2023

MWCOG Salt Application Area Assessment

Prepared for the Metropolitan Washington Council of Governments (MWCOG)
By Corona Environmental Consulting
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CORONA ENVIRONMENTAL CONSULTING

Contents

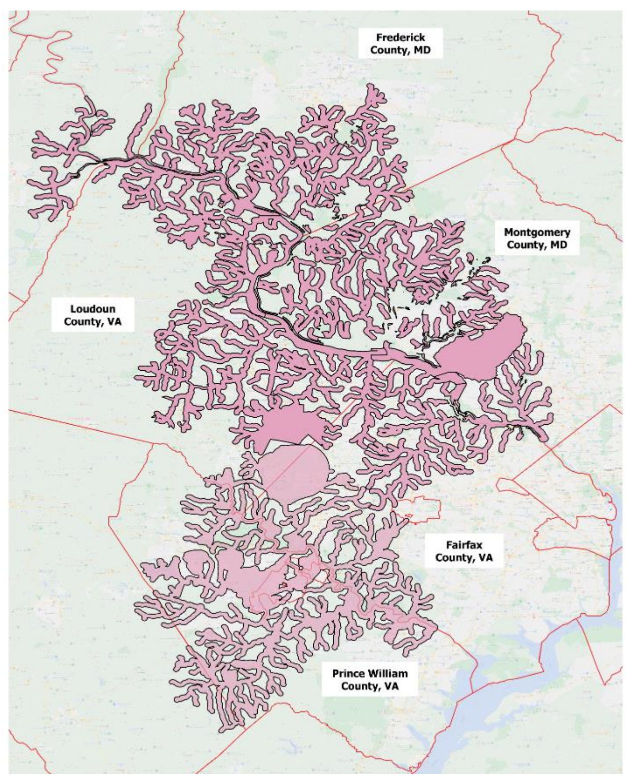
Salt Application Area Assessment

Background and Objectives

Increasing chloride levels in the Potomac River are a concern for drinking water utilities that draw raw water from the river. Road salt runoff can greatly impact surface and groundwater quality, soils, biota, infrastructure, and properties (Virginia Department of Environmental Quality, 2020). The consequences of salt runoff and infiltration into drinking water systems range from taste complaints from customers to the total loss of drinking water sources. High salt concentrations can also put dialysis patients or consumers on low-sodium diets at risk. The corrosiveness of salt and chemical reactions between salt and cement can damage pipes and other infrastructure, leading to additional leaching of chemicals like lead into consumers' tap water.

The Metropolitan Washington Council of Governments, representing drinking water utilities on the river, sought to develop an inventory of chloride loading sources in the Occoquan, Watts Branch, and other watersheds. Key objectives included identifying and estimating salt use in areas of high salt application, understanding the relative contribution of road versus parking lot salting practices, and mapping areas of high salt application relative to MS4 collection systems. Part of the project included a thorough literature review and communication between various contacts to understand the salt application practices and rates within their watershed. Project findings may be used to: 1) evaluate the difference in estimated application rates and chloride loads derived from public roads versus private or commercial parking areas to inform discussions of how to best reduce chloride loading from parking lot salting practices; 2) predict or calculate estimated chloride loading from particular storms based on weather patterns; and 3) identify stormwater outfall locations with the greatest estimated chloride loadings to target outreach or BMPs.

Figure 1: Metropolitan Washington Council of Governments' member utilities' source water zones of concern and intersecting counties



Study Area

Salt application rates and general salt application practices including best management practices for roadways, private parking lots, and other impervious surfaces were evaluated for the following counties that intersected the MWCOG zone of concern: Washington (MD), Frederick (MD), Montgomery (MD), Fairfax Co (VA), Fairfax (VA), Prince William (VA), Manassas (VA), Manassas Park (VA), Fauquier (VA), Loudoun (VA), and Jefferson (VA). These counties encompass the majority of the surface water zones of concern designed for MWCOG's member water utilities.

Virginia State and County Application Salt Application Practices

Various members of the Department of Transportation (DOT) and Department of Public Works (DPW) at the state and county levels, and the VA Department of Environmental Protection (DEP) were contacted to obtain data and information on local salt application practices. A list of these contacts and their corresponding email addresses are provided in Appendix A.

Table 1. Key Contacts for Salt Application Estimation Effort

Maryland	Virginia
Frederick County Division of Energy and Environment	Fairfax County MS4 Program Coordinator
Montgomery County Watershed Outreach Planner	Virginia Department of Transportation
Washington Suburban Sanitary Commission (WSSC) Water	
Maryland Department of Transportation	
Maryland Department of Environment: Planning, Outreach, Monitoring Section of Watershed Restoration Division	

The Virginia Department of Transportation (VDOT) is responsible for applying salt to the majority of Virginia roads. Virginia roads are pretreated with brine prior to a winter weather event if pavement temperatures are above 20°F and if there is no rain in the forecast. The brine that is applied is a 23% salt solution covering 40 to 50 gallons per 12-ft lane mile (Virginia Department of Public Works, 2021). Magnesium chloride is only occasionally used on interstates, if ideal conditions occur. Granular salt is used as the de-icing chemical and is applied prior to snow accumulation. Auger speed and gate height controls on spreaders are used to place the minimum effective level of material based on current and forecasted weather conditions. Salt application is not reduced near watersheds or source water protection areas at this time. However, areas where excess salt has been applied are identified so the extra material can be collected after each storm. If the temperature drops below freezing, de-icing materials can be supplemented with sand at a 2:1 ratio. These abrasives also help with traction on the roads. Once snow begins to accumulate, the use of de-icing materials ceases and the focus turns to plowing. After the roads are clear and accumulation has stopped, towns may apply more de-icing materials to prevent freezing.

