or practices that could be used in the program, and expansion or elimination of RSZs.

The 2022 ESPR should review historical data and practices, as well as provide updated data and information regarding the Snow and Ice Control Program. As stated in the DSW, the ESPR should clearly identify sections that provide new data and/or review the results of new programs and studies undertaken by MassDOT. In addition to providing data, the 2022 ESPR should summarize trends since the last ESPR and contextualize the changes based on factors such as weather, new or revised BMPs, policies or practices, and changes or additions to designated RSZs. A summary of how impacts from climate change have been incorporated into the Snow and Ice Control Program should be provided, or how they may be incorporated in the future if they currently are not. The ESPR should describe the RSZ designation process, the factors considered by MassDOT in designating an RSZ, and the effectiveness of the designation for protecting water supplies.

The 2022 ESPR should review past or current pilot projects being undertaken to determine the effects of the Snow and Ice Control Program on water quality and ecological resources and expand the pilot program effort to evaluate the effectiveness of new BMPs for minimizing environmental impacts. The DSW provided preliminary responses and brief updates to initiatives identified for further analysis in the Certificate on the 2017 FESPR. The 2022 ESPR should provide a detailed description of these initiatives and the current status of their implementation, as well as data and analyses based on their results where appropriate. These initiatives include:

1. Additional snow and ice control training programs;
2. Installation of pavement friction and pavement temperature sensors to help determine when deicing material may be needed and to monitor road surface conditions;
3. Construction of a brine manufacturing facility in Deerfield to facilitate the use of roadway pretreatment in MassDOT Districts 1, 2 and 3, and investigation of the feasibility of constructing a brine facility in District 4;
4. Expansion of the availability of tanker trucks, brine storage and pretreatment capabilities in environmentally-sensitive areas;
5. Ongoing monitoring of spreader equipment calibration;
6. Expansion of the use of GPS/AVL systems with the goal of having all contractors use this equipment by 2022;
7. Reduction of the amount of sand applied in RSZ by using better plowing methods, improved forecasting and minimizing salt application rates;
8. Exploration of the use of variable message signs to inform travelers of roadway conditions and road speeds;
9. Continuation of participation in research projects to explore new technologies and methods for reducing salt use, including use and standardization of vehicle-mounted sensor equipment, updated material application guidelines and BMPs, performance of porous pavements, and enhanced snowplow training and operations;
10. Review of potential anti-corrosion methods;
11. Replacement and/or upgrade of salt storage sheds;
12. Providing updates of annual salt usage in comparison to the Winter Severity Index (WSI) statewide and by District, including a comparison of current usage to that used prior to 2011 before anti-icing practices were introduced while adjusting for differences in the WSI;
13. An update on salt usage in specific sensitive areas such as in the Dedham-Westwood Water District (DWWD) watershed using the recently installed AVL/GPS equipment. Updates on the locations of expanded equipment implementation will be provided in the intervening Annual Reports;
14. An update on sodium concentrations in Public Water Supplies (PWS) using data reported to MassDEP and a comparison of the percentage of PWS that exceed certain

concentration thresholds for PWS located within and outside of a 0.5-mile radius of a MassDOT road, including time series graphs of average sodium concentration over time for major municipal PWS using available historical data;

15. A summary of observed chloride concentrations in water bodies based on data collected by MassDEP and others, including chloride-impaired water bodies noted in MassDEP's 305(b)/303(d) integrated report. MassDOT will include and share any data collected as part of targeted field investigations completed under its agreement with UMass-Amherst;
16. Collaboration with MassDEP and other State or municipal agencies to develop a work scope to conduct a watershed study in the Cambridge Water District to update the 1985 study and estimate the relative sodium and chloride contributions from various sources;
17. Conduct a limited desktop study for the Dedham-Westwood Water District (DWWD) to update sodium and chloride contributions related to increased development in the watershed;
18. Continue a study with NHESP to investigate the impacts of road salt in the Kampoosa Bog;
19. Work with the Auburn Water District to study the impacts of snow and ice operations on the surrounding watershed, specifically the recharge sources for their supply wells;
20. Collaborate with MassDEP in developing appropriate outreach and training materials to educate the public, commercial applicators and other road salt users on various salt reduction or efficiency measures; and
21. Evaluate technology implementation and other alternatives (i.e., BMPs) in select locations with a goal of reducing overall material usage as measured by the WSI.

Wetlands and Water Quality

The 2022 ESPR should describe water sampling performed by MassDOT and/or its partners, and how data provided by communities or environmental groups is incorporated into its datasets and analyses. It should discuss how this data is used to determine the impacts of the Snow and Ice Control Program on wetlands, wildlife habitat, and surface water and groundwater quality. The ESPR should provide an update on available data for concentrations of sodium, chloride, calcium, and magnesium in waters adjacent to state highways. It should describe MassDOT's current sampling program and explore alternatives for improving data collection and the feasibility of these alternatives.

The ESPR should provide an update on the implementation and results of the Salt Remediation Program. As described in comments from MassDEP, the Salt Remediation Program specifies the levels of salt concentrations in drinking water at which MassDOT will perform an investigation of a private water supply. According to the Salt Remediation Program, following the investigation, MassDOT will decide the appropriate course of action which may include: construction of a replacement well, connection to a public water, installation of a water treatment system, denial of a complaint, highway drainage modifications or improvements, and improvements to operational BMPs. The 2022 ESPR should provide an update as to which of these mitigation measures have been employed by MassDOT and where. The economic analyses included in the ESPR should include the cost of salt remediation in public and private water supply based on available data, or alternatively, it may provide a description of what would be required to perform this analysis if not possible at this time.

The Certificate on the 2017 FESPR directed MassDOT to continue to meet with MassDEP to identify opportunities for targeting the implementation of initiatives proposed for environmentally sensitive areas and for technical assistance in developing outreach materials. Comments from MassDEP on the 2017 FESPR recommended that this coordination include targeting the expanded use of GPS/AVL; partnering with municipalities, watershed groups, academics and to develop educational programs; and expanding watershed-based study areas. As stated in the Certificate on the 2017 FESPR, the 2022 ESPR should identify additional recommendations that have been adopted by MassDOT entirely or in modified form, or explain why they were not adopted. A summary of outreach and training efforts undertaken since the 2017 ESPR process should be provided. The 2022 ESPR should include a discussion of the feasibility of a certification program for private contractors that offers snow and ice management training and certification in salt reduction practices.

Response to Comments

The 2022 ESPR should contain a copy of this Certificate and a copy of each comment letter received. In order to ensure that the issues raised by commenters are addressed, the ESPR should include direct responses to comments to the extent that they are within MEPA jurisdiction. This directive is not intended to, and shall not be construed to enlarge the Scope of the ESPR beyond what has been identified in this Certificate. I recommend that MassDOT consult with MassDEP regarding the issues raised in its comment letter prior to preparing the 2022 ESPR.

Circulation

The Proponent should circulate the 2022 ESPR to those parties who commented on the DSW (identified under "Comments received" below) and to any parties specified in section 11.16 of the MEPA regulations, including MassDEP, DCR, and NHESP. A copy of the 2022 ESPR should be made available for public review at the State Transportation Library. The ESPR submitted to the MEPA office should include a digital copy (e.g., CD-ROM, USB drive) of the complete document. The ESPR should be submitted in 2022 and include the most recent data available.

K. Theoharides

March 19, 2021
Date

Kathleen A. Theoharides

Comments received:

03/12/2021	City of Cambridge Water Department
03/12/2021	Massachusetts Division of Fisheries and Wildlife – Natural Heritage and Endangered Species Program (NHESP)
03/12/2021	WalkBoston
03/16/2021	Massachusetts Department of Environmental Protection (MassDEP)

KAT/ELM/elm

CITY OF CAMBRIDGE
MASSACHUSETTS
Water Department
250 Fresh Pond Parkway
Cambridge, MA 02138
617 349 4770
fax 617 349 6616

March 12, 2021

sent via email
Eva Murray
MEPA Office
100 Cambridge Street Suite 900
Boston, MA 02114

Environmental Status and Planning Report Draft Scope of Work for MassDOT Snow and Ice Control Program (EEA No. 11202)

Dear Ms. Murray:

The Cambridge Water Department (CWD) appreciates the opportunity to comment on the Massachusetts Department of Transportation's (MassDOT) Draft Scope of Work for the 2022 Snow and Ice Program Environmental Status and Planning Report (ESPR). Sodium and chloride pollution is a topic of great concern in the Cambridge drinking water supply source area. The entire Hobbs Brook watershed, including the Hobbs Brook Reservoir, which is a primary source of drinking water for the City of Cambridge, is chloride impaired per the 2016 Integrated List of Waters. Interstate 95 and Route 2 border and intersect with two of Cambridge's three reservoirs. The Cambridge drinking water supply watershed also contains other state roads, such as Route 20 and five interchanges. MassDOT has worked with CWD in the past to study sodium and chloride pollution in the Cambridge drinking water supply watershed, most recently to update a 1985 study to identify the current distribution of salt concentrations and salt sources in the watershed. Given the chronically elevated levels of sodium and chloride in the Cambridge drinking water supply watershed, CWD requests that MassDOT include the following in the 2022 Scope of Work:

1. Include the costs of chloride pollution to drinking water supplies in their proposed economic analyses; and
2. Add a commitment to prioritize the Cambridge drinking water supply watershed when implementing pilot programs that could result in reduced salt use.

Sincerely,

Jamie O'Connell, Watershed Protection Supervisor, CWD
joconnell@cambridgema.gov
617-349-4781

Cc: Cambridge Water Board
Sam Corda, CWD, Managing Director
David Kaplan, CWD, Watershed Manager

Murray, Eva (EEA)

From:	Paulson, David (FWE)
Sent:	Friday, March 12, 2021 7:59 AM
To:	Murray, Eva (EEA)
Cc:	Cheeseman, Melany (FWE)
Subject:	Draft Scope of Work: 2022 Snow and Ice Control Program Environmental Status and Planning Report (11202/06-20527)

Executive Office of Environmental Affairs
Attention: MEPA Office
Eva Murray, EEA No. 11202
100 Cambridge St. Suite 900
Boston, Massachusetts 02114

Project Name:	MassDOT Snow and Ice Control Program
Proponent:	MassDOT Highway Division
Location:	Statewide
Document Reviewed:	Draft Scope of Work: 2022 Snow and Ice Control Program Environmental Status and Planning Report.
EEA No.:	11202
NHESP No:	06-20527

Dear Secretary Theoharides:

The NHESP has provided comment on MassDOT Snow and Ice Program since the 2006 GEIR. Since 2012, MassDOT has been in early consultation with the NHESP regarding their Snow & Ice Program. During this time, the NHESP recognizes the implementation of new technologies and BMPs that have led to reductions in salt application statewide. This is further detailed in the Draft Scope of Work. During our consultations we have identified key wetlands and areas of Priority Habitat that have been influenced or are sensitive to road salt. Road salt has had an effect on wetland chemistry and species composition.

The proposed Draft Scope of Work that has been developed for the 2022 Snow and Ice Control Program Environmental Status and Planning Report does an effective job of outlining the progress made since the 2018 MEPA Certificate. In addition, the inclusion of new and ongoing initiatives in the Scope is useful in understanding the state of science and what MassDOT is implementing locally.

We look forward to the continued interagency coordination, especially the responses detailed in Section 2.3 of the Scope.

We appreciate the opportunity to comment on this project. If you have any questions about this letter, please contact David Paulson, Endangered Species Review Biologist, at (508) 389-6366 or david.paulson@state.ma.us.

David Paulson
Senior Endangered Species Review Biologist
Massachusetts Division of Fisheries & Wildlife
1 Rabbit Hill Road, Westborough, MA 01581
Temporary Phone: (845)-262-0481 | e: david.paulson@state.ma.us
mass.gov/masswildlife | facebook.com/masswildlife

Important: Our offices are currently closed and all non-essential state employees, including Environmental Review staff, are working remotely. We will respond to your inquiry as quickly as possible. Thank you for your patience. Please visit our website (www.mass.gov/nhesp) for updates.

March 12, 2021

Secretary Kathleen A. Theoharides
Executive Office of Energy and Environmental Affairs
Attn via email: Eva Murray

Re: MassDOT Snow and Ice Control Program EEA#11202

Dear Secretary Theoharides:

WalkBoston commented on MassDOT's Environmental Status and Planning Report (ESPR) on Snow and Ice Control in 2018 and has continued to follow the agency's efforts regarding the clearance of sidewalks, curb ramps and traffic islands that are under MassDOT's jurisdiction. While we do believe that MassDOT's staff agree that sidewalk snow clearance is an important safety, equity and mobility issue, we are disappointed in their lack of progress since 2018.

Our comments reiterate this importance and report on some of the work that WalkBoston has done to urge MassDOT to take more effective planning and operational steps.

As laid out by MEPA in 2018 (page 4), MassDOT's scope relative to sidewalks was as follows:

> "The DSW for the 2022 ESPR should include a response to comments received on the FESPR. In its comments on the DESPR, WalkBoston requested that the ESPR include more information about snow and ice control measures for pedestrian facilities. The FESPR noted that MassDOT will soon complete a statewide Pedestrian Transportation Plan that will include recommendations for improving pedestrian conditions affected by snow and ice. Consistent with MassDOT's policy to promote alternate modes of transportation, including walking and bicycling, and implementation of its Complete Streets design program, the 2022 ESPR should provide a summary of the findings and recommendations of the Pedestrian Transportation Plan and describe any snow and ice control measures that will be implemented by MassDOT to improve pedestrian conditions. The DSW for the 2022 ESPR should identify any additional analyses or tracking of salt use associated with pedestrian facilities that will be included in the ESPR consistent with the scope and purpose of the SICP ESPRs."

The Statewide Pedestrian Transportation Plan was completed in 2019 and very clearly called out sidewalk snow clearance as critically important, and as one of the responsibilities for MassDOT to lead on as a transportation and equity issue. It also stated that MassDOT needs to assume responsibility for sidewalk snow removal for some roadways that are under MassDOT's direct care and control. The text of the Plan which describes these responsibilities is shown below (highlights provided by WalkBoston).

Introduction

With its abundance of historic town centers, compact neighborhoods, urban areas, and natural resources, Massachusetts is home to premier walking environments. However, conditions for walking vary widely from one place to another. A simple stroll can quickly turn challenging or even impossible in the face of discontinuous sidewalks, missing curb ramps, **unplowed snow**, or unsafe intersections.

Principles

Prioritize improvements for people walking by proactively addressing gaps and barriers that discourage walking and are known to increase likelihood of crashes. MassDOT shall address deficiencies– from sidewalks gaps and missing crosswalks, access to transit, **and snow and ice removal**, for example.

Initiatives

Initiative 5: Launch a year-round maintenance and operations plan for MassDOT-owned pedestrian facilities and support municipalities to do the same.

Year-round maintenance of pedestrian facilities ensures the continual comfort and safety of the people who use them, but also extends the lifespan of the facilities themselves. MassDOT has a comprehensive process for inventorying the condition of curb-to-curb roadway pavement and for clearing snow and ice on all roadways and bridges travelled by vehicles. **This initiative establishes actions to add pedestrian facility maintenance and operations to this work.** MassDOT is moving towards a proactive and systematic data collection strategy to identify facilities in need of attention. MassDOT has already gathered data on curb ramp condition as part of the **Statewide ADA Transition Plan**.

Actions

Action 2: **Pilot a winter snow and ice removal initiative on pedestrian facilities in order to provide the basis for development of a comprehensive plan – and an understanding of potential barriers to make such a program permanent.**

Measures for tracking progress (on Actions)

Note: Part of the initiative is defining the maintenance standards and operational plans for snow and ice removal that will apply to these measures.

- **Percentage of MassDOT pedestrian facilities that are covered by regular snow and ice operations**
- **Equity check: Do certain populations live in areas where fewer pedestrian facilities are covered by regular snow and ice operations?**

The Plan outlines significant and important attention to sidewalk snow and ice removal, and we applaud the Plan. However, MassDOT's efforts to date have not improved sidewalk snow clearance rates on MassDOT-owned facilities. Our March 1, 2021 letter to MassDOT Highway Administrator Jonathan Gulliver is included below and outlines our disappointment in the progress since the 2019 Plan.

Specific comments regarding the Status Report that MassDOT submitted to MEPA in February 2021

Page 2, Section 1.2 Organization and Format - We are disappointed that sidewalks are not called out here as a section and not mentioned as one of the issues to be addressed.

Section 2.1 Preliminary responses - A number of the preliminary responses are quite specific and note progress toward addressing the issues. Given the specificity of MassDOT's Pedestrian Plan regarding sidewalk snow clearance, and the requirements in the MEPA Certificate, we think that MassDOT's answer (shown below) is incomplete and does not accurately characterize the barriers described in a recent presentation by MassDOT to the Massachusetts Bicycle and Pedestrian Advisory Board (a Board established by legislation whose members are appointed by the Governor) where staff indicated that MassDOT had not been able to secure contractors to clear additional sidewalks, or enter into meaningful agreements with municipalities to clear MassDOT-owned facilities.

> MassDOT Answer (page 6 of the update) **-** In the last few years, MassDOT has committed additional resources to provide snow and ice control on approximately 10% of the sidewalks adjacent to their roadways focusing on key areas with relatively high pedestrian usage. This effort is in the early stages of development and MassDOT will likely add more sidewalks into its winter maintenance program as resources become available. The status of this effort will be updated in the 2022 ESPR.

Following the MABPAB meeting (January 27, 2021) WalkBoston reached out to MassDOT staff to secure clarification on progress on sidewalk clearance. We followed this up with a letter to the Highway Administrator Jonathan Gulliver and are awaiting his response.

Forwarded message ---------
From: **Stacey Beuttell** <sbeuttell@walkboston.org>
Date: Mon, Mar 1, 2021 at 11:12 AM
Subject: MassDOT Sidewalk Snow Removal Pilot
To: <Jonathan.Gulliver@dot.state.ma.us>
Cc: Jacqueline DeWolfe (DOT) <jacqueline.dewolfe@state.ma.us>

Hi Jonathan.
I wanted to check in with you regarding MassDOT's sidewalk snow shoveling pilot program that is now in its second year. Several members of the MassDOT Operations and Maintenance team recently updated MABPAB on the current status of the program and relayed the many barriers that have prevented MassDOT from entering into meaningful agreements with vendors to clear MassDOT-owned sidewalks. They reported that only 8.7% of MassDOT-owned sidewalks are currently being cleared by either MassDOT staff or by contractors. Furthermore, they reported that despite making changes to the sidewalk snow removal RFP this year, no qualified vendors applied for the contract. So, needless to say,

people have been unable to walk safely on most MassDOT sidewalks throughout this snowy winter. I'm reaching out to see if there are ways WalkBoston can help with this issue, one that we feel is vitally important for year-round safe walking across the state.

I followed up with Jackie DeWolfe who suggested that I reach out to you. She reiterated MassDOT's commitment to clearing sidewalks of ice and snow, and suggested that some of the barriers are outside of MassDOT's control - for example, lack of labor market for sidewalk snow removal; and varying rules and capacities within municipalities to clear sidewalks. WalkBoston is eager and excited to find ways that we can support MassDOT and we are hoping to better understand the contract/municipal agreement issues and to get more sidewalks plowed. What next steps do you suggest we take to better understand the barriers and MassDOT's work to date to overcome them? I would be happy to set up a Zoom call to discuss these questions with you.

We know that this is an incredibly complex issue to solve. We know that you are likely as disappointed that the pilot program has now stalled for two snow seasons, as we in the advocacy community are, due to vendor/contract issues. I look forward to talking with you and discussing ways we can support forward movement on this important MassDOT priority.

