Development of a reasoned approach to chloride reduction in Michigan's surface waters

Client:
Michigan Department of Environment, Great Lakes, and Energy (EGLE)

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Executive Summary:
Through our partnership with Michigan's Department of Environment, Great Lakes, and Energy (EGLE), we developed a comprehensive statewide assessment of both point and nonpoint source contributions of chloride and generated sector-specific strategies for reducing chloride concentrations in Michigan's surface waters.

Introduction

Chloride concentrations in United States lakes have steadily risen over the past several decades as a result of anthropogenic activity, including increased urbanization and its associated chloride discharge.[1] Among those waters affected are the Great Lakes, two of which are currently at record chloride levels, and the other three are experiencing increases.[2] This is problematic because chloride can have significant harmful effects on aquatic life. Due to the potential harmful effects chloride has on aquatic life, Michigan's Department of Environment, Great Lakes, and Energy (EGLE) recently developed water quality values (WQV) for chloride. These were developed to reduce overall concentrations in Michigan's surface waters. All surface water systems in the state of Michigan eventually drain into the Great Lakes Basin. While the EPA has set general criteria for chloride concentration levels on a national scale, Michigan has implemented even more conservative values for their surface waters as a means of protecting local aquatic animal and plant life.

The Great Lakes have been described as "a crown jewel of North America".[3] They represent the largest group of freshwater lakes in the world by surface area, as well as almost a quarter (21%) of all the planet's fresh surface water.[4] The Great Lakes and Michigan's inland waters are important sources of drinking water, economic livelihood, and recreation opportunities for millions of people, including citizens of Michigan's 12 federally recognized indigenous tribes.[3-5] The quality of the surface waters is often a direct reflection of land use activities such as agriculture, mining, and logging practices as well as the level of commercial and residential development that is occurring within the watersheds.[6,7] Michigan's watersheds act as contributors to the water quality of the Great Lakes due to the fact that all waterways in the state eventually drain into either Lake Superior, Lake Michigan, Lake Huron, or Lake Erie.[8] A listing of the major watersheds in the state is found in Figure 1.[9]

Figure 1. Michigan's major watersheds characterized by major and subbasin boundaries.

Over the past 150 years, the Great Lakes and their watersheds have experienced increased chloride loadings.[2] Research has shown that chloride in the Great Lakes began rising during the mid-19th century and then began accelerating in the 20th century.[2] As the surrounding watersheds became more urbanized and associated chloride discharges became more prevalent, the water quality of the lakes began to decline.[10] Some inland Michigan lakes, including Earl Lake in Livingston county, have experienced increased chloride loadings too.[11] We are currently in a situation where both inland waters and the Great Lakes are experiencing unprecedented chloride levels. The increase of chloride in surface waters is not a unique problem to the Great Lakes Basin, however. Numerous North American lakes currently face the same predicament.[10] Although lakes only cover 3% of the continental land surface,[12] long-term trends in lakes are often early warning indicators of significant local, regional, and global change.[13] The increased usage of chloride over the past several decades has led to surface waters becoming increasingly burdened to the point where concentrations become excessive.[14] This is problematic, as a plethora of scientific data negatively links an excessive concentration of chloride in surface waters with ecological degradation and impacts on infrastructure, some of which may directly impact human health.[15]

Excessive chloride has been shown to have deleterious effects on aquatic plants and wildlife.[16-20] Mussels, fish, aquatic insects, and many other animals known to inhabit Michigan's waters suffer when chloride levels are too high.[21] Excessive chloride can inhibit plant growth, impair the reproductive ability of aquatic organisms, and reduce the diversity and productivity of organisms in streams.[22] Chloride also has the ability to disrupt an organism's osmoregulation, which can hinder its ability to survive and reproduce.[23]

Additionally, chloride has been found to have severely negative impacts on infrastructure. Chloride-based deicers are known to be corrosive,[24,25,] and can impact vehicles, roadways, and bridges.[26] For example, chloride has the ability to progress the physical deterioration of the top surface of the road, a process known as "salt scaling." It can also lead to the deterioration in the cement matrix of infrastructure due to chloride's reactions with cement paste, as well the enablement and/or acceleration of the corrosion of rebar.[24-28] While not directly toxic to human health, increased chloride levels increase the corrosivity of drinking water distribution systems which increases the rate of heavy metal leaching, including lead.[15] Recent research has concluded that the overuse of road salt likely contributed to higher levels of corrosive chloride in the water supply in Flint, Michigan in 2014 which led to the release of lead from water distribution pipes.[29]

Water Quality Values

In accordance with Public Law 92-500, as amended, 33 U.S.C. 1251 et seq., Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act (NREPA), 1994 PA 451, as amended, MCL 324.3101 to 324.3119, each state is required to adopt water quality standards (WQS) for all surface waters as a means of restoring the integrity of the nation's waters.[30] This act is usually referred to as the Clean Water Act (CWA). WQS are developed specifically for each state. Michigan, along with other states and/or tribes within the Great Lakes water basin, must develop WQS in accordance with both the CWA and the United States Environmental Protection Agency's (USEPA) Final Water Quality Guidance for the Great Lakes System following 40 CFR Part 132 (known as the Great Lakes Initiative).[31] WQS are reviewed and approved by the USEPA. Within Michigan's WQS, Rule 323.1057 contains a narrative process for deriving numeric values for toxic substances. What Michigan has adopted, and EPA approved, is a narrative criterion prohibiting toxic conditions and procedures for deriving a numeric expression of that narrative criterion. To protect the designated uses of Michigan's surface waters, EGLE developed aquatic life water quality values (WQV) for chloride in August of 2019.[32] These values define the numeric threshold for chloride, the specific concentration below which there are no anticipated consequences on the health of animals and other aquatic life in, or in proximity to the water. Final Acute Values are reflected as daily maximum limits in permits, and Final Chronic Values are used to calculate the monthly average limits which reflect some mixing with background drought flow, as applicable. The Aquatic Maximum Value represents the concentration that should not be exceeded in surface waters at any time. The ultimate values as set by the state of Michigan are listed below in Table 1.[32]

Pollutant	Final Acute Value (ug/L)	Aquatic Maximum Value (ug/L)	Final Chronic Value (ug/L)
Chloride	640,000	320,000	150,000

Table 1. Aquatic Life Values for chloride developed following Rule 57 of the water quality standards (WQS).

Sources of Chloride

Sources of chloride to surface waters in Michigan include anthropogenic and natural sources. Anthropogenic sources include road salt, water softener backwash, wastewater from municipalities and industrial facilities, cleaning products, fertilizer use, and human and livestock excreta. Non-anthropogenic sources include natural bedrock and atmospheric deposition.

Research has shown that the use of deicing salt in the winter for road maintenance acts as a major contributor of chloride to both surface water and groundwater.[33-35] Since 1975, road salt usage in the United States has doubled (Figure 2).[36] This rise parallels an increase in roads and other pavement requiring winter maintenance. In addition to being used on paved roads, road salt is applied to parking lots, sidewalks, driveways, and service roads.[37] The state of Minnesota, for example, just recently conducted an analysis and found that the Twin Cities Metropolitan Area (TCMA) alone sees an estimated average of 365,000 metric tons of deicing salt applied to surfaces each year.[38] Deicing salt has become the dominant source of chloride in TCMA groundwater resources.[39] In Michigan, the cumulative actions from all public road agencies in the state results in nearly 2 million tons of road salt being used for de-icing purposes per year.[40] Further research has shown that about 40 to 45% of the contribution of chlorides to Lake Michigan and about 11% of the contribution of chloride to Lake Erie are directly attributed to road deicing salt.[41,42]

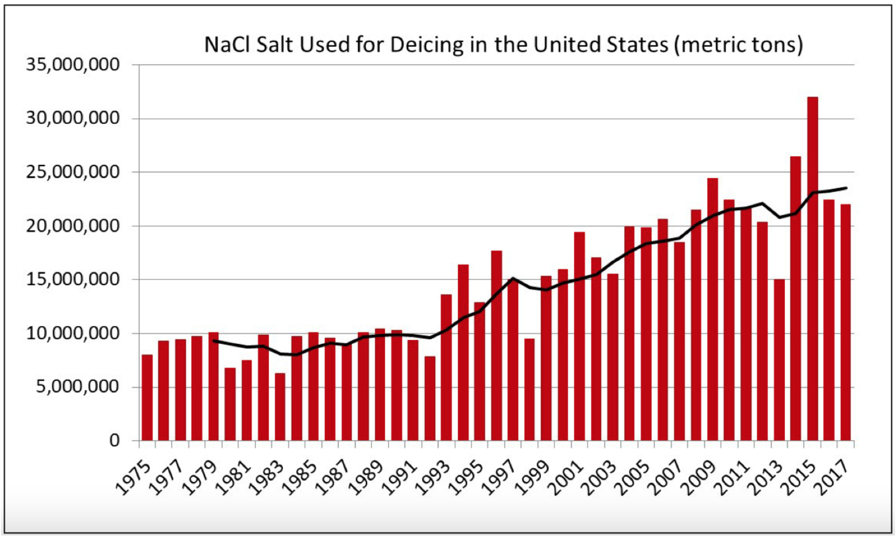


Figure 2. Annual metric tons of NaCl salt used for deicing in the United States.

While road salt application has been shown to be a major chloride source to surface waters, there are many other sources that need to be considered. For example, households often use ion exchange water softeners to remove ions that cause water hardness, such as magnesium and calcium. Sodium chloride is used in the ion exchange process to replace magnesium and calcium with sodium. Eventually this is discharged to sewers or septic tanks.[42] In Michigan, water is often characterized as hard or very hard.[43] The Detroit Metro area has moderately hard water (104 ppm), while Grand Rapids has high water hardness (380 ppm).[43,44] Because of this, it's plausible that water softener use in the state is high, although this cannot be confirmed until a statewide chloride budget is produced.

Minnesota Study

Like in Michigan, Minnesota's surface and groundwaters have experienced rises in chloride concentrations. This led the state to develop a chloride budget: a determination of the major point and nonpoint sources of chloride to surface water and groundwater .[45] While several chloride sources have already been well-established in research (i.e. road salt use), others, like water softener use, remain less well characterized. Part of the research aimed at determining the effect these less characterized sources play in the statewide budget. The researchers also created a wastewater treatment plant (WWTP) budget which represented the discharge levels from water softeners and other household, commercial, and industrial sources to the WWTP and ultimately to surface waters or groundwater. The WWTP budget was finalized and determined that household water softening was the largest contributor of chloride to WWTPs (40%). Industrial use and commercial water softening were also among the largest contributing sources (26% and 14%, respectively). The results indicated that WWTPs were the largest point sources of chloride in the analysis and water softener use was the largest contributor to their discharge. Furthermore, road salt use was by far the largest contributing nonpoint source of chloride to the state's waters. Fertilizer use also represented more than one-fifth of all chloride discharged. A distributional count of chloride for Minnesota can be found in Figure 3.[45]

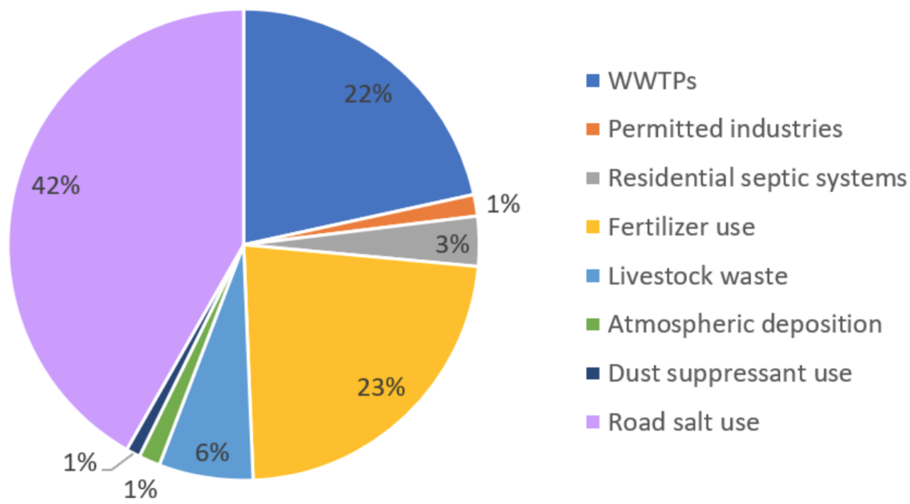


Figure 3. Fraction of annual chloride contributions from point and nonpoint sources in the state of Minnesota.

Research Goals

Based on methods used in Minnesota, we conducted our own research in conjunction with Michigan's Department of Environment, Great Lakes, and Energy (EGLE). Our main objective was to understand the contributions of major point and nonpoint sources of chloride to Michigan's surface waters. Secondly, we developed a set of educational/outreach tools aimed at various stakeholders to reduce chloride discharges and protect aquatic life. (See Appendices F-J). The differences between our effort and methods described in the Minnesota study are discussed in the *Overall Results* and *Limitations* sections of this report. One significant difference is that Minnesota sought to understand the contributions of chloride to the state's surface and groundwaters, whereas we focused solely on Michigan's surface waters. Furthermore, Minnesota utilized data for a three-year period, whereas we expanded our efforts to create a more robust, longer-term snapshot of chloride entering the state's waters. We deliberately omitted data from the year 2020, given that the COVID-19 pandemic might produce results not in congruence with the overall trends occurring in the state.

Methods

The methods we incorporated were taken directly from Minnesota's budgeting efforts, with details listed below for each potential source. Our goal was to determine the average of all potential point and nonpoint sources over a five-year span, beginning with the year 2015 and ending in 2019.

According to the Clean Water Act, a point source is "any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged." This term does not include agricultural stormwater discharges and return flows from irrigated agriculture".[30] For the purposes of our research, we broke down point sources into the categories of (1) specific industrial point sources permitted to discharge under the National Pollutant Discharge Elimination System (NPDES sources), (2) Residential water softener use, (3) human excreta from sewer systems and finally (4) cleaning products from individual sources. A nonpoint source is thus any other source not included in the aforementioned definition. This includes the contributions from (1) statewide road salt application and (2) atmospheric deposition of chloride.

Point source results:

NPDES-permitted facilities

Thirty industrial facilities in Michigan have NPDES permits for direct surface water discharge with monitoring requirements for chloride (Appendix A). Of these, twenty-six reported chloride discharge from 2015 to 2019. Using EGLE's MiWaters website, chloride concentration (milligrams per liter, mg/L) and flow rate (million gallons per day, MGD) data were found in each facility's discharge monitoring reports (DMRs).[46] Because Michigan's State Environmental Laboratory's reporting limit on chloride is 4 mg/L, all data points with a chloride concentration of 0 mg/L were corrected to 4 mg/L (C. Alwin, personal communication, November 5, 2021). These were used to determine the load (lbs/day):

$$MGD * mg/L * 8.34\ L * lb * mg^{-1} * million\ gallons^{-1} = lbs/day$$

For facilities with several days of chloride data per month, the average was used to calculate the load per month. Otherwise, a single data point was used to calculate the load per month. For facilities monitoring quarterly, the missing months were assumed to have a load equal to the average of the other months. The months' loads were added to find the lbs/year of chloride. This was then converted to metric tons per year. This averaging method does not take into account seasonal fluctuations in chloride discharge, especially in quarterly reports. However, given that the monthly average was used to compute the reported values, rather than a maximum, our estimates are likely conservative. Furthermore, not all NPDES-permitted facilities that discharge to surface water are required to monitor for chloride. As chloride monitoring expands, the NPDES-permitted facility contribution will be larger than our current estimate.

