An Environmental Monitoring Project to Evaluate the New York State Department of Transportation Road Salt Reduction Pilot Program in the Lake George Drainage Basin

----- FINAL REPORT -----

NYSDOT reduced salt application sign on Route 9N "pilot" segment with Tongue Mountain Range in background.

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PREFACE

This report describes the results of a 40-month monitoring project conceived, designed, and implemented in response to a proposed initiation of a road salt reduction pilot program on Route 9N in the Lake George basin by the New York State Department of Transportation (NYSDOT). Although the NYSDOT initially expressed interest in cooperating with the Lake George Waterkeeper (LGW) and the Lake George Association (LGA) scientists on a water quality monitoring project, the agency later became reticent to any discussions on this topic. As a result, the LGW and LGA designed and implemented their own project to monitor the effect of road salt reduction on the water quality of Lake George tributaries along the pilot segment of Route 9N. Two "test" and two "control" watersheds were selected for the monitoring project which included field excursions to each site on about bi-weekly intervals to collect raw water samples for analysis of anions/cations and a series of field measurements. Specific conductance was collected at all four ***lower*** sampling stations continuously at 5-minutre intervals and correlated with laboratory chloride [Cl^-] concentrations to determine tributary concentrations exported to Lake George. Tributary water level was measured in-situ at the ***lower*** stations with level loggers and correlated with manual gagings to determine tributary flow entering Lake George. Following three separate FOIL requests and extensive delays, the NYSDOT finally provided road salt data that allowed us to evaluate the impact of the road salt reduction pilot program in the Lake George basin. The purpose of this Final Report is to describe the entire process in detail.

ABSTRACT

A major 30-year report on water quality monitoring in Lake George brought awareness to the fact that the sodium and chloride levels in the lake had increased substantially from 1980 through 2009, and that winter deicing practices in the basin were the primary cause of these increases.

The FUND for Lake George, a 501 (c)(3) organization immediately became proactive and made a concerted effort to unite local governments in the basin in a road salt reduction policy which became very successful. It was soon recognized, however, that efforts to reduce the impact of road salt on Lake George water quality would require participation of the New York State Department of Transportation (NYSDOT) to achieve a meaningful impact.

The NYSDOT became an active participant in the discussions which included not only Lake George but also portions of the Adirondacks where water quality of drinking water wells and contamination by road salt was becoming an issue. The NYSDOT eventually proposed two separate road salt reduction "pilot" programs, one along Route 86 in the Lake Placid-Whiteface Mountain area, and the other pilot program along a segment of Route 9N on the western side of Lake George. Although there were initial discussions about water quality monitoring associated with the Lake George pilot program, the NYSDOT later became uncommunicative regarding this topic, which prompted the Lake George Waterkeeper (LGW) and the Lake George Association (LGA) to design and initiate their own project.

"Test" and "control" tributaries and associated watersheds were carefully selected within and outside the Route 9N pilot segment, respectively, to evaluate the water quality response to road salt reduction. Monitoring was initiated during mid-2018 and involved bi-weekly sampling to collect raw water samples for analysis of anions/cations and a series of field measurements. The ***lower*** stations below the influence of highway road salt were instrumented to continuously collect water level (flow) and specific conductance concentration (chloride) at 5-minute intervals.

Beginning in February 2020, three separate Freedom of Information Law (FOIL) requests were submitted to the NYSDOT to obtain road salt application information that was essential to evaluate the pilot program in the Lake George basin. All requested road salt application data eventually were received by November 2022 and then required extensive communication and considerable time to accomplish the processing of two different data management systems into a single compatible workbook (Excel) file.

Initially, the NYSDOT proposed to start the 10 percent road salt reduction at the end winter 2017-2018. From our analysis of the data, however, it appears that the reduction process actually began during the winter period 2018-2019 with a reduction of the road salt *application rate* (~ 20 percent/lane mile) and was followed during the winter period 2019-2020 by another reduction of *application rate* (~ 10-12 percent/lane mile). Furthermore, it was determined that the application rate reduction occurred basin-wide and not just along the proposed Route 9N pilot segment. Coincident with the reduction of *application rate* during winter period 2019-2020, however, there was a substantial increase in the number of *application events* that occurred during the remaining winter periods. Our analysis of the road salt application data showed that the combination of reduced *application rate* and increased *application events* resulted in an increase in the amount of road salt applied within the basin and not a reduction.

There was good agreement between the annual amount of Cl^- applied to highway surfaces versus the annual amount of Cl^- exported to Lake George only in the two "test" watersheds and the amount of precipitation and groundwater levels were important factors in this regard. In the "control" watersheds, there was considerably more Cl^- exported to the lake than applied to the affected highway surfaces indicating significant areas of soil depth to bedrock where storage of groundwater and high concentrations of Cl^- could occur. In the case of T41, the export of Cl^- to Lake George was about 4-fold greater than the amount applied during each winter period where flow and Cl^- data were complete.

The findings highlighted in Chapter 11 with regard to the annual loading of Cl^- to Lake George should be of great concern to everyone advocating for future improved water quality. An earlier study of all tributaries and stormsewers flowing in the Lake George basin found that (1) English Brook (T41) contributed about 5.5-8.0 percent of the total flow entering the lake, and that (2) about 60 percent of the 109 tributaries flowing into the lake at the time of the study (141 total; only 109 with flow) had road/highway systems traversing their watersheds. All of the major tributaries including East, West, Finkle, Indian, Northwest Bay, and Hague Brooks are included in the category of tributaries with networks of road systems that receive and export winter deicing products. While the exact total amount is not known, the export of Cl^- from these watersheds into Lake George on an annual basis must be staggering given the amount of Cl^- exported to the lake by the four watersheds under investigation and reported herein (~ 100 tons/y).

ACKNOWLEDGEMENT

The authors extend a special acknowledgement to the elected officials of the municipalities within the Lake George basin for their leadership on committing to the Lake George Road Salt Reduction Initiative by signing the basin-wide Memorandum of Understanding starting with Mayor Robert Blais (Village of Lake George), and including Supervisor Dennis Dickinson (Town of Lake George), Supervisor Ron Conover (Town of Bolton), Supervisor Edna Fraiser (Town of Hague), Supervisor Joe Giordano (Town of Ticonderoga), Supervisor John LaPointe (Town of Putnam), Supervisor George Gang (Town of Dresden), and Supervisor John Strough (Town of Queensbury). We also would like to acknowledge the Late Supervisor Fred Monroe, of the S.A.V.E. Lake George Partnership, and the Warren County Board of Supervisors. The Lake George Road Salt Reduction Initiative would not have commenced without their leadership and interest in the protection of Lake George.

A special acknowledgement is extended to the New York State Department of Transportation including previous Commissioner Paul Karas, current Commissioner Marie Therese Dominguez, former Chief of Staff Todd Westhuis, Rob Fitch (NYSDOT Transportation Maintenance Supervisor), Sam Zhou (NYSDOT Assistant Commissioner for Operations and Maintenance), and Joe Thompson (NYSDOT Snow & Ice Management) as well as others unnamed, for their vision to implement and their commitment to the Route 9N Road Salt Reduction Pilot Program.

We acknowledge New York State Department of Environmental Conservation Commissioner Basil Seggos and his staff for facilitating meetings and recognizing the need to address impacts from road salt pollution.

We extend a special acknowledgement to landowners who granted access to place instrumentation for data collection on their property including the Bruce Ashby Revocable Living Trust (T63a), Walker Bay Partners (T61) and Joan Lange (T36a), for which this report would not have been possible without the ability to collect data.

We greatly appreciate and acknowledge our partners on the Adirondack Road Salt Working Group, starting with the late Supervisor Randy Preston (who was recognized with the passing of the legislation forming the Adirondack Road Salt Reduction Task Force), as well as Dr. Dan Kelting, Brittany Christenson and Lee Keet for their unwavering commitment and passion to successfully addressing this issue. We extend thanks to Phill Sexton for his guidance and expertise on road salt reduction.

Funds for this monitoring program were provided by The FUND for Lake George, The Lake George Association (LGA) and The Lake Champlain Sea Grant Program. The FUND for Lake George and The LGA provided in-kinds services, which allowed the participation of Chris Navitsky, The Lake George Waterkeeper, Brea Arvidson, LGA Manager of Water Quality Research and Randy Rath, LGA Lake Protector and Geospatial Systems Analyst.

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Chapter 1

Executive Summary

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1.0 Lake George and the Chloride Water Quality Problem

Lake George is the largest body of water located entirely within the Adirondack Park in New York State. Historically, Lake George has been called the “Queen of American Lakes” for its crystal-clear waters and inherent natural beauty, and it has been a popular tourist attraction since the late 1800s (West et al. 2001).

Local concern for the preservation of water quality in Lake George has existed for many decades, primarily the result of activities initiated by The Lake George Association (LGA), the first lake conservation organization in the United States, formed in 1885. As a result of LGA efforts, the lake was classified as “AA Special” (Class AA-S) meaning that (1) water taken from the lake could be used as a public drinking water supply following treatment with chlorine and (2) there shall be no discharge or disposal of sewage, industrial wastes or other wastes into these waters or into tributaries discharging to the lake (6 CRR-NY 701.3).

Increased tourism and development in the drainage basin resulted in environmental consequences to Lake George ranging from (1) concerns over nutrient loading from wastewater and stormwater runoff, to (2) acidification from atmospheric pollutants, to (3) effects of invasive species and (4) salt loading from road salt de-icing in winter. These concerns prompted scientific investigations to better understand these ecosystem stressors and their effects and led to an extensive lake-wide water quality monitoring program initiated during 1980. The program was conducted by Rensselaer Polytechnic Institute’s Darrin Fresh Water Institute (DFWI) with financial support from The FUND for Lake George. The result of this study was a long-term, 30-year dataset which was described, discussed, and published in a 2014 report entitled *The State of the Lake: Thirty Years of Water Quality Monitoring on Lake George, New York, 1980-2009* (Boylen et al. 2014).

The most disturbing trend evident from the 30-year monitoring program was the steady rise in sodium chloride, which nearly tripled from about 9 mg NaCl L^{-1} in 1980 to ~26 mg NaCl L^{-1} in 2009. The source of salt was road de-icing applications within the watershed during winter and was well above the background of <1 mg NaCl L^{-1} typical of Adirondack lakes in undeveloped watersheds.

Sustained increases of salt loading at the 2009 rate to the Lake George basin would result in lake concentrations of 34 mg Cl L^{-1} by about 2050 (Sutherland er al. 2018), which implies a corresponding Na^+ concentration of 20 mg L^{-1}, which may be harmful for heart or kidney patients (US EPA 1976). Limiting the load of de-icing salt to near 2009 levels or reducing the load would ensure that this health threshold concentration is never approached.

1.1 The S.A.V.E. Lake George Partnership

The State of the Lake report described three fundamental threats to Lake George including invasive species, rising salt levels, and declining water quality and clarity, which prompted The FUND for Lake George to develop a mission leading the way to lasting protection with one goal: stop the present decline of water quality and achieve sustained protection of Lake George for the next generation. This strategy for environmental and economic success relied on three main pillars for success including bold partnerships, program innovations and direct investments.

The formation of bold collaborations started with the S.A.V.E. (**S**top **A**quatic in**V**asives from **E**ntering) Lake George Partnership, a diverse organization of municipal representatives, conservation organizations and scientific experts speaking with one voice and demonstrating the power of diverse public and private interests acting in common purpose to uphold natural, community and economic values that make Lake George unique. This partnership successfully produced, through concerted action and investment, the first mandatory invasive species inspection and decontamination program east of the Mississippi River.