Thanks Jonathan. I hope you have a good week.
Stacey Beuttell

We urge MEPA to require MassDOT to include specific, trackable and documented progress toward meeting the scope of pedestrian needs in its next filing on the MassDOT Snow and Ice Control Program, and to use its own Pedestrian Plan commitments as the baseline for reporting.

Thank you for the opportunity to comment on this critical issue for the safety, equity and mobility of Massachusetts residents.

WalkBoston would be pleased to answer any questions you may have about our comments.

Sincerely,

Stacy Beuttell   Wendy Landman

Stacey Beuttell
Executive Director

Wendy Landman
Senior Policy Advisor

Commonwealth of Massachusetts
Executive Office of Energy & Environmental Affairs

Department of Environmental Protection

One Winter Street Boston, MA 02108 • 617-292-5500

March 12, 2021

Secretary Kathleen Theoharides
Executive Office of Energy and Environmental Affairs
Attn: Eva Murray, MEPA Office
100 Cambridge Street, 9th Floor
Boston, MA 02114

RE: MassDOT Snow and Ice Control Program 2022
Draft Scope of Work Environmental Status and Planning Report
MEPA #11202

Dear Secretary Theoharides:

The Massachusetts Department of Environmental Protection (MassDEP) Bureau of Water Resources appreciates the opportunity to provide comments on the above-referenced Draft Scope of Work (DSW). This DSW describes various topics, initiatives and data analyses anticipated to be included in the next Environmental Status and Planning Report (ESPR) related to MassDOT's Snow and Ice Control Program (SICP) scheduled to be completed in 2022.

MassDEP acknowledges that ensuring the public safety of our roads, especially during the winter months, is paramount. It is also clear that protection of our public drinking waters, waterways and wetlands is vital to public health and environmental resource protection. Salt levels in our public drinking waters, surface waters, and wetlands are increasing. Salt impacts are attributable to a variety of sources (e.g., snow and ice removal on MassDOT roadways, as well as de-icing of municipal roadways and commercial/institutional/residential parking lots, wastewater discharges, and other anthropogenic sources). Solutions to these impacts are challenging, and additional collaborative efforts between MassDOT and MassDEP, and engagement with other stakeholders, are necessary to further understand and mitigate salt impacts to the Commonwealth's water resources from roadway de-icing.

We have the following general and section-specific comments regarding the Draft Scope of Work (MassDOT responses from the draft scope are in italics):

General

1) Please provide an update to the Salt Remediation Program in the 2022 ESPR SICP.

2) MassDOT's Salt Remediation Program specifies the levels of salt concentrations in drinking water at which MassDOT will perform an investigation of a private water supply. According to the Salt Remediation Program, following the investigation, MassDOT will decide the appropriate course of action which may include: construction of a replacement well, connection to a public water, installation of a water treatment system, denial of a complaint, highway drainage modifications or improvements, and improvements to operational BMPs. Please provide an update as to which of these mitigation measures have been employed by DOT and where.

3) In coordination with MassDEP as needed, MassDOT should explore establishment or expansion of a surface water quality monitoring program for conductivity using continuous data loggers. Continuous conductivity data can be used to estimate chloride using MassDEP's conductivity:chloride regression model. Continuous data help to capture maxima and minima and to calculate rolling averages to compare against acute and chronic Surface Water Quality Standards. Long-term, fixed sites could be established by MassDOT to monitor trends, and shorter-term sites could be monitored based on project-specific needs.

4) MassDOT should consider certification of private contractors similar to the NHDES Green SnowPro Program which offers snow and ice management training and certification in salt reduction practices. Certified commercial salt applicators are then granted liability protection against damages arising from snow and ice conditions (contingent upon legislative action).

Section-Specific

Initiative 1: *Training sessions this last fall had to be curtailed due to the COVID-19 pandemic.* The extent of curtailment is unclear. Was any remote training organized and conducted? What are MassDOT 's training plans for Fall 2021?

Initiative 11*: The 2022 ESPR will provide an update on new and replaced storage sheds completed since 2017.* A comprehensive inventory of salt storage sheds, priority of upgrades and schedule for future improvements should be provided in the 2022 ESPR.

DEP-2: *In FY19, MassDOT began using AVL/GPS equipment on its own vehicles in the Dedham-Westwood area. The initial rollout of this equipment and associated service contractor had several software and equipment glitches that produced inconsistent and unreliable data. MassDOT has subsequently hired a new service provider to improve the data collection process and anticipates that the data collected in the upcoming FY21 winter season will be much improved. MassDOT has initiated pilot-testing of AVL/GPS equipment in Andover and in the Zone II area of the Auburn Water District. It is* *anticipated that the data obtained from these efforts will be presented in the 2022 ESPR as the data collection process and annual usage tracking improves.* It appears that the AVL/GPS data from two winters (FY19, FY20) is unusable. The acquisition of accurate and reliable data on specific sensitive areas such as the Dedham-Westwood Water District is critical. Data reliability must be ensured during the next winter season so that this data may be presented in the 2022 ESPR report. Presumably, data will include the pilot testing of equipment in Andover and in the Zone II area of the Auburn Water District. MassDEP also recommends that MassDOT to expand the use of AVL/GPS equipment on vendor vehicles in future.

DEP-3: *MassDOT is addressing the recommendations and plan to update the 2017 ESPR data by including the most recent sodium data reported by PWSs, along with the time series graphs for the historical sodium concentrations in final ESPR 2022 report. MassDOT is planning to coordinate with MassDEP in 2021 to acquire the most up to date data reported by PWS. MassDOT also stated on page 5 of the DSW document that they will provide the information against the MassDEP comment in 2022 ESPR.* MassDEP appreciates the MassDOT intention to update the sodium concentration data in ESPR 2022 report according to the recommendations. As mentioned in the comment letter, MassDEP would like MassDOT to include data comparisons between PWSs located within and outside of a 0.5-mile radius of MassDOT road based on concentration threshold exceedances.

DEP-4: *MassDOT Response: MassDOT will share any monitoring data collected in recent field investigation efforts and will identify and delineate subcatchment areas associated with the latest chloride impaired waters included in most recent 303(d) list.* The most recent 303(d) list is the draft/final combined 2018/2020 Integrated Report. The SOW should state specifically that the data summary based on the draft/final 2018/20 Integrated Report will be included in the 2022 ESPR.

DEP-6: *MassDOT Response: MassDOT plans to collect more detailed salt usage data in the Dedham-Westwood Water District area using AVL/GPS equipment. As discussed above, although the initial rollout of this equipment was unsuccessful due to various software and technical issues, MassDOT has initiated several changes with the goal of collecting more consistent and reliable data in the 2020/21 season.* The Scope of Work should state specifically that the data and results of the study will be included in the 2022 ESPR. See also related comment for DEP-2.

DEP-9: *In 2018, MassDOT submitted a grant application to the NEIWPCC to obtain grant funding to support a regional training program that would provide educational and training opportunities for municipal employees and private contractors. The grant application, however, was not approved.* Despite not receiving the grant, it is unclear what if any efforts have taken place to develop outreach and training materials to educate the public, commercial applicators and other road salt users on various salt reduction or efficiency measures. Regardless of grant funding, MassDOT needs to develop an effective and sustainable educational outreach. UMass Transportation Center's Bay State Roads Program is a resource for outreach and training. MassDEP will assist, if requested.

DEP-11*: In addition to the Dedham-Westwood area, MassDOT is pilot-testing the use of AVL/GPS equipment in the Andover area and plans to expand the use of this equipment in the Auburn Water District wellfield area and along Route I-90 near the Kampoosa Bog. These efforts are in the very early stages of implementation but….MassDOT would be happy to discuss with MassDEP other priority* *locations for potential future use of AVL/GPS equipment as resources become available, as part of the planned agency meetings to be scheduled in finalizing this Draft Scope of Work.* MassDEP would be pleased to coordinate with MassDOT on locations for expansion of the AVL/GPS equipment deployment which could be done, for example, in areas with current 303(d)-listed impairments for chloride. In addition, it is noted that MassDOT is currently only installing this equipment on MassDOT-owned vehicles. MassDOT should also evaluate expansion of the use of these technologies to instrument vendor vehicles, to the extent practicable.

DEP-12: *As mentioned above, MassDOT had applied for a NEIWPCC grant to help support a potential regional training and outreach effort that would involve collaborative efforts across multiple states. Unfortunately, this initiative was not selected for funding by the NEIWPCC Program. At this time, MassDOT does not have funding or staff resources in its current budget to support this effort but would be willing to discuss with MassDEP the need and potential options for a regional training and outreach initiative for commercial and municipal operators as part of regional collaborative partnership.* See comment for DEP-9.

DEP-13*: MassDOT is actively participating and funding several ongoing watershed-based field efforts to evaluate the effects of winter road maintenance on surface and ground water quality in key priority areas. These efforts involve collaborative efforts with academia and major public water suppliers. Prior to initiating any new studies, MassDOT prefers to first evaluate the findings of these recent studies to help guide the scope and needs of any future studies and to ensure that any future studies are done effectively and efficiently using the information learned from previous studies.* It would be helpful to MassDEP to have a better understanding from MassDOT of its existing studies as well as any plans for future studies, including the addition of sites.

MassDEP looks forward to continued work with MassDOT on water resource protection related to implementation of the SICP.

Please feel free to contact Heidi Davis of the Wetlands Program at heidi.davis@mass.gov if you have any questions regarding MassDEP's comments.

Sincerely,

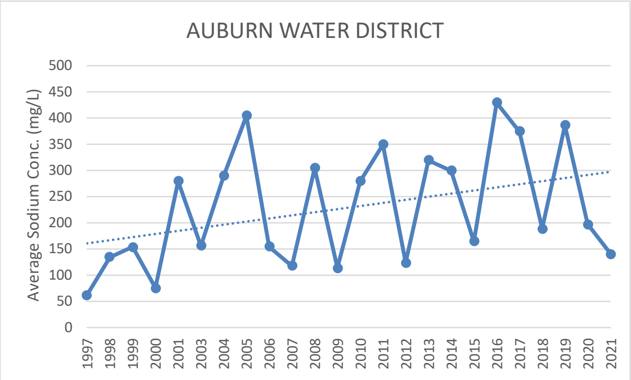
Kathleen M. Baskin
Assistant Commissioner
Bureau of Water Resources

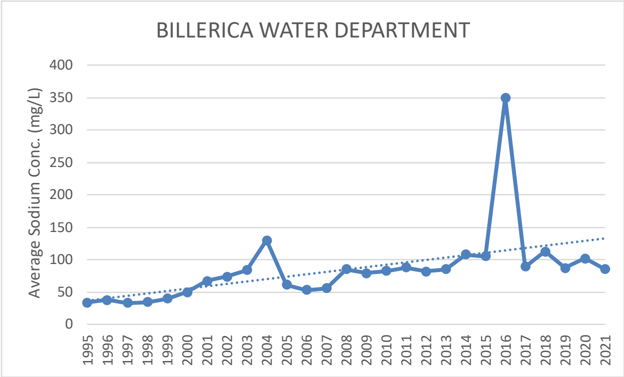
Cc: Stephanie Moura, Director, Wetlands and Waterways Program
Laura Blake, Director, Watershed Planning Program
Richard Chase, Watershed Planning Program
Yvette DePeiza, Director, Drinking Water Program

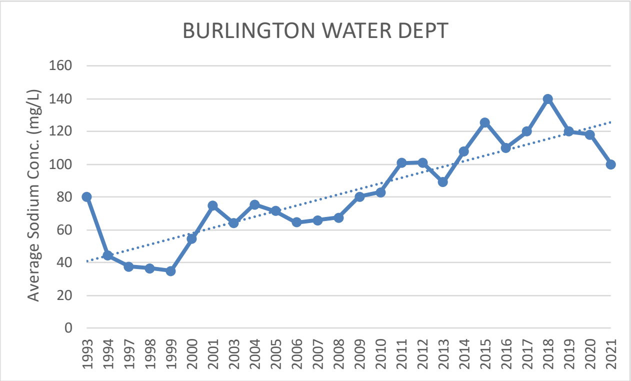
B

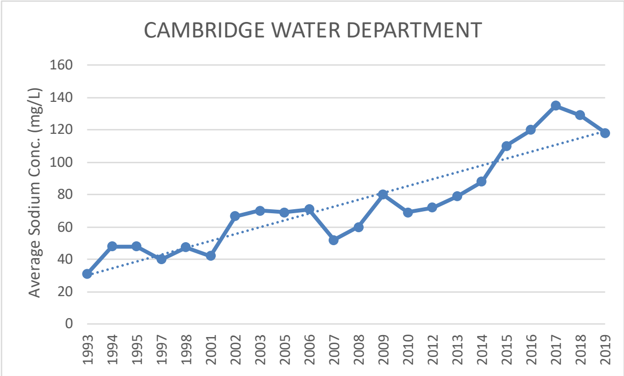
Average Annual Sodium Time Series Graphs for Various Municipal Public Water Supplies

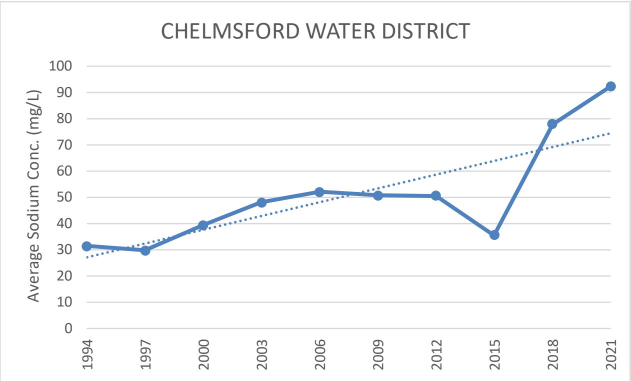
This page intentionally left blank.

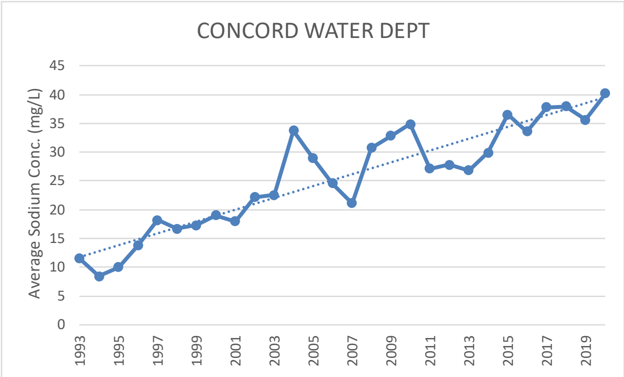

AUBURN WATER DISTRICT
Average Sodium Conc. (mg/L)
0 50 100 150 200 250 300 350 400 450 500
1997 1998 1999 2000 2001 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021

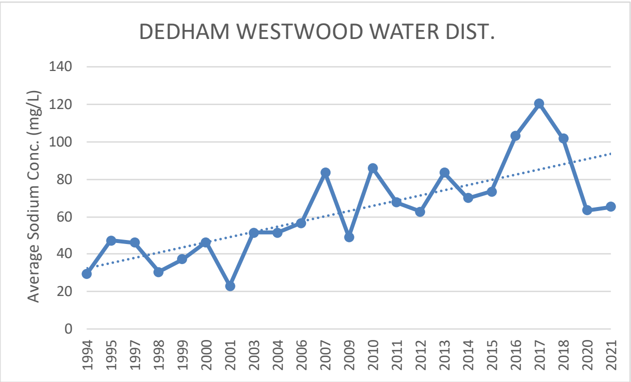

BILLERICA WATER DEPARTMENT
Average Sodium Conc. (mg/L)
0 50 100 150 200 250 300 350 400
1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021

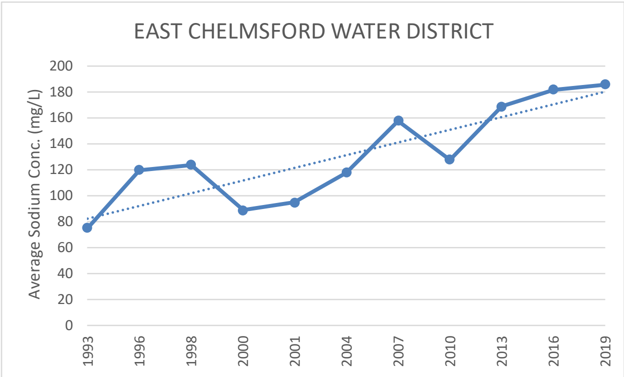

BURLINGTON WATER DEPT
Average Sodium Conc. (mg/L)
0 20 40 60 80 100 120 140 160
1993 1994 1997 1998 1999 2000 2001 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021

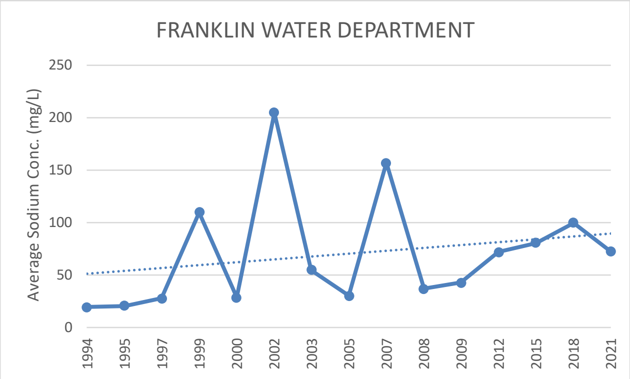

CAMBRIDGE WATER DEPARTMENT
Average Sodium Conc. (mg/L)
0 20 40 60 80 100 120 140 160
1993 1994 1995 1997 1998 2001 2002 2003 2005 2006 2007 2008 2009 2010 2012 2013 2014 2015 2016 2017 2018 2019

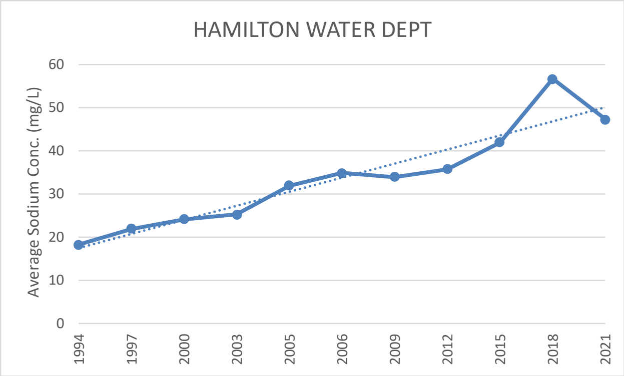

CHELMSFORD WATER DISTRICT
Average Sodium Conc. (mg/L)
0 10 20 30 40 50 60 70 80 90 100
1994 1997 2000 2003 2006 2009 2012 2015 2018 2021

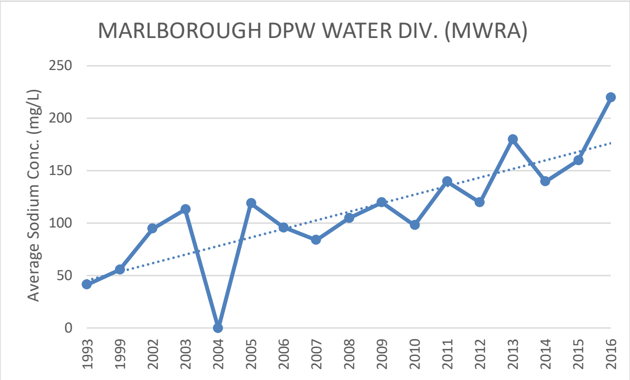

CONCORD WATER DEPT
Average Sodium Conc. (mg/L)
0 5 10 15 20 25 30 35 40 45
1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015 2017 2019

