Impact of Road Salt in Baltimore County: Overview and recommendations for best practices

December 2024

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EXECUTIVE SUMMARY

The frequent and persistent use of road salt as the primary method to deal with snowstorms may effectively clear the motorways, but it has numerous and substantial unintended negative consequences, namely regarding our drinking water, infrastructure, and the overall health of our environment. This report documents many of these points in the context of Baltimore County, Maryland and offers some suggestions for alternative courses of action. Specifically, the CEQ encourages the Baltimore County Council and Executive to consider the following recommendations:

1) ESTABLISH an ongoing Road Salt Task Force, as mandated by County Council Resolution 15-10 with the following goals:
    a. EDUCATE, monitor and publicize with a high-level media event, the state of our reservoir drinking water with annual sodium and chloride levels.
    b. DEVELOP and disseminate public education materials about the proven impacts of road salt, which includes harmful effects on drinking water systems, property, soil, plants, animals including pets, groundwater, surface water and aquatic life.
    c. REVIEW and implement public education, Best Management Practices, and other recommendations from the Northern Virginia Salt Management Strategy Toolkit. Include information about best practices anyone can use at their own residence that either do not use salt or that utilize minimal yet effective salt application (from SaMS Toolkit):
    d. HIGHLIGHT how to report all DPW problems, including salt spills and inappropriate storage: 'BaltCo 311 allows you to quickly report problems or request a service in three easy ways. Call 311 (outside of BC, dial 410-887-0311), fill out the online form below, or download and submit using our mobile app.'
2) DOCUMENT AND PUBLICIZE annual road salt usage by County employees and contractors on public roads and on County facilities and properties (i.e., schools, libraries, parks, buildings, etc.).
3) MONITOR Baltimore County DPWT's progress as they implement best road salt practices (e.g., fully fund DPWT to purchase trucks with advanced road salt calibration capabilities: tract road salt use).
4) STRATEGIZE AND COORDINATE regional and commercial efforts to monitor and implement BMPs
    a. COORDINATE with the State Highway Department to ensure BMPs for road salt applications are implemented on State roads in the County (e.g., post-storm cleanup of spilled road salt).
    b. COORDINATE with Baltimore City to limit road salt application near the three reservoirs (e.g., salting and plowing only one lane within a specified number of feet from any waterway on reservoir property).
    c. DEVELOP strategies to educate and encourage implementation of road salt BMPs at commercial sites (i.e., sidewalks and parking lots of shopping centers, apartment complexes, professional buildings). Develop enforcement strategies for consideration.
    d. PARTICIPATE in regional efforts to monitor and implement BMPs across Maryland as well as states with shared watersheds and neighboring watersheds (e.g. tributaries to the Chesapeake Bay as well as to the Delaware Bay).

CALL TO ACTION

The water we drink is impacted by everything we do, everything we put in the air, and everything we put on our land.

- **THE PROBLEM**: Our 'salt', as measured by chloride concentrations in tributaries feeding the Baltimore region drinking water reservoirs, has doubled since the 1980s, even in relatively low impervious cover watersheds in rural parts of Baltimore County (Hurley, 2023).
- **HEALTH RISKS**: One result is that the sodium content of our drinking water has increased to the point of posing a health risk for persons on sodium-restricted diets and/or for persons with sodium sensitivities (including elderly residents as well as people with hypertension, decreased kidney function, or people on dialysis).
- **INFRASTRUCTURE RISKS:** Taxpayer costs for infrastructure repair are high.
- **NO CHEAP FIX**: The treatment requirements of methods to remove salts from drinking water are expensive (MPCA 2016). The technology is not considered a viable option for drinking water treatment, as it produces more wastewater than drinking water (Benham 2011).
- **WANTS VS. NEEDS:** We are faced with balancing a public need with a public want. Baltimore County residents need safe, clean drinking water that they want at a reasonable price. Residents also need safe roads but want to be able to drive ASAP during and/or after a storm event. These two goals are currently not compatible.
- **TRADEOFFS**: When tradeoffs and full cost of these needs and wants are shared with residents, everyone can better understand financial and safety decisions. Currently the public tends to assume that the water that flows from their taps is safe in every way, without any consideration of trade-offs and risks inherent to the decision-making about water quality.
- **TIMING**: The 2009 CEQ report "Road Salt Recommendations to the Baltimore County Council" identified many of the same problems as the current report. Some of the recommendations were implemented in subsequent successful policy changes and others have yet to be implemented. The current report includes additional recommendations based on an up-to-date review of extensive work from other groups as well.
- **RESEARCH AND SUPPORTIVE FACTS:** The following is a comprehensive distillation of scientific research and of regulatory measures motivated by those research findings to reduce salt use by Baltimore County over the past 15 years. While some progress has been made in reducing salt use, salt levels in our drinking water continue to exceed safe levels in many instances. Substantial work still needs to be done, particularly targeted efforts around the drinking water reservoirs. There is no quick, simple, inexpensive approach to solving this problem.
- **ADDITIONAL IMPACTS**: Every facet of our life is connected to our access to clean water. The health of our people, as well as our pets and other animals, our farms, natural areas, infrastructure, streams and the Chesapeake Bay all suffer impacts from excessive salt levels.

Contents

Introduction

What is in the handful of white rocks we throw out on the streets and sidewalks when it snows? Where does it go and what impact does it have?

Road Salt Chemistry

In everyday usage, 'salt' refers to the specific compound sodium chloride, NaCl, or common table salt. Chloride salts are the most commonly used salts for deicing roads, parking lots, and sidewalks because of their easy availability and their property of lowering the freezing point of water. Sodium chloride is most effective above 20º F; the effectiveness drops off rapidly below 20º F. While one pound of salt can melt about 45 pounds of ice at 30º F, its ability to melt ice drops to 5 pounds of ice at 5º F.

Road salt (NaCl) dissolves in water, dissociating into sodium and chloride ions. While some of the sodium may bond to soil particles or be taken up in biological processes, the chloride is less reactive. All the chloride eventually reaches streams with a fraction quickly transported (hours to days) to streams via surface runoff and another fraction slowly (months to decades) traveling through soil to groundwater and eventually to streams (Church and Friesz, 1993). Either way, both sodium and chloride generally leach into sources of drinking water and into natural systems.

In addition to sodium chloride, deicing operations may use calcium, potassium, or magnesium chlorides, which may be applied in crystalline form or as a liquid. They may be used in conjunction with abrasives such as sand, or they may be mixed with other substances that reduce corrosive effects or enhance their effectiveness. These other substances are often agricultural by-products of corn or sugar beets. Sodium ferrocyanide is sometimes used to prevent clumping.

Current Road De-Icing Practices in Baltimore County

In the preparation for this Road Salt Update Report, on January 24, 2024, Anthony Russell Jr., Deputy Director of the Department of Public Works and Transportation (DPWT), presented to the CEQ about current road de-icing practices by Baltimore County agencies, which are summarized below. Note that no information is available for salt application by private entities in Baltimore County, e.g., businesses or homeowners.

Demand for clear roads

The goal of road de-icing is for public safety and to satisfy the public demand for clear roads. Baltimore County acknowledges the need to mitigate the amount applied to roads and has tried significant changes in the last four years. Best management practices advise that salt application should be initiated as soon as snow or ice begins to accumulate, not before except in cases where liquid brine is applied (see below).

Salt purchase and storage

BC currently pays $75/ton for 1/8-1/4 inch diameter salt from Utah and Chile. Salt lasts indefinitely as long as it is under cover and dry. The County can store up to 90,000 tons at 17 different locations, including two 20,000-ton barns, which protects against interruption in deliveries. All inlets and drainage structures on the barn are protected, and after delivery, all salt is under cover by day's end. All salt is stored on impervious surfaces. Once salt has been stored, all excess is cleaned off by sweeping the lot. Entrances of barns and domes are always blocked after loading.

Training truck drivers

Each winter, DPWT training academy puts on a 'snow college' for all employees. Since FY 21, contractors follow BC salt usage guidelines which promotes the importance of 'sensible salting.'

Everyone who does salting from any agency has to go through the same training. All those applying road salt for the County are required to hold various stormwater permits.

Application: Truck calibration, application and cleaning
Trucks are calibrated yearly to ensure the correct amount of material is being applied. After each event, trucks and equipment must be cleaned of any excess material. The truck or equipment then must be thoroughly washed within a wash bay. By using a wash bay equipped with an oil/water separator, the introduction of salt or other sediment is minimized. The following day, after each event, drivers must re-ride their assigned route to make sure there is no salt left on the roadway. They pick it up and return it to the barn. County staff check for spilled salt on contractors' routes. All these measures apply to County roads.

Application: Lane miles treated and amount of salt used
BC truck drivers treat over 6700 lane miles on 172 snow routes using 500 lbs per lane mile per inch of snow. Note that refreezing may occur, creating the need for multiple applications for a single event. The Maryland State Highway Administration uses the same standard. Truck drivers make sure tailgate chains are properly set; this prevents excess material from falling onto the roadway. With 400 trucks and 8 tons of salt per truck, this makes a difference. Outside the Urban-Rural Demarcation Line (URDL) because of fewer utilities in the ground, metal blades can be used and roads may be more clear.

The County employs up to 317 contracted trucks and pieces of equipment during any given event. Contractors are held to the same standards as county employees, and this is part of their contract. The County does not require them to clean their trucks on county property. Contractors are paid hourly, not on a tonnage basis.

Application: Liquid brine application
Brine is salt dissolved in water. It is used as a road pretreatment to prevent snow and ice from bonding to the road surface. The practice of using salt brine requires less than ⅕ of the amount of salt needed to prevent ice from forming. To treat 50 center miles of road it takes 40 tons of salt. It only takes 6 tons of salt to make enough brine to treat the same area. Brine not only cuts costs, but also cuts down on the amount of salt we introduce to the surrounding environment. Brine can be applied 48 hours prior to a snow event. In FY21, the County purchased a brine making machine along with six 1000-gallon spray tanks that slide into the back of trucks; these are used on over 600 miles of primary roads throughout the County.

Application: Alternative liquid applications
The state experimented with beet juice for a couple of years but that has other drawbacks including impacts on stream ecosystems. Neither the County nor the State currently use beet juice.