Utilizing the energy of the S.A.V.E. Lake George Partnership, the core constituency started a public/private program to reduce salt levels and expanded S.A.V.E. to mean **S**alt **A**batement is **V**ital to the **E**cology of Lake George. These discussions on the need to reduce road salt application resulted in the preparation of a Memorandum Of Understanding (MOU), the organizing tool successfully used by S.A.V.E. on invasive prevention, which had wide sign-on and support from all municipalities within the Lake George basin. This MOU detailed the case, provisions and timeline for an aggressive salt reduction plan called the Lake George Road Salt Reduction Initiative.

The MOU was an agreement among municipal governments to address the levels of chlorides entering Lake George by reducing the application of road salt for winter maintenance and de-icing practices, and a statement of intent to work in good faith to create a program to reduce road salt application levels. The signing municipalities agreed to the following steps to reduce road salt application through the following: (1) utilize Best Management Practices as demonstrated in New Hampshire, (2) investigate and consider equipment to better manage and monitor the application of road salt, (3) collect data using consistent methods on the quantities and application rates of road salts, (4) assess and adjust application rates based on level of service, road grades, proximity to water bodies, (5) establish an education and training program for all highway department employees, and (6) participate in an annual "Road Salt Summit" to discuss new technologies, application methods, best management practices and research.

The S.A.V.E. Lake George Partnership held the first annual Lake George Road Salt Summit at the Sagamore Resort on September 28, 2015 which is considered the inauguration of the Lake George Road Salt Reduction Initiative. This event invited municipal, and county elected officials, municipal and county highway department superintendents and staff, state agencies, private maintenance contractors and business owners to fulfil the initial steps of the MOU. Sessions included discussing the 'return on investment' on road salt reduction, local research projects, live equipment demonstrations and a best practice session sharing solutions and development.

This Salt Summit prompted a meeting in October 2015 to develop an accurate baseline of road salt application rates within the Lake George basin to identify strategies for reducing road salt while maintaining road safety and was attended by all municipal and county superintendents as well as representatives from the New York State Department of Transportation. These first steps would be accomplished by utilizing GPS tracking software to track equipment and real-time application rates, track pavement temperatures, install onboard camera systems to record road conditions, and provide data analysis to optimize efforts to reduce road salt. Along with the tracking equipment, mechanical snow removing equipment improved by using Live Edge plows provided by MetalPless, and was when operators began to embrace a change in practice and realize the potential of road salt reduction.

During the first few years of the Lake George Road Salt Reduction Initiative, the S.A.V.E. Partnership continued to support the Salt Summits and used the regular meetings to update elected officials on municipal program progress. The members of S.A.V.E. realized that to make the basin-wide reduction approach successful, it would be necessary to include the New York State Department of Transportation ("NYSDOT") in road salt reduction efforts. The NYSDOT were attendees at the first summits and participated during a panel discussion on obstacles to reduction during the second summit, but they were not active participants in actual reduction efforts.

Mayor Robert Blais, S.A.V.E. Lake George Partnership Chair, raised concern regarding the observed excessive salt applications by NYSDOT which were counterproductive to reduction efforts being practiced by local basin municipalities. Mayor Blais' letter to NYSDOT Warren County Assistant Engineer Jim Davis stressed the need for the Partnership to fully engage NYSDOT in the road salt reduction initiative. This prompted a November 27, 2017 letter to Governor Andrew Cuomo from the S.A.V.E. Lake George Partnership introducing him to the Lake George Road Salt Reduction Initiative and asking for a partnership at the State level with the following requests:

- For New York State to match the local investment of $150,000 towards implementing Best Practices in salt reduction by applying continuous measuring of application rates, training, and upfitting highway departments with latest equipment. It cited the dramatic progress already achieved by the Town of Lake George with 30% reduction in application rates, and
- For NYSDOT winter maintenance crews to participate directly as partners in the Lake George Road Salt Reduction Initiative.

The November correspondence resulted in a February 2018 meeting at NYSDOT headquarters between S.A.V.E. and NYSDOT upper-level management. Discussion topics included an introduction to the Lake George Road Salt reduction Initiative, NYSDOT current salt reduction initiatives and possible partnership opportunities. NYSDOT stated that (1) using treated salt (Clear Lane® Enhanced Deicer), they were able to reduce road salt application 40 percent in Cascades Lake (Lake Placid) region, (2) they were using two-stage plows for improved mechanical removal, (3) they implemented brine making in Warren County that was being applied and (4) they were at the lower threshold of salt application rates of 180 lbs./lane mile. It was relayed to NYSDOT that reduced salt application was not the perception of the municipalities or residents in the basin. The NYSDOT stated that they were looking into a designated reduced salt zone along Lake George.

These proceedings resulted in an April 2018 NYSDOT response that they were going to commit to a Pilot Program that would be Region 1 Priority. This Pilot would work with the Warren County Resident Engineer to minimize salt through the use of (1) two stage plows (relocate existing equipment), (2) AVL (Automated Vehicle Location) tracking equipment on trucks to determine location and amount of material, (3) existing brine capability, and (4) having Snow & Ice Supervisors meet to reinforce the use of salt and develop an operation plan for reduction. It was said that the reduction plan would be implemented during the last four weeks of the 2017-2018 winter season.

In May 2018, a meeting with NYSDEC, NYSDOT and NYSDOH executive staff was held to describe NYSDOT plans for a second Pilot Program for Mirror Lake (Lake Placid) to support the previous discussed Lake George Pilot Program and to show state agencies and environmental advocates working together. The Action Plan would work with local municipalities and utilize brine, buy Live-Edge plows, use two-stage plows, expand the use of treated salt, implement AVL tracking on equipment, monitor water quality, apply post storm evaluations, assess drainage and environmental conditions, evaluate the use of abrasives and mixes with varying topography, and establish a driver's education program. NYSDOT also wanted to establish a tactical working group at the municipal level and partner with private landowners and formalize a Strategic Work Group with the RSWG.

1.2 The NYSDOT Road Salt Reduction Pilot Program

On May 30, 2018, NYSDOT Acting Commissioner Paul Karas announced two innovative pilot programs to help rejuvenate Mirror Lake and Lake George by reducing the application of road salt while still protecting the safety of the travelling public. Commissioner Karas was quoted as saying "Lake George and Mirror Lake are known worldwide for their pristine beauty, and these new pilot programs will strive to keep our roadways safe while enhancing environmental sustainability. The Adirondacks are a national treasure and as stewards of many roads within the Park, we are committed to collaborating with the stakeholders to reduce salt and retain the Park's beauty for generations to come."

The Lake George pilot program would span a 17-mile length of State Route 9N on the west side of Lake George and would leverage all the DOT's best management practices to reduce salt application rates. It was stated that road salt was one of the challenges impacting the Adirondack Park's cherished aquatic ecosystems and these best management practices were intended to help protect the environment and encourage commercial and private landowners to implement similar reductions.

In addition, the NYSDOT, along with NYSDEC and NYSDOH, would establish a strategic working group which would include participating municipalities and organizations such as AdkAction, The FUND for Lake George and The Lake George Waterkeeper to evaluate the effectiveness of the pilots, which could potentially have an impact on snow and ice practices statewide.

The NYSDOT stated that the intent of these pilots was to utilize all the Department's best management practices, and then evaluate the degree of salt reduction it can implement without negatively affecting the safety of the traveling public. The pilots were to be implemented for the 2018-19 snow and ice season. At the close of the season, a review would be performed to determine the effectiveness of the pilots, including on safety, and to consider the feasibility of expanding the salt reduction practice.

These pilot projects were discussed formally at a meeting convened at Paul Smith's College on June 18, 2018 with representatives from NYSDOT, NYSDEC, NYSDOH and the RSWG. The discussion topics included a MOU between state agencies and the RSWG, review of the Draft Group Charter and a presentation on the 2018-19 Salt Reduction Pilots, which included discussion of the monitoring program. It was determined that a subgroup should meet to continue development of, and finalize, the monitoring program.

1.3 The NYSDOT Road Salt Reduction Pilot Monitoring Program

As a sequel to the meeting on June 18, 2018, a meeting to discuss monitoring for the two NYSDOT Road Salt Reduction Pilot Programs was scheduled for July 18, 2018, at The FUND for Lake George office. Dan Kelting, Jim Sutherland, and Chris Navitsky prepared a Draft Monitoring Plan titled "Environmental Monitoring Work-Plan to Evaluate the NYSDOT Reduced Road Salt Pilot Projects in the Ausable River and Lake George Watersheds." The Draft Plan contained background and rationale for the program, goals and objectives, study design, instrumentation, summary of sampling, processing, and data analysis, reporting and program budget. Each pilot project would establish two instrumented tributaries within and outside the "pilot" route and establish two instrumented wells downslope and upslope along each pilot route, based on NYSDOT input.

The July 18th meeting was attended by Rob Fitch, Mike Lashmet, and Joe Thompson (NYSDOT), and Dan Kelting, Jim Sutherland, and Chris Navitsky. Discussions at the meeting focused on the need for consistent lab processing and analysis, required instrumentation, whether existing wells could be used or were new wells required, and the need for a data sharing agreement. It also was noted that tributaries already were being sampled within the Route 9N Pilot due to concern about the need to develop a database of existing conditions before the start of the 2018-

2019 snow and ice season. Meeting follow-up included a request from NYSDOT attendees for an electronic copy of the proposal for Department review and future revisions including sampling of the groundwater wells.

It was shortly after the July 18th meeting that a disconnect in communications occurred with the NYSDOT regarding the proposed study. It was at this time that residents in the Adirondack Park had filed a Notice of Intent to sue NYSDOT regarding the high chloride and sodium concentrations in the individual drinking wells that were a part of an Adirondack Watershed Institute study. There was concern that Kelting would be an expert witness in potential legal action and that NYSDOT would have to distance themselves from Kelting. There also were concerns regarding (1) the need for a third party to conduct the research, someone not involved with the working groups, and (2) liability concerns expressed by NYSDOT about using an existing well for sampling, variables around unknown construction and the need for easements if new wells were installed and associated liabilities.

It was at this time that The FUND for Lake George decided to proceed with the planned study without any support or involvement from the NYSDOT. Soon thereafter it was learned that NYSDOT had contracted with the USGS to develop and implement a monitoring program for the proposed Road Salt Reduction Pilot Project for the State Route 86 project. There never was a reason provided by the NYSDOT regarding the decision to not study the State Route 9N Pilot Project, but it was stated at a Strategic Working Group meeting on October 15, 2018, attended by NYSDOT, NYSDEC and the RSWG that these projects are "no small investment by the DOT which includes trucks, equipment, etc.", so perhaps funding was a reason. It should be noted that as of January 2019, not all groundwater sampling wells had been installed for the State Route 86 study.

1.4 The Lake George Association Road Salt Reduction Pilot Program Monitoring Project

The incentive for development of a long-term monitoring project to assess the NYSDOT Road Salt Reduction Pilot Program was two-fold including (1) to monitor tributaries impacted by road salt from highway segments traversing watersheds to determine whether the proposed 10 percent reduction would translate to changes in water chemistry, and (2) the reluctance of NYSDOT to collaborate on an assessment project within the Lake George drainage basin at the time when critical decisions had to be made.

It did not make sense to miss a scientific opportunity to collect data and evaluate whether a 10 percent reduction in road salt application would translate to measurable changes in the water chemistry of tributaries receiving drainage from the 'pilot' road segments. The FUND for Lake George, therefore, committed personnel and financial support to conduct the assessment of the Route 9N road salt reduction Pilot Program. Since mid-2018 when monitoring was initiated, The FUND and The Lake George Association (LGA) merged into a single organization.