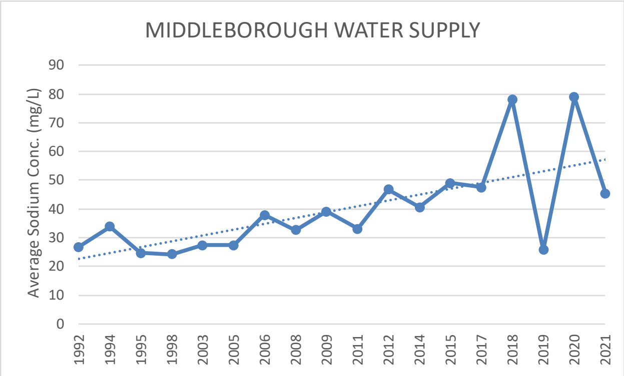

DEDHAM WESTWOOD WATER DIST.
Average Sodium Conc. (mg/L)
0 20 40 60 80 100 120 140
1994 1995 1997 1998 1999 2000 2001 2003 2004 2006 2007 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2020 2021

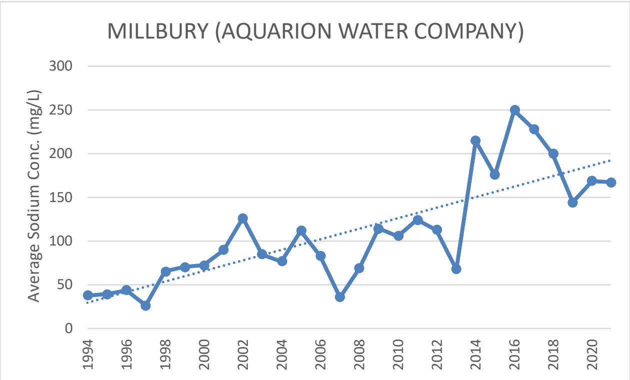

EAST CHELMSFORD WATER DISTRICT
Average Sodium Conc. (mg/L)
0 20 40 60 80 100 120 140 160 180 200
1993 1996 1998 2000 2001 2004 2007 2010 2013 2016 2019

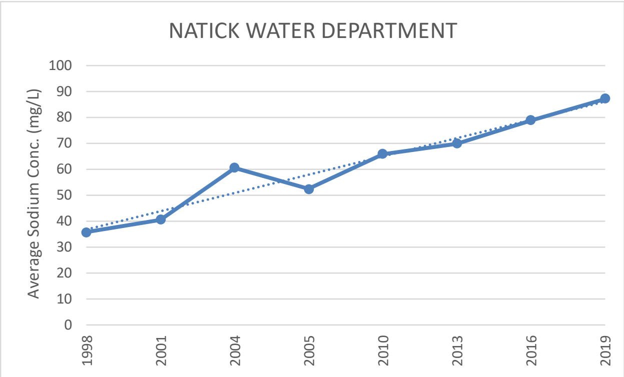

FRANKLIN WATER DEPARTMENT
Average Sodium Conc. (mg/L)
0
50
100
150
200
250
1994
1995
1997
1999
2000
2002
2003
2005
2007
2008
2009
2012
2015
2018
2021

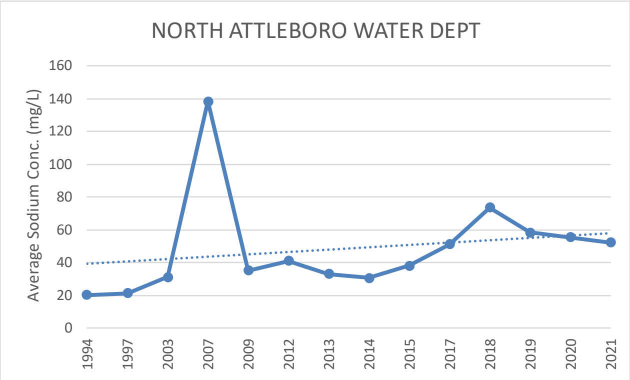

HAMILTON WATER DEPT
Average Sodium Conc. (mg/L)
0
10
20
30
40
50
60
1994
1997
2000
2003
2005
2006
2009
2012
2015
2018
2021

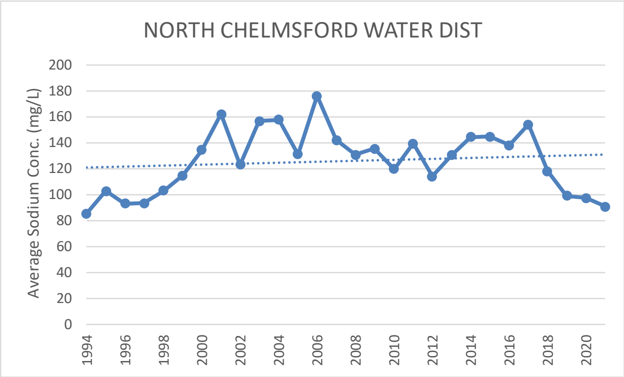

MARLBOROUGH DPW WATER DIV. (MWRA)
Average Sodium Conc. (mg/L)
0
50
100
150
200
250
1993
1999
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016

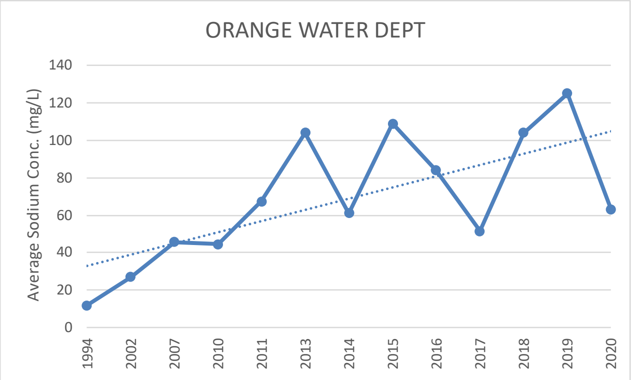

MIDDLEBOROUGH WATER SUPPLY
Average Sodium Conc. (mg/L)
0
10
20
30
40
50
60
70
80
90
1992
1994
1995
1998
2003
2005
2006
2008
2009
2011
2012
2014
2015
2017
2018
2019
2020
2021

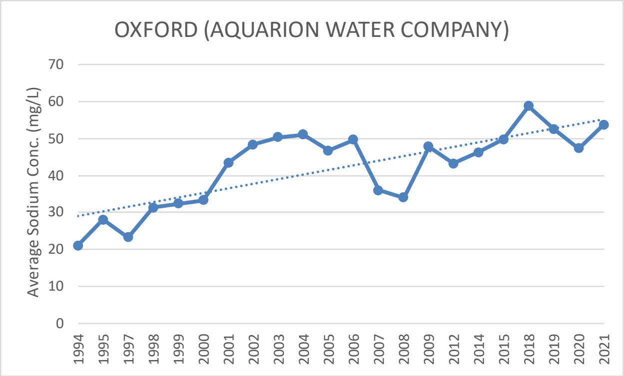

MILLBURY (AQUARION WATER COMPANY)
Average Sodium Conc. (mg/L)
0
50
100
150
200
250
300
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020

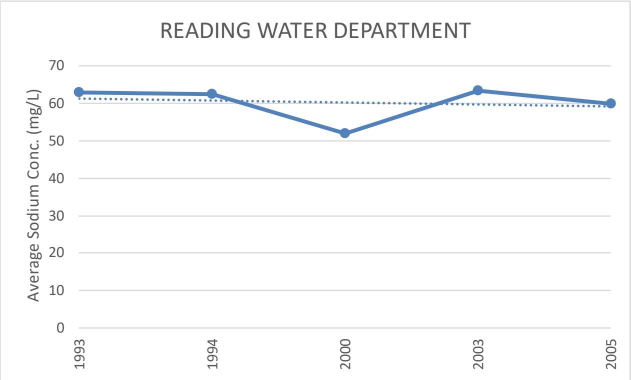

NATICK WATER DEPARTMENT
Average Sodium Conc. (mg/L)
0
10
20
30
40
50
60
70
80
90
100
1998
2001
2004
2005
2010
2013
2016
2019

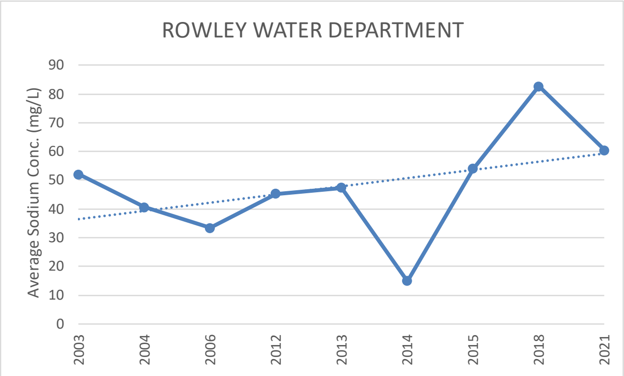

NORTH ATTLEBORO WATER DEPT
Average Sodium Conc. (mg/L)
0
20
40
60
80
100
120
140
160
1994
1997
2003
2007
2009
2012
2013
2014
2015
2017
2018
2019
2020
2021

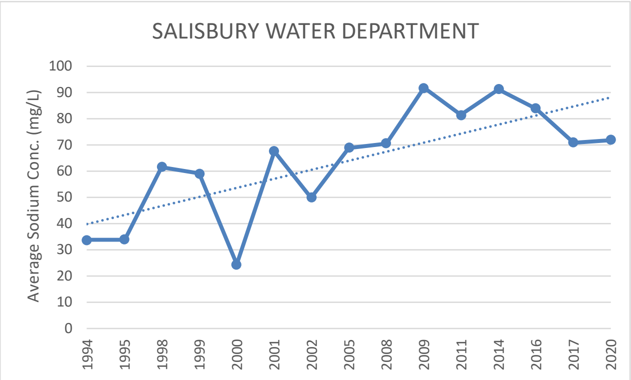

NORTH CHELMSFORD WATER DIST
Average Sodium Conc. (mg/L)
0
20
40
60
80
100
120
140
160
180
200
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020

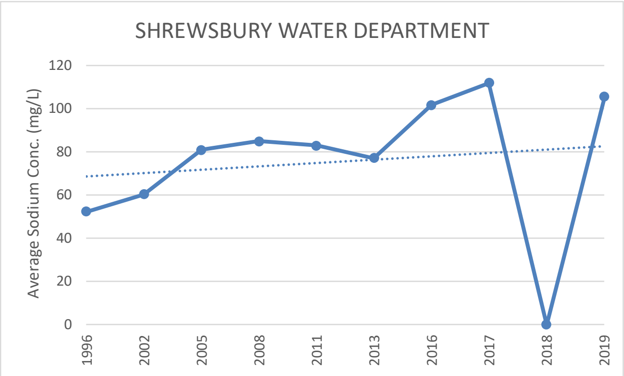

ORANGE WATER DEPT
Average Sodium Conc. (mg/L)
0 20 40 60 80 100 120 140
1994 2002 2007 2010 2011 2013 2014 2015 2016 2017 2018 2019 2020

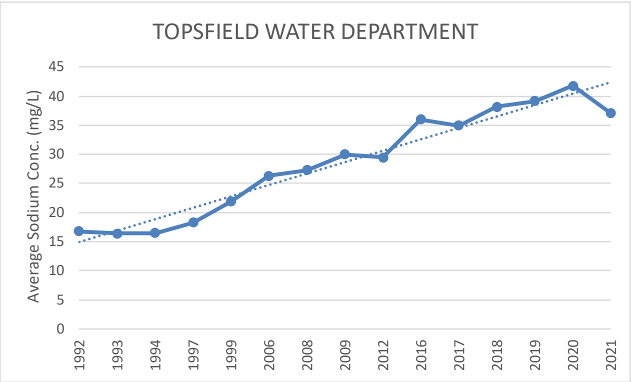

OXFORD (AQUARION WATER COMPANY)
Average Sodium Conc. (mg/L)
0 10 20 30 40 50 60 70
1994 1995 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2012 2014 2015 2018 2019 2020 2021

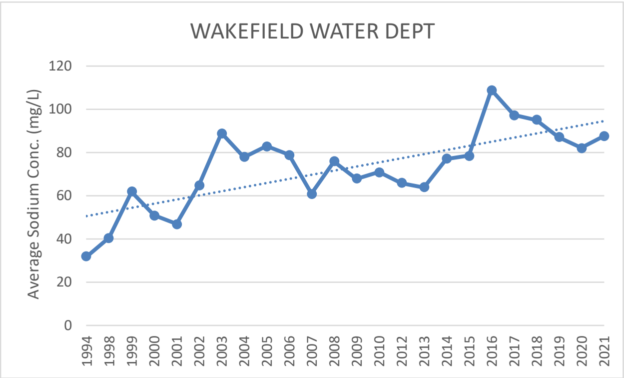

READING WATER DEPARTMENT
Average Sodium Conc. (mg/L)
0 10 20 30 40 50 60 70
1993 1994 2000 2003 2005

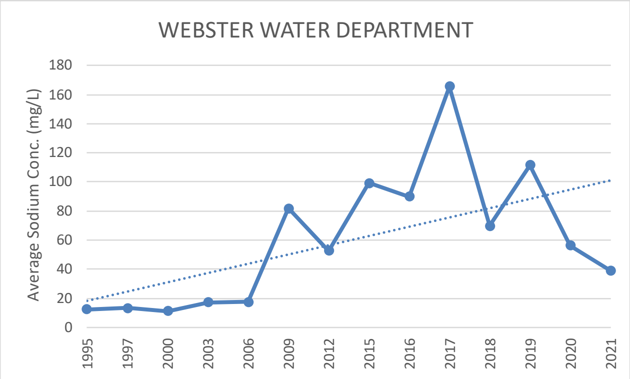

ROWLEY WATER DEPARTMENT
Average Sodium Conc. (mg/L)
0 10 20 30 40 50 60 70 80 90
2003 2004 2006 2012 2013 2014 2015 2018 2021

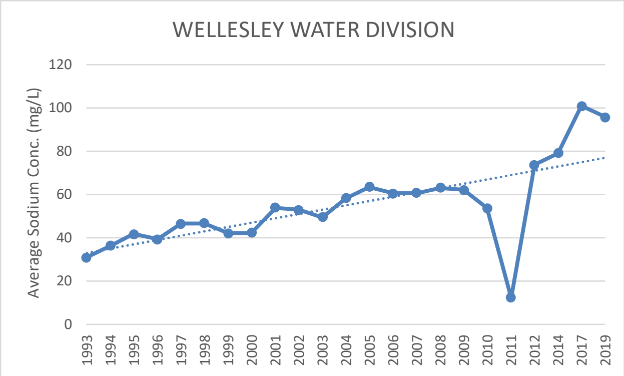

SALISBURY WATER DEPARTMENT
Average Sodium Conc. (mg/L)
0 10 20 30 40 50 60 70 80 90 100
1994 1995 1998 1999 2000 2001 2002 2005 2008 2009 2011 2014 2016 2017 2020

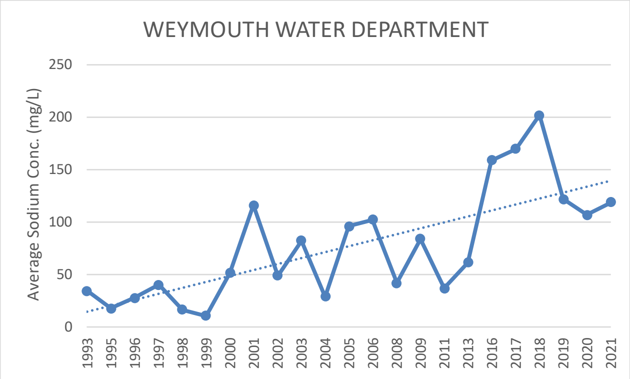

SHREWSBURY WATER DEPARTMENT
Average Sodium Conc. (mg/L)
0 20 40 60 80 100 120
1996 2002 2005 2008 2011 2013 2016 2017 2018 2019

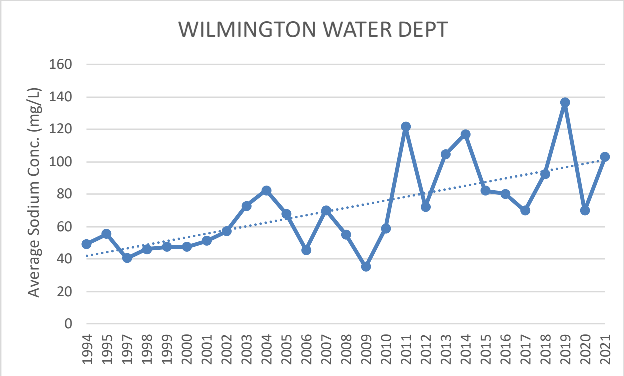

TOPSFIELD WATER DEPARTMENT
Average Sodium Conc. (mg/L)
0 5 10 15 20 25 30 35 40 45
1992 1993 1994 1997 1999 2006 2008 2009 2012 2016 2017 2018 2019 2020 2021

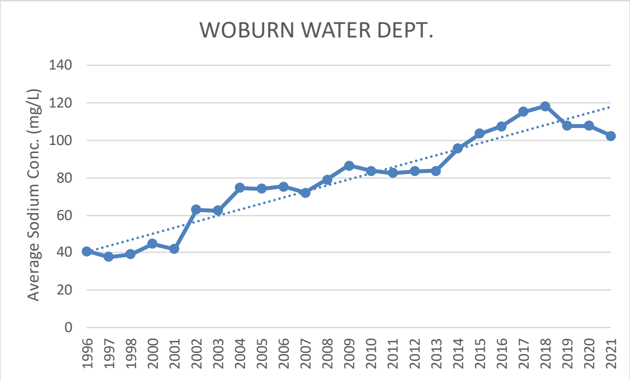

WAKEFIELD WATER DEPT
Average Sodium Conc. (mg/L)
0 20 40 60 80 100 120
1994 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021


WEBSTER WATER DEPARTMENT
Average Sodium Conc. (mg/L)
0
20
40
60
80
100
120
140
160
180
1995
1997
2000
2003
2006
2009
2012
2015
2016
2017
2018
2019
2020
2021


WELLESLEY WATER DIVISION
Average Sodium Conc. (mg/L)
0
20
40
60
80
100
120
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2014
2017
2019


WEYMOUTH WATER DEPARTMENT
Average Sodium Conc. (mg/L)
0
50
100
150
200
250
1993
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2008
2009
2011
2013
2016
2017
2018
2019
2020
2021


WILMINGTON WATER DEPT
Average Sodium Conc. (mg/L)
0
20
40
60
80
100
120
140
160
1994
1995
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021

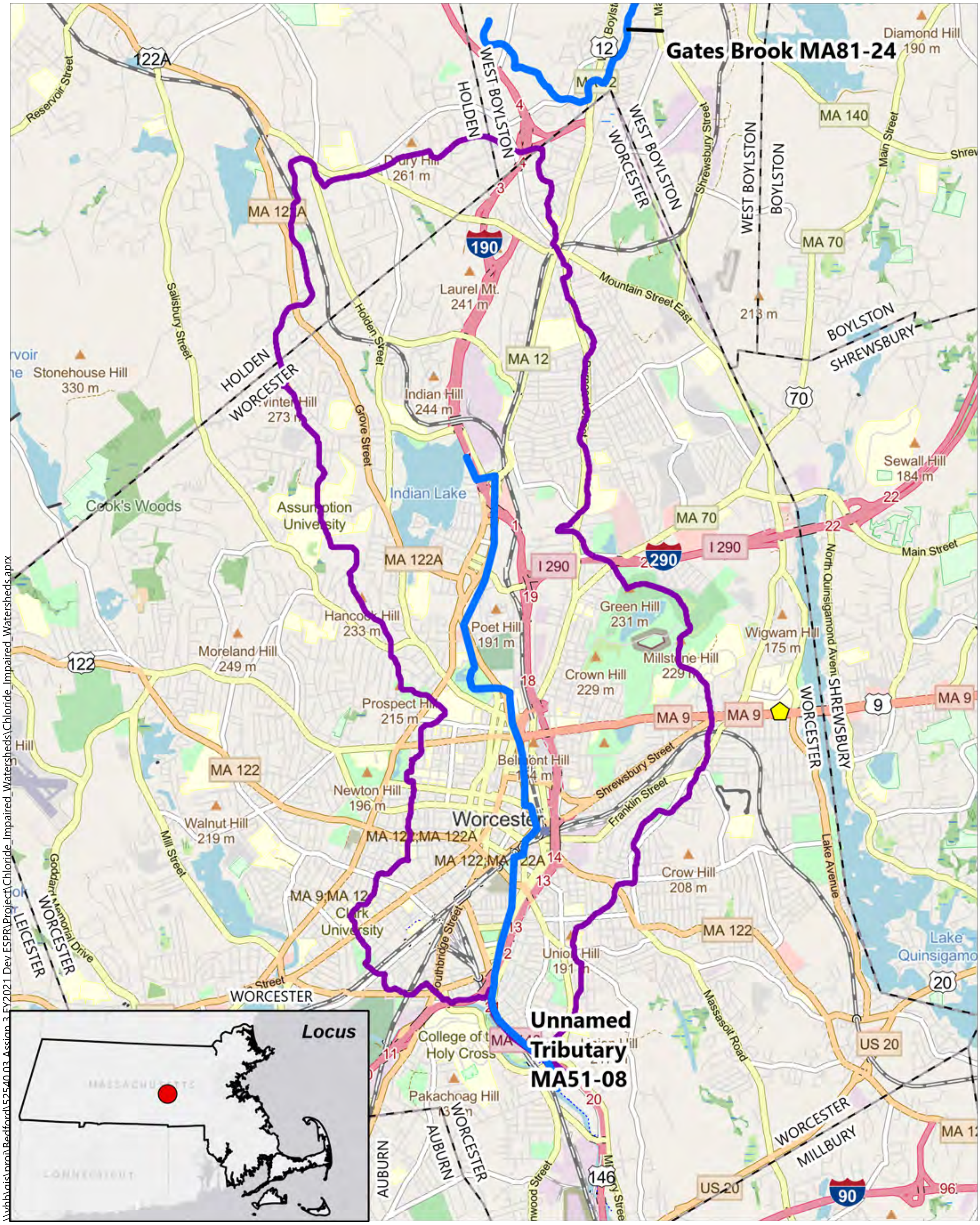

WOBURN WATER DEPT.
Average Sodium Conc. (mg/L)
0
20
40
60
80
100
120
140
1996
1997
1998
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021

C

Watershed Maps of Chloride Impaired Waters

This page intentionally left blank.