Our estimates indicate that on average, Michigan's NPDES-permitted facilities discharge 176,858 metric tons of chloride per year (Appendix B). Outlier years (> 50% error from the average) were excluded from the reported value. The biggest contributors by the facility are Coca-Cola Paw-Paw at 71, 661 metric tons (40.5%), Dow Chemical-Midland 60, 284 metric tons (34.1%), and Martin Marietta Magnesia Specialties Inc. at 29, 521 (16.7%) (Figure 4).

We determined that there were seven facility types: cooling tower blowdown, food processing, mine dewatering water, process wastewater, calcium chloride, RO concentrate, and RO concentrate from WTP. The biggest contributors by wastewater type are "Process Wastewater" (90, 373 metric tons per year or 51.1%) and "Food Processing" (76,372 metric tons per year or 43.2%). These contributors are illustrated in Figure 5.

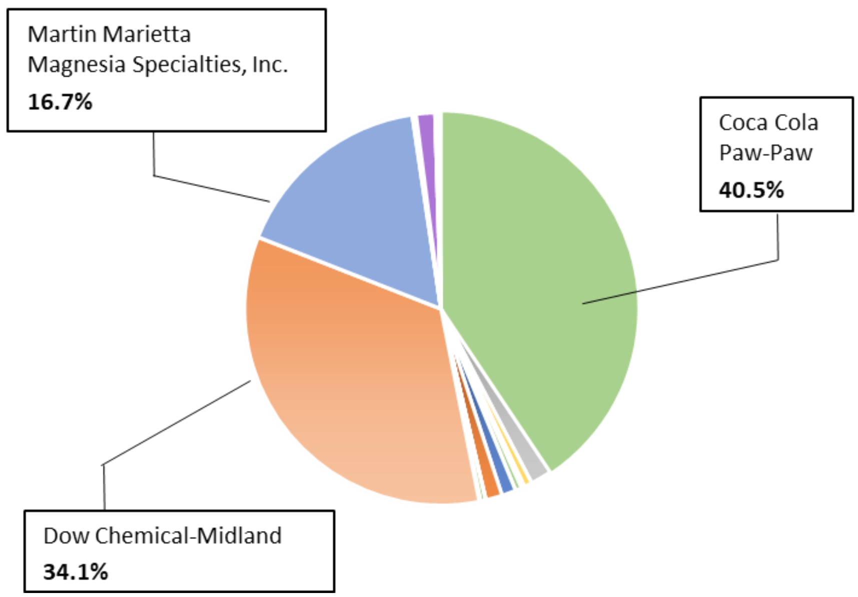


Figure 4. Main chloride contributors among NPDES-permitted facilities.

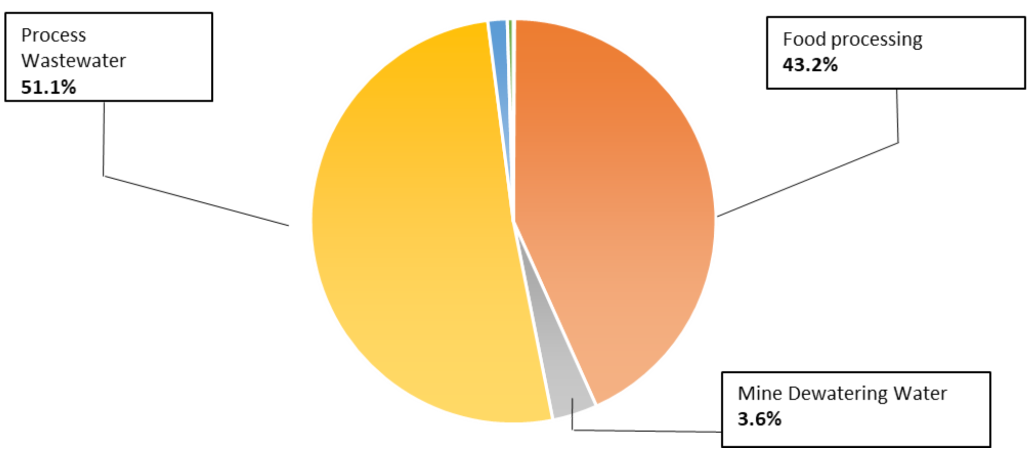


Figure 5. Main chloride contributors among NPDES-permitted facility types.

Residential water softener use

Water softeners are used to remove water hardness from the water supply. Hardness is caused by calcium, magnesium, and iron ions (Ca^{2+}, Mg^{2+}, and Fe^{2+}, respectively). Water softeners work to exchange these ions with sodium (Na^{+}) or potassium (K^{+}) from sodium chloride or potassium chloride.[47] This occurs in the water softener's exchange resin. Once the resin's sodium or potassium ions have been exchanged, it needs to be replaced in a process called regeneration. The backwash, or depleted resin bed's calcium, magnesium, iron, and chloride ions, is disposed of through city sewers, direct surface water discharges, dry wells, groundwater, or a septic system.

To estimate residential water use and ultimately chloride discharge to surface waters, we needed to understand the following for each of Michigan's 83 counties:

- The average water hardness in publicly and privately sourced water
- The number of people using publicly and privately sourced water
- The number of people softening publicly and privately sourced water
- The number of people whose water softener discharge eventually reaches surface water
- The amount of water used per person softening water
- Efficiency of the water softeners
- The level of softness obtained by those who use water softeners

To determine average water hardness, we used raw water hardness data from EGLE. Each data point had three descriptors for location: city, county, and zip code. Because the three descriptors did not always agree, we were directed to correct the data by assuming that if two of these descriptors matched, the third would need to be corrected. Using Excel and a published list of matching city, county, and zip code data, we corrected the data set.[48,49] Some data were left uncorrected because none of the three geographic markers corresponded or at least two were unknown or missing for the data point; such data points were discarded. Furthermore, all entries with a water hardness result of 0 ppm were removed because this indicates softened water.

Assuming the descriptions for each datapoint were correct, the data was truncated to sampling descriptions that were labeled as "Untreated Private Well" (UPW), "Untreated Public Distribution System" (UPDS), or "Treated Public Distribution System" (TPDS). UPW refers to water from private wells that has not been softened. UPDS refers to water in the distribution system that is untreated groundwater that is pending arrival to private or public taps (L. Graham, personal communication, January 27, 2022). TPDS refers to water that has been centrally softened and is in the distribution system pending arrival to private or public taps. It is impossible to distinguish between TPDS and UPDS in a distribution system that offers both because they are mixed (L. Graham, personal communication, January 27, 2022). For the purpose of this analysis, data points with the descriptor TPDS and UPDS were grouped as residentially unsoftened publicly distributed water.

Some counties had no water hardness data for either the public and/or private supply. For these counties, the average water hardness (public or private) in bordering counties was used.

The table below shows the counties that were missing hardness data and the counties' average water hardness used to predict water hardness values (Table 2):

County with Missing Hardness Data	Public/ Private	Bordering Counties
Alger	Public	Delta, Luce, Marquette, Schoolcroft
Crawford	Public	Antrim, Missaukee, Montmorency, Ogenaw, Oscoda, Roscommon,
Dickinson	Public	Marquette, Menominee
Iron	Both	Baraga, Gogebic, Houghton, Marquette
Kalkaska	Public	Antrim, Grand Traverse, Missaukee, Roscommon, Wexford
Midland	Public	Bay, Clare, Gladwin, Gratiot, Isabella, Saginaw
St. Joseph	Private	Branch, Cass, Calhoun, Kalamazoo, Van Buren
Ontonagon	Public	Gogebic, Houghton
Otsego	Public	Antrim, Charlevoix, Cheboygan, Montmorency, Oscoda
Wayne	Private	Macomb, Monroe, Oakland, Washtenaw

Table 2. Counties with missing hardness data and a list of each one's neighboring counties.

The average hardness for publicly and privately supplied water was calculated from the data points for each county. These were not separated by year given that groundwater hardness remains fairly constant throughout time.

Once the water hardness was known, the number of people served by public water supplies and privately sourced water were estimated. To understand the proportion of people served by publicly distributed water per county, we used 2019 census-estimated population size and 2019 EGLE data on the population served by public water supplies per county.[50] These proportions were assumed to remain constant from 2015 to 2019 and multiplied by the census-estimated populations by county for Michigan for each year between 2015 and 2019 inclusive.[51] This calculation provided the number of people served per county by public or private water per year. In EGLE's 2019 public water supply data, the population served by public water in Iron County was 11,293, larger than the 2019 census-estimated population of 11,066.

Rather than use the incorrect proportion of 100% of people served by publicly sourced water, an average of the bordering counties' proportions of the publicly serviced population was used.

To understand the number of people softening publicly and privately sourced water and the number of people whose water softener discharge eventually reaches surface water, we surveyed water softener professionals in Michigan (Appendix C). This was the best approach given that a statewide survey of households in Michigan was not feasible for the length of our study. By surveying water softener professionals, we could survey fewer people and obtain generalized results for the state of Michigan. In consultation with the Water Quality Association (WQA) and EGLE, we designed a survey and submitted it to the University of Michigan's Institutional Review Board (IRB). We were granted an exemption from ongoing IRB reviews and distributed the survey to Michigan members of WQA. The number of respondents varied per question. For the purposes of water softener use estimation, two questions were used. The first was "Do you install water softeners for customers whose water is municipally softened (e.g. lime softened, reverse osmosis)?" From a total of ten respondents, four indicated that they do. Six indicated that they do not. This implies that about 40% of people in Michigan soften municipally softened water. However, ten respondents is not an adequate sampling size. Thus, we relied on the estimate from Overbo et al. in Minnesota, which assumed that 35% of people served by public water softened their water based on a survey of 184 water softener professionals.[52] While the softening practices in Michigan may be different, our own survey corroborates this result in that 4 out of 10 water softener professionals stated that their customers softened municipally softened water. Because untreated groundwater is generally harder than centrally softened water, it was assumed that all people served by private well water softened their water.[53] The second question we examined was "Do you direct backwash discharge to the following? Select all that apply:" The choices were septic systems, drywells, ground surface, municipal wastewater treatment plants, and surface waters. The latter two indicate that discharge makes it to surface water. Out of twenty-nine respondents, seven indicated that their customers discharge to municipal wastewater treatment plants via sewer lines. Once answered that their customers discharge directly to surface water. From these results, we estimated that 27. 59% of total water softener backwash was discharged into surface water.

To determine water consumption by water softener users, we used The National Environmental Education Foundation's estimate that the average Michigander uses 79 gallons of water daily.[54] We assumed that if a person softens water, their entire daily water supply is softened. It was assumed that those who consumed softened water softened to 1 gpg or 17.14 ppm (Michigan's Water Quality Association, personal communication, November 19, 2021). Finally, to keep our estimate conservative, we assumed that all water softeners in Michigan operate at the highest efficiency of 4,000 grains/lb NaCl. This figure was also used by Overbo et. al in Minnesota.[45] From these values, the yearly consumption of chloride was calculated as shown below. The equation was modified to 366 days/year for 2016.

$$\frac{(\bar{x}-17.14\ ppm)*(1gpg/17.14\ ppm)*(79\ Gallons/day)*population(\alpha)*365\ days/year)*(0.2759)}{(4{,}000\ grains/lb\ NaCl)(1lb/453.59g)(58.44g/mol\ NaCl)(1\ mol\ NaCl/\ 1\ mol\ Cl^{-})(1\ mol\ Cl^{-}/35.45\ g)(10^{6}g/tonnes)} = metric\ tons\ of\ Cl^{-}$$

Where

$\bar{x}$ is the average hardness for publicly or privately sourced water

α is the proportion of people softening water (1 for private wells, 0.35 for public systems)

Our method indicates that residential water softeners in Michigan discharge 46,700 metric tons of chloride per year on average. This value omits discharge from failing septic systems. In Michigan, septic systems have a predicted 10%-25% failure rate.[55-57] Sewage from these septic systems eventually reaches groundwater and surface water. According to our survey, ten of twenty-nine respondents (34.48%) of residential softener backwash flows into septic systems. Assuming that 10% of these are failing and ultimately discharging to surface water, the yearly chloride discharge increases to an average of 52, 539 metric tons.

The water softener professionals survey also provided general insights about the installation, use, and maintenance of water softeners. Of these respondents, 80% identified specifically as water treatment professionals (Appendix C, Question 1). Our survey netted responses from all seven of the Michigan Department of Transportation's regional service areas designated in Figure 6 (Appendix C, Question 2). Furthermore, the responses represented serving a large number of residents in all but the Metro and Superior Region (Appendix C, Question 3).
100% of respondents said their customers exclusively use sodium chloride (NaCl) in their softeners as opposed to potassium chloride (KCl) (Appendix C, Question 14). Our final question asked for additional comments. One respondent said "When setting a water conditioner you have to take into account both the water chemistry and the number of people using water in the house. Both are important for getting the most efficient salt dosage." Another respondent agreed with the importance of getting the right settings for their customers. However, they took a different approach: "All of our systems use a computer setting for salt dosage."

Human excreta and household cleaning products

Humans regularly ingest and excrete salt through their diets. Furthermore, household cleaning products such as soaps, detergents, and toilet cleansers typically contain chloride.[45] This led us to develop estimates on the amount of chloride discharged from common household and personal care products and human excreta.

To determine this, we first needed to understand the number of household units in Michigan with sewer lines. The number of households in Michigan counties from 2015 to 2019 inclusive were predicted by dividing the population of each county for each year by 2.47, the average household size in Michigan from 2015 to 2019.[58] EGLE provided estimated data on the total housing units with septic systems in each of Michigan's counties in 2015 (Appendix D). The number of household units with sewer lines were estimated by subtracting the housing units with a septic tank from the total housing units for 2015. The proportion of household units with septics and those with sewer were calculated for each county and assumed to be constant from

2015 to 2019. The number of people per year per county using sewer or septic was determined by multiplying the number of household units by 2.47.

To estimate the chloride discharge from human excreta we multiplied the number of people with a sewer line by 4,818 mg/day/capita. This value was determined by Thompson et al. and estimates the total chloride in feces and urine.[59] This number was multiplied by the days in each year. The values were converted to metric tons per year. To estimate the chloride discharge from cleaning products, we multiplied the number of people with a sewer line by 10.8 g/week/capita. This value was estimated by Tjandraatmadja et al. (2010) and estimates the chloride discharged from cleaning product.[60] This was then multiplied by 52 weeks/year. The values were then converted to metric tons per year.

We estimate that human excreta in Michigan contributed to 8,257 metric tons of chloride. However, this figure does not account for failed septic systems that discharge into surface waters. Assuming 10% of septic systems in Michigan are failing and ultimately discharging into surface waters, the number increases to 9,185 metric tons. Another method suggests that people, on average, discharge 2.9 pounds of chloride per day.[61] If all Michiganders discharged this amount of chloride per day, the total discharge would be 13,137 metric tons of chloride yearly. Thus, 8,257 metric tons and 9,185 metric tons are potential underestimates.

From our estimates, chloride in household products contributed to 2,638 metric tons of chloride per year. However, this figure does not account for failed septic systems that ultimately discharge into surface waters. Assuming 10% of septic systems in Michigan are failing and discharging into surface waters, the load increases to 2,934 metric tons.