1.4.1 Monitoring Project Goals, Objectives, and Hypothesis

The NYSDOT Road Salt Reduction Pilot Program was conceived and initiated to reduce winter deicing road salt application along the Route 9N "pilot" segment on the west side of Lake George compared with normal application rates on other state highways in the basin while maintaining winter highway safety.

Goal. The goal of the LGA Monitoring Project was to collect water quality data to evaluate the effect of the NYSDOT Road Salt Reduction Pilot Program on the chemistry of tributaries flowing into Lake George.

Objectives. The major objectives of the LGA Monitoring Project can be stated as follows:

- Primary - Evaluate changes in tributary chemistry in response to reduced road salt application with respect to chloride and cations and determine whether these changes are significant when compared with road salt application at un-reduced normal application rates.
- Secondary - Establish a valid field sampling protocol that can be used in the long-term monitoring of Lake George tributaries to document changes in the chemical characteristics.

The fulfillment of the first objective assumes that there will be a reduced rate of road salt application along the "pilot" segment of Route 9N.

Hypothesis. The **null hypothesis** (**H_0**) being evaluated can be stated as follows:

*There will be no difference in the water chemistry response of ("**test**") tributaries within the Route 9N "pilot" reduced road salt application segment when compared with the chemistry of ("**control**") tributaries outside the Route 9N segment where normal rates of road salt application continue to occur.*

To reiterate, the incentive for development of this long-term monitoring project was the proposed NYSDOT 10 percent reduction in road salt application along the Route 9N "pilot" segment on the western shoreline of Lake George as compared with other segments of state highway that receive road salt application in the drainage basin.

1.4.2 The Selection of Tributary Watersheds for Investigation

The success of the effort to evaluate the NYSDOT road salt reduction program along the '***pilot***' segment of the Route 9N area is dependent upon many factors including, but not limited to, the following:

(1) the selection of suitable "**test*"*** tributary sites for evaluation of flow and anion-cation chemistry at ***upper*** and ***lower*** sites relative to the Route 9N segment that crosses the watershed and will undergo reduced road salt application,

(2) the selection of suitable "**control**" tributary sites for evaluation of flow and anion-cation chemistry at ***upper*** and ***lower*** sites relative to highway segments that will receive normal road salt application rates,

(3) the collection of reliable long-term flow and chemistry data during regular bi-weekly site visits in conjunction with loggers installed at ***lower*** sites to collect continuous specific conductance and water level data at and the maintenance of these loggers to minimize any loss in the continuous data records,

The site selection process began during mid-summer 2018 with the focus on suitable "test" tributary sites along the 17-mile segment of Route 9N that starts at the intersection of Route 9N-Route 9 in the Village of lake George and extends north to the intersection of Route 9N and Padanarum Road at the head of Northwest Bay and the base of the Tongue Mountain Range (Figure 1-1).

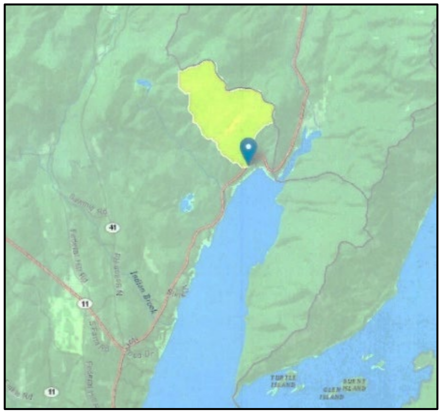
Figure 1-1.

The selection of "***test"*** tributary sites proved to be particularly challenging due to the extensive developed area up-gradient of the Route 9N '***pilot***' segment between the Village of Lake George and Padanarum Road. In fact, after considerable reconnaissance, less than 5 tributaries flow into Lake George that were not influenced by some form of development up gradient where salt application to road surfaces during winter deicing practices could interfere with the evaluation of road salt application and reduction related to the pilot program segment along Route 9N.

The two ***"test"*** tributaries selected within the ***"pilot"*** segment are located along the northern extent of the Route 9N segment, adjacent to Northwest Bay, and include (1) Tributary 61 (**T61**) that drains Wing Pond and enters Northwest Bay near Walker Point (Figure 1-2), and (2) Tributary 63a (**T63a**) located about 0.9 miles north of T61 and is adjacent to the NYSDEC Pole Hill Pond trailhead (Figure 1-3).

Figure 1-2.

Figure 1-3.



Both tributaries drain extensive undeveloped areas of private or state-owned land up-gradient of the Route 9N 'pilot' segment where there is no anthropogenic influence of development or road salt application during winter deicing practices.

Two tributaries were selected outside the Route 9N **pilot** test area to serve as '**control**' sites where the NYSDOT would continue to apply winter road salt according to standard practices without any purposeful reduction policy.

Tributary 41 (**T41**) is a segment of English Brook that begins near the intersection of Route 9 and Somerville Road (***upper*** sampling site) and extends about 1.2 miles southwest, ending just above the area where the tributary crosses under the Interstate 87 (I-87) overpass (***lower*** sampling site) (Figure 1-4).

Tributary 36a (**T36a**) is on the east shore of Lake George at the southern end of the lake and flows across Route 9L about 0.85 miles north of the intersection of Route 9L and Beach Road, north of Amitola Lane (Figure 1-5).

Figure 1-4.

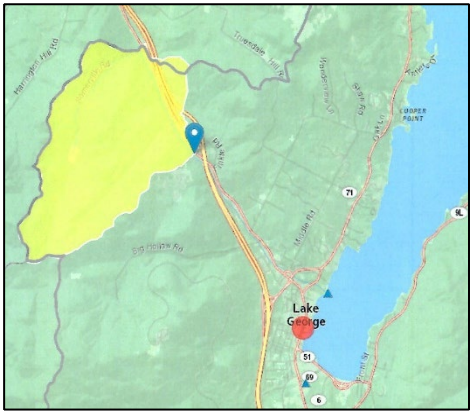
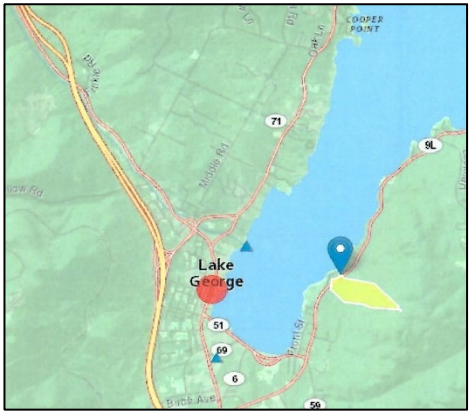


Figure 1-5.



T41 at the intersection of Route 9N and Somerville Road receives drainage from an extensive up-gradient forested and undeveloped area of private and state-owned land. The lower watershed portion receives drainage from Route 9 and also Interstate 87 (I-87), a multi-lane north-south highway that connects Albany New York with the Canadian border. All of the runoff and groundwater drainage at the lower portion of the watershed is from highway infrastructure.

T36a has no developed area up-gradient and east of the Route 9L state-maintained highway segment that crosses the watershed. In contrast to the other three watersheds selected for the current investigation, flow at the lower sampling site is primarily the result of groundwater emergence from higher elevations just east of the highway.

A set of ***upper*** and ***lower*** sampling sites was selected within each tributary watershed included in the current investigation. It was important that the ***upper*** sampling sites were a sufficient distance up-gradient from the highway segment crossing the watershed to ensure that salt spray from winter highway de-icing would not affect the background levels of chloride and cations in water flowing from the higher elevations. It also was important to select placement of the ***lower*** sampling sites along the channel where all runoff and groundwater drainage from the highway segment would be recorded by installed data loggers and collected during routine monitoring.

1.4.3 The Collection and Management of Dependable Project Data

Data collection was initiated in August 2018 at all four Project watersheds at biweekly intervals whenever possible. With a few exceptions due to inclement weather, all tributaries were sampled on the same day to minimize variability due to changing climate conditions. Each sampling excursion included visits to both ***upper*** and ***lower*** sampling stations at all four watersheds with on-site field measurements followed by the collection of raw water samples for the chemical analysis of anions and cations at the DFWI Laboratory in Bolton Landing. All data and observations at each sampling station were recorded on field sheets. See Chapter 3 for a more detailed explanation.

In addition to the bi-weekly chemistry samples collected at each ***lower*** watershed sampling site and analyzed for chloride, continuous chloride concentration data were measured indirectly in each tributary channel by installing a dedicated temperature-conductivity logger. It was known from previous investigations (Sutherland, unpublished data) that there is a robust relationship between instantaneous specific conductance measured in a tributary channel and the corresponding chloride concentration of water flowing through the channel at that time.

Onset HOBO® (U24-001) temperature-conductivity loggers were installed at the ***lower*** sampling site on each Project tributary to continuously record conductivity in the channel at 5-minute intervals. Water level logging instrumentation purchased from *In-Situ* Inc. and installed at each ***lower*** site included the Rugged TROLL 200 Level Logger with cable and download connection port and a Rugged Baro TROLL which was used to correct logger levels recorded at 5-minute intervals for local barometric pressure.

All four lower sites were fully instrumented with conductivity-temperature loggers and water level loggers by November 2020.

With the instrumented collection of reliable data and bi-weekly field excursions to check the stations, collect samples and provide quality assurance with respect to the logger data storage, the consequent phase of data management and analysis becomes the focus of attention.

All Project data were stored and summarized in Excel spreadsheet software. Table 1-1 summarizes the primary files that store data collected as part of this "pilot" project.

Table 1-1.

FILE NAME	# FILE WORKSHEETS	WORKSHEETS INCLUDED IN FILE
TRIBUTARY MASTER CHEM-FIELD DATA FILE	13	(1) 'Read me' first (2) sample accession summary (3) ***upper*** station chemistry and field measurements (4) ***lower*** station chemistry and field measurements (5) interactive data summary by analyte, year; each cell updated when data entered in the upper-lower worksheets (6) summary graphs of data (7) ***lower*** site tributary flow calculations (8) ***lower*** site flow rating curve data (9) table of field & HOBO® spC, measured $[Cl^-]$ equations (10) USGS StreamStats ***upper-lower*** sub-watershed data (11) site photographs (12) extra gaged flow data (13) local precipitation data
TRIBUTARY MASTER spCONDUCTANCE FILE	45	(1) 'Read me' first (2) daily summaries for each year (column data) (3) missing/bad data inventory (4) summary graphs of data (5) a separate worksheet for each month of conductivity data collected – currently December 2019 thru June 2022
TRIBUTARY TROLL 200 COMPILED DATA FILE	1	A single worksheet that includes a continuous string of 5-minute flow data beginning with the first station download
TRIBUTARY MASTER FLOW-CHLORIDE EXPORT FILE	31	(1) 'Read me' first (2) master flow and Cl^- loading tables for each year (3) flow, $[Cl^-]$ and ppt column data for each year (4) summary graphs of data (5) a separate worksheet for each month of flow and chloride loading data available – currently May 2020 through June 2022 (6) missing-bad data inventory

This Project component requires good organization, and the entire process has gone through a period of trial-and-error to determine the best way to store data and yet make it continually accessible for update and interpretation. In addition to being used during the 'active' Project by Lake George Association and Waterkeeper personnel, it also was necessary to keep in mind during development that end users following completion of the Project should be provided with a system that affords ease of access and understanding in spite of having no familiarity with the system as originally developed.

Careful design and implementation of a suitable data management system provides ease of access and the ability to perform the calculations necessary to track flow and chloride export in each "**test**" and "**control**" tributary on a regular basis. Individual data files downloaded in the field and transferred to the Cloud-based storage system are accessed on a regular basis and downloaded/copied to the appropriate Master file to provide an update and aid to subsequent calculations. The full series of data calculations performed on a regular basis were tedious but not complicated and are explained in detail in Chapter 4.