December 2022



0 1500 3000 6000 Feet

2022 Snow & Ice Control ESPR | MassDOT

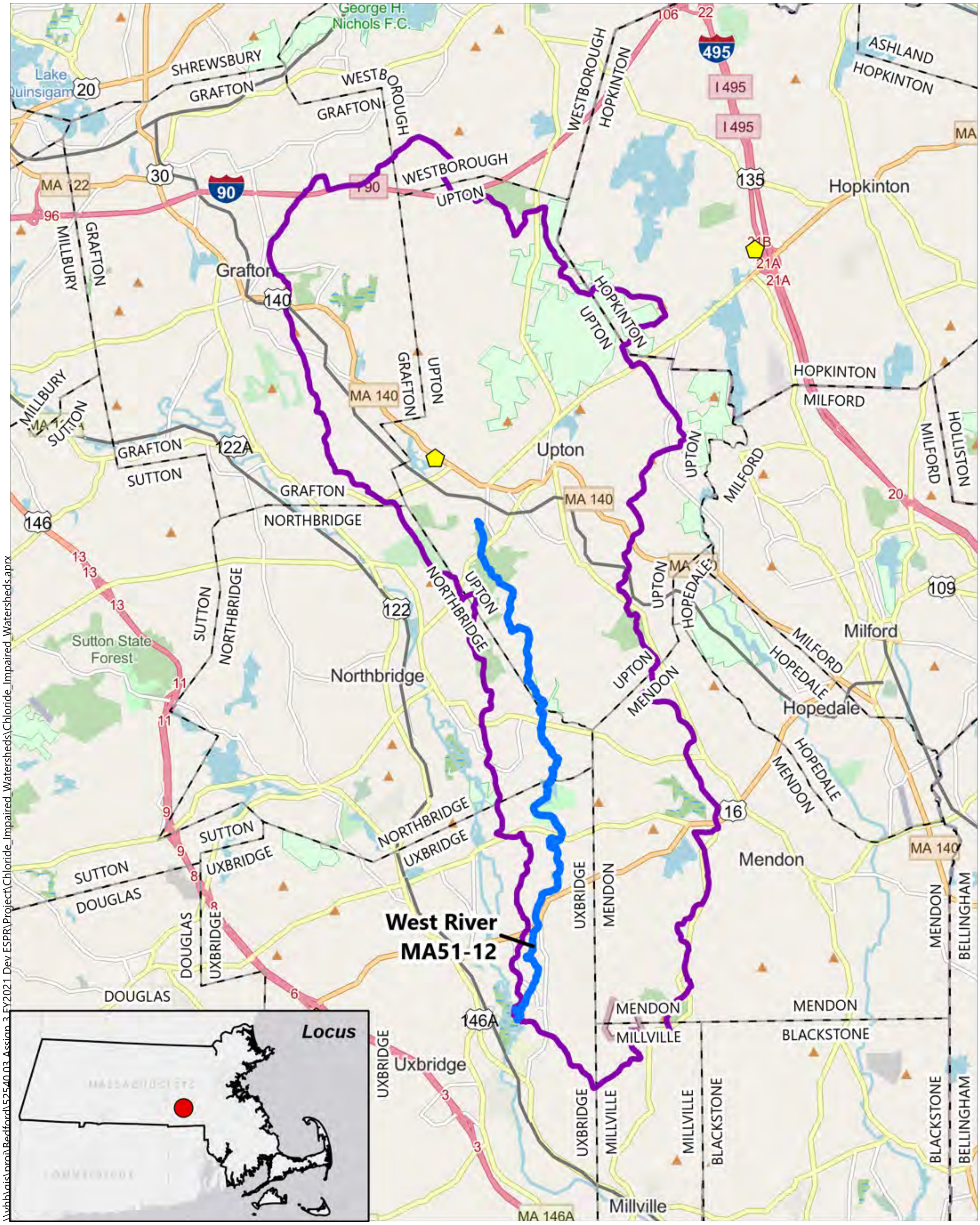
Legend

Chloride Impaired Stream
Town Boundary
Drainage Sub Basin
MassDOT Maintenance Depot

Chloride Impaired Watershed
Unnamed Tributary
MA51-08

Sources: MassGIS, MassDOT, VHB

\\vhb\gis\proj\Bedford\52540.03 Assign 3 FY2021 Dev ESPR\Project\Chloride_Impaired_Watersheds\Chloride_Impaired_Watersheds.aprx



0 3000 6000 12000 Feet

2022 Snow & Ice Control ESPR | MassDOT

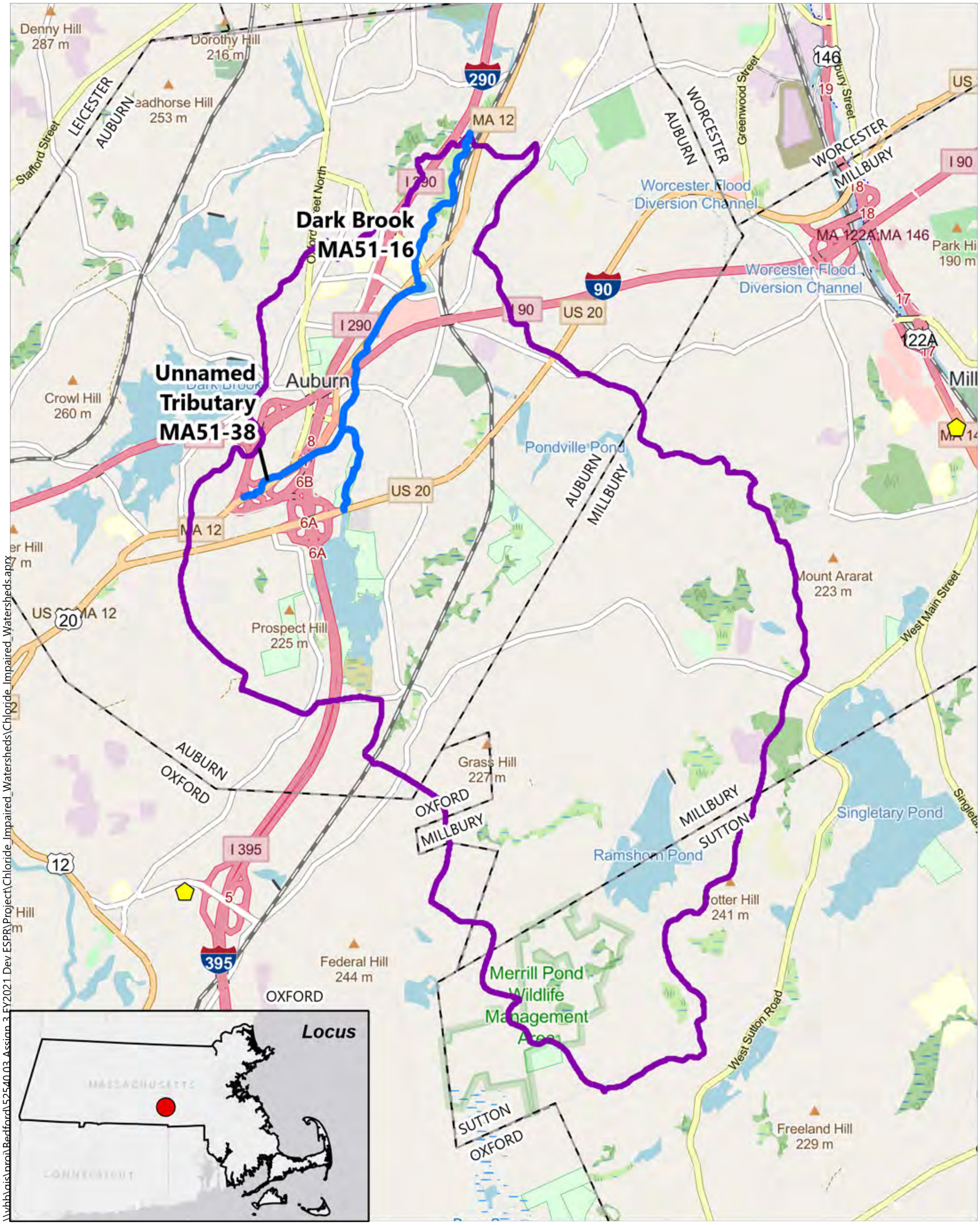
Legend

Chloride Impaired Stream
Town Boundary
Drainage Sub Basin
MassDOT Maintenance Depot

Chloride Impaired Watershed
West River
MA51-12

Sources: MassGIS, MassDOT, VHB

December 2022



0 1250 2500 5000 Feet

2022 Snow & Ice Control ESPR | MassDOT

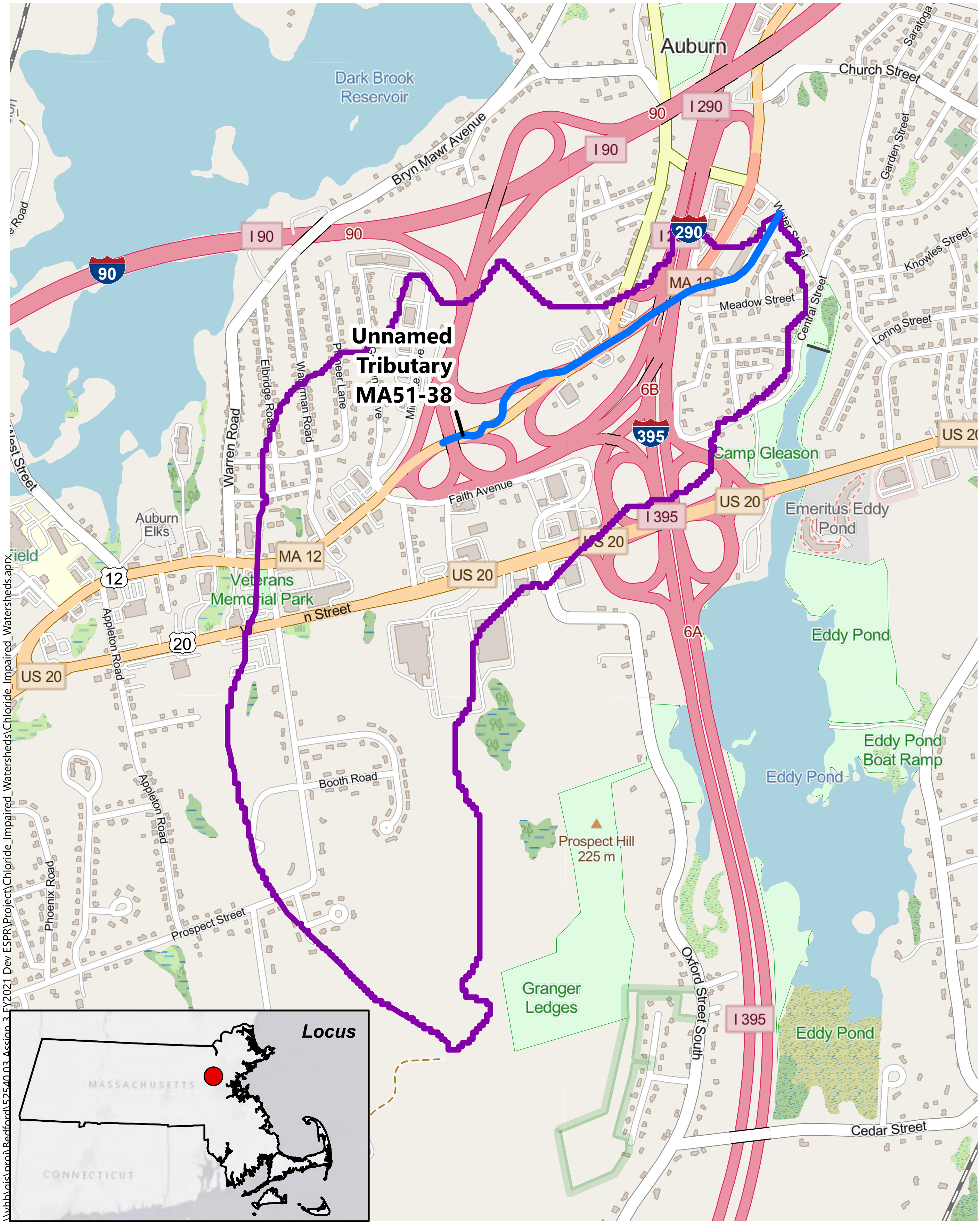
Legend

- Chloride Impaired Stream
- Drainage Sub Basin
- Town Boundary
- MassDOT Maintenance Depot

Chloride Impaired Watershed
Dark Brook
MA51-16

Sources: MassGIS, MassDOT, VHB

December 2022



0 420 840 1680 Feet

2022 Snow & Ice Control ESPR | MassDOT

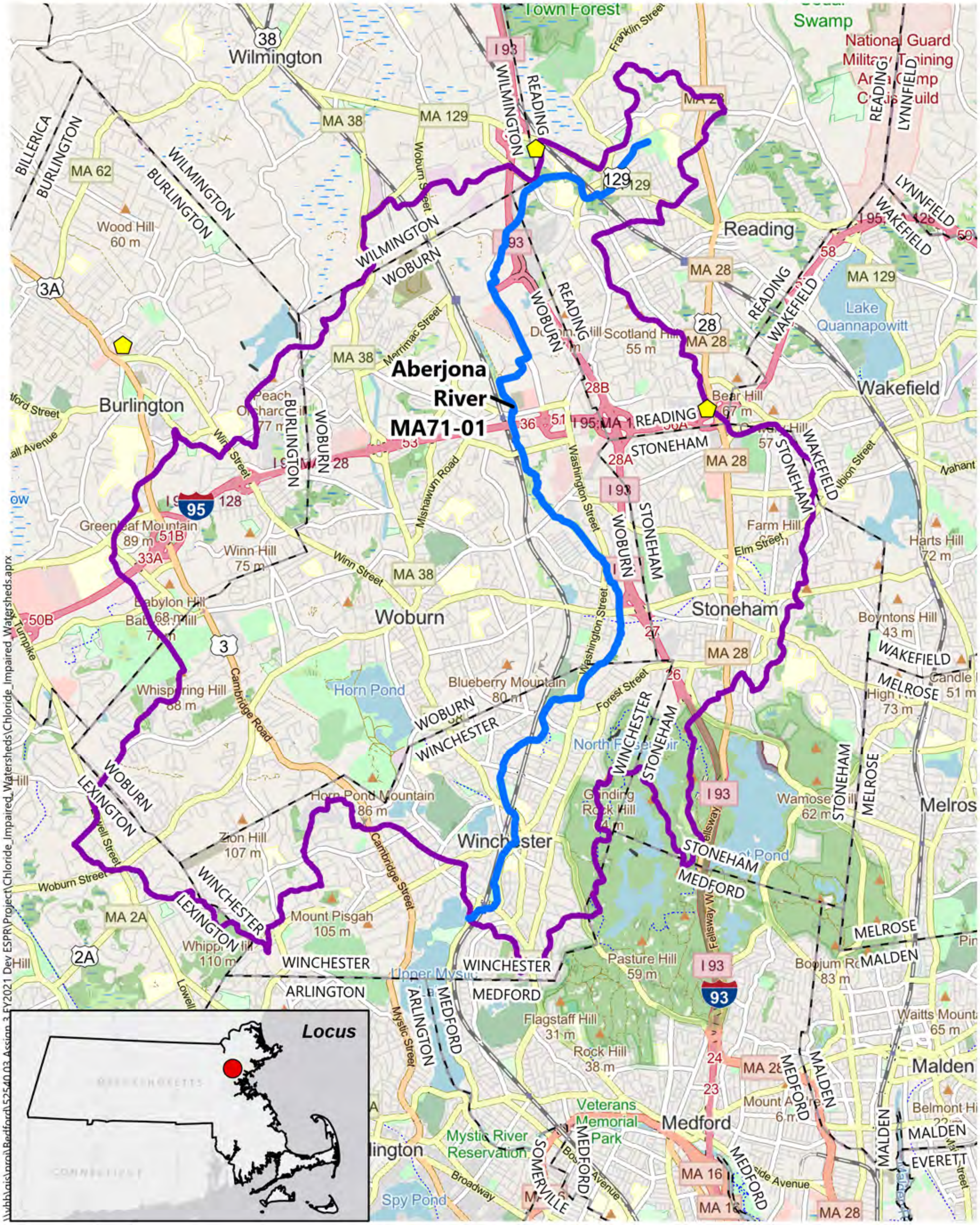
Chloride Impaired Watershed
Unnamed Tributary-MA51-38

Legend

- Chloride Impaired Stream
- Town Boundary
- Drainage Sub Basin

Source: MassGIS, MassDOT, VHB

\\vhb\gis\proj\Bedford\15254.03 Assign 3 FY2021 Dev ESPR\Project\Chloride_Impaired_Watersheds\Chloride_Impaired_Watersheds.aprx



