

VIRGINIA

SaMS

Salt Management Strategy

A toolkit to reduce the environmental impacts of winter maintenance practices

- December 2020 -

Prepared for

SaMS Stakeholder Advisory Committee
(See page xii for a list of members)

Facilitated by

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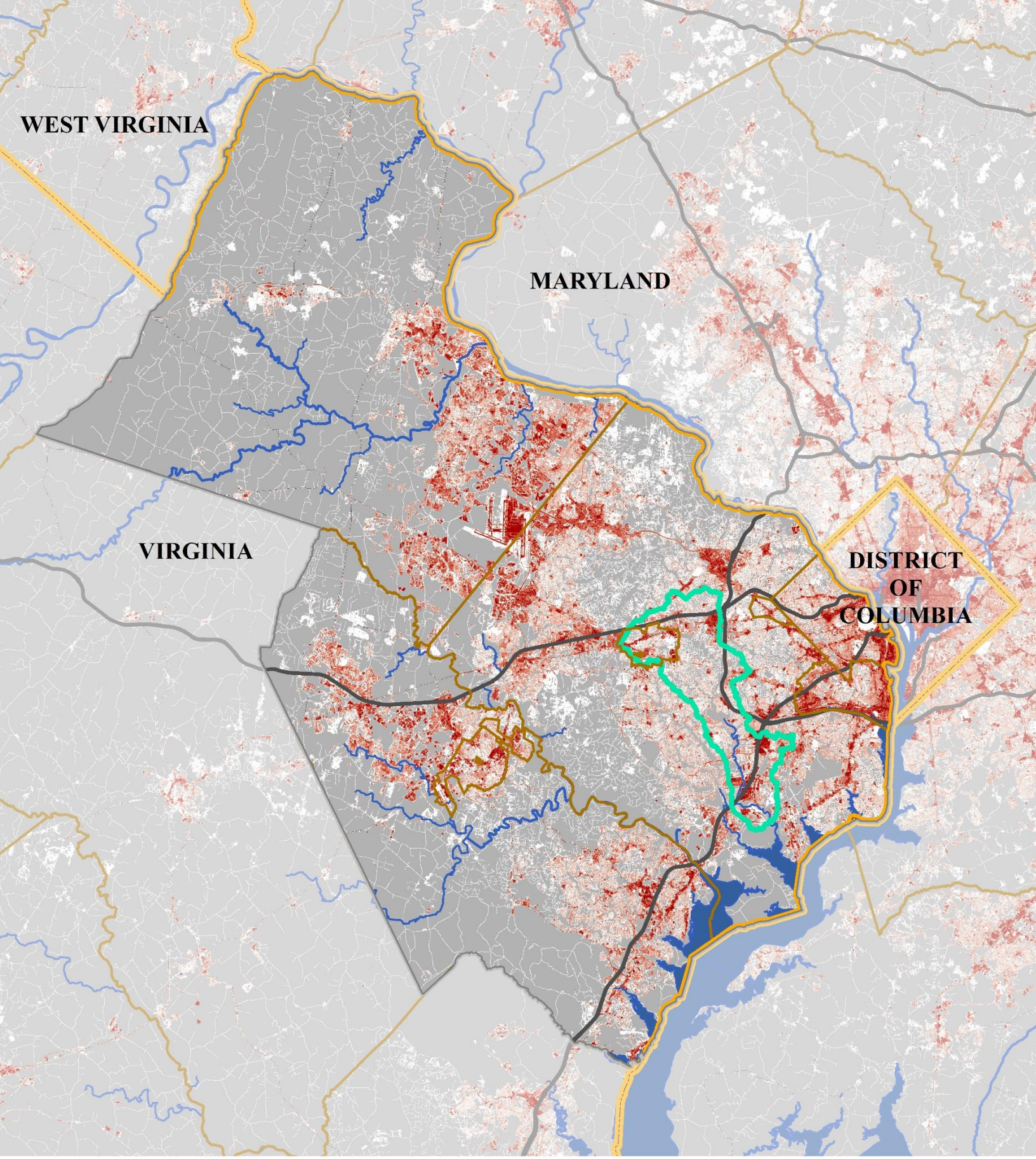
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WEST VIRGINIA
MARYLAND
VIRGINIA
DISTRICT OF COLUMBIA
Interstate Highways
Rivers and Streams
Accotink Watershed
SaMS Project Area
County Boundaries
State Boundaries
Percent Impervious (2016)
1 - 20
20.1 - 40
40.1 - 60
60.1 - 80
80.1 - 100
N
ICPRB
potomacriver.org
0 2 4 8 12
Miles



SaMS Goals

Use a stakeholder-driven process to proactively address salt loads in the region and address the Accotink Creek chloride (salt) TMDLs.

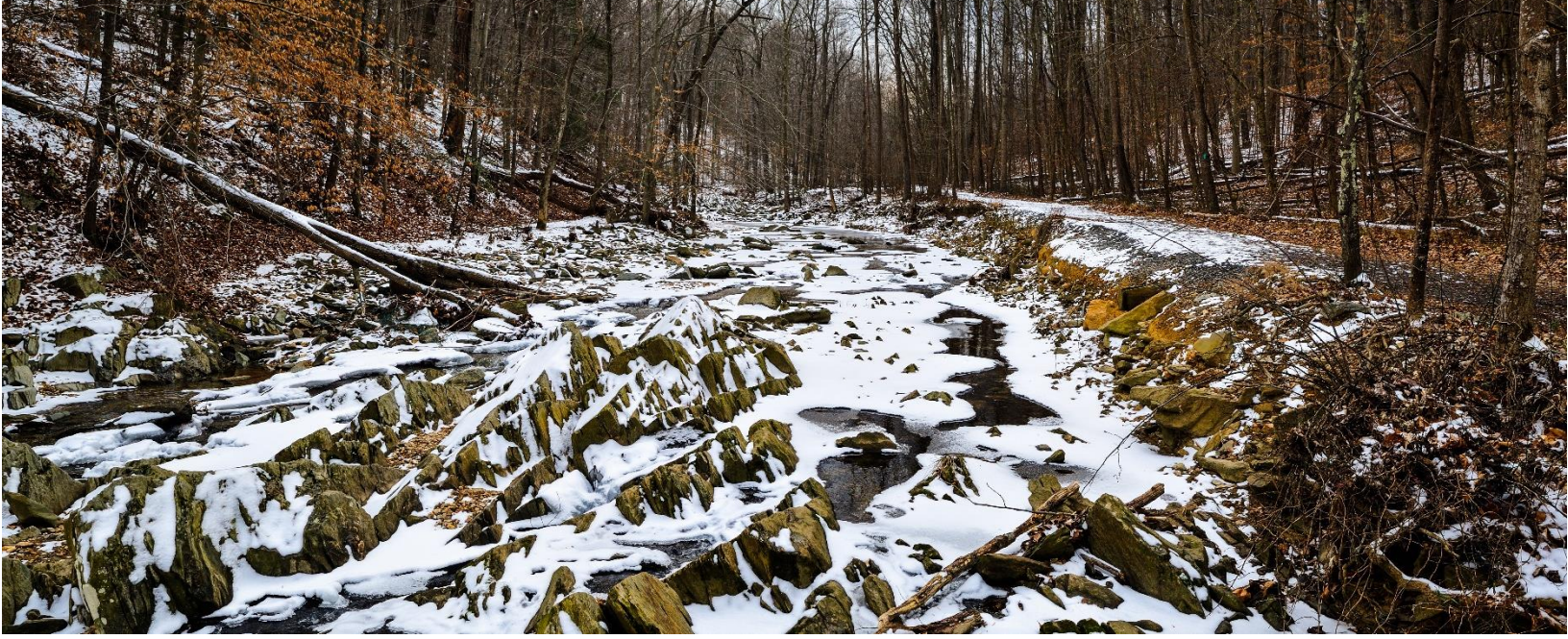
—

Generate increased public awareness that leads to positive behavior changes, and long-term support for the continual improvement of deicing/anti-icing practices and actions.

—

Ensure continued protection of public safety, improve water quality and terrestrial habitat, and lessen the effects of deicing/anti-icing salts on drinking water resources, property and road infrastructure through information sharing and implementation of best practices over time.





Introducing the Salt Management Strategy (SaMS) Toolkit

Purpose and Intent of SaMS

Salt used to melt snow and ice can help provide safe passage for pedestrians, cyclists and drivers. However, salt use can harm water quality (especially our drinking water), impact plants and animals, and damage infrastructure and vehicles. The Salt Management Strategy (SaMS) Toolkit provides a balance between the benefits and the negative impacts of salt use with practices that can minimize the consequences of salt use. The Toolkit includes these practices in a variety of resources and recommendations that organizations and individuals can use. Each resource and recommendation addresses the **SaMS Goals** that were developed by a diverse Stakeholder Advisory Committee (SAC) listed on page xii. Everyone who uses public roads, parking lots and sidewalks contributes to the need for and is affected by salt use. Because all of us have a role to play in addressing the challenges caused by salt use, the SaMS Toolkit has multiple parts.

This document is called the "SaMS Toolkit" since it is intended to be a resource from which readers can pick and choose the practices that work best for them and their situation. All practices and recommendations have the common objective of improving the efficiency of winter salt use, so that only the amount needed to achieve the snow and ice management goal is used, and excessive use is avoided. Because of the variety of audiences the Toolkit addresses, and because of differences among organizations within the same audience, no recommendation is expected to be used by everyone.

It is important to stress that the Toolkit is a voluntary, non-regulatory resource developed by a diverse stakeholder body to address an emerging and complicated societal issue. It does not establish or identify any regulatory requirements. It is intended to provide guidance and could be changed in the future.

The SaMS Toolkit is designed to direct readers to the resources or recommendations that are the most applicable and may work best for them. Sections 1 through 11 have summary-level information to help audiences identify the resources or recommendations that will work best for them. Sections 1 and 2 provide relevant context and purpose information, Sections 3 through 8 include and explain the majority of the recommendations, and the final sections discuss implementation and ongoing efforts to improve winter salt management in the future. The appendices contain the fully described resources and recommendations.

The Toolkit is the product of a stakeholder-driven effort to strike a balance between the benefits and consequences of winter salt use. The stakeholder organizations that comprised the SaMS SAC developed and approved the contents of this document with the expectation that it will evolve over time through stakeholder-driven adaptive management and a continual improvement process.

Audience Considerations

This toolkit was designed with the following audiences in mind:

- Winter maintenance professionals
- Businesses, HOAs, other groups contracting services
- Elected officials and local leaders
- Governments, commissions, and councils
- Drinking water providers
- Non-governmental organizations
- Researchers and water monitoring groups
- General public

Everyone from winter maintenance professionals to the general public can find something of use in this document. All audiences are encouraged to visit the Table of Contents to find the topics, tools, and recommendations of interest and value to them. Although the toolkit is designed so readers do not need to read it in its entirety, something can be learned from each part of this toolkit and everyone is encouraged to read each section of the main body.

How to Use This Document

The main body of this toolkit is structured to provide summary content with the more detailed information contained in the appendices. As readers jump to the sections of interest to them, they may find acronyms that were spelled out in previous sections and are unfamiliar. All acronyms and abbreviations are spelled out in the **Abbreviations** section of the toolkit that follows the **Table of Contents**.

Navigation within the document and links to information external to it are provided throughout the toolkit through the use of **hyperlinks on key words**. **Bold hyperlinks** take the reader to locations within the document. All references to a particular section or appendix are hyperlinked to that section in the report. **Non-bolded hyperlinks** are to external websites or files.

For simplicity's sake, all winter salts that contain chloride will be referred to as "salt" throughout the document. This includes salts used as dry product or in liquids. The term **deicer** is used when generally referring to any substance that is used to manage snow and ice and may or may not be a salt.



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Abbreviations

AORS	Association of Ontario Road Supervisors
APWA	American Public Works Association
ASCA	Accredited Snow Contractors Association
ASDWA	Association of State Drinking Water Administrators
AVL	Automated Vehicle Location
BMP	Best Management Practice
BOD	Biological Oxygen Demand
CASE	Connecticut Academy of Science and Engineering
CCME	Canadian Council of Ministers of the Environment
CFR	Code of Federal Regulations
CMA	Calcium Magnesium Acetate
CRS	Congressional Research Service
DDOT	District Department of Transportation
DEQ	Virginia Department of Environmental Quality
DLA	Direct Liquid Application
GPS	Global Positioning System
HOA	Homeowners Association
ICPRB	Interstate Commission on the Potomac River Basin
LIDAR	Light Detection and Ranging
LOS	Level of Safety
MDOT	Minnesota Department of Transportation
MDSS	Maintenance Decision Support Systems
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer System
MWCOG	Washington Metropolitan Council of Governments
NASA	National Aeronautics and Space Administration
NASEM	National Academies of Sciences, Engineering, and Medicine
NFWF	National Fish and Wildlife Foundation
NHD	National Hydrography Dataset
NHDES	New Hampshire Department of Environmental Services
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NoVA	Northern Virginia
NVRC	Northern Virginia Regional Commission
PFD	Personal Flotation Devices
PPE	Personal Protective Equipment
QAQC	Quality Assurance Quality Control
RWIS	Road Weather Information Systems
SAC	Stakeholder Advisory Committee
SaMS	Salt Management Strategy
SASC	Smart About Salt Council
SC	Specific Conductance
SIMA	Snow and Ice Management Association
SMCL	Secondary Maximum Containment Level
SOP	Standard Operating Procedure
SWiM	Sustainable Winter Management
TMDL	Total Maximum Daily Load
TNC	The Nature Conservancy
TRB	Transportation Research Board

TRS	Transportation Research Synthesis
USACE	United States Army Corps of Engineers
USD	United States Dollar
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VDOT	Virginia Department of Transportation
VELAP	Virginia Environmental Laboratory Accreditation Program
VGIN	Virginia Geographic Information Network
WHO	World Health Organization
WLA	Wasteload Allocation
WQMR	Water Quality Monitoring and Research
WRF	Water Research Foundation
WSSC	Washington Sanitary Sewer Commission

Units of Measurement

°	Degrees
F	Fahrenheit
gal	Gallon
mg/L	Milligrams per liter
%	Percent
mi^2	Square miles
µS/cm	Microsiemens per centimeter

Acknowledgements

The SaMS Toolkit is an aggregation of the work of numerous stakeholders, including government agencies, winter service providers, non-profit organizations, and concerned citizens to name a few. Collaborators gave their time and expertise to produce the quality products contained in the toolkit. Without their commitment, this toolkit would not have been possible. Names of Stakeholder Advisory Committee (SAC) members, other state participants, and advisers of the effort are provided below.

Stakeholder Advisory Committee

Arlington County
Audubon Society of Northern Virginia
Center for Watershed Protection
Chesapeake Bay Foundation
City of Alexandria
City of Fairfax
City of Fredericksburg
City of Manassas
Clean Water Action
Fairfax County
Fairfax County Public Schools
Fairfax Master Naturalists
Fairfax Water
Friends of Accotink Creek
Friends of Dyke Marsh
Friends of Huntley Meadows Park
GKY & Associates, Inc.
Greenspring Village – Environmental Subcommittee
Izaak Walton League of America
Loudoun County
Loudoun Water
Master Gardeners of NoVA
McLean Citizens Association
Metropolitan Washington Airports Authority
Metropolitan Washington Council of Governments
Mount Vernon Council of Citizens' Associations
Northern Virginia Regional Commission
Northern Virginia Trout Unlimited
Prince William County
Private Citizens
Rock Hard Excavation
Ruppert Landscaping
SES Construction and Fuel Services LLC
Snow and Ice Management Co.
Towson University
U.S. Army, Fort Belvoir
U.S. National Park Service, George Washington Memorial Parkway
Virginia Department of Health - Office of Drinking Water
Virginia Department of Transportation
Virginia State Police
Virginia Tech - Occoquan Watershed Monitoring Laboratory
Virginia Tech - Transportation Institute
Washington REIT

Advisers

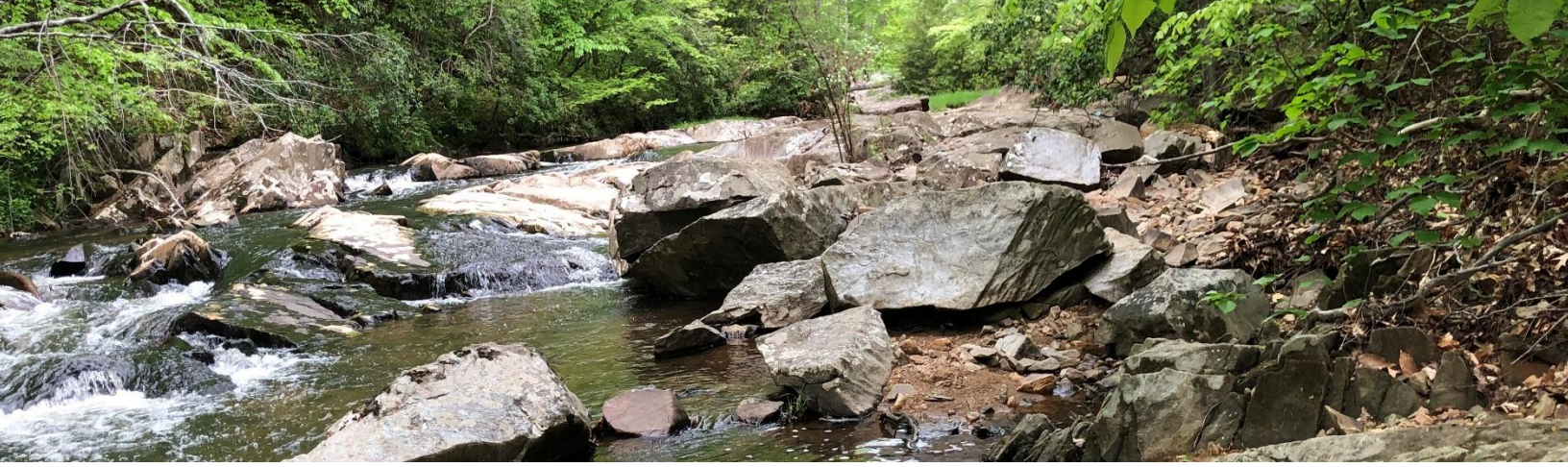
Wilfrid Nixon (Professional Snowfighters Association)
Phill Sexton (WIT Advisers)

Support

Minnesota Pollution Control Agency – provided significant guidance and the initial strategy framework via the Twin Cities Metro Area Chloride Management Plan
New Hampshire Department of Environmental Services – provided significant guidance
Smart About Salt Commission – provided guidance and resources
Region of Waterloo Canada – provided guidance
KatieDid Designs – developed SaMS Logo
Virginia Commonwealth University, Center for Environmental Studies – developed **Appendix Q**

Photo Credits

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1 Why It Matters

Salt use for transportation safety has been increasing throughout the United States since the 1930s (Rubin et al., 2010) and has skyrocketed since 1960 (Murray and Ernst 1976) (**Figure 1**). Salts are applied with the intent of maintaining public safety and are very effective at achieving that goal. However, after application, the salts are washed off into local waterways or seep through soils into groundwater systems causing many unintended negative impacts. Salts pollute drinking water sources and are very costly to remove. Salts can wreak havoc on local plants and animals. Due to their corrosive nature, salts increase the costs of maintenance, repair, and replacement of infrastructure like roads, sidewalks, driveways, bridges, and pipes; similar effects are seen on vehicles and other property. Improved management and use of salts during winter weather events can maintain public safety and minimize the negative impacts of salty runoff. SaMS stakeholders aim to do just that through the implementation of this Salt Management Strategy (SaMS).

Staff conducted a literature review of the impacts of salts and on the economic costs and benefits of improved salt management. A summary of the literature review is described in **Section 1.1** and **Section 1.2**, with the full review in **Appendix A**. For background, a description of the Accotink Creek chloride Total Maximum Daily Loads (TMDL) (the impetus for the SaMS effort) and the Northern Virginia region (the implementation area for the SaMS Toolkit) are provided in **Section 1.3** and **Section 1.4**, respectively.

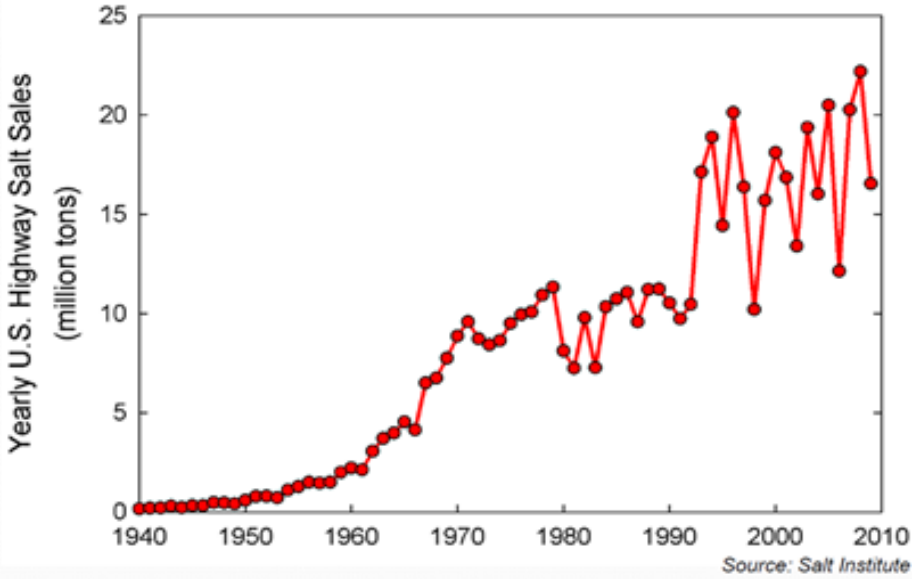


Figure 1. Trend in salt sales in the United States (1940-2010) (reprinted from MPCA 2016).

1.1 Proven Impacts of Salts

There are many documented environmental impacts of salt applications including harm to surface- and groundwater quality, soils, biota, infrastructure, and property. The specific impacts for any given location depend on a number of factors like the nature of local water resources, plants and animals living in the region, infrastructure resources present, existing land uses, recent weather, and the salt products and application practices used. This section provides a broad overview of the literature on these topics.[1] The full literature review can be found in **Appendix A**.

> All salts applied to impervious surfaces ultimately enter the environment.

The vast majority of salts applied to **impervious surfaces** (i.e., walkways, parking lots, and roads) ultimately enter the environment including surface water and groundwater. Impacts of salts on surface waters like streams and lakes depend on where, how, and how fast the salt travels through the local environment to nearby waters. In general, salt applications can result in far more salt found in the water than would typically be expected.

Sodium and chloride, the components of traditional salt, naturally occur in groundwater; however, high levels of salts in non-coastal groundwater is usually associated with pollution from mining or salt application and storage. Salts primarily enter groundwater by infiltration of salt contained in melting snow or infiltration of snowmelt and stormwater runoff in swales and wetlands near surfaces where salts are applied.

Salt also changes the quality of soils, with sodium and chloride reacting differently. Sodium can be attracted to negatively charged components of the soils like clays and organic matter and/or sodium can cause positively charged components of the soil such as nutrients and metals to leach into the environment. Chloride, however, is highly soluble and readily travels with the water as it moves in surface runoff, through the soil, or via groundwater.

Negative effects of salts also are observed in plants, aquatic life, and wildlife (e.g., amphibians, birds, and mammals). Plants are negatively impacted from banks of salty snow deposited by plows, direct and wind-driven spray, and runoff from impervious surfaces. Damage to plants occurs mainly from salt accumulating directly on the plant and nearby soils. Aquatic life such as benthic macroinvertebrates, fish, amphibians, and mussels are impacted by salty water disrupting fundamental biological processes. Amphibians, are known to be sensitive to elevated salt levels given their very permeable skin, the way their bodies interact with the local environment, and their early life stage spent in wetland

> "The outcome of this process will provide an important baseline to collectively move forward with a toolbox of strategies to find ways to keep our roads safe while reducing the impact on our natural resources." – Stakeholder Advisory Committee Member

[1] References used to develop the content of this section are listed here and are fully cited with applicable findings in **Appendix A**. References include: Benham 2011; CASE 2015; CCME 2011; Darwin et al. 2008; Environment Canada 2001; Health Canada 2012; Karraker et al. 2008; Kelting and Laxson 2010; Langen et al. 2006; Madison 2006; NASEM 2007; Mineau and Brownlee 2005; MPCA 2016; Mullaney et al. 2009; Murray and Ernst 1976; Stranko et al. 2013; Westchester 2007; and Williams et al. 1999.

habitats. Terrestrial animals are also affected by the use of salts. For example, salt use attracts mammals and birds to roads because they are attracted to its taste, increasing the number of collisions with vehicles. The toxicity of the salt can also lead to other potential health problems for wildlife.



Salt also negatively impacts infrastructure and property including transportation infrastructure, road surfaces, vehicles, and drinking water systems. Damage to metal surfaces on vehicles, concrete and steel-reinforced concrete and metal structural supports of transportation infrastructure, and road surfaces occur due to the processes of corrosion, chemical reactions between salt and cement, and the increased number of freezing/thawing cycles.

Winter applications of salt can have a number of implications for drinking water systems including the total loss of or need to mitigate drinking water sources, taste complaints from customers, impacts to customers on low-salt diets, pipe corrosion that can release toxins, modified treatment needs, and release of nutrients potentially causing harmful algal blooms. A description of the drinking water systems and sources in Northern Virginia can be found in **Section 1.4**.

In short, there are many detrimental environmental, economic and societal impacts of salts. Minimizing these impacts while continuing to ensure the safety of the public is the primary goal of the SaMS Toolkit.

1.2 Economic Benefits and Costs of Improved Salt Management

As applications of salts during winter events steadily increase at a rate that outpaces the increases in impervious surfaces (Corsi et al., 2015), efforts are being made to understand the financial benefits and costs of salt products and best practices available for snow removal. Dollar amounts have been documented by local communities and state agencies and there is a robust body of knowledge in peer-reviewed literature. This section presents a literature overview of the economic costs and benefits of improved salt management.[2] A thorough literature review can be found in **Appendix A**. Cost categories considered include environmental, infrastructure and property, and indirect costs, discussed in turn below.

The costs to aquatic ecosystems have not been documented due to the difficulty in quantifying and monetizing related impacts. Instead, costs of environmental damage from salt use are captured in metrics like damage to fisheries (e.g., lost revenue), lost recreational opportunities, and costs of damaged vegetation (e.g., buffers and riparian restorations). Example calculations from other organizations that are quoted by Minnesota Pollution Control Agency (MPCA 2016) have resulted in estimates like an "aesthetic damage cost of $73 per ton" of salt applied, “a $2,320 per lane mile per year reduction in environmental value,” and “the aesthetic damage to trees in the Adirondacks due to road salt was $75 per ton.” It is worth noting that all costs presented in this document have not been adjusted for inflation.

[2] References used to develop the content of this section are listed here and are fully cited with applicable findings in **Appendix A**. References include: Fay et al. 2015; Fortin Consulting 2014; Koch et al. 2002; MPCA 2016; and Vitaliano 1992.



Salts impact infrastructure, leading to costly maintenance and replacement. Specifically, corrosion of roads, bridges, and sidewalks is a documented consequence of winter road activities, as is corrosion of vehicles. The annual cost of corrosion for highway bridges has been estimated at $8.3 billion for replacing deficient bridges, bridge maintenance, painting, and capital costs. Other estimates document an increase in roadway maintenance of over $600 per ton of salt applied and the damage to vehicles at $113 per ton of salt applied.

The indirect costs of salt use are difficult to quantify, some more than others. Researchers on this topic tend to focus on quantifying one or two of the cost variables, thus making it difficult to get a sense of all the costs in a single location at a single point in time. Direct costs incurred from winter maintenance include materials (salt, brine, fuel etc.), equipment (trucks, plows, spreaders, GPS, weather tracking systems etc.), and labor.

The benefits of improved salt application practices are the inverse of the costs and the environmental impacts. This includes reduced direct costs to winter service providers, avoided costs to address corrosion and damage to infrastructure, fewer environmental impacts, and reduced public health risks. These benefits can be achieved while still providing the same level of service and safety based upon experiences in other parts of the United States.



Reductions in salt application achieved by other communities through improved management practices are noteworthy. While no two communities can expect the same results, having a sense of the upper and lower bounds on salt reductions and costs can inform SaMS implementation. Salt reduction estimates in the Twin Cities Metro Area have been documented to be between 32% and 70%, in some cases those reductions occurred a single year. Direct winter maintenance cost savings were provided in dollar figures over different time periods, making generalizing difficult. The University of Minnesota, Twin Cities found that in their initial year of using **Best Management Practices (BMPs)** their new equipment cost $10,000 but they saw a savings of $55,000. The City of Waconia, Minnesota estimated a savings of $1.80 per lane mile, with all providers reporting cost savings from improved practices.

Managing the costs and benefits of salt applications requires an understanding of how and when they are applied and for what purpose. Numerous strategies are used prior to and during winter storm events to minimize costs and maximize benefits. Example cost/benefit ratios are provided in **Appendix A**.

1.3 Accotink Creek Chloride TMDL

The Accotink Creek watershed drains 52 mi^2 of Northern Virginia (outlined in green in **Figure 2**). Elevated chloride levels from winter deicing salts were identified in this highly urbanized watershed and, as a result, DEQ was required to develop TMDLs pursuant to the federal Clean Water Act and Virginia's State Water Control Law to address an impairment of the benthic macroinvertebrate community.

By way of background, Virginia has adopted aquatic life **chronic** and **acute** water quality criteria for chloride (9VAC25-260-140). The chronic and acute numeric criteria are 230 mg/L and 860 mg/L with durations of four days and one hour, respectively. The acute criterion is for a one-hour average not to be exceeded more than once every three years, and the chronic criterion is a four-day average, which is also not to be exceeded more than once every three years.

Total Maximum Daily Load (TMDL)

Identifies the maximum amount of a pollutant that a waterbody can receive and still not exceed water quality standards.

A stressor analysis (ICPRB 2017b), conducted on three segments consisting of upper Accotink Creek, lower Accotink Creek, and Long Branch (central), indicated that chlorides, hydromodification, habitat modification, and sediment were the most probable stressors of the biological communities in the Accotink Creek watershed. Of these, TMDLs were developed for chlorides and sediments that are classified as "pollutants" for which TMDLs can be developed under the Clean Water Act (ICPRB 2017a). As part of the study, chloride data collected in the Accotink Creek watershed demonstrated exceedances of the chronic and acute chloride criteria (ICPRB 2017a). The Accotink Creek chloride TMDLs were the first chloride TMDLs in Virginia that focused on winter anti-icing and deicing salts used in winter storm maintenance activities.

The chloride TMDLs for Accotink Creek watershed's benthic impairments were developed to address a macroinvertebrate benthic impairment. Chloride loads were calculated only for an extended winter season, November through April, representing the months in which snow events occurred in the last 30 years. The TMDLs, however, are expressed as average annual loads, since implementation initiatives are expected to occur throughout the year. Consistent with USEPA regulations (40 CFR 130.2, 130.7), the TMDLs were assigned or allocated among regulated and non-regulated sources and a margin of safety was included.

DEQ, with input from several stakeholders during finalization of the TMDLs, identified that development of a regional strategy with an implementation focus on continual improvement through non-numeric, BMP implementation across all source sectors was the most effective means to implement the Accotink Creek chloride TMDLs (ICPRB 2017a). Although the TMDLs were developed specific to the Accotink Creek watershed, the winter maintenance activities (e.g., clearing roads, parking lots and sidewalks during winter storm events) that are the subject of SaMS occur broadly throughout the region. Therefore, SaMS was designed to be applicable to the 4 counties and 5 cities that comprise Northern Virginia (described in **Section 1.4**), where, it is fair to assume, similar chloride impacts are occurring. The SaMS Toolkit was developed with the fundamental principle that public safety is the highest priority for winter maintenance, while recognizing that the water quality concerns identified through the chloride TMDLs can be addressed without harm to public safety during winter weather events. Similar strategies around the country like the Twin Cities Metropolitan Area Chloride Management Plan (MPCA 2016) have had great success and serve as foundational resources for the development of this plan.

SaMS Project Area

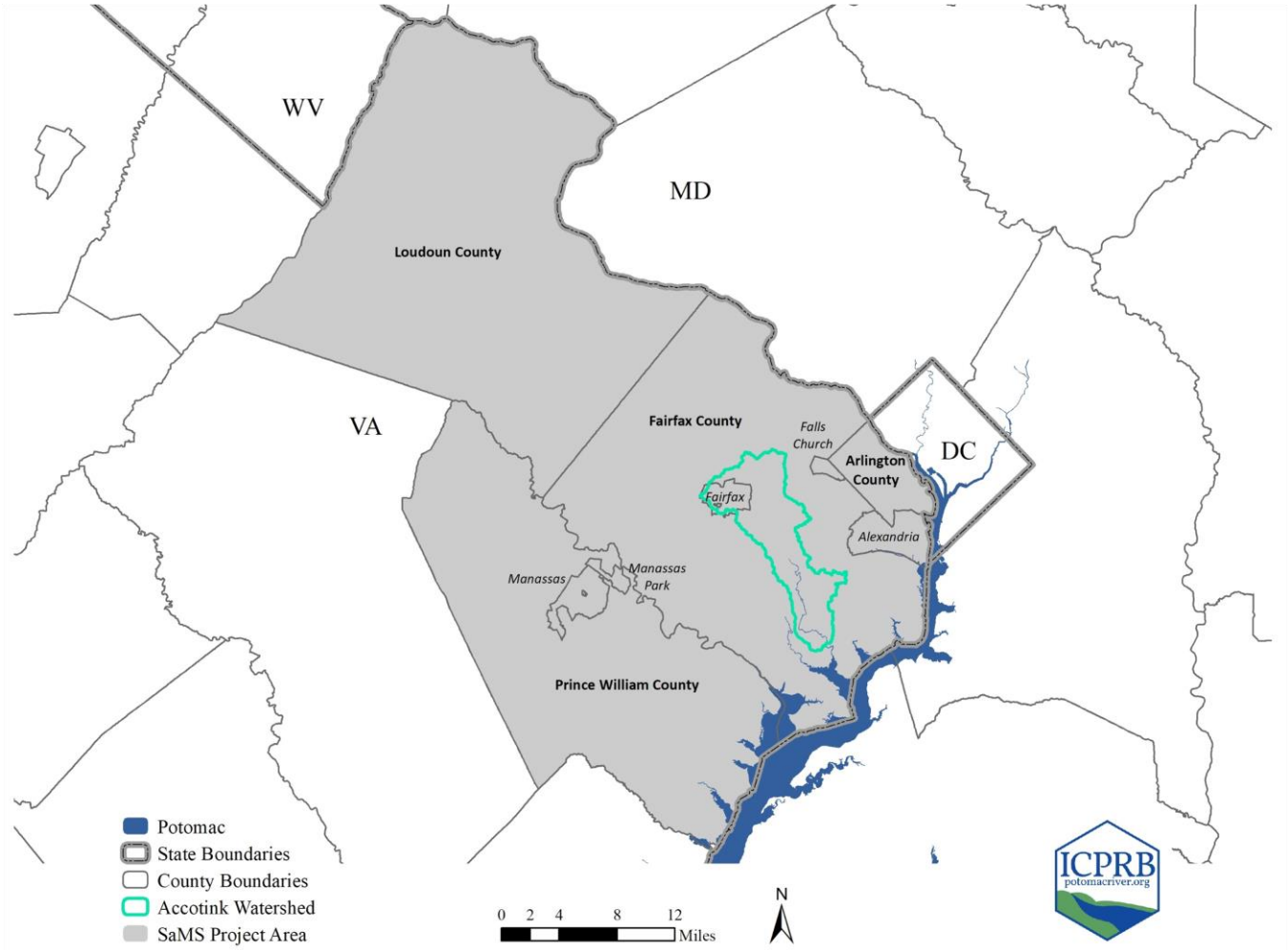


Figure 2. SaMS project area (the Northern Virginia region), shown in light grey, and surrounding areas including the Accotink watershed.

1.4 Description of Northern Virginia Region

The Northern Virginia region, as defined in this toolkit, covers nearly 1,330 square miles (mi^2) of largely suburban development, some beautiful rolling countryside, historic and agricultural properties, and some of the most rapidly urbanizing areas in the nation (**Figure 2**). The Northern Virginia region includes Arlington, Fairfax, Loudoun, and Prince William counties and the cities of Alexandria, Manassas, Manassas Park, Falls Church, and Fairfax. The area also includes the towns of Clifton, Dumfries, Hamilton, Haymarket, Herndon, Hillsboro, Leesburg, Lovettsville, Middleburg, Occoquan, Purcellville, Quantico, Round Hill, and Vienna. The American Community Survey 5-year estimates from 2016 reported a population of 2.4 million people.

The region spans portions of four ecoregions[3] (USEPA 2012). In order of coverage, 62% of the region falls in the Northern Piedmont, 24% in the Piedmont, 10% in the Southeastern Coastal Plains, and 4% in the Blue Ridge ecoregion. A brief description of each of these ecoregions is provided in the order one would encounter them if traveling northwest to southeast through the region. The Blue Ridge is a narrow mountain range on the northwestern border of the Northern Virginia region (as defined by the study area boundary in **Figure 2**). According to Woods et al., (1999), this ecoregion is primarily forested with comparitively steep slopes, rugged terrain, and shallow soils. The Northern Piedmont and the Piedmont ecoregions extend from the Blue Ridge on the west to the Fall Line on the east. This area consists of rolling hills and open valleys. The Fall Line divides the Piedmont and Southeastern Plain ecoregions. The Southeastern Plain is a low-lying area with low slopes and sandy soils.



According to the National Elevation Dataset (USGS 2012), elevations in the region range from 1,919 feet above sea level to about sea level along the Potomac River. The high point is in Loudoun County near Raven Rocks in the Blue Ridge ecoregion.

Land use in Northern Virginia, depicted in the 2016 National Land Cover Dataset (NLCD), is 39% developed land, 36% forest, 20% crops, 3% wetlands, and 1% open water.[4] Average impervious cover as of 2016 was nearly 26%, an 11% increase since 2011.[5] During that same time period, some areas of the region experienced a much larger increase in impervious cover. For example, Loudoun County had a 57% increase (from 4.25 to 6.68% impervious cover), Prince William County had a 45% increase (from 6.41 to 9.27% impervious cover). A nationwide study on small watersheds from the Center for Watershed Protection (Schueler et al., 2009) documents a shift from sensitive to impacted general stream health, which occurs within impervious cover proportions of 5-10%. Recent work by the ICPRB and others in the Potomac basin have found significant adverse hydrologic impacts when impervious cover in a watershed increases above 2% (Moltz et al., 2018; USACE et al., 2014).

To gain an idea of the possible amount of salts used by the different source sectors (e.g., residential, transportation, commercial/industrial), a spatial analysis of impervious surfaces was conducted for Northern Virginia (**Appendix Q**). In this study, the 2016 Virginia Geographic Information Network (VGIN) land cover dataset was used to identify impervious surfaces with potential to be treated with salts and eliminating those that do not have such potential, such as rooftops. In this analysis, the highest levels of impervious cover are found in City of Falls Church (38%), City of Alexandria (37%) and Arlington County (34%). Locality parcel data was then used to divide the impervious surfaces layer into different land use clategories, such as residential, transportation, commercial/industrial, open space/parks, etc. Based on this assessment, the largest classified land uses with potential to receive salt application are residential (23%), transportation (23%), and commercial/industrial (16%). For more information on this analysis, including breakdowns by City or County, see **Appendix Q**.

[3] As defined by the USEPA, ecoregions are areas where the type, quality, and quantity of environmental resources are similar.
[4] NLCD land use categories were aggregated for simplification. The following land use classes were included in each category. Forest: Deciduous Forest, Evergreen Forest, Mixed Forest, Shrub/scrub, and Herbaceous. Crops: Hay/Pasture and Cultivated Crops. Developed: Developed Open Space, Developed Low Intensity, Developed Medium Intensity, Developed High Intensity, and Barren Land. Wetlands: Woody Wetlands and Emergent Herbaceous Wetlands.
[5] Source: 2016 and 2011 NLCD urban imperviousness layers.

Analyses from three different studies at multiple locations all point to an increasing trend in freshwater salinization in Northern Virginia. Although it is important to interpret watershed specific trends cautiously, there is a mounting weight of evidence. In particular, an analysis (**Appendix K**) conducted by Interstate Commission on the Potomac River Basin (ICPRB) on trends in specific conductance (an indicator of salt concentrations) at four different watersheds in the SaMS project area indicates that there are increasing trends in specific conductance at all four watersheds. This analysis also show clear seasonal patterns over the 11+ year records, where values are elevated in winter months and following winter precipitation events. A similar analysis of trends conducted by USGS and Fairfax County (Porter et al., 2020) at fourteen sites also shows increasing trends with comparable magnitudes of increase. Lastly, concentrations of sodium at Fairfax Water's drinking water intake in the Occoquan Reservoir also shows an increasing trend (**Figure 3**). If the trends in freshwater salinization indicated by these analyses continue, water purveyors may face challenges in the future in managing their drinking water supply source.

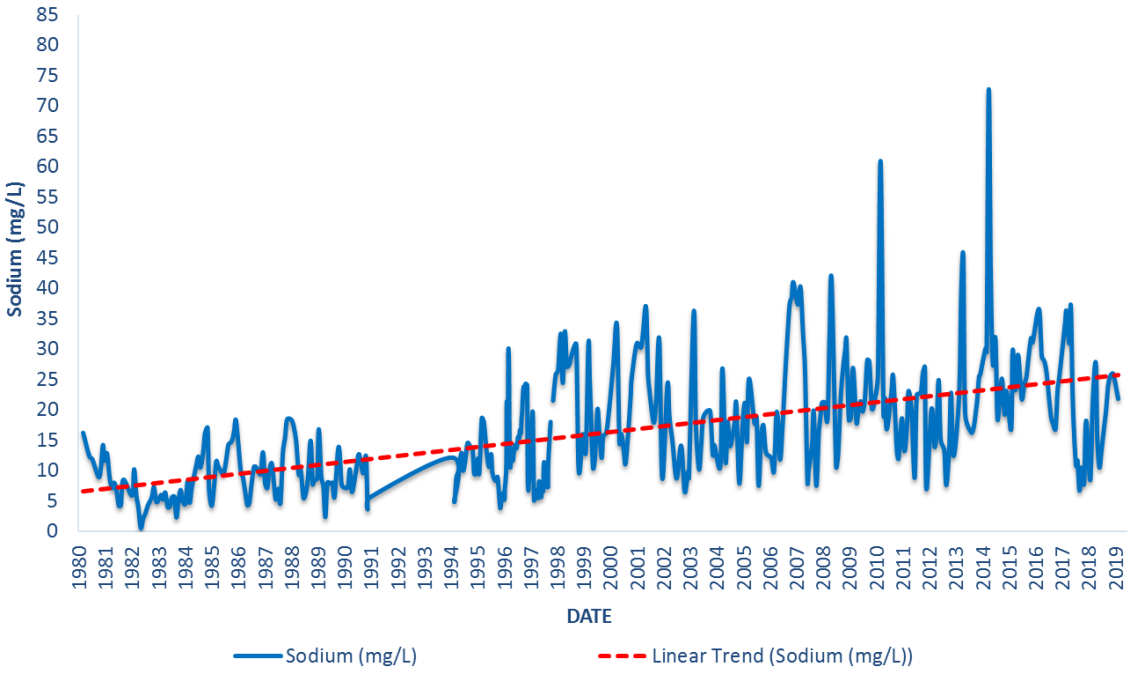


Figure 3. Trends in sodium levels at the drinking water intake on the Occoquan Reservoir.

The major drinking water utilities in Northern Virginia, in terms of population served, are Fairfax Water, Loudoun Water, and Washington Aqueduct (as a wholesale distributor to Fairfax Water, Arlington County and Vienna). There are also a number of interconnections and wholesale agreements between these and other, smaller drinking water utilities in the region. Although there are smaller drinking water systems using surface and groundwater resources, these major suppliers rely on the surface water resources of the Potomac River, the Occoquan Reservoir, and additional upstream reservoirs operated cooperatively by ICPRB, the U.S. Army Corps of Engineers-Baltimore District, Washington Aqueduct, Washington Sanitary Sewer Commission (WSSC), and Fairfax Water under the Water Supply Coordination Agreement of 1982. Future surface raw water storage is being designed to meet growing demands using abandoned hard rock quarries in the region. A complete description of the region's water supplies is available in NVRC (2020). These systems and the populations they serve are vulnerable to the effects of salting during winter weather events. Specific impacts of salts on drinking water systems are discussed in **Appendix A**.

2 How SaMS is Addressing the Issue

Recognizing the public safety and economic benefits of salt use, SaMS seeks to strike a better balance between these benefits and the associated negative costs and impacts to our drinking water, environment, infrastructure, and vehicles and human health. To accomplish this, a comprehensive approach is required since winter storm maintenance activities are influenced by most people and many are affected by them. As a result, SaMS encourages everyone to be "Winter Salt Smart".

2.1 Purpose and Scope of the Salt Management Strategy and Plans for the Future

SaMS is Virginia's first comprehensive effort by a diverse stakeholder body to design, in a cohesive and collaborative manner, a strategy seeking to improve the balance between the impacts and benefits of salt application. This SaMS initiative is guided by three goals, developed by the Stakeholder Advisory Committee (SAC) and embodied in this toolkit. The toolkit is designed to achieve these goals by encouraging the continual improvement in winter maintenance practices, tracking salt use, evaluating implementation of best practices, monitoring improvements in water quality and increasing public awareness of the benefits and the unintended impacts of salt use.

Goals

The aim of this effort is to develop a salt management strategy for Northern Virginia that:

- Uses a stakeholder-driven process to proactively address salt loads in the region and address the Accotink Creek chloride (salt) TMDLs.
- Generates increased public awareness that leads to positive behavior changes, and long-term support for the continual improvement of deicing/anti-icing practices and actions.
- Ensures continued protection of public safety, improves water quality and terrestrial habitat, and lessens the effects of deicing/anti-icing salts on drinking water resources, property and road infrastructure through information sharing and implementation of best practices over time.

The SaMS Toolkit is a resource to aid the initiative and continually advance efforts towards achieving SaMS goals. As such, completion of the toolkit does not signal the end of the SaMS initiative, but instead establishes a solid foundation for the beginning of area-wide adaptive implementation of SaMS into the future.

This solid foundation stems from many positive practices already in place at the onset of SaMS development. Perhaps most significant is the adoption of **anti-icing** of area roads by VDOT, a practice that has grown from testing to standard practice in the past decade. While the size of the possible reduction will vary among organizations, various operations have reported that anti-icing alone can produce substantial reductions in salt use (see **Appendix B** for specific examples). Other area government agencies and private applicators have also already incorporated some of the recommended winter maintenance BMPs into their current operations. Much can be learned from testing the effectiveness of best practices in achieving desired results while minimizing the unintended impacts. Therefore, it is critical that the SaMS Toolkit is adaptive and continually improved upon as knowledge is gained over time. From these lessons learned implementing the best practices, conducting outreach and education efforts to build awareness, and tracking progress, the resources in the toolkit can be added to, updated or revised.

The SaMS initiative is a non-regulatory, voluntary and largely proactive approach to address this emerging issue in Northern Virginia. SaMS, as a regional approach, offers the potential that water quality impacts from salts can be avoided or reduced such that an impairment listing and associated TMDL development is no longer necessary. By encouraging the adaptive implementation of the SaMS Toolkit, new actions will build upon the positive developments already in place, to prevent impacts from progressing to a point from which there is no easy return. However, should region-wide implementation efforts prove insufficient to address the water quality concerns, new impairments may be identified in the

future and development of TMDLs to achieve pollutant reductions through a network of TMDL-driven permit requirements may prove necessary.

2.2 Scope of SaMS

The comprehensive scope of SaMS encompasses winter road maintenance, large and smaller scale winter property maintenance, commercial and residential communities and individual residents' winter maintenance of roads, driveways, steps and sidewalks. It includes technical information as well as background and practices related to communications. It is designed to meet the interests and needs of senior organizational decision makers, maintenance supervisors, maintenance professionals, and individuals.

> The central purpose of SaMS is to reduce current salt levels in area waters to levels protective of aquatic life and drinking water sources.

The SaMS Toolkit is a product of a stakeholder-driven effort that facilitates and promotes continual improvement in winter maintenance practices, tracking and measuring progress and generating increased public awareness. Its recommendations will allow all users to build on the successful practices they currently employ, and enhance them with additional or more refined BMPs over time. Salinity levels in area surface waters have increased incrementally over time. The central purpose of SaMS is to reverse that trend and reduce the amount of salt in area waters to ensure protection of aquatic life and drinking water while continuing to maintain the current high standards of public safety and accessibility during the winter season.

SaMS provides technical information on winter BMPs and processes to plan for, implement, track and evaluate their use. SaMS education and outreach recommendations are designed to increase public awareness and support for improved winter maintenance practices. Among the many other recommendations are some pertaining to monitoring and analyzing



water quality and tracking salt use, implementation actions, and experience. This essential information will inform future efforts to assess and refine SaMS recommendations over time, to ensure SaMS remains current and relevant into the future.

2.3 Stakeholder Involvement

Development of the SaMS Toolkit was a collaborative effort by a stakeholder body, facilitated by DEQ. Due to the scale and breadth of the stakeholder community this issue touches, a strong effort was made to bring together the broadest possible group of potential partners to have a wide range of opinions and ideas represented. This enabled comprehensive discussions to share ideas, concerns, knowledge and experiences in developing SaMS.

As is seen in **Figure 4** below, the SAC consisted of 64 individuals from 43 separate organizations. SAC members are identified within 10 stakeholder categories in the charts below, which show that while individual participants were heavily focused on government agency staff, the organizational affiliation of participants was more broadly balanced.

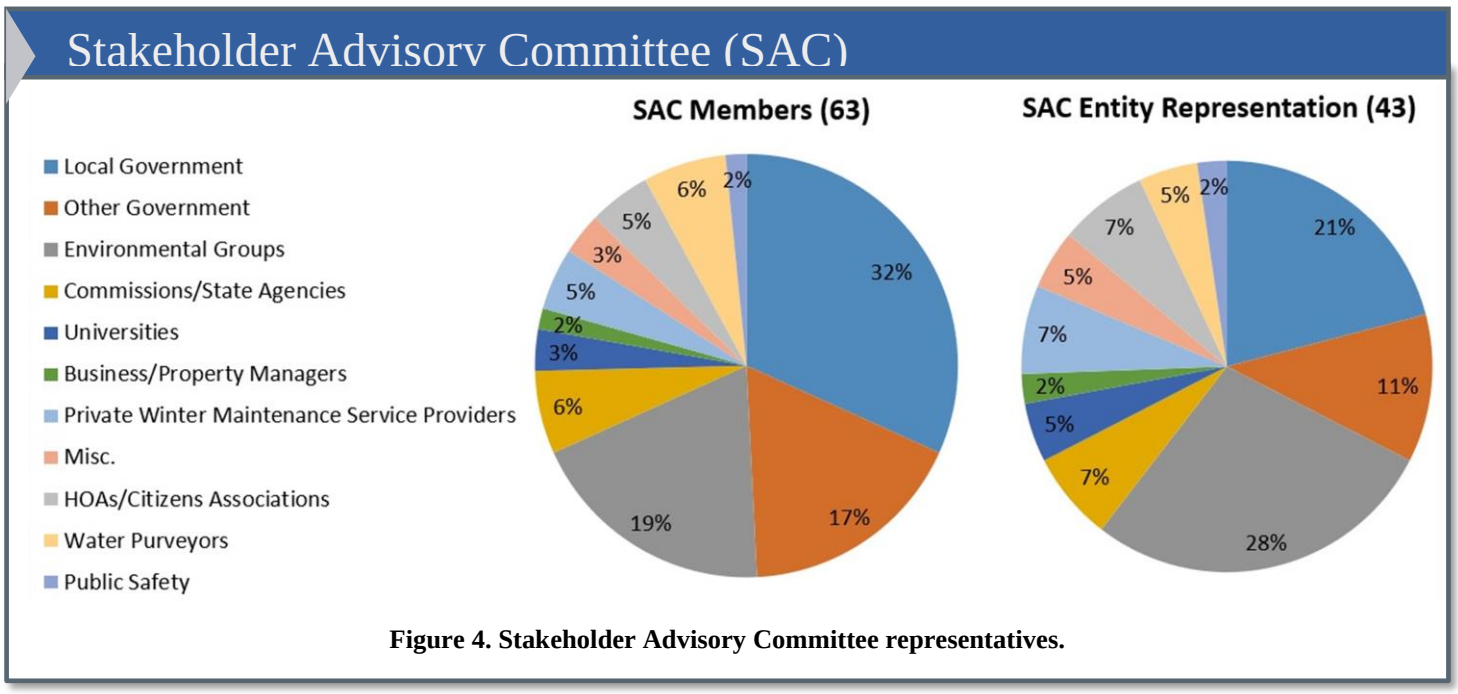


Figure 4. Stakeholder Advisory Committee representatives.



2.4 SaMS Goals and Objectives

In addition to the three goals described earlier in this section, SAC members developed a set of more detailed objectives to help guide development of the SaMS Toolkit and steer the SaMS initiative during implementation. The SAC approved the following detailed objectives, and also the SaMS goals, during its second meeting on June 13, 2018.

1) Comprehensively describe the effects of deicing/anti-icing salt use and identify and summarize the costs and benefits of winter storm operations.
2) Collaboratively develop a suite of best practices to minimize the negative effects of deicing/anti-icing salts.
3) Develop a comprehensive education and outreach plan to increase awareness of the benefits and impacts of winter salt use for both the public and political leaders to promote positive behavioral changes.
4) Explore funding opportunities, operational cost savings, and broader incentives, such as certification requirements/tort reform, to support implementation.
5) Develop recommendations for a monitoring and research program to better understand water quality patterns and impacts related to salt application throughout Northern Virginia.
6) Develop options to assess effectiveness and methods to track and report salt usage.

SAC members provided ideas, guided by the SaMS goals and objectives, that evolved into SaMS recommendations and resources during a total of 23 individual meetings held by the six SaMS workgroups between September 2018 and March 2020. A record of SAC and workgroup meetings is the **Appendix S**, Public Participation.

3 Planning and Application Practices

The SAC, through the efforts of the smaller workgroups, collected and analyzed available information and evaluated practical solutions to address the detrimental impacts of salts used for winter maintenance. This section summarizes the resulting recommendations and resources regarding best practices, with supporting information and implementation tools included in the Appendices. The term "practices" is used broadly and include: application and planning practices, continual program improvement processes, deicing product options, and a summary of certification and training programs. Note, measuring and tracking of salt use is also a best practice. However, because of the detail of that discussion, it is addressed in its own section (**Section 4**).

To provide the reader a roadmap of this section, the contents are outlined below:

- **Section 3.1** details the audience considerations for this section, and in some cases directs the audience to subsections of interest.
- **Section 3.2** provides context for the menu of operational BMP Pros and Cons and a recommended continual improvement process for implementing winter maintenance BMPs in phases, both of which are provided in whole in **Appendix B** and **Appendix C**, respectively.
- **Section 3.3** includes information on different deicing products, including how deicers work (**Section 3.3.1**), traditional salt products (**Section 3.3.2**), alternative products that do not contain chloride (**Section 3.3.3**), a recommended process for piloting new deicers and mixtures of deicers (**Section 3.3.4**), and recommendations to consider in future versions of the SaMS Toolkit related to deicer product research (**Section 3.3.5**).
- **Section 3.4** addresses application rates, and provides the context for a recommended application rate evaluation process that is provided in whole in **Appendix D**.
- **Section 3.5** provides the context for the information from **Appendix F**, which summarizes the different winter maintenance certification and training programs.
- **Section 3.6** documents a recommendation to consider best practices for property management winter maintenance contracting in future versions of the SaMS Toolkit.

3.1 Audience Considerations

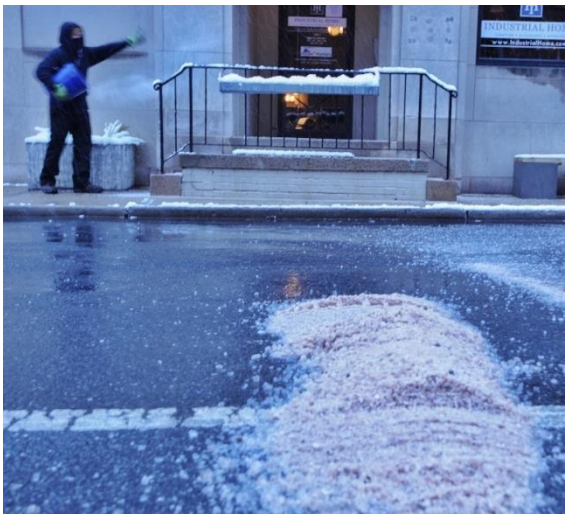
The planning and application practices discussed in this section were designed with specific audiences in mind. Specifically, these audiences include winter maintenance professionals and decision makers like elected officials, government agency leaders, property managers, and other winter maintenance contracting organizations such as homeowners associations. However, all other audiences are encouraged to read through **Section 3** as it is important to understanding the challenges winter maintenance organizations face and the opportunities these organizations have for reducing their salt use. Because of the diversity of audiences within the winter maintenance profession and those that have influence over the profession, the section below discusses these various audiences.



3.1.1 Winter Maintenance Professionals

Winter maintenance professionals include those focused on transportation infrastructure (keeping the roads clear) and those who manage properties (clearing parking lots, sidewalks, and the like). Both have important roles to play managing salt use, but the most effective strategies and communications techniques likely differ between these two groups. Similarly, winter maintenance professionals can be grouped by whether they work in the public or private sector. A comparison of these categories is provided in the sections below. In addition, three tiers of influence have been identified for the winter maintenance profession. A discussion of these tiers is also provided to assist in implementation.

Transportation versus Property Maintenance



Transportation professionals are focused on keeping the roads clear and safe and traffic flowing. Property maintenance professionals are focused on the safety of parking lots and sidewalks and other property-related infrastructure. While the end goal of usable, safe access for people and goods is the same, the tools, techniques, and considerations of these two groups sometimes differ. For example, community expectations, levels of service, and cost-effective materials and practices can be different between the transportation and property maintenance sectors. Within the SaMS project area (**Figure 2**), transportation surfaces make up about 23% of impervious surfaces that can be treated with salts (i.e., not rooftops), whereas property surfaces make up about 29%. For more information on this breakdown, see **Appendix Q**.

Public Sector versus Private Sector

This toolkit provides resources for implementation of BMPs by public and private sector entities. Special consideration was given to both.

Public sector agencies can have substantial winter maintenance responsibilities and many are subject to regulatory requirements through permit requirements or TMDL implementation. The public sector, including local, county, state, and federal government agencies can often set precedents for accepted practices and policies. While often leading by example, public sector agencies may have limited direct influence over activities on private properties.

Conversely, private sector companies have responsibility for management activities on private properties under a variety of contractual arrangements. The businesses that provide these important services are numerous and mostly independent. Private sector participants in SaMS development indicated that providing private entities with additional resources for sustainable action in an easy-to-implement format will be most helpful. Further, having a proactive public sector to lead will ease the way for private sector action as well.

"Some of the most important takeaways [from the SaMS process] were the conversations that took place between the different stakeholders and learning the delicate balance of managing salt for a variety of user groups and interests."
– Stakeholder Advisory Committee Member

Three Tiers of Winter Maintenance Audiences

The winter maintenance profession was divided into three tiers in the development of this toolkit to both highlight the roles each tier plays in effective implementation of winter maintenance operations, and to tailor the recommendations and resources more appropriately. Tier 1 is comprised of decision-makers, Tier 2 includes supervisors, and Tier 3 professionals are the applicators. Each of the tiers is responsible for different aspects of winter maintenance. The SaMS resources directly applicable to each of these groups will be different. For example, as the Tier 1 decision-makers generally are most focused on levels of service, resources most pertinent to this group might be related to education and outreach of performance standards for winter maintenance such as levels of service. There are also certification programs designed for Tier 1 decision-makers that are described in **Section 3.5**. On-the-ground BMP recommendations and planning processes found in **Section 3.2** through **Section 3.4** may be most applicable for Tier 2 and Tier 3 audiences. Effective communication of tier-specific recommended practices, as well as a general understanding of the different resources and recommendations by all tiers of influence, is essential to success. All tiers should be accountable to each other to carry out the winter storm response as planned.

Decision-Makers

Tier 1 includes the "decision-makers," leadership positions like elected officials, government agency leaders, property managers, and other contracting organizations like homeowners associations. Tier 1 is responsible for setting expectations and the levels of service.

Supervisors

Tier 2 includes "supervisors" such as program managers and crew chiefs. This tier is responsible for developing the winter maintenance plans (i.e., establishing routes, identifying operational improvements, setting application rates, identifying BMPs and alternative products, etc.) and directing the execution of the plans both annually and in response to each storm.

Applicators

Tier 3 audiences include the operators, both truck and hand/push applicators. These operators execute the winter maintenance plans and storm response. They are responsible for equipment calibration, on-the-ground application, and measuring/tracking product use.

3.2 Improving Operational Practices

Improving operational practices by all salt users is an essential component of minimizing salt use while maintaining public safety. The improvement options and processes included in this SaMS Toolkit are based on a continual improvement framework of options and processes to improve the efficiency of their unique operations. Therefore the recommendations and resources provided below are intended for use with an inherent flexibility that accomodates changing conditions and varied needs while promoting sustainable salt use.

3.2.1 BMP Pros and Cons

Each winter storm is different. Each winter maintenance organization and individual is different. As such, effective management and use of salt requires flexibility to adapt to changing social and environmental conditions. To this end, a resource was developed for SaMS implementation that identifies a menu of operational BMPs and their associated pros and cons (**Appendix B**). With this information in hand, decision-makers, supervisors, and applicators (the three tiers of influence described in **Section 3.1.1**) can make well-informed locale-specific decisions that make sense for the community, their organization, and the environment.

Appendix B (the BMP Pros and Cons menu) pulls together information from 31 different resources including winter maintenance BMP manuals, research projects, industry presentations, personal communications, and success stories to provide an extensive list of over 50 operational BMPs and their associated pros and cons (or benefits and challenges). The intent is to present as many practices as possible, with the understanding that all practices will not work for a single organization and that a single practice cannot be used under all circumstances. Since the menu is a high level summary of practices, organizations are encouraged to learn more about each practice, and if they see it as favorable, they can learn more about it using the BMP manuals referenced in **Appendix B** and through their own research using the wealth of existing materials on the web. Transportation audiences may benefit from the research of https://clearroads.org/[6] and property management audiences may benefit from the research of http://www.sicops.ca/[7] and the resources at https://www.sima.org/.[8]

Best Management Practices (BMPs)

Best Management Practices (BMPs) are defined as any practice that promotes the most efficient and effective use of deicers either directly or indirectly through more efficient and effective plans, program organization, equipment, and/or actual practices.

The practices in the BMP Pros and Cons menu are divided into two major categories – planning BMPs (those typically performed in advance of storms) and storm-related BMPs (those used during a storm). Practices are also organized by audience, the need for which is discussed in **Section 3.1.1**. For the purposes of this resource, practices are broken down into those applicable to all audiences, transportation audiences, and property management audiences.

When an organization identifies BMPs they would like to implement from the menu in **Appendix B**, they can incorporate them into their operations through a winter maintenance planning process. These plans will differ by private versus public sector. Winter service providers in the public sector are encouraged to develop organization-specific manuals/winter maintenance plans to meet the expectations of their Tier 1 decision makers (for example, VDOT's Maintenance Best Practices Manual, Section 6: Snow & Ice Control). Alternatively, winter service providers in the private sector can

[6] Clear Roads is a research program that "brings together transportation professionals and researchers from around the country to drive innovation in the field of winter maintenance."
[7] SICOPS is a research project underway at the University of Waterloo working to "identify the right snow and ice control methods, materials, and the right amounts of materials to be applied under specific winter weather conditions."
[8] SIMA is a "North American trade association for snow and ice industry professionals."

develop planning documents in collaboration with property managers for which they have contracted service (see the Snow and Ice Management Association's "Purchasing Snow & Ice Management: Quality RFP Creation and Best Practices" for related concepts presented to a property management audience). For both audiences, this provides an opportunity to use the Winter Maintenance BMP Implementation Process recommendation as a guide (discussed in the next section of this document).

To help organizations in their planning efforts, the relative, potential costs associated with the winter maintenance BMPs provided in the BMP Pros and Cons menu are identified in **Table 1** and **Table 2.** Costs are split into two categories, those for staff time, and other costs that include equipment, infrastructure, materials, and services. Staffing costs include any contracted workers. Potential cost savings related to each BMP are also included in **Table 1** and **Table 2**. These savings can include reduced costs associated with reduced deicer use, reduced staff time from operational efficiencies, and reduced equipment damage costs (e.g., from cleaning equipment and containing wastewater).



The scale of the operation will affect the magnitude of estimated costs and cost savings, but the assumption is that these are proportional to the size of the organization. Therefore, costs and cost savings are presented on a relative scale of high, medium, and low. To help illustrate the difference, BMPs like calibration, accountability at every level, and levels of service can be implemented with little to no financial investment in equipment, infrastructure, or materials (i.e., "Other Costs" in the table below are "low"). On the other hand, BMPs such as pre-wetting, anti-icing, and equipment that measures deicer use at the spreader require equipment or tools that come at a medium to high cost. It is necessary to emphasize that these two tables should be used cautiously as a springboard for further investigation. In some cases, the relative costs or cost savings provided in each table may vary more from organization to organization based on existing equipment, organizational structure, or organizational decisions.

BMPs listed in the table are summarized titles for more detailed recommendations in the BMP Pros and Cons menu (**Appendix B**). Users should follow up on BMPs of interest in the menu to better understand the context for the relative costs and cost savings provided here. The order of BMPs in **Table 1** and **Table 2** are the same as the order of BMPs in the menu. Lastly, because cost savings can occur when winter maintenance organizations partner together, opportunities for organizations to share BMP costs and execution are also highlighted. Some of these partnership opportunities are in line with the recommendations provided in **Section 8**, Inter-governmental Coordination. Although opportunities to partner have been identified in **Table 1** and **Table 2,** organizations are encouraged to look for opportunities to partner in all of their activities.

Table 1. Partnership opportunities and expected costs for planning practices in the BMP Pros and Cons menu.

Planning BMPs	BMPs	Potential Cost[1]		Potential Cost Savings[1, 2]	Are there opportunities to partner between organizations?
		On Staff Time	Other Costs[3]		
Winter Operations Planning	Develop a winter maintenance plan	High	n/a	High	No
	Preseason meetings	Medium	n/a	Medium	Yes[4]
	Postseason meetings	Medium	n/a	Medium	Yes[4]
	Accountability at every level	Low	n/a	High	No
	Transportation Audience - Plan snowplow routes	Medium	n/a	Medium	Yes
	Property Management Audiences - Visit the property before the season	Low	n/a	Medium	No
Levels of Service	***Transportation Audiences*** - Communicate levels of service internally	Medium[5]	n/a	Medium	No
	Transportation Audiences - Communicate levels of service externally	Medium	Medium	Medium	Yes[4]
	Property Management Audience - Discuss and agree upon levels of service	Low	n/a	Medium	No
Training	Training	Medium[5]	Medium	High	Yes[4]
Salt Storage/Handling	Proper storage of deicer piles	Medium[5]	High	High	Yes[4]
	Proper storage for liquid products	Medium[5]	High	Medium	Yes[4]
	Proper loading and hauling of deicers	Medium[5]	Medium	Medium	Yes
	Clean equipment and contain wastewater	Medium[5]	Medium	Medium	No
	Property Management Audiences - Proper storage of deicers and abrasive piles delivered to a property	Low[5]	Low	High	No
	Property Management Audiences - Proper storage and handling of deicer bags	Low[5]	Low	Medium	No
Calibration	Establish a calibration process	Low	n/a	High	Yes
	Calibrate equipment	Medium[5]	Low	High	No
Storm Meetings	Pre-storm meetings	Low	n/a	Medium	Yes
	Post-storm meetings	Low	n/a	Medium	Yes[4]
Weather Forecasts & Surface Temperature Information	Weather forecasting	Low[5]	Medium	High	Yes[4]
	Know the surface temperature	Low[5]	Low	High	Yes[4]
Enhanced Equipment & Technology	Plows (e.g., side wing, tow plows, flexible or sectional blades, etc.)	Low	High	High	Yes[4]

Planning BMPs	BMPs	Potential Cost[1]		Potential Cost Savings[1, 2]	Are there opportunities to partner between organizations?
		On Staff Time	Other Costs[3]		
	Spreaders that can deliver low rates, collect data, and/or are ground controlled/speed-synchronized	Low	High	High	Yes[4]
	Equipment needed for making liquid products	Medium	High	Medium	Yes[4]
	Transportation Audiences - Automated Vehicle Location (AVL)	Medium	High	Medium	Yes[4]
	Transportation Audiences - Maintenance Decision Support System (MDSS)	Medium	High	High	Yes[4]
	Transportation Audiences - Precision Deicing	Low	High	High	Yes[4]

[1]Potential costs and deicer savings may vary more significantly since existing equipment, organizational structure, or organizational decisions may influence the outcome.
[2]Savings on reduced deicer use, reduced staff time, and reduced equipment damage costs.
[3]Equipment costs, infrastructure costs, materials costs, and costs for services.
[4]These partnership opportunities are in line with the recommendations provided in **Section 8**, Inter-governmental Coordination.
[5]Considers training costs.



Table 2. Partnership opportunities and expected costs for storm related practices in the BMP Pros and Cons menu.

Storm Related BMPs	BMPs	Potential Cost[1]		Potential Cost Savings[1, 2]	Are there opportunities to partner between organizations?
		On Staff Time	Other Costs[3]		
Anti-Icing	Anti-icing	Medium[4]	Medium	High	No[5]
Plowing Practices	Plowing early and often	Medium	Low	High	No
	Transportation Audiences - Coordinate plowing activities	Low[4]	n/a	Medium	Yes
	Transportation Audiences - Plow trains	High[4]	n/a	Medium	No
	Property Management Audiences - Choose the right plow, shovel, pusher, blower, blade, or broom for the property	n/a	Medium	High	No
	Property Management Audiences - Opportunities to close areas with a small footprint and use the proper tool to remove snow/ice in these areas when you cannot close the area	n/a	Low	Medium	No
	Property Management Audiences - Snow is placed in proper places	n/a	n/a	Medium	No
Product Application Practices	Dyed deicers	n/a	Low	Low	No[5]
	Use of abrasives	n/a	Low	Low	No[5]
	Post-storm clean-up	High	Medium	Low	No[5]
	Transportation Audiences - Spinners set-up using a chute or spinner close to the ground	Low	Medium	Medium	No
	Transportation Audiences - Plows drive 17-25 mph on non-high-speed roads	n/a	n/a	Medium	No
	Transportation Audiences - On high-speed roads deicer is applied to the center of the road or high side of a curve	n/a	n/a	Medium	No
	Transportation Audiences - Turn off auger, shoots, or conveyors when stopped	n/a	n/a	Medium	No
	Transportation Audiences - Reduce deicer application rate on successive passes	Medium	n/a	Medium	No
	Property Management Audiences - Spread patterns that prevent overlapping applications	Low	n/a	Medium	No
	Property Management Audiences - Drop spreaders or rotary spreaders with shields are used for sidewalks	n/a	Medium	Medium	No

Storm Related BMPs	BMPs	Potential Cost[1]		Potential Cost Savings[1, 2]	Are there opportunities to partner between organizations?
		On Staff Time	Other Costs[3]		
	Property Management Audiences - Use a hand-held spreader and the exact amount of salt for the area on stairways or areas with a small footprint	n/a	Medium	Medium	No
Vary Application to Conditions	Variable application rates	Medium[4]	Medium	High	No
	Use deicers within their temperature range	Medium[4]	Medium	Medium	No
Use of Liquids	Pretreat deicers	Medium[4]	Medium	Medium	No[5]
	Prewet deicers	Medium[4]	High	High	No
	Direct Liquid Application	Medium[4]	High	High	No[5]
Measurement	Measure and record deicer use	Medium[4]	Medium	High	No

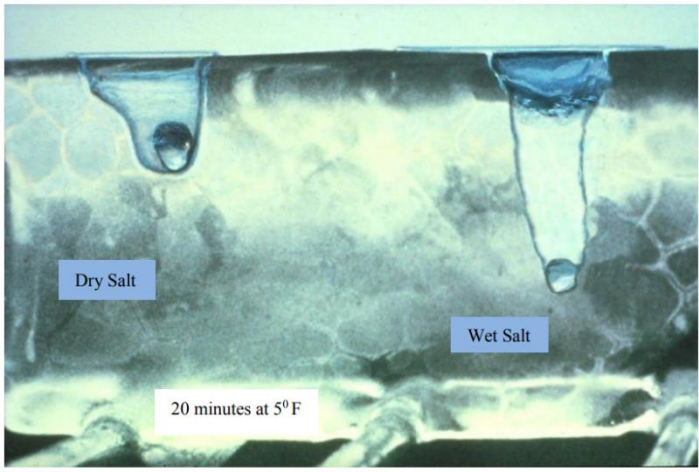
[1]Potential costs and deicer savings may vary more significantly since existing equipment, organizational structure, or organizational decisions may influence the outcome.
[2]Savings on reduced deicer use, reduced staff time, and reduced equipment damage costs.
[3]Equipment costs, infrastructure costs, materials costs, and costs for services.
[4]Considers training costs.
[5]Since these are practices to be implemented in the storm, the activity is not seen as an opportunity for partnership, but resources to accomplish the activity can be secured through a partnership.



3.2.2 Planning to Implement Winter Maintenance Best Management Practices in Phases: A Continual Improvement Process

The planning process for BMP implementation described in **Appendix C** is based on a concept of continual improvement. Winter maintenance planning is a comprehensive task that provides a plan for the entire operation. One facet of that planning process is the identification and implementation of BMPs, which **Appendix C** outlines as a recommended voluntary process. The focus is on reducing excess salt use by identifying BMPs to be implemented either in the short-term or over a longer-term planning horizon. This process recommendation acknowledges that some BMPs are readily available, effective at reducing salt, simple to implement, and can be added to existing winter maintenance plans and guidance without increasing operational costs. Others, in contrast, will require considerable financing and long-term planning.

The SaMS Toolkit does not identify priority BMPs, instead it provides organizations options to select what works best for them. However, short- and long-term BMPs are distinguished, however, in an effort to help organizations determine what can be readily implemented now (or at any given time) and what will require planning and investment for the long-term.



For successful implementation, winter maintenance decision makers, supervisors, and applicators (**Section 3.1.1**) must be on board and in communication. In particular, winter maintenance plans must be discussed with decision-makers, including highlighting the tie between levels of service and the winter maintenance plan.

3.3 Products

Winter maintenance products are used in winter operations to prevent accumulation (**anti-icing**) and/or after accumulation to melt ice and snow (**deicing**)[9] to enhance public safety during winter storm events. There are many materials and strategies available, each with costs and benefits. Selecting the right products and application methods for a particular job can increase benefits while reducing costs, environment impacts, and harm to the built environment. Products that contain phosphorus or nitrogen, such as ammonia, are banned for sale by law in Virginia.

This section discusses how the products work, explores traditional and alternative products, and discusses a process for piloting new deicers and mixtures. Potential environmental impacts, costs, and benefits are discussed in detail in **Appendix A**.

3.3.1 How Deicers Work

Deicers work by lowering the freezing point of water, which melts the ice when conditions are right. Deicers also prevent the bonding of ice on paved surfaces. In order to lower the freezing point of water, deicers must be dissolved, which is why many deicer application BMPs involve liquids (e.g., brines, pre-wetting, and pretreating; see **Appendix B**). There are different types of products available to achieve the goals of deicing that can be grouped broadly into traditional and alternative product categories. Traditional products are salts that are commonly used for deicing and have broad applicability. Alternative products are emerging materials and/or have benefits that are selected for more localized use. Traditional and alternative products have pros and cons, discussed in the sections below and in detail in **Appendix A**.

[9] http://www.safewinterroads.org/anti-icing/

3.3.2 Traditional Products

Traditional deicing products include chloride-based materials such as sodium chloride, magnesium chloride, and calcium chloride. Of these, the most commonly used deicing product is sodium chloride. It is readily available, inexpensive, and effective. Sodium chloride is also versatile as it can be applied in granular form as a deicing agent (rock salt), or as a liquid brine for anti-icing and deicing purposes (Westchester 2007). The cost of sodium chloride is approximately $70/ton (MDOT 2014). While sodium chloride is not appropriate in very cold weather (less than 15°F), pavement temperatures seldom drop below this level in Northern Virginia.

Other available chloride-based materials include magnesium chloride and calcium chloride, which are effective at lower temperatures than sodium chloride and can be used to -10° and -20°F, respectively. While these three chloride products are inexpensive compared to the alternative products discussed in the next section, they are known to be corrosive and have numerous negative environmental impacts (**Appendix A**).

3.3.3 Alternative Products

To reduce the negative effects on the natural and built environment that are well documented in the literature (see **Section 1.1** and **Appendix A**), it is important to consider alternative solutions, including those that do not use salt. Three groups of alternative deicers that are intended for use on paved surfaces were evaluated in **Appendix E** since the available information suggested only moderate environmental impacts. These alternative products include acetates (potassium acetate, sodium acetate, calcium magnesium acetate), formates (sodium formate and potassium formate), and potassium succinate. Each of these products has a unique set of pros and cons (see **Appendix E**), and it is worth noting that all of these alternative products contain cations (sodium, potassium, calcium, and magnesium) that are also contained in many of the traditional products and contribute to freshwater salinization. These materials can be expensive, especially when compared to traditional rock salt. In addition, acetates and formates are corrosive to certain kinds of metal and both are reactive on concrete. Non-chloride products can exert a high biochemical oxygen demand, creating detrimental conditions for aquatic species (TRS 2017). However, the fact that these compounds can exert a high biochemical oxygen demand is a result of their ability to biodegrade a portion of the compound and not persist entirely in the environment. Additionally, during winter temperatures, the actual ability for the products to depress oxygen levels in aquatic environments may be very low (Tanner and Wood, 2000; USGS, 1999).

Given the unique characteristics of traditional and alternative products, careful consideration of the most appropriate product for the job is important in winter operations.

"The real issue is not rock salt, it is the misuse of rock salt."
– Stakeholder Advisory Committee Trainer

3.3.4 Process for Piloting New Deicers and Mixtures

As the interest for alternative products grows and existing products are combined into engineered mixtures, new deicers and mixtures will be experimented with by winter maintenance organizations. Although this is a progressive endeavour, these new deicers and mixtures should be thoroughly vetted prior to on-the-ground application. Typically, industry practices evaluate deicer performance and impacts to infrastructure before field testing deicers and mixtures of deicers. An evaluation of potential environmental impacts is usually left unaddressed or is done at later stages after deicers are used in the field. Proactively understanding potential impacts to the environment is important prior to field and full scale application. Since industry practices typically miss these vital studies, it is recommended that winter mainteance organizations with the resources to run these tests do so, and share their results for other organizations to evaluate. Accordingly, **Appendix E - Section 2** diagrams a process for piloting new deicing compounds or mixtures that inserts an evaluation of environmental impacts after initial deicer performance tests and before field tests. The two basic tests recommended in this process include Biochemical Oxygen Demand (BOD) at 20ºC and 2ºC and acute and chronic toxicity bioassays using 3 species (alga, invertebrate, and fish species). Standard methods for BOD tests are run at 20ºC, however it is also recommended to run BOD tests at 2ºC to evaluate BOD impacts at melt water temperatures. Clear Roads developed a process for Determining the Aquatic Toxicity of Deicing Materials, determining both acute and chronic toxicity of deicers and deicer mixtures. For both BOD and the two toxicity tests, the **eutectic concentrations** of the deicers (e.g., eutectic concentration by mass for NaCl is 23.3%) should be evaluated in order to establish a consistent and comparable method. The eutectic concentration is used because it is assumed to be the maximum concentration expected in stormwater since that is the most efficient concentration for deicing.

Eutectic Concentration

The **eutectic concentration** is used to determine the ideal mixture in brines but can also be used to determine the expected maximum concentration in stormwater. Phase diagrams showing the deicer proportion in the solution (% by weight) against the temperature can be used to determine the eutectic temperature and the eutectic concentration

3.3.5 Future Recommendation for Products Research

Continued efforts to pilot new deicers and mixtures can identify viable and effective non-chloride deicers that lessen the adverse impacts of traditional products and expand the suite of products available to practitioners. Additional research, including pilot programs, can be conducted to identify non-chloride deicers for paved surfaces. The aim is to identify products that have less adverse human health and environmental impacts and better efficacy, potential availability, and cost-benefits than chloride deicers.

3.4 Application Rates

Optimizing the rate at which deicing products are applied to maintain public safety while minimizing negative environmental and infrastructure impacts calls for a delicate balance of many factors including: level of service, characteristics of the storm, pavement temperatures, type of property/surface, characteristics of the route/property and the product used. Given the many factors at play and the fact that every winter maintenance operation is unique, each operation will need to determine its own numeric target application rates.

Even with the best planning, target application rates cannot always be achieved. Challenges to achieving the goal include changing weather, equipment limitations, untrained applicators, route/site conditions, and social and political conditions. Acknowledging these unique challenges, SaMS implementation is a voluntary process focused on improving application rates over time rather than prescribing specific numeric rate targets to be met right away. A variety of numeric application

rate guidelines exist and can serve as a resource for identifying appropriate targets. Some are listed in **Appendix D** while others are readily available online. Specifically, **Appendix D.a** provides selected existing application rates for transportation operations and **Appendix D.b** contains comparable information for property management operations (e.g., parking lots and sidewalks).

3.4.1 Application Rate Evaluation Process

The SaMS Toolkit includes a voluntary application rate evaluation process that was developed to support continual improvement of winter maintenance operations through focused attention on application rates and levels of service (**Appendix D**). The process involves selecting a target application rate(s), determining the quantity of deicer used, evaluating whether or not the levels of service were achieved, and evaluating whether or not the target application rate(s) was/were achieved. The result of the evaluations can highlight challenges and/or areas for improvement.

Challenges to fully implementing this process are 1) the scale of the operation and the ability to measure deicer use during storm response, 2) the use of contractors and different equipment, 3) subjectivity and inconsistency of levels of service evaluation, and 4) the availability of automated deicer measuring equipment. Overcoming these challenges will be an ongoing, iterative process that may depend on staff training, contract language, budget processes, and long-term planning efforts. Despite anticipated challenges, this approach encourages operations to take the first step, initiating the evaluation process, with a continual growth framework in mind and to use the results to learn and improve over time.



3.5 Certification and Training Programs

Certification and training programs for winter service providers have had numerous direct and indirect benefits in other parts of the United States. Direct benefits seen in other regions of the USA have included reduced materials cost, possible liability protection, more responsible application, and environmental and drinking water improvements. Indirect benefits have included heightened awareness of the impacts of over-salting and enhanced public perception of certified entities. While these benefits have been documented in parts of the country where certification and training programs have been implemented to date, Northern Virginia does not have experience with all of these benefits. Discussions should be held as part of SaMS implementation to further consider certification and training programs for use in Northern Virginia. Such a program could expand out to the National Capital region, or even to mid-Atlantic jurisdictions to benefit from enhanced resources and legitimacy. If a certification and training program approach is adopted, strategies for encouraging certifications will need to be reviewed periodically.

During development of the SaMS Toolkit, ten existing winter service provider certification programs were identified and reviewed, and are listed in alphabetical order below. Based on readily available information, five of those programs, bolded in the list below, could readily be administered in Virginia by the certifying program. These programs either host online training, or are known to hold in-person trainings at requested locations, making it viable for applicators in Virginia to access the training. A detailed description of each program can be found in **Appendix F**. This information on certification and training programs is provided as a resource for organizations to consider what, if any, would be beneficial to the training and professional development of their staff as part of the effort to improve their organization's efficiencies.



- AORS: Association of Ontario Road Supervisors Certified Road Supervisor, Winter Operation Training Series
- **APWA: American Public Works Association Winter Maintenance Supervisor Certificate**
- **ASCA: Accredited Snow Contractors Association Certification**
- City of Madison, Wisconsin Winter Salt Certification
- McHenry County, Illinois Sensible Salting Workshop and Certification
- MPCA: Minnesota Pollution Control Agency's Smart Salting Certification
- NHDES: New Hampshire Department of Environmental Services' Green SnowPro Training – NHDES Salt Applicator Certification
- **SASC: Smart About Salt Council Certification**
- **SIMA: Snow and Ice Management Association Credential Programs**
- **SWIM: Sustainable Winter Management Certification**

3.6 Recommended Future Practices

The above sections make recommendations regarding research into alternative deicing products (**Section 3.3.5**) and for considering certification and more ambitious training programs (**Section 3.5**). Another recommendation involved

improving winter maintenance contracts for property management to systematically improve the efficiency of salt application.

Different types of property management contracts used to provide winter maintenance services were discussed during the initial development of the SaMS Toolkit. These are the contracts used to maintain parking lots, sidewalks and travel ways. Contract terms can influence the extent to which best practices are implemented. Contract terms to encourage greater BMP use are being considered in other parts of the United States. One example is the contract template developed by the City of Edina, Minnesota in late 2018. SaMS stakeholders discussed this topic and concluded that more information and expertise in contracting matters are needed before a specific recommendation can be made. Also, early experiences from the City of Edina implementation of their contract template could reveal whether using such a template could help efforts in Virginia. Therefore, it is recommended that after experience is gained through SaMS implementation and from other contract models pursued in other areas of the country, the entity that assumes leadership of SaMS implementation should revisit the topic of contracts for property management through the SAC or a similar stakeholder body. Specifically, this future evaluation should identify either a specific recommended contract model or specific components property management contract for winter maintenance activities should contain to promote the use of better practices.

4 Tracking and Reporting

"You can't manage what you don't measure" is a common phrase used to explain the need for organizations to quantitatively track their work processes, if they wish to improve their operations. Thus the SaMS Toolkit, in support of continual improvement, provides recommendations on:

1) Salt use tracking, including uniform metrics for data comparability and region-wide trend analyses, and
2) BMP implementation tracking, including a process to track iterative BMP adoption and monitor the success of BMPs.

An important criterion for recommendations on winter maintenance operations tracking was to meet the information needs of both public and private sectors at various scales, as well as individuals at all levels (operator to senior leadership) within an organization. Accordingly, this section is relevant to all three tiers in both public and private organizations that perform winter maintenance. Tier 1 decision-makers should consider what tracking information will be most helpful to their leadership roles and to public or client communications. Tier 2 supervisors should be involved both in deciding what information should be tracked and overseeing its collection by operators. Tier 3 applicators are the essential lynchpin for tracking salt use and BMP implementation; without their priority attention to tracking, the information may be incomplete and of little value for performance management.

Comprehensive voluntary tracking forms and associated instructions are available in **Appendix J** as an example tool to facilitate improved and more consistent documentation of winter maintenance activities. A set of core elements (the key initial information to track) is identified to encourage a basic level of winter operations data collection, as a foundation for enhanced future tracking and reporting (**Figure 5**). Core elements are shown first, and in bold, for each section of the tracking form in the conceptual diagram below:

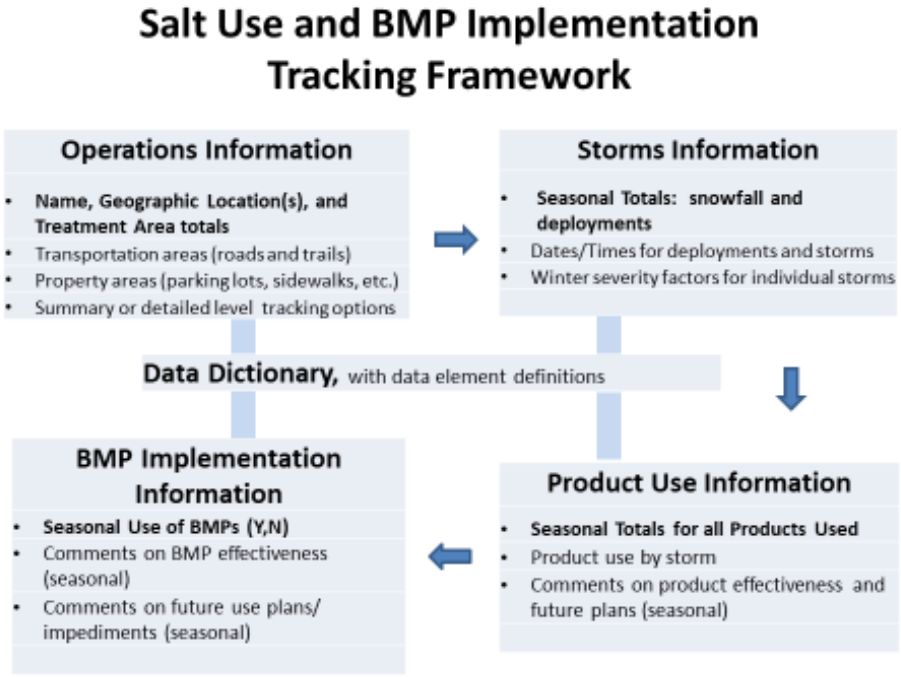


Figure 5. Salt use and BMP implementation tracking framework.

The tracking forms provided here are generalized and not tailored to meet the specific needs of any given organization. It is recommended that organizations adapt them to best meet their interests and needs. For organizations that already have established internal reporting processes, some data elements in the forms discussed here could be valuable additions to enhance existing tracking practices. In the future, it could be valuable to prepare model forms or constituent handouts customized for use by small private service providers, civic/homeowner associations, and other specific audiences.

This section addresses recommendations and resources for salt use and BMP implementation tracking that include:

- The seasonal, storm-specific and operational area levels of detail organizations may use in their tracking activities (**Section 4.1**)
- A data dictionary to clarify the reporting metrics contained in tracking forms (Section 4.2)
- Salt product use reporting metrics (Section 4.3)
- Seasonal BMP implementation questions (Section 4.4)
- Reporting salt use and BMP implementation in the future (Section 4.5)

4.1 Seasonal, Storm-Specific, and Operational Area Tracking

In addition to meeting the needs of different organization types, and the three tiers of winter maintenance audiences within them, the data elements contained in forms found in Appendix J allow for tracking at varied levels of detail. Tracking can be done at a coarse level (e.g., winter season summary) or for individual storm deployments, either for the organization as a whole, or for sub-units within an organization. The tracking forms developed to support SaMS implementation provide a comprehensive framework with various levels of detail that can be readily adapted to meet the unique interests and needs of different organizations.

In the preparation of these forms, stakeholders stressed that initial tracking efforts will generally be at a summary level; observed that most tracking will need to be done manually in the near-term; and noted that large scale storm deployments constrain the attention needed to ensure detailed operations tracking.

Seasonal level tracking at the organization scale will document winter operations for the entire organization, and more detailed tracking would capture storm-specific deployments within the organization. At greater precision, given that some organizations' winter maintenance operations cover large areas and use multiple distribution centers or garages, the forms also support tracking by season or storm for each center/garage, or other sub-grouping of the organization.

The tracking forms were developed in a spreadsheet, and each section (separate spreadsheet tab) is formatted to allow printing and use in hardcopy by field personnel. A core set of tracking elements that identify areas of operation, snowfall and storm deployments, the amount of deicer products used, and the BMPs implemented during the season is encouraged for all winter maintenance organizations.

4.2 Data Dictionary of Reporting Metrics

The tracking forms provide a comprehensive set of data elements to enable organizations to document the extent of their winter maintenance activities in a scalable level of detail. Winter storms can be characterized simply as the total snowfall and number of storm deployments for the entire season, or through tracking "winter storm severity" metrics for each storm. Similarly, use of winter maintenance treatment products can be reported for the entire season for the organization as a whole, or storm-specifically for sub-groupings of the organization. Finally, BMP implementation metrics apply at the seasonal level, and can be used to document all BMPs currently being implemented, their effectiveness, as well as future plans or impediments to overcome to be able to use additional BMPs. The forms are organized in **Appendix J** and in a hyperlinked Microsoft Excel spreadsheet as separate tabs, as was illustrated in **Figure 5** above: Tab 1 documents the organization's treatment areas; Tab 2, the winter storm season; Tab 3, product use data; and Tab 4, BMP implementation.



"You can't manage what you don't measure. Agencies have been performing winter maintenance in one manner or another for a hundred years. Measuring how well we've been doing is a much harder proposition…"
– Episode 17: SICOP Talks Winter Ops Podcast

A data dictionary and tracking instructions (Tab 5) are also found in **Appendix J** to help foster consistency in data tracking practices. Brief explanations are provided regarding the information desired and how to respond to each data element in the tracking forms. Core tracking elements are highlighted in the forms and data dictionary (in red font). The complementary tracking instructions provide introductory context for data tracking, along with basic step-by-step instructions for data tracking using these forms.

4.3 Tracking Salt Use

As noted, Tab 3 contains the data elements that enable coarse-to-detailed tracking of salt products (as well as abrasives or alternative deicers) used by the organization in its winter operations. For organizations wishing to track at the seasonal level, total volumes for each product used during the winter can be reported. At a seasonal level, product use volumes may be determined by the difference in pre- and post-season product inventory, being careful to account for the amount of products purchased (or sold) during the winter season as part of the overall inventory.

At a more detailed level, product use can be tracked on an individual storm basis, based on product loading and unloading operations. And even greater detail can be captured if product use is tracked at the sub-organization level, or by individual transportation routes or property management groupings. If detailed tracking is used, formulas are included in the forms to calculate seasonal product use totals.

4.4 Tracking BMP Implementation

Tab 4 contains the data elements that enable seasonal tracking of BMPs implemented by the organization in its winter operations. BMP implementation data elements correspond to the individual practices presented in the BMP Pros and Cons menu (**Appendix B**) discussed in **Section 3.2.1** above. Tracking is done by responding to 'Yes' or 'No' questions of whether the BMP was used and, for those implemented, space to provide a brief narrative on its effectiveness. Additional questions ask whether individual practices are planned for future use. For those BMPs not currently in use, the questions seek a brief narrative to indicate future plans for adding the practice to operations and/or impediments that need to be addressed to allow for new BMP use. This information can play a helpful role for organizations that use the planning process to implement BMPs discussed in **Section 3.2.2**. The tracking form has space to allow organizations to add any other comments desired to document their BMP implementation activities and experiences.

4.5 Reporting Salt Use and BMP Implementation

An important goal for this effort was to lay the groundwork for greater consistency in winter operations tracking. In the near-term, use of tracking information will primarily inform internal organizational improvements. More consistent tracking across organizations will also facilitate the sharing of information and lessons learned across organizations.

Enabling regional scale reporting and analysis, including studies to assess the impact of enhanced BMPs on water quality outcomes, is a longer-term goal for Northern Virginia winter operations tracking. Integrating individual organizations' data to enable regional analysis and public communications will require additional discussions and decisions by the region's government agencies and winter service organizations.

As will be discussed later, periodic forums to assess the status and progress of carrying out SaMS recommendations are envisioned in the years to come. While the nature and frequency of these forums is yet to be determined, it is expected that they will provide the opportunity for organizations to discuss their winter operations and consider how internal tracking data could be shared externally to support peer learning, regional analysis and public communications in the future. External reporting of winter maintenance activities is identified as one of the future SaMS recommendations in **Section 9**.

5 Best Practices for the General Public

There are several ways the general public can participate and be "winter salt smart" to help strike a balance between the benefits and impacts from salts applied in their communities and neighborhoods. These include:

- Best practices they can use at their own residences that either do not use salt or promote efficient and effective salt application.
- Changes they can effect in their communities and neighborhoods through promoting use of best practices within organizations of which they are members.
- Decisions they make regarding travel during and around storm events.

Although individuals may feel their actions are ineffective or insignificant in addressing a wide-scale challenge, each and every person has a role to play. Their combined actions lead to a larger effect when viewed from a regional perspective.

Section 5 includes recommended practices for the general public, which includes best practices for individuals to use around their residence (**Section 5.1**), practices that commuters and drivers can use to help road maintenance crews be efficient in their salt use (**Section 5.2**), and information to help individuals report winter salt concerns (**Section 5.3**). More detailed information and educational resources related to these recommendations are also included in **Appendix I – Section 5** and **Appendix I – Section 6.**



5.1 Residential Best Practices

Every resident must decide the best ways to manage snow and ice removal for their residence and their unique situation. When feasible, shoveling early and often during and after a winter storm is a best practice that does not involve salt use. One practice residents can consider is waiting for the sun to melt snow and ice left behind after shoveling[10] or using a traction material, such as a native blend of bird seed, on slick areas. Alternatively, if salt is chosen, it is recommended the user 1) apply only where salt is needed, 2) allow time for salt to work and 3) sweep up any excess or leftover salt to be reused next time. Residents can find more specific information on best practices for their residences, including recommended salt application rates, in the materials provided in **Appendix I – Section 5**. To help individuals be informed consumers, **Appendix I – Section 5** also contains information on different materials to treat snow and ice, their effective temperature ranges and terminology.



Additionally, residents can promote the use of best practices within their communities. By talking to their neighbors and encouraging organizations such as homeowners or property owners associations to employ winter maintenance professionals that use best practices, they can effect change within their communities. Those in community leadership positions may have additional opportunities to effect positive change through their direct input on decisions for winter maintenance contracting services. For example, community leaders responsible for contracting winter maintenance services may want to ask prospective contractors whether or not they implement best practices to efficiently use deicer, and whether or not the contractor's staff are trained or certified. Those in leadership positions can find more information relevant to their role as a "decision maker" in **Section 3.1.1** and information on a wide range of best practices in **Section 3**.

5.2 Commuter/Driver Best Practices

Many people in Northern Virginia expect to be able to travel during or immediately after winter storm events. This expectation creates an additional challenge for winter maintenance professionals. Depending on the severity and timing of the storm, it can be difficult for these professionals to follow best management practices that promote efficient salt application due to traffic on the roads. Traffic congestion keeps snowplows from doing their job efficiently. Salt takes time to work and dilutes when it mixes with the snow. Since traffic can extend the time between each pass along a snowplow route, snowplow operators may have to put down more salt to keep it working between passes of their route.

By taking a moment to consider the questions on the page below, individual drivers and commuters can identify when their situation may allow them to wait to drive. Every commuter and driver must make decisions based on their unique situation and needs. But where flexibility allows, this seemingly small action by individuals can make a difference when those actions multiply across a regional scale.

[10] Make sure to check with your local government for any requirements to clear certain areas within a certain timeframe.

Those who commute or regularly drive are encouraged to pause and consider the following questions before getting into their vehicles when the forecast calls for winter weather:

- Is the travel essential or can it wait?
- If it is an event you are hosting, can it be postponed?
- Can travel be planned around the storm to avoid travel during or immediately after the storm, enabling road conditions to improve?
- Is public transportation or telework an option?
- Are there updates to the weather forecast that affect travel plans?

5.3 Reporting Winter Salt Concerns

For most of Northern Virginia, VDOT is responsible for winter road maintenance, and issues related to salt used on area roads can be raised to VDOT's attention at the following site: https://my.vdot.virginia.gov/. Additionally, Arlington County provides a tool for residents to report salt concerns, which can be found at the following address: https://emergency.arlingtonva.us/weather/snow-ice/snow-prep/.

Roads and paved surfaces managed by local governments are within the purview of these local jurisdictions. Because there are no uniform regulatory standards for winter salt use, local jurisdictions have limited authority to address salt issues not associated with their own winter maintenance activities. Local governments are encouraged to develop ways that members of the public can bring winter salt concerns within their jurisdictions to their attention.



What you can do…

In your community:

- Be the change you want to see by using best practices at your own home that either do not use salt or promote efficient and effective salt application.
- Effect change in your community through promoting use of best practices within your HOA, religious community, educational institution, employer, etc.
- Carefully consider decisions regarding travel during and around storm events.

At your home:

- Shovel early and often during and after a winter storm.
- Wait for the sun to melt snow and ice left behind after shoveling[1] or use a traction material, such as a native blend of bird seed, on slick areas.
- If you choose to use salt,
  - apply only where salt is needed,
  - allow time for salt work, and
  - sweep up any excess or leftover salt to be reused next time.

[1]Make sure to check with your local government for any requirements to clear certain areas within a certain timeframe



6 Education and Outreach

While safety is a vital part of the levels of service provided by winter maintenance professionals in the public and private sectors, the expectations and needs of the general public play a critical role. As more members of the general public become aware of the benefits and impacts of salt use, they will have the information necessary to make informed decisions and potentially support use of improved best practices within their communities.

> Talking with neighbors, friends and co-workers about appropriate expectations for driving during and following winter storms is something everyone can do to help promote positive and impactful behavioral changes.

Outreach can increase general awareness and educate the public on best practices a specific audience may use to help balance the pros and cons of salt use. In the future, education programs targeted for school ages K-12 are recommended to increase awareness and build understanding of the topic.

This section of the SaMS Toolkit discusses large scale outreach. However, it is anticipated that these outreach efforts will stimulate conversations on a smaller scale, creating a ripple effect to reach a wider audience. Talking with family, friends, neighbors, and co-workers about the benefits and impacts of salt use, and the best practices to balance those, is something everyone can do to help spread awareness and promote positive and impactful behavioral changes. These seemingly small actions by individuals help to continue the conversation, making a difference when those actions multiply across a regional population.

6.1 Purpose of the Education and Outreach Resources

The recommendations and materials presented in this section will help guide education and outreach efforts and encourage organizations across the region to "speak with one voice." However, there is need for flexibility in messaging to enable each organization to speak directly to its specific audience. Therefore, the materials and recommendations that comprise the Education and Outreach Resources (**Appendix I**) lays out a framework to help guide those efforts.

This section provides the following resources to support education and outreach efforts:

- The principles for use in development of messages or materials are covered in **Section 6.2**.
- The SaMS logo use policy, which provides an identity and framework for "speaking with one voice" is provided **Section 6.3**.
- Information collected from the pilot outreach campaign held in November and December 2019 is provided in **Section 6.4**.
- The results of a baseline public awareness survey conducted in December 2019 are provided in **Section 6.5**.
- Context for the use of the education and outreach resources in **Appendix I** is provided in **Section 6.6**.
- Recommendations for current and future education and outreach efforts are identified in **Section 6.7**.

6.2 Principles to Guide Development of Messages and Materials

The principles highlighted here are intended to promote "speaking with one voice" and influenced the development of messages and materials in **Appendix I**. These principles are applicable to all stakeholders who develop communications to support and further the goals of SaMS. The intent of these principles is to ensure consistency of messaging with SaMS goals, *not* to identify specific content. The SaMS logo should only be used with messaging that considers all five principles, whether the messaging is in print or digital formats, including social media posts.

Further explanation of the intent of each principle, including the SaMS goal it supports and references to related information, can be found in **Appendix I**.

All messaging should incorporate the following five principles:

1) The importance of public safety.
2) The unintended environmental impacts of salt use.
3) Why minimizing salt application matters.
4) The pros and cons of winter salt use (keeping in mind the concerns of all stakeholders).
5) Information on ways the target audience can address the issue.

6.3 SaMS Logo Use Guidelines

The intent of the SaMS logo is to brand and eliminate the need to affix approximately 40 different stakeholders' logos on various materials. The logo will provide a strong identity for SaMS, which is a collaborative effort comprised of a diverse stakeholder community.

The full logo consists of an abstract design, SaMS in both abbreviated ("SaMS") and full ("Salt Management Strategy") forms and the tagline "Winter Salt Smart" in blue, black and gray. To facilitate its use in a variety of formats, deconstructed versions of the full logo are provided, along with several color options. A one-page logo user guide is provided under **Appendix I – Section 3** for easy reference on proper use of the different logo formats.



In order to "speak with one voice," oversight of the logo will be provided by either individual member organization(s) of SaMS or a SaMS Communications Subcommittee (reviewing body), as approved by the voting members of SaMS. The decision of oversight and formation of the subcommittee will be made by the SAC. The subcommittee, if chosen to be the overseeing body, should be formed to provide representation reflective of the SaMS SAC. It is recommended that one of the first orders of business for the subcommittee or other reviewing body is to determine how oversight of the SaMS Logo use guidelines and standards will occur.

Appendix I – Section 3 contains the SaMS logo use guidelines that are intended to promote brand consistency and awareness. These guidelines may be amended as the SaMS initiative progresses and further insights are gained.

6.4 Pilot Outreach Campaign Results

As part of the initial SaMS Toolkit development, the SaMS Education and Outreach Workgroup conducted a pilot outreach campaign to identify whether drafted messages resonated with the general public. The campaign was conducted

during November and December 2019 and consisted of two parts: digital message testing and an in-person community listening session.