In the past, salt application rate data was not collected in Virginia, and actual application rates were not available upon request for use in this assessment. However, the VDOT has been working on a pilot to monitor salt application. The pilot initially monitored the salt output of 4 spreaders with sensors and has increased to 12 – 16 spreaders. The goal of the pilot is to find the optimal salt application rate and to see if recommended application rates (Virginia Department of Transportation, 2021) from the Salt Institute are still applicable (Table 1).

Table 2. VDOT Maintenance Best Practices for Winter Weather Salt Application.

Winter Weather Mobilization Guideline

Weather Forecast	Mobilization Level	Response Plan	Salt Application Rate*
Precipitation: 20% or greater Accumulation: Ice/Snow Possible Ambient or Pavement Temp: 30-36	Anti-ice	Spot treatment of critical structures and locations	Application Liquid Mag: 36 gal/ln mi Application Liquid salt brine: 50 gal/ln mi Application Salt: 325 lbs./ln mi
Precipitation: 20-49% or greater Accumulation: Snow Possible Ambient or Pavement Temp: 30-36	1	Spot treatment of critical structures and locations	325 lbs./ln mi
Precipitation: 50-100% chance Accumulation: Up to 1 inch of snow Ambient or Pavement Temp: 25-29	2	Light Salting Operation	400 lbs./ln mi
Precipitation: 50-100% chance Accumulation: Up to 2 inches of snow or up to 1/10 inch of ice Ambient or Pavement Temp: 20-24	3	Salting Operation	475 lbs./ln mi
Precipitation: 50-100% chance Accumulation: Up to 6 inches of snow or up to ¼ inch of ice Ambient or Pavement Temp: 15-19	4	Salting/Plow Operation	550 lbs./ln mi
Precipitation: 50-100% chance Accumulation: More than 6 inches of snow or more than ¼ inch of ice Ambient or Pavement Temp: 10-14	5	Salting/Heavy Plow Operation; All resources are deployed	625 lbs./ln mi

* Based on Salt Institute Standards **VDOT Single Axle Capacity: 12,000 lbs. ***Pickup Capacity: 3,000 lbs.
**VDOT Tandem Axle Capacity: 28,000 lbs.

Virginia's water quality standards for chloride include a maximum one-hour (acute) average of 860 mg/L not to be exceeded more than once every three years and a maximum four-day (chronic) average of 230 mg/L, also not to be exceeded once every three years (Virginia Department of Public Works, 2021). Elevated chloride levels from winter deicing salts in the Accotink Creek watershed in Fairfax County, VA also led the VA Department of Environmental Quality (DEQ) to develop total maximum daily loads (TMDLs) for chloride to address the watershed's benthic impairments (Table 3).

Table 3. Average Annual Chloride TMDLs for Upper Accotink Creek, Lower Accotink Creek, and Long Branch

Watershed	**Average Annual Chloride TMDL (lbs/yr)** (excluding upstream impairments)
Upper Accotink Creek	8,217,030
Lower Accotink Creek	6,241,688
Long Branch	1,292,997

Following the setting of TMDLs for the Accotink Creek watershed, the Interstate Commission on the Potomac River Basin (ICPRB) and Virginia Department of Environmental Quality (VDEQ) developed a Salt Management Strategy (SaMS) Toolkit to implement best practices for improved efficiency of winter salt use in the Northern Virginia region and to raise public awareness of the environmental impacts of salt. The SaMS Toolkit includes many strategies to reduce impacts of winter weather practices while maintaining public safety (Virginia Department of Environmental Quality, 2020). To help prioritize strategies, the SaMS identified best management practices (BMPs) that the Salt Institute considers the "Fundamental 5," which can be implemented in the short term with little to no financial investment, and the "Second 6," which require equipment, tools, and/or training to implement (Table 4). For more details on these practices, reference the *Salt Management Strategy – A Toolkit to Reduce the Environmental Impacts of Winter Maintenance Practices* (Virginia Department of Environmental Quality, 2020).

Table 4. The Salt Institute's Best Management Practices (BMPs) for efficient salt use

The "Fundamental 5"	**Examples**
Calibration	• Establish a calibration process • Calibrate equipment
Measurement	• Measure and record deicer use
Accountability	• Develop a winter maintenance plan • Pre- and post-season meetings • Plan snowplow routes
Level of service	• Communicate levels of service internally and externally
Training	• Implement training programs for winter service providers
The "Second 6"	**Examples**
Variable application rates	• Use recommended application rates that are based on the following factors: (1) pavement temperature, (2) precipitation rate and type, and (3) cycle time/bare pavement regain time
Forecasts	• Weather forecasting • Forecast surface and ambient temperature
Cold temperature usage	• Know the effective temperature ranges for all deicers used.
Liquid usage	• Pre-treat (apply liquid in truck or to stockpile before road application) or pre-wet (add liquid to the salt as it is being applied to the pavement) deicers to help material stick to surfaces and speed up the melting process. • Apply mixtures of water and deicer directly to a surface

Pre-wetting	• Pre-wet deicers
Anti-icing	• Treat surfaces with liquids (usually the most efficient) or solids prevent or significantly reduce the bonding of snow and ice and make plowing/shoveling much more efficient and complete. While anti-icing with liquids is usually more efficient, anti-icing with solids can be more effective in storms that begin as as rain or freezing rain since solid salt crystals last longer.