Monitoring and tracking salt usage
For fiscal year 2025 and beyond, DPWT will work with Baltimore County Office of Information Technology department to set up a device to do a better job tracking the amount of material used by the fleet. Currently, 47 out of 215 trucks in the fleet are equipped with Force America controls to regulate the amount of salt spread. The school system is using these, too. All new trucks ordered will be equipped with these; and the County orders 5-10 new trucks per year. Without state regulations for salt application amounts, the County follows the Salt Institute of America policy, which is the definitive voice of the U.S. salt industry.

Table 1. Annual Deicing material (lbs.), snowfall (in.), and number of winter storm events. 2012 only reflects data collected between January and June 2012. Since 2013, data are reported by the fiscal year (July 1 – June 30).

Year	Deicing Mat.	Snowfall (in.)	Number of Winter Weather Events
1999	83,978,000	12.4	8
2000	94,467,750	27.2	7
2001	48,566,400	7.4	5
2002	100,437,859	12.0	7
2003	205,164,341	58.0	8
2004	147,537,040	8.7	5
2005	185,118,740	24.5	7
2006	23,888,950	13.1	1
2007	156,690,026	14.4	11
2008	65,456,420	4.3	15
2009	151,208,045	28.6	9
2010	162,724,620	58.1	7
2011	133,892,760	13.2	7
2012[1]	23,162,196	1.8	3
2013 FY	65,614,500	8.0	3
2014 FY	251,133,425	39.0	20
2015 FY	205,325,015	28.7	20
2016 FY[2]	89,838,190	38.5	7
2017 FY	59,366,300	12.0	7
2018 FY	167,405,138	14.3	14
2019 FY	141,904,712	17.9	9
2020 FY	17,062,530	4.5	4
2021 FY	170,669,481	17.3	8
2022 FY	63,678,883	11.0	10

Maryland State Policy, Goal Statement, and Current Road Salt Practices as of 2024

The 2023/2024 MDSHA Salt Management Plan (SMP) outlines a comprehensive strategy for reducing and managing salt usage.

Since the last report from the Baltimore County Commission on Environmental Quality (CEQ) in 2009, the state legislature has enacted two bills in 2010: House Bill 0903 and Senate Bill 0775, both of which mandate a statewide SMP.

This MDSHA Salt Management Plan (SMP) 2023/2024 serves two primary objectives:

1) **Framework for Safe and Efficient Roadway Systems**: It provides a framework for highway agencies to deliver safe and efficient roadway systems during winter storms. The goal is to achieve this in a cost-effective, environmentally sound, and sustainable manner.

2) **Consolidation of Practices and Manuals**: The secondary objective is to consolidate the State Highway Administration (SHA)'s current practices and manuals into a single comprehensive guidance document. This consolidation streamlines procedures and ensures consistency across the state.

The overarching mission of the SMP is to enhance the Level of Service (LOS) while maintaining environmental stewardship. By optimizing salt usage and minimizing adverse impacts, the plan aims to strike a balance between safety, efficiency, and sustainability. This is done by setting common goals for all jurisdictions listed below:

- Public Safety
- Environmental Protection
- Efficient Transportation
- Fiscal Responsibility
- Continual Improvement
- Local Development of Salt Management Plans.

The purpose of MDSHA Salt Management Plan is for the local development of SMPs using the MDSHA process. These plans should be developed and "should include the key elements of environmental management. Commitment to the plan should include accountability, goals, measurement of progress, communication, reporting, and periodic review. These aspects will ensure that local SMPs are living documents that allow for continual improvement." Specifically, MDSHA has implemented several effective techniques to enhance winter road maintenance while minimizing environmental impact:

Pre-Wetting Salt: By pre-wetting salt, they reduce "bounce and scatter." This means that the salt adheres better to the road surface, improving its effectiveness in melting ice and snow.

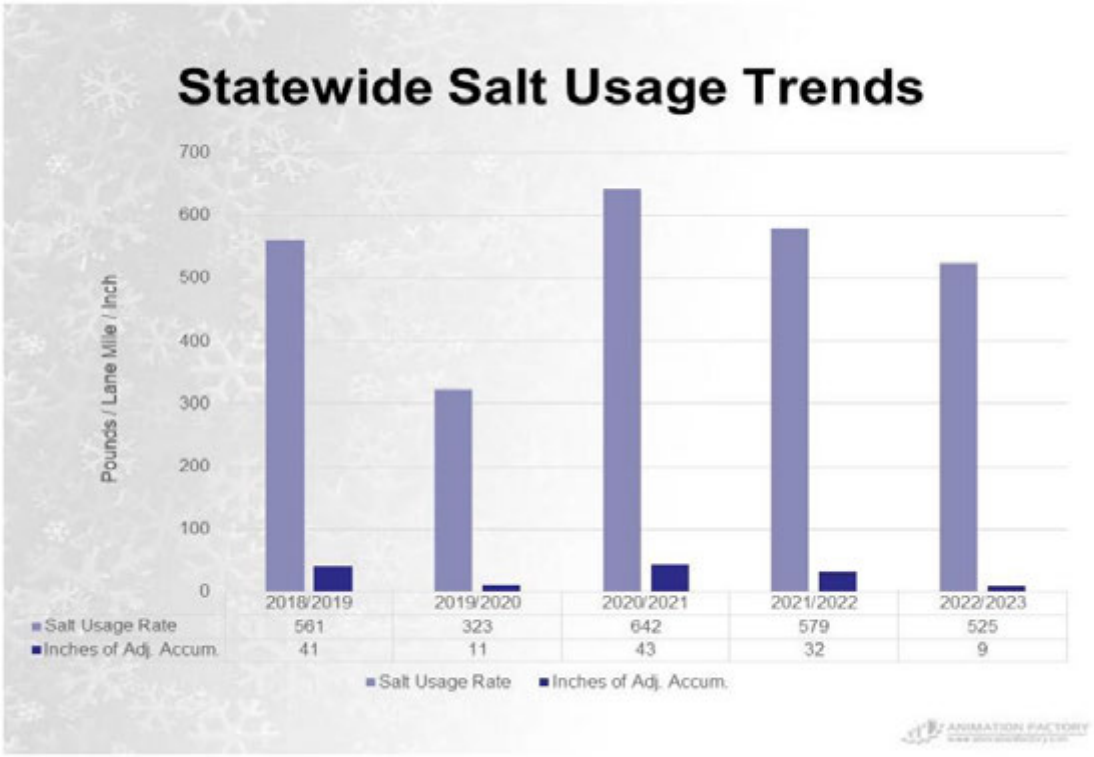
Anti-Icing (Pre-Treating with Brine): Anti-icing involves applying a brine solution to roadways before a storm. This protective coating prevents snow and ice from bonding to the pavement, making it easier to clear later.

Training for Equipment Operators: Ensuring that equipment operators are well-trained in anti-icing techniques is crucial. Proper application of salt and brine requires skill and knowledge to achieve the desired results.

Advanced Spreader Technology: New technology allows spreaders precise adjustment of salting rates, ensuring efficient salt usage while maintaining safety.

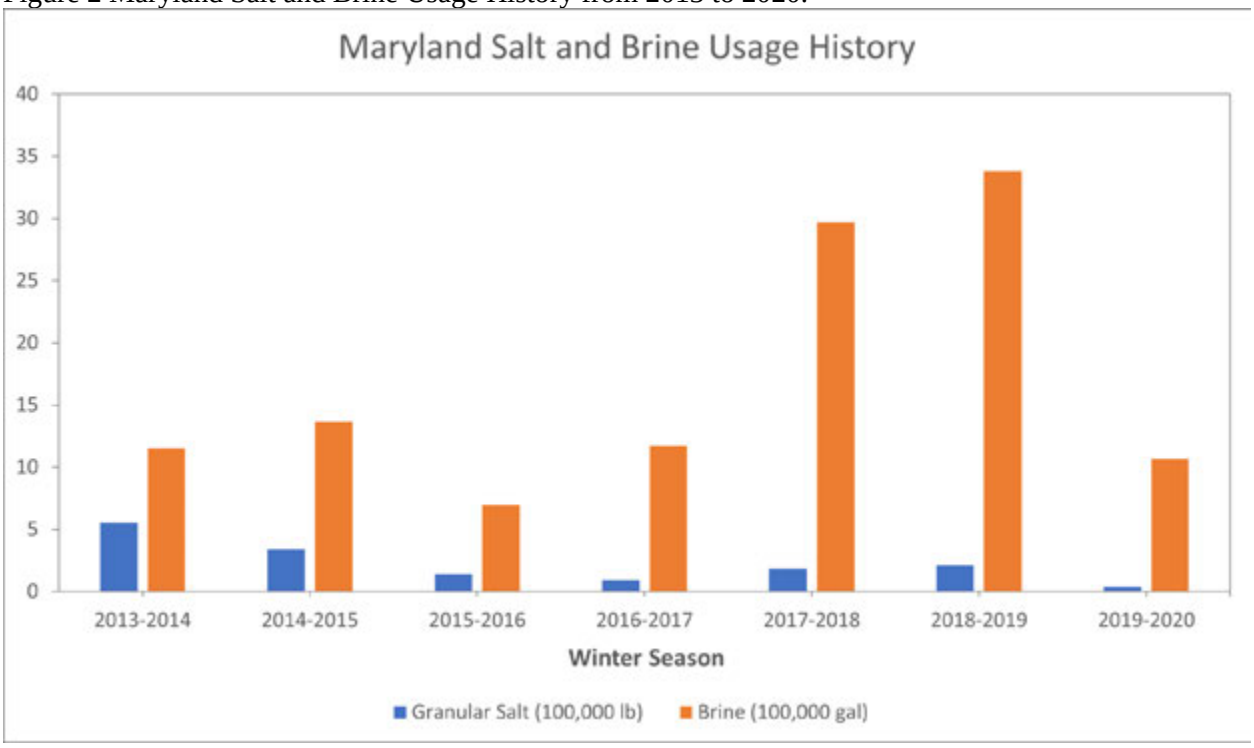
Winter Operations Trainings: All new equipment operators undergo winter operations training. This ensures that they are well-prepared to handle winter weather conditions effectively.

Figure 1. Statewide salt usage in comparison to snow accumulation.



(PG 47, 2023/2024 MDSHA Salt Management Plan)

Figure 2 Maryland Salt and Brine Usage History from 2013 to 2020.



Clean Water Action September 29, 2021

Best Management Practices (BMPs) for De-icing

> "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." (SaMS Toolkit, Appendix B, p. 103)

Northern Virginia Salt management Strategy Toolkit

In December 2020, Northern Virginia released the Virginia SaMS Salt Management Strategy: A Toolkit to reduce the environmental impacts of winter maintenance practices. The Toolkit was released after a multi-year process facilitated by the Virginia Dept of Environmental Quality that included relevant stakeholders such as the Virginia Dept of Transportation, watershed groups, scientists, watershed managers, and educators. It provides a balance between the benefits and the negative impacts of salt use with practices that can minimize the negative impacts. This comprehensive, 400+ page Toolkit includes these practices in a variety of resources and recommendations that organizations and individuals can use. (www.novaregion.org/DocumentCenter/View/13054/SaMS_Toolkit_final?bidId).

Since Northern Virginia so closely resembles Baltimore County in climate and geography, this section of the report refers to that Toolkit. Unfortunately, the Toolkit does not allow hyperlinking directly to its parts, so the reader must link to the entire Toolkit and use the overview, excerpts, and page numbers below to navigate the Toolkit and learn about De-icing BMPs. The Toolkit is internally hyperlinked, so navigation around it is easy. All section numbers and page numbers below refer to the Toolkit.

The Toolkit addresses three tiers of the winter maintenance professions (decision makers, supervisors, and applicators) and addresses recommendations and resources to those different audiences.

The Toolkit highlights five BMPs for salt application that can be implemented in the short-term with little to no financial investment:

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

and six BMPs for salt application that require equipment, tools, and/or specific training to implement:

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

The report continues with recommendations for the **Planning and Application Practices** - Section 3 The BMPs in Section 3 include:

Continual Improvement Process
Section 3.2 (p.16) recommends a continual improvement process for implementing winter maintenance BMPs.

Deicing Products
Section 3.3 (p.22) 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).

Application Rates
Section 3.4 (p.24) addresses application rates and provides the context for a recommended application rate evaluation process that is provided in detail in Appendix D (p.136).

Winter Maintenance Certification and Training
Section 3.5 (p.26) "Certification and training programs for winter service providers have had numerous direct and indirect benefits. Direct benefits include 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." These programs are further developed in Appendix F (p.153), which summarizes different winter maintenance certification and training programs.

Winter Maintenance Contracting
Section 3.6 (p. 26) "Contract terms to encourage great BMP use can influence the extent to which best practices are implemented." Sample contracts are included.

Section 4 (p. 27) of the Northern Virginia Toolkit deals with measuring and tracking of salt use. Best practices include:

Levels of Tracking Detail - Section 4.1 covers the seasonal, storm-specific, and operational area levels of detail that organizations may consider using in their tracking activities.
Data Dictionary - Section 4.2 includes a data dictionary to clarify the reporting metrics contained in tracking forms.
Reporting Metrics - Section 4.3 focuses on metrics for reporting salt product use
Tracking Seasonal BMP implementation - Section 4.4 highlights Tracking seasonal BMP implementation questions

BMPs: Pros and Cons of planning and storm-related practices
Appendix B of the Toolkit (p.102) evaluates these BMPs and offers benefits and costs of each, compiled "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 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). The main con listed throughout is the increased time, training, and cost to implementation. They are

organized for different audiences (property management, transportation, general) and include pros and cons for:

Planning Practices (Section 1 - p. 106) (Develop a Winter Maintenance Plan, Preseason meetings, Postseason meetings, Accountability at every level, Plan snowplow routes, Levels of Service, Levels of service knowledge, Training)

> **Salt Storage and Handling** (p.110) (Storage for deicer piles and bags, Storage for liquid products, loading/hauling of deicers)
>
> **Calibration of spreading equipment** (p.112) (Establish a calibration process, Calibrate equipment)
>
> **Pre- and Post-Storm Meetings to Review Plans and Performance** (p.113)
>
> **Weather Forecasting** (p.114) (Surface Temperature Information)
>
> **Enhanced Equipment/Technology** (p.114) (Spreaders, Equipment needed for making liquid products, Automated Vehicle Location (AVL), Maintenance Decision Support System, Precision Deicing)

Storm-related BMPs (Section 2 - p.118) include:

- Anti-icing
- Plowing Practices
- Plow early and often
- Coordinate plowing activities
- Plow train
- Choose the right plow, shovel, pusher, blower, blade, or broom for the property
- Manage stairways or areas with a small footprint
- Snow placement
- Product application practices
- Dyed deicers
- Use of abrasives
- Post-storm clean-up
- Spinner set-up
- Drive 17-25 mph on high-speed roads
- Turn off auger, chute, shoot, or conveyor when stopped
- Reduce deicer application rate on successive passes
- Spread patterns
- Spreaders for sidewalks
- Vary application rates to conditions
- Variable application
- Use of deicers at cold temperatures
- Use of Liquids (Liquids & Prewetting, Pretreat deicers, Prewet deicers, Direct liquid application, Measuring deicer use, Measure and record deicer use)

See Appendix C for further resources and references.

Additives and Alternatives to De-icing Materials

Anticaking agents are often utilized to maintain the granular consistency of road salt and to prevent clumping. Various chemical compositions are utilized and must comply with all state and local regulations (see Table 2). While some are considered more environmentally friendly, studies on the long-term effects are not available. Furthermore, most incur greater front-end cost when compared to more commonly found compounds.

Table 2. Summary of some of the most commonly used anti-caking additives

Anti-caking agent	**Chemical formula**	**Uses**
Sodium ferrocyanide	$Na_4Fe(CN)_6 \cdot 10H_2O$	common and effective anticaking agent used in road salt, table salt, animal feed and sometimes even water treatment
Tricalcium phosphate	$Ca_3(PO_4)_2$	often used as an anticaking agent in various salts such as food additives, nutritional supplements, fertilizers, animal feed and road salt
Calcium silicate	$CaSiO_3$	common anticaking agent added to road salt. It is commonly found in construction materials such as cement and ceramics due to a high melting point.
Magnesium carbonate	$MgCO_3$	sometimes used as an anticaking agent in road salt. It is utilized in construction materials such as ceramic and cement but also found in antacids, supplements and pharmaceutical products.
Silicon dioxide	SiO_2	one of the most abundant compounds within the Earth's crust and can be found in glass, sand and quartz. Industrial use is common in production of cement, electronics and semiconductors, ceramics and glass.

Below is a list of alternative deicing compounds that are generally considered more environmentally friendly and a brief description of their chemistry (Table 3). Most of the following are much more expensive than the most commonly compound used as road salt: NaCl. Numbers 1 through 3 can be utilized as salt while 4 and 5 are alternatives for anticaking agents commonly used in road salt.

Table 3: Alternative deicing compounds.

Alternative deicing compounds	**Chemical formula**	**Uses**
Calcium Magnesium Acetate	$CaMg_2(CH_3COO)_6$	It is less corrosive to infrastructure, less harmful to vegetation and aquatic life, and less likely to cause groundwater contamination.
Calcium Chloride	$CaCl_2$	sometimes considered more environmentally friendly than sodium chloride due to its lower toxicity to plants and aquatic life as well as in terms of chloride runoff.
Potassium Acetate	CH_3COOK	less harmful to the environment compared to some other deicing agents. It is less corrosive to metal surfaces and less toxic to plants and aquatic life.
Organic-based Anticaking Agents		anticaking agents derived from organic compounds or plant-based materials may offer environmental benefits compared to synthetic anticaking agents, although their effectiveness and environmental impact has not been extensively studied.
Natural Mineral Additives		Certain natural mineral additives, such as diatomaceous earth or finely ground limestone, can be used as anticaking agents and may have the least environmental impact when compared with synthetic anticaking agents.

Chloride Impairment in Maryland

> All the added Chloride in the water leads to human health and environmental impacts.

The following draws heavily from the 2020–22 Integrated report on surface water quality that the Maryland Department of Environment (MDE) submitted to, and was approved by, the United States EPA mde.maryland.gov/programs/Water/TMDL/Integrated303dReports/Pages/Combined_2020_2022IR.aspx. In this integrated report, MDE created a new subcategory for watersheds impaired by chloride: Category 5s (Waterbody impairment is caused by chloride from road salt). Previously, MDE had listed watersheds impaired by chloride under Category 5 (impaired and needs a TMDL). MDE stated in that report: "Other persistent water quality challenges facing the state include the continued increasing trends of conductivity and related aquatic life toxicant, chloride, in non-tidal streams due to road deicers."

MDE listed 28 watersheds as impaired by chloride in the 2020-22 integrated report. Seven of those watersheds are located, at least in part, in Baltimore County. The watersheds and years in which the chloride impairment was listed are Back River (2012), Gwynns Falls (2010), Jones Falls (2010), Liberty Reservoir (2012), Loch Raven Reservoir (2014), Lower Gunpowder Falls (2012), and Patapsco River Lower North Branch (2010). Baltimore Harbor was listed in 2014, and watersheds listed in the previous sentence—other than Liberty Reservoir and the Lower Gunpowder Falls—drain into Baltimore Harbor.

Maryland has adopted several strategies for reducing salt use and chloride impacts. First, in 2010 the state legislature passed a law requiring that Maryland Department of Transportation State Highway Administration (MDSHA) develop a salt management plan. Implementation of that plan has resulted in a ~50% reduction in deicing salt application by MDSHA. Second, MDE began requiring the development of salt management plans for large MS4* permits in 2021, including for Baltimore County. MS4 permits are revised and re-issued on a 5-year basis. Third, MDE is working to promote voluntary action to reduce salt application, including through training of private applicators, increasing public awareness by other state agencies, non-governmental organizations, and elected officials.

MDE also hosts web pages focused on salt issues, e.g., mde.maryland.gov/programs/Water/319NonPointSource/Pages/411-on-Salt.aspx. Additionally, in early 2024 MDE began the process of hiring a Natural Resource Planner II who will coordinate MDE's deicing salt reduction strategy (www.jobapscloud.com/MD/sup/bulpreview.asp?R1=24&R2=002501&R3=0004).

*MS4 = municipal separate storm sewer systems

Sodium Levels at Ashburton and Montebello Water Treatment Plants

Baltimore City measures and records sodium levels at the two main water treatment plants. The EPA (2003) suggests that for individuals on a low-sodium diet, drinking water should not exceed 20 mg/1 (www.epa.gov/sites/default/files/2014-09/documents/support_cc1_sodium_dwreport.pdf). Note that the values in Table 4 are close to or above 20 mg/l.

Table 4. Average Sodium Concentrations measured in the finished water in ppm (parts per million)

Water Treatment Plant	2015	2016	2017	2018	2019	2020	2021	2022
Ashburton	19.6	19.1	18.7	20.0	19.4	17.3	19.6	20.4
Montebello	23.7	20.9	20.1	21.8	19.6	17.0	23.5	20.3

(https://publicworks.baltimorecity.gov/water-quality-reports)

Data and trends for the Baltimore City drinking water reservoirs and tributaries to those reservoirs

To provide context for the problems that road salt causes related to drinking quality, we included two figures for water chemistry in the Baltimore City drinking water reservoirs and two figures for the chemistry of selected tributaries that feed those reservoirs. The three reservoirs are Liberty, Loch Raven, and Prettyboy Reservoirs. These reservoirs are entirely or partially within Baltimore County. We gratefully acknowledge the staff of Baltimore City Department of Public Works (BC-DPW) who have collected those data since the 1980s, and we thank BC-DPW for making the data available.

Scientists and managers measure specific conductance (or electrical conductivity) values and chloride concentrations because both are useful for determining water quality. Specific conductance values are a measure of the total dissolved ions (charged species) in water. Both specific conductance and chloride give information about deicing salt inputs to streams, especially when collected through time. BC-DPW has been collecting these data on a monthly basis since the early 1980s for streams that feed Liberty, Loch Raven, and Prettyboy Reservoirs; BC-DPW also has collected specific conductance data profiles with depth at multiple locations in each reservoir across the same period. In many Maryland streams and across the mid-Atlantic, chloride and sodium from deicing salt are the main cause of elevated and increasing specific conductance (Moore et al, 2020).

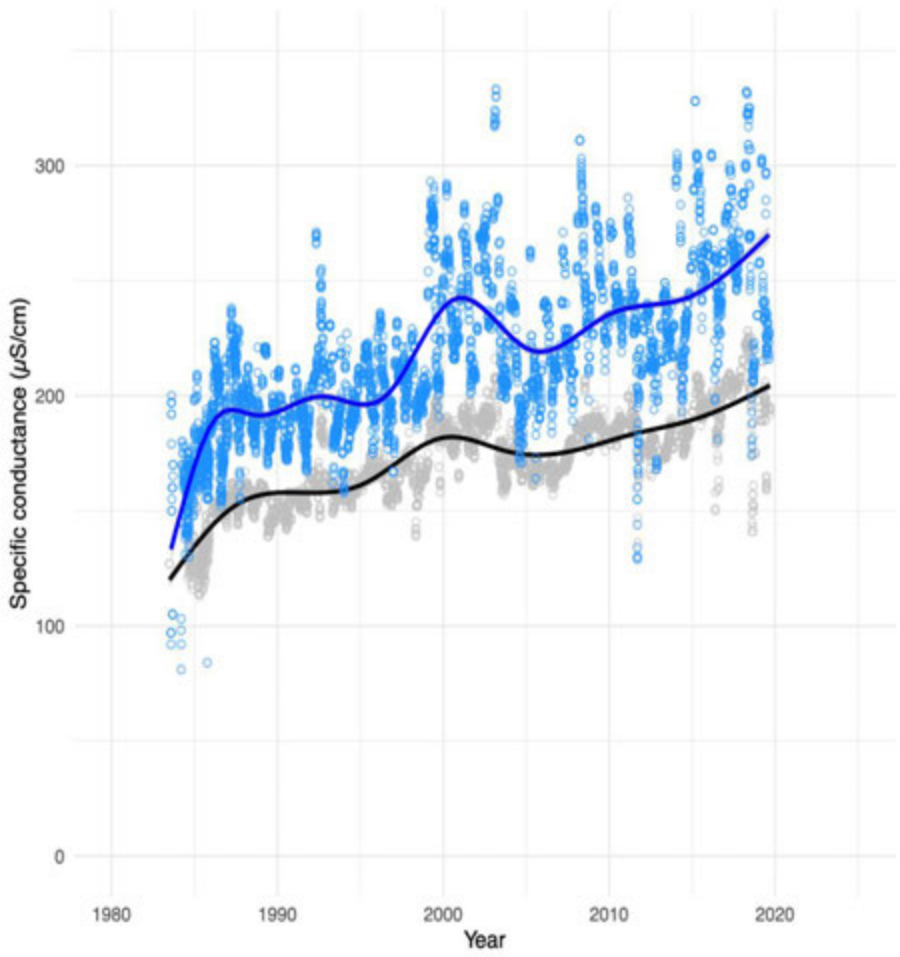


Figure 3. Specific conductance values for 0–30 feet depth for Liberty (grey) and Loch Raven (blue) reservoirs. Specific conductance is a measure of the total dissolved ion concentrations and has increased substantially in both reservoirs over the last four decades. The lines represent a *loess* (local regression) fit to the data. Specific conductance data were collected every 5 feet from the surface to the bottom by the Baltimore City Department of Public Works at the gatehouses (lower portion) of each reservoir (Liberty NPA0042, Loch Raven GUN 0142). Data were collected approximately every 2–4 weeks with more frequent collection during the growing season (roughly April – September).

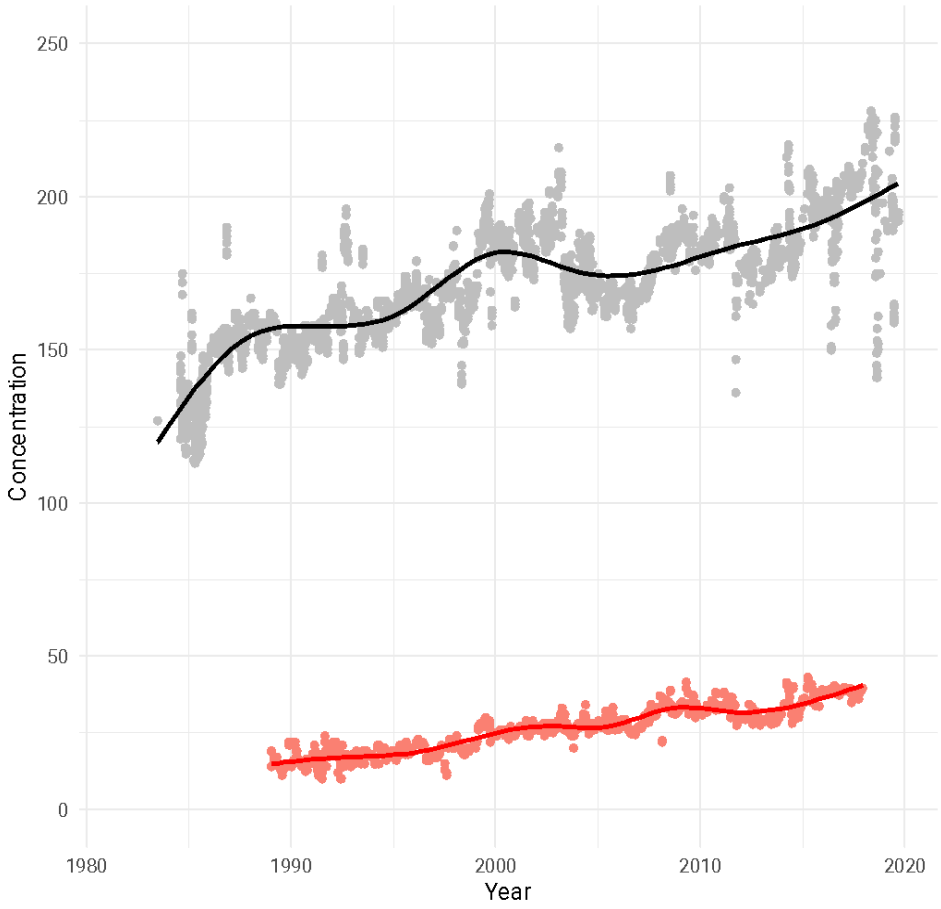


Figure 4. Specific conductance values (grey, µS/cm) and chloride concentrations (red, mg/L) for 0–30 feet depth for Liberty Reservoir. Increases in chloride concentrations are the biggest contributor to increasing specific conductance in Liberty Reservoir. The lines represent a *loess* (local regression) fit to the data. Data are from profile data collected by the Baltimore City Department of Public at the gatehouse (lower portion) of Liberty Reservoir (NPA0042). Data were collected approximately every 2–4 weeks with shorter intervals during the growing season (roughly April – September). That increasing chloride concentrations drive increases in specific conductance is evidenced from the linear correlation between the two (slope = 0.29, R^2 of 0.63 for 2006–2017 end of chloride data). The slope of 0.29 is similar to a regional relationship for specific conductance and chloride (Moore et al., 2020).

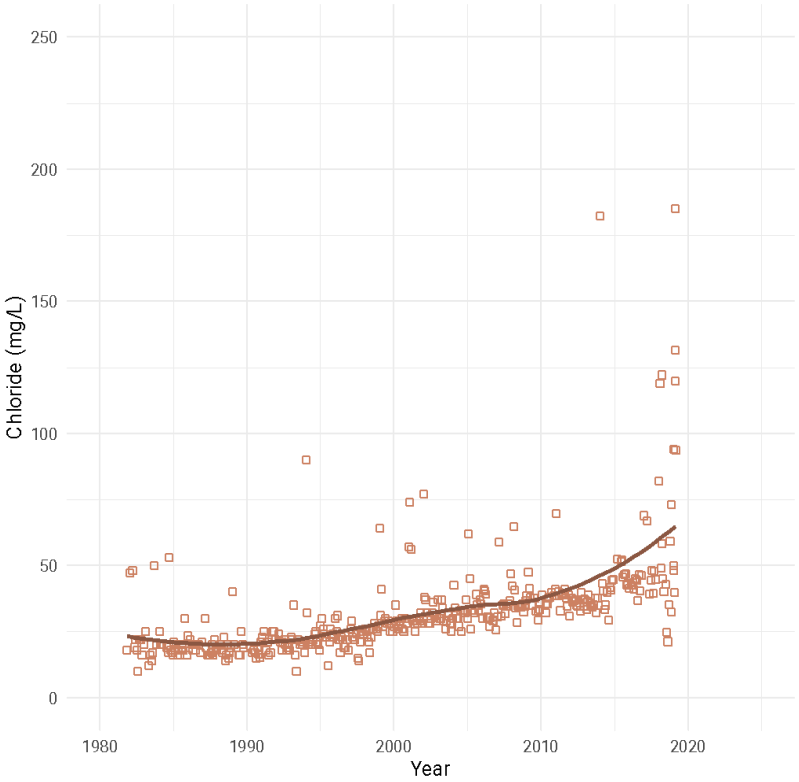


Figure 5. Monthly chloride concentrations (squares) with a *loess* fit for the North Branch, Patapsco River, which is the largest tributary feeding Liberty Reservoir and has impervious cover of ~4% based on 2011 land use data. Chloride concentrations more than doubled from the early 1980s to 2019. It is highly likely that most of the chloride is from road salt. Water is more corrosive when chloride concentrations are higher, and the rate of disinfection by-product formation increases. Some disinfection byproducts are regulated because they are carcinogenic. Data from 1982–2017 is from Baltimore City DPW and data from 2018 and 2019 are from the Maryland Department of Environment (with chloride characterization as a primary goal of that sampling campaign).

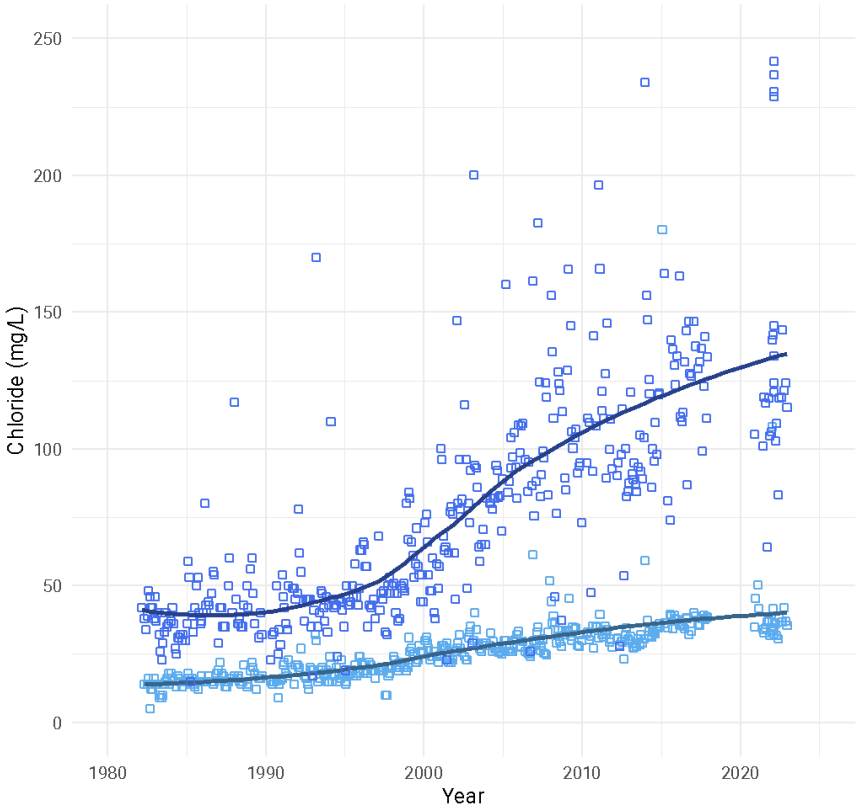


Figure 6. Monthly chloride concentrations with *loess* fits for Gunpowder Falls at Glencoe (lighter blue squares), which is the largest stream feeding Loch Raven Reservoir and has impervious surface cover of ~0.9% based on 2011 land use data, and Beaverdam Run (darker blue squares), which has the highest surface cover (~13%) of any large tributary feeding Liberty or Loch Raven. Data from 1982–2017 is from Baltimore City DPW and data from 2020–2023 are from the laboratory of Joel Moore (Towson University) with chloride characterization as the chief goal of the sampling campaign. Much more detail on trends for these streams and others can be found in a 2023 master's thesis by Kyle Hurley (Towson University, Joel Moore advisor).

Baltimore Reservoir Watershed Management Program

Baltimore County and Baltimore City (among others) collaborate to manage the three reservoirs and their respective watersheds as sources of high-quality water.

The Reservoir Agreement which governs the operation of the City reservoirs was established in 1979 and most recently expanded by agreement in 2005. The 2005 Agreement was accompanied by a *2005 Action Strategy for the Reservoir Watersheds*. As part of the Reservoir Agreements, the Baltimore Reservoir Watershed Management Program (a joint undertaking of Baltimore City, Baltimore County and other jurisdictions and organizations) assesses the water quality in the Baltimore Metropolitan water supply reservoirs and their watersheds through monitoring programs, and publishes documentation periodically including most recently in 2004, 2009, 2011 and 2016. The next assessment is expected to be completed in 2025.

The findings in the 2004 report are representative of these ongoing reports and were based on data collected at the reservoirs and from their tributaries as part of the on-going monitoring program. The relevant data pertaining to sodium and more generally to chlorides were collected beginning in the 1980s and continuing thereafter. In the report road salt was identified as the major contributor to sodium levels and rising chloride levels in the reservoirs and the watersheds. The report noted that "elevated chloride levels in the raw [pre-treated] water are not reduced by the processes used at the city's treatment plants...Since 1973, sodium levels in the finished (treated) drinking water have increased almost three-fold in the water withdrawn from Liberty Reservoir (and treated at the Ashburton plant) and almost four-fold in the water drawn from Loch Raven (and treated at the Montebello plant)" (p.13). Noting that the … levels of sodium and chlorides are lower than those that cause "taste or health problems for the end consumers," the report stated that "the trends observed in the reservoirs over the past two decades seem to represent a cause for concern" (p. 14), as noted in Figures 4–6 above. The report also stated that "chlorides in the watershed most often originate from the use of road deicing compounds" (p.14), while recognizing that some are due to animal waste on farms and from residential septic systems.

Road Salt and Overall Water Quality

These data and comments suggest that drinking water is being impacted and road salt is a main contributor.

- Mean annual chloride concentration has increased because of increased salt use over the last several decades even in watersheds with low impervious cover (<5–10%), including tributaries of the Baltimore region drinking water reservoirs. Concentrations are commonly higher in watersheds with more impervious surface (pavement). Chloride concentrations **exceed tolerance for freshwater life in many suburban and urban watersheds.**
- **Chloride concentrations in the northern U.S. have approximately doubled from 1990 to 2011**, increasing more rapidly than the rate of urban development. Concentrations were highest in winter but increases occurred in all seasons, suggesting that chloride was stored in shallow groundwater and slowly released throughout the year. Concentrations at a series of study sites show that 29% of those sites exceeded USEPA chronic water quality criteria of 230 mg/l for an average of more than 100 days/yr during 2006-2011 (Corsi et al. 2015).
- In the Mid-Atlantic, some watersheds with median chloride higher than 30 mg/L and all with chloride higher than 50 mg/L exhibit multiple annual exceedances of the EPA freshwater chronic criterion of 230 mg/L (over a 4-day period, not to be occur more than once a 3-year period). (Moore et al. 2015)
- Increasing chloride concentrations **continue to degrade freshwater quality** in the Northeastern and Mid-Atlantic United States. Increases in roadways and deicer use are **salinizing fresh waters**, degrading habitat for aquatic organisms, and impacting large supplies of drinking water for humans throughout the region. Chloride concentrations of up to 25% of the concentration of seawater are reported in streams of Maryland, New York, and New Hampshire during winters, and chloride concentrations remaining up to 100 times greater than unimpacted forest streams during summers (Kaushal et al. 2005).
- **Excess salt concentrations may lead to increased mobilization and higher concentrations of other pollutants in soil, groundwater, surface water, and water pipes.** This phenomenon, known as Freshwater Salinization Syndrome (FSS), has been studied in watersheds in the Baltimore-Washington metro area (including Herring Run, Scotts Level Branch, and Jones Falls), and results show contaminant pulses of metals concentrations in streams that can last for days, weeks, and even months following snowstorms (Galella et al., 2021). These effects have been seen elsewhere also, e.g., New England (Wilhelm et al., 2019). Elevated chloride also is associated with greater Pb (lead) exceedances. These effects are accentuated by impervious cover and proximity of roadways to streams.
- Recent research, including by John Sivey at Towson University, **demonstrates that higher chloride concentrations increase the rate of disinfection by-product (DBP) formation. DBPs are toxic, sometimes carcinogenic compounds formed by reaction of chlorine with residual organic matter during drinking water treatment** (Broadwater et al., 2018; Rose et al., 2020).

Negative Impacts of Road Salt on Humans

> Sodium is an essential element for humans, but high levels can cause adverse health effects.

While small amounts of sodium are necessary for humans to function, too much can contribute to a range of human health problems (Winter Salts, a story map from the MD Department of the Environment(https://maryland.maps.arcgis.com/apps/Cascade/index.html?appid=b3c8425c387348659273eb889b007edb). **Sodium concentrations in the Baltimore water supply have already exceeded the EPA health advisory limit (20 mg/L) for persons with sodium sensitivities (such as diabetics and dialysis patients).**

Chloride and sodium contamination can happen in reservoirs, rivers, streams, and groundwater (including wells). These ions remain in solution and are not subject to any significant natural removal mechanisms, nor can they be easily removed during water purification for drinking water. Distillation and reverse osmosis are the only means of removing salt impurities. Not every Baltimore County household can afford these systems. The best solution is a widespread, decreased use of winter salts.

Winter Salts – MDE - How Excessive Use of Winter Salts are Affecting You – Public Health
maryland.maps.arcgis.com/apps/Cascade/index.html?appid=b3c8425c387348659273eb889b007edb

Effect on public health and safety

As pointed out in Winter Salts, elevated levels of salt in drinking water are associated with increased risk of cardiovascular and heart disease and hypertension, as well as kidney and liver disease. Increased blood pressure (hypertension) increases the risk of heart attacks, strokes, and kidney failure. Indeed, people on kidney dialysis should not be exposed to higher levels of salt in the dialysis process.

- The EPA has advised that persons on a "very restricted diet for sodium," where intake should not exceed 500 mg/day, should not consume drinking water with sodium concentrations exceeding 20 mg/liter of sodium. “The sodium concentrations in the finished water leaving the Montebello plant repeatedly exceeded this level...and were consistently higher than the levels seen at that plant in the preceding decades" (p. 13). **Thus, public drinking water may pose a health risk for persons on sodium-restricted diets.**
- **Impacts to water quality can be particularly acute when busy roads are adjacent to drinking-water reservoirs** insulated by narrow buffers.
- Degradation of soils and vegetation in buffer areas between roads and watercourses **compromises the retention and processing of pollutants transported in stormwater runoff** and **diminishes the beneficial value of buffer zones to groundwater sources and reservoirs**.
- The Federal Highway Administration (FHWA) noted, in its study of sodium in public water supplies, that consumers readily identify the "too salty" taste in drinking water, finding it unpalatable.
- There are many studies documenting the effect of road salt on the increasing corrosivity of water, increasing leaching of heavy metals from natural geologic materials and soils and from plumbing.

Radionuclide concentrations in well samples have also been found to increase with total dissolved solids associated with road salts (Lazur et al., 2020; McNaboe et al., 2017).

- A recent Maryland Geological Survey (MGS) study of groundwater in the Maryland Piedmont found elevated chloride concentrations in wells, including a maximum of 571 mg/L in a well near I-95 and five wells that exceeded the EPA secondary standard for chloride (250 mg/L). They also found that "Baltimore County has had an increasing number of complaints regarding high-chloride groundwater." Additionally, chloride concentrations had increased by 25% or more in 15 of the 25 wells studied.
- Drawdown by wells creates a cone of depression that allows recharge into the well from seepage. The latter mechanism **provides a local groundwater recharge system that captures surface water and dissolved salts and leads them directly to the well** at the center of the cone of depression.
- A study by the Delaware Geological Survey of salt in groundwater beneath an infiltration basin showed that groundwater is impacted by road salt throughout the year, not just during winter.
- Once a well is salty, dissipation of **salt requires many years** due to the slow travel times in groundwater.
- A study by the Water Institute at University of Waterloo suggests that after a long-term slow increase associated with road salt application, salt reduction Best Management Practices were associated with reductions in groundwater chloride concentrations in public supply wells of ~60% and cumulative stored chloride mass of ~40% over a 6-year period after measures were introduced. Efficacy of such measures is highly dependent on the local hydrogeological environment. Decreases in chloride concentrations may take much longer in private wells, which have much lower rates of water extraction.

Road Salt Effects on Plants and Animals

All life is impacted by the increase in salt concentration.

Effects on Plants

"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)." (Introduction from Northern VA Salt Management Toolkit p. 81).

1. Most native and cultivated plants in Maryland display reduced vigor and rapid decline when exposed to elevated levels of sodium or chloride concentrations due to road salt applications. Salt concentrations of 100 ppm in soil have been shown to disrupt water and nutrient uptake through the alteration of soil pH levels. The following plant responses have been documented:
    - Reduced seed germination
    - Reduced root & stem growth
    - Decreased internode length
    - Foliar (leaf) burns
    - Leaf drop
    - Twig dieback
    - Inhibition of flowering
    - Decreased production of viable seed
    - Lowered resistance to insect pests and plant diseases

2. Damage to vegetation growing up to 200 meters (656 feet) from roadways treated with deicing salts is commonly observed.
3. Common woody plant species popular in home and roadside landscape such as oak and maple are particularly susceptible to salt toxicity.
4. Chloride exposure has been shown to destroy bud scales on branches, exposing more tender tissue to winter injury.
5. As a result of high salt levels, naturally occurring native plant density is significantly reduced.
6. Plant diversity decreases in salt-compromised areas.

Effects on Animals

"One teaspoon of salt in a five-gallon bucket adds enough chloride to increase concentrations above the US EPA recommended value for protection of aquatic life" (www.thewatermain.org/road-salt).

1. AQUATIC INVERTEBRATES

Intolerant Benthic Macroinvertebrates:

- Moderate levels of road salts have been shown to alter the population dynamics of benthic macroinvertebrate populations. Benthic macroinvertebrates are essential to stream ecosystems and are key bioindicators of stream health. Salt toxicity responses in these invertebrates include reduced growth, impaired larval development, and species extirpation.
- Studies have demonstrated predatory behaviors and immune responses of dragonfly larvae are altered when exposed to high NaCl concentrations.

2. AQUATIC/ SEMI-AQUATIC VERTEBRATES

Amphibians & Reptiles

- All life stages of amphibians are known to be intolerant of changes in the osmolar environment. Reduced egg and larval stage survival of *A. maculatum* (spotted salamander) has been observed up to 50 meters from a treated roadside. High salt levels combined with low larval population density can lead to local extirpation of this threatened species.
- In studies of chronic exposure to increased salinity, *Glyptemys muhlenbergii* (bog turtle) adults and immatures showed signs of rapid body water loss, decreased muscle moisture levels, and in some cases, mortality after seven days.

Fish

- Multiple studies have confirmed that the most common effect from road salt contamination for both warm water finfish (e.g. largemouth bass) and cold-water species (e.g. brook trout) is not a sudden mass fish kill. More commonly seen in studies using rainbow trout were significant reductions in body length and weight. Immature trout life stages have been shown to be most susceptible to high salinity concentrations with associated low growth rates and low body mass indices.

- Subsequent studies suggest that a wide range of salt tolerances has been observed within freshwater fish assemblages in Maryland.

- However, high concentrations of NaCl from road salt are strongly associated with impaired osmoregulation, changes in prey availability, and reduced food consumption of trout and other species.

3. TERRESTRIAL VERTEBRATES

General effects

- Road salt exposure has been shown to cause? be associated with? behavioral changes in addition to toxic impacts on animals. As plant species sensitive to salt die, wildlife populations are affected. The loss of shelter, habitat corridors, and breeding sites that plant colonies provide impedes re-colonization by wildlife.

Mammals

- Deer and other large animals seek out road salt to fulfill dietary needs. Toxicity signs in animals closely resemble those observed in humans.

- Both large and small mammals that have ingested water contaminated with salts display altered behavior. Changes include loss of flight instinct, mating behavior interference, and general confusion.
- Pets can be sickened by drinking water with elevated levels of salt.

Birds

- Many bird species seek out road salt to ingest as a grinding agent to aid digestion
- Studies have shown that salt exposure increases the vulnerability of birds to car strikes.

Negative Impacts of Road Salt on Infrastructure and Private Property

> The impacts of road salt to infrastructure are costly and well documented, with the costliest impact on infrastructure, as seen on motor vehicles, bridges and parking structures, and on concrete pavement, underground utilities, and roadside objects—all of which are corroded or degraded by salt.

The impacts of road salt to infrastructure are costly and well documented (Transportation Research Board Special Report 235, National Research Council, Washington, D.C., 1991, 'Highway Deicing Comparing Salt and Calcium Magnesium Acetate' p.5) – updated as of 6/20/2000. In the early 1990s, Congress sponsored a study to examine the direct and indirect cost of road salt, quantifying costs which included damage to the environment, infrastructure, and motor vehicles. Experts in engineering, science and maintenance documented in detail the estimated total costs of use of road salt. The costliest impact on infrastructure is seen on motor vehicles, bridges and parking structures, and on concrete pavement, underground utilities, and roadside objects, all of which are corroded or degraded by salt. In addition, 'road salt can also cause many issues for homeowners with a private water supply. Excessive chloride levels can accelerate the corrosion of drinking water infrastructure. One study from 2018 (5) evaluated various private water supplies in New York near a road salt storage facility. This study found that rising chloride levels in well water resulted in increased galvanized corrosion of the pipes. In addition, they created a model that found that roughly 25% of the private water supply population in New York could be affected by chloride contamination from road salts.' (4)

In the 1991 study, the cost of corrosion-resistant technology for cars was found to add on average $500 to the cost of the vehicle (NRC, 1991, p38); $500 in 1991 is equivalent to $1171 in 2024. Damage to bridge decks is well understood and 'under low or no-salt conditions [bridge decks] are normally protected from corrosion by the highly alkaline environment of the concrete' (NRC, 1991, p.43). Under high salt conditions, the damage is severe and replacement expensive.

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(2) Minnesota Pollution Control Agency. 2022. Minnesota Stormwater Manual: Environmental Impacts of Road Salt and Other De-icing Chemicals
(3) Columbia University Climate School, State Of the Planet. 2018. "How Road Salt Harms the Environment"
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(5) Pieper, K. J., M. Tang, C. N. Jones, S. Weiss, A. Greene, H. Mohsin, J. Parks, & M. A. Edwards (2018), Impact of road salt on drinking water quality and infrastructure corrosion in private wells, Environmental Science and Technology, 52, 14078-14087. https://doi.org/10.1021/acs.est.8b04709

Environmental Impacts of Road Salt: Effects on Infrastructure

Salt impacts infrastructure, including the drinking water system.

Transportation Infrastructure

- "Asphalt is susceptible to the impacts from salts through the increase in the number of freezing and thawing cycles. Over time, this can increase the rate of roadway deterioration, especially in already damaged roads." (section 2.2.2 VA Road Salt Strategy Toolkit)
- 'Although road salt rarely jeopardizes the structural integrity of bridges, its corrosivity damages bridge decks. Chloride ions penetrate concrete and corrode reinforcing rods, causing the surrounding concrete to crack and fragment' (NRC, 1991, p.3).
- 'Road salt causes reinforcing steel in parking garages to rust, thereby compromising the structural integrity of the surrounding concrete.' (NRC, 1991, p.4).

Utilities Infrastructure

- 'Corrosion damage to utility lines, pipelines, and steel storage tanks buried under or alongside highways is sometimes linked to the use of road salt, especially in urban areas with a high density of underground utility lines and heavy salt usage' (NRC, 1991, p.144)

Drinking water Infrastructure

- The majority of the County's population is supplied by public water suppliers using surface water sources from Liberty, Loch Raven, and Pretty Boy Reservoirs. "These surface waters are subject to receiving deicing chemicals especially in urban and suburban areas and near roadways…. 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. 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)."

- "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…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

Road Salt and Climate Change Impacts

The impacts of climate change which include increasing temperatures will result in an expected decrease of the number of days with temperatures conducive to frozen precipitation throughout the century in the region (Kim and Kimball, 2022) According to the Maryland.gov site, the Baltimore area currently has an average of 10.3 winter storms each year, which likely will decrease as we move into the future. This, in turn, will lead to fewer days in which road salt application would be necessary and therefore will create an overall decrease in the potential negative side effects of road salt application.

As a counterpoint, however, because of climate change overall precipitation is expected to increase as we move into the future. This increase in precipitation is projected to include an annual total volume of up to 10 % greater by the end of the century generally in the region. In addition, significant storm events are projected to increase by as much as 50% in the same time frame. (NASEM, 2023) This increase in precipitation for the region will result in greater mobilization, and transport of deposited road salt to surface and groundwater.

Environmental Justice and Winter Storm Deicing

> As all Baltimore County communities confront the challenges posed by winter weather, it is imperative to ensure that deicing practices uphold principles of diversity, equity, and inclusion—the three hallmarks of Environmental Justice.

In Baltimore County the environmental and social implications of de-icing practices center on these questions:

- Is deicing uniformly distributed across the County's diverse communities?
- Does the deicing process consider the importance of environmental justice?

During winter storm and deicing period, Baltimore County proceeds according to EPA's environmental justice mandate, including:

- setting standards
- permitting facilities
- awarding grants
- issuing licenses
- regulations
- reviewing proposed actions by the federal agencies like EPA

https://www.epa.gov/environmentaljustice/learn-about-environmental-justice

Diversity, Equity, and Inclusion:

Diversity, equity, and inclusion are important concepts that help to advance and embrace people of different characteristics. Various communities face differential impacts from winter storm deicing procedures.

Health Impacts
Low-income communities and communities of color often show an unequal burden of environmental hazards

Safe and Efficient Access
Access to safe and efficient transportation during winter storms is essential for all communities, regardless of socioeconomic status or location. However, unequal access to transportation infrastructure and services can further impact already vulnerable populations. Confirming reasonable access to safe travel routes requires addressing general barriers and advancing comprehensive infrastructure planning and assets by meaningful community engagement.

Impartial Distribution of Resources
The County can ensure equitable distribution of resources for winter storm awareness and response by listing and tracking underserved people that may have limited access to transportation infrastructure, emergency facilities, and further critical resources during risky weather conditions.

Community Encounter
Meaningful meetings with affected communities are essential in developing and implementing winter storm deicing strategies. Community input can help identify local concerns, prioritize solutions, and ensure that decision-making processes are transparent, inclusive, and equitable.

Decrease Reliance on Deicing Chemicals
Strategies that decrease the dependance on deicing chemicals may abate the need for chemical treatments and decrease health and environmental risks to vulnerable populations.

Environmental Monitoring and Mitigation
The County can implement robust monitoring programs to trace the environmental effects of deicing operations and mitigate any harmful effects on water quality, soil health, and ecosystem reliability. The County can increase transparency and accountability by encouraging communities to observe and report impacts of road salt.

Environmental justice must remain central to Baltimore County's winter storm deicing efforts. By prioritizing the equitable distribution of resources and services and engaging communities, the County can ensure winter storm management strategies advance safety, strength, and social diversity, equity, and inclusion for all residents. Adopting the principles of environmental justice in winter storm deicing is not only a matter of justice but also a fundamental step toward developing healthier, more robust communities for generations to come.

Education and Public Outreach About Road Salt

> Effective community outreach and education increase the likelihood of people making informed decisions as individuals and in support of changed community practices that are best for their health, and that address the tax burden of high infrastructure maintenance costs.

Outreach and education can increase the public's awareness and understanding of the benefits and impacts of salt use, so residents can support the use of improved best practices within their communities. Outreach and education can also change individual behaviors by encouraging conversations with family, friends, neighbors, and co-workers about the benefits and impacts of salt use, and the best practices to balance those. Education increases the likelihood of people making informed decisions as individuals and in support of changed community practices.

The Virginia Salt Management Strategy Toolkit highlights successful strategies from a pilot education-outreach program (www.novaregion.org/DocumentCenter/View/13054/SaMS_Toolkit_final?bidId= - and Appendix I. The Toolkit thoroughly describes its effective road salt education-outreach approach based on these 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); and
5) information on ways the target audience can address the issue.

The Toolkit emphasizes the importance of coordinating the messaging from different organizations and communities to convey a single message. The Toolkit describes messaging targeted for local residents means that Baltimore County should consider practices that may differ from Northern Virginia:

- residential best practices (including infographic, pamphlet and information to populate future webpages)
- charts of temperature ranges for effective use of different kinds of salt; advice (Section 5.2.3.1)
- what to look out for when purchasing salt;
- materials to avoid (nitrogen and phosphorus salts); what to do during and after a storm (Section 5.2.4);
- advice on clearing snow and applying salt
- how to report winter salt concerns

The Izaak Walton League's Salt Watch materials (Salt Watch - iwla.org) offer other ideas and materials for public outreach and education include. Their material includes:

- Be a Smart Salter: Flyer to educate neighbors
- Be a Smart Salter: Flyer to inform local businesses
- Be a Smart Salter: Flyer for visual of how much salt to use

Public outreach can also include:

- Designate a Road Salt Awareness Week
- Salt Responsibly: Distribute yard signs (Yard sign template) so neighbors can inform their community about road salt pollution
- What is the Correct Amount of Salt: Distribute public service announcements for local TV, radio, newspapers, e-news (e.g., Patch), social media groups (Next Door, etc.)
- Distribute brochures (in English and in Spanish) to educate communities about road salt pollution and what to do

Key audiences for message about the costs and impacts of road salt and best practices include:

- Taxpayers: emphasizing the true financial costs, short- and long-term
- Seniors via senior centers, local AARP, local hospitals/medical center/insurance executives
- Community/watershed groups via the Baltimore County Green Alliance
- Businesses that sell salt to residents
- Business groups/Business contractors
- Families and children via schools and environmental classes
- All residents via schools, libraries, parks, senior centers, and golf courses
- All residents via DPW: Salt reduction brochure included with trash/recycling brochure

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Appendices

Appendix A. National Pollution Discharge Elimination System (NPDES) – Baltimore County 2022 Annual Report – excerpts

> The County acknowledges its permit requirements are to develop Good Housekeeping Plans for eligible county owned sites and to develop a Salt Management Plan for winter deicer use, with efforts being made to reduce the amount of chemicals applied.

What is NPDES?
The NPDES permit program addresses water pollution by regulating point sources that discharge pollutants to waters of the United States. Created in 1972 by the Clean Water Act, the NPDES permit program is authorized to state governments by EPA to perform many permitting, administrative, and enforcement aspects of the program.

2022 NPDES – Baltimore County Report - EXECUTIVE SUMMARY

D. Management Programs
5. Property Management and Maintenance (Page 19-20: ES-2-3)
Chemical application of fertilizer, pesticide/herbicide, and **deicer** is reported for all county property; efforts are being made to reduce the amount of chemicals applied. ES-3 During FY 2022 the County removed 572 tons of debris through the street sweeping program and 110 tons of debris through the storm drain cleaning program. **The County acknowledges its new permit requirements to develop Good Housekeeping Plans for eligible county owned sites and to develop a Salt Management Plan for winter deicer use**. Dialogs with relevant county agencies have been initiated.

6. Public Education (Page 20: ES-3)
The County has continued to enhance and expand its education and outreach efforts across multiple media. Baltimore County has recorded a significant increase in direct personal engagement over the past years, due largely to greater engagement of the County's on-call outreach contract. Continued focus on enhancing social media reach, chiefly through the "Clean Green Baltimore County" Facebook page, have also been recorded. Baltimore County's MS4 permit (effective Nov 2021) requires a minimum of 150 education and outreach efforts to be achieved each year. In FY22 Baltimore County and its contributing partners have recorded 318 education and outreach efforts.

SECTION 7
7.0 Permit Requirements, Existing Permit Conditions as of November 5, 2021

PART IV. STANDARD PERMIT CONDITIONS (Page 134)
D. Management Programs
4. Property Management and Maintenance
d. (p136) **The County shall reduce the use of winter weather deicing and anti-icing materials, without compromising public safety, by developing a County Salt Management Plan (SMP) to be submitted to the Department in its third year annual report and implemented thereafter. The SMP shall be based on the guidance provided on best road salt management practices described in the Maryland Department of Transportation, State Highway Administration's Maryland Statewide**

Salt Management Plan, developed and updated annually as required by the Maryland Code, Transportation

§8-602.1. The County's **SMP** shall include, but not be limited to:

i. A plan for evaluation of new equipment and methods, and other strategies for continual program improvement;

ii. ii. Training and outreach:

• Creating a local "**Salt Academy**" that annually provides County winter weather operator personnel and contractors with the latest training in **deicer** and **anti-icer** management, or the participation of County personnel and contractors in a "Salt Academy" administered by another MS4 permittee or State agency; and

• Developing and distributing best salt management practices outreach for educating residents within the County.

iii. Tracking and reporting:

• Starting with the fourth year annual report, during storm events where deicing or anti-icing materials are applied to County roads, track and record the amount of materials used and snowfall in inches per event, if applicable, and;

• Report the deicing or anti-icing application by event or date, and the monthly and annual pounds used per lane mile per inch of snow.

7.3.4 Fertilizer, Pesticide, and **Deicing** Statistics (p.151)

Members of the Baltimore County NPDES Management Committee have submitted statistics for usage of fertilizers, pesticides and **deicing** materials. Baltimore County provides data for the total salt used and snow accumulation - https://www.baltimorecountymd.gov/departments/public-works/highways.

Fiscal Year	Number of Storms	Total Cost	Tons of Salt	Salt Cost Per Ton	Snow Accumulation (inches)
06	4	$3,871,158	33,947	$45.41	19
07	7	$6,769,421	62,858	$47.36	12
08	7	$5,912,602	47,806	$55.68	10
09	5	$5,858,860	43,632	$65.45	7
10	10	$20,807,570	94,477	$57.17	84
11	12	$11,530,092	82,504	$58.93	23
12	5	$1,862,505	10,611	$58.93	4
13	18	$3,715,188	36,902	$52.93	17
14	19	$13,722,622	125,309	$54.77	87
15	20	$14,877,290	101,893	$59.84	51
16	7	$15,737,025	45,116	$59.90	39
17	7	$5,813,717	29,543	$59.90	12
18	14	$10,684,852	70,385	$59.90	25
19	9	$8,874,294	70,645	$59.90	18.50
21	9	$8,130,862	53,517	$48.60	20
Average	10	$8,245,186	60,789	$50.05	28.47

7.3.4.3 **Deicing** (p 154)
Deicing materials (generally road **salts**) are used by several county agencies. As expected, because of its responsibility to clear 2,705 miles of roads (6,762 lane miles), the DPWT Bureau of Highways remains the biggest user of **deicing** materials. In FY 2022, the Bureau of Highways applied 62,570,000 pounds of dry road **salt** and an additional 35,388 pounds of **salt** were used in a **brine** mixture; 29,490 gallons of **brine** was applied. The County applied a total of 63,678,883 pounds of **deicer**, 98% of which was used by Highways. Efforts will continue to be made to reduce the amount of **deicing** materials used through research, testing, equipment calibration, employee training, and effective decision making.

The amount of **deicing** materials used depends not only on accumulation of snow, but also the number of winter weather events. Icy road conditions are not tracked at this time.

Efforts to reduce deicer usage by the Department of Public Works and Transportation - Bureau of Highways:

- **DPWT has outfitted all snow removal equipment outside of the County's Urban-Rural Demarcation Line (URDL)** with independent **salting** controls. Just over a quarter of the entire fleet has been replaced and all new vehicle replacements are being equipped with this technology. DPWT conducts annual staff reviews of our Snow Management Plan which includes best practices of **salt** usage. This information is also now shared with our contractual **snow** vendors.
- In an attempt to reduce the total amount of **salt** applied, a trial run of **brine** (23% rock **salt**) was used as pre-treatment on a few heavily traveled roads in the Reisterstown and Cockeysville areas. It is undecided if the County will continue using brine.
- County crews receive extensive training and begin each **snow** season with a review of salt application procedures and best-practices. One aspect of the training is a "**Snow** College" which is held yearly for all personnel involved with **snow** operations.
- Crews use manually adjusted **salt** spreaders and spinners to restrict **salting**, **except in North County where computerized salt spreading technology is used.** These **computerized spreading systems will be mandated on each new piece of snow removal equipment starting with a quarter of the fleet by 2021. Salt spreader calibrations are checked yearly. Spreading volumes are maintained between 500 and 600 pounds of salt for each lane mile (for every inch of snow).**
- Efficiencies have been made in **salt** storage. The County's full supply (91,000 tons located at 17 sites) is stored under cover, on impervious surfaces and surrounded by berms (or straw bales) to deter or prevent leaching.

Efforts to reduce deicer usage by other County agencies: (p155)

- **Property Management** applies deicer only as needed for safety.
- Department of **Public Works and Transportation** – Bureau of Solid Waste applies deicer as conservatively as possible at the landfill and resident drop sites; Bureau of Utilities purchased a walk-behind snow blower for its Fullerton site.
- **CCBC** reduces their use of deicer by closing certain parking lots to concentrate parking in select treated areas only.
- **Baltimore County Public Schools** only uses deicer on sidewalks where icy conditions are a safety issue; they use shovels and use lower settings on deicer spreaders.
- Deicer is used by **Golf** Courses only as needed.

Table 7-9 of that report shows the annual usage of fertilizer, pesticides and **deicing** material from 1999 through 2022 (not included here). As of 2016, EPS obtains winter storm data from DPWT Highways.

Snowfall is measured at the Highways shops. There is a complex relationship of snowfall and amount of deicer used due to size/frequency of storms, freezing rain events, and the effect of freeze and thaw on localized road treatment. Due to its location along the boundary of the Piedmont Plateau and Coastal Plain geographic provinces, the County experiences considerable weather variability.

Prior to 2016, snowfall data was obtained from NOAA's online preliminary monthly weather (summary) data archive for BWI Airport. The number of winter weather events is attributable to the events with measurable snowfall ("heavy snow" and "snow" categories); the number of winter storms does not include "freezing rain" events, although road salt may be applied for these storms as well. (Note: there is a considerable difference in data between the data sources, but the Highways data reflects actual conditions, averaged across the County. Conditions at BWI are often different than Baltimore County, hence the change.)

Appendix B: County Council of Baltimore County, Maryland. Resolution No. 15-10 to create a task force to investigate and report on the environmental and health issues emanating from the use of road salt to melt ice and snow. March 15, 2010

COUNTY COUNCIL OF BALTIMORE COUNTY, MARYLAND
Legislative Session 2010, Legislative Day No. 6

Resolution No. 15-10

Councilmembers Gardina & McIntire

By the County Council, March 15, 2010

A RESOLUTION of the Baltimore County Council requesting the County Executive to create a task force to investigate and report on the environmental and health issues emanating from the use of road salt to melt ice and snow.

WHEREAS, most jurisdictions, including Baltimore County, use road salt to clear County roads of snow and ice during the winter months; and

WHEREAS, the Baltimore County Advisory Commission on Environmental Quality has reviewed the environmental impacts of road salt application in the County; and

WHEREAS, the Commission report concluded that there are significant negative environmental impacts - on drinking water, human health, private property, ecosystem sustainability, and the infrastructure - associated with the use of road salt; and

WHEREAS, the Commission believes that the County should seek to reduce the use of road salt by investigating alternatives and by promoting sustainable road salt application practices for County operations; now, therefore

BE IT RESOLVED BY THE COUNTY COUNCIL OF BALTIMORE COUNTY, MARYLAND, that the County Executive is requested to appoint a task force composed of representatives of the Office of Budget and Finance, the Departments of Health, Environmental Protection and Resource Management, and Public Works, and such other public and private sector representatives, in the Executive's discretion, to:

1. Analyze and evaluate the effects of using salt on County roads versus the use of other possible alternatives, considering not only the short-term financial costs, but also the impacts on the environment, public health, and the infrastructure;

2. Prepare a cost-benefit analysis of the use of road salt and alternatives;

3. Establish stricter guidelines and protocols to regulate the distribution of road salt in order to minimize environmental impacts; and

4. Increase awareness of the environmental impacts of road salt.

AND BE IT FURTHER RESOLVED, that the task force shall report its findings and recommendations to the County Executive and County Council on or before August 1, 2010.

r01510.wpd

Appendix C: Resources about Best Management Practices for Road Salt

Table of Contents from Appendix B, the BMP section of the Virginia SaMS Salt Management Strategy: A toolkit to reduce the environmental impacts of winter maintenance practices lists the 52 best practices of winter maintenance practices
https://www.novaregion.org/DocumentCenter/View/13054/SaMS_Toolkit_final?bidId=

Outline of Practices

Appendix B - 104

Table 1 on page 18 of the Virginia SaMS Salt Management Strategy: A toolkit to reduce the environmental impacts of winter maintenance practices lists the 52 best practices of winter maintenance practices https://www.novaregion.org/DocumentCenter/View/13054/SaMS_Toolkit_final?bidId= summarizes "**Partnership opportunities and expected costs for planning practices** (i.e, winter operations planning, levels of service, training, salt Storage/handling, Calibration, Storm Meetings, Weather Forecasts and Surface Temperature information, enhance equipment and technology) of the BMP Pros and Cons."

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 on page 20 of the Virginia SaMS Salt Management Strategy: A toolkit to reduce the environmental impacts of winter maintenance practices lists the 52 best practices of winter maintenance practices https://www.novaregion.org/DocumentCenter/View/13054/SaMS_Toolkit_final?bidId= summarizes

Partnership opportunities and expected costs for storm-related practices (plowing practices, product application practices, storm-related BMPs, vary application to conditions, use of liquids, measurement) in the BMP Pros and Cons menu. These tables provide thorough overviews and include potential costs on staff time, other costs, and potential cost savings.

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.

The Virginia SaMS Salt Management Strategy: A toolkit to reduce the environmental impacts of winter maintenance practices lists the 52 best practices of winter maintenance practices https://www.novaregion.org/DocumentCenter/View/13054/SaMS_Toolkit_final?bidId= notes other actions that can support implementation of Road Salt BMPs:

Intergovernmental Coordination (Section 8)
Enhanced coordination among Baltimore County government "organizations that perform winter maintenance activities can provide important support for Road Salt BMP 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." (p.)

Section 8 of the SaMS Toolkit addresses recommendations and reference information for intergovernmental coordination that include:

Pooled Funding and Shared Services (Section 8.2 – p.47)).

- Training Winter Operations Personnel: "all area county and city 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.

- **Water Quality Monitoring and Research**: "Pooled monitoring activities can maximize resources and avoid duplication of efforts in the region." Enhanced coordination of government water quality monitoring programs Baltimore County, Baltimore City, and surrounding Counties will enable more ambitious and efficient monitoring, research, and analysis in support of Road Salt BMP implementation.

Other appendices of the Salt Toolkit summarize references and resources about de-icing practices

Further Resources About Best Road Salt Management Practices

Virginia SaMS Salt Management Strategy: A toolkit to reduce the environmental impacts of winter maintenance practices
(https://www.novaregion.org/DocumentCenter/View/13054/SaMS_Toolkit_final?bidId=)

Adirondack Road Salt Reduction Task Force Assessment and Recommendations
https://extapps.dec.ny.gov/docs/administration_pdf/adirondackroadsaltreport.pdf

Road Salt Management: snow and ice control for parking lots and sidewalks
https://sustainabletechnologies.ca/home/urban-runoff-green-infrastructure/pollution-prevention/road-salt-management/snow-and-ice-control-for-parking-lots-and-sidewalks-sicops/ and Winter Salt Management - https://sustainabletechnologies.ca/home/urban-runoff-green-infrastructure/pollution-prevention/road-salt-management/
The Sustainable Technologies Evaluation Program (STEP) is a multi-agency initiative developed to support broader implementation of sustainable technologies and practices within a Canadian context to "identify the right snow and ice control methods, materials, and the right amounts of materials to be applied under specific winter weather conditions."

https://www.clearroads.org/ - Clear Roads, a national research consortium focused on rigorous testing of winter maintenance materials, equipment, and methods for use by highway maintenance crews.

Toxicological effects of chloride-based deicers in the natural environment. Prepared for: Association of American State Highway and Transportation Officials Standing Committee on the Environment. Laura Fay and Xianming Shi. Western Transportation Institute Montana State University PO Box 174250 Bozeman, MT 59717 Marie Venner, Venner Consulting and Eric Strecker, Geosyntec Consultants February 6, 2014 https://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP25-25(86)_FR.pdf

Maryland Department of Environment National Pollutant Discharge Elimination System ((NPDEA) Municipal Separate Storm Sewer System (MS4) Permits: 2020 MS4 Monitoring Guidelines: BMP Effectiveness and Watershed Assessment 2020 MS4 Monitoring Guideline.pdf (maryland.gov)