1.4.4 Affiliation with the Lake Champlain Sea Grant Program

During September 2019, following a full year of tributary data collection, report co-author Sutherland realized that, contrary to expectations, there was no accurate relationship between specific conductance and tributary flow at three of the four sites selected for investigation. Only T41 exhibited the relationship expected to occur based upon several decades of investigation at Finkle Brook in Bolton Landing (Sutherland unpublished data).

The Project cooperators were faced with the following realizations:

- That in the absence of continuous and reliable tributary flow data, water level data loggers had to be installed at each ***lower*** sampling site so that data could be collected and then paired with tributary gaging data collected every 2 weeks to establish a flow rating curve for each ***lower*** sampling station, and
- That funding was not available in the budget to purchase the necessary equipment.

Whereas this Lake George project was designed to specifically address the non-point source input of chloride in the Lake George drainage basin, the successful completion and evaluation of the Project also would benefit Lake Champlain which has Lake George within its drainage and where road salt also is problematic with respect to road runoff entering the lake from road deicing practices that occur in New York and Vermont as stated in several different literature sources (Shambaugh 2008; Smeltzer et al. 2012; Lake Champlain Basin Program 1992-2018).

A proposal was prepared and submitted to the Lake Champlain Sea Grant (LCSG) Program in response a to a Fall 2019 Request For Proposals (RFP), and was approved for funding for the period from February 1st, 2020, through January 31st, 2022. The funds from this grant were allocated to purchase water level data-loggers for the four tributaries and to compensate personal services for assistance with the field sampling, data analysis and summary, and report writing associated with the Project. Subsequent delays in receiving the road salt application data from the NYSDOT necessitated a no-cost time extension of the LCSG award through March 31st 2023.

1.5 NYSDOT Road Salt Application Data – Acquisition, Processing, Calculations, Evaluation

The Freedom of Information Law (FOIL) process was required for successful completion of this study because NYSDOT would not share data outside of the legal process. Three separate FOIL requests were submitted beginning in February 2020; the final group of requested data was received from NYSDOT in November 2022.

Two data formats were received from NYSDOT for road salt application data that we requested through five different winter periods including SnoMat and Automatic Vehicle Locator (AVL) data. Both formats required additional conversations and meetings with NYSDOT representatives to review and identify material used as well as understand data terminology, abbreviations, reference codes, units, and overall data formatting.

SnoMat data were provided for all winter periods; however, the data for winter periods 2019-2020 and 2020-2021 were incomplete and had to be supplemented with data from the AVL tracking system. Integrating the data from the two different data management systems into an effective system was tedious and extremely time-consuming which added to the frustration already associated with the process following the unreasonable FOIL request delays.

The process of data evaluation is explained in step-by-step detail in Chapter 10 and even includes 'sceenshots' of the Excel file where different worksheets were set up to accommodate the various calculations performed to 'blend' the two application data formats into material applied during each winter period within the four tributary watersheds under investigation.

Multiple issues occurred throughout the integration of the datasets for analysis from the SnoMat and AVL data management systems. The primary problems were the lack of any consistency in data management systems used within and among different winter periods. As a result, assumptions had to be made and were stated quite clearly in order for the analysis of the NYSDOT road salt application database to occur. A very extensive list of issues and assumptions that resulted from the data analysis process are presented at the end of Chapter 10 and also in Attachment 1 at the end of this report.

1.6 NYSDOT Road Salt Application Data and LGA Tributary Monitoring Cl^- Export Data

Three basic types of data were extracted from the road salt application information once it was compiled and reformatted from the different versions received including (1) the amount of road salt applied, (2) the number of application events, and (3) the average road salt application rates. Each data type was obtained for each tributary watershed included in the present monitoring project and for each winter period beginning with 2017-2018.

We attempted to use local Lake George basin snowpack information to determine the severity of winter weather but concluded that the NYSDOT recorded number of application events for each watershed was a better indicator. In general, the order of winter severity from most severe to least severe was determined from the application events and was as follows: 2019-2020, 2020-2021, 2021-2022, 2017-2018, and 2018-2019.

There was good agreement between the annual amount of Cl^- applied to highway surfaces versus the annual amount of Cl^- exported to Lake George only in the two “test” watersheds and the amount of precipitation and groundwater levels were key factors in this regard. In the “control” watersheds, there was considerably more Cl^- exported to the lake than applied to the affected highway surfaces indicating significant areas of soil depth to bedrock where storage could occur. In the case of T41, the export of Cl^- to Lake George was about 4-fold greater than the amount applied during each of the winter periods where flow and Cl^- data were complete.

Based upon road salt application rates for each watershed and each winter period, we determined that the NYSDOT did not initiate the road salt reduction “pilot” program on Route 9N during the end of winter 2017-2018 as planned. Instead, the data indicated that the reduction program began during the winter of 2018-2019 and occurred throughout the Lake George basin, not just on the Route 9N pilot segment.

Furthermore, it was shown through an exercise of simple calculations that the amount of road salt applied to Lake George highway systems actually increased significantly since winter period 2019-2020 due to an increased number of application events that occurred within each tributary watershed.

1.7 Presentation Format of Report

The material presented in this report describes and clarifies the specific protocol and variety of data collected since mid-summer 2018 when this monitoring project was initiated and also provides conclusions and recommendations. The report is organized as follows:

Chapter 1 is an Executive Summary of the 2018-2022 project and its findings, including conclusions and recommendations based upon evaluation of the data.

Chapter 2 is a review of material related to chloride and Lake George water quality including a detailed description of the timeline which resulted in the New York State Department of Transportation Road Salt Reduction Pilot Program in the Lake George basin and the Lake George Association tributary monitoring project to evaluate the road salt reduction effort.

Chapter 3 presents a detailed overview of the Lake George Association monitoring project including goals, objectives and hypotheses, the selection of tributary watersheds for investigation, chloride characteristics of the selected watersheds, the collection of dependable, sampling site equipment requirements, and monitoring project operational issues.

Chapter 4 presents a detailed description of the pilot monitoring project data management process including major project files and specific data calculations used.

Chapters 5-8 describe each tributary watershed (T63a, T61, T41, and T36a) in the current investigation including general characteristics, ***lower*** site equipment installations, a summary of project field measurements, analytical chemistry and flow, a summary of site-specific conductance and chloride concentrations, rating curve development from onsite manual gagings and recorded data logger water levels, and summaries of tributary Road Salt Application Period (RSAP) chloride and flow data.

Chapter 9 is a detailed summary and evaluation of the Lake George Association tributary watershed monitoring data including the difference between ***upper*** and ***lower*** monitoring sites, a summary of "test" and "control" watershed characteristics, the methodology involved in determining watershed precipitation and snowpack and, finally, a summary of chloride and flow data collected for RSAPs 2020-2021 and 2021-2022.

Chapter 10 presents a detailed description of the acquisition, challenges, interpretation, evaluation, and problems associated with the NYSDOT road salt application data received following three time-consuming FOIL requests.

Chapter 11 compares the winter period road salt application loads calculated for the four watersheds under investigation from the data provided by the NYSDOT with the Lake George Association tributary watershed chloride loads exported to Lake George calculated from the long-term monitoring project.

Chapter 12 is the closing chapter that provides a brief summary of background, the 2017-2022 NYSDOT Road Salt Reduction Pilot Program, the 2018-2022 LGA road salt reduction "pilot" Monitoring Project, the results of the pilot program evaluation, summary, conclusions, and recommendations.

1.8 Summary

The LGA Tributary Monitoring Project was initiated during mid-summer 2018 in conjunction with the "proposed" NYSDOT Road Salt Reduction Pilot Program and collected flow and chemistry data from ***upper*** and ***lower*** sampling sites at two "test" and two "control" watersheds on about a bi-weekly basis since that time. For reasons explained in the report, however, complete sets of flow and chloride concentration data only were available for two winter periods including 2020-2021 and 2021-2022,

With considerable effort explained in Chapter 10, we were able to extract the required data from the NYSDOT road salt application data files in order to obtain complete sets of information related to total road salt applications, total road salt application events, and average road salt application rates for each of the four watersheds included in the investigation and the five winter periods since 2017-2018.

Based upon the NYSDOT data analyzed from winter period 20187-2018 and beyond and presented/discussed in Chapter 11, *the reduction of road salt application rates* combined with the significant increase in *the number of road salt application events* resulted in an increased amount of road salt added to Lake George basin highways, with the amount dependent upon which RSAP and watershed was being queried.

It was not possible to either prove or dis-prove the null hypothesis (**H_0**) for the following reasons:

- The NYSDOT reduced the road salt *application rate* on all state-maintained highways in the Lake George basin and not just the "pilot" segment of Route 9N, and
- The NYSDOT did not reduce the total amount of road salt applied to the "pilot" segment of Route 9N during the five winter periods (RSAPs) under consideration in the current investigation reported herein.

In other words, the NYSDOT altered the original design of the Route 9N Road Salt Reduction "Pilot" Program without communicating this key factor to other interested groups such as the LGA.

1.9 Conclusions

The following conclusions are presented in the order of chapter sequence in the Final Report and are not listed in any ranking of priority indicating importance.

Chapter 2:

- The NYSDOT did not exhibit interest in any aspect of a water quality monitoring program (participating, reviewing, funding) for the Lake George Drainage Basin Route 9N Pilot Project.
- The NYSDOT did not establish consistent stakeholder working group meetings throughout the entire project, especially during and after the COVID pandemic, more so relating to the Tactical Working Group but with the Strategic Work Group as well.
- NYSDOT needs to improve implementation of best management practices that are proven to reduce road salt applications, specifically the use of brine as anti-icing on Route 9N.
- NYSDOT needs to improve interested user access to data related to winter maintenance record keeping that should include road salt application rates, brine application rates and a winter storm severity index.
- NYSDOT should implement year-end self-assessment reporting for the winter maintenance activity goals of the Pilot Program and use the assessment to guide continuous improvement of the Program.

Chapter 10:

- Multiple issues were described throughout the integration of the datasets for analysis from the SnoMat and AVL data management systems which required that assumptions had to be made in order for analysis of the Pilot Program data to occur. The list of these issues is too extensive to be presented here and is located at the end of Chapter 10 and also in Attachment 1 at the end of the report.
- Based upon the information received following three separate FOIL requests and the extensive associated delays, it is apparent that the NYSDOT did not exercised consistency in terms of the data management system related to the Lake George Route 9N Road Salt Reduction Pilot Program, which resulted in extensive problems and assumptions related to interpretation and evaluation of the database.

Chapter 11:

- The NYSDOT Road Salt Reduction Pilot Program was initiated during the winter 2018-2019, not at the end of winter of 2017-2018 as originally intended.
- Based upon the analysis of data provided by the NYSDOT during the five winter periods (RSAPs), the application rates per lane mile were reduced on all highways throughout the Lake George basin and not just on the "pilot" segment of Route 9N.
- The analysis of data for the five RSAPs provided by the NYSDOT showed that the Cl^- application rates per lane mile were reduced on all highways throughout the Lake George basin and not just on the "pilot" segment of Route 9N.
- Based upon the data analyzed in this chapter, *the reduction of road salt application rates* combined with the significant increase in *the number of road salt application events* resulted in an increased amount of road salt added to Lake George basin highways, with the amount dependent upon which RSAP and watershed was being queried. Increased amounts ranged from 300-354 percent in the T63a/T61 watersheds and from 70-258 percent in the T41 watershed. T36a had increases of 119 percent for RSAP 2020-2021 and 258 percent for RSAP 2021-2022.
- The NYSDOT implemented an increased *number of application events* during RSAP 2019-2020 in association with the *reduced application rates* to maintain public safety and not necessarily in response to local weather severity.