Nonpoint source results:

Road salt

We used data from Michigan's Department of Transportation (MDOT) as a crucial component to understanding the contributions of road salt applications to chloride in Michigan surface waters. Road salt application rate data from MDOT was used in conjunction with data from road agencies that had contracts with MDOT. We expected that the true amount of chloride entering the water from road salt would be larger, as we were unable to quantify the amount from individual home applications, private applicators, or any road agency not under contract with MDOT. Before we even began our initial research, we expected that road salt usage would be the largest nonpoint contributing source of chloride to Michigan's surface waters, due to the data Minnesota used in their research.[45] Application rates of salt through MDOT/MDOT contracts were broken down by specific regions of the state, as shown in Figure 6.[62]

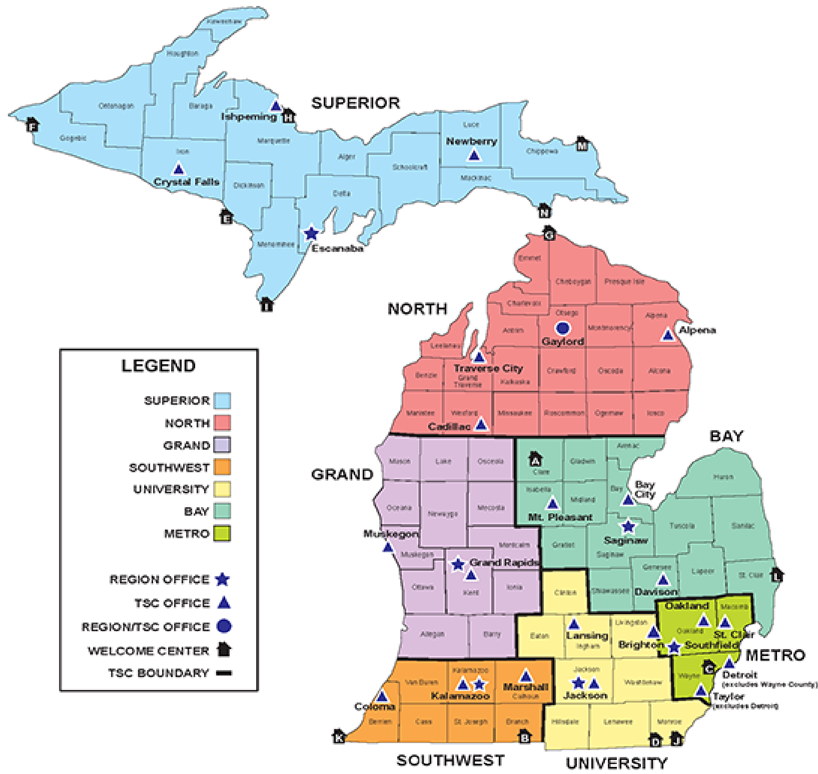


Figure 6. Michigan Department of Transportation's regional service areas.

Between 2015 and 2019 the state averaged 508,010 metric tons of rock salt applied to roads per year. Using the following conversion, it was converted to metric tons of chloride:

$$(metric\ tons\ road\ salt)\frac{1{,}000{,}000\ g}{metric\ ton} * \frac{1\ mol\ NaCl}{58.44\ g\ NaCl} * \frac{1\ mol\ Cl-}{1\ mol\ NaCl} * \frac{35.45\ g\ Cl-}{1\ mol\ Cl-} * \frac{1\ metric\ ton}{1,000,000\ g}$$

This resulted in approximately 308,161 tons of chloride entering surface waters per year. Throughout this timeframe, the Superior (58,429 tons) and Metro (57,370 tons) regions were responsible for the highest chloride discharges, whereas the Bay (35,511 tons) and Southwest (24,675) regions of the state contributed the least amount of chloride. The full 5-year average of the results can be found in Table 3.

This data shows that different areas of the state contribute varying amounts of chloride to the state's surface waters. While it is important that statewide chloride concentrations be below the recently established WQV, it is not appropriate to prioritize reduced road salt application rates for specific areas of the state. This is because areas vary in terms of how many road miles are present, as well as how much snowfall occurs on an annual basis, which ultimately affects how much salt is needed per area. The most efficient way to reduce chloride discharge levels associated with road salt application is for all areas of the state to establish best management practices that reduce the amount of unnecessary salt being applied for winter maintenance.

Region	Road Salt Application (metric tons)						Total Chloride (metric tons)
	2015	**2016**	**2017**	**2018**	**2019**	**5 Year Average**	**5 Year Average**
Superior	72,278	107,051	96,544	100,214	105,523	96,322	58,429
North	49,756	88,646	76,718	77,070	87,894	76,017	46,112
Grand	63,571	83,771	71,187	83,212	83,826	77,113	46,777
Bay	45,436	52,089	68,862	68,862	57,457	58,541	35,511
Southwest	39,855	51,500	37,921	39,445	34,665	40,677	24,675
University	59,960	72,225	59,823	67,440	64,370	64,764	39,286
Metro	86,799	87,616	94,046	94,649	109,767	94,575	57,370
Statewide	**417,654**	**542,899**	**505,102**	**530,892**	**543,501**	**508,010**	**308,161**

Table 3. A breakdown of the average chloride contributions from road salt applications to surface waters in different regions of the state from the years 2015-2019, as reported by MDOT.

Atmospheric Deposition

Atmospheric chloride deposition refers to chloride from rainfall. To estimate this contribution, we used annual precipitation data from the National Atmospheric Deposition Program's National Trends Network (NTN) across sites in Michigan between 2015 and 2019.[63] There are 7 monitoring sites across Michigan: NTN-MI09, NTN-MI26, NTN-MI48, NTN-MI51, NTN-MI52, NTN-MI53, and NTN-MI99. The table below summarizes their locations and whether they are in the upper peninsula (UP) or lower peninsula (LP) (Table 4). If the sites are in the lower peninsula, their locations were further divided into a southwestern lower peninsula (SWLP) and northeastern lower peninsula (NELP) according to the thick black boundary in Figure 7.[64] This boundary was drawn to account for the diminishing lake effect that causes a northeastern/southwestern gradient in the lower peninsula (Dr. F. Marsik, personal communication, June 2, 2021). This gradient is an artificial means of explaining the reduced lake effect that occurs southward through the western lower peninsula which implies higher rainfall and lower snowfall. The boundary is roughly based on a map from the Oregon Climate Service which demonstrates average annual precipitation from 1961 to 1990 (Figure 8).[65]

Site	Location	LP/UP	NELP/SWLP
MI09	Douglas Lake	LP	NELP
MI26	Kellogg	LP	SWLP
MI51	Unionville	LP	NELP
MI52	Ann Arbor	LP	SWLP
MI53	Wellston/Lud	LP	SWLP
MI48	Seney	UP	-

MI99	Chassell	UP	-

Table 4. National Trends Network's list of atmospheric deposition sites across the state.

Figure 7. The counties are divided into three regions based on the lake effects across the state.

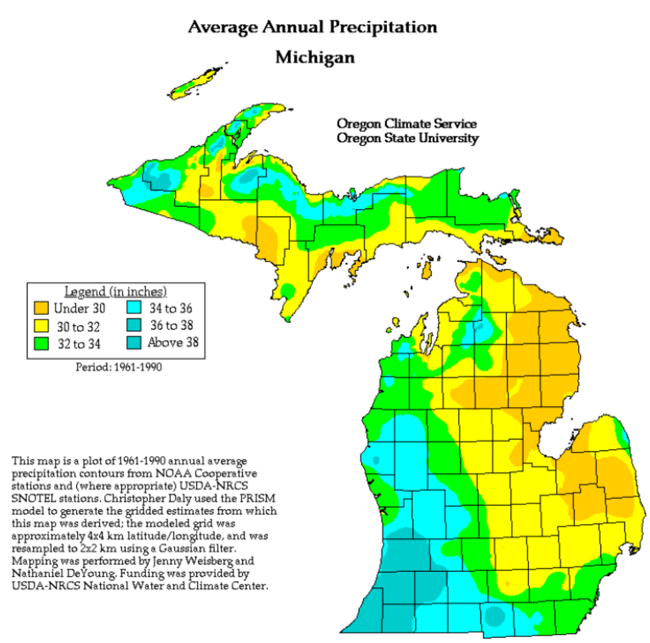


Figure 8. Average annual precipitation in Michigan from 1961-1990.

Because we were only interested in surface water chloride deposition, and not land deposition, we found the total water area in each county.[66] These areas were added for the counties in each of the three regions (hectares, ha). To estimate chloride deposition, they were multiplied by the average chloride deposition (kilograms/hectare, kg/ha) in each region for each year between 2015 and 2019. The results were added and converted to metric tons of chloride (Appendix E).

The total chloride deposition for each region and the total for Michigan are summarized below (Table 5):

Region	Chloride Deposition [metric tons]
UP	2185
NELP	1112
SWLP	1865
Total	**5163**

Table 5. Annual atmospheric chloride deposition levels by region of the state.

Overall Results

Between 2015 and 2019, the average yearly chloride load into Michigan's surface waters was 547,777 metric tons (Table 6). This number is similar to the 3-year average estimated in Minnesota–591,524 metric tons (a 7.4% difference). A significant difference in the final results is that Minnesota's average included discharge to both ground and surface waters, whereas ours only took into consideration surface water. Because of this, we believe that this is a fairly accurate representation of the contribution to Michigan's surface waters.

In comparison to Minnesota's estimates, the estimated values for Michigan in the same source categories are different (Table 6). The chloride discharge for all sources except NPDES-permitted facilities was lower in Michigan than in the Minnesota counterparts.

Chloride Budget [Metric Tons]		
Source	**Minnesota (3 year average - Surface and Groundwater)**	**Michigan (5 year average Surface Water only)**
NPDES-permitted Facilities	68,774	176, 858
Residential Water Softening	92,356	46,700
Human Excreta	8,396	8,257

Chloride Budget [Metric Tons]		
Source	**Minnesota (3 year average - Surface and Groundwater)**	**Michigan (5 year average Surface Water only)**
NPDES-permitted Facilities	68,774	176, 858
Residential Water Softening	92,356	46,700
Household Products	4,198	2,638
Road Salt Application	403,600	308,161
Atmospheric Deposition	14,200	5,163
Total	**591,524**	**547,777**

Table 6. Comparison of the chloride budgets for Michigan and Minnesota.

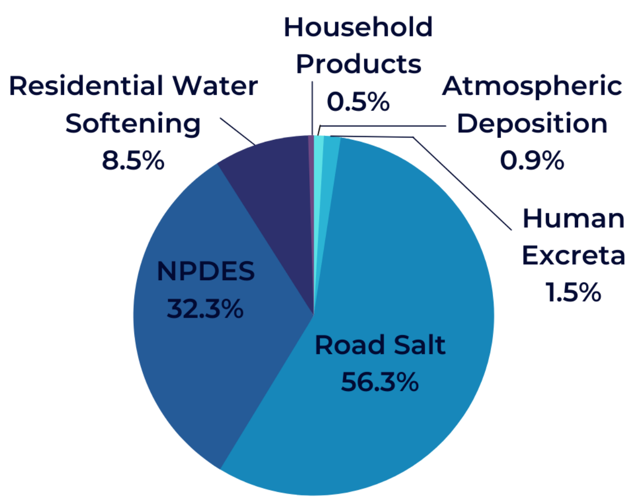


Figure 9. Average annual chloride contributions from point and nonpoint sources in Michigan.

Limitations

While we believe that our results present a fairly accurate depiction of the extent to which chloride pollutes Michigan's surface waters, there are several limitations in our methods. These include the absence of chloride discharge into surface waters from livestock excreta and fertilizer use, not accounting for private road salt use, the inability to conduct a residential water softener use statewide survey, and the absence of holistic WWTP chloride discharge monitoring.

The Minnesota study found that fertilizer use accounted for 23% of the chloride budget and livestock excreta for 6%.[41] These numbers pertain to chloride discharge into both surface and groundwater. To calculate fertilizer-sourced chloride, the researchers used data from the Minnesota Department of Natural Resources (MDNR) to estimate the number of fertilizers used and then, based on the fertilizer, the amount of chloride discharged yearly. The total amount of chloride in livestock excreta is based on the livestock population in Minnesota and the amount of chloride excreted daily based on the animal type and weight. We were unable to include those estimates in our results because current scientific methods regarding how these sources directly contribute to surface water concentrations alone are not well understood. Minnesota was able to utilize this information because they were interested in groundwater and surface waters. We were unable to find a predictor for chloride runoff into surface waters in the literature. In an email correspondence with Dr. Shamitha Keerthi from The Nature Conservancy, she wrote that "without hydrological modeling, it is hard to come up with exact ratios between surface/overland flow and infiltration. But if we could estimate this ratio, you could defensibly assume Cl- [chloride] is proportionally distributed in both, being fully soluble." To estimate this, she suggested a water balance (personal communication, October 4, 2021). This was outside the scope of the project timeframe. Future research should incorporate estimates of these specific sources into their results to establish a more accurate depiction of discharges to the state's surface waters.

Another limitation of our results is that we only looked at data from MDOT with regards to how much road salt is being discharged into surface waters. This estimate completely disregards the discharge coming from private applicators and the general public. We expect the total amount of chloride discharged from this source to be much higher than our current results indicate. Because of this, future research should focus on including estimations of the application rates from private applicators and individual households. Research should target the application rates of all private applicators of chloride in the state. This may be conducted through surveys regarding road salt practices. Additionally, surveys of residential homeowners and associations could be utilized to understand individual household application rates. Furthermore, in future research, contacting salt contractors directly about road salt sold could serve to cross-reference between road salt purchased and road salt applied. In Minnesota, a cooperative purchasing venture exists where cities, counties, and organizations can purchase road salt separately from Minnesota's Department of Transportation (MnDOT). Michigan has a similar purchasing venture as well called MiDEAL which allows various groups to purchase road salt separately from the state's DOT. Future research needs to utilize application rates reported through MiDEAL in order to determine a more realistic outlook on statewide salt application. By including these various aspects, future estimates regarding road salts' influence on surface waters will become even more accurate and robust.

Additionally, we found that there were limitations regarding our water softening survey. Unfortunately, we were unable to use the survey to determine the number of residents in Michigan that use water softeners. First, we determined that it would be impractical to survey water softener professionals to determine water softener usage statewide as not all homeowners consult with a water softener professional for installation or maintenance. For those residents that do consult professionals, we could not be sure we were capturing every water softener professional in the state by targeting only companies that were registered WQA members. Finally, residents may use different water softener professionals at different times, thus company records may not be entirely accurate. We also were unable to accurately account for commercial water softening rates, which were thus omitted from our overall results. We found it impractical to survey all commercial industries in the state regarding their water softening use. Thus, this information is not included in our final budget. In the future, we recommend assessing how many Michigan residents use water softeners through a household-by-household survey, as well as incorporating commercial water softening data from industries into our results. While these methods will be time-consuming and costly, it would provide in even greater detail about how much chloride is being discharged from the ion-exchange process utilized by water softeners.

Finally, Minnesota's researchers were able to determine a WWTP budget because a larger number of WWTPs monitor chloride in their discharge. This is not the case for most WWTPs in Michigan: most do not monitor for chloride in discharge. With the establishment of chloride WQV in 2019, however, this will change. This was a major advantage for the Minnesota researchers: estimates of chloride use from multiple sources (e.g.,water softener backwash discharge, industrial wastewater, and human sources) could be cross-referenced with the total WWTP chloride discharge to verify all sources had been accounted for. In Michigan, such data would help ensure complete accounting of chloride and elucidate any other sources. Ultimately, this would provide a Michigan-centered approach to strategies reducing chloride use.