↑ 0 1500 3000 6000 Feet

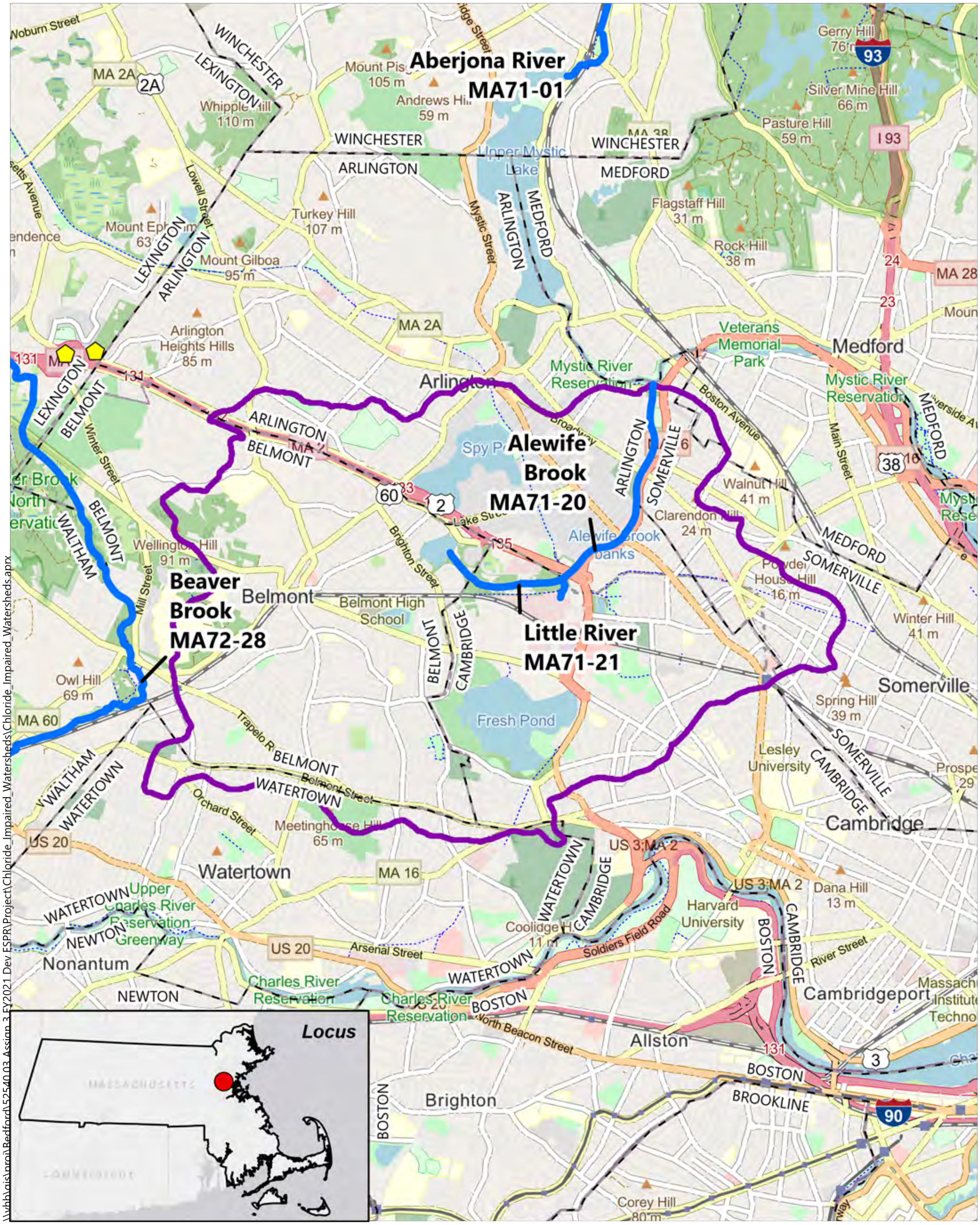
2022 Snow & Ice Control ESPR | MassDOT

Legend

- Chloride Impaired Stream
- Chloride Impaired Lake
- Drainage Sub Basin
- MassDOT Maintenance Depot
- Town Boundary

Chloride Impaired Watershed
Aberjona River - MA71-01

Source: MassGIS, MassDOT, VHB



\\vhb\gis\proj\Bedford\52540.03 Assign 3 FY2021 Dev ESPR\Project\Chloride_Impaired_Watersheds\Chloride_Impaired_Watersheds.aprx

0 1250 2500 5000 Feet

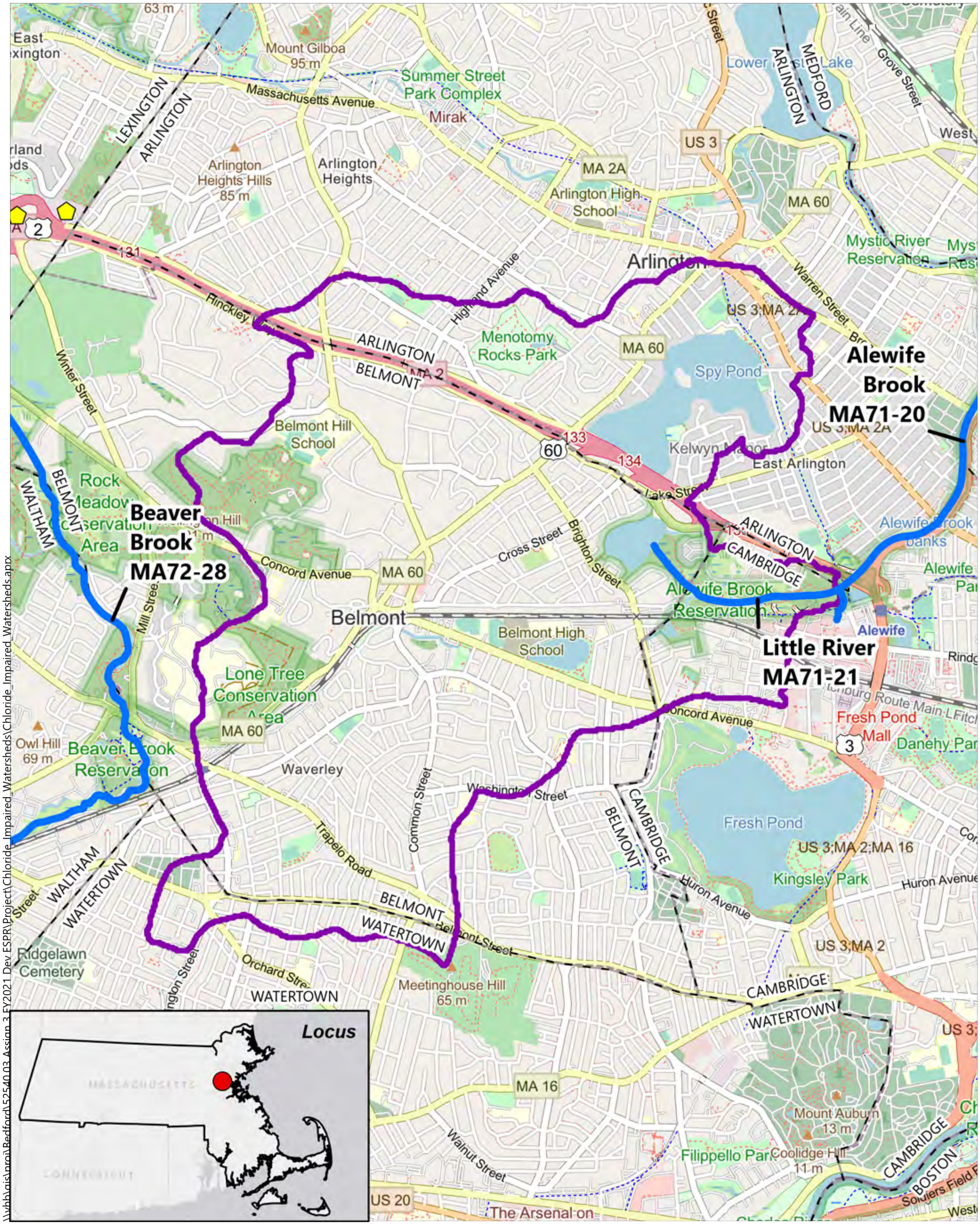
2022 Snow & Ice Control ESPR | MassDOT

Legend

- Chloride Impaired Stream
- Drainage Sub Basin
- Town Boundary
- MassDOT Maintenance Depot

Chloride Impaired Watershed
Alewife Brook
MA71-20

Sources: MassGIS, MassDOT, VHB



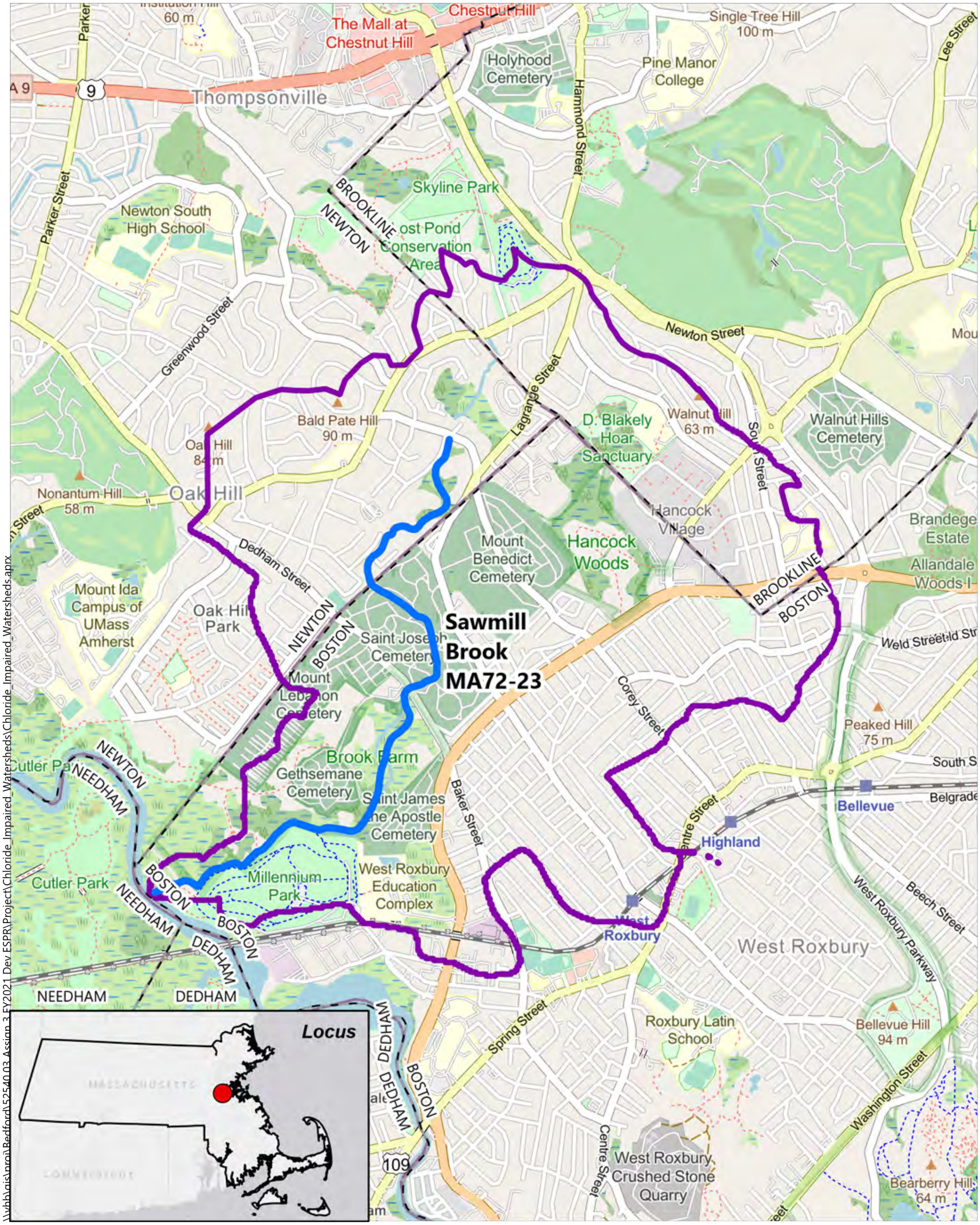
2022 Snow & Ice Control ESPR | MassDOT

Legend

- Chloride Impaired Stream
- Drainage Sub Basin
- Town Boundary
- MassDOT Maintenance Depot

Chloride Impaired Watershed
Little River
MA71-21

Sources: MassGIS, MassDOT, VHB



0 500 1000 2000 Feet

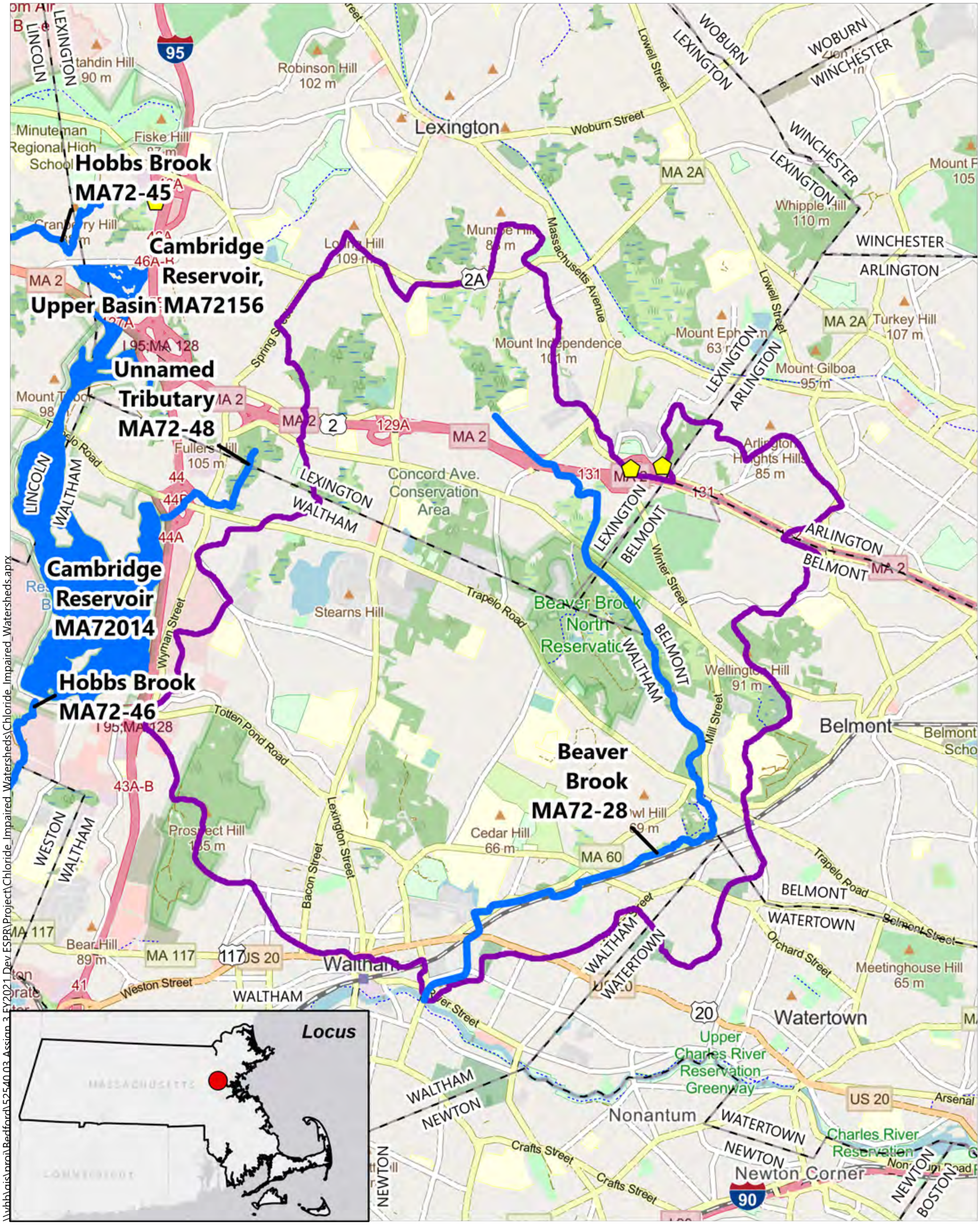
2022 Snow & Ice Control ESPR | MassDOT

Legend

- Chloride Impaired Stream
- Town Boundary
- Drainage Sub Basin

Chloride Impaired Watershed
Sawmill Brook
MA72-23

Sources: MassGIS, MassDOT, VHB



0 1250 2500 5000 Feet

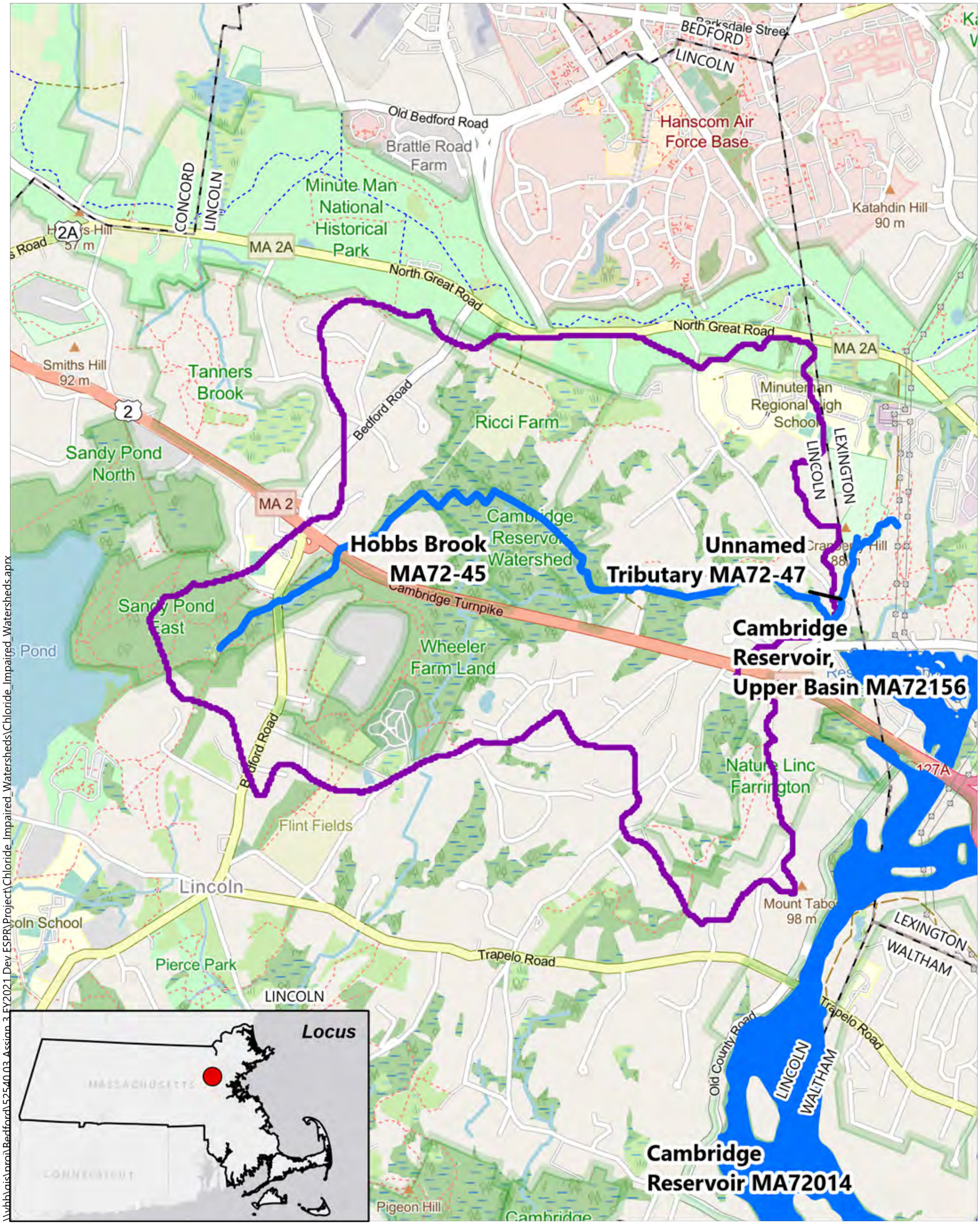
2022 Snow & Ice Control ESPR | MassDOT

Legend

- Chloride Impaired Stream
- Chloride Impaired Lake
- Drainage Sub Basin
- Town Boundary
- MassDOT Maintenance Depot

Chloride Impaired Watershed
Beaver Brook
MA72-28

Sources: MassGIS, MassDOT, VHB



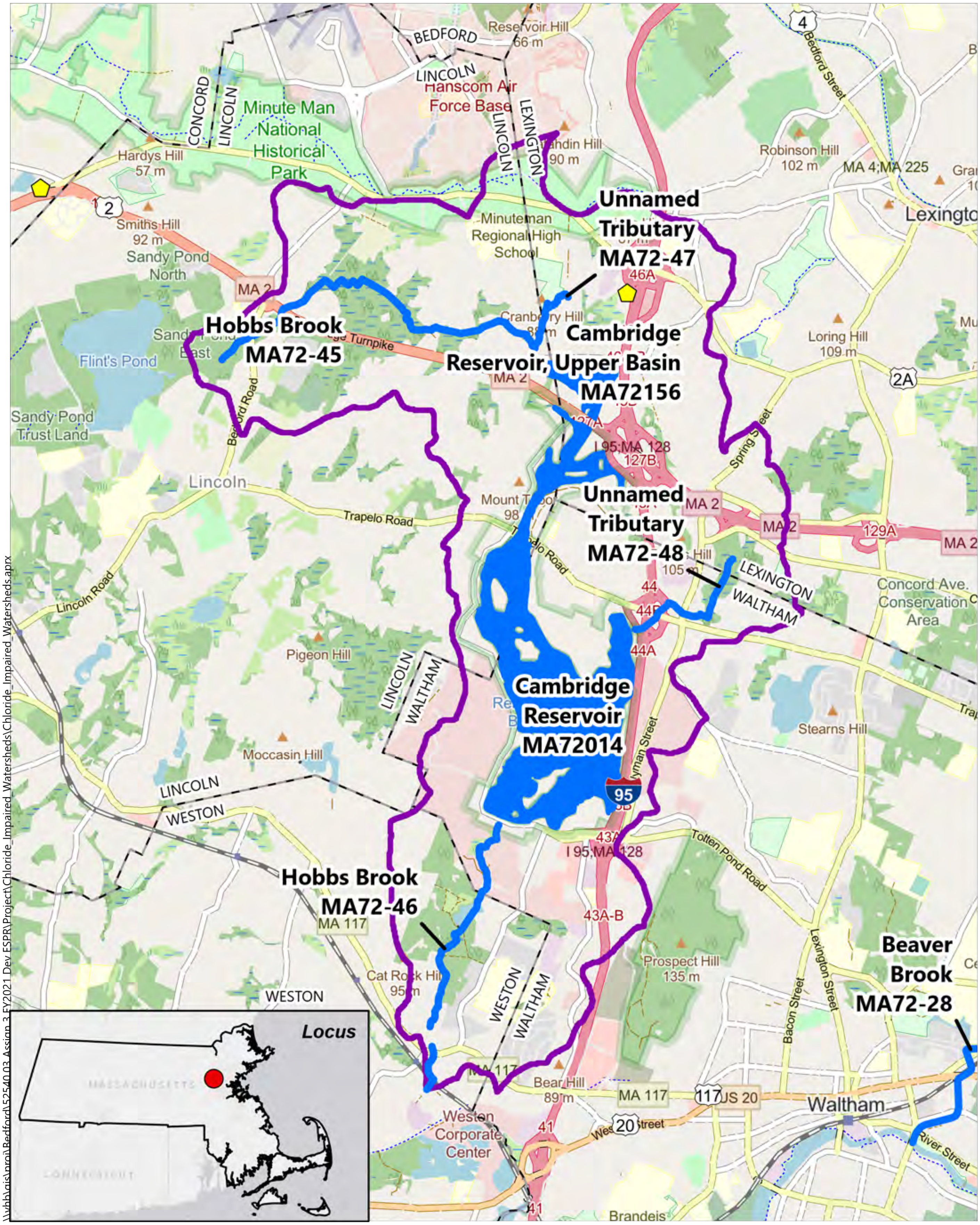
2022 Snow & Ice Control ESPR | MassDOT

Legend

- Chloride Impaired Stream
- Chloride Impaired Lake
- Drainage Sub Basin
- Town Boundary

Chloride Impaired Watershed
Hobbs Brook
MA72-45

Sources: MassGIS, MassDOT, VHB



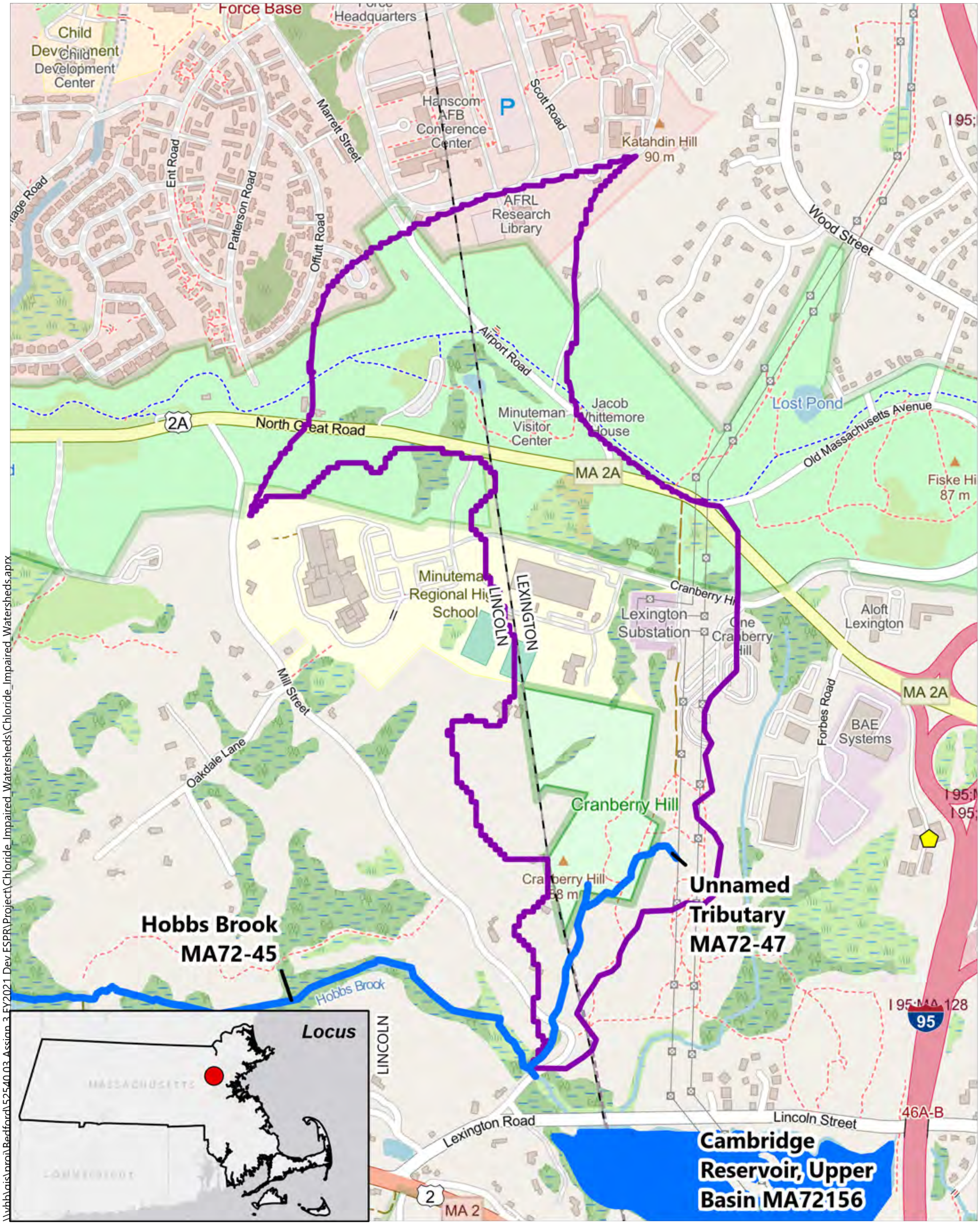
\\vhb\gis\proj\Bedford\52540.03 Assign 3 FY2021 Dev ESPR\Project\Chloride_Impaired_Watersheds\Chloride_Impaired_Watersheds.aprx

2022 Snow & Ice Control ESPR | MassDOT

Legend
- Chloride Impaired Stream
- Chloride Impaired Lake
- Drainage Sub Basin
- Town Boundary
- MassDOT Maintenance Depot

Chloride Impaired Watershed
Hobbs Brook
MA72-46

Sources: MassGIS, MassDOT, VHB



\\vhb\gis\proj\Bedford\52540.03 Assign 3 FY2021 Dev ESPR\Project\Chloride_Impaired_Watersheds\Chloride_Impaired_Watersheds.aprx

0 305 610 1220 Feet

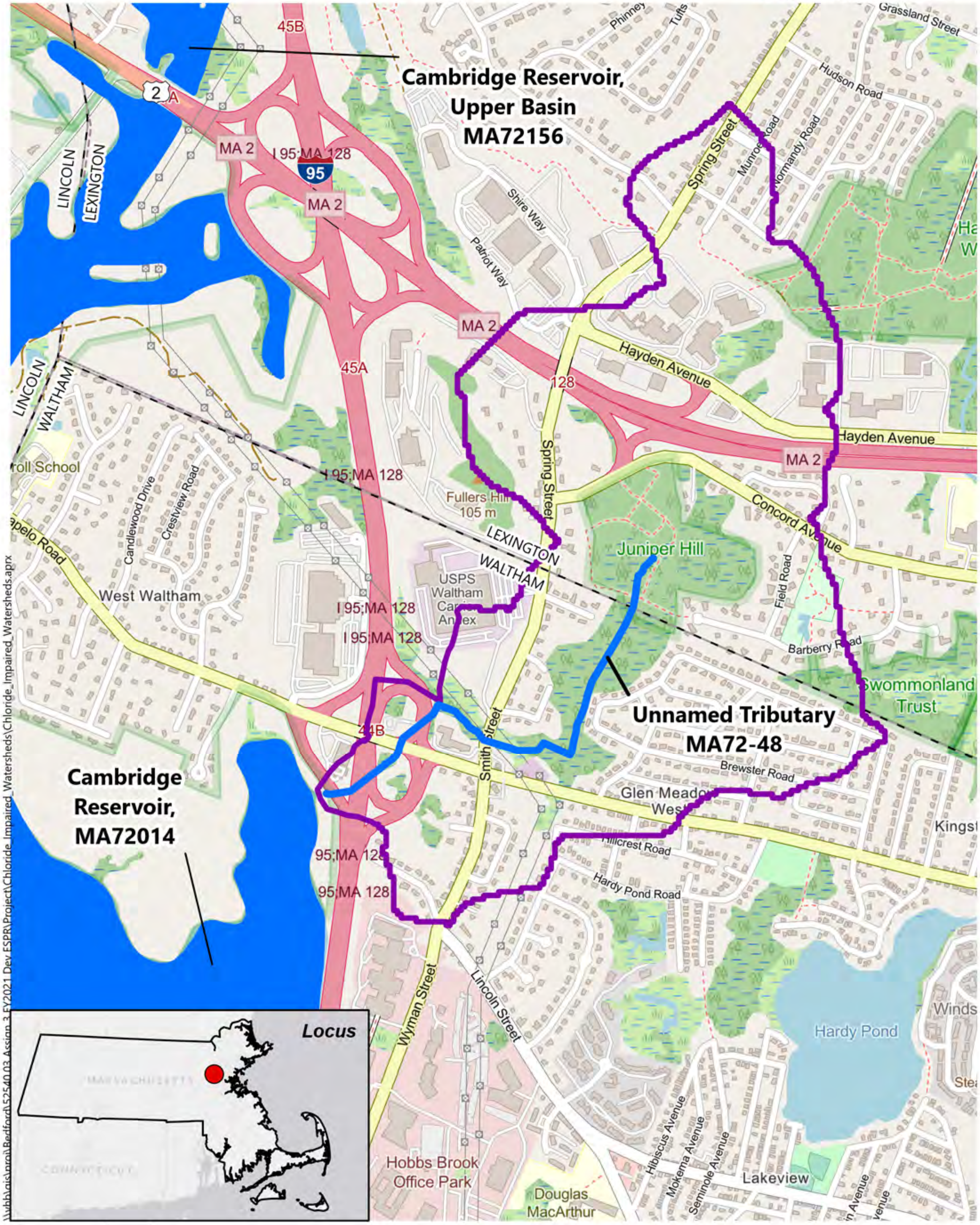
2022 Snow & Ice Control ESPR | MassDOT

Legend

- Chloride Impaired Stream
- Chloride Impaired Lake
- Drainage Sub Basin
- Town Boundary
- MassDOT Maintenance Depot

Chloride Impaired Watershed
Unnamed Tributary
MA72-47

Sources: MassGIS, MassDOT, VHB



↑ 0 390 780 1560 Feet

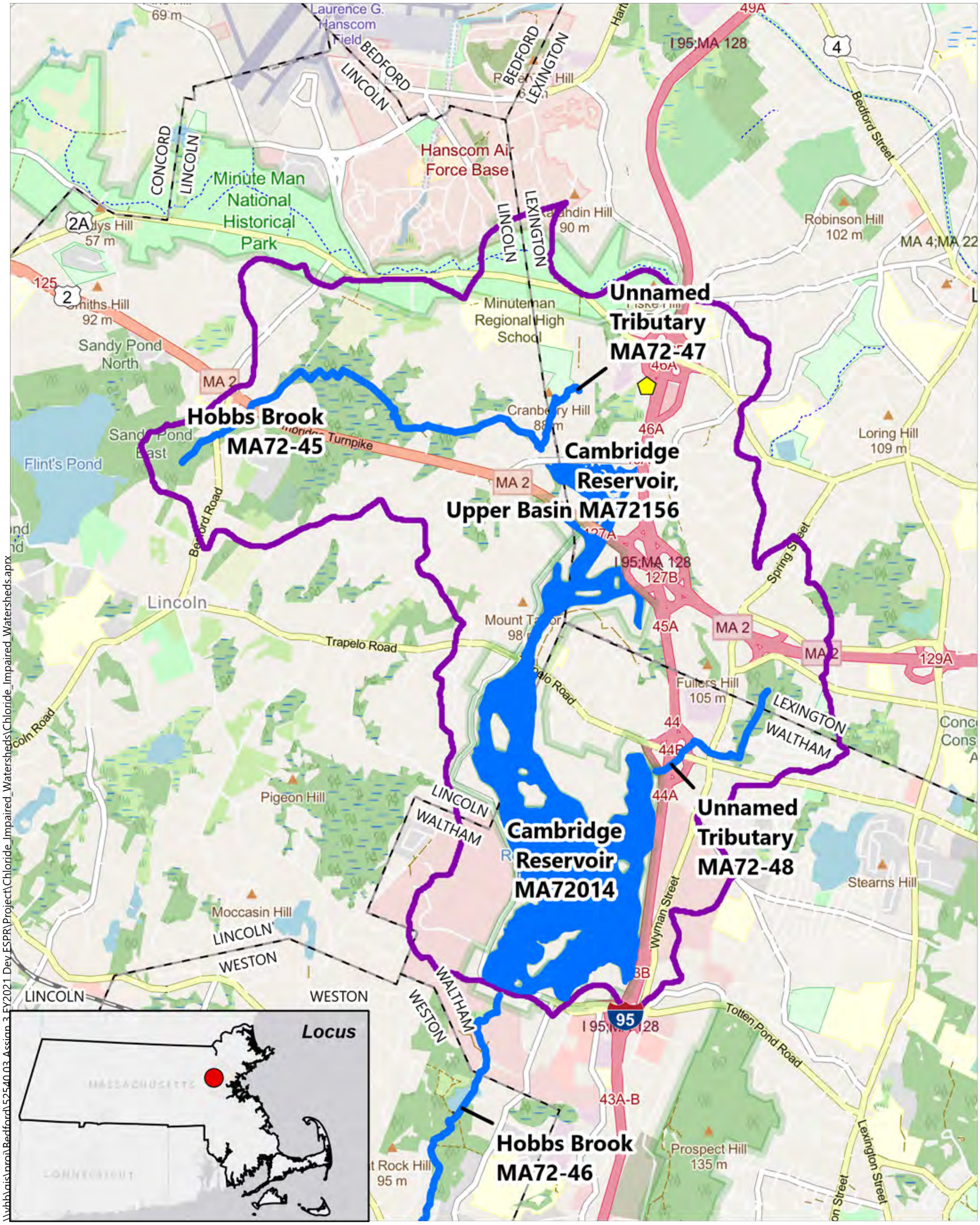
2022 Snow & Ice Control ESPR | MassDOT

Legend

- Chloride Impaired Stream
- Chloride Impaired Lake
- Drainage Sub Basin
- Town Boundary