1.10 Recommendations

The following recommendations are presented in the order of chapter sequence in the Final Report and are not listed in any ranking of priority indicating importance.

Chapter 2:

- The NYSDOT should continue the Route 9N Road Salt Reduction Pilot Program in Lake George and implement the best practices including continuous improvement based on review of previous seasons as well as collaboration with the existing SWiM® Lake George municipal models of the Towns of Lake George and Hague, and the Warren County DPW.
- The NYSDOT should partner with this study's investigators to support the monitoring program developed to determine the potential environmental changes from implementation of road salt reduction practices.
- The NYSDOT should reconvene the Adirondack Road Salt Strategic Working Group and the Route 9N Pilot Tactical Work Group (TWG).
- The NYSDOT should make record-keeping and data publicly accessible and require reporting of dates, sources, types of materials used including anti-icing, amounts of materials applied, applications rates, treated lane miles, road conditions including temperature, and storm weather statistics.
- The NYSDOT should continuously apply best practices for road salt reduction for the Route 9N segment as per their detailed Action Plan, which would include more consistent use of brine for anti-icing.
- The NYSDOT should base snow and ice winter operation and management decisions on data collected and analyzed in post-storm evaluations applying technology from AVL salt tracking, road-side weather stations, and road-side cameras.
- New York State should utilize the Adirondack Road Salt Reduction Task Force Report to guide the state to become a national leader in sustainable snow and ice management and demonstrate the protection of vital natural resources including surface and ground water while maintaining public winter travel safety.

Chapter 10:

- Based upon our experience described herein with extracting, compiling, and re-formatting the NYSDOT road salt application data, it is clear that the agency needs to adopt a standard protocol for the road salt reduction pilot program currently on-going in the Lake George basin with input from others familiar with the current status of the data management systems currently in use.

Chapter 12

- The NYSDOT needs to accept the current evaluation of the road salt application program that has occurred in the Lake George basin during the previous five winter periods and design a program that applies 10 percent less on the "pilot" segment of Route 9N and maintains regular application rates on other state-maintained basin highways.

1.11 Literature Cited

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New York State Department of Transportation Road Salt Reduction Pilot Program

Final Report for the Lake Champlain Sea Grant Program

Chapter 2

Lake George Water Quality, Chloride and Road Salt Reduction in the Basin

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2.0 The State of the Lake: Thirty Years of Water Quality Monitoring on Lake George

Lake George is the largest body of water located entirely within the Adirondack Park in New York State. Historically, it has been called the "Queen of American Lakes" for its crystal clear waters and inherent natural beauty, and the lake has been a popular tourist attraction since the late 1800s (Farrell, personal communication).

Local concern for the preservation of water quality in Lake George has existed for many decades, primarily the result of activities initiated by The Lake George Association (LGA), the first lake conservation organization in the United States, formed in 1885. As a result of LGA efforts, the lake was classified as "AA Special" (Class AA-S) meaning (1) that water taken from the lake could be used as a public drinking water supply following treatment with chlorine and (2) that there shall be no discharge or disposal of sewage, industrial wastes or other wastes into these waters or into streams discharging to the lake (6 CRR-NY 701.3).

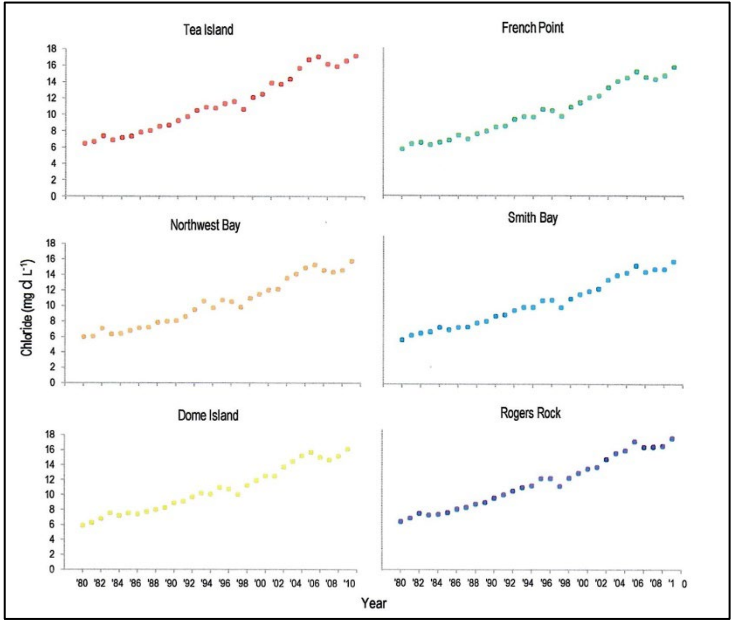
Increased tourism and development inflicted environmental consequences to Lake George ranging from concerns over nutrient loading from wastewater and stormwater runoff to acidification from atmospheric pollutants to effects of invasive species and salt loading from road salt de-icing in winter. These concerns prompted scientific efforts to better understand these ecosystem stressors and their effects and led to an extensive lake water quality monitoring program initiated during 1980. The program was conducted by Rensselaer Polytechnic Institute's Darrin Fresh Water Institute (DFWI) with financial support from The FUND for Lake George. The result was a long-term 30-year dataset which was described, discussed and published in a 2014 report entitled *The State of the Lake: Thirty Years of Water Quality Monitoring on Lake George, New York, 1980-2009* (Boylen et al. 2014).

The clearest trend evident from the 30-year monitoring program was the steady rise in sodium chloride, nearly tripling from about 9 mg NaCl L^{-1} in 1980 to nearly 26 mg NaCl L^{-1} in 2009. The salt comes from road de-icing applications within the watershed during winter and was well above the background of <1 mg NaCl L^{-1} typical of Adirondack lakes in undeveloped watersheds.

Calcium is usually the most abundant cation in lakes owing to chemical weathering of widespread calcareous rocks. While this was formerly true of Lake George, sodium chloride had now displaced calcium carbonate as the dominant dissolved salt. Concerns regarding the increases of sodium chloride were that it was near or possibly above the threshold for altering the phytoplankton community composition based on statistical analysis of diatom presence in sediment cores. Continued increases of salt loading in the watershed could also affect the circulation pattern of the lake, which might result in subtle alteration of its biological functioning.

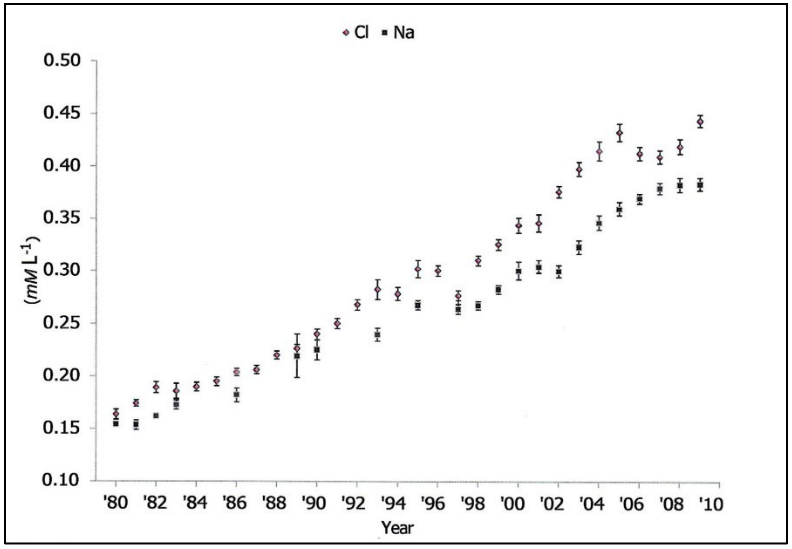
The concentrations of chlorides tripled in the lake from 1980 to 2017 from 5.8 mg L^{-1} to 17.76 mg L^{-1} (Boylen et al. 2014) (Figure 2-1).

Figure 2-1.



Sodium concentrations follow nearly identical trends as chloride when compared on a molar basis (Boylen et al. 2014) (Figure 2-2). Sodium concentrations on average were around 15% less than chloride concentrations in molar terms. This deficit is likely the result of catatonic exchange as salt-laden water moves through watershed soils (Mason et al. 1999). When present in excess, sodium displaces other soil cations because of simple mass action rather than a greater charge attraction (Langen et al. 2006, Kelting and Laxson 2010). The close molar correspondence of sodium and chloride ions in the lake samples leaves very little doubt that the main source is sodium chloride from road de-icing in the winter.

Figure 2-2.



As reported elsewhere, salt concentrations in Lake George had already increased substantially from pristine concentrations by 1980 (Sutherland et al. 2018 [reported in Lipka and Aulenbach, 1976]). Chloride concentrations in Adirondack lakes within roadless watersheds are typically below 1 mg L^{-1} (Baker er al. 1990b), compared with 5.8 mg L^{-1} in Lake George in 1980. The higher concentration in Lake George in 1980 is almost certainly the result of road salt application in the decades prior to 1980 (Sutherland et al. 2018). These increases in other Adirondack lakes within developed watersheds, including Lake Champlain, where chloride concentrations are nearly as high as in Lake George (Vermont and New York State Departments of Environmental Conservation 2012), confirm widespread watershed salinization from road salt application throughout the region (Langen et al. 2006).

Sustained increases of salt loading at the 2009 rate to the Lake George basin would result in lake concentrations of 34 mg Cl L^{-1} by about 2050 (Sutherland er al. 2018), which implies a corresponding Na^+ concentration of 20 mg L^{-1}, which may be harmful for heart or kidney patients (Hanes et al. 1970). Limiting loads of roadway de-icing salt to near current levels or reducing the load would ensure that this health threshold concentration is never approached.

2.1 The S.A.V.E. Lake George Partnership

The State of the Lake report issued in 2014 described three fundamental threats to Lake George including invasive species, rising salt levels and declining water quality and clarity. These threats prompted The FUND for Lake George to develop a mission leading the way to lasting protection with one goal: stopping the present decline of water quality and achieving sustained protection of Lake George for the next generation. This strategy for environmental and economic success relied on three main pillars for success including bold partnerships, program innovations and direct investments.

The formation of bold partnerships started with the S.A.V.E. (**S**top **A**quatic in**V**asives from **E**ntering) Lake George Partnership, a diverse organization of municipal representatives, conservation organizations and scientific experts speaking with one voice and demonstrating the power of diverse public and private interests acting in common purpose to uphold natural, community and economic values that make Lake George unique. This partnership successfully produced, through concerted action and investment, the first mandatory invasive species inspection and decontamination program east of the Mississippi River. Members of this partnership included Mayor Robert Blais (Village of Lake George), Supervisor John Strough (Town of Queensbury), Supervisor Dennis Dickinson (Town of Lake George), Supervisor Ron Conover (Town of Bolton), Supervisor Fred Monroe (Town of Chester/Warren County Board of Supervisors Chair), Supervisor Matt Simpson (Town of Horicon), Supervisor Bill Mason (Town of Queensbury at Large), Walt Lender (Executive Director, Lake George Association), Eric Siy

(Executive Director, The FUND for Lake George), Jeff Killeen (Chair, The FUND for Lake George) and Chris Navitsky (Lake George Waterkeeper).

To harness the energy of the S.A.V.E. Lake George Partnership, the core constituency started a concerted public/private program to reduce salt levels and expanded S.A.V.E. to mean **S**alt **A**batement is **V**ital to the **E**cology of Lake George. These discussions on the necessity of reducing road salt application resulted in the preparation of an MOU, the organizing tool successfully used by S.A.V.E. on invasive prevention, which had wide sign-on and support from all municipalities within the Lake George basin. This MOU detailed the case, provisions and timeline for an aggressive salt reduction plan called the Lake George Road Salt Reduction Initiative.