Some towns in Virginia have come up with additional best management practices for salt storage and handling, equipment, plowing practices, and application practices to reduce chloride from public property. Table 5 provides additional best management practices established by the Town of Vienna in Fairfax County, VA and is derived from the town's *Snow and Deicing/Anti-icing Operations Stormwater Pollution Prevention Standard Operating Procedure (SOP)* for all town operations and operations conducted by contractors on behalf of the town (Virginia Department of Public Works, 2021). The SOP was developed in 2015 and is periodically updated to incorporate additional best practices and standards. For more details on the SOP, reference the *Chloride TMDL Action Plan for Accotink Creek: Appendix A.* A summary of the SOP is provided below:

Table 5. Additional Best Management Practices (BMPs) for efficient salt use developed by the Town of Vienna, VA

BMP Category	Description
Salt Storage and Handling	Proper storage of deicer piles
	Proper storage for liquid products
	Proper loading and hauling of deicers
	Clean equipment and Contain wastewater
Storm meetings	Pre- and post-storm meetings
Enhanced Equipment and Directional Technology	Plows (side wing, tow plows, flexible or sectional blades)
	Spreaders that can deliver at low rates, collect data, and/or are ground-controlled or speed-synchronized
	Equipment needed for making liquid products
	Automated vehicle location
	Maintenance decision support system
	Precision deicing
Plowing practices	Plowing early and often
	Coordinate plowing activities
	Plow trains
Product Application Practices	Dyed deicers
	Use of abrasives
	Post-storm cleanup
	Spinners set up using a chut or spinner close to the ground
	Plows drive 17-25 mph on non-high-speed roads
	Turn off auger, shoots, or conveyors when stopped
	Reduce application rate on successive passage

Maryland State and County Application Salt Application Practices

The Maryland Department of Transportation (MDOT) State Highway Administration (SHA) and other agencies in MD rely on the National Weather Service (NWS) or contracted weather services and their own network of Road Weather Information System (RWIS) sites and Mobile Advanced Road Weather Information Sensors (MARWIS) to track weather and pavement conditions at each stage of winter storm management.

As in Virginia, granular sodium chloride is the primary snow and ice control material used in MD by the Maryland Department of Transportation (MDOT), State Highway Administration (SHA) and other agencies. (Maryland Department of Transportation, 2022c) Research has been conducted into the use of other materials, but none have been able to replace granular salt in benefit, cost-effectiveness, and reliability. Salt brine (liquid sodium chloride at 23.3%) is used primarily as pre-treatment and directly applied prior to the onset of frozen precipitation to prevent snow and ice from bonding to the pavement. Salt brine can also be used to pre-wet granular salt in deicing operations to reduce the bounce and scatter of the salt. If snow or ice bonds to the pavement, heavy plowing and salting is needed to break the bond.

Certain high-chloride areas within watersheds have also been designated by the MD SHA as brine-only routes. Liquid magnesium chloride (mag) is also used in limited amounts only to pre-wet salt prior to application. Mag is typically used in winter storms with very cold pavement temperatures; however, it can make surfaces slippery under certain conditions. Abrasives (sand or crushed stone) mixed with salt are also used during winter operations to increase traction for motorists during storms with freezing rain or with very cold pavement temperatures when salt becomes less effective. These mixes are typically used in Western Maryland due to its steep topography; however, the rest of Maryland has strict environmental regulations limiting use of abrasives. Abrasives are maintenance-intensive since they can clog drainage structures, thereby necessitating storm drain or ditch cleaning, and they need to be mechanically removed post-storm via street sweeping or berm removal.

Many agencies, including the MDOT SHA, have a “snow college” training every year for new employees and an updated training at least once every five years to train employees on salt use best practices and the importance of using the smallest amount of deicing material possible while providing safe, passable roads for motorists. (Maryland Department of Transportation, 2022c) In addition to holding trainings, the MDOT sends representatives to each of the 28 DOT SHA maintenance facilities every fall to present on the previous season’s salt usage, equipment and storage upgrades, and winter operation best management practices (BMPs). This outreach has greatly impacted the salt reduction successes. The “snow college” presentation, as well as information on previous seasons’ salt usage, equipment and storage upgrades, and winter operation BMPs can be referenced in the Appendices of the *Maryland Statewide Salt Management Plan*. (Maryland Department of Transportation, 2022c)

Municipalities and counties permitted to discharge stormwater under MS4 permits are required to report salt application in annual reports to the MDE and the US EPA as well as develop and implement their own salt management plans to reduce excess salt use. Representatives from Montgomery and Frederick Counties shared their application data for granular road salt and salt brine from the past several years. Granular salt and brine use data from Montgomery County were provided for the years 2011 through 2021 (Table 6). (Patuxent Reservoirs Watershed Protection Group, 2021) Granular salt totals were applied to a total of 5,300 lane miles and salt brine totals were applied to 3,200 lane miles. As of the October 2022 data request date, the Montgomery County Department of Transportation (MCDOT) applied approximately 30,071 tons of granular sodium chloride and 200,000 gallons of sodium chlorine salt brine in response to 5 storm events in fiscal year 2022 (FY22). Granular sodium chloride was used to treat the roads during most winter storm events.

Table 3. Winter-Weather Deicing Material for Montgomery County (FY11 - FY21).

Fiscal Year	Winter Storms (no.)	Snow (inches)	Salt (NaCl) (tons)	Sand (tons)	Salt Brine (gallons)
FY11	NR[1]	13[2]	85,600	21,400	NR
FY12	NR	4[2]	15,200	3,800	122,031
FY13	NR	13[2]	31,309	0	93,005
FY14	NR	53[2]	111,787	10,000	121,787
FY15	28	37[2]	87,900	0	36,400
FY16	5	40	133,517	0	43,000
FY17	9	6	20,408	0	147,122
FY18	15	16	53,479	0	168,000
FY19	13	28	57,692	0	500,000
FY20	11	3	6,410	0	97,097
FY21	11	18	68,818	0	485,000

[1] NR – not reported
[2] NOAA Local Climatological Data, Washington, D.C., Washington Dulles International Airport

Montgomery County's efforts to reduce the amount of salt applied to county roads includes implementing a Road Salt Management Plan based on the Maryland Statewide Salt Management Plan, using rubber-tipped snowplow blades on a trial basis to begin plowing earlier, calibrating contractor salt-spreading equipment, requiring contractors to clean up excess salt, and expanding the use of salt brine.

Granular salt and brine use totals from Frederick County were provided for the years 2018 through October 2022 (Table 7). The number of lane miles to which granular salt and brine were applied was not provided by the data source. Granular road salt, anti-skid material, and liquid caliber (M1000)[1] use data by watershed for 2021 and 2022 as well as per-watershed liquid brine use data for 2022 are provided in Appendix B. (Frederick County Office of the County Executive, 2021)

Table 4. Approximate Winter-Weather Deicing Material Usage from FY18 to FY22 for Frederick County.

Material	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Road Salt (tons)	30,384	1,845	8,749	20,517	13,807
Liquid Brine (gallons)	158,488	144,328	65,795	21,364	82,874
*The FY 2022 totals represents partial data, as of October 2022.					

[1] Liquid Caliber (M1000) is a 30% magnesium chloride solution with an agricultural by-product that is used when the temperature is less than or equal to 25°F. Caliber M1000 not only increases the speed at which the salt begins working, but also increases the melting capacity of the salt, permits the use of salt at lower temperatures, reduces corrosion, inhibits crystal formation and product fallout at lower temperatures, and improves roadway traction when compared to other liquid products.

Another contact from the MD DOT was able to provide data on sodium chloride use per maintenance shop in Montgomery, Prince George, and Frederick counties, measured in both tonnage and lbs/lane mile/inch of snow accumulation. Total tons of salt used per maintenance shop were provided for fiscal year 2012 through October 2022 (Table 8) and lbs of salt per lane mile and inch of snow were provided for fiscal year 2014 through October 2022 (Table 9).

Table 8. Montgomery and Frederick County Maintenance Shop Sodium Chloride Use in Tons, 2012 – Oct. 2022.

Maintenance Shop Location	Lane Miles	FY 12 (tons)	FY 13 (tons)	FY 14 (tons)	FY 15 (tons)	FY 16 (tons)	FY 17 (tons)	FY 18 (tons)	FY 19 (tons)	FY 20 (tons)	FY 21 (tons)	FY 22 (tons)
Montgomery County: Gaithersburg	777	3,403	12,269	33,096	16,770	5,615	2,593	9,366	12,223	922	16,519	4,403
Montgomery County: Fairland	858	2,498	7,351	18,716	13,497	6,929	4,748	9,342	11,286	594	13,944	5,600
Frederick County	1,049	8,384	14,569	34,881	21,480	7,314	5,731	11,154	17,877	2,962	18,895	9,752

Table 9. Montgomery and Frederick County Maintenance Shop Sodium Chloride Use per Lane Mile per Inch of Snow, 2014 – Oct. 2022.

Maintenance Shop Location	Lane Miles	FY 14 (lbs/ ln mi/ in)	FY 15 (lbs/ ln mi/ in)	FY 16 (lbs/ ln mi/ in)	FY 17 (lbs/ ln mi/ in)	FY 18 (lbs/ ln mi/ in)	FY 19 (lbs/ ln mi/ in)	FY 20 (lbs/ ln mi/ in)	FY 21 (lbs/ ln mi/ in)	FY 22 (lbs/ ln mi/ in)
Montgomery County: Gaithersburg	777	1,220	862	377	345	820	941	572	1,017	454
Montgomery County: Fairland	858	785	816	460	636	769	1,059	442	1,043	710
Frederick County	1,049	737	644	280	258	355	463	445	648	614

The MDOT SHA also provided a graph depicting pounds of granular salt use per lane mile and inch of snow for state roads in 2019 and 2020 (Table 10) (Maryland Department of Transportation, 2022c). These values were multiplied by the total inches of snow for 2019 and 2020 taken from the National Weather Service to get total lbs of salt use per lane mile for each county and year.

Both Virginia and Maryland are proactively working to reduce the amount of salt applied to roads during winter events. Implications to their drinking water system, watershed, and water quality as well as environmental, economic, and societal impacts from salt applications will be greatly reduced from their continued success at salt reduction.

Table 10. Lbs of granular salt use per lane mile and inch of snow on MD state roads for years 2020 and 2021

County	2019-'20	2020-'21
Leonardtown	111	216
La Plata	105	239
Snow Hill	71	297
Prince Frederick	139	338
La Vale	366	347
Easton	146	407
Hagerstown	510	417
Princess Anne	29	459
Salisbury	167	525
Centreville	106	528
Westminster	372	533
Cambridge	32	573
Keyseys Ridge	514	576
Denton	204	582
Frederick	444	648
Churchville	337	696
Owings Mills	336	725
Laurel - Prince George	384	731
Elkton	415	734
Chestertown	368	735
Annapolis	384	775
Dayton	457	836
Glen Burnie	627	870
Hereford	426	899
Marlboro - Prince George	673	961
Gathersburg - Montgomery	572	1016
Fairland - Montgomery	441	1042
Golden Ring	409	1261

Estimation of Salt Application for Parking Lots

Delineation of Parking Lot Areas

The actual application data and target application rates provided by agencies in Virginia and Maryland were used to estimate past salt application for roads and other paved areas within the study area, as well as rates (per inch of snow) that may be used to predict future salt application for specific roads and parking lots. The first step in the process was to identify parking lots and other large impervious surface areas likely to be salted in winter. Paved areas were extracted from parcel data using QGIS (QGIS Development Team, 2023). Parcel and land use data as well as building footprints were collected for all counties in the study area.[2] Impervious surface data were also collected for VA counties (Fairfax County Department of Information Technology GIS Division, 2022; Prince William County Department of Information Technology, 2022a; Virginia Department of Emergency Management, 2022) but were not readily available for MD. Parcels that did not contain parking lots or other significant expanses of impervious surface cover were filtered out (Table 11). In Virginia, this meant excluding agricultural land, conservation land, outdoor recreational properties (e.g., parks), and vacant land from the parcel data, since these property types include little to no impervious surface area. Single family homes were also excluded because the impervious surfaces on these properties typically include only private driveways. Salt application on private driveways is also managed by independent citizens and is too variable to estimate using the method implemented in this project for commercial, industrial, and municipal property. Cemeteries and other facilities where impervious surface cover is only found on walkways and private roads were also filtered out.

Table 11. Land use types excluded from MD parcel data.

ALCOHOL Winery	OFFICE Office: Medical, Converted Dwelling
BURIAL Cemetary	OFFICE Office: Veterinary
CANNABIS Cannabis: Licensed Processor	PIPE Cove Point LNG
CARE Assisted Living (Ambulatory)	PIPE Dominion Transmission
CARE Day Care Center	PIPE Texas Eastern
CARE Day Care: Converted Dwelling	PUBLIC Federal Property
CARE Life Care Facility	RAIL Canton Rail
COMMUNITY School	RAIL Light Rail (Old Baltimore-Annapolis)
ELEC Delmarva Power & Light	RAIL MD & DE Railroad
ELEC Peco Energry	RAIL National Railroad Passenger Corp.
ELEC Potomac Electric	RAIL Norfolk & Southern
ELEC Southern MD Electric	REC Golf Courses Subject to Use Agreement
GAS Sandpiper Energy	REC Health Club

[2] Building footprints were collected at the state level (Maryland Department of Information Technology, 2020; Virginia Geographic Information Network, 2022a). MD parcel data was also collected at the state level (Maryland Department of Planning, 2022), while VA parcel data was collected by county (Fairfax County Tax Administration, 2022; Loudoun County Office of Mapping & Geographic Information, 2021; Prince William County Planning Department, 2022; Virginia Geographic Information Network, 2022b). The parcel data used for Fairfax County, VA was a combination of tabular parcel info for parcels within the county and statewide parcel boundaries (Fairfax County Tax Administration, 2022; Virginia Geographic Information Network, 2022b).

HOUSING Apartment	REC Miniature Golf / Driving Range / Batting Cage
HOUSING Apartments: Student Housing	REC Museums
HOUSING Apartments: Subsidized	REC Roller / Ice Skating Rink
HOUSING Apartments: Townhouse	RESTAURANT Banquet / Catering Facilities
HOUSING Mobile Home Park	STORE Barber Shop / Hair Salon
HOUSING Rural Development Multifamily Subsidized Property	STORE Nursery / Retail Garden Center
HOUSING Senior Apartment Units	STORE Retail / Apartment Upstairs
INDUSTRY Cement Plant	STORE Retail: Converted Dwelling
MISC Properties Unlocatable; No Value	STORE Store: Retail Condo
MISC Residence on Commercial or Industrial Zoned Land	TELECOM AT&T Comm. of MD
MISC Rezoned Real Property	WATER Artesian Water Maryland (formerly CECO UTILITIES)
OFFICE Office: Converted Dwelling	WATER Artesian Water Maryland (frm CARPENTERS PT. WATER)

Once the parcel data were filtered, any remaining grassy areas were removed by clipping the data to the impervious surface cover data and removing building footprints. The resulting polygons precisely delineated the impervious surface surrounding of the targeted property types (see Figure 2).

Figure 2: Snapshot of Virginia parking lot delineations (colored areas)

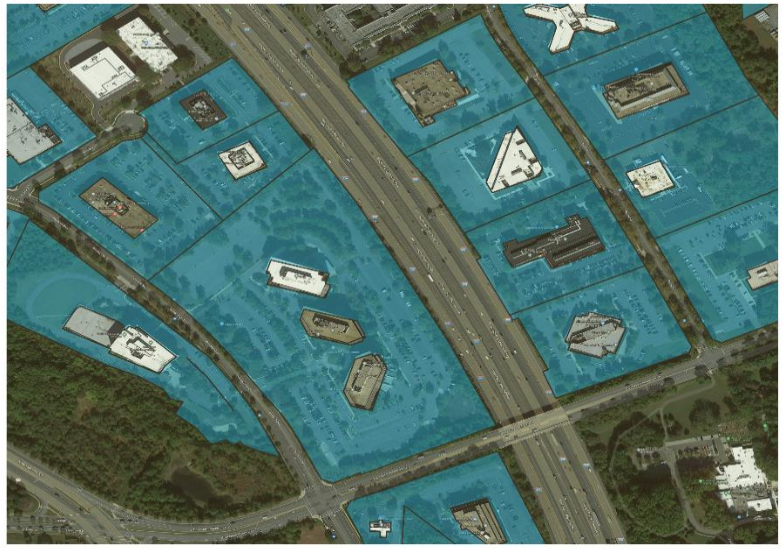
Because impervious surface cover data was unavailable for Maryland, only building footprints could be removed from parcels of targeted property types, using building outline data obtained from each state (Maryland Department of Information Technology, 2020; Virginia Geographic Information Network, 2022). Any grassy areas or waterbodies included within the same parcels as impervious surfaces could not be excluded. Therefore, more property types had to be excluded from the Maryland parcel data during the filtering process. The same types of properties filtered out of the Virginia data were removed from the Maryland data, but any parcels that did not almost entirely consist of impervious surfaces were also excluded. Commercial shopping centers and heavily industrial regions were left largely intact, while many residential areas, office parks, and schools were excluded because they consisted largely of natural (unpaved) areas and building footprints. The list of land use categories excluded from the final parking lot dataset for MD parking lots is provided in Table 12.

Table 12. Land use and parcel types excluded from VA county parcel data

County Parcel Data	Land Use or Parcel Type Category	County Parcel Data	Land Use or Parcel Type Category
Fairfax County	Agricultural Activities & services	Loudoun	Vacant: Unentitled
Fairfax County	Comm Use in Res Condo Dev	Prince William	Apartments (Age Restricted)
Fairfax County	Conservation Easement	Prince William	CEMETERY
Fairfax County	Convenience grocery	Prince William	Cemetery
Fairfax County	Multiplex in ownership development	Prince William	Dominion Power
Fairfax County	Multiplex in rental development	Prince William	Duplex (Elderly)
Fairfax County	Nondurable Manufacturing(in clust/notIP)	Prince William	Electric Utilities
Fairfax County	Nursery Schools	Prince William	Forestry Related Services
Fairfax County	Other transient lodging NEC	Prince William	Govt. Owned Golf Course
Fairfax County	Single-family structure NEC	Prince William	Mobile home in park or court
Fairfax County	Single-family, Detached	Prince William	Mobile home in park or court
Fairfax County	Swimming pools - outdoor	Prince William	Mobile Home not in park
Fairfax County	Townhouse or Multiplex NEC	Prince William	Other 2+ Family SFD
Fairfax County	Two or more Single-family, detached	Prince William	Other 2+ Family SFD
Fairfax County	Two-family NEC	Prince William	Other Condominiums
Fairfax County	Unknown Parcels	Prince William	Other SFD
Fairfax County	Water areas	Prince William	Outbldg on Adjacent Parcel
Loudoun	Farm	Prince William	Outbldg on Adjacent Parcel
Loudoun	Golf Course	Prince William	Private Golf Course
Loudoun	Heavy Industrial	Prince William	Private Golf Course
Loudoun	HOA	Prince William	Pvt Streets (owned by HOA)
Loudoun	Multi-Family Attached	Prince William	SFD, Duplex
Loudoun	Multi-Family Stacked	Prince William	Solid Waste Disposal
Loudoun	Public	Prince William	Townhouse, Owner Dvlpmnt
Loudoun	Single-Family Attached	Prince William	Water Utilities
Loudoun	Single-Family Detached	Prince William	Water Utilities
Loudoun	Vacant: Entitled	Prince William	Winery

As with the VA parcel data, building footprints were removed once the Maryland parcel data were filtered. Any remaining non-impervious areas (e.g., landscaped portions of parking lots) mixed in with impervious surface areas were left in the final dataset. While non-impervious areas could not be removed with the same precision as they were removed from Virginia parcels, the property types that remained after filtering and the removal of building footprints still resulted in a fairly precise delineation of major parking lots and other commercial and industrial impervious surface areas most likely to be heavily salted in winter (see Figure 3).

Figure 3: Snapshot of Maryland parking lot delineations



Calculation of Salt Application Totals and Rates for Parking Lots

Recommended salt application rates for parking lots from various studies were obtained from a Harvard study on the sustainability of commercial road salt use (Table 13). (Sexton, 2017)

Table 13: Select parking lot salt application rate guidelines

	Dry Salt (NaCl) Application Rate in Pounds per 1000 sq. ft.				
Pavement Temp (F) and Trend	Wisconsin - SICOPS	SSI Case Study	Minnesota Guidelines	New Hampshire Guidelines	Snow and Ice Management Association (SIMA) Guidelines
15-20 ↑	18	14	3	10	14
15-20 ↓	18	13.5	2.75	10	14
20-25 ↑	9	13.25	2.75	9.5	13
20-25 ↓	9	12.75	2.25	8.25	13
25-30 ↑	3	12.5	1.5	8.25	12
25-30 ↓	3	11	1.5	6.5	12
30 ↑	3	11	1.5	6.5	11
>30 ↓	3	10	0.75	4.5	11
** Up arrows indicate temperatures are moving upward in the table (i.e., toward colder temperature ranges)*					

GIS was used to estimate the area of each parking lot polygon. The square footage of each parking lot was divided by 1000 and multiplied by each application rate in the blue rows in Table 3 to get, for each parking lot, each study or guideline's recommended application rates for each decreasing temperature range and temperatures greater than 30 °F (see Figure 4). These values were attached to the final dataset, with their corresponding study or guideline and temperature range.

Figure 4. Example calculation of recommended application rates for a 2,000 sq-ft parking lot, by temperature range and source

Pavement Temp (F) and Trend	Wisconsin - SICOPS		SSI Case Study		Minnesota Guidelines		New Hampshire Guidelines		Snow and Ice Management Association (SIMA) Guidelines	
15-20 ↑	2 x 18	= 36	2 x 14	= 28	2 x 3	= 6	2 x 10	= 20	2 x 14	= 28
20-25 ↑	2 x 9	= 18	2 x 13.25	= 26.5	2 x 2.75	= 5.5	2 x 9.5	= 19	2 x 13	= 26
25-30 ↑	2 x 3	= 6	2 x 12.5	= 25	2 x 1.5	= 3	2 x 8.25	= 16.5	2 x 12	= 24
>30 ↓	2 x 3	= 6	2 x 10	= 20	2 x 0.75	= 1.5	2 x 4.5	= 9	2 x 11	= 22

*Red values are calculated (2,000 sq ft parking lot / 1000 sq foot unit from Table 13).

Historical weather data from the National Weather Service website were then used to estimate the number of times each application rate for decreasing temperatures up to 30 degrees and above 30 degrees (each blue row in Table 3) would have been applied each year from 2018 through 2022 if the recommended rates in Table 3 were used. The counts were derived from the number of times the ambient temperature fell within each highlighted range in Table 3 on each day that it snowed in a given year, then summed by year (Table 14). Temperatures below 15 degrees Fahrenheit were counted as 15 degrees. The total number of times each rate would have been used each year was then multiplied by the area of each parking lot polygon divided by 1000 to get the total amount of salt that would have been applied each year if recommended rates were used (see Figure 5). This process was repeated for each set of rates listed in Table 3.

Table 14. Counts of the number of snow days within each temperature range for years 2018 through 2022.

	Number of Snow Days				
Pavement Temp (F) and Trend	**2018**	**2019**	**2020**	**2021**	**2022**
15-20 ↑	4	10	0	2	10
20-25 ↑	2	0	6	11	5
25-30 ↑	18	16	7	14	8
>30 ↓	122	109	118	109	85
Totals:	**146**	**135**	**131**	**136**	**108**

Figure 4. Example calculation of the total amount of salt that would have been applied to a 2,000 sq-ft parking lot in 2018 if the Wisconsin – SICOPS rates were used.

Pavement Temp (F) and Trend	Wisconsin - SICOPS		Number of Snow Days in 2018	Lbs. of Salt Applied
15-20 ↑	2 x 18	= 36	x 4	= 144
20-25 ↑	2 x 9	= 18	x 2	= 36
25-30 ↑	2 x 3	= 6	x 18	= 108
>30 ↓	2 x 3	= 6	x 122	= 732

Municipal Storm Sewer System (MS4) Data

MS4 outfall locations and collection areas were collected for MD and VA (Maryland Department of the Environment, 2021; Virginia Department of Transportation, 2022a) and used to estimate distance to nearest MS4 outfall for parking lots. MS4 outfall locations and collection areas can be used to predict drainage patterns of salt runoff from roadways and other impervious surface areas. There are opportunities to expand upon this project by quantifying and comparing chloride loading potential from different MS4 or other storm sewer outfalls. These efforts were beyond the scope of the assessment described in this report.

Parking Lot Dataset Deliverable

A spatial dataset was created for MD and VA parking lots. The dataset includes:

1. Land use type (where available)
2. Distance to nearest MS4 outlet
3. Estimated application rate for each temperature range and study or guideline (4 temperature ranges, 5 studies and guidelines)
4. Annual amount of salt that would have been applied based on weather conditions during each of the past 5 years if estimated application rates were used, according to each study or set of guidelines (one average per study and set of guidelines)

Estimation of Salt Application for Roadways

Roadway Delineation

Four roadway datasets were collected from the state of Maryland's GIS data catalog (iMap) (Maryland Geographic Information Office, n.d): *County Maintained Roads, MD State Highway Administration (SHA) Roads, Municipal Maintained Roads,* and *Baltimore City Roads (Maryland Department of Transportation, 2022a; 2022b; 2022d; 2022e)*. For Virginia roads, roadway datasets were obtained from Fairfax, Loudoun, and Prince Williams Counties (Fairfax County Department of Information Technology GIS Division, 2015; Loudoun County Office of Mapping & Geographic Information, 2020; Prince William

County Department of Information Technology, GIS Division, 2022b). These datasets covered county-maintained and municipal roads. State-maintained roads were identified with data from the VDOT (Virginia Department of Transportation, 2022b). Roadway data from the US Census Bureau website (U.S. Census Bureau, 2023) were used to fill in any gaps in these datasets. Once all roadways were accounted for, segmented road lines in the collected datasets were merged to create single, continuous lines for every road, to the extent possible. Multi-lane highways with different route names (e.g., north- and southbound routes) were treated as separate roads.

Calculation of Road Salt Application Rates and Totals for MD Roadways

GIS was used to estimate total lane miles for each roadway. Actual application rates (lbs of salt/year) for each of the past 5 years were provided for all county roads in total in Montgomery and Frederick Counties, and for all state roads in all MD counties by various transportation agency personnel (Appendix A).

For county, municipal, and private roads in Montgomery and Frederick Counties, the total tons of salt applied each year in Table 8 were converted to lbs and divided by the total number of lane miles in the county to calculate lbs of salt per lane mile. These values were then multiplied by each county, municipal, and private road length to estimate total road salt application per road per year from 2011 through October 2022. The average of these values across all available years of data was also calculated. The values in Table 9 were multiplied by each road length in miles to establish application rates (in lbs/inch) that can be used to predict future average salt application for each road given predicted inches of snowfall.

The annual brine volumes in Table 7 were used to estimate pounds of NaCl from brine applied to each county, municipal, and private road in Frederick County each year from 2018 through October 2022. The gallons of brine per year were converted to lbs of NaCl equivalent based on the MDOT's use of a 23.3 % NaCl brine solution and the density of NaCl (2.16 g/cm^3). These values were then divided by the total number of lane miles in the county to calculate lbs of NaCl from brine per lane mile, which were then multiplied by the length of each roadway to estimate lbs of NaCl use from brine per year from 2018 through October 2022. Pounds of NaCl use from brine in Montgomery County per year were calculated using the same method and the data in Table 6 for years 2012 through October 2022. The averages of these values across all available years of data was also calculated for each county. The NaCl use totals for each year and county were also divided by total inches of snow from each corresponding year (using National Weather Service data) and averaged to generate application rates (in lbs of NaCl from brine per inch) that can be used to predict future salt application from brine for each road given predicted inches of snowfall.

For state and federal roads in the study area, the Montgomery and Frederick County annual granular salt usage per lane mile and inch of snow values in Table 10 were used to calculate pounds of granular salt use per lane mile. The Table 10 value used for each state or federal road was selected based on the county containing the majority of the road length. These values were multiplied by each road length in miles to establish application rates (in lbs/inch) that can be used to predict future salt application for each road given predicted inches of snowfall. They were also multiplied by the total inches of snowfall in 2019 and 2020 taken from the National Weather Service to calculate total lbs of salt use per lane mile for each county and year. The total pounds of salt use per lane mile per year were multiplied by the mile length of each state and federal roadway to estimate the total pounds of salt used in 2019 and 2020. The average pounds of salt used across both years was also calculated. Brine use data for state roads was not available.

Calculation of Road Salt Application Rates and Totals for VA Roadways

Actual application rates were not provided for VA roadways. However, recommended road salt application rates for VA roadways were acquired from the VDEQ SaMS Toolkit (Table 15). The length of each road in miles was multiplied by the recommended application rate for each mobilization level to get the recommended salt application rates for each mobilization level specific to each road (e.g., a 10-mile road would have a recommended application rate of 3,250 lbs. for mobilization level 1 weather, 4,000 lbs. for mobilization level 2 weather, etc.). These road-specific application rates for each mobilization level can be used to estimate how much salt is likely to be applied to a specific road, given anticipated weather conditions.

Table 15. Recommended salt application rates by mobilization level, from the VDEQ Salt Management Strategy Toolkit

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

Actual salt application totals for past years were also estimated using the recommended rates in Table 15. Historical weather data from 2018 to 2022 were downloaded from the National Weather Service website. As was done for the parking lot application rates in Table 13, the weather data were used to estimate the number of times each application rate in Table 15 would have been applied each year if one or more of the recommended rates in Table 15 were used. The mobilization level and corresponding rates that should have been used on any given day were determined by the inches of snow and temperature on snow days and by the temperature on rainy days (assuming road salt was also applied in recommended amounts on days when there was a risk of freezing rain). For each year, the total number of times each mobilization level would have been used was then multiplied by the mobilization level's corresponding application rate. For example, if mobilization level 1 should have been used 20 times in 2018, 325 lbs/ln mi would be multiplied by 20 to get the total amount of per-mile salt that would have been applied in 2018. The products were then multiplied by the length in miles of each Virginia road to estimate the total amount of salt that would have been applied to each road each year in the past 5 years (e.g., if a total of 6,375 lbs of salt per ln mi were applied in 2018 based on inches of snowfall and temperature, this would equate to 63,750 lbs of salt applied in 2018 along a 10-mi road). The average amount of salt applied to each road across all 5 years was also calculated.

Roadway Dataset Deliverables

One roadway dataset was produced for each state, due to the different methods and data between Maryland and Virginia.

Each Maryland road line includes:

- Road name
- Road owner (agency that manages the road)
- Whether rates are based on county or state data
- For both granular salt and salt from brine:
    - Amount of salt applied, in lbs each year for past 5 years
    - Average amount of salt applied, in lbs across all years
    - Number of years on which average is based (i.e., number of years of data available)
- Average amount of salt/inch applied across all years of available data (average rate of application, in lbs)
- Number of years of data on which the average rate of application is based (i.e., number of years of data available).

Each Virginia road line includes:

- Road name
- Road owner (agency that manages the road)
- Total amount of salt that would have been applied each year for past 5 years if the recommended rates were used
- Recommended application rate per mobilization level

Next Steps

Deliverable datasets have been loaded into MWCOG's WaterSuite project, an online GIS for source water protection and emergency response (www.WaterSuite.com). The datasets can also be made available to share with other utilities or researchers in GIS or spreadsheet format.

I. Opportunities to Fill Data Gaps and Enhance Data Quality

Notably, the body of data used to estimate past salt application for individual roads and to develop road- and parking-lot specific application rates for predicting future salt application given forecasted inches of snow was a mix of actual application data (e.g., the county totals provided for Frederick and Montgomery Counties in MD) and recommended salt application rates (e.g., the Salt Institute Standard rates provided for VA roadways and various "mobilization levels"). An investigation may be made into the extent to which actual salt use is consistent with recommended and predicted salt use by comparing recommended application rates for roads and parking lots to actual salt use data. This would require obtaining actual salt use data where previously none was collected, and actual salt use data may not be available for certain portions of the target study area. However, actual and predicted salt use data may be sampled from other states. Alternatively, private salt management contractors and/or private business owners who operate within the study area may be interviewed directly to assess current parking lot salting practices, application rates and opportunities for reduction.

There is also an opportunity to further refine the MD parking lot area estimates by acquiring MD impervious surface data. This would depend on the availability and quality of impervious surface cover data. The more precisely impervious areas may be defined, the more parcel types may be included in the assessment, allowing for the salt loading potential of additional parking lot areas to be analyzed.

II. Opportunities for Further Analysis of Chloride Loading Potential and Evaluation of Best Management Practices

The data developed in this project can also be used to estimate "hot spot" locations for chloride loading to specific MS4 outfalls and partition loading estimates by contributions from road and parking lot areas. MS4 drainage areas were already obtained for the state of MD, and may be requested from state or county agencies in VA for further analysis of chloride loading potential.

Model-derived chloride loading estimates could be compared to measured water quality data from multiple sources (drinking water utilities, USGS, OWL, universities, etc.) using a USGS model relating chloride concentrations to specific conductance (Rosemary M Fanelli et al., 2019) to ground-truth the model's estimated loadings for specific storms and locations and investigate any departures from current assumptions, such as over- or under-application in storms where predicted temperatures and snowfall were inaccurate. Model results for specific sub-watersheds could also be compared to annual chloride loading rates cited in VA's chloride TMDLs to identify sub-watersheds that may impact or approach human health, aquatic life and/or state water quality standards.

Hot spot loading estimates derived from model results could also be used to help identify locations where stormwater BMPs may have the greatest potential to reduce acute impacts, such as reducing event mean concentrations below biological thresholds (Tabrizi et al., 2022), or to focus outreach or support regarding salt application reduction techniques on DOTs or private contractors in areas that will produce the greatest water quality benefit.

Appendix A: County and State Research Contacts

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Appendix B: Winter-Weather Deicing Material Usage for FY21 and FY22 by Watershed Intersecting Frederick County, MD[3]

Watershed	Gallons of Liquid Brine		Gallons of Liquid Caliber (M1000)		Tons of Road Salt		Tons of Anti-skid	
	2021	2022	2021	2022	2021	2022	2021	2022
Catoctin Creek	*Not provided*	18,414	4,960	1,250	4,574.5	2,695	181	152
Double Pipe Creek	*Not provided*	2,650	138	0	746	434	24	0
Lower Monocacy	*Not provided*	31,070	5,569	1,834	7,833.5	5,456	78.5	49
Lower Mon/Upper Mon	*Not provided*	350		0	228	96	0	0
Potomac	*Not provided*	9,600	2,105	650	857.5	567	0	0
Upper Monocacy	*Not provided*	17,790	3,632	2,180	5,657	4,236	152	160
UM/LM	*Not provided*	3,000	4,960	120	372	208	0	0
Total	*N/A*	**82,874**	**16,133**	**6,034**	**24,291**	**13,692**	**525**	**361**

[3] (Frederick County Office of the County Executive, 2021)

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