Chloride Impaired Watershed
Unnamed Tributary - MA72-48

Source: MassGIS, MassDOT, VHB



0 1000 2000 4000 Feet

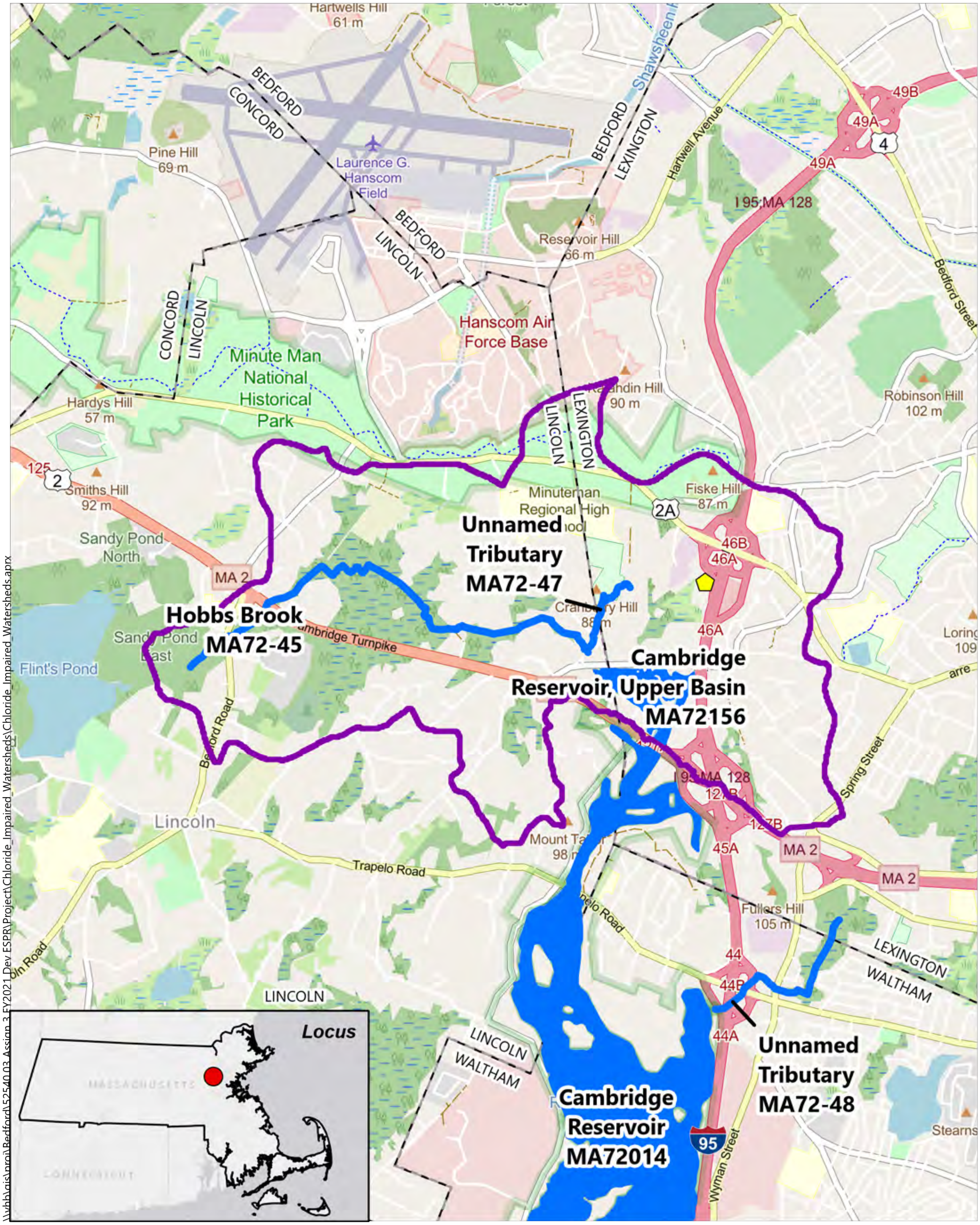
2022 Snow & Ice Control ESPR | MassDOT

Legend

- Chloride Impaired Stream
- Chloride Impaired Lake
- Drainage Sub Basin
- Town Boundary
- MassDOT Maintenance Depot

Chloride Impaired Watershed
Cambridge Reservoir
MA72014

Sources: MassGIS, MassDOT, VHB



\\vhb\gis\proj\Bedford\52540.03 Assign 3 FY2021 Dev ESPR\Project\Chloride_Impaired_Watersheds\Chloride_Impaired_Watersheds.aprx

0 1000 2000 4000 Feet

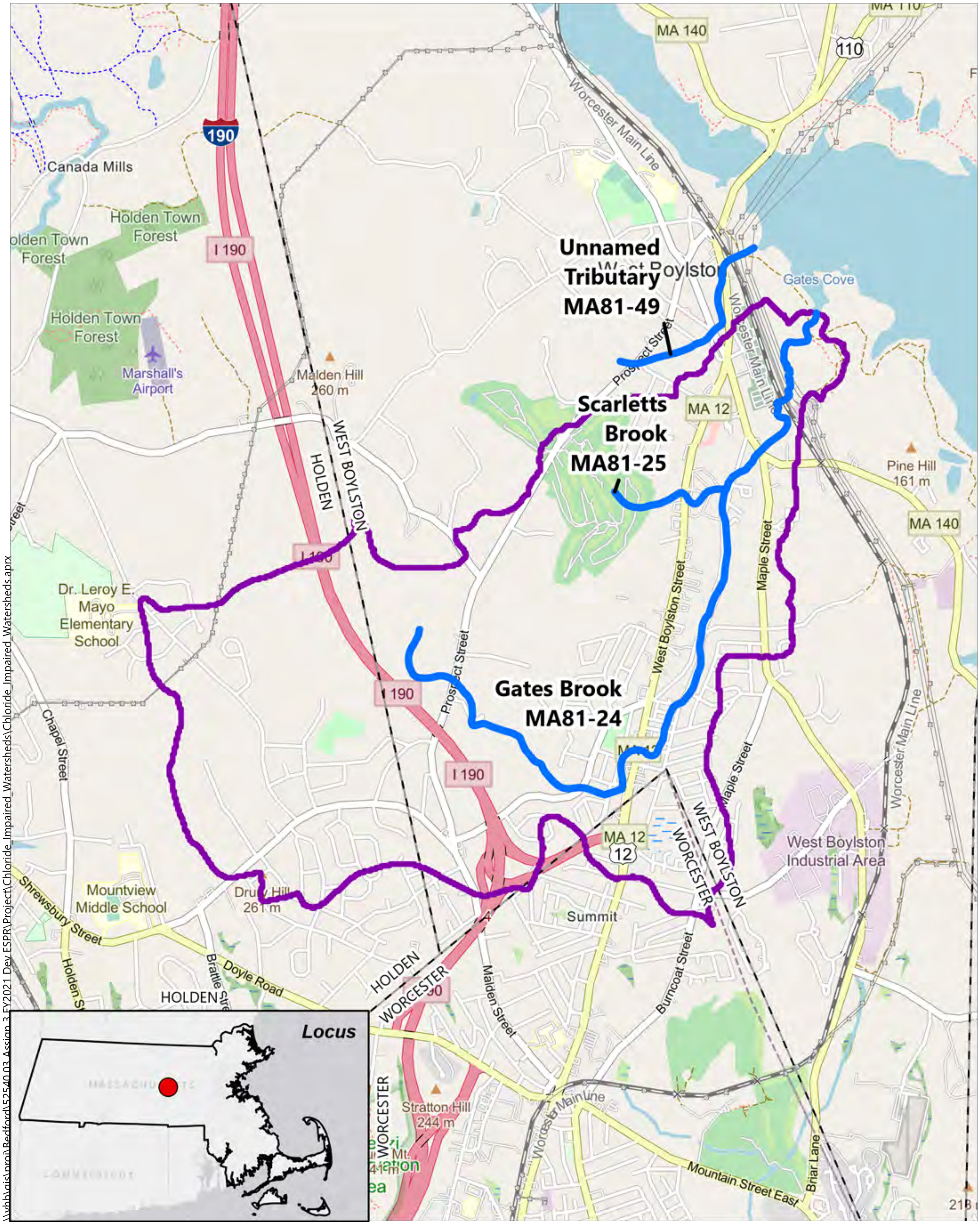
2022 Snow & Ice Control ESPR | MassDOT

Legend

- Chloride Impaired Stream
- Chloride Impaired Lake
- Drainage Sub Basin
- Town Boundary
- MassDOT Maintenance Depot

Chloride Impaired Watershed
Cambridge Reservoir, Upper Basin
MA72156

Sources: MassGIS, MassDOT, VHB



0 500 1000 2000 Feet

2022 Snow & Ice Control ESPR | MassDOT

Legend

Chloride Impaired Stream

Town Boundary

Drainage Sub Basin

Chloride Impaired Watershed
Gates Brook
MA81-24

Sources: MassGIS, MassDOT, VHB

\\vhb\gis\proj\Bedford\52540.03 Assign 3 FY2021 Dev ESPR\Project\Chloride_Impaired_Watersheds\Chloride_Impaired_Watersheds.aprx

December 2022

0 250 500 1000 Feet

2022 Snow & Ice Control ESPR | MassDOT

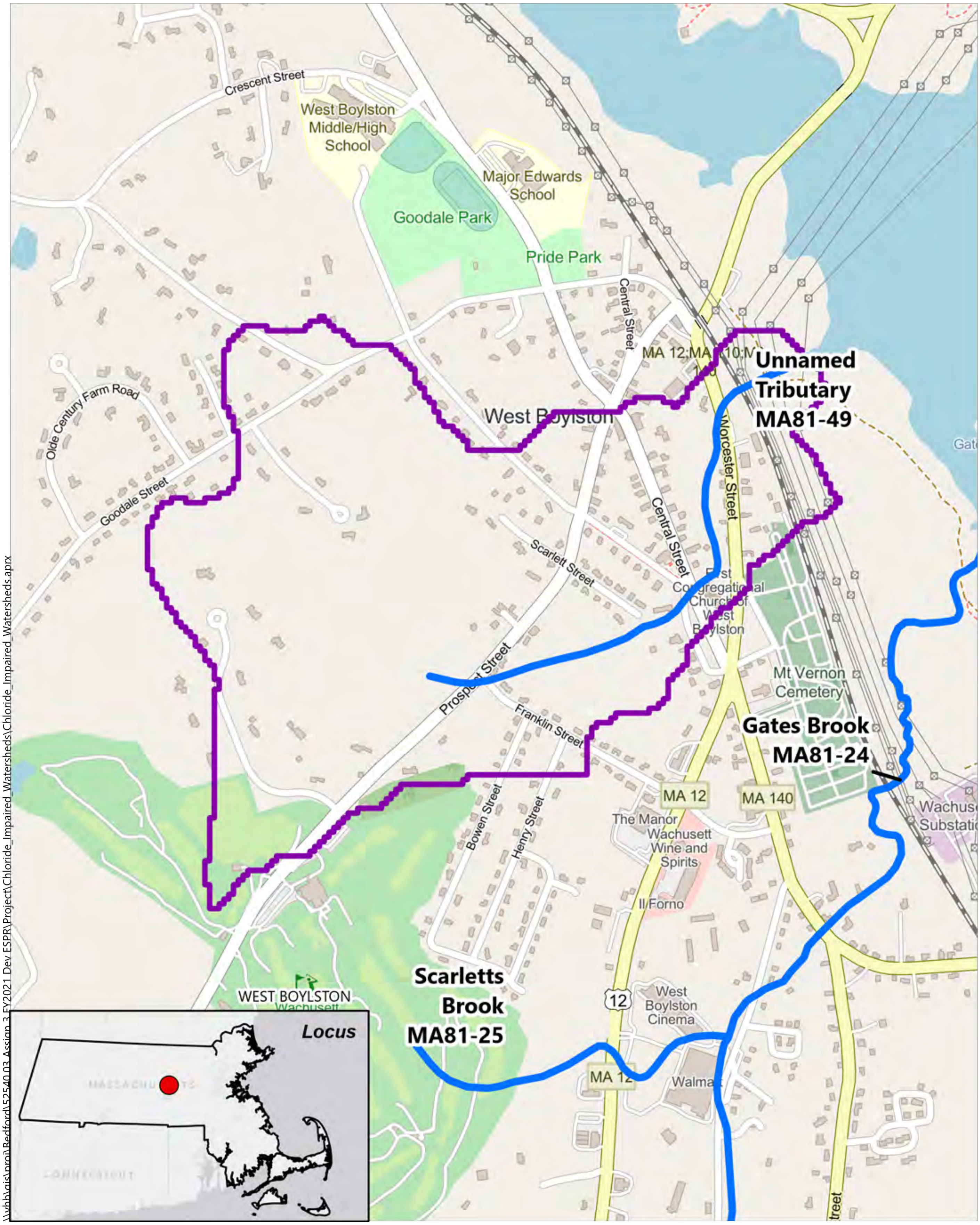
Legend

- Chloride Impaired Stream
- Town Boundary
- Drainage Sub Basin

Chloride Impaired Watershed
Scarletts Brook
MA81-25

Sources: MassGIS, MassDOT, VHB

\\vhb\gis\proj\Bedford\52540.03 Assign 3 FY2021 Dev ESPR\Project\Chloride_Impaired_Watersheds\Chloride_Impaired_Watersheds.aprx



2022 Snow & Ice Control ESPR | MassDOT

Legend

- Chloride Impaired Stream
- Town Boundary
- Drainage Sub Basin

Chloride Impaired Watershed
Unnamed Tributary
MA81-49

Sources: MassGIS, MassDOT, VHB

December 2022

0 280 560 1120 Feet

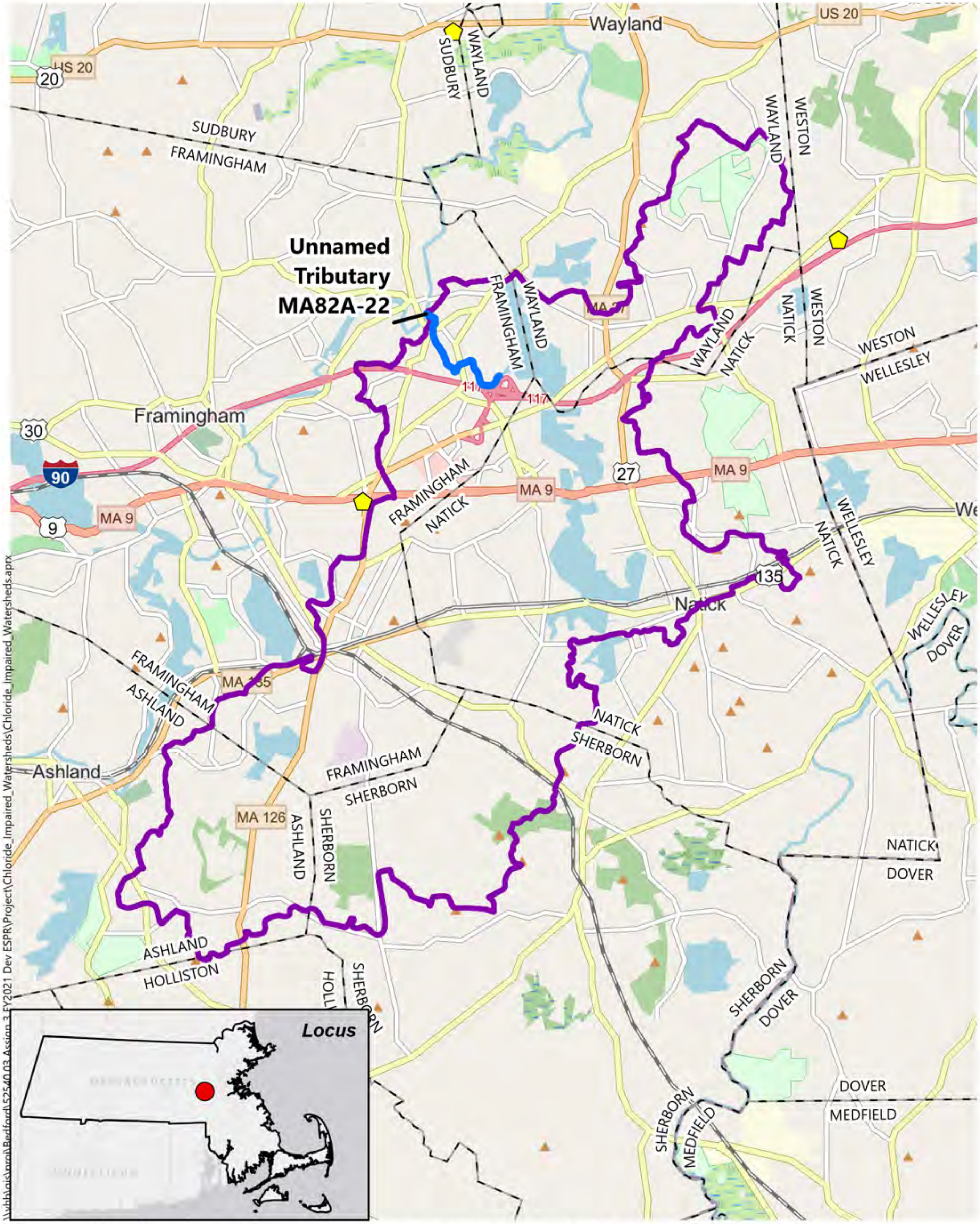
2022 Snow & Ice Control ESPR | MassDOT

Legend

- Chloride Impaired Stream
- Town Boundary
- Drainage Sub Basin

Chloride Impaired Watershed
Unnamed Tributary
MA81-54

Sources: MassGIS, MassDOT, VHB



↑ 0 2000 4000 8000 Feet

Legend

- Chloride Impaired Stream
- Drainage Sub Basin
- Town Boundary
- MassDOT Maintenance Depot

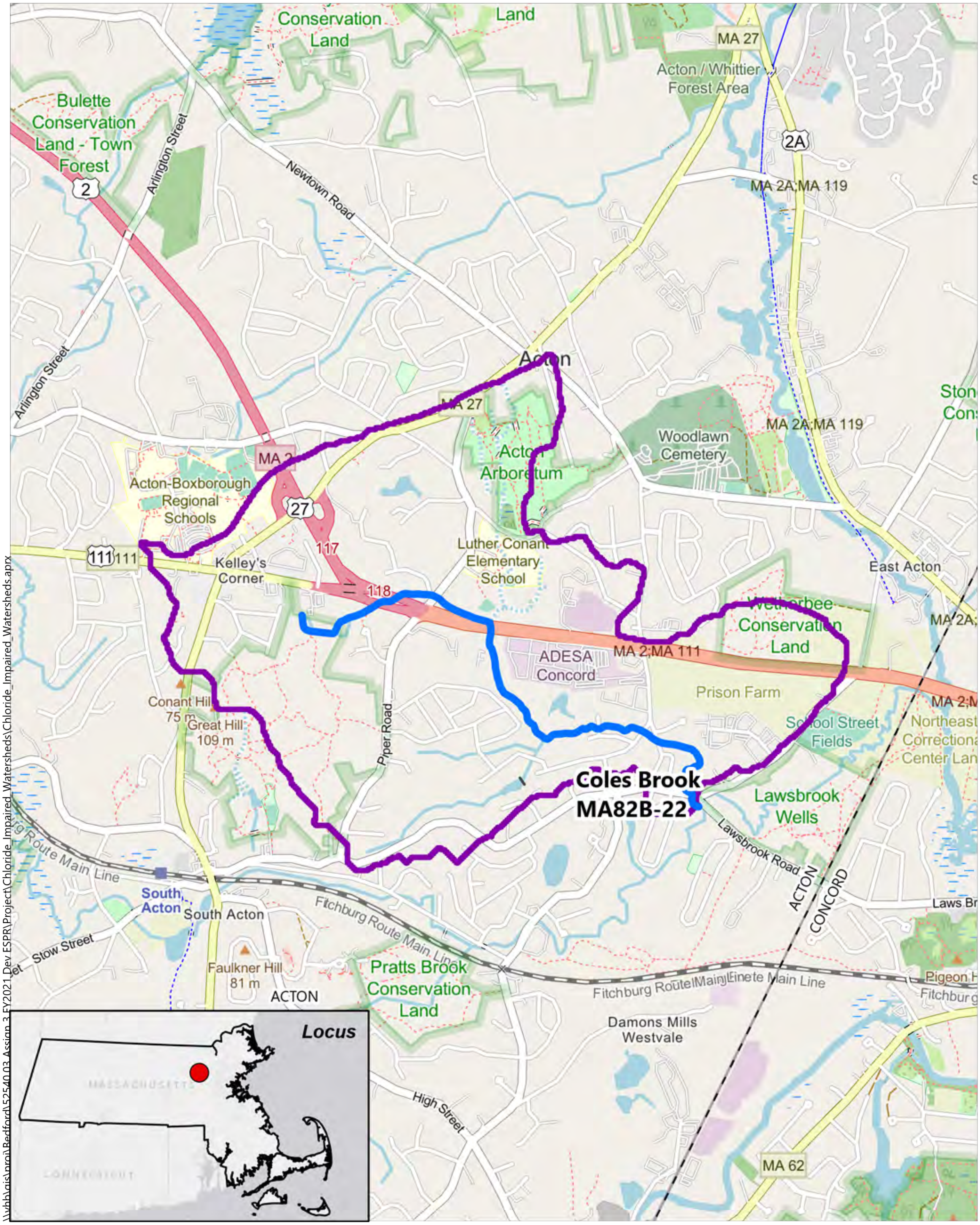
2022 Snow & Ice Control ESPR | MassDOT

Chloride Impaired Watershed
Unnamed Tributary - 82A-22

Source: MassGIS, MassDOT, VHB

\\vhb\gis\proj\Bedford\52540.03 Assign 3 FY2021 Dev ESPR\Project\Chloride_Impaired_Watersheds\Chloride_Impaired_Watersheds.aprx

December 2022



0 500 1000 2000 Feet

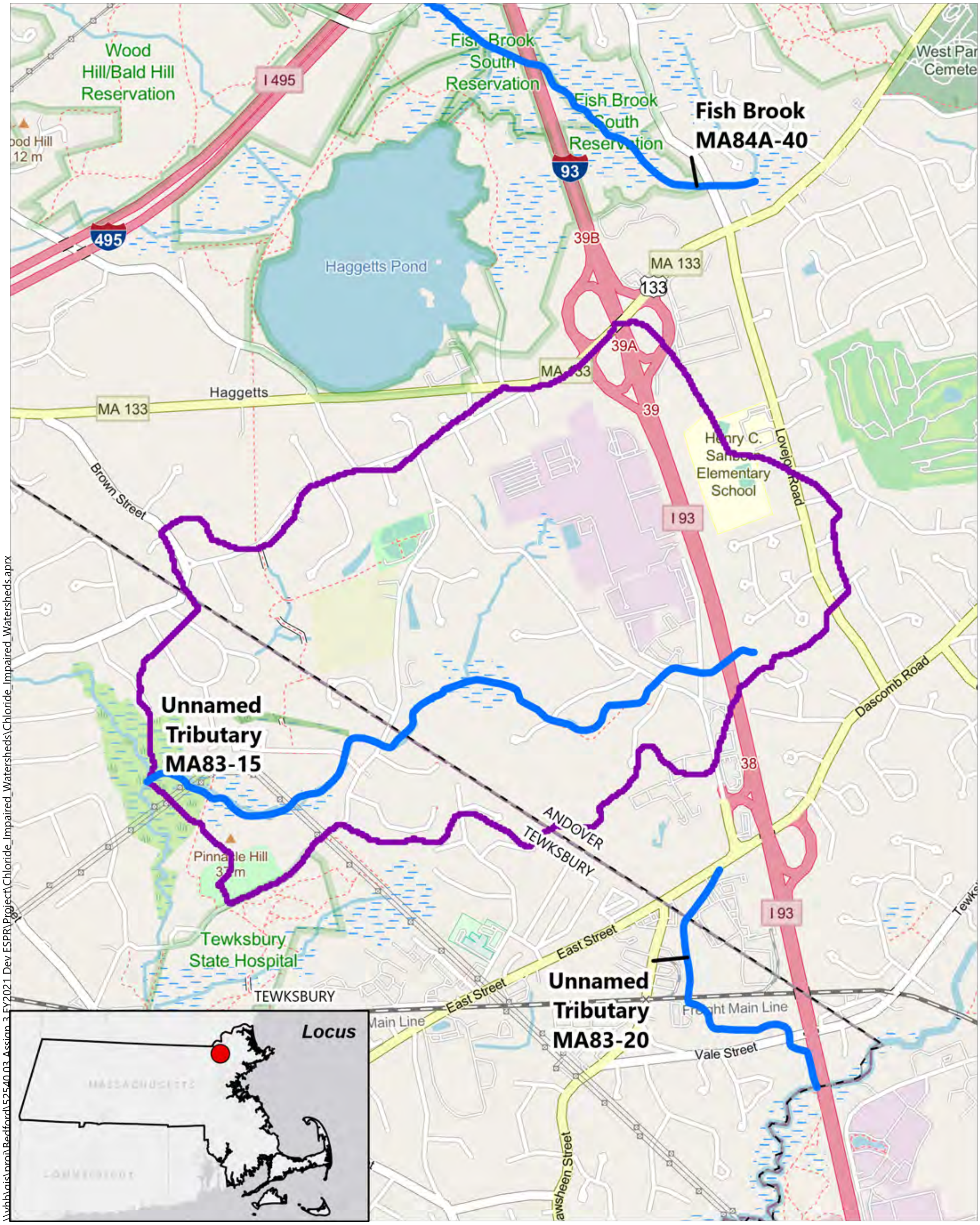
2022 Snow & Ice Control ESPR | MassDOT

Legend

- Chloride Impaired Stream
- Town Boundary
- Drainage Sub Basin

Chloride Impaired Watershed
Coles Brook
MA82B-22

Sources: MassGIS, MassDOT, VHB



2022 Snow & Ice Control ESPR | MassDOT

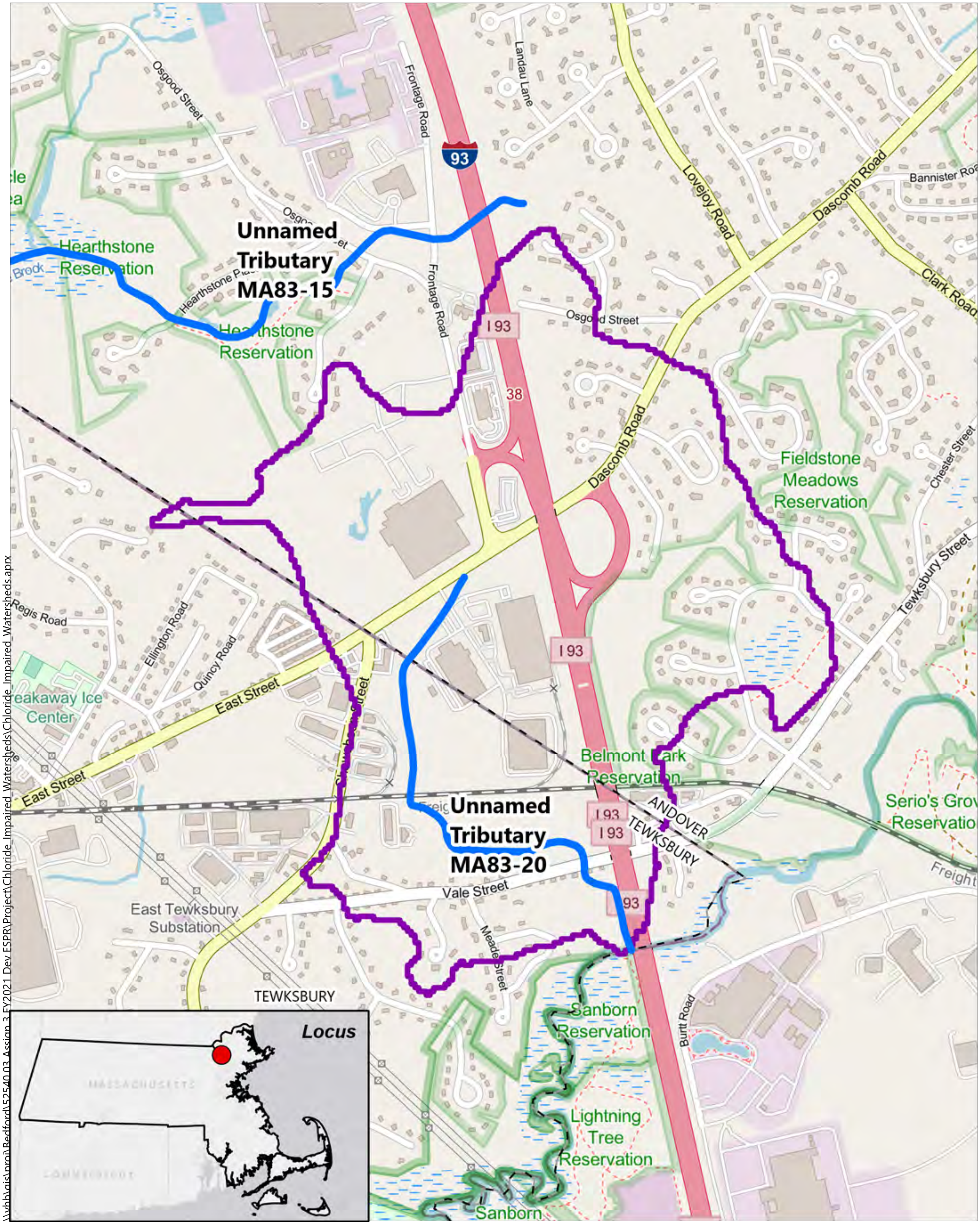
Legend

- Chloride Impaired Stream
- Town Boundary
- Drainage Sub Basin

Chloride Impaired Watershed
Unnamed Tributary
MA83-15

Sources: MassGIS, MassDOT, VHB

December 2022



0 390 780 1560 Feet

2022 Snow & Ice Control ESPR | MassDOT

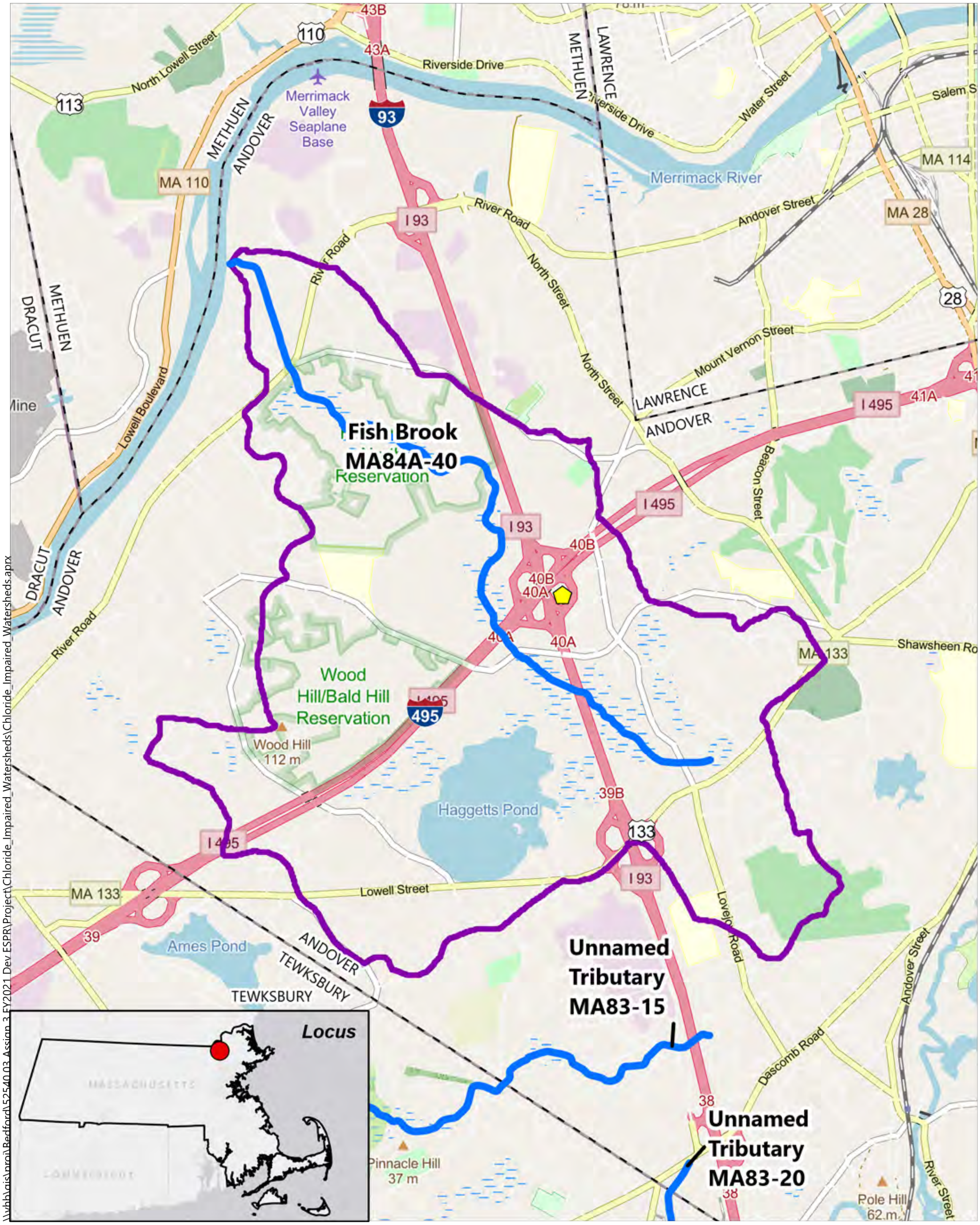
Legend

- Chloride Impaired Stream
- Town Boundary
- Drainage Sub Basin

Chloride Impaired Watershed
Unnamed Tributary
MA83-20

Sources: MassGIS, MassDOT, VHB

\\vhb\gis\proj\Bedford\52540.03 Assign 3 FY2021 Dev ESPR\Project\Chloride_Impaired_Watersheds\Chloride_Impaired_Watersheds.aprx



↑

0 1000 2000 4000 Feet

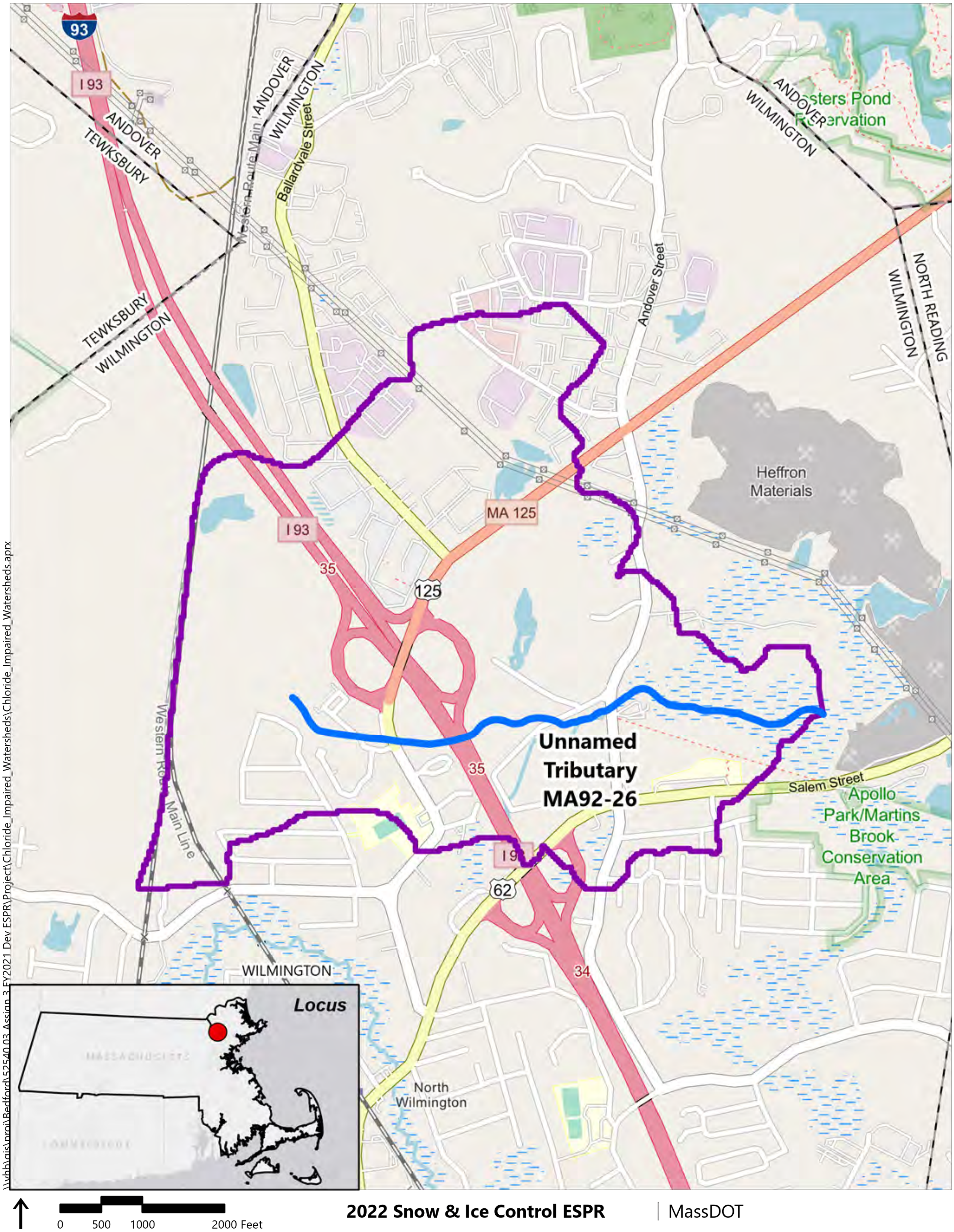
2022 Snow & Ice Control ESPR | MassDOT

Legend

- Chloride Impaired Stream
- Drainage Sub Basin
- Town Boundary
- MassDOT Maintenance Depot

Chloride Impaired Watershed
Fish Brook
MA84A-40

Sources: MassGIS, MassDOT, VHB



2022 Snow & Ice Control ESPR | MassDOT

Chloride Impaired Watershed
Unnamed Tributary
MA92-26

Sources: MassGIS, MassDOT, VHB

Legend

- Chloride Impaired Stream
- Town Boundary
- Drainage Sub Basin

D

MassDOT Contractor Calibration Form

This page intentionally left blank.

Attachment G

Closed Loop Ground Speed Control System Calibration, Data and Volume Verification Form 2022-2023

Vendor or Company's Name: ________________________________ Depot Name/No.________________

Vehicle Information

Equipment No. _____________ Registration No. ______________ VIN (Last 5 digits): _____________

Year: ______________ Make: ________________ Model: __________________

Closed Loop Ground Speed Control System

Make:_______________________ Model/Serial No.:________________

Spreader Equipment

Make: _______________________ Model/Serial No: ____________________________________

Gate Opening 2.5" YES NO - Other _____" Spreader Body Vol. ______CY and/or Tank(s) Vol. __________Gal.
Circle One

Gate & Spreader Body Markers: YES NO Circle One

Spinner Height ____________ Inches **Calibration Company: Do not sign/stamp/issue this form for vehicles with spinner height outside of 16" +/- 4" (12"-20" above pavement) – NO EXCEPTIONS!**

All vehicles must be capable of consistently dispensing highway deicing materials at the application rates dictated by the MassDOT's Policy and Procedures relative to Snow and Ice Operations. MassDOT shall require the transfer of the data gathered by having a closed loop ground speed control system. This information may be transferred by either electronic download, or paper printout at the Vendor's discretion at the end of each event. The closed loop systems will have data logging capabilities and shall include at a minimum, but not be limited to the following data: Pounds or Tons of Material Applied, Types of Material, Gallons of Liquid Dispensed, Miles Traveled, Location of Dispensed Material, Lane Miles Applied, Time of Application, Application Rates. The information shall be provided (by the Vendor) to the timekeeper or other MassDOT representative at the Depot. All pre-wetting systems shall be equipped with a flow meter to accurately dispense deicing chemicals. All information gathered shall remain the property of MassDOT and used at its discretion.

Authorized Calibration Company: ____

Certifies that the above listed closed loop ground speed control system is operating according to the Manufacturer's Specifications and that the spreader has been properly calibrated. **Place official company stamp atop form**.

Calibration Company Signature:______________________________ Date:____________________

NOTE: One copy of this completed certification is to be kept in the vehicle and the **original** copy shall be submitted to MassDOT's District Office. **Calibration Contractor shall also submit a copy to Boston Snow and Ice office**.

IN ASSOCIATION WITH

vhb

101 Walnut Street, PO Box 9151
Watertown, Massachusetts 02471
P 617.924.1770 **F** 617.924.2286
www.vhb.com