Stakeholder Outreach Materials

In addition to determining the overall chloride budget for the surface waters of the state of Michigan, another important goal was to use the results to create stakeholder-specific outreach and educational tools aimed at reducing chloride loading to Michigan waters. While determining the chloride budget itself was important for us to conduct, we felt as though it was necessary to provide additional sector-specific outreach materials. This way, stakeholders would have access to specific, easily disseminated information and strategies that would be useful to implement as we all try to reduce surface-level chloride concentrations for the sake of protecting aquatic life. We were particularly interested in creating useful strategies of chloride mitigation targeted towards the larger contributing sources, such as road salt applicators and NPDES-permitted industrial facilities. Our goal was to help support EGLE's efforts and meet their needs of understanding chloride contributions by sectors and providing them with outreach tools that they could disseminate to relevant stakeholders. Importantly, we sought to create educational outreach materials that presented strategies/solutions in a manner that was less authoritarian and more open-minded and flexible. We made sure to recommend strategies in a manner that both highlighted why high chloride levels in water are a problem and useful ways in which stakeholders could address the issue. The last thing we wanted to do was to present stakeholders with strategies in an authoritarian, nonflexible manner that would suggest limited options. Afterall, this would dissuade stakeholders from using them in the future. The key for us was to recommend strategies in ways that would be accessible and useful for each stakeholder group to implement moving forward. We wanted to present strategies in ways that were simple, concise, and easy for the specific stakeholders to understand.

The deliverables we developed include a road salt checklist useful to road agencies/private applicators, departments of transportation (DOTs), and the general public which lists the best practices with regards to the transportation, use, and storage of road salt for winter maintenance that mitigates the impact on the environment (Appendix F) . This checklist was accompanied by an easy-to-read handout directed at transportation departments, which briefly summarizes the best practices listed in the checklist (Appendix G). Additionally, a brochure targeted at the general public was also developed that summarizes the best practices related to road salt (Appendix H). Furthermore, a concise summary of our overall efforts and findings throughout the project was developed that highlights the issue of elevated chloride in surface waters and makes brief recommendations on how to mitigate its effects on the environment (Appendix I). Lastly, briefs were developed for food processors and WWTPs. The former addresses specific chloride mitigation efforts food processors could use in their standard operating procedures to optimize their chloride use and reduce chloride discharge (Appendix J). The latter deals with a case study in The Village of Pinckney, Michigan where elimination of water softener backwash to the sewer system reduced chloride levels in its WWTP's discharge (Appendix K).

Conclusion

The effects of excessive chloride on the environment are well established; it is harmful to aquatic plants and animals and corrosive to infrastructure. As increased concentration trends continue to rise across the country, it is crucial now more than ever to understand the major point and nonpoint sources of chloride discharged into statewide water systems. Our results have shown that the major contributors of chloride to Michigan's surface water include discharge from road salt application and NPDES-permitted facilities. While our results have several limitations, our efforts represent a meaningful milestone for the state in its efforts to protect the water system from additional pollution. We hope that our results can be useful to other states/the country as we move forward and develop meaningful solutions to combat this problem. Excessive chloride polluting our nation's waters has been a developing problem for decades. With these results, however, we hope to educate stakeholders and the public at large about the issue to ensure that this problem will be solved in the future. Solving this problem is going to be a group effort, and we expect that our research will make it easier for everyone to work together to combat this issue.

Acknowledgments

We would like to acknowledge and personally thank several individuals for their assistance in helping us complete this research. We would like to start by thanking our clients from Michigan's Department of Environment, Great Lakes and Energy (EGLE), Christe Alwin and

Kevin Goodwin, for their continued assistance and support throughout the process. We could not have completed this project without their knowledge and expertise. We would also like to thank the Minnesota Pollution Control Agency's Chloride Program Administrator Brooke Asleson for helping us develop our water softener survey. We are also very grateful to Water Quality Association (WQA) members Matt Carey, Tanya Lubner, Eric Yeggy, Ann Spagnuolo, Kathleen Burbidge for advising us on the water softening survey and helping us distribute our water softening amongst softening professionals. We must also thank Dr. Frank Marsik from the University of Michigan's Department of Climate and Space Sciences Engineering Program (CLASP) for reviewing our estimations regarding chloride contributions from atmospheric deposition. We also appreciate the assistance from Rick Andrew, an employee from the NSF International, Brian Marx, a licensed Master Plumber, and Lois Graham, Senior PFAS Analyst at EGLE, who provided us with additional information on water softener use. EGLE employees Lisa Dygert and Molly Rippke also deserve thanks for providing us with data collection for our chloride budget. We also thank Alycia Overbo for providing clarification regarding Minnesota's budgeting methods. Furthermore, we'd like to acknowledge the expertise given to us by Celia Bravard from the University of Michigan with regards to chloride reduction strategies in food processing methods. Lastly, we'd like to thank Rebecca Foster from the Village of Pinckney, Michigan for helping to clarify their water softening rebate program.

Appendix A.
Yearly chloride discharge per NPDES facility per year [metric tons]

Site Name	2015	2016	2017	2018	2019	2020
Lansing BWL-Erickson Station	164.12	157.01	191.85	173.01	150.74	141.75
Coca Cola-Paw Paw	53123.33	50143.53	61588.21	109152.4	84297.84	91402.57
ConAgra Foods-Imlay City	3022.19	3351.24	2914.07	2568.65	3499.38	3102.05
Hillshire Brands-Zeeland	1102.86	1128.09	1038.31	1158.97	1391.2	1112.68
MMPA-Ovid Plant	431.68	471.22	435.97	522.85	518.57	479.44
Carmeuse Lime & St-Rogers City	N/A	N/A	N/A	923.23	882.12	839
Copper Range Co	2434.26	1799.7	2190.19	1856.3	2076.88	1231.29
Great Lakes Aggregate-Sylvania	3008.68	2481	2200.44	2274.86	2069.95	1864.83
Nat Gypsum-Tawas Quarry	5.51	6.37	5.95	5.87	1.07	10.75
Stoneco Inc-Denniston	61.19	50.43	49.36	39.71	31.73	33.58
Stoneco Inc-Maybee	21.49	24.03	22.51	13.95	19.32	8.13
Stoneco Inc-Newport	633.65	709.32	794.65	615.07	771.97	698.83
Stoneco Inc-Ottawa Lake	187.28	238.53	207.57	169.36	222.42	220.23
Dow Chemical-Midland	56840.1	57376.09	58538.3	64082.66	64583.19	57148.38
Martin Marietta-Magn Spec Inc	7660.94	26512.38	34508.5	27631.49	29432.4	20861.73
Morton Salt	118.93	163.61	149.87	121.61	145.76	155.98
Wacker Chem Corp	46.24	41.77	40.96	53.21	35.31	57.16
PCA-Filer City Mill	354.29	352.75	379.06	418.92	414.27	369.57
Occidental Chem Corp-Ludington	3020.42	2555.62	2409.43	3093.99	2625.63	2144.3
Abbott Nutrition	N/A	N/A	N/A	12.62	13.22	12.39
Burkland Inc-Goodrich	129.21	162.66	217.68	121.61	145.54	157.45
Chrysler-Chelsea Proving Grds	153.47	148.9	177.71	282.25	235.4	189.03
Sherwin Williams Co-Holland	N/A	N/A	N/A	0	0	0
Davison WTP	23.72	23.41	20.71	24.84	14.64	12.32
Saline WTP	52.72	62.1	49.73	41.7	33.08	53.46
Saline WWTP	364.71	343.38	391.53	467.25	457.51	503.94

Site Name	5-year average	% Contribution
Lansing BWL-Erickson Station	167.35	0.09%
Coca Cola-Paw Paw	71661.06	40.52%
ConAgra Foods-Imlay City	3071.11	1.74%
Hillshire Brands-Zeeland	1163.89	0.66%
MMPA-Ovid Plant	476.06	0.27%
Carmeuse Lime& St-Rogers City	902.67	0.51%
Copper Range Co	2071.46	1.17%
Great Lakes Aggregate-Sylvania	2406.99	1.36%
Nat Gypsum-Tawas Quarry	5.93	0.00%
Stoneco Inc-Denniston	46.49	0.03%
Stoneco Inc-Maybee	20.26	0.01%
Stoneco Inc-Newport	704.93	0.40%
Stoneco Inc-Ottawa Lake	205.03	0.12%
Dow Chemical-Midland	60284.07	34.09%
Martin Marietta-Magn Spec Inc	29521.19	16.69%
Morton Salt	139.96	0.08%
Wacker Chem Corp	43.5	0.02%
PCA-Filer City Mill	383.86	0.22%
Occidental Chem Corp-Ludington	2741.02	1.55%
Abbott Nutrition	12.92	0.01%
Burkland Inc-Goodrich	155.34	0.09%
Chrysler-Chelsea Proving Grds	199.54	0.11%
Sherwin Williams Co-Holland	0	0.00%
Davison WTP	21.46	0.01%
Saline WTP	47.87	0.03%
Saline WWTP	404.87	0.23%
Total (5-year average)	176858.81	

Appendix B.
Yearly chloride discharge per NPDES waste stream facility per year [metric tons].

Site Name	5-year average	Facility Type	5-Year Average by Facility Type	% Contribution By Facility Type
Lansing BWL-Erickson Station	167.35	**Cooling Tower Blowdown**	167.35	0.09%
Coca Cola-Paw Paw	71661.06	Food Processing		
ConAgra Foods-Imlay City	3071.11	Food Processing		
Hillshire Brands-Zeeland	1163.89	Food Processing		
MMPA-Ovid Plant	476.06	**Food Processing**	76372.12	43.18%
Carmeuse Lime& St-Rogers City	902.67	Mine Dewatering Water		
Copper Range Co	2071.46	Mine Dewatering Water		
Great Lakes Aggregate-Sylvania	2406.99	Mine Dewatering Water		
Nat Gypsum-Tawas Quarry	5.93	Mine Dewatering Water		
Stoneco Inc-Denniston	46.49	Mine Dewatering Water		
Stoneco Inc-Maybee	20.26	Mine Dewatering Water		
Stoneco Inc-Newport	704.93	Mine Dewatering Water		
Stoneco Inc-Ottawa Lake	205.03	**Mine Dewatering Water**	6363.76	3.60%
Dow Chemical-Midland	60284.07	Process Wastewater		
Martin Marietta-Magn Spec Inc	29521.19	Process Wastewater		
Morton Salt	139.96	Process Wastewater		
Wacker Chem Corp	43.5	Process Wastewater		
PCA-Filer City Mill	383.86	**Process Wastewater**	90372.58	51.10%

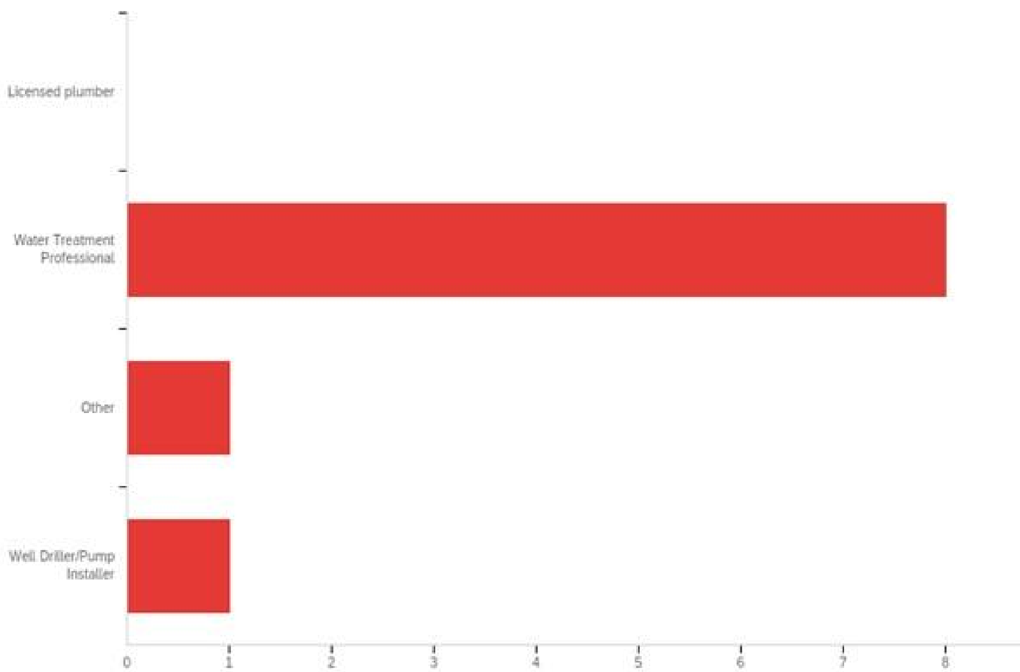
Occidental Chem Corp-Ludington	2741.02	**Produces Calcium Chloride**	2741.02	1.55%
Abbott Nutrition	12.92	RO Concentrate		
Burkland Inc-Goodrich	155.34	RO Concentrate		
Chrysler-Chelsea Proving Grds	199.54	RO Concentrate		
Sherwin Williams Co-Holland	0	RO Concentrate		
Davison WTP	21.46	RO Concentrate		
Saline WTP	47.87	**RO Concentrate**	437.13	0.25%
Saline WWTP	404.87	**RO Concentrate from WTP**	404.87	0.23%

Appendix C.
Complete results for the Water Softener Survey

Water Softener Chloride Survey Report

February 1st, 2022

Q1 - Please indicate your profession below

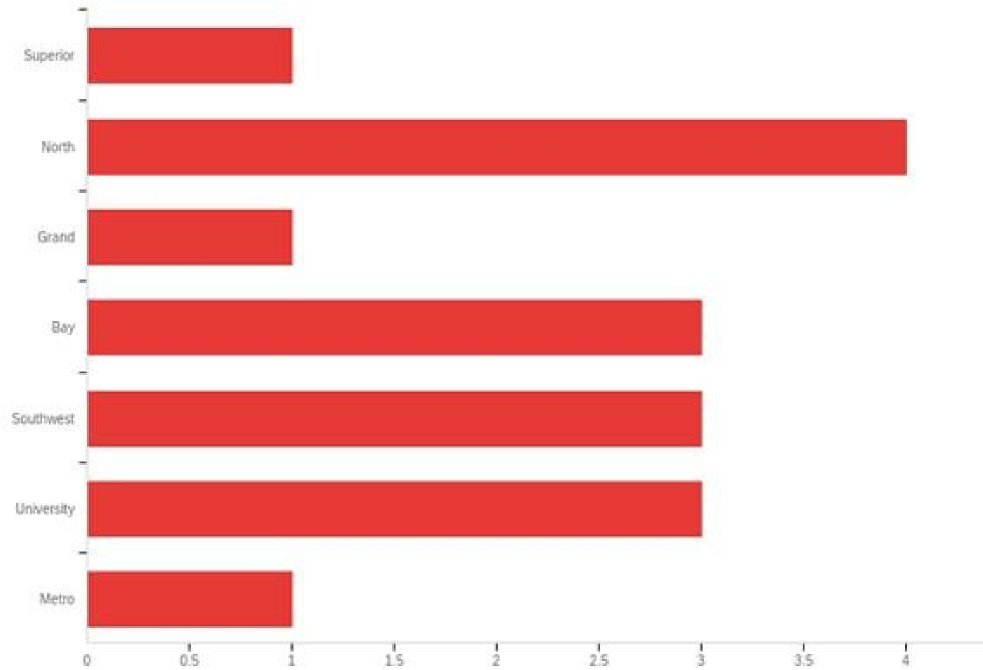


#	Answer	%	Count
1	Licensed plumber	0.00%	0
3	Water Treatment Professional	80.00%	8
5	Other	10.00%	1
6	Well Driller/Pump Installer	10.00%	1
	Total	100%	10

Q1_5_TEXT - Other

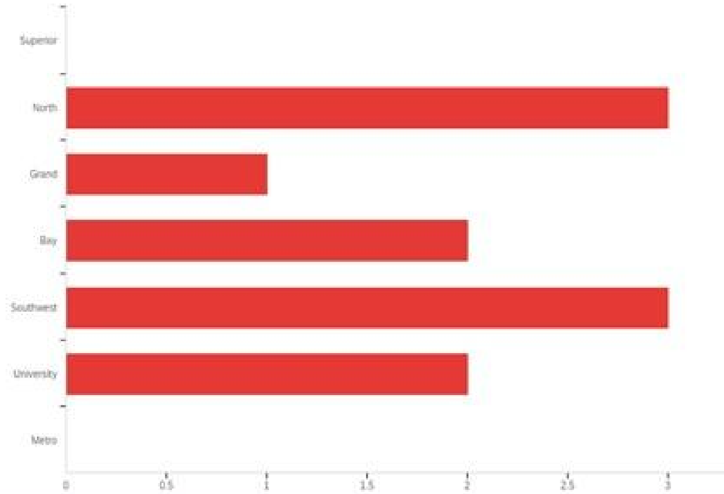
Other - Text
All of the above

Q2 - What regions of Michigan do you generally work in? Please check all that apply. (See map below)



#	Answer	%	Count
1	Superior	6.25%	1
2	North	25.00%	4
3	Grand	6.25%	1
4	Bay	18.75%	3
5	Southwest	18.75%	3
6	University	18.75%	3
7	Metro	6.25%	1
	Total	100%	16

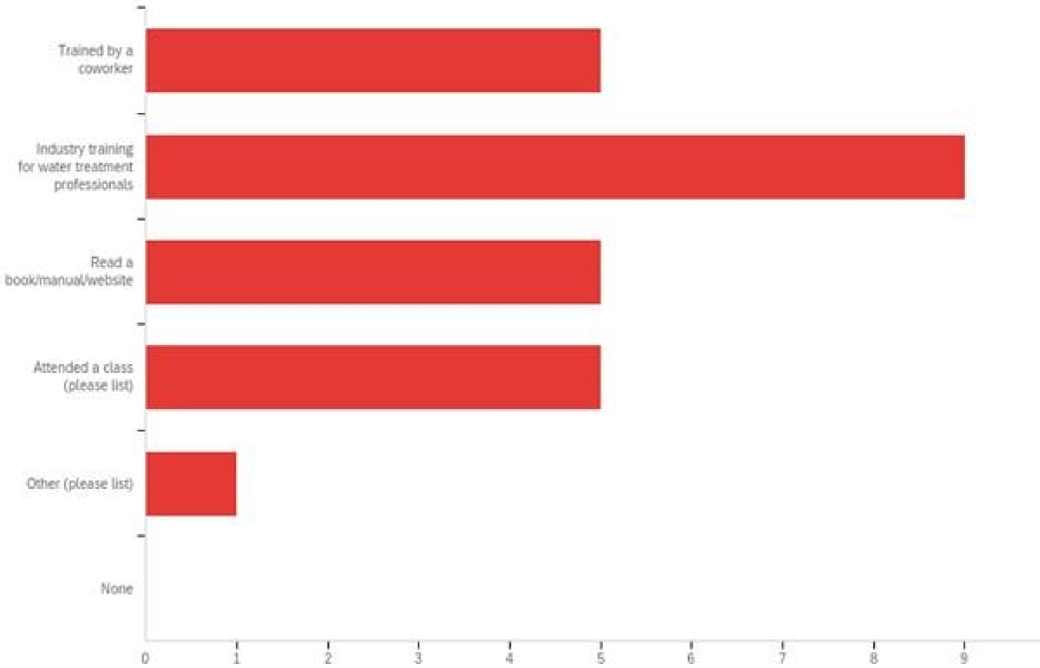
Q3 - Approximately how many customers do you serve in each region?



North - Text
30
3000
100!
Grand - Text
5000
Bay - Text
10,000
1500
Southwest - Text
15-2k
800
5000
University - Text
1500
9500

Metro & Superior – No Text Response

Q4 - What training have you had to set water softener settings (i.e. regeneration and salt dose settings)? Please check all that apply.



#	Answer	%	Count
1	Trained by a coworker	20.00%	5
2	Industry training for water treatment professionals	36.00%	9
3	Read a book/manual/website	20.00%	5
4	Attended a class (please list)	20.00%	5
5	Other (please list)	4.00%	1
6	None	0.00%	0
	Total	100%	25

Q4 - What training have you had to set water softener settings (i.e. regeneration and salt dose settings)? Please check all that apply.

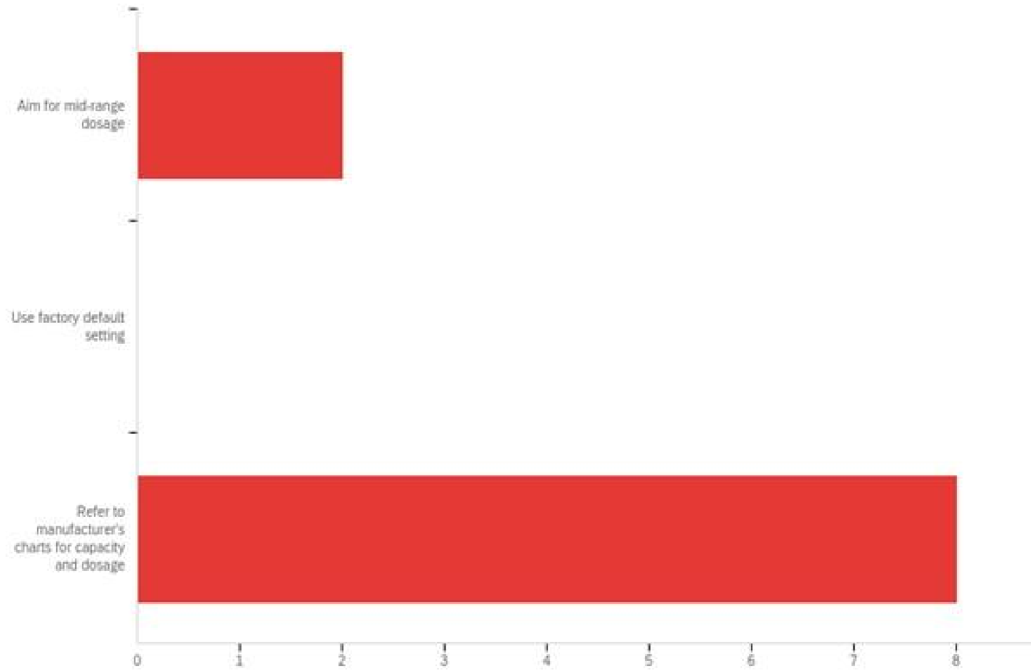
Q4_4_TEXT - Attended a class (please list)

Attended a class (please list) - Text
WTer treatment service school for water softener and filters
Wqa
Culligan and WQA training classes
WQA Master Water Treatment Specialist
WQA

Q4_5_TEXT - Other (please list)

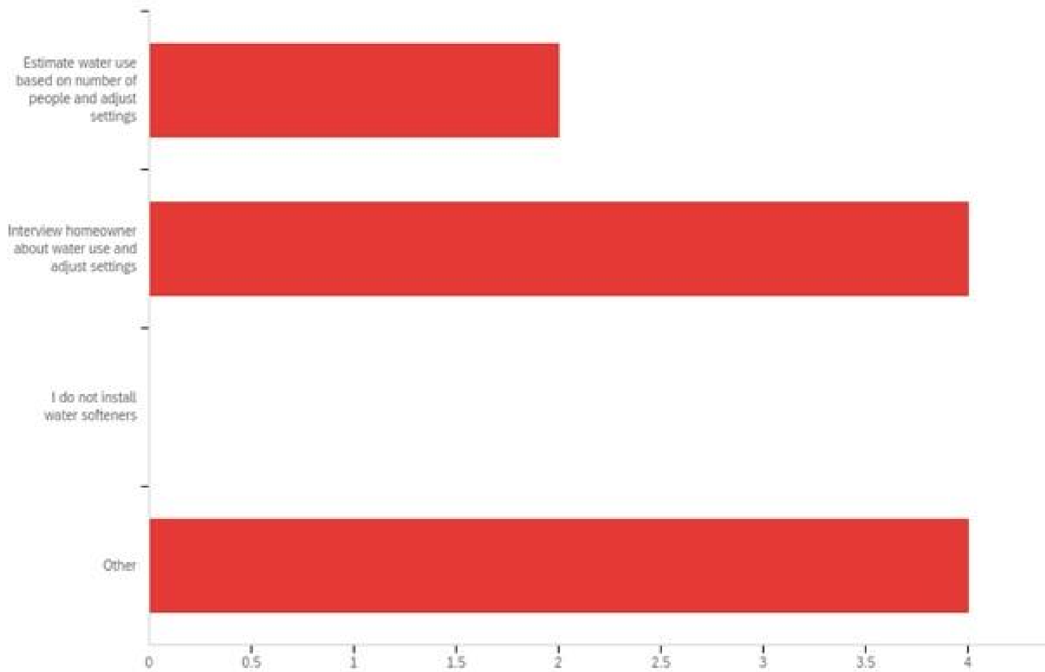
Other (please list) - Text
Experience

Q5 - How do you typically determine what the salt dosage should be?



#	Answer	%	Count
1	Aim for mid-range dosage	20.00%	2
2	Use factory default setting	0.00%	0
3	Refer to manufacturer's charts for capacity and dosage	80.00%	8
	Total	100%	10

Q6 - When installing water softeners, how do you determine the reserve volume or capacity?



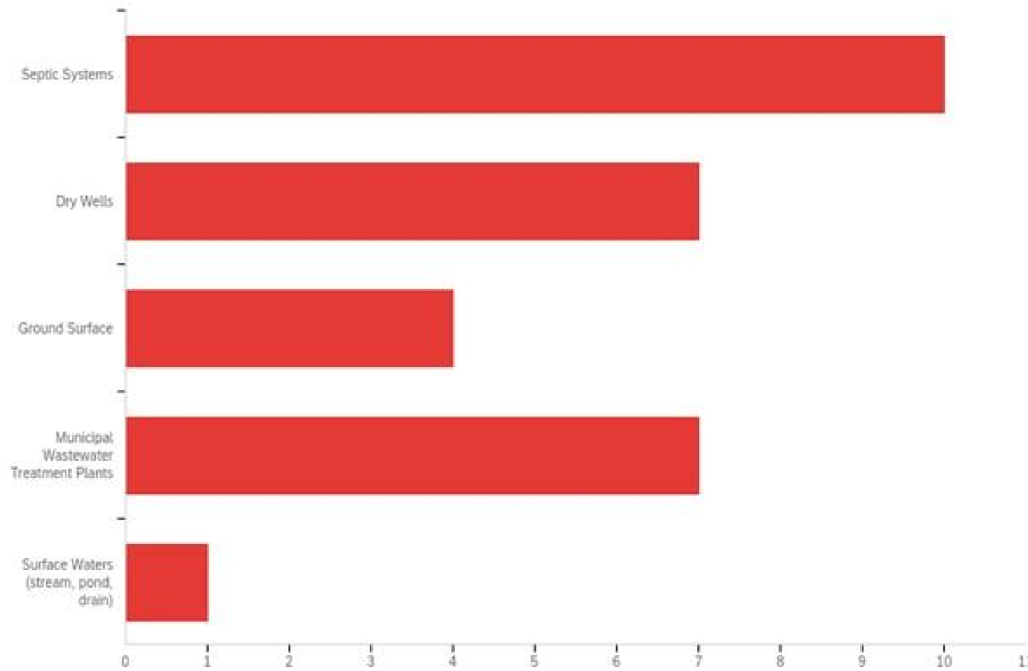
#	Answer	%	Count
2	Estimate water use based on number of people and adjust settings	20.00%	2
3	Interview homeowner about water use and adjust settings	40.00%	4
4	I do not install water softeners	0.00%	0
5	Other	40.00%	4
	Total	100%	10

Q6 - When installing water softeners, how do you determine the reserve volume or capacity?

Q6_5_TEXT - Other

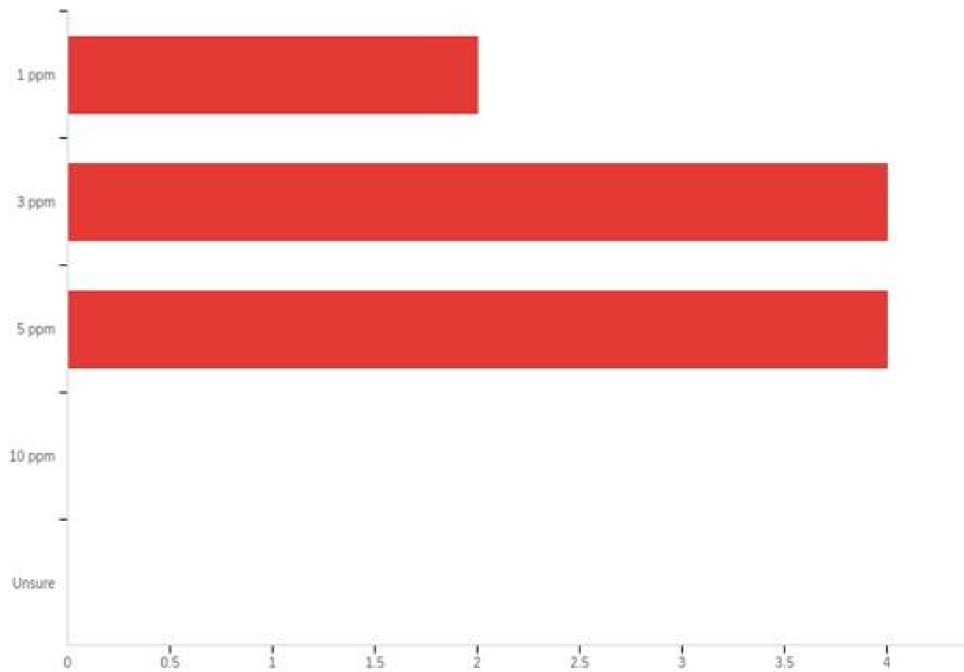
Other - Text
hardness of raw water
We use a computer setting baised on how many people actuall live there
Formula
Water analysis/calculated metered regeneration. Iron filtration when applicable to reduce water softener regen and minimize salt usage

Q7 - Do you direct backwash discharge to the following? Select all that apply:



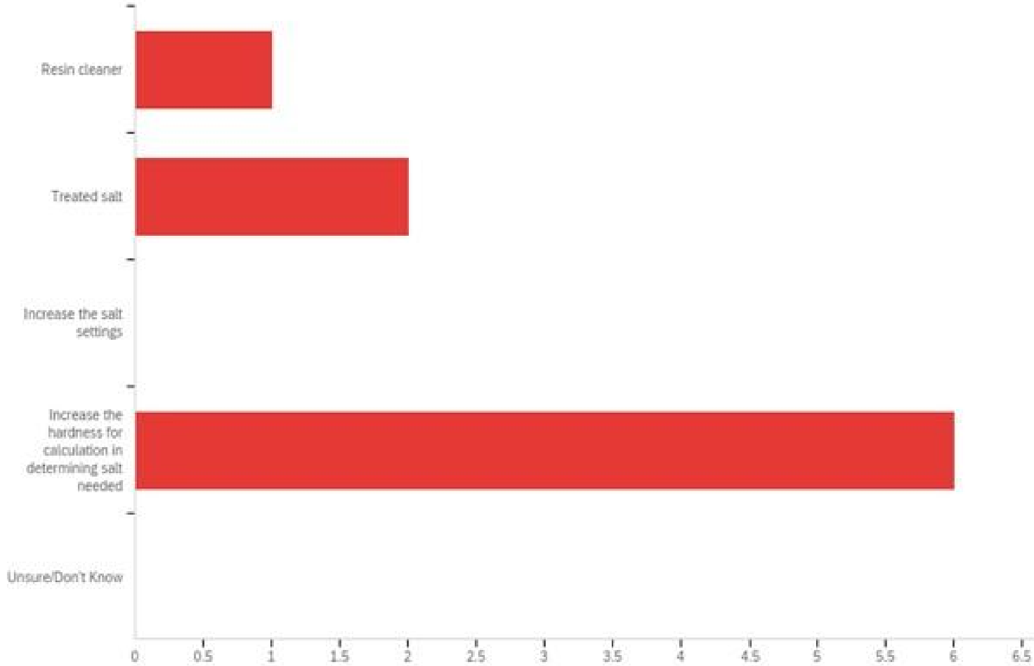
#	Answer	%	Count
1	Septic Systems	34.48%	10
2	Dry Wells	24.14%	7
3	Ground Surface	13.79%	4
4	Municipal Wastewater Treatment Plants	24.14%	7
5	Surface Waters (stream, pond, drain)	3.45%	1
	Total	100%	29

Q8 - What is the maximum Iron concentration that you would treat with a water softener before recommending an iron filter?



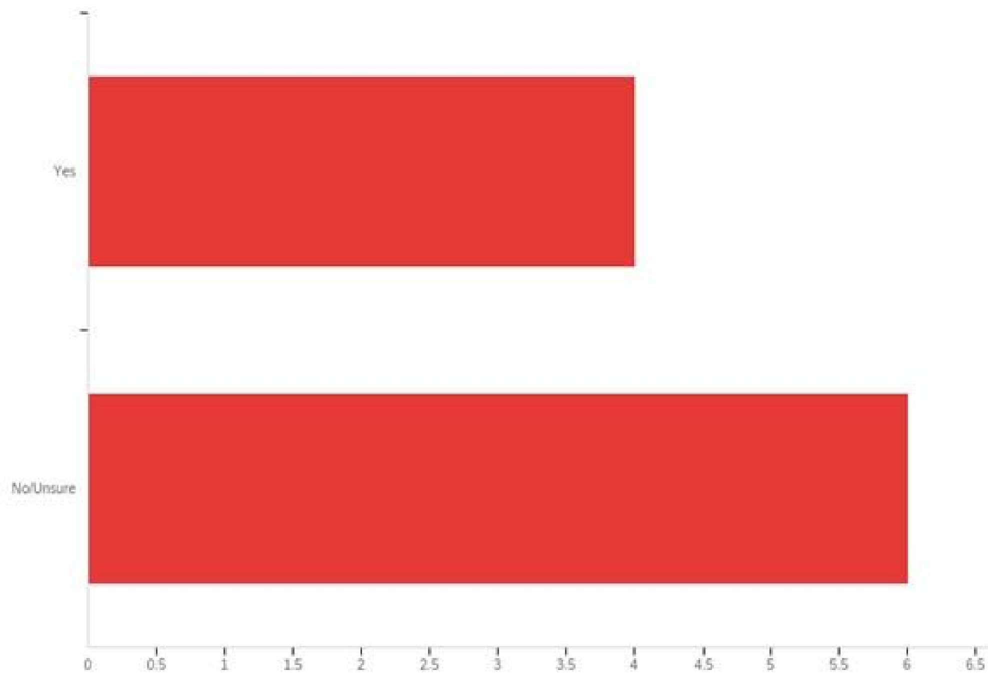
#	Answer	%	Count
1	1 ppm	20.00%	2
2	3 ppm	40.00%	4
3	5 ppm	40.00%	4
4	10 ppm	0.00%	0
5	Unsure	0.00%	0
	Total	100%	10

Q9 - For water with high iron levels, do you use a:



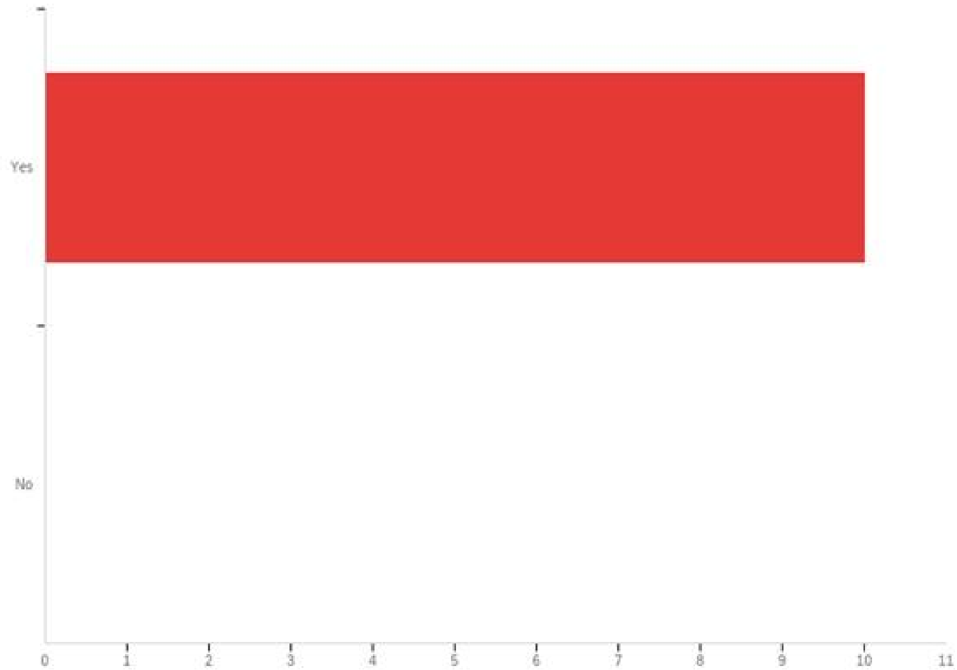
#	Answer	%	Count
1	Resin cleaner	11.11%	1
2	Treated salt	22.22%	2
3	Increase the salt settings	0.00%	0
4	Increase the hardness for calculation in determining salt needed	66.67%	6
6	Unsure/Don't Know	0.00%	0
	Total	100%	9

Q10 - Do you install water softeners for customers whose water is municipally softened (e.g. lime softened, reverse osmosis)?



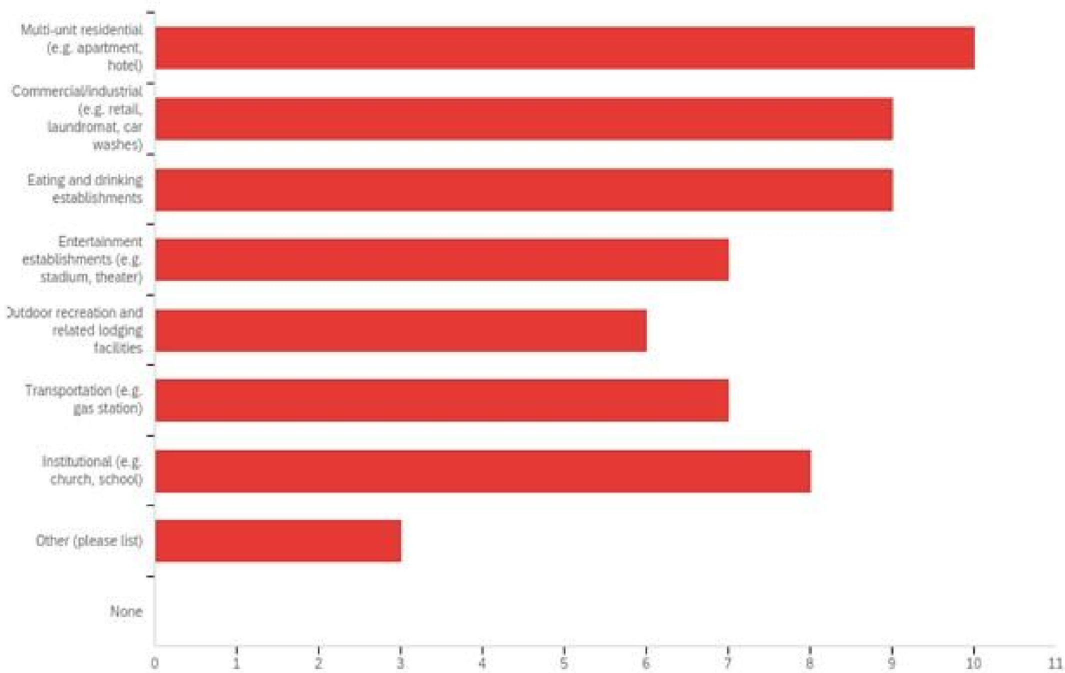
#	Answer	%	Count
1	Yes	40.00%	4
2	No/Unsure	60.00%	6
	Total	100%	10

Q11 - Do you service non-residential water softeners?



#	Answer	%	Count
1	Yes	100.00%	10
2	No	0.00%	0
	Total	100%	10

Q12 - Please check all businesses, industries, or facilities where you service water softeners.



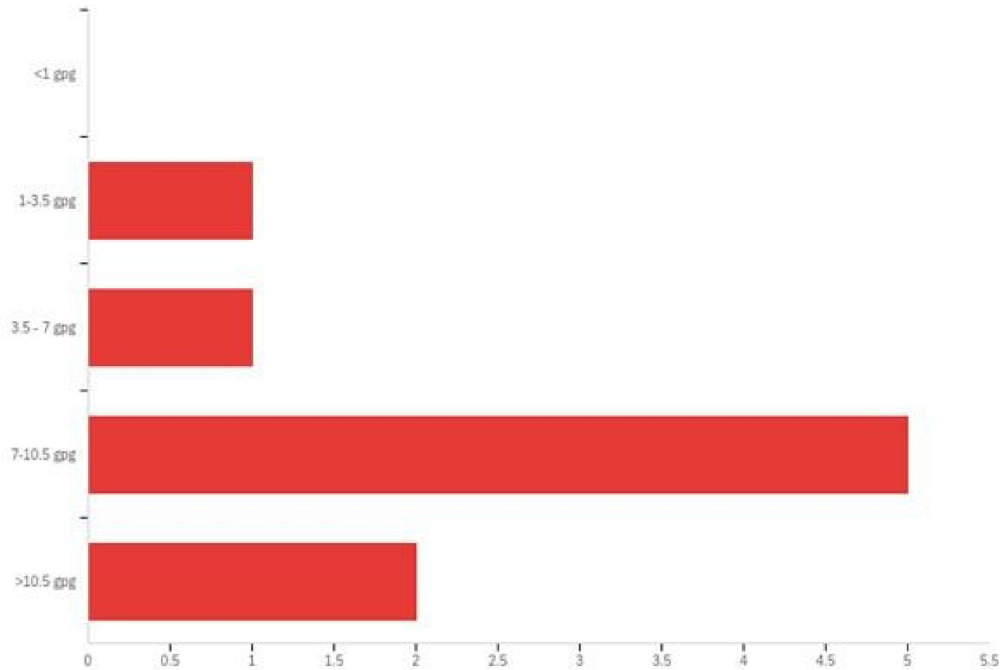
Q12 - Please check all businesses, industries, or facilities where you service water softeners.

#	Answer	%	Count
1	Multi-unit residential (e.g. apartment, hotel)	16.95%	10
2	Commercial/industrial (e.g. retail, laundromat, car washes)	15.25%	9
3	Eating and drinking establishments	15.25%	9
4	Entertainment establishments (e.g. stadium, theater)	11.86%	7
5	Outdoor recreation and related lodging facilities	10.17%	6
6	Transportation (e.g. gas station)	11.86%	7
7	Institutional (e.g. church, school)	13.56%	8
8	Other (please list)	5.08%	3
9	None	0.00%	0
	Total	100%	59

Q12_8_TEXT - Other (please list)

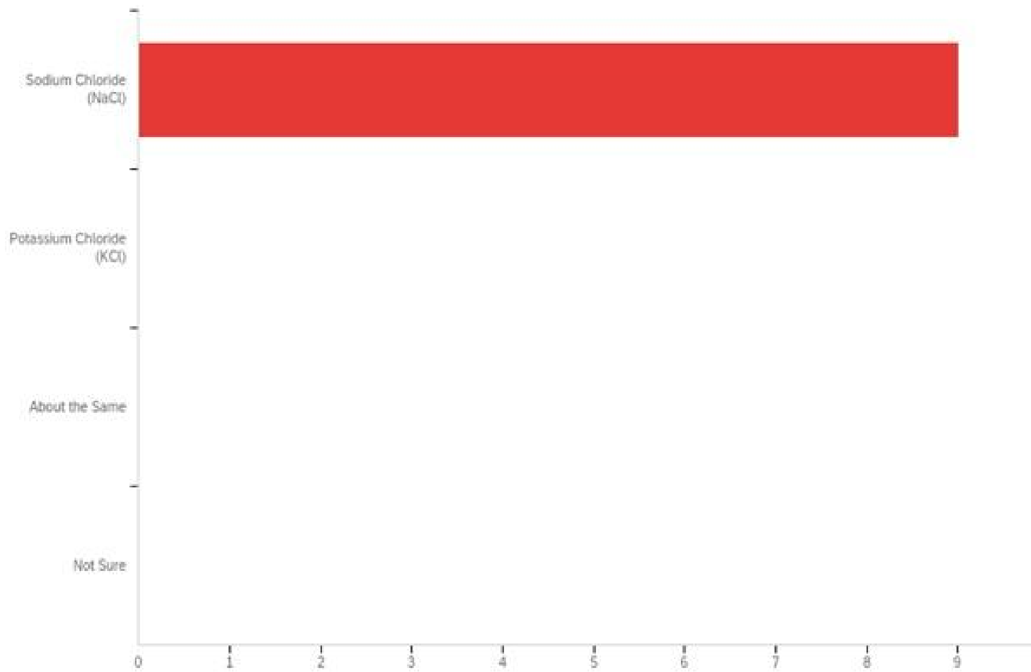
Other (please list) - Text
Manufacturing
office buildings
Establishments that use boilers for heating/cooling

Q13 - At what level of water hardness do your customers begin to request a water softener?



#	Answer	%	Count
1	<1 gpg	0.00%	0
2	1-3.5 gpg	11.11%	1
3	3.5 - 7 gpg	11.11%	1
4	7-10.5 gpg	55.56%	5
5	>10.5 gpg	22.22%	2
	Total	100%	9

Q14 - Which type of salt is used more frequently by your customers?



#	Answer	%	Count
1	Sodium Chloride (NaCl)	100.00%	9
2	Potassium Chloride (KCl)	0.00%	0
3	About the Same	0.00%	0
4	Not Sure	0.00%	0
	Total	100%	9

Appendix D.
Septic system data for each county in Michigan

County	TotalHUs	Septics
Alcona County	11073	10741
Alger County	6554	5156
Allegan County	49426	30793
Alpena County	16053	9117
Antrim County	17824	14669
Arenac County	9803	8326
Baraga County	5270	3629
Barry County	27010	15319
Bay County	48220	7130
Benzie County	12199	10379
Berrien County	76922	20052
Branch County	20841	13678
Calhoun County	61042	17442
Cass County	25887	23498
Charlevoix County	17249	10081
Cheboygan County	18298	14912
Chippewa County	21253	12309
Clare County	23233	20242
Clinton County	30695	13467
Crawford County	11092	10221
Delta County	20214	11861
Dickinson County	13990	4965

Eaton County	47050	16584
Emmet County	21304	12443
Genesee County	192180	36236
Gladwin County	17672	13531
Gogebic County	10795	4666
Grand Traverse County	41599	22085
Gratiot County	16339	8338
Hillsdale County	21757	14843
Houghton County	18636	7753
Huron County	21199	14111
Ingham County	121281	17711
Ionia County	24778	13915
Iosco County	20443	14130
Iron County	9197	7377
Isabella County	28381	14423
Jackson County	69458	22091
Kalamazoo County	110007	24343
Kalkaska County	12171	11073
Kent County	246901	41361
Keweenaw County	2467	1847
Lake County	14966	13769
Lapeer County	36332	26733
Leelanau County	14935	12493
Lenawee County	43452	19881
Livingston County	72809	24127

Mackinac County	11010	8161
Macomb County	356626	39487
Manistee County	15694	10704
Marquette County	34330	15091
Mason County	17293	11066
Mecosta County	21131	15563
Menominee County	14227	9010
Midland County	35960	17396
Missaukee County	9117	7777
Monroe County	62971	26684
Montcalm County	28221	18422
Montmorency County	9597	9192
Muskegon County	73561	21853
Newaygo County	25075	20095
Oakland County	527255	97208
Oceana County	15944	12495
Ogemaw County	16047	14543
Ontonagon County	5672	3420
Osceola County	13632	11323
Oscoda County	9118	7950
Otsego County	14731	13001
Ottawa County	102495	23168
Presque Isle County	10428	8333
Roscommon County	24459	10130
Saginaw County	86844	23367

St. Clair County	71822	30278
St. Joseph County	27778	16351
Sanilac County	22725	16950
Schoolcraft County	6313	4643
Shiawassee County	30319	15139
Tuscola County	24451	17211
Van Buren County	36785	25957
Washtenaw County	147573	38196
Wayne County	821693	33827
Wexford County	16736	10186
Luce County	4343	4343

Appendix E.
Calculations to determine the 5-year average atmospheric deposition of chloride in Michigan 2015-2019

Site	Location	2015 (kg/ha)	2016 (kg/ha)	2017 (kg/ha)	2018 (kg/ha)	2019 (kg/ha)	5-year average (kg/ha)
MI09	Douglas Lake	0.354	0.427	0.392	0.558	0.460	0.438
MI26	Kellogg	0.710	0.690	0.738	0.680	0.643	0.692
MI51	Unionville	0.462	0.344	0.367	0.331	0.504	0.402
MI52	Ann Arbor	0.531	0.534	0.867	0.786	0.507	0.645
MI53	Wellston/Lud	0.712	0.639	1.433	0.579	0.630	0.799
MI48	Seney	0.317	0.336	0.535	0.345	0.394	0.385
MI99	Chassell	0.446	0.404	0.604	0.425	0.464	0.469

Site	Location	LP/UP	NELP/SWLP
MI09	Douglas Lake	LP	NELP
MI26	Kellogg	LP	SWLP
MI51	Unionville	LP	NELP
MI52	Ann Arbor	LP	SWLP
MI53	Wellston/Lud	LP	SWLP
MI48	Seney	UP	-
MI99	Chassell	UP	-

Region	Total Water Area (ha)	Average Chloride Depostion (kg/ha)	Average Chloride Deposition (kg)	Average Chloride Deposition (metric tons)
UP	5118079.239	0.427	2185419.835	2185.420
SWLP	2619256.887	0.420	1112441.394	1112.441
NELP	2649300.771	0.712	1864736.286	1864.736

Total Chloride (metric tons)
5163

Appendix F.
Road Salt Best Management Practices.

Road Salt Best Management Practices (BMP's)

Why it's important to reduce road salt levels

- 1 teaspoon of salt permanently pollutes between 5-10 gallons of water
- 50 lbs. of salt entering the water system permanently pollutes 10,000 gallons of water
- Salt is a permanent pollutant. The only way to get it out of water is through the process of reverse osmosis, which is costly and time-consuming
- Excessive chloride can disrupt the natural mixing of lakes which can affect their overall health and nutrient makeup, which can determine which organisms are able to survive in them
- Excessive chloride negatively affects the health and well-being of numerous aquatic plants and animals by:
    - Inhibiting plant growth
    - Impairing reproductive abilities of aquatic organisms such as fish, mussels, and aquatic insects
    - Disrupting aquatic organisms' osmoregulation, which hinders its ability to survive
    - Industries such as recreational fishing and ecotourism can suffer due to loss of resources
- Salt is incredibly corrosive to infrastructure (steel, concrete, water pipes, asphalt, parking garages)
- Salt is best addressed at the source by implementing operational and structural best management practices (BMPs) to prevent or reduce salt from entering surface waters.

Key:	
»	Information useful for Road Agencies (Cities/Counties) and Private Applicators
*	Information useful for Departments of Transportation (DOT's)
†	Information useful for Homeowners/General Public
~	Required under Michigan's Department of Environment, Great Lakes, and Energy (EGLE) Part 5 Rules

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Road Salt Best Management Practices (BMP's)

Practice safe salt/brine storage and environmental protection techniques

Solid Salt

- Store salt in an enclosed, indoor facility or covered with waterproof tarps when stored outside (», *, ~)
- Bulk salt must be stored on an impervious surface (», *, ~)
  - Best storage has floors that are sloped so that no rain runs in or out
  - Best storage has sloped parking lot to prevent rain from entering the facility
- All solid salt and sand-salt mixture must be stored at lead 50 feet from the shore or bank of any lake, stream, or designated wetland (», *, ~)
- Spray salt piles with brine as a starting point for pre-wetting solutions as a part of storage (», *)
- Implement BMP's to reduce the exposure of salt to the environment when transferring stored materials from different locations (», *, ~)
  - Load salting equipment inside as much as possible
  - Temporarily cover catch basins while loading
  - Sweep promptly after transferring
  - Provide containment for outside loading area
- Prevent runoff through storage sites (», *, ~)
  - Practice good housekeeping measures (tarp off any large quantity of salt not currently being used to reduce change of it leaking into water system; make sure bagged salt is correctly sealed to reduce further exposure to environment)
  - Know specific location of salt in storage facility and its quantity
  - Be educated in safe storage practices (store in elevated, dry areas that have little chance of being exposed to the environment; keep assigned storage areas clean and orderly on daily basis)
  - Properly store salt at the end of the winter season. If sufficient summer storage is not available, contact city, county, or state about relocating.
  - Properly maintain salt barns and plan for building improvements to prevent further runoff

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Road Salt Best Management Practices (BMP's)

Brine Solutions

- All above ground brine storage tanks should have secondary containment (e.g., spill containment dikes, doubled walled tanks, etc.) Storage of 1,000 or more gallons of salt in liquid form (including brine solutions that have a salt concentration of more than 1%) must have secondary containment. (», *, ~)
- Tanks set on ring foundations should be tested each year to ensure that there is no leaking inside the ring. (», *, ~)
- All accessory pipes, hoses, valves, and pumps must also be located within the containment area. Top loading and unloading piping are recommended (», *, ~)
- The containment area should be designed so it is always accessible and capable of containing any spilled, leaked, or discharged polluting materials so that the brine does not discharge directly or indirectly to surface waters or groundwater. (», *, ~)

Recommended BMP's for effective salt application

Groups should be knowledgeable regarding:

- Which products work best under certain conditions (», *, †)
  - Knowledge of the lowest practical melting point of each material being applied
    - CMA (Calcium Magnesium Acetate) = 20 ˚F
    - NaCl (Sodium Chloride) = 15 ˚F
    - MgCl2 (Magnesium Chloride) = -10 ˚F
    - KAc (Potassium Acetate) = -15˚F
    - CaCl2 (Calcium Chloride) = -20 ˚F
    - Winter sand/Abrasives = never melts – only traction
  - Never apply dry rock salt in blowing weather conditions, as it will blow away and not melt targeted area (Utilizing pre-wetted salt or brine solutions are useful options in this scenario as they target specific areas with reduced exposure to the environment)
- Where it is acceptable to plow/dump snow (», *, †)
  - Illegal to plow/dump snow into lakes, rivers, wetlands, or any state waters
  - Plow/dump snow onto grassy areas where infiltration can occur
- Weather Data/Information needed for proper maintenance (», *)
  - Pavement temperature
  - Air temperature trends
  - Type of precipitation and quantity expected
    - Understanding these variables will allow for a more accurate understanding of the types of materials needed to be utilized once a winter storm hits. This information can be used to better predict the type of deicing and/or anti-icing material needed to be used, as well as what mechanical options would work best for the given scenario)

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Road Salt Best Management Practices (BMP's)

Recommended BMP's for effective salt application, continued

- How to properly transport materials (», *)
  - Don't overfill vehicles or it may blow or fall out
  - Cover load with tarp or other protective materials
  - Fill in gaps in tailgates or equipment with spill shields
- Difference between anti-icing, prewetting, and deicing techniques (», *)
  - Anti-icing: application of brine/chemical solutions before storm hits and/or ice bond can form
  - Prewetting: strategy of applying a liquid deicing chemical to a dry solid salt solution before or during its application to the pavement.
  - Deicing: Application of salt after the storm hits and or ice bond has formed
- BMP's involve removing as much snow possible during the storm in conjunction with salting application. Anticipate aspects of the storm such as temperature conditions, quantity of precipitation, and type of precipitate to properly apply the techniques above.
- How labels of products are often misleading (», *, †)
  - No deicing product that is marketed as being "environmentally friendly" is. They all negatively impact the environment in some manner
- Optimize salt application (», *, †)
  - Shovel/snow blow areas first
  - Salt only patches that are icy
  - Scatter salt so that there is space between grains
  - Use brine/prewetted salt solutions as often as possible, particularly when wind speeds are high
  - Sweep excess salt up and store in a safe location
  - Remove excess salt from spills and/or overapplication scenarios (sweep streets before spring rains to reduce residual salt)
  - Perform post-storm evaluations to understand whether application rates were effective/appropriate
  - Understand ideal application rates for various dry salt/prewetted solutions
    - Information can be found at (https://chlorideconscious.com/application-rates-rock-salt/)
- Regularly train staff in accordance with best management practices (», *)
- Understand level of service considerations (», *)
  - Communities and DOTs should decide what level of maintenance to provide for:
    - Bare Roads
    - Main Thoroughfares
    - Hills
    - Intersections

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Road Salt Best Management Practices (BMP's)

Calibrate Equipment

- Calibration of equipment several times a year, as opposed to just once, has been shown to be an effective strategy that reduces unnecessary salt entering the water system (», *, †)
  - Implement programs where equipment is calibrated before the winter season and several times during the winter season.
  - Regular calibration of spreader mechanisms ensures accurate application at all times
  - Operations managers and supervisors should perform spot-checks during the season to make sure that units are properly functioning within calibration specifications
  - Re-calibrate equipment after any repairs, when stockpiles are replenished, or when material calculations show a discrepancy
  - Equipment should be calibrated separately for all application methods (solid and liquid, and for each product type – sand, salt, brine, etc.)
- Calibrate application rates for vehicles (», *)
  - Discharge at each setting for one minute to get rate of application
  - Discharge at different speeds to determine pounds of salt discharged per minute
  - Update to automated spreader controls
- Calibrate liquid solutions (», *)
  - Determine the amount of gallons discharged per minute and compare to calibration specifications
- Calibrate manual sanders/drop spreaders (», †)
  - Determine pounds per minute discharged or pounds per 1000 square feet and compare to calibration specifications

Use up-to-date weather reports

- Helps to understand the types of conditions expected from storm and thus, the best techniques/products to use for snow and ice removal. (», *, †)
  - Data from remote weather information systems (RWIS)
  - Data from satellite imagery/radar
  - Data from Geographic Information Systems (GIS)
  - Data from local weather reports, updates as they occur

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Road Salt Best Management Practices (BMP's)

Use proactive techniques such as prewetting and anti-icing techniques as opposed to deicing techniques (», *, †)

- Anti-icing
  - Strategy of applying chemical solutions before ice has been able to form on the road
  - Prevents snow or ice from forming a bond on the road (includes solutions such as liquid salt, calcium chloride, magnesium chloride, or blends of these materials)
    - Requires about ¼ the material of deicing techniques at roughly 1/10th the overall cost
    - Results include:
      - Better pavement conditions (improved surface friction), resulting in fewer traffic collisions
      - Prevention of frost from forming, particularly on bridge decks, as applications have been reported to last for several days
      - Easier overall storm cleanup, as less ice will have become bonded with pavement
- Prewetting
  - Prewetting is a strategy of applying a liquid deicing chemical to a dry solid salt solution before or during its application to the pavement.
  - Wet salt: increases the speed of melting. Salt can work immediately as it is already going into solution
  - Greatly reduces the amount of deicing needed later.
  - 30% less solid salt material will be used in the end by prewetting practices

Understand how salt application speed affects how far material disperses (», *)

- Speed is the biggest factor affecting how much salt bounces and scatters across surfaces
  - 25 mph speeds retain the most rock salt in target zone
  - MDOT expects salt savings by lowering speed of application

Consider non-chemical options and strategies (», *, †)

- Heated surfaces
- Conductive concrete
- Pavement grooving
- Solar Roads
- Snow fences
- Enhanced winter tires
- Asphalt pavements with anti-icing properties

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Road Salt Best Management Practices (BMP's)

Update Equipment (», *)

- Automated spreaders allow operations to program salt application rates to change with ground speeds.
    - These programs account for curves and hills that require more salt than flat roads
        - Pre-wetted salt applied close to roads at low speeds (25mph) reduces the amount of salt scatter and bounce
- Add boots or salt sleeves to salt distribution vehicles as a means of further reducing bounce and scatter
- Use advanced techniques such as salt slurry generators or zero-velocity spinners to reduce salt bounce and scatter
- Mechanical Snow Removal (Exercise mechanical removal before the use of deicers; better mechanical removal = less deicer required)
    - Advanced snowplows with flexible rubber and/or squeegee cutting edges/blades
        - Useful for removing slush and light snow from highways
        - Can extend the life overall life of the plow and lead to additional cost savings long term
        - Do not damage roadways, effective on cobblestone and brick
            - Polar Flex blades
            - Joma blades
            - Metal Press blades
            - Kueper blades
            - Sharqedges
    - Multi-segmented plow blades
        - Able to conform to roadways
        - Allow for better cleaning of roadways
        - Can reduce damage to roadways markings and other obstacles
    - Live-edge plow blades
        - Have articulated segments that conform to uneven ground surfaces
        - Snow removal using this type of blade has been shown to reduce overall salt usage by as much as 40% in certain areas
    - Mechanical Brooms/Sweepers
        - Commonly used on airports, sidewalks, and roadways
        - Are NOT plows. They will not scrape snow or ice the road
        - Use on light snow only
        - Reduces the amount of deicers needed
        - Reduced the amount of slush left on roadways
        - Allows road to dry quicker
        - Fewer complaints from road users

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Road Salt Best Management Practices (BMP's)

Update Equipment, continued (», *)

- Ice Breakers
  - Used by Alaska's DOT, Minnesota's DOT, and Utah's DOT currently
  - Work well on breaking up packed ice
  - Ideal driving speed is between 15-17mph
  - Turning should be kept at a minimum
  - Use caution when crossing railroads and bridge expansions

References

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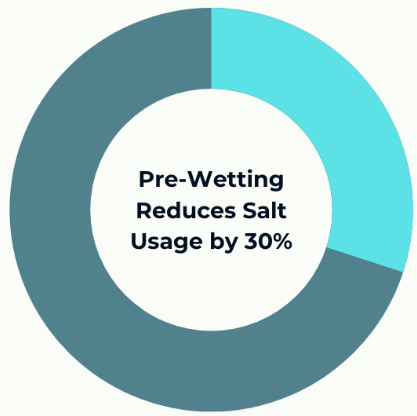
Appendix G.
Road Salt Quick Reference Sheet.

Road Salt
Quick Reference Sheet

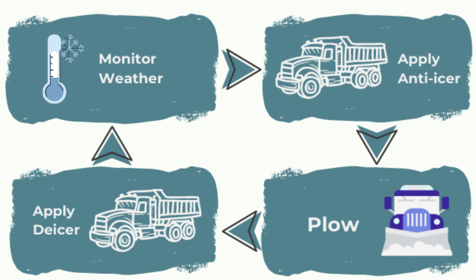


Safe Salt Storage

- Cover and store salt indoors whenever possible *
- Store salt on an impervious surface *
- Use sloped floors and parking lots to direct water away from salt storage area
- Reduce exposure of salt to the environment during transfer operations *
- Keep staff educated on best practices

Use Proactive Techniques

- Apply anti-icing material before ice/snow bond has formed
- Plow before using deicing material
- Use brine or pre-wetted salt during the storm to facilitate the melting process



Keep Equipment Calibrated and Up to Date

- Calibrate equipment multiple times throughout the season to maintain efficiency
- Modify and calibrate existing equipment
- Purchase new, more efficient equipment

Additional Tips

- Use up to date weather reports
- Apply salt at a speed of 25 mph or slower

** Additional requirements may apply in accordance with the Michigan Department of Environment, Great Lakes, and Energy Part 5 Rules*

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Appendix H.
Brochure for the Public.

DE-ICING SALT

SHOVEL/SNOW BLOW AREAS FIRST

SALT ONLY PATCHES THAT ARE ICY

SWEEP EXCESS SALT UP AND STORE IN A SAFE LOCATION

UTILIZE SAND INSTEAD OF DEICING SALT FOR TRACTION

WATER SOFTENER SALT

CHECK TO SEE IF YOUR WATER REALLY NEEDS TO BE SOFTENED (IS YOUR WATER ALREADY MUNICIPALLY SOFTENED?)

USE A DEMAND-BASED WATER SOFTENER INSTEAD OF A TIME-BASED WATER SOFTENER

HAVE YOUR SOFTENER SERVICED BY A WATER SOFTENER PROFESSIONAL TO MAINTAIN TOP EFFICIENCY

UNSALTED

MICHIGAN'S FRESH WATERS AND HOW YOU CAN HELP KEEP THEM THAT WAY

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WHAT'S THE PROBLEM?

RISING LEVEL OF CHLORIDE IN MICHIGAN'S SURFACE WATERS DUE TO INCREASED INDUSTRIALIZATION, URBANIZATION, AND GROWTH

CAUSING:

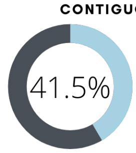
DAMAGE TO AQUATIC LIFE

DAMAGE TO INFRASTRUCTURE

DRINKING WATER CORROSIVITY

WHY IT MATTERS

MICHIGAN HAS MORE SURFACE WATER THAN ANY OTHER STATE IN THE CONTIGUOUS U.S.



MICHIGAN'S SURFACE AREA IS 41.5% WATER

THERE ARE 64,980 INLAND LAKES AND PONDS & THE GREAT LAKES

1 TEASPOON OF SALT PERMANENTLY POLLUTES BETWEEN 5-10 GALLONS OF WATER

SALT IS A PERMANENT POLLUTANT. THE ONLY WAY TO GET IT OUT OF WATER IS THROUGH THE PROCESS OF REVERSE OSMOSIS, WHICH IS COSTLY AND TIME-CONSUMING.

HOW YOU CAN HELP

RESIDENTS CAN DECREASE USE OR INCREASE EFFICIENCY OF THE FOLLOWING PRODUCTS:

WATER SOFTENER SALT

DEICING SALT

HOUSEHOLD PRODUCTS

HOUSEHOLD PRODUCTS HIGH IN CHLORIDE:

AUTOMATIC DISHWASHING DETERGENTS

LAUNDRY DETERGENTS

CHLORINE BLEACH

CHLORINATED DISINFECTANT

MILDEW REMOVERS,

TOILET BOWL CLEANERS

Appendix I.
Summary Handout.

Chloride in Michigan Surface Waters

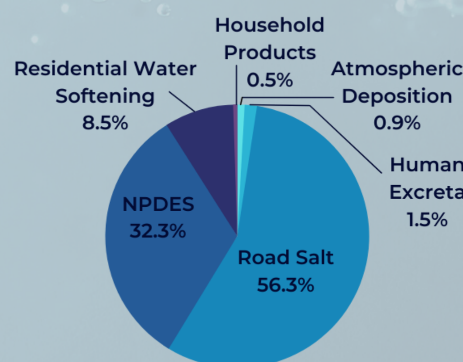
Introduction

Chloride concentrations in many United States lakes have steadily risen over the past several decades as a result of anthropogenic activity, including increased urbanization and associated chloride runoff. All of the Great Lakes have been affected by rising chloride concentrations, with Lake Superior and Lake Michigan currently at record levels. This is problematic because chloride harms aquatic life and degrades critical infrastructure. Michigan, the "Great Lakes State", has the potential for chloride to impact both vast inland surface water resources and the watersheds which ultimately drain to 4 of the 5 Great Lakes.. Due to the harmful effects chloride has on aquatic life, Michigan's Department of Environment, Great Lakes, and Energy (EGLE) recently developed water quality values (WQV) for chloride. These were developed to protect Michigan's surface waters and aquatic ecosystems' long-term use. In conjunction with EGLE, our team conducted research to understand the sources of chloride to the surface waters of Michigan.

Highlighting Road Salt

Michigan averages 308,161 metric tons/year of chloride from road salt application. The Superior and Metro regions of the state contribute the most chloride and the Bay and Southwest regions of the state contribute the least. These regions also vary greatly in their level of precipitation and total road miles. Each area should focus on increasing road salt efficiency according to their own conditions.

Chloride Contributions to Surface Waters in Michigan



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Chloride Contributions to Surface Waters in Michigan (Metric Tons)		
Source	MI 5-Year Average	% of Total
Atmospheric Deposition	5,163	0.9%
Human Excreta	8,257	1.5%
Road Salt	308,161	56.3%
NPDES Facilities	176,858	32.3%
Residential Water Softening	46,700	8.5%
Household Products	2,635	0.5%
Total = 547,777 Metric Tons per Year		

Highlighting NPDES Facilities

The average (2015-2019) reported level of chloride from NPDES facilities is 176,858 mt/yr. The biggest contributors by source are Process Wastewater (90,373 mt/yr or 51%) and Food Processing (76,372 mt/yr or 43%). Monthly averages were used to compute the reported values, rather than the maximum. Thus, our estimates are likely conservative. Furthermore, not all NPDES-permitted facilities are required to monitor for chloride. Once they are, the NPDES-permitted facility contribution will be larger than our current estimate.

Conclusion

Excessive chloride is harmful to aquatic plants and animals, and corrosive to infrastructure. As concentration trends continue to rise in Michigan, it is crucial now more than ever to understand the major point and nonpoint sources of chloride discharged into our water systems. Our results have shown that road salt application and water softener use are the major contributors of chloride to Michigan's surface waters. While our results have several limitations, our efforts represent a meaningful milestone for the state in its efforts to protect aquatic ecosystems and critical infrastructure. We hope that our results can be useful to other places as they also develop meaningful solutions to combat this problem. Excessive chloride polluting our nation's waters has been a developing problem for decades. With these results, however, we hope to educate stakeholders and the public at large about the issue to ensure that this problem will be solved in the future. Solving this problem is going to be a group effort, and we expect that our research will make it easier for everyone to work together to combat this issue.

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Advisor: Dr. Sara Hughes (hughessm@umich.edu)

Appendix J.
Food Processing Handout.[32, 59, 60, 67-72]

Reducing Chloride Discharge in Food Processing

Why it Matters

Chloride levels in Michigan surface waters are rising, one of the sources being discharges from food processing. This trend poses threats to aquatic life, freshwater ecosystems, and infrastructure. To mitigate these impacts, the Department of Environment, Great Lakes, and Energy (EGLE) developed aquatic life water quality values for chloride to limit chloride discharge to Michigan's surface waters to protect ecosystems.

Some NPDES wastewater permittees may need to reduce chloride depending on concentrations in the effluent and discharge location. In response to these requirements, this brief discusses strategies for chloride use optimization among food processors with NPDES discharge permits. By our estimates, NPDES-permitted facilities currently subject to chloride monitoring requirements discharge 176, 858 metric tons of chloride to surface water in Michigan per year. 76, 372 metric tons (43%) is generated from food processors.

Main Sources of Chloride and Alternatives

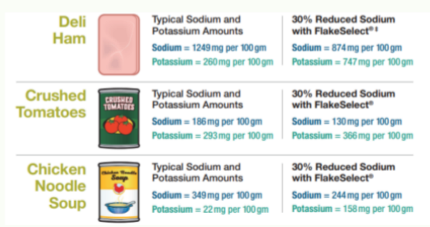
Water Softening

Water softeners replace ions related to water hardness such as calcium, magnesium and iron ions with sodium ions in an ion exchange resin containing sodium or potassium chloride. Once this reservoir of sodium ions is exhausted, what remains, including chloride, is discharged to a septic system or city sewer. Every time the water softener's resin needs to be washed to have potassium or sodium chloride replaced, it is said to "regenerate."

Water softening can be an essential aspect in food processing to ensure adequate solubility of food ingredients and prevention of mineral deposits on equipment surfaces. While the elimination of water softening is unfeasible, salt use can still be optimized. Demand-based softeners regenerate when a predetermined amount of water has been softened. Furthermore, most water softeners are programmed to soften to 1 grain per gallon (gpg) of hardness. This amount of softening may not be necessary for all processes. Finally, salt-free softeners may be another option.

Flavoring

Sodium chloride often provides necessary flavoring and preservation properties to food. One way to reduce chloride discharge levels is by replacing some sodium chloride in products with potassium chloride. Although chloride is still discharged, the overall amount is decreased. One example is Cargill's FlakeSelect. In Figure 1, they demonstrate that in using this sodium chloride alternative, there is a 30% reduction in sodium by mass. There is also a 6.32% reduction by mass of chloride.



Source: Cargill's FlakeSelect

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Cleaning Agents

Cleaning agents for raw foods or equipment in the food processing industry may contain chloride. Cleaning alternatives provide the benefits of being safer for personnel use and the environment. These include
- ozone cleaning
- dry steam deep cleaning
- cold and heated pressure wash
- steam pressure cleaning

Selection Process for a Cleaning Agent

1. What are the reasons for the cleaning method? What respective guidelines must be met for the following considerations:
    a. Product Safety
    b. Product Quality
    c. Compliance with Government Regulations
2. When deciding on the cleaning method, the following should be known:
    a. The surface that needs to be cleaned.
    b. The nature of the material or residue that needs to be removed.
    c. The quality of the plant's water supply.
        i. What is the hardness?
        ii. Are there other trace elements of concern?
    d. The method of application for the cleaning method.
        i. How might it impact worker safety?
    e. Any environmental concerns associated with the cleaning method
        i. How might it impact wastewater or air emissions?
3. Upon selecting a method, the following should be known about its application:
    a. The time required for application.
        i. The time needed for the cleaning method to fully react to remove the residue/material.
    b. The adequate temperature for application.
    c. The concentration of the method (if applicable).
    d. The physical requirements of the application (ie scrubbing, brushing, etc.)

Appendix K.
Pinckney Case Study. [32, 52, 61, 73-78]

Reducing Chloride in Wastewater Plant Discharge

A Case Study of the Village of Pinckney Michigan

The Village of Pinckney, Michigan launched a water softener rebate program to reduce chloride in wastewater treatment plant (WWTP) discharge. This strategy involved the following components:

1. All sewer users in the Village of Pinckney were asked to provide information about their residence's water softener.
2. The Department of Public Works provided some reimbursement to sewer users who spent money on projects to stop water softener discharge from entering a sewer line.
3. The Department of Public Works conducted an inspection to verify the compliance or absence of a water softener.

In 2007, the Village of Pinckney's WWTP was exceeding its sodium and chloride discharge limits

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By July 2008, the Village of Pinckney's WWTP reduced its chloride levels below the groundwater discharge permit requirement.

Why it matters

Chloride levels in Michigan surface waters are rising. This trend poses threats to aquatic life, freshwater ecosystems, and infrastructure. To mitigate these impacts, the Department of Energy, Great Lakes, and Environment (EGLE) developed aquatic life water quality values for chloride. Their purpose is to understand where chloride is potentially a problem in Michigan's surface waters and determine whether chloride limits are needed to protect ecosystems.

One major source of chloride to WWTPs is chloride discharge from residential and commercial water softeners. Discharge from water softeners causes an increase in chloride and sodium levels in wastewater streams.

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Reducing Chloride in Wastewater Plant Discharge

What Was Done

- First, and ordinance was issued asking residents to stop routing water softener discharge into sewer lines. However, chloride levels were not reduced. To avoid penalties from EGLE they decided to launch a rebate program.
- The Village of Pinckney sewer users completed a “Softener Discharge Inspection and Rebate Form” for the Department of Public Works (DPW) indicating whether they owned a water softener and whether it complied with the Village's Ordinance prohibiting discharge to the city sewer.
- Sewer users were provided ideas for alternatives to having a water softener/conditioner that discharged into a sewer line. These included running the discharge line elsewhere, at least 50 feet from a groundwater source, installing a drywell, diverting discharge to a septic tank, or installing a no-discharge softener. The DPW reimbursed residents with 50% of the cost of their project for a value of up to $300.
- The DPW completed water softener discharge inspections to all Village of Pinckney sewer users. Those who failed to comply with this inspection were asked to fill an affidavit.
- Funding for this project was assured by the Village of Pinckney sewer fund.

Outcomes

- Chloride levels in the WWTP's discharge were reduced and the Village of Pinckney has not exceeded the discharge permit requirement since July 2008.
- The program did not necessarily reduce the use of chloride salts in the community unless a resident decided to install a no-discharge softener. However, given the effect this had on the reduction of chloride levels in the WWTP’s discharge, it is clear that residential water softener use is a significant component in the overall chloride discharge to the WWTP.
- The DPW also provided information about cost and water savings which included switching to a demand-based water softener. This also helps reduce use of the exchange resin and ultimately lowers chloride and sodium discharge levels.
- The enforcement of this ordinance was met with controversy. Many sewer users questioned its constitutionality. Furthermore, many could not install a dry well given the elevation of their homes.

This case study demonstrates the importance of WWTPs working in conjunction with the government of the communities they serve to maintain compliance.

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