The MOU was an agreement among municipal governments to address the levels of chlorides entering Lake George by reducing the application of road salt for winter maintenance and de-icing practices, and a statement of intent to work in good faith to create a program to reduce road salt application levels. The case statement was:

- There are a total of approximately 680 lane miles of local, county, state , and federal roads and the average purchase rates as report by municipal staff totals and estimated 15,000 metric tons of salt per year,
- Salt levels have tripled in Lake George since 1980 and are thirty times above natural background characteristics of Adirondack lakes in undeveloped watersheds,
- Recent concentrations of chlorides in Lake George are at thresholds that can alter the composition of the phytoplankton, periphyton and macroinvertebrate communities altering the food web and hence change biological productivity of Lake George,
- Increase in salt loading in the watershed may affect the physical circulation of the lake by increasing vertical density gradients that are more difficult to mix, and,
- Toxic effects of road salt are observed in roadside vegetation where high concentrations of salt accumulate and persist, and damage is observed with the browning of foliage, premature defoliation and die back of terminal roots.

The signing municipalities agreed to the following steps to reduce road salt application through the following:

- Utilize Best Management Practices as demonstrated in New Hampshire,
- Investigate and consider equipment to better manage and monitor the application of road salt,
- Collect data using consistent methods on the quantities and application rates of road salts,
- Assess and tailor road salt application rates based on level of service, road grades and proximity to water bodies,
- Establish an education and training program for all highway department employees, and
- Participate in an annual "Road Salt Summit" to discuss new technologies, application methods, best management practices and research.

The S.A.V.E. Lake George Partnership held the first annual Lake George Road Salt Summit at the Sagamore Resort on September 28, 2015 which is considered the launch of the Lake George Road Salt Reduction Initiative. This event invited municipal and county elected officials, municipal and county highway department superintendents and staff, state agencies, private maintenance contractors and business owners to fulfil the initial steps of the MOU. Sessions included discussing the 'return on investment' on road salt reduction, local research projects, live equipment demonstrations and a best practice session sharing solutions and development. Figure 2-3 is a photograph from a presentation on brine application from the equipment demonstration session.

This Salt Summit prompted a meeting in October 2015 to develop an accurate baseline of road salt application rates within the Lake George basin to identify strategies for reducing road salt while maintaining road safety and was attended by all municipal and county superintendents as well as representatives from the New York State Department of Transportation. These first steps would be accomplished by utilizing GPS tracking software to track equipment and real-time application rates, track pavement temperatures, install onboard camera systems to record road conditions, and provide data analysis to optimize efforts to reduce road salt. Along with the tracking equipment, mechanical snow removing equipment improved by using Live Edge plows provided by MetalPless, and this was when operators began to embrace a change in practice and realize the potential of road salt reduction.

During the first few years of Lake George Road Salt Reduction Initiative, the S.A.V.E. Partnership continued to support the Salt Summits and used the regular meetings to update elected officials on municipal program progress. The members of S.A.V.E. recognized that to make the basin-wide reduction approach successful, it would be necessary to include New York State Department of Transportation ("NYSDOT") in reduction efforts. The

NYSDOT were attendees at the first summits and participated during a panel discussion on obstacles to reduction during the second summit, but they were not active participants in reduction efforts.

Figure 2-3

Mayor Robert Blais, S.A.V.E. Lake George Partnership Chair, raised concern regarding the observed excessive salt applications by NYSDOT which were counterproductive to reduction efforts being practiced by local municipalities. Mayor Blais' letter to NYSDOT Warren County Assistant Engineer Jim Davis brought the need for the Partnership to fully engage NYSDOT in the road salt reduction initiative. This prompted a November 27, 2017 letter to Governor Andrew Cuomo from the S.A.V.E. Lake George Partnership introducing him to the Lake George Road Salt Reduction Initiative and asking for a partnership at the State level with the following requests:

- For New York State to match the local investment of $150,000 towards implementing Best Practices in salt reduction by applying continuous measuring of application rates, training, and upfitting highway departments with latest equipment. It cited the dramatic progress already achieved by the Town of Lake George with 30% reduction in application rates, and
- For NYSDOT winter maintenance crews to participate directly as partners in the Lake George Road Salt Reduction Initiative.

This correspondence resulted in a February 2018 meeting at NYSDOT headquarters between S.A.V.E. and NYSDOT upper management including Bob Martz, Deputy Commissioner, and Todd Westhuis, Chief of Staff. Discussion topics included an introduction to the Lake George Road Salt reduction Initiative, NYSDOT current salt reduction initiatives and possible partnership opportunities. NYSDOT stated that (1) using treated salt (Clear Lane [MgCl]), they were able to reduce road salt 40 percent in Cascades Lake (Lake Placid) region, (2) they were using two-stage plows for improved mechanical removal, (3) they implemented brine making in Warren County that was being applied and (4) they were at the lower threshold of salt application rates of 180 lbs./lane mile. It was related to NYSDOT that reduced salt application was not the perception of the municipalities or residents in the basin. The NYSDOT said that they were looking into a designated reduced salt zone along Lake George.

This above proceedings resulted in NYSDOT responding in April 2018 that they were going to commit to a Pilot Program that would be Region 1 Priority, according to Bob Martz and Rob Fitch. This Pilot would work with the Warren County Resident Engineer to minimize salt through (1) the use of two stage plows (relocate existing equipment), (2) the use of AVL (Automated Vehicle Location) tracking equipment on trucks to determine location and amount of material, (3) the use of existing brine capability, and (4) having Snow & Ice Supervisors come and meet to reinforce the use of salt and develop an operation plan for reduction parameters. It was said that the reduction plan would be implemented during the last four weeks of the 2017-2018 winter season.

2.2 The Adirondack Road Salt Working Group

Road salt has been an ongoing concern throughout the Adirondack Park and has been highlighted through the research of the Adirondack Watershed Institute ("AWI") led by Dr. Dan Kelting and through earlier road salt conferences held by AdkAction in the early 2010s. This prompted a core group of involved individuals, self labelled the Adirondack Road Salt Working Group ("RSWG") to move this issue further by highlighting the findings of the research that showed the regional salinization of Adirondack lakes by road salt and greater influence from state roads. The RSWG consisted of the late Randy Preston, Town of Wilmington Supervisor; Dr. Dan Kelting, Adirondack Watershed Institute; Lee Keet, Adirondack Council Board member; Brittany Christenson, AdkAction Executive Director; Dr. Brendan Wiltse, Adirondack Watershed Institute; and Chris Navitsky, Lake George Waterkeeper.

The RSWG would hold routine meetings, typically every other month or more frequently, if necessary, to discuss how to raise attention to this issue from NYSDOT and Albany state government. During 2016, when the AWI was conducting a groundwater study to determine the influence of road salt runoff from roads to residential drinking wells in the Adirondack Park, meetings were held with New York State Department of Environmental Conservation (NYSDEC) Commissioner Seggos and executive staff. At a December 2016 meeting with NYSDEC, the RSWG presented the science of road salt impacts to surface waters and biological communities and requested that the administration:

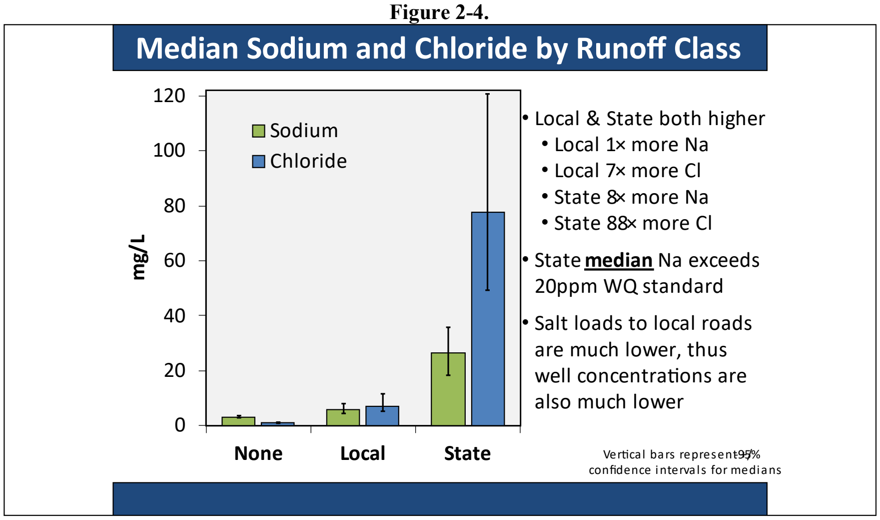
- Implement a park-wide Sustainable Salt Reduction Program,
- Establish an advisory committee similar to one created for aquatic invasive species for the Park and,
- Consider appointing a "Salt Czar" for coordinate the work, possibly NYSDOT Director of Operations.

Through 2017, meetings continued to be held with NYSDEC and NYSDOT to keep them updated on findings. Throughout these meetings, NYSDOT continued to state (1) that their salt applications were just enough to prevent hard pack from forming, (2) that their focus was to remove snow via plow combined with using MgCl, CaCl, and NaCl brines for pretreatment, (3) that every truck was equipped with saddle tanks, and (4) that they have other plow updated technology (i.e. Live-Edge plows). NYSDOT also stated that they had $25 M for salt storage infrastructure funding and there was $5M in Environmental Protection Fund (EPF) for Source Water Assessment Planning Studies.

Meanwhile, during 2017 and 2018, Kelting conducted the Adirondack Resident Individual Drinking Well Survey where individuals were contacted through cold calls, contact list emails, or through flyers. Interested parties would participate in an online survey of general well construction and plumbing information, and receive a sample kit with instructions to return with a water sample. Through early 2018, a total of 358 private wells were sampled with 132 receiving no road runoff, 112 receiving local road runoff and 114 receiving state road runoff. The following were the findings of the study and previous efforts:

- Road salting has resulted in regional salinization of surface and groundwater (Kelting et al. 2012),
- State roads had the highest salt loads and the greatest impact on Adirondack waters (Kelting et al. 2012),
- 84% of variation in lake salinization (Kelting, D. 2018. Unpublished presentation),
- 55 percent of wells exceeded Na water quality standard (Kelting, 2018. Unpublished presentation), and,
- 25 percent of wells exceeded chloride water quality standard (Kelting, 2018. Unpublished presentation).

Figure 2-4.



These data were presented by Kelting and the RSWG to NYSDEC and NYSDOT, and a joint meeting with NYSDEC and NYSDOT executive staff was held in February 2018. At this meeting, the data were questioned by state agencies including (1) whether chloride input from septic systems were evaluated, (2) whether fecal coliform testing was performed to determine influence from septic systems, (3) concern regarding the construction of wells, (4) was information obtained regarding the setback from road, (5) did the survey include the number of water softeners and (6) could it be proven that the wells were properly flushed. These questions were rebutted by Kelting based on his analysis of unconfined versus confined groundwater, which were similarly contaminated, and there was a 95% confidence interval. NYSDOT Chief of Staff Todd Westhuis then stated that the agency was looking at opportunities for improvement, to work on this important issue as a team and would like to meet again.

In May 2018, a meeting with NYSDEC, NYSDOT and NYSDOH executive staff was held to describe NYSDOT plans for a second Pilot Program for Mirror Lake (Lake Placid) to support the previous discussed Lake George Pilot Program and to show state agencies and environmental advocates working together. The Action Plan would work with local municipalities and utilize brine, buy Live-Edge plows, use two-stage plows, expand the use of treated salt, implement AVL tracking on equipment, monitor water quality, apply post storm evaluations, assess drainage and environmental conditions, evaluate the use of abrasives and mixes with varying topography, and establish a driver's education program. NYSDOT also wanted to establish a tactical working group at the municipal level and partner with private landowners and formalize a Strategic Work Group with the RSWG.

2.3 The NYSDOT Road Salt Reduction Pilot Program

On May 30, 2018, NYSDOT Acting Commissioner Paul Karas announced two innovative pilot programs to help rejuvenate Mirror Lake and Lake George by reducing the application of road salt while still protecting the safety of the travelling public. Commissioner Karas was quoted as saying "Lake George and Mirror Lake are known worldwide for their pristine beauty, and these new pilot programs will strive to keep our roadways safe while enhancing environmental sustainability. The Adirondacks are a national treasure and as stewards of many roads within the Park, we are committed to working with the stakeholders to reduce salt and retain the Park's beauty for generations to come."

The pilot program on Lake George would span a 17-mile length of State Route 9N from the Village of Lake George to the Town of Bolton and would leverage all the DOT's best management practices to reduce salt application rates. It was stated that road salt was one of the challenges impacting the Adirondack Park's cherished aquatic ecosystems and these best management practices were intended to help protect the environment as well as encourage commercial and private landowners to implement similar reductions.

In addition, the NYSDOT, along with NYSDEC and NYSDOH, would establish a strategic working group which would include participating municipalities and organizations such as AdkAction, The FUND for Lake George and The Lake George Waterkeeper to evaluate the effectiveness of the pilots, which could potentially have an impact on snow and ice practices statewide.

The NYSDOT stated that the intent of these pilots was to utilize all of the Department's best management practices, and then evaluate the degree of salt reduction it can implement without negatively affecting the safety of the traveling public. The best management practices (BMPs) that the Department would implement as part of the pilot programs were:

- Using brine for pre-storm anti-icing.
- The use of a truck with a segmented plow blade and other alternative blade technologies to mechanically remove as much snow and ice from the pavement as possible.
- Using treated salt, which is more effective at colder temperatures.
- Using Automatic Vehicle Location (AVL) equipment that can track salt application rates and regularly calibrate the salt usage.
- Closely monitoring salt use during storms while performing post-storm evaluations to review application rates and the performance of those rates.
- State agencies will work with partners in the park to monitor surface/groundwater quality in pilot areas.
- Evaluation of cutting back some trees in key locations to allow the sun to melt the snow and ice on portions of shaded roadways.
- Evaluation of abrasives and abrasive mixes.
- Leveraging other Maintenance Program Areas (drainage, pavement, environmental) to see how they can be used to facilitate snow and ice operations, and subsequently reduce the dependence on road salt.

- Consider other measures, such as new signage for motorists along State Route 9N, to ensure that pilots are conducted in a safe manner.

The pilots were to be implemented for the 2018-19 snow and ice season. At the close of the season, a review would be performed to determine the effectiveness of the pilots, including on safety, and to consider the feasibility of expanding the salt reduction practice.

These pilot projects were discussed formally at meeting convened at the Paul Smith's College on June 18, 2018 with representatives from NYSDOT, NYSDEC, NYSDOH and the RSWG. Attendees from NYSDOT included Chief of Staff Todd Westhuis, Bob Martz, Rob Fitch (Transportation Maintenance), Assistant Commissioner Sam Zhou, Steve Kokkoris (Region 7 Director), Nicholas Choubah (Region 9 Director), Assistant Commissioner Thomas McIntyre and Assistant Commissioner Sean Hennessey. Attendees from the NYSDEC included Executive Deputy Commissioner Ken Lynch, Fred Dunlap (Lake Champlain Basin Coordinator) and Tom Cohen; and from the NYSDOH, Lloyd Wilson (Research Scientist). The discussion topics included a MOU between state agencies and the RSWG, review of the Draft Group Charter and a presentation on the 2018-19 Salt Reduction Pilots, which included discussion of the monitoring program. It was determined that a subgroup should meet to continue development of, and finalize the monitoring program.

2.4 The NYSDOT Road Salt Reduction Pilot Program Monitoring Project

As a sequel to the meeting held on June 18, 2018, a meeting to discuss a monitoring program for the two NYSDOT Road Salt Reduction Pilot Projects was scheduled for July 18, 2018 at the offices of The FUND for Lake George. Dan Kelting, Jim Sutherland and Chris Navitsky prepared a Draft Monitoring Plan titled "Environmental Monitoring Work-Plan to Evaluate the NYSDOT Reduced Road Salt Pilot Projects in the Ausable River and Lake George Watersheds". The Draft Plan contained background and rationale for the program, goals and objectives, study design, instrumentation, summary of sampling, processing and data analysis, reporting and program budget. Each pilot project would establish two instrumented tributaries within the pilot route, two instrumented tributaries outside each pilot route, and establish two instrumented wells downslope and 2 instrumented wells upslope along each pilot route, based on NYSDOT input.

The July 18 meeting was attended by Rob Fitch (NYSDOT), Mike Lashmet (NYSDOT), Joe Thompson (NYSDOT), Dan Kelting, Jim Sutherland and Chris Navitsky. Discussions at the meeting focused on the need for consistent lab processing and analysis, instrumentation to be installed, whether existing wells could be used or were new wells required, and the need for a data sharing agreement. It also was noted that the tributaries already were being sampled within the Route 9N Pilot as there was concern about the need to develop a strong sampling database of existing conditions before the start of the 2018-19 snow and ice season. Follow-up from the meeting included a request from NYSDOT attendees for an electronic copy of the proposal for Department review and future revisions including sampling of the groundwater wells.

It was shortly after that meeting that there was a break in communications from NYSDOT regarding the proposed study. It was at this time that residents in the Adirondack Park had filed a Notice of Intent to sue NYSDOT regarding the high chloride and sodium concentrations in the individual drinking wells that were a part of the Adirondack Watershed Institute study. It was reported there was concern that Kelting would be an expert witness in the potential legal action and that NYSDOT would have to be quiet around Kelting. There also was concern of the need for a third party to conduct the research, someone not involved with the working groups. There also was concern expressed by NYSDOT about the groundwater well sampling – liability concerns of using an existing well, variables around unknown construction and the need for easements if new wells were installed and associated liabilities.

It was at this time that The FUND for Lake George decided to proceed with the planned study without any support or involvement from the NYSDOT. It soon was learned that NYSDOT had contracted with the USGS to development and implement a monitoring program for the proposed Road Salt Reduction Pilot Project for the State Route 86 project. There was never a reason communicated by the NYSDOT regarding the decision to not study the State Route 9N Pilot Project, but it was stated at a Strategic Working Group meeting on October 15, 2018 attended by NYSDOT, NYSDEC and the RSWG that these projects are "no small investment by the DOT which includes trucks, equipment, etc.", so perhaps funding was a reason. It should be noted that as of January 2019, not all groundwater sampling wells had been installed for the State Route 86 study.

2.5 The NYSDOT Rt 9N Road Salt Reduction Pilot Program Assessment

The NYSDOT Route 9N Pilot has completed four snow and ice seasons since it was first implemented for the 2018-2019 snow and ice season. The following material is an assessment of the NYSDOT Route 9N Road Salt Reduction Pilot Program utilizing the BMPs that were cited in the Press Release Announcement in May 2018 and in NYSDOT presentations. The assessment is based on the minutes from the Strategic Work Group (SWG) meetings that discussed the pilot status (October 10, 2019), the 2019-2020 Seasonal Wrap-Up document (distributed during a July 27, 2020 SWG meeting) and from the author's (Chris Navitsky) personal experiences from driving the entire pilot route nearly every day.

2.5.1 Use of brine for pre-storm anti-icing

Brine, or water solution consisting of 23.7 percent sodium chloride, is a pretreatment practice to assist in anti-icing or the prevention of snow creating a direct bond to the road and forming ice. When this occurs, the ice becomes very difficult to remove mechanically and requires more solid rock salt for removal. Brine typically is applied to road surfaces 24-48 hours ahead of a snow event, dries on the road in white lines (Figure 2-5) and turns back into brine when the first snowfall liquifies it (Figure 2-6). This creates a layer preventing the bonding to the road surface. Numerous studies provide evidence that brine applications reduce road salt use and application rates (Clonch and Pickworth 2016; Clear Roads 2015; Hensley and Valenti 2015; APWA 2015; Snow Business Magazine 2017).

Figure 2-5.

Figure 2-6.

The NYSDOT assessment of the implementation and use of brine was as follows:

- 2018-2019: Continued deployment of improved practices – pre-storm anti-icing with salt brine when appropriate. This will continue to be part of our anti-icing solution here and throughout NYSDOT. (NYSDOT 2019)
- 2019-2020: Brining operations on Lake George beats were limited due to lack of opportunities. The 9N beat was able to perform anti-icing operations with brine on a few occasions and reported that it worked well. Next season brine will continue to be used to further wet the treated salt both activating and continuing to curb the bounce and scatter of material. (NYSDOT 2020).

The author's observations from daily commuting on the entire Route 9N Pilot segment was that brine application was very limited, perhaps only once to twice during a season. NYSDOT stated that applications were limited due to lack of opportunities. It is not clear what "the lack of opportunities" means; is it related to road temperature conditions, anticipated air temperatures, infrastructure, supplies, etc.? It is noted that the Town of Hague applied brine on the 15-mile stretch of Route 9N north of the pilot segment, including over Tongue Mountain as documented in Figures 2-5, 2-6 and 2-7, for most storm events during this time period, and expanded their brine operations. The Town of Lake George, whose roads interconnect with the Route 9N Pilot continually has applied brine as pre-treatment for storm events since 2017. It is also noted that NYSDOT has been applying brine regularly ahead of storms on the Northway (I-87) and its ramps on Exit 22, which intersections Rote 9N near the southern extent of the Pilot Project area.

Figure 2-7.

2.5.2 Use of segmented edge plow blades

Segmented edge plow blades are a new technology developed in the 2010s that segment the plow blade into a series of shorter blades instead of a single continuous blade. This allows the smaller blade(s) to better conform with the micro-contours of the road surface, such as wheel ruts, superelevated roads, etc., along the blade-road interface and results in improved, more efficient mechanical snow removal (Figure 2-8). This is a BMP that prevents the bond of snow with the road surface through better mechanical removal and provides better opportunity for bare pavement conditions which leads to less road salt application. It has been stated that road salt use has been decreased by 40% though the use of the LiveEdge plow, model produced by MetalPless (Vanderson 2017). Reductions were verified through data from an unpublished study presented at the 2017 Lake George Salt Summit where the Town of Lake George operators reduced road salt applications by 25 percent during initial use of the plow (Omer 2017).

Figure 2-8.

The improved Level of Service is demonstrated with the use of roadside cameras that have been used in the Lake George Road Salt Reduction Initiative, funded through the Lake George Association. This set of photos (Figures 2-9 and 2-10) were taken at the same time during a storm event in the Town of Lake George and compares two similar route conditions but one serviced without a truck with a segmented plow (Figure 2-9) and one with a segmented plow (Figure 2-10). The photo on the left was taken just after a plow passed through and the one on the right shows a segmented plow in action. It is obvious that the road serviced with the segmented plow provides a condition of more bare pavement.

Figure 2-9.

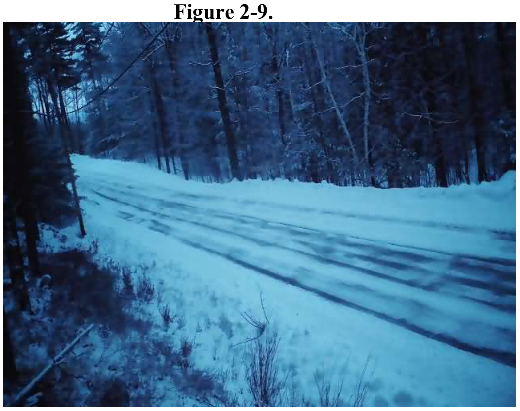


Figure 2-10.

The NYSDOT assessment of the use of the segmented plow technology was as follows:

- 2018-2019: Continued deployment of improved practices; two-stage plow (two separate plows/drag behind plow) use vs. LiveEdge plow. It was mentioned that the LiveEdge plow caused significant damage to the pavement on Route 86. NYSDOT will look to use two staged plow here for better snow removal without damaging the pavement (NYSDOT 2019).
- 2019-2020: The two-stage plow removed snow very well but was most effective for cleanup operations. The pre-season paving shim course did hold up well to the two-stage plow, the ability to not use it on every trip proved to be very beneficial in the operators and supervisors' eyes. There were a few instances when the operators would want to go back to the heavier application rates but in those cases the shift supervisors intervened. Last year's paving project continues now and should contribute to next year's S&I operations by strengthening the pavement section and producing a smooth surface to plow. (NYSDOT 2020)

The NYSDOT were utilizing the two-stage plow, which consisted of a second plow similar to a York Rake dragging behind the main plow blade. Observations of the Route 9N Pilot route were that the pavement surface was at or near bare conditions during the Pilot. NYSDOT was asked on several occasions why the segmented plow technology was not implemented since it had been used successfully and supported by municipalities that were participants in the Lake George Road Salt Reduction Initiative. NYSDOT stated there were concerns about the damage the plows had caused to pavement due to the compression of the blades on the road as well as problems with timely and reliable servicing on the plow. It is the author's understanding that NYSDOT even held special meetings with the product supplier and determined the segmented plow would not be the preferred applied technology for the Pilot.

2.5.3 Use of treated salt

Treated salt refers to regular rock salt (sodium chloride) that is pre-wet and treated with a series of additives, including liquid magnesium chloride, for a longer lasting, more environmentally friendly and less corrosive snow melt (Cargill 2023). Treated salt (1) is proven to reduce cost per lane mile by achieving 30 percent less road scatter versus untreated rock salt, (2) melts faster and deices snow and ice at lower temperature, (3) is provided in a green color that is easy to see and reduces spreading waste, (4) is designed to reduce clumping and binding in spreaders, and (5) reduces corrosion on equipment up to 67 percent.

The NYSDOT assessment of the use of treated salt was as follows:

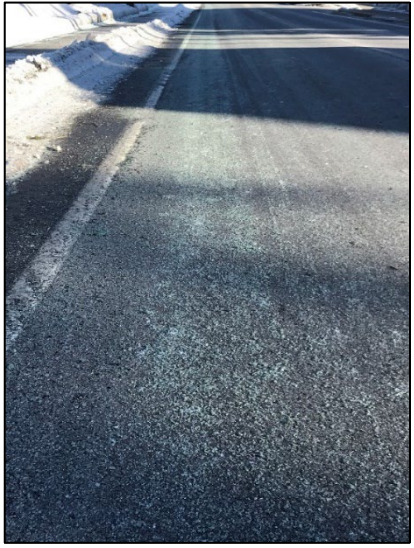
- 2018-2019: Warren County went to full treated magnesium chloride salts after last round of pilots. The magnesium chloride is considered "prewet". Exclusive use of treat salt. (NYSDOT 2019)
- 2019-2020: Both Pilot locations were using treated material at a lower application rate and to control bounce and scatter. Next season brine will continue to be used to further wet the treated salt both activating and continuing to curb bounce and scatter of material. (NYSDOT 2020).

The author's (CN) observations from daily commuting on the entire Route 9N Pilot segment were that that the use of treated salt was utilized by NYSDOT since the first season of the pilot (2018-19). However, there did appear to be instances of over application and/or application at times it may not have been necessary. For example, refer to

Figures 2-11 and 2-12 for examples of excessive and/or unnecessary road salt application on Route 9N that were provided to NYSDOT leadership at a December 19, 2018 meeting. There are many instances of observations of treated salt applications that appear to have been in excess of amounts needed based on the weather conditions. However, it is recognized that the safety of the public is the first priority of the NYSDOT and weather forecasts and road conditions can change suddenly and instantly or may never develop into the event that was predicted.

Figure 2-11

Figure 2-12.

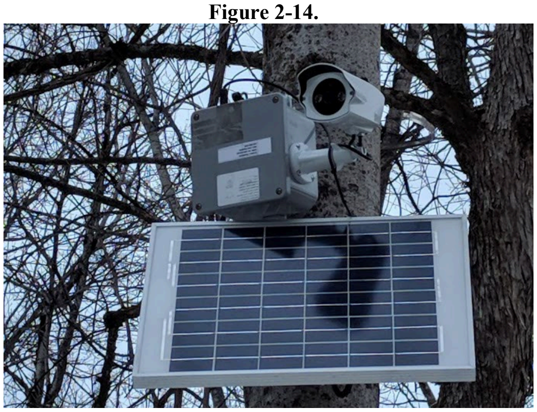


2.5.4 Use of enhanced AVL/GPS trackers

Automated Vehicle Location (AVL) and Global Positioning System (GPS) trackers have been utilized for winter maintenance operations by highway departments and private operators around the country. In general, these devices track vehicle locations for operational and safety purposes, but some agencies apply the devices and technology to collect data for planning, operations, and inventory tracking to improve efficiency and response (Figure 2-13). For example, AVL/GPS technology can be integrated with spreader controllers, plow position sensors, and air and pavement temperatures sensors to track material use and road weather for operational analysis (Clear Roads 2018). Another example is the Lake George Road Salt Reduction initiative where local municipalities have used AVL/GPS in coordination with plow technologies and roadside cameras (Figure 2-14) to monitor weather conditions that document reduction of road salt use of up to 50 percent.

Figure 2-13.

Figure 2-14.



The NYSDOT assessment of the use of AVL/GPS technology was as follows:

- 2018-2019: No information was provided by NYSDOT (NYSDOT 2019)
- 2019-2020: No information was provided by NYSDOT (NYSDOT 2020

The author's observations regarding the utilization of AVL/GPS tracking units are from interactions with NYSDOT staff at meetings and through data information requests. At a Pilot Kickoff meeting with the RSWG and NYSDOT on June 18, 2018, NYSDOT stated they would utilize enhanced AVL/GPS tracking with "extra equipment to communicate on 30 second pings". Data tracking and the sharing of that information was discussed during the initial environmental monitoring work plans for the Pilot Program on July 18, 2018 with questions regarding the type of equipment NYSDOT would utilize and how the data would be shared, possibly with an agreement. NYSDOT representatives wanted to share knowledge with The FUND for Lake George consultant WIT Advisers regarding tracking information systems.

At an October 2018 meeting, NYSDOT expressed concerns with the ATT Webtech system and they were unsure of the frequency of data collection available via AVL/GPS units. At a December 11, 2018 meeting, the RSWG was told that NYSDOT legal team informed the NYSDOT representative they should not share any data or results in response to the potential legal claims by residents whose drinking wells have been claimed to have been impacted. Therefore, any data would have to requested through Freedom Of Information Law (FOIL). At a September 2019 RSWG/NYSDOT meeting, NYSDOT stated that road sensors were installed in trucks as part of a new build and AVL Precise Solution (new tracking instrument) with Samsara interface tracking were installed and they were gathering information. However, from Freedom of Information Law (FOIL) requests that the authors had to submit to obtain salt application data in the pilot study areas, it appeared that the data provided for snow and ice season 2019-2020 and 2021-2022 was not collected via AVL/GPS units since the salt application rates were not broken out into individual data points but totalized and averaged for the entire beat/route of the truck. But the salt application data received for the snow and ice season 2020-2021 was provided in individual segments every 10 seconds of the route and would be the data format of AVL/GPS. Therefore, it appears that there was no consistent use of AVL/GPS tracking units during the Pilot Study.

2.5.5 Monitoring of practices during events and post-event reviews

Monitoring of road salt applications during events and in post-event reviews is extremely beneficial to determine the result of the application of best practices including an analysis of weather conditions. This is when the AVL/GPS tracking data is valuable, especially when cameras are implemented to record actual road conditions and Level of Service (LOS) in relation to operator's decisions and supervisor directives. The road cameras installed as part of the Lake George Road Salt Reduction Initiative have been extremely useful to determine the effectiveness of brine application and whether or when to deploy operators to specific routes or hot spots.

NYSDOT assessment of monitoring of practices during events and post-event reviews was:

- 2018-2019: Continued to improve practices through focused S&I performance measurements and focused training for operators and supervisors. Monitor accident history related to snow and ice conditions and subsequent yearly analysis will be done and baseline accident information has been conducted and subsequent yearly analysis will be done as part of a larger Level of Service S&I Program (NYSDOT 2019)
- 2019-2020: In terms of Level of Service resulting from the reduced application rates, the observation was that the general conditions of the beat were worse than in previous years with more run off the road accidents. Of note was a jackknifed tractor trailer that closed the road for several hours, but supervisors indicated it was operator judgement not highway conditions. Other accidents were minor with most not requiring emergency response for injuries; personal property damage was minimal (NYSDOT 2020)

The author's observations regarding the monitoring of practices during events and post-events reviews are from interaction with NYSDOT staff at various meetings. At a May 20, 2019 meeting with NYSDOT Commissioner Dominquez, she stated that the pilot was a success, DOT was committed and this was a cultural change. At a September 2019 meeting with NYSDOT, DOT stated there seems to be improvement with application rates and the pilots were going well. One aspect DOT referenced at several meetings was the new partnership with University of Albany Center for Excellence and Mesonet that would help with forecasting for better planning and developing a Storm Severity Index to be utilized for post-event analysis.

2.5.6 Utilizing Management Program Areas to address conditions to reduce road salt

Specific conditions of the road or the very localized surroundings can have a direct effect on snow and ice management and subsequent road salt usage. Examples include the evaluation of cutting back trees in key locations to allow the sun to melt the snow and ice on portions of shaded roadways or addressing drainage from adjacent upland sources that could create runoff that freezes. Pavement condition, such as potholes or wheel ruts, and cross slope can greatly affect how runoff flows from a road surface, whether ponding occurs or whether a plow can effectively remove snow that can build up into ice.

NYSDOT assessment of Management Program Area improvements to address conditions to reduce road salt was:

- 2018-2019: Paving and drainage improvements and repairs were performed. This will hopefully reduce the need for spot treatment applications.
- 2019-2020: Recommended program area improvements include:
    - Environmental – Tree removal locations typically on the south and east sides of the corridor have been identified as cold spots. Pavement temperatures in these locations will typically run 5°F colder which is significant. The number of trees to be removed is significant and will require additional survey for scope and cost of work. Again, considerations for what is on state forest preserve will need to be made and might possibly require a land bank transfer.
    - Drainage – There are several areas where drainage improvements can be made along this beat that include driveway grading in cut sections where driveway runoff produces icing conditions, the Forest Hill section should be looked at for drainage improvements, and approximately 20 other locations have been identified for work including closed drainage, gutter and regrading improvements. These improvements will help S&I operations and these locations should be considered for work through the Where and When D contract.
    - Pavement Management – Last year's paving project continues now and should contribute to next year's S&I operations by strengthening the pavement section and producing a smooth surface to plow. As indicated earlier, residential driveway grading and possible drainage interceptors could be introduced but this work is beyond what maintenance forces could deliver considering the other safety sensitive work required each year.

The author's observations regarding the Maintