Establishing a Stream Salinization Monitoring Framework in the Susquehanna River Basin: Final Report 2022-2025

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INTRODUCTION

Salt pollution and human-accelerated salinization of fresh water is increasing across North America, in what is commonly being referred to in the literature as freshwater salinization syndrome (Kaushal et al., 2018). Some estimates speculate that as many as 90 percent of the drainage areas in the United States have been impacted. The syndrome is caused by salt pollution (e.g., road deicers, irrigation runoff, sewage, potash), accelerated weathering and soil cation exchange, mining and resource extraction, and the presence of easily weathered minerals used in agriculture (lime) and urbanization (concrete) (Kaushal et al., 2018; Kane et al., 2024). Unless regulated and managed, the freshwater salinization can have significant impacts on ecosystem services such as safe drinking water, contaminant retention, and biodiversity.

The Susquehanna River Basin Commission (Commission) has a wealth of data throughout the basin that is useful in documenting increased salinization within the basin and monitoring its potential impacts on stream biota. Phase I focused on historic data compilation and new data collection at 10 sites with historically high chloride concentrations and two reference sites. During Phase II, staff pared down the site list to those that were most obviously impacted by road salt runoff and added some macroinvertebrate analysis. Additionally in Phase II, staff made an effort to obtain salting records from New York and Pennsylvania for the roadways adjacent to sampling locations. This was somewhat successful, but it was difficult to conclusively link amount of salt or brine (salt solution dissolved in water) used to chloride concentrations. During the third and final phase of the project, sampling was focused only on winter events, targeting snow melt or rain events after salting. Additional analysis was completed on long-term changes in macroinvertebrate communities using aquatic life use thresholds derived from Ohio EPA. As this is the final summary of the three-year pilot project, this report will include overall takeaways as well as recommendations for better salt management and potential next steps.

SAMPLING METHODS

In Phases I and II, sites were sampled monthly from October through May during primarily ambient conditions, with an additional winter storm sampling effort when conditions warranted. In Phase III, all sites were sampled once in either October or November 2024, and twice more during targeted storm events January through March 2025. In all phases, samples were analyzed for parameters representing the “Development” category in the Susquehanna River Water Quality Index (Berry et al., 2020), including sodium, chloride, and sulfate. Three times a year in Phases I and II and once during targeted storm events in Phase III, major ions were analyzed in order to create Mauchino diagrams to compare ion composition temporally and spatially. Water samples were collected using standard methods, including depth integrated sampling across the width of the stream, composited into a churn, and mixed well before filling bottles that were sent to Pace Laboratory for analysis. Field measurements were taken each sampling round using an YSI multi-meter and recorded for cross-checking with data collected from associated Continuous Instream Monitoring (CIM) sites.

A HOBO sensor was deployed at sites that were not part of the CIM network in October 2022. These standalone units continuously measured temperature and specific conductance. Data from HOBO units were downloaded every 4-6 months, and the unit was redeployed immediately. Between the HOBO and CIM networks, continuous conductivity data were available at all but one site, Paxton Creek (Figures 1 and 2).

Flow records for calculating loads were largely synthesized from reference gage and drainage area ratio methods, but instantaneous flow measurements were taken at each site up to three times per year for additional checks on accuracy of estimated flows. Macroinvertebrate samples taken within the study period were completed using the Pennsylvania Department of Environmental Protection (PADEP) wadeable freestone streams protocol, regardless of in which state the sites were located (PADEP, 2023).

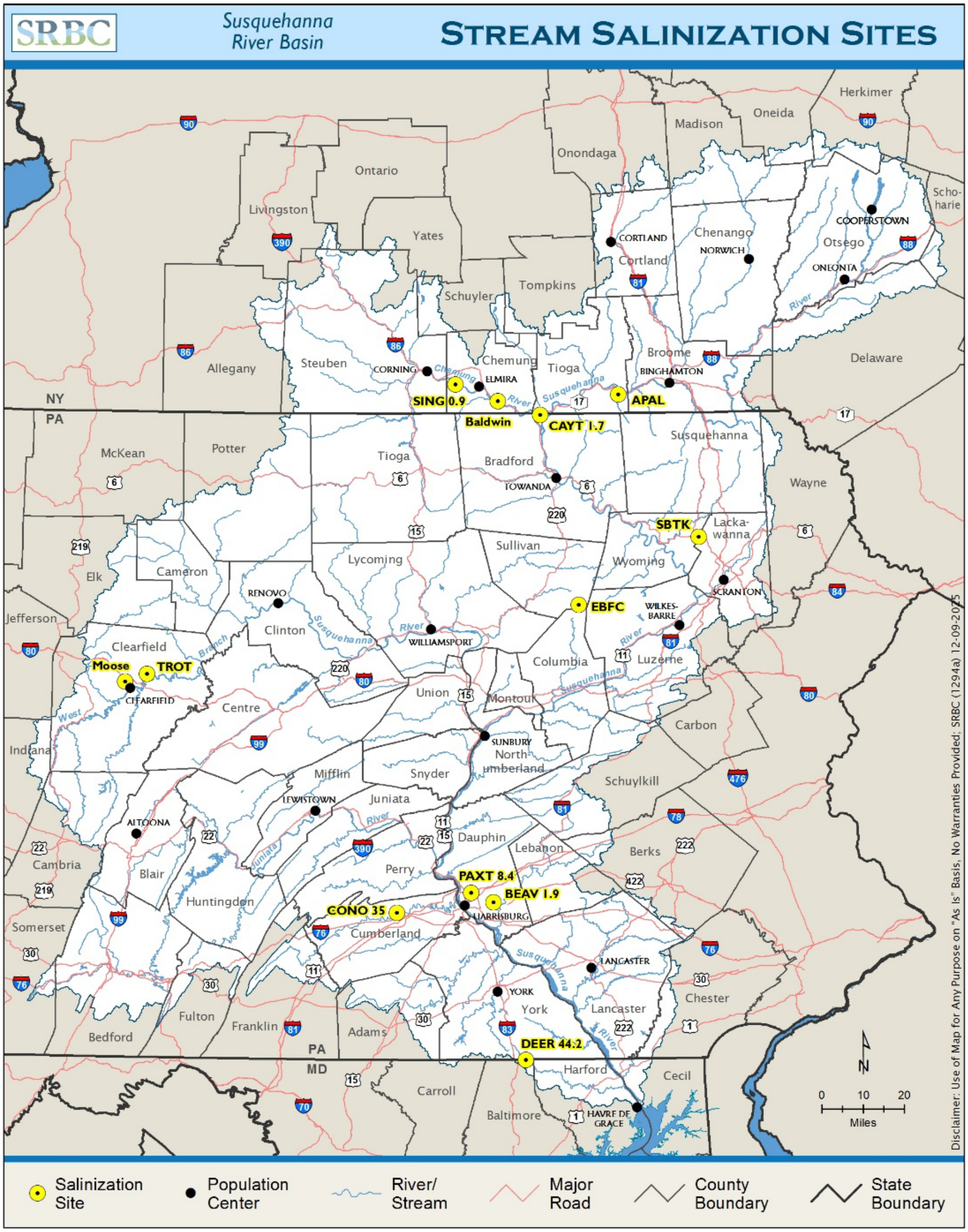


Figure 1. Map of Salinization Sample Sites with Major Roads

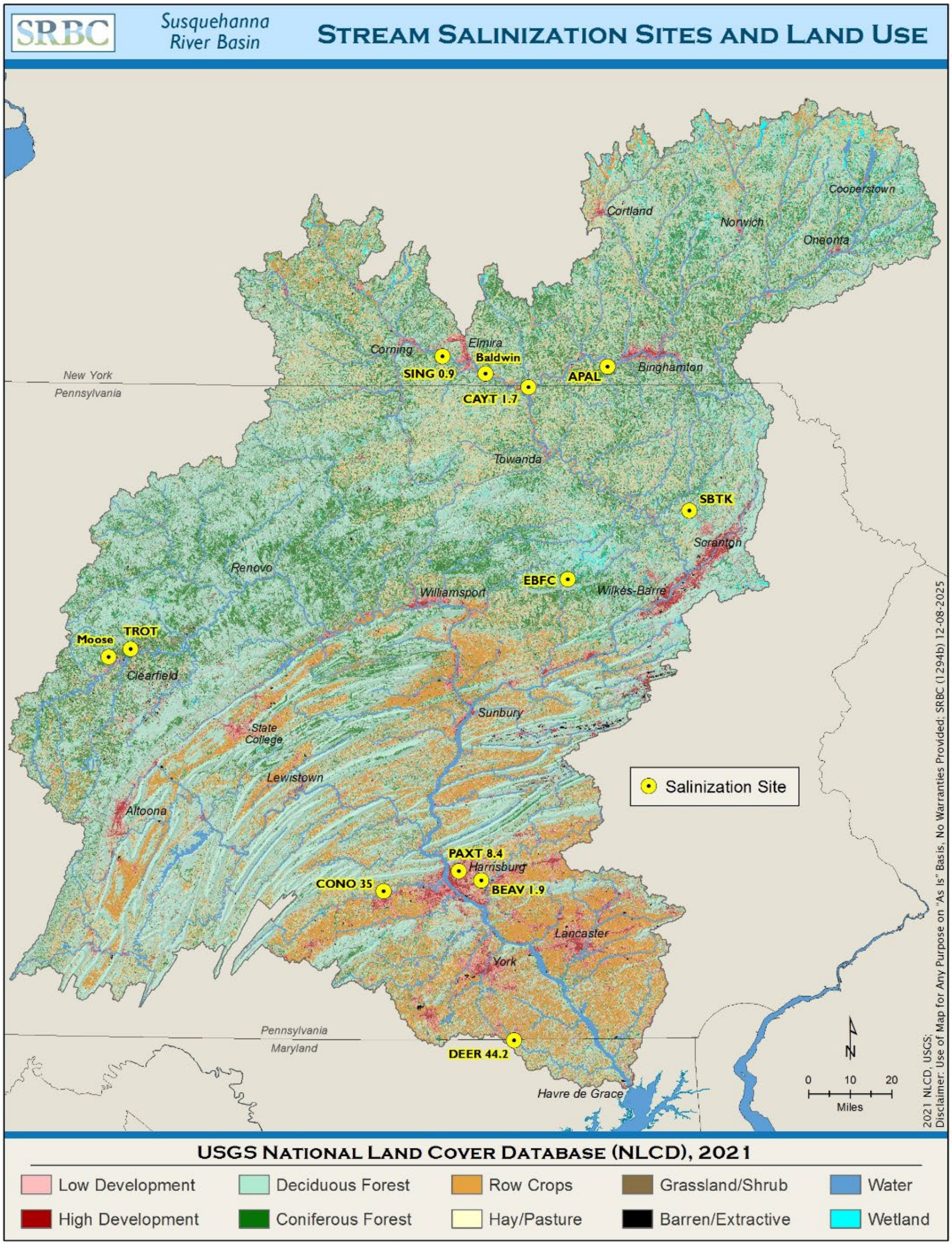


Figure 2. Map of Salinization Sample Sites with Land Use

RESULTS AND DISCUSSION

CIM Data and Chloride Estimations

General site information, results of long-term CIM discrete chloride and continuous conductivity data analysis, and land use data are summarized in Table 1. Results include physical site characteristics (drainage area, site description), full period of record, strength of linear relationship between chloride and conductivity, maximum observed chloride values, percent of chloride values below detection limit), changes in land use per site (between 2006-2021), and overall development per site as of 2021 (USGS National Land Cover Database (NLCD). Reference sites (East Branch Fishing Creek and Trout Run) are in red.

Table 1. Site Information, Descriptions and Summarized Select Results (Reference Sites in Red)

Site	Drainage Area (mi²)	Type	Period of Record	R^2 Chl-SpC	# of Discrete Pairs	Max Discrete Cl^- (mg/L)	% Cl Below Detection	% Change in Overall Development 2006-2021	%Overall Development 2021
Beaver Creek	23.8	Urban	2016-2025	0.82523	29	487	0	13.7	30.3
Cayuta Creek (CAYT 1.7)	139.97	Long-term Dataset	1986-2025	0.9067	147	153	0	21.5	1.9
Conodoguinet Creek (CONO35)	386	Urban	2018-2025	0.1157^	24	135	0	46.9	6.7
Deer Creek (DEER 44.2)	12.72	Long-term Dataset	1986-2025	0.3922	155	156	0	53.19	11.88
Moose Creek (MOOSE)	3.34	CIM - along transportation corridors	2011-2025	0.947	69	152	0	-12.88	2.74
Paxton Creek (PAXT 8.4)	11.18	Urban	1985-2025	0.9299	24	690	0	12.43	47.00
Sing Sing Creek (SING 0.9)	35.7	CIM - along transportation corridors	2000-2025	0.534	65	105	0	30.16	8.86
South Branch Tunkhannock Creek (SBTK)	70.3	CIM - along transportation corridors	2010-2025	0.6212	67	97	0	3.03	5.45
East Branch Fishing Creek (EBFC)	12.55	CIM-Reference	2012-2023	NA	51	29	35	-71.43	0.01
Trout Run (TROT)	32.78	CIM - Reference	2010-2025	NA	56	10	43	440.62	0.37

^One outlier point removed from analysis

Chloride concentration data alone are important, but calculating loads and yields by incorporating flow and accounting for drainage area allows for better comparison across sites. Mean concentrations across all experimental sites ranged from 22-175 mg/L, with a single sample maximum of 690 mg/L. Maximum yields (lbs/day/mi^2) across all experimental sites ranged from 132-21,337. Max yields occurred consistently in winter-early spring (Table 2). Alternatively, the reference site had a mean chloride concentration about 1 mg/L and yields under 6 lbs/day/mi^2.

Table 2. Summary of Discrete Chloride Concentrations, Loads and Yields Across All Sites, August 2022-May 2025

Experimental Sites	Mean (Max Cl (mg/L)	Mean Load (lbs/day)	Mean Yield (lbs/day/mi^2)	Max Yield (lbs/day/mi^2)	Month of Max Yield
Apalachin	22 (49.60)	2,228	52.0	132.3	January
Baldwin	29.25 (44.20)	2,666	75.1	211.6	March
Beaver	95.31 (487.00)	21,793	915.7	5,365.3	February
Cayuta	24.70 (61.30)	22,448	160.4	1,264.6	January
Conodoguinet	35.75 (135.00)	66,572	172.5	476.4	January
Deer	49.4 (156.00)	5,364	421.	3,603.5	January
Moose	27.89 (64.40)	3,285	983.5	2,737.0	April
Paxton	175.29 (690)	21,983	1966.1	21,337.3	January
South Branch Tunkhannock	39.5 (70.20)	26,615	378.6	2,176.5	January
Sing Sing	65.6 (89.20)	18,458	517.0	3,703.6	January
Reference Sites					
East Branch Fishing Creek	4.56 (28.90)	609.55	48.57	328.22	March
Trout Run	1.02 (2.00)	187	5.7	14.2	March

At sites where conductivity is highly correlated with chloride, it is possible to use continuous records of conductivity to provide a good estimate of continuous chloride concentrations. Estimated chloride and discrete chloride results were compared for each site, with means and medians indicating similar values. This gave staff confidence in using the synthesized continuous chloride record to evaluate how much of the time during the study period that chloride concentrations exceeded several important water quality thresholds. These included published values by the Ohio EPA (Miltner, 2021), Canada (CCME, 2011), and the PADEP drinking water standard of 250 mg/L (25 Pa. Code § 93.7) (Table 3).

Table 3. Summary of Chloride Mean and Median for Estimated and Discrete Chloride Data, and Percent of Continuous Data Points Exceeding Various Chloride Thresholds (From This Study 2022-2025) For All Sites (Reference Sites in Red)

	Mean Chloride (mg/L)		Median Chloride (mg/L)		Percent Continuous Data Standard Exceedance		
Site	**Estimated Continuous**	**Discrete**	**Estimated Continuous**	**Discrete**	**Aquatic Life Standard, Ohio EPA, US (52 mg/L)**	**Aquatic Life Chronic Standard, Canada (120 mg/L)**	**PA Drinking Water Standard (250 mg/L)**
Apalachin	22.44	22.00	19.76	18.3	2.3%	0%	0.00%
Baldwin	29.13	29.26	28.9	28.2	0.09%	0%	0.00%
Beaver	91.56	95.31	84.27	61.75	93.3%	17.0%	0.3%
Cayuta	30.99	24.70	31.39	20.5	0.0%	0%	0.00%
Conodoguinet	30.76	35.76	30.83	27.15	0.0%	0%	0.00%
Deer	43.81	49.40	40.34	48.1	18.0%	0%	0.00%
Moose	35.63	27.89	28.04	22.5	20.3%	1.45%	0.00%
Paxton*	NA	175.29	NA	140.5	NA	NA	NA
South Branch Tunkhannock	49.87	39.50	40.09	36.2	40.1%	0%	0.00%
Sing Sing	61.87	65.60	58.61	64.1	76.92%	0%	0.00%
East Branch Fishing Creek	1.71	4.56	1.69	0.855	0%	0%	0%
Trout Run	0.68	1.02	0.60	0.91	0.00%	0%	0.00%

*Paxton does not have continuous conductivity data available.

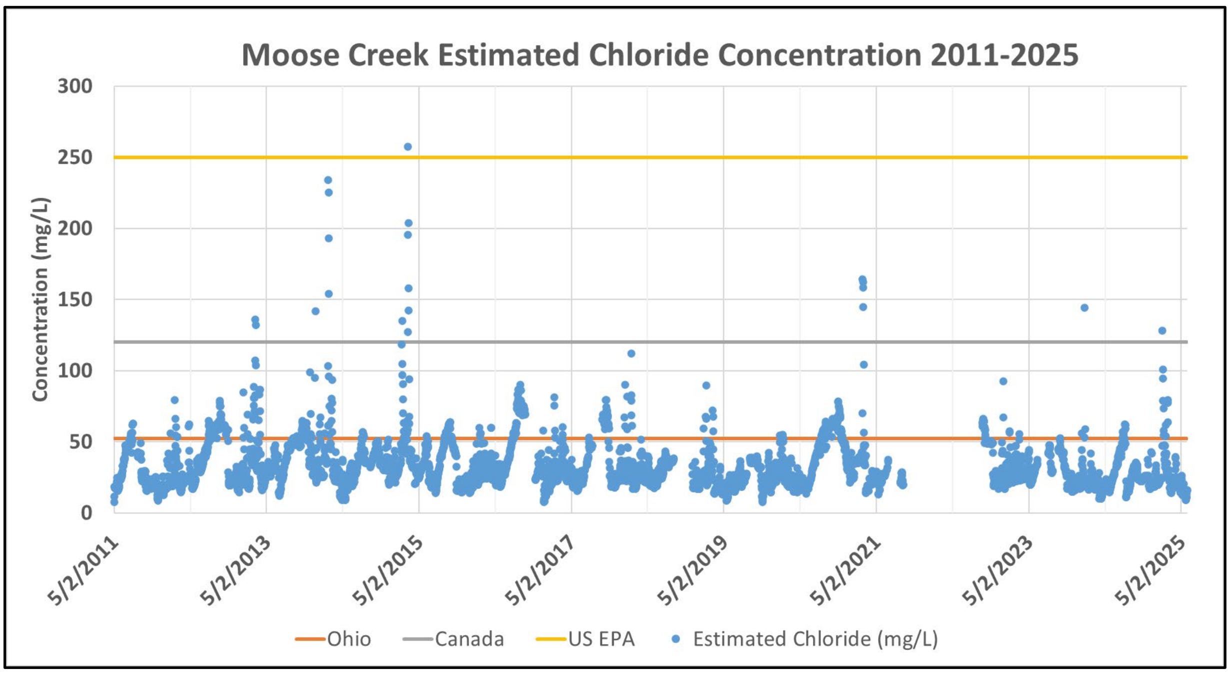
CASE STUDIES

Staff also examined the magnitude and duration of chloride concentrations after road salting events or other runoff episodes using estimated chloride concentrations. Using continuous data from the CIM Network or recorded by a standalone HOBO unit, continuous estimates of chloride were created from conductivity readings.

Moose Creek

Moose Creek is a small, forested watershed that receives significant road runoff from Interstate 80, west of Clearfield, PA. Estimate calculations from CIM records show Moose Creek often has a chloride concentration hovering around 50 mg/L, which already falls in the 95th percentile across the basin, but can experience peaks of over 200 mg/L primarily in the winter months (Figure 3). Two examples of chloride concentration estimation are at Moose Creek and Deer Creek (Steffy, 2023).

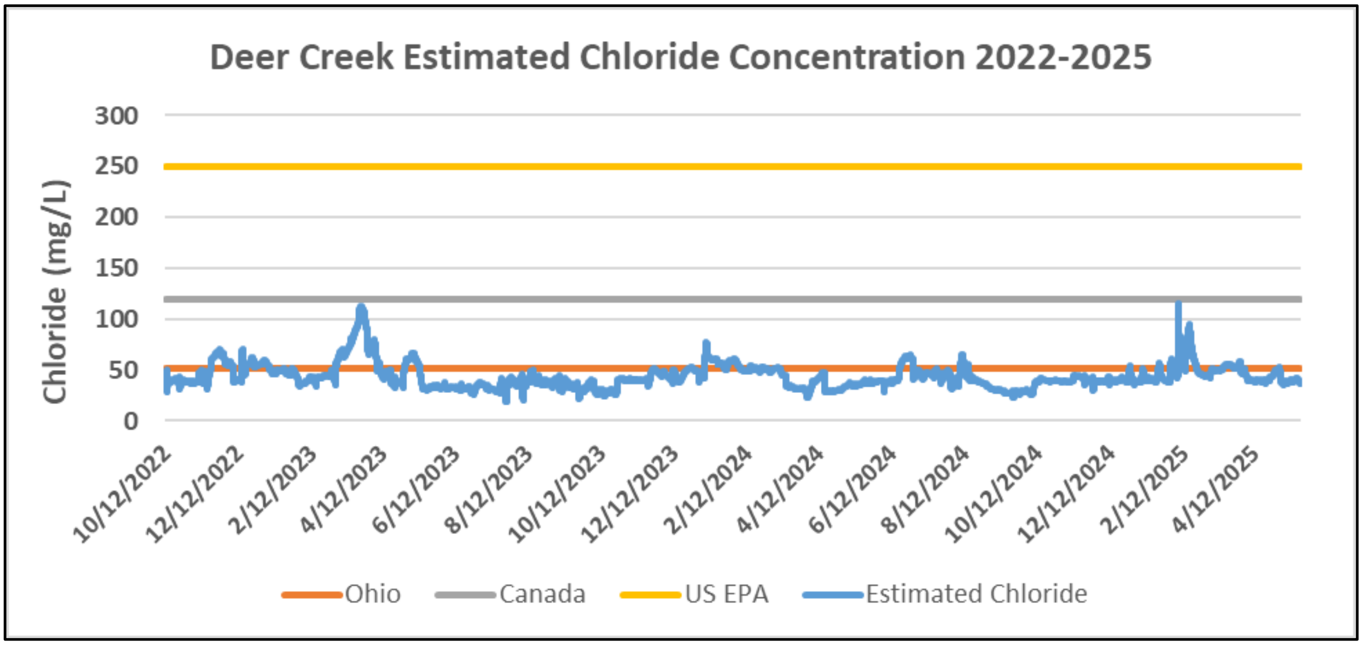
Figure 3. Continuous Estimated Chloride Concentrations at Moose Creek, 2011-2025 and Various Chloride Standards



Deer Creek

Deer Creek is not in the CIM network, so a standalone HOBO was deployed in 2022 to provide a continuous conductivity record. Deer Creek is located along the Pennsylvania/Maryland border in Harford County, MD, and empties into the Susquehanna River approximately 25 miles southeast of the site, which sits near cropland and pasture in a rural area in northern Maryland. Continuous data from October 2022–May 2025 show high consistent estimated chloride concentrations across all seasons (Figure 4). Highest spikes occurred during winter 2023 (March) and a targeted storm sample in February 2025. However, summer 2024 saw smaller spikes in estimated chloride which may point to chloride being stored on the landscape or in soil and released into the stream during rain events long after the initial winter salt application.

Figure 4. Continuous Estimated Chloride in Deer Creek, Derived from HOBO Conductivity Data 2022-2025



Other CIM sites such as South Branch Tunkhannock Creek on the Keystone College Campus and Sing Sing Creek along Route 17 in the southern tier of New York State, show similar patterns across the last decade such as winter spikes, but the estimated concentrations of chloride are not as high compared to more urban sites (Table 2).

Discrete Samples/Direct Measurements

Mauchino diagrams are symbolized ways to show the chemical composition of major ions in water. Each color represents a specific ion as shown in Figure 5. Key colors for salinization impacts are orange for chloride and tan for sodium (CBSS, 2026). If all ions are equally represented in the sample, the size of each spike would be roughly the same and all spikes contained within the circle. Not every stream in the study reacts similarly to increased salt exposure. Below are two examples of how ions change in water samples over time and how that may be impacted by road salt. For sites presented below and others with year-round salt signatures, future study may help shed light on the cause of elevated levels. Potential sources include physical storage of road salt in nearby facilities, biological salt storage in adjacent wetlands, vernal pools or riparian areas leading to discharge under high flow conditions, and/or vegetation and microbial mediated impacts of salt retention.

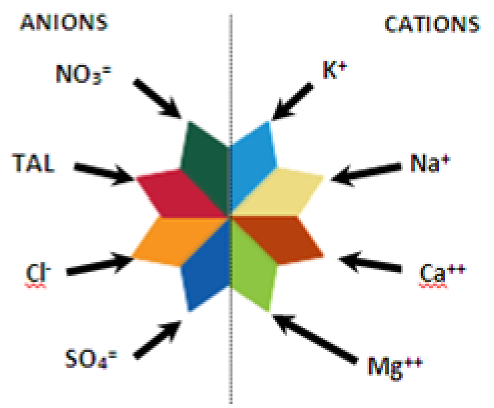


Figure 5. Legend for Mauchino Diagram Interpretation

In Beaver Creek, measured chloride signals are strongest directly after a January rain event where salt or brine was applied and immediately ran off into the stream, and also the month following this event (Figure 6). Other samples through the year show calcium and alkalinity signals likely geological in nature as the underlying chemical signature of that stream.

Moose Creek reacts much differently, as the sodium and chloride signals are quite strong regardless of season (Figure 7). This is likely a function of a few factors. First, the sandstone geology naturally leads to fewer ions in the water. However, decades of road salt runoff from Interstate 80 are impacting the chemical composition of the water. The signal is not quite as strong in summer months, but they are still the dominant ions, indicating the potential of soil-bound sources of chloride leaching out during any rain event.

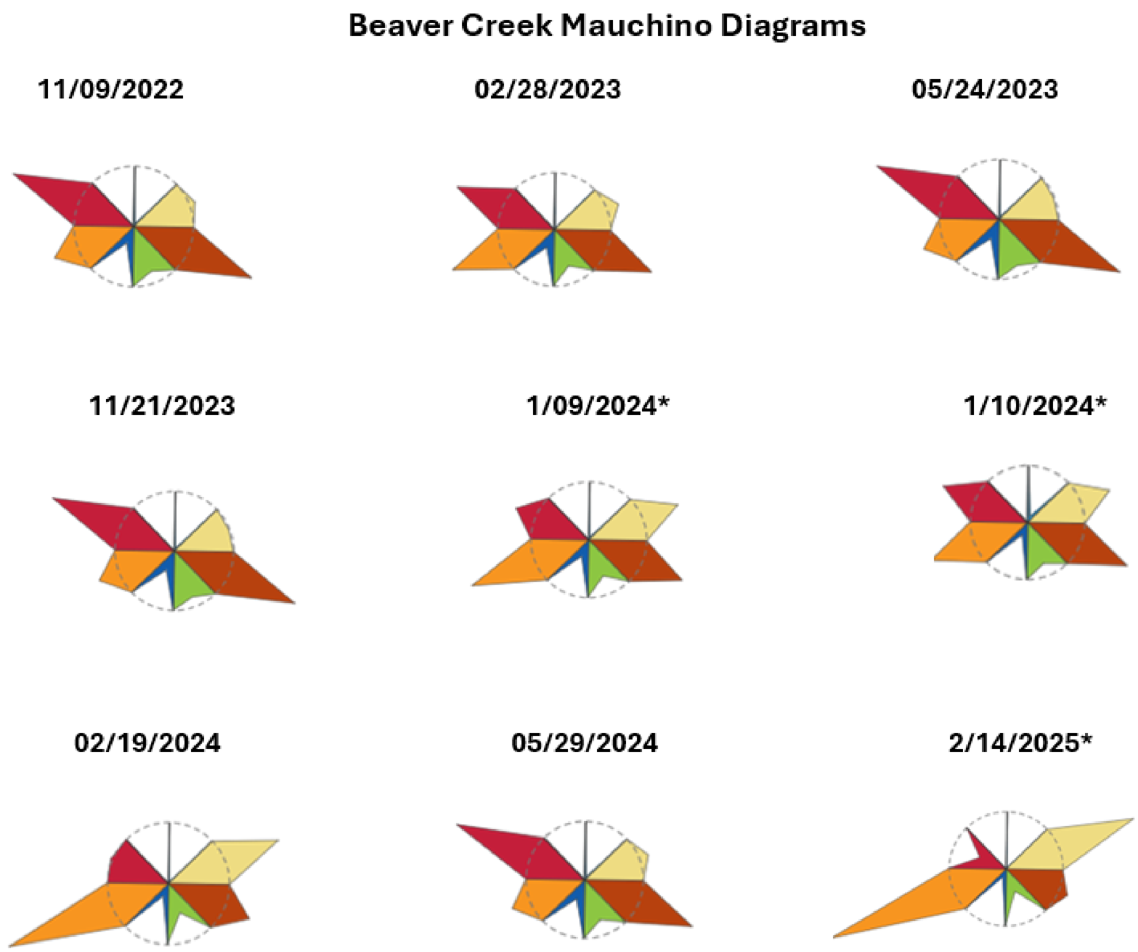


Figure 6. Time Series of Mauchino Plots in Beaver Creek, 2022-2025

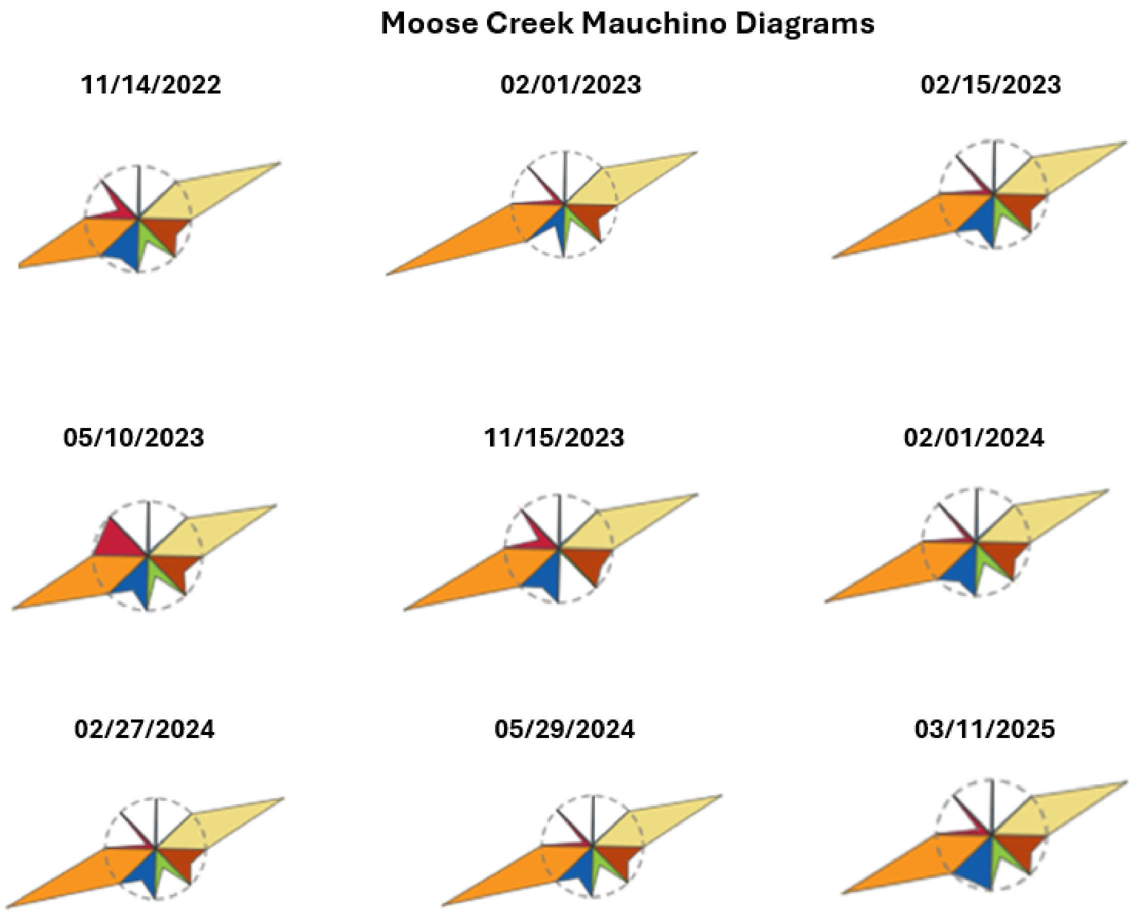


Figure 7. Time Series of Mauchino Plots in Moose Creek, 2022-2025

Long-term Datasets

From 1986-2013, the Commission routinely collected water quality and macroinvertebrate samples in streams that crossed the state borders in the basin: Pennsylvania-Maryland and Pennsylvania-New York. Two of these sites, one on each border (Deer Creek and Cayuta Creek), were selected to be part of this study because of the long-term available dataset of discrete samples, the pattern of increasing chloride concentrations over the past three decades, and proximity to roads. Deer Creek, on the border of Maryland and Pennsylvania, in particular, shows a pattern of increasing chloride that is apparent, despite no samples being collected from 2014-2021 (Figure 8).

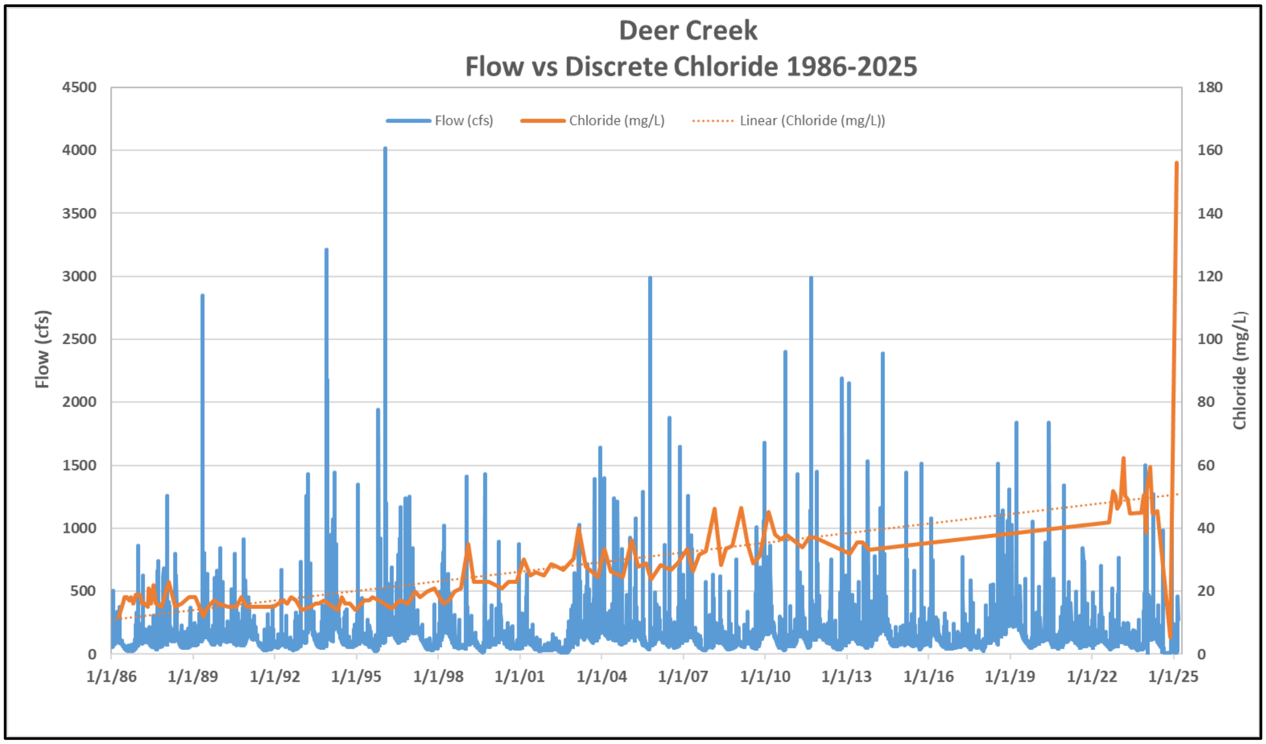


Figure 8. Long-term Record of Streamflow and Chloride at Deer Creek, 1986-2025 (Note: no samples were taken from 2014-2021.

Cayuta Creek is on the border of Pennsylvania and New York, in Sayre, PA, and has a similar long-term dataset to Deer Creek, although there is not an increasing trend in chloride (Figure 9). Cayuta Creek shows a stronger pattern of non-winter spikes in chloride which could be a result of chloride (e.g., residual salt piles) being stored on the landscape and entering the stream through runoff long after the salt was originally spread. Alternatively, there may be other significant sources of chloride besides road salt in the upstream catchment, particularly obvious in the 1980s-1990s. Overall, the winter chloride concentrations are trending slightly up, and the non-winter concentrations are trending down (Figure 10). Also of note is that in years where winter chloride spikes, summer chloride often also spikes, which points to the salt lingering in the system past the winter months.

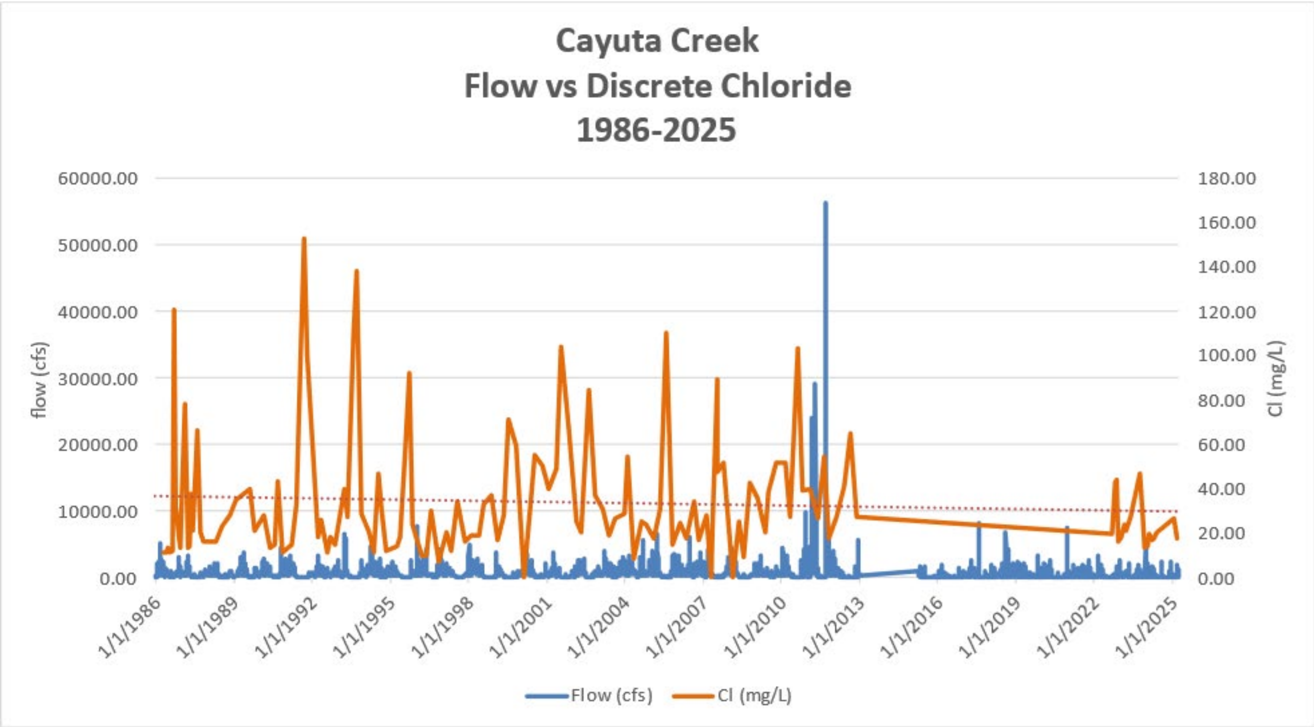


Figure 9. Long-term Record of Streamflow and Chloride at Cayuta Creek, 1986-2025 (Note: no samples were taken from 2014-2021)

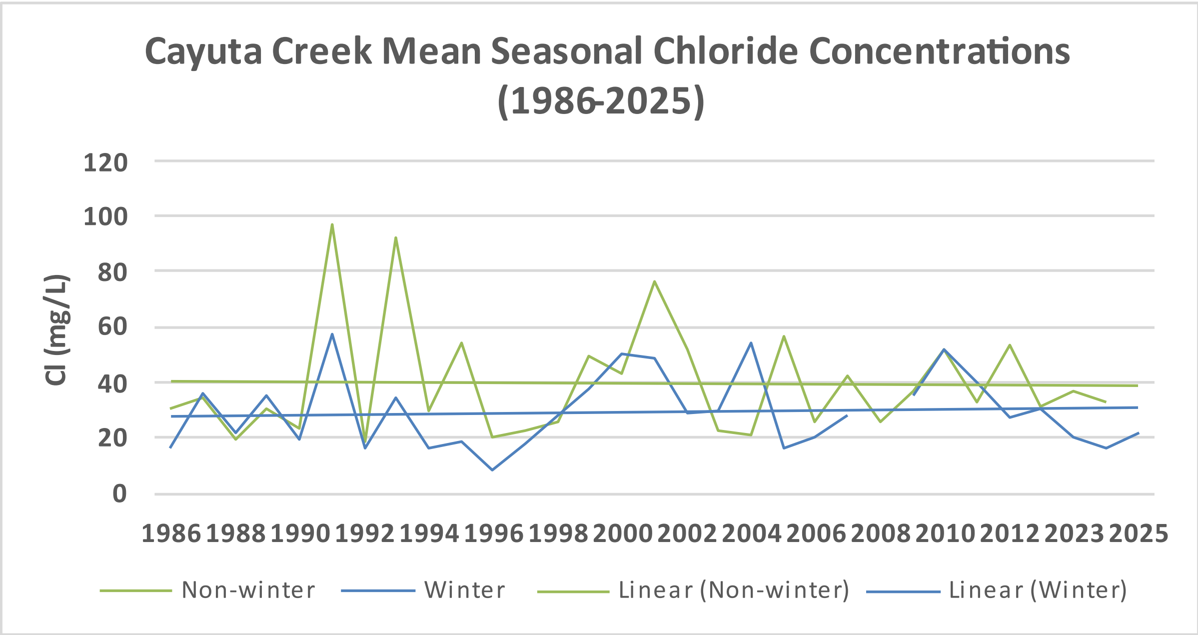


Figure 10. Long-term Seasonal Chloride Concentrations in Cayuta Creek

Evaluating Changes in Macroinvertebrate Communities

One of the goals of the project was to take a closer look at the macroinvertebrate data from the past two decades at both Deer Creek and Cayuta Creek to evaluate if any changes in community structure can be attributed to increased salinization. Generally, and as expected, macroinvertebrate IBI scores were strongly negatively correlated with chloride concentration (Figure 11). All macroinvertebrate samples were collected in the same index period.

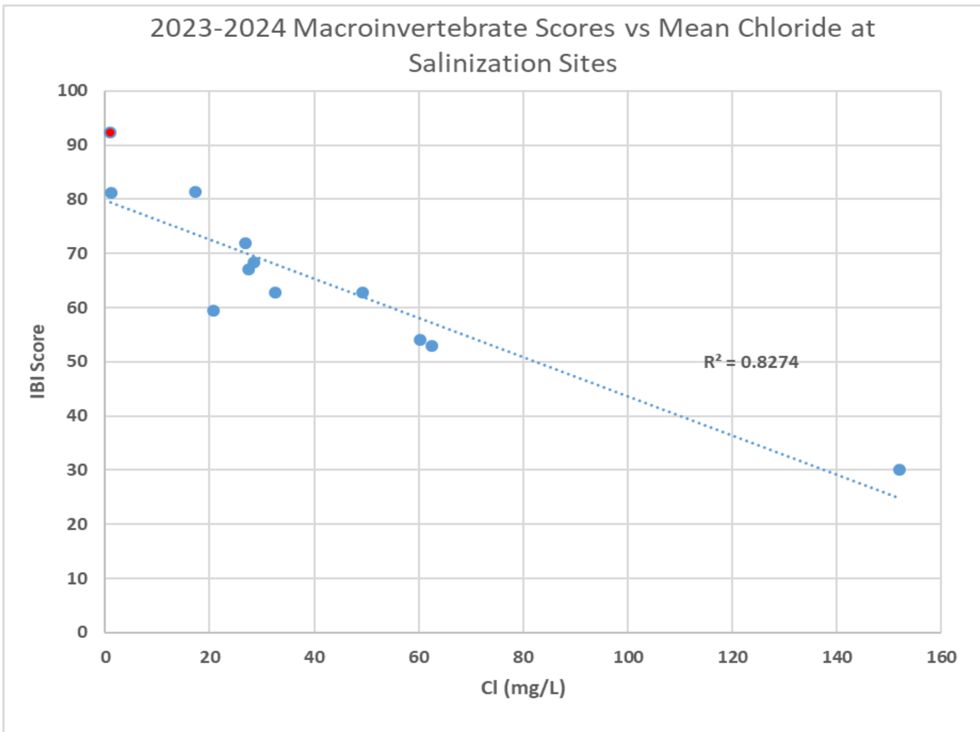


Figure 11. IBI Scores from Macroinvertebrate Samplings Versus Mean Chloride Concentrations Across Sites (Reference site (Trout Run) in Red)

Digging deeper into the genera of taxa observed at these two streams over the past 25 years, staff found interesting patterns that mirror the patterns of chloride concentrations. A recent paper based on work completed by the Ohio EPA suggested that an aquatic life use standard for macroinvertebrates is 52 mg/l of chloride (Miltner 2021). In that same paper, a salt tolerance ranking was reported for taxa where enough data were available (about 50-60 taxa depending on season). This ranking was used to calculate a sum product ranked value for each sample at these long-term sites. Note that each individual sample was subsampled to a 200 subsample, so it is possible that not all taxa were represented in the sample. Figures 12 and 13 show the results of the salt tolerance ranking over the past two decades of macroinvertebrate data. High scores represent more salt-tolerant taxa, so any upward trajectory indicates that the stream could be losing taxa due to influences of road salt. At both Deer Creek and Cayuta Creek, the results of changes in salt-tolerant genera roughly mirror the long-term chloride patterns. Staff observed an obvious increasing trend in chloride and an increase in salt-tolerant taxa in Deer Creek and a slight decrease in chloride concentrations and a fairly stable pattern of salt-tolerant macroinvertebrate taxa in Cayuta. Note that no samples were taken in Deer Creek from 2014-2021, and no samples were taken in Cayuta from 2012-2021, so it is not known what happened between those discrete points.

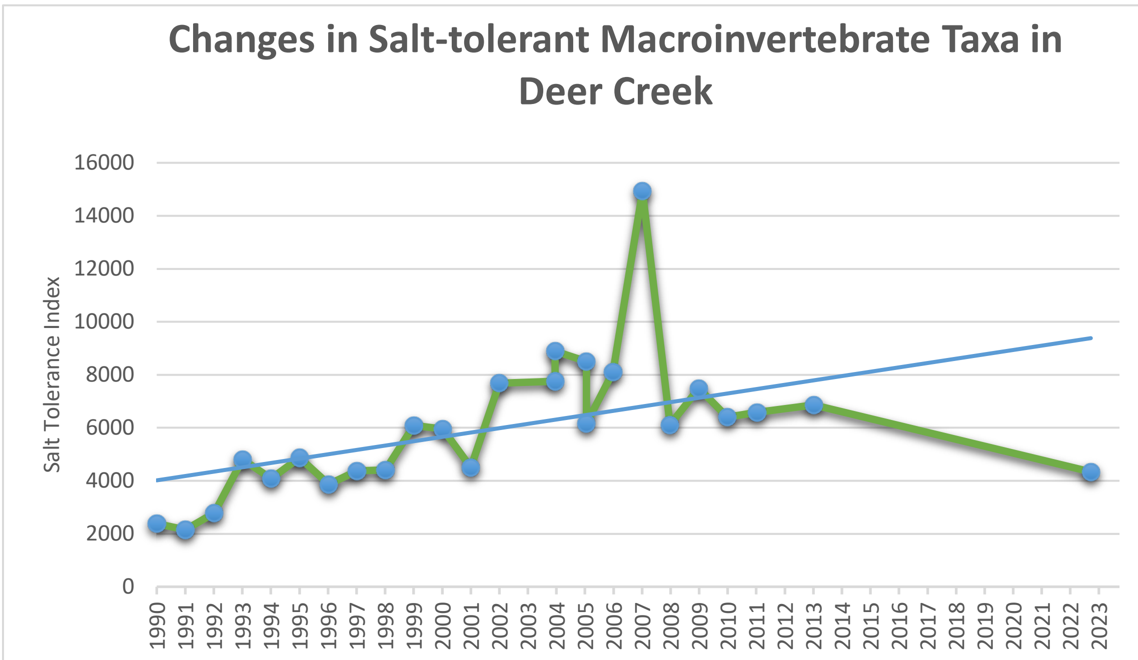


Figure 12. Changes in Salt-tolerant Macroinvertebrate Taxa in Deer Creek, 1990-2023

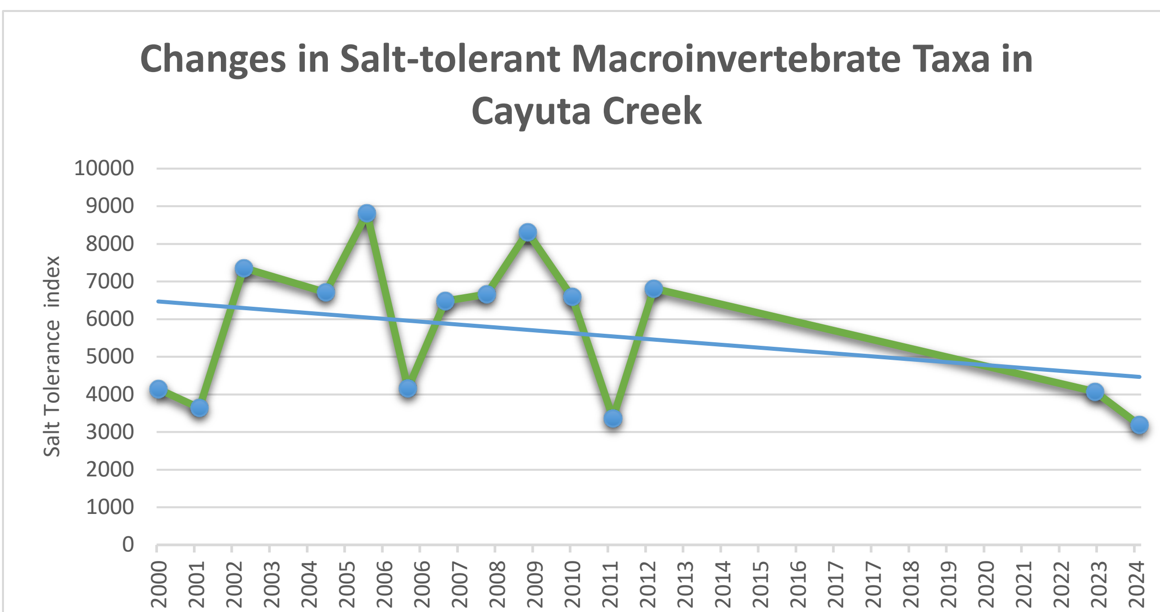


Figure 13. Changes in Salt-tolerant Macroinvertebrate Taxa in Cayuta Creek, 2000-2023

KEY TAKEAWAYS AND RECOMMENDATIONS

Each phase of this study targeted different but overlapping goals, and together these results offer insight into the state of stream salinization impacts across the Susquehanna River Basin. The first year of this study (Phase 1) began initial investigations into the viability and feasibility of creating a small network of sampling sites within the Susquehanna River Basin from which staff could monitor chloride and specific conductance, develop a chloride estimation method from CIM data, determine chloride patterns and trends, and document and evaluate impacts of freshwater salinization. This was successfully completed through historical data mining, collecting new data, and leveraging existing data to evaluate 10 streams that exhibited consistently high chloride concentrations with spikes in winter related to road salt runoff. Chloride concentration peaks are lasting 2-3 days in streams after significant runoff events and can occur with high frequency during winter months. Estimated concentrations of chloride occasionally briefly exceeded the PADEP drinking water standard of 250 mg/L after runoff events and more frequently exceeded the Canadian-based chronic threshold of 120 mg/L. However, half the sampling sites exceeded the Ohio-based aquatic life use threshold of 52 mg/L at least 20 percent of the time from 2022-2025, with some sites showing those concentrations nearly year-round.

Seasonal analysis revealed that peaks in conductivity recorded during storm events and trends in winter (November-April) and non-winter (May-October) were often coincident, meaning residual salt signatures from winter can remain in the system in some form and can be observed in summer months as well. Mauchino diagrams help visualize the ion contribution of sodium and chloride to the chemical signature of streams in winter versus non-winter months.

Road salting application varies widely across state, regional, and local entities, making it difficult to calculate salting input across specific watersheds. However, the Commission obtained brine (gallons) and road salt (tons) application data via a FOIA request for NY Highway 17 in Tioga County, NY, from NYDOT for 2022-2023, and county-wide (total) salt and brine application data for state-managed roads in Pennsylvania from PennDOT from 2021-2023. From these data, staff was able to roughly estimate total brine and road salt applied to each watershed by total county and state roads, but it was difficult to link the amount of salt applied to the magnitude of chloride observed during any one sampling event.

The evaluation of impacts to biota from decades of road salt application on adjacent drainage roadways using two long-term datasets revealed a corresponding increase of salt-tolerant taxa in Deer Creek, where chloride has been increasing, and no change in salt-tolerant taxa in Cayuta Creek, where chloride concentrations have stayed the same or even declined slightly. Staff plans to use this same method to evaluate other long term macroinvertebrate data sets across the basin, even if they were not specifically used in the current study.

A recommendation going forward includes advocating for aquatic life use standards for PA and NY similar to the 50 mg/L used in Maryland or the 52 mg/L used in Ohio. Most states have a drinking water standard but have not adopted an aquatic life use standard despite ample evidence that it is much lower than most drinking water thresholds. The Commission's CIM network is a great long-term monitoring tool to track increasing conductivity over time, especially at sites that have been shown to have elevated chloride concentrations. The Susquehanna River

Basin definitely has streams that are being impacted by road salt runoff both chemically and biologically. As a spinoff of this project, staff has begun to be involved in outside work groups and outreach opportunities to encourage better use of salting and educational outlets for best management practices.

BEST MANAGEMENT PRACTICES

Achieving reductions in road salt application requires balancing safety, economic, and environmental needs with both residential and commercial efforts. One teaspoon of salt permanently pollutes five gallons of water (Fig. 14, Minnesota Pollution Control Agency, 2022) with only reverse osmosis removing chloride from the water, which is costly and not widely available in public drinking or wastewater treatment systems. Chloride pollution comes from both point and nonpoint sources, with approximately 42 percent of chloride loading attributed to road salt use (Overbo et al., 2019). Of this, the majority used in road salt application (50 percent) comes from parking lot runoff, followed by municipal (9 percent) and state road runoff (7 percent) (New Hampshire Department of Environmental Services, 2007).

Various best management practices exist for those responsible for large-scale salt application. Before storms, managing public expectations of roadways during weather events – such as using well-timed hyper-local weather alerts when available – can equip the public to make informed travel decisions. Roadway managers can also identify low or no salt areas near sensitive or threatened waterways using best judgment. During storms, pre-wetting salt before application to allow enhanced road adhesion and reduce kickback, pre-treating roads with brine, and advances in low technology such as live-edge plows that flex with the road surface allowing better adhesion, can all reduce total salt needed. After storms, proper salt storage and equipment calibration can contribute to salt use reductions and preparedness (Kelly et al., 2019). When properly applied, these procedures may result in less salt used throughout an average winter, a potential economic benefit to salt purchasers. Voluntary trainings also exist to help applicators achieve these measures, such as the New Hampshire Green SnowPro Certification, which upon successful completion offers limited liability protection to commercial or municipal applicators (New Hampshire Department of Environmental Services, 2025).

Everyday changes at the individual level can also make an impact. When storms begin, individuals can shovel early and often to prevent snow from turning to ice under safe conditions. Using the right kind of salt and amount also matters. A 12-ounce mug contains enough salt to cover 10 sidewalk squares (Izaak Walton League of America, 2025). Traditional rock salt will melt ice until 9°C (15 °F), while calcium chloride and magnesium chloride can withstand lower temperatures of -15°C (5 °F) and -32°C (-25 °F), respectively (Kelly et al., 2019). After storms, salt can be swept up and reused in the next storm event. Being aware of different types of salt and their ideal temperatures to prevent freezing is important as well for both residential and commercial applicators. Additionally, joining volunteer chloride monitoring groups such as Stroud Research Water Center's SaltSnapshot or the Izaac Walton League's SaltWatch are also good ways to enhance current datasets on chloride levels in streams.

Figure 14. Example of Road Salt Reduction Outreach Poster (Franklin Soil and Water Conservation District, Be Smart for Water Quality, 2025)

ADVOCACY AND OUTREACH

The volunteer-led Pennsylvania Road Salt Action Working Group (PARSA) was founded through a partnership between Little Lehigh Watershed Stewards and Pennsylvania Organization for Watersheds and Rivers (POWR) in January 2025 to increase awareness of excess salt application and advocate for attainable salt reduction solutions to protect the environment, human health, and critical infrastructure. Various state groups with overlapping goals meet monthly (including, but not limited to, watershed associations, county and state environmental agencies, community science groups, roadway and property managers, contractors, and individual volunteers) to share resources and support outreach efforts. PARSA has centralized and created various advocacy resources (available upon request) including safe salt reduction techniques, grant opportunities for salt application equipment upgrades, and outreach materials such as presentations designed to be adapted for regional use. Subgroups offer technical assistance to interested members of the public or organizations, including locating and visualizing dissolved chloride data from local waterways and providing resources to begin discussions with local salt application contractors, local government, or state representatives. The Commission provides technical support on current stream salinization research (including this study), chloride data management, and advocacy outreach through community presentations and written articles (Pennsylvania Trout Unlimited, Spring 2025). To learn more, visit https://www.littlelehigh.org/salt-deep-dive.

In addition, the Commission joined Southern Tier 8 Regional Economic Development Board (ST8, Binghamton, NY) in partnership with the Stroud Water Resource Center's (Avondale, PA) annual fall salt pollution Stream Snapshot in October 2025. By testing in October under low flow conditions, results indicated residual chloride levels fed by groundwater as opposed to surface flow, possibly indicating salt retained in the system outside of winter salting events. After ST8 and the Commission presented on the impacts of stream salinization in the classroom, students had two days of hands-on experience sampling streams for conductivity and dissolved chloride along a forested-to-urban gradient, followed by a salt storage facility and equipment tour with presentations by local town managers. Partnerships like these allow for continued education of the impacts of stream salinization across the Susquehanna River Basin while offering practical solutions to reduce excessive salt application.

ACKNOWLEDGEMENTS

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