The SaMS Education and Outreach Workgroup designed the message testing portion to be implemented through electronic media (e.g., social media, newsletters, and email) by the participating workgroup member organizations over two weeks. The first test was conducted the week of November 18-24 and focused on introducing SaMS. The second test, conducted December 9-15, shared messages and content to raise public awareness of the benefits and impacts from salt use.

The community listening session was designed to be a one-time, in-person event which was held at the Kings Park Library in Burke, Virginia, on December 2, 2019. Because the outreach materials and messages were developed to engage the general public, the workgroup agreed it was important to hear directly from the public in-person, both in terms of their interest in and awareness of the topic and their impressions of the outreach materials and messages.

The pilot outreach campaign was an overall success, since many of the objective performance metrics were met. The message testing portion consisted of 35 digital communications that garnered an audience of almost 21,000 impressions. The community listening session was attended by thirteen members of the public, who provided informative feedback through group discussions. The results from this pilot campaign can help direct future outreach efforts for both digital and in-person formats. Readers can learn more about this effort by viewing the pilot outreach campaign plan that outlines the 2019 effort, provided as an example in **Appendix G – Section 2**. The summary of the results and the detailed lessons learned from the 2019 pilot campaign are provided in **Appendix G – Section 1**.

Takeaways from the pilot outreach campaign:

- Collaborative outreach efforts among a variety of organizations are effective when each are provided the flexibility to speak directly to their audiences. Instead of prescribing language to be shared by each organization, outreach messages should include common key elements to provide unity across messaging. **Section 6.2** provides high-level examples of such elements.
- Messages should use a positive tone. However, if unpleasant news must be shared, such as negative impacts, it should be done in a nondramatic tone and include an actionable item for the audience.
- A focus on impacts to drinking water could increase engagement on the topic, especially since this is the least known impact of winter salt use according to the SaMS Awareness Survey (see **Section 6.5** below).
- Include in messages best practices for residents to manage snow and ice around their residences. Further evidence for the population's interest in this is covered in **Section 6.5** below.
- Social media is an efficient outreach tool.
- For social media campaigns, infographics that share information as an image performed better than other outreach materials (e.g., hyperlinked flyers, landscape pictures, etc.). See **Appendix I – Sections 4** through **6** for infographics on salt use benefits and impacts, driver best practices, and residential best practices.
- In larger organizations that have communications staff, it is best if organizations involve their communications staff to benefit from their expertise when designing an outreach plan.

6.5 Awareness Survey Results Summary

During the development of the SaMS Toolkit, the SaMS Education and Outreach Workgroup proposed the idea of administering a survey in Northern Virginia to better understand the public's awareness of the benefits and impacts of salt use that existed at that time. The intent of this effort was to 1) establish a baseline against which future changes in awareness could be measured and 2) obtain information on the public's understanding of the issue that could be used to direct outreach efforts.

Amplitude Research, Inc. was engaged to finalize and administer the questionnaire drafted by the workgroup. This private survey research firm was secured through the efforts of the Northern Virginia Regional Commission (NVRC) and Metropolitan Washington Council of Governments (MWCOG), with financial support from Arlington County, the City of Fairfax, Fairfax County, Fairfax Water, Loudoun County, Loudoun Water, Prince William County and VDOT.

The survey was administered in December 2019 and achieved 500 responses, which is a statistically valid representation of Northern Virginia. The majority of respondents lived in Fairfax County (37.2%), followed by Prince William County (14.0%) and then equally in third place were Loudoun County, the City of Alexandria and Arlington County (11% each). The distribution of survey respondents resembled the population distribution of Northern Virginia. The demographics of those surveyed represented a relatively even split among all age groups and between males and females. Half of those that responded have lived in Northern Virginia for 20 years or more (47%) and half noted they live in a single-family residence (50%). The majority (76%) indicated they use a personal vehicle to get to work or other places regularly. The exceptions were Arlington County and the City of Alexandria, which noted higher usage of Metro to get to work (45% and 30% of those populations, respectively).

Takeaways from the awareness survey:

- There is opportunity to create more public awareness of the consequences of winter salt use since the majority of respondents did not know salt impacts the environment and drinking water. Drinking water impacts were the least understood with only 30% of the respondents indicating they are aware of impacts to drinking water from salt.
- The public is open to supporting reductions in salt use and changing their travel habits if salt use has to be reduced, based upon the majority of respondents indicating their willingness to change if they understood the environmental impacts of salt application.
- Residents are open to changing their current property maintenance practices based upon a majority of respondents indicating their willingness to use less salt if they understood the environmental impacts of salt application.

The information gathered from the results of this survey can help direct future outreach efforts, including the potential to target the location and message of outreach efforts. As the main takeaways indicate, there are opportunities to generate more public awareness, encourage telework and other options for commuters, and promote the use of best practices that residents can use around their residences. Readers interested to learn more and assess whether this information may help their outreach efforts can find the summary report and a link to a spreadsheet that provides the breakdown of the survey results in **Appendix H**.

A follow-up survey is recommended after initial implementation of the SaMS Toolkit, to gauge any shifts in awareness and/or satisfaction with winter maintenance activities. Conducting the follow-up survey three years after the SaMS Toolkit is finalized would allow for two full winters of SaMS awareness campaign implementation. Revisions to the existing questionnaire could include additional questions to better target messaging, explore more specific topics or gain an understanding of how the season or weather may potentially influence answers. Alternatively, it may be desirable to conduct two surveys, one revised to gain further insight and the original questionnaire summarized in this section to measure any shifts from the baseline survey results.

6.6 Outreach Messages

The SaMS Toolkit provides several messages and materials for use by those who will conduct outreach on this important topic. The SaMS tagline of *Winter Salt Smart*, the SaMS Logo, best practices for residents and drivers, and general information on the pros and cons of salt use are all available to support future outreach efforts.

The materials prepared as infographics are brief, which works well for social media distribution (such as Instagram, Twitter or Facebook) distribution. Therefore, the content of the infographic may not cover the entire range of information the user may desire. Users are encouraged to include their own context in the caption of the post that accompanies the infographic, to speak directly to their specific audience. For example, the context could include why using best practices is important.

Those messages and materials are provided under the Education and Outreach Resources in **Appendix I**.

6.7 Recommendations to Further Education and Outreach Opportunities

Many great ideas were generated during the development of SaMS to further develop awareness and understanding of the issue by the general public. However, not all ideas could be pursued due to time constraints. Recommendations to advance education and outreach opportunities include:

- Encourage the SaMS SAC to continue their efforts to build awareness and understanding through education and outreach efforts by maintaining and, if possible, accelerating the current pace of their efforts.
- Re-conduct the awareness survey in winter 2023/2024 to gain understanding of any shifts in levels of awareness, use of best practices and public satisfaction with winter maintenance activities.
- Develop an education program for grade levels K-12 that focuses on the benefits and impacts of salt application and things individuals can do to minimize their salt use. It is important that the program development involve educators to ensure the information and material is useful in the curriculum, age appropriate and engaging to the targeted age group. It is recommended that the Virginia Department of Education be engaged to ensure proposed material is suitable.

7 Water Quality Monitoring



Monitoring water quality conditions is essential to understanding the extent of the region's freshwater salnization challenge, assess the effectiveness of site-specific and regional implementation efforts and support adaptive implementation strategies. Further, scientifically-based decision making is critical to long-term success and achievement of water quality goals. There is limited **ion** or ion-related monitoring data throughout Northern Virginia, making it difficult to analyze and fully document the impacts related to salt application throughout the region. To encourage the collection of valuable and comparable water quality data, this section addresses recommendations and resources for monitoring programs that include:

- Trends in regional watersheds and an analysis of different approaches to evaluating trends (**Section 7.1**)
- Recommended criteria for an ambient water quality monitoring program (Section 7.2)
- Description of a pilot monitoring program that aims to evaluate the impact of BMP implementation on water quality (Section 7.3)
- Regional models to estimate chloride concentrations from cost-effective specific conductance data (Section 7.4)
- A conceptual model of salt origin, transport, and fate (Section 7.5)
- An inventory of existing ion or ion-related monitoring data and monitoring organizations (Section 7.6)
- Opportunities to partner in water monitoring efforts (Section 7.6 and Section 7.7)

The monitoring and research recommendations discussed in this section were developed for public, private, and volunteer audiences (Section 3.1). Although the discussion of the pilot monitoring approach (Section 7.3) identifies recommended monitoring groups and their roles in the effort, the rest of the recommendations are intended to be used by all of these audiences.



7.1 Trends in Regional Specific Conductance

Regional trends in specific conductance (**Appendix K**) were reviewed to provide tools for evaluating changes in water quality that may be helpful information to support future monitoring and analysis efforts, such as the pilot water quality monitoring program. Over 1.5 million data records containing individual specific conductance values were analyzed for four USGS gages (01645704 Difficult Run Above Fox Lake Near Fairfax, 01645762 South Fork Little Difficult Run Above Mouth Near Vienna, 01646305 Dead Run at Whann Avenue Near McLean, and 01656903 Flatlick Branch Above Frog Branch at Chantilly). The analyses identified some statistically significant trends and areas for potential additional study. The major findings were:

Salts, as they dissolve in water, break into positively and negatively charged particles (i.e., ions) that increase the ability for water to carry an electric current. Specific conductance is a measure of water's ability to conduct electric current, and therefore, provides an indirect measure of the amount of ions in the water.

- Seasonal and precipitation-related patterns observed in-stream specific conductance data. Elevated spikes in specific conductance were observed in winter months with spikes occurring during or after winter precipitation events.
- Trends in long-term, high resolution (15-minute) specific conductance are difficult to discern due to large variability from other factors like intensity and duration of precipitation, rate and timing of winter deicing material applications, land use, and percent impervious cover. The increasing trends are, however, appreciable and statistically significant.
- Increasing trends are visually observed in median monthly and median annual specific conductance. However, not all of the relationships are statistically significant. This is especially the case at gages with large ranges in specific conductance. Median annual specific conductance values exhibited the most statistically significant increases.
- The magnitude and duration of spikes in specific conductance during the winter increase with increasing precipitation based on 15-minute data (except for USGS gage 01645762); however, long-term trends in magnitude and duration are not statistically significant.
- Background trends in summer median values are increasing both at a median annual and a 15-minute temporal resolution. The only exception is the non-significant median summer trend for USGS gage 01656903 (Flatlick Branch Above Frog Branch at Chantilly).

In general, a weight-of-evidence approach should be used to assess changes in water quality as a response to BMP implementation. By building a case from several perspectives, confidence in the results becomes stronger. While there is room for elaborating on the water quality trends analysis (**Appendix K**) with more complex statistical approaches and incorporation of other factors like land use and impervious cover, this study in combination with results from others in the region (Porter et al., 2020) build confidence in trends over time as well as in the effectiveness of the metrics used to evaluate those trends. It is worth noting that the magnitude of change demonstrated in both the water quality trend analysis (**Appendix K**) and (Porter et al., 2020) are comparable, despite the differences in approach. It should be noted



that monitoring locations provide site-specific information that, in combination, have been extrapolated to provide a regional picture. These regional patterns should be used with caution as there is more certainty regarding the local watershed trends associated with each gage. Extrapolation of the regional trends outside of the SaMS region is not advised, due to differing conditions such as the physiographic differences and varying land uses.

Statistical evaluation of trends is one step to understanding implementation success; however, it will be necessary to consider what "success" means. Diminishing or reversing water quality trends may be a sign of "success" prior to fully meeting **water quality standards**, which is expected to be a long-term process. The different approaches for evaluating trends documented in the the water quality trend analysis (**Appendix K**) should be considered when evaluating implementation success. For example, it was thought that the magnitude and duration of spikes in specific conductance in winter might show an increasing trend over time that is driving the overall increasing trend. However, it turned out that precipitation, not time, was the most significant driver of spikes. Therefore, the magnitude and duration of spikes may not be a good evaluation metric to judge implementation success.

Other studies can also provide useful tools to help identify success. Recent work by Yang and Moyer (2020) provides an approach for assessing trends in high-frequency datasets like those collected for specific conductance throughout Northern Virginia. Because water quality parameters such as specific conductance exhibit strong regular patterns that can be influenced by other parameters like flow and time of year (i.e., season), it can be helpful to use models that do not assume any particular form of trend (e.g., linear). The Generalized Additive Model approach used in Yang and Moyer (2020) incorporates these covariates into the model and reveals the effect of each covariate allowing users to assess the independent trend over time.

7.2 General Criteria for an Ion Monitoring Program

Monitoring water quality is essential to understanding in-stream conditions and how those conditions change over time. The effects from BMP implementation on water quality conditions will take time to be realized. To successfully evaluate those effects, long-term ion monitoring records are needed to support the analysis. **Appendix L** presents general criteria to help organizations develop an ion monitoring program focused on salts that will meet their needs and generate valuable and comparable data to better understand regional water quality patterns. The recommendations center around:

- Sampling methods
- Analytical methods
- Sampling season and what type of data to collect
- Monitoring study design considerations
- Health, safety, and training
- Precautions for sampling/data collection

These water quality monitoring efforts dovetail with the tracking and reporting efforts described in **Section 4** to provide a complete picture of BMP implementation success. Changes in water quality are expected after BMP implementation and/or with a decrease in salt use. As noted, these changes will likely take time to be visible in the water chemistry.

Therefore, in order to make informed monitoring decisions and conclusions, information exchange between winter maintenance operations and water monitoring organizations is crucial.

7.3 Pilot Project Approach: Monitoring Water Quality Response to BMP Implementation



A pilot study process is recommended to learn the best approach to evaluate changes in water quality as a result of changes in salt use and BMP implementation (**Appendix M**). Monitoring the impact of BMP implementation may be a challenging pursuit given the numerous variables in both winter storms and winter storm maintenance. Since the best ways to evaluate changes in water quality related to changes in salt use and BMP implementation may not be currently known, the use of a pilot project allows methods to be improved through experience. Through implementation of iterative pilot studies, lessons can be learned and an optimal evaluation approach can be defined.

The recommended pilot monitoring program proposes sampling two small watersheds to control for outcomes and compare results. The two small watersheds should consist of a pilot watershed where new BMPs are implemented and a control watershed where no changes in salt use practices occur. Differences between both watersheds can be measured using a number of metrics, such as trends analyses (see **Appendix M - Section 6.1**) that must be viewed in the context of other variables such as snowfall, types of BMPs implemented, and the amount of salt used (see **Appendix M - Section 6.2**). Using this information, the changes in water quality that may be driven by BMP implementation can be evaluated using a weight-of-evidence approach.

Collection of the following information on salt application and BMP implementation within both watersheds of the pilot study is recommended to allow for informed conclusions:

- Salt application (listed in order from the more basic and easily obtained information to the more detailed and difficult to obtain level of information):
    - The number of days that salting operations were deployed and if brine and/or solid salt was used.
    - Seasonal totals of salt used plus the total area serviced by the operation.
    - Storm event totals plus the total area serviced by the operation.
    - Storm event salt application totals per location (e.g., snowplow route, property, etc.) plus the total area serviced by the operation. This level of detailed information provides location-specific application rates.
- BMP Implementation: Information on the type of BMPs implemented, and if applicable, the level of implementation (e.g., every storm, only once) is essential for understanding the magnitude of implementation impact on water quality.

The success of this pilot program depends on voluntary partnerships between many stakeholders, including public and private winter maintenance professionals. Partnerships between government agencies, academia, and water authorities will also bolster the success of the pilot monitoring program.

Material/analytical costs for the project are estimated to be about $20,000-$100,000 for a 5-year project. This pilot monitoring program represents an iterative approach that will be modified with improved methods after each pilot program runs its course (2-5 years).

7.4 Regional Models for Predicting Chloride Concentration

In-stream chloride data are often not readily available and are more costly and time intensive to collect than readily available specific conductance data. Statistical relationships can translate the available specific conductance data into estimated chloride concentrations. Ideally, watershed-specific models are developed for this purpose (i.e., based on data from within the watershed); however, resources or data may be limited. In the absence of watershed specific models, a regional model can be used to predict chloride concentrations from specific conductance data. Since specific conductance is an affordable parameter to measure continuously, chloride levels can be estimated using these models prior to further investigation.

Use of the regional Mid-Atlantic piecewise model developed by Joel Moore and USGS colleagues is recommended for application in the Northern Virginia region (Moore et al., 2020). This model is appropriate for predicting chloride concentrations in watersheds without paired specific conductance and chloride data and do not drain primarily Triassic Basin soils (**Appendix N**). The piecewise regional model is:

Equation 1: y = 0.171x - 0.580 below 321 µS/cm
Equation 2: y = 0.291x - 44.5 above 321 µS/cm

In other words, when specific conductance values are below 321 µS/cm, use Equation 1 to estimate chloride concentrations, and when values are above 321 µS/cm, use Equation 2.

In addition to the published journal article, all data used to produce the Mid-Atlantic regional model along with the model results can be found in a USGS data release by Fanelli and colleagues.

Probe-collected specific conductance data are extremely valuable because they are affordable and can produce high frequency data and insights into the magnitude of salt impacts. The manuscript (Moore et al., 2020) also provides evidence that median estimated chloride concentrations calculated from continuous monitoring of specific conductance can help highlight watersheds where estimated chloride concentrations may surpass the chronic and acute criteria. As such, specific conductance data are also valuable for identifying watersheds that should be monitored more extensively.

Additional Recommendation

Since the Triassic Basin model's dataset was limited and since the influence of the Accotink Creek watershed data on the regression equation was strong, it is additionally recommended that:

1) The Mid-Atlantic piecewise model only be used for watersheds draining primarily non-Triassic Basin soils, and
2) The Mid-Atlantic piecewise model only be used in the absence of watershed specific models. The ultimate goal when studying any watershed should be to develop catchment specific models.



7.5 Salt Origin, Transport, and Fate Conceptual Model

Critical questions for understanding salt use and its impacts on water quality involve the origin, fate, and transport of salts. The conceptual model presented in **Appendix P** identifies critical variables that should be understood and can stimulate/guide new monitoring and research efforts. The model describes the stakeholder-identified significant origin, fate, and transport pathways and can be used to inform monitoring recommendations and be refined as monitoring work and discussions proceed.

The conceptual model should be updated as more is learned from SaMS implementation. The model should be revisited every time recommendations/resources are reviewed as a part of SaMS adaptive implementation.

7.6 Inventory of Existing Salt-related Water Quality Data and Monitoring Groups

The purpose of the resource provided in **Appendix O** is to provide an inventory of existing and historical monitoring work that has collected data on ions or ion related parameters. With this resource, organizations interested in working with existing data or partnering with existing ion monitoring groups have an initial source of contacts for data, to seek their help in developing a monitoring program, or for collaboration with on future monitoring efforts.

Based upon the findings of the effort to pull this information together, at present there appears to be little ion or ion-related monitoring work in the region, offering ample opportunity for future monitoring work. Therefore, it is recommended that this resource be reviewed for potential updates as a part of SaMS adaptive implementation.



7.7 Monitoring Partnerships

Coordinated data collection efforts are recommended to meet the Northern Virginia region's need to understand trends over time and assess implementation results. Pooled/shared monitoring programs enable resources to be maximized and coordinated. Partnerships will also help newly interested organizations begin their monitoring efforts. Coordination with multi-jurisdictional groups like NVRC and MWCOG can leverage existing networks to make this a reality.

The recommended pilot monitoring program (**Section 7.3**) will also benefit from a coalition of partnering organizations coordinating salt application and BMP implementation with water quality monitoring activites. An academic institution is suggested to be the principal investigator in this effort with local governments and other partners contributing in-kind resources.

8 Inter-Governmental Coordination

Enhanced coordination among Northern Virginia government organizations that perform winter maintenance activities can provide important support for SaMS implementation. A number of opportunities to build on existing coordination exist, and specific recommendations are identified to improve communications and increase support for implementation, enable cost-sharing, and exchange lessons learned to improve on existing winter maintenance practices. This section addresses recommendations and reference information for intergovernmental coordination that include: Enhancing Government Communications and Coordination (**Section 8.1**); Pooled Funding and Shared Services (**Section 8.2**); and Discussion of Legislation (**Section 8.3**).

8.1 Enhancing Government Communications and Coordination

Several recommendations are offered to build on existing communication and coordination efforts to support implementation of SaMS in the years to come.

8.1.1 Communicating Levels of Service and Winter Maintenance Plans

A best practice identified in the BMP Pros and Cons document discussed in **Section 3.2** is to inform citizens and political leaders of winter maintenance levels-of-service plans. At the beginning of the winter season, MWCOG hosts a forum where the National Weather Service presents its regional forecast and the District of Columbia, Maryland and Virginia transportation agencies discuss their winter plans. Other Northern Virginia government organizations may participate in this forum, and there could be benefits to increased understanding of metro-wide winter season expectations and plans.

As appropriate to their scope and interests, other existing forums (see **Appendix R**) present opportunities to increase awareness of Northern Virginia government storm planning, BMPs used, and communications during snow events. The Clean Water Partners forum has been identified as the most appropriate existing forum to hold pre-winter discussions of plans for public communications on winter levels of service, enhanced BMPs, and related matters.

In discussions held during SaMS development, local government stakeholders expressed support for increased consistency in public communications about levels–of-service goals for winter maintenance, while at the same time underscoring the need for each jurisdiction to decide the specific content and format of communications with its constituents.

8.1.2 Advancing Coordination Among Area Governments

Given the breadth of SaMS recommendations discussed in this document, many existing Northern Virginia and Metropolitan Washington forums provide opportunities to advance coordination among area governments on specific aspects of SaMS. These range from issue-specific forums, such as the Clean Water Partners that focus primarily on stormwater management, to broadly-scoped senior leadership groups. Forums coordinated by NVRC, MWCOG and ICPRB provide opportunities to engage water quality monitoring experts and drinking water/source water professionals to advance monitoring, research and other more technical aspects of SaMS.

Several other forums identified in **Appendix R** will have interest in various aspects of SaMS implementation. Ensuring their members are well informed can broaden support for implementation of SaMS. Most of these are government coordination bodies, a few include public participation, and all provide opportunities to exchange information and support SaMS implementation. As appropriate to their scope and interests, existing forums should be used to share relevant information about SaMS implementation as it relates to water quality management, public works, public education/outreach, and other related topics.

It is also recommended that a new annual event be created to provide the opportunity for participating organizations to share the effectiveness of new or refined BMPs they implement, challenges and successes of their winter operations overall, and the lessons they learned that may be transferable to others. A post-season winter maintenance operations forum for Northern Virginia area governments would enhance area winter management professionals' ability to learn from each other, share expertise, and share resources to improve service and reduce environmental impacts throughout the region.

8.2 Pooled Funding/Shared Services

Effective coordination related to SaMS implementation will facilitate peer-support and learning, while also enhancing cost-saving opportunities for area governments. Three specific opportunities have been identified:

- Training Winter Operations Personnel: all area governments provide training of varying types at present, but few have held in-depth training on enhanced winter maintenance BMPs. Pooling resources and coordinating schedules is recommended so national winter maintenance training experts can share their expertise with the greatest number of individuals at the lowest overall cost.
- Alternative Deicer Products: area governments already benefit from shared service deicer product contracts managed by MWCOG. Some area governments also contract for relatively high-priced alternative products, and others have interest to test promising alternative products. Alternative (non-chloride) deicer products that are more costly than traditional deicers could be more economical if purchased in bulk through a shared services contract, and local governments and MWCOG are encouraged to work together to explore such future opportunities.
- Water Quality Monitoring and Research: pooled monitoring activities were recommended to maximize resources and avoid duplication of efforts. As noted in **Section 7** above, enhanced coordination of government water quality monitoring programs in the SaMS project area will enable more ambitious and efficient monitoring, research, and analysis in support of SaMS implementation. Pursuit of the pilot monitoring program discussed in **Section 7.3** will be aided greatly by such collaboration among area water quality monitoring programs.

8.3 Discussion of Legislation

The SaMS Toolkit does not include legislative policy recommendations. However, on several occasions during SaMS development there was brief discussion of ideas for legislative policies that could support SaMS implementation. The topic most frequently mentioned was liability reform (slip and fall liability relief). Under current liability provisions, property owners and winter maintenance professionals may apply more winter salts than necessary to reduce the potential that they will be found liable for damages in the event of an injury suffered by someone who slipped and fell on the property. If operators with a winter maintenance BMP certification, and the property owners who contract with them, had limits to their liability for slip and fall claims, the perceived incentive to over apply salts may be reduced. Several SAC members perceived this as potentially the most impactful policy support for SaMS recommendations. However, as this document is a collaboration of a variety of stakeholders which include Virginia state agencies, it was recognized that state agencies do not take a position on or offer legislative recommendations in advance of Virginia's Governor taking a position on a given issue.

During workgroup discussions several non-state government SAC members noted their interest to pursue legislative recommendations outside of the SaMS development process. They recognize that legislative policy often requires long-term efforts to frame proposals, build support, and prepare for formal legislative consideration. Consideration of legislative policy support for SaMS implementation is an example of a topic that could be coordinated among non-state government SAC members in the future.

9 Future Recommendations and Research Needs

During SaMS development, there were many concepts identified for future evaluation, research, and discussion. In most cases, these were concepts that did not receive enough workgroup discussion and vetting to warrant including in the SaMS Toolkit. Additionally, the workgroups explicitly identified the need for future toolkit updates and evaluations of existing resources and recommendations. A brief description of all future recommendations and research needs discussed throughout the SaMS Toolkit is consolidated in this section. Additional detail on each can be found in their respective toolkit section.



Unless otherwise identified, the recommended timeline to revisit and address these items is suggested to occur during the first recommended SaMS Implementation Assessment Forum. **Section 11** discusses the SaMS Implementation Assessment Forum, as it was envisioned at the time the SaMS Toolkit was completed.

Future Recommendations and Research Needs

- Planning and Application Practices (**Section 3**)
  - Piloting/evaluating new alternative deicing products to identify whether effective and environmentally safe through future research is encouraged. (**Section 3.3.5**)
  - During the first SaMS Assessment Forum, discussing adoption of a certification and training program approach for use in Northern Virginia. If such an approach is adopted by the SAC or similar body, strategies for encouraging certifications are recommended to be reviewed periodically by that body. (**Section 3.5**)
  - Continuing discussions, led by the entity that assumes SaMS implementation, regarding improved property management contracts after experience is gained through SaMS implementation and review of other contract models from around the country(e.g., the contract template developed by the City of Edina, Minnesota in late 2018). Specifically, future evaluation should identify either a specific recommended contract model or certain components any property management contract for winter maintenance activities should contain to promote the use of best practices. (**Section 3.6**)
- Tracking and Reporting (**Section 4**)
  - Developing model forms for tracking and reporting product use and BMP implementation that are customizable for small private service providers, civic/homeowner associations, and other specific audiences. (**Section 4**)
  - Evaluating opportunities to conduct regional scale reporting, analysis, peer learning, and to develop improved future communications. This effort relies on organizations voluntarily adopting more consistent tracking of product use and BMP implementation, such as the information recommended to be collected in **Appendix J**. (**Section 4.5**)

(Continued on the following page)

Future Recommendations and Research Needs (Cont.)

- Education and Outreach (**Section 6**)
  - Re-conducting the awareness survey in winter 2023/2024 to gain understanding of any shifts in the level of awareness and use of best practices and in public satisfaction with winter maintenance activities. (**Section 6.5**)
  - Developing an education program about winter salt use and impacts for grade levels K-12. (**Section 6.7**)
- Water Quality Monitoring (**Section 7**)
  - Updating the conceptual model of salt origin, transport, and fate developed during SaMS development (**Section 7.5**). Updates for this conceptual model should be identified as more is learned through implementation of SaMS and the water quality monitoring recommendations.
  - Updating the inventory of existing salt-related water quality data and monitoring groups (**Section 7.6**).
  - Every 2-5 years, evaluating the results of the pilot water quality monitoring program designed to analyze the impacts of BMP implementation on water quality (**Section 7.3**). This evaluation should involve a review of the study design and the metrics for evaluating changes in water quality to identify if those need to be adjusted or improved (see **Appendix M** for specific recommendations).
- Inter-governmental Coordination (**Section 8**)
  - The SaMS Toolkit does not include legislative policy recommendations as this toolkit includes the participation of state agencies, which do not take a position or offer legislative recommendations in advance of the Governor of Virginia taking a position. However, discussions on legislative options to promote more efficient and effective uses of salts may be held in the future depending on the member roles of state agencies (**Section 8.3**).

"I'm hopeful that SaMS' efforts to reduce our creek's load can be something of a successful pilot project for the rest of the Commonwealth and beyond."
– Stakeholder Advisory Committee Trainer

10 Funding Sources and Financial Considerations

While some of the recommendations in this toolkit can be incorporated into existing operations with minimal or no costs, other strategies require varying degrees of financial resources. Fortunately, there are funding opportunities available for consideration, some of which are described below. However, this is not an exhaustive list. Identifying project-specific funding sources will be beneficial after specific courses of action are identified. In addition, it should be noted that working together and collaborating on efforts can save time and resources as well as leverage resources to achieve multiple goals (See recommended opportunities in **Table 1** and **Table 2** of **Section 3.2.1** and **Section 8**).

Private Nonprofit Foundations: Several private, non-profit foundations offer funding opportunities that may be worth pursuing. See the textbox for examples.

Public Agency Research Partners (in source water protection): A number of public agencies offer funding opportunities that may be applicable to implementation of SaMS recommendations. Relevant public agencies include the USEPA, United States Department of Agriculture (USDA), National Fish and Wildlife Foundation (NFWF), and National Aeronautics and Space Administration (NASA). For example, USDA conservation programs have ten percent of their funds set aside for source water protection actions (CRS 2019). Additionally, the NFWF Five Star and Urban Waters Restoration Grant may be beneficial to education and outreach efforts among partnered organizations.

Other: Another potential partner is the Association of State Drinking Water Administrators (ASDWA) Source Water Collaborative. The collaborative has developed resources on the "Intersection of Roads and Drinking Water, Opportunities for Collaboration between State Programs."

Examples of Private Nonprofit Foundations

- The Water Research Foundation: The WRF is funded by subscribers comprised of private water, wastewater, and stormwater service providers and supporting companies. The WRF has two programs that may be appropriate for funding various aspects of needed research outlined in this toolkit. First, the Emerging Opportunities Program funds time-critical, high priority issues. Second, the Tailored Collaboration Program matches and leverages funds from groups of utilities involved in regional research projects. In addition, the WRF has a source water protection, land use and water quality program track that may have viable opportunities.
- The Chesapeake Bay Trust: The trust provides funding for other chloride-related studies and may have additional capacity for SaMS work.
- The Center for Watershed Protection: A partner helping to enhance the chloride monitoring program in Baltimore.
- The Rockefeller Foundation: The foundation is committed to tackling acute and chronic stressors through programs such as the Resilient Cities Initiative.
- The Trust for Public Land: Relevant activities include the Climate-Smart Cities Program.
- There are also national and international general, private non-profit foundation grants tied to climate resilience and sustainability.

"The outcome of this process will provide an important baseline to collectively move forward with a toolbox of strategies to find ways to keep our roads safe while reducing the impact on our natural resources."
– Stakeholder Advisory Committee Member

11 Implementation

The most impressive strategy produces nothing without tangible plans and actions to put it into practice. Accordingly, this section provides a summary of the SAC's ideas for effectively implementing SaMS in the years ahead.

As has been noted, SaMS is voluntary and largely proactive. Although SaMS originated as an outgrowth of the Accotink Creek Chloride TMDL, it offers the potential that water quality impacts from salts can be avoided or reduced such that future regulatory actions are unnecessary. Using a regional approach, SaMS seeks to protect healthy waters and restore those with elevated chloride levels to meet **water quality standards** by encouraging proactive and adaptive implementation of the toolkit. However, should area-wide implementation prove to be insufficient, new impairments may be identified in the future and development of TMDLs may prove necessary to achieve pollutant reductions through a network of TMDL-driven permit requirements. Nonetheless, the forecast for a successful voluntary implementation of SaMS is optimistic based on the level of stakeholder contribution and consensus, opportunities for operational costs savings, public support to change winter storm behaviors and expectations and the increasing concern of the negative impacts from "no action."

To achieve the goals of SaMS, a multitude of public and private organizations will need to take actions identified in this toolkit. While many SaMS recommendations can and will occur through individual actions, the most effective implementation will be a coordinated approach facilitated by regional leadership and support.

11.1 Role of the MS4 Permit Program

While SaMS is voluntary, it is important to acknowledge a regulatory program that can serve as a foundation for broader action. Holders of a Municipal Separate Storm Sewer System (MS4) permit (e.g., counties, cities and other quasi-government entities), with regulated areas within the Accotink Creek Chloride TMDL watershed will need to address the requirements of the TMDL in accordance with the special conditions of their respective permits. These entities include the City of Fairfax, Fairfax County, Fairfax County Public Schools, Fort Belvoir, Northern Virginia Community College, the Town of Vienna, and the Virginia Department of Transportation. Other MS4 permittees in the SaMS project area may also be expected to address chloride loadings in future permits. Permittees will continue to implement their local action plans in an iterative fashion to address the water quality goals of the chloride TMDL.

This will be a good start, but will be inadequate to mitigate the many negative impacts of salt use in the Northern Virginia since MS4s are not the only users of salt in the region.



11.2 Voluntary SaMS Implementation

Many of the needed implementation actions for SaMS are envisioned to be voluntary in nature. The opportunity to save operational expenses is a very important element of winter maintenance BMPs that provides motivation for voluntary implementation actions – reduced salt application means less money spent. As was discussed in **Section 1.2**, there is much evidence of costs savings and other benefits greatly exceeding the cost of implementing enhanced BMPs. With this economic driver complementing organizations' interest to minimize their environmental impacts, voluntary actions, with SaMS support systems backing them up, can produce the needed improvements.

For many organizations, reducing costs of winter maintenance may free-up resources to support infrastructure improvements or meet other funding needs. Additionally, reducing material (salt product) costs can be consistent with business profitability under certain property management contracting frameworks. There are many opportunities to enhance winter maintenance BMPs in ways that pay for themselves, and produce near-term cost savings. Other BMPs, such as enhanced equipment, have capital costs that are substantial; however, these can be cost-effective when phased in over time or when resources are pooled. Lastly, businesses interested in applying for the Virginia Environmental Excellence Program (VEEP) should consider including salt management practices (including planning and application practices found in **Section 3** and tracking and reporting practices found in **Section 4**) in their VEEP facility-based applications. For more information on the VEEP program and the benefits of the program, visit https://www.deq.virginia.gov/get-involved/pollution-prevention/virginia-environmental-excellence-program.

11.3 Coordination and Leadership of SaMS Implementation

A number of Northern Virginia regional functions were identified to promote effective implementation of SaMS recommendations by the many entities engaged in winter maintenance. Among these are:

- *Website Hosting*: a dedicated website that provides a central source of SaMS related information, such as the SaMS report and associated documents, with the ability to update the website with new information over time.
- *Winter Salt Training*: coordinated training of enhanced winter maintenance practices through two avenues of training, one for local governments and one for private applicators, could have broad benefits.
- *SaMS Implementation Assessment Forum*: periodic (annual or bi-annual) forums of the SaMS SAC (or a similar inclusive future forum) to ensure SaMS remains relevant to guide improved winter maintenance operations, improved public awareness, and improved tracking of progress. Such forums may also identify needed updates to portions of the SaMS Toolkit in the future. In the preceding sections of this toolkit, many resources and recommendations were highlighted to revisit and reevaluate in the future.
- *Pre-Season Government Communications Coordination*: increased coordination and consistency in public communications by area governments can foster the level of public understanding and support needed for successful implementation.
- *SaMS Branding*: oversight of the SaMS brand is needed to ensure appropriate logo use and public messaging consistent with the established logo use guidelines and standards.
- *SaMS Reporting*: development of a central repository to collect data tracked at an individual organizational level on salt use and BMP effectiveness to facilitate regional level analysis to measure progress. Also, development of a meaningful way to share the data with the public and government leadership. Additional needs will become clear over time, with additional discussions about leadership coordination and experiences implementing SaMS recommendations.
- *Post-Season Lessons Learned Government Coordination:* convening a new post-season forum of winter maintenance government organizations to take stock and share lessons learned from the preceding season. This could be done by private sector winter maintenance contractors as well, to assess improvements and share lessons learned.

Many of the tasks above will require central coordinating, organizing, convening, and documentation roles, which can likely only be accomplished consistently with dedicated staffing support. The adaptive management approach envisioned for SaMS implementation will guide strategy adjustments over time based on implementation experience to maximize the success of SaMS in achieving its important goals.

***

Glossary

Acute – A condition occurring that is brief and severe, as opposed to **chronic**. Virginia adopted an acute chloride level of 860 mg/L with an exposure of one hour (9VAC25-260-140).

Anion – An ion or group of ions having a negative charge.

Anti-icing – The application of chemicals to roads to prevent accumulation of ice and snow.

Baseflow – The portion of stream flow that is discharged from groundwater and not associated with stormflow.

Best Management Practices (BMPs) – Structural and non-structural practices to prevent or reduce pollution of surface and groundwater systems.

Brine – Liquid salt solutions used as an anti-icing or pre-wetting agents.

Cation – An ion or group of ions having a positive charge.

Chloride – An inorganic negatively charged ion (**anion**) with the chemical formula Cl^-. One mechanism for the formation of chloride is the dissociation of salts (e.g., **sodium chloride**) in water.

Chronic – A condition continuing a long time or recurring frequently, as opposed to **acute**. Virginia adopted a chronic chloride level of 230 mg/L with an exposure duration of four days (9VAC25-260-140).

Deicing – The application of chemicals to surfaces to melt accumulated ice and snow.

Eutectic concentration – The specific concentration at which an equilibrium exists between ice, salt and a solution - used to identify the appropriate composition for brine.

Impervious cover/surfaces – Streets, sidewalks, driveways, roofs, and other surfaces that prevent water from infiltrating into the soil.

Interflow – The water from precipitation that infiltrates the soil surface and then moves laterally through the upper layers of soil above the water table until it reaches a stream channel or returns to the surface at some point downslope from its point of infiltration.

Ion – An atom or molecule with a net electric charge due to the loss or gain of one or more electrons.

Macroinvertebrate – A macroscopic invertebrate, especially an aquatic organism such as a crustacean, a mollusk, or an aquatic insect.

Maintenance Decision Support Systems (MDSS) – "An integrated software application that addresses the fundamental questions of what, how much, and when in applying treatments according to the forecast road weather conditions, the resources available, and local rules of practice" (Veneziano et al., 2014).

Osmotic regulation – The active regulation of the osmotic pressure of an organism's body fluids to maintain the concentration of salts in solution to keep the organism's fluids from becoming too diluted or concentrated.

Reverse osmosis – A drinking water treatment process that uses a semipermeable membrane to remove ions, molecules, and large particles from drinking water.

Road salt – Chloride salts of sodium, calcium, magnesium, and potassium in rock form – the most common chemicals used for winter road maintenance.

Rock salt – The mineral, crystal form of **sodium chloride**.

Road Weather Information Systems (RWIS) – Technologies to support snow and ice control decision-making (Boselly 2001).

Secondary maximum contaminant level – Non-mandatory water quality standards established by the USEPA as guidelines for aesthetic considerations in drinking water, such as taste, color, and odor. These contaminants are not considered to present a risk to human health at the SMCL.

Sodium chloride – Commonly referred to as "salt" or table salt with the chemical formula NaCl.

Specific conductance – A measure of how well water can conduct an electrical current. An indirect measure of the presence of dissolved solids such as chloride and sodium.

Total Maximum Daily Load (TMDL) – Identifies the maximum amount of a pollutant that a waterbody can receive and still not exceed water quality standards. The pollutant budget is broken down into the different sources of the pollutant, which provides the targets for watershed restoration efforts.

Trophic level – The level an organism occupies in an ecosystem's food web.

Water Quality Standards (WQS) – Provisions of state, territorial, authorized tribal or federal law approved by EPA that describe the desired condition of a water body and the means by which that condition will be protected or achieved.

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Appendix A. Environmental Impacts and Potential Economic Costs and Benefits of Improved Management Practices

Environmental Impacts and Potential Economic Costs and Benefits of Improved Management Practices in Northern Virginia



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Virginia street after a winter storm. Photo by Jim Palmer, ICPRB.

Disclaimer

The opinions expressed in this report are those of the authors and should not be construed as representing the opinions or policies of the United States government or the signatories or Commissioners to ICPRB.

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In this appendix, **Section 1** provides a brief background on the impacts of salts, related Virginia **Water Quality Standards**, trends in salt use for winter storm events across the country, the importance of public safety, and common **deicing** products. **Section 2** includes information on the impacts of salts on the environment (e.g., aquatic resources, soils, and biological resources), and infrastructure (e.g., bridges and roads, vehicles, and drinking water systems). **Section 3** identifies the potential economic costs and benefits of improved salt management practices. Costs discussed in this section include those associated with direct winter maintenance, corrosion, information systems, environmental impacts, and public health concerns.

1 Background

Salts applied prior to and during winter storm events in urban and suburban areas increase the amount of **chlorides** in the environment. Salts are applied for the important purpose of maintaining public safety during winter storm events; however, the components are subsequently washed off into local waterways or seep through soils into groundwater systems with numerous negative impacts. The salts can contaminate drinking water resources and are often cost prohibitive to remove. Salts can wreak havoc on local plants and animals. Salts also have negative impacts on infrastructure, vehicles, and other property. Due to their corrosive nature, salts increase the costs of maintenance, repair, and replacement of infrastructure like roads, sidewalks, driveways, bridges, and pipes. Improved management of the use of salts in winter weather events has potential to balance the dual goals of public safety and minimizing the negative impacts of salty runoff to the natural and built environments.

The United States Environmental Protection Agency (USEPA) established a **secondary maximum contaminant level** in drinking water for chloride of 250 mg/L (USEPA 2017b). In line with the USEPA recommendation, Virginia has adopted aquatic life **chronic** and **acute** Water Quality Standards for chloride (9VAC25-260-140). The chronic and acute numeric criteria are 230 mg/L and 860 mg/L with durations of four days and one hour, respectively. The acute criterion is for a one-hour average not to be exceeded more than once every three years; the chronic criterion is a four-day average, which is also not to be exceeded more than once every three years.



District Department of Transportation (DDOT) salt distribution center. DDOT uses rock salt for deicing and brine (salt solution with beet juice) for anti-icing. Photo taken on November 15, 2017, by Jim Palmer, ICPRB.

The USEPA also established a drinking water guidance level of 20 mg/L of sodium based on a recommendation by the American Heart Association for individuals at risk for cardiovascular disease or hypertension (NASEM 2007). Drinking water with a higher salt concentration can be a problem for those with hypertension, cardiovascular diseases, renal and liver diseases, and metabolic disorders (Murray and Ernst 1976).

Chloride data collected in Accotink Creek demonstrated exceedance of the aquatic life criteria, leading to the development of chloride **TMDLs** in the watershed (ICPRB 2017a). The challenge faced with respects to high levels of chlorides in the Accotink watershed and Northern Virginia is not novel. This is a common and growing issue across the country, especially in urban/suburban environments that experience regular winter storm events that are addressed with salt products. Salt use in winter maintenance started in the 1930s (Rubin et al., 2010) and has greatly expanded since 1960 (Murray and Ernst 1976) (**Figure 6**).

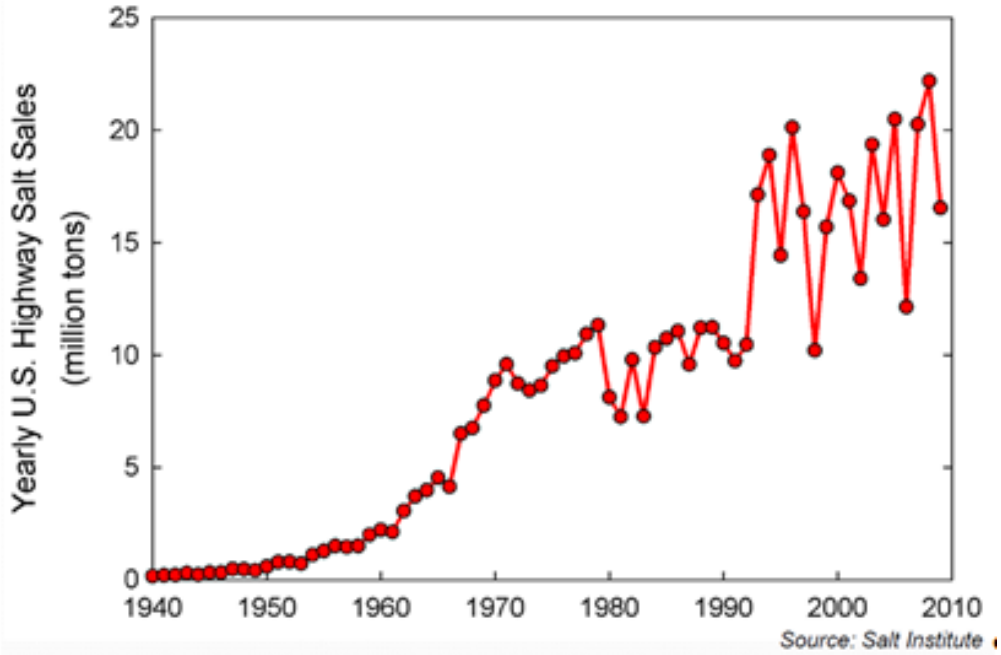


Figure 6. Trend in salt sales in the United States (1940-2010) (reprinted from MPCA 2016).

Studies have looked at the environmental impacts of salts since the 1950s and many scientific studies have documented impacts on water quality and the environment (CASE 2015, Cooper et al., 2014, Freshwater Society 2016, Madison and Dane County 2016, and MPCA 2016). In fact, it has been reported that 40 percent of urban streams in the United States exceed guidelines for aquatic life, primarily due to deicing salts (Stromberg 2014). As such, it is expected that the information contained in the final SaMS will be broadly applicable to the Northern Virginia region.

Pollution from salt impacts the biota, drinking water resources, infrastructure, and other property. The costs of these impacts to society can be considerable, but the benefit of salt application to public safety is unquestionably of great value. Winter maintenance practices help clear roads and reduce traffic accidents – two fundamental needs for maintaining economic activity and public safety. A Marquette University study found that winter maintenance reduced accidents by 88 percent, injuries by 85 percent, and reduced accident costs by 85 percent (Kuemmel and Hanbali 1992).

Comparing deicing products highlights the need to balance the associated costs and benefits (**Table 3**).[11] Each product is associated with pros and cons. For example, the chloride products (sodium chloride, magnesium chloride, and calcium chloride) are relatively inexpensive, but are corrosive. **Sodium chloride** is the most commonly used deicer and the least expensive option, but is not appropriate in very cold weather (less than 20°F). Sand is a viable option at all temperatures, but it does not melt ice. Instead, sand creates traction on top of the ice or snow.

[11] Costs change over time and depend on many factors. As such, different studies estimate different costs.

Table 3. Some common deicers and abrasives, temperatures for use, and associated costs (data source MDOT 2014 unless noted otherwise). Costs are given in dollars per ton or gallon (gal) as appropriate.

Product	Temperature Range for Use	Cost[1]
Sodium chloride	> 15°F*	$70/ton
Magnesium chloride	> -10°F*	$1.20/gal
Calcium chloride	> -20°F*	$1.40/gal
Calcium magnesium acetate (CMA)	> 20°F**	$1,900/ton
Potassium acetate	> -15°F*	$4.50/gal
Abrasives (sand)	All	$10/ton

[1]Application rates can vary significantly between products and temperature regimes. These costs are provided as an incomplete first glimpse into relative costs.
*https://stormwater.pca.state.mn.us/index.php?title=Lowest_practical_melting_temperature.
**http://www.michigan.gov/documents/ch2-deice_51438_7.pdf.

Products can be applied prior to precipitation to prevent accumulation (**anti-icing**) and/or after accumulation to melt ice and snow (**deicing**).[12] Sodium chloride, for example, can be used as **rock salt** as a deicing agent or mixed into a **brine** solution and applied to surfaces in advance of a winter storm. Selecting application methods depends on local capabilities, the characteristics of the products, and the characteristics of any particular storm event. The cost of these products cannot be ignored when deciding on which ones best fit a community's needs. State-wide costs can run up to $300 to $700 million for a single-day shutdown during a significant snow event, exceeding the cost of timely snow removal (IHS Global Insight undated).

2 Literature Review, Impacts of Salts

The environmental impacts of salt applications are potentially numerous; however, impacts in any particular locality depend on a number of factors including the nature of the local water resources, aquatic and terrestrial life in that region, the infrastructure resources present, existing land uses, meteorological conditions, and the application products and practices used.

The most common salts used by winter service providers contain chloride (sodium chloride, calcium chloride, and magnesium chloride). **Table 12** through **Table 14** in **Appendix A.a** compares potential impacts of chloride deicers. These common salts have also been compared to alternative deicing chemicals in many studies, e.g., CASE (2015), Kelting and Laxson (2010), Westchester (2007), Langen et al., (2006), and Environment Canada (2001).

Section 2.1 describes environmental impacts from salt applications documented in literature from the Northern Virginia region, the United States, and Canada. **Section 2.2** documents the impacts to infrastructure and property.

2.1 Environmental Impacts

Salts impact aquatic resources (including surface and groundwater), soils, and local biota. These impacts are discussed in turn in **Section 2.1.1**, **Section 2.1.2**, and **Section 2.1.3**, respectively.

2.1.1 Aquatic Resources Impacts

Numerous studies have documented that all salts applied to **impervious surfaces** (i.e., walkways, parking lots, and roads) ultimately enter the environment (Environment Canada 2001). The associated impacts depend on the transport paths and

[12] http://www.safewinterroads.org/anti-icing/

rates through the local environment (CASE 2015). **Figure 7** illustrates the pathways for a hypothetical area. About 55 percent of applied salts travel through surface runoff and the remaining 45 percent enter the soil and make their way into groundwater (Venner 2004). Aerosolized sprays containing salts from traffic can sometimes travel hundreds of feet and impact vegetation, soils, surface water swales, and wetlands. Runoff from impervious surfaces can travel greater distances and impact streams and surface waterbodies. Salts in infiltrated waters can impact shallow groundwater and potentially deeper groundwater after traveling greater distances through the subsurface. In any particular locale, the prevalent transport pathways depend on the physical characteristics of the landscape (slope, vegetation, soil characteristics, stormwater conveyance, etc.), the type and form of the chloride used (e.g., solid or liquid), and weather conditions (e.g., temperature, precipitation type and amount, and humidity). Surface and groundwater transport pathways are discussed in the following sections.

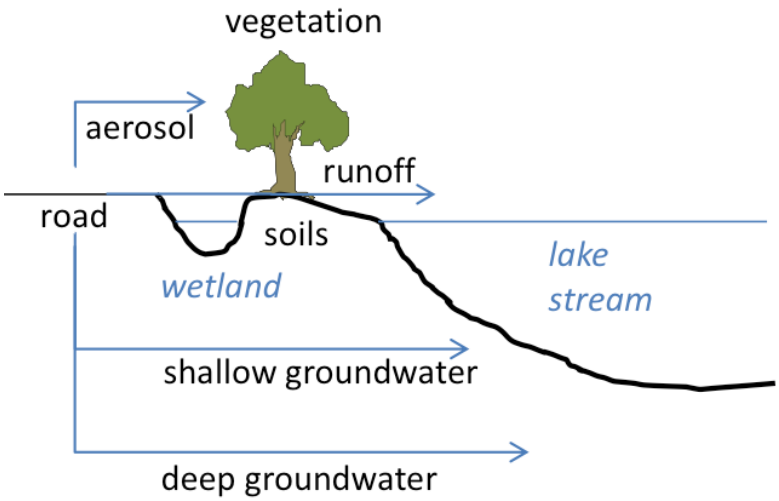


Figure 7. Salt pathways to the environment (reprinted from CASE 2015).

2.1.1.1 Surface waters

Freshwater usually has chloride concentrations less than 300 mg/L (CCME 2011; Freshwater Society 2016; and Stranko et al., 2013). In most parts of North America, surface waters have concentrations of chloride ranging from less than 10 milligrams per liter (mg/L) to approximately 120 mg/L with an average of 8 mg/L (CASE 2015; Environment Canada 2001; Kelting and Laxson 2010; NASEM 2007; and Wenck Associates 2009). In the Mid-Atlantic, a forested watershed and an agricultural watershed in the Maryland Piedmont with no impervious surface cover had average chloride concentrations of less than 5–8 mg/L (Bird et al., 2018; Kaushal et al., 2005; Moore et al., 2017; and Moore et al., 2020), and three Coastal Plain watersheds in Virginia and Maryland with low impervious surface cover (<1.25% of watershed area) had average chloride less than 15 mg/L (Moore et al., 2020). Concentrations can spike into the thousands or tens of thousands (mg/L) during and after winter storm events, especially in urbanized areas (CASE 2015; Kelting and Laxon 2010) as salts are carried to nearby streams by runoff from rainfall events and melting snow (Williams et al., 1999). Based on approximately 30 million high-frequency observations of estimated chloride concentrations across the eastern US, including the Mid-Atlantic, estimated concentrations above the EPA chloride criteria were frequent and pervasive in watersheds with greater than 9–10% impervious surface cover and in the Mid-Atlantic occurred in some watersheds where estimated annual median chloride concentrations were greater than 30 mg/L and all watersheds where estimated annual median chloride was higher than 50 mg/L (Moore et al., 2020).

2.1.1.1.1 Rivers and Streams

The ratio of chloride to **specific conductance** was estimated to be 0.32 as part of the Accotink Creek stressor identification analysis (ICPRB 2017b).[13] At a ratio of chloride to specific conductance of 0.32, the **acute** chloride criterion would be exceeded at specific conductance measurements of 2,688 microsiemens per centimeter (µS/cm). Specific conductance measurements at or above this threshold are not uncommon in the Accotink Creek watershed. Monitoring data from upper Accotink Creek are shown in **Figure 8**. Exceedances are also common in lower Accotink Creek and Long Branch (a tributary to Accotink Creek).

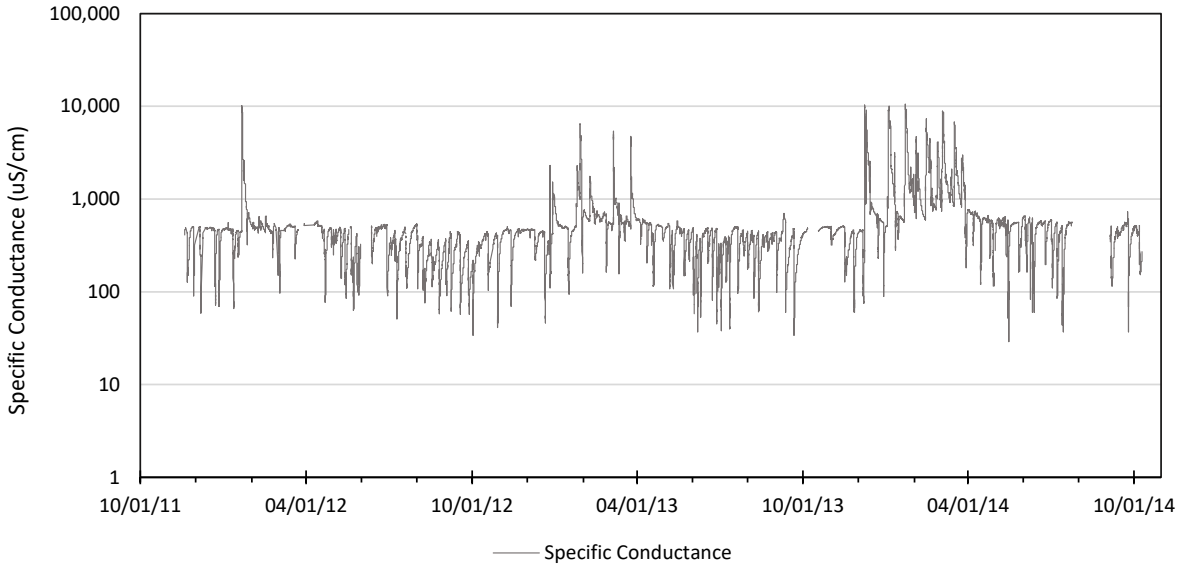


Figure 8. Observed specific conductance (µS/cm), continuous monitoring, Accotink Creek near Ranger Road. The acute chloride criterion corresponds to specific conductance measurements of 2,580 µS/cm. Note that the y-axis is a log scale.

This problem is not isolated to Accotink Creek. Recent USGS monitoring of neighboring watersheds demonstrates spikes of specific conductance in surface waters corresponding with winter storm events. Monitoring data for USGS station 01646000 on Difficult Run is shown in **Figure 9**. The largest spike corresponds to a winter storm event comprised of snowfall followed by rainfall. The rain washed the salts into the nearby waterways resulting in the spike.

[13] Another resource for predicting chloride concentrations from specific conductance data is provided in **Appendix N**, the regional Mid-Atlantic piecewise model developed by Joel Moore and USGS colleagues.

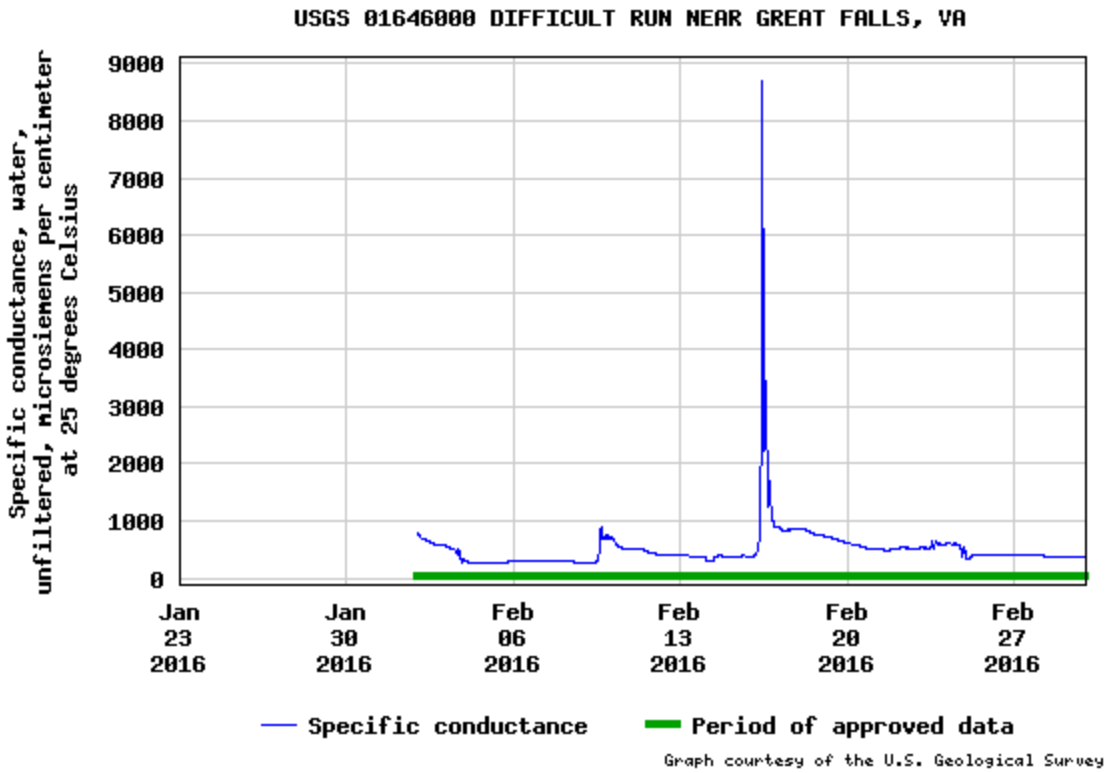


Figure 9. Specific conductance data for Difficult Run near Great Falls, Virginia (USGS 01646000) (Source: USGS).

Background concentrations of chlorides have also been rising steadily in the region. Since 1994, median non-winter chloride concentrations have increased approximately four percent per year in the Accotink Creek watershed and throughout the Northern Virginia region (see **Appendix K**), a rate that is consistent with increases in applications of salts (ICPRB 2017a). **Figure 10** shows the increases in average annual chloride concentrations from 1990 to 2014 using boxplots on data collected in discrete water samples. The boxplots summarize each year's data, where the bold line represents the median of samples collected that year and the top and bottom of the box represents the 75th and 25th percentile, respectively.

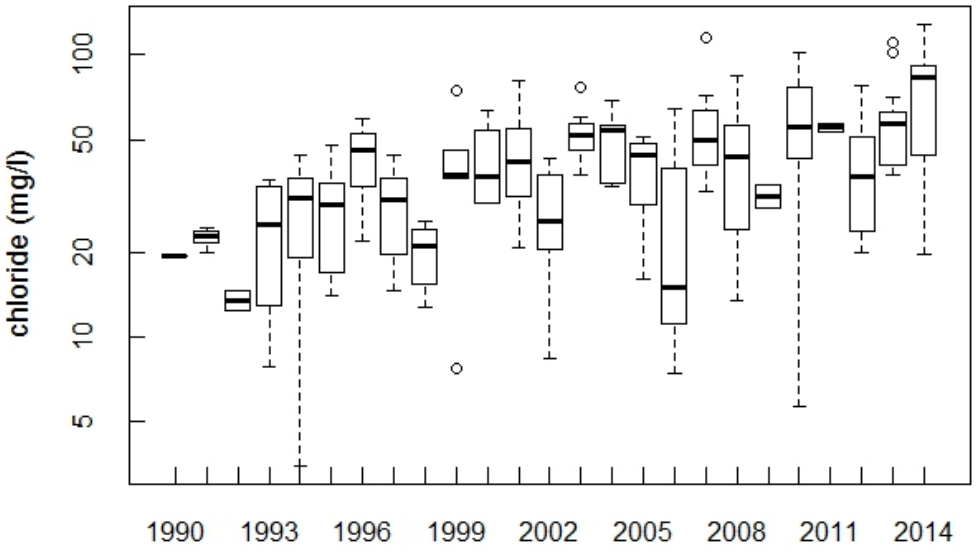


Figure 10. Boxplots of observed annual chloride concentrations on Accotink Creek near Braddock Road (1990-2014).

Beyond the Northern Virginia region, trends in chloride concentration in streams have been extensively documented in recent years due to increasing concentrations as a result of salt use and a growing concern about the impacts. For more information, see: Canedo-Arguelles et al., 2013; CCME 2011; Cooper et al., 2014; Corsi et al., 2015; Environment Canada 2001; Freshwater Society 2014; Freshwater Society 2016; Kaushal et al., 2005; Kelly et al., 2009; Langen et al., 2006; Medalie 2012; MPCA 2016; MPCA 2013; Murray and Ernst 1976; Venner 2004; Westchester 2007; and Wenck Associates 2009.

2.1.1.1.2 Lakes and Ponds

Increases in chloride concentrations due to salts have been found in surface runoff and subsequently in the streams and lakes receiving surface water flows. Small urban stormwater management basins are included in this pattern (Environment Canada 2001). **Table 4** presents some major findings from the literature about the effects of salt use on water quality in lakes and ponds.

Table 4. Literature findings on effects of salt use on water quality in lakes and ponds.

Location	Finding(s)	Citation
Lake Simcoe, southern Ontario	Highest chloride loads associated with tributaries with highest percentage of roads and urbanization; highest concentrations at deepest parts of lake.	Winter et al., (2011)
Adirondack Park, New York	Lower concentrations of chlorides found in lakes not influenced by deicing salts, 168 lakes monitored in all.	Kelting and Laxson (2010)
Twin Cities Metropolitan Area	Lakes with at least one monitoring event greater than the acute or chronic standard had chloride concentrations increasing with depth.	Wenck Associates (2009)
Twin Cities Metropolitan Area	23 lakes identified as impaired due to violations of water quality standards, linked to deicing salt applications.	MPCA (2016)
Lake Wingra, Madison, Wisconsin	Increased chloride concentrations due to urbanization.	Madison (2015)
Midwest and Northeast North America	70 percent of lakes with greater than 1 percent impervious land cover within 500 meters of lake shores had increasing chloride concentrations. Estimate that at least 7,700 lakes in the Midwest and Northeast United States may be at risk of elevated chloride concentrations.	Dugan et al., (2017)

In addition to biological impacts (discussed in **Section 2.1.3**), increases in salt can affect processes such as mixing and stratification (Winter et al., 2011 and Environment Canada 2004). Natural annual mixing can be disrupted by dissolved salts that produce a dense, salty layer that sinks. The lack of vertical mixing can result in oxygen depletion in lower layers of the lake and a reduction in the cycling of nutrients (Kelting and Laxson 2010; Langen et al., 2006; and Environment Canada 2004). Increased salts can prevent this density-driven mixing (Environment Canada 2004 and Environment Canada 2001).

2.1.1.2 Groundwater

Chloride and sodium naturally occur in groundwater (CCME 2011, Health Canada 2012, Kelting and Laxson 2010, and Mullaney et al., 2009); however, high levels of salts in non-coastal groundwaters are typically associated with pollution like salt application and storage (Benham 2011). The pathways for chloride and sodium from salts are primarily infiltration of salt contained in melting snow or infiltration of snowmelt runoff in swales and wetlands near surfaces where salts are applied (CASE 2015; Kelting and Laxson 2010; Madison 2006).

Salts in groundwater can be discharged as **baseflow** to local or regional streams. This contribution of salt loads to surface waters may follow a lag time of tens to hundreds of years (CASE 2015, Heath and Morse 2013, and Kelting and Laxson 2010), but travel times depend heavily on local hydrogeology and other site-specific factors. For example, stormwater management practices that promote the infiltration of stormwater have been shown to facilitate the transport of chloride contaminated groundwater to streams during winter storms and throughout the year (Snodgrass et al., 2017).

Increasing background concentrations of chlorides in surface waters in the Northern Virginia region, discussed in **Section 2.1.1.1**, indicate that chloride is seeping into groundwater and steadily increasing over time. Baltimore County conducted groundwater studies in 1998 and 2002 and found a positive correlation between increased chloride levels and distance to roads. Chlorides in streams and reservoirs in Baltimore City have doubled in the last 30 years, driven partly by increases in groundwater levels since half of the streamflow is estimated to be from groundwater (Koepenick, undated). Numerous

studies from the United States and Canada support these findings by demonstrating links between increased groundwater levels of chloride and sodium and increased applications of salts (Freshwater Society 2016; Heath and Morse 2013; MPCA 2013; and Medalie 2012).

2.1.2 Soil Impacts

Sodium and chloride react differently depending on the reactive components of a particular soil. Soils contain a mixture of chemically reactive components such as clays, oxides, and organic matter (CASE 2015 and Kelting and Laxson 2010). Clays and organic matter in soils generally have negative charges at the normal pHs found in soil (Kelting and Laxson 2010 and CASE 2015). Positively charged sodium ions are attracted to and are absorbed to negatively charged soil surfaces while negatively charged chloride ions are not (Langen et al., 2006). In addition, sodium causes leaching of other **cations**, positively charged ions, present in the soil (CASE 2015; Kelting and Laxson 2010; and Langen et al., 2006). When sodium becomes the prevalent cation, it can strip the soil of numerous components required by plants (calcium, magnesium, potassium, ammonium, copper, lead, zinc, and nickel) (CASE 2015 and Kelting and Laxson 2010) similar to the effect of acid rain. The leaching of these soil components, some of which are toxic to plants, soil biota, and aquatic organisms, can release them to surface and groundwaters (CASE 2015 and Langen et al., 2006). In addition, increased sodium in the soils decreases the suitability of soils for all but the most salt-tolerant plants (Murray and Ernst 1976). Chloride is highly soluble and conservative and is transported as surface runoff, subsurface **interflow**, or infiltrates to groundwater where at least some of it will eventually discharge to nearby surface waterbodies (Environment Canada 2001). Salts have also been suspected to impact carbon and nitrogen cycling in soils (CASE 2015 and Kelting and Laxson 2010).

2.1.3 Biologic Impacts

Impacts to biological systems can occur as a result of the increased chloride concentrations in surface and groundwater systems discussed in the previous section. Impacts to vegetation, aquatic life, and wildlife are discussed below.

2.1.3.1 Vegetation

Vegetation is negatively impacted from banks of salty snow deposited by plows, direct and wind-driven spray, and runoff from impervious surfaces (CASE 2015; Environment Canada 2001; Langen et al., 2006; and Murray and Ernst 1976). Damage to vegetation occurs primarily through the effects of salt accumulation in soil and directly on plants (Kelting and Laxson 2010). High concentrations of salts in soil affect plants in several ways; 1) the inhibition of water and nutrient absorption due to osmotic imbalances resulting in reduced shoot and root growth, 2) nutritional imbalances in some species by altering uptake of other nutrients, 3) growth inhibition and direct toxicity at higher concentrations to plant cells as seen by leaf burn, and 4) deterioration of soil structure as discussed in **Section 2.1.2** (Environment Canada 2001; Kelting and Laxson 2010; and Langen et al., 2006).

Salts transported by plows, direct spray, and surface runoff can affect vegetation at different distances from the application site. Deposition from plows affects vegetation close to the site. When salts are transported by spray, some studies have indicated that vegetation is negatively affected within 5 to up to 50 feet of the salted surface due to direct spray and within 30 to 300 feet due to wind-driven spray (CASE 2015 and Kelting and Laxson 2010). Most effects on vegetation occur within 55 feet (CASE 2015). Runoff travels farther than spray and can enter surface water bodies and groundwater (CASE 2015).

The cumulative effect of salts on soils and wetlands can result in the establishment of non-native salt tolerant species (CASE 2015; Environment Canada 2004; and Kelting and Laxson 2010). Environment Canada (2001) developed lists of trees, shrubs, and other plants evaluated for their tolerance to salts.

2.1.3.2 Aquatic life

In 1988 the USEPA set aquatic life chronic and acute toxicity levels for chloride of 230 mg/L and 860 mg/L with durations of four days and one hour, respectively (USEPA 2017a), because elevated concentrations of chloride can disrupt the **osmotic regulation** of aquatic organisms. These criteria have been adopted as Virginia Water Quality Standards (9VAC25-260-140).

Osmotic regulation is the process whereby an organism maintains the internal balance between water and solute concentration relative to external environmental conditions. Disruption of an organism's ability to maintain osmotic regulation can be toxic. Toxicity is measured as related to the concentration, or dose, at which 50 percent mortality occurs (CASE 2015). Environment Canada (2001) has several tables of lethal concentrations for various species. **Table 12** and **Table 13** in **Appendix A.a** have lethal exposure times and sodium chloride concentrations for various species (Kelting and Laxson 2010, based on data from Environment Canada 2001). In addition to impacting aquatic life through osmotic regulation (CASE 2015; Kelting and Laxson 2010; and Langen et al., 2006), aquatic life is also impacted by salts through changes in waterbody circulation as described in the section on lakes and ponds (**Section 2.1.1.1.2**). The Virginia Water Quality Standards, described above, are designed to minimize these negative impacts to aquatic life and overall, support the growth of aquatic life in the Commonwealth.

Recent studies give further evidence for the toxic effects of elevated chloride on aquatic species (Brand et al., 2010; Corsi et al., 2010; Findlay & Kelly, 2011; Hintz & Relyea, 2019; van Meter et al., 2011; Searle et al., 2016; and Soucek et al., 2011). Complementary studies focused on elevated specific conductance, for which deicing salt use is the primary driver in urban watersheds in regions with frozen precipitation (Moore et al., 2020), report similar results. Natural, or background, stream conditions play a controlling role in the adaptability of organisms to elevated chloride with greater negative effects in macroinvertebrate communities adapted to low specific conductance conditions (Bray et al., 2019; Clements and Kotalik, 2016; Cormier et al., 2013; Cormier et al., 2018; Entrekin et al., 2019; Fanelli et al., 2019; Pond et al., 2017; and Utz et al., 2016). Benthic macroinvertebrates seem to be generally susceptible to elevated chloride (and specific conductance) with some groups being particularly sensitive, for example, the order Ephemeroptera which includes mayflies (e.g., Bray et al., 2019; Clements and Kotalik, 2016). An experiment examining several stressors on a multi-**trophic level** community found that deicing salt had the broadest negative effects and caused significant productivity decreases at all trophic levels (Dalinsky et al., 2014).

Perhaps particularly concerning is that some recent studies found negative effects of elevated chloride were common at concentrations below the EPA aquatic life criteria. For example, changes in fish communities in the Maryland Piedmont were observed at chloride concentrations of 33–108 mg/L (Morgan et al., 2012). Community changes in benthic macroinvertebrates were observed at 50–90 mg/L chloride (Wallace and Biastoch, 2016). Reduced consumption of detritus by benthic macroinvertebrates in experiments occurred at sodium concentrations of 14 and 140 mg/L with associated chloride concentrations being approximately 28.2 and 282 mg/L (Tyree et al., 2016). Based on results from laboratory experiments where food conditions were adjusted to be representative of a number of freshwater bodies (rather than the abundant food conditions often used in experiments), the lethal concentration for 50% of *Daphnia* (LC_{50}) was lower than the EPA chronic criterion in 7 of 8 experiments with the lowest LC_{50} being 52 mg/L (Brown and Yan, 2015). Overall water chemistry also plays an important role with negative effects, including lethality, observed at chloride concentrations below the EPA chronic criterion in waters with low hardness (Elphick et al., 2011). Additionally, studies focused on specific conductance found substantial community changes at conductivity levels that are representative of chloride concentrations well below the EPA chronic criterion (e.g., Cormier et al., 2018; Pond et al., 2017); see Moore et al., (2020) for relationships between chloride and conductivity in the Mid-Atlantic.

Stranko et al., (2013) reviewed the literature for salt and chloride toxicity for four aquatic animal groups (benthic **macroinvertebrates**, fish, amphibians, and mussels). The findings indicate that these groups experience negative impacts due to elevated chloride concentrations. Additional information on the impacts of salts on amphibians is provided in **Section 2.1.3.3.1**.

2.1.3.3 Wildlife

2.1.3.3.1 Amphibians

Amphibians are known to be sensitive to elevated salt levels given their very permeable skin, their physiological dependence on osmotic processes, and their early stage wetland habitat (Stranko et al., 2013; Kelting and Laxson 2010; and Karraker et al., 2008). Specifically, negative effects are reported for the development of wood frog (*Rana sylvatica*) tadpoles from chronic exposure to salt concentrations as low as 78 mg/L (Langen et al., 2006). Kelting and Laxson (2010) report that various studies have shown reduced growth and survivorship in early stages of several frog, toad, and salamander species exposed to elevated salinity conditions. The most severe impacts from salts were found in populations of wood frogs and spotted salamanders located within 50 meters of salt application sites (Karraker et al., 2008). An example potential impact on wood frog populations from salt is altered sex ratios resulting in more male frogs (Lambert et al., 2016). Laboratory experiments that compared the toxicity of pure NaCl and deicing salt collected from an operator found that effects were similar between the two for green frogs and Northern Two-Lined salamander embryos, which pointed to loss of osmoregulatory control as the driver of negative effects on the organisms; the estimated LC_{50} was 2410 mg/L (Jones et al., 2015). The distribution of wood frogs in stormwater ponds in the Maryland Piedmont is strongly predicted by chloride concentration with wood frogs not found in any ponds where chloride concentrations exceeded 260 mg/L, and both field and laboratory results suggest that wood frogs are negatively affected by chloride concentrations less than 230 mg/L (Gallagher et al., 2014). Green frog tadpole larvae exposed to elevated chloride in the laboratory exhibited higher mortality at 22˚ and 25˚C than at 18˚C, indicating that warm days in particular winters and overall warming temperatures driven by climate change may contribute to the chloride toxicity problem for amphibians (Green et al., 2019).

2.1.3.3.2 Birds and Mammals

The use of sodium chloride as a deicing agent is widely recognized as a factor in attracting mammals and birds to roads. Their increased presence in roadways due to available salts increases the number of collisions with vehicles (Kelting and Laxson 2010 and Environment Canada 2001). Other potential health problems are associated with the toxicity of salt ingestion. For example, there is some evidence that ingestion of salts may be contributing to bird mortality (Environment Canada 2001; Kelting and Laxson 2010; and Mineau and Brownlee 2005). Deicers that do not contain sodium, such as magnesium chloride and calcium chloride, are not known to attract birds or mammals (Venner 2004).

2.2 Infrastructure and Property Impacts

2.2.1 Vehicles

Vehicle corrosion is the result of exposure of the metal surfaces to oxygen and water. This process is accelerated by the presence of chlorides (CASE 2015). Trends in vehicle corrosion are difficult to evaluate due to changes in car manufacturing and design as well as deicing compounds and application

> *"Due to the construction of a vehicle with most of the underbody being wide open, most salt damage occurs underneath the car and as a result can be difficult to detect visually."*
>
> *Rodman (2016)*

methods used (CASE 2015; Spiegel 2015; Kelting and Laxon 2010). In addition, vehicle corrosion is dependent on local variables such as weather conditions, local treatment practices, vehicle type, and maintenance practices (Murray and Ernst 1976).

2.2.2 Transportation Infrastructure

Various types of materials can be used in the design of bridges and other transportation infrastructure; however, impacts from salts are primarily found in concrete and steel-reinforced concrete structures as well as metal structural supports (e.g., tunnels, stormwater structures, curbs). As such, damage to concrete and steel-reinforced infrastructure has been widely documented (e.g., Darwin et al., 2008; Kelting and Laxson 2010; MPCA 2016; Murray and Ernst 1976; NASEM 2007; and Westchester 2007).

Concrete and steel reinforced concrete structures are negatively impacted by salts by three processes, namely:

1) the corrosion of reinforced steel from chloride;
2) reactions between the salt and the cement, reducing the strength of the cement (Shi et al., 2011 and Wang et al., 2006); and
3) increases in the number of freezing and thawing cycles in the concrete, allowing penetration of more water (Kelting and Laxson 2010; Shi et al., 2010; and NASEM 2007).

Table 5 provides the results of a review of the effects of three salts. Based on this information, sodium chloride appears to have fewer adverse effects than other chemicals studied (Sumsion and Guthrie 2013).

Table 5. Concrete impacts of deicing chemicals reported in 10 studies (adapted from Sumsion and Guthrie 2013).

Concrete Impacts	Sodium Chloride	Calcium Chloride	Magnesium Chloride
Minor	9 of 10 studies		1 of 8 studies
Significant	1 of 10 studies	8 of 8 studies	7 of 8 studies

2.2.3 Road Surfaces

In the Northern Virginia region, roads are primarily surfaced with asphalt. Asphalt is susceptible to the impacts from salts through the increase in the number of freezing and thawing cycles, as described in **Section 2.2.1**. Over time, this can increase the rate of roadway deterioration, especially in already damaged roads. Concrete and reinforced steel concrete infrastructure like curbs, stormwater structures, and bridges are addressed in **Section 2.2.1**.

2.2.4 Drinking Water Systems

According to Chapter 4 of the Virginia State Water Plan, the majority of the Commonwealth's population is supplied by public water suppliers using surface water sources (DEQ 2015). These surface waters are subject to receiving deicing chemicals especially in urban and suburban areas and near roadways as previously described. Winter applications of salt can have a number of implications for drinking water systems including the loss or need to mitigate drinking water sources, taste complaints from customers, pipe corrosion, modified treatment needs, and mobilization of nutrients in the source waters, potentially causing harmful algal blooms. Each of these will be discussed in more detail in this section.

The treatment requirements of removing salts from drinking water are extensive and expensive. In fact, removing salts at water supply treatment plants is not considered a viable option as the only technology available to water suppliers for removing salts is **reverse osmosis** which is cost prohibitive (MPCA 2016) and inefficient as it produces more wastewater than drinking water (Benham 2011). In the event that treatment or source water protection is not a viable option for

economic or other reasons, contamination can lead to the loss of the drinking water source (Fay et al., 2015 and MPCA 2016).

Large amounts of chloride in drinking water are associated with a salty taste and unwanted odors. For this reason, the USEPA established a **secondary maximum contaminant level** in water for chloride of 250 mg/L (USEPA 2017b) for taste and odor. The specific thresholds at which consumers might notice these negative impacts of the chloride **anion** are dependent on the associated **cation** (sodium, calcium, or magnesium for example) and on an individual's specific taste and smell sensitivities (WHO 2003). Salty tasting water results in customer complaints and associated public perception issues for drinking water utilities.

Pipe corrosion from salts is another major issue for drinking water utilities. As discussed in previous sections, chloride is commonly associated with increased corrosion. Corroded drinking water pipes require costly pipe repairs or replacements. In addition, the process of pipe corrosion can release metals such as lead into the drinking water system (Stets et al., 2017) and into the drinking water of homes with contaminated well water (Pieper et al., 2018).

Some aspects of drinking water treatment change depending on the amount of chlorides in the raw water. For example, to minimize corrosion in the distribution pipes, utilities may need to adjust the type and/or amount of corrosion inhibitors added during the treatment process. Also, additional chlorine may be needed to ensure continued disinfection in the distribution system. Specifically, materials from corroding pipes can react with chlorine in the distribution system. The portion of the chlorine that reacts in this way is not available to serve as a disinfectant. As a result, additional chlorine is needed in the distribution system to maintain the required chlorine residuals. Utilities must then carefully balance the need for increased chlorine use with the potential formation of disinfection byproducts.

Soil processes associated with salt contamination, discussed in **Section 2.1.2**, may result in more nutrients being mobilized (CASE 2015). Increased nutrients in waterways lead to surface water eutrophication and can increase the chance of harmful algal blooms. Harmful algal blooms can be difficult for drinking water suppliers to treat (WSSC, personal communication, 4/19/2017).

3 Literature Review, Economic Costs and Benefits of Improved Salt Management

3.1 Economic Costs of Salt Application

As **deicing** and **anti-icing** activities steadily increase across the United States, a significant effort is being made to understand the financial costs and benefits of the various salt products available for snow removal. Dollar amounts have been documented by local communities and state agencies and there is a robust body of knowledge in peer-reviewed literature. This section presents information on this topic as gathered by two significant research efforts:

> *"To understand the full cost of a product, you need to consider how much you are paying to buy and ship the product, apply the product, clean-up or manage the product in the environment, and costs of direct impacts to the environment. The environmental impacts of road salts are difficult to quantify in monetary terms, as they are site-specific and depend on a wide range of factors unique to each formulation and spatial and temporal factors of the location, further complicating the issue."*
>
> Fay et al. (2015)

- Benefit-Cost of Various Winter Maintenance Strategies (Fay et al., 2015) and
- Twin Cities Metropolitan Area Chloride Management Plan (MPCA 2016).

These two papers were selected based on their breadth of both peer-reviewed literature and supplemental surveys and interviews conducted to gather detailed cost information on salt use, potential reductions in salt use from various advanced approaches, and the benefits to the environment from such reduced use. Together these papers reference nearly 200 unique sources, not including survey and interview respondents. Fay et al., (2015), in particular, focuses on the costs and benefits of different winter maintenance strategies, summarizing the available literature in convenient tables which are provided at the end of this section.

The cost benefit analysis was identified for a limited set of BMPs and is reported below for reference use by those considering use of any of the practices discussed in this section (**Figure 11**). The costs of salt use include both direct and indirect costs. Direct costs are those that stem from the purchase and application of the salt. Indirect costs are those that are unintended consequences of salt use; these are often difficult to quantify. The benefits of salt use include fewer accidents and falls, maintaining the flow of commerce, and avoided lost productivity. It has been demonstrated that winter maintenance costs can be reduced while still providing the same level of service and safety (Fay et al., 2015).

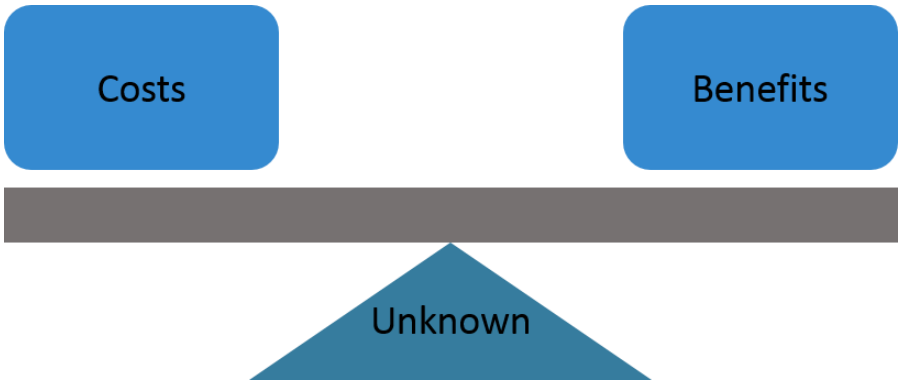


Figure 11. Costs and benefits must be balanced when selecting a winter maintenance strategy. Estimating costs and benefits is needed to determine the balance, previously unknown.

Improved winter management practices are available for the use of salts for winter weather management – each with their own set of pros and cons (see **Appendix B**). Generally speaking, the use of alternative deicers and/or **BMPs** when applying these products can decrease the amount of salt used, thus reducing costs and environmental impacts all while maintaining the public's expected level of service.

In addition to the selection of the salt to meet a winter service provider's specific needs, there are certain BMPs that can reduce the related environmental impacts as detailed in **Section 2**. For instance, pre-wetting can reduce the scatter of solid products and improve adhesion to the surface, thus reducing the amount needed for the same level of service to be achieved. If corrosion is of particular concern, a winter service provider may select a product with a corrosion inhibitor. While the product may cost more to purchase than others, savings may be seen later from reduced repairs to vehicles and infrastructure. Massachusetts DOT has gone as far as creating "Reduced Salt Zones" where they use alternative strategies or products to clear surfaces. These areas include surfaces adjacent to wetlands, sources of drinking water, salt sensitive agricultural and vegetative locations, and groundwater recharge areas (MassDOT 2017). While not the focus of this section, it is important to remember that it is not just what is applied to the surfaces, but also how (i.e., before or during a storm, equipment used to apply materials, where different types of salt are applied etc.) the products are applied that has an implication for the environment.

The rest of this section outlines the various costs associated with salt application and other maintenance strategies. Following this there is a brief discussion of road information and decision systems.

3.1.1 Environmental Costs

The costs to aquatic ecosystems have not been documented due to the difficulty in quantifying and monetizing related impacts. Below are some examples of how costs could be assigned to environmental damage from salt use.

- Damage to fisheries – lost revenue to fisherman
- Lost recreational opportunities – less pleasant visitor experiences, fewer fish and/or less desirable species to catch
- Costs of damaged vegetation in buffers, BMPs, riparian restorations, stormwater ponds, etc.; costs of addressing influx of more salt-tolerant species; costs to winter service providers (and others) of replacing vegetation killed or damaged by salt spray

Fay et al., (2015) cite a few efforts to estimate the environmental costs of salts. These include assigning value to damaged fruit trees (Bacchus 1986) and surveys of state park visitors assessing how the damage from winter maintenance affected their experience in the park (Vitaliano 1992). Vitaliano estimated that there was an "aesthetic damage cost of $73 per ton" of salt applied. It is worth noting that the costs presented in this document have not been adjusted for inflation.

MPCA (2016) also cites work done to estimate environmental damage. Specifically, they mention three efforts to quantify impacts in the Adirondacks. One estimate from Kelting and Laxson (2010), as quoted from MPCA (2016), "showed a $2,320 per lane mile per year reduction in environmental value" via an environmental services evaluation. Citing Vitaliano (1992), MPCA reports that "the aesthetic damage to trees in the Adirondacks due to road salt was $75 per ton."

Instead of trying to estimate the economic impacts to the environment, it could be assumed that the products with greater environmental risks will also have greater environmental costs. Fay et al., (2015) cite interesting work by Fitch et al., (2013) and Pilgrim (2013) which use a relative ranking system to compare the environmental impacts of the different products over the entire life cycle of the product, not just the impacts after application during winter storm events (**Figure 12**). So while acetate-based chemicals like calcium magnesium acetate (CMA) are commonly thought of as environmentally friendly products, Fitch et al., (2013) and Pilgrim (2013) point out the high environmental impacts, especially associated with the processes required to generate the CMA.

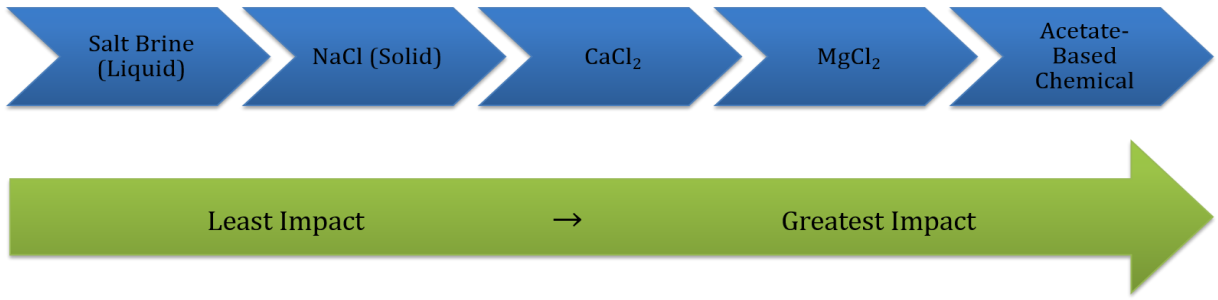


Figure 12. Relative ranking of toxicity of corrosion inhibited products used during snow and ice control operations (reprinted from Fay et al., 2015).

3.1.2 Infrastructure and Property Costs

The application of salts impacts infrastructure, leading to required maintenance and replacement. Specifically, corrosion of roads, bridges, and sidewalks is a documented consequence of winter road activities, as is corrosion of vehicles. The earliest cost estimate for infrastructure damages was provided by Murray and Ernst (1976); they estimated that total annual damage to just bridge decks was more than $500 million nationwide. In 2001, Koch et al., (2002) estimated the annual cost of corrosion for highway bridges to be $8.3 billion for replacing deficient bridges, bridge maintenance, painting, and capital costs. Vitaliano (1992) estimated an increase in roadway maintenance of over $600 per ton of salt applied and the damage to vehicles at $113 per ton of salt applied.

Another infrastructure element impacted by salts is vehicle parking garages, which suffer the same corrosion damage as bridge decks, compromising their structural integrity. It is estimated that in 1991, the annual cost to repair and protect parking structures in the northeast and Midwest United States was between $75 and $175 million (Westchester 2007).

Fay et al., (2015) gathered a significant number of references of the cost of corrosion, some of the most relevant findings are reported here. Michigan DOT found costs of $715-$8,558 per vehicle (Michigan DOT, undated). Corrosion to cars and trucks costs as much as $6.5 billion per year in the United States to repair corrosion damage from winter highway maintenance (CASE 2015). Another study in Michigan (Public Sector Consultants 1993) estimated annual corrosion costs based on the amount of product required to treat roads under Michigan DOT's jurisdiction to their bare-pavement guidelines at the time (**Table 6**).

Table 6. Estimates of vehicle and bridge deck corrosion in Michigan per ton of applied product in 1993 dollars (data gathered from Public Sector Consultants 1993).

Deicing Product	Estimated Vehicle Corrosion Costs		Estimated Bridge Deck Corrosion Costs	
	Low Estimate ($USD/ton)	High Estimate ($USD/ton)	Low Estimate ($USD/ton)	High Estimate ($USD/ton)
Sodium Chloride	321	715	30	69
2:1 Salt-Sand Mixture	214	476	20	46
CMA	19-32	17-71	3.02	96.48
CG-90 Surface Saver*	117	328	13.86	30
Calcium Chloride	241	457	19	44

* "A corrosion-inhibiting salt produced by Cargill that can be used as a deicer" (Public Sector Consultants 1993).

Shi et al., (2013) estimated repair costs for service vehicles used by Washington State DOT as a result of corrosion. These cost estimates are presented below in **Table 7**.

Table 7. WA DOT service vehicle maintenance costs due to corrosion (adapted from Shi et al., 2013).

Year	All corrosion-related maintenance	Total repair costs for all equipment	Corrosion-related maintenance as percentage of all repair
2008	$457,956	$15,781,512	3%
2009	$712,969	$16,073,479	4%
2010	$558,516	$15,757,417	4%
2011	$736,362	$16,771,625	4%

Additionally, water supply, wastewater, and stormwater systems have to address pipe corrosion by high cost repair or replacement of conveyance pipes. In addition to corrosion, water suppliers may face other challenges due to increased salt content in the source water. These could include increased chlorine demand during treatment, unpleasant taste - prompting complaints from customers (WSSC, personal communication, 4/19/2017), and loss or mitigation of wells due to contamination. For example, the Transportation Research Board found in the 1970s that nine northeastern states reported costs for mitigation of salt contaminated shallow wells at about $10 million per year (TRB 1991). Away from the treatment plant, but with implications for a supplier's treatment costs, increases in **chloride** could cause changes to soil,

leading other contaminants to enter source waters (WSSC, personal communication, 4/19/2017). Similarly, more nutrients could be mobilized from sediment, increasing the chance of harmful algal blooms which can be difficult for suppliers to treat (WSSC, personal communication, 4/19/2017).

3.1.3 Indirect Cost Summary

As discussed, the indirect costs of salt use are difficult to quantify. Even within this category some costs are more difficult to estimate than others (i.e., public health costs and costs to drinking water suppliers). Researchers on this topic tend to focus on quantifying one or two of the cost variables, thus making it difficult to get a sense of all the costs in a single location at a single point in time.

Fortin Consulting (2014) reviewed the indirect cost literature and gathered the various estimates. The high and low estimates across the studies are shown in **Table 8**. Categories overlap in this table as data were compiled from multiple studies that looked at a variety of costs. For example, some studies looked at just damage to trees whereas as other tried to estimate the total economic impact to an ecosystem; both fall under a general "environmental damage" category.

Table 8. Indirect costs ($USD/ton of salt applied) of salt use for winter maintenance from literature review (adapted from Fortin Consulting 2014).

		Infrastructure Damage		Environmental Damage	
Estimate	Vehicle Corrosion	Extra Road Maintenance	Infrastructure Damage	Tree Damage	Ecosystem Damage
Low Estimate	$30	$600		$75	$172
High Estimate	$113	$615	$1,460	$110	$227

Murray and Ernst (1976) compiled over 320 sources of information on the impacts of **road salts** in order to estimate their costs (**Table 9**). The estimated annual indirect costs to snowbelt states are summarized below (in 1976 dollars[14]).

Table 9. Annual cost estimates of road salt and its impacts in snowbelt states (adapted from Murray and Ernst 1976).

Impacts	Total Cost (Millions, $USD in 1976)
Water supplies and health	150
Vegetation	50
Highway structures	500
Vehicles	2,000

3.1.4 Direct Winter Maintenance Costs

Direct costs incurred from winter maintenance include:

- materials (salt, brine, fuel etc.);
- equipment (trucks, plows, spreaders, GPS, weather tracking systems etc.); and
- labor.

Fay et al., (2015) list the different categories of labor as "snow plow operators, dispatch personnel, mechanics, and all other winter maintenance staffing." They also note several off-season activities, such as driver and safety training.

Material cost can be some of the easier information to gather from winter service provider since they are often recorded in financial records. Fay et al., (2015) provides estimates for commonly used materials (**Table 10**).

[14] $100 in the year 1976 is worth approximately $421 in 2016, using the average inflation rate of 3.66% per year from the Bureau of Labor Statistics.

Table 10. Estimated material costs (adapted from Fay et al., 2015).

Winter Maintenance Strategy	Cost per Lane Mile ($USD)	Average Cost ($USD)
Plowing	1,335 (average)	N/A
Abrasives		9.32/ton
Abrasive-salt mixtures		20.86/ton
Solid Salt	68.41 (average for anti-icing use)	71.04/ton
Salt Brine	37.92 (average)	0.16/gallon
Corrosion Inhibitors	695.55 - 1,652.93	1.18/gallon
Inhibited Salt Brine		0.31/gallon
Magnesium Chloride		Inhibited solid – 150.00/ton Inhibited liquid – 1.00-1.50/gallon Uninhibited liquid – 1.20/gallon

In 1991, the Transportation Research Board found that materials accounted for 30 percent of a state's winter maintenance costs, 30 percent was spent on equipment, and the remaining 40 percent was spent on labor. The actual amount spent in a given year will depend on a locality's climate and weather, current cost of salt products, and the desired level of service.

"Efficient winter maintenance practices can reduce salt use without lowering the level of service. The improved practices are intended to maintain a consistent level of service in terms of safe roads, parking lots, and sidewalks with lower salt use. Implementation of improved winter maintenance activities may come with an initial investment cost to address training, new equipment, and public outreach. However, as a result of reduced salt usage, a cost savings is expected based on information provided by several local winter maintenance organizations. A net cost-savings has been shown by many organizations who have tracked cost before and after the implementation of winter maintenance BMPs."

MPCA 2016

3.2 Economic Benefits of Best Management Practices in Salt Application

In short, the benefits of improved salt application practices are the inverse of the costs discussed above and the environmental impacts covered in **Section 2**. This would include reduced direct costs to winter service providers, avoided costs to address corrosion and damage to infrastructure, fewer environmental impacts, and reduced public health risks. This can be achieved while still providing the same level of service and safety (Fay et al., 2015 and MPCA 2016).

3.2.1 Reductions in Salt Application

The reduction in the amount of salt applied that other communities have been able to achieve through improved management practices is noteworthy.

As no two communities are exactly the same in their weather, tolerance for snow on roadways and other surfaces, or in their methods to remove it, it is inappropriate to directly apply one communities' salt reduction or cost data to another's. That said, having a sense of the upper and lower bounds on salt reductions and costs can inform SaMS. MPCA (2016) documents salt reduction and cost savings estimates from winter service providers in the Twin Cities Metro Area. Salt reduction estimates were between 32 and 70 percent. The reductions shown are in line with additional estimates from Fortin Consulting in Minnesota that found a 30 to 70 percent reduction in salt use following participation in their training classes on BMPs (Fortin Consulting 2014). Direct winter maintenance cost savings were provided in dollar figures over different time periods, making generalizing difficult. The University of Minnesota, Twin Cities found that in their initial

year of using BMPs their new equipment cost $10,000 but they saw a savings of $55,000. The City of Waconia, Minnesota estimated a savings of $1.80 per lane mile. Of the nine providers who supplied information, all indicated a cost savings from improved practices. **Table 12** through **Table 14** in **Appendix A.a** provide the salt reduction and cost information for each provider.

3.3 Cost-Benefit Analyses

There are currently no studies that have conducted benefit-cost analyses for all BMPs in the SaMS Toolkit (**Appendix B**). This section, therefore, is meant to provide an example of BMPs and their benefit-cost ratios.

3.3.1 Winter Maintenance Strategies

Managing the costs and benefits of salt applications requires an understanding of how and when they are applied and for what purpose. Numerous strategies are used prior to and during winter storm events.

Using a literature review, surveys, and interviews, Fay et al., (2015) calculated benefit-cost ratios for the select winter maintenance products shown in **Table 11**. The authors' goal in developing these ratios was to assist winter service providers in making decisions about which strategy best meets their unique needs. As the results indicate, for the limited strategies discussed except abrasives, the benefits outweigh the costs. Using corrosion inhibitors was found to be the most cost-effective strategy of those evaluated.

Table 11. Benefit-cost ratios of winter maintenance strategies (reprinted from Fay et al., 2015).

Activities	Winter Maintenance Strategy	Benefit/Cost Ratio
Basic	Plowing	5.3
	Abrasives	0.2
Intermediate	Rock salt (solid NaCl)	2.4
	Salt brine (liquid NaCl)	3.8
Advanced	Corrosion inhibitors	8.0-13.2*
	Inhibited salt brine	3.8
	Magnesium Chloride ($MgCl_2$)	3.6
	Calcium Chloride ($CaCl_2$)	3.8
	Blended products	3.8-4.0

* The B/C ratios represent the use of proactive maintenance and corrosion prevention. Calculated by Shi et al., 2013; Honarvarnazari et al., 2015.

3.3.2 Road Weather Information Systems and Maintenance Decision Support Systems

Depending on the extent of interest, stakeholders may want to consider investment in a **road weather information system** (RWIS) or **maintenance decision support system** (MDSS). Multiple benefit-cost analyses look specifically at these systems, and indicate a financial benefit of their use.

A RWIS supplies the user with roadway and air temperature to inform decisions about which type of salt product to use, how much is needed, and how to prioritize the use the staff and equipment (Veneziano et al., 2014). MDSS is a real-time software package that provides guidance on how much salt should be applied and when for individual maintenance routes (Veneziano et al., 2014). The benefits of these systems include, but are not limited to, labor savings and improved level of service with the ultimate goal being better decision-making capabilities (Veneziano et al., 2014).

The authors pulled together benefit-cost ratios for these two systems from other research efforts. For RWIS the ratios ranged from 1.1 to 11.0. For MDSS the ratios ranged from 1.33 to 8.67.

4 Conclusion

Salts are essential to public safety during winter storm events. Numerous materials and strategies are available with varying degrees of effectiveness and costs. The materials, however, can remain in the environment once applied and can have numerous ecological and infrastructure related impacts. The use of optimal products and application methods can reduce tangible and intangible costs. The reviewed literature demonstrates the ability to successfully reduce the costs and negative impacts of salt products applied to manage snow and ice while maintaining high standards of public safety.

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For Additional Information

Two comprehensive resources for additional information on the topics discussed in this document are provided below.

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Appendix A.a Key Information from Literature Sources Cited in Appendix A

This appendix contains tables reprinted from literature sources to inform the discussion of topics covered in **Appendix A**.

Table 12. Comparison of the impacts of chloride deicers: sodium chloride, calcium chloride, and magnesium chloride (adapted from Kelting and Laxson 2010).

Impact	Road Salt (NaCl)	Calcium Chloride ($CaCl_2$)	Magnesium Chloride ($MgCl_2$)
Soils	Na can bind to soil particles, break down soil structure and decrease permeability. Cl may form complexes with heavy metals increasing their mobility.	Cl may form complexes with heavy metals increasing their mobility. Ca improves soil structure	Cl may form complexes with heavy metals increasing their mobility. Mg improves soil structure
Groundwater	Elevated levels of Cl can occur in groundwater during periods of low flow or spring thaws. Potential impact for drinking water, especially near heavily salted roadway or uncovered salt piles	Similar to NaCl, cation exchange action of Ca may increase potential for metal contamination	Similar to NaCl and CaCl2
Surface Water	Excessive chloride loading possible in small waterbodies with limited potential for dilution or a high ratio of paved surfaces. Saline stratification in small waterbodies resulting in anoxia in bottom waters. Limited evidence for ferrocyanide contamination.	Excessive chloride loading possible in small waterbodies with limited potential for dilution or a high ratio of paved surfaces. Saline stratification in small waterbodies resulting in anoxia in bottom waters.	Excessive chloride loading possible in small waterbodies with limited potential for dilution or a high ratio of paved surfaces. Saline stratification in small waterbodies resulting in anoxia in bottom waters.
Vegetation	Negatively effects through traffic spray, osmotic stress, and nutrient imbalance. Shown to influence vegetation up to 120 meters downwind from heavily traveled roadways. May influence spread of salt-tolerant or non-native species.	Osmotic stress and leaf scorch, similar to NaCl. Ca is an important macronutrient for plant growth.	Osmotic stress and leaf scorch, similar to NaCl. Mg is an important element in plant physiology.

Impact	Road Salt (NaCl)	Calcium Chloride ($CaCl_2$)	Magnesium Chloride ($MgCl_2$)
Wildlife	Linked to salt toxicosis in birds, may influence vehicle strikes in birds and mammals although the magnitude is unclear.	Little or no adverse effects	Little or no adverse effects
Automobiles and Highway Structures	Initiates and accelerates corrosion of exposed metal and concrete reinforcement bars. Exacerbates scaling.	Similar to NaCl, surfaces stay wet longer, potential increasing corrosion rate	Similar to NaCl. Risk of cement paste deterioration due to Mg reactions.

Table 13. Toxicity responses of organisms to NaCl at various exposure times (reprinted from Kelting and Laxson 2010).

Exposure Time	Species	Common Name	NaCl (mg/L)	Cl (mg/L)
0.25 hour	*Salvelinus*	brook trout	50,000	30,000
6 hours	*Lepomis macrochirus*	bluegill	20,000	12,132
	Oncorhynchus mykiss	rainbow trout	20,000	12,132
12 hours	*Chironomus attenatus*	midge larva	9,995	6,063
24 hours	*Lepomis macrochirus*	bluegill	14,100	8,553
	Catla catla	Indian carp fry	7,500	4,550
	Daphnia magna	daphnia	7,754	4,704
	Daphnia pulex	daphnia	2,724	1,652
4 days	*Anguilla rostrata*	American eel	21,571	13,085
	Gambusia affinis	mosquito fish	17,500	10,616
	Lepomis macrochirus	bluegill	12,964	7,864
	Oncorhynchus mykiss	rainbow trout	11,112	6,743
	Pimephales promelas	flathead minnow	10,831	6,570
	Carassius auratus	goldfish	7,341	4,453
	Catla catla	Indian carp fry	4,980	3,021
	Culex sp.	mosquito	10,254	6,222
	Limnephilus stigma	caddisfly	7,014	4,225
	Chironomus attenatus	midge larva	6,637	4,026
	Lirceus fontinalis	isopod	4,896	2,970
	Physa gyrina	snail	4,088	2,480
	Daphnia magna	daphnia	3,054	1,853

Table 14. Salt reduction and cost savings estimates from municipalities and private entities in the Twin Cities Metro Area (reprinted from MPCA 2016).

Entity	Implementation Period	Main Actions Implemented	Salt Reduction	Cost Savings
University of Minnesota, Twin Cities	Start 2006	Began making salt brine and anti-icing and adopted several other salt reduction BMPs.	48%	New equipment cost $10,000 $55,000 cost savings first year
City of Waconia	Start 2010	Switch from 1:1 sand:salt to straight salt & liquid anti-icing; calibration; equipment changes; use of air and pavement temperatures.	70%	$8,600 yearly cost savings ($1.80 per lane-mile)
City of Prior Lake	2003-2010	Upgrade to precision controllers & sanders; anti-icing & pre-wetting; use of ground temperatures, best available weather data; on-site pre-mix liquid & bulk-ingredient storage, mixing & transfer equipment; staff education.	42%	$2,000 per event estimated cost savings; 20 – 40 mg/L decrease in receiving-water chloride (liquid app-only watershed)
City of Richfield	Start 2010	All-staff Training; yearly sander calibration; use of low-pavement-temp deicers; road crown-only application; minor-arterial-road policy adjustments.	> 50%	$30,000: 2010-2011 $70,000: 2011-2012
Rice Creek Watershed District Cities	2012-2013	Staff training; purchased shared anti-icing equipment	32%	$26,400 in one winter
City of Cottage Grove	2011-2012	Staff training	Not available	$40,000 in one winter
City of Shoreview	Start 2006	Stopped using a salt/sand mixture and moved on with straight salt; set up all its large plow trucks with state of the art salt spreading controls, pre-wetting tanks and controls and pavement sensors; use of calcium chloride in the pre-wetting tanks reduced the amount of rock salt as well; all applicators and supervisors annually attend *Training; crews attend an annual snowplow meeting to review procedures and talk about salt use and conservation methods; trucks set up for anti-icing main roads with calcium chloride.	44% since 2006	$24,468 in 2014
City of Eagan	Start 2005	Moved from a 50/50 salt/sand mix to straight salt; eliminated purchase of safety grit; EPOKE winter chemical application technology; use AVL; pre-wet at spinner.	Not available	$70,000 annual savings
Joe's Lawn & Snow, Minneapolis	Start 2013-2014	Owner & staff Training*; purchase of new spreader, temperature sensors; equipment calibration; use of temperature data; on-going experimentation.	50%	$770 estimated cost savings in 2014 Expected to use 20 tons, only use 9 tons

Appendix B. Menu of Operational Best Management Practices: Pros and Cons

SaMS: Operational Best Management Practices – Pros & Cons

About this Document: Best Management Practices (BMPs) are defined here as any practice that promotes the most efficient and effective use of deicers either directly or indirectly through more efficient and effective plans, program organization, equipment, and/or actual practices. This document pulls together information from 31 different resources (see **References**), which include various winter maintenance best management practice manuals, research projects, industry presentations, personal communications, and success stories to provide an exhaustive list of operational BMPs and their associated pros and cons (or benefits and challenges).

How this Document is Organized: Individual practices are organized below in two major categories: 1) Planning BMPs, and 2) Storm Related BMPs. The primary difference between these two categories is that "Planning BMPs" typically are not performed during a storm, where as the "Storm Related BMPs" are used during a storm. Underneath each major category are groupings of BMP types. Each grouping of BMP type may have one or more individual BMPs described. The individual BMPs are organized by the operational audience for which the BMP(s) apply. The different audiences include:

- **All Audiences**, or any winter maintenance operation, regardless of the type(s) of surface the operation treats
- **Transportation Audiences**, or winter maintenance operations that treat roads and/or highways, and
- **Property Management Audiences**, or winter maintenance operations that treat parking lots, sidewalks, and/or any other surface associated with a property

Where appropriate, the BMPs are organized chronologically and/or sequentially (e.g., Anti-icing will occur before plowing). For a full list of the BMPs and their order in this document, see the "Outline of Practices" on the next page.

How to Use this Document: Using the Outline of Practices, users can select items that are of interest and read about the BMPs and their associated pros and cons. Understanding that all operations are unique, the pros and cons associated with each BMP are provided to help users choose what BMPs will work best for them. Where pros and cons come with costs, cost savings, and/or material savings, those resources are footnoted. Additionally, when BMPs are referenced throughout the document, hyperlinks to the sections that describe their details are provided for easy navigation. During the development of this document, it was recommended that the Salt Institute's **Fundamental 5** and **Second 6** deicer application BMPs be highlighted to help provide examples of BMPs that can be implemented in the short-term with little to no financial investment **(Fundamental 5)**, or over the long-term **(Second 6)** where they require equipment, tools, and/or specific training to implement. These application practices are highlighted in the Outline of Practices and throughout the document with a "**(Fundamental 5)**" or "**(Second 6)**" next to the applicable practices. The specific **Fundamental 5** and **Second 6** are outlined below and more information on these 11 application practices can be found here: https://www.youtube.com/watch?v=bzjLGAAypPI

Fundamental 5:

1. Calibration
2. Measurement
3. Accountability
4. Level of Service
5. Training

Second 6:

6. Variable Application Rates
7. Forecasts
8. Cold Temperature Usage
9. Liquid Usage
10. Pre-Wetting
11. Anti-icing

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1 Planning Practices

1.1 Winter Maintenance Planning (Fundamental 5 – Accountability)

1.1.1 All Audiences

1. *Develop a Winter Maintenance Plan:* and Review the Winter Maintenance Plan with crew and managers. Include the following components:
   - □ Defined service area(s), levels of service, and communication plans for the levels of service (see **"Levels of Service"** section).
   - □ Outlined operational activities for pre-winter procedures, pre-storm planning procedures, during storm procedures (including application rate guidelines), post-storm procedures, and post-winter procedures.
   - □ Established goals for reducing negative impacts of deicers. In this evaluation identify any salt sensitive areas (e.g., drinking water source water watersheds) for special protection.
   - □ Inventory resources and evaluate improvement opportunities. Resources should include, but are not limited to existing equipment, types of winter materials and their use, storage facilities and storage/handling practices, and BMPs currently in use.
   - □ Identify opportunities for improvement and develop a timeline and objectives for achieving those improvements. Identify new equipment needs and develop a long-range capital investment plan.
   - □ Establishment of a training program to foster efficient operations and pursue long-term goals.
   - □ Plans for a continual improvement process specific to the operation.
     - **Pros:**[15]
       - Provides a practical guide for all operational staff and managers to implement.
       - Plan can be communicated to applicable stakeholders (e.g., elected officials, property managers, and attorneys), to improve understanding/support.
       - Outlines opportunities, goals, and plans to guide operational improvements for more efficient attainment of levels of service and safety. Additionally, the efficiencies will provide for more efficient deicer use, thereby reducing the associated costs and impacts (public health, environmental, and infrastructural).
     - **Cons:**
       - Requires an investment of time and planning, with associated costs.

2. *Preseason meetings:* Before the winter, hold a meeting to review the Winter Maintenance Plan, highlight any changes in operations, and revisit lessons learned from postseason meetings (see below). Where possible hold these meetings with the maintenance crew, supervisors, and management/property manager(s). Large and geographically spread operations may be better suited by having pre-season meetings for each operations office.
   - **Pros:**
     - Provides an opportunity to coordinate operations across different levels of the operation/region.
     - Provides an opportunity for advanced planning and to identify changes or issues that need resolution prior to the season.

[15] Many of the success stories in Minnesota's Chloride Management Plan reflect the benefits of holistic winter maintenance planning that identifies opportunities for new BMPs that can provide reductions in a number of areas (e.g., use of liquids before and during storms, AVL, training impacts on operator's practices, forecasting services, etc.). For examples of program benefits from the planned incorporation of multiple BMPs into an operation see section 3.5 of Minnesota's Chloride Management Plan for these success stories (MPCA 2016). https://www.pca.state.mn.us/sites/default/files/wq-iw11-06ff.pdf.

        - For operations that rely heavily on contractual staff, this may be a more viable opportunity to discuss coordination and plans than prior to storms.
        - This process can lead to more efficient achievement of levels of service and safety and/or more efficient deicer use, thereby reducing associated costs and impacts (public health, environmental, and infrastructural).
    - **Cons:**
        - Requires dedicated time for meeting, with associated costs.
        - It may be difficult to schedule a meeting where all operations staff can attend.

3. *Postseason meetings:* After the season is done, evaluate how well the season went, what worked, and what could be changed to improve operations. Where possible hold these meetings with the maintenance crew, supervisors, and management/property manager(s). Large and geographically spread operations may be better suited by having postseason meetings for each geographically different office.
    - **Pros:**
        - Provides an opportunity for all members of the operation to share insight/observations.
        - Provides a process for a continuous improvement.
        - Provides a group learning opportunity that may be more tailored and specific than general training.
        - For operations that rely heavily on contractual staff, this may be a more viable opportunity to discuss coordination and plans than prior to individual storms.
        - Insights gained from this process may lead to more efficient attainment of levels of service and safety and/or more efficient deicer use, thereby reducing costs and impacts (public health, environmental, and infrastructural) related to deicers.
    - **Cons:**
        - Requires dedicated meeting time, with associated costs.
        - It may be difficult to schedule a meeting where all operations staff can attend.

4. *Accountability at every level* of the operation provides for shared ownership and insights into all parts of the operation. The Winter Maintenance Plan should clearly state everyone's accountability. Management is accountable for decisions on storm response (i.e., type of material, number of deployed operators, etc.). Operators are responsible to follow these decisions and work within the operation's guidelines/policy. Accountability is reinforced through **pre- and post-storm meetings**, preseason and postseason meetings (#2 & #3 above), **measuring deicer use** with as much detail as possible, and maintaining records of the deicer use and other objectives/performance measures. This information supports continual improvement, where storm-by-storm and season-by-season evaluations identify opportunities for improvement.
    - **Pros:**
        - Provides a mechanism to evaluate performance and identify corrective actions/operational adjustments.
        - Provides a known structure of policy and accountability so that actions are planned and not reactive. In other words, the policy is known and decisions are accountable.
        - In some cases with safety in mind, operators may choose to use more deicer than conditions and policy require. Detailed measurement of deicer use provides a mechanism to identify these situations. In this way it has the potential to reduce the costs and impacts (public health, environmental, and infrastructural) related to excess deicer use

- **Cons:**
  - Challenges for holding **pre-and post-storm meetings** and **measuring deicer use** are described in those sections of this document.
  - Reducing flexibility to deviate from policy may result in delayed achievement of levels of service and safety. Operators may react poorly to reduced discretion in application rates.

1.1.2 Transportation Audiences

5. *Plan snowplow routes:* As a part of a Winter Maintenance Plan for an operation managing roads, plan each snowplow route strategically to maximize efficiency. Consider cycle time and levels of service when planning each route. Where possible, avoid having separate routes cross so that deicers are not plowed off and reapplied. Where routes must cross and where other special circumstances are known, highlight this information in the Winter Maintenance Plan.
   - **Pros:**
     - Provides the operators with clear expectations and accountability.
     - By strategically planning snowplow routes, levels of service and safety can be achieved more efficiently. This allows for optimizing the amount of deicer used to meet the levels of service and safety, reducing associated costs and impacts (public health, environmental, and infrastructural).
   - **Cons:**
     - It is not always possible to plan for efficient snowplow routes given the layout of the road network. Nonetheless, planning routes, documenting their characteristics, and identifying circumstances that may need special attention are beneficial.
     - Requires an investment of time and planning, which comes at a cost.

1.1.3 Property Management Audiences

6. *Visit the property before the season* and walk the property with the property manager. Inspect the property for challenging areas, deicer storage areas (if applicable), drainage issues (e.g., roof that drips on steps, downspout directed at a sidewalk, and low spots/collection areas), and clogged storm drains. Inventory issues (particularly drainage issues) and report to property manager for repair.
   - **Pros:**
     - Provides an opportunity to know the property and plan accordingly before the first storm of the season. With this advanced knowledge, spread patterns, equipment needs, and other considerations can be planned so that levels of service and safety can be achieved more efficiently, thereby reducing the associated costs and impacts (public health, environmental, and infrastructural) of deicers.
     - Provides an opportunity to highlight problems with the property manager, and document and resolve them. As a result, it is more possible to achieve of levels of service and safety goals and minimize potential liability claims.
   - **Cons:**
     - Requires an investment of time and planning, which comes at a cost.

1.2 Levels of Service (Fundamental 5)

1.2.1 Transportation Audiences

7. *Internal Level of Service Knowledge:* Have all operations staff know the levels of service for the various routes.
    - **Pros:**
        - When all staff know the levels of service, the prescribed levels of service can best be achieved.
        - Best assures that public safety will be maintained at the level that is determined by the operation.
    - **Cons:**
        - Requires additional training investment.
8. *External Level of Service Knowledge:* Inform residents and political leaders of the different levels of service.
    - **Pros:**
        - Ensures that political leaders and the residents know what to expect in terms of levels of service, and expected levels of safety.
        - Helps to reduce the demand/request for levels of service greater than what is pre-determined.
        - Reduces additional costs over what is necessary to meet levels of service.
    - **Cons:**
        - Additional costs to publish/promote public understanding of levels of service information.

1.2.2 Property Management Audiences

9. *Level of Service Agreement:* Property managers and service providers discuss and agree to levels of service standards for all winter service areas.
    - **Pros:**
        - Ensures the contractor and property manager have a common expectation, which can reduce the need for revisits and additional treatments, and minimizes unnecessary treatment costs.
        - Allows for advanced planning prior to a storm event, to limit the potential overuse of deicers (i.e., exceeding level of service). Reduced over use of deicers saves material costs and reduces impacts to public health, environmental, and infrastructural.
    - **Cons:**
        - Reaching agreement on levels of service may require additional time and costs.

1.3 Training Programs (Fundamental 5)

1.3.1 All Audiences

10. *Training:* Train all staff including managers, operators, contract employees, seasonal employees, etc. on winter operations. Important elements of a training program for both classroom and hands on training include:
    - □ Agency planning and policies for managers and operators
    - □ Understanding weather
    - □ How materials work
    - □ Materials selection for the given conditions
    - □ Proper materials storage
    - □ Proper snow and ice removal
    - □ Proactive approaches, including liquids use
    - □ Equipment choices and maintenance

- □ Calibration of equipment
- □ Environmental impacts
- □ Data collection and analysis
    - **Pros:**
        - Provides the base-level knowledge for operators to get the job done, while also providing context to the benefits and impacts of deicer use.
        - Reduced confusion during storm events, making operations more efficient and effective.
        - Successful training can reduce material use while maintaining levels of service[16], therefore reducing costs and impacts (public health, environmental, and infrastructural) from the deicers.[17]
        - Improved staff awareness of operations work, possibly identifying areas for improvement and cost savings.
        - When staff and leadership are all a part of the training, this allows for cross-pollination of ideas and comradery, and fosters a collaborative environment for continuous improvement.
    - **Cons:**
        - Training programs that cover recommended elements may likely come at a high upfront cost.
        - Challenges around staff retention, mid-season hires, or contracted support may complicate the efficacy of a training program and its long-term sustenance.

1.4 Salt Storage and Handling

1.4.1 All Audiences

11. *Storage for deicer piles:* Enclose or cover storage piles to prevent exposure to precipitation and situated on an impervious surface. Have stormwater diversions for storage piles. Collect and contain all runoff from the pile and runoff that comes in contact with deicer (including under drain systems) within a bermed basin lined with concrete or other impermeable materials, or within an underground storage tank or tanks. Practice good housekeeping around storage piles.
    - **Pros:**
        - Limits or eliminates wasted product, thereby saving costs.
        - Prevents environmental and public health impacts from deicers that enter the environment.
        - Captured salty wash water, sometimes called “green brine”, can be reused in snow/ice management operations, which can save costs.[18]
    - **Cons:**
        - These storage protections come at a high initial cost.
        - Depending on space availability, these storage provisions may or may not be possible.
12. *Storage for liquid products:* Store liquids in double walled tanks or have secondary containment in case of a leak or spill. Similarly, know the freezing point of the liquid products and prevent product freezing.

[16] Eckman et al. 2011. Conducted at a DOT in Minnesota – https://conservancy.umn.edu/bitstream/handle/11299/182377/cfans_asset_340511.pdf?sequence=1&isAllowed=y.
[17] The City of Cottage Grove, MN saw a decline in salt used per event after attending training. In the 2011-2012 winter, there was a savings of 694 tons of salt which was equal to $40,000 saved. https://www.pca.state.mn.us/sites/default/files/wq-iw11-06ff.pdf.
[18] In a Virginia DOT study, compared to the cost of disposal, significant financial benefits were observed when salt storage area stormwater was captured, processed into a brine solution, and used in road maintenance activities. All scenarios analyzed yielded a return on investment in 2-4 years. In this study, the return on investment was greater when the brine was applied directly such as in anti-icing, as opposed to pretreating/prewetting the dry salt (Craver et al. 2008). https://journals.sagepub.com/doi/pdf/10.3141/2055-12.

- **Pros:**
  - Limits or eliminates wasted product, thereby saving costs.
  - Prevents environmental and public health impacts from deicers that enter the environment.
- **Cons:**
  - For liquids, the equipment for production, storage, and application is different than the equipment needed for solids. This capital investment in this equipment presents a significant additional cost.[19]

13. *Loading/hauling of deicers:* Load deicers under cover and on a level surface. Do not overload spreading equipment to avoid spilling deicer and cover the deicer on the spreader. Practice good housekeeping around the loading area. Where deicer has spilled, recover it and return it to the stockpile.
    - **Pros:**
      - Limits or eliminates wasted product, thereby saving costs.
      - Prevents environmental and public health impacts from deicers that enter the environment.
    - **Cons:**
      - These loading protections may not always be possible depending on the site layout or equipment limitations.
      - The equipment needed to cover the deicer on the spreader comes at a cost if not already owned.

14. *Clean equipment and contain wastewater*
    - **Pros:**
      - Limits or eliminates wasted product, thereby saving costs.
      - Prevents environmental and public health impacts from deicers that enter the environment.
      - Captured salty wash water, or "green brine," can be reused in snow/ice management operations, which can result in cost savings.[20]
      - Maintains equipment and limits the corrosive impacts of deicers on the equipment, thereby reducing costs and extending the life of equipment.
    - **Cons:**
      - Requires additional staff time, which comes at a cost.
      - Requires specially designated wash areas with wastewater containment, which comes at a cost.
      - Management of wastewater comes at a cost. "Green brine," which is reused for snow and ice management may require processing before it can be used, and this may come at a cost. Wastewater that is disposed of must be done so properly, which comes at a cost.[21]

[19] This example shows that brine is made at about $0.21/gallon including labor, equipment, and material costs (Keep 2015). https://www.sima.org/news2/2015/08/01/calculating-true-costs-of-salt-brine.

[20] In a Virginia DOT study, compared to the cost of disposal, significant financial benefits were observed when salt storage area stormwater was captured, processed into a brine solution, and used in road maintenance activities. All scenarios analyzed yielded a return on investment in 2-4 years. In this study, the return on investment was greater when the brine was applied directly such as in anti-icing, as opposed to pretreating/prewetting the dry salt (Craver et al. 2008). https://journals.sagepub.com/doi/pdf/10.3141/2055-12.

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1.4.2 Property Management Audiences

15. *Storage of deicers and abrasive piles delivered to a property:* Place deicer and abrasive piles delivered to a property on an impervious surface, and if possible in a covered or indoors storage facility. If no covered or indoor storage facility is available, cover the pile with a durable waterproof material (e.g., a tarp) that prevents interaction between precipitation and stormwater. Shape the pile properly to avoid interaction with precipitation. For covered outside storage on an impervious surface, the pile should be windrowed with well-sloped sides. Conical piles are not recommended because they are difficult to cover effectively (i.e., tarps are typically rectangles). For an example of windrowed versus conical, see Fairfax County's Salt and Sand Piles Storage Guidance. Locate deicer and abrasive piles delivered to a property up-gradient, out of the path of stormwater/meltwater and away from waterbodies, wetlands, storm drains, and stormwater capture areas.
    - **Pros:**
        - Limits or eliminates wasted product, thereby saving costs.
        - Prevents environmental and public health impacts from deicers that enter the environment.
    - **Cons:**
        - These storage protections come at a low cost, but may present logistical challenges.
        - Selecting the appropriate site may close off areas of the property that have high usage.

16. *Storage and handling of deicer bags:* Protect deicer bags from precipitation, and locate them up-gradient, out of the path of stormwater/meltwater and away from waterbodies, wetlands, storm drains, and stormwater capture areas. When done with the deicer bags, dispose of them in a lined/contained receptacle.
    - **Pros:**
        - Limits or eliminates wasted product, thereby saving costs.
        - Prevents environmental and public health impacts from deicers that enter the environment.
    - **Cons:**
        - These storage protections come at a low cost, but may present logistical challenges.
        - Selecting the appropriate site may close off areas of the property that have high usage.

1.5 Calibration (Fundamental 5)

1.5.1 All Audiences

17. *Establish a calibration process* for all salt application equipment that takes into account flow settings, conveyor/auger and spinner speeds, ground speed, and material (size, density, etc.). Standardize application rates across equipment types.
    - **Pros:**
        - Allows for flexibility across a diverse set of equipment, and provides certainty among similar equipment types.
    - **Cons:**
        - Additional cost/time investment to address different equipment separately.

18. *Calibrate equipment* (solid and liquid dispensers) in the preseason, mid-season, and any time changes are made to equipment or change is made to the material (including dry deicer to pretreated/pre-wetted salt). Calibrate application rates for minimum required deicer output. Document settings, rates, and maximum deicer output in manuals, site binders, and include in training. Calibrate/test new material.

- **Pros:**
  - Relatively simple process that requires only a few pieces of inexpensive equipment (e.g., tarp, bucket, and scale).
  - Calibrated spreaders help to achieve target application rates, especially when equipment is calibrated for the minimum required deicer output. This promotes efficient use of deicer and enables a more precise actual application rate, which allows for a more efficient achievement of levels of service and safety. Efficient deicer use reduces material costs and reduces the impacts (public health, environmental, and infrastructural) from the deicers.[22, 23]
  - Direct costs for additional staff/contractor time to calibrate equipment (typically 1-3 staff members for 10-60 minutes, based on a nationwide survey)[24] may offset through a reduction in excess deicer use (from uncalibrated spreaders).
- **Cons:**
  - Requires cost investment in training.
  - Calibrating equipment requires additional staff/contractor time to complete, and therefore may involve an increase in direct costs.
  - For operations with a large equipment fleet, significant resources are needed to calibrate equipment, especially over multiple times in the season.

1.6 Pre- and Post-Storm Meetings to Review Plans and Performance

1.6.1 All Audiences

19. *Pre-storm meetings:* Before a storm begins, review operations plans, highlight any potential challenges and associated solutions that the forecasted storm may present, and revisit lessons learned from post-storm meetings (see below). Where possible hold these meetings with the maintenance crew, supervisors, and management/property manager(s), and any partner operations. Large and geographically spread operations may be better suited by having pre-storm meetings for each operations office.
    - **Pros:**
      - Provides an opportunity to coordinate operations across different levels of the operation/region.
      - Provides an opportunity for advanced planning and a more strategic storm response.
      - It is possible that this process can lead to efficient achievement of levels of service and safety and/or efficiencies in deicer use, thereby reducing costs and impacts (public health, environmental, and infrastructural) related to deicers.
    - **Cons:**
      - Requires dedicated time for meeting, which may come at an additional cost.
      - It may be difficult to schedule a meeting with all operations staff.
      - Depending on the nature of the storm, there may not be time to hold a pre-storm meeting before each storm event.
      - May not be possible or productive for operations that rely heavily on contractual support. In such cases, preseason meetings to review plans and coordinate operations may be more appropriate.

[22] The City of Waconia, MN reduced salt use by 70% by implementing calibration and equipment changes (MPCA 2016). https://www.pca.state.mn.us/sites/default/files/wq-iw11-06ff.pdf.
[23] A small agency in Wisconsin saved $75,000 after calibrating their spreaders and realizing a huge discrepancy in application rates (Nixon 2017).
[24] Fay et al. 2013a – https://transportationops.org/research/revised-chapter-8-winter-operations-and-salt-sand-and-chemical-management-final-report.

20. *Post-storm meetings:* After the storm event is done, evaluate what was done, how well it worked, and what could be changed to improve operations. Where possible, hold these meetings with the maintenance crew, supervisors, and management/property manager(s), and any partner operations. Large and geographically spread operations may be better suited by having post-storm meetings for each operations office.
    - **Pros:**
        - Provides an opportunity for all members of the operation to share insight/observations.
        - Provides a process for a continuous improvement.
        - Provides a group learning opportunity that may be more tailored and specific than general training.
        - Insights gained from this process can lead to efficient achievement of levels of service and safety and/or identified efficiencies in deicer use, and reduce costs and impacts (public health, environmental, and infrastructural) related to deicers.
    - **Cons:**
        - Requires dedicated time for meeting, which may come at an additional cost.
        - It may be difficult to schedule a meeting with all operations staff.
        - There may not be time to hold a post-storm meeting after each storm event.
        - May not be possible or productive for some operations that rely heavily on contractual support. In these cases, an end of season evaluation or informal storm performance assessment may be more appropriate.

1.7 Weather Forecasting (Second 6)/Surface Temperature Information

1.7.1 All Audiences

21. *Weather Forecasting:* Obtain accurate forecasts that detail the 1) start of precipitation, 2) type of precipitation, 3) total precipitation expected/storm intensity, 4) expected event length, 5) wind conditions (speed, gusts, directions), and temperature trends. Where possible share forecasts with partner operations and seek additional forecasts. Evaluate actual storm conditions relative to the forecasts.
    - **Pros:**
        - Provides storm start information so that anti-icing can be planned and implemented, equipment can be staged, and other actions can be taken to minimize the time snow/ice has to bond to the pavement. A good forecast can allow operations to be efficient with resources, thereby reducing costs. Additionally, efficiencies realized in deicer use can minimize the associated impacts (public health, environmental, and infrastructural).
    - **Cons:**
        - Weather forecasting, while frequently improving, is still only a prediction that is subject to change. This is especially the case for forecasts issued well in advance of a storm, which influence decisions around anti-icing (e.g., should an operation anti-ice, if so, how should it be done).
        - While there are free forecasting services (e.g., https://www.weather.gov/), some must be procured at an additional cost.

22. *Know the surface temperature:* Use equipment and/or remote technology to know the temperature of the surface that will/may be treated with deicers. Use this information to determine the appropriate application rate

for the conditions (in addition to precipitation rate and type, and cycle time/bare pavement regain time – see **Varying Application Rates to Conditions**). Options for measuring the surface temperature in the field include mounted infrared thermometers or hand-held infrared thermometers that can accurately measure in cold temperatures (important to verify). Additionally, infrared thermometers can be installed in the field and programmed to share surface temperature remotely through an internet connection. A sophisticated example of this is a Road Weather Information System (RWIS), which also measures and shares atmospheric data.

- **Pros:**
  - Knowing the surface temperature allows operators to determine the optimal application rate, therefore allowing for efficient use of deicers. With efficient use of deicers, the associated costs are reduced and the impacts (public health, environmental, and infrastructural) are minimized.[25]
  - Although sophisticated systems like RWIS are large investments, studies looking at DOTs in Indiana and Idaho have shown that there is a 3.8 benefit cost ratio to the purchasing agency.[26]
- **Cons:**
  - All sensors and technology if not currently owned, come at a cost. In particular, sophisticated systems like RWIS come at a large installation, maintenance, and operation cost.
  - The relationship between surface temperature and deicer application rate may involve training, with associated costs.

1.8 Enhanced Equipment/Technology (not previously mentioned)

1.8.1 All Audiences

23. *Plows:* Make use of plows that maximize the plow-able area. Examples include 1) side wing plows (to increase plow-able area per truck), tow plows (to increase plow-able area per truck), and flexible or sectional blades (to maximize the contact between the plow on uneven surfaces).[27]
    - **Pros:**
      - Provide the most efficient removal of snow/ice, therefore allowing for efficient use of deicers. Through both efficient plowing and deicing, there can be reduction in plow time and deicers used, thereby reducing their associated costs and impacts (public health, environmental, and infrastructural).
    - **Cons:**
      - If not owned, there are associated purchase, maintenance, and replacement costs.

24. *Spreaders:* Where possible, use spreaders that can deliver very low rates of deicers. Additionally, where possible, use electronic spreaders that can lock in specific application rates and can be used to collect data. For even more sophisticated and efficient deicing application, use ground controlled/speed-synchronized spreaders that are managed by a computer that uses the speedometer to determine auger or conveyor speeds for the spreader.

[25] A study conducted in Idaho found a 40% reduction in material savings due to the introduction of RWIS (ITD 2009) Actual citation no longer available; case study reported in http://clearroads.org/wp-content/uploads/dlm_uploads/Manual_ClearRoads_13-01_FINAL.pdf.

[26] Veneziano et al. 2014 – https://www.researchgate.net/publication/262103948_A_Benefit-Cost_Analysis_Toolkit_for_Road_Weather_Management_Technologies.

[27] Table 21 of Clear Roads 2015b shows the costs and benefits of various plowing types/techniques. http://clearroads.org/wp-content/uploads/dlm_uploads/Manual_ClearRoads_13-01_FINAL.pdf.

- **Pros:**
  - More sophisticated spreaders, allow for more versatile and precise application of deicers. Sophisticated spreaders enable more efficient deicer use and reduce costs and impacts (public health, environmental, and infrastructural).
  - The more sophisticated the spreader, the more possible it is to attain levels of service and safety accurately and promptly.
  - If the spreader collects data on the deicer use, it is possible to evaluate whether or not target application rates were achieved and determine any areas where efficiencies can be realized and costs minimized (for more information see **Measuring Deicer Use**)
- **Cons:**
  - If not owned, there are associated purchase, maintenance, and replacement costs.

25. *Equipment needed for making liquid products:* In order to make and store liquid products, operations minimally need 1) an open top mixing tank, 2) a holding tank, 3) pumps to transport liquid from mixing tank to holding tank and from holding tank to the applicator tank, and 4) a salimeter or a hydrometer to measure the salinity or density of water, respectively. If the tanks are not double walled, then some sort of secondary containment structure is required.
    - **Pros:**
      - With the proper equipment, liquid products can be made accurately and ready for use when needed. Accurately prepared liquid products (i.e., the proper **eutectic concentration**) allow efficient product use, and reduce associated costs and impacts (public health, environmental, and infrastructural).
      - Having liquid products on hand, **anti-icing**, **pretreating, prewetting, and direct liquid application** are all possible. Click on the links to see the associated "Pros."
    - **Cons:**
      - The equipment needed to make liquid products comes at a high cost. Because of the need for specific equipment, it may take more than one winter season to recover the investment.

1.8.2 Transportation Audiences

26. *Automated Vehicle Location (AVL)* can track the position, spreader rate, and plow activity of different snow plows in the fleet. With this information, it can show results live to supervisors, other plow operators, and the public. All of the data collected can be reported to a database.
    - **Pros:**
      - Can increase efficiency/reduce waste in operations, reducing the costs and impacts of deicers (public health, environmental, and infrastructural).
      - Provides information to ensure and possibly improve achieving levels of service and safety.
      - Providing the location of plow trucks can inform the public of service expectations. This has the potential to limit resource strains during a winter storm event.
      - The City of Eagan, MN realized with AVL, snowplow operators could inform police of cars remaining on streets during emergencies. This improved the mechanical removal of snow.[28]
      - Reduces the paperwork associated with operations, and associated costs.

[28] MPCA 2016 – https://www.pca.state.mn.us/sites/default/files/wq-iw11-06ff.pdf.

- Records deicer use, which provides information to evaluate whether or not target application rates were achieved, and highlights areas where efficiencies can be realized and therefore costs minimized (for more information see **Measuring Deicer Use**). Can also provide information for **post-storm** or **postseason** meetings that can result in more efficient operations.

- **Cons:**
  - Costs associated with hardware and software are high, and therefore may take more than one winter season to recover.

27. *Maintenance Decision Support System (MDSS):* Using existing and new data (weather, road conditions, etc.) this tool, originally developed by the Federal Highway Administration, integrates data and generates diagnostic and prognostic maps of road conditions, in addition to a decision support tool that provides recommendations on road maintenance actions (e.g., treatment types, timing, rates, and locations).
    - **Pros:**
      - Can reduce deicer use, improve scheduling/assignment of personnel, and generally improve decision making, thereby reducing associated costs and impacts of the deicer (public health, environmental, and infrastructural).[29]
      - Can reduce the number of vehicle round trips to meet levels of service, thereby providing more prompt levels of service and safety at a reduced cost.
      - Can also work as an effective training tool through simulated services.
      - Provides an evaluation tool for performance measures, thereby providing information for **post-storm** or **postseason** meetings that can result in more efficient operations.
    - **Cons:**
      - Requires good weather prediction inputs and properly sited and appropriately maintained environmental sensor stations. If input information is inaccurate, then the MDSS will generate unreliable outputs.
      - There are costs associated with MDSS (unknown at this time as the vendor transitions from research to production), weather forecast provider, and internal agency support costs (e.g., computers and training).

28. *Precision Deicing:* This new technology is being piloted by Oak Ridge National Laboratory in Knoxville, and integrates LIDAR data, road condition index (severity based on road angles/curves and solar radiation), precipitation data, AVL, and automated spreaders into a MDSS like system. In essence, precision deicing dynamically adjusts application rates of chemicals/liquids based on site-specific, local road conditions and characteristics.
    - **Pros:**
      - Can reduce deicer use thereby reducing associated costs and impacts of the deicers (public health, environmental, and infrastructural).
      - Can reduce the number of vehicle round trips to meet levels of service, thereby providing more prompt levels of service and safety at a reduced cost.
    - **Cons:**
      - Requires sophisticated and detailed data inputs (e.g., LIDAR) and the collection of that data comes at a high initial cost.

[29] For the Minnesota DOT the use of MDSS in conjunction with AVL had an average savings of 53% or $2,308,866, which is equivalent to a reduction of 38,000 tons of salt (MPCA 2016). https://www.pca.state.mn.us/sites/default/files/wq-iw11-06ff.pdf.

- While promising and functionally similar to MDSS, the actual benefits and costs are unknown at this time since this is a pilot system.

2 Storm Related BMPs

2.1 Anti-Icing (Second 6)

2.1.1 All Audiences

29. *Anti-icing* surfaces with liquids or solids prevents or significantly reduces the bonding of snow and ice to pavement, which makes plowing/shoveling much more efficient and complete. Anti-icing with liquids (e.g., brines) is the most efficient form of anti-icing which can be done up to 48 hours in advance of the start of snow/ice fall, and it uses significantly less deicer than solids. However, anti-icing with solids can work better if the event may start as rain or freezing rain since the salt crystals last longer. Anti-icing with solids is best done with pre-wet or pretreated deicer (see below).
    - **Pros:**
        - Anti-icing returns surfaces to safe conditions faster, resulting in less delay/risk for accidents/slips and falls on surfaces. One study showed an 85% reduction in crashes compared to a de-icing only strategy.[30]
        - When anti-icing with liquids, the liquids stick to the surface and are not blown away, allowing deicers to be used efficiently.
        - Anti-icing is a proactive approach to snow and ice management that allows flexibility for mobilization since it starts working once the snow falls, even if the snow is delayed or comes earlier than predicted.
        - Reduction in material needs since the bond between snow and ice is prevented, and therefore reduced material costs [31,32] and impacts (public health, environmental, and infrastructural).[33]
    - **Cons:**
        - For liquids, the equipment for production, storage, and application is different than the equipment needed for solids. This capital investment in this equipment presents a significant additional cost.[34]
        - Pre-storm mobilization may come at an additional cost, but also may be offset by less need for plowing and deicing during/after the storm.

[30] Clear Roads 2015a – http://clearroads.org/wp-content/uploads/dlm_uploads/0537_2015-Clear-Roads-Best-Practice-Guide-WEB.pdf.
[31] Reported 75% savings versus deicing a roadway that has become ice bonded (Clear Roads 2015a). http://clearroads.org/wp-content/uploads/dlm_uploads/0537_2015-Clear-Roads-Best-Practice-Guide-WEB.pdf.
[32] The North Fayette Township in Pennsylvania saved 35% of their winter maintenance operations costs when they started anti-icing with brine (SPC & PaDEP 2016). https://spcregion.org/water/pdf/WinterMaintenanceBMPs.pdf.
[33] Six cities in the Rice Creek Watershed (MN) collaborated to purchase anti-icing equipment and hold training for the equipment. The six cities reduced their salt use by 32% as a result. At $50/ton of salt, that equated to $26,400 saved (MPCA 2016). https://www.pca.state.mn.us/sites/default/files/wq-iw11-06ff.pdf.
[34] Calculating the labor, equipment, and material costs, this example shows that brine is made at about $0.21/gallon (Keep 2015). https://www.sima.org/news2/2015/08/01/calculating-true-costs-of-salt-brine.

2.2 Plowing Practices

2.2.1 All Audiences

30. *Plowing early and often* is the best defense to prevent snow and ice from bonding to pavement. To the extent possible, it is better to remove snow/ice by plowing than using deicers to "burn off" any accumulations. Additionally, depending on the conditions (i.e., precipitation rate/type), keeping up with snow/ice accumulations through frequent plowing limits the time for snow/ice to compact and bond with the pavement. When plowing, avoid placing snow into bodies of water, wetlands, or stormwater infiltration/retention structures.
    - **Pros:**
        - As a core practice in all snow and ice management operations, implementation comes with no start-up costs.
        - Plowing at a rate appropriate to minimize the bonding of snow/ice to the surface reduces the amount of deicer needed to break that bond. This cuts material costs and reduces the impacts (public health, environmental, and infrastructural) from the deicers.[35]
    - **Cons:**
        - Challenges to plowing early and often may include resource limitations (e.g., equipment, staff, etc.) and the rate and type of precipitation. Overcoming these resource limitations increases equipment and/or staff costs.
        - More frequent plowing may cause damage to surfaces and equipment (e.g., blades, trucks, etc.)

2.2.2 Transportation Audiences

31. *Coordinate plowing activities* to prevent plowing off another operator's material.
    - **Pros:**
        - Maintains levels of service and public safety by keeping the applied deicer working.
        - Reduces the need for more deicers to replace those plowed off. This cuts material costs and reduces the impacts (public health, environmental, and infrastructural) from the deicers.
    - **Cons:**
        - Requires advanced planning and coordination, which may not always be possible in certain storm events.

32. *Plow Train:* On multilane highways use a plow train to remove as much snow as possible in one coordinated sweep. In this practice, trucks are arranged in a staggered order and continue down all lanes of the highway in a coordinated sweep.
    - **Pros:**
        - Reduces the need for successive passes of the same highway, allowing for increased public safety and potential cost savings.
        - Reduces the need for more deicers, by more effectively clearing snow/ice. This cuts material costs and reduces the impacts (public health, environmental, and infrastructural) from the deicers.
    - **Cons:**
        - Requires cost investment in specialized training so that deicer is applied in areas that won't be plowed up by trucks behind the lead trucks.

[35] A case study in Otterburn Park, Quebec reported a significant salt reduction of 73% through the implementation of effective plowing practices and improved training (Environment Canada 2000). Actual citation no longer available; case study reported in http://clearroads.org/wp-content/uploads/dlm_uploads/Manual_ClearRoads_13-01_FINAL.pdf.

- Requires multiple plows on one route, thereby taking plows off other routes.

2.2.3 Property Management Audiences

33. *Choose the right plow, shovel, pusher, blower, blade, or broom for the property.* Recommendations for plows, shovels, pushers, blowers, blades, and brooms are provided in **Table 15** through **Table 17**.

Table 15. Estimates of plowing area by equipment type.

Plowing Equipment Area per Hour Estimates (based on 2-3 inches of snow)
Pickup truck can clear between 30,000 and 43,000 ft^2 per hour depending on the difficulty of the site.
Skid steer with an 8-10 ft pusher box can clear between 50,000 - 65,000 ft^2 per hour depending on the difficulty of the site.
Backhoe with a 14 ft pusher box can clear between 90,000 - 125,000 ft^2 per hour depending on the difficulty of the site.
Front-end loader with a 14 ft pusher box can clear between 95,000 - 125,000 ft^2 per hour depending on the difficulty of the site.

Table 16. Equipment selection based on site size.

Type of Equipment to Use Based on Site Size
Pickup truck (0 - 172,000 ft^2)
Skid Steer (172,000 to 300,000 ft^2)
Backhoe (390,000 - 520,000 ft^2)
Front-end loader (520,000+ ft^2)

Table 17. Sidewalk equipment selection basaed on clearing ability per hour.

Sidewalk clearing equipment	Clear ability per hour (based on 2-3 inches of snow)
Shovel - 2 ft shovel	1,500 ft^2 per hour
Shovel - 3 ft snow-pushers	3,000 ft^2 per hour
Snow Blower - Broom - 24 inch	5,000 ft^2 per hour
ATV - 4 ft Blade	8,000 - 12,000 ft^2 per hour
Skid Steer / Ventrac 4 ft Broom	10,000 - 21,000 ft^2 per hour

- **Pros:**
  - Using the proper clearing equipment cuts down on wasted time and associated costs while achieving intended levels of service and safety.
  - Allows for efficient time management and avoids labor costs associated with inadequate equipment choice. When an operation is managing multiple properties, planning to use the appropriate equipment at each site can maximize the number of sites an operation can manage.
  - Reduces the strain put on equipment and/or operator. Reduces costs associated with equipment repair or replacement.

        - Allows for plowing rates that minimize the bonding of snow/ice to the surface. This reduces the amount of deicer needed to break that bond, therefore cutting material costs and reducing the impacts (public health, environmental, and infrastructural) from the deicers.[36]
    - **Cons:**
        - If the appropriate equipment is not owned, there are associated purchase, maintenance, and replacement costs.

34. *Managing stairways or areas with a small footprint #1:* Look for opportunities to close areas, and when that is not an option, use the proper tool for snow/ice removal such as a push shovel, scoop shovel, broom or blower (for light fluffy snow), ice scraper (for ice and compaction), or an ice chisel (for breaking open compaction/ice).
    - **Pros:**
        - May reduce the area that requires management, thereby reducing associated costs and impacts (public health, environmental, and infrastructural). Allows for the most efficient use of deicers thereby reducing material costs and impacts (public health, environmental, and infrastructural).
        - When managing the snow/ice, using the proper tool cuts down on wasted time and associated costs while achieving intended levels of service and safety.
    - **Cons:**
        - Requires specific snow/ice removal tool(s), which if not owned must be purchased at a small cost.

35. *Snow Placement:* Store snow plowed from properties downhill from deicer storage areas. Stops melt water from interacting with deicers.
    - **Pros:**
        - Prevents melt water from transporting deicer into storm drains and the environment.
        - Eliminates the waste of deicer transported in melt water, and not used for deicing/anti-icing.
    - **Cons:**
        - Viable spaces for snow storage may limit parking or other property use. Property manager may not accept this loss of use.
        - Viable spaces for snow storage may be in areas that drain directly to a waterbody. Since the snow may have salt and/or other pollutants in it, this may increase the impacts to the waterbody.

[36] A case study in Otterburn Park, Quebec reported a significant salt reduction of 73% through the implementation of effective plowing practices and improved training (Environment Canada, 2000). Actual citation no longer available; case study reported in http://clearroads.org/wp-content/uploads/dlm_uploads/Manual_ClearRoads_13-01_FINAL.pdf.

2.3 Product Application Practices

2.3.1 All Audiences

36. *Dyed deicers:* Use dyed deicers to observe and show product presence.
    - **Pros:**
        - Allows for a visual confirmation of deicer coverage. Often times, once the deicer has gone into solution, or even when it blends in with the snow/ice, more deicer than is necessary may be applied due to inaccurate visual assessments by third-parties (e.g., members of the public, customers, etc.). With dye in place, the extent of treated areas is easy to confirm, allowing for cost savings on deicers not applied in excess.
        - Some dyed deicers are colored with an anti-corrosion inhibitor (e.g., Prussian Blue) and therefore may cause less damage to surfaces/property and reduce maintenance or mitigation costs.
        - Some dyed deicers are colored with anti-caking agents (e.g., Prussian Blue), which allows for more predictable deicer movement. Target application rates and levels of service are more obtainable with the anti-caking agents.
    - **Cons:**
        - Some dyed deicers are colored with pigments containing cyanide (e.g., Prussian Blue), which may become mobilized when in solution. While the environmental impact from the cyanide is not well studied, it may present human health and environmental impacts.
        - Some dyes can stain and/or be tracked into untreated areas, potentially causing damages with associated costs.

37. *Use of Abrasives:* For most circumstances, either use abrasives or deicers, but not both combined. There are a narrow set of circumstances where a 50/50 blend of deicers and abrasives can be used, but this practice should be limited to those circumstances defined by the organization. Otherwise, do not mix deicers and abrasives (except to keep the abrasives from freezing/clumping) because one of the products will only be half as effective. Abrasives work best on top of snow/ice to provide traction. However, if deicer is mixed in significant proportions (e.g., 50/50) to the abrasive, the deicer will melt the snow/ice and the abrasive will no longer work as well. Generally, abrasives alone should be used to provide traction during 1) freezing rain events, 2) in slow-moving traffic areas, and 3) when deicers are ineffective because it is too cold.
    - **Pros:**
        - By only using abrasives when deemed appropriate, the function of the abrasive will last until the snow/ice melts naturally. As a result, the abrasive material that was applied will function 100% of the time it is needed.
        - If temperatures are too cold for deicers to work, the use of only abrasives ensures that deicers will not be used in a situation where they are plowed up before ever melting the snow/ice.
    - **Cons:**
        - There are situations where an abrasive/deicer mix may maximize the operation's results, by strategically stretching resources. For example, storms with temperatures that start too cold for effective deicing, but that change to a temperature within the effective range of the deicer. In these cases, an abrasive/deicer mix may provide for an efficient return to levels of service with limited resources.

38. *Post-storm clean-up:* clean-up left over deicers/abrasives after the snow/ice has melted away.
    - **Pros:**
        - By cleaning-up left over deicers/abrasives, the potential impacts (public health, environmental, and infrastructural) from the left over deicers/abrasives are prevented.
        - If routine post-storm clean-up is a practice, areas of excess application may be identified and practices can be refined in those areas. If this evaluation is possible, then there may be associated reductions in material costs and impacts (public health, environmental, and infrastructural).
    - **Cons:**
        - Post-storm clean-up is an additional operational step in winter maintenance operations and comes at an additional cost.

2.3.2 Transportation Audiences

39. *Spinner set-up:* Use a chute or set spinners closer to the ground to reduce bounce and scatter.
    - **Pros:**
        - Allows for efficient use of deicers therefore reducing material costs and impacts (public health, environmental, and infrastructural).
    - **Cons:**
        - May not be possible on all equipment. If equipment presents a challenge, then new equipment purchases will come at a cost.

40. *Drive 17-25 mph* when applying deicer to keep material on road.
    - **Pros:**
        - Allows for efficient use of deicers thereby reducing material costs and impacts (public health, environmental, and infrastructural).
    - **Cons:**
        - May not be possible to maintain these speeds at all times and on all roads.

41. *On high-speed roads*, apply deicers in center of road or high side of curve
    - **Pros:**
        - Allows for efficient use of deicers thereby reducing material costs and impacts (public health, environmental, and infrastructural).
    - **Cons:**
        - May not be possible to apply in these locations at all times and on all roads.

42. *Turn off auger, shoot, or conveyor when stopped*, even briefly
    - **Pros:**
        - Allows for more precise use of deicers, and reduces material costs and impacts (public health, environmental, and infrastructural).
    - **Cons:**
        - May not be possible on all equipment. If equipment presents a challenge, then new equipment purchases will come at a cost.

43. *Reduce deicer application rate on successive passes* to leverage deicing capacity of the remaining deicer.
    - **Pros:**
        - Allows for efficient use of deicers thereby reducing the associated material costs and impacts (public health, environmental, and infrastructural).
    - **Cons:**
        - May involve some trial and error, and if the operation chooses to audit the experimental applications, there will be associated costs (e.g., staff time).

2.3.3 Property Management Audiences

44. *Spread patterns:* Survey the property and develop and utilize a spread pattern that prevents applying deicers over areas that have already been treated.
    - **Pros:**
        - Allows for efficient use of deicers thereby reducing material costs and impacts (public health, environmental, and infrastructural).
    - **Cons:**
        - Requires advanced planning, which may not always be possible and may come at an additional cost.

45. *Spreaders for sidewalks:* Use drop spreaders or rotary spreaders with shields to prevent spreading deicer off of the sidewalk.
    - **Pros:**
        - Allows for efficient use of deicers thereby reducing material costs and impacts (public health, environmental, and infrastructural).
    - **Cons:**
        - Requires specific equipment, which if not owned must be purchased at a cost.

46. *Managing stairways or areas with a small footprint #2:* To apply deicer in these small areas, calculate the area, and using an application rate chart to calculate the total amount of deicer to be applied over that area (Amount = Application rate * Area). When applying deicer in these areas, use a hand-held spreader for more precise application.
    - **Pros:**
        - Allows for the most efficient use of deicers thereby reducing material costs and impacts (public health, environmental, and infrastructural).
    - **Cons:**
        - Requires specific equipment (hand spreader), which if not owned must be purchased at a small cost.

2.4 Varying Application Rates to Conditions (Second 6)

2.4.1 All Audiences

47. *Variable application rates:* Use recommended application rates that are based on the following factors: 1) pavement/surface temperature, 2) precipitation rate and type, and 3) cycle time/bare pavement regain time (i.e., levels of service). When considering these factors, target application rates will vary.

- **Pros:**
  - Allows for efficient use of deicers thereby reducing material costs and impacts (public health, environmental, and infrastructural).
  - Ensures that the appropriate amount of deicer is used to achieve levels of service and safety goals.

- **Cons:**
  - Requires more training, the cost of which can increase if staff retention is a challenge.
  - Requires adaptable equipment (i.e., spreader settings), which if not owned come at a cost.

2.5 Use of Deicers at Cold Temperatures (Second 6)

2.5.1 All Audiences

48. *Variable application rates:* Know the effective temperature ranges for all deicers used. Deicers become ineffective (i.e., take hours to work) at some point before their eutectic temperature. Develop plans for what deicers and/or abrasives to use at different temperatures, and purchase adequate amounts of the necessary deicers/abrasives to be prepared for extremely cold temperatures. At some temperatures, abrasives may be the best option as deicers may be ineffective.
    - **Pros:**
      - Allows for efficient use of deicers, thereby reducing material costs and impacts (public health, environmental, and infrastructural).
      - Ensures levels of service and safety goals are achieved, even at extremely cold temperatures
    - **Cons:**
      - Requires more training, the cost of which can increase if staff retention is a challenge.
      - Requires stockpiles of various deicers, some of which may not be used every season. These stockpiles of different, often more expensive deicers come at a high cost.

2.6 Use of Liquids (Second 6 – Liquids & Prewetting)

2.6.1 All Audiences

49. *Pretreat deicers* with a liquid, typically brine, to help material stick to surfaces and speed up the melting process. Pretreating the load in the spreader/truck bed allows for more uniform mixing. Alternatively, the entire stockpile can be treated as well, but may not be as uniformly mixed. While both pretreating and prewetting (see below) improve deicer efficiency, prewetting is the most efficient practice.
    - **Pros:**
      - Pretreated deicers bounce less and stick more to surfaces, reducing material losses due to bounce and scatter. This allows for 20-30% less material to be used[37] and reduces material costs and impacts (public health, environmental, and infrastructural).
      - Allows for lower application rates and therefore can reduce material costs and impacts (public health, environmental, and infrastructural) from deicer use.
      - Allows for efficient use in cold temperatures by providing the water necessary for the deicer to begin working (i.e., does not need to be slowly melted to become available). Therefore, pretreating allows for reduced material costs and impacts (public health, environmental, and infrastructural) from deicer use.

[37] Minnesota Local Road Research Board 2012 – http://www.mnltap.umn.edu/publications/handbooks/documents/snowice.pdf.

- **Cons:**
  - When the stockpile is pretreated, it must be stored on a covered and impervious pad because the brine that leaches from the stockpile can impact the environment. Not all operations have these sorts of facilities available, and therefore may not be possible or may come at an increased cost.

50. *Prewet deicers* to help material stick to surfaces and speed up the melting process. Prewetting involves adding liquid, typically brine, to the salt as it is being applied. This approach can work particularly well with higher liquid to deicer ratios on heavy traffic routes since the slurry can be made at the point of application and will drop directly onto the surface, working immediately. While both pretreating and prewetting allow for efficient and effective use of deicers, prewetting is the most efficient.
    - **Pros:**
      - Pretwetted deicers bounce less and stick more to surfaces, reducing material losses due to bounce and scatter. This allows for 20-30% less material to be used[38, 39] and reduces material costs and impacts (public health, environmental, and infrastructural).
      - Allows for lower application rates[40] and therefore can reduce material costs and impacts (public health, environmental, and infrastructural) from deicer use.
      - Allows for efficient use in cold temperatures by providing the water necessary for the deicer to begin working (i.e., does not need to be slowly melted to become available). Therefore, prewetting allows for reduced material costs and impacts (public health, environmental, and infrastructural).
    - **Cons:**
      - The equipment necessary to prewet deicers involves a significant investment in new and retrofitted equipment. Since prewetting happens at the auger or spreader, liquid tanks need to be added to the vehicle/machine (where space exists). Additionally, the options for mounting liquids may be driven by the type of vehicle/machine used for spreading salts, therefore limiting options for liquids and as a result the ranges of cost for the equipment.

51. *Direct Liquid Application:* Apply mixtures of water and deicer directly to a surface (Direct Liquid Application, or DLA) during or after a storm to deice immediately. Since the deicer is already in liquid, there is no lag time for the deicer solution to form as is the case when a dry (or even wet) deicer is applied.
    - **Pros:**
      - Allows for efficient use in general and particularly in cold temperatures by providing the solution that performs the deicing (i.e., does not need to be slowly melted to become the solution).

[38] Minnesota Local Road Research Board 2012 – http://www.mnltap.umn.edu/publications/handbooks/documents/snowice.pdf.
[39] A case study in Michigan observed that 96% of the pre-wetted materials were retained on the road surface, whereas only 70% of the dry material was retained on the road surface (Michigan DOT 2012). https://www.michigan.gov/documents/mdot/Final_ReportNov2012_404228_7.pdf.
[40] The City of Prior Lake, MN reduced their application rates on average from 500 pounds per lane mile of dry salt to 200-250 pounds per lane mile using prewet salt (MPCA 2016). https://www.pca.state.mn.us/sites/default/files/wq-iw11-06ff.pdf.

Therefore, direct liquid application allows for reduced material costs[41, 42, 43] and impacts (public health, environmental, and infrastructural) from deicer use.
    - Because the deicer can begin to work immediately, levels of service and safety can be achieved much faster than with other practices and across a wider variety of conditions.[44]
    - If anti-icing with liquids, the equipment to perform this practice is already available.
    - If standard practices or legal requirements require cleaning up deicer after a storm, direct liquid application minimizes post-storm cleanup, and therefore reduces associated costs.
- **Cons:**
    - For liquids, the equipment for production, storage, and application is different than that needed for solids. Therefore, the capital investment in this equipment presents a significant additional cost.[45]
    - Since there may be dilution of the liquid deicer, the eutectic concentration may need to be enriched with a follow up, light application of solid deicer. This may add to operational costs/resource demands and complicate storm event logistics.
    - This is a relatively new process, so there is limited experience with this practice. While promising, implementing this may involve more trial and error than other more tested practices.

2.7 Measuring Deicer Use (Fundamental 5)

2.7.1 All Audiences

52. *Measure and Record Deicer Use:* Using a standardized process, measure and record deicer use as frequently, accurately, and refined (e.g., per shift, site, etc.) as possible. To the extent possible, 1) use technology to accurately automate the process of measuring deicer use, and 2) measure deicer use using more than one method to verify values.
    - **Pros:**
        - Provides information to evaluate whether or not target application rates were achieved. Where target application rates were exceeded, this information can identify efficiency opportunities and reduce costs.
        - Provides information to evaluate deicer use, which can highlight areas (beyond application rates) where efficiencies can be realized and costs minimized.
        - Provides a record of performance, which may be useful in slip and fall law suits.

[41] The Maryland Highway Safety Administration uses DLA on some routes, where the average application rate is 160 lbs/lane mile/inch. The reported cost is about 14.8 cents per gallon to make (MSHA 2019). https://www.mwcog.org/file.aspx?&A=vG8T0kKoe21vtAc2C22WMtuDhFjmOWkZArTVhoqonaY%3d.

[42] City of Prior Lake used an all liquid route, where application rates equated to 100 pounds per lane mile or less (MPCA 2016). https://www.pca.state.mn.us/sites/default/files/wq-iw11-06ff.pdf

[43] Switching from solids rock salt to liquid brine was reported to have produced approximately 50% materials savings as compared to the use of solid rock salt (Fay et al. 2013b). https://www.in.gov/indot/files/Strategies_to_Mitigate_the_Impacts_of_Chloride_Deicers.pdf.

[44] The Maryland Highway Safety Administration uses DLA on some routes, where it out performs granular salt form a Level Of Service perspective (MHSA 2019). https://www.mwcog.org/file.aspx?&A=vG8T0kKoe21vtAc2C22WMtuDhFjmOWkZArTVhoqonaY%3d.

[45] Calculating the labor, equipment, and material costs, this example shows that brine is made at about $0.21/gallon (Keep 2015). https://www.sima.org/news2/2015/08/01/calculating-true-costs-of-salt-brine.

- **Cons:**
  - Requires additional planning and administrative actions to measure, record, and maintain records of deicer use, with associated costs.
  - Significant costs for manual data tracking and recording for large operations. While new measurement/recording technology has promise, integrating new technology into operations requires additional training and investment costs.

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Appendix C. Planning to Implement Winter Maintenance Best Management Practices in Phases: A Continual Improvement Process

Planning to Implement Winter Maintenance Best Management Practices in Phases: A Continual Improvement Process

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1 Goal of this Process

Winter maintenance planning is an extensive process that covers a number of aspects important to successfully preparing, executing, and improving operations. The process outlined below does not cover the winter maintenance planning process entirely. Instead it focuses on a critical portion of winter maintenance planning aimed at reducing excess salt use. Therefore, the purpose of this process is to identify Best Management Practices (BMPs) that can be implemented in the **short-term** and over the **long-term** to achieve the Salt Management Strategy (SaMS) goal of reducing excess salt use.

In order to ensure the success of any winter maintenance planning, including this BMP planning portion, the winter maintenance plans must be discussed with decision makers. As a part of this discussion, the crucial tie between levels of service and the winter maintenance plan must be highlighted.

2 Short-term and Long-term BMPs

While every operation is different, this process assumes that every operation has room for improvement and can therefore identify both short-term BMPs and long-term BMPs through a continual evaluation and improvement process that is described in detail below. Short-term BMPs include any BMPs that can be implemented with little to no major changes in the operation. Alternatively, long-term BMPs may take some long-term planning to accommodate the changes necessary to bring the BMP into regular operation. To help illustrate the difference, the Salt Institute's Fundamental 5 and Second 6 BMPs can provide examples of short-term versus long-term BMPs. Using these examples, the Fundamental 5 BMPs, which include Calibration, Measurement, Accountability, Level of Service, and Training, can be implemented in the short-term with little to no financial investment. On the other hand the Second 6 BMPs, which include Variable Application Rates, Forecasts, Cold Temperature Usage, Liquid Usage, Pre-wetting, and Anti-icing, require equipment, tools, and/or specific training to implement. For more information on the Fundamental 5 and the Second 6 BMPs click https://www.youtube.com/watch?v=bzjLGAAypPI to see the presentation that outlines these given by Dr. Wilf Nixon of the Salt Institute.

3 Example Forms for Tracking Salt Use and BMP Implementation

The SaMS Toolkit includes example forms (**Appendix J**) to support internal tracking of winter maintenance operations, salt product and BMP usage, and how effectively the BMPs used achieved levels of service goals and efficient use of winter salts. These forms can be very helpful in compiling much of the information needed to reap the benefits of the recommended continual improvement process described below.

4 Phase I: Assess Current Practices, Set Goals, Choose Initial Actions for Improvement

In order to improve a Winter Maintenance Program the first step is to try to understand what is currently being done and identify where practices can be improved. Therefore, setting a baseline for current resources and practices at a facility will be essential. Once the current operations are understood steps can be taken to improve on existing operations in order to meet a set goal.

Self-Assessment Worksheet was used to assist in constructing the iterative process for improvement.

In Phase I of the assessment, current operations should be documented in a Winter Maintenance Plan to include site maps and the following aspects:

1. Define the Service Area
    a. Define areas where winter maintenance occurs (acres, lane miles, storage, etc.)
    b. Define the Level of Service based on locations to be treated (roads, sidewalks, parking)
    c. Define Key personnel and their duties in the overall process (managers, operators, contract, seasonal, etc.)
2. Determine a baseline for application rate control based on current practices (this can potentially be used to determine progress towards the goals set)
    a. Define current equipment types, calibration protocols, and tracking procedures
    b. Define current salt application rates (see Application Rate Evaluation Process in **Appendix D** for examples) and measuring/tracking procedures
    c. Define current training program and measuring/tracking procedures
3. Determine other operational controls in place for minimizing the impacts of salts to the environment
    a. Are liquid materials used?
    b. Are low or non-chloride practices used?
    c. How is salt being stored?
    d. How are sand/salt mixtures mixed and stored?
    e. How are liquid materials stored?
    f. How are materials handled in the off-seasons?
    g. Is plowing used and when?
4. Use information collected and documented above to evaluate operations and determine areas for improvement based on the self-assessment worksheet (the goal here would be to have a program where all aspects of the worksheet are rated at the best level of 4)
    a. Identify the categories of the worksheet where the facility rated below a level of 4
    b. For each category rated below a 4 – Identify short-term and long-term actions that can be taken to improve that particular category. For a list of over 50 winter maintenance BMPs and their pros and cons, see **Appendix B**.

c. Define a proposed schedule of implementation for each action (BMP) defined in 4.b.
d. Define measurable goals for each action defined in 4.b. (e.g., ensure 100% of equipment is fitted with calibration units by year 5, ensure 100% of personnel are trained annually)

5 Phase II: Implement Facility Salt Management Plan, Track Progress, Reevaluate

Once current practices are understood and achievable goals are set, there should be continuous monitoring, tracking, evaluation, and internal reporting of progress toward achieving the organization's goals. This will ensure accountability by all levels of the organization. Additionally, the program should be set up to work with the iterative process since not all operations are equal and not all BMPs will work for all operations.

In Phase II, the Plan and all actions proposed should be evaluated for their effectiveness in reference to the facility and its operations. The following should be evaluated:

1. Service Area
    a. Has the amount of treated surfaces changed?
    b. Has the Level of service changed?
    c. Have Key Personnel changed?
    d. If not established during Phase I:
        i. Develop a Site Map
            1. Areas to be serviced
            2. Environmentally sensitive areas
            3. Snow storage location(s)
            4. Hazard areas
        ii. Develop an inspection/maintenance schedule to identify factors that can work against the goal (e.g., drainage issues and snow storage location(s))
2. Application Rate Control
    a. Equipment and Calibration
        i. Has the type or amount of equipment changed?
        ii. Have any BMPs been implemented as a part of Phase I?
        iii. What is the progress of BMP implementation and has implementation led to improvements?
        iv. Have equipment been fitted with additional measures (GPS, chutes, sensors)?
        v. If not established during Phase I:
            1. Define when and how equipment should be calibrated
            2. Define what the equipment should be calibrated to
            3. Define how calibration records will be maintained
    b. Salt Application Rates
        i. What application rates were achieved during Phase I (see **Appendix D** - Application Rate Evaluation Process)?
        ii. Have any BMPs been implemented as a part of Phase I?
        iii. What is the progress of BMP implementation and has implementation led to improvements?
        iv. Are/can mechanical techniques like plowing/shoveling be used? When does plowing/shoveling occur? How often should plowing/shoveling occur?

v. Are/can liquid materials used (pre-mixing, pre-wetting, anti-icing)? When will these techniques be used? What concentrations should be used in brine? How will brine be prepared, measured, recorded to ensure proper concentration?
vi. Have Variable Application Rates been considered or implemented? What will be considered in order to determine the variable rates?
vii. If not established during Phase I:
    1. Define the maximum/acceptable application rate
    2. Define when salt would be applied
    3. Define when and how application rates can be adjusted
    4. Define what resources would be used in determining application rates such as (precipitation, pavement temp, etc.)
    5. Define how and when application rates are tracked (by event, by lane mile, by surface type, etc.)
    6. Define how application rates will be tracked (sensors, weight, etc.)

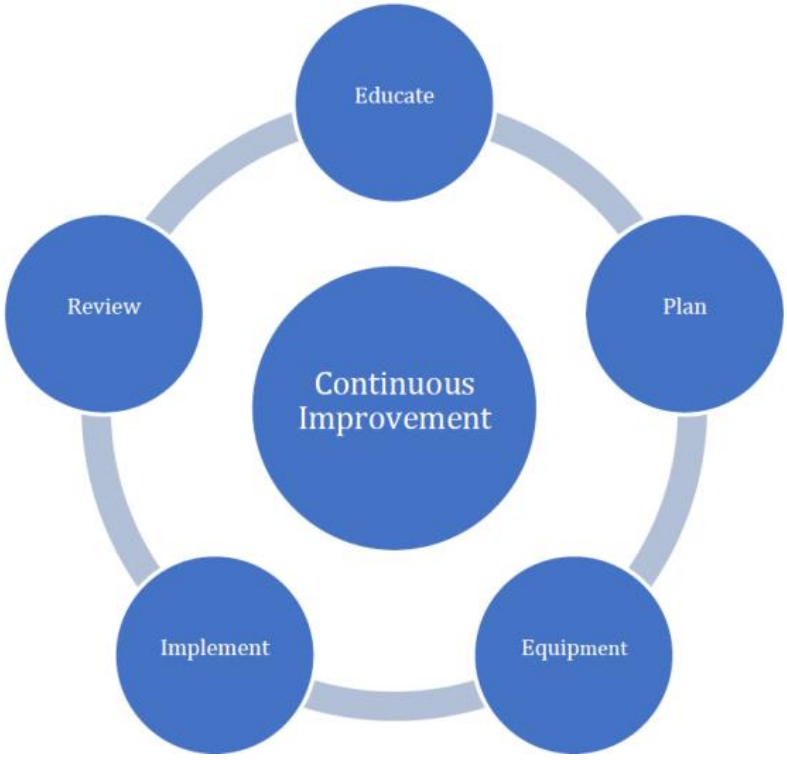
3. Operational Controls
    a. Define pre-storm planning procedure
        i. Forecasting
        ii. Anti-icing
    b. Define post-storm procedure
        i. Weight in/out
        ii. Equipment cleaning/maintenance
        iii. Stockpile maintenance
        iv. Post-storm reviews (what worked, what didn't, what can be improved)
    c. Post-winter procedure
        i. Proposed vs. actual application rates
        ii. Areas for Improvement
        iii. Equipment improvement
    d. Salt Storage and handling
        i. How is salt being stored?
        ii. How are sand/salt mixtures mixed and stored?
        iii. How are liquid materials stored?
        iv. How are materials handled in the off-seasons?
        v. If not established during Phase I:
            1. Develop a storage facility site map detailing
                a. Delivery areas
                b. Loading areas
                c. Mixing areas
                d. Equipment cleaning areas
                e. Stormwater Drainage features
4. Training Program
    a. What level of training was achieved during Phase I (Supervisors, Operators, Both)?
    b. What is the progress of training related BMP implementation and have there been any improvements?
    c. If not established during Phase I:
        i. Define who should be trained

ii. Types of training required (equipment, operations, record keeping)
iii. Define when and how often training should occur
iv. Define what training materials will be used
v. Define how training or certifications will be tracked/recorded

5. Use information collected and documented above to assess operations and determine areas for improvement based on the self-assessment worksheet (the goal here would be to have a program where all aspects of the worksheet is rated at the best level of 4)
    a. Identify the categories of the worksheet where the facility rated below a level of 4
    b. For each category rated below a 4 – Identify short-term and long-term actions that can be taken to improve that particular category. For a list of over 50 winter maintenance BMPs and their pros and cons, see **Appendix B**.
    c. Define a proposed schedule of implementation for each action (BMP) defined in 5.b.
    d. Define measurable goals for each action defined in 5.b. (e.g., ensure 100% of equipment is fitted with calibration units by year 5, ensure 100% of personnel are trained annually)
6. Report on progress of BMP implementation and other improvements towards the goal of reducing excess salt use.

6 Phase III: Continual Improvement

Phases I and II should set a baseline for daily winter operations and give both operators and supervisors an idea of how things currently run and common issues that arise. Through annual evaluation and reporting on operations, facilities are able to better understand where improvements can be made.



Facilities should consider new ideas in the form of different winter materials, tweaking existing equipment, and trying new strategies. Testing new strategies is a part of the continual improvement process. Although not all strategies attempted will work in a given operation, the same strategies may prove to be very effective for others.

It is recommended that operations annually go through the evaluation process once winter activities have concluded. The evaluation should cover the goals set compared to what was actually achieved. Reporting can occur as a presentation of qualitative data collected through the tracking of both material usage and storm data, or through the achievement of goals identified for each BMP.

Appendix D. Application Rate Evaluation Process

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1 Purpose

The purpose of this **voluntary process recommendation** is to provide a continual improvement process for winter maintenance operations that is focused on application rates and Levels of Service (LOS). **In summary, the process involves selecting a target application rate(s), determining the quantity of deicer used, evaluating whether or not LOS were achieved, and evaluating whether or not the target application rate(s) was/were achieved. The result of the evaluations can highlight challenges and/or areas for improvement.** Because of the many factors that complicate the implementation of this approach, this process is recommended as a voluntary process that is to be implemented at scales that make sense for the operation (i.e., all treatments may not be able to be evaluated).

Implementing specific application rates can be a challenge. Whether an operation is beginning to try a single application rate or is working towards varying application rates based on the weather, achieving the intended application rate(s) is a challenging pursuit. This document summarizes steps that can be taken to choose an application rate(s), measure deicer use, establish the winter storm severity, evaluate if LOS were achieved (and if not, why), and evaluate whether or not the target application rate was achieved (and if not, why). Whenever the answer is "no" for the two evaluation steps, identifying the reasons why will highlight areas for improvement or provide insight into areas where application rates may need to be adjusted. Depending on the scale of the operation, conducting this process for all surfaces managed may be impractical. In such cases, it is recommended that operations exercise this process on one to a few treatments (**see "treatment" definition below, "Process Details" 1.a**) to spot check the application rate and LOS achievement. Furthermore, since the calculations provided in the Process Details section below are capable of providing deicer use for a single treatment, the estimates derived are suitable for calculating "Storm-Specific" and "Operational Unit" (i.e., "Storm-Specific" for a single treatment area) deicer totals. These two categories of deicer use totals are described in the Salt Management Strategy (SaMS) Toolkit as more detailed (i.e., not "Seasonal") totals to track salt use.

2 Application Rates

Because of the variety of application rate guidelines that already exist, stakeholders involved in the development of SaMS recommended that the toolkit not include specific application rate recommendations. While many operations already have guidelines for application rates, some may not. For operations that would like an application rate resource to use as a guide, selected existing application rates for transportation operations and for property management operations (e.g., parking lots and sidewalks) are provided in **Appendix D.a** and **Appendix D.b** of this document, respectively. There are also plenty of resources on the internet.

3 Process

3.1 Process Summary

The basic process involves selecting a target application rate(s), determining the quantity of deicer used, establishing storm severity, evaluating whether or not LOS were achieved, and evaluating whether or not the target application rate(s) was/were achieved. The evaluations will identify challenges and/or areas for improvement. It is worth noting that all of the processes described below apply to dry deicer. Therefore, if practices include prewetting (i.e., applying a liquid to the deicer as it is spread), then the calculations below will only account for the dry deicer spread and not any deicer contributed through the liquid.

For many operations, implementing the recommendations below for the entire operation is not practical. In cases where the size and/or complexity (e.g., staff and contract operators) of the operation complicate the broad-scale use of these processes, it is recommended that the operation implement the process below as random spot checks at a proportion of the total operation that is practical and appropriate.

3.2 Process Details

1. Choosing a **target application rate** for a "treatment":
    a. Note – what constitutes a "treatment" varies by the operation type and is defined below.
        i. For transportation operations, a "treatment" is defined here as the application of deicer over a single pass of a specified route.
        ii. For property management operations, a "treatment" is defined here as the one-time application of deicer over all surfaces treated at a property (i.e., reapplications are separate "treatments").
    b. Some operations may have application rate guidelines already in place. In these cases, follow the guidelines to choose the appropriate application rate(s).
    c. Where operations do not have application rate guidelines in place, use the information in **Appendix D.a** or **Appendix D.b**. If this is the first time an operation has used a specific application rate, it is recommended to start on the high end of the chart, regardless of the weather condition. If the operation achieves these higher application rates and the defined LOS ("Process Details" steps 4 and 5 = "yes"), the operation can experiment with lower/more weather-specific application rates.
2. Determine the **quantity of deicer used** for each treatment:
    a. For operations with automated deicer measuring equipment, a best practice is to periodically compare the measurements to the estimates calculated using steps 2.b and 2.c below.
    b. For transportation operations, the amount of deicer applied can be estimated two different ways depending on whether or not the operation has a scale and/or can use the scale effectively during the storm. *NOTE: the examples provided below do not necessarily represent industry standard sizes (e.g., loader bucket sizes). Make sure to know your equipment, including the weight of deicer a truck can safely handle, before using the equations provided below.*
        i. Measuring Salt Weight for a Single Treatment: For operations where a **loader scale is available**, the amount of deicer applied can be estimated by measuring the weight of the truck after it has been loaded (T_L), and then measuring the weight of the truck after it has returned from its route (T_R), even if it is empty. The units for weight should be in pounds (lbs). With these values the amount of deicer applied during a single treatment (D_A) can be estimated by:

$$D_A = T_L - T_R$$

Example: A truck is loaded with salt and drives onto a scale. The scale measures the loaded truck's weight as 80,000 lbs (T_L). When it returns from the treatment, it drives onto a scale that measures its weight as 60,000 lbs (T_R). Therefore, the amount of deicer applied during a single treatment (D_A) is 20,000 lbs using the calculation below:

$$20{,}000 \text{ lbs} = 80{,}000 \text{ lbs} - 60{,}000 \text{ lbs}$$

ii. Estimating Salt Weight for a Single Treatment: For operations where a **loader scale is not available** (i.e., the operation does not have one or it is not possible to use effectively during an event), a rough estimate of the weight of deicer loaded (D_L) can be estimated two ways based on the bucket used to load the deicer. The units for weight should be in pounds (lbs). With the estimate of deicer loaded (D_L) known, step 2.b.ii.3 below explains how to estimate the amount of deicer applied during a single treatment (D_A). Depending on the material, the volume to weight conversion ($D_{V\text{-}W}$) may be known (e.g., from the provider), or it may have to be measured if a scale is available (see 2.b.ii.1.a below):

1. If the volume to weight ratio for the deicer ($D_{V\text{-}W}$) is known and the loading equipment's bucket volume (B_V) is known, the deicer weight of a full loader's bucket (B_W) can be estimated. The units for volume matter only so much as they can convert a volume to weight ratio into weight in pounds (lbs). This estimate can be calculated by:

$$B_W = B_V * D_{V\text{-}W}$$

Example: A 10 cubic yard bucket (B_V) is used to load a truck. The operation knows that the volume to weight ratio ($D_{V\text{-}W}$) is 2,000 lbs of salt per 1 cubic yard. Therefore, the weight of salt in a loader's full bucket (B_W) is estimated to be 20,000 lbs based on the calculation below:

$$20{,}000 \text{ lbs} = 10 \text{ cubic yards} * 2{,}000 \text{ lbs/cubic yard}$$

   a. If the deicer weight for a full loader's bucket (B_W) is unknown and a scale is available, then the weight for a full loader's bucket can be estimated during periods when there is no storm activity. This calculation involves weighing an empty truck before it has been loaded (T_E) and then weighing the same truck after one bucket has been loaded into the truck (T_L). With that information the weight for a full loader's bucket (B_W) can be estimated by:

$$B_W = T_L - T_E$$

Example: A truck with no salt loaded into it drives onto a scale. The scale reads the weight of that empty truck (T_E) as 50,000 lbs. One full bucket is loaded into the truck's bed. The truck with one bucket loaded is weighed again (T_L), and the scale reads 70,000 lbs. Therefore, the weight of salt in a loader's full bucket (B_W) is 20,000 lbs based on the calculation below:

$$20{,}000 \text{ lbs} = 70{,}000 \text{ lbs} - 50{,}000 \text{ lbs}$$

2. With the deicer weight of a full loader's bucket (B_W) known, then the estimate of deicer loaded (D_L) can be estimated by the number of buckets (B_N) loaded into the truck. If partially full buckets are loaded, then an eyeballed fraction of the bucket ($B_{fraction}$) can be multiplied by the deicer weight of a full loader's bucket (B_W) and added to the equation to estimate the deicer loaded (D_L).

$$D_L = (B_W * B_N) + (B_W * B_{fraction})$$

Example: The weight of salt in a full loader's bucket is 20,000 lbs (B_W). A truck is loaded with 1 whole bucket load (B_N) and what appears to be about ½ of a bucket load ($B_{fraction}$). Therefore, the weight of salt loaded (D_L) is estimated to be 3000 lbs based on the calculation below:

30,000 lbs = (20,000 lbs/bucket * 1 bucket load) + (20,000 lbs/bucket * ½ bucket load)

3. With the estimate of deicer loaded (D_L) known, then the amount of deicer applied during a single treatment (D_A) can be estimated by estimating the remaining weight of deicer in the truck after the treatment (D_R) and subtracting that from the estimate of deicer loaded (D_L).

$$D_A = D_L - D_R$$

Example: A truck had 30,000 lbs of salt loaded into it (D_L). When it returned, the amount of salt remaining after a single treatment (D_R) was determined to be 10,000 lbs using one of the two methods described in 2.b.ii.3.a or 2.b.ii.3.b below. Therefore, the amount of salt applied during a single treatment (D_A) is estimated to be 20,000 lbs based on the calculation below:

20,000 lbs = 30,000 lbs – 10,000 lbs

Methods for estimating the remaining weight of deicer in the truck after the treatment (D_R) will vary based on the availability of a scale.

a. Measuring Deicer Remaining: If a **scale is available,** then the remaining weight of deicer in the truck after the treatment (D_R) can be estimated by measuring the weight of the truck when it has returned from its route (T_R), and measuring it again after it has unloaded the deicer and is empty (T_E). With these values the remaining weight of deicer in the truck after the treatment (D_R) can be estimated by:

$$D_R = T_R - T_E$$

Example: A truck returns from a treatment and drives onto a scale that measures its weight as 60,000 lbs (T_R). After the truck empties the remaining salt from its bed, it drives back onto the scale where its weight is measured as 50,000 lbs (T_E). Therefore, the weight of the salt remaining in the truck after a single treatment (D_R) is 10,000 lbs based on the calculation below:

10,000 lbs = 60,000 lbs – 50,000 lbs

b. Estimating Deicer Remaining: If a **scale is not available**, then the remaining weight of deicer in the truck after the treatment (D_R) can be estimated visually assuming that the truck was fully loaded when the estimate of deicer loaded (D_L) was established following the process of 2.b.ii.2 above. To do this, the remaining fraction of the truck bed that is full of deicer will have to be estimated visually ($T_{fraction}$). With this visual estimate, the remaining weight of deicer in the truck after the treatment (D_R) can be estimated by:

$$D_R = D_L * T_{fraction}$$

Example: The estimated weight of salt loaded into a truck (D_L) was determined to be 30,000 lbs using 2.b.ii.2 above. A visual estimate suggests about $^1/_3$ of the truck

bed is full of salt after the truck returned from a single treatment ($T_{fraction}$). Therefore, the remaining weight of deicer in the truck after the treatment (D_R) is estimated to be 10,000 lbs based on the calculation below:

$$10{,}000 \text{ lbs} = 30{,}000 \text{ lbs} * {}^{1}/_{3}$$

c. For **property management** operations, the amount of deicer can be estimated in a number of ways depending on the source of the deicer.
   i. If the deicer is in **bags,** then the amount of deicer applied (D_A) can be estimated by the number of bags (B_N) used multiplied by their weight (B_W). The units for weight should be in pounds (lbs). If partial bags remain, a ballpark estimate can be made of the pounds of deicer used (PB_{est}).

$$D_A = B_N * B_W + PB_{est}$$

   Example: Each bag of salt weighs 50 lbs (B_W). A property was treated one time with 10 whole bags of salt (B_N). Additionally a half bag was used, and therefore the weight of salt used from the partial bag was estimated at 25 lbs (PB_{est}). Therefore, the amount of salt used in a single treatment (D_A) is estimated to be 525 lbs based on the calculation below:

$$525 \text{ lbs} = 10 \text{ bags} * 50 \text{ lbs/bag} + 25 \text{ lbs}$$

   ii. If the deicer is in a **loose pile** (i.e., bulk salt), then the amount of deicer applied (D_A) can be estimated in a couple ways.
      1. If the deicer is loaded into a spreader where a scale can measure the weight of the spreader, follow the process outlined in step 2.b.i above.
      2. If the deicer is loaded into a spreader with a loading device (e.g., backhoe) and no scale is available, follow the process outlined in step 2.b.ii above.
      3. If no scale is available, then estimates for the average deicer applied ($D_{A\text{-}avg}$) in a single treatment can be estimated by knowing the total weight of the deicer pile (P_{TW}) and the number of total treatments sourced from that pile (t_N). The units for weight should be in pounds (lbs).

$$D_{A\text{-}avg} = P_{TW}/t_N$$

      Example: 8000 lbs of salt were delivered to a property (P_{TW}). That pile was used to service 4 treatments (t_N). Therefore, the average weight of salt applied ($D_{A\text{-}avg}$) per treatment is estimated to be 2000 lbs based on the calculation below:

$$2000 \text{ lbs per treatment} = 8000 \text{ lbs}/4 \text{ treatments}$$

3. Establish the **winter storm severity**
   a. For all types of operations, the evaluations in steps 4 and 5 below will be more informed with information on the winter storm's characteristics. Therefore, operations should consider documenting six different factors to help establish the winter storm severity. The six factors that are helpful to track when documenting winter storm severity include storm type, in-storm road temperature, early storm behavior, wind condition in storm, post-storm temperature, post-storm wind condition. With these six factors identified, the evaluations in step 4 and 5 will have information to provide context and the winter storm severity can be calculated based on the method described in Nixon & Qiu (2005).[46]
      i. Storm type can be documented as follows:

[46] Nixon, W. A., & Qiu, L. 2005. Developing a Storm Severity Index. Transportation Research Record, 1911(1), 143–148. https://doi.org/10.1177/0361198105191100114.

1. Heavy snow (>6 inches in 24 hours)
2. Medium snow (2-6 inches)
3. Light snow (<2 inches)
4. Freezing rain

ii. In-storm road temperature can be documented as follows:
1. Warm (>32°F)
2. Mid range (25-32°F)
3. Cold (<25°F)

iii. Early storm behavior can be documented as follows:
1. Starts as snow
2. Starts as rain

iv. Wind condition in storm
1. Light (<15 mph)
2. Strong (>15 mph)

v. Poststorm temperature
1. Same range as in storm
2. Warming
3. Cooling

vi. Poststorm wind condition
1. Light (<15 mph)
2. Strong (>15 mph)

4. **Evaluate if LOS** were **met** for the treatment:
   a. LOS may vary by the operation, the weather, the type of surface, or even the specific treatment. As a result, the methods for spot checking, auditing, or otherwise assessing the attainment of prescribed LOS will vary by operation. Some operations have mechanisms in place for assessing the achievement of LOS. However, if an operation does not have anything in place, the steps outlined in 4.b below can provide some examples.
   b. Where LOS are clearly prescribed for an operation, their attainment may be evaluated as follows:
      i. For transportation operations, the route can be evaluated after X amount of time from the treatment to document the road condition. In this case, X = the amount of time for the LOS to be met (typically taking into consideration the precipitation rate and total amount). The evaluator can spot check various areas on the route that may have different conditions (e.g., turns, hills, and shady spots). The more information that is documented, the more detailed the evaluation can be.
      ii. For property management operations, a LOS evaluator can visit the property after X amount of time from the treatment to document the surface conditions. In this case, X = the amount of time for the LOS to be met (typically taking into consideration the precipitation rate and total amount). The evaluator can spot check various areas on the property that may have different conditions and that are covered by the contract (e.g., slopes, walkways, driving lanes, parking spots, steps, shady areas, and areas near snow piles). The more information documented, the more detailed the evaluation can be.
   c. **When LOS** were **not met,** document the potential reasons for why the LOS were not met. Potential reasons may include:
      i. Weather changes/severity:

1. Examples include changes in the precipitation totals/type/moisture content that was forecasted, changes in the temperature including refreeze, etc.

ii. Route/Site conditions:
1. Examples include left over accumulations/piles from previous events, changes in the route/site, obstructions, traffic/customer presence, etc.

iii. Equipment/Product limitations:
1. Examples include equipment failure, imprecise spreaders, deicer scatter, issues with deicing material, etc.

iv. Application rate appropriateness:
1. An example includes areas that require different (i.e., higher) application rates.

v. Other
1. An example may include operator error.

5. Evaluate if the chosen application rate(s) were achieved for the treatment:
   a. Automated Equipment**:** Some operations may have **automated deicer measuring equipment**. In these cases, the application rate(s) may be known at the time of treatment if spreaders have recently been calibrated. Therefore, if this rate is known with confidence (i.e., calibrated and verified), then the known application rate(s) can be compared to the application rate(s) chosen for the treatment in step 1 above.
   b. Estimating Application Rates: Where the actual rate of application has to be estimated (i.e., 5.a above does not apply), this can be accomplished by dividing the amount of deicer applied during a single treatment (D_A or $D_{A\text{-}avg}$, calculated in steps 2.b or 2.c above) by the total area of the surface treated (A_T) to get the average application rate for the treatment (AR_{avg}). This estimated average application can then be compared to the application rate(s) chosen for the treatment in step 1 above.
      i. For **transportation** operations, the total area of the surface treated (A_T) will be in units of lane miles.
      ii. For **property management** operations, the total area of the surface treated (A_T) will be in units of 1000 ft^2 or units of acres.

$$AR_{avg} = D_A/A_T$$

   c. Exceeding Target Application Rates: When the application rate(s) known in 5.a or calculated in 5.b exceed the application rate(s) chosen in step 1 above, document the potential reasons for why the application rate(s) were not met. Potential reasons may include:
      i. Weather changes/severity that necessitated more deicer application:
         1. Examples include changes in the precipitation totals/type/moisture content than was forecasted, changes in the temperature including refreeze, etc.
      ii. Route/Site conditions that necessitated more deicer application:
         1. Examples include left over accumulations/piles from previous events, changes in the route/site, shady areas, bridges, slopes, areas with drainage problems, or other areas that require different (i.e., higher) application rates.
      iii. Equipment/Product limitations:
         1. Examples include uncalibrated spreaders, non-variable spreaders, spreaders with limited settings, issues with deicing material, etc.
      iv. Measurement of deicer use after reapplication during the same property visit:
         1. Examples include LOS not being met requiring additional application, owner/manager/constituents requested reapplication, etc.
      v. Other

1. Examples include the impact of traffic/customer obstructions, operator error, plowing operations were not adequate/successful, etc.

6. Identifying **areas for improvement**:
    a. If **either** of the evaluations in steps 4 and 5 concluded that LOS or the chosen application rate(s) were not achieved, then the reasons identified in steps 4 and 5 can help to identify options for improvement. While not all reasons identified will provide immediate improvement options, many will highlight something that can be modified, invested in, or otherwise improved over time. Some reasons identified may highlight the challenges of winter maintenance, and these reasons (e.g., challenging areas for treatment) can play a role in adaptive and informed winter maintenance planning.
    b. If **both** of the evaluations in steps 4 and 5 concluded that LOS and the chosen application rate(s) were achieved, well done! In these cases, if the application rate(s) used for the treatment was identified in step 1.c, discuss the application rate's applicability to the conditions and consider whether a lower application rate may have been possible. If so, identify ways to refine operations and work towards more precise, variable, and temperature specific application rates.
    c. For steps 6.a and 6.b above, include documentation of the evaluation process and its conclusions in winter maintenance plans or planning processes.
    d. Finally, it is worth noting that most application rates apply to dry deicer. If LOS have been achieved (6.b above), there may be an opportunity to reduce application rates. As BMPs are implemented, including those that integrate liquids into operations, overall deicer use for a particular treatment (including anti-icing operations beforehand) may be decreased. All operations who achieve the condition outlined in 6.b are encouraged to experiment with deicer rates lower than those initially targeted in order to optimize application rate(s) for a treatment considering all BMPs being used. When experimenting, caution should be exercised to minimize any unintended impacts on LOS and public safety. In other words, efforts to optimize salt use should not compromise public safety.

Appendix D.a Example Application Rates for Transportation Operations

WINTER WEATHER MOBILIZATION GUIDELINE

Weather Forecast	Mobilization Level	Response Plan	Salt application Rate*
Precipitation: 20% or Greater **Accumulation:** Ice/Snow Possible **Ambient or Pavement Temp:** 30-36	**Anti-Ice**	Spot treatment of critical structures and locations	Application Liquid Mag: 36 gal/ln mi Application Liquid salt brine: 50 gal/ln mi Application Salt: 325 lbs./ln mi
Precipitation: 20-49% or greater **Accumulation:** Snow Possible **Ambient or Pavement Temp:** 30-36	**1**	Spot treatment of critical structures and locations	325 lbs./ln mi
Precipitation: 50-100% chance **Accumulation:** Up to 1 inch of snow **Ambient or Pavement Temp:** 25-29	**2**	Light Salting Operation	400 lbs./ln mi
Precipitation: 50-100% chance **Accumulation:** Up to 2 inches of snow or up to $^{1}/_{10}$ inch of ice **Ambient or Pavement Temp:** 20-24	**3**	Salting Operation	475 lbs./ln mi
Precipitation: 50-100% chance **Accumulation:** Up to 6 inches of snow or up to $^{1}/_{4}$ inch of ice **Ambient or Pavement Temp:** 15-19	**4**	Salting/Plow Operation	550 lbs./ln mi
Precipitation: 50-100% chance **Accumulation:** More than 6 inches of snow or more than $^{1}/_{4}$ inch of ice **Ambient or Pavement Temp:** 10-14	**5**	Salting/Heavy Plow Operation; All resources are deployed.	625 lbs./ln mi

*Based on Salt Institute Standards

Appendix D.b Example Application Rates for Property Management Operations

Rates derived from the Sustainable Salt Initiative[1]			
		Dry Rock Salt (NaCl)	
Pavement Temperature (°F) and Trend (↑↓)	Surface Condition and LOS	Pounds per 1000 ft²	Pounds per acre
15-20 ↑	The surface has been cleared of snow/ice; Application Rate for Bare Pavement LOS	14	610
15-20 ↓		13.5	588
20-25 ↑		13.25	577
20-25 ↓		12.75	555
25-30 ↑		12.5	545
25-30 ↓		11	479
30 ↑		11	479
>30 ↓		10	436

[1]The Sustainable Salt Initiative (SSI) rates are representative of the average of total rates collected from winter management companies participating in the Snow and Ice Management Association's SSI during 2015-2016 and 2016-2017 winter seasons. For more information and to access "Sexton, Phillip Charles. 2017. Sustainability Analysis of the Commercial Winter Management Industry's Use of Salt. Master's thesis, Harvard Extension School" visit https://dash.harvard.edu/handle/1/33826971.

Appendix E. Alternative Deicers

1 Comparison of Non-Chloride Deicers

A comparison of non-chloride deicers is provided below. The selected non-chloride deicers are intended for use on paved surfaces (e.g., roads, parking lots, sidewalks, etc.) and are known to exhibit only moderate environmental impacts based upon the available information. Specifically, the tables below compile information on specified acetates (potassium acetate (KAc) and sodium acetate (NaAc)), formates (potassium formate (KFm) and sodium formate (NaFm)), and potassium succinate.

Information gathered in **Table 18** includes the lowest practical melting temperature, whether it is available as a liquid and/or solid, any required equipment or training, corrosivity to steel, impacts to concrete, and environmental impacts. **Table 19** lists regional vendors to contact for additional information on the deicers identified in **Table 18**.

Table 18. Non-chloride deicer information.

Non-Chloride Deicer	Lowest Practical Melting Temperature		Specialized Equipment, Handling, Application and or Storage Required?	Metal Corrosivity	Impacts to Concrete	Environmental Impacts	Notes about Performance
Acetates	KAc (potassium acetate)	-15°F	Yes	Corrosive to galvanized steel	Reactive on concrete	Moderate BOD[47] and moderate toxicity	Fast acting with a high melting capacity. Less material needed than NaCl
	NaAc (sodium acetate)	0°F					Excellent melting properties, works faster and at lower temperatures than NaCl.
	CMA (calcium magnesium acetate)	20°F					Works slowly and requires more material than NaCL. Otherwise performs similarly to NaCl.
Formates	NaFm (sodium formate)	0°F	Yes	Corrosive to mixed metal	Reactive on concrete		Fast acting
	KFm (potassium formate)	-20°F					Efficient at deicing
Potassium Succinate	-4°F		Yes	None	Minimal to none		Functions similar to that of NaCl at improving friction on roadways during snow and ice conditions, but functions at lower temperatures.

[47] Biochemical Oxygen Demand – a measure of how much a substance can reduce the amount of dissolved oxygen available to aquatic species.

Table 19. Regional vendors of non-chloride deicers.

Non-Chloride Deicer	Vendor Name	Web Address	Vendor Location and Contact Information	Notes
Acetates	Chemical Solutions, Inc.	http://meltsnow.com/products/acetates	Franklin, Massachusetts 508-520-3900	Wholesaler only; minimum order of 22 tons. Delivers to NoVA
	Cryotech	http://www.cryotech.com	Fort Madison, Iowa 800-346-7237 or 319-372-6012	Offers free training on use of products. Delivers to NoVA
	NASi	https://www.nasi-tm.com/alpine-ice-melt	Marion, Ohio 800-622-4877 ext. 300	
	Hawkins, Inc.	https://www.hawkinsinc.com/groups/oil-field-chemicals/liquid-potassium-acetate-60	Roseville, Minnesota 800-328-5460 customer.service@hawkinsinc.com	Supplier for companies, municipalities, and government entities. Delivers to NoVA
	Midwest Industrial	https://midwestind.com/enviro-mlt	Canton, Ohio 866-662-3878	
	Seneca Mineral	http://senecamineral.com	Erie, Pennsylvania 800-291-9222	
Formates	Hawkins, Inc.	https://www.hawkinsinc.com/groups/oil-field-chemicals/liquid-potassium-formate-53	Roseville, Minnesota 800-328-5460 customer.service@hawkinsinc.com	Supplier for companies, municipalities, and government entities.
	Five Star, Inc.	https://www.fyvestar.com/sodiumformatesafeway.html	Layton, Utah 801-552-9100 info@Fyvestar.com	Distributor, not manufacturer.
	NASi	https://www.nasi-tm.com/nasi-sf---dot	Marion, Ohio 800-622-4877 ext. 300	
	Seneca Mineral	http://senecamineral.com/potassium-formate-deicer	Erie, Pennsylvania 800-291-9222	
	Envirotech	https://envirotechservices.com/deicing-anti-icing/non-chloride-based-deicing-products/apogee	New Cumberland, Pennsylvania 877-664-3401	Accepts both large and small orders.
Potassium Succinate	City Chemicals	https://www.citychemical.com/potassium-succinate.html	West Haven, Connecticut 800-248-2436, 203-932-2489 sales@citychemical.com	

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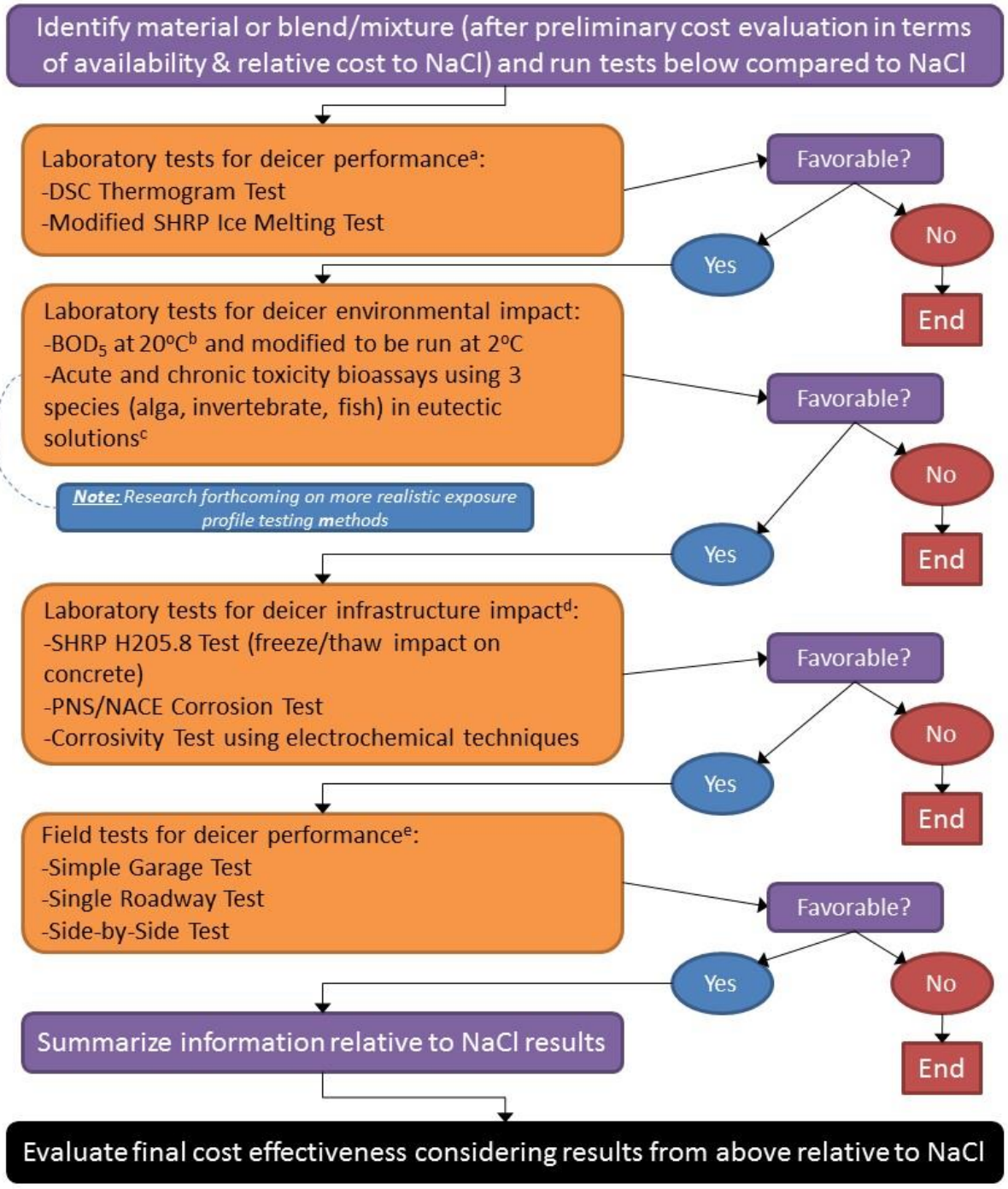
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Minnesota Department of Transportation. 2017. Transportation Research Synthesis 1706: Field Usage of Alternative Deicers for Snow and Ice Control. Prepared by The Western Transportation Institute. 24p. http://dot.state.mn.us/research/TRS/2017/TRS1706.pdf.

Minnesota Department of Transportation. 2014. Transportation Research Synthesis 1411: Chloride Free Snow and Ice Control Material. Prepared by Fortin Consulting. 42p. https://lrrb.org/media/reports/TRS1411.pdf.

2 Process for Piloting New Compounds/Mixtures



[a] https://clearroads.org/project/development-of-standardized-test-procedures-for-evaluating-deicing-chemicals/
[b] https://www.nemi.gov/methods/method_summary/5715/
[c] https://clearroads.org/project/11-02/
[d] https://www.codot.gov/programs/research/pdfs/2009/antiicing.pdf/at_download/file
[e] http://clearroads.org/project/determining-effectiveness-of-deicing-materials-and-procedures/

Appendix F. Evaluation of Winter Service Provider Certification Programs

Evaluation of Winter Service Provider Certification Programs



Prepared to support development of a
Virginia Salt Management Strategy

Prepared for
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1 Introduction

Ten existing winter service provider certification programs, listed below, are identified and information on each are summarized in alphabetical order in **Section 2** of this appendix. **Table 20** provides summary information about the programs for easy comparison.

Further evaluation of five programs that can be administered in Virginia was conducted and is summarized in **Section 3** of this appendix. Program names selected for further evaluation are bolded in the list below and in **Table 20**.

- AORS: Association of Ontario Road Supervisors Certified Road Supervisor, Winter Operation Training Series
- **APWA: American Public Works Association Winter Maintenance Supervisor Certificate**
- **ASCA: Accredited Snow Contractors Association Certification**
- City of Madison, Wisconsin Winter Salt Certification
- McHenry County, Illinois Sensible Salting Workshop and Certification
- MPCA: Minnesota Pollution Control Agency's Smart Salting Certification
- NHDES: New Hampshire Department of Environmental Services' Green SnowPro Training – NHDES Salt Applicator Certification
- **SASC: Smart About Salt Council Certification**
- **SIMA: Snow and Ice Management Association Credential Programs**
- **SWIM: Sustainable Winter Management Certification**

Table 20. Summary information for winter service provider certification programs. All programs (except SWiM, SIMA, ASCA, and APWA that did not have readily available information on the topic) address multiple surface types like roads, sidewalks, and driveways. The five programs selected for further evaluation in Section 3 of this document are labeled in bold in the table.

	Training				Level			
Program Name	**In Person**	**Online**	**Exam**	**Reporting**	**Organization**	**Individual**	**Cost‡**	**Liability Protection**
AORS Certified Road Supervisor, Winter Operation Training Series	✓					✓		
APWA Winter Maintenance Supervisor Certificate	✓		✓			✓	$$	
ASCA Certification		✓	✓			✓	$$$	✓
City of Madison, Wisconsin Winter Salt Certification	✓		✓	✓ *	✓ *	✓	$	
McHenry County, Illinois Sensible Salting Workshop and Certification	✓		✓			✓	$	
MPCA's Smart Salting Certification	✓ *			✓ *	✓ *	✓ *		
NHDES Salt Applicator Certification	✓		✓	✓		✓	$$	✓
SSASC Certification	✓	✓	✓	✓	✓ *	✓ *	$$$	
SIMA Certified Snow Professional and Advanced Snow Manager Certification		✓	✓			✓	$$$	
SWiM Certification	✓			✓	✓		Variable	

*Required for specific levels/types of certification

‡Cost breakdown:

$=<$100

$$=$100-$250

$$$=>$250

Information not readily available

2 General Program Information

Each program is described in more detail below. Please note that much of the language describing programs is taken directly from online source materials. The accuracy of the information has not been verified. In some cases, edits were made to original language to make this document concise and pertinent for the intended purpose.

2.1 Association of Ontario Road Supervisors (AORS) Certified Road Supervisor, Winter Operation Training Series

http://aors.on.ca/education/winter-operation-series/

Ontario has a certification program designed for various kinds of snow operators and public works employees. The trainings are developed and delivered by Ground Force Training, Inc. Ground Force Training is a Canadian heavy equipment and driver training company, providing heavy equipment training to townships, counties, districts and rural municipalities as well as private industries including farms, construction and utility companies

Many of the trainings for different types of plow operators (listed below) cover topics related to smart salting: Front end loader plot

- Motor grader-snowplow
- Pick-up truck with plow
- Sidewalk plow
- Snow plow defensive driving course
- Snow plow operator
- Snowplow – classroom only
- Snowplow – one person plowing
- Tractor loader backhoe snowplow
- Winter patroller

2.2 American Public Works Association (APWA) Winter Maintenance Supervisor Certificate

http://www3.apwa.net/learn/Certificates/Winter-Maintenance-Supervisor-Certificate

This certification program is designed to be held annually at The North American Snow Conference. Participants include supervisors with winter maintenance responsibilities, operators who aspire to be supervisors, and operators who want a greater understanding of winter maintenance processes.

Training topics include:

- Expand knowledge of planning and preparation in winter maintenance operations
- Increase understanding of winter weather and how it affects operations
- Identify how to better use traditional and alternative chemicals
- Consider what equipment is available and how to maintain it
- Expand understanding of snow and ice control techniques
- Gain understanding about the environmental impacts of winter maintenance policies

The winter maintenance supervisor certificate workshop costs $25 in addition to conference registration. The most recent conference registration cost $225.

2.3 Accredited Snow Contractors Association (ASCA) Certification

https://www.ascaonline.org/

This certification program was designed to help address the rising cost of comprehensive insurance coverage. The ASCA worked with Mills Insurance Group to develop the ASCA certification. Certified members are provided with access to insurance programs that offer exclusive discounts to ASCA members.

Snow and ice professionals who complete 10 hours of ASCA-approved educational programming and are ASCA members in good standing earn the designation "ASCA Certified." Topics are listed on the ASCA website. Each course includes a presentation followed by a short quiz. Once the quiz is passed, the course is completed and a certificate-of-completion document is issued. ASCA provides an all-encompassing certificate for achieving initial certification and for renewal. Certification is renewed on an annual basis and requires the completion of 10 hours of ASCA-approved education to meet the renewal requirements.

Each hour course is $15. ASCA membership costs are based on annual snow revenue, ranging from $200-$400 for a one-year membership.

2.4 City of Madison, Wisconsin Winter Salt Certification

https://wisaltwise.com/Winter-Salt-Certification

This is a voluntary certification program open to all Dane County contractors that discusses parking lots, roads, sidewalks, and driveways. Certification is available for both individuals and organizations.

The individual certification includes a six-hour training and a written exam. To become certified, the individual must also agree to use practices that reduce impacts on the environment. Two types of individual trainings offered are the roads class for high/low speed snowplow drivers and the parking lot/sidewalk class for those who maintain private/public walkways and/or parking lots and service roads. Individual certification lasts 5 years. The class includes the chemistry or salt use, recommended salt application rates, how to calculate the amount of salt needed based on weather conditions, and technological advancements like brining, new spreading equipment, and alternative products.

The organizational certification requires 30% of the salt related staff to be certified and submission of an annual report. The organizational certification is valid for 1 year. Organizational certification includes 1) submission and acceptance of the application that describes current de-icing practices, 2) hands on equipment calibration training, 3) tracking use of salt per storm, and 4) submission of an annual salt savings report.

2.5 McHenry County, Illinois Sensible Salting Workshop and Certification

https://www.mchenrycountyil.gov/county-government/departments-j-z/planning-development/water-resources/sensible-salting

This certification is for public and private sector employees responsible for maintenance of roads, sidewalks, and parking lots in McHenry County, Illinois. Trainings and certification workshops are hosted through the University of Wisconsin, McHenry County, or the American Public Works Association. The training topics include application rates, liquids, weather conditions, materials storage, levels of service, truck washing, new maintenance methods, environmental effects, state/local law, and NPDES compliance. It also includes demonstration/hands-on discussion of calibrating equipment.

Operators are required to be recertified every three years. Refresher courses are offered annually. The training costs $25.

There is a $12 registration fee for the certification training for parking lots, sidewalks, and trail maintenance professionals currently listed on the website.

2.6 Minnesota Pollution Control Agency's (MPCA) Smart Salting Certification

https://www.pca.state.mn.us/water/smart-salting-training

The Smart Salting Certification is conducted at two levels (Level 1 and Level 2).

Level 1 certification is for individuals like public road maintenance staff (state, city, and county), winter service providers, staff responsible for maintaining public and private walkways and/or parking lots, property managers, and other snowplow drivers. Level 1 certification includes attending an in-person training, held in Minnesota. Training manual and videos available online.

Level 2 certification is for organizations and requires submission of data each year for the previous year. Level 2 reporting includes best management practices and salt savings assessments using the Smart Salting Assessment Tool for the most recent fully completed winter maintenance season. To maintain certification, reports have to be submitted each year for the previous year. Individuals at the organization do not need to be Level 1 certified for the organization to become Level 2 certified. Level 2 certification is valid for 2 years. Organizations remain certified as long as they update and resubmit their best management practices and salt savings reports each year.

2.7 New Hampshire Department of Environmental Services' (NHDES) Green SnowPro Training – NHDES Salt Applicator Certification

https://www.des.nh.gov/organization/divisions/water/wmb/was/salt-reduction-initiative/categories/faq.htm#two

This certification program is for snow removing contractors, municipalities, and anyone running a plow. By completing the program, certified parties become eligible for liability protection for self and client from slips and falls per New Hampshire Code of Administrative Rules. To become a certified NHDES Salt Applicator, individuals must take a Green SnowPro workshop, pass the exam, and fill out the initial or renewal certification form. The initial course is five hours and covers proper salt use and efficiency issues related to winter maintenance. The training is held at various locations around New Hampshire. Annual salt usage reporting is also required for recertification. Additional information like storm-specific reporting can also be kept in the online system to ensure maximum liability protection.

For recertification, a new certification form must be submitted each year in June. A minimum of two hours of professional development courses are required every two years for recertification. This obligation can be met through a two-hour Green SnowPro refresher course, an Annual New Hampshire Salt Symposium, or a SIMA on-line refresher course.

There is no fee to apply for certification. The Green SnowPro trainings cost $100 per person for municipalities and $200 per person for private companies. The Green SnowPro refresher training is $25 per person for municipalities and $50 for private companies. Other professional development courses and the salt symposium have separate fees.

2.8 Smart About Salt Council (SASC) Certification

http://www.smartaboutsalt.com/becomesascertified

The Smart About Salt Council is a non-profit organization that offers training to improve salting practices and protect freshwater from negative impacts of salting. This is a certification program for both contracting companies and sites and is valid for five years. Certification includes completing the Essentials of Salt Management training. Individual training and accreditation are also available. Training is available online or as a one-day in-person class. An example training course agenda is available online. To maintain certification, an annual report is required and random program verifications may

be conducted. Online course registration including all modules, review, and exam is $375. Businesses in certain locations may qualify for stormwater credits to save on monthly utility bill.

2.9 Snow and Ice Management Association (SIMA) Credential Programs

https://www.sima.org/education/certified-snow-professional/certified-snow-professional-faq

SIMA is a non-profit trade association. The Certified Snow Professional certification program is designed for business owners and executives. It is focused on business elements like marketing, human resources, snow-specific operations, and legal aspects. The Advanced Snow Manager certification program is designed for operations managers and personnel. Four courses are included: core principles, sidewalk operations, plowing operations, and ice management. Annual continuing education is required to maintain good standing.

Certification is for individuals only, not for companies. The certification of an individual's competence is accomplished through a written exam. The 200 question exam is designed to measure the individual's knowledge in six areas: Business, Human Resource Management, Marketing, Sub-Contractors, Snow and Ice Science, and Snow and Ice Operations and Techniques. Exams are given online once-per-month through SIMA's Training Center. A candidate will determine eligibility, complete an application and submit any necessary application materials, be approved by SIMA, and then take the exam.

This certification program does not require records of salt use or BMP implementation.

The exam fee is $350 for SIMA members and $500 for non-members. The fee must be paid before taking the exam. Study materials cost: $300 for the set of six, or $400 for the set of six plus the recorded study presentations for members. Non-members pay $400 for the set of six, or $500 for the set of six plus the recorded study presentations.

Recertification requires an annual renewal fee of $130 to SIMA. Fifteen continuing education credits are also required per year, starting the year after initial certification. Credits can be obtained through various activities such as educational seminars, SIMA's annual symposium, publishing industry related articles, and mentoring new SIMA members.

1.10 Sustainable Winter Management (SWiM) Certification

http://witadvisers.com/swim/

The SWiM Certification is administered through a private firm, WIT Advisers, that consults with property owners, municipalities and contractors. SWiM is a systematized approach to implementation of efficient practices that includes policy guidelines and standards of practice, the nuts and bolts. There are three types of certifications offered through the SWiM program: a) *SITE* certification, b) *ROAD* certification, and c) *CF* Certification (Chloride Free). Trainings are provided for property owners, managers, contractors, highway departments, and public officials. The program includes a needs assessment, implementation training, program management, automated monitoring, and SWiM certification. Maintaining certification includes operations audits and monitoring of salt tracking and level of service.

SWiM certified SITES and ROADS require automated monitoring (ongoing tracking of salt use and level of service achieved through SITE / ROAD weather cameras). Periodic monitoring includes engagement with contractors, highway operators, property owners, and public officials to improve performance and reduce salt use by implementing more efficient practices. In addition to automated monitoring, random in-person/on-site audits are performed with contractors, highway operators, and property owners.

A future certification / accreditation for contractors (service companies) is being considered for contractors who follow SWiM guidelines and service a minimum number of SWiM sites.

3 Further Evaluation of Five Programs

This section provides a comparison of five salt management certification training programs selected by stakeholders during SaMS Toolkit development. These programs were selected for further comparison as these five programs appear, based upon readily available information, to be transferable to Virginia and also covers recommended BMPs identified by the Traditional BMPs workgroup. The programs reviewed are:

1. American Public Works Association (APWA) Winter Maintenance Supervisor Certification
2. Accredited Snow Contractors Association (ASCA) Certification
3. Smart About Salt Council (SASC) Certification
4. Snow and Ice Management Association (SIMA) Certified Snow Professional and Advanced Snow Manager Certification
5. Sustainable Winter Management (SWiM) Certification

This comparison is on the extent to which each program covers environmental impacts (**Section 3.1**), economic benefits (**Section 3.2**), and the **BMPs** identified in the SaMS Toolkit (**Section 3.3**). Note that the intent of this document is to provide a broad overview of each program and is not an endorsement of any program reviewed. Additionally, the information provided in this review may not identify the full extent of a program's offering, due to limited details on the programs' websites on the content of information covered by the trainings as the material is often proprietary and there is a fee for participating in trainings and receiving materials. For the SASC, ASCA, APWA, and SIMA programs the information presented below was gathered from the organizations' websites. The SWiM information is based upon a phone interview with the program's founder Phill Sexton.

3.1 Environmental Impacts

3.1.1 APWA Winter Maintenance Supervisor Certification Programs

Environmental issues associated with chemicals and abrasives are both discussed during the certification programs. This covers corrosion, damage to vegetation, soil, waterbodies (including sources of drinking water), aquatic life, and air quality.

3.1.2 ASCA Certification

Environmental impacts are covered in a variety of the ASCA courses but are not the focus of this program.

3.1.3 SASC Certification

SASC's training begins with a section titled, "The Environmental Effects of Salt." It covers the effects of excessive salt on soil, vegetation, surface water and its biota, wildlife, and groundwater. It also covers Environment Canada's perspective on salt management.

3.1.4 SIMA Certification

The target audience for the Certified Snow Professional certification is business owners and executives and, as such, the primary focus of training materials is key business elements; however, environmental considerations are an underpinning of the program. The Advanced Snow Manager certification, which is designed for operations managers and personnel, directly addresses environmental considerations. Both certifications rely on the recommended best practices for sustainable salt use and training modules are available that focus on environmental impacts such as "Salt Application Oversight and Environmental Responsibility".

3.1.5 SWiM Certification

SWiM certification is different from the other programs discussed in this document. This program focuses on property owners and managers, and to a more limited extent, municipalities, and how to practically implement training so that salt use and reductions can be quantified. To this end, recognition of the environmental impacts of salt use are embedded in an organization's decision to have their facility or roads SWiM certified.

3.2 Economic Benefits of Practices

3.2.1 APWA Winter Maintenance Supervisor Certification Programs

This program only briefly discussed this topic in the context of that economic losses due to closed roads exceeds the cost of snow removal.

3.2.2 ASCA Certification

This topic is not covered during training.

3.2.3 SASC Certification

This topic does not appear to be covered during training.

3.2.4 SIMA Certification

This topic is not covered directly during training, but is briefly discussed in some SIMA library articles such as "Is anti-icing worth the ROI [Return on Investment]". Other economic components such as finance, building a bid, and job costing are included in SIMA training materials.

3.2.5 SWiM Certification

Cost reduction is a goal of the program. It specializes in GPS tracking of salt use so the rate of application is always known allowing for changing costs to be tracked. The program's website promotes its ability to prevent delayed business openings, thus protecting revenue.

3.3 Best Management Practices

The list of BMP categories in this section correspond to the practices presented in the BMP Pros and Cons menu (**Appendix B**) discussed in **Section 3.2.1**. **Table 21** provides a summary of BMP coverage in the five training courses.

Table 21. Summary of BMP coverage.

BMP	APWA	ASCA	SASC	SIMA	SWiM
Plowing Practices	✓	✓	✓	✓	✓
Calibration	✓	✓	✓	✓	✓
Measurement	✓	✓	✓	✓	✓
Level of Service	✓	Unknown	No	✓	✓
Training	✓	✓	✓	✓	✓
Anti-Icing	✓	Unknown	✓	✓	✓
Liquids	✓	✓	✓	✓	✓
Application Practices, Varying Application Rates, Use of Deicers at Cold Temperatures	✓	✓	✓	✓	✓
Pre- and Post-Storm Meetings to Review Plans and Performance	✓	✓	✓	✓	✓
Weather Forecasting/Surface Temperature Information	✓	Unknown	✓	✓	✓
Enhanced Equipment/Technology	✓	✓	✓	✓	✓
Salt Storage and Handling	✓	No	✓	✓	✓
Winter Maintenance Planning	✓	✓	✓	✓	✓
Accountability/Tracking and Reporting	✓	✓	✓	✓	✓
Additional Practices	Contracting guidelines, liability and risk management, safety, management skills and tips, interacting with the public and media, driver's licenses and training.	Training courses are tailored to private contractors and, specifically, how to reduce their liability. There are many courses dedicated to meeting industry standards.	None identified	Business-focused topics related to human resources, subcontractors, sales, and management.	None identified

3.3.1 APWA Winter Maintenance Supervisor Certification Programs

APWA's training is coordinated through the organization's chapters. For Virginia, any training would be hosted by the Mid-Atlantic Chapter. There is a fee to hold a standalone training, as well as any meeting facility and speaker costs. Trainings are also often conducted in association with APWA conferences. In addition to the eight-hour supervisor training reviewed here, a four-hour operator training is also available.

Information on this training program comes from a handout provided to training attendees (APWA 2019). As stated, the goal of the program is "more effective, efficient, equitable & environmentally-friendly snow & ice control." Topics covered include:

- Policy and planning
- Weather
- Materials
- Equipment and fleet
- Snow and ice control

The information below summarizes what is covered during the training and sometimes includes details of what is presented. In all cases, this is not a comprehensive representation of the training.

3.3.1.1 Plowing Practices

The various types of plows (one-way, two-way/reversible, V, underbody, wing), plow blades, controllers, and hydraulic systems are discussed as well as how to select the one best-suited for local needs. Operational speed for plowing, special snow operations (multi-modal areas, gravel roads), optimizing routes, and using automatic vehicle locations systems are also covered during training.

3.3.1.2 Calibration

APWA's main message regarding calibration is that it is important to know what and how much is being applied.

3.3.1.3 Measurement

This is taught as part of the discussion about how to calibrate equipment.

3.3.1.4 Level of Service

The level of service determined is the "desired, usually achievable, condition of pavement surface."

3.3.1.5 Training

Training at all staff levels is encouraged.

3.3.1.6 Anti-Icing

The difference between anti-icing and deicing is explained, as well as the benefits of anti-icing: Reduced material usage and effort. Details on how anti-icing works, how to account for pavement temperature, when it should be used, and how to calculate how much material is needed are provided.

3.3.1.7 Liquids

It is recommended that the material selected should meet the level of service needed and account for "societal, economic, and environmental concerns." The training course presentation includes general information on liquids and selecting the appropriate material. In addition to what is covered in this training, APWA offers four additional courses on liquids. These are offered as in-person trainings and as recordings for APWA members.

3.3.1.8 Application Practices, Varying Application Rates, Use of Deicers at Cold Temperatures

The APWA training covers application practices, including variable application rates, in breadth and depth. Highlights are conditions for using direct liquid application, the benefits of pre-treating salt, recommendation to plow first, and encouragement to check pavement temperature before applying salt.

3.3.1.9 Pre- and Post-Storm Meetings to Review Plans and Performance

Both how to prepare for a storm and review actions taken during one are explained. Additionally, adjusting operations during a storm as needed is also recommended.

3.3.1.10 Weather Forecasting/Surface Temperature Information

The basics of weather and forecasting are taught as well as how this interacts with road conditions. The benefits of using advanced forecasts for winter road maintenance is also explained.

3.3.1.11 Enhanced Equipment/Technology

A number of enhanced equipment and technologies are discussed including:

- Mobile sensors,
- Road Weather Information System (RWIS),
- Maintenance Decision Support System (MDSS) forecasts, and
- New types of equipment: dual blade, tow plows, expandable plows, ice breakers, satellite assisted GPS controller, alternative fuel fleets.

3.3.1.12 Salt Storage and Handling

The reasons for proper storage and handling and best practices for doing so are covered in detail.

3.3.1.13 Winter Maintenance Planning

APWA training covers the planning cycle by activities that need to occur during each season. The use of a written plan is encouraged.

3.3.1.14 Accountability/Tracking and Reporting

Setting performance measures and how to track them are taught. This is discussed in large part in relation to the use of automatic vehicle location systems.

3.3.2 ASCA Certification

Specific information on the content covered in the many course offerings is not available. The list of courses can be found on the ASCA website, and are offered in a series of 5 levels (100 through 500). Initial certification requires that all ten 100-level courses are completed. The information below summarizes readily available information from the program's website. In all cases, this is not a comprehensive representation of the training.

3.3.2.1 Plowing Practices

Based upon course titles, this topic may be addressed under "Snow Management Basics" and/or "Ice Management Basics."

3.3.2.2 Calibration

Based upon course titles, this topic may be addressed under "Snow Management Basics" and/or "Ice Management Basics."

3.3.2.3 Measurement

Course offered that covers this topic, but specifics of the course are unknown.

3.3.2.4 Level of Service

Based upon course titles, unknown if this program addresses this topic.

3.3.2.5 Training

Course offered that covers this topic, but specifics of the course are unknown.

3.3.2.6 Anti-Icing

Course offered that covers this topic, but specifics of the course are unknown.

3.3.2.7 Liquids

Course offered that covers this topic, but specifics of the course are unknown.

3.3.2.8 Application Practices, Varying Application Rates, Use of Deicers at Cold Temperatures

Course offered that covers this topic, but specifics of the course are unknown.

3.3.2.9 Pre- and Post-Storm Meetings to Review Plans and Performance

Course offered that covers this topic, but specifics of the course are unknown.

3.3.2.10 Weather Forecasting/Surface Temperature Information

Based upon course titles, unknown if this program addresses this topic.

3.3.2.11 Enhanced Equipment/Technology

Course offered that covers this topic, but specifics of the course are unknown.

3.3.2.12 Salt Storage and Handling

Based upon course titles, unknown if this program addresses this topic.

3.3.2.13 Winter Maintenance Planning

Course offered that covers this topic, but specifics of the course are unknown.

3.3.2.14 Accountability/Tracking and Reporting

Course offered that covers this topic, but specifics of the course are unknown.

3.3.3 SASC Certification

The SASC Training Workbook for operators and winter maintenance contractors covers most of the BMPs endorsed by the Traditional BMPs workgroup. The information below summarizes readily available information from the program's website. In all cases, this is not a comprehensive representation of the training.

3.3.3.1 Plowing Practices

Suggests that mechanical removal should be the first approach to snow removal. The training covers the benefits of doing so and how to best do it.

3.3.3.2 Calibration

Topics covered in this section are "the importance of calibration, how to calibrate equipment, how often to calibrate, and the importance of documentation."

3.3.3.3 Measurement – Measuring Deicer Use

This is covered during training. No additional details are available.

3.3.3.4 Level of Service

Based upon readily available information, it does not appear this topic is covered.

3.3.3.5 Training

In addition to the training described in this section for operators and winter maintenance contractors, SASC provides a similar training for facility owners and operators.

3.3.3.6 Anti-Icing

This program covers this topic and the various materials for winter road maintenance.

3.3.3.7 Liquids

The workbook provides guidelines for when it is and is not appropriate to use anti-icing/Direct Liquid Application (DLA). Training covers how one can make his or her own liquid, document procedure, and concentration made. Emphasis is placed on the best temperatures to use each liquid and the advantages and disadvantages of each. The liquids discussed during training are:

- Salt Brine (Sodium Chloride) (23.3%)
- Magnesium Chloride (various concentrations)
- Calcium Chloride (36.0%)
- Agricultural blends mixed with above liquids
- Sugar beets (exclusively mixed with salt brine)
- Corn (mixed with Magnesium Chloride)

3.3.3.8 Application Practices, Varying Application Rates, Use of Deicers at Cold Temperatures

Application practices are in terms of the "5 Rs of Salt Management." The "5 Rs" are "Right material," "Right time," "Right amount," "Right place," "Retain it." The benefits of having the option for low, medium, and high application rates are discussed. Also covered are how to calculate the amount of salt needed for a given area and the corresponding application rate.

3.3.3.9 Pre- and Post-Storm Meetings to Review Plans and Performance

Participants are encouraged to have these meetings to review performance and to proactively address known issues.

3.3.3.10 Weather Forecasting/Surface Temperature Information

SASC training covers the essential weather conditions to monitor and the different types and sources of forecasts.

3.3.3.11 Enhanced Equipment/Technology

The need to invest in new equipment is discussed in order to implement advanced winter maintenance techniques.

3.3.3.12 Salt Storage and Handling

General procedures for storage and handling are discussed, as well as how to treat solids and liquids differently.

3.3.3.13 Winter Maintenance Planning

How to conduct a site assessment is covered. The goal of this assessment is to identify high-risk areas and estimate salt requirements.

3.3.3.14 Accountability/Tracking and Reporting

This topic is covered under the training's section on Risk Management and Record-Keeping. An example of a daily log sheets is provided and discussed.

3.3.4 SIMA Certification

All of the BMPs are covered as part of the SIMA program. The summary below provides available information from the SIMA member's website. In all cases, this is not a comprehensive representation of the training.

3.3.4.1 Plowing Practices

"Instruction on best practices for snow plowing techniques" is a key focus of the Advanced Snow Management Plowing Operations course.

3.3.4.2 Calibration

Calibration is considered a key best practice area by SIMA and is covered in several training courses. "Understanding principles of calibration" is discussed in the Advanced Snow Management Ice Management course; calibration of liquid spray systems is covered in the "Fundamentals of Anti-Icing and Liquids" course; and field operations trainings include a calibration component.

3.3.4.3 Measurement

Measurement is considered a key best practice area by SIMA.

3.3.4.4 Level of Service

Defining level of service is included, especially as it relates to designing, communicating, and executing contracts.

3.3.4.5 Training

The importance of training is highlighted in several SIMA modules including "Assessing Operations and Creating a Hands-On Snow Safety Program" and "Pre-Season Snow Operations Training".

3.3.4.6 Anti-Icing

Anti-icing is considered a key best practice area by SIMA. "Applying anti-icing and deicing techniques" is a key focus of the Advanced Snow Management Ice Management course.

3.3.4.7 Liquids

The training materials include a "Fundamentals of Anti-Icing and Liquids" course.

3.3.4.8 Application Practices, Varying Application Rates, Use of Deicers at Cold Temperatures

"The effects of moisture and temperature on snow plowing strategy" is a key focus of the Advanced Snow Management Plowing Operations course. "Understanding principles of various application rates" is a key focus of the Advanced Snow Management Ice Management course.

3.3.4.9 Pre- and Post-Storm Meetings to Review Plans and Performance

This topic is covered through SIMA training modules like "Post-Snow Season Review".

3.3.4.10 Weather Forecasting/Surface Temperature Information

This topic is covered through SIMA training modules like "Making Weather Work for You".

3.3.4.11 Enhanced Equipment/Technology

This topic is covered in publications such as "Tech innovations clear paths to a better way" and training modules like "Upfitting Vehicles for Snow Management".

3.3.4.12 Salt Storage and Handling

Salt storage and transport is considered a key best practice area by SIMA. Storage of liquids is discussed in the "Fundamentals of Anti-Icing and Liquids" course.

3.3.4.13 Winter Maintenance Planning

The importance of pre- and post- season planning are underscored in multiple courses and modules offered through SIMA.

3.3.4.14 Accountability/Tracking and Reporting

Tracking and reporting is considered a key best practice area by SIMA. "The importance of onsite documentation of operations" is highlighted in the Advanced Snow Management Core Principles course. Field operations trainings include discussion of the importance of verification and documentation.

3.3.5 SWiM Certification

All of the BMPs are covered as part of the SWiM program. A 100-point matrix of policy guidelines is used to ensure that winter maintenance materials use is optimized (Sexton 8/27/19). The program is focused around a target application rate, working to reduce it, and verifying material use via technology. The information below summarizes information obtained from a phone interview with the program's founder. In all cases, this is not a comprehensive representation of the training.

3.3.5.1 Plowing Practices

Topic covered by this program, but specifics are unknown.

3.3.5.2 Calibration

Topic covered by this program, but specifics are unknown.

3.3.5.3 Measurement

Topic covered by this program, but specifics are unknown.

3.3.5.4 Level of Service

Topic covered by this program, but specifics are unknown.

3.3.5.5 Training

Topic covered by this program, but specifics are unknown.

3.3.5.6 Anti-Icing

Topic covered by this program, but specifics are unknown.

3.3.5.7 Liquids

Topic covered by this program, but specifics are unknown.

3.3.5.8 Application Practices, Varying Application Rates, Use of Deicers at Cold Temperatures

Topic covered by this program, but specifics are unknown.

3.3.5.9 Pre- and Post-Storm Meetings to Review Plans and Performance

Topic covered by this program, but specifics are unknown.

3.3.5.10 Weather Forecasting/Surface Temperature Information

Topic covered by this program, but specifics are unknown.

3.3.5.11 Enhanced Equipment/Technology

Topic covered by this program, but specifics are unknown.

3.3.5.12 Salt Storage and Handling

Topic covered by this program, but specifics are unknown.

3.3.5.13 Winter Maintenance Planning

Topic covered by this program, but specifics are unknown.

3.3.4.14 Accountability/Tracking and Reporting

Topic covered by this program, but specifics are unknown.

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The information in this document was compiled using readily available web-based information and existing materials in the sources listed below.

Accredited Snow Contractors Association. 2016. Course Selection. http://learning.ascaonline.org.

American Public Works Association. 2019. APWA's Winter Maintenance Supervisor Certificate Workshop (workshop handout).

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Smart About Salt Council. 2018. Training Workbook. www.smartaboutsalt.com/resources/Documents/Training%20Workbook%2020180222v3.pdf.

Snow and Ice Management Association. Members access at www.sima.org.

Appendix G. Outreach Pilot Outreach Campaign (2019): Communications Plan and Lessons Learned

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1 Education and Outreach Workgroup Pilot Communications Plan

1.1 Purpose

The Education and Outreach Workgroup of the Salt Management Strategy (SaMS) is conducting this pilot outreach effort to:

- Test messages and materials developed by the Education and Outreach Workgroup to gauge the extent to which they resonate with the general public and target audience.

1.2 Background

- *What's the issue?*
  In winter, salt helps keep us safe during slick weather conditions. Salt applied to paved surfaces prevents slip and fall injuries, reduces vehicle crashes and keeps businesses and government open. However, winter salts have negative impacts on the environment, such as increased salinity in streams and groundwater, increased costs for maintenance and replacement of corroded vehicles and infrastructure, and public health problems associated with saltier drinking water sources. Our challenge is to find the balance between the benefits of salt application and the unintended impacts while continuing to keep the same levels of safety. Increasing awareness as well as ways individuals and organizations can optimize their winter practices and encouraging them to take action will put Northern Virginia on the path toward minimizing these negative effects.
- *What's being done to address it?*
  A diverse set of stakeholders, coordinated by the Virginia Department of Environmental Quality, is developing the SaMS with recommendations for improving winter practices that promote the efficient and effective use of salts. The strategy will also contain options for raising awareness of these impacts, ways individuals can make a difference, and recommendations for a monitoring and research program to implement an adaptive management strategy for the SaMS.
- *Who is leading the effort on communications for this pilot?*
  The Education and Outreach Workgroup, a subcommittee of the SaMS Stakeholder Advisory Committee, will coordinate this pilot outreach plan. Information learned from the pilot outreach effort will be used to refine this workgroup's final recommendations for the SaMS.

1.3 Pilot Framework

- Long Branch Watershed Outreach (part of the larger Accotink Creek watershed, located within Fairfax County)
    - Postcard mailers
        - In the beginning of November 2019, mailers will be sent to residents in the Long Branch watershed advertising a listening session to be held on December 3, 2019 and will include the SaMS logo.
    - Listening session
        - On December 3, 2019, the Education and Outreach workgroup members, in coordination with local watershed leaders (such as Long Branch Civic Association, Friends of Long Branch Stream Valley and Friends of Accotink Creek), will hold one listening session to gather feedback from watershed residents on the overarching SaMS message and outreach methods/materials.
- Northern Virginia Outreach - SaMS message testing
    - Step 1: "What is SaMS," Introduce SaMS and encourage SaMS newsletter sign up
        - Partner organizations distribute content as a single social media post or once as part of a newsletter or email.
        - Timing:
            - Week of November 18, 2019
        - Content:
            - SaMS Logo and the option to include a picture
            - Partner organizations can share the suggested language provided below, or have the option to draft their own message using the message elements in the bullets below:
                - Suggested language for a newsletter or email: "In the winter, salt provides many benefits. However, salt has negative impacts. Learn how partners in Northern Virginia are working to strike a balance with a Salt Management Strategy (SaMS) by signing up to learn more here. #WinterSaltSmart #LearnAboutSalt"
                - Suggested language for social media:
                    - **Facebook:** "Winter salt use provides many benefits, but also has serious negative impacts. That's why DEQ and a group of stakeholders are taking part in SaMS, a Salt Management Strategy working to balance responsible environmental stewardship with safety in Northern Virginia. To learn more and signup for further information, click here: https://www.deq.virginia.gov/water/water-quality/tmdl-development/salt-management-strategy-development #WinterSaltSmart #LearnAboutSalt"
                    - **Twitter:** "Winter salt use has many benefits, but also negative impacts. That's why stakeholders are taking part in SaMS, a Salt Management Strategy working to balance these benefits and impacts. Learn more and sign up to get informed: https://www.deq.virginia.gov/water/water-quality/tmdl-development/salt-management-strategy-development #WinterSaltSmart"
            - Message elements to compile a unique message:
                - Winter salt use has benefits and impacts (aim to strike a balance)

        - The SaMS is being developed by a group of stakeholders that aim to strike a balance between the benefits and impacts of winter salt use.
            - *Optional*: include a link to this page that outlines the organizations developing SaMS: https://www.deq.virginia.gov/home/showpublisheddocument?id=2149
            - *Optional:* include a link to the SaMS webpage: https://www.deq.virginia.gov/water/water-quality/tmdl-development/salt-management-strategy-development
        - Invite audience to sign up to learn more at https://visitor.r20.constantcontact.com/d.jsp?llr=nyolw7cab&p=oi&m=1102622079757&sit=txrp5oieb&f=94db84a4-6844-41be-afcb-b25f07c94ac8
        - Include the hashtags #WinterSaltSmart and #LearnAboutSalt
        - *Optional*: Perspective on why the organization distributing the message is participating in the SaMS
- Step 2: "Awareness," Share awareness information
    - Partner organizations distribute content as a single social media post, and the 1st SaMS awareness newsletter will be distributed to the contact list.
    - Timing:
        - Week of December 9, 2019
    - Content:
        - Social Media Posts:
            - SaMS Logo and the option to include a picture
            - Partner organizations can share 1 of the 3 options for suggested language provided below, or have the option to draft their own message using the message elements in the bullets below:
            - Suggested language (use 1 of the 3):
                - #WinterSaltSmart #LearnAboutSalt Learn more about salt use in Northern Virginia at: https://www.deq.virginia.gov/Portals/0/DEQ/Water/TMDL/SaMS/SaMS_1pg_flyer_201910.pdf [link no longer active]
                - #WinterSaltSmart Want to learn how we're doing this in Northern Virginia? https://www.deq.virginia.gov/Portals/0/DEQ/Water/TMDL/SaMS/SaMS_1pg_flyer_201910.pdf [link no longer active] #LearnAboutSalt
                - #WinterSaltSmart #LearnAboutSalt The pluses and minuses of salt use in Northern Virginia at: https://www.deq.virginia.gov/Portals/0/DEQ/Water/TMDL/SaMS/SaMS_1pg_flyer_201910.pdf [link no longer active]
            - Message elements to compile a unique message:
                - Language that entices the reader to learn more about the topic. As much as possible, this language should maintain a balance between the benefits and impacts of winter salt use.
                - Include the hashtags #WinterSaltSmart and #LearnAboutSalt

        - Include the infographic in the post or provide the link to the 1-page flyer (https://www.deq.virginia.gov/Portals/0/DEQ/Water/TMDL/SaMS/SaMS_1pg_flyer_201910.pdf [link no longer active])
    - SaMS Awareness Newsletter
        - A reformatted version of the 1 page flyer, formatted into a newsletter that includes the SaMS logo.

1.4 Objectives and Measures of Success

- Identify reactions to overarching SaMS message and associated topic flyer through feedback from:
    - Social media posts
        - Background information for calculating success
            - Name of social media platform
            - Number of "followers" in organization's network
            - Post Reach/Impressions (i.e., the size of the audience)
            - Date of Post
            - If known, the average post reach/impressions for the organization
        - Engagement metrics for calculating success for each post
            - Number of likes per post (goal: >1%)
            - Comments (goal: > 50% positive sentiment)
            - Number of shares and retweets (goal: >0.5%)
    - Social media traction
        - Tracking of hashtag use
    - Email/Newsletter distribution
        - Background information for calculating success
            - Size of the audience
            - Was it part of an email or part of a newsletter
            - Date/time of email or newsletter
            - If distributing through a newsletter, the average open rate and click rate for the organization
            - Open rate
    - Interest in newsletter
        - Number of newsletter sign ups
    - For social media and email/newsletter message distribution
        - Flyer linked to message distributions
            - Number of page views
                - Using a link shortener and tracking the number of clicks on the link (goal: >2%)
            - SaMS website page views after outreach effort is implemented
                - Linking to the SaMS website (goal: 20% increase)
- Information learned from this pilot project will:
    - Refine this workgroup's recommendations for the final SaMS, such as revising the overarching SaMS message and materials to improve reception by the intended audience.

1.5 Key Messages

- Tagline: Winter Salt Smart
- Hashtags:
  - #WinterSaltSmart
  - #LearnAboutSalt
- Teaser to encourage the reader to click on link:
  - Learn more about salt use in Northern Virginia at: [insert web link]
  - Want to learn how we're doing this in Northern Virginia? Click here: [insert web link]
  - The pluses and minuses of salt use in Northern Virginia at: [insert web link]
- Awareness message (pulled from one-page flyer)

  In the winter, salt helps keep us safe during storms and icy conditions. Salt applied to paved surfaces provide important benefits

  - **For People and Businesses:** Fewer incidents of slip and fall injuries
  - **For Transportation:** Reduces frequency of vehicle crashes by 88%-95%[48,49]
  - **For the Economy:** Enables businesses, government and social services to continue with minimal interruption (avoiding roughly $300-$700 million in direct/indirect costs for a major, one-day, statewide storm[50]).

  However, winter salts also have impacts to the environment, water quality, infrastructure and public health. After the storm is over, these salts wash off into our streams, causing:

  - **Public Health Impacts:** Harm to public health for those serviced by drinking water supplies with higher salt concentrations.[51] Salt levels in both the Potomac River and Occoquan Reservoir, local drinking water sources, have risen noticeably over the past several decades, with average concentrations more than doubling.
  - **Infrastructure Impacts:** Corrosion to vehicles and infrastructure (such as roads, bridges, sidewalks and parking lots) causes higher frequency of replacement and higher maintenance costs.[52]
  - **Environmental Impacts:** Increases the salinity in our streams and groundwater, impacting freshwater fish and other aquatic life.

  We can balance these unintended impacts from salt use with the important benefits these salts provide during winter storms. The challenge is finding the best balance for Northern Virginia.

- "What is SaMS" message:
  - The Virginia Salt Management Strategy (SaMS) was established by a diverse group of stakeholders coordinated by the Virginia Department of Environmental Quality (DEQ). This will provide recommendations for improving winter practices through efficient and effective use of salts while

[48] University of Waterloo: http://www.saltinstitute.org/wp-content/uploads/2014/01/Final-Report-L-Fu-Taimur.pdf
[49] Marquette University: http://www.trc.marquette.edu/publications/IceControl/ice-control-1992.pdf
[50] Global Insight: http://www.saltinstitute.org/wp-content/uploads/2013/10/economic-costs-of-snowstorms.pdf
[51] Murray, D.M. and U.F. Ernst. 1976. An economic analysis of the environmental impact of highway deicing. USEPA-600/2-76-105. USEPA Office of Research and Development, Municipal Environmental Research Laboratory. Cincinnati, OH

[52] Vitaliano, D. 1992. An economic assessment of the social costs of highway salting and the efficiency of substituting a new deicing material. Journal of Policy Analysis and Management 11(3):397-418.

maintaining the same levels of safety. The strategy will also offer ways to raise awareness of these impacts, ways individuals and organizations can participate, and guidance for monitoring and research to support action on SaMS recommendations.

- Where to go for more info?
    - https://www.deq.virginia.gov/water/water-quality/tmdl-development/salt-management-strategy-development
- Where to go to provide feedback on outreach?

    Please share your feedback on the message and flyer that you viewed by completing this short form https://www.surveymonkey.com/r/LMK6MD6

    1. What is your interest in winter salt issues?
    2. What do you think about the information shared in the flyer?
    3. Any additional thoughts on winter salt use or our outreach efforts?

1.6 Key Audiences

- Residents in the Long Branch watershed (within the larger Accotink Creek watershed in Fairfax County.
- General public of Northern Virginia – more specifically, commuters, homeowners, business owners, winter storm professionals and educators.

1.7 Communication/Distribution Channels:

- Long Branch Watershed Mailers
    - Post card mailers sent to residents of the Long Branch watershed inviting them to the listening session and includes the over-arching message. The distribution of these mailers will be coordinated with Clean Water Action who has funding to support this distribution.
- Long Branch Watershed Listening Session:
    - An informal event to provide opportunity for those in the community to talk with Education & Outreach workgroup members about the SaMS and their thoughts and opinions on the outreach materials and messages drafted. Venue will be selected within the Long Branch watershed. Below is a list of organizations that will be contacted to distribute the meeting invite:
        - Friends of Accotink Creek
        - Long Branch Civic Association
        - Friends of Long Branch Stream Valley
        - Fairfax County Braddock District Supervisor John Cook's network
        - Posting flyers
            - On neighborhood social media pages
            - At park bulletin boards
            - At local churches
            - At local schools
- Web-based media outlets:
    - Encourage Education and Outreach Workgroup members to share information on their organizations' social media outlets, emails and/or newsletters. Additionally, local governments and other media outlets with a general public audience will be prioritized so that the receiving audience is not unintentionally targeted to a special interest.

1.8 Frequency of Communications:

Outreach efforts are recommended, per organization, to proceed at the following frequency for each method of distribution:

- SaMS message distribution and testing: two times (one time for Step 1 and one time for Step 2). Step 1 will be distributed the week of November 18, 2019, and Step 2 will be distributed the week of December 9, 2019
- Listening session: one session held on December 3, 2019

1.9 Timeframe

Two months: November – December 2019

Initiate the effort in November and end in December 2019. The timeframe was selected to overlap with the beginning of the winter season, when the topic of winter storms will be on the minds of the targeted audience. The information gathered will be used to refine and inform recommendations for inclusion into the final SaMS.

1.10 Obstacles and/or Emergencies Encountered

Potential obstacles that may arise and proposed solution to address it are:

- Broken links or typographical errors in materials.
    - Inform DEQ contact, who will either correct the error or coordinate with the person who has access to correct the error.
- Misunderstanding and/or negative response to overarching SaMS message.
    - Distribution channels have the option to use the language provided below, or simply direct individuals to the DEQ contact.
    - "We are participating in the SaMS because ____[entity enters their perspective]____, but understand you may have concerns about the initiative in general. Please send your concerns/comments to William.Isenberg@DEQ.Virginia.gov."

1.11 Contacts

Education and Outreach Workgroup Member Contact:

Will Isenberg, DEQ
804-698-4228
William.Isenberg@deq.virginia.gov

2 Summary and Outcomes of SaMS Pilot Outreach Campaign

2.1 Summary of Findings

2.1.1 Pilot Outreach Campaign Results

The pilot outreach campaign conducted in November and December of 2019 reached an audience of almost 21,000 people. It was an overall success, since many of the objective performance metrics were met.

The results from the message testing portion of the pilot campaign were:

- The SaMS pilot campaign was a success with regard to SaMS webpage views, with a traffic increase of 450%-780% over the extent of the pilot campaign.
- Twelve individuals signed up for the SaMS newsletter as a result of this portion of the pilot campaign.
- Social Media:
    - 100% of the comments were positive or neutral.
    - Throughout the campaign, social media posts had an average like rate (likes as a % of the audience) of 0.99%, which was slightly below the goal of >1%. However, the second step of the message testing portion of the campaign met objectives, receiving an average like rate of 1.37%, indicating that audiences prefer information on the topic rather than announcements.
    - Throughout the campaign, the average share/retweet rate (shares/retweets as a % of the audience) was 0.16%, which is well below the goal of >0.5%.
    - The hashtag #WinterSaltSmart gained traction on social media after the campaign ended.
    - When organizations used their own language (i.e., not the language developed by the SaMS Education and Outreach workgroup), the posts performed better.
    - Social media posts with infographics tended to have the most successful engagement with the audience.
- Emails and newsletters can be successful engagement methods since there was evidence that those lead to increased webpage traffic.

The results from the community listening session portion of the pilot campaign were:

- Twelve members of the SaMS Education and Outreach workgroup and thirteen members of the public attended the meeting.
- The informal cafeteria portion of the meeting facilitated a lot of discussion between attendees and the seven organizations from the SaMS Education and Outreach workgroup members. This format consisted of each organization having a table set up around the room.
- Eight meeting attendees signed up for the SaMS newsletter.
- Most attendees found out about the event from an organization, all of which appear to focus on environmental topics.
- The group discussions were informative and provided recommendations pertaining to:
    - Ways to get the message out
    - Ways to tailor the message (by interest)
    - What information to share
    - SaMS hashtags
    - Message tone (positive, balanced, etc.)
    - Concerns about the outreach effort

2.1.2 Recommendations for SaMS Education and Outreach Messages, Materials and Outreach Methods

The recommendations below come from both the message testing and the community listening session portions of the pilot outreach campaign.

2.1.2.1 Messages

1. Messages should highlight recommended elements and not be prescriptive.
2. The hashtag #LearnAboutSalt was not very popular.
3. Using a positive tone in messages was supported, but when "bad news" has to be shared, it should be presented directly and not dramatized. When sharing bad news, give actionable items of what you can do.
4. Messages could be more successful if focused on drinking water impacts.
    a. *Note, the results of the SaMS awareness survey indicate that the general public knows the least about these impacts.*
5. Messages should include information on things individuals can do, like salting tips/ideas for alternative deicers around their homes.
    a. *Note, the results of the SaMS awareness survey suggest that the majority of the population is willing to reduce their own salt use, knowing that there are negative impacts from salts on drinking water and the environment.*

2.1.2.2 Materials

1. Infographics performed better than other outreach materials
2. Photos alone did not improve engagement
3. Engagement went up when the logo was used, indicating awareness of the SaMS brand

2.1.2.3 Outreach Methods

1. Social media is a very efficient outreach method. This may be particularly valuable when raising awareness on this topic. Note, this pilot campaign did not test any messages related to behavior change.
2. Emails and newsletters can be successful methods for outreach, but may be dependent on the organization and the contact list.
3. For community listening sessions and related efforts, depending on the goal for the specific outreach event, the organizer may want to target communities that are not already involved and interested in this topic if the goal is to expand the general awareness of the topic and learn from new audiences.

2.2 Pilot Campaign Purpose and Design

At the first meeting of the SaMS Education and Outreach workgroup, the workgroup identified the need for a pilot outreach campaign that would test the messages and materials developed by the workgroup to gauge the extent to which they resonate with the general public. The workgroup expected the outcomes of this pilot campaign would inform the final recommendations and resources developed by this workgroup prior to finalizing them in the SaMS Toolkit. The workgroup designed the pilot outreach campaign over a series of meetings and ultimately agreed to implement it in November and December 2019.

The pilot outreach campaign had two portions: 1) Digital message testing; 2) An in-person community listening session to discuss and receive feedback. The workgroup designed the message testing portion to be implemented through electronic media (e.g., social media, newsletters, and email) by the participating SaMS Education and Outreach workgroup organizations over two weeks – November 18-24 ("Step 1") and December 9-15 ("Step 2"). Alternatively, the workgroup

designed the community listening session to be a one-time, in-person event held at the Kings Park Library in Burke, Virginia, on December 2, 2019.

2.3 Message Testing

2.3.1 Background

The message testing portion of the outreach pilot was intended to test messages, materials, and methods for disseminating those messages and materials. All outreach methods were electronic, and included newsletters, emails, and social media posts. Organizations in the SaMS Education and Outreach workgroup were invited to participate in this portion of the pilot by disseminating messages and materials through their electronic media.

There were two "steps" to the message testing portion of the pilot, which were simply called "Step 1" and "Step 2." Organizations were asked to send out one social media post and/or newsletter/email with messages and materials pertaining to Step 1 during the week of November 18-24, 2019. For Step 2, organizations were asked to send out one social media post with messages and materials pertaining to Step 2 during the week of December 9-15, 2019. Initially the plan intended to have all organizations disseminate messages on the same day. However, because each group has a different audience with different peak times, the decision was made to provide flexibility and give organizations a week to disseminate the messages and materials. Details on each of the steps are provided below:

"Step 1" of the message testing was an announcement. It introduced "What is SaMS," identified the stakeholders involved, and encouraged the audience to sign up for the SaMS newsletter. Organizations also were encouraged to provide their perspective on why they are participating in SaMS. Step 1 also introduced the SaMS hashtags, which include #WinterSaltSmart as the primary hashtag and #LearnAboutSalt as the secondary hashtag. These two hashtags were developed by the SaMS Education and Outreach workgroup to provide context and introduce the tagline for SaMS, "Winter Salt Smart." Below is an example of the proposed language for Step 1:

> "*Winter salt use provides many benefits, but also has serious negative impacts. That's why DEQ and a group of stakeholders are taking part in SaMS, a Salt Management Strategy working to balance responsible environmental stewardship with safety in Northern Virginia. To learn more and signup for further information, click here:* https://www.deq.virginia.gov/water/water-quality/tmdl-development/salt-management-strategy-development *#WinterSaltSmart #LearnAboutSalt"*

"Step 2" of the message testing shared messages and content to raise public awareness on the topic of salt use benefits and impacts. Emails and newsletters were not supposed to be a part of this step since the SaMS Awareness Newsletter would be distributed during this step to those on the SaMS contact distribution list, including those contacts who signed-up for the newsletter during Step 1. Therefore, Step 2 consisted of a single social media post from participating organizations and the distribution of the SaMS Awareness Newsletter. Initially the social media posts were supposed to include a brief statement to entice the audience to click on a link to a 1-page flyer to learn more about the benefits and impacts of salts. However, learning that click-through rates are typically low, an infographic that summarized the content of that 1-page flyer was prepared, and groups were given the option to share the infographic or a link to the 1-page flyer. Below is an example of the Step 2 proposed language with the link to the 1-page flyer:

> "#WinterSaltSmart #LearnAboutSalt Learn more about salt use in Northern Virginia at: https://www.deq.virginia.gov/Portals/0/DEQ/Water/TMDL/SaMS/SaMS_1pg_flyer_201910.pdf "[link no longer active]""

2.3.2 Participation and Audience Reached

Of the 23 organizations in the SaMS Education and Outreach workgroup, 10 participated. Overall, there were 35 total **digital communications**, which are being defined here as any single electronic distribution of content. Digital communications include social media posts, items in an email or newsletter and entire newsletters or emails. These 35 digital communications occurred during the period that spanned November 18 through December 16. This included some digital communications that were distributed in between the week designated for Step 1 and the week designated for Step 2. Of the 35 digital communications, 6 were newsletters/emails and 29 were posts on social media. Collectively, the digital communications reached an audience of almost 21,000 people. See **Table 22** for a detailed breakdown of the digital communications, the audiences they reached, whether or not the organization used the proposed language for Step 1 and/or Step 2, and for social media posts, what type of visuals were used. Information on the language used and the visuals used will be discussed later as this seemed to influence the success of the digital communications. **Figure 13** displays the audiences reached over time with each digital communication and as a cumulative total.

Table 22. Pilot campaign message testing summary of digital communications.

	Entire Effort			Step 1		Step 2	
Organizations Participating	10			9		7	
	Total	**Social Media**	**Email or Newsletter**	**Social Media**	**Email or Newsletter**	**Social Media**	**Awareness Newsletter**
Audience Engaged	20,948[a]	19,368	1,580[a]	12,285	1,480	7,083	100
Number of Digital Communications	35[a]	29	6[a]	18	5	11	1
Digital Communication Used Provided Language	21[a]	16	5[a]	12	4	4	1
Digital Communication Used Their Own Language	14	13	1	6	1	7	n/a[b]
Digital Communication Included a Picture	3	3	n/a[c]	2	n/a[c]	1	n/a[c]
Digital Communication Included the SaMS Logo	10	10	n/a[c]	10	n/a[c]	0	n/a[c]
Digital Communication Included a Picture and the SaMS Logo	3	3	n/a[c]	3	n/a[c]	0	n/a[c]
Digital Communication Included an Infographic	9	9	n/a[c]	0	n/a[c]	9	n/a[c]
Digital Communication Did Not Use Any Visual	4	4	n/a[c]	3	n/a[c]	1	n/a[c]

[a]Includes Awareness Newsletter
[b]The Awareness Newsletter was prepared using language the workgroup developed
[c]Information on use of visuals was only available for social media posts

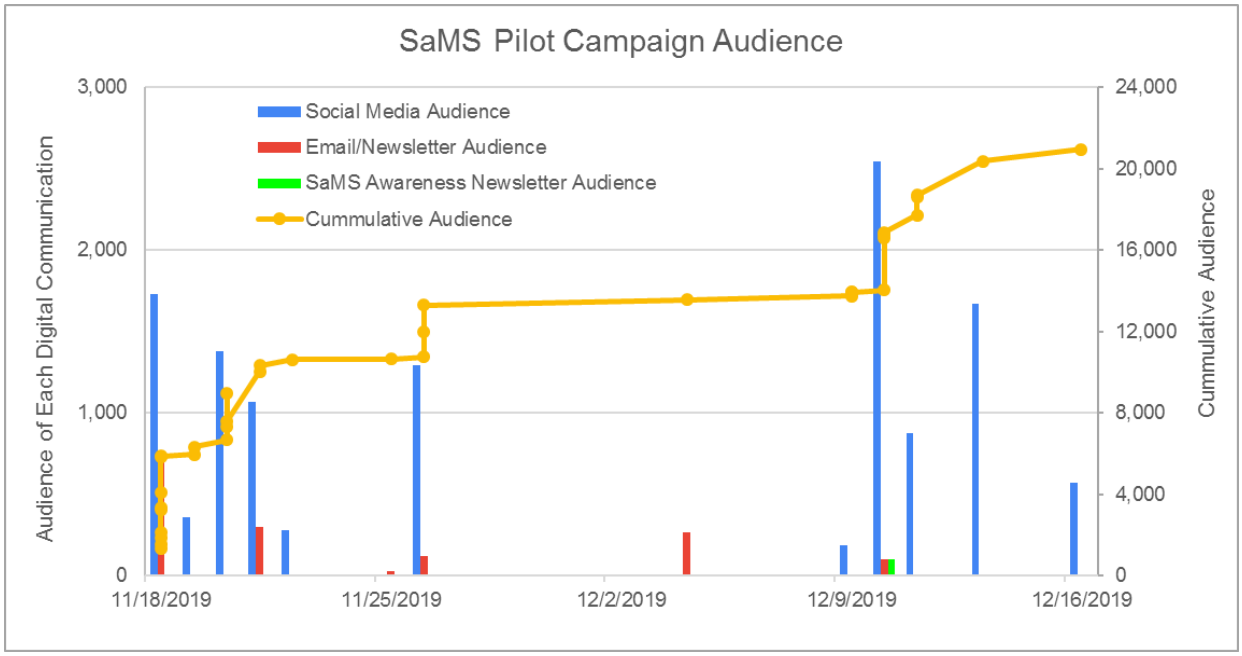


Figure 13. Audience reached by SaMS Pilot Campaign.

2.3.3 Performance Metrics

The SaMS Education and Outreach workgroup identified a number of objective measures of success in the pilot outreach campaign prior to its launch. The purpose of these measures was to evaluate the performance of the messages, materials and outreach methods. Social media generated the most detailed statistics; however, newsletters and emails also provided valuable information. Evaluation metrics are discussed in further detail below.

2.3.4 Evaluating the Campaign Elements

2.3.4.1 Social Media

Social media posts were evaluated by sentiment and engagement (number of comments, likes, shares and retweets). Positive performances were determined if a <50% negative sentiment rate, >1% of likes and >0.5% of shares and retweets were achieved. For detailed statistics, see **Table 23**.

Sentiment: From November 18, 2020 to January 9, 2020, there were 45 mentions of SaMS and the hashtag #WinterSaltSmart on social media (Facebook, Instagram and Twitter) as well as various online news outlets. The average sentiment of the mentions was 89% positive, 7% negative and 4% neutral. The sentiment was calculated using Falcon.io, an online social media marketing platform, and a manual quality assurance review.

Comments: There were 12 total comments on the 29 social media posts, **none of which were negative**. All 12 comments were either **positive** or **neutral**.

Likes: For the entire pilot period, the average like rate was 0.99% based on the total social media audience (19,368) and the total number of likes (192), which **falls below the goal of >1%.**

However, certain individual posts demonstrated high performance rates, giving insight that will help generate increased engagement in the future. As such, the following should be noted:

- Organizations that used their own captions had an average like rate of 1.20%, with 7 of these 13 posts having like rates >1%.
- Posts that used boilerplate language had an average like rate of 0.85%, with only 8 of these 16 posts having like rates >1%.
- **Step 2 had an average like rate of 1.37%** in contrast to Step 1, which had an average like rate of 0.77%. This suggests that information on the topic connected more with the audience than the announcement in Step 1.
- The infographic in Step 2 also seemed to resonate with followers, receiving an average like rate of 1.57%, with 8 of the 9 posts with infographics having like rates >1%.

Share/Retweet Rate: For the entire pilot, the average percent of the audience that shared or retweeted posts **was under half of our goal**.

- Only six of the 29 posts did exceed the goal of a share/retweet rate >0.5%.
- There did not seem to be an impact on the share/retweet rate by the choice of language (i.e., using the provided language or using original captions).
- Step 1 had the lowest average share/retweet rate at 0.12%. Interestingly, including a logo in the post did relate to higher share/retweet rates (0.21%), but posts that included a picture (e.g., French fries with salt, a salt pile, or a winter scene), even with a logo had 0% share/retweet rates.
- Step 2 had higher share/retweet rates, with an average of 0.23%.
- Posts with infographics had higher average share/retweet rates (0.24%).
- Posts without visuals (including posts from Step 1 and Step 2) had an average share/retweet rate of 0.23%.

Table 23. Social media metrics summary.

	Entire Effort	Step 1	Step 2	Impact of Language		Impact of Visuals			
				Used Provided Language	Used Their Own Language	Used a Picture[2]	Used the Logo	Used an Infographic[3]	Did Not Use a Visual
Number of Social Media Posts	29	18	11	16	13	6	10	9	4
Total Audience	19,368	12,285	7,083	11,733	7,635	4,712	8,168	5,404	1,084
Number of Comments	12	7	5	10	2	1	6	5	0
Number of Negative Comments	0	0	0	0	0	0	0	0	0
% of Comments Positive or Neutral[1]	100%	100%	100%	100%	100%	100%	100%	100%	100%
Number of Likes	192	95	97	100	92	40	55	85	12
Number of Posts Above 1% Likes	15, or 52%	6, or 33%	9, or 82%	8, or 50%	7, or 54%	2, or 33%	3, or 30%	8, or 89%	2, or 50%
Average % Likes	0.99%	0.77%	1.37%	0.85%	1.20%	0.85%	0.67%	1.57%	1.11%
Number of Shares/Retweets	31	15	16	20	11	0	17	13	1
Number of Posts Above 0.5% Share/Retweet	6, or 21%	3, or 17%	3, or 27%	2, or 13%	4, or 31%	0, or 0%	3, or 30%	2, or 22%	1, or 25%
Average % Shares/Retweets	0.16%	0.12%	0.23%	0.17%	0.14%	0.00%	0.21%	0.24%	0.23%
# of posts where average audience reached is known						3	2	3	0
Average % of average audience reached (where known)						71%	161%	204%	n/a
Average Audience % of Followers						11%	29%	23%	37%

[1]Metric of success is >50% positive comments. Only one comment was positive, the rest were neutral.

[2]Includes 3 posts that had a picture and the logo.

[3]All but 1 of the posts had the same infographic. The unique infographic had the same content.

2.3.4.2 Social Media Traction

The use of the SaMS hashtag #WinterSaltSmart was tracked using Falcon.io, an online social media marketing platform. The analysis did not include the secondary SaMS hashtag #LearnAboutSalt in order to streamline the algorithm. From November 18, 2019, through January 9, 2020, there were 36 mentions tracked by the software on social media (Facebook, Instagram and Twitter). **Figure 14** shows the number of mentions over that period. Since there was no objective measure of success for social media traction, the most effective approach was to look at the mentions over time. **While SaMS pilot outreach posts contributed to the mentions, it is clear that traction did occur following the pilot campaign, which can be considered a success.** However, this conclusion should be cautioned since a twitter hashtag search conducted on January 28, 2020, showed usage of this hashtag in parts of Pennsylvania. Whether or not this pilot outreach campaign contributed to its use in Pennsylvania is not known. However, since the goal was to gain traction in Northern Virginia, posts in Pennsylvania do not speak to that goal.

Falcon.io also determines the sentiment of the hashtag use. Based on that assessment, the platform determined the hashtag use to be overwhelmingly positive.

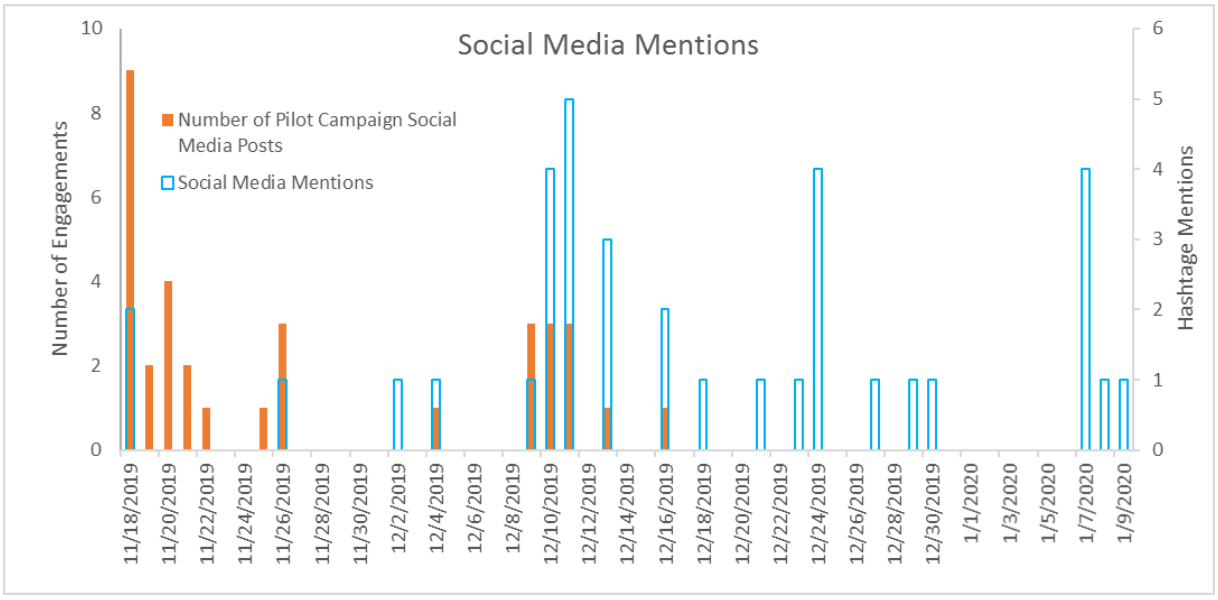


Figure 14. Mentions that include mentions with the hashtag #WinterSaltSmart over time and compared to the number of SaMS pilot outreach campaign posts.

2.3.4.3 Email and Newsletter Distributions

There were no objective measures of success for emails and newsletter distributions determined in the pilot outreach campaign. Furthermore, success is difficult to measure for these forms of communication since many of the communications were not solely focused on SaMS. Instead, many included a small snippet of information about SaMS in them. Nonetheless, these methods of communication did allow for the audience to be estimated. The total audience engaged through emails and newsletters was 1,580 individuals, which includes 100 from the SaMS Awareness Newsletter (more in the **section below**). For newsletters, where the information was available, the open rate ranged from 20% to 114% of the average open rate. However, since the content is not viewable prior to opening, this metric is not very useful for determining success.

With the audience known, the success of emails and newsletters can be evaluated in terms of their impact on page views from links included in them. All of the emails or newsletters included a link to the SaMS webpage. However, this is a

difficult evaluation to make since emails and newsletters last longer in inboxes when compared to social media posts. So the impact on page views may be distributed over time following the delivery of the email or newsletter. Complicating things further, it is difficult to tease out the impact of any specific digital communication on page views since they were all distributed around the same time. Nonetheless, there were two instances where 100% of the daily audience engaged was from an email or newsletter. **Figure 15** shows there were large jumps in page views around these two instances, especially when the following days were included in the analysis. Therefore, it is possible that emails and newsletters have the potential to be successful outreach methods.

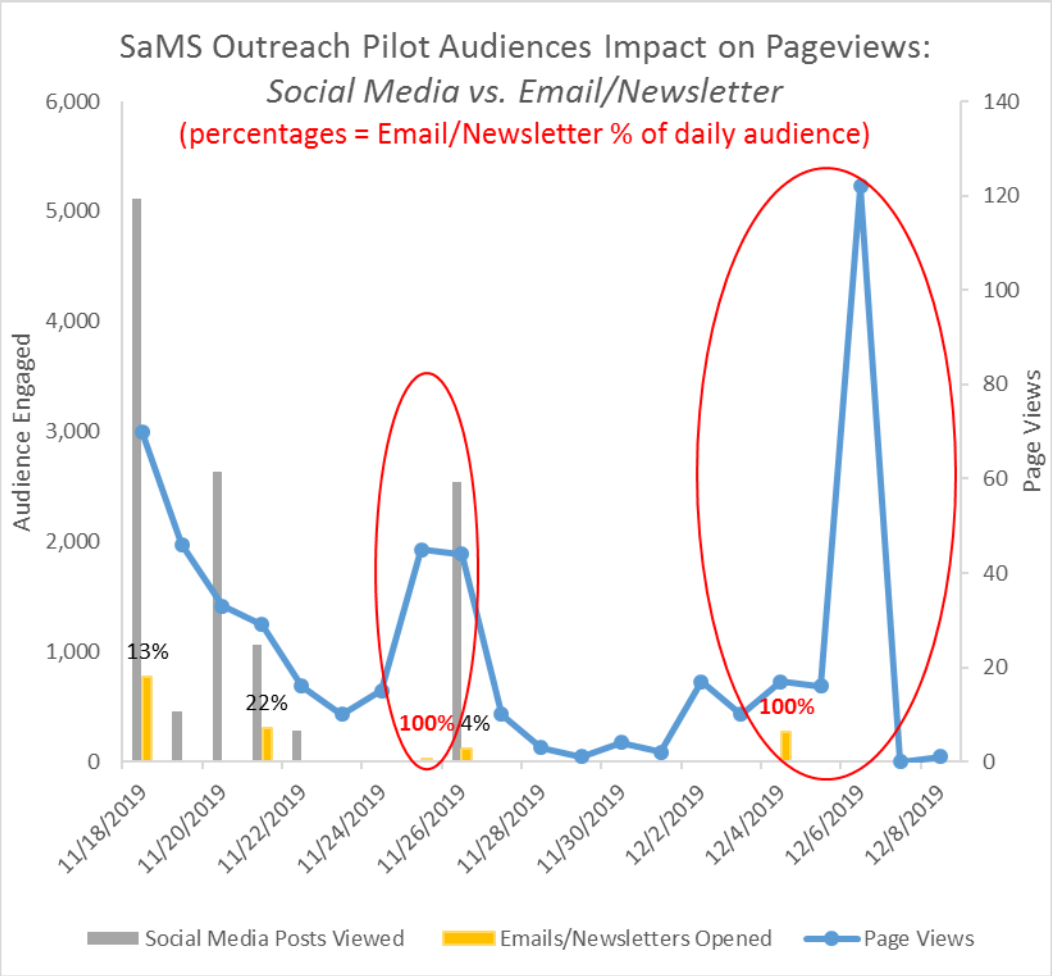


Figure 15. Two examples of the impact of newsletters and emails on pageviews.

2.3.4.4 SaMS Webpage:

During the pilot outreach campaign period (November 18 through December 16, 2019), there were 684 page views, with 643 of those being unique. **Figure 16** shows how much higher the average daily page views were during the pilot period compared to two different baseline periods. The SaMS pilot outreach campaign set the objective measure of success for webpage views as an increase >20%. **This goal was greatly surpassed as the increase in the number of page views was between 450-780%.** Furthermore, during the pilot outreach campaign period, the average time a user spent on the page was about 3.5 minutes, which indicates views where viewers read and engaged with the content. Additionally, 12 (1.87%) of the 643 individuals who visited the webpage signed up for the SaMS newsletter. The impact of digital communications on page views and newsletter sign-ups can be seen in **Figure 17.** It is also worth noting that 329 of the 684 page views linked to the webpage from social media posts on Facebook.

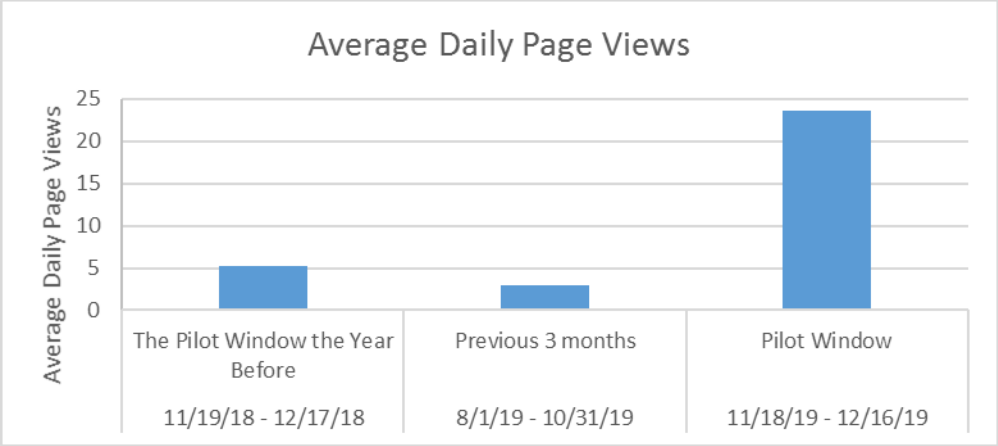


Figure 16. Average daily webpage views for two baseline periods compared to the pilot window.

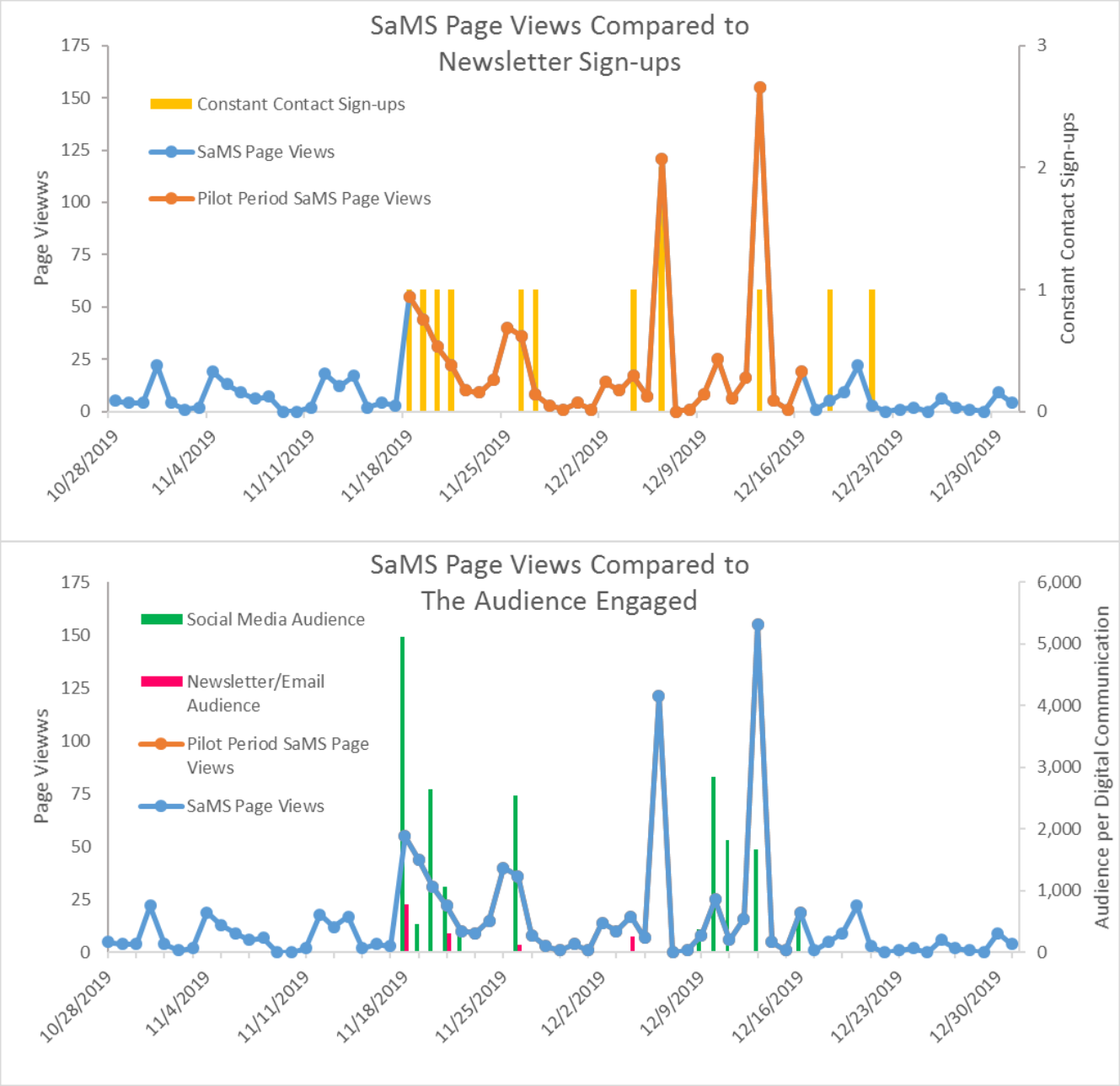


Figure 17. SaMS webpage views compared to newsletter sign-ups and the audience of each digital communication.

2.3.4.5 SaMS Awareness 1-page Flyer

As part of Step 2, a 1-page flyer was prepared that outlined the benefits and impacts of salt use. The number of page views for this flyer were supposed to be tracked through a link shortener. However, this detail was overlooked when preparing outreach materials and therefore was not available for all organizations to use. Nonetheless, one organization did use a link shortener, which recorded only 3 clicks from an audience of 1,713 individuals. **Based on that one organization, the click through rate of 0.18% was well below our goal of 20%.** Because this is based on one organization's audience, it is difficult to draw any certain conclusions from this finding. Additionally, it is worth noting that the infographic was inspired by the idea that click through rates are known to be low. Therefore, it may be that organizations already know

their click through rates, and can determine whether or not a linked flyer like this would be successful. Organizations should evaluate their own data to draw this conclusion.

2.3.4.6 SaMS Awareness Newsletter

The SaMS awareness newsletter contained the same content as the 1-page flyer, and was sent to the SaMS newsletter contact list. This contact list was first assembled in 2018, and has been growing throughout the development of SaMS. During the pilot campaign (Step 1), this list grew by 12 individuals, and after the Listening Session (more in **Section 2.4**), 8 additional individuals signed-up. On December 10, 2019, the SaMS awareness newsletter was distributed to the 210 contacts on the list. There were 190 successful deliveries, and of that 100 individuals opened the newsletter. This results in an open rate of 56.2%, which is slightly below the average open rate of other SaMS newsletters (~60%). There was a click rate of 18% meaning 18 of the 100 individuals clicked on the various links in the newsletter. The most popular link was to the SaMS webpage (18 times) followed by the link to the list of SaMS organizations (5 times). One individual clicked on the link to the survey in the newsletter (see **Section 2.3.4.7** below). **Since there was no objective measure of success related to this distribution, it is hard to evaluate this tool's success. Nonetheless, an open rate of 56.2% is relatively high, and it bears mention that 100% of the 20 individuals who signed up for the newsletter during the pilot campaign opened the newsletter.**

2.3.4.7 Survey Attached to Awareness Newsletter and 1-page Flyer

A survey to collect feedback on the pilot outreach campaign was included in the 1-page flyer and the SaMS awareness newsletter. While it is known that the survey was clicked on once in the awareness newsletter, there were never any responses contributed. While this seemed like a good option for feedback, it may not be worth the effort to include in future outreach efforts. **Since there was no objective measure of success related to this survey, it is difficult to evaluate its success. However, since there was no participation, it is not considered to be a successful tool.**

2.4 Community Listening Session

2.4.1 Background

The purpose of the community listening session was to hear directly from the public in-person. Since the outreach materials and messages were being developed to engage the general public, the SaMS Education and Outreach workgroup agreed that it is important to hear directly from the public in-person, both in terms of their interest and awareness on the topic and their impressions of our outreach materials and messages. To implement this community listening session, members of the SaMS Education and Outreach workgroup in partnership with the Friends of the Long Branch Stream Valley worked to develop and advertise the community listening session. Originally, when the community listening session was first envisioned in the spring of 2019, a robust advertising plan was developed, which included 1) coordination with civic associations, 2) posting flyers in places of worship, parks, and other public spaces, and 3) mailers to be delivered to all of the households in the Long Branch (central) watershed. One of the primary reasons for this level of effort was the goal to engage with a population that represents the general public. Unfortunately, when the pilot was put on hold, these partnerships and opportunities were no longer available for the December community listening session. Regardless, advertisements were made through SaMS Education and Outreach workgroup members' outreach channels (e.g., social media), in addition to civic associations' social media accounts, other public community events, and through a public notice.

The community listening session was split into two portions. The first portion was a cafeteria style meeting, where various members from the SaMS Education and Outreach workgroup set up tables around the room. These tables included information related to each organization, SaMS, and in some cases information on the organization's participation in

SaMS. This portion of the meeting was intended to be informal, allowing the attendees to participate at their own comfort level. Following the cafeteria portion, the attendees assembled into a big group for a large group discussion. This portion began with a brief presentation that covered the basics on what SaMS is and what kind of feedback was sought from this listening session. After the background presentation and some time for questions, the group split up into two smaller discussion groups to learn directly from the meeting attendees. Meeting attendees received surveys when they arrived and again after the end of the group discussion to evaluate any change in the attendees' perspective. The surveys asked 1) how attendees found out about the community listening session, 2) why they attended the event, 3) how important winter salt use is to them, 4) how important the benefits of winter salt use are to them, and 5) how important the impacts of winter salt use are to them. Questions 3-5 were ranking questions based on a scale of 1-5, and these three questions were repeated in the second survey.

In the sections below, the community listening session and its outcomes will be discussed in further detail.

2.4.2 Attendance

The meeting attendance consisted of 12 members of the SaMS Education and Outreach workgroup attending and 13 members of the public. Prior to the meeting, there was a concern that meeting attendees may be overwhelmed if outnumbered by the SaMS Education and Outreach workgroup members, but this turned out to be a nonissue for this event. As was mentioned previously, 8 meeting attendees signed up for the SaMS newsletter using the sign-in sheet.

2.4.3 Survey Results

Ten attendees completed surveys, with only 6 filling out both surveys. While this is a small sample size, there were some conclusions that could be drawn from the information (**Table 24**). For example, most attendees found out about the event from an organization, all of which appear to focus on environmental topics. This is additionally evident in the reasons for attending, since 40% of the respondents indicated that their reason for attending was related to environmental concerns.

Table 24. Summary of responses to survey questions 1 and 2.

Questions	Major Responses		
1. How did you find out about tonight's event?	From an Organization	Social Media	A friend/neighbor
Question #1 details	Friends of Accotink Creek, Soil and Water Conservation District, A watershed group	Facebook	
Question #1 Category count	5	2	2
2. What was your reason for attending tonight?	To better understand	Environmental	To stay informed (already aware)
Question #2 details	The strategy, the topic, to educate	Concern for stream health, severity of salt loading	
Question #2 Category count	5	4	1

2.4.3.1 Importance Rankings

Attendees were surveyed to see how important they considered the benefits and impacts of winter salt use both before and after they attended the meeting. The goal of gathering this information was to see if existing outreach materials/exposure to the topic would sway opinions, and to assess the perspectives of the attendees. Since the sample size was so low, there are not many conclusions that can be drawn from this information. Nonetheless, the information is summarized below since it may serve as a good template for future endeavors.

Figure 18 represents the averages of the responses. Since there was too much variability in the responses, changes in responses from the beginning to the end of the meeting cannot be evaluated. On average, winter salt use was seen as somewhat important, salt use benefits were valued the least and salt use impacts were valued the most.

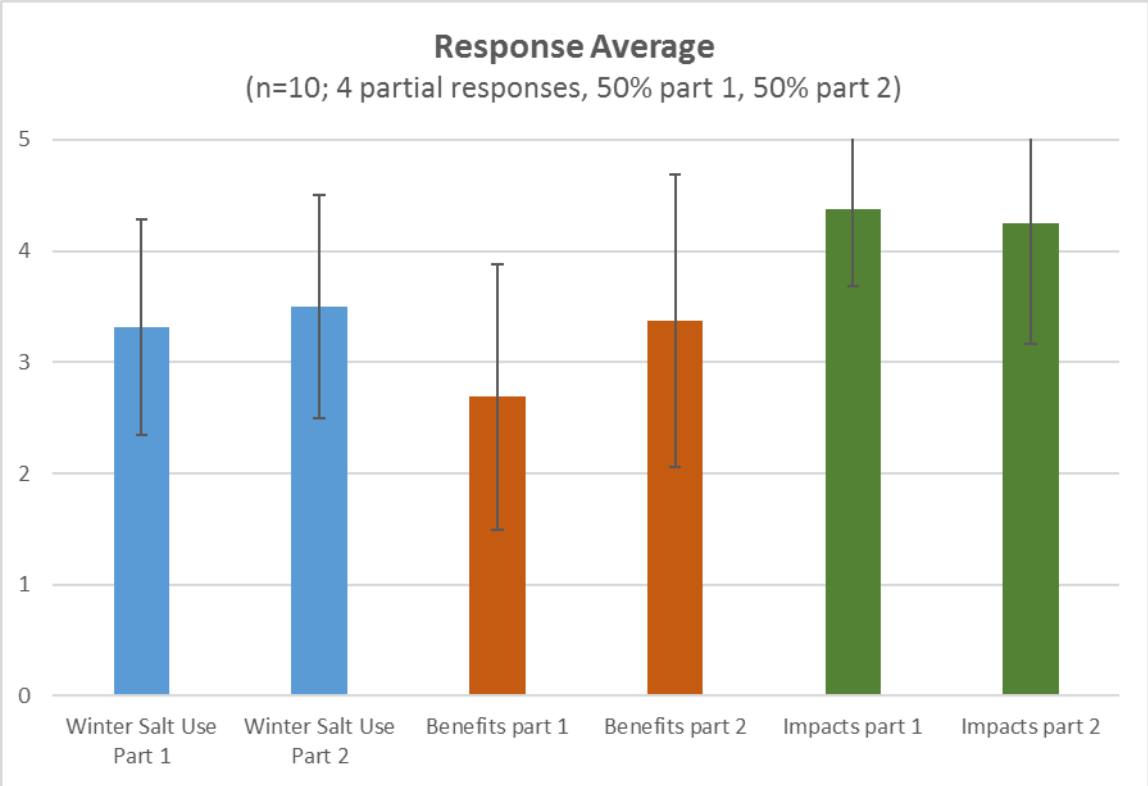


Figure 18. Average of survey response questions for the three importance ranking questions. Part 1 was administered before the meeting and part 2 was administered after the meeting.

Figure 19 displays the individual responses to the importance ranking questions. Of the 6 respondents who completed both surveys, most responses did not change from the beginning of the meeting to the end. With only 6 respondents to analyze and each of them behaving in unique ways, there is little to conclude from this data. Nonetheless, winter salt use importance increased by 2 units in one respondent and decreased by 1 unit for another respondent. The importance of salt use benefits increased by 1 unit for 2 of the respondents and the importance of salt use impacts went down by 1 unit for one of the respondents.

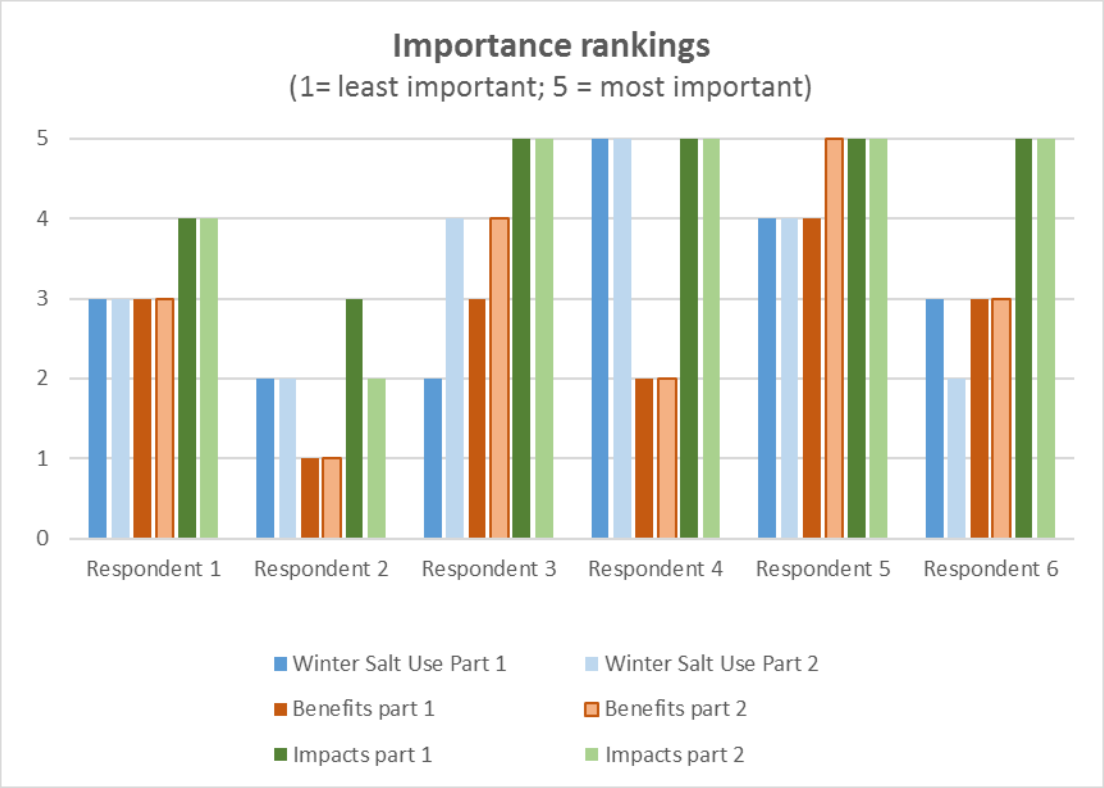


Figure 19. Individual importance rankings for the 6 survey respondents that filled out both surveys.

2.4.4 The Meeting

2.4.4.1 Cafeteria Portion

Seven organizations staffed tables set around the room for the cafeteria portion, which lasted 30 minutes. This portion of the event provided a nice buffer time for people to arrive. A few people left during this period because they did not intend to stay for discussion, and no one left during the discussion. That can be considered a benefit since they may not have attended if it was only going to be a discussion. Additionally, many attendees talked with different SaMS Education and Outreach workgroup members at their booths and around the room. Through this portion of the event, the group was able to gain an understanding of the project and the various partners prior to the next portion of the agenda.

2.4.4.2 Group Discussion

2.4.4.2.1 Background Presentation

The background presentation was supposed to be brief and prime the discussion. While it took the entire allotted time (20 minutes), a good level of discussion and questioning did occur.

2.4.4.2.2 Breakout Discussions

The meeting participants broke into 2 groups of 8-10 people. Each small discussion group used the discussion questions as a guide. In many cases, the discussion carried on past the discussion questions, but with many good ideas shared.

The discussion questions included the following:

1. How can we best engage the broader community on this complicated topic?
2. What are you and your peers concerned about?
3. What would you like to know about this topic?
4. What do you think of the SaMS hashtags

5. What do you think about our outreach materials
6. What do you think about our approach to outreach of balancing benefits and impacts in communications and striking a positive tone?

The information discussed in the groups is organized below:

- Ways to get the message out:
    - Newsletters/Water Bills/Blogs/Webpages
        - Civic and homeowners associations and their newsletters
        - Next door community pages
            - Police sometimes can do special announcements, maybe SaMS topics can be shared similarly.
        - Local newsletters
        - Local blogs
        - Water bill – short message tied to them (online or in print)
        - County supervisor newsletters
            - Can provide reminders seasonally and resources for how to do things
    - Social Media
        - Important to have pre-developed materials for social media, so that groups can share it widely
    - Video Media
        - Local weathermen – they have public trust
        - Virginia Public Access TV Channels
        - YouTube – including "how-to's"
    - School communities
        - Student discussions with parents can change the behavioral norm
        - Science fair projects
        - High school environmental groups
    - Retailers selling salts
        - Have information where salt is sold
        - Balance impacts of salts with alternatives (maybe alternatives have a higher unit price that is attractive to retailers)
    - Environmental Groups/Forums
        - Northern Virginia Soil and Water Conservation District Green Breakfast
        - Environmental groups (e.g., "Friends" groups, Lands & Waters, Master Naturalists)
- Ways to tailor the message (by interest)
    - General public - Drinking Water Concerns
        - Keep messages to drinking water concerns since most people may not care about aquatic life
        - Physicians (Sodium has a health advisory level)
            - Some physicians are focused on environmental issues.
        - Drinking water outreach to residents and Fairfax City Health Department
    - Pet impacts are also important to people.
        - "Make sure to sweep up your salt after the storm to help protect pets' paws – you can also use it again next time!"
    - Vegetation impacts
        - Garden centers

        - VA Native Plant Society
        - Master Gardeners
        - Salt tolerant plants
        - Farmers Markets
    - Fishery impacts
        - Trout Unlimited
        - Virginia Department of Game and Inland Fisheries
- What information to share:
    - Inform them of levels of service to expect so they can plan accordingly.
    - People like to know what to do so share salting tips/ideas for alternative deicers around their homes.
    - People need to know what to do so that they can share in that discussion in their neighborhood. Most people just assume/don't know.
    - Use social media to inform the public of road maintenance challenges so that you can manage expectations and prepare/plan accordingly. It is important to highlight the purpose/intent of salting and the differences between transportation and property management applications.
    - Alternatives to salt
        - What about Beet Juice?
    - Water/aquatic impacts – consequences, stress drinking water/health concerns
- The SaMS hashtags
    - #LearnAboutSalt is too ambiguous
    - Favored #WinterSaltSmart, but general impression was not strong
- Message tone (positive, balanced, etc.)
    - Sometimes the negative needs to be stated to get attention, but it should not be dramatized and should be presented directly.
    - When sharing bad news, give actionable items of what you can do
- Concerns about the outreach effort
    - Need to engage commercial & institutional property managers
        - Chamber of commerce
        - Fairfax County "Committee of 100"
        - Leadership Fairfax
    - Non-English language constituencies – role of church communities

2.5 Lessons Learned

2.5.1 Message Testing

The lessons learned during the message testing portion of the pilot campaign, fall into three categories: 1) Coordinating a multi-organization outreach campaign, 2) Metrics for success, and 3) Outreach methods.

1) Coordinating a Multi-organization Outreach Campaign: When there are multiple organizations involved, there are multiple audiences and multiple communication strategies involved. This can be an asset. However, it presents a challenge when the campaign is prescriptive. Since organizations know how to best speak to their audiences, messages should highlight the points that need to be addressed and avoid prescribing specific language. The data on likes and shares/retweets tends to support this concept that messages are more successful when scripted to their audience. Coordinating these multi-organization campaigns are further complicated by the fact that the different audiences have different peak use times/days. A week-long interval seemed to balance the need for flexibility while also concentrating the

campaign to a period of time. Even still, it seemed like there needs to be flexibility to post outside of the prescribed campaign windows since this happened during this pilot. Finally, this type of outreach campaign would benefit by improved coordination and quality assurance among the participating organizations. For instance, mishaps that occurred during the pilot, like the link shortener not being created and information being misunderstood (e.g., when/what to post, what information to record), may have been avoided. Planning ahead may help communications programs integrate campaigns like this into their communication plans and help avoid some of the challenges experienced in this pilot.

2) Metrics for Success: When designing this campaign, the SaMS Education and Outreach workgroup identified individual engagement metrics such as comments, likes, shares and retweets to evaluate the success of social media posts. However, these engagement metrics varied significantly between organizations and between Step 1 and Step 2 of the campaign, suggesting overall that the campaign was not as successful as it actually was. Therefore, it is recommended that the overall engagement rate be used to measure success instead of the individual metrics. In other words, the comments, likes, shares and retweets should be summed for each social media post to determine the total number of engagements with the post. This value should be compared to the actual audience reached by each post to determine the engagement rate. This overall metric will allow for better comparison between different types of posts, and provide an overall measure of success that can be used to see how the engagement rate changes over time. Additionally, this is more in line with how social media performance is actually measured.

3) Outreach Methods: Social media seems to be a very inexpensive and successful outreach method. Since the goal for outreach efforts is to raise the level of awareness to promote behavior change, social media may prove to be very efficient and effective tool. It is important to note emails and newsletters are also viable outreach methods, although the success of email and newsletter communications may be influenced by the contact list or organization administering the email or newsletter. Beyond the method of communication, infographics tended to be popular and successful engagement materials. This may be because these share information people are interested in since pictures alone were not very successful. It may be worth considering the difference in engagement metrics between infographics or posts that share information on a topic versus infographics or posts that share information with actionable items (i.e., what you can do about it). The infographic was inspired by a discussion on click through rates. While click through rates (i.e., clicking on a link in a post and going to the hyperlinked page) are generally known to be low, organizations should consult their data to determine how successful links versus infographics may be for their audience. Lastly, since the survey attached to the flyer and awareness newsletter had no responses, it may not be worth the effort in future campaigns.

2.5.2 Community Listening Session

The lessons learned in the community listening session can be grouped into two categories: 1) Advertising the session, and 2) Running the event.

1) Advertising the Community Listening Session: Since there was an opportunity to do more widespread outreach when the listening session was first planned, it would have been ideal to capitalize on that opportunity while it existed. Depending on the goal for the specific outreach event, the organizer may want to target communities that are not already involved and interested in this topic if the goal is to expand the general awareness of the topic and learn from new audiences. While the groups that are involved and interested should not be excluded, these groups tend to be comprised of persons already engaged and aware. Connecting with other groups not related to the topic will require more extensive outreach efforts.

2) Running the Community Listening Session: A 60 minute discussion is recommended over the 40 minutes used in this community listening session. In terms of the survey, identify means to encourage higher completion rates. During the pilot effort, there was a low survey completion rate; 3 of 13 participates did not complete a survey and less than half filled out both surveys. Lastly, if attendance is expected to be low, surveys may not be useful due to large variation in results.

Appendix H. Awareness Survey Results Summary

Note that the format and style of **Appendix H** has been maintained as submitted by Amplitude Research, Inc.

Northern Virginia Salt Management Strategy Toolkit

Summary of Report of Findings

1/6/2020

Amplitude Research, Inc.

Study Methodology & Respondent Characteristics

- The Northern Virginia Regional Commission (NVRC) hired Amplitude Research, Inc. to conduct a survey of residents of Northern Virginia to measure beliefs, attitudes, and behaviors involving salt usage during winter storm events, and related topics.

- Amplitude Research administered the study online in December of 2019. In the end, 500 surveys were completed by web panelists who live in one of the areas of Virginia shown in the table below.

Which of the following best describes where you live?

	Frequency	Percent
Alexandria	57	11.4%
Arlington County	56	11.2%
Town of Clifton	2	0.4%
Town of Dumfries	7	1.4%
Fairfax (city of)	9	1.8%
Fairfax (county of)	186	37.2%
Falls Church	17	3.4%
Town of Haymarket	1	0.2%
Herndon	12	2.4%
Town of Leesburg	9	1.8%
Loudoun County	57	11.4%
Town of Lovettsville	3	0.6%
City of Manassas	8	1.6%
City of Manassas Park	1	0.2%
Prince William County	70	14.0%
Town of Round Hill	1	0.2%
Vienna	4	0.8%
Total	500	100.0%

- *In a separate Excel file (**Appendix H – Section 1**) provided along with this report, results are "broken out" by area and demographics*. However, the specific areas listed above were grouped together into larger areas so that each larger area used for analysis had a reasonable number of respondents.

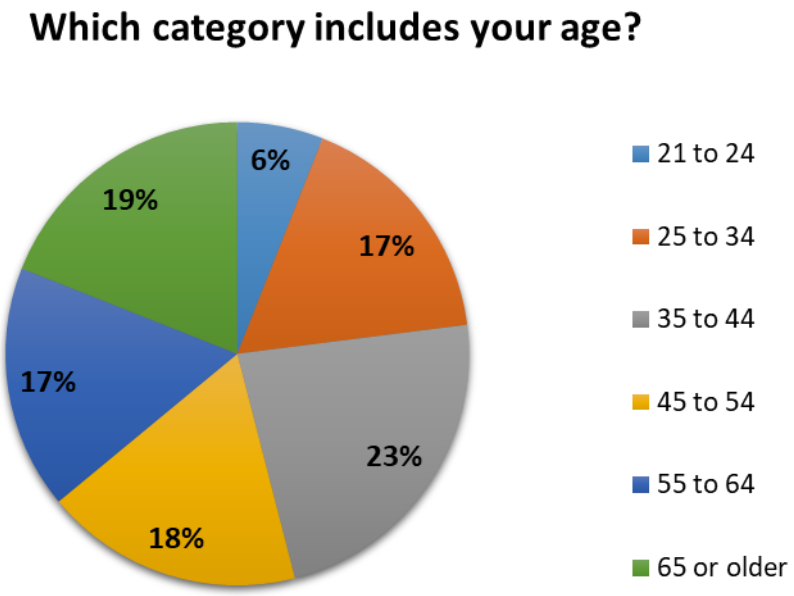
  - Residents of Leesburg, Lovettsville, and Round Hill are grouped with those selecting Loudoun County and labeled as "Loudoun," since these towns lie within Loudoun County.

- Another category for analysis purposes is labeled “Prince William,” which includes Prince William County, Dumfries, Haymarket, Manassas, and Manassas Park. Dumfries and Haymarket lie within Prince William County. Although Manassas and Manassas Park are distinct geographic entities, they border Prince William County.

- The City of Fairfax, Clifton, Falls Church, Herndon, and Vienna can be combined with Fairfax County to create a category that is labeled “Fairfax Inclusive,” since these cities and towns lie within, or are circumscribed by, the Fairfax County area.

- Alexandria and Arlington each had a sufficient number of respondents so that each of these areas can be examined separately.

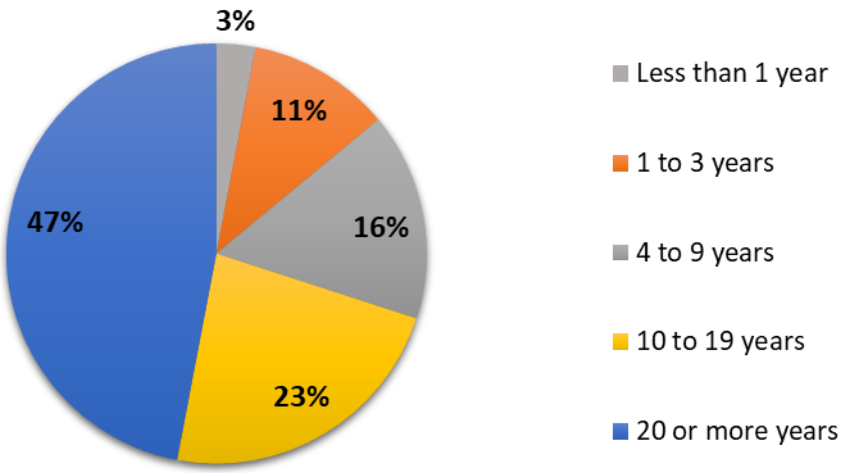
- The minimum age to participate in the survey was 21. As shown in the chart below, each age group was well represented in the survey. Although a small proportion were age 21 to 24, this category has fewer years than the other categories shown.



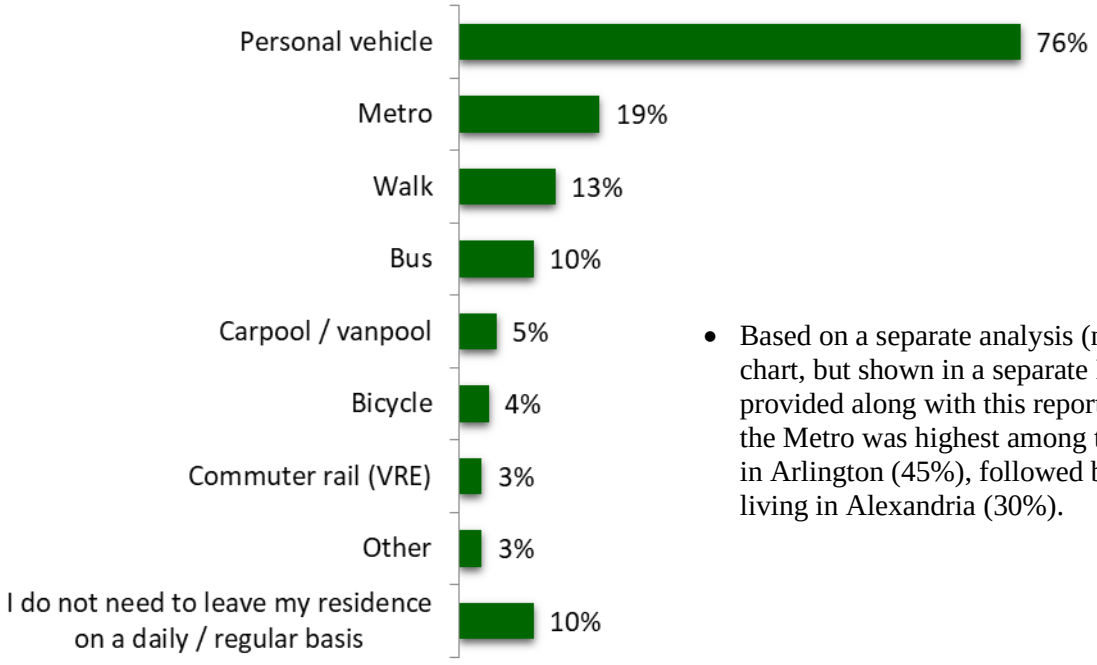
- The survey respondents were split between males (48%) and females (52%). There was one respondent (accounting for less than .5% of the total sample) who selected “Non-binary / third gender” instead of male or female, and there was one respondent who selected “Prefer to self-describe.”

- The type of residence mentioned most often as where they live was single family home (50%), followed by townhouse (20%), apartment (19%), and condominium (11%).
- The charts below show how long respondents have lived in the Northern Virginia area and how they get to work or other destinations on a regular basis.

For how many years have you lived in the northern Virginia area?



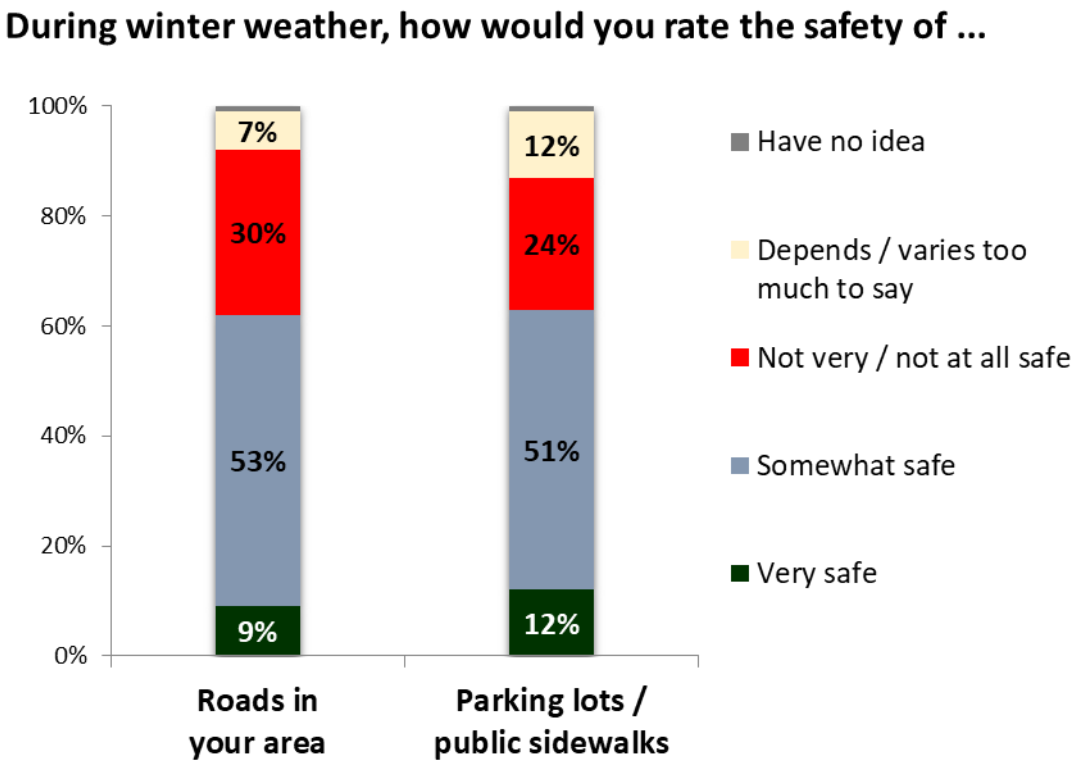
How do you get to work or other destinations on a regular basis?



- Based on a separate analysis (not shown in chart, but shown in a separate Excel file provided along with this report), usage of the Metro was highest among those living in Arlington (45%), followed by those living in Alexandria (30%).

Winter Safety

- Slightly more than half gave a rating of "Somewhat safe" during winter weather for roads in their area (53%). A similar proportion gave this rating for parking lots and sidewalks at stores, restaurants, and/or other places in the area (51%). (Note that the label in the chart was shortened for easier readability. That is, "Parking lots / public sidewalks" in the chart = "Parking lots and sidewalks at stores, restaurants, and/or other places in the area.")



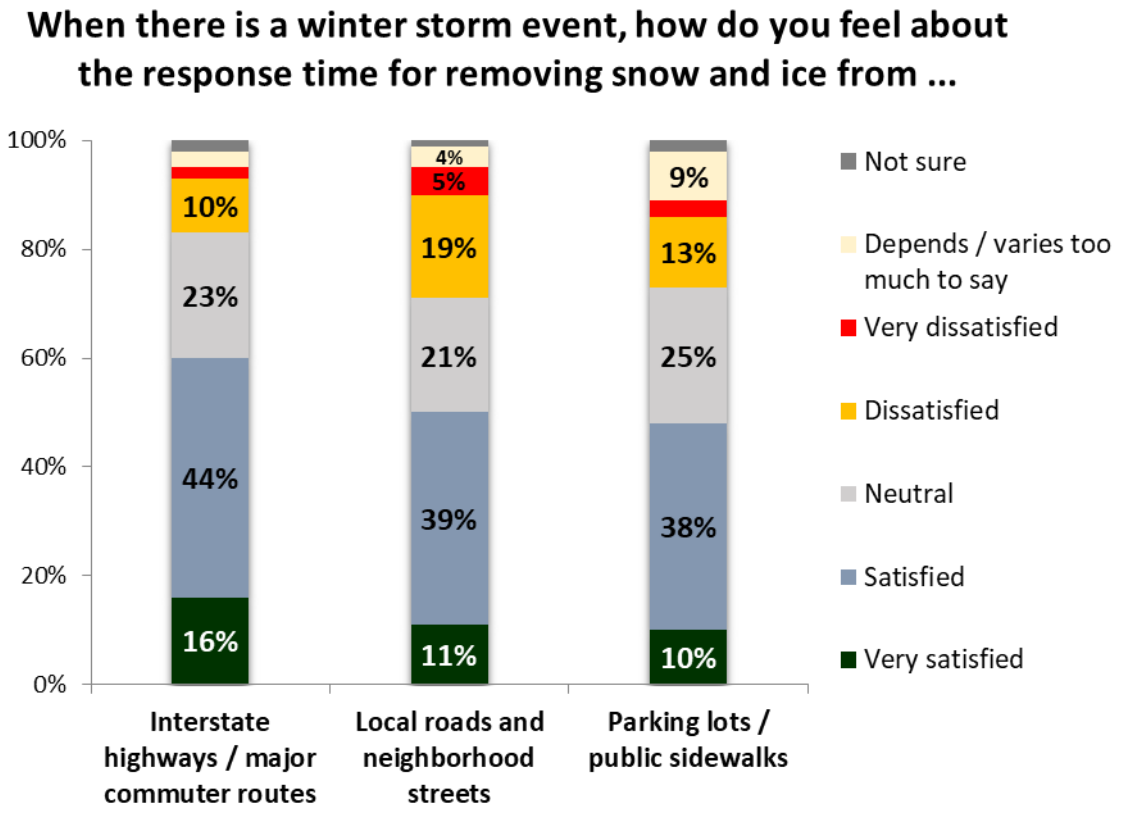
- As shown in a separate Excel file, **Appendix H – Section 1**, the proportion rating "Somewhat safe" did not differ significantly by area.

- A minority of respondents gave a rating of "Very safe," while sizable proportions felt that roads and public places were not very or not at all safe during winter weather.

- The results above (and on following pages) provide "Benchmark" measurements of current perceptions. If there are future changes in the amount of salt used in winter, and accompanying communications about reasons for the changes, the same questions can be asked again in future surveys to assess changes in perceptions.

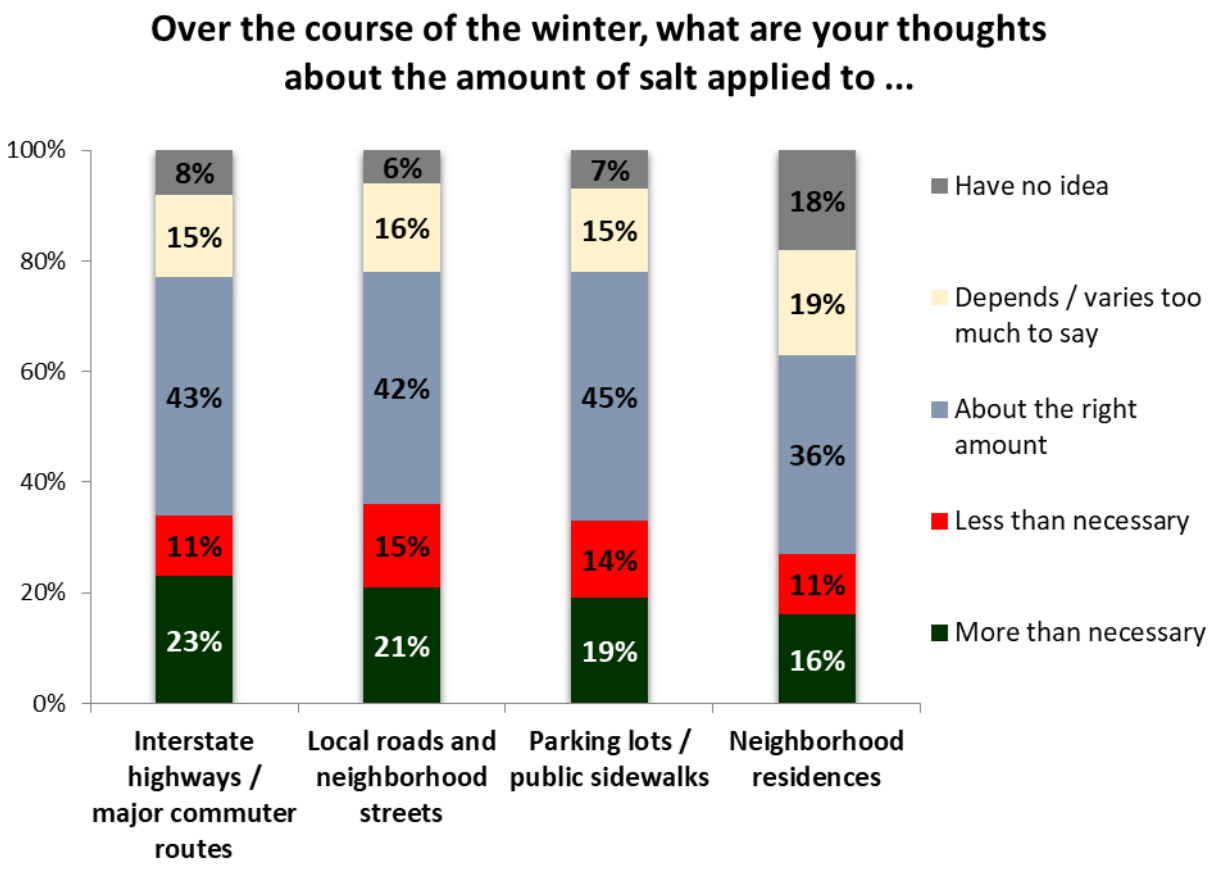
- When asked to rate their satisfaction with the response time for removing snow and ice from interstate highways and major commuter routes in their area (such as Route 7, Route 1, Fairfax County Parkway, etc.), 16% gave a rating of "Very satisfied," while 44% gave a rating of

"Somewhat satisfied." Combined, 60% expressed satisfaction. On the other end of the scale, 12% expressed dissatisfaction (combining "Very dissatisfied" and "Dissatisfied"). Others were "Neutral" or felt it depends or were not sure.



- Results for *local* roads and parking lots / public sidewalks were not quite as strong as for interstate highways / major commuter routes. However, noticeably more expressed satisfaction than expressed dissatisfaction for each.

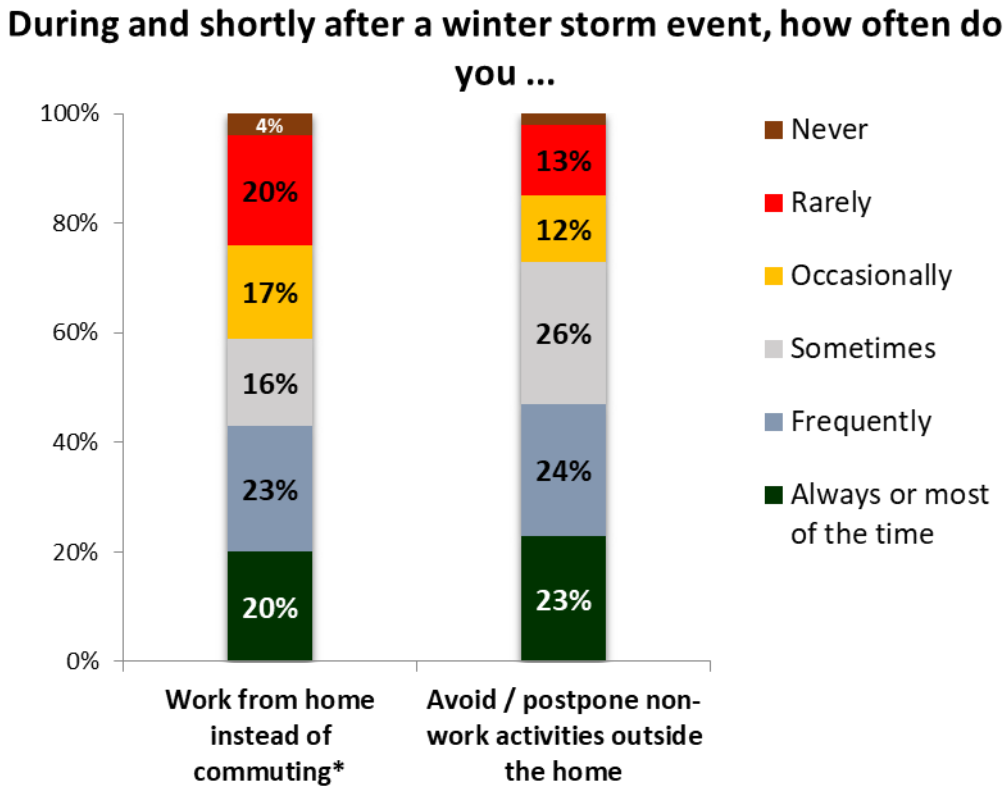
- For each area where salt can be applied during the winter, a higher proportion felt that the amount of salt used was *more* than necessary than felt that it was *less* than necessary. However, the most common response was that about the right amount of salt was used.



- For "Neighborhood residences" in the chart above, the full wording in the survey was "In general, what do you think about the amount of salt that residents in your neighborhood apply during snowy and icy conditions?" Some (18%) had no idea, but 16% felt that more salt was used than necessary, while 11% felt that less salt was used than necessary, and more than one-third (36%) felt that about the right amount was used.

Winter Behaviors

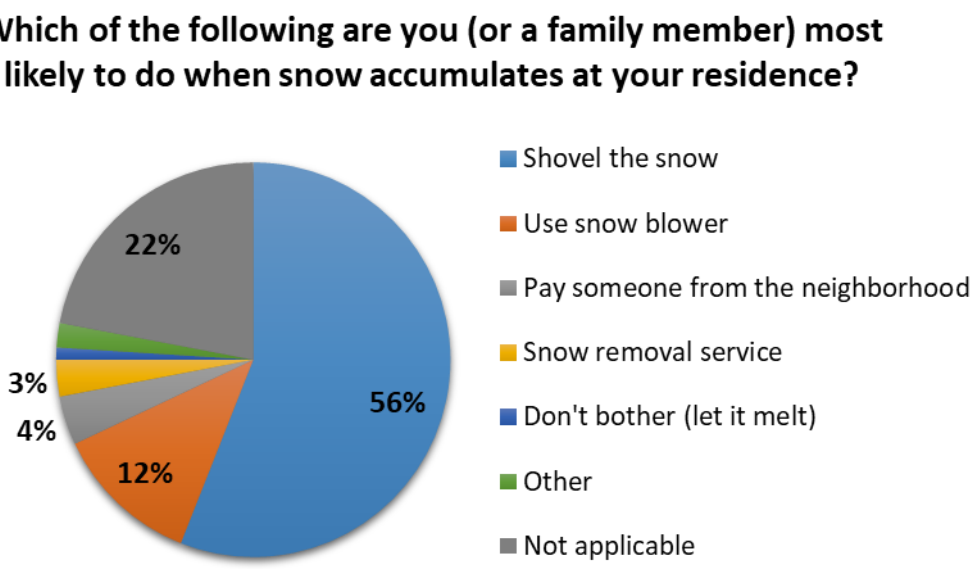
- The majority of respondents (63%) indicated that they commute to work (based on a separate question not shown in the chart below). When these respondents were asked if their employer allows them to work from home when there is a winter storm event, 53% answered "Yes," while 15% answered "Maybe, if there is very severe weather," and 32% answered "No." As shown in the chart below, among those who commute to work and are or may be allowed to work from home during bad winter weather, 20% work from home "Always or most of the time" during or shortly after a winter storm event. Another 23% do so frequently. On the other end of the scale, nearly one-fourth (24%) rarely or never work at home instead of commuting during bad winter weather.



* Among those who commute to work and are or may be allowed to work from home when there is a winter storm event.

- Nearly one-fourth (23%) "Always or most of the time" avoid or postpone non-work activities outside the home (e.g., going to a restaurant, shopping, going to the gym, etc.) during and shortly after a winter storm event. A similar proportion gave a rating of "Frequently."

- When snow accumulates at their residence (e.g., on their driveway and/or sidewalks), the majority (56%) shovel the snow themselves (or a family member does it).



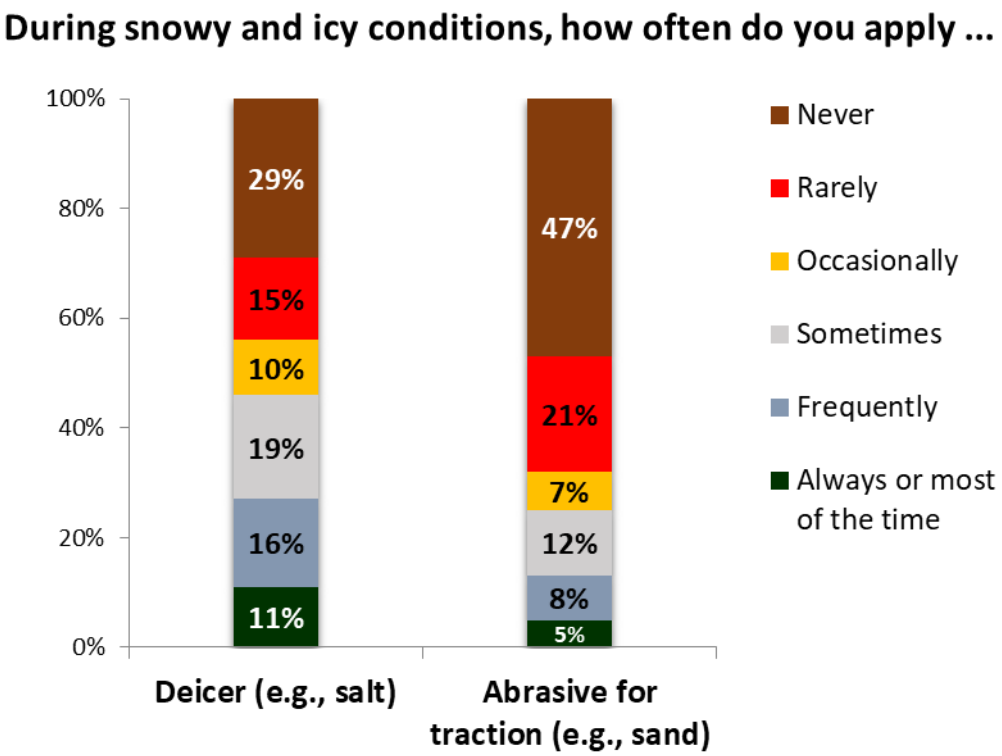
- It is interesting that only 12% reported using a snow blower vs. 56% who shovel. One might wonder if the proportion using a snow blower would be higher if a similar survey was conducted among those living in other states that are north of Virginia.

  - Even when focusing only on respondents living in a single family home, only 20% reported using a snow blower, while 69% shovel. Separately, among those living in a Townhouse, 78% shovel.

- Slightly more than one-fifth (22%) felt that the question was not applicable to them. This was often the case because an apartment landlord handles snow removal, or a condominium service handles it. However, this is not always the case, as some of those who live in an apartment or condominium reported shoveling snow themselves (19% and 25%, respectively).

  - Those living in Arlington and Alexandria had much higher proportions selecting "Not applicable" for this question (59% and 42%, respectively) compared to those living in other areas (7% to 16%). At the same time, those living in Arlington and Alexandria were more likely than those from other areas to report living in an apartment or condominium.

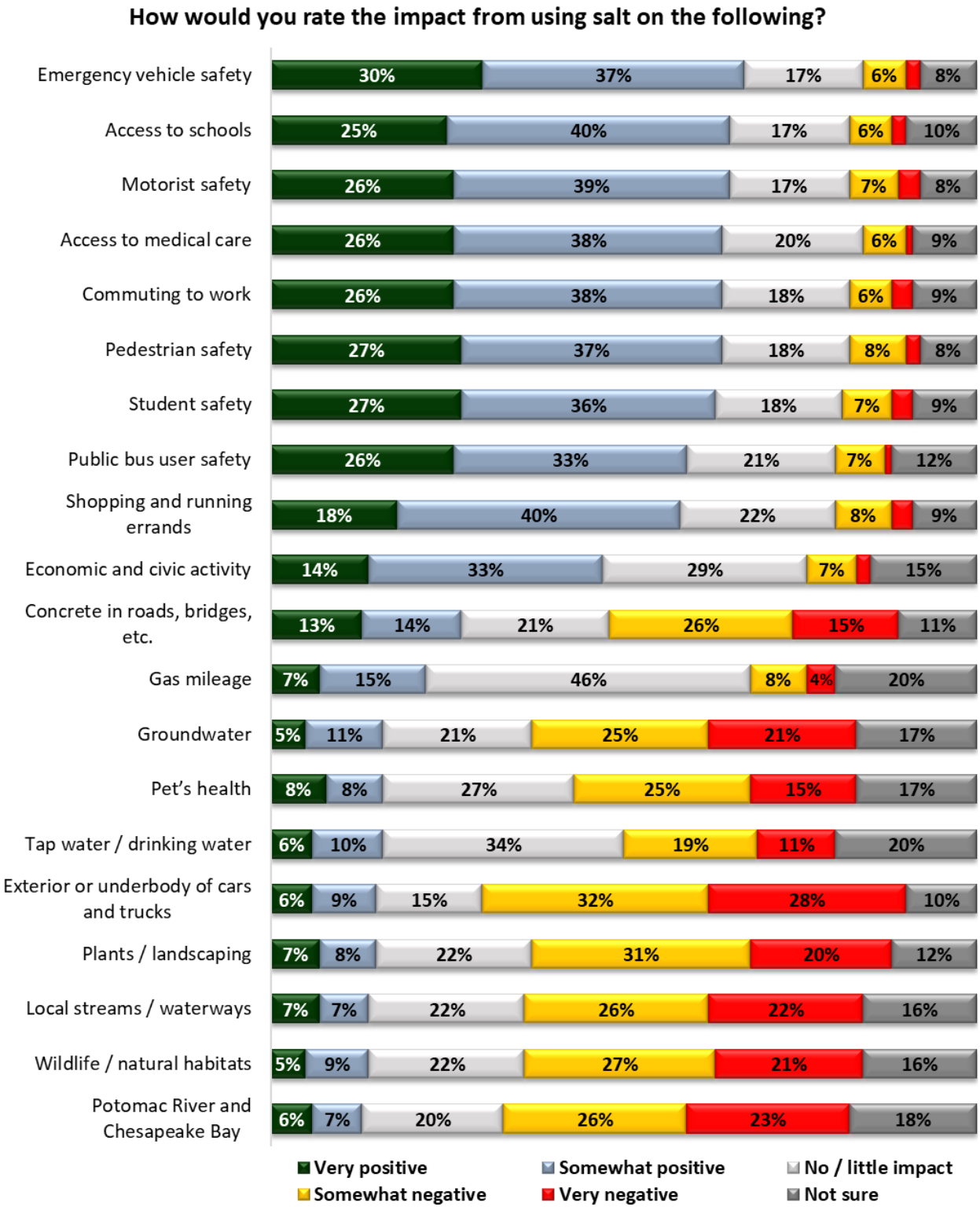
- The majority (56%) use deicer *at least* occasionally at their residence. However, many rarely or never use deicer (44%).



- Nearly half (47%) reported that they never use an abrasive during snowy and icy conditions. However, nearly one-third (32%) use an abrasive *at least* occasionally.

- In a separate question, asked only of those who use deicer occasionally or more often, 43% reported that they typically apply deicer *before* a winter storm event, while the same proportion (43%) reported that they apply deicer *after* a winter storm event. Approximately one-third (34%) apply deicer *during* a winter storm event, while 19% indicated that it depends / varies too much to say. These proportions add to more than 100% because it was possible to select more than one response for this question. For example, a respondent could indicate applying deicer *both* before and after a winter storm event.

Perceived Salt Impact (comments about chart below on next page)



- As shown in the chart on the previous page, 30% gave a rating of "Very positive" when rating the impact on emergency vehicle safety of using salt during winter storm events. Another 37% gave a rating of "Somewhat positive." Combined, two-thirds (67%) felt that applying salt had a positive impact on emergency vehicle safety. Note that the results in the chart on the previous page are sorted in descending order by the proportion rating *at least* "Somewhat positive."

- Some (8%) felt that applying salt had a *negative* impact on emergency vehicle safety. It is not clear why a respondent would expect a negative impact. But, the much higher proportion who would expect a positive impact shows that many understand that applying salt during a winter storm event can help to operate emergency vehicles more safely.

- For each of the items related to safety and access (e.g., motorist safety, access to medical care, etc.), the majority felt that applying salt would have a positive impact.

- For many other items that are not related to safety or access, many expected a negative impact. For example, 60% felt that salt has a negative impact on the exterior or underbody of cars and trucks.

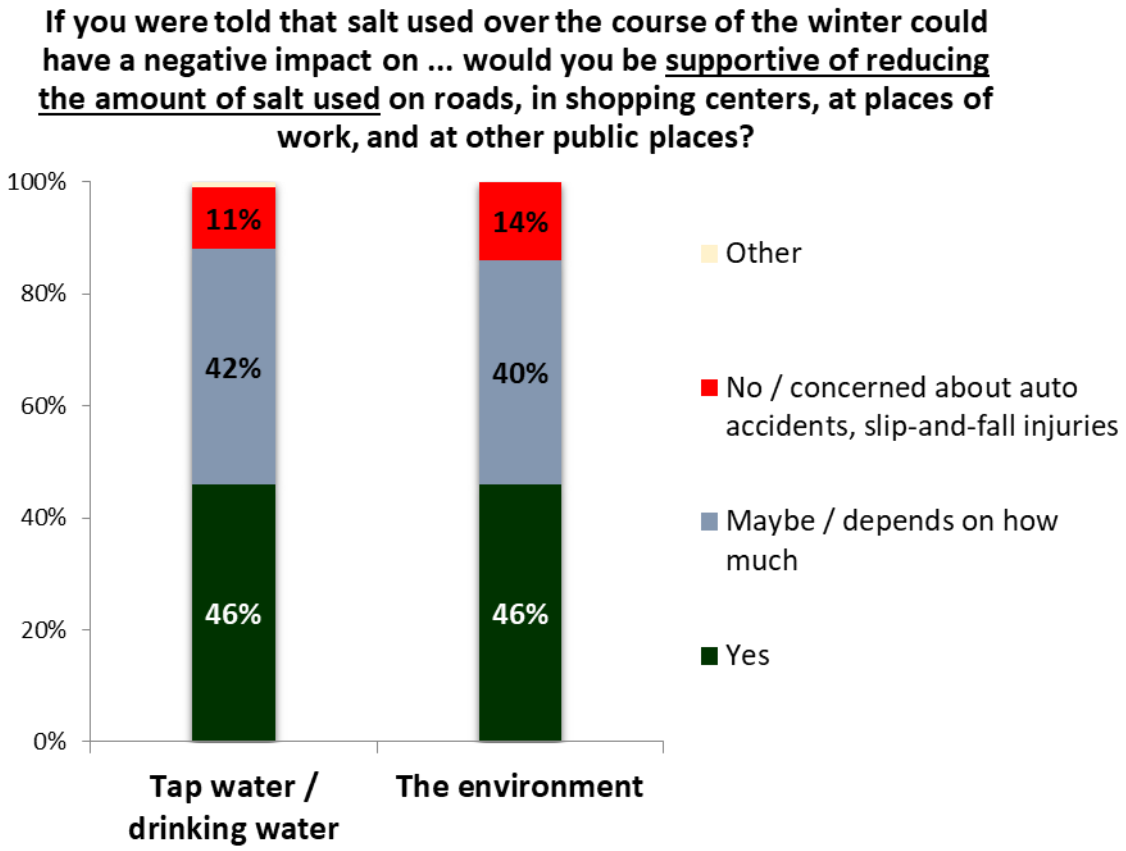
- At the same time, many expected a negative impact on different aspects of the environment, such as plants / landscaping, wildlife / natural habitats, local streams / waterways, and the Potomac River and Chesapeake Bay. As one respondent wrote in an optional comment section of the survey, "Salt makes things safer for humans, but damages the environment, animals, and machines." However, some can still support using salt despite recognizing negative impacts. For example, one respondent commented "As someone who has broken an arm because of a fall on ice, I strongly support the use of salt to decrease ice, regardless of any impacts because of it."

- For "Tap water / drinking water" – which is of particular interest in this study – the results were more mixed, with 34% feeling salt had little or no impact, while 30% felt it had a negative impact, and 16% felt it had a positive impact. This suggests that there is significant room for educating Northern Virginia residents about the impact of salt on their tap water. It is not clear why a respondent would think that applying salt for winter storm events would have a *positive* impact on tap water, but this suggests that some may be confused about the various impacts of salt.

- "Gas mileage" was included as an item in the survey, even though it is not expected to be impacted by applying salt, and it turns out that this item had the highest proportion expecting little or no impact (46%).

Openness to Change Given New Information

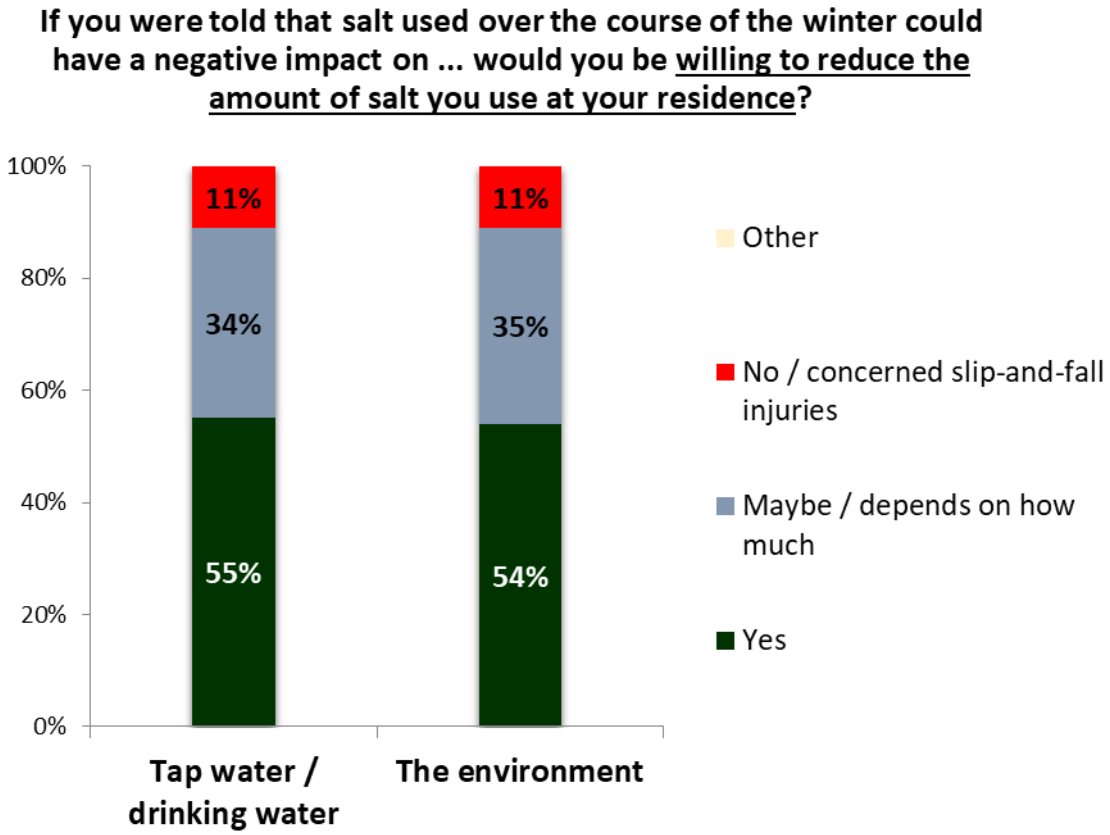
- Toward the end of the survey, respondents were asked how they would react if they were told that using salt in the winter could have a negative impact on tap water / drinking water and/or the environment. For each issue, 46% indicated that they would be supportive of reducing the amount of salt used on roads and public places.



- Many others did *not* rule out (i.e., "Maybe") supporting the reduction of salt, while only 11% to 14% were solidly against reducing salt, as they were too concerned about auto accidents and/or slip-and-fall injuries.

- Based on a separate analysis (not based on chart), the 46% who said "Yes" in the question about tap water / drinking water were not 100% the same as the respondents who said "Yes" in the question about the environment, but there was a high degree of overlap. For example, of those who said "Yes" for tap water / drinking water, 82% also said "Yes" for the environment.

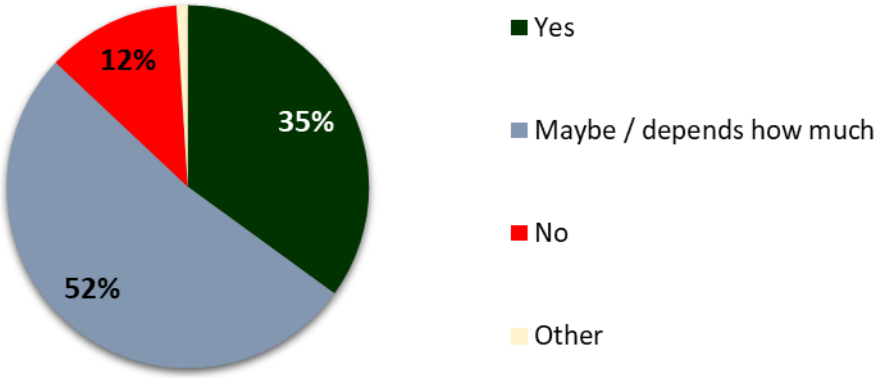
- While the results on the previous page were about reducing salt usage on roads and public places, the results below are about reducing the amount of salt respondents use at their residence. Some respondents selected "Not applicable" as their response, but these respondents were excluded from the results below. In both the question about tap water / drinking water being negatively impacted and the question about the environment being negatively impacted, more than half indicated that they would be willing to reduce salt used at their residence, while only 11% would rule this out.



- In a section of the survey where respondents had the option to write in comments, one respondent stated "I did not know that using salt will have a negative impact. All I thought was it would help clearing the roads and making commute and life easy during winter. I would definitely try to reduce or stop using salt if it has a negative impact."

- Results on the previous page address support for reducing salt usage. The question below asks the respondent to assume that there was a reduction in salt usage. In this scenario, 35% indicated that they would be willing to reduce or eliminate their travels. More than half responded "Maybe," while only 12% ruled it out.

If you were told that salt used over the course of the winter needed to be reduced, potentially creating unsafe roads, would you be willing to reduce or eliminate your travels?



Comparisons by Ethnicity / Race

- When examining comparisons between African American, Asian American, and Hispanic respondents vs. all others, most of the differences were not statistically significant. However, there were some significant differences, and noteworthy results are summarized below. To be sure, the number of respondents was not large for African American (N=52), Asian American (N=58), and Hispanic (N=50) respondents, and caution is recommended when interpreting the results. These results can also be examined in a separate Excel file, **Appendix H – Section 1**, provided along with this report.

AFRICAN AMERICANS WERE …

- More likely than others to report living in an apartment (37% vs. 17%, respectively) and less likely to report living in a single family home (23% vs. 53%).

- More likely to "Always or most of the time" avoid or postpone non-work activities outside the home when there is a winter storm event (35% vs. 22%).

- More likely to be "Very satisfied" with the response time for removing snow and ice from parking lots and sidewalks at stores, restaurants, and/or other places of business that they visit in their area (21% vs. 9%).

- More likely to "Always or most of the time" apply deicer (21% vs. 10%) and abrasive (13% vs. 4%) at their residence.

- More likely to give a "Very positive" rating for the impact of salt on the following: emergency vehicle safety, student safety, access to medical care, commuting to work, economic activity, shopping, and pedestrian safety. The difference between African Americans vs. others on these items ranged from 13 to 21 percentage points.

- Less likely than others to give a "Very negative" rating for the impact of salt on the Potomac River and Chesapeake Bay (10% vs. 25%).

- More likely to rule out supporting the reduction of salt on roads and public places if told that salt could have a negative impact on tap water / drinking water (21% vs. 9%).

- Since the differences noted above were not huge, and the sample size of African Americans was not large, we do not recommend forming firm conclusions based on these results. However, if the distinctions above are replicated in future surveys, then this may increase confidence that the results are truly reflective of differing tendencies.

ASIAN AMERICANS WERE …

- More likely than others to report living in a townhouse (36% vs. 18%, respectively) and less likely to report living in an apartment (9% vs. 20%).

- Less likely to report living in the Northern Virginia area for 20 or more years (33% vs. 49%).

- More likely to carpool (12% vs. 5%) and less likely to walk (3% vs. 14%) to work or other destinations a regular basis.

- More likely to "Always or most of the time" avoid or postpone non-work activities outside the home when there is a winter storm event (34% vs. 22%).

- Less likely to say that more salt than necessary is used on interstates (12% vs. 24%) and local roads (10% vs. 22%).

- More likely to give a "Not very safe" rating for parking lots and public sidewalks (36% vs. 22%).

- Less likely to rate "Very satisfied" for the response time for removing now and ice from parking lots and public sidewalks (2% vs. 11%).

- Less likely to give a "Very negative" rating for the impact of salt on concrete (5% vs. 16%) and local streams (10% vs. 24%).

- Since the differences noted above were not huge, and the sample size of Asian Americans was not large, we do not recommend forming firm conclusions based on these results. However, if the distinctions above are replicated in future surveys, then this may increase confidence that the results are truly reflective of differing tendencies.

HISPANIC AMERICANS WERE …

- More likely to report commuting to work (86% vs. 60%). (This might be related to the younger age mix of Hispanic respondents in this survey.)

- Less likely to "Never" use deicer (16% vs. 31%) and abrasive (28% vs. 49%) at their residence.

- More likely to say residents in their area use less salt than necessary (24% vs. 10%).

- More likely to give a "Very positive" rating for the impact of salt on the following: gas mileage, Potomac River and Chesapeake Bay, groundwater, exterior or underbody of cars and trucks, plants / landscaping, groundwater, and tap water / drinking water. Since these items are not actually impacted in a positive way by application of salt in the winter, it is not clear why these differences emerged. However, the differences between Hispanic respondents were not huge – ranging from 9 to 16 percentage points for the items noted here. We would not recommend forming firm conclusions based on these results at this stage. More consideration could be given to the results in the future if these findings are replicated in a future survey.

- More likely to say "Yes" that they would be willing to reduce or eliminate travels if reduced salt application potentially created unsafe roads (52% vs. 33%).

- More likely to say "Yes" that they would reduce the amount of salt they use at their residence (70% vs. 53%) if they were told that using salt in the winter can negatively impact tap water / drinking water.

Appendix: Sampling Variability

While examining the survey findings, it is helpful to keep in mind that the results are based on a sample and are therefore subject to sampling variability, often referred to as "sampling error." The degree of uncertainty for an estimate (e.g., a particular percentage from the survey) arising from sampling variability is represented through the use of a margin of error. A sampling margin of error at the "95% confidence level" can be interpreted as providing a 95% probability that the interval created by the estimate plus and minus the margin of error contains the true value. (The "true" value would be known only if everyone in the target market was surveyed rather than just a sample.) In addition to sampling variability, results may be subject to various sources of non-sampling error (e.g., non-response bias, respondent misinterpretation of question wording, etc.). The degree of non-sampling error is not represented by the sampling margin of error and is usually unknown.

For a "sample size" of 500 survey respondents, the "maximum" margin of sampling error for percentages from the survey is +/- 4.4 percentage points at the 95% confidence level. Here, "maximum" refers to the margin of error being highest for proportions from the survey near 50%, while the margin of error declines as percentages get further from 50%. For example, given the same sample size of 500 respondents, a result from the survey near 10% or 90% would have a margin of sampling error of +/- 2.6 percentage points.

The margin of sampling error increases as the sample size decreases. Thus, when a question is asked of only a subset of the total sample, the associated margin of sampling error is larger than that quoted above. Also, even if a question is asked of all respondents, when examining results for a particular subgroup, the margin of sampling error depends on the number of respondents in that subgroup. For example, the "maximum" margin of sampling error would be +/- 9.8 percentage points at the "95% confidence level" when based on a subgroup of 100 survey respondents.

Questionnaire

Welcome, and thank you for participating in this important research survey. Please be candid and honest in your responses. There are no “right” or “wrong” answers. We are interested in your unique perspective and opinions.

S1. Are you:

- Female
- Male
- Non-binary / third gender
- Prefer not to answer
- Prefer to self-describe: _____

S2. Which of the following categories includes your age?

- Under 18 **[END SURVEY]**
- 18 to 20 **[END SURVEY]**
- 21 to 24
- 25 to 34
- 35 to 44
- 45 to 54
- 55 to 64
- 65 to 74
- 75 or older
- Prefer not to answer

S3. Do you live in the state of Virginia?

- Yes
- No **[END SURVEY]**

S4. Which of the following best describes where you live (county or city or town)?

- Alexandria
- Arlington County
- City of Manassas
- City of Manassas Park
- Town of Clifton
- Town of Dumfries
- Fairfax (city of)
- Fairfax (county of)
- Falls Church
- Town of Haymarket
- Town of Hamilton
- Herndon
- Town of Hillsboro
- Town of Leesburg
- Loudoun County
- Town of Lovettsville
- Town of Middleburg
- Town of Occoquan
- Prince William County
- Town of Purcellville
- Town of Round Hill
- Vienna
- None of the above **[END SURVEY]**

S5. Which of the following describes your ethnicity? (Please select all that apply.)

- African American / Black
- American Indian / Alaska Native
- Asian
- Hispanic / Latino
- Native Hawaiian / Pacific Islander
- White / Caucasian
- Prefer not to answer
- Other: _____

Q1. What type of residence do you live in?

- Apartment
- Condominium
- Townhouse
- Single family home
- Other (e.g., dorm, group home, etc.): _____

Q2. How many years have you lived in the Northern Virginia area?

- Less than 1 year
- 1 to 3 years
- 4 to 9 years
- 10 to 19 years
- 20 or more years

Q3a. How do you get to work or other destinations on a regular basis? (May select more than one if applicable.)

- Personal vehicle
- Carpool / vanpool
- Bus
- Commuter rail (VRE)
- Metro
- Bicycle
- Walk
- I do not need to leave my residence on a daily / regular basis
- Other: _____

Q3b. Do you currently commute to work?

- Yes
- No / not employed outside the home **[SKIP TO Q3e]**

Q3c. Does your employer allow you to work from home when there is a winter storm event?

- Yes
- No **[SKIP TO Q3e]**
- Maybe, if there is very severe weather

Q3d. How often do you work from home rather than commuting to avoid snowy and icy conditions during or shortly after a winter storm event?

- Always or most of the time
- Frequently
- Sometimes

- Occasionally
- Rarely
- Never

Q3e. When it comes to non-work activities outside the home (e.g., going to a restaurant, shopping, going to the gym, etc.), how often do you avoid or postpone these activities during and shortly after a winter storm event?

- Always or most of the time
- Frequently
- Sometimes
- Occasionally
- Rarely
- Never

Q3f. During winter weather, how safe would you say the roads are in your area?

- Very safe
- Somewhat safe
- Not very safe
- Not at all safe
- Depends / varies too much to say
- Have no idea

Q4a. When there is a winter storm event, how do you feel about the response time for removing snow and ice from interstate highways and major commuter routes (such as Route 7, Route 1, Fairfax County Parkway, etc.) in your area?

- Very satisfied
- Satisfied
- Neutral
- Dissatisfied
- Very dissatisfied
- Depends / varies too much to say
- Not sure

Q4b. Over the course of the winter, what are your thoughts about the amount of salt applied to interstate highways and major commuter routes in your area?

- More than necessary
- Less than necessary
- About the right amount
- Depends / varies too much to say
- Have no idea

Q5a. When there is a winter storm event, how do you feel about the response time for removing snow and ice from local roads and neighborhood streets in your area?

- Very satisfied
- Satisfied
- Neutral
- Dissatisfied
- Very dissatisfied
- Depends / varies too much to say
- Not sure

Q5b. Over the course of the winter, what are your thoughts about the amount of salt applied to local roads and neighborhood streets in your area?

- More than necessary
- Less than necessary
- About the right amount
- Depends / varies too much to say
- Have no idea

Q6a. During winter weather, how safe would you say parking lots and sidewalks at stores, restaurants, and/or other places are in your area?

- Very safe
- Somewhat safe
- Not very safe
- Depends / varies too much to say
- Have no idea

Q6b. When there is a winter storm event, how do you feel about the response time for removing snow and ice from parking lots and sidewalks at stores, restaurants, and/or other places of business that you visit in your area?

- Very satisfied
- Satisfied
- Neutral
- Dissatisfied
- Very dissatisfied
- Depends / varies too much to say
- Not sure

Q6c. Over the course of the winter, what are your thoughts about the amount of salt applied to parking lots and sidewalks at stores, restaurants, and/or other places of business that you visit in your area?

- More than necessary
- Less than necessary
- About the right amount
- Depends / varies too much to say
  Have no idea

Q7. Which of the following are you (or a family member) most likely to do when snow accumulates at your residence (e.g., on your driveway and/or sidewalks)?

- Shovel the snow myself (or a family member does it)
- Use a snow blower myself (or a family member does it)
- Pay someone from the neighborhood to clear the snow
- Hire a snow removal service / company to handle it
- Don't bother clearing the snow (just let it melt)
- Not applicable to me (e.g., landlord or condominium service handles it)
- Other: _____

Q8a. During snowy and icy conditions, how often (if at all) do you (or a family member) apply deicer (e.g., salt) at your residence?

- Always or most of the time
- Frequently
- Sometimes
- Occasionally
- Rarely **[SKIP TO Q9]**
- Never **[SKIP TO Q9]**

Q8b. Do you (or a family member) typically apply deicer (e.g., salt) at your residence before, during, or after a winter storm event? (May select more than one response if applicable.)

- Before
- During
- After
- Depends / varies too much to say
- Other: _____

Q9. During snowy and icy conditions, how often (if at all) do you (or a family member) apply an abrasive for traction (e.g., sand) at your residence?

- Always or most of the time
- Frequently
- Sometimes
- Occasionally
- Rarely
- Never

Q10. In general, what do you think about the amount of salt that residents in your neighborhood apply during snowy and icy conditions?

- More than necessary
- Less than necessary
- About the right amount
- Depends / varies too much to say
- Have no idea

---------- Web Page Break ----------

Q11a. In general, how would you rate the impact (if any) on each of the following from using salt for winter storm events? That is, for each item, please indicate if you feel that applying salt for winter storm events has a very positive, somewhat positive, somewhat negative, very negative, or little or no impact on that item. [PROGRAMMING NOTE: RANDOMIZE ORDER IN WHICH ITEMS APPEAR.]

	Very positive impact	Somewhat positive	No Impact or very little impact	Somewhat negative	Very negative impact	Don't know / not sure
Motorist safety	O	O	O	O	O	O
Pedestrian safety	O	O	O	O	O	O
Emergency vehicle safety (e.g., police, fire trucks, ambulances)	O	O	O	O	O	O
Student safety	O	O	O	O	O	O
Public bus user safety	O	O	O	O	O	O
Access to medical care	O	O	O	O	O	O
Access to schools	O	O	O	O	O	O
Economic and civic activity	O	O	O	O	O	O

Shopping and running errands	○	○	○	○	○	○
Commuting to work	○	○	○	○	○	○
Concrete in roads, bridges, driveways, and sidewalks	○	○	○	○	○	○
Exterior or underbody of cars and trucks	○	○	○	○	○	○
Plants / landscaping	○	○	○	○	○	○
Wildlife / natural habitats	○	○	○	○	○	○
Local streams / waterways	○	○	○	○	○	○
Potomac River and Chesapeake Bay	○	○	○	○	○	○
Groundwater	○	○	○	○	○	○
Gas mileage	○	○	○	○	○	○
Tap water / drinking water	○	○	○	○	○	○
Pet's health	○	○	○	○	○	○

Q11b. If you have any comments about any of your ratings, please explain below:
_____

---------- Web Page Break ----------
Q12a. If you were told that salt used over the course of the winter could have a negative impact on tap water / drinking water, would you be supportive of reducing the amount of salt used on roads, in shopping centers, at places of work, and at other public places?

- Yes
- Maybe / depends on how much
- No, I'd be concerned that there could be an increase in automobile accidents and slip-and-fall injuries
- Other: _____

Q12b. If you were told that salt used over the course of winter needed to be reduced, potentially creating unsafe roads, would you be willing to reduce or eliminate your travels?

- Yes
- Maybe / depends how much
- No
- Other:_____

Q12c. If you were told that salt used over the course of the winter could have a negative impact on tap water / drinking water, would you be willing to reduce the amount of salt you use at your residence?

- Yes
- Maybe / depends on how much
- No, I'd be afraid of a slip-and-fall injury
- Not applicable / don't use salt at my residence
- Other: _____

Q12d. If you were told that applying salt over the course of the winter could have a negative impact on the environment,

would you be supportive of reducing the amount of salt used on roads, in shopping centers, at places of work and at other public places?

- Yes
- Maybe / depends on how much
- No, I'd be concerned that there could be an increase in automobile accidents and slip-and-fall injuries
- Other: _____

Q12e. If you were told that applying salt over the course of the winter could have a negative impact on the environment, would you be willing to reduce the amount of salt you use at your residence?

- Yes
- Maybe / depends on how much
- No, I'd be afraid of a slip-and-fall injury
- Not applicable / don't use salt at my residence
- Other: _____

Q13. Do you have any comments about treating snow and ice in the winter that you would like to share?

_____

1 Awareness Survey, Data Cross Tabulation Results

The cross-tabulation results from the awareness survey described in the previous section are available for download here.

Appendix I. Education and Outreach Resources

Several messages and materials are contained in this appendix that are ready to be used to conduct outreach. As more materials are generated and approved to use the SaMS logo (see **Appendix I – Section 3** for the SaMS Logo Use Guidelines and Standards), those will be added to this toolkit.

Users of these materials are encouraged to include their own context in their distribution of the material. Doing so will enable the user to speak directly to their audience and provide additional information than what may be contained in the materials provided in this appendix. This is particularly relevant to infographics, which are necessarily brief as these are developed for use in social media posts. For these, the user is encouraged to use the caption of the post to add their desired context, such as why exercising best practices is important.

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1 Principles to Guide Development of Messages and Materials

The principles highlighted below are to promote consistency in the creation of education and outreach materials and messaging for SaMS. The intent is for consistency with SaMS goals and *not* to identify specific content. Therefore, these principles are applicable to all stakeholders who develop communications to support and further the goals of SaMS. Each principle is a key consideration in the use of the SaMS logo on any material, whether print or digital, including social media posts.

Listed below for each principle is the corresponding SaMS goal, the intent, and reference to the relevant section within the SaMS document.

1) **The importance of public safety**
   a) This principle supports SaMS goal number 3, which acknowledges that the continued protection of public safety is a priority equal to reducing the negative impacts from the application of winter salt.
   b) Materials and messages proposing actions and/or impacts should not diminish the importance of public safety.
   c) Information on the critical role winter salt plays in maintaining public safety can be found in **Section 1.2**.
2) **The unintended environmental impacts of salt use**
   a) All of the goals of SaMS are supported by this principle, which is an effort to minimize environmental impacts from salt use in Northern Virginia using a balanced approach.
   b) Materials and messages should acknowledge that negative environmental impacts result from the application of salt.
   c) For information on impacts from winter salt use, see **Section 1.1**.
3) **Why minimizing salt application matters**
   a) This principle supports SaMS goal number 2, which is to increase public awareness, resulting in informed decisions regarding salt use and achieving desired benefits.
   b) Provide information to promote why the target audience should care, become engaged and take action to change their behavior.
   c) For information on the impacts from winter salt use, see **Section 1.1**.

All messaging should incorporate the following five principles:

1) The importance of public safety.
2) The unintended environmental impacts of salt use.
3) Why minimizing salt application matters.
4) The pros and cons of winter salt use (keeping in mind the concerns of all stakeholders).
5) Information on ways the target audience can address the issue.

4) **Pros and cons of winter salt use (keeping in mind the concerns of all stakeholders)**

   a) This principle is in support of SaMS goal number 3, which identifies the need to balance the pros and cons of the application of winter salt. It also supports SaMS goal number one by acknowledging this is a collaborative effort of a wide variety of stakeholders, taking a balanced approach.

   b) Develop balanced material for specific audiences – such as to residents to encourage best practices – but without "blaming" a source(s) or stakeholder(s).

      i) When considering sources of salt from winter maintenance activities, for example, avoid the impression there is a sole cause.

      ii) Use a positive tone when framing messages to promote positive engagement and reactions from the general public.

   c) For information on the pros and cons of winter salt use, see **Section 1.1** and **Section 1.2**.

5) **Information on ways the targeted audience can address the issue.**

   a) This principle supports SaMS goal number 2, to increase public awareness that leads to positive behavior changes.

   b) Provides the target audience with ways they can participate to make a difference. Stakeholders are encouraged to share information on actions they are taking to maintain consistency in messaging.

   c) The actions various audiences can take is provided in the SaMS document as noted below:

      i) Winter maintenance professionals: **Section 3**
      ii) Residents: **Section 5.1**
      iii) Commuters: **Section 5.2**

2 Messages

Below are messages to encourage "speaking with one voice" by individuals and organizations conducting education and outreach efforts to create awareness of the benefits and impacts of winter salt application and best practices for the effective use of salt.

Slogan: Winter Salt Smart

This is the slogan of SaMS and is part of the SaMS logo. Users are encouraged to use the slogan in contexts that encourage best practices, and therefore, encourage their audience to be "Winter Salt Smart."

Hashtag: #WinterSaltSmart

Users are encouraged to use the above hashtag in social media posts that are related to or promote SaMS, such as promoting winter maintenance best practices and/or that discuss the benefits and impacts of winter salt use.

3 SaMS Logo Use Guidelines and Standards

The SaMS logo and the use guidelines and standards contained in this appendix is intended to promote brand consistency and provide a strong identity for SaMS, which is a collaborative effort comprised of a stakeholder community. These guidelines may be amended as the SaMS initiative progresses and further insights are gained.

3.1 SaMS Logo Use Guidelines

3.1.1 Logo Use

The below policies are subject to change depending on the future leadership of SaMS.

1. Oversight of logo use must be reviewed by the SaMS Communications Subcommittee or individual member organization(s) of SaMS (reviewing body), as approved by voting members.
    a. The process for approval will be developed by the reviewing body, but at a minimum should include identifying voting rules, review timeframes, how to handle no response from subcommittee members, and information needed to complete such a review. The information to be provided to the Committee at a minimum, should include:
        i. format and intent of the document/material/message for which the use of the logo is requested,

SaMS Slogan: Winter Salt Smart
SaMS Hashtag: #WinterSaltSmart

        ii. distribution channels,
        iii. intended audience,
        iv. discussion on how the **five principles** for developing education and outreach materials are addressed, and
        v. a draft or sample.
    b. The approval process is not necessary for previously approved content or content that is sourced from the SaMS media toolbox. However, if any of the material is altered or updated, the approval process is applicable.
2. The logo may not be used on documents, materials, messages or in any other content or statement that supports legislative actions, legislative opinions or legislative initiatives.
3. Encourage users of the logo to share copies of the final documents/materials to help grow and enhance the SaMS Education and Outreach Resources in **Appendix I**. Flexibility is given for materials developed at significant cost to the requestor or for materials highly specific to their organization and, therefore, not suitable for wider distribution and use.

3.1.2 Logo Size and Resolution

1. No alternations of any kind, such as changes to color, size, font or format of a portion or all of the logo is permitted. However, this does not prevent the resizing of the logo (when done to the entire image as a whole) to fit the desired material.
2. Please refer to the one-page logo user guide (entitled Virginia SaMS Logo Standards) under **Appendix I – Section 3.2** for detailed information on proper logo use.

3.1.3 Logo Placement

1. It should be free-standing, not boxed or have any type or design superimposed on it.
2. It is to be used by itself, without the use of any other logos.
3. It may only be used on documents that follow **SaMS principles** for messages as well as outreach and education materials.
4. It can be used with or without the slogan "Winter Salt Smart," as per the logo user guide.

3.1.4 Logo Availability

A digital copy of the SaMS logo is available to all SaMS SAC members. In receiving the logo, they agree to follow the policies outlined in **Appendix I – Section 3**.

3.2 Virginia SaMS Logo Standards

Virginia Salt Management Strategy (SaMS) Logo Standards

color versions

full color



blue



black



color values

Pantone® Matching System (PMS)
blue - PMS 7684
dark gray - PMS 431
light gray - PMS 428

4-color (CMYK) printing
blue - C:88, M:68, Y:10, K:0
dark gray - C:68, M:52, Y:44, K:18
light gray - C:24, M:18, Y:16, K:0

RGB (red, green, blue)
blue - R:51, G:95, B:159
dark gray - R:88, G:102, B:112
light gray - R:193, G:195, B:200

HEX/HTML
blue - 335F9F
dark gray - 586570
light gray - C1C3C8

Virginia Salt Management Strategy (SaMS) Acceptable Versions

official logo



no tagline



logo mark for social media



Virginia Salt Management Strategy (SaMS) Logo Usage

	full color	blue	black
white			
light/midtone			
dark background			
	reverse	reverse	reverse

4 Awareness Infographic and Flyer

The awareness infographic and flyer provide information on the benefits and impacts of winter salt use. Users are encouraged to use the awareness infographic in digital communications. The flyer may be used in print or digital format. However, if users are providing the flyer as a hyperlinked document in electronic communications, users are encouraged to evaluate their "click' or "click-through" rates to assess the potential for their audience to click on the hyperlink and interact with the flyer. If that information is not readily available, it is recommended that users share the infographic instead of a hyperlinked flyer since it presents the information directly to the audience without needing to click on a link.



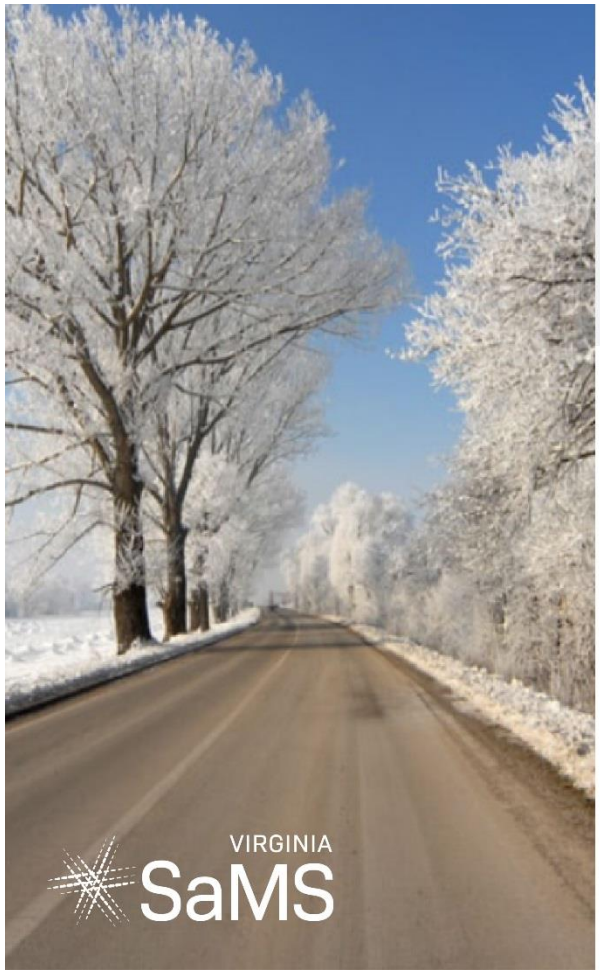
Did you know...

Salt applied to paved surfaces during slick weather conditions helps keep us safe, and businesses and vital services open. However, after a snow event, salt residue lingers and impacts:

Public health:
Affecting those serviced by drinking water supplies with higher salt concentrations.

Infrastructure:
Corrosion and damage to roads, bridges, sidewalks and parking lots leads to higher maintenance and replacement costs.

The environment:
Increases in stream and groundwater salinity impact freshwater fish and other aquatic life.



Did you know...

Salt applied to paved surfaces during slick weather conditions helps keep us safe, and businesses and vital services open. However, after a snow event, salt residue lingers and impacts:

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The environment:

Increases in stream and groundwater salinity impact freshwater fish and other aquatic life.



VIRGINIA SaMS
Salt Management Strategy

Making Sense of Winter Salt Use

What is SaMS?

The Virginia Salt Management Strategy (SaMS) was established by a diverse group of stakeholders coordinated by the Virginia Department of Environmental Quality (DEQ). SaMS provides recommendations for improving winter practices through efficient and effective salt use while maintaining the same levels of safety. The strategy also offers ways to raise awareness of these impacts, how individuals and organizations can participate, guidance for water quality monitoring and research to support action.

Why Should I Care?

In winter, salt helps to keep us safe. Salt applied to paved surfaces provide important benefits:

- **For People and Businesses:** Fewer incidents of slip and fall injuries
- **For Transportation:** Reduces frequency of vehicle crashes by 88%-95%
- **For the Economy:** Enables businesses, government and social services to continue with minimal interruption (estimated avoiding roughly $300-$700 million in direct/ indirect costs for a major, one-day, statewide storm).

However, after a snow event, salt residue lingers and impacts:

- **Public health:** Salt levels in the Potomac River and Occoquan Reservoir – both of which are local drinking water sources – have risen noticeably over the past several decades, with average concentrations more than doubling.
- **Infrastructure:** Corrosion and damage to vehicles, roads, bridges, sidewalks and parking lots leads to higher maintenance and replacement costs.
- **The environment:** Increases in stream and groundwater salinity impact freshwater fish and other aquatic life.

The focus of SaMS is to balance the unintended impacts of salt use with the important safety benefits in Northern Virginia.

How Can I Learn More?

Visit www.deq.virginia.gov/SaMS.

Your feedback is valuable. Please share your thoughts on this outreach effort by completing this form: https://www.surveymonkey.com/r/LMK6MD6

5 Residential Best Practices: Infographic, Pamphlet and Information to Populate Future Webpages

The residential best practices infographic and pamphlet introduces practices that residents can use around their property to efficiently and effectively use salt. The infographic is designed for use in digital communications, whereas the pamphlet is intended to be printed and folded into a trifold brochure. When sharing the residential best practices infographic, consider recommending viewers check with their local government for any requirements to clear certain areas within a specified timeframe. Detailed information on residential best practices is available in the information to populate future webpages located below the infographics and pamphlet.





What to do during and after a storm?

Clear snow by shoveling early and often, and apply salt only where needed.

If the sun comes out and you can wait, let the sun do some of the work before you apply salt.

Apply salt after clearing snow. Never use salt to “burn off” snow. It will quickly dilute and requires more salt.

After the storm, sweep up the extra salt or traction material and use it again next time.



Although we rely on winter salt use to help us safely move around during a weather event, when the salt is done working it causes negative impacts to our drinking water, vehicles, infrastructure and environment throughout Northern Virginia. We can all do our part and learn to be #WinterSaltSmart using the tips in this guide.

What should you do before a storm?

- Have your shovel or snow blower ready.
- Make sure you have the necessary provisions to stay home for a few days.
- Prepare your salt and/or materials to provide traction and store them indoors.

VIRGINIA SaMS
Salt Management Strategy

A Resident's Guide to Smart Salting



For more information

Visit our #WinterSaltSmart tips for residents at ~~websitegoeshere.com.~~

VIRGINIA SaMS

What to do during and after a storm?

- Clear snow by shoveling early and often, and apply salt only where needed.
- If the sun comes out and you can wait, let the sun do some of the work before you apply salt.[1]
- Apply salt *after* clearing snow. Never use salt to "burn off" snow. It will quickly dilute and requires more salt.
  - » Salts should be applied as follows:
    - » Sodium chloride (rock salt): One 12-oz coffee mug holds enough salt to treat a 20-foot driveway or 10 sidewalk squares.
    - » Aim for about three inches between pieces. *(See Figure 1.)*
    - » Calcium chloride should be applied at a rate about one-third that of sodium chloride.
    - » *Note: when applying dry material, it's best to use a hand spreader, like those used for fertilizer.*
- Be patient and give the salt time to work. The colder it is, the longer it will take for the salt to melt what snow or ice remains after shoveling.
- If it is too cold for your salt to work, or you'd rather not use salt, use traction materials instead, like sand, wood ash, or native bird seed.
- After the storm, sweep up the extra salt or traction material and use it again next time.

Figure 1

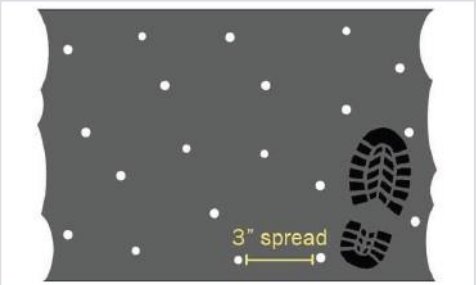


Image credit: Vadnais Lake Area Water Management Organization

Did you know?

Many people who use salt to melt snow may not know how much to use. It only takes one teaspoon of salt to permanently pollute five gallons of water, harming the life in our waterways. Because there aren't any good options for removing salt from water, use this guide to help limit your impact.

1 Make sure to check with your local government for any requirements to clear certain areas within any specified timeframe.

Choosing the right salt

Below is a table with the lowest temperatures that the more common salts will work. Salts that do not contain chloride are more expensive, but have less of an impact on the environment.

Type of Salt	Chemical	Lowest Temperature the Salt Will Work
Salts that contain chloride	NaCl (sodium chloride), also called "rock salt"	15 F
	MgCl2 (magnesium chloride)	-10 F
	CaCl2 (calcium chloride)	-20 F
	KCl (potassium chloride)	25 F
Salts that do not contain chloride	CMA (calcium magnesium acetate)	20 F
	KAc (potassium acetate)	-15 F

Always read the ingredients to determine what is legitimately "safe," "pet-safe" and "environmentally friendly." Any deicing materials that contain nitrogen or phosphorus are illegal to sell in Virginia.

5.1 Residential BMP Information to Populate Future Webpages

The content in the sections below is proposed to populate three different webpages. The first content for the webpage "Snow and Ice Maintenance Tips for Residents" is proposed as the primary landing page for residential BMPs. The other two webpages are proposed to be secondary, topical pages nested under the first that provides content on "Materials to Treat Snow and Ice" and "Temperature Ranges and Terminology for Salts." This information in this document is proposed to be uploaded to a SaMS webpage during the initial stages of SaMS implementation.

5.2 Snow and Ice Maintenance Tips for Residents

5.2.1 Do you know…

- It only takes one teaspoon of salt to permanently pollute 5 gallons of water.
- Salt seeped into the environment can:
    - Raise sodium levels in our drinking water and increase treatment costs.
    - Harm fish, plants and other wildlife.
    - Corrode vehicles, roads, bridges and parking lots.
- Salt can make it safer for us to walk and drive around. It helps keep roads open, and allows businesses, government and social services to stay open with little interruption.
- Since there's no easy or cheap way to remove salt from our environment, we can all do our part to reduce the amount of salt we use and be #WinterSaltSmart by following the below tips.

5.2.2 What should you do before a storm?



- Have your shovel or snow blower ready
    - Shovels may be all that you need around NoVA. To make it easier on your back, there are versions with wheels. Remember to take breaks and avoid overloading your shovel with wet snow.
    - For big storms or heavy weight snow, snow blowers can be helpful.
- Gather all the provisions you'll need to stay home for a few days
    - Make sure to stock up on enough food, drinks and medicine (including prescriptions) before the storm.
    - Always make sure to assemble an emergency or storm preparedness kit.
- Have your salt and/or traction materials ready (for more details visit "**Materials to Treat Snow and Ice**")
    - Always store your materials indoors and away from rain and snow.

5.2.3 Choosing the right salt

Table 25 provides temperature ranges for some of the more common salts. For more information on these salts and some alternatives, visit "**Materials to Treat Snow and Ice**," and for more information on the temperature ranges of the different salts visit "**Temperature Ranges and Terminology for Salts**."

Table 25. Temperature ranges for select common salts.

Type of Salt	Chemical	Lowest Practical Melting Temperature[1]	Eutectic Temperature[2]
Salts that contain chloride	**NaCl (sodium chloride) also called "Rock Salt"[3]**	15 F	-6 F
	$MgCl_2$ (magnesium chloride)[3]	-10 F	-28 F
	$CaCl_2$ (calcium chloride)[3]	-20 F	-60 F
	KCl (potassium chloride)[4]	25 F	13 F
Salts that do not contain chloride	**CMA (calcium magnesium acetate)[3]**	20 F	-18 F
	KAc (potassium acetate)[3]	-15 F	-76 F

[1]The temperature that a salt will melt ice in a reasonable amount of time. Also called "Lowest Effective Temperature."
[2]The lowest temperature that a salt can melt ice. This is not a practical temperature to reference (see the warnings below).
[3]Source: https://stormwater.pca.state.mn.us/index.php?title=Lowest_practical_melting_temperature
[4]Source: http://www.dot.state.oh.us/Divisions/Operations/Maintenance/SnowandIce/Snow%20and%20Ice%20Best%20Practices/Liquid%20Chemicials%20Presentation.ppt

5.2.3.1 What to look out for when purchasing salt

- Labels like "safe," "pet-safe" and "environmentally friendly" can be used inaccurately on certain products, so be sure to read the ingredients.
- Choose the material based on the "Lowest Practical Melting Temperature" not the "Eutectic Temperature."
  - To understand this better, visit "**Temperature Ranges and Terminology for Salts**."
- Materials to avoid: All nitrogen and phosphorus salts are illegal in Virginia.
  - Nitrogen salts include urea, ammonium sulfate and potassium nitrate, etc.
  - Phosphorus salts may have "phosphate" (PO_4) in the ingredients, although these are rare.

5.2.4 What to do during and after a storm

- Clear snow by shoveling early and often.
- Make sure to clear snow and apply salt only where it is needed.
- Apply salt *after* clearing snow. Never use salt to "burn off" snow. It will quickly dilute and requires excess use.
  - Salts should be applied as follows:
    - Sodium chloride: One 12-oz coffee mug holds enough salt to treat a 20-foot driveway or ten sidewalk squares. Aim for about 3 inches between pieces of rock salt

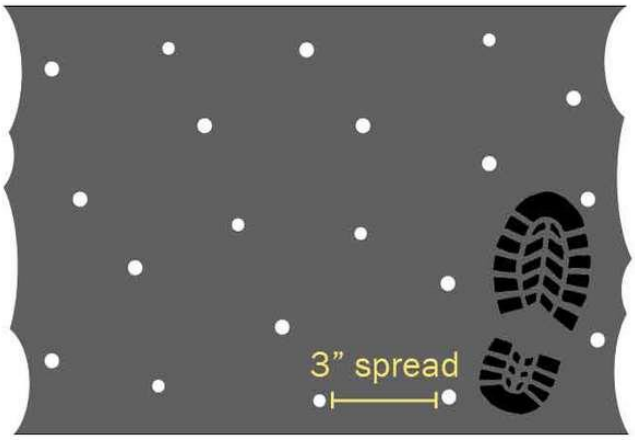


Image Credit: Vadnais Lake Area Water Management Organization

        - Calcium chloride: apply at a rate that is one third of the rate used for sodium chloride.
        - *Note: when applying dry material, it's best to use a hand spreader, like those used for fertilizer.*
- Be patient and give the salt time to work. The colder it is, the longer it will take for the salt to melt what snow or ice remains after shoveling.
- If the sun comes out and you can wait, let the sun do some of the work before you apply salt.
    - *Note: Make sure to check with your local government for any requirements to clear certain areas within a certain timeframe*
- If it is too cold for your salt to work, or you'd rather not use salt, use traction materials instead. These include, sand, bird seed (make sure to use a native blend) and zeolite crystals (like EcoTraction™).
- After the storm, sweep up the extra salt or traction material and use it again next time.

5.3 Materials to Treat Snow and Ice

5.3.1 Types of materials

- **Salts** – Materials that melt ice or prevent snow and ice from sticking to a surface, like a driveway.
- **Homemade alternatives to salt** – These materials can work similarly to store bought salts, but can have less of an impact on the environment. Plus, they can be made from supplies you may have around your home.
- **Traction materials** – Substances spread on top of snow and ice to provide better traction. Depending on your circumstances, these can be used anytime instead of salts or their alternatives.

5.3.1.1 Salts

- Salts dissolve in water and lower the freezing temperature, so snow and ice cannot form. Different salts are effective at different temperatures and the amount needed varies a lot. For information on the temperature ranges of different salts, visit "**Temperature Ranges and Terminology for Salts**," and for salt application rates, see "**Snow and Ice Maintenance Tips for Residents**."
- Types of salts used to melt or prevent snow and ice from sticking to a surface include:
    - Salts that contain chloride
        - Rock salt, also known as sodium chloride (NaCl)
        - Magnesium chloride ($MgCl_2$)
        - Calcium chloride ($CaCl_2$)

        - Potassium chloride (KCl)
    - Salts that do not contain chloride and have less of an impact on the environment
        - Calcium magnesium acetate (CMA)
        - Potassium acetate (KA)

5.3.1.2 Homemade alternatives to salt

- Rubbing alcohol
    - In a bucket, combine half a gallon of hot water and one-quarter cup of rubbing alcohol. Once you pour the mixture onto your sidewalk or driveway, the snow and ice will begin to melt. Just keep a shovel handy to scrape away any leftover ice.
- Wood ash
    - Contains potash or potassium salts, which work like the salts described above. If you already own a fireplace or wood stove, this option has the added benefit of being free. Plus, wood ash also provides great traction.
- *Note: For homemade alternatives to salt, the correct amount to apply will change with each storm and the concentration of your material. You should experiment in a small area to find the correct measurements.*

5.3.1.3 Materials for traction

- Sand
- Bird Seed (make sure to use a native blend)
- Wood ash
    - Wood ash not only contains potash or potassium salts, but it also provides great traction!
- Zeolite crystals for traction and moisture absorption
    - Like products that contain EcoTraction™
- *Note: The amount necessary to provide traction will change with each storm. You should experiment in a small area to find the correct measurements.*

5.4 Temperature Ranges and Terminology for Salts

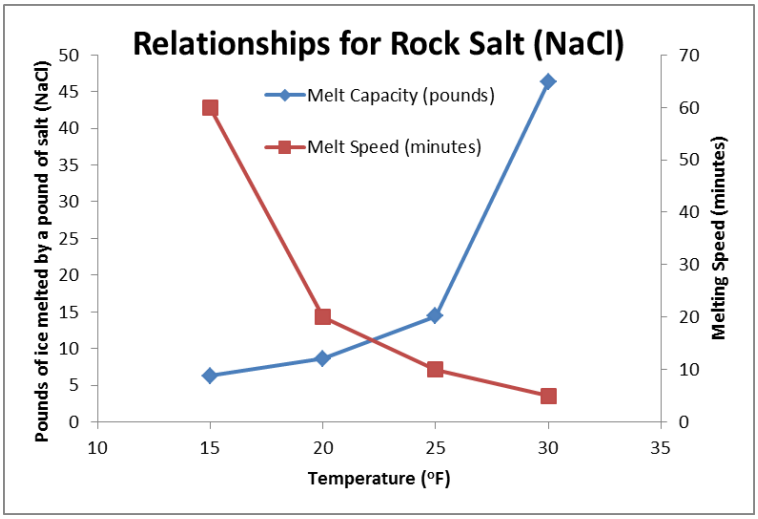
Salts dissolve in water and lower the freezing temperature, so snow and ice cannot form. Different salts are effective at different temperatures and the amount needed varies greatly. For more information on the different salts, visit "**Materials to Treat Snow and Ice**.

5.4.1 Terms Used to Describe Salt Temperatures

Below are the two most important phrases used to describe temperature ranges:

- **"Lowest Practical Melting Temperature"** or **"Lowest Effective Temperature"**
    - The temperature that a salt will melt ice in a reasonable amount of time. The melting rate slows down tremendously below this temperature until the "Eutectic Temperature" is met.
    - *Note: Different manufacturers and organizations may list different temperatures for the same salt.*
- **"Eutectic Temperature"**
    - The lowest temperature that a salt can melt ice.

To help explain the concept of a "Lowest Practical Melting Temperature" or "Lowest Effective Temperature" the graph on the right shows how the melting speed and capacity (or the amount of ice the salt can melt) reach a point where the salt will not be very "effective." We put "effective" in quotation marks because that is a judgement call. For most homeowners rock salt may still be effective at 15 ˚F.



5.4.2 Temperature Ranges for Salts

Table 26 presents temperature ranges for some of the more common salts:

Table 26. Temperature ranges for select common salts.

Type of Salt	Chemical	Lowest Practical Melting Temperature	Eutectic Temperature
Salts that contain chloride	NaCl (sodium chloride) also called "rock salt"[1]	15 F	-6 F
	$MgCl_2$ (Magnesium Chloride)[1]	-10 F	-28 F
	$CaCl_2$ (Calcium Chloride)[1]	-20 F	-60 F
	KCl (Potassium Chloride)[2]	25 F	13 F
Salts that do not contain chloride	CMA (Calcium Magnesium Acetate)[1]	20 F	-18 F
	KAc (Potassium Acetate)[1]	-15 F	-76 F

[1]Source: https://stormwater.pca.state.mn.us/index.php?title=Lowest_practical_melting_temperature
[2]Source: http://www.dot.state.oh.us/Divisions/Operations/Maintenance/SnowandIce/Snow%20and%20Ice%20Best%20Practices/Liquid%20Chemicials%20Presentation.ppt

6 Commuter/Driver Best Practices Infographic

The commuter/driver best practices infographic is designed for use in digital communications.





Help Virginia be Winter Salt Smart

Follow these winter safety tips to give snowplows the room and time to operate, allowing roads to get cleared more efficiently with appropriate salt application:

Stay home, avoid non-essential travel and telework if possible.

If you *must* go out, take public transportation.

Monitor weather closely, as forecasts can change quickly.

Plan travel times to avoid driving during and immediately after a storm.

Wait to drive until road conditions improve.

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Appendix J. Salt/BMP Tracking Forms and Instructions

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1 Instructions

The information to track both product use and effectiveness of Best Management Practices (BMPs) is recommended as a component of a comprehensive strategy to facilitate improved winter maintenance that minimizes over use of salt products. Varied levels of data tracking detail are provided in light of organizations unique operations. While tracking this information is **voluntary**, winter maintenance organizations are recommended to perform some level of tracking to support enhanced internal operations, and in time, enable regional scale analysis. A core set of data elements is recommended to serve as a starting point for those new to tracking winter operations data, and promote greater consistency among those already tracking their winter operation activities. This appendix provides the instructions on how to use the example tracking forms and the forms themselves in hard copy. **The example tracking forms are also available electronically in spreadsheet format here.**

The recommended tracking metrics are compiled into "ready to use" forms to provide an example for organizations to use as is, or to modify or draw upon to create their own tracking forms. The example forms provide the ability to track and report at one of three levels of detail. **Seasonal** tracking will provide basic information which could serve as a foundation for more in-depth future tracking and reporting. **Storm-specific** tracking documents each organization's winter maintenance activities for individual storms. **Operational Area** tracking using data at the "treatment area" (transportation route or property groupings) level of detail, necessitates data collection and entry for each treatment area for each storm. Tracking at the operational area level can support more refined analysis of the data and winter management strategies, as well as geographically focused water quality monitoring analysis. As previously noted, tracking any of the recommended information, including use of the example forms, is **voluntary**.

In the spreadsheet, cells that are not applicable for data entry have been **grey shaded**, with a dot pattern. Light blue shading indicates **seasonal** level of detail elements, and light green shading indicates **more detailed** tracking information.

Operations Information: Tab #1

1. Fill in **Organization Name (B2)**
2. If Applicable, fill in **Sub-Organization Name (B3)**
3. Select the **Geographic Area(s) (B4 – F4)** in NoVA where the organization operates, if > 5 areas, add narrative to identify additional areas **(G4).**
4. Enter the years of the reporting **Winter Season (B5). Note** that these first four elements are auto-populated from Tab #1, in Tabs #2-4.
5. **Highways and Roads**: enter **total lane miles (B7)** of Highways, Primary Roads, and Local Roads.
6. **Trails**: enter **total miles (B8)** of Bike or other trails maintained by organization.
7. **Property Maintenance**: Select units and enter the area of Parking Lots, Sidewalks, and Other Areas.
    a. Enter **Parking Lot area (B9)** in total acres or sq.ft. Select the units used for Parking Lots as Acres or Sq. Ft. ***(E9)***
    b. Enter **Travelways (B10)**, which includes driveways, alleys, and other off-road vehicular paths, in total acres or sq.ft. Select the Travelways units as Acres or Sq. Ft. ***(E10)***
    c. Enter **Sidewalk area (B11)** in linear ft. or sq.ft. Select the units used for Sidewalks as Linear Ft. or Sq. Ft. ***(E11)***

d. Enter **Other Treatment areas (B12-13)** in total acres or sq.ft. Select the units used for Other Areas as Acres or Sq. Ft. ***(E12-13)***

8. **Detailed Property/Route Groupings**. These fields enable an organization to track data at a sub-organizational level of detail, either as **Property groupings** or **Transportation routes**. For more than five property/route groupings, expand by inserting additional columns beyond column G. If comprehensive data is entered for Property/Routes, treatment area totals will be calculated for data elements described in #5-7 above.
    a. Enter the **name** of the property/route grouping **(C15-G15)**.
    b. Highways and Roads: enter **total lane miles (C16-G16)** of Highways, Primary Roads, and Local Roads.
    c. Trails: enter **total miles (C17-G17** of Bike or other trails maintained by organization.
    e. Select **Parking Lot area units** as total acres or sq.ft. **(B18)**, and enter the size of the parking areas maintained by each grouping ***(C18-G18).***
    f. Select **Travelways area units** as total acres or sq.ft. **(B19)**, and enter the size of the Travelways (driveways, alleys, etc.) areas maintained by each grouping ***(C19-G19).***
    g. Select **Sidewalk area units** as linear ft. or sq.ft. **(B20)** and enter the size of the sidewalk area maintained by each grouping ***(C20-G20).***
    h. Select **Other Treatment areas units** as total acres or sq.ft. **(B21-22)** and enter the size of the Other Areas maintained by each grouping ***(C21/22 – G21-22).***

Storm Tracking: Tab #2

1. For **Seasonal** level Reporting, enter the **Number of Storm Deployments (F5)**, the total inches of **Snow** for the season **(B14)**, the source(s) used for **weather information (B21)**, and any narrative notes to describe winter season storm **conditions (B22).**
2. **Storm-specific** reporting, enter data for each Storm Deployment**.** Expand spreadsheet by "unhiding" Columns K-T for Storms 5-9, and add additional columns beyond V as needed for >10 storms.
    a. Enter the **beginning Date and Time** for each storm operations **deployment (C8-V8).**
    b. Enter the **ending Date and Time** for each storm operations **deployment (C9-V9)**
    c. Enter the **beginning Date and Time** for each storm's **precipitation (C10-V10).**
    d. Enter the **ending Date and Time** for each storm's **precipitation (C11-V11)**
    e. Select the **Storm Type** (Heavy Snow > 6", Medium 2-6", Light < 2") **(C9-O9).**
    f. Select **Full or Partial Deployment (C12-V12).**
    g. Select the applicable **Storm Type** entry **(C13-V13).**
    h. Enter the amount of **Snow** for each storm **(C14-V14).**
    i. Select Yes or No to indicate whether **Freezing Rain** occurred during storm **(C15-V15).**
    j. Select **Road Temperature during** the Storm (Warm, >32, Mid, 25-32, Cold, <25 degrees F) **(C16-V16).**
    k. Select **Early Storm Conditions** (Starts as Snow, SS, or Starts as Snow, SS) **(C17-V17).**
    l. Select the **Winds during** the Storm (Light, < 15 mph, Strong, > 15 mph) **(C18-V18).**
    m. Select the **Winds after** the Storm (Light, < 15 mph, Strong, > 15 mph) **(C19-V19).**
    n. Select the **Forecasted Post Storm Temperature** (Same, Rising, Falling) **(C20-V20).**
    o. Enter **Other Notes** describing Storm Conditions (narrative) as desired, at Storm-specific levels **(C22-V22).**

Product Use: Tab#3

Information can be entered either at a **Seasonal** level in Column B, or **Storm-specific** levels in Columns D-O. Expand spreadsheet by "unhiding" Columns H-L for Storms 5-9, and add additional columns beyond M as needed for >10 storms.

1. Enter the **amount of Sodium Chloride** (NaCl) used for the season **(B8),** or for each storm **(D8-M8),** and select the **Units** for NaCL (dry lbs. or tons) **(C8).**
2. Enter the **amount of Magnesium Chloride** (MgCl) used for the season **(B9),** or for each storm **(D9-M9),** and select the **Units** for MgCL (dry lbs. or tons) **(C9).**
3. Enter the **amount of Calcium Chloride** (CaCl) used for the season **(B10),** or for each storm **(D10-M10),** and select the **Units** for CaCL (dry lbs. or tons) **(C10).**
4. Enter in **A11**, second line, the % **Sodium Chloride** (NaCl) in the brine product. Enter the **amount of NaCl brine** in gallons used for the season **(B11),** and select 'Yes' or 'No' to indicate its use during individual storms **(D11-M11).**
5. Enter in **A12**, second line, the % **Magnesium Chloride** (MgCl) in the brine product. Enter the **amount of MgCl brine** in gallons used for the season **(B12),** and select 'Yes' or 'No' to indicate its use during individual storms **(D12-M12).**
6. Enter in **A13**, second line, the % **Calcium Chloride** (CaCl) in the brine product. Enter the **amount of CaCl brine** in gallons used for the season **(B13),** and select 'Yes' or 'No' to indicate its use during individual storms **(D13-M13).**
7. Enter the **amount of Abrasives** applied for the season **(B14),** or during each storm **(D14-M14),** and select the **Units** for abrasives (sq. yards, tons or other) **(C14).**
8. Enter the **amount of Other Products** used for the season **(B15-17),** or for each storm **(D15-17 to M15-17),** and enter the **Product Name (A15-17)** and **Units** for Other Products used **(C15-17).** Add additional rows after row 17 if more than one additional product was used during the winter season.
9. **Product Effectiveness and Future Plans**: Enter narrative information, as desired, to briefly discuss product effectiveness in achieving treatment goals **(N8-N17)**, and select 'Yes' or 'No' to indicate whether the product is planned for use in future winter seasons **(O8-O17).**
10. **Notes of Treatment Products Used**: Enter narrative information, as desired, to document information on products used at either the seasonal or storm-specific level: if storm-specific, identify the storm the note pertains to.

BMP Implementation Reporting: Tab #4

1. **BMP Use**: Select '**Yes', 'No', or 'N/A' (C8-C61)** to indicate whether each listed practice was used during the winter season by your organization. Use Row 62 to describe any BMPs used in winter operations that are not listed, and add rows beyond 62 as needed for additional BMPs used.
2. **BMP Effectiveness:** Enter **narrative information (D8-D61)** to briefly explain, as desired, the effectiveness of each listed practice that was used during the winter season by your organization.
3. **BMP Future Use Plans:** Select a '**Yes' or 'No'** response to indicate plans for future use of each BMP **(E7-58).** Enter **narrative information (F8-F61)** to explain plans for use of practices during future winter seasons by your organization. This field provides an opportunity to discuss any **impediments** to use of specific BMPs that may take time to overcome (capital expenditures, specialized training, contracting changes, etc.), as well as any **specific plans** to implement additional BMPs in the future.
4. **Additional BMPs:** Enter the name of any additional BMPs implemented (**B62)** and enter narrative information to briefly discuss, as desired, the effectiveness of additional BMPs **(C62).** Add rows beyond row 62 to track more than one additional BMP.

2 Example Forms

Operations Information: Tab #1

Salt Tracking and Reporting Data: Sheet #1 - Operations						
Organization Name:						
Sub-Organization Name:						
Geographic Area(s) of Operations:	Area 1	Area 2	Area 3	Area 4	Area 5	Other (insert text)
Winter Season:						

Operational Area Description			
Total Highways and Roads (lane miles)	0		
Total Bike/Other Maintained Trails (miles)	0		
Total Area of Treated Parking Lots	0	Parking Area Units of Measure	Acres
Total Area of Treated Travelways	0	Driveways Units of Measure	Linear Ft or Sq. Ft.
Total Area of Treated Sidewalks	0	Sidewalks Units of Measure	Linear Ft or Sq. Ft.
Total Area of "Other#1" Types of Treated Surfaces	0	Units for "Other"	Acres or Sq. Ft.
Total Area of "Other#2" Types of Treated Surfaces	0	Units for "Other"	Acres or Sq. Ft.

Detailed Property /Route Information						
	Units	Property/ Route #1	Property/ Route #2	Property/ Route #3	Property/ Route #4	Property/ Route #5
Total Highways and Roads (lane miles)	lane miles					
Total Trails (miles)	miles					
Total Area of Treated Parking Lots	Acres or Sq. Ft.					
Total Area of Treated Travelways	Acres or Sq. Ft.					
Total Area of Treated Sidewalks	Sq. Ft. or Linear Ft.					
Total Area of "Other#1" Types of Treated Surfaces	Acres or Sq. Ft.					
Total Area of "Other#2" Types of Treated Surfaces	Acres or Sq. Ft.					

Storm Tracking: Tab #2

Salt Tracking and Reporting Data: Sheet #2 - Storms Tracking													
Organization Name:													
Sub-Organization Name:													
Geographic Area(s) of Operations:	Area 1	Area 2	Area 3	Area 4	Area 5	Other (insert text)							
Winter Season:	0	# Storm Operations (Seasonal Total):											
Storm Descriptions													
	Seasonal Total	Storm 1		Storm 2		Storm 3		Storm 4		Storm 10			
Beginning Date, Time of Each Storm Operations Deployment		Date	Time	Date	Time	Date	Time	Date	Time	Date	Time		
End Date, Time of Operations:		Date	Time	Date	Time	Date	Time	Date	Time	Date	Time		
Beginning Date, Time of Storm Precipitation		Date	Time	Date	Time	Date	Time	Date	Time	Date	Time		
End Date, Time of Precipitation:		Date	Time	Date	Time	Date	Time	Date	Time	Date	Time		
Full or Partial Deployment?		F, P		F, P		F, P		F, P		F, P			
Storm Type (Heavy Snow > 6", Medium 2-6", Light < 2")		H, M, L		H, M, L		H, M, L		H, M, L		H, M, L			
Inches of Snowfall:	0	0		0		0		0		0			
Ice or Freezing Rain?		Y, N		Y, N		Y, N		Y, N		Y, N			
Road Temperature During Storm (Warm, >32, Mid, 25-32, Cold, <25 degrees F)		W, M, C		W, M, C		W, M, C		W, M, C		W, M, C			
Early Storm Conditions: Starts as Snow, SS; Starts as Rain, SR		SS, SR		SS, SR		SS, SR		SS, SR		SS, SR			
Winds During Storm (Light, < 15 mph, Strong, > 15 mph)		L, S		L, S		L, S		L, S		L, S			
Winds After Storm (Light, < 15 mph, Strong, > 15 mph)		L, S		L, S		L, S		L, S		L, S			
Forecasted Post Storm Temps (Same, Rising, Falling)		S, R, F		S, R, F		S, R, F		S, R, F		S, R, F			
Sources Used for Storm Information (NWS, Own Observation, other?)													
Other Notes Describing Storm Conditions (narrative)													

Product Use: Tab#3

Salt Tracking and Reporting Data: Sheet #3 - Product Use									
Organization Name:									
Sub-Organization Name:									
Geographic Area(s) of Operations:	Area 1	Area 2	Area 3	Area 4	Area 5	Other (insert text)			
Winter Season:	0								
Product Use Data									
Treatment Products	**Seasonal Total**	**Units of Measure**	**Amount used in Storm 1**	**Amount used in Storm 2**	**Amount used in Storm 3**	**Amount used in Storm 4**	**Amount used in Storm 10**	**Was this product effective? (narrative as applicable):**	**Is product planned for continuation? (Yes or No)**
Sodium Chloride (NaCl)	0	dry lbs, tons							Y, N
Magnesium Chloride (MgCl)	0	dry lbs, tons							Y, N
Calcium Chloride (CaCl)	0	dry lbs, tons							Y, N
Sodium Chloride Brine % Brine Mixture: ____	0	gallons	Y, N	Y, N	Y, N	Y, N	Y, N		Y, N
Magnesium Chloride Brine % Brine Mixture: ____	0	gallons	Y, N	Y, N	Y, N	Y, N	Y, N		Y, N
Calcium Chloride Brine % Brine Mixture: ____	0	gallons	Y, N	Y, N	Y, N	Y, N	Y, N		Y, N
Abrasives Applied	0	sq. yds, tons							Y, N
Other Products Used? Name:	0	Units							Y, N
Other Products Used? Name:	0	Units							Y, N
Other Products Used? Name:	0	Units							Y, N
Notes on Treatment Products Used									

BMP Implementation Reporting: Tab #4

Salt Tracking and Reporting Data: Sheet #4 - Best Management Practices (BMPs)					
Organization Name:					
Sub-Organization Name:					
Geographic Area(s) of Operations:	Area 1	Area 2	Area 3	Area 4	Area 5
Winter Season:	0				
Planning BMPs					
	BMPs	**Was This BMP Used?**	**BMP Effectiveness: Briefly discuss whether this practice was effective**	**Is practice planned for future use?**	**Impediments/Plans: Briefly discuss any impediments/requirements to address or plans for future use of this practice**
Winter Operations Planning	Winter Maintenance Plan is developed	Y, N		Y, N	
	Preseason meetings are held	Y, N		Y, N	
	Postseason meetings are held	Y, N		Y, N	
	Accountability is at every level	Y, N		Y, N	
	Transportation Audiences - Snowplow routes are planned	Y, N		Y, N	
	Property Management Audiences - the properties are visited before the season	Y, N		Y, N	
Levels of Service	***Transportation Audiences*** - LOS are communicated internally	Y, N		Y, N	
	Transportation Audiences - LOS are communicated externally	Y, N		Y, N	
	Property Management Audience LOS are discussed and agreed upon	Y, N		Y, N	

Planning BMPs (cont'd)					
Training	Training is held	Y, N		Y, N	
Salt Storage/Handling	Deicer piles are properly stored	Y, N, N/A		Y, N	
	Liquid products are properly stored	Y, N, N/A		Y, N	
	Loading and hauling of deicers are done properly	Y, N		Y, N	
	Equipment is cleaned and wastewater is contained	Y, N		Y, N	
	Property Management Audiences - Storage of deicers and abrasive piles delivered to a property:	Y, N, N/A		Y, N	
	Property Management Audiences - Storage and handling of deicer bags is done properly	Y, N, N/A		Y, N	
Cali-bra-tion	A calibration process is established	Y, N		Y, N	
	Equipment is calibrated	Y, N, Partial		Y, N	
Storm Meetings	Pre-storm meetings are held	Y, N		Y, N	
	Post-storm meetings are held	Y, N		Y, N	
Weather Fore-casts	Accurate weather forecasting is obtained and is a part of decision making	Y, N		Y, N	
	Know the surface temperature	Y, N		Y, N	

Planning BMPs (cont'd)					
Enhanced Equipment & Technology	Advanced plows are used	Y, N, N/A		Y, N	
	Advanced spreaders are used	Y, N, N/A		Y, N	
	Proper/Advanced equipment needed for making liquid products is used	Y, N, N/A		Y, N	
	Transportation Audiences - Automated Vehicle Location (AVL) is used	Y, N		Y, N	
	Transportation Audiences - Maintenance Decision Support System (MDSS) is used	Y, N		Y, N	
	Transportation Audiences - Precision Deicing is used	Y, N		Y, N	

Storm Related BMPs					
	BMPs	**Was This BMP Used?**	**BMP Effectiveness: Briefly discuss whether this practice was effective**	**Is practice planned for future use?**	**Impediments/Plans: Briefly discuss any impediments/requirements to address to allow use of this practice**
Anti-Icing	Anti-icing is used	Y, N		Y, N	
Plowing Practices	Plowing early and often is common practice	Y, N		Y, N	
	Transportation Audiences - Plowing activities are coordinated	Y, N		Y, N	
	Transportation Audiences - Plow trains are used	Y, N		Y, N	
	Property Management Audiences - The right plow, shovel, pusher, blower, blade, or broom for the property is used	Y, N		Y, N	
	Property Management Audiences - Opportunities to close areas with a small footprint,	Y, N, N/A		Y, N	
	Property Management Audiences - Snow is placed in proper places	Y, N		Y, N	

Storm Related BMPs (cont'd)					
Product Application Practices	Dyed deicers are used	Y, N		Y, N	
	Use of Abrasives	Y, N		Y, N	
	Deicers are cleaned up after storm	Y, N		Y, N	
	Transportation Audiences - Spinners set-are up properly	Y, N		Y, N	
	Transportation Audiences - Plows drive 17-25 mph on non-high-speed roads	Y, N		Y, N	
	Transportation Audiences - On high-speed roads deicer is applied to the center of the road or high side of a curve	Y, N		Y, N	
	Transportation Audiences - Auger, shoots, or conveyors are turned off when stopped	Y, N		Y, N	
	Transportation Audiences - Deicer application rate is reduced on successive passes	Y, N		Y, N	
	Property Management Audiences - Spread patterns that prevent overlapping applications are used	Y, N		Y, N	
	Property Management Audiences - Drop spreaders or rotary spreaders with shields are used for sidewalks	Y, N		Y, N	
	Property Management Audiences - Managing stairways or areas with a small footprint #2	Y, N, N/A		Y, N	
Vary Application to Conditions	Variable application rates are used for surface temperature, precipitation type/rate, and intended levels of service	Y, N		Y, N	
	Deicers are used within their temperature range	Y, N		Y, N	
Use of Liquids	Deicers are pretreated	Y, N		Y, N	
	Deicers are prewetted	Y, N		Y, N	
	Direct Liquid Application is used	Y, N		Y, N	

Storm Related BMPs (cont'd)					
Measurement	Deicer use is measured and recorded	Y, N		Y, N	
Additional BMPs and Notes	**Additional BMPs and Comments: Seasonal or Storm-specific** **Name of BMP: _____** **Notes: _____**				

Data Dictionary: Tab #5

Salt Tracking and Reporting Form Data Dictionary	
This tool is provided for winter pavement treatment operators to record data that can be used over time to reduce costs while maintaining standards of service.	
Service Area (Tab #1) data can be entered by Operational Units (light green shaded section of Tab #1), which will sum for the whole organization, or simply enter data at the organizational level (light blue shaded portion of Tab #1).	
Winter Weather (Tab #2) data can be entered by Storm Events (light green shaded section of Tab #2), which will sum for the season, or simply enter data at the seasonal level (light blue shaded portion of Tab #2).	
Product Use (Tab #3) data can be entered by storm event (light green shaded section of Tab #2), which will sum for the season, or simply enter data at the seasonal level (light blue shaded portion of Tab #2).	
BMP Implementation (Tab #4) data is only entered at the seasonal level (light blue shaded portion of Tab #4).	
Data Element	**Data Element Definition/Data Entry Instructions**
Tab 1: Operations	Organization Name, Geographic Areas of Operations, Winter Season Years, and the total extent of Transportation and Property Management areas maintained are **Core Tracking Elements**
Organization Name:	**Enter** name of Public or Private Organization tracking its winter operations
Sub-Organization Name:	**Enter** name of Sub-unit of the Organization for tracking information being recorded. Example Transportation Division, Property Maintenance Div., etc.
Geographic Area(s) of Operations:	**Select** all NoVA jurisdictions in which the organization conducts winter operations (B4-F4), with All NoVA an option. If > 5 individual areas, can specify any remaining areas of operations (G4)
Winter Season:	**Enter** the years corresponding to the winter season being tracked (i.e., 2020-21).
Seasonal Tracking	
Total Highways and Roads (lane miles)	**Enter t**otal lanes miles for all road surfaces maintained in the winter by the organization
Total Bike/Other Maintained Trails (miles)	**Enter t**otal miles for all trails maintained in the winter by the organization
Total Area of Treated Parking Lots	**Enter** total area for all Parking Lots treated by the organization. **Select** either Acres or Sq. Ft in the reporting unit field
Total Area of Treated Travelways	**Enter** total area for all "Travelways" treated by the organization, which include driveways, alleys, and other off-road vehicular paths. **Select** either Acres or Sq. Ft in the reporting unit field
Total Area of Treated Sidewalks	**Enter** total area for all Sidewalks treated by the organization. **Select** either Sq. Ft or Linear Ft. in the reporting unit field
Total Area of "Other #1" Treated Surfaces	**Enter** the type of surface (Column A) and its total area (Column B) for Other Areas #1 treated by the organization. **Select** either Acres or Sq. Ft in the reporting unit field

Salt Tracking and Reporting Form Data Dictionary	
Total Area of "Other #2" Treated Surfaces	**Enter** the type of surface (Column A) and its total area (Column B) for Other Areas #2 treated by the organization. **Select** either Acres or Sq. Ft in the reporting unit field
Operations Area Tracking	
Total Highways and Roads (lane miles)	**Enter** lanes miles for road surfaces treated for this Route, add additional columns for >5 Routes/Property Groupings. **Note** that for this and other treatment area fields, if comprehensive data is enterred at "Property/Route" level of detail, organziational totals will be computed.
Total Bike/Other Maintained Trails (miles)	**Enter** Trail miles treated for this Route
Total Area of Treated Parking Lots	**Enter** total area for all Parking Lots treated for this Property Grouping. **Select** either Acres or Sq. Ft in the reporting unit field
Total Area of Treated Travelways	**Enter** total area for all "Travelways" (driveways, alleys, and other off-road vehicular paths) treated for this Property Grouping. **Select** either Acres or Sq. Ft in the reporting unit field
Total Area of Treated Sidewalks	**Enter** total area for all Sidewalks treated for this Property Grouping. **Select** either Sq. Ft or Linear Ft. in the reporting unit field
Total Area of "Other#1" Treated Surfaces	**Enter** the type of surface (Column A) and its total area (Column B) for Other Areas #1 treated for this Property Grouping. **Select** either Acres or Sq. Ft in the reporting unit field. Examples might include stairs, bus stops, etc.
Total Area of "Other#2" Treated Surfaces	**Enter** the type of surface (Column A) and its total area (Column B) for Other Areas #2 treated for this Property Grouping. **Select** either Acres or Sq. Ft in the reporting unit field. Examples might include stairs, bus stops, etc.
Tab 2: Storms Tracking	Number of Storm Operation Deployments and Total Inches of Snowfall for Season are **Core Tracking Elements**
Organization Name:	Auto Populates from Tab #1, similarly done for Tabs #3 and 4
Sub-Organization Name:	Auto Populates from Tab #1, similarly done for Tabs #3 and 4
Geographic Area(s) of Operations:	Auto Populates from Tab #1, similarly done for Tabs #3 and 4
Winter Season:	Auto Populates from Tab #1, similarly done for Tabs #3 and 4
Number of Storm Operations (Seasonal Total):	**Enter** the number of winter storms during which plowing and/or anti- or deicing activities were conducted.
Beginning Date, Time of Each Storm Operations Deployment	**Enter** the Date and Time that Storm Operations Deployment began - this could be a couple days in advance of forecast winter precipitation
End Date, Time of Operations:	**Enter** the Date and Time that Storm Operations Deployment ended - this could be a couple days after winter precipitation ended.
Beginning Date, Time of Storm Precipitation	**Enter** the Date and Time that Storm Precipitation actually began.
End Date, Time of Precipitation:	**Enter** the Date and Time that Storm Precipitation actually ended.

Salt Tracking and Reporting Form Data Dictionary	
Storm Type (Heavy Snow > 6", Medium 2-6", Light < 2")	**Select** the code for the Storm Type; Heavy Snow (HS = > 6"), Medium Snow (M = 2-6"), or Light Snow (L = < 2").
Inches of Snowfall:	**Enter** the total amount of Snowfall during the winter season (Column B) for your organization, or enter the snowfall for individual storms (Columns C-V), and the seasonal total will be calculated. Add additional columns as needed to allow tracking of > 10 storms for the season.
Ice or Freezing Rain?	**Select** Yes or No to indicate whether the storm precipitation included ice or freezing rain.
Road Temperature During Storm (Warm, >32, Mid, 25-32, Cold, <25 degrees F)	**Select** the code for the Road Temperatures during Storm; Warm (W > 32F), Mid (M = 25-32F), or Cold (C < 25F).
Early Storm Conditions: Starts as Snow, SS; Starts as Rain, SR	**Select** the code for Early Storm Conditions; Starts as Snow (SS), Starts as Rain (SR).
Winds During Storm (Light, < 15 mph, Strong, > 15 mph)	**Select** the code for Wind Conditions during the Storm; Light (L, 15 mph) or Strong (S > 15 mph).
Winds After Storm (Light, < 15 mph, Strong, > 15 mph)	**Select** the code for Wind Conditions after Storm Precipitation ended; Light (L, 15 mph) or Strong (S > 15 mph).
Forecasted Post Storm Temps (Same, Rising, Falling)	**Select** the code for the **Forecasted** Post-Storm Temperatures; Same (S), Rising (R), or Falling (F).
Sources Used for Storm Information (NWS, Own Observation, other?)	**Enter** narrative information to identify the source of storm weather information reported above.
Other Notes Describing Storm Conditions (narrative)	**Enter** narrative information to document details or clarify any additional information desired to describe storm. This could include differences between forecast information and actual storm conditions, or anything else the organization wishes to record for future reference.
Tab #3: Treatment Products	Seasonal Totals for all Products Used are a **Core Tracking Element**
Sodium Chloride (NaCl)	**Enter** the amount of NaCl applied at the Seasonal level (Column B) or for individual storms (Columns D-M, expand for > 10 storms), which will calculate seasonal totals. ***For this and subsequent products***, ***Select*** *the units (dry lbs or tons) in Column C,* ***Enter*** *narrative information to indicate the product's effectiveness (Column N), and* ***Select*** *a response to indicate whether the product is planned for future use; Yes (Y), or No (N).*
Magnesium Chloride (MgCl)	**Enter** the amount of MgCl applied at the Seasonal level (Column B) or for individual storms (Columns D-M), which will calculate seasonal totals.
Calcium Chloride (CaCl)	**Enter** the amount of CaCl applied at the Seasonal level (Column B) or for individual storms (Columns D-M), which will calculate seasonal totals.
Sodium Chloride Brine	In Column A, second line**, enter the % NaCl** in the brine product**. Enter** the gallons of NaCl **brine** applied at the Seasonal level (Column B), and **Select** Yes or No for brine application during individual storms (Columns D-M).

Salt Tracking and Reporting Form Data Dictionary	
Magnesium Chloride Brine	In Column A, second line, **enter the % MgCl** in the brine product**. Enter** the gallons of MgCl **brine** applied at the Seasonal level (Column B), and **Select** Yes or No for brine application during individual storms (Columns D-M).
Calcium Chloride Brine	In Column A, second line, **enter the % CaCl** in the brine product. **Enter** the gallons of CaCl **brine** applied at the Seasonal level (Column B), and **Select** Yes or No for brine application during individual storms (Columns D-M).
Abrasives Applied	**Enter** the amount of abrasives applied at the Seasonal level (Column B) or for individual storms (Columns D-M), which will calculate seasonal totals.
Other Products Used? Name:	**Enter** the Product name (Column A). **Enter** the amount of other products applied at the Seasonal level (Column B) or for individual storms (Columns D-M, expand as needed), which will calculate seasonal totals. **Enter** the units used for Other Products (Column C).
Notes on Treatment Products Used	**Enter** narrative information to document and explain anything desired about products used during the winter season. This might include any use of Sand/Salt mixes, Use of Brines with Additives - such as beet juice, use of brines not at Industry Standard/Eustectic composition (23.3%), etc.
Tab #4: BMP Implementation	Indicating (Yes/No) for BMP Implementation at a Seasonal level is a recommended **Core Tracking Element**
Winter Maintenance Plan is developed	**Select** Yes or No (Column C) to indicate whether a written Winter Maintanence Plan has been prepared by organization and reviewed with crew and managers. ***For this and subsequent BMPs,*** *if Yes,* ***Enter*** *narrative information (Column D) to briefly explain the effectiveness of the BMP. If No,* ***Select*** *Yes or No to indicate Future Plans to use BMP (Column E), and, if Yes,* ***Enter*** *narrative information to explain plans to address any impediments or requirements needed to enable future use of the BMP.*
Preseason meetings are held	**Select** Yes or No (Column C) to indicate whether meeting(s) were held with the maintenance crew, supervisors, and management/property manager(s) to review the Winter Maintenance Plan, highlight any changes in operations, and revisit past lessons learned.
Postseason meetings are held	**Select** Yes or No (Column C) to indicate whether meeting(s) were held with the maintenance crew, supervisors, and management/property manager(s) to evaluate how well the season went, what worked, and what could be changed to improve operations.
Accountability is at every level	**Select** Yes or No (Column C) to indicate whether the winter maintenance plan clearly states everyone's accountability; Management accountability for decisions on storm response (i.e., type of material, number of deployed operators, etc.), and Crew Leaders and Operators accountability to follow these decisions and work within the operation's guidelines/policy.
Transportation Audiences - Snowplow routes are planned	**Select** Yes or No (Column C) to indicate whether the plan for road maintenance strategically plans each snowplow route to maximize efficiency, considering cycle time and levels of service for each route.

Salt Tracking and Reporting Form Data Dictionary	
Property Management Audiences - the properties are visited before the season	**Select** Yes or No (Column C) to indicate whether a property visit/walk with the property manager was conducted to inspect for challenging areas, deicer storage areas (if applicable), and drainage issues prior to the winter season.
Transportation Audiences - Levels of Service are communicated internally	**Select** Yes or No (Column C) to indicate whether the levels of service for the various routes have been communicated to all operations staff.
Transportation Audiences - Levels of Service are communicated externally	**Select** Yes or No (Column C) to indicate whether the levels of service have been communicated to Inform residents and political leaders of the different levels of service for roads treated by the organization.
Property Management Audience - Levels of Service are discussed and agreed upon	**Select** Yes or No (Column C) to indicate whether property managers and service providers have discussed and agreed to the levels of service standards for all winter service areas.
Training is held	**Select** Yes or No (Column C) to indicate whether all staff have been trained on winter operations plans, including managers, operators, contract employees, seasonal employees.
Deicer piles are properly stored	**Select** Yes, No, or N/A to indicate whether storage piles are covered/enclosed to prevent exposure to precipitation, and situated on an impervious surface with stormwater collected and contained within a bermed basin lined with concrete or other impermeable materials or an underground storage tank(s); good housekeeping is practiced around storage piles.
Liquid products are properly stored	**Select** Yes , No, or N/A to indicate whether liquids are stored in double walled tanks or have secondary containment in case of a leak or spill, and that operators know the freezing point of the liquid products and prevent product freezing.
Loading and hauling of deicers are done properly	**Select** Yes or No (Column C) to indicate whether deicers are loaded under cover and on a level surface, and spreading equipment is not overloaded (to avoid spills) and the deicer is covered on the spreader. Good housekeeping practices are used around the loading area, and when deicer spills occur, products are recovered and returned to the stockpile.
Equipment is cleaned and wastewater is contained	**Select** Yes or No (Column C) to indicate whether equipment is cleaned after storm operations conclude, and that wastewater from the cleaning process is contained properly to avoid a discharge.
Property Management Audiences - Storage of deicers and abrasive piles delivered to a property:	**Select** Yes, No, or N/A to indicate whether deicers and abrasive piles delivered to a property are placed on an impervious surface, and covered with durable/waterproof material or placed in a covered storage facility. Storage piles are shaped properly to avoid interaction with precipitation, and if outdoors, piles are windrowed with well-sloped sides.
Property Management Audiences - Storage and handling of deicer bags is done properly	**Select** Yes, No, or N/A to indicate whether deicer bags are protected from precipitation, and located up-gradient/out of the path of stormwater/meltwater and away from waterbodies, wetlands, storm drains, and stormwater capture areas. Empty deicer bags are disposed of in a lined/contained receptacle.
A calibration process is established	**Select** Yes or No (Column C) to indicate whether a calibration process is in place for salt application equipment that takes into account flow settings, conveyor/auger and spinner speeds, ground speed, and material (size, density, etc.). Application rates are standardized across equipment types.

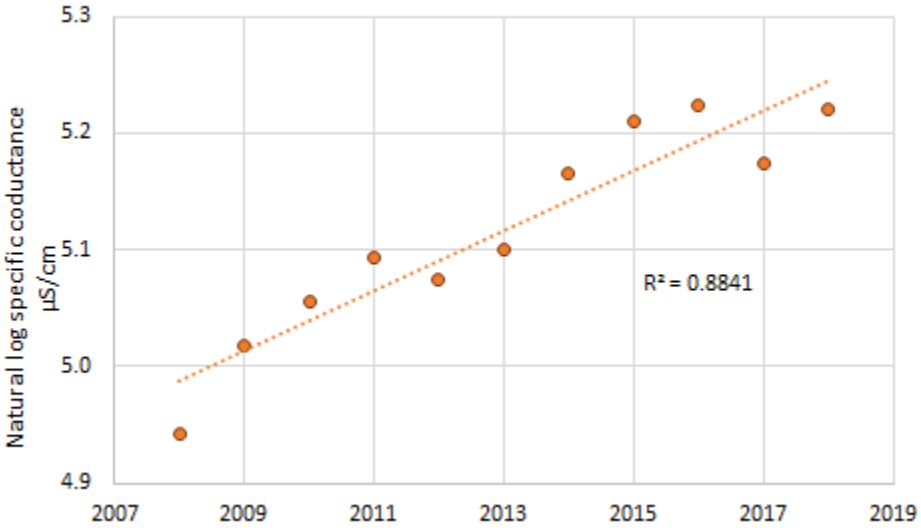
Salt Tracking and Reporting Form Data Dictionary	
Equipment is calibrated	**Select** Yes ,No, or Partially (Column C) to indicate whether (solid and liquid dispensers) are calibrated in the preseason, mid-season, and when equipment or deicer material changes are made to ensure accurate application rates relative to treatment plans.
Pre-storm meetings are held	**Select** Yes or No (Column C) to indicate whether, prior to the start of each storm operation, the maintenance crew, supervisors, and management/property manager(s) review operations plans, highlight potential challenges and solutions for the forecasted storm, and revisit lessons learned from post-storm meetings.
Post-storm meetings are held	**Select** Yes or No (Column C) to indicate whether, after storm operations conclude, the maintenance crew, supervisors, and management/property manager(s) evaluate what was done, how well it worked, and what could be changed to improve operations.
Accurate weather forecasting is obtained and is a part of decision making	**Select** Yes or No (Column C) to indicate whether accurate forecasts that detail the 1) start of precipitation, 2) type of precipitation, 3) total precipitation expected/storm intensity, 4) expected event length, 5) wind conditions (speed, gusts, directions), and temperature trends are considered prior to each storm operation.
Know the surface temperature	**Select** Yes or No (Column C) to indicate whether equipment and/or remote technology is used to know the temperature of the surface that will/may be treated with deicers, and use this information to determine the appropriate application rate for the storm conditions.
Advanced plows are used	**Select** Yes, No, or N/A to indicate whether organization uses plows that maximize the plow-able area; examples include 1) side wing plows, 2) tow plows, and 3) flexible or sectional blades.
Advanced spreaders are used	**Select**Yes, No, or N/A to indicate whether organization uses spreaders that can apply very low rates of deicers, including electronic spreaders that can lock in specific application rates and collect data.
Proper/Advanced equipment needed for making liquid products is used	**Select** Yes, No, or N/A to indicate whether organization has equipment to make and store liquid products, including 1) an open top mixing tank, 2) a holding tank, 3) pumps to transport liquid from mixing tank to holding tanks, to applicator tanks, and 4) a salimeter or a hydrometer to measure the salinity or density of water.
Transportation Audiences - Automated Vehicle Location (AVL) is used	**Select** Yes or No (Column C) to indicate whether organization tracks the position, spreader rate, and plow activity of different snow plows in the fleet (to show results live to supervisors, other plow operators, and the public).
Transportation Audiences - Maintenance Decision Support System (MDSS) is used	**Select** Yes or No (Column C) to indicate whether organization uses existing and new data (weather, road conditions, etc.) to integrate data and generate diagnostic and prognostic maps of road conditions, and provide recommendations on road maintenance actions.
Transportation Audiences - Precision Deicing is used	**Select** Yes or No (Column C) to indicate whether organization integrates LIDAR data, road condition index (severity based on road angles/curves and solar radiation), precipitation data, AVL, and automated spreaders to direct precision deicing that dynamically adjusts application rates of chemicals/liquids based on site-specific, local road conditions.
Anti-icing is used	**Select** Yes or No (Column C) to indicate whether either liquids or solids are used for anti-icing. Anti-icing with liquids (e.g., brines) can be done up to 48 hours before snow/ice fall, and uses significantly less deicer than solids. However, solid anti-icing can work best for events that start as rain or freezing rain.

Salt Tracking and Reporting Form Data Dictionary	
Plowing early and often is common practice	**Select** Yes or No (Column C) to indicate whether frequent plowing is used to remove snow/ice, rather than using deicers to "burn off" any accumulations; frequent plowing limits the time for snow/ice to compact and bond with the pavement.
Transportation Audiences - Plowing activities are coordinated	**Select** Yes or No (Column C) to indicate whether operators plowing activities are coordinated to prevent plowing off another operator's material.
Transportation Audiences - Plow trains are used	**Select** Yes or No (Column C) to indicate whether plow trains are used on multilane highways to remove as much snow as possible in one coordinated sweep.
Property Management Audiences - The right plow, shovel, pusher, blower, blade, or broom for the property is used	**Select** Yes or No (Column C) to indicate whether plows, shovels, pushers, blowers, blades, and brooms are selectively used in accordance with recommended best practices (such as those contained in BMP Pro/Con guide table for this BMP).
Property Management Audiences - Opportunities to close areas with a small footprint,	**Select** Yes, No, or N/A to indicate whether organization utilizes opportunities to close selected property areas to reduce treatment needs.
Property Management Audiences - Snow is placed in proper places	**Select** Yes or No (Column C) to indicate whether plowed snow is stored downhill from deicer storage areas to stop melt water from interacting with deicers.
Dyed deicers are used	**Select** Yes or No (Column C) to indicate whether dyed deicers are used to observe and show deicer product presence.
Use of Abrasives	**Select** Yes or No (Column C) to indicate whether abrasives are used by organization. Abrasives alone provide traction during 1) freezing rain events, 2) in slow-moving traffic areas, and 3) when deicers are ineffective because it is too cold. For narrowly defined circumstances, a 50/50 blend of deicers and abrasives can be used, but this practice should be limited to those circumstances specifically defined by the organization.
Deicers are cleaned up after storm	**Select** Yes or No (Column C) to indicate whether left over deicer materials are cleaned-up after the snow/ice has melted away.
Transportation Audiences - Spinners set-are up properly	**Select** Yes or No (Column C) to indicate whether organization uses a chute or sets spinners close to the ground to reduce bounce and scatter of solid deicer products.
Transportation Audiences - Plows drive 17-25 mph on non-high-speed roads	**Select** Yes or No (Column C) to indicate whether operators drive at speeds of 17-25 mph when applying deicer to keep material on road.
Transportation Audiences - On high-speed roads deicer is applied to the center of the road or high side of a curve	**Select** Yes or No (Column C) to indicate whether operators apply deicers in center of high speed roads and on the high side of curves.
Transportation Audiences - Auger, shoots, or conveyors are turned off when stopped	**Select** Yes or No (Column C) to indicate whether operators turn off auger, shoot, or conveyor when stopped, even briefly.
Transportation Audiences - Deicer application rate is reduced on successive passes	**Select** Yes or No (Column C) to indicate whether operators reduce application rates on second/subsequent passes of a treated route to leverage deicing capacity of the remaining deicer.
Property Management Audiences - Spread patterns that prevent overlapping applications are used	**Select** Yes or No (Column C) to indicate whether service provider/operator surveys the property, and develops and utilizes a spread pattern that prevents applying deicers over areas that have already been treated.

Salt Tracking and Reporting Form Data Dictionary	
Property Management Audiences - Drop spreaders or rotary spreaders with shields are used for sidewalks	**Select** Yes or No (Column C) to indicate whether drop spreaders or rotary spreaders with shields are used to prevent spreading deicer off of the sidewalk.
Property Management Audiences - Managing stairways or areas with a small footprint #2	**Select** Yes, No, or N/A to indicate whether when deicers are applied in small areas, the deicer needed is calculated (using an application rate chart) based on the total area to be treated, uses the proper tool (push shovel, scoop shovel, broom or blower, ice scraper, or an ice chisel) to most effectively remove snow and ice from small/challenging areas, and uses hand-held spreaders for more precise application in small treatment areas.
Variable application rates are used for surface temperature, precipitation type/rate, and intended levels of service	**Select** Yes or No (Column C) to indicate whether recommended application rates are varied based on: 1) pavement/surface temperature, 2) precipitation rate and type, and 3) cycle time/bare pavement regain time.
Deicers are used within their temperature range	**Select** Yes or No (Column C) to indicate whether treatment plans (which deicer and/or abrasives will be used) are based on forecasted temperatures/conditions, and organization maintains adequate amounts of the necessary deicers/abrasives to be prepared for extremely cold temperatures, when abrasives alone may be the best option.
Deicers are pretreated	**Select** Yes or No (Column C) to indicate whether solid deicers are pre-treated with a liquid, typically brine, to help deicer material stick to surfaces and speed up the melting process.
Deicers are prewetted	**Select** Yes or No (Column C) to indicate whether liquids, typically brine, are added to solid deicers as they are being applied (prewetting) to help material stick to surfaces and speed up the melting process.
Direct Liquid Application is used	**Select** Yes or No (Column C) to indicate whether mixtures of water and deicer are applied directly to a surface (Direct Liquid Application, or DLA) during or after a storm to deice immediately (there is no lag time for the deicer solution to form).
Deicer use is measured and recorded	**Select** Yes or No (Column C) to indicate whether a standardized process is used to measure and record deicer use as frequently, accurately, and refined (e.g., per route, shift, site, etc.) as possible.
Additional BMPs and Comments: Seasonal or Storm-specific	**Enter** the name of any additional BMPs implemented (Column B) and narrative information as desired to identify and discuss the effectiveness of any other BMPs used in the organization's winter operations (Column C). Additional comments may pertain to overall seasonal operations, or could be specific to individual storm operations. If storm specific, identify the storm that comments pertain to. Add additional rows as desired to accommodate all comments.

Appendix K. Regional Long-Term Trends in Specific Conductance

Regional long-term trends in specific conductance



Prepared to support development of a
Virginia Salt Management Strategy

Prepared for
Virginia Department of Environmental Quality (DEQ)
Northern Regional Office
13901 Crown Court
Woodbridge, VA 22193

with a portion of ICPRB's USEPA Section 106 funds
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1 Introduction

The need to evaluate long-term patterns in specific conductance, and the various ways to evaluate these patterns, is important for understanding changes in water quality as it relates to salts used for snow and ice management. Therefore, USGS gage data were downloaded for non-tidal, non-Potomac USGS sites in the region with sufficient periods of record. The following evaluations were conducted:

- **Long-term trends in specific conductance**;
- **Trends in the magnitude of storm-specific spikes** in specific conductance and **how magnitude of spikes in specific conductance relate to precipitation**;
- **Trends in the duration of storm-specific spikes** in specific conductance and **how duration of spikes in specific conductance relate to precipitation**; and
- **Trends in background summer specific conductance**.

The sections below describe the data, methods, and results for each of these analyses. Throughout the analyses, "winter" is defined as November 1st through April 30th and "summer" includes the rest of the year (May 1st through October 31st).

2 Monitoring Stations and Data

Daily specific conductance data were downloaded on May 15, 2019 from the USGS Surface-Water Daily Data for Virginia website as minimum, maximum, mean, median values. Instantaneous (15 minute) specific conductance data were obtained on May 16, 2019 from the USGS Instantaneous Values REST Web Service URL Generation Tool in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

The USGS website was queried for data of non-Potomac USGS sites in Arlington, Fairfax, Loudon, and Prince William counties and the cities of Alexandria, Fairfax, Falls Church, Manassas, and Manassas Park. Eight stations in the specified geographic area were identified with specific conductance measurements (**Table 27**). Of those, four stood out with sufficient data for inclusion in this analysis, defined as having an unbroken record that started before 2010 and remains in operation.

Table 27. USGS stations measuring specific conductance in the geographic area of interest. Selected gages are shown in bold text.

USGS Gage	Location	Sampling	
		Start Date	End Date
01645704	**Difficult Run Above Fox Lake Near Fairfax**	**10/1/2007**	**4/30/2019**
01645762	**S F Little Difficult Run Above Mouth Near Vienna**	**10/1/2007**	**4/29/2019**
01646305	**Dead Run at Whann Avenue Near Mclean**	**11/30/2007**	**4/30/2019**
01656903	**Flatlick Branch Above Frog Branch at Chantilly**	**10/1/2007**	**4/29/2019**
01646000	Difficult Run Near Great Falls	10/2/2007	4/30/2019*
0165389205	Accotink Creek Near Ranger Road at Fairfax	11/19/2011	1/8/2015
01654000	Accotink Creek Near Annandale	2/15/2015	4/28/2019
01654500	Long Branch Near Annandale	2/8/2013	4/28/2019

*No data 2009-2011.

The selected USGS specific conductance monitoring stations were paired with a neighboring precipitation station for further analysis. Daily precipitation data were obtained from NOAA's Climate Data Online: Dataset Discovery website. The list of paired stations is provided in **Table 28**.

Table 28. Paired USGS gages and NOAA precipitation monitoring stations.

USGS Gage	Precipitation Station
01645704	USC00448737
01645762	US1VAFX0001
01646305	US1MDMG0003
01656903	US1VAFX0001

The locations of USGS specific conductance monitoring stations and nearby precipitation stations are shown in **Figure 20.**

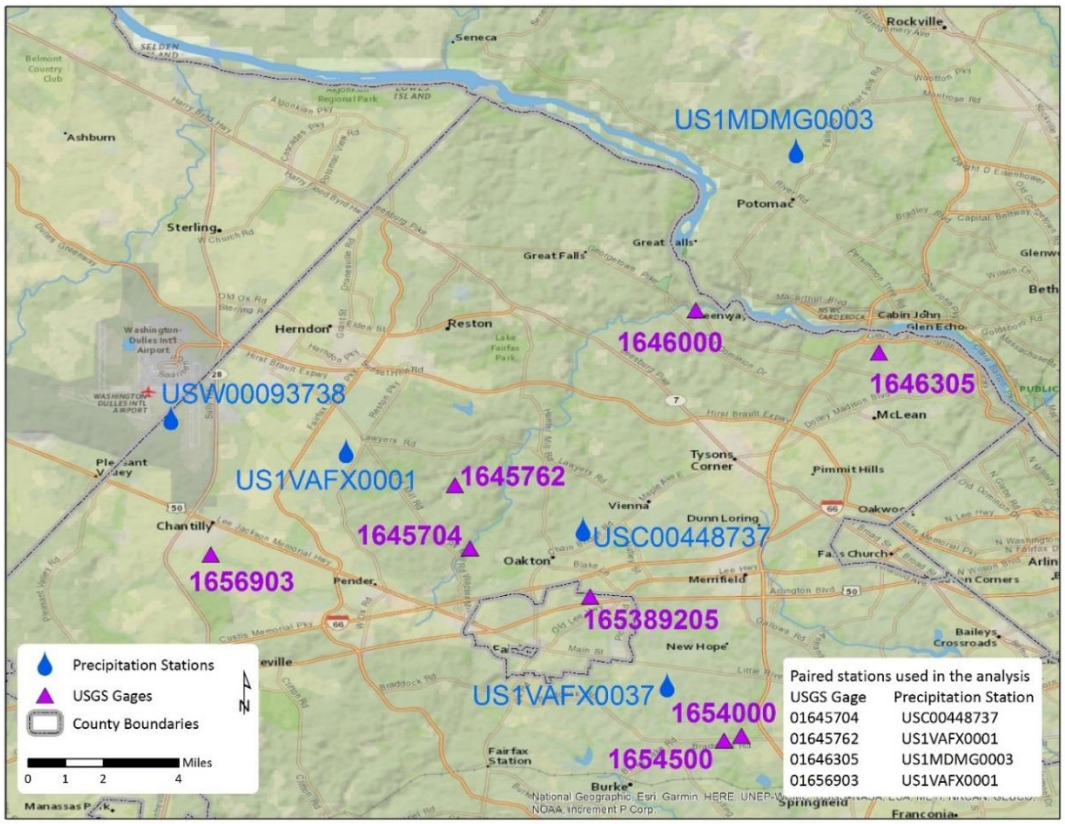


Figure 20. Locations of USGS specific conductance monitoring stations and NOAA precipitation monitoring stations.

2.1 Specific Conductance Data Summary

Summary statistics for the specific conductance data collected at the four USGS gages are provided in **Table 29**. Seasonal statistics for the same gages are provided in **Table 30**.

Table 29. Summary statistics for 15-minute specific conductance data collected at selected USGS gages.

USGS Gage	Count	Min	1st Quantile	Median	Mean	3rd Quantile	Max	Std Dev	10th %ile	90th %ile
01645704	390,394	34	299	370	487	479	8,620	456.47	227	830
01645762	382,109	23	153	167	175	187	1,620	55.40	138	200
01646305	388,243	34	248	294	379	349	13,400	486.14	184	488
01656903	390,218	36	366	433	480	517	7,260	266.37	295	643

Table 30. Seasonal summary statistics for 15-minute specific conductance data collected at selected USGS gages.

USGS Gage	Season	Count	Min	1st Quantile	Median	Mean	3rd Quantile	Max	Std Dev	10th %ile	90th %ile
01645704	Summer	189,595	34	264	332	326	385	681	93.97	199	442
	Winter	200,799	80	340	441	638	722	8,620	591.08	273	1150
01645762	Summer	180,457	23	148	164	161	180	381	25.98	130	191
	Winter	201,652	29	158	172	187	193	1,620	70.02	146	222
01646305	Summer	188,356	34	217	270	258	303	1,390	71.86	158	335
	Winter	199,887	42	282	331	492	425	13,400	653.92	230	778
01656903	Summer	191,354	36	344	408	401	471	795	95.44	266	516
	Winter	198,864	87	388	466	556	603	7,260	344.33	330	864

Mean and maximum monthly specific conductance, calculated based on the 15-minute data, are shown by USGS gage in **Figure 21** and **Figure 22**, respectively. Box plots showing the distribution of 15-minute data by month are shown in **Figure 23**, **Figure 24**, **Figure 25**, and **Figure 26**. The same data are shown by season in **Figure 27**, **Figure 28**, **Figure 29**, and **Figure 30**. Increases in specific conductance during winter months are visible in these figures.

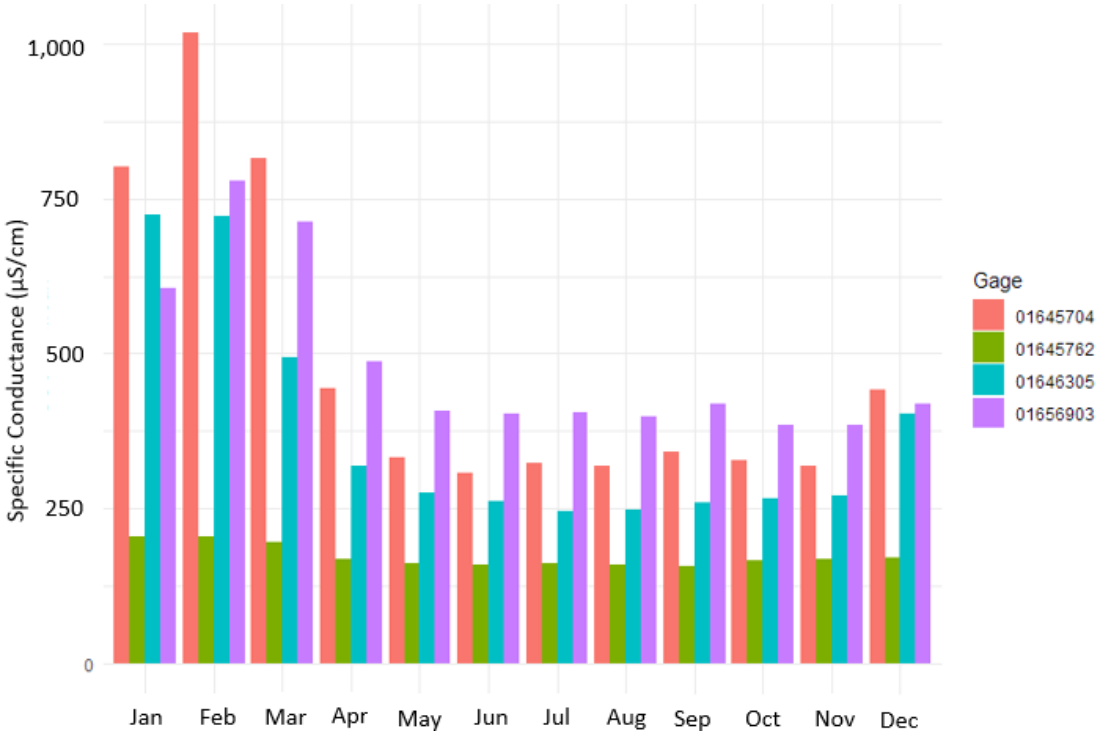


Figure 21. Mean monthly specific conductance by gage. Mean specific conductance values (y-axis) are in units of µS/cm.

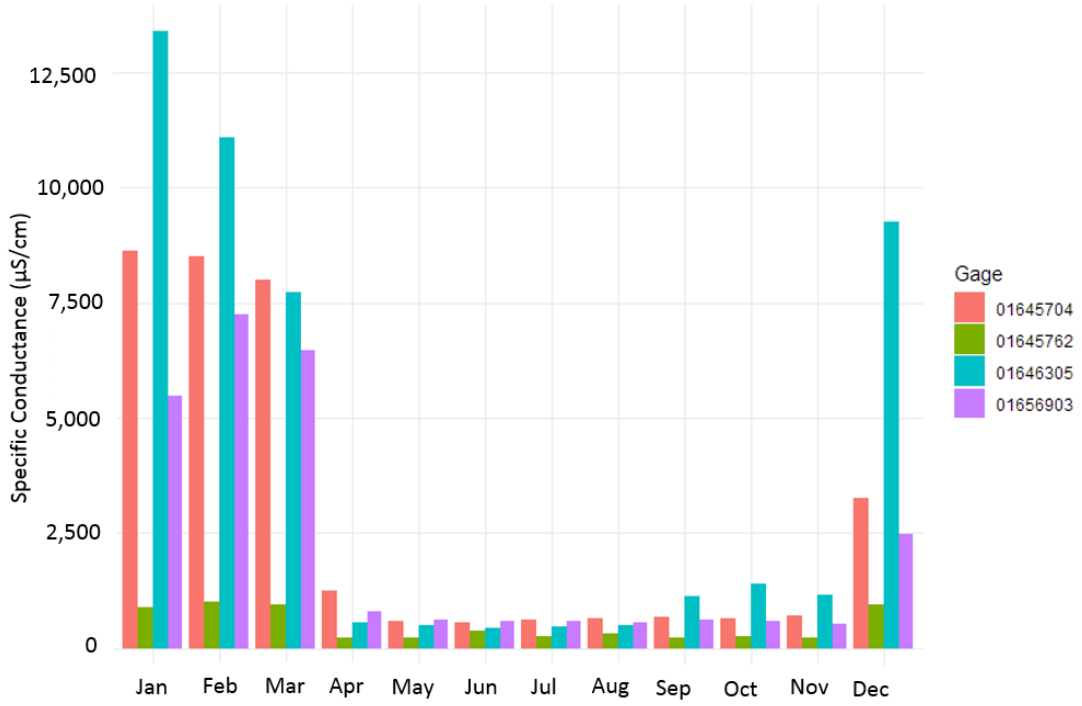


Figure 22. Maximum monthly specific conductance by USGS gage. Maximum specific conductance values (y-axis) are in units of µS/cm.

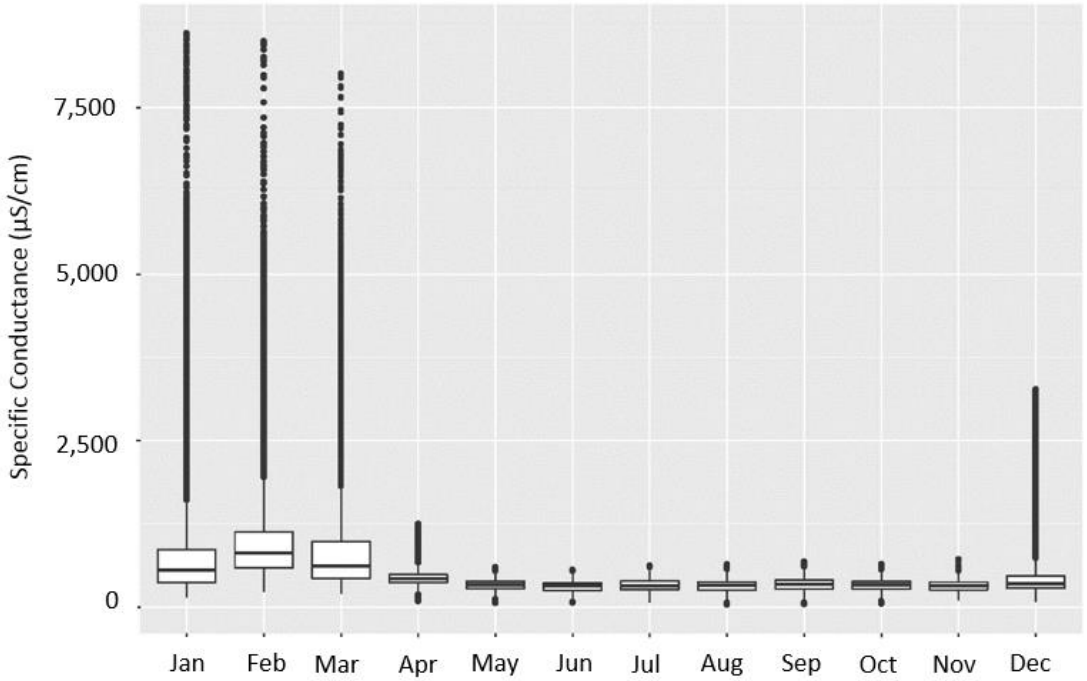


Figure 23. Box plots of 15-minute data by month for USGS gage 01645704 (Difficult Run Above Fox Lake Near Fairfax). Specific conductance values (y-axis) are in units of µS/cm.

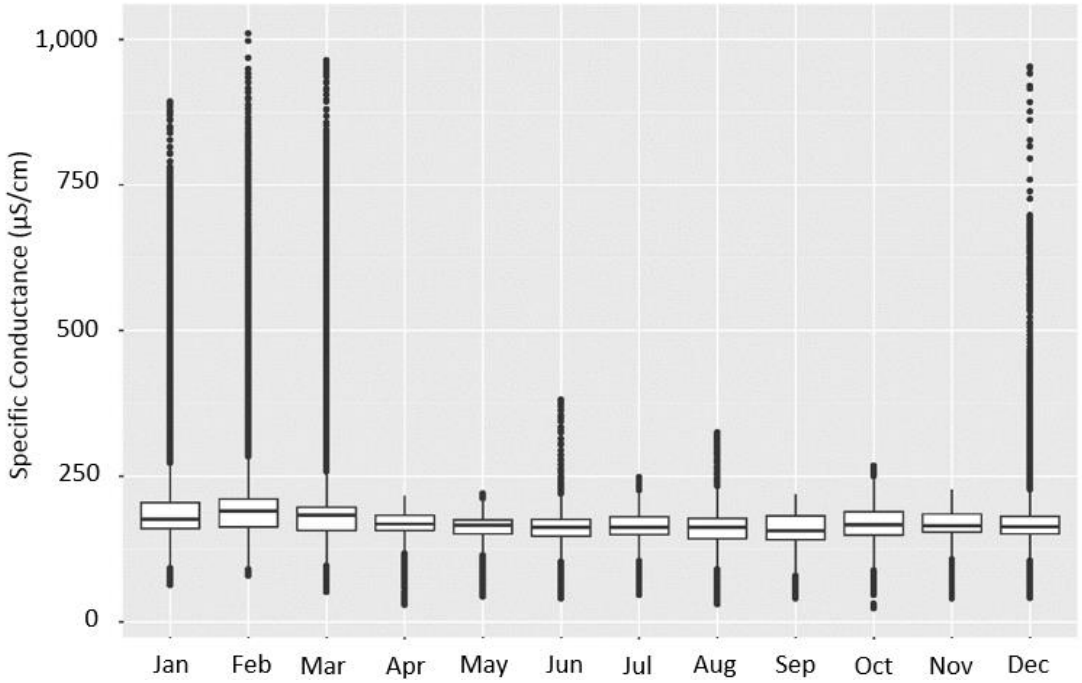


Figure 24. Box plots of 15-minute data by month for USGS gage 01645762 (S F Little Difficult Run Above Mouth Near Vienna). Specific conductance values (y-axis) are in units of µS/cm.

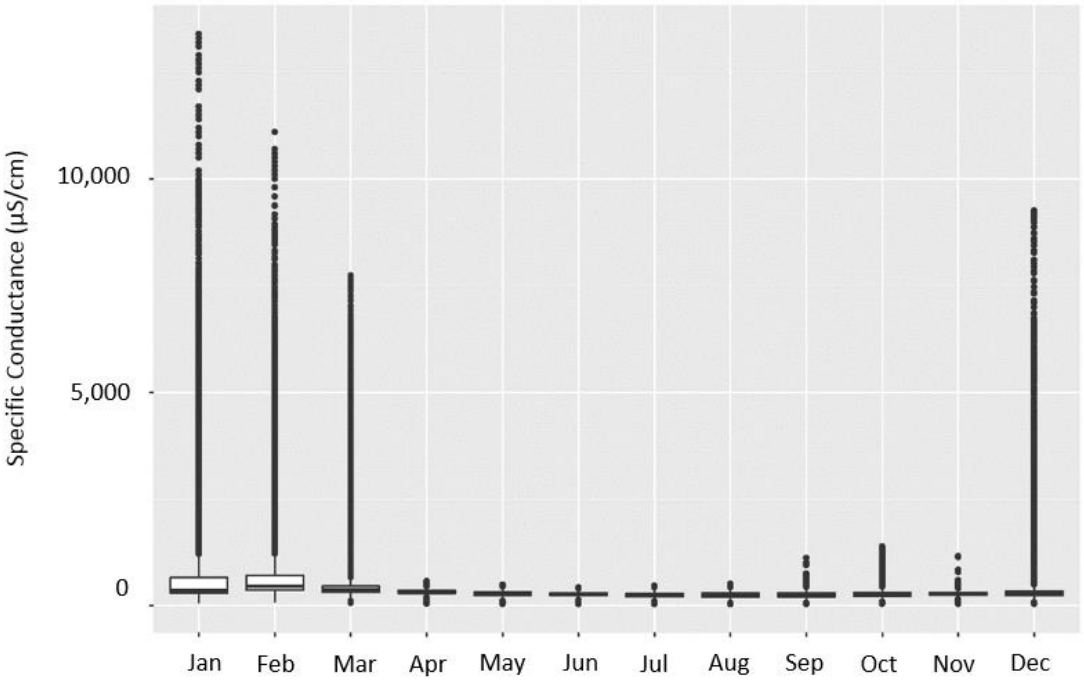


Figure 25. Box plots of 15-minute data by month for USGS gage 01646305 (Dead Run at Whann Avenue Near Mclean). Specific conductance values (y-axis) are in units of µS/cm.

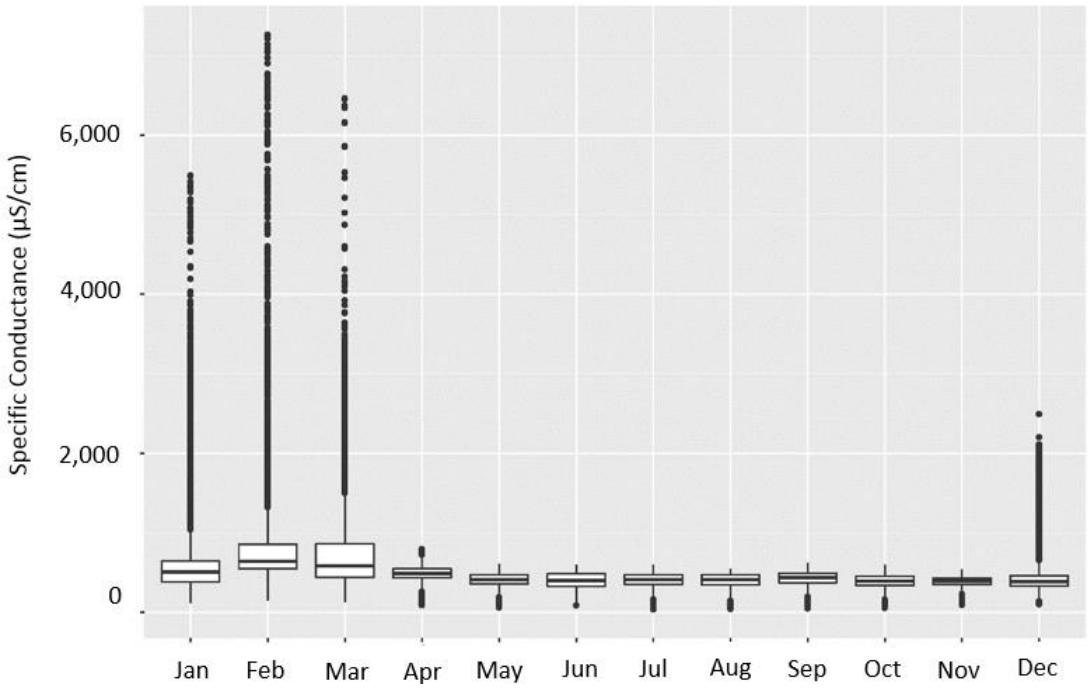


Figure 26. Box plots of 15-minute data by month for USGS gage 01656903 (Flatlick Branch Above Frog Branch at Chantilly). Specific conductance values (y-axis) are in units of µS/cm.

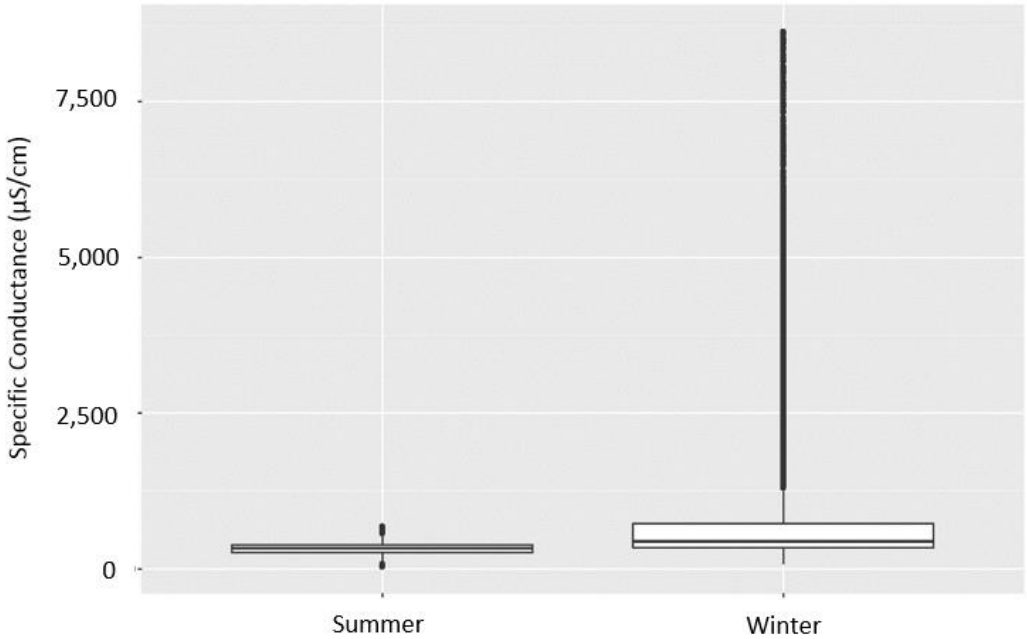


Figure 27. Box plots of 15-minute data by season for USGS gage 01645704 (Difficult Run Above Fox Lake Near Fairfax). Specific conductance values (y-axis) are in units of µS/cm. The winter season is defined as November 1st through April 30th. The summer season is defined as May 1st through October 31st.

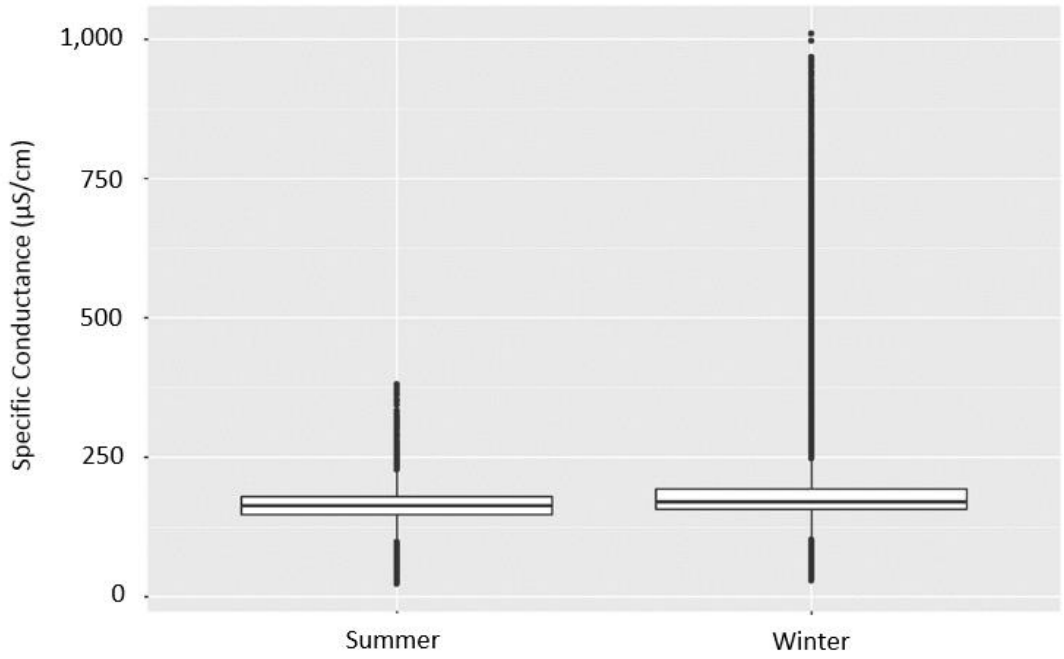


Figure 28. Box plots of 15-minute data by season for USGS gage 01645762 (S F Little Difficult Run Above Mouth Near Vienna). Specific conductance values (y-axis) are in units of µS/cm. The winter season is defined as November 1st through April 30th. The summer season is defined as May 1st through October 31st.

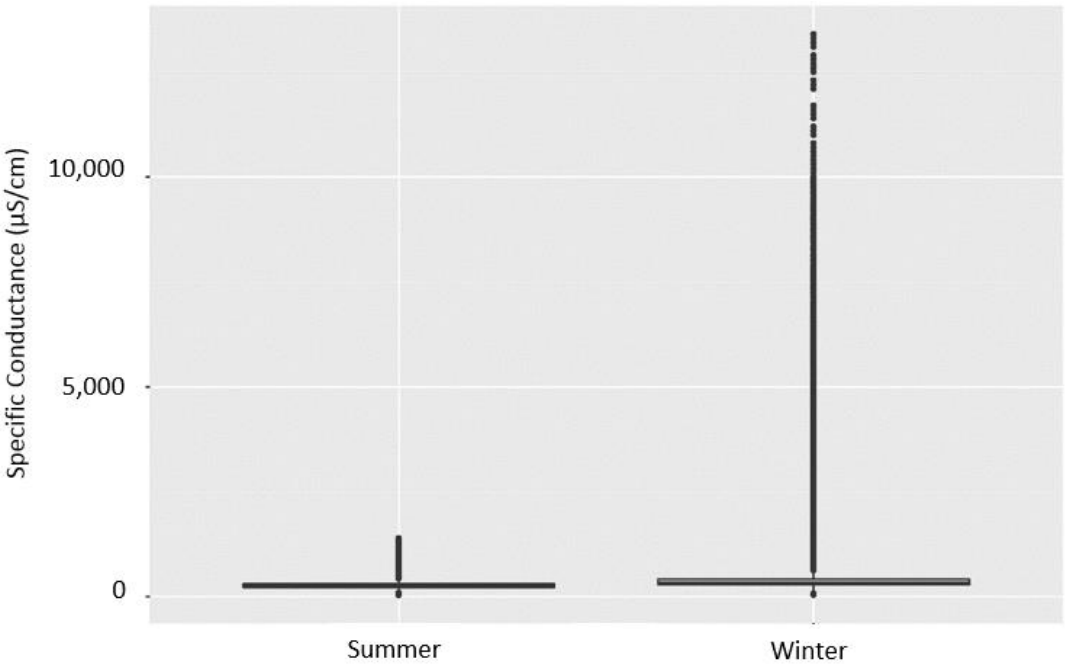


Figure 29. Box plots of 15-minute data by season for USGS gage 01646305 (Dead Run at Whann Avenue Near Mclean). Specific conductance values (y-axis) are in units of µS/cm. The winter season is defined as November 1st through April 30th. The summer season is defined as May 1st through October 31st.

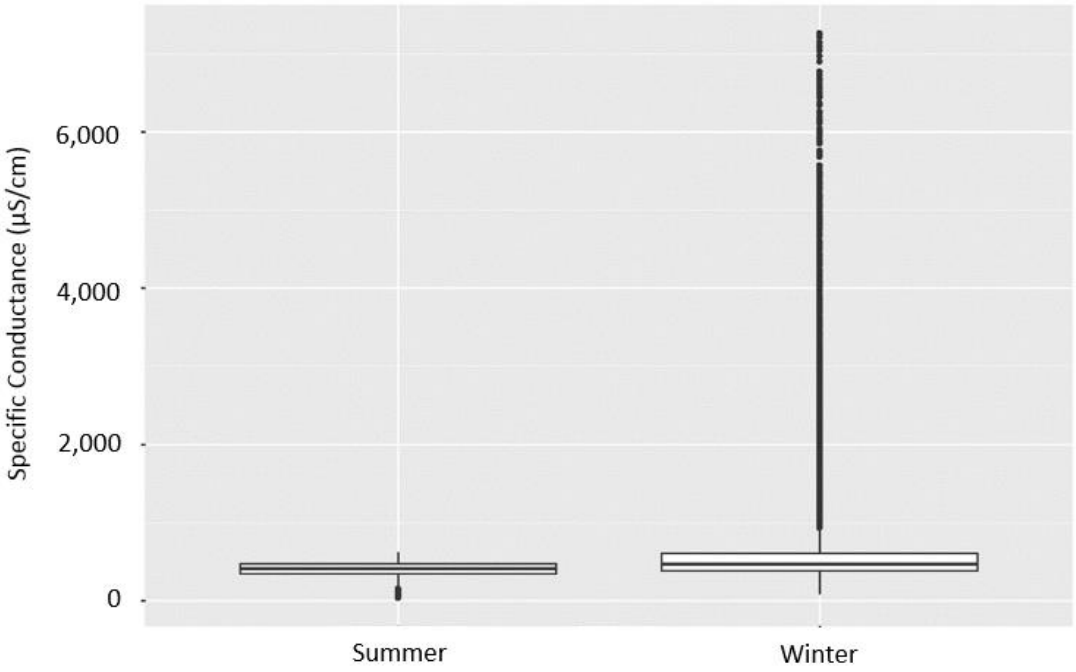


Figure 30. Box plots of 15-minute data by season for USGS gage 01656903 (Flatlick Branch Above Frog Branch at Chantilly). Specific conductance values (y-axis) are in units of µS/cm. The winter season is defined as November 1st through April 30th. The summer season is defined as May 1st through October 31st.

2.2 Precipitation Data Summary

Average monthly total precipitation was calculated for the three selected precipitation stations as a way of summarizing the data (**Figure 31**). Average monthly snowfall totals were also calculated (**Figure 32**).

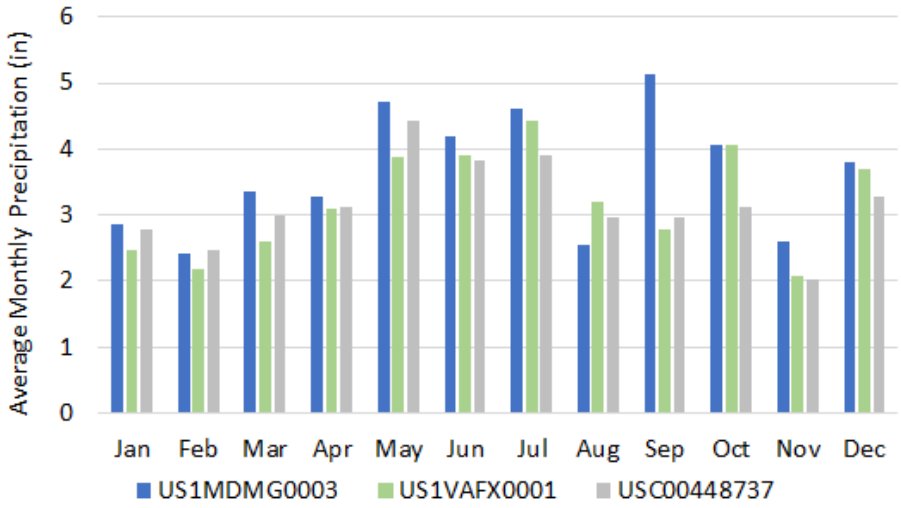


Figure 31, Average monthly total precipitation for selected NOAA stations (2007-2019).

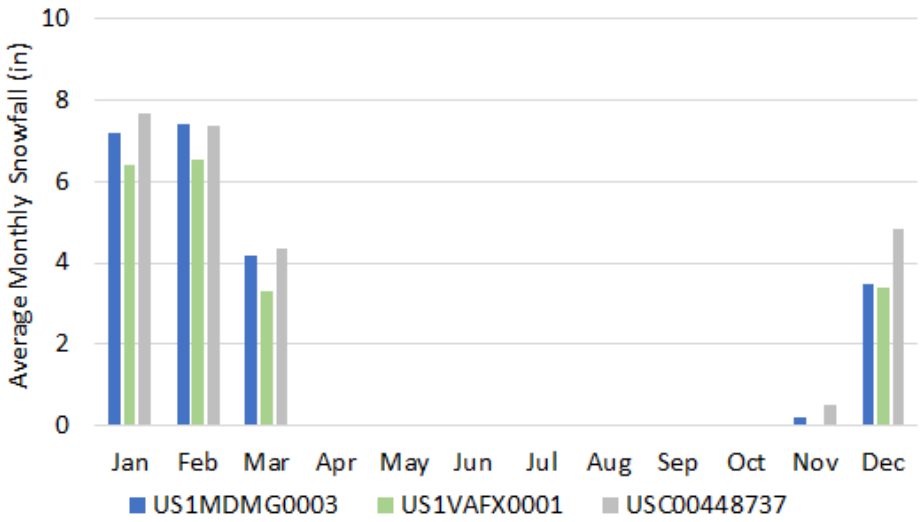


Figure 32. Average monthly total snowfall for selected NOAA stations (2007-2019).

A summary of snowfall totals and number of days for each year (2008-2019) is provided in **Table 31**. The largest snowfall totals occurred in 2010 for all three stations.

Table 31. Snowfall summary by year for selected NOAA stations (2008-2019). For the purpose of this table, summary information is provided for winter end year. For example, summary information for the year 2008 represents the winter of 2007-2008.

	US1MDMG0003 Snowfall		US1VAFX0001 Snowfall		USC00448737 Snowfall		Average Snowfall	
Year	Days (#)	Total (in)	Days (#)	Total (in)	Days (#)	Total (in)	Days (#)	Total (in)
2008	5	8.8	4	8.3	3	7.1	4.0	8.1
2009	8	10.1	8	9.2	7	11.6	7.7	10.3
2010	12	86.2	13	80.3	13	74.2	12.7	80.2
2011	13	14	10	5.2	13	14.4	12.0	11.2
2012	7	2.6	6	1.2	3	1.7	5.3	1.8
2013	12	10.1	11	7.5	9	10	10.7	9.2
2014	13	34.5	22	44.8	17	44.4	17.3	41.2
2015	16	32.1	22	18.7	17	27.9	18.3	26.2
2016	11	34.9	18	34	8	41.2	12.3	36.7
2017	5	5.1	5	3.4	5	5.3	5.0	4.6
2018	10	11.5	15	5.3	10	10.9	11.7	9.2
2019	12	25.3	18	19.4	13	24.4	14.3	23.0

3 Long-Term Trends in Specific Conductance

3.1 Methodology

Long-term trends in 15-minute, median monthly, and median annual specific conductance at the four USGS gages were evaluated by statistical regression and visual evaluation (**Figure 33** through **Figure 44**). Statistically, the 15-minute specific conductance data were modeled as a function of time using R's linear model function (lm()). The linear model function is calculated using an internal time step of seconds. The median monthly and median annual specific conductance data were modeled using Regression analysis in Excel. The time step for the Regression analysis was months

and years, respectively. The regression results were used to determine the statistical significance of the trends in specific conductance from 2007 to 2019. Visual evaluation was used to look at the data in graphical form, confirm results of the regression analysis, and inspect the data for anomalies or other notable features.

3.2 Results

3.2.1 15-Minute

Long-term trends in 15-minute specific conductance show statistically significant increases at the four USGS gages (**Table 32**). The magnitude of the change in specific conductance at these gages ranges from approximately 16 to 117 µS/cm over the period of record noted in **Table 27** and **Table 32**. More detailed information for each USGS gage is provided below.

Table 32. Regression summary statistics by gage for trends in 15-minute specific conductance data over the period of record.

Gage	p-value	R^2	Equation	Magnitude of Change over period of record (µS/cm)	Average Annual Increase (µS/cm)	Start Date	End Date
01645704	<0.0001	0.0056	y=45.8+0.000000321x	117.32	10.13	10/1/2007	4/30/2019
01645762	<0.0001	0.041	y=28.4+0.00000011x	40.18	3.47	10/1/2007	4/29/2019
01646305	<0.0001	0.00009	y=318+0.000000044x	15.85	1.39	11/30/2007	4/30/2019
01656903	<0.0001	0.003	y=29.4+0.00000014x	51.14	4.42	10/1/2007	4/29/2019

For USGS gage 01645704 (Difficult Run Above Fox Lake Near Fairfax), there is a considerable, statistically significant, increasing trend in specific conductance since 2007 (based on 15-minute data, y=45.8+0.000000321x, R^2=0.0056, p-value<0.0001). Over this time period, the magnitude of change in specific conductance is approximately 117 µS/cm. This statistically significant relationship exists despite the many other factors that influence 15-minute fluctuations in specific conductance than simply long-term changes (e.g., land use, percent impervious cover, intensity and duration of precipitation, and rate and timing of winter deicing material applications). The plot of daily maximum specific conductance and daily precipitation data for the gage is shown in **Figure 33**. The y-axis for the figure is log transformed for visual convenience; however, the data in the regression analysis of the 15-minute data were not transformed.

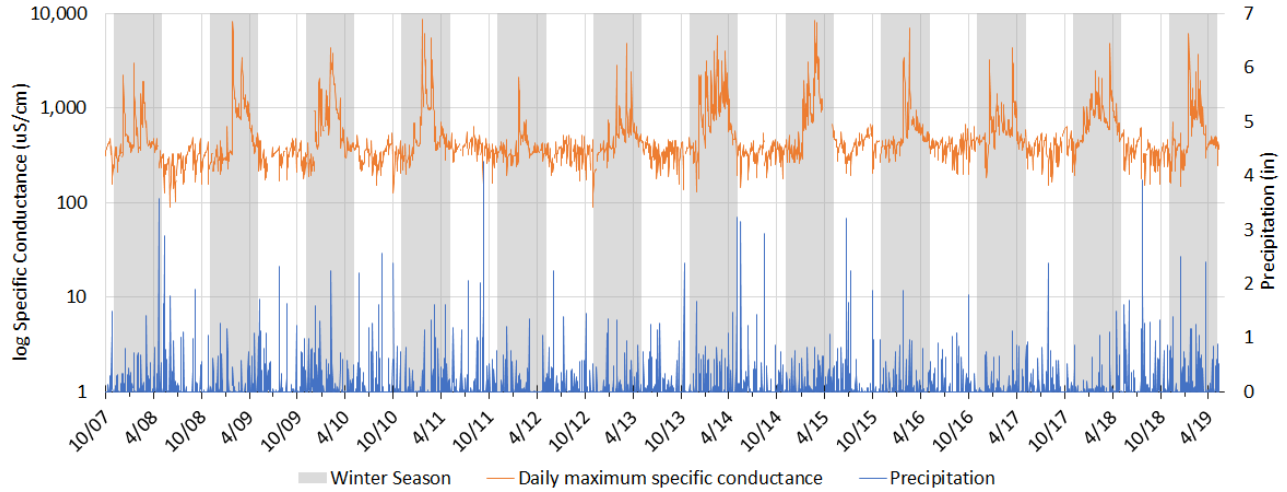


Figure 33. Long-term plot of daily maximum specific conductance and daily total precipitation for USGS gage 01645704 (Difficult Run Above Fox Lake Near Fairfax). Winter seasons, November 1st through April 30th, are shaded in gray. The y-axis is log transformed for ease of viewing.

For USGS gage 01645762 (S F Little Difficult Run Above Mouth Near Vienna), there is again an appreciable, statistically significant, increasing trend in specific conductance since 2007 (based on 15-minute data, y=28.4+0.00000011x, R^2=0.041, p-value<0.0001). Over this time period, the magnitude of change in specific conductance is approximately 40 µS/cm. The plot of daily maximum specific conductance and daily precipitation data for the gage is shown in **Figure 34**. The y-axis for the figure is log transformed for visual convenience; however, the data in the regression analysis of the 15-minute data were not transformed.

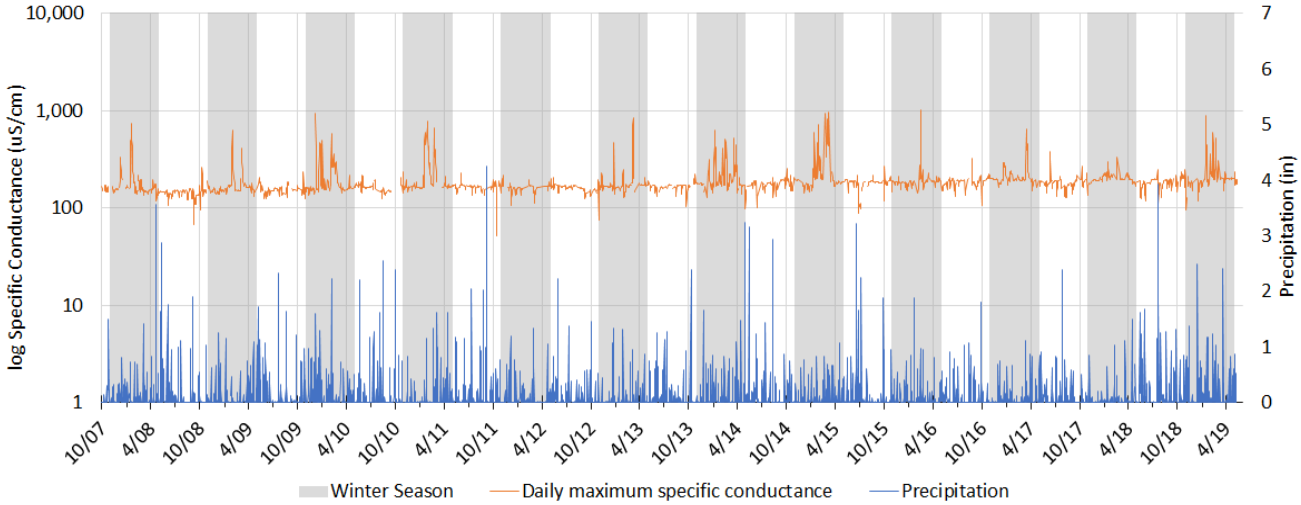


Figure 34. Long-term plot of daily maximum specific conductance and daily total precipitation for USGS gage 01645762 (S F Little Difficult Run Above Mouth Near Vienna). Winter seasons, November 1st through April 30th, are shaded in gray. The y-axis is log transformed for ease of viewing.

There is a statistically significant, increasing trend in specific conductance since 2007 for USGS gage 01646305, Dead Run at Whann Avenue Near Mclean, (based on 15-minute data, y=318+0.000000044x, R^2=0.0000895, p-value<0.0001). The magnitude of change in specific conductance at this gage is approximately 16 µS/cm over the period of record. The plot of daily maximum specific conductance and daily precipitation data for the gage is shown in **Figure 35.** The y-axis for the figure is log transformed for visual convenience; however, the data in the regression analysis of the 15-minute data were not transformed.

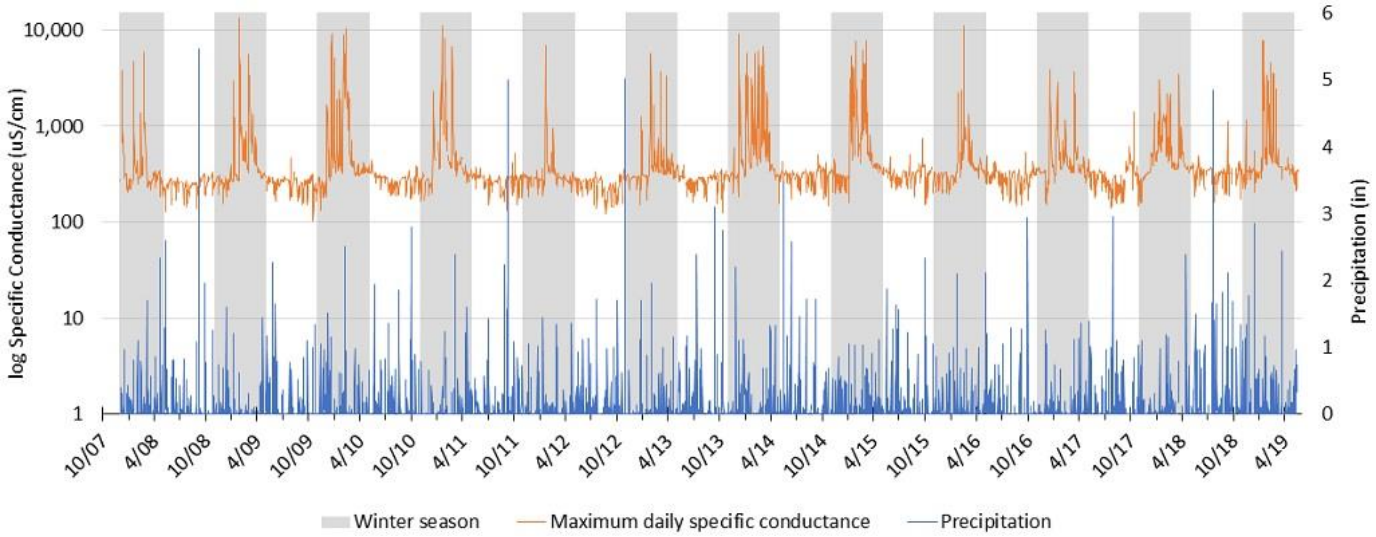


Figure 35. Long-term plot of daily maximum specific conductance and daily total precipitation for USGS gage 01646305 (Dead Run at Whann Avenue Near Mclean). Winter seasons, November 1st through April 30th, are shaded in gray. The y-axis is log transformed for ease of viewing.

For USGS gage 01656903 (Flatlick Branch Above Frog Branch at Chantilly), there is a considerable, statistically significant, increasing trend in specific conductance since 2007 (based on 15-minute data, y=29.4+0.00000014x, R^2=0.003, p-value<0.0001). The magnitude of change in specific conductance at this gage is approximately 51 µS/cm over the period of record. The plot of daily maximum specific conductance and daily precipitation data for the gage is shown in **Figure 36**. The y-axis for the figure is log transformed for visual convenience; however, the data in the regression analysis of the 15-minute data were not transformed.

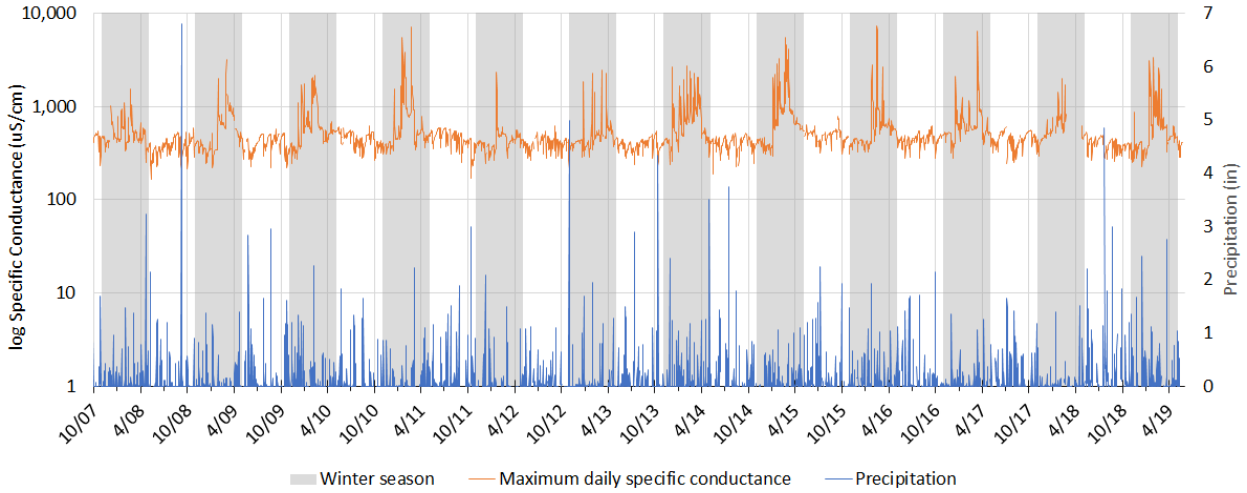


Figure 36. Long-term plot of daily maximum specific conductance and daily total precipitation for USGS gage 01656903 (Flatlick Branch Above Frog Branch at Chantilly). Winter seasons, November 1st through April 30th, are shaded in gray. The y-axis is log transformed for ease of viewing.

3.2.2 Median Monthly

Long-term trends in median monthly specific conductance show statistically significant increases at one of the four USGS gages (**Table 33**). The three gages with large ranges in specific conductance (**Table 29**) do not have statistically significant increases. More detailed information for each USGS gage is provided below.

Table 33. Summary statistics for median monthly trends in specific conductance by USGS gage. A p-value above 0.1 is considered not significant, "ns", for the purposes of this table. Numeric p-values are provided for all relationships in the detailed explanations in the respective results sections.

Gage	p-value	R^2	Equation
01645704	ns	0.0179	y=0.7613x+392.2862
01645762	<0.0001	0.4781	y=0.3276x+148.99
01646305	ns	0.0087	y=0.345x+308.1754
01656903	ns	0.0105	y=0.3417x+445.6737

For USGS gage 01645704 (Difficult Run Above Fox Lake Near Fairfax), there is a visually evident increasing trend since 2007 (**Figure 37**); however, the trend is not statistically significant (based on median monthly data, y=0.7613x+392.2862, R^2=0.0179, p-value>0.1).

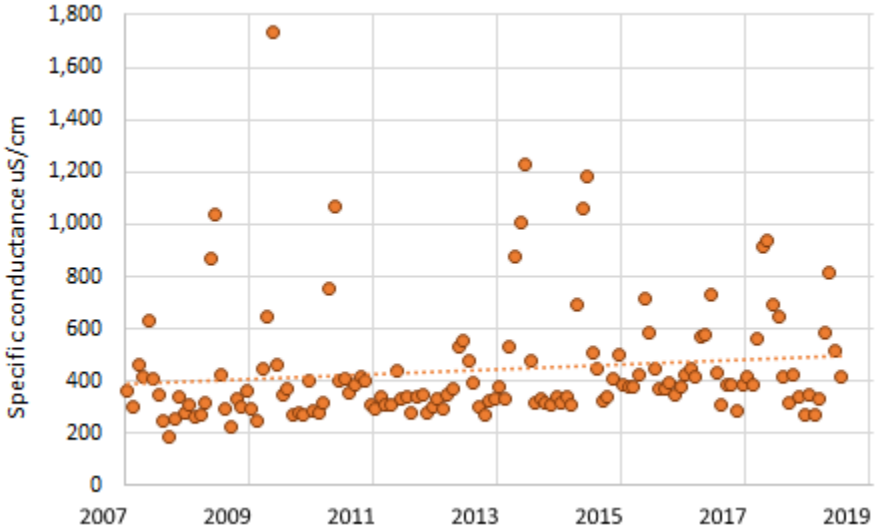


Figure 37. Long-term plot of median monthly specific conductance for USGS gage 01645704 (Difficult Run Above Fox Lake Near Fairfax).

For USGS gage 01645762 (S F Little Difficult Run Above Mouth Near Vienna), there is a statistically significant, increasing trend in median monthly specific conductance since 2007 (**Figure 38**) (based on median monthly data, $y=0.3276x+148.99$, $R^2=0.4781$, p-value<0.0001).

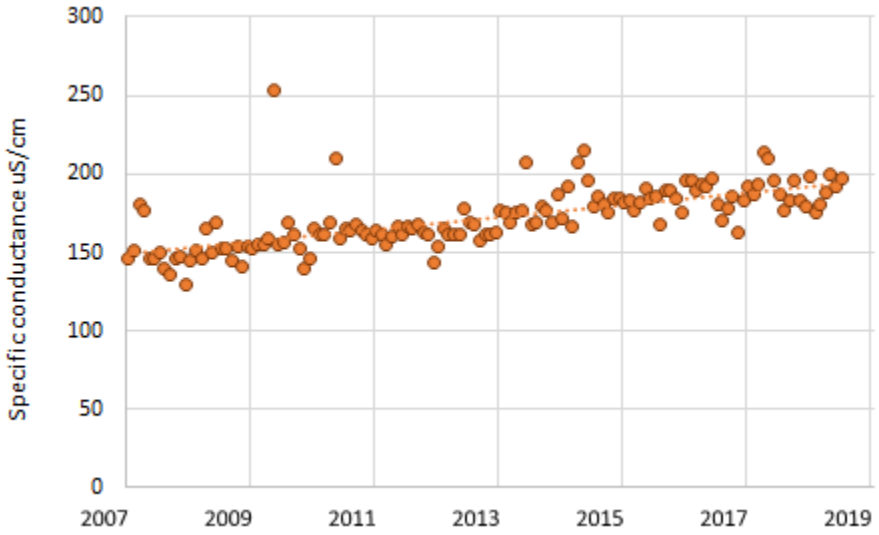


Figure 38. Long-term plot of median monthly specific conductance for USGS gage 01645762 (S F Little Difficult Run Above Mouth Near Vienna).

There is a visually evident increasing trend since 2007 for USGS gage 01646305, Dead Run at Whann Avenue Near Mclean (**Figure 39**); however, the trend is not statistically significant (based on median monthly data, $y=0.345x+308.1754$, $R^2=0.0087$, p-value>0.1).

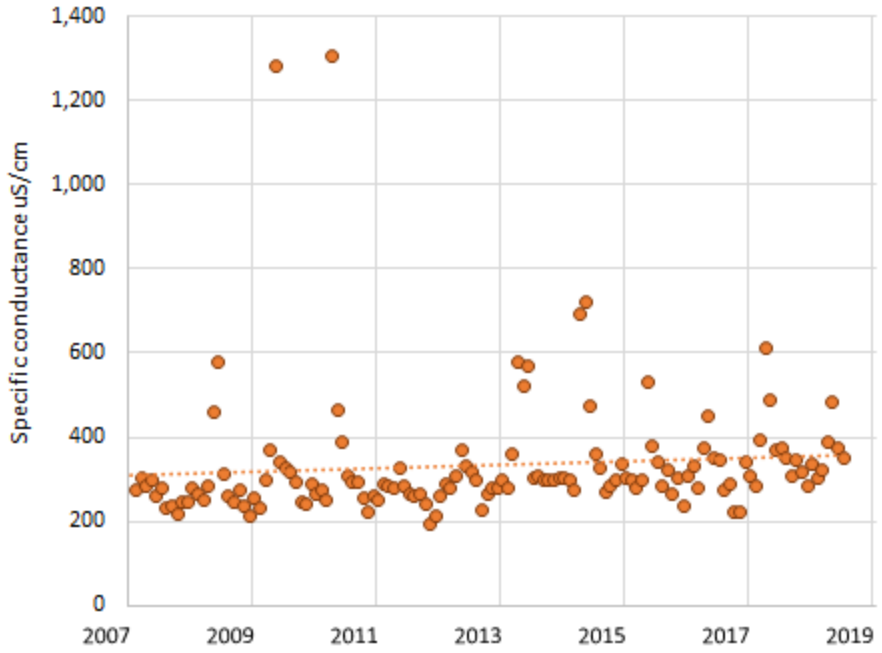


Figure 39. Long-term plot of median monthly specific conductance for USGS gage 01646305 (Dead Run at Whann Avenue Near Mclean).

For USGS gage 01656903 (Flatlick Branch Above Frog Branch at Chantilly), there is a visually evident increasing trend since 2007 (**Figure 40**); however, the trend is not statistically significant (based on median monthly data, $y=0.3417x+445.6737$, $R^2=0.0105$, p-value>0.1).

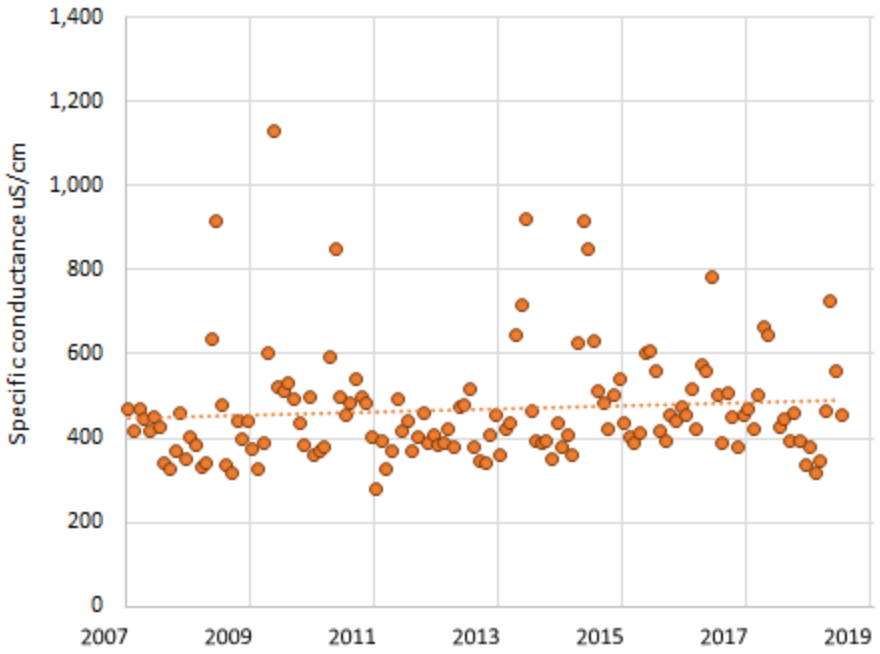


Figure 40. Long-term plot of median monthly specific conductance for USGS gage 01656903 (Flatlick Branch Above Frog Branch at Chantilly).

3.3.3 Median Annual

Long-term trends in median annual specific conductance values show statistically significant increases at three of the four USGS gages (**Table 34**). More detailed information for each USGS gage is provided below.

Table 34. Summary statistics for median annual trends in specific conductance by USGS gage. A p-value above 0.1 is considered not significant, "ns", for the purposes of this table. Numeric p-values are provided for all relationships in the detailed explanations in the respective results sections.

Gage	p-value	R^2	Equation
01645704	0.01	0.5303	y=8.9011x+318.1841
01645762	<0.0001	0.9500	y=4.5591x+141.9409
01646305	<0.001	0.7380	y=6.8532+253.7273
01656903	ns	0.0649	y=3.0875+426.46.36

For USGS gage 01645704 (Difficult Run Above Fox Lake Near Fairfax), there is a statistically significant, increasing trend in median annual specific conductance since 2007 (**Figure 41**) (based on median annual data, y=8.9011x+318.1841, R^2=0.5303, p-value=0.01).

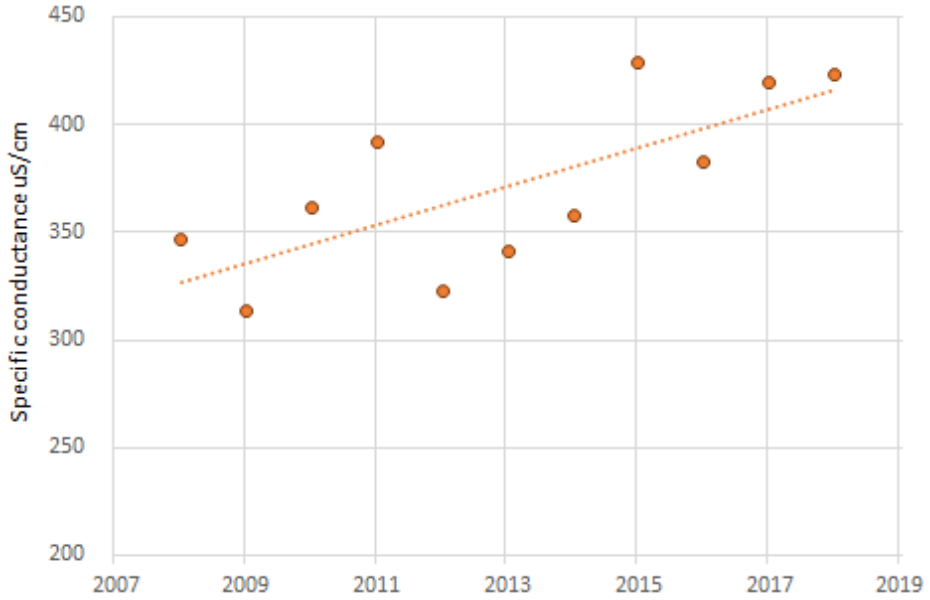


Figure 41. Long-term plot of median annual specific conductance for USGS gage 01645704 (Difficult Run Above Fox Lake Near Fairfax).

For USGS gage 01645762 (S F Little Difficult Run Above Mouth Near Vienna), there is a statistically significant, increasing trend in median annual specific conductance since 2007 (**Figure 42**) (based on median annual data, $y=4.5591x+141.9409$, $R^2=0.95$, p-value<0.0001).

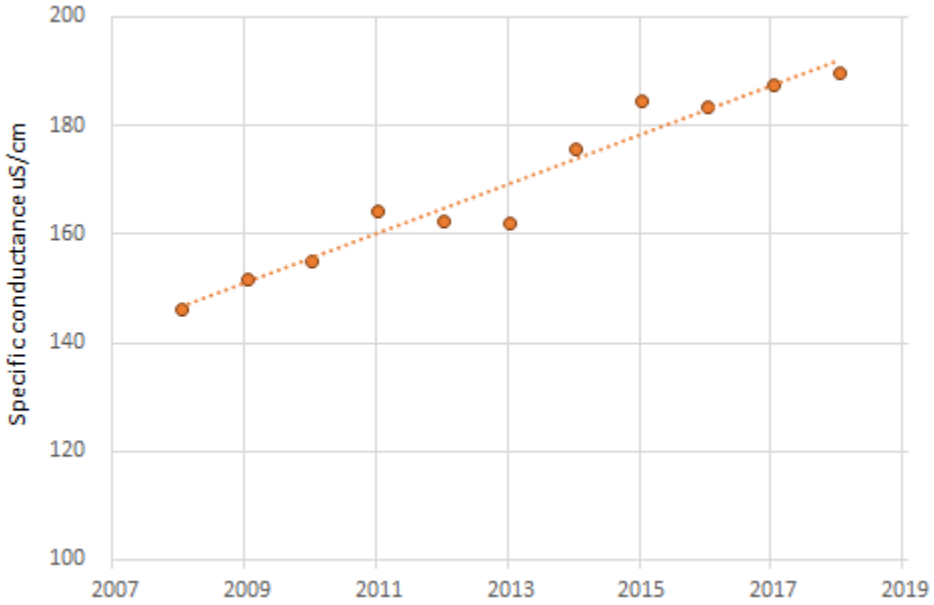


Figure 42. Long-term plot of median annual specific conductance for USGS gage 01645762 (S F Little Difficult Run Above Mouth Near Vienna).

For USGS gage 01646305, Dead Run at Whann Avenue Near Mclean, there is a statistically significant, increasing trend in median annual specific conductance since 2007 (**Figure 43**) (based on median annual data, y=6.8532x+253.7273, R^2=0.7380, p-value<0.001).

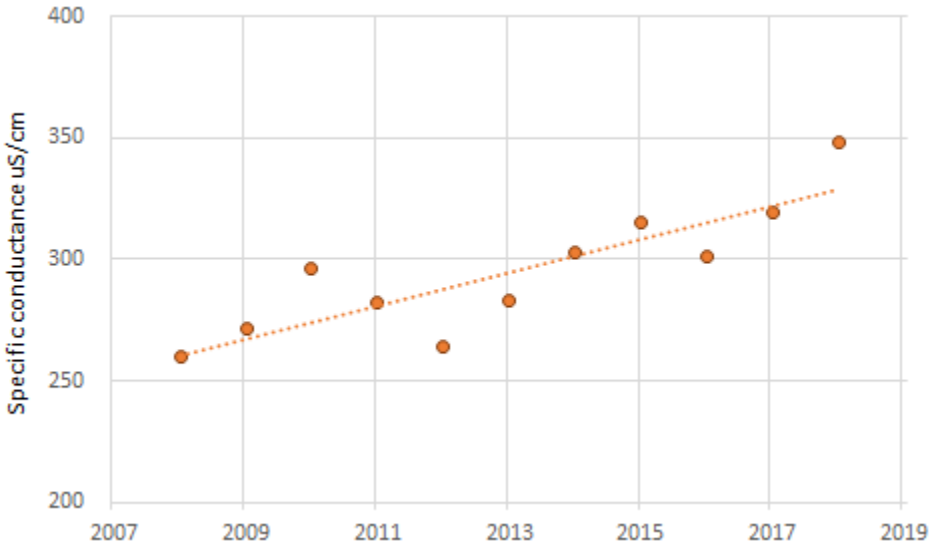


Figure 43. Long-term plot of median annual specific conductance for USGS gage 01646305 (Dead Run at Whann Avenue Near Mclean).

For USGS gage 01656903 (Flatlick Branch Above Frog Branch at Chantilly), there is a visually evident increasing trend since 2007 (**Figure 44**); however, the trend is not statistically significant (based on median annual data, y=3.0875x+426.46.36, R^2=0.0649, p-value>0.1).

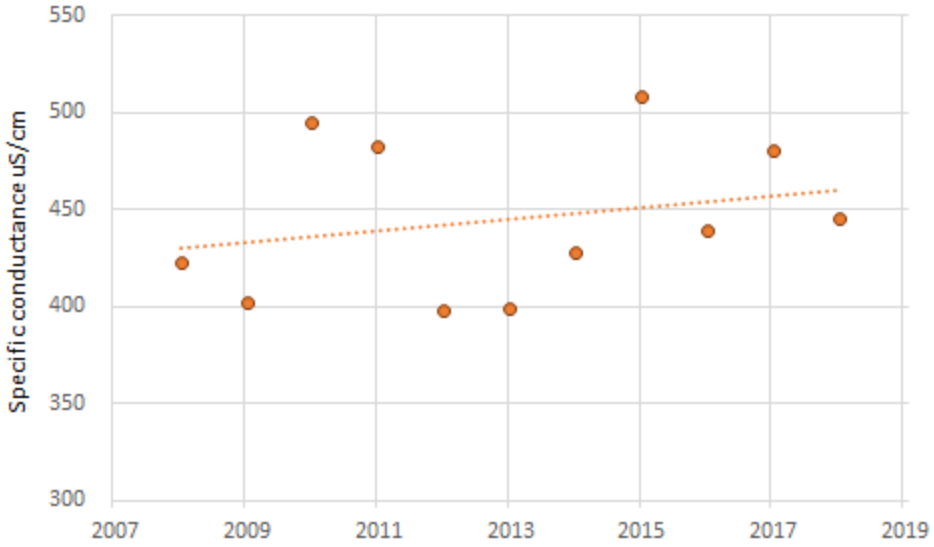


Figure 44. Long-term plot of median annual specific conductance for USGS gage 01656903 (Flatlick Branch Above Frog Branch at Chantilly).

4 Trends in Storm-Specific Spikes

4.1 Methodology

Winter[53] spikes in daily and 15-minute specific conductance were identified for the 2007-2019 period for the four selected USGS gages. To identify spikes, the "BaseflowSeparation" function in the R-Package EcoHydRology (Fuka et al., 2018) was used. Traditionally, this function reads a streamflow dataset and produces baseflow and quickflow (i.e., direct runoff). In this context, it was used to statistically separate spikes from background levels. Running the package results in an output file with a background specific conductance and a spike specific conductance for each time step that, when summed, equal the original total USGS concentration. This process was followed for daily and 15-minute data sets for each gage. An example of this separation technique using daily specific conductance data for USGS gage 01645704 (Difficult Run Above Fox Lake Near Fairfax) is provided in **Figure 45**.

For the purpose of the analyses described in this section, spike events in specific conductance were defined as time steps where background values (from the separation package) were greater than 500 µS/cm with consecutive periods no more than one hour apart and no more than one storm per day, although the event could span multiple days. Background values above the threshold were used (instead of spike values) because many occurrences of greater than 500 µS/cm can occur within a short period of time, even within a single precipitation event. Using background values enables selection of "spike events" as opposed to individual spikes. **Table 35** shows the number of spike events by USGS gage using this method.

The magnitude of each spike event, quantified in µS/cm, was defined as the maximum specific conductance for that event (as recorded at the gage). The duration of each spike event was quantified in decimal hours as the length of time of the event. Total precipitation was calculated for each spike event as the sum of observed precipitation during the event and in the preceding five days. Rain and snow events were distinguished using available NOAA data. Events were categorized as snow if snow occurred on any day during the event period. If no snow occurred during a particular spike event, then the

[53] For the purposes of this analysis, winter is defined as November 1st through April 30th.

event was considered a non-snow winter precipitation event. Non-snow winter precipitation types include all other types of precipitation except snow (e.g., rain, freezing rain, and sleet).

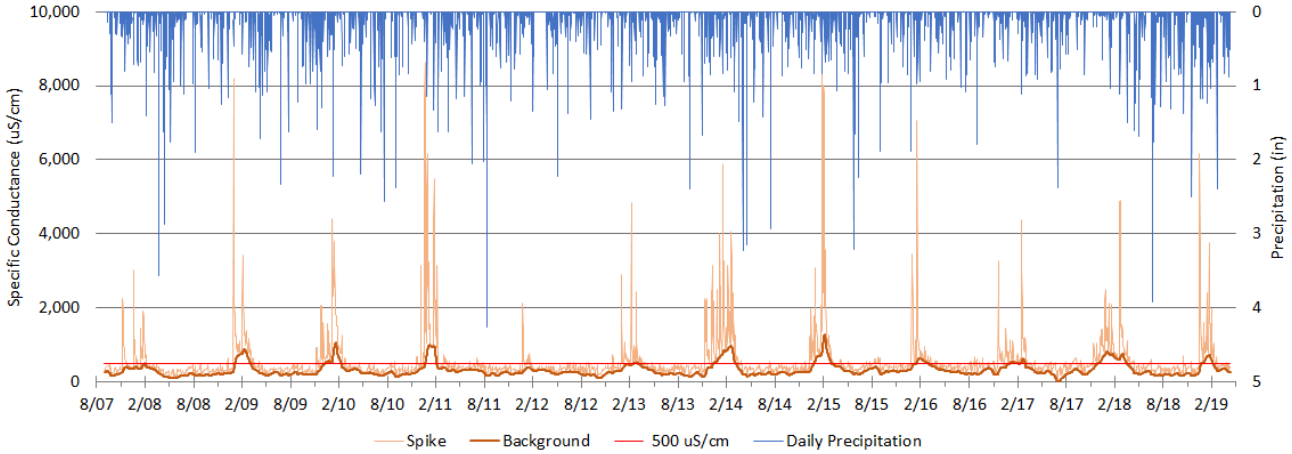


Figure 45. Example separation of background and spike concentrations of daily specific conductance. Precipitation is shown in blue. Spike events are periods of time when the background levels (dark orange) exceed the 500 µS/cm threshold. This plot was created using daily data for easy viewing. The results presented in the next section are based on the 15-minute data sets.

Table 35. Number of spike events by USGS gage.

Gage	Number of Spike Events
01645704	99
01645762	15
01646305	91
01656903	99

A series of regressions were developed based on spike events and the corresponding magnitude, duration, and total precipitation. The next section presents results for trends in magnitude since 2007 (“long-term trends”) and the relationship between spike magnitude and precipitation. The results for trends in duration since 2007 (“long-term trends”) and the relationship between spike duration and precipitation are also presented.

4.2 Results

A summary table of regression statistics for trends in storm-specific spikes is provided in **Table 36**. A p-value above 0.1 is considered not significant, “ns“, for the purposes of this table. Numeric p-values are provided for all relationships in the detailed explanations in the respective results sections.

Table 36. Summary regression statistics for tested relationships.

Winter Spike Characteristic	Regressed With…	Gage	p-value	R^2
Magnitude	Long-term	01645704	ns	0.0103
		01645762	ns	0.0649
		01646305	ns	0.0493
		01656903	ns	0.0052
	Precipitation	01645704	<0.0001	0.3084
		01645762	ns	0.0048
		01646305	<0.0005	0.1434
		01656903	<0.0001	0.3941
Duration	Long-term	01645704	ns	0.0044
		01645762	ns	0.0029
		01646305	ns	0.0003
		01656903	ns	0.001
	Precipitation	01645704	<0.0001	0.4058
		01645762	ns	0.0689
		01646305	<0.0001	0.1588
		01656903	<0.0001	0.6799

In addition to the relationships presented in **Table 36**, it should also be noted that there is a statistically significant relationship when spike magnitude is regressed with spike duration at all gages except 01645762 (S F Little Difficult Run Above Mouth Near Vienna). That particular gage has the fewest number of storms (n=15).

4.2.1 Magnitude

The maximum specific conductance value from the four selected USGS gages for each winter spike event were utilized to evaluate long-term trends in spike magnitude as well as the relationship of spike magnitude to precipitation. The findings are presented below.

4.2.1.1 Long-term trends in spike magnitude

Long-term trends in spike magnitude are not statistically significant at the four USGS gages. Details of the relationships are provided for each gage in this section.

There is a slight visible decrease in winter spike maximum specific conductance values over time for USGS gage 01645704, Difficult Run Above Fox Lake Near Fairfax, (**Figure 46**, R^2=0.0103); however, with a p-value of 0.32, this trend is not statistically significant. The R^2 value decreases to 0.0007 when only snow events are evaluated.

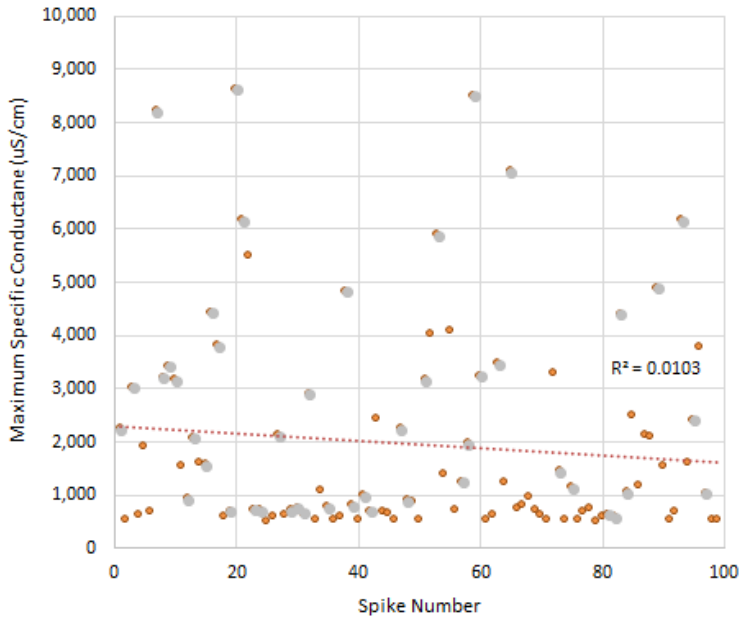


Figure 46. Long-term trend in winter spike magnitude for USGS gage 01645704 (Difficult Run Above Fox Lake Near Fairfax) for snow events (gray) and non-snow precipitation events (orange).

There is an increase in winter spike maximum specific conductance since 2007 for USGS gage 01645762, S F Little Difficult Run Above Mouth Near Vienna, (**Figure 47**, R^2=0.0649); however, with a p-value of 0.36, this trend is not statistically significant. It should be noted that this gage has considerably fewer spike events where background specific conductance exceed 500 µS/cm (n=15) and only one of the spike events is not associated with snow.

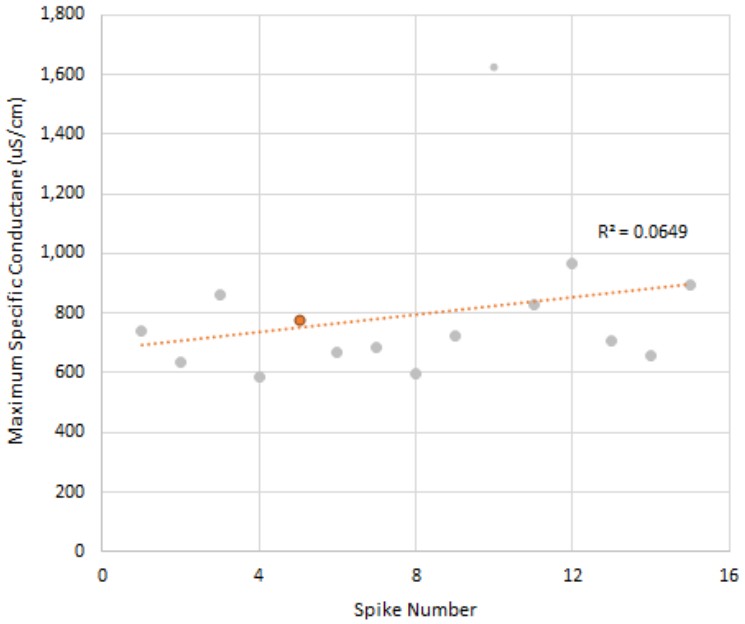


Figure 47. Long-term trend in winter spike magnitude for USGS gage 01645762 (S F Little Difficult Run Above Mouth Near Vienna) for snow events (gray) and non-snow precipitation events (orange).

There is a small decrease in winter spike maximum specific conductance values over time for USGS gage 01646305, Dead Run at Whann Avenue Near Mclean, (**Figure 48**, R^2=0.0493); however, with a p-value of 0.34, this trend is not statistically significant. The R^2 value increases to 0.1339 when only snow events are evaluated.

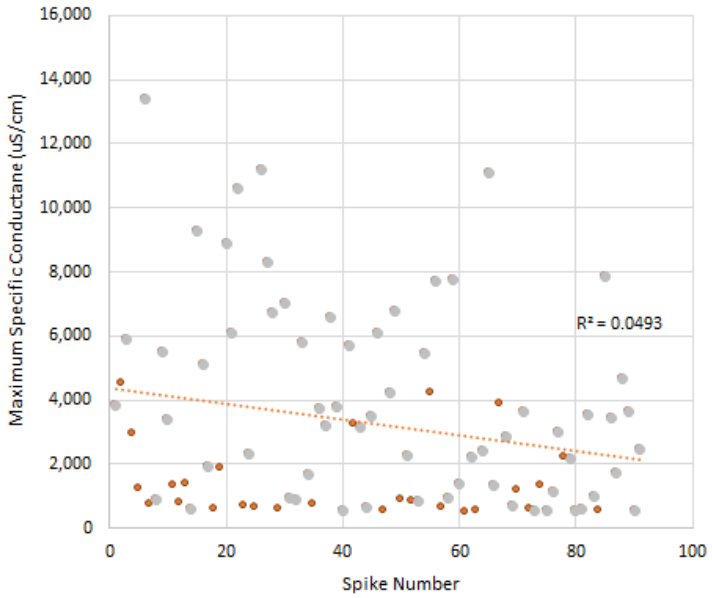


Figure 48. Long-term trend in winter spike magnitude for USGS gage 01646305 (Dead Run at Whann Avenue Near Mclean) for snow events (gray) and non-snow precipitation events (orange).

There is a small increase in winter spike maximum specific conductance values over time for USGS gage 01656903, Flatlick Branch Above Frog Branch at Chantilly, (**Figure 49**, R^2=0.0052); however, with a p-value of 0.48, this trend is not statistically significant. The R^2 value decreases to 0.0022 when only snow events are evaluated.

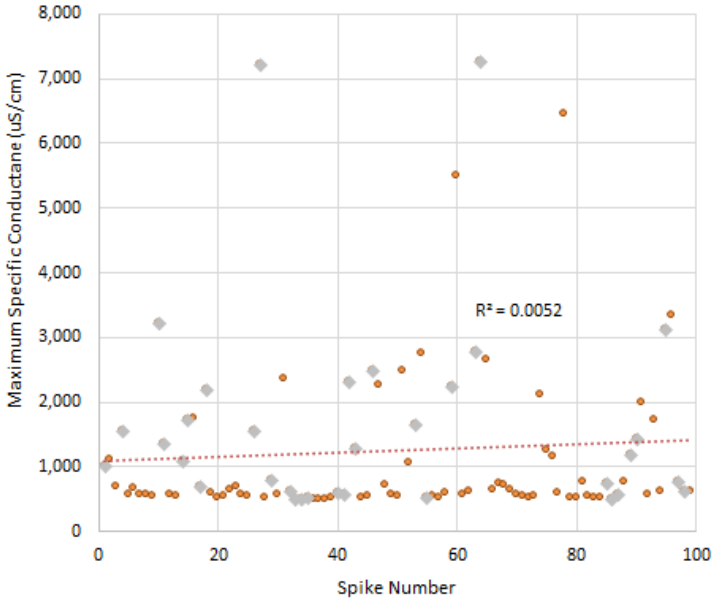


Figure 49. Long-term trend in winter spike magnitude for USGS gage 01656903 (Flatlick Branch Above Frog Branch at Chantilly) for snow events (gray) and non-snow precipitation events (orange).

4.2.1.2 Relationship of spike magnitude to precipitation

There is a statistically significant relationship between spike magnitude and total precipitation for three of the four USGS gages. USGS gage 01645762, S F Little Difficult Run Above Mouth Near Vienna, does not have a significant relationship.

There is statistically significant increase in winter spike magnitude with increased precipitation for USGS gage 01645704, Difficult Run Above Fox Lake Near Fairfax, (**Figure 50**, R^2=0.3084, p-value<0.0001). The R^2 value decreases to 0.2 when only snow events are evaluated.

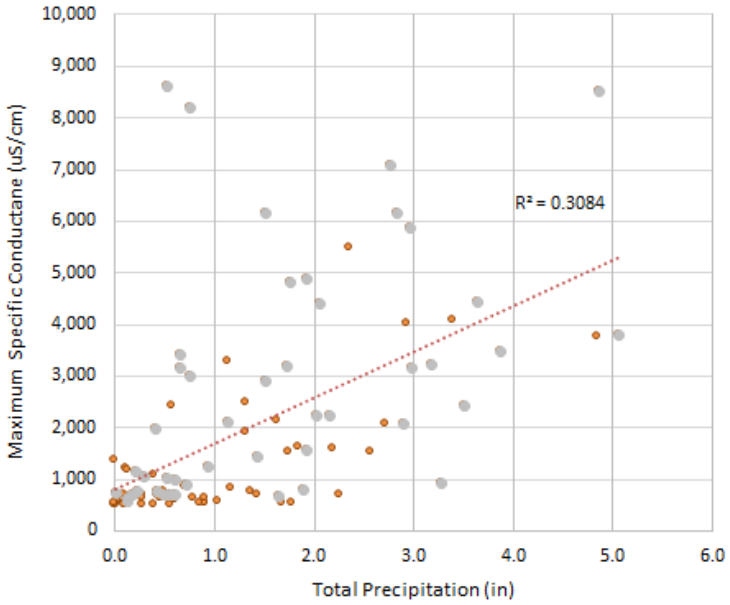


Figure 50. Relationship of winter spike magnitude to precipitation for USGS gage 01645704 (Difficult Run Above Fox Lake Near Fairfax) for snow events (gray) and non-snow precipitation events (orange).

There is not a statistically significant change in winter spike magnitude since 2007 for USGS gage 01645762, S F Little Difficult Run Above Mouth Near Vienna, (**Figure 51**, R^2=0.0048, p-value=0.81).

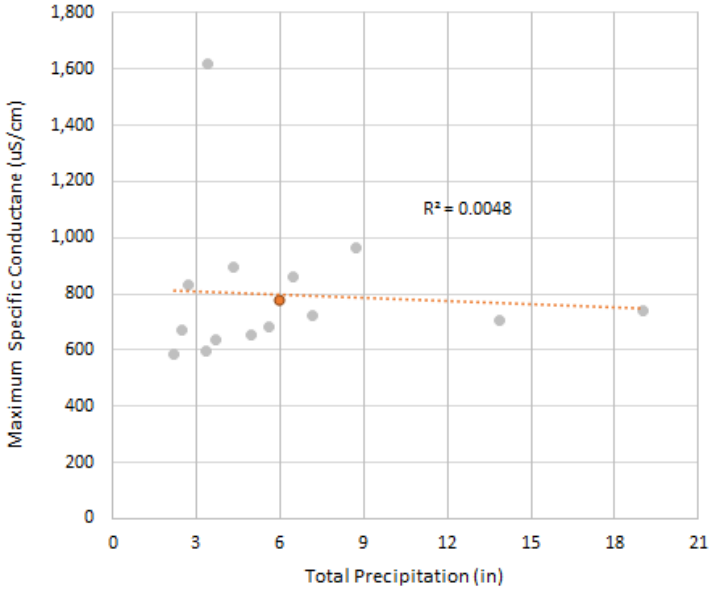


Figure 51. Relationship of winter spike magnitude to precipitation for USGS gage 01645762 (S F Little Difficult Run Above Mouth Near Vienna) for snow events (gray) and non-snow precipitation events (orange).

There is statistically significant increase in winter spike magnitude with increased precipitation for USGS gage 01646305, Dead Run at Whann Avenue Near Mclean, (**Figure 52**, R^2=0.1434, p-value<0.0005). The regression model results

indicate that precipitation accounts for slightly over 14 percent of the variability in maximum winter specific conductance. The R^2 value decreases to 0.1005 when only snow events are evaluated.

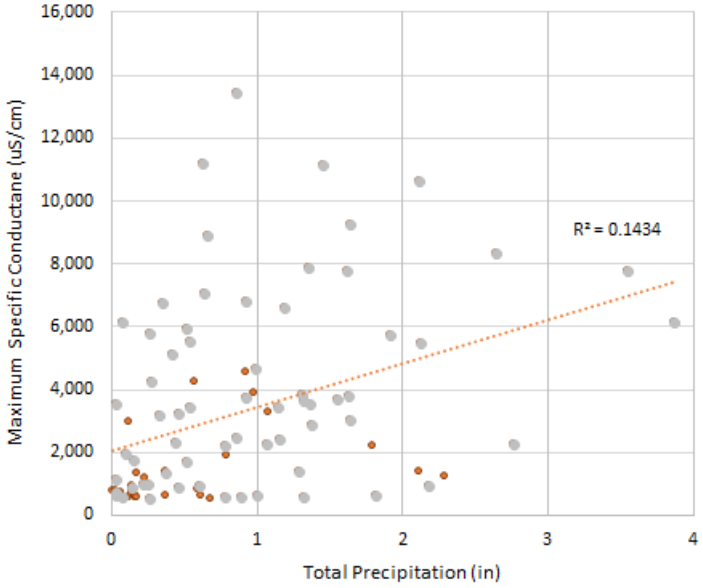


Figure 52. Relationship of winter spike magnitude to precipitation for USGS gage 01646305 (Dead Run at Whann Avenue Near Mclean) for snow events (gray) and non-snow precipitation events (orange).

There is statistically significant increase in winter spike magnitude with increased precipitation for USGS gage 01656903, Flatlick Branch Above Frog Branch at Chantilly, (**Figure 53**, R^2=0.3941, p-value<0.0001). The regression model results indicate that total precipitation accounts for almost 40 percent of the variability in maximum winter specific conductance. The R^2 value decreases to 0.3329 when only snow events are evaluated.

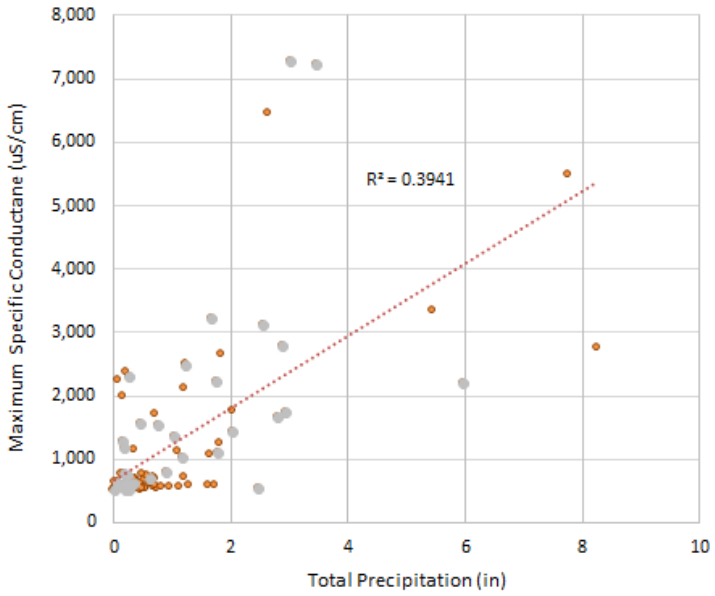


Figure 53. Relationship of winter spike magnitude to precipitation for USGS gage 01656903 (Flatlick Branch Above Frog Branch at Chantilly) for snow events (gray) and non-snow precipitation events (orange).

4.2.2 Duration

The duration of winter spike events, calculated in hours, at the four selected USGS gages were utilized to evaluate long-term trends in spike duration as well as the relationship of event duration to precipitation totals. The findings are presented below.

4.2.2.1 Long-term trends in spike duration

Long-term trends in spike duration are not statistically significant at the four USGS gages. Details of the relationships are provided for each gage in this section.

There is a slight increase in winter spike duration over time for USGS gage 01645704, Difficult Run Above Fox Lake Near Fairfax, (**Figure 54**, R^2=0.0044); however, with a p-value of 0.51, this trend is not statistically significant. The R^2 value increases to 0.0213 when only snow events are evaluated.

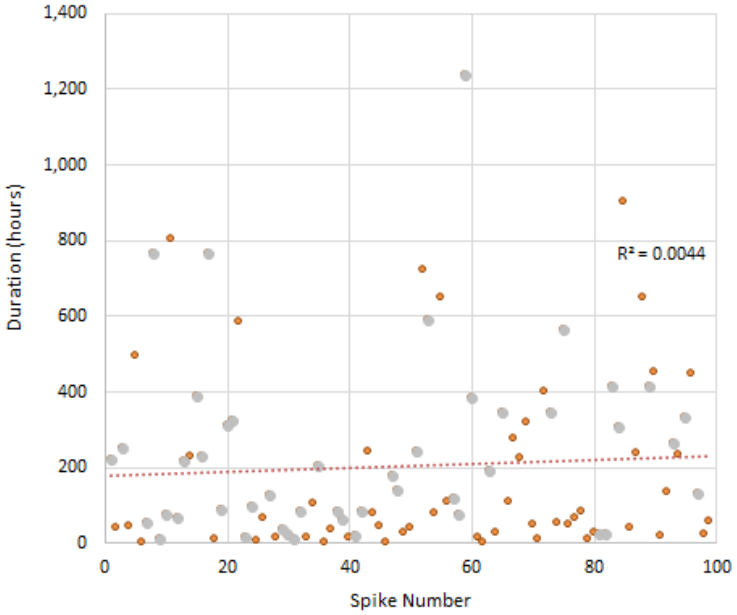


Figure 54. Long-term trend in winter spike duration for USGS gage 01645704 (Difficult Run Above Fox Lake Near Fairfax) for snow events (gray) and non-snow precipitation events (orange).

Similarly, there is a slight increase in winter spike duration over time for USGS gage 01645762, S F Little Difficult Run Above Mouth Near Vienna, (**Figure 55**, R^2=0.0029); however, with a p-value of 0.85, this trend is not statistically significant. It should be noted that this gage has considerably fewer spike events where background specific conductance exceed 500 µS/cm (n=15) and only one of the spike events is not associated with snow

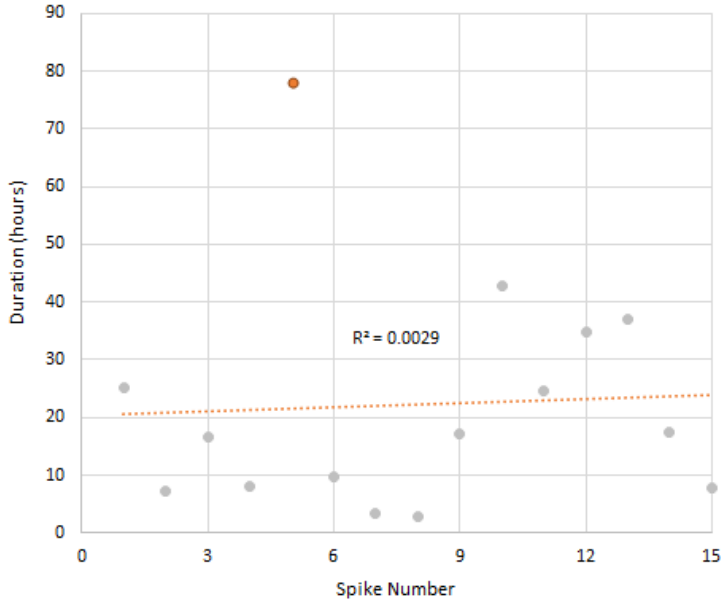


Figure 55. Long-term trend in winter spike duration for USGS gage 01645762 (S F Little Difficult Run Above Mouth Near Vienna) for snow events (gray) and non-snow precipitation events (orange).

There is very slight decrease over time in winter spike duration for USGS gage 01646305, Dead Run at Whann Avenue Near Mclean, (**Figure 56**, R^2=0.0003); however, with a p-value of 0.87, this trend is not statistically significant. The R^2 value increases to 0.0117 when only snow events are evaluated.

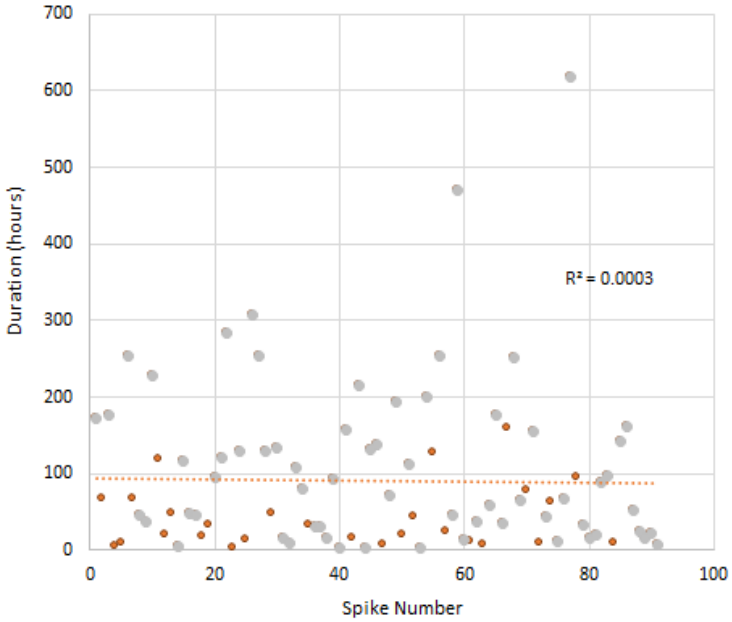


Figure 56. Long-term trend in winter spike duration for USGS gage 01646305 (Dead Run at Whann Avenue Near Mclean) for snow events (gray) and non-snow precipitation events (orange).

There is not a statistically significant trend in winter spike duration for USGS gage 01656903, Flatlick Branch Above Frog Branch at Chantilly, (**Figure 57**, R^2=0.001, p-value=0.76). The R^2 value increases to 0.0522 when only snow events are evaluated.

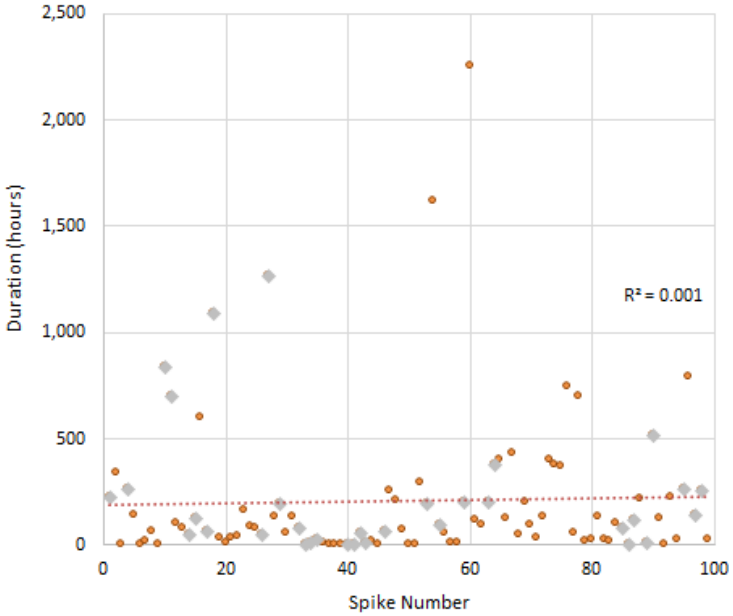


Figure 57. Long-term trend in winter spike duration for USGS gage 01656903 (Flatlick Branch Above Frog Branch at Chantilly) for snow events (gray) and non-snow precipitation events (orange).

4.2.2.2 Relationship of spike duration to precipitation

There is a statistically significant relationship between spike magnitude and total precipitation for three of the four USGS gages. USGS gage 01645762, S F Little Difficult Run Above Mouth Near Vienna, does not have a significant relationship.

There is statistically significant increase in winter spike duration in specific conductance with increased precipitation for USGS gage 01645704, Difficult Run Above Fox Lake Near Fairfax, (**Figure 58**, R^2=0.4058, p-value<0.0001). The R^2 value decreases to 0.3502 when only snow events are evaluated.

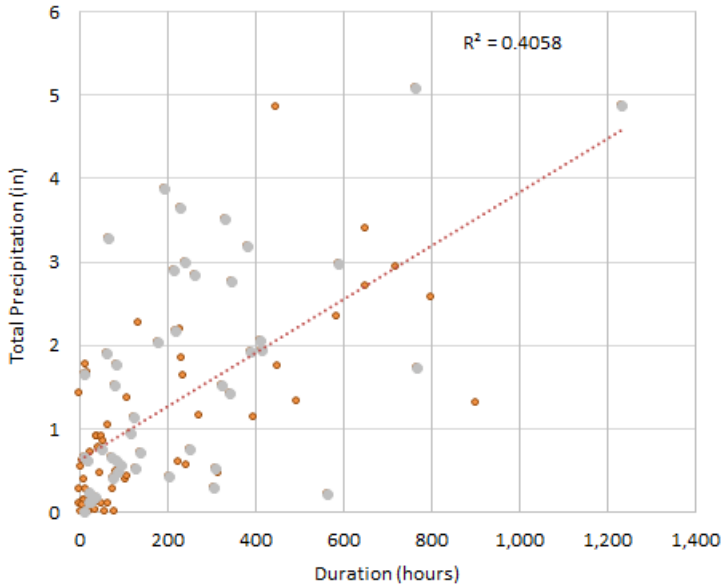


Figure 58. Relationship of winter spike duration to precipitation for USGS gage 01645704 (Difficult Run Above Fox Lake Near Fairfax) for snow events (gray) and non-snow precipitation events (orange).

There is not a statistically significant change in winter spike duration in specific conductance with increased precipitation for USGS gage 01645762, S F Little Difficult Run Above Mouth Near Vienna, (**Figure 59**, R^2=0.0689, p-value=0.34).

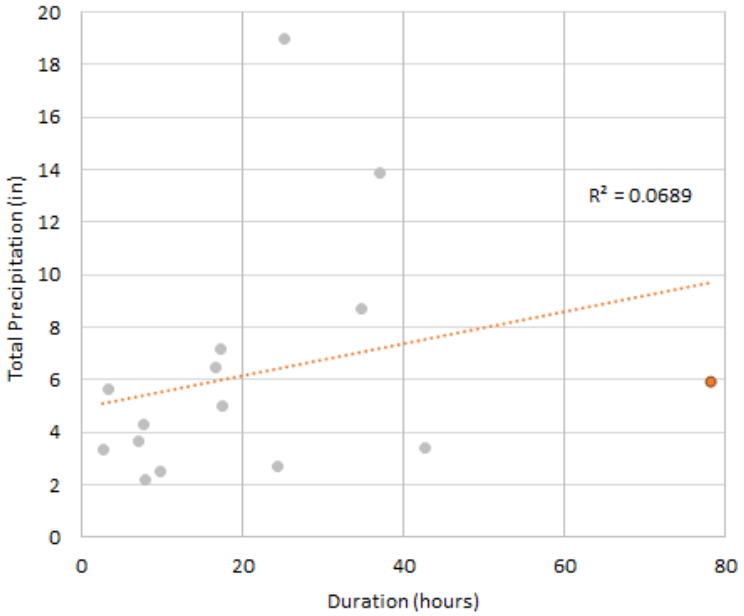


Figure 59. Relationship of winter spike duration to precipitation for USGS gage 01645762 (S F Little Difficult Run Above Mouth Near Vienna) for snow events (gray) and non-snow precipitation events (orange).

There is statistically significant increase in winter spike duration in specific conductance with increased precipitation for USGS gage 01646305, Dead Run at Whann Avenue Near Mclean, (**Figure 60**, R^2=0.1588, p-value<0.0001). The R^2 value decreases to 0.1407 when only snow events are evaluated.

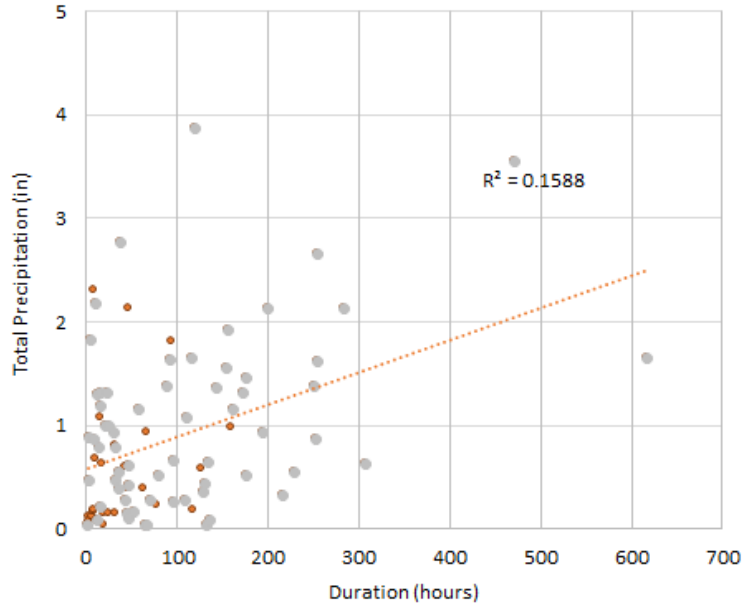


Figure 60. Relationship of winter spike duration to precipitation for USGS gage 01646305 (Dead Run at Whann Avenue Near Mclean) for snow events (gray) and non-snow precipitation events (orange).

There is statistically significant increase in winter spike duration in specific conductance with increased precipitation for USGS gage 01656903, Flatlick Branch Above Frog Branch at Chantilly, (**Figure 61**, R^2=0.6799, p-value<0.0001). The R^2 value decreases to 0.4547 when only snow events are evaluated.

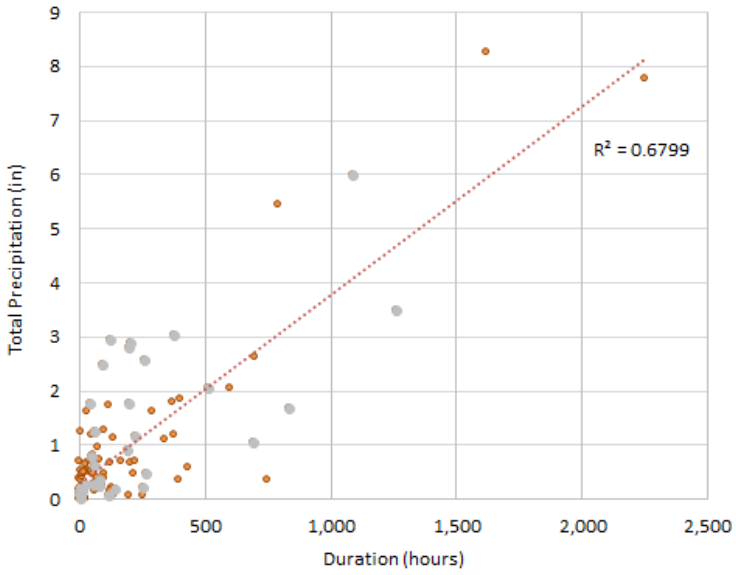


Figure 61. Relationship of winter spike duration to precipitation for USGS gage 01656903 (Flatlick Branch Above Frog Branch at Chantilly) for snow events (gray) and non-snow precipitation events (orange).

5 Trends in Background Summer Specific Conductance

5.1 Methodology

Background summer trends in specific conductance were evaluated for the Northern Virginia region. First, trends in median summer specific conductance for each year (2007-2019) were evaluated for the four USGS gages. Three versions of this analysis were developed: 1) trends in median summer specific conductance over time (presented in the results section below), 2) trends in flow weighted concentrations over time, and 3) trends in median baseflow concentrations over time where summer was defined as September to October (instead of May to October). Flow weighting and adjusting the definition of summer introduced additional variability and, in general, weakened the trends over time. The results of those investigations (numbers 2 and 3 above) are not presented here. In addition, trends were evaluated for the 15-minute summer data for the selected time period at each gage (**Table 37**).

5.2 Results

Trends in median concentrations for each year are provided for USGS gage 01645704 (Difficult Run Above Fox Lake Near Fairfax) in **Figure 62**. The increasing trend visible in the figure is statistically significant with an R^2 value of 0.5031, a p-value<0.05, and an equation of y=0.0241x-42.796.

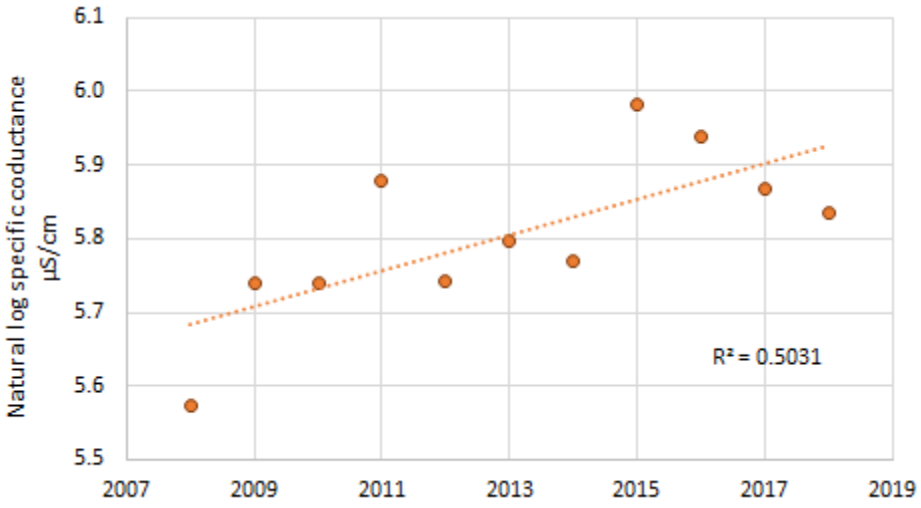


Figure 62. Increasing trend in background summer specific conductance for USGS gage 01645704 (Difficult Run Above Fox Lake Near Fairfax).

Trends in median concentrations for each year are provided for USGS gage 01645762 (S F Little Difficult Run Above Mouth Near Vienna) in **Figure 63**. The increasing trend visible in the figure is statistically significant with an R^2 value of 0.8841, a p-value<0.0001, and an equation of y=0.0258x-46.842.

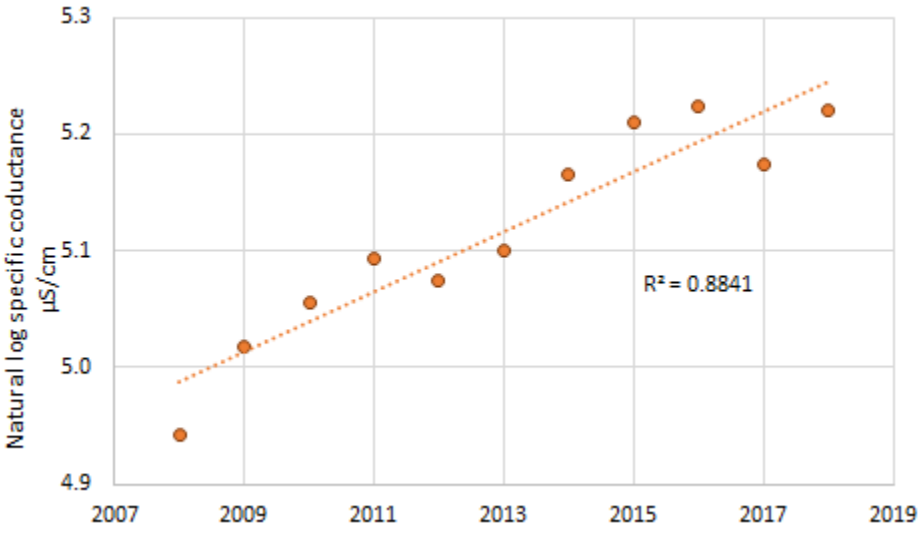


Figure 63. Increasing trend in background summer specific conductance for USGS gage 01645762 (S F Little Difficult Run Above Mouth Near Vienna).

Median specific conductance values from 2007 through 2019 are provided for 01646305 (Dead Run at Whann Avenue Near Mclean) in **Figure 64**. The increasing trend visible in the figure is statistically significant with an R^2 value of 0.4823, a p-value<0.05, and an equation of y=0.0202x-35.089.

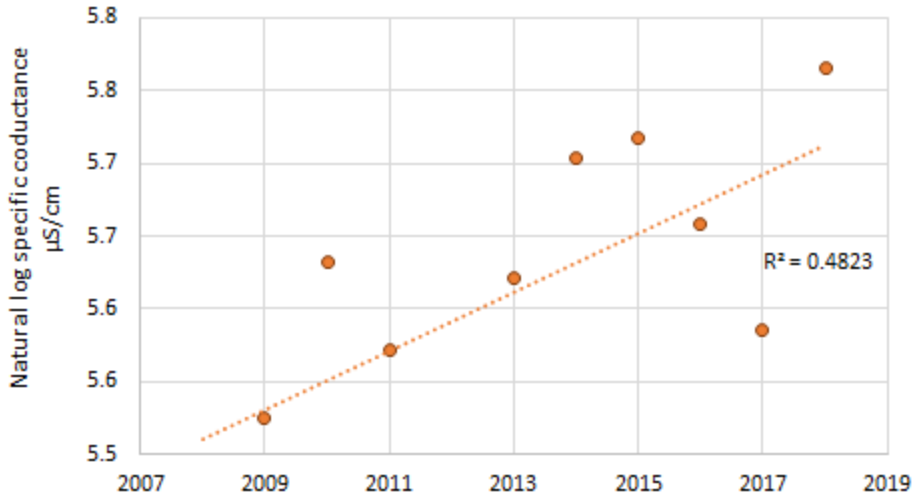


Figure 64. Increasing trend in background summer specific conductance for USGS gage 01646305 (Dead Run at Whann Avenue Near Mclean).

Trends in median concentrations for each year are provided for USGS gage 01656903 (Flatlick Branch Above Frog Branch at Chantilly) in **Figure 65**. The increasing trend visible in the figure is not statistically significant with an R^2 value of 0.1052, a p-value>0.1, and an equation of y=0.0088x-11.605.

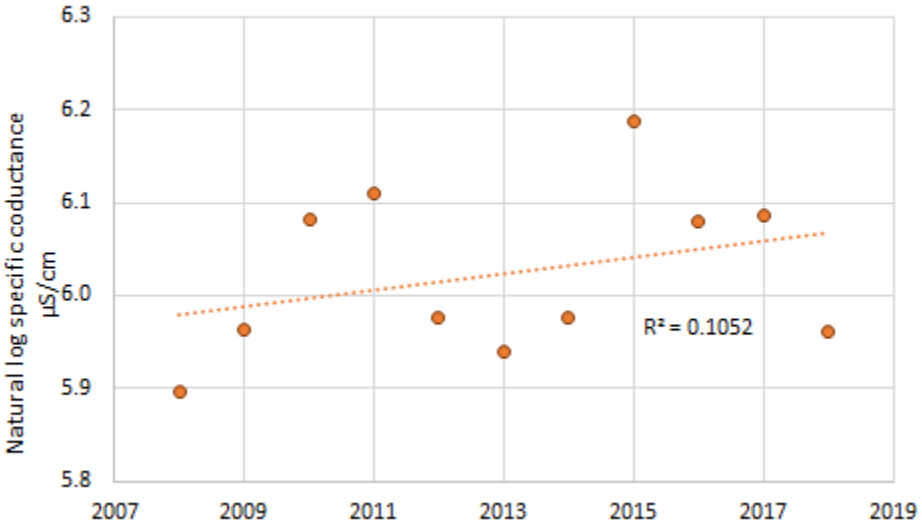


Figure 65. Increasing trend in background summer specific conductance for USGS gage 01656903 (Flatlick Branch Above Frog Branch at Chantilly).

Regression summary statistics by gage for 15-minute summer specific conductance over the period of record are provided in **Table 37**. All of the gages show statistically significant, increasing trends; however, much of the variability in the 15-minute data is explained by other factors as demonstrated by the low R^2 values. Exploration of these other factors (e.g., land use, percent impervious cover, intensity and duration of precipitation, and rate and timing of winter deicing material applications) is a potential analysis for future exploration.

Table 37. Regression summary statistics by gage for 15-minute summer specific conductance over time.

Gage	p-value	R^2	Equation
01645704	<0.0001	0.07245	y=-14.9+0.00000025x
01645762	<0.0001	0.2026	y=3.06+0.000000115x
01646305	<0.0001	0.05652	y=21.6+0.00000017x
01656903	<0.0001	0.006756	y=295+0.0000000767x

6 Conclusions

Over 1.5 million data records were analyzed as part of this assessment. Some statistically significant trends are evident while other relationships may require additional analyses to further flesh out:

1. Looking at the observed data, seasonal patterns are visible in the regional precipitation regime and in water quality conditions for specific conductance.
2. Trends in long-term, 15-minute specific conductance are difficult to discern due to large variability from other factors like land use, percent impervious cover, intensity and duration of precipitation, and rate and timing of winter deicing material applications. The increasing trends are, however, appreciable and statistically significant.
3. Increasing trends are visually observed in median monthly and median annual specific conductance. Not all of the relationships are statistically significant, however; this is especially the case at gages with large ranges in specific conductance. Median annual specific conductance values exhibited the most statistically significant increases.
4. Winter spike magnitudes and durations increase with increasing precipitation based on 15-minute data (except for USGS gage 01645762); however, long-term trends in winter spike magnitudes and durations are not statistically significant.
5. Background trends in summer medians are increasing both at a median annual and a 15-minute temporal resolution. The only exception is the non-significant median summer trend for USGS gage 01656903 (Flatlick Branch Above Frog Branch at Chantilly).

6.1 Additional Analyses of Possible Interest

The initial analyses of data described in this report bring to light some interesting relationships and potential additional questions of interest. For example, the activities listed below may be worth pursuing:

- Identify areas where more nuanced analyses may be warranted – This cursory evaluation used all available data, packaged software, and standard techniques to generate a first-pass look at the data. As such, the results may be improved with further refinement like case-specific handling of outliers in developing statistical relationships.
- Teasing out the numerous factors that influence the amount and timing of changes in water quality conditions will foster an understanding of the long-term trends noted in this report. These factors may include land use, impervious cover, and the specifics of de-icing material applications for individual storm events:
    - Evaluate relationships of land uses in the gaged watersheds to specific conductance – Differences in specific conductance values between gaged watersheds and in any given watershed over time are expected to be related to land use differences. Exploring these relationships may prove valuable in understanding the changing water quality dynamics in Northern Virginia.
    - Evaluate the response of specific conductance to impervious cover and the associated surface runoff – The amount of impervious cover in a watershed is related to the amount of winter deicing materials applied.
    - Relate storm specific timing and amount of deicing material applications to specific conductance – Each winter storm is different. The application amount, rate, and timing of deicing materials are expected to be related both temporally and spatially to the changing water quality conditions.

References

Fuka, D.R., M.T. Walter, J.A. Archibald, T.S. Seenhuis, and Z.M. Easten. 2018. EcoHydRology: A Community Modeling Foundation for Eco-Hydrology, version 0.4.12.1. https://rdrr.io/cran/EcoHydRology/. Functions can be accessed through https://rdrr.io/cran/EcoHydRology/f/.

Appendix L. General Criteria for a Water Quality Monitoring Program

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1 Purpose of the Monitoring Criteria

The monitoring criteria were developed for the Virginia SaMS effort. Under this effort a monitoring program was designed to evaluate both ambient water quality patterns in relation to winter salt application and the impact of winter salt application and deicing operations Best Management Practices (BMPs) on the quality of surface waters. The main parameters to be measured include chloride, other related ions (e.g., sodium), specific conductance, and flow. The purpose of this document is to provide recommendations on sample collection, possible methods used for analysis and guidelines on protocols that need to be developed. Additionally, considerations for designing and implementing a robust BMP effectiveness/monitoring study are provided.

2 Scope and Application

The scope of this guidance document is generally limited to collection of surface water samples from streams and other waterbodies.

3 Sampling Methods

Though no single method can be recommended for all sampling situations, a sampling kit with the following items is likely to be sufficient for most situations. The items in the kit can be as follows:

- Two or more sampling bottles depending on the number of ions to be analyzed
- Cooler for sample preservation
- Sample preservative, if needed for a particular parameter
- Ice
- Equipment to filter the samples and 0.45 µm filters
- Powder free Nitrile Gloves (PPE)
- Bag of Kay-Pees®, Kim-wipes, or other lint-free paper towels
- Ziploc® bags
- Chain of Custody (CoC) form (placed in Ziploc® bag)
- Bottle labels with Sharpie® or other water proof pen
- Disposable lab coat/ overalls (PPE)
- Plastic beaker with handle
- Long handle sample pole
- Rope
- GPS unit for accurate location

- Weighted bucket (if needed)
- Thermometer (for measuring air temperature)
- Field measurement equipment, such as a water quality meter that measures conductivity, Specific Conductance (SC), water temperature, and pH. It is worth noting that the parameter of interest here is SC reported in units of µS/cm at 25ºC and not conductivity (i.e., the measurement of electrical resistance in water that is not temperature corrected). While it is necessary to collect conductivity to derive specific conductance, calibrate some sensors, and evaluate sensor drift, to avoid confusion, **from here forward the document will only refer to SC since that is the parameter of interest.**

Water samples from surface waters can be collected in any one of the following ways, at or near the thalweg (deepest point in cross-section) of the stream:

- Hand-Collected Sample – immersing bottle directly in the stream to collect a sample. Rinse the bottle three times in flowing stream water, then collect sample with bottle mouth facing upstream and hand holding bottle downstream to avoid contamination of the sample. If sampling from a boat, the sample should be collected upstream of the boat.
- Pole-or swing sampler – attaching a bottle to an extended pole sampler to collect the sample. Rinse the sample collector 1-3 times in stream water, then collect the sample. If sampling from a boat, the sample should be collected upstream of the boat.
- Weighted bucket – used for sampling in open water off bridges. Immerse the bucket without touching the bottom (which will release sediments). If sediment is released, wait some time for it to settle, or move a few feet away and repeat sampling.

The water temperature and SC of the sample should be measured either by direct immersion of the probe into the stream, or via a sample collected in a bottle (and then discarded). If on-site pH measurements are feasible (via probe or portable meter, etc.), then these should be done in the same manner. SC units are microsiemens per centimeter (µS/cm) normalized to 25ºC. SC readings are instantaneously provided on most common, multi-parameter water quality meters and allow for value comparisons without needing further conversions.

Any samples that require preservation other than cooling should be collected in a separate bottle and the appropriate preservative added.

When discharge (flow) is considered a valuable parameter to include in a monitoring program, it is recommended that sampling be done at USGS flow gages to avoid any variation in estimation methods. However, if discharge information is valuable for other monitoring locations (e.g., perennial first order streams), guidance on how to measure discharge with pressure loggers can be found in a 2014 USEPA report, *Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams*[54].

4 Analytical Methods

All grab samples intended for ion analysis must be filtered using 0.45 micron (µm) filters. Filtration can occur in the field or at the lab. If filtering is done in the lab, then it should be done within a specified period, ideally less than 24 hours after sample collection, and unfiltered samples should be kept on ice during transport and refrigerated in the lab. Cross contamination should be avoided by cleaning the filtration equipment between samples and using a new filter for each sample.

[54] https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NCEA&dirEntryId=280013

The analytical methods that are generally used by the Virginia Department of Environmental Quality (DEQ) are listed in **Table 38**. Many of them are the United States Environmental Protection Agency (USEPA) recommended methods. It is not necessary that methods listed in **Table 38** be exclusively used. A few other examples of analytical methods are provided following **Table 38**. It should be noted that the examples listed below do not constitute an all-inclusive list. While any method can be used, it is important that a uniform and consistent method and approach for collecting and analyzing samples be used for all sites under the program. It is also important that the Lower Reporting Limits for all analytical methods be considered when choosing the method. For example, chloride test strips with a Lower Reporting Limit of 300 mg/L may be helpful as a screening tool, but not as a primary analytical method. Furthermore, because chloride test strips provide a colorimetric result that is compared to a scale, the result is less precise than other methods and should not be used for the development of chloride and specific conductance regressions. Given the purpose of the monitoring program (see **Section 1** of this appendix), it is recommended that all ion Lower Reporting Limits be at or below 5 mg/L.

Table 38. Analytical methods used by DEQ.

Parameter Name	Lower Reporting Limit	Measure Unit	Method Description	Analytical Method[1, 2, 3]
Specific Conductance (µS/cm at 25ºC)	n/a	µS/cm at 25ºC	Electrode	SM 2510 B
Alkalinity, Total (mg/L as $CaCO_3$)	5.00	mg/L	Titrametric	SM 2320 B
Nitrate Nitrogen, Dissolved (mg/L as N)	0.05	mg/L	Ion Chromatography	USEPA 300.0
Calcium, Dissolved (mg/L as Ca)	1.00	mg/L	Ion Chromatography	ASTM D 6919-09
Magnesium, Dissolved (mg/L as Mg)	0.50	mg/L	Ion Chromatography	ASTM D 6919-09
Sodium, Dissolved (mg/L as Na)	1.00	mg/L	Ion Chromatography	ASTM D 6919-09
Potassium, Dissolved (mg/L as K)	0.50	mg/L	Ion Chromatography	ASTM D 6919-09
Chloride, Dissolved (mg/L as Cl)	5.00	mg/L	Ion Chromatography	USEPA 300.0
Sulfate, Dissolved (mg/L as SO_4)	5.00	mg/L	Ion Chromatography	USEPA 300.0

[1]SM = Standard Methods for the Examination of Water and Wastewater
[2]USEPA = Environmental Protection Agency
[3]ASTM = American Society for Testing and Materials

For chloride analysis, ion chromatography is highly recommended. However, a few examples of possible additional methods for analyzing chloride are listed below:

- Chloride specific test kits are available for purchase
- Ion selective electrodes

For sodium analysis, ion chromatography is highly recommended. However, a few examples of possible additional methods for analyzing sodium are listed below:

- ICP Optical Emission Spectrophotometer (also highly recommended).

- Inductively Coupled Plasma (ICP) Mass Spectrometer (not ideal for expected high concentrations – may require extensive dilution).
- Atomic Absorption Spectrophotometer
- Ion selective electrodes.

SC in streams can be measured by the following methods:

- Multi parameter Sondes equipped with SC sensors with data logging capability (i.e., capable of recording data to either be downloaded periodically in the field or remotely reported to the cloud). This is an expensive option but can be used where there is a need to collect data on multiple parameters like pH, specific conductance, oxidation-reduction potential, etc. at the same site.
- Single continuous SC meter and probe with data logging capability.
- Portable field and/or laboratory SC meter and probe capable of SC conversion.

In some cases, where resources permit, measurements of the charge balanced full ionic suite can be useful for determining what ionic species are contributing to measures of specific conductance. While local soils and geology may influence the ionic suite analyzed, **Table 38** represents a charge balanced ionic suite that typically represents the major ionic species responsible for SC measurements in Virginia.

There are a number of labs within the SaMS project area that can run ion and specific conductance analyses on water samples. A list of Virginia Environmental Laboratory Accreditation Program (VELAP) accredited labs in the SaMS project area is provided in **Table 39**. VELAP certification is required for the analysis of any samples in Virginia that are collected for purposes of the Virginia State Water Control Law (e.g., 303(d) impairment listing decisions). For other VELAP certified labs that are not within the SaMS project area, visit the Virginia Department of General Services Division of Consolidated Laboratory Services "Find a Lab" webpage. While VELAP certification indicates a high level of quality assurance quality control (QAQC), it does not mean that non-VELAP certified labs cannot obtain similar levels of QAQC. If an organization chooses to work with a non-VELAP certified lab, it is recommended that the organization request and review the lab's QAQC policies and records.

Table 39. Laboratories in the SaMS project area that can run ion and specific conductance analyses on water samples.

Lab Name	City	State	Method	Analyte	Type of Lab
H2O Quality Laboratory a Division of the Prince William County Service Authority	Woodbridge	VA	SM 2320 B-2011	Alkalinity as $CaCO_3$	Commercial
	Woodbridge	VA	SM 3111 B-2011	Calcium	Commercial
	Woodbridge	VA	SM 3500-CA B-2011	Calcium	Commercial
	Woodbridge	VA	USGS I-2187-85 (AS LACHAT 10-117-07-1-B)	Chloride	Commercial
	Woodbridge	VA	SM 3111 B-2011	Magnesium	Commercial
	Woodbridge	VA	USEPA 353.2 REV 2 (AS LACHAT 10-107-04-1-A)	Nitrate as Nitrogen	Commercial
	Woodbridge	VA	SM 3111 B-2011	Potassium	Commercial
	Woodbridge	VA	SM 3111 B-2011	Sodium	Commercial
I.W.T.P. Laboratory	Manassas	VA	USEPA 200.7 REV 4.4	Potassium	Non-Commercial*
	Manassas	VA	USEPA 200.7 REV 4.4	Sodium	Non-Commercial*
Occoquan Watershed	Manassas	VA	SM 4500-$NO3^-$ F-2011 MINUS USEPA 353.2	Nitrate as Nitrogen	Commercial
	Manassas	VA	ASTM D6919-09	Potassium	Commercial

Lab Name	City	State	Method	Analyte	Type of Lab
Monitoring Laboratory					
Upper Occoquan Service Authority Laboratory	Centreville	VA	SM 2320 B-2011	Alkalinity as $CaCO_3$	Non-Commercial*
	Centreville	VA	SM 3111 B-2011	Calcium	Non-Commercial*
	Centreville	VA	SM 4500-CL^- B-2011	Chloride	Non-Commercial*
	Centreville	VA	SM 3111 B-2011	Magnesium	Non-Commercial*
	Centreville	VA	SM 3111 B-2011	Potassium	Non-Commercial*
	Centreville	VA	SM 3111 B-2011	Sodium	Non-Commercial*
	Centreville	VA	SM 2510 B-2011	Specific Conductance	Non-Commercial*
	Centreville	VA	SM 4500-$SO4^-$ E-2011	Sulfate	Non-Commercial*

*Non-commercial labs may not be able to process samples for external parties and should be contacted prior to sample collection.

5 Sampling Season and Sample Collection

Sampling should be conducted year-round to characterize ambient conditions. Sampling seasons for measuring the impact of deicing on water quality can include the following seasons:

- Winter – December 1 through March 31; for measuring the impact of deicing operations and winter precipitation events, and the freeze-thaw cycle. This winter season definition was chosen because it is the period during which chloride criteria exceedances have been observed in this region.
- Spring – April 1 through May 31; for measuring the impact of deicing operations and winter precipitation events and the freeze thaw cycle, plus flushing from some large rain events in the latter part of spring.
- Growing season – June 1 through November 30 for measuring the impacts of deicing operations on background concentrations and impacts of salt from other watershed sources.

Recommendations for collecting data are listed below:

- Continuous specific conductance data (i.e., high-frequency) should be collected year-round. High-frequency specific conductance data should be collected at preset intervals. Unless resources present limitations (e.g., storage space and scheduled frequency of logger downloads), 15-minute preset intervals (or 5-minute intervals if that is the interval for which the USGS is collecting data at a study site) for continuous specific conductance provide valuable short-term information on specific conductance spikes during and/or after winter storms. It is worth noting that the USEPA acute criterion for chloride is based on a 1-hour average concentration. If criteria exceedances are of interest to the study, then high-frequency data logging intervals should be no more than 30 minutes to calculate the hourly average.
- Year-round discrete samples for chloride, specific conductance, and other parameters discussed in **Section 3** of this appendix should be collected at least monthly. These monthly samples should be collected on a predetermined schedule (e.g., the 15th, or the third week of each month). These measurements will be used to determine watershed specific relationships between specific relationships between specific conductance and chloride (and other ions), and used to calibrate and verify the specific conductance data collected by continuous loggers or gages.
- If resources permit, collecting discrete samples at greater frequencies is recommended, particularly during the winter season, which the WQMR workgroup has defined as December 1 through March 31. This winter season definition was chosen because it is the period during which chloride criteria exceedances have been observed in

the Mid-Atlantic. Discrete samples for chloride and other ions along with in-situ specific conductance measurements also need to be collected during winter storm events or other times when specific conductance is above the baseline. Although the frequency of storm event sampling will be resource dependent, collecting more samples during these events provides for more confident, watershed-specific regression models for chloride, sodium, and other ion concentrations related to specific conductance.

High-frequency data loggers need to be regularly monitored and provided with regular calibration and maintenance as needed. Probes should be calibrated at least every 1-2 months, and all manufacturer's recommended calibration instructions should be followed. Some factors that can potentially corrupt readings are listed below:

- Instrument error or malfunction
- Calibration drift
- Biofouling
- Debris and foreign objects in the stream flow
- Burial or movement
- Sensor out of the water by low flow or disruption from debris or high flows
- Temporal variability (e.g., time lag between the logger measurement and actual site measurements)
- People and/or animals interfering with equipment
- Electronic data acquisition/collection and communication failure

6 Monitoring Study Design Considerations

Because SC in streams can be influenced by a variety of sources and dissolved constituents, it is strongly suggested that reliable relationships (regressions) between SC and chloride be established and maintained. This requires taking regular ion suite grab samples concurrently with in-stream meter readings of SC at various flow stages (base and storm flows) across the seasons in order to capture as many seasonal and flow variances as possible. Doing so will allow for the proper characterization of which ions are dominant of a stream's conductance (e.g., Magnesium Chloride or Sodium Chloride). In certain areas of Virginia, SC of stream baseflows are also elevated due to geologic factors (i.e., Triassic Basin soils). It is critical to determine baseline/background conditions of the water quality in terms of major ions and SC before attempting to attribute changes in SC to salt-related BMP activities being implemented in the catchment. While it is recommended that catchment-specific relationships between SC and chloride be developed to use SC as a surrogate for chloride and associated ion concentrations, regional regression models for estimating chloride concentrations from SC can be used cautiously as these catchment-specific relationships are developed. For more information on the appropriate regional regressions to use, see **Appendix N**. Examples of these catchment specific regressions can be found in the Accotink Creek Chloride TMDL[55] and a 2012 USGS report[56] (see page 27 in USGS report).

In the absence of a derived relationship between chloride and SC, conclusions as to actual chloride levels should be avoided. Nonetheless, in-stream conductance values can be used as a monitoring tool that provide the general ionic concentration of surface waters and may imply the potential trends related to contamination from deicing salts. Based on the relationships between chloride and SC in the Accotink Creek watershed in addition to a similar relationship observed for watersheds throughout the Mid-Atlantic region, it is recommended that discrete chloride samples be collected when

[55] https://www.deq.virginia.gov/Home/ShowDocument?id=4033
[56] https://pubs.usgs.gov/sir/2011/5198/pdf/2011-5198.pdf

SC values exceed 800-950 µS/cm. Around these SC values, chloride concentrations can exceed the chronic criterion of 230 mg/L.

Establishing several monitoring locations around salt BMP locations, and focusing monitoring sites with small drainage areas treated by a limited number of applicators will help to minimize confounding effects on water quality parameters. The collection of pre-BMP implementation data at these monitoring locations in order to establish baseline levels of chloride or SC is critical to measuring the effectiveness of the BMPs once they are implemented. This requires setting aside resources and time to pick sites to assess pre-implementation conditions. Consider using control areas paired with your area of salt application BMP implementation that are not participating in the larger implementation. In certain situations, an upstream/downstream paired monitoring approach may be appropriate within both the watershed with BMP implementation occurring and the control watershed (e.g., above and below a culvert). Dilution effects can be quite pronounced in high flows, so any monitoring program should attempt to accommodate flexible sampling timeframes that include targeting initial thaw and runoff following a salt application event. For more detailed recommendations on measuring the impact of BMP implementation on water quality, see the Pilot Monitoring Program Recommendations (**Appendix M**).

7 Health, Safety and Training

The following health, safety and training guidelines should be followed:

- It is important that sampling site conditions are evaluated for potential risks before collection of samples. In-river sampling shall not take place if unsafe conditions are present. This includes but is not limited to extremely cold weather, ice, high flows, and darkness.
- Personal Flotation Devices (PFDs) should be worn when sampling in-stream.
- Collection of samples from storm pipes can require individuals to enter confined spaces. All rules and regulations regarding confined spaces should be adhered to. Sampling in storm pipes should only be conducted if necessary and with appropriate permission.
- It is also important that sampling personnel are dressed for the weather with slip resistant footwear and/or snow boots as needed.
- Field staff should be trained and familiar with proper sampling, handling, safety and record keeping procedures. It is recommended that a Standard Operating Procedure (SOP) be developed to aid field staff with the proper techniques and methods for sample collection and shipping.
- Sampling at some sites may require that sampling personnel work in two-member teams. All sampling sites should be evaluated for this aspect.

8 Precautions for Sampling/Data Collection

The following precautions must be taken while handling samples

- Proper rinse protocols should be followed for the sampling devices.
- Care should be taken to not disturb the sediments while sampling, as this can contaminate the sample.
- pH probes, if used, need to be calibrated each sampling day. It is recommended that all other probes be calibrated weekly, at minimum.
- Sampling kits can be assembled and kept ready before hand.
- A CoC form containing sample details should be included with the samples.

- All Quality Assurance/Quality Control (QAQC) procedures as outlined in the SOP should be followed. These may include the taking of duplicate samples, field blanks, trip blanks, and other QAQC samples. All sampling programs typically require some level of these types of samples.

Appendix M. Pilot Project Approach: Monitoring Water Quality Response to BMP Implementation

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1 Aim of the Pilot Monitoring Program

The present document outlines the framework of a pilot water quality monitoring program which would be implemented as an iterative approach, initially performed as a pilot study and eventually leading to a routine monitoring program. The development of the pilot water quality monitoring plan originated during the development of a Salt Management Strategy (SaMS) for Northern Virginia, which was developed to address water quality concerns throughout the Northern Virginia region, including the Accotink Creek watershed. Virginia has adopted chronic and acute criteria for chloride and analytical data from water quality samples collected in the Accotink Creek watershed exceeded the criteria leading to development of a Total Maximum Daily Load (TMDL) for the watershed. The pilot water quality monitoring program is an integral component of a multifaceted SaMS, which will help improve water quality throughout the Northern Virginia region and will support achievement of the Accotink Creek TMDL.

The aim of the pilot water quality monitoring program is to measure the impact of winter salt application Best Management Practices (BMPs) implementation on water quality. Monitoring the impact of BMP implementation may be a challenging pursuit given the numerous variables in both winter storms and winter storm maintenance. Therefore, the use of a pilot project approach to iteratively assess the impact of BMP implementation on water quality is recommended. This pilot monitoring program document represents the first iteration of this approach. As lessons are learned and methods are improved, this pilot monitoring program will be modified. The SaMS Toolkit provides a BMP Menu (**Appendix B**) that assembles a list of over 50 operational BMPs that can be implemented to reduce the impact of salt on streams and waterways. The toolkit also includes recommendations for non-traditional deicers (**Appendix E**), best practices for residents to use around their homes (**Section 5.1**), and practices for commuters/drivers to consider (**Section 5.2**), that promote behavior connected to reductions in salt use.

After salt is applied on roads, parking lots and other impervious surfaces, it is washed into the streams and rivers via runoff from meltwater and/or liquid precipitation as well as infiltrating into groundwater. The influx of these salt ions into the streams and waterways via quick transport by runoff or slower transport by groundwater negatively impacts water quality. It is envisioned that by implementing one or more of the recommended BMPs, over time there will be a decrease

in the amount of salt applied and therefore a decrease in the salt loading into the water bodies. It will be difficult to isolate the impact of any one particular BMP, and therefore it may be more appropriate to assess the total benefits resulting from implementation of multiple BMPs. This assessment can be done by measuring and studying the changes in water quality parameters. This monitoring program is therefore designed to analyze these changes in water quality parameters to help quantify the improvements.

The recommendations for this pilot monitoring project are outlined below. These recommendations were developed for a future circumstance when winter maintenance operations partners are identified and resources to implement the pilot are secured. Therefore, the recommendations are intentionally framed in a flexible fashion, acknowledging that resource availability may be the biggest determinant of the actual study design.

2 Identifying a Pilot Watershed and Monitoring Locations

2.1 Choosing a Pilot Watershed

Different watersheds have different characteristics. Therefore, it is important to choose a watershed that will help evaluate the impact of salt application on streams and rivers. Some considerations to be taken into account are:

- It would be ideal to include watersheds with existing data that can provide a pre-BMP baseline.
- Watersheds that have relatively higher impervious areas might be better pilot watershed candidates since the higher proportion of impervious surface may provide more opportunity to see changes in salt loads following BMP implementation.
- There are often other regulatory drivers for monitoring, like regulated stormwater. If there are existing regulatory drivers in a watershed, the monitoring already in place can be leveraged or expanded upon.
- Ultimately, the pilot watershed will be a watershed where one or more winter maintenance organizations is/are willing to partner with the monitoring organization(s) as a pilot monitoring program will require geographically specific/detailed reporting of BMP implementation and salt products used.

2.2 Location of a Control Site

When assessing the change in water quality parameters, it is crucial to have a comparison site that does not have BMPs implemented during the study period and receives runoff from salt applications that impact water quality. Control sites provide this comparison.

Control sites are generally monitoring sites that are as similar as possible to the sites being monitored except that they are not influenced by the change in BMP implementation (i.e., business as usual). A second site that is in a different but similar watershed should be used as a control in any pilot project proposals submitted to the larger SaMS effort. A list of sites located at US Geological Survey (USGS) gaging stations with existing specific conductance and chloride data that are ideal for the pilot project, either as the watershed chosen for implementation of BMPs or as a control site, is included in **Table 40** (see end of this appendix).

2.3 Location of Monitoring Sites

The location of monitoring sites is dependent on the characteristics of the watershed. In the most basic sense, one site in the pilot watershed and one site in the control watershed are necessary to develop the comparison. However, as much as resources allow, it is recommended that additional sites in both the pilot and control watersheds be added to account for spatial variability in stormwater loads. Some general considerations to be taken into account while selecting monitoring sites are listed below:

- Consider accessibility of the monitoring location. Easy access is important. Where appropriate, use easements, publicly accessible locations, or seek land owner permission before finalizing a monitoring location.
- Consider locations with existing monitoring data, especially known problem areas with notable water quality problems.
- Consider proximity to salt application areas or facilities. Sites near impervious surfaces and/or salt storage facilities (depending on the BMPs being implemented/assessed) are more likely to show the impact of salt on the water quality in streams and can also be used to better measure the impact of BMPs.
- Drinking water sources are of utmost importance. Therefore, sites upstream and within drinking water source areas should be considered.
- If flow is deemed important for the pilot study (e.g., to derive loads and mass balances), then the monitoring location should be at a USGS flow gage to avoid variation in flow estimation methods.

If resources allow and data from additional sampling locations are deemed beneficial, more than one sampling location can be selected for both the pilot and control watersheds. In these cases, some general considerations to be taken into account while selecting additional monitoring sites are listed below:

- Stormwater outlets – During winter precipitation events, the salt loading from stormwater outlets can be significant as they carry runoff from parking lots, roadways and residential areas, often treated with deicers. Therefore, having monitoring locations upstream and downstream of significant stormwater outlets may be helpful for better understanding the ways in which salt enters streams. Similarly, if BMPs are applied to the contributing area of the outlet, then its impacts can be better quantified.
- If a larger scope pilot project is selected, then data from monitoring stations upstream and downstream of major tributaries can help understand the contributions from different parts of the watershed.

3 Recommended Parameters for Monitoring

3.1 Recommended Primary Parameters

As the goal of the monitoring program is to evaluate the impact of BMP implementation on water quality, the following two primary parameters are recommended for the monitoring program:

- Chloride
- Specific conductance (collected both as discrete and high-frequency measurements)

Chloride is recommended as the primary ion to monitor due to its presence in most traditional deicers (e.g., NaCl, $CaCl_2$, and $MgCl_2$) and its limited interaction with soils and sediments compared to other ions. Specific conductance measurements (i.e., normalized to a temperature of 25°C) are recommended over conductivity measurements since conductivity measurements vary with temperature and must be converted for comparability. It is worth noting that the parameter of interest here is specific conductance reported in units of µS/cm at 25°C and not conductivity (i.e., the measurement of electrical resistance in water that is not temperature corrected). While it is necessary to collect conductivity to derive specific conductance, calibrate some sensors, and evaluate sensor drift, to avoid confusion, **from here forward the document will only refer to specific conductance since that is the parameter of interest.**

High frequency specific conductance data (5–15 minute intervals) collected with continuous loggers or at USGS gage stations collecting continuous specific conductance, is paired with chloride and specific conductance data measured from periodic discrete samples. The information from the discrete samples are used to estimate the relationship between chloride concentration and specific conductance, which can then be applied to the high frequency specific conductance

data to provide a continuous record of estimated chloride concentration over time. This relationship between specific conductance and chloride when combined with high frequency specific conductance data provide valuable insight into short-term variations in water quality, and are necessary for estimating peak concentrations (e.g., acute chloride criterion exceedances). The specific conductance loggers are fairly inexpensive, and can be easily deployed in streams. Therefore, it is recommended that to assess the impact of BMP implementation on water quality, specific conductance data should be collected continuously along with discrete samples of both chloride and specific conductance used to estimate chloride concentrations.

3.2 Recommended Secondary Parameters

Secondary parameters that should be considered for the monitoring program include:

- Discharge (flow) at USGS gages
- Sodium
- Water Temperature

To convert ion concentrations to loads, discharge must be estimated. Discharge from USGS gage stations should be used, which is often readily available for download from their website https://waterdata.usgs.gov/nwis. However, if discharge information is valuable for other monitoring locations (e.g., perennial first order streams), guidance on how to measure discharge with pressure loggers can be found in a 2014 USEPA report, *Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams*.[57] Since sodium chloride is the most common deicing salt, sodium is included in the list of secondary parameters. Water temperature is important for understanding snow melt, runoff, and flow relationships. Additionally, it is necessary for data quality control (e.g., when water freezes).

3.3 Recommended Other Parameters

Other parameters that should be considered to supplement the collection of primary and secondary parameters include common physical parameters, common ions, and ancillary parameters needed to more fully understand ionic concentrations.

Other physical parameters include:

- Air temperature
- pH

Air temperature is an easily acquired parameter that is helpful for understanding snow melt, runoff, and flow relationships during winter months. Specific conductance is affected by pH, which measures the concentration of hydrogen ions in the water. Additionally, pH can be recorded using a common water chemistry probe.

[57] https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NCEA&dirEntryId=280013

Common ions and ancillary parameters include:

- Magnesium
- Calcium
- Potassium
- Sulfate
- Nitrate
- Nitrite
- Ammonium
- Orthophosphate
- Alkalinity (as $CaCO_3$)

Not all deicing products contain sodium, and not all ions in runoff and surface water result from deicing operations. Magnesium chloride, calcium chloride, and potassium chloride are important, common salts used in deicing products. Measuring these three additional parameters should be a priority after measuring sodium, since it allows practitioners to determine and quantify the contribution of different products to water quality. Sulfates are common ions found in surface waters and precipitation, which also contribute to observed measures of pH and specific conductance throughout the year. Certain soil types and nutrient inputs can affect measures of specific conductance, independent of winter deicing operations (e.g., elevated levels in the Triassic Basin). This is especially true during baseflow conditions outside of winter. Lastly, where resources permit, measurements of the charge balanced full ionic suite (including alkalinity) are often useful for determining what ionic species are contributing to measures of specific conductance.

3.4 Groundwater Monitoring

Groundwater monitoring may provide useful insight into the transport of ions related to winter salt use. However, groundwater monitoring is not currently recommended as a priority for this pilot water quality monitoring program due to the costs related to establishing groundwater monitoring sites. While dedicated groundwater monitoring sites may be worth considering in the future, a short-term affordable option is available. Specifically, after periods of no precipitation, longitudinal (or synoptic) studies of water quality may provide useful insight into groundwater inputs at a lower cost.

4 Sample Collection Recommendations

A combination of continuous monitoring and discrete ion sampling is recommended. Specific conductance should be collected by continuous data loggers while chloride, sodium, and other ion samples should be collected as grab samples submitted to a lab for analysis. Consistent with the recommendations of the General Criteria for a Monitoring Program (**Appendix L**), discrete specific conductance measurements by laboratory methods or in-situ measurements with handheld devices are recommended to occur with every sampling of discrete ion sample(s) to validate and confirm the continuous data logger's results.

Recommendations for collecting data are listed below. Note, while **Section 3** of this appendix describes different levels of parameters (i.e., primary, secondary, and other) the recommendations below are phrased considering all parameters for ease of description:

- Continuous specific conductance data (i.e., high-frequency) should be collected year-round. High-frequency specific conductance data should be collected at preset intervals. Unless resources present limitations (e.g., storage space and scheduled frequency of logger downloads), 15-minute preset intervals (or 5-minute intervals if that is the interval for which the USGS is collecting data at a study site) for continuous specific conductance provide valuable short-term information on specific conductance spikes during and/or after winter storms. It is

worth noting that the USEPA acute criterion for chloride is based on a 1-hour average concentration. If criteria exceedances are of interest to the study, then high-frequency data logging intervals should be no more than 30 minutes to calculate the hourly average.

- Year-round discrete samples for chloride, specific conductance, and other parameters discussed in **Section 3** of this appendix should be collected at least monthly. These monthly samples should be collected on a predetermined schedule (e.g., the 15th, or the third week of each month). These measurements will be used to determine watershed specific relationships between specific relationships between specific conductance and chloride (and other ions), and used to calibrate and verify the specific conductance data collected by continuous loggers or gages.
- If resources permit, collecting discrete samples at greater frequencies is recommended, particularly during the winter season, which the WQMR workgroup has defined as December 1 through March 31. This winter season definition was chosen because it is the period during which chloride criteria exceedances have been observed in the Mid-Atlantic. Discrete samples for chloride and other ions along with in-situ specific conductance measurements also need to be collected during winter storm events or other times when specific conductance is above the baseline. Although the frequency of storm event sampling will be resource dependent, collecting more samples during these events provides for more confident, watershed-specific regression models for chloride, sodium, and other ion concentrations related to specific conductance.

High-frequency data loggers need to be regularly monitored and provided with regular calibration and maintenance as needed. Probes should be calibrated at least every 1-2 months, and all manufacturer's recommended calibration instructions should be followed. Some factors that can potentially corrupt readings are listed below:

- Instrument error or malfunction
- Calibration drift
- Biofouling
- Debris and foreign objects in the stream flow
- Burial or movement
- Sensor out of the water by low flow or disruption from debris or high flows
- Temporal variability (e.g., time lag between the logger measurement and actual site measurements)
- People and/or animals interfering with equipment
- Electronic data acquisition/collection and communication failure

5 Duration of the Monitoring Program

Weather patterns vary from year to year. From the winter of 2008-2009 to the winter of 2018-2019 the total snowfall measured at Dulles airport has varied from 3.7 inches to 73.2 inches. The variability in snow events also means variability in salt application. Therefore, to account for all possible conditions, the recommended duration of the pilot study proposed is 2-5 years based on the availability of baseline data.

If the pilot project is conducted at sites without any existing data, then a proposed pilot project may need to be conducted for 5 years to gain sufficient data to gage the effects of BMPs. However, if the pilot project is conducted at one of the USGS sites with existing data, then a study duration of 2-3 years will likely be sufficient since the effects of fluctuations in snowfall and application of deicing salts on water quality can be understood based on data from the control watershed.

6 Evaluating the Impact of BMPs on Water Quality

6.1 Recommended Measures to Evaluate the Impact of BMPs on Water Quality

Several measures can be used to evaluate the impact of BMPs on water quality by comparing water quality trends in the pilot watershed to the control watershed. They are listed below:

- Specific conductance, chloride, sodium, and other ion trends can be plotted and studied. For examples of different trend analyses, see the Regional Long-Term Trends in Specific Conductance (**Appendix K**) conducted for the SaMS project area and Porter et al. (2020)[58].
- Regression models (see **Section 6.3** below) developed for the site and high-frequency data can be used to understand day-to-day trends, calculate the number and duration of estimated chloride criteria[59] exceedances, as well as understand weather-related trends.
- If flow data is available from USGS gages, salt loads can be calculated and related to the treated surfaces to derive unit area loads. Trends in the unit area loads can be evaluated.

It is worth mentioning that despite the mitigating impacts of the BMPs, it is possible that the changes in water quality trends may not be immediate. It can take some time for trends to be reversed or even plateau. It can be several years before a significant change in observed

6.2 Recommended Context for an Evaluation of the Impact of BMPs on Water Quality

Evaluating the impact of BMP implementation on water quality can be done using the measures outlined in the section above. However, it is recommended that an evaluation also be contextualized considering information on salt use and BMP implementation. **Appendix J** provides recommended salt use and BMP implementation information that can be collected at different tiers of detail. For the purposes of this pilot project, considerations for salt use data and BMP implementation data are provided below:

- Data on the amount of salt applied, even if it is by season, is important to quantify the benefits. If a decrease in the amount of salt applied was documented, then water quality data can be analyzed to determine if a corresponding change in water quality was observed.
- If data is available on salt application rates for each storm event, then the data can be used to correlate the impact of changed application rates on water quality. This level of information should be the primary goal since it allows for more robust analysis and conclusions. While this information should be the primary goal, lack thereof should not be grounds for rejecting a partnership with a winter maintenance operation.
- Where data on the amount of salt applied is not available, then the number of days that operations were deployed and whether or not the deployment used brine and/or solid salt can still provide information to evaluate changes in water quality.
- Information on the type of BMPs implemented, and if applicable, the level of implementation (e.g., every storm, only once, etc.) is essential for understanding the magnitude of implementation impact on water quality.

[58] https://doi.org/10.3133/sir20205061

[59] USEPA Chloride Criteria adopted by Virginia into the Commonwealth's Water Quality Standards (9VAC25-260). These criteria include a chronic criterion and an acute criterion (9VAC25-260-140.B). The chronic criterion is a 4-day average chloride concentration not to exceed 230 mg/L more than once in a three year period. The acute criterion is a 1-hour average chloride concentration not to exceed 860 mg/L more than once in a three year period.

- Precipitation and snowfall data can provide useful insight into water quality patterns. NOAA's Climate Data Online: Dataset Discovery website provides daily precipitation data at numerous stations throughout the SaMS project area. Some stations also have detailed snowfall information.

6.3 Developing Regression Models to Estimate High Frequency Ion Concentrations

Analysis of chloride, sodium, and other ion data can be expensive and also requires significant personnel resources; therefore, it might not be feasible to have frequent sample collection (see recommended frequencies in **Section 4**, Sample Collection Recommendations). High-frequency specific conductance loggers are fairly inexpensive and can be easily deployed in streams. Various studies have shown that specific conductance is a good surrogate for estimating chloride concentrations (frequently with $R^2 > 0.95–0.99$). Once paired chloride and specific conductance data becomes available, regression models can be developed (Note: regressions can also be developed for other ions of interest once the data is available). Prior to data availability, regional regression models for estimating chloride concentrations from specific conductance can be used with some caveats. Regional models should only be used if the underlying geology and climate match where the model was created, especially if the model is used to estimate chloride concentration during non-winter months. For example, soils in the Triassic Basin (located in parts of Fairfax, Loudon, and Prince William counties) have elevated background levels of specific conductance. For more information on the appropriate regional regressions to use, see **Appendix N**.

7 Pilot Monitoring Program Success

The pilot monitoring program and any other monitoring program that is established has the potential to be more successful if multiple stakeholders are involved. To help with analysis and interpretation of data, development of regression equations and to ensure unbiased evaluations, partnerships with academia might be especially beneficial.

Furthermore, the pilot monitoring program is intended to be implemented iteratively. Following the first 2-5 years of study (see **Section 5**, Duration of the Monitoring Program), the results will be analyzed, and discussed among SaMS stakeholders. Any potential improvements identified in study design that facilitate better characterization of the impacts of BMP implementation on water quality will be evaluated and considered for incorporation in future iterations of the pilot monitoring program. Therefore, over time, an adaptive and continual improvement process will foster the development of various methods for achieving the goal of this monitoring effort – evaluating the impact of salt use BMP implementation on water quality.

Table 40. Possible watersheds to include pilot project as pilot/experimental or control/comparison watersheds.

Abbreviated name	USGS site ID	State	Ideal as a *pilot* watershed	Ideal as a *control* watershed	Discrete samples with both chloride & SC (#)	Watershed area (sq mi)	Impervious surface cover (%) *	Duration of high-frequency data	Total years of data thru water year 2018 **
DeadRunW	01646305	VA	high	high	0	2.05	17.6	2008 – 2018	11
DiffRFxL	01645704	VA	high	high	20	5.49	22.7	2008 – 2018	11
SFLiDifR	01645762	VA	med.	high	20	2.71	4.73	2009 – 2018	10
LongBran	01654500	VA	med.	high	2	3.72	14.4	2014 – 2018	5
Accotin2	0165389205	VA	med.	high	0	3.99	30.0	2012 – 2014	3
FlatlicB ***	01656903	VA	med	med	0	4.2	24.6	2008 – 2017	10
Accotink	01654000	VA	low	high	87	23.9	23.4	2016 – 2018	3
DifficuR	01646000	VA	low	med.	155	57.8	11.9	2008, 2013 – 2018	7
Plumtree	01581752	MD		high	156	2.5	27.3	2014 – 2018	5
SligoCre	01650800	MD		high	198	6.45	27.1	2014 – 2018	5
PaintBra	01649190	MD		high	209	13.1	13.4	2008 – 2018	11
FosterBr	01585075	MD		med.	67	1.83	12.1	2016 – 2018	3
HerringR	01585219	MD		med.	0	16.3	32.6	2016 – 2018	3
RockCree	01648010	MD		med.	311	63.7	18.0	2013 – 2018	6
NeBrAnac	01649500	MD		med.	158	72.8	19.7	2009 – 2018	10
HickeyRu	01651770	MD		low	90	0.99	57.1	2014 – 2018	5

* The impervious surface cover (ISC) was estimated by a couple different techniques with information from 2011 National Land Cover Database (NLCD). While the values should be close to those estimated by any method, it may be worth using a consistent approach, and perhaps with 1-m resolution data as well as the 30-m resolution NCLD data, to estimate ISC in any watersheds included in a pilot project.

** The total years of data is based on both collected data and ≥85% data coverage for Dec–Mar in a given year. For example, data were collected in water year 2018 for FlatlicB (Flatlick Branch) but the Dec–Mar period only had 61.8% data coverage so it was excluded from the SC-chloride study done by Moore, Fanelli, and Sekellick. The completeness of data coverage has not been evaluated for DiffRFxL (Difficult Run above Fox Lake).

*** FlatlicB is listed as a *medium* for a control site because it is underlain by Triassic rift basin sediments whereas the other *medium/high* ideal watersheds are underlain predominantly by silica-rich (felsic) metamorphic rocks. If FlatlicB were to be used as a control site, then it would be ideal to collect >20 discrete samples at that site.

Appendix N. Recommended Regional Models for Predicting Chloride Concentration from Specific Conductance

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1 Primary Recommendation

It is recommended that we use a regional Mid-Atlantic piecewise model developed by Joel Moore and USGS colleagues to predict chloride concentrations for watersheds without paired specific conductance and chloride data and that do not drain primarily Triassic Basin soils. The piecewise regional model is:

$$y = 0.171x - 0.580 \text{ below } 321\ \mu S/cm$$

$$y = 0.291x - 44.5 \text{ above } 321\ \mu S/cm$$

In addition to the published journal article, all data used to produce the Mid-Atlantic regional model along with the model results also can be found in a USGS data release by Fanelli and colleagues: https://www.sciencebase.gov/catalog/item/5d2c98e8e4b038fabe22ce86

Justification for recommendation:

- The SaMS project area models are skewed to the Accotink Creek watershed (especially on the high end).
- The Mid-Atlantic model has a dataset that is over 2 times larger than the dataset for the SaMS area and drains watersheds comprised of similar soils to the SaMS project area, with the exception of Triassic Basin soils.
- The piecewise approach will allow for better prediction of chloride at lower specific conductance values.
- The slightly lower slope of the piecewise regional model as compared to the Accotink will result in lower (or more conservative) estimates of chloride concentrations near the chronic chloride criterion of 230 mg/L. For example, with the SaMS study area single regression model, 230 mg Cl/L is predicted when SC equals 813 µS/cm, whereas with the Mid-Atlantic regional piecewise regression model, 230 mg Cl/L is predicted when SC equals 943 µS/cm. This difference in predicted Cl is unlikely to make much difference in estimating chronic chloride criterion exceedances since Moore and USGS colleagues found that maximum chloride concentrations during exceedance events commonly exceed 1000 mg Cl/L.
- The methods are being peer reviewed and can be referenced.

Conditions for recommendation: Since the Triassic Basin model's dataset was limited and since the influence of the Accotink Creek watershed data on the regression equation was strong, it is additionally recommended that:

- The Mid-Atlantic piecewise model only be used for watersheds draining primarily non-Triassic Basin soils, and
- The Mid-Atlantic piecewise model only be used in the absence of catchment specific models. The ultimate goal when studying any watershed should be to develop catchment specific models.

2 Background

At the second Water Quality Monitoring & Research (WQMR) workgroup meeting, the workgroup agreed that "developing specific conductance and chloride relationships can help to develop an area-specific regression model to allow for chloride concentration estimates." Considering that data collected by Fairfax County suggests that watersheds draining primarily Triassic Basin soils have elevated Specific Conductance, the workgroup agreed to "identify geographic gaps in chloride-conductivity relationships for the different physiographic provinces in the SaMS project area." This action item was step 1 towards the ultimate goal of developing models to predict chloride concentrations from specific conductance.

The analysis for gaps in paired chloride and specific conductance was conducted on USGS stations. This analysis was presented at the third WQMR workgroup meeting and concluded the following:

- The major physiographic provinces in the SaMS area include Northern Piedmont (37.1%), Triassic Basin (25.0%), Piedmont (23.9%), Coastal Plain (10.0%), and Blue Ridge (3.9%) provinces.
- There are no monitoring stations in the Coastal Plain with the paired data.
- Much of the paired data is comprised of lower concentrations where regression relationships are more variable/less confident.

When the workgroup discussed the content of this analysis, they agreed on the following:

- The relationships did not need to be watershed-specific, but there should be 2 regional models developed. One model should be developed for watersheds draining primarily Triassic Basin soils and one model should be for watersheds draining majority other physiographic provinces.
- Because of the lack of data in Virginia draining primarily Triassic Basin soils, the workgroup also agreed the model could be supplemented by data from outside the SaMS project area.

So to prepare for the fourth and final WQMR workgroup meeting, an attempt was made to develop these 2 regional models.

3 Summary of Results

Triassic Basin Model: For watersheds draining primarily Triassic Basin soils, the available data were limited to the SaMS project area. Investigating watersheds in Maryland identified one watershed (Monocacy River at Bridgeport, MD; 01639000) that drained 73.7% Triassic Basin soils. However, the remaining portion of the watershed was characterized by physiographic provinces not included in the SaMS project area and that may have different influences on specific conductance (e.g., Piedmont Limestone/Dolomite Lowlands). Therefore, the data supporting the development of a model for watersheds draining primarily Triassic Basin soils was limited to three gages in the SaMS project area (**Table 41**). The total dataset (n = 97) comprised a range of chloride (max = 218 mg/L; min = 0.7 mg/L) and specific conductance (max = 1030 µS/cm; min = 25 µS/cm) values that were somewhat limited (**Figure 66**).

Table 41. USGS gages used in Triassic Basin model.

Gage	% Triassic
01644290	94.44%
01644280	73.90%
01644291	91.30%

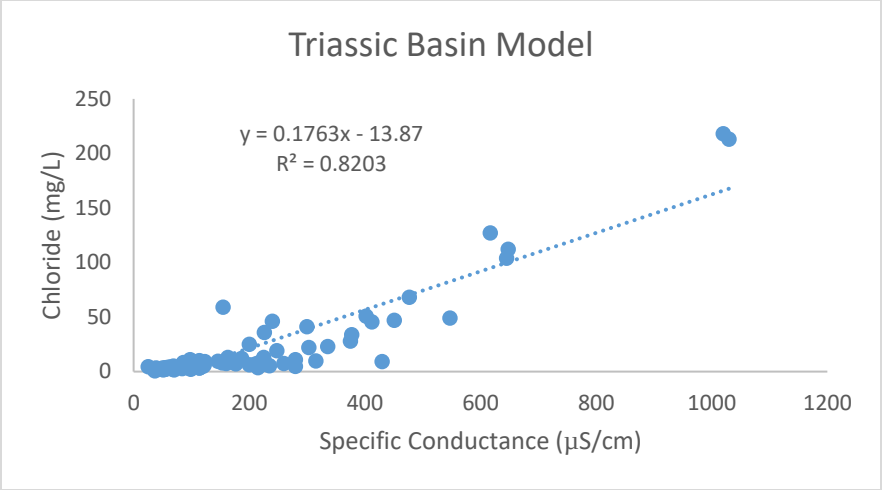


Figure 66. Relationship between specific conductance and chloride in watersheds located in the SaMS project area that drain primarily Triassic Basin soils.

Non-Triassic Basin Model: Paired specific conductance and chloride data were pulled from 29 USGS gages (n = 674). All but one of the gages did not drain any Triassic Basin soils. The gage that did (01644000) was comprised of less than 4% Triassic Basin Soils. This data was supplemented with data from the Accotink Creek Stressor Analysis that included additional paired chloride and specific conductance data (n = 217). The total dataset (n = 891) represented a wide range of chloride (max = 2570 mg/L; min = 1.25 mg/L) and specific conductance (max = 7986 µS/cm; min = 26 µS/cm) values (**Figure 67**).

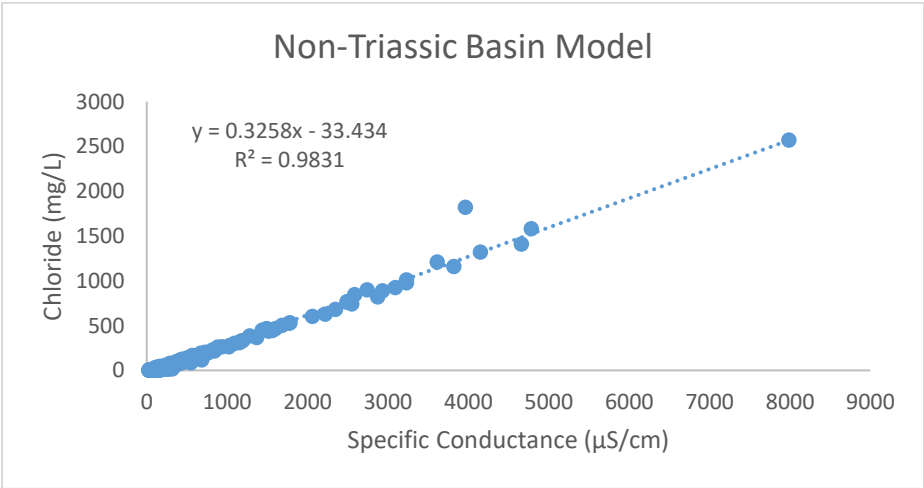


Figure 67. Relationship between specific conductance and chloride in watersheds located in the SaMS project area that drain watersheds with <4% Triassic Basin soils.

4 Mid-Atlantic Regional Model Comparison

Joel Moore (Towson University) and colleagues have been working on regional models for specific conductance and chloride, which includes a regional model for the Mid-Atlantic. These models are currently under peer review for publication. For this Mid-Atlantic dataset (n = 2401; all data collected by USGS) of watersheds that primarily drain Piedmont (and a few Coastal Plain) streams, the piecewise regression relationship (two-part linear regression) between chloride and specific conductance is:

$$y = 0.171x - 0.580 \text{ below } 321\ \mu S/cm$$

$$y = 0.291x - 44.5 \text{ above } 321\ \mu S/cm$$

Similar to the regressions above, the "x" is specific conductance and the "y" is chloride. The uncertainty on that breakpoint is 11.2 µS/cm. This piecewise regression was performed in R using the segmented library. Additionally, the R^2 for the Mid-Atlantic regression is 0.979 and $p < 0.001$. When considered as a single dataset (i.e., not piecewise), the single linear regression equation for the same dataset is:

$$y = 0.283x - 32.2,\ R^2 = 0.976$$

In an attempt to see if the data from within the SaMS study area (i.e., non-Triassic Basin watersheds + Triassic Basin watersheds; n = 1081) could be analyzed in a similar fashion, the same breakpoint of 321 µS/cm was used (**Figure 69)**. Since this was not computed using the same R software, individual regressions were developed based around that breakpoint. Based on this approach, the piecewise regression relationship between chloride and specific conductance in the SaMS dataset is:

$$y = 0.2069x - 9.8144 \text{ below } 321\ \mu S/cm,\ R^2 = 0.8048$$
$$y = 0.3337x - 50.963 \text{ above } 321\ \mu S/cm,\ R^2 = 0.9811$$

When considered as a single dataset (not piecewise), the single linear regression equation for the same dataset is:

$$y = 0.3231x - 32.541,\ R^2 = 0.9783$$

Note, about 20% of the data in the combined dataset (n = 217) came from a single watershed, Accotink Creek. When looking exclusively at data from the Accotink Creek watershed, the single linear regression equation is:

$$y = 0.3221x - 37.19,\ R^2 = 0.9975$$

While the dataset is limited (n = 97), a piecewise regression was run using the same R software used in the Mid-Atlantic regional model developed by Joel Moore and USGS colleagues. This analysis was done since the slope for the higher values (i.e., above the breakpoint) appeared to be similar to those in non-Triassic Basin watersheds when comparing **Figure 66** to **Figure 67** and **Figure 69**. Predictably the first segment equation had a low slope due to the influence of other ions on specific conductance. However, although the dataset is small, the second segment equation is very similar to the second segment equation of the Mid-Atlantic regional piecewise model (**Figure 68**).

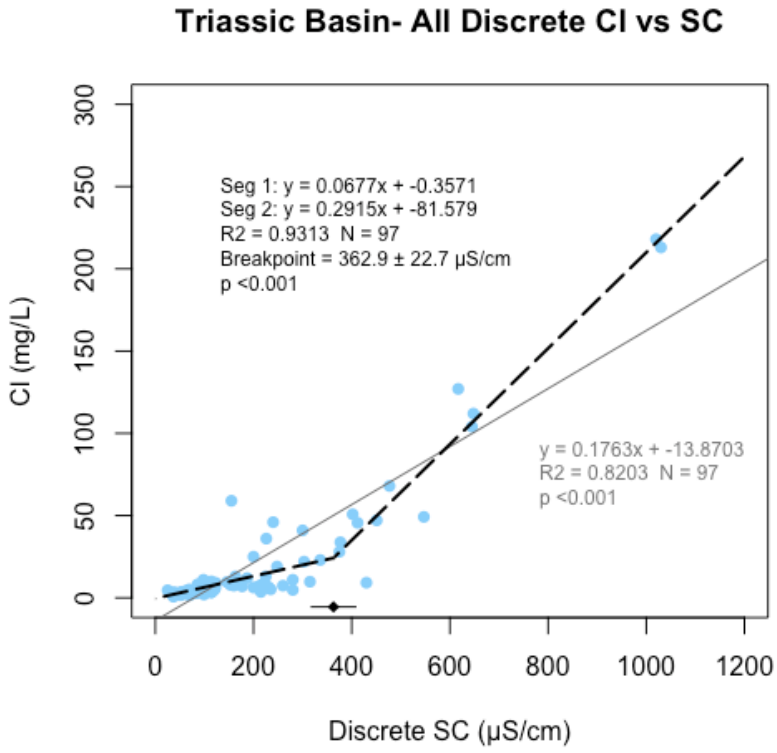


Figure 68. Piecewise relationship between specific conductance and chloride in 3 watersheds draining primarily Triassic Basin soils that are located in the SaMS project area.

Given the reasons below, it is recommended that we use the Mid-Atlantic piecewise model developed by Joel Moore and USGS colleagues for watersheds not draining primarily Triassic Basin soils:

- The SaMS project area models are skewed to the Accotink Creek watershed (especially on the high end).
- The Mid-Atlantic model has a dataset that is over 2 times larger than the SaMS area dataset and drains watersheds comprised of similar soils to the SaMS project area, with the exception of Triassic Basin soils.
- The piecewise approach will allow for better prediction of chloride at lower specific conductance values.
- The slightly lower slope of the piecewise regional model as compared to the Accotink will results in lower (or more conservative) estimates of chloride concentrations near the chronic chloride criterion of 230 mg/L. For example, with the SaMS study area single regression model, 230 mg Cl/L is predicted when SC equals 813 µS/cm, whereas with the Mid-Atlantic regional piecewise regression model, 230 mg Cl/L is predicted when SC equals 943 µS/cm. This difference in predicted Cl is unlikely to make much difference in estimating chronic chloride criterion exceedances since Moore and USGS colleagues found that maximum chloride concentrations during exceedance events commonly exceed 1000 mg Cl/L.
- The methods will be peer reviewed and can be referenced.

Furthermore, given that the Triassic Basin model's dataset was limited and that the influence of the Accotink Creek watershed data on the regression equation was strong, it is additionally recommended that:

- The Mid-Atlantic piecewise model only be used for watersheds draining primarily non-Triassic Basin soils, and
- The Mid-Atlantic piecewise model only be used in the absence of catchment specific models. The ultimate goal when studying any watershed should be to develop catchment specific models.

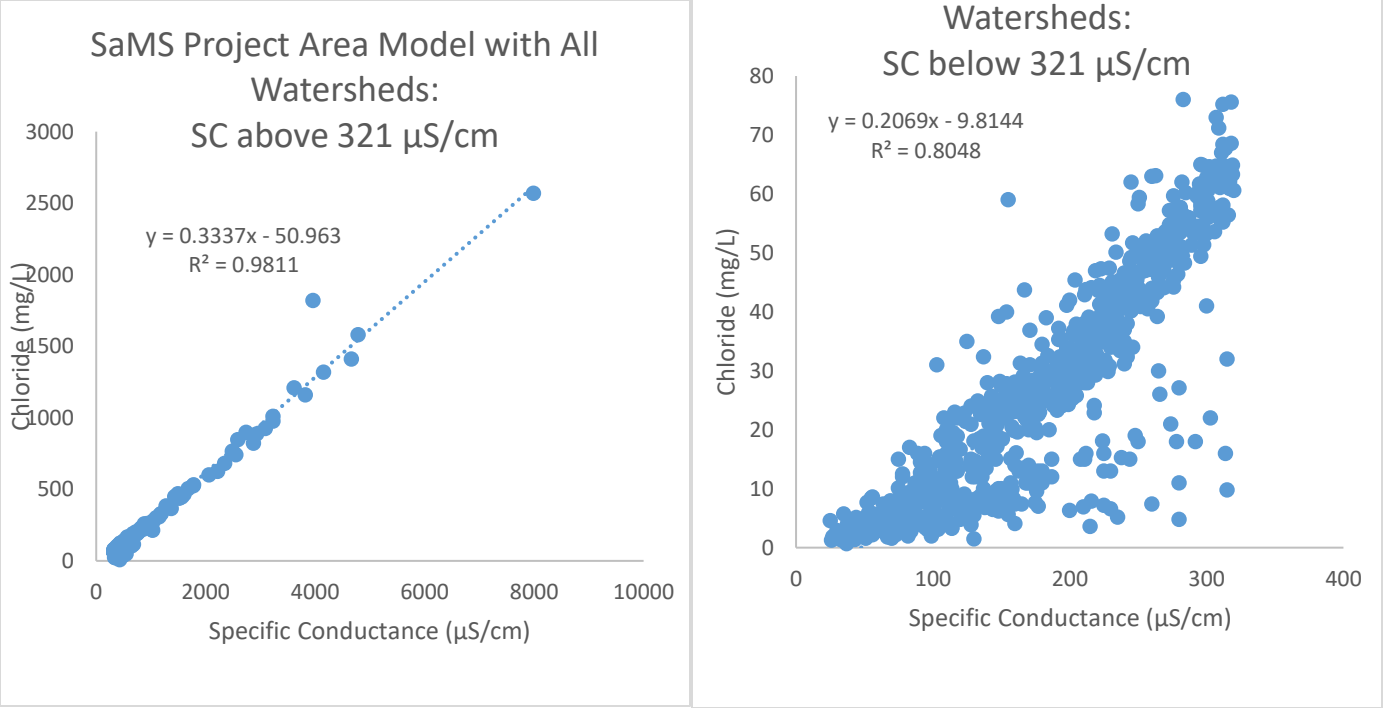


Figure 69. Piecewise relationship between specific conductance and chloride in watersheds located in the SaMS project area where a breakpoint of 321 µS/cm was used.

Appendix O. Inventory of Existing Salt-related Water Quality Data and Monitoring Groups

The grab-and-go resource for existing water quality data was assembled to provide information on existing/historical monitoring work that relates to ions. Additionally, this resource identifies organizations that may be willing to partner with other interested monitoring groups (government, volunteer, and/or academic). Download the spreadsheet resource here.

Appendix P. Conceptual Model of Salt Origin, Transport, and Fate

The conceptual model contributes to the SaMS by identifying variables that should be understood and by stimulating/guiding new monitoring and research efforts. Download the spreadsheet conceptual model here.

Appendix Q. SaMS Project Area and Impervious Analysis

In order to get a sense of the possible amount of salts used by the different sources (e.g., residential, transportation, and commercial/industrial), a spatial analysis of impervious surfaces was conducted for the Northern Virginia region (**Appendix Q**). In this study, the 2016 VGIN land cover dataset was used to identify all impervious surfaces that were not rooftops. In other words, all impervious surfaces that could possibly be treated with salts. City/County parcel data was then used to divide the impervious surfaces layer into different land use categories: residential, transportation, commercial/industrial, open space/parks, mixed use, special development area (e.g., military bases and schools), and unclassified (i.e., the City/County parcel data did not specify a use). The analysus methods and results are summarized below.

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1 Methods

Virginia Department of Environmental Quality sought a volunteer project intern from Virginia Commonwealth University's Center for Environmental Studies to complete specified spatial analyses in support of the Salt Management Strategy development. The complete list of requested deliverables can be found in the project Scope of Work document.

Input Datasets

- Virginia Geographic Information Network (VGIN) Land Cover Dataset (2016) (A1)
- VGIN VA_COUNTY feature class (A2)
- VGIN Buildings Footprint (A3)
- United States Geological Survey (USGS) National Hydrography Dataset 5th level HUs (HUC 8) (A4)
- Virginia Department of Transportation (VDOT) LRS Route Master, version 19.1 (A5)
- Accotink Creek Watershed boundary (supplied by DEQ)
- City/County Parcel Data supplied by individual cities/counties or downloaded
    - Parcels layer by Open Data Group for the City of Alexandria, Virginia downloaded (A6)
    - Parcels layer received directly from representative of Arlington County
    - Property Polygons layer received directly from representative of City of Fairfax
    - Parcels, Generalized Land Use received directly from representative of Fairfax County
    - Parcels, Zoning and Land Use layers received directly from representative of City of Falls Church
    - Loudoun Parcels layer by Loudoun County Open Data Group, downloaded (A7)
    - Manassas City Parcels layer received directly from representative of City of Manassas
    - Parcels layer by Prince William County (A8)

1.1 Data Preparation

Two file geodatabases were created to house and process all data related to this project (SaMS.gdb, SaMSbyHUC.gdb). For all of the following processes unless otherwise noted, raster and vector data are stored in SaMS.gdb. VGIN VA_COUNTY feature class was downloaded and projected to Lambert Conformal Conic Virginia projected coordinate system. The boundaries for the City of Alexandria, Arlington County, the City of Fairfax, Fairfax County, the City of Falls Church, Loudoun County, the City of Manassas, the City of Manassas Park, and Prince William County were extracted from this layer to form a collection of each city/county boundary (Nine_Boundaries.shp). The nine cities/counties were also merged to create a Northern Virginia study area boundary (NOVA_Boundary.shp).

VGIN's Land Cover Dataset (Bay Area 1: N16_88, N16_89; Bay Area 2: N16_69, N16_78, N16_79, N16_88, N16_89, N16_99, N17_60, N17_61, N17_70, N17_71, N17_80) was downloaded. A new dataset containing only Impervious Surfaces (CLASS_ID 21, 22) was created from VGIN's Land Cover Dataset and clipped to the NoVA study area boundary to create the Impervious Surface layer for the study area projected in Lambert Conformal Conic Virginia projected coordinate system (Impervious.shp). VGIN Buildings Footprint was erased from the Impervious Surface layer and created the layer representing Impervious Surface minus Buildings for the study area (Impervious_MinusBldgs.shp). This Impervious Surface layer was clipped to each city/county to form individual Impervious Surface minus Buildings Footprints for each individual city/county of the study area. These layers were then dissolved by Name to create one multi-part feature for each municipality's impervious surface (AlexandriaImp.shp, AlringtonImp.shp, FairfaxImp.shp, FallsChurchImp.shp, LoudonImp.shp, ManassasImp.shp, ManassasParkImp.shp, PrinceWilliamCoImp.shp). Due to the size and processing restrictions, the Impervious Surface layer for Fairfax County was not able to be dissolved into a single multi-part feature. A workaround for the remainder of the analysis was performed.

USGS National Hydrography Dataset Best Resolution (NHD) for Hydrologic Unit 02070008, 02070010, and 02070011 file geodatabases were downloaded. The Watershed Boundary Data HUC10 feature classes for each HUC 8 were imported and projected to Lambert Conformal Conic Virginia projected coordinate system. All HUC 10 features were clipped to the NoVA study area boundary and merged to create a layer of HUC10s falling within the study area (HUC10sforAnalysis.shp).

VDOT LRS Route Master data was downloaded, clipped to the NoVA study area boundary, and projected in Lambert Conformal Conic Virginia projected coordinate system. A field (Class) was added and Route Categories were assigned a Class value of Interstate, Primary or Secondary roads, where 'Interstate', 'Interstate Frontage Road', and 'Interstate Ramp' were considered 'Interstate'; 'State Highway Primary' and 'US Highway Primary' were considered 'Primary'; remaining Route Categories were considered 'Secondary'. Using a definition query by each class, layers were created for Interstate, Primary and Secondary road classes with appropriately sized buffers and then all output features were dissolved into single feature. Interstate roads received a 14 foot buffer, Primary roads received a 12 foot buffer, and Secondary roads received a 10 foot buffer (VDOTmasterRteNova_Interstate.shp, VDOTmasterRteNova_Primary.shp, VDOTmasterRteNova_Secondary.shp). Road class layers were merged together to form one layer representing NoVA study area roads by classification with appropriate buffers (NOVA_roads.shp). Using a definition query of the City/County boundaries layer, the NoVA study area roads layer was clipped by each city/county to represent the roads within each boundary (AlexandriaRoads.shp, ArlingtonRoads.shp, FairfaxCityRoads.shp, FairfaxCountyRoads.shp, FallsChurchRoads.shp, LoudonCoRoads.shp, ManassasCityRoads.shp, ManassasParkRoads.shp, PrinceWilliamCoRoads.shp). A field for LandUseCat was added to each individual layer and the classification 'Transportation' was assigned to all road classes within each layer.

All city/county parcel data was imported and projected in Lambert Conformal Conic Virginia projected coordinate system. Fields were cleaned up, removing those not needed for the analyses in this project, and land use category code was identified for future classification.

1.2 Land Use Classification

A broad land use classification system was developed in effort to maintain consistence across all cities and counties. The developed classification system includes the following Commercial/Industrial, Residential, Mixed Use, Open Space/Parks, Special Development Areas, and Transportation (**Appendix Q – Section 1.5, No. 1**). Researcher discretion was used when selecting classifications to each zoning or land use code presented by the municipality (**Appendix Q – Section 1.5, Nos. 2 – 9**). Where land classification data from municipalities existed but was not in direct agreement with this land classification system, municipality land classification stood. For example, in the City of Falls Church, West End

Park falls within a polygon designated as Residential that also covers residential parcels. Therefore, the land classification as Residential stood for this project. Where no classification was assigned by municipality data but could be discerned, classification was digitized and assigned. For example, in the City of Falls Church, the land area of Mary Ellen Middle School and George Mason High School were not included in the parcels data but the boundary could be easily discerned so it was digitized and added to the City of Falls Church land use layer as a Special Development Area.

Tables were created in .CSV format, imported, and copied to the SaMS file geodatabase as standalone tables for each municipality (LUCsAlexandria, LUCsArlington, LUCsFairfaxCity, LUCsFairfaxCounty, LUCsLoudon, LUCsManassas, LUCs PrinceWillCo). Using the existing land use designation codes for each municipality found in both the parcels layers and the standalone tables, the tables were joined to the individual city/county layers and the new field containing the classification system for this project (LandUseCat) was added. Each city/county layer was then dissolved by LandUseCat to produce a layer that contained only one multi-part feature for each different land use category.

To accurately combine the Transportation land use category in with the other established parcel classifications, each city/county roads layer was erased from the corresponding dissolved parcels layer (to prevent any overlap of transportation and parcels), and then merged together to form one overall land use layer for each city/county. A field was added to each output table and geometry was calculated to represent total area in acres for each different land use category. Transportation remained separated by class (interstate, primary, secondary) in case future calculations were needed based on road levels, and total area was manually calculated for the land use category (**Appendix Q – Section 1.6, Nos. 1 – 8**). All totals of land use by city/county were recorded in the spreadsheet for future calculations.

One layer was created to represent the entire NoVA study area land use categories by merging each Land Use layer and dissolving the output features by LandUseCat (MuniciMerge.shp) (**Appendix Q – Section 1.6, No. 9**).

1.3 Imperviousness Analysis

The tabulate intersect tool was used to calculate the total area of imperviousness by land use category for 5 out of 8 of the cities/counties. All cities/counties Land Use layers served as Input Feature Zones with the Land Use Cat field serving as the Zone Field for the Tabulate Intersect. The Input Class Features were the Impervious Surface layer for that city/county. Acres were chosen as the Output Units. The output table for each tabulate intersect includes the Land Use Cat, the Area in Acres, and the Percentage of that land use category covered in Impervious Surface (**Appendix Q – Section 1.7, Nos. 1 – 5**). Due to the size and processing restrictions, the Impervious Surface layers for the counties of Fairfax, Loudoun and Prince William could not be analyzed using the Tabulate Intersect tool. These impervious surface layers required additional processing steps. The layers were first converted to raster format with a 1-meter cell size so that cell count could be easily used to calculate area. The Tabulate Area tool was then used in place of the Tabulate Intersect tool, and acreage of each land use category was calculated from the Value output using the square meter to acreage conversion equation; Sq. Meters * 0.000247105 = acres. The Loudoun County and Prince William County impervious layers also required different processing steps. The Summarize Within tool was used for both of these layers, where the impervious surface layer for the city/county was used as the Input Polygons and the corresponding Land Use layer was selected as the Input Summary Features. All input polygons were kept, the sum of the shape area was calculated in acres, and Land Use Cat served as the Group Field (**Appendix Q – Section 1.7, Nos. 6 – 8**). This data was imported to the master spreadsheet. Formulas for percentages and totals were also used within the spreadsheet as a way to cross-check input data values. Because 100% of the total impervious surface in each city/county did not intersect with a land use classification polygon, an ‘Unclassified’ land use category was created to account for the remaining impervious surface. The ‘Unclassified’ land use category does not contain any specific land use designations, but is made up of any physical space within the city/county boundary that was not classified by the city/county for the purpose of this analysis. It is my belief that much of the impervious surface within ‘Unclassified’ area could be categorized as Transportation (as it appears to be composed of

many sidewalks, medians, cul-de-sacs, etc.), but without any digital intersection of this part of the Impervious Surface layer and any part of the land use category layer, it cannot be categorized as so for this analysis. Totals for the 'Unclassified' land use category were calculated in the data spreadsheet, by finding the difference between total acreage within the city/county boarder and the total acreage of land that was classified by the city/county (total acreage of land in the Land Use layer). The values generated from these steps were input into the spreadsheet with formulas to determine the totals for the entire Northern Virginia study area.

To calculate the amount of imperviousness by land use category in the Accotink Creek watershed and the HUC10 watersheds within the study area, land use layers from the cities/counties intersecting with the watershed boundaries were clipped and merged to fill the watershed boundaries within a separate file geodatabase named 'SaMSbyHUC.gdb'. VGIN's Land Cover Dataset (Bay Area 1: N16_88, N16_89; Bay Area 2: N16_69, N16_78, N16_79, N16_88, N16_89, N16_99, N17_60, N17_61, N17_70, N17_71, N17_80) was downloaded. A new dataset containing only Impervious Surfaces (CLASS_ID 21, 22) was created from VGIN's Land Cover Dataset and clipped to the HUC10 study area boundary to create the Impervious Surface layer for the watershed study area projected in Lambert Conformal Conic Virginia projected coordinate system (Bay1Bay2Merge_Clip.shp). VGIN Buildings Footprint was erased from the Impervious Surface layer and created the layer representing Impervious Surface minus Buildings for the HUC10 study area (Bay1Bay2_Erase.shp). This Impervious Surface layer was then clipped to each individual HUC10 to form Impervious Surface minus Buildings Footprints for each HUC10 of the study area. These layers were then dissolved by Name to create one multi-part feature for each HUC10's impervious surface (Imp0207000802_Dissolve, Imp0207000803_Dissolve, etc.). The Tabulate Intersect tool was used as previously outlined to calculate the same values within a watershed boundary instead of a city/county boundary (**Appendix Q – Section 1.8, #1 – 17**). Totals were entered into the data spreadsheet and the same formulas were used to cross-check input data values.

1.4 Data Sources

1. https://vgin.maps.arcgis.com/home/item.html?id=d3d51bb5431a4d26a313f586c7c2c848
2. https://www.arcgis.com/home/item.html?id=777890ecdb634d18a02eec604db522c6
3. https://www.arcgis.com/home/item.html?id=994d0afa44c046498f9774613671ce9a
4. https://viewer.nationalmap.gov/basic/?basemap=b1&category=nhd&title=NHD%20View#productSearch
5. http://www.virginiaroads.org/datasets/lrs-route-master
6. https://cityofalexandria-alexgis.opendata.arcgis.com/datasets/parcels
7. https://geohub-loudoungis.opendata.arcgis.com/datasets/loudoun-parcels
8. http://gisdata-pwcgov.opendata.arcgis.com/datasets/d95d455a6c30452794816c6d8bb3f150_0

1.5 Land Use Classifications

1. Overall Land Use Classification system used for entirety of the project

Assigned Land Use Category (LandUseCat)	Included Land Uses
Transportation	Interstate, primary and secondary roads
Residential	Single family or multiple family dwellings not attached to businesses
Commercial/Industrial	Commercial or industrial properties not attached to residential properties
Mixed Use	Combinations of residential, commercial, and/or agricultural properties
Open Space/Parks	Open areas not designated for residential or commercial use, parks
Special Development Area	Public education, local/state/federal government or military properties

2. Land Use Classification as applied to existing **City of Alexandria** parcels data

Assigned Land Use Category (LandUseCat)	Included 'LANDCODE' from Parcels data
Residential	100, 110, 120, 130, 140, 145, 150, 300, 310, 320, 330, 600, 739, 743, 782, 801, 802, 911, 930
Commercial/Industrial	400, 401, 402, 445, 449, 450, 451, 452, 460, 470, 472, 474, 475, 481, 484, 485, 486, 487, 488, 489, 492, 493, 495, 496, 610, 614, 616, 735, 736, 750, 760, 762, 780, 790, 792, 940, 941, 942, 983
Mixed Use	160, 770
Open Space/Parks	731, 734, 744, 910, 980
Special Development Area	700, 710, 712, 720, 730, 732, 733, 740, 742

3. Land Use Classification as applied to existing **Arlington County** parcels data

Assigned Land Use Category (LandUseCat)	Included 'property_class' from Parcels data
Residential	300, 301, 310, 311, 312, 313, 410, 411, 412, 413, 414, 415, 510, 511, 512, 513, 514, 515, 518, 519, 528, 540, 541, 542, 611, 612, 613, 614, 616, 630, 640, 641, 642
Commercial/Industrial	100, 101, 110, 111, 112, 212, 213, 214, 215, 216, 217, 218, 219, 251, 252, 253, 254, 290
Mixed Use	201, 210, 266
Open Space/Parks	200
Special Development Area	N/A

4. Land Use Classification as applied to existing **City of Fairfax** parcels data

Assigned Land Use Category (LandUseCat)	Included 'ELU' from Parcels data
Residential	Residential – Multifamily, Residential – Single Attached, Residential – Single Detached
Commercial/Industrial	Auto Dealer, Auto Repair, Commercial/Industrial – Lodging, Commercial/Industrial – Office, Commercial/Industrial – Retail, Industrial
Mixed Use	Vacant
Open Space/Parks	Open Space – Preserved, Open Space – Recreation & Historic, Open Space – Undesignated
Special Development Area	Institutional – City of Fairfax, Institutional – Fairfax County, Institutional – General

5. Land Use Classification as applied to existing **Fairfax County** parcels data

Assigned Land Use Category (LandUseCat)	Included 'CATEG' from Parcels data
Residential	High-density Residential, Low-density Residential, Medium-density Residential
Commercial/Industrial	Commercial, Industrial – light and heavy, Utilities
Mixed Use	Agricultural
Open Space/Parks	Open land, not forested or developed, Recreation
Special Development Area	Institutional, Public

6. Land Use Classification as applied to existing **City of Falls Church** parcels data

Assigned Land Use Category (LandUseCat)	Included 'CATEG' from Parcels data
Residential	R-1A, R-1B, R-C, R-M, R-TH
Commercial/Industrial	B-1, B-2, B-3, M-1, T-2
Mixed Use	C-D, O-D, T-1
Open Space/Parks	N/A
Special Development Area	N/A

7. Land Use Classification as applied to existing **Loudoun County** parcels data

Assigned Land Use Category (LandUseCat)	Included 'OCCUPANCY CODE' from Parcels data
Residential	11, 12, 13, 14, 15, 16, 18, 24, 25, 26, 60
Commercial/Industrial	29, 30, 31, 32, 33, 34, 35, 36, 40, 41, 42, 43, 50, 51, 52, 53, 55, 56, 57, 62, 63, 70, 80, 81, 82, 91
Mixed Use	27
Open Space/Parks	54
Special Development Area	61, 64

8. Land Use Classification as applied to existing **City of Manassas** parcels data

Assigned Land Use Category (LandUseCat)	Included 'ZONING' from Parcels data
Residential	A1, R1, R2, R2S, R3, R4, R5, R6, R7
Commercial/Industrial	B1, B2, B3, B3.5, B4, I1, I2, IA, MULT
Mixed Use	PMD
Open Space/Parks	N/A
Special Development Area	N/A

9. Land Use Classification as applied to existing **Prince William County** parcels data

Assigned Land Use Category (LandUseCat)	Included 'Land_Use' from Parcels data
Residential	11, 12, 13, 14, 15, 16, 21, 28, 29, 31, 33, 38, 39, 41, 42, 43, 44, 45, 46, 47, 49, 50, 52, 54, 57, 58, 59, 61, 62, 71, 73, 77, 79, 93, 99
Commercial/Industrial	72, 74, 75, 76, 81, 82, 83, 84, 85, 86, 87, 89, 111, 112, 121, 126, 127, 131, 135, 136, 137, 140, 146, 147, 150, 151, 156, 157, 160, 166, 167, 190, 191, 211, 212, 213, 214, 216, 217, 218, 219, 221, 222, 223, 224, 225, 226, 229, 231, 232, 239, 311, 312, 313, 314, 315, 316, 317, 318, 320, 331, 332, 333, 334, 335, 336, 337, 341, 342, 343, 344, 349, 351, 352, 353, 354, 361, 362, 363, 364, 365, 366, 369, 390, 410, 421, 422, 425, 426, 427, 428, 429, 431, 432, 435, 436, 490, 510, 520, 530, 540, 550, 590, 610, 620, 630, 640, 650, 660, 680, 690, 710, 718, 720, 751, 753, 754, 755, 759, 760, 790, 821, 822, 972, 973, 990, 972, 973, 990
Mixed Use	48, 56, 91
Open Space/Parks	92, 811, 812, 813, 960, 971
Special Development Area	423, 424, 433, 434, 670, 730, 750, 752, 823

1.6 Output Tables of Total City/County Land Use

1. Land Use attribute table for the **City of Alexandria**

OBJECTID	Shape	Land Use Cat	Class	Shape_Length	Shape_Area	Area Acres
1	Polygon	Commercial/Industrial	<Null>	249753.711557	7492406.838826	1851.412413
2	Polygon	Mixed Use	<Null>	19049.262717	342407.326335	84.610618
3	Polygon	Open Space/Parks	<Null>	268503.79503	3093373.348166	764.388525
4	Polygon	Residential	<Null>	747671.647616	16646077.409475	4113.331672
5	Polygon	Special Development...	<Null>	65252.933713	2559264.745694	632.407532
6	Polygon	Transportation	Primary	119800.127557	443547.359874	109.602843
7	Polygon	Transportation	Secondary	773673.79023	2393887.148214	591.541874
8	Polygon	Transportation	Interstate	86861.558274	381913.912306	94.3729

2. Land Use attribute table for **Arlington County**

OBJECTID	Shape	Land Use Cat	Class	Shape_Length	Shape_Area	Area Acres
1	Polygon	Mixed Use	<Null>	191077.649131	5143060.488872	1270.876801
2	Polygon	Commercial/Industrial	<Null>	309351.871183	13459659.498901	3325.951355
3	Polygon	Mixed Use	<Null>	22382.24377	288804.564525	71.365099
4	Polygon	Open Space/Parks	<Null>	150636.89833	4016016.101163	992.378313
5	Polygon	Residential	<Null>	1109978.101472	28581266.284814	7062.578464
6	Polygon	Transportation	Primary	246447.158161	927492.990652	229.188307
7	Polygon	Transportation	Secondary	1337299.985269	4132326.442717	1021.119199
8	Polygon	Transportation	Interstate	134154.706274	593366.199668	146.623851

3. Land Use attribute table for **City of Fairfax**

OBJECTID	Shape	Land Use Cat	Class	Shape_Length	Shape_Area	Area Acres
1	Polygon	Commercial/Industrial	<Null>	68546.595931	2843505.048153	702.644778
2	Polygon	Mixed Use	<Null>	6372.376364	82949.628691	20.497282
3	Polygon	Open Space/Parks	<Null>	35014.360205	2138448.490582	528.421663
4	Polygon	Residential	<Null>	258565.549523	7645947.813381	1889.353181
5	Polygon	Special Development...	<Null>	31342.75375	1186618.964273	293.219673
6	Polygon	Transportation	Primary	67644.185215	250849.196621	61.986132
7	Polygon	Transportation	Secondary	258286.350346	796880.71919	196.91334
8	Polygon	Transportation	Interstate	147.504826	557.096237	0.137661

4. Land Use attribute table for **Fairfax County**

OBJECTID	Shape	Land Use Cat	Class	Shape_Length	Shape_Area	Area Acres
1	Polygon	Commercial/Industrial	<Null>	1424258.48765	64831287.598691	16020.145891
2	Polygon	Mixed Use	<Null>	8273.231693	270985.353942	66.96188
3	Polygon	Open Space/Parks	<Null>	8618311.590358	271579580.755293	67108.716574
4	Polygon	Residential	<Null>	13590939.99586	455967343.588581	112671.884767
5	Polygon	Special Development...	<Null>	1636709.123864	105411857.87584	26047.814324
6	Polygon	Transportation	Primary	1289477.029515	4784727.735941	1182.330927
7	Polygon	Transportation	Secondary	12488554.723073	38412155.842827	9491.842031
8	Polygon	Transportation	Interstate	736233.999552	3249511.200654	802.970995

5. Land Use attribute table for **City of Falls Church**

OBJECTID	Shape	Land Use Cat	Class	Shape_Length	Shape_Area	Area Acres
1	Polygon	Commercial/Industrial	<Null>	27464.685305	729285.946497	180.210323
2	Polygon	Mixed Use	<Null>	11665.013165	301052.021495	74.391509
3	Polygon	Residential	<Null>	107054.317177	3131302.641035	773.76105
4	Polygon	Transportation	Primary	21468.028582	81171.977476	20.058015
5	Polygon	Transportation	Secondary	102451.22188	311862.933617	77.062941
6	Polygon	Special Development...	<Null>	1683.158957	133969.50542	33.104556

6. Land Use attribute table for **Loudoun County**

OBJECTID	Shape	Land Use Cat	Class	Shape_Length	Shape_Area	Area Acres
1	Polygon	Commercial/Industrial	<Null>	807445.14615	50557237.981274	12492.954533
2	Polygon	Mixed Use	<Null>	7036581.409322	360734321.025645	89139.313202
3	Polygon	Open Space/Parks	<Null>	212512.746021	17510632.068832	4326.967592
4	Polygon	Residential	<Null>	9003490.193721	777029059.695307	192007.892464
5	Polygon	Special Development...	<Null>	617167.619835	58261528.378555	14396.724468
6	Polygon	Transportation	Primary	647605.468974	2375151.319548	586.912154
7	Polygon	Transportation	Secondary	7585933.22306	23318090.366762	5762.020521

7. Land Use attribute table for the **City of Manassas**

OBJECTID	Shape	Land Use Cat	Class	Shape_Length	Shape_Area	Area Acres
2	Polygon	Commercial/Industrial	<Null>	138008.650057	9836511.225217	2430.65271
3	Polygon	Mixed Use	<Null>	8626.517615	332574.705478	82.180927
4	Polygon	Residential	<Null>	327011.164849	11828318.655196	2922.838609
5	Polygon	Transportation	Primary	48765.736082	183486.658278	45.340501
6	Polygon	Transportation	Secondary	405800.413755	1246192.647299	307.940637

8. Land Use attribute table for **Prince William County**

OBJECTID	Shape	Land Use Cat	Class	Shape_Length	Shape_Area	Area Acres
1	Polygon	Commercial/Industrial	<Null>	2047121.036545	162159608.102066	40070.476395
2	Polygon	Mixed Use	<Null>	12807.171128	314727.528634	77.770797
3	Polygon	Open Space/Parks	<Null>	5774465.271947	253005818.32757	62519.043982
4	Polygon	Residential	<Null>	6980196.761922	291546481.302063	72042.640789
5	Polygon	Special Development...	<Null>	392416.210536	115105425.636747	28443.144966
6	Polygon	Transportation	Primary	560649.144667	2083294.247997	514.792765
7	Polygon	Transportation	Secondary	5742082.348803	17617831.9834	4353.457244
8	Polygon	Transportation	Interstate	306031.465077	1325240.323674	327.473726

9. Land Use attribute table for **NoVA study area**

OBJECTID	Shape	Land Use Cat	Shape_Length	Shape_Area	Area Acres
1	Polygon	Commercial/Industrial	5059319.892074	311848160.972904	77059.290653
2	Polygon	Mixed Use	7312644.553095	367810882.385258	90887.968051
3	Polygon	Open Space/Parks	15042622.283323	551308738.715523	136231.235752
4	Polygon	Residential	32087821.940795	1592302412.548776	393466.147222
5	Polygon	Special Development...	2738701.133131	282656201.435743	69845.806733
6	Polygon	Transportation	32738335.812909	104554960.070019	25836.070452

1.7 Output Tables of Land Use/Impervious Surface Tabulate Intersect for Cities/Counties

1. Tabulate Intersect output for the **City of Alexandria**

OBJECTID	Land Use Cat	AREA	PERCENTAGE
1	Commercial/Industrial	719.713943	38.873743
2	Mixed Use	15.083295	17.826701
3	Open Space/Parks	139.892076	18.301158
4	Residential	841.967831	20.469224
5	Special Development...	171.165508	27.065673
6	Transportation	786.06183	98.811279

2. Tabulate Intersect output for **Arlington County**

OBJECTID	Land Use Cat	AREA	PERCENTAGE
1	Commercial/Industrial	1090.120699	32.776178
2	Mixed Use	501.410624	37.356171
3	Open Space/Parks	160.524352	16.175707
4	Residential	1035.828788	14.666426
5	Transportation	1370.011042	98.07281

3. Tabulate Intersect output for the **City of Fairfax**

OBJECTID	Land Use Cat	AREA	PERCENTAGE
1	Commercial/Industrial	402.733665	57.316773
2	Mixed Use	1.392924	6.795647
3	Open Space/Parks	39.314086	7.439901
4	Residential	269.600457	14.269445
5	Special Development...	99.703645	34.003024
6	Transportation	256.323491	98.952325

4. Tabulate Intersect output for the **City of Falls Church**

OBJECTID	Land Use Cat	AREA	PERCENTAGE
1	Commercial/Industrial	98.389511	54.596997
2	Mixed Use	34.522653	46.40667
3	Residential	140.838531	18.201796
4	Special Development...	10.616373	32.069192
5	Transportation	96.947684	99.821503

5. Tabulate Intersect output for **City of Manassas**

OBJECTID	Land Use Cat	AREA	PERCENTAGE
1	Commercial/Industrial	765.597396	31.497577
2	Mixed Use	13.025733	15.850055
3	Residential	358.07782	12.251019
4	Transportation	334.369076	94.646655

6. Tabulate Area output **Fairfax County**

OBJECTID	LANDUSECAT	VALUE_1	Area Acres
1	Commercial/Industrial	25145283	6213.525156
2	Mixed Use	64502	15.938767
3	Open Space/Parks	13816338	3414.086201
4	Residential	38846368	9599.131765
5	Special Development...	15449039	3817.534782
6	Transportation	44896716	11094.203007

7. Tabulate Area output for **Loudoun County**

OBJECTID	LANDUSECAT	VALUE_1	Area Acres
1	Commercial/Industrial	12736445	3147.239242
2	Mixed Use	8212272	2029.293473
3	Open Space/Parks	1090716	269.521377
4	Residential	29451723	7277.668012
5	Special Development...	11815240	2919.60488
6	Transportation	22940712	5668.764639

8. Tabulate Area output for **Prince William County**

OBJECTID	LANDUSECAT	VALUE_1	Area Acres
1	Commercial/Industrial	15983394	3949.576574
2	Mixed Use	15765	3.89561
3	Open Space/Parks	7386927	1825.346596
4	Residential	17806675	4400.118426
5	Special Development...	4651092	1149.308089
6	Transportation	19418851	4798.495176

1.8 Output Tables of Land Use/Impervious Surface Tabulate Intersect for Huc10 Watersheds

1. Tabulate Area output for the **Accotink Creek**

OBJECTID	LANDUSECAT	VALUE_1	Area Acres
1	Commercial/Industrial	6353988	1535.79067
2	Mixed Use	4274	1.033047
3	Open Space/Parks	1933826	467.415413
4	Residential	5293704	1279.514725
5	Special Development...	3026930	731.624116
6	Transportation	7569447	1829.573187

2. Tabulate Intersect output for **Piney Run-Potomac River (0207000802)**

OBJECTID	Land Use Cat	AREA	PERCENTAGE
1	Commercial/Industrial	24.277225	5.132977
2	Mixed Use	49.693242	0.652929
3	Open Space/Parks	0.849754	17.706594
4	Residential	320.812713	2.212105
5	Special Development...	0.969354	42.324136
6	Transportation	166.158347	74.814523

3. Tabulate Intersect output for **South Fork Catoctin Creek (0207000803)**

OBJECTID	Land Use Cat	AREA	PERCENTAGE
1	Commercial/Industrial	100.519328	7.099792
2	Mixed Use	77.43334	0.559498
3	Open Space/Parks	3.357677	31.020737
4	Residential	1015.55188	2.462202
5	Special Development...	28.234049	18.153665
6	Transportation	586.654492	79.807043

4. Tabulate Intersect output for **Tuscarora Creek-Potomac River (0207000804)**

OBJECTID	Land Use Cat	AREA	PERCENTAGE
1	Commercial/Industrial	27.158456	3.345652
2	Mixed Use	51.903379	0.855739
3	Open Space/Parks	11.96948	3.183696
4	Residential	431.912563	2.517982
5	Special Development...	99.163907	6.389925
6	Transportation	281.458949	81.191335

5. Tabulate Intersect output for **Upper Goose Creek (0207000805)**

OBJECTID	Land Use Cat	AREA	PERCENTAGE
1	Commercial/Industrial	28.515828	9.225749
2	Mixed Use	31.395537	0.420696
3	Open Space/Parks	0.673132	36.943453
4	Residential	297.021607	1.353175
5	Special Development...	53.452955	7.620481
6	Transportation	192.279621	88.264597

6. Tabulate Intersect output for **North Fork Goose Creek (0207000806)**

OBJECTID	Land Use Cat	AREA	PERCENTAGE
1	Commercial/Industrial	69.081153	15.260461
2	Mixed Use	79.134813	0.484823
3	Open Space/Parks	33.468962	8.065654
4	Residential	1041.465094	2.426806
5	Special Development...	56.013164	20.028182
6	Transportation	675.589425	90.381735

7. Tabulate Intersect output for **Lower Goose Creek (0207000807)**

OBJECTID	Land Use Cat	AREA	PERCENTAGE
1	Commercial/Industrial	574.452925	21.820148
2	Mixed Use	416.916701	2.633659
3	Open Space/Parks	62.205908	5.563709
4	Residential	1357.017762	4.320183
5	Special Development...	347.406803	19.011476
6	Transportation	1089.947236	94.052285

8. Tabulate Intersect output for **Broad Run-Potomac River (0207000809)**

OBJECTID	Land Use Cat	AREA	PERCENTAGE
1	Commercial/Industrial	2797.397181	37.918764
2	Mixed Use	975.093098	6.196353
3	Open Space/Parks	415.901465	7.785552
4	Residential	2929.904203	13.06626
5	Special Development...	2241.172313	25.997168
6	Transportation	3100.866191	93.925746

9. Tabulate Intersect output for **Difficult Run-Potomac River (0207000810)**

OBJECTID	Land Use Cat	AREA	PERCENTAGE
1	Commercial/Industrial	955.421106	42.877978
2	Mixed Use	5.253648	7.760154
3	Open Space/Parks	557.645992	4.146349
4	Residential	2307.369318	7.505184
5	Special Development...	443.406173	12.998545
6	Transportation	2127.454689	96.376048

10. Tabulate Intersect output for **Rock Creek-Potomac River (0207001001)**

OBJECTID	Land Use Cat	AREA	PERCENTAGE
1	Commercial/Industrial	644.828678	31.675895
2	Mixed Use	276.565024	44.550944
3	Open Space/Parks	128.445105	10.639357
4	Residential	917.652409	12.83871
5	Special Development...	93.001721	19.957004
6	Transportation	1117.565814	97.719207

11. Tabulate Intersect output for **Cameron Run-Potomac River (0207001003)**

OBJECTID	Land Use Cat	AREA	PERCENTAGE
1	Commercial/Industrial	2661.166903	42.567094
2	Mixed Use	276.030662	30.894799
3	Open Space/Parks	830.589982	9.228516
4	Residential	3755.91731	13.715166
5	Special Development...	1106.040538	16.135882
6	Transportation	4073.043431	98.363476

12. Tabulate Intersect output for **Pohick Creek (0207001004)**

OBJECTID	Land Use Cat	AREA	PERCENTAGE
1	Commercial/Industrial	1831.938512	46.418598
2	Mixed Use	6.081247	20.7802
3	Open Space/Parks	904.025579	6.504619
4	Residential	2113.63182	9.774863
5	Special Development...	1519.762542	14.774565
6	Transportation	3046.664028	97.933858

13. Tabulate Intersect output for **Broad Run (0207001005)**

OBJECTID	Land Use Cat	AREA	PERCENTAGE
1	Commercial/Industrial	1651.627554	10.305644
2	Mixed Use	3.149941	5.119904
3	Open Space/Parks	358.190717	2.682028
4	Residential	769.406363	5.205553
5	Special Development...	73.788276	19.354412
6	Transportation	1038.852192	89.895088

14. Tabulate Intersect output for **Cedar Run (0207001006)**

OBJECTID	Land Use Cat	AREA	PERCENTAGE
1	Commercial/Industrial	52.719871	0.833407
2	Mixed Use	1.890113	5.594548
3	Open Space/Parks	29.962157	0.78469
4	Residential	198.937815	2.198037
5	Special Development...	120.369406	1.163887
6	Transportation	152.621755	84.787958

15. Tabulate Intersect output for **Bull Run (0207001007)**

OBJECTID	Land Use Cat	AREA	PERCENTAGE
1	Commercial/Industrial	2841.872283	18.116492
2	Mixed Use	361.26602	5.901608
3	Open Space/Parks	1134.603594	3.352009
4	Residential	3180.361061	6.571208
5	Special Development...	1154.159362	16.99008
6	Transportation	3483.06831	93.362566

16. Tabulate Intersect output for **Occoquan River-Potomac River (0207001008)**

OBJECTID	Land Use Cat	AREA	PERCENTAGE
1	Commercial/Industrial	1615.454432	22.825942
2	Mixed Use	5.769869	26.640371
3	Open Space/Parks	1018.125077	4.56594
4	Residential	2524.863624	7.059838
5	Special Development...	288.348884	12.204216
6	Transportation	2328.446686	94.891961

17. Tabulate Intersect output for **Quantico Creek-Potomac River (0207001101)**

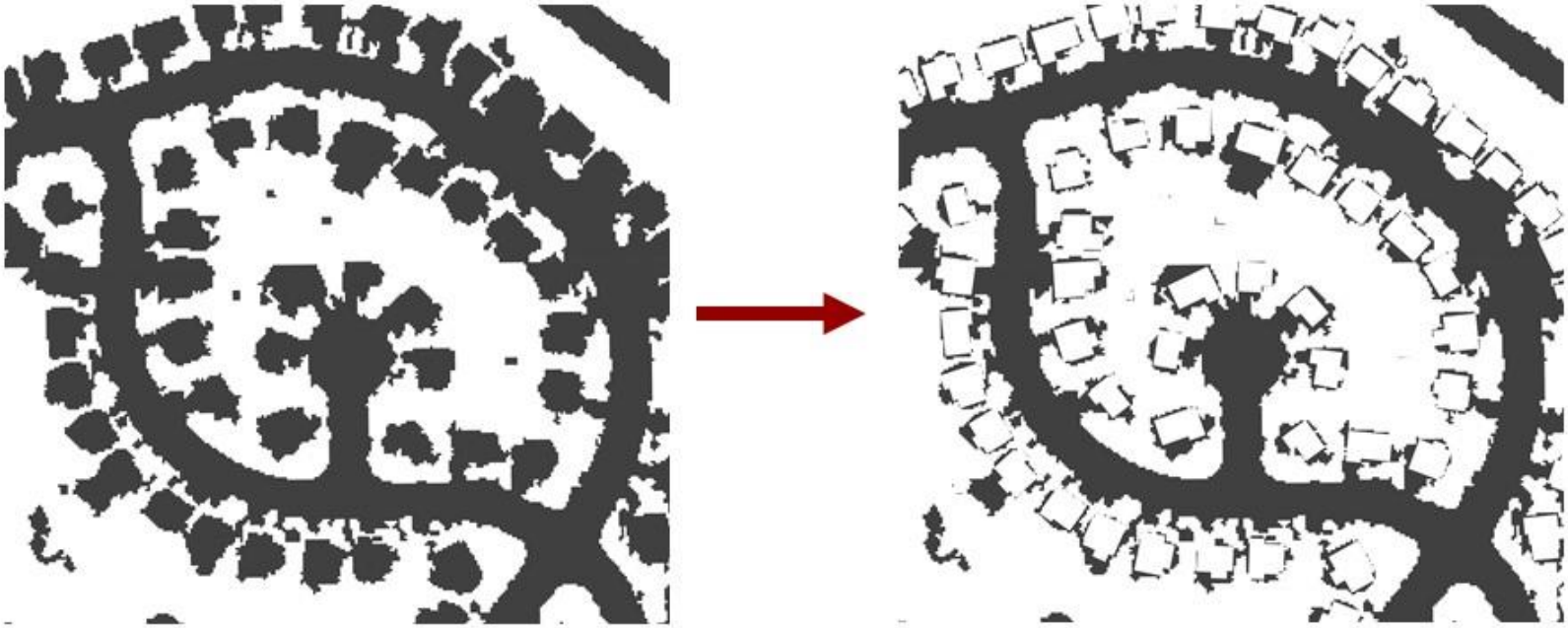
OBJECTID	Land Use Cat	AREA	PERCENTAGE
1	Commercial/Industrial	509.917339	12.721649
2	Mixed Use	1.079088	9.668991
3	Open Space/Parks	379.179032	2.097645
4	Residential	807.825504	11.708885
5	Special Development...	631.056294	4.119756
6	Transportation	913.883016	92.837872

2 Geospatial Analysis Results

Note that the format and style of this has been maintained as submitted by Virginia Commonwealth University's Center for Environmental Studies.

Impervious Surface classified by Land Use Category within Cities and Counties of Northern Virginia study area

METHODS

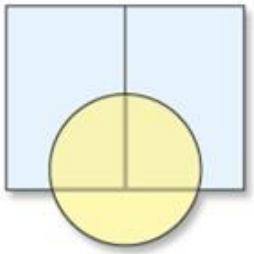


Rooftops were removed from the impervious layer to identify impervious surfaces on the ground, capable of receiving deicing treatments.

Classification Name	Included Land Use
Residential	Single family dwellings, multiple family dwellings
Special Dev Area	Local and Federal government property
Transportation	Interstate, Primary and Secondary roads
Commercial/Industrial	Commercial/Industrial property
Mixed Use	Any combination of residential and commercial/industrial/agricultural
Open Space/Parks	Open spaces, parks
Unclassified	Any land not classified by parcel coverage from city/county government

METHODS

Land Use Categories



Impervious Surface



OUTPUT

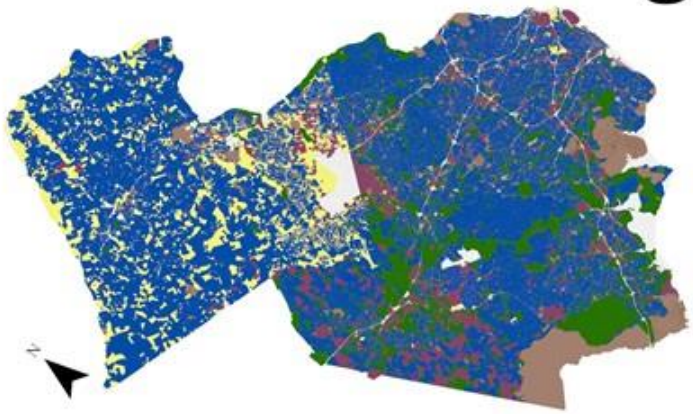


Acres of Impervious Surface

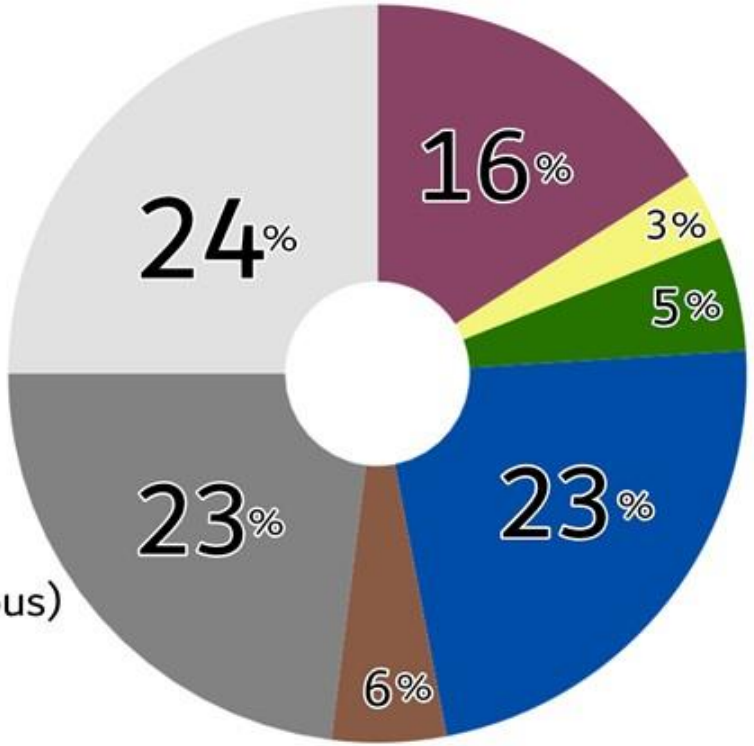
% of this Land Use Cat covered by Impervious Surface

OBJECTID	Land Use Cat	AREA	PERCENTAGE
1	Commercial/Industrial	719.713943	38.873743
2	Mixed Use	15.083295	17.826701
3	Open Space/Parks	139.892076	18.301158
4	Residential	841.967831	20.469224
5	Special Development Area	171.165508	27.065673
6	Transportation	786.06183	98.811279

Northern Virginia Study Area

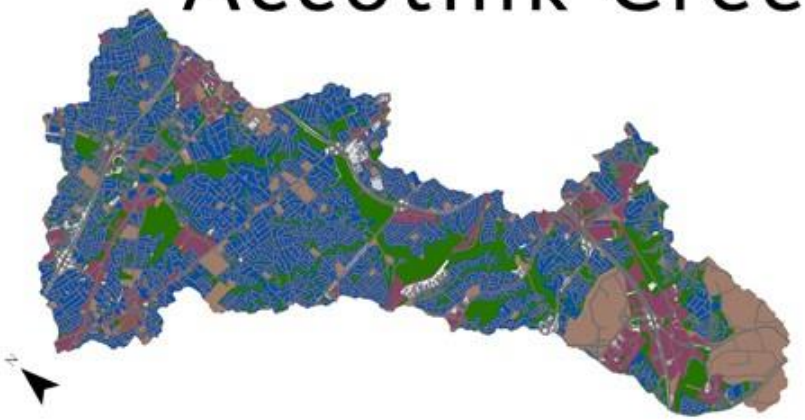


- Residential (is 6% impervious)
- Special Dev Area (is 10% impervious)
- Transportation (is 95% impervious)
- Commercial/Industrial (is 21% impervious)
- Mixed Use (is 3% impervious)
- Open Space/Parks (is 4% impervious)
- Unclassified (is 38% impervious)

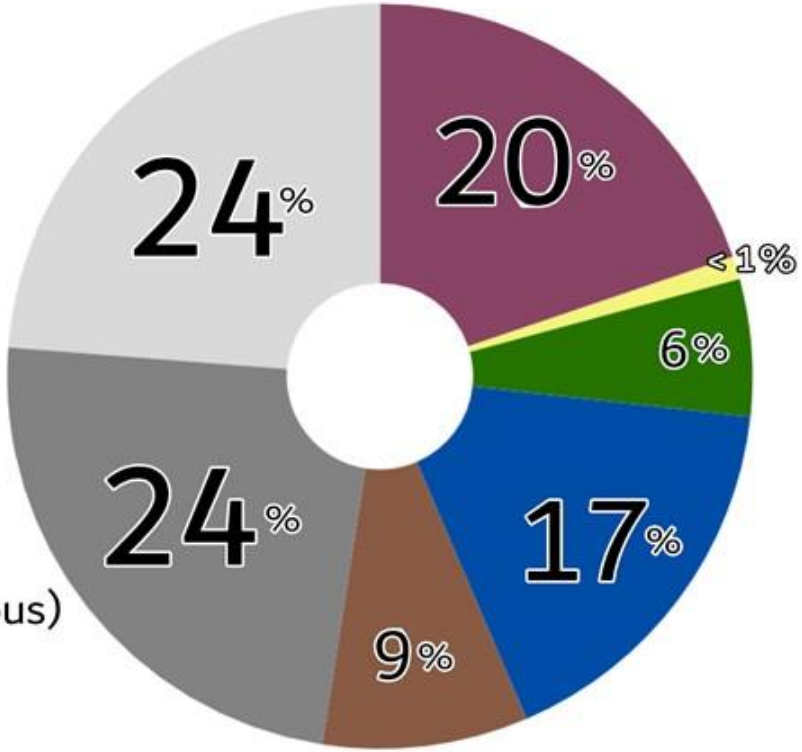


Percentage of Total Imperviousness in Study Area made up by each Land Use Category

Accotink Creek Watershed

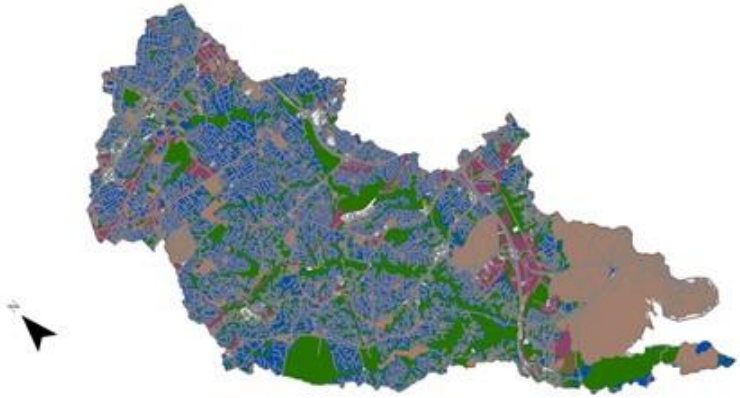


- Residential (is 10% impervious)
- Special Dev Area (is 19% impervious)
- Transportation (is 96% impervious)
- Commercial/Industrial (is 47% impervious)
- Mixed Use (is 6% impervious)
- Open Space/Parks (is 8% impervious)
- Unclassified (is 53% impervious)

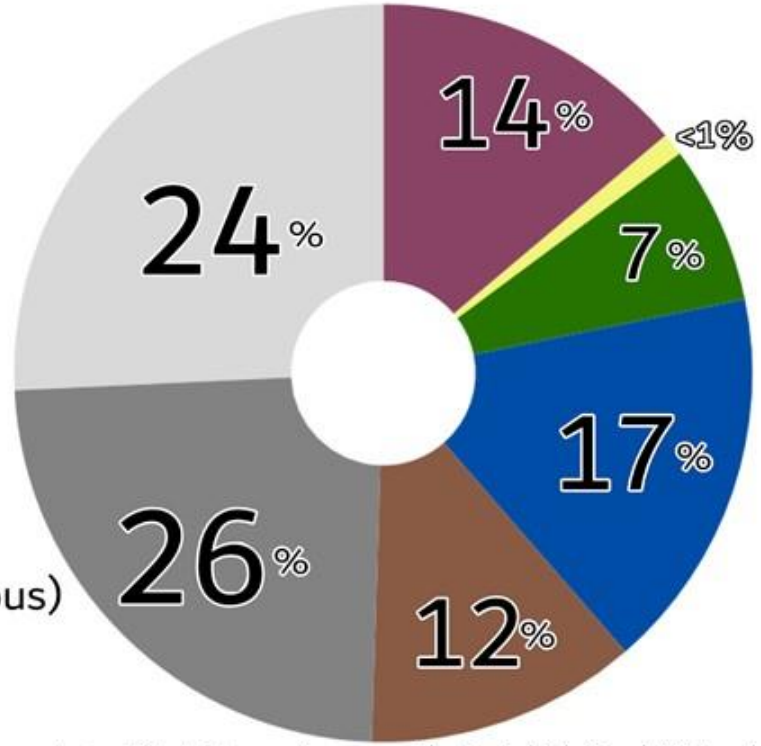


Percentage of Total Imperviousness in the Accotink Creek Watershed made up by each Land Use Category

Pohick Creek Watershed



- Residential (is 9% impervious)
- Special Dev Area (is 14% impervious)
- Transportation (is 95% impervious)
- Commercial/Industrial (is 45% impervious)
- Mixed Use (is 17% impervious)
- Open Space/Parks (is 6% impervious)
- Unclassified (is 62% impervious)

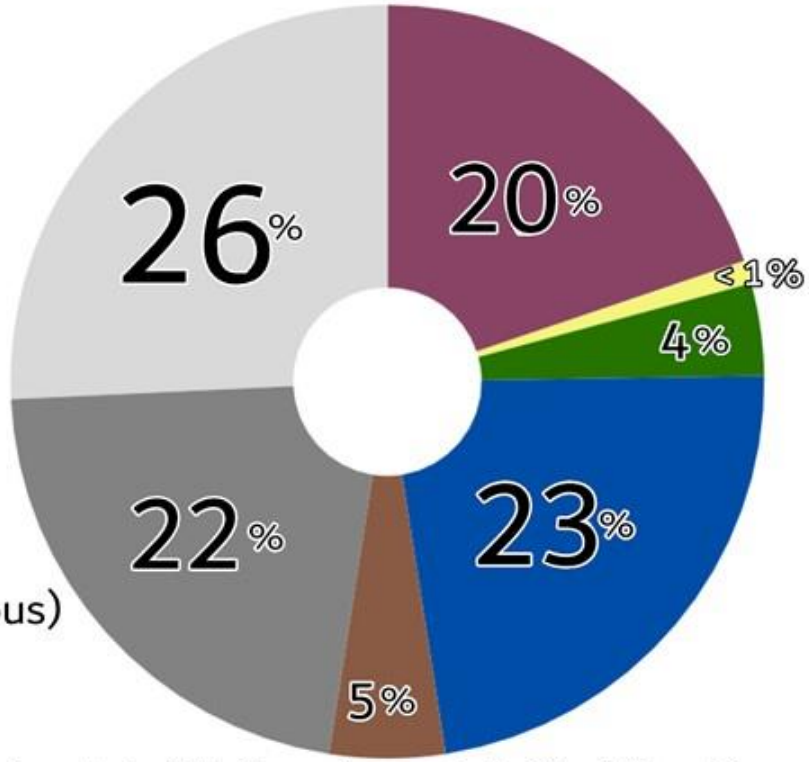


Percentage of Total Imperviousness the in Pohick Creek Watershed made up by each Land Use Category

City of Alexandria

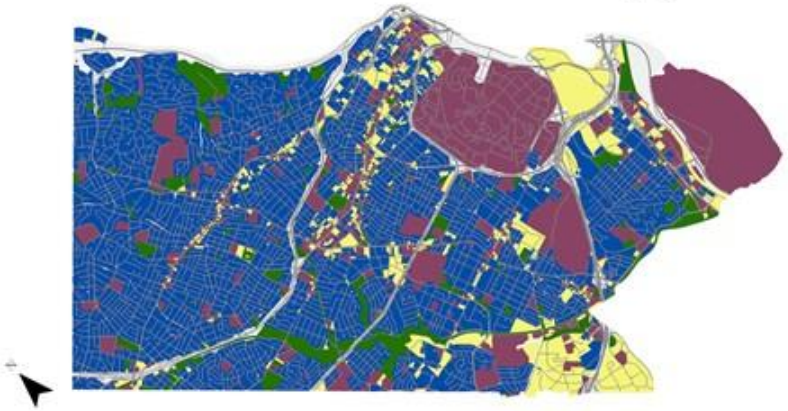


- Residential (is 20% impervious)
- Special Dev Area (is 27% impervious)
- Transportation (is 99% impervious)
- Commercial/Industrial (is 39% impervious)
- Mixed Use (is 18% impervious)
- Open Space/Parks (is 18% impervious)
- Unclassified (is 60% impervious)

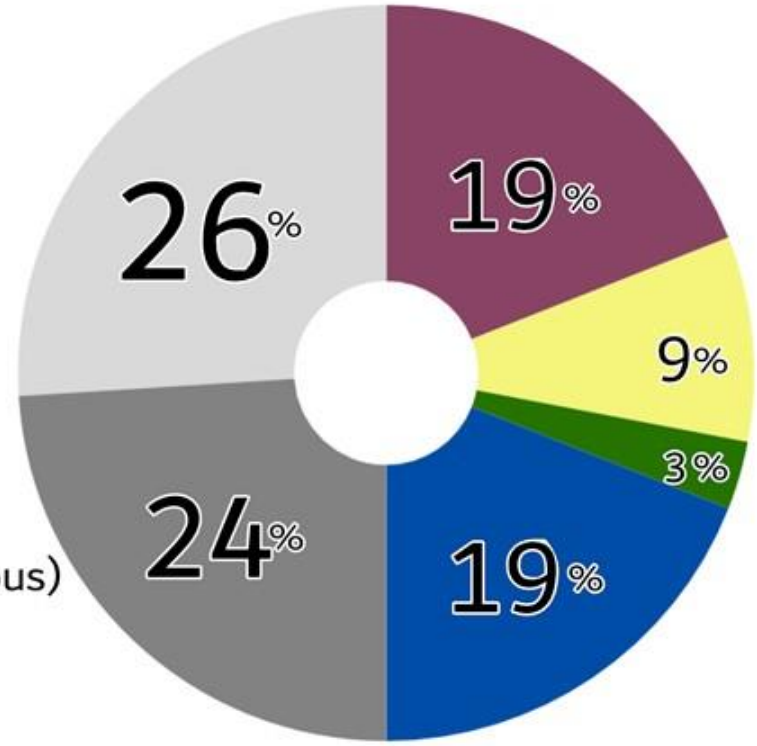


Percentage of Total Imperviousness in the City of Alexandria made up by each Land Use Category

Arlington County



- Residential (is 15% impervious)
- Transportation (is 98% impervious)
- Commercial/Industrial (is 33% impervious)
- Mixed Use (is 37% impervious)
- Open Space/Parks (is 16% impervious)
- Unclassified (is 58% impervious)

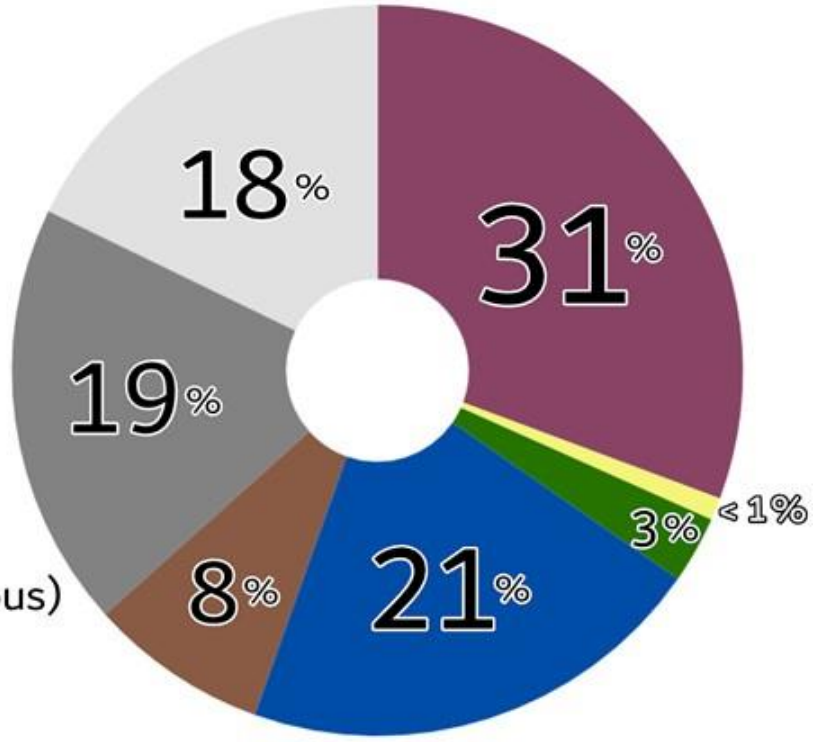


Percentage of Total Imperviousness in Arlington County made up by each Land Use Category

City of Fairfax

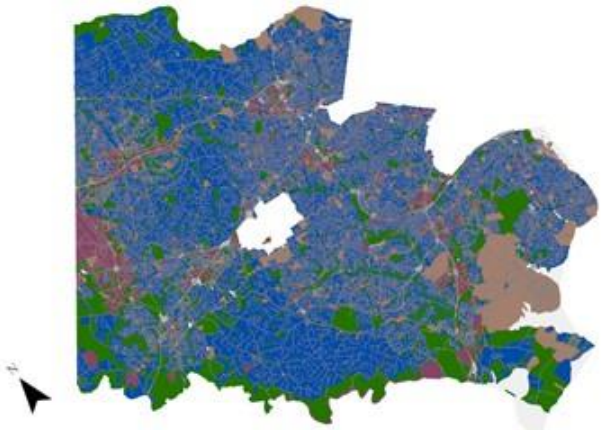


- Residential (is 14% impervious)
- Special Dev Area (is 29% impervious)
- Transportation (is 99% impervious)
- Commercial/Industrial (is 57% impervious)
- Mixed Use (is 7% impervious)
- Open Space/Parks (is 7% impervious)
- Unclassified (is 86% impervious)

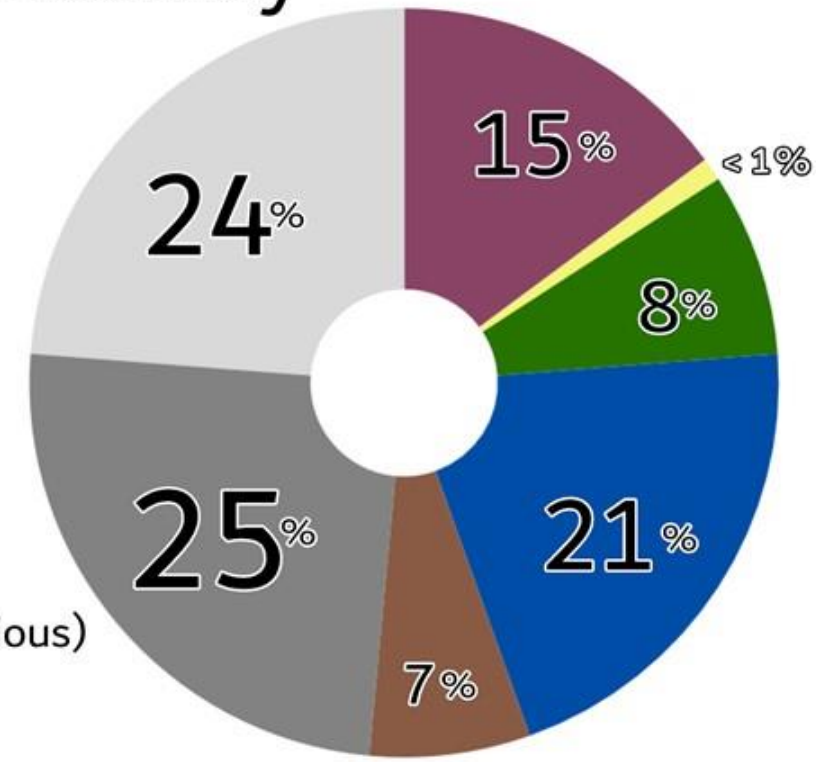


Percentage of Total Imperviousness in City of Fairfax made up by each Land Use Category

Fairfax County

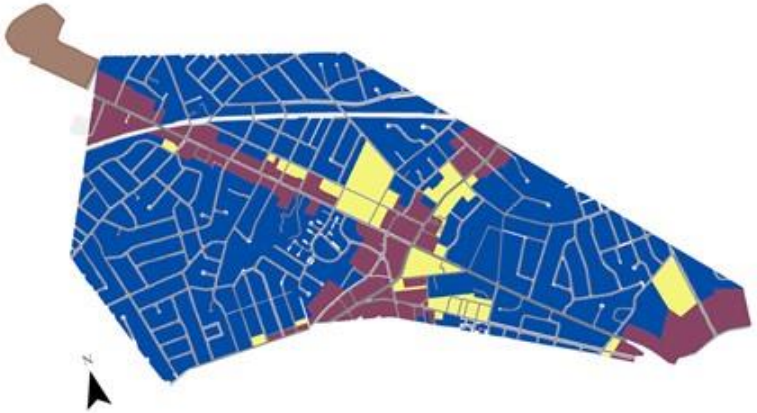


- Residential (is 9% impervious)
- Special Dev Area (is 14% impervious)
- Transportation (is 97% impervious)
- Commercial/Industrial (is 36% impervious)
- Mixed Use (is 24% impervious)
- Open Space/Parks (is 5% impervious)
- Unclassified (is 40% impervious)

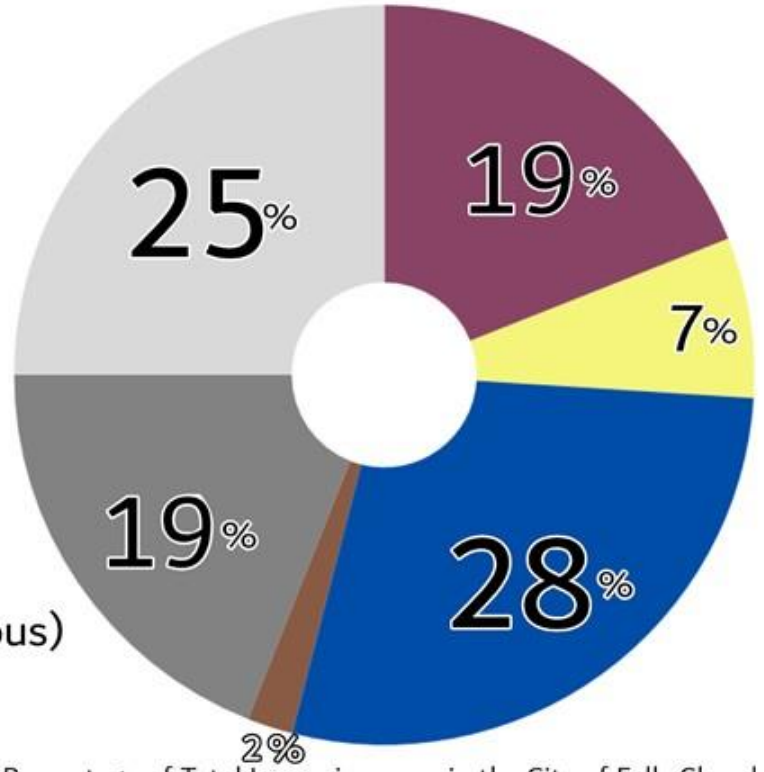


Percentage of Total Imperviousness in Fairfax County made up by each Land Use Category

City of Falls Church

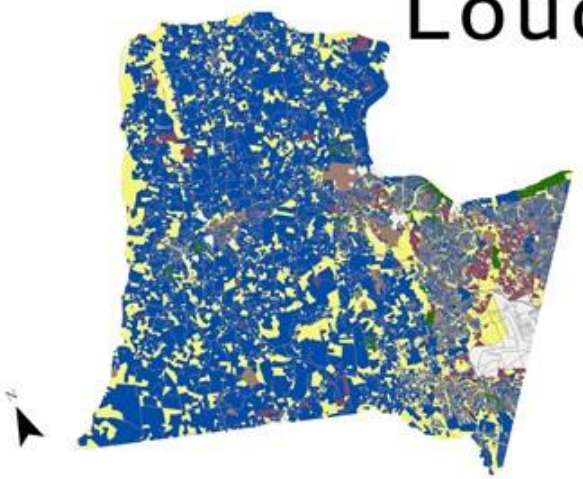


- Residential (is 18% impervious)
- Special Dev Area (is 32% impervious)
- Transportation (is 99% impervious)
- Commercial/Industrial (is 55% impervious)
- Mixed Use (is 46% impervious)
- Unclassified (is 84% impervious)

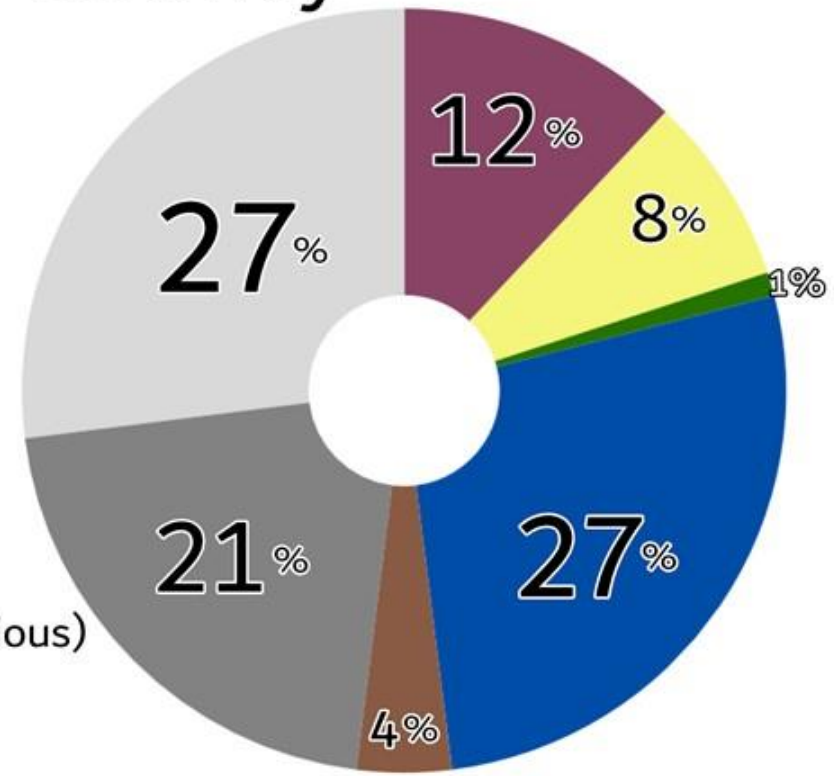


Percentage of Total Imperviousness in the City of Falls Church made up by each Land Use Category

Loudoun County

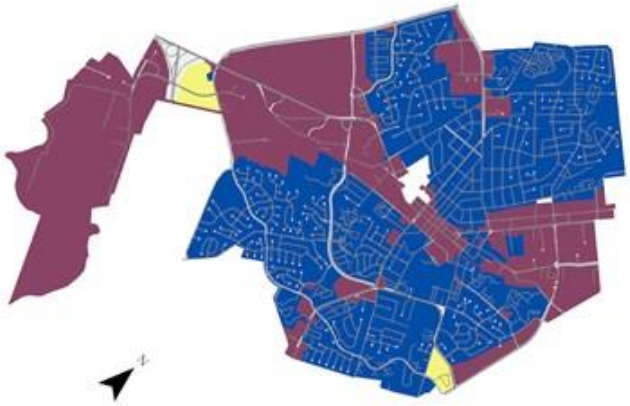


- Residential (is 4% impervious)
- Special Dev Area (is 17% impervious)
- Transportation (is 89% impervious)
- Commercial/Industrial (is 25% impervious)
- Mixed Use (is 2% impervious)
- Open Space/Parks (is 6% impervious)
- Unclassified (is 33% impervious)

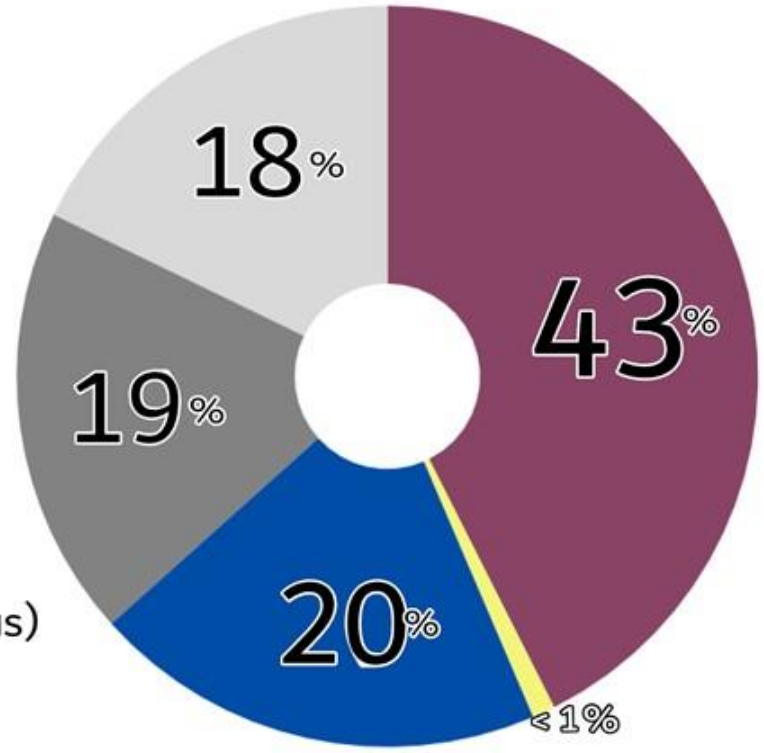


Percentage of Total Imperviousness in Loudoun County made up by each Land Use Category

City of Manassas

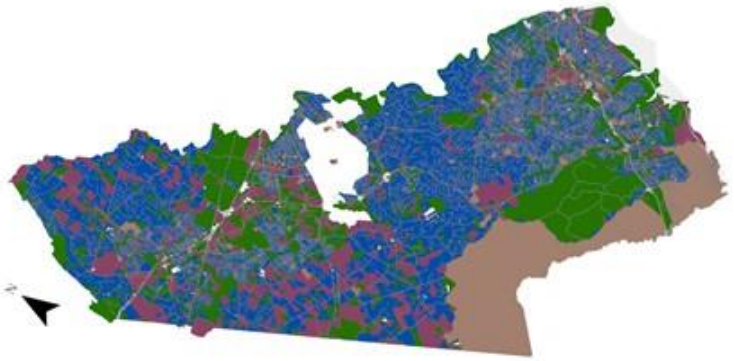


- Residential (is 12% impervious)
- Transportation (is 95% impervious)
- Commercial/Industrial (is 32% impervious)
- Mixed Use (is 16% impervious)
- Unclassified (is 55% impervious)

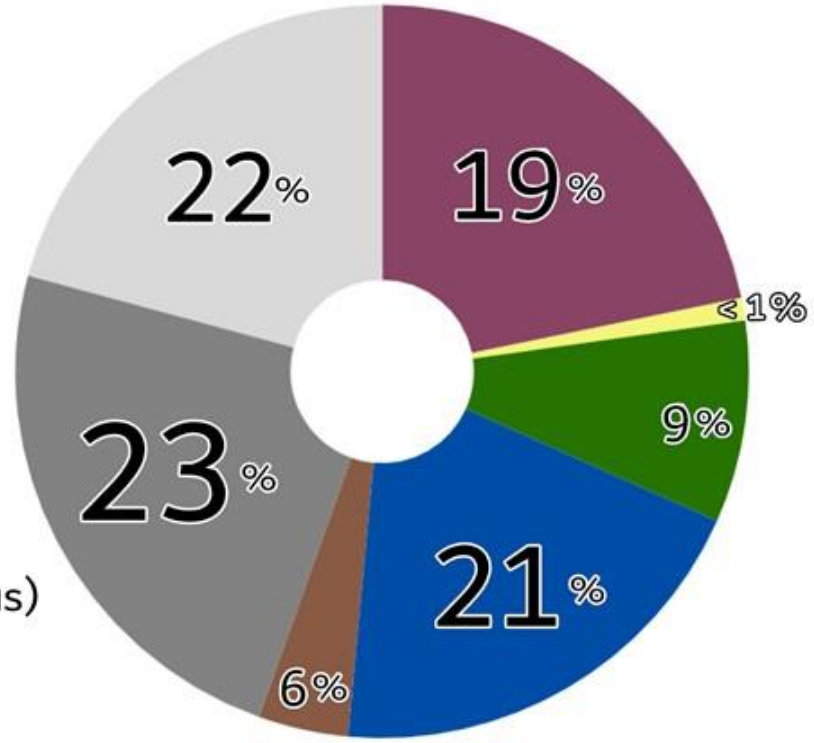


Percentage of Total Imperviousness in the City of Manassas made up by each Land Use Category

Prince William County



- Residential (is 6% impervious)
- Special Dev Area (is 4% impervious)
- Transportation (is 92% impervious)
- Commercial/Industrial (is 9% impervious)
- Mixed Use (is 5% impervious)
- Open Space/Parks (is 3% impervious)
- Unclassified (is 32% impervious)



Percentage of Total Imperviousness in Prince William County made up by each Land Use Category

3 Spatial Analysis Statistics

3.1 NoVA Study Area

Municipality Name	**ALL NOVA STUDY AREA EXCLUDING ANY DATA FROM MANASSAS PARK**				
Total Impervious Acres	105395.09				
Total Classified Land Use Cat Acres	793326.53				
				% of Land Use Cat covered in Impervious Surface	**% of total Impervious Surface**
Land Use Cat	**Total Acres**	**Imp Acres**	**Imp Sq Ft**		
Commercial/Industrial	77059.29	16386.83	713810314.8	21.27	15.55
Mixed Use	90887.97	2614.64	113893718.4	2.88	2.48
Open Space/Parks	136231.24	5848.68	254768500.8	4.29	5.55
Residential	393466.15	23923.24	1042096334	6.08	22.70
Special Development Area	69845.81	6431.83	280170514.8	9.21	6.10
Transportation	25836.07	24405.15	1063088334	94.46	23.16
Unclassified	61034.37	25784.72	1123182403	42.25	24.46
TOTAL	**854360.9**	**105395.09**	**4591010120**		*100*

Total Acreage within study area boundary	854360.9	
Total Classified land Acreage	793326.53	
Total Unclassified land Acreage	61034.37	
Total Impervious Surface Acreage within Boundary		105395.09
% of Total Acreage covered by Impervious Surface		12.336132
% of Unclassified land within Boundary	7.14	

Municipality Name	**ALL NOVA STUDY AREA INCLUDING MANASSAS PARK (WHICH IS ALL UNCLASSIFIED)**				
Total Impervious Acres	105809.45				
Total Classified Land Use Cat Acres	793326.53				
				% of Land Use Cat covered in Impervious Surface	**% of total Impervious Surface**
Land Use Cat	**Total Acres**	**Imp Acres**	**Imp Sq Ft**		
Commercial/Industrial	77059.29	16386.83	713810314.8	21.27	15.49

Mixed Use	90887.97	2614.64	113893718.4	2.88	2.47
Open Space/Parks	136231.24	5848.68	254768500.8	4.29	5.53
Residential	393466.15	23923.24	1042096334	6.08	22.61
Special Development Area	69845.81	6431.83	280170514.8	9.21	6.08
Transportation	25836.07	24405.15	1063088334	94.46	23.07
Unclassified	62647.22	26199.08	1141231925	41.82	24.76
TOTAL	**855973.75**	**105809.45**	**4609059642**		*100*

Total Acreage within study area boundary	855973.75
Total Classified land Acreage	793326.53
Total Unclassified land Acreage	62647.22

Total Impervious Surface Acreage within Boundary	105809.45
% of Total Acreage covered by Impervious Surface	12.361296
% of Unclassified land within Boundary	7.32

3.2 All Municipality Data

Municipality Name	**Alexandria**
Total Impervious Acres	3625.6
Total Classified Land Use Cat Acres	8241.67

Land Use Cat	Total Acres	Imp Acres	Imp Sq Ft	% of Land Use Cat covered in Impervious Surface	% of total Impervious Surface
Commercial/Industrial	1851.41	719.71	31350567.6	38.87	19.85
Mixed Use	84.61	15.08	656884.8	17.82	0.42
Open Space/Parks	764.39	139.89	6093608.4	18.30	3.86
Residential	4113.33	841.97	36676213.2	20.47	23.22
Special Development Area	632.41	171.17	7456165.2	27.07	4.72
Transportation	795.52	786.06	34240773.6	98.81	21.68
Unclassified	1582.35	951.72	41456923.2	60.15	26.25
TOTAL	**9824.02**	**3625.6**	**157931136**		*100*

Total Acreage within city/county boundary	9824.02

Total Classified land Acreage	8241.67
Total Unclassified land Acreage	1582.35

Total Impervious Surface Acreage within Boundary	3625.6
% of Total Acreage covered by Impervious Surface	36.905462
% of Unclassified land within Boundary	16.11
% of Unclassified Imperviousness within Boundary	26.25

Municipality Name	**Arlington**
Total Impervious Acres	5646.45
Total Classified Land Use Cat Acres	14120.1

Land Use Cat	Total Acres	Imp Acres	Imp Sq Ft	% of Land Use Cat covered in Impervious Surface	% of total Impervious Surface
Commercial/Industrial	3325.96	1090.12	47485627.2	32.78	19.31
Mixed Use	1342.25	501.41	21841419.6	37.36	8.88
Open Space/Parks	992.38	160.52	6992251.2	16.18	2.84
Residential	7062.58	1035.83	45120754.8	14.67	18.34
Transportation	1396.93	1370.01	59677635.6	98.07	24.26
Unclassified	2561.13	1488.56	64841673.6	58.12	26.36
TOTAL	**16681.23**	**5646.45**	**245959362**		*100*

Total Acreage within city/county boundary	16681.23
Total Classified land Acreage	14120.1
Total Unclassified land Acreage	2561.13

Total Impervious Surface Acreage within Boundary	5646.45
% of Total Acreage covered by Impervious Surface	33.849123
% of Unclassified land within Boundary	15.35
% of Unclassified Imperviousness within Boundary	26.36

Municipality Name	**Fairfax City**
Total Impervious Acres	1306.83

Total Classified Land Use Cat Acres 3740.17

Land Use Cat	Total Acres	Imp Acres	Imp Sq Ft	% of Land Use Cat covered in Impervious Surface	% of total Impervious Surface
Commercial/Industrial	702.64	402.73	17542918.8	57.32	30.82
Mixed Use	20.5	1.39	60548.4	6.78	0.11
Open Space/Parks	528.42	39.31	1712343.6	7.44	3.01
Residential	1889.35	269.6	11743776	14.27	20.63
Special Development Area	340.22	99.7	4342932	29.30	7.63
Transportation	259.04	256.32	11165299.2	98.95	19.61
Unclassified	276.56	237.78	10357696.8	85.98	18.20
TOTAL	**4016.73**	**1306.83**	**56925514.8**		*100*

Total Acreage within city/county boundary	4016.73
Total Classified land Acreage	3740.17
Total Unclassified land Acreage	276.56

Total Impervious Surface Acreage within Boundary	1306.83
% of Total Acreage covered by Impervious Surface	32.534674
% of Unclassified land within Boundary	6.89
% of Unclassified Imperviousness within Boundary	18.20

Municipality Name **Fairfax County**

Total Impervious Acres 44962.84

Total Classified Land Use Cat Acres 233392.66

Land Use Cat	Total Acres	Imp Acres	Imp Sq Ft	% of Land Use Cat covered in Impervious Surface	% of total Impervious Surface
Commercial/Industrial	16020.15	6213.53	270661366.8	38.79	13.82
Mixed Use	66.96	15.94	694346.4	23.81	0.04
Open Space/Parks	67108.72	3414.09	148717760.4	5.09	7.59

Residential	112671.88	9599.13	418138102.8	8.52	21.35
Special Development Area	26047.81	3817.53	166291606.8	14.66	8.49
Transportation	11477.14	11094.2	483263352	96.66	24.67
Unclassified	26845.43	10808.42	470814775.2	40.26	24.04
TOTAL	**260238.09**	**44962.84**	**1958581310**		*100*

Total Acreage within city/county boundary	260238.09	
Total Classified land Acreage	233392.66	
Total Unclassified land Acreage	26845.43	
Total Impervious Surface Acreage within Boundary		44962.84
% of Total Acreage covered by Impervious Surface		17.277578
% of Unclassified land within Boundary	10.32	
% of Unclassified Imperviousness within Boundary		24.04

Municipality Name	**Falls Church**
Total Impervious Acres	506.46
Total Classified Land Use Cat Acres	1158.58

Land Use Cat	**Total Acres**	**Imp Acres**	**Imp Sq Ft**	**% of Land Use Cat covered in Impervious Surface**	**% of total Impervious Surface**
Commercial/Industrial	180.21	98.39	4285868.4	54.60	19.43
Mixed Use	74.39	34.52	1503691.2	46.40	6.82
Residential	773.76	140.84	6134990.4	18.20	27.81
Special Development Area	33.1	10.62	462607.2	32.08	2.10
Transportation	97.12	96.95	4223142	99.82	19.14
Unclassified	148.65	125.14	5451098.4	84.18	24.71
TOTAL	**1307.23**	**506.46**	**22061397.6**		*100*

Total Acreage within city/county boundary	1307.23
Total Classified land Acreage	1158.58
Total Unclassified land Acreage	148.65

Total Impervious Surface Acreage within Boundary	506.46
% of Total Acreage covered by Impervious Surface	38.742991
% of Unclassified land within Boundary	11.37
% of Unclassified Imperviousness within Boundary	24.71

Municipality Name	**Loudon County**
Total Impervious Acres	26936.71
Total Classified Land Use Cat Acres	318711.58

Land Use Cat	**Total Acres**	**Imp Acres**	**Imp Sq Ft**	**% of Land Use Cat covered in Impervious Surface**	**% of total Impervious Surface**
Commercial/Industrial	12492.95	3147.17	137090725.2	25.19	11.68
Mixed Use	89139.31	2029.37	88399357.2	2.28	7.53
Open Space/Parks	4326.97	269.52	11740291.2	6.23	1.00
Residential	192006.7	7277.67	317015305.2	3.79	27.02
Special Development Area	14396.72	1183.51	51553695.6	8.22	4.39
Transportation	6348.93	5668.77	246931621.2	89.29	21.04
Unclassified	14792.11	7360.7	320632092	49.76	27.33
TOTAL	**333503.69**	**26936.71**	**1173363088**		*100*

Total Acreage within city/county boundary	333503.69
Total Classified land Acreage	318711.58
Total Unclassified land Acreage	14792.11

Total Impervious Surface Acreage within Boundary	26936.71
% of Total Acreage covered by Impervious Surface	8.0768851
% of Unclassified land within Boundary	4.44
% of Unclassified Imperviousness within Boundary	27.33

Municipality Name	**Manassas City**

Total Impervious Acres	1786.77
Total Classified Land Use Cat Acres	5788.95

Land Use Cat	Total Acres	Imp Acres	Imp Sq Ft	% of Land Use Cat covered in Impervious Surface	% of total Impervious Surface
Commercial/Industrial	2430.65	765.6	33349536	31.50	42.85
Mixed Use	82.18	13.03	567586.8	15.86	0.73
Residential	2922.84	358.08	15597964.8	12.25	20.04
Transportation	353.28	334.34	14563850.4	94.64	18.71
Unclassified	574.68	315.72	13752763.2	54.94	17.67
TOTAL	**6363.63**	**1786.77**	**77831701.2**		*100*

Total Acreage within city/county boundary	6363.63	
Total Classified land Acreage	5788.95	
Total Unclassified land Acreage	574.68	
Total Impervious Surface Acreage within Boundary		1786.77
% of Total Acreage covered by Impervious Surface		28.077842
% of Unclassified land within Boundary	9.03	
% of Unclassified Imperviousness within Boundary		17.67

Municipality Name	**Manassas Park**
Total Impervious Acres	414.36
Total Classified Land Use Cat Acres	0

Land Use Cat	Total Acres	Imp Acres	Imp Sq Ft	% of Land Use Cat covered in Impervious Surface	% of total Impervious Surface
Commercial/Industrial	0	0	0	0	0
Mixed Use	0	0	0	0	0
Open Space/Parks	0	0	0	0	0
Residential	0	0	0	0	0
Special Development Area	0	0	0	0	0

Transportation	0	0	0	0	0
Unclassified	0	0	0	0	0
TOTAL	**0**	**0**	**0**	0	*0*

Total Acreage within city/county boundary	1612.85
Total Classified land Acreage	0
Total Unclassified land Acreage	1612.85

Total Impervious Surface Acreage within Boundary	414.36
% of Total Acreage covered by Impervious Surface	25.691168
% of Unclassified land within Boundary	100
% of Unclassified Imperviousness within Boundary	100

Municipality Name	**Prince William County**
Total Impervious Acres	20623.43
Total Classified Land Use Cat Acres	208348.79

Land Use Cat	**Total Acres**	**Imp Acres**	**Imp Sq Ft**	**% of Land Use Cat covered in Impervious Surface**	**% of total Impervious Surface**
Commercial/Industrial	40070.48	3949.58	172043704.8	9.86	19.15
Mixed Use	77.77	3.9	169884	5.01	0.02
Open Space/Parks	62519.04	1825.35	79512246	2.92	8.85
Residential	72042.64	4400.12	191669227.2	6.11	21.34
Special Development Area	28443.14	1149.3	50063508	4.04	5.57
Transportation	5195.72	4798.5	209022660	92.35	23.27
Unclassified	14077.49	4496.68	195875380.8	31.94	21.80
TOTAL	**222426.28**	**20623.43**	**898356611**		*100*

Total Acreage within city/county boundary	222426.28
Total Classified land Acreage	208348.79
Total Unclassified land Acreage	14077.49

Total Impervious Surface Acreage within Boundary	20623.43
% of Total Acreage covered by Impervious Surface	9.2720294
% of Unclassified land within Boundary	6.33
% of Unclassified Imperviousness within Boundary	21.80

3.3 Watershed Data

Watershed Name/HUC12	**Accotink Creek Watershed**
Total Impervious Acres	7668.78
Total Classified Land Use Cat Acres	27656.16

Land Use Cat	**Total Acres**	**Imp Acres**	**Imp Sq Ft**	**% of Land Use Cat covered in Impervious Surface**	**% of total Impervious Surface**
Commercial/Industrial	3300.47	1535.8	66899448	46.53	20.03
Mixed Use	17.9	1.03	44866.8	5.75	0.01
Open Space/Parks	5760.23	467.41	20360379.6	8.11	6.09
Residential	12714.88	1279.51	55735455.6	10.06	16.68
Special Development Area	3954.02	731.62	31869367.2	18.50	9.54
Transportation	1908.66	1829.57	79696069.2	95.86	23.86
Unclassified	3439.55	1823.84	79446470.4	53.03	23.78
TOTAL	**31095.71**	**7668.78**	**334052057**		*100*

Total Acreage within watershed boundary	31095.71
Total Classified land Acreage	27656.16
Total Unclassified land Acreage	3439.55

Total Impervious Surface Acreage within Waterhsed Boundary	7668.78
% of Total Acreage covered by Impervious Surface	24.66
% of Unclassified land within Boundary	11.06

Watershed Name/HUC10	**Pohick Creek / 0207001004**					
Total Impervious Acres		12345.48				
Total Classified Land Use Cat Acres		52894.41				
Land Use Cat	**Total Acres**		**Imp Acres**	**Imp Sq Ft**	**% of Land Use Cat covered in Impervious Surface**	**% of total Impervious Surface**
Commercial/Industrial		3946.56	1831.94	79799306.4	46.42	14.84
Mixed Use		29.26	6.08	264844.8	20.78	0.05
Open Space/Parks		13898.2	904.03	39379546.8	6.50	7.32
Residential		21623.12	2113.63	92069722.8	9.77	17.12
Special Development Area		10286.33	1519.76	66200745.6	14.77	12.31
Transportation		3110.94	3046.67	132712945.2	97.93	24.68
Unclassified		5390.86	2923.37	127341997.2	54.23	23.68
TOTAL		**58285.27**	**12345.48**	**537769109**		*100*

Total Acreage within watershed boundary		58285.27	
Total Classified land Acreage		52894.41	
Total Unclassified land Acreage		5390.86	
Total Impervious Surface Acreage within Watershed Boundary			12345.48
% of Total Acreage covered by Impervious Surface			21.18
% of Unclassified land within Boundary	9.25		

Watershed Name/HUC10	**Piney Run-Potomac River / 0207000802**					
Total Impervious Acres		659.27				
Total Classified Land Use Cat Acres		22815.55				
Land Use Cat	**Total Acres**		**Imp Acres**	**Imp Sq Ft**	**% of Land Use Cat covered in Impervious Surface**	**% of total Impervious Surface**
Commercial/Industrial		472.97	24.28	1057636.8	5.13	3.68
Mixed Use		7610.82	0.6	26136	0.01	0.09

Open Space/Parks	4.8	17.71	771447.6	368.96	2.69
Residential	14502.58	2.21	96267.6	0.02	0.34
Special Development Area	2.29	42.32	1843459.2	1848.03	6.42
Transportation	222.09	166.16	7237929.6	74.82	25.20
Unclassified	909.58	405.99	17684924.4	44.63	61.58
TOTAL	**23725.13**	**659.27**	**28717801.2**		*100*

Total Acreage within watershed boundary	23725.13	
Total Classified land Acreage	22815.55	
Total Unclassified land Acreage	909.58	
Total Impervious Surface Acreage within Watershed Boundary		659.27
% of Total Acreage covered by Impervious Surface		2.78
% of Unclassified land within Boundary	3.83	

Watershed Name/HUC10	**South Fork Catocin Creek / 0207000803**
Total Impervious Acres	2205.33
Total Classified Land Use Cat Acres	57402.68

Land Use Cat	**Total Acres**	**Imp Acres**	**Imp Sq Ft**	**% of Land Use Cat covered in Impervious Surface**	**% of total Impervious Surface**
Commercial/Industrial	1415.81	100.52	4378651.2	7.10	4.56
Mixed Use	13839.78	77.43	3372850.8	0.56	3.51
Open Space/Parks	10.82	3.36	146361.6	31.05	0.15
Residential	41245.65	1015.56	44237793.6	2.46	46.05
Special Development Area	155.53	28.23	1229698.8	18.15	1.28
Transportation	735.09	586.65	25554474	79.81	26.60
Unclassified	1761.65	393.58	17144344.8	22.34	17.85
TOTAL	**59164.33**	**2205.33**	**96064174.8**		*100*

Total Acreage within watershed boundary	59164.33
Total Classified land Acreage	57402.68
Total Unclassified land Acreage	1761.65

Total Impervious Surface Acreage within Watershed Boundary		2205.33
% of Total Acreage covered by Impervious Surface		3.73
% of Unclassified land within Boundary	2.98	

Watershed Name/HUC10	**Tuscarora Creek-Potomac River / 0207000804**
Total Impervious Acres	1067.94
Total Classified Land Use Cat Acres	26304.68

Land Use Cat	**Total Acres**	**Imp Acres**	**Imp Sq Ft**	**% of Land Use Cat covered in Impervious Surface**	**% of total Impervious Surface**
Commercial/Industrial	811.75	27.16	1183089.6	3.35	2.54
Mixed Use	6065.32	51.9	2260764	0.86	4.86
Open Space/Parks	375.96	11.97	521413.2	3.18	1.12
Residential	17153.11	431.91	18813999.6	2.52	40.44
Special Development Area	1551.88	99.16	4319409.6	6.39	9.29
Transportation	346.66	281.46	12260397.6	81.19	26.36
Unclassified	826.01	164.38	7160392.8	19.90	15.39
TOTAL	**27130.69**	**1067.94**	**46519466.4**		*100*

Total Acreage within watershed boundary	27130.69	
Total Classified land Acreage	26304.68	
Total Unclassified land Acreage	826.01	
Total Impervious Surface Acreage within Watershed Boundary		1067.94
% of Total Acreage covered by Impervious Surface		3.94
% of Unclassified land within Boundary	3.04	

** A portion of this HUC10 falls outside of the NOVA Study Area, therefore the amount of Unclassified Land Use/Unclassified Impervious Surface will be higher*

Watershed Name/HUC10	**Upper Goose Creek / 0207000805**
Total Impervious Acres	2153.4
Total Classified Land Use Cat Acres	30642.9

Land Use Cat	Total Acres		Imp Acres	Imp Sq Ft	% of Land Use Cat covered in Impervious Surface	% of total Impervious Surface
Commercial/Industrial		309.09	28.52	1242331.2	9.23	1.32
Mixed Use		7462.75	31.39	1367348.4	0.42	1.46
Open Space/Parks		1.82	0.67	29185.2	36.81	0.03
Residential		21949.96	297.02	12938191.2	1.35	13.79
Special Development Area		701.44	53.45	2328282	7.62	2.48
Transportation		217.84	192.28	8375716.8	88.27	8.93
Unclassified		77167.29	1550.07	67521049.2	2.01	71.98
TOTAL		**107810.19**	**2153.4**	**93802104**		*100*

Total Acreage within watershed boundary	107810.19	
Total Classified land Acreage	30642.9	
Total Unclassified land Acreage	77167.29	
Total Impervious Surface Acreage within Watershed Boundary		2153.40
% of Total Acreage covered by Impervious Surface		2.00
% of Unclassified land within Boundary	71.58	

Watershed Name/HUC10	**North Fork Goose Creek / 0207000806**
Total Impervious Acres	2342.07
Total Classified Land Use Cat Acres	61132.21

Land Use Cat	Total Acres		Imp Acres	Imp Sq Ft	% of Land Use Cat covered in Impervious Surface	% of total Impervious Surface
Commercial/Industrial		452.68	69.08	3009124.8	15.26	2.95
Mixed Use		16322.41	79.13	3446902.8	0.48	3.38
Open Space/Parks		414.96	33.47	1457953.2	8.07	1.43
Residential		42915.01	1041.47	45366433.2	2.43	44.47
Special Development Area		279.67	56.01	2439795.6	20.03	2.39
Transportation		747.48	675.59	29428700.4	90.38	28.85
Unclassified		1527.4	387.32	16871659.2	25.36	16.54

TOTAL	**62659.61**	**2342.07**	**102020569**	*100*

Total Acreage within watershed boundary	62659.61
Total Classified land Acreage	61132.21
Total Unclassified land Acreage	1527.4
Total Impervious Surface Acreage within Watershed Boundary	2342.07
% of Total Acreage covered by Impervious Surface	3.74
% of Unclassified land within Boundary	2.44

** A portion of this HUC10 falls outside of the NOVA Study Area, therefore the amount of Unclassified Land Use/Unclassified Impervious Surface will be higher*

Watershed Name/HUC10	**Lower Goose Creek / 0207000807**
Total Impervious Acres	5290.78
Total Classified Land Use Cat Acres	53978.38

Land Use Cat	**Total Acres**	**Imp Acres**	**Imp Sq Ft**	**% of Land Use Cat covered in Impervious Surface**	**% of total Impervious Surface**
Commercial/Industrial	2632.7	574.45	25023042	21.82	10.86
Mixed Use	15830.31	416.92	18161035.2	2.63	7.88
Open Space/Parks	1118.06	62.21	2709867.6	5.56	1.18
Residential	31411.09	1357.02	59111791.2	4.32	25.65
Special Development Area	1827.35	347.41	15133179.6	19.01	6.57
Transportation	1158.87	1089.95	47478222	94.05	20.60
Unclassified	22690.71	1442.82	62849239.2	6.36	27.27
TOTAL	**76669.09**	**5290.78**	**230466377**		*100*

Total Acreage within watershed boundary	76669.09
Total Classified land Acreage	53978.38
Total Unclassified land Acreage	22690.71
Total Impervious Surface Acreage within Watershed Boundary	5290.78
% of Total Acreage covered by Impervious Surface	6.90

% of Unclassified land within Boundary	29.60

Watershed Name/HUC10	**Broad Run-Potomac River / 0207000809**
Total Impervious Acres	16292.16
Total Classified Land Use Cat Acres	62801.47

Land Use Cat	Total Acres	Imp Acres	Imp Sq Ft	% of Land Use Cat covered in Impervious Surface	% of total Impervious Surface
Commercial/Industrial	7377.33	2797.4	121854744	37.92	17.17
Mixed Use	15736.55	975.09	42474920.4	6.20	5.99
Open Space/Parks	5341.96	415.9	18116604	7.79	2.55
Residential	22423.41	2929.9	127626444	13.07	17.98
Special Development Area	8620.82	2241.17	97625365.2	26.00	13.76
Transportation	3301.4	3100.87	135073897.2	93.93	19.03
Unclassified	6882.15	3831.83	166914514.8	55.68	23.52
TOTAL	**69683.62**	**16292.16**	**709686490**		*100*

Total Acreage within watershed boundary	69683.62	
Total Classified land Acreage	62801.47	
Total Unclassified land Acreage	6882.15	
Total Impervious Surface Acreage within Watershed Boundary		16292.16
% of Total Acreage covered by Impervious Surface		23.38
% of Unclassified land within Boundary	9.88	

Watershed Name/HUC10	**Difficult Run-Potomac River / 0207000810**
Total Impervious Acres	8433.2
Total Classified Land Use Cat Acres	52107.35

Land Use Cat	Total Acres	Imp Acres	Imp Sq Ft	% of Land Use Cat covered in Impervious Surface	% of total Impervious Surface

Commercial/Industrial	2228.23	955.42	41618095.2	42.88	11.33
Mixed Use	67.7	5.25	228690	7.75	0.06
Open Space/Parks	13449.07	557.65	24291234	4.15	6.61
Residential	30743.65	2307.37	100509037.2	7.51	27.36
Special Development Area	3411.2	443.41	19314939.6	13.00	5.26
Transportation	2207.5	2127.45	92671722	96.37	25.23
Unclassified	4444.56	2036.65	88716474	45.82	24.15
TOTAL	**56551.91**	**8433.2**	**367350192**		*100*

Total Acreage within watershed boundary	56551.91	
Total Classified land Acreage	52107.35	
Total Unclassified land Acreage	4444.56	
Total Impervious Surface Acreage within Watershed Boundary		8433.20
% of Total Acreage covered by Impervious Surface		14.91
% of Unclassified land within Boundary	7.86	

Watershed Name/HUC10 **Rock Creek-Potomac River / 0207001001**

Total Impervious Acres	4284.12
Total Classified Land Use Cat Acres	12620.95

Land Use Cat	**Total Acres**	**Imp Acres**	**Imp Sq Ft**	**% of Land Use Cat covered in Impervious Surface**	**% of total Impervious Surface**
Commercial/Industrial	2035.71	644.83	28088794.8	31.68	15.05
Mixed Use	620.78	276.57	12047389.2	44.55	6.46
Open Space/Parks	1207.26	128.45	5595282	10.64	3.00
Residential	7147.54	917.65	39972834	12.84	21.42
Special Development Area	466.01	93	4051080	19.96	2.17
Transportation	1143.65	1117.57	48681349.2	97.72	26.09
Unclassified	2273.71	1106.05	48179538	48.65	25.82
TOTAL	**14894.66**	**4284.12**	**186616267**		*100*

Total Acreage within watershed boundary	14894.66
Total Classified land Acreage	12620.95

Total Unclassified land Acreage	2273.71	
Total Impervious Surface Acreage within Watershed Boundary		4284.12
% of Total Acreage covered by Impervious Surface		28.76
% of Unclassified land within Boundary	15.27	

Watershed Name/HUC10	**Cameron Run-Potomac River / 0207001003**
Total Impervious Acres	17007.65
Total Classified Land Use Cat Acres	54525.85

Land Use Cat	**Total Acres**	**Imp Acres**	**Imp Sq Ft**	**% of Land Use Cat covered in Impervious Surface**	**% of total Impervious Surface**
Commercial/Industrial	6251.69	2661.17	115920565.2	42.57	15.65
Mixed Use	893.45	276.03	12023866.8	30.89	1.62
Open Space/Parks	9000.25	830.59	36180500.4	9.23	4.88
Residential	27385.12	3755.92	163607875.2	13.72	22.08
Special Development Area	6854.53	1106.04	48179102.4	16.14	6.50
Transportation	4140.81	4073.04	177421622.4	98.36	23.95
Unclassified	8724.85	4304.86	187519701.6	49.34	25.31
TOTAL	**63250.7**	**17007.65**	**740853234**		*100*

Total Acreage within watershed boundary	63250.7	
Total Classified land Acreage	54525.85	
Total Unclassified land Acreage	8724.85	
Total Impervious Surface Acreage within Watershed Boundary		17007.65
% of Total Acreage covered by Impervious Surface		26.89
% of Unclassified land within Boundary	13.79	

** A portion of this HUC10 falls outside of the NOVA Study Area, therefore the amount of Unclassified Land Use/Unclassified Impervious Surface will be higher*

Watershed Name/HUC10	**Broad Run / 0207001005**
Total Impervious Acres	5964.55

Total Classified Land Use Cat Acres	45760.51

Land Use Cat	Total Acres	Imp Acres	Imp Sq Ft	% of Land Use Cat covered in Impervious Surface	% of total Impervious Surface
Commercial/Industrial	16026.42	1651.63	71945002.8	10.31	27.69
Mixed Use	61.52	3.15	137214	5.12	0.05
Open Space/Parks	13355.21	358.19	15602756.4	2.68	6.01
Residential	14780.48	769.41	33515499.6	5.21	12.90
Special Development Area	381.25	73.79	3214292.4	19.35	1.24
Transportation	1155.63	1038.85	45252306	89.89	17.42
Unclassified	42903.97	2069.53	90148726.8	4.82	34.70
TOTAL	**88664.48**	**5964.55**	**259815798**		*100*

Total Acreage within watershed boundary	88664.48	
Total Classified land Acreage	45760.51	
Total Unclassified land Acreage	42903.97	
Total Impervious Surface Acreage within Watershed Boundary		5964.55
% of Total Acreage covered by Impervious Surface		6.73
% of Unclassified land within Boundary	48.39	

** A portion of this HUC10 falls outside of the NOVA Study Area, therefore the amount of Unclassified Land Use/Unclassified Impervious Surface will be higher*

Watershed Name/HUC10	**Cedar Run / 0207001006**
Total Impervious Acres	3010.25
Total Classified Land Use Cat Acres	29750.65

Land Use Cat	Total Acres	Imp Acres	Imp Sq Ft	% of Land Use Cat covered in Impervious Surface	% of total Impervious Surface
Commercial/Industrial	6325.82	52.72	2296483.2	0.83	1.75
Mixed Use	33.78	1.89	82328.4	5.60	0.06
Open Space/Parks	3818.34	29.96	1305057.6	0.78	1.00

Residential	9050.7	198.94	8665826.4	2.20	6.61
Special Development Area	10342.01	120.37	5243317.2	1.16	4.00
Transportation	180	152.62	6648127.2	84.79	5.07
Unclassified	95576.74	2453.75	106885350	2.57	81.51
TOTAL	**125327.39**	**3010.25**	**131126490**		*100*

Total Acreage within watershed boundary	125327.39	
Total Classified land Acreage	29750.65	
Total Unclassified land Acreage	95576.74	
Total Impervious Surface Acreage within Watershed Boundary		3010.25
% of Total Acreage covered by Impervious Surface		2.40
% of Unclassified land within Boundary	76.26	

Watershed Name/HUC10	**Bull Run / 0207001007**
Total Impervious Acres	15765
Total Classified Land Use Cat Acres	114578.75

Land Use Cat	**Total Acres**	**Imp Acres**	**Imp Sq Ft**	**% of Land Use Cat covered in Impervious Surface**	**% of total Impervious Surface**
Commercial/Industrial	15686.64	2841.87	123791857.2	18.12	18.03
Mixed Use	6121.48	361.27	15736921.2	5.90	2.29
Open Space/Parks	33848.43	1134.6	49423176	3.35	7.20
Residential	48398.38	3180.36	138536481.6	6.57	20.17
Special Development Area	6793.13	1154.16	50275209.6	16.99	7.32
Transportation	3730.69	3483.07	151722529.2	93.36	22.09
Unclassified	9416.32	3609.67	157237225.2	38.33	22.90
TOTAL	**123995.07**	**15765**	**686723400**		*100*

Total Acreage within watershed boundary	123995.07	
Total Classified land Acreage	114578.75	
Total Unclassified land Acreage	9416.32	
Total Impervious Surface Acreage within Watershed Boundary		15765

% of Total Acreage covered by Impervious Surface	12.71
% of Unclassified land within Boundary	7.59

** A portion of area within this HUC10 boundary is made up of Occoquan and Belmont Bay, therefore the amount of Unclassified Land Use Category will be higher*

Watershed Name/HUC10	**Occoquan River-Potomac River / 0207001008**
Total Impervious Acres	10175.67
Total Classified Land Use Cat Acres	69977.38

Land Use Cat	**Total Acres**	**Imp Acres**	**Imp Sq Ft**	**% of Land Use Cat covered in Impervious Surface**	**% of total Impervious Surface**
Commercial/Industrial	7077.27	1615.45	70369002	22.83	15.88
Mixed Use	21.66	5.77	251341.2	26.64	0.06
Open Space/Parks	22298.24	1018.13	44349742.8	4.57	10.01
Residential	35763.73	2524.86	109982901.6	7.06	24.81
Special Development Area	2362.7	288.35	12560526	12.20	2.83
Transportation	2453.78	2328.45	101427282	94.89	22.88
Unclassified	10843.88	2394.66	104311389.6	22.08	23.53
TOTAL	**80821.26**	**10175.67**	**443252185**		*100*

Total Acreage within watershed boundary	80821.26
Total Classified land Acreage	69977.38
Total Unclassified land Acreage	10843.88

Total Impervious Surface Acreage within Watershed Boundary	10175.67
% of Total Acreage covered by Impervious Surface	12.59
% of Unclassified land within Boundary	13.42

** A portion of area within this HUC10 boundary is made up of the Potomac River,*

Watershed Name/HUC10	**Quantico Creek-Potomac River / 0207001101**

therefore the amount of Unclassified Land Use Category will be higher

Total Impervious Acres	4148.69
Total Classified Land Use Cat Acres	45297.25

Land Use Cat	**Total Acres**	**Imp Acres**	**Imp Sq Ft**	**% of Land Use Cat covered in Impervious Surface**	**% of total Impervious Surface**
Commercial/Industrial	4008.26	509.92	22212115.2	12.72	12.29
Mixed Use	11.16	1.08	47044.8	9.68	0.03
Open Space/Parks	18076.4	379.18	16517080.8	2.10	9.14
Residential	6899.25	807.83	35189074.8	11.71	19.47
Special Development Area	15317.79	631.06	27488973.6	4.12	15.21
Transportation	984.39	913.88	39808612.8	92.84	22.03
Unclassified	2978.35	905.74	39454034.4	30.41	21.83
TOTAL	**48275.6**	**4148.69**	**180716936**		*100*

Total Acreage within watershed boundary	48275.6
Total Classified land Acreage	45297.25
Total Unclassified land Acreage	2978.35

Total Impervious Surface Acreage within Watershed Boundary	4148.69
% of Total Acreage covered by Impervious Surface	8.59
% of Unclassified land within Boundary	6.17

Appendix R. Northern Virginia and D.C Metro Area Forums Relevant to SaMS Implementation

1 Northern Virginia Forums

- Chief Administrative Officers (CAOs) forum: NVRC convenes
    - This forum is a periodic gathering of Northern Virginia CAOs to discuss issues of shared interest among local political jurisdictions.
    - Northern Virginia CAO's were briefed (abbreviated) on SaMS at their March 2019 meeting.
    - To the extent that SaMS implementation may require additional funding resources, and especially any collaborative funding, additional discussions with the CAO's will be valuable.
- Clean Water Partners (CWP, a stormwater management network): NVRC convenes
    - CWP is a partnership of Northern Virginia local governments, schools, water and sanitary sewer authorities, businesses, and the Virginia Coastal Zone Management Program, which is convened by the Northern Virginia Regional Commission.
    - The CWP's have observed that uncontrolled stormwater is the number one cause of poor stream and river quality in Northern Virginia, and they share the goal of working together to keep residents healthy and safe by eliminating pollution that reaches local surface waters.
    - With its focus on uncontrolled stormwater, the CWP have high interest in many aspects of SaMS, and their network is seen as an important forum to explore opportunities for collaborative implementation of SaMS.
    - Communications on levels of service and plans for implementing enhanced winter maintenance BMPs with the public and elected officials is a specific element of SaMS implementation that CWP anticipates addressing in the future.
- Potomac Watershed Roundtable: administered by NVSWCD, with funding from DEQ.
    - The Potomac Watershed Roundtable is a regional government-citizen forum whose purpose is to promote collaboration and cooperation on environmental concerns, especially water quality issues, among various local governments and stakeholder interest groups residing within the Virginia side of the middle and lower Potomac River watershed.
    - The Roundtable's quarterly forums provide an opportunity to discuss and support SaMS though engaging its broad set of stakeholders.
    - The Roundtable featured a discussion of SaMS in July 2017.
- Fairfax County Green Breakfasts: administered by NVSWCD
    - NVSWCD hosts bi-monthly Green Breakfast programs in Fairfax, which provide an opportunity to discuss and support SaMS though engaging its broad set of stakeholders, especially high participation by area "master naturalists."
    - NVSWCD featured a discussion of SaMS in 2018 and 2020 and expects to continue to periodically spotlight SaMS implementation in the future.
- Occoquan Watershed Monitoring Subcommittee: DEQ oversees
    - The past several Subcommittee meetings have included discussion of SaMS, and the subcommittee provides an opportunity to ensure member organizations are current on SaMS implementation efforts.
    - The subcommittee focuses primarily on technical and scientific information, and could serve to advance understanding and action planning in those aspects of SaMS, including the water quality monitoring and research recommendations in **Section 7**.

2 D.C. Metro Area Forums

- Chesapeake Bay & Water Resources Policy Committee (CBPC), chaired by Metropolitan Washington Council of Governments (MWCOG)
    - The CBPC meets bi-monthly, with elected officials, utilities and technical staff membership/participation.
    - Winter salts were a primary topic of their May 2019 meeting and the committee has a high level of interest to support SaMS during its implementation.
- Water Resources Technical Committee (WRTC), chaired by MWCOG
    - The WRTC meets bi-monthly; members include stormwater technical staff and wastewater utility staff.
    - Its subcommittee on WQ Monitoring has identified winter salts as an issue of significant interest. This forum plans quarterly meetings in 2020 and could be a prime opportunity to support SaMS WQ monitoring and research recommendations.
- Potomac River Basin Drinking Water Source Protection Partnership, chaired by ICPRB
    - The Source Protection Partnership meets quarterly; members are government agencies and water utilities.
    - Informal coordination among water utilities on the issue of winter salts is already well established and will likely continue into future.
    - This forum would likely have great interest to support SaMS implementation efforts, including public education and awareness and may have interest/ability to provide funding support for selected activities to support SaMS implementation.
- MWCOG Snow Call Coordination
    - This forum convenes calls in advance of winter storms so that DOTs and jurisdictions can make weather decisions.
    - About 100 people have a conference call that includes representatives from the National Weather Service, Office of Personnel Management, local jurisdictions, local transportation agencies and public works agencies, Washington Metropolitan Area Transit Authority (Metrobus and rail) and State Departments of Transportation for Maryland and Virginia.
- MWCOG Water Security Work Group
    - Water utility General Managers meet quarterly on a variety of water sector issues.
- MWCOG Community Engagement Campaign
    - Ad hoc MWCOG committee of water utilities and local jurisdictions for education and outreach on water and wastewater topics, including source water protection.

3 Additional Forums

- **Potomac Watershed Partnership** is a collaboration of federal, state, and local partners to restore the health of Potomac River Basin land and waters, to enhance the quality of life and overall health of the Chesapeake Bay. The Cacapon Institute coordinates and typically hosts annual information exchanges.

- **Chesapeake Bay Program's Work Groups:** the Local Government Advisory Group, Local Leadership Work Group, Communications Workgroup and Urban Stormwater Workgroup provide many potential forums for additional government engagement and communications, information sharing, and messaging to seek feedback with wide audiences and learn of others' salt management activities.

Appendix S. Public Participation

Development of the SaMS Toolkit involved the considerable, ongoing participation of diverse stakeholders. This appendix provides a list of participation events related to SaMS development. Comments and responses from the public review process are also provided.

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1 Participation Events

Table 42, below, summarizes the participation events held as part of the SaMS process. Meeting minutes are available for download for workgroup, SAC, and Steering Committee meetings.

Table 42. SaMS public participation events.

Meeting Type	Name	Date	Participants (#)
Public	First Meeting	January 17, 2018	37
	Community Listening Session	December 3, 2019	25
	Second Meeting	January 21, 2021	77
Steering Committee	Meeting	September 30, 2020	18
Stakeholder Advisory Committee (SAC)	First Meeting	February 27, 2018	48
	SAC Technical Training	May 24, 2018	44
	Second Meeting	June 13, 2018	36
	Third Meeting	May 29, 2019	55
	Fourth Meeting – Part I	November 18, 2020	38
	Fourth Meeting – Part II	December 2, 2020	43
Education and Outreach Workgroup	First Meeting	September 6, 2018	16
	Second Meeting	January 24, 2019	24
	Third Meeting	August 29, 2019	21
	Fourth Meeting	February 25, 2020	17
Government Coordination Workgroup	First Meeting	December 3, 2018	22
	Second Meeting	July 31, 2019	18
	Third Meeting	December 18, 2019	15
	Fourth Meeting	November 18, 2020	22
Non-Traditional Best Management Practices Workgroup	First Meeting	October 24, 2018	11
	Second Meeting	March 5, 2019	16
	Third Meeting	October 3, 2019	9
	Fourth Meeting	January 23, 2020	12
Salt Tracking and Reporting Workgroup	First Meeting	October 16, 2018	17
	Second Meeting	April 16, 2019	16
	Third Meeting	September 12, 2019	13
	Fourth Meeting	January 9, 2020	12
Traditional Best Management Practices Workgroup	First Meeting	September 13, 2018	19
	Second Meeting	March 14, 2019	22
	Third Meeting	August 8, 2019	17
Water Quality Monitoring and Research Workgroup	First Meeting	November 8, 2018	16
	Second Meeting	February 14, 2019	16
	Third Meeting	June 19, 2019	13
	Fourth Meeting	November 21, 2019	15

2 Summaries of Public Comments and Staff Responses

Summary of Public Comments and Staff Responses
Salt Management Strategy
Finalized on February 22, 2018

The Virginia Department of Environmental Quality (DEQ) sought public comments from January 17 – February 16, 2018 on (1) its overall plans to develop a Salt Management Strategy (SaMS); (2) a technical report on the Impacts of Salt on the Environment, Infrastructure and Property; and (3) interest to serve as a member of the Stakeholder Advisory Committee (SAC).

A total of seven written communications were received during the public comment period. Six of these were either new or confirming expressions of interest to participate in the SAC. DEQ had already received many volunteers to participate in the SAC in response to earlier stakeholder communications.

The additional comment was received from Russ Short of Northern Virginia chapter of Trout Unlimited, and pertained to an aspect of the technical report on salt impacts. Mr. Short's comment and the DEQ staff response follows:

Mr. Short wrote "Since the TMDLs are based on exposure, there is a need to have more detail included on the exceedance timelines. While whisker plots are nice, implementing a monitoring program and BMPs tied to the strategy requires a better understanding of the salt discharges."

Staff Response: Mr. Short's recommendations for an effective monitoring program are appreciated and will benefit the overall Salt Management Strategy. Staff encourages Mr. Short to bring this suggestion to stakeholder discussions on the water quality monitoring objective for the Salt Management Strategy. A better understanding of salt discharges will help implement the strategy and inform the effectiveness of Best Management Practices (BMPs).

The referenced box and whisker plots in Figure 6 of the report titled "Salt Management Strategy: Environmental Impacts and Potential Economic Costs and Benefits of Improved Management Practices in Northern Virginia" was included to show the increasing trend in average annual chloride concentrations from 1990 to 2014. While this figure does not provide information on the magnitude or timeframe of chloride pulses after deicing salts are applied, it does communicate the concerning, increasing trend in annual average chloride concentrations. Figures 4 and 5 provide observed specific conductance measurements that are measured at 15 minute intervals and illustrate the magnitude and duration of salt discharges. While specific conductance is not a direct measure of chloride or other salts, it provides a surrogate measure for the magnitude of dissolved solids such as salts. Including specific conductance and measurements of salt concentrations in a monitoring program will provide a picture on the instream impact of salt application and the stormwater discharges of those salts. However, staff does acknowledge that the connection between salt application rates, runoff, and instream impacts are an unknown at this point. Therefore, staff encourages discussions on how to best understand these relationships.

Summary of Public Comments and Staff Responses

Salt Management Strategy
Finalized on March 9, 2021

The Virginia Department of Environmental Quality (DEQ) sought public comments from January 22 – February 22, 2021 on the "Salt Management Strategy: A toolkit to reduce the environmental impacts of winter maintenance practices." The Toolkit was developed in collaboration with the Salt Management Strategy (SaMS) Stakeholder Advisory Committee (SAC).

A single written communication was received during the public comment period. This comment was from Connie Fortin, of Fortin Consulting, Inc., and pertained to an aspect of the "Snow and Ice Maintenance Tips for Residents" section of the Toolkit, contained in Appendix I. Ms. Fortin's comment is summarized below, followed by DEQ staff response.

Ms. Fortin commented on a recommendation in Appendix I of the Toolkit directed towards residents that advises them to apply rock salt based upon a concept of 3 inch spread pattern, which includes an image depicting that concept. She stated she does not support the concept and recommended DEQ revise the Toolkit to remove it as guidance for residents. She mentioned she has voiced opposition to the concept in her work in Minnesota and has worked with Minnesota Pollution Control Agency (MPCA) to remove it from their guidance. She noted that the 3 inch spread pattern concept stems from someone several years ago calculating spacing using Fortin Consulting, Inc.'s application recommendation of 4 pounds or less per 1,000 square feet, but which does not take into consideration a number of variables that also need to be included.

Ms. Fortin provided background for her recommendation that the concept be removed from the Toolkit as a recommendation. She commented that it is too simplified and "can be a misleading concept to the public and a dangerous one to promote the 3 inch spread pattern as it will only work in a narrow range of conditions." She commented that professionals understand that to determine an accurate application rate, one needs information such as pavement temperature, amount of moisture on the surface and type and form of deicer. Also, that an application rate is just a target and one may apply more or less depending on many factors. Ms. Fortin noted that a simple concept that advises residents is desirable, but the problem is not that simple. Rather, she recommended using something along the lines of "use half as much as last year" or similar.

Staff Response: Ms. Fortin is a national expert in the field of optimizing chloride product use in winter maintenance, to achieve both winter safety/service goals and minimize the attendant negative impacts chlorides have on the environment. She was a primary contributor to development of the Minnesota Twin Cities Metro Area Chloride Management Plan, is a leader in Minnesota's ongoing statewide chloride management efforts, and has trained thousands of winter maintenance professionals in best management practices for winter salt use. DEQ appreciates the expert input Ms. Fortin has shared on communicating with the public and winter service professionals about salt application rates.

DEQ acknowledges the validity of the points Ms. Fortin has communicated and challenges in simplifying technical information to share with the general public. However, given the detailed level of review and full consensus of the recommendation by the SaMS workgroup that worked on this item, which was followed by full consensus of the SAC in the SaMS Toolkit as written, we are not revising the Toolkit to remove inclusion of the 3" spread pattern diagram and accompanying text contained in Appendix I. Although there are many factors that play in identifying the optimal target application rate, for residents in Virginia, we believe this concept will aid in helping this audience take the first step of addressing over application of winter salt. We note that many of the caveats that Ms. Fortin suggests, such as clear the snow first and apply salt only where needed, are included in the recommendations for residents. Additionally, a fundamental point Ms. Fortin makes, that optimal application rates are highly variable based on site and weather conditions, is effectively conveyed throughout the SaMS Toolkit.

While we have not revised Appendix I of the SaMS Toolkit in response to Ms. Fortin's comment, we expect that it will receive future attention by SaMS stakeholders as they discuss implementation experiences and consider refinements to the Toolkit to enhance its ability to guide efforts toward optimizing winter salt use in the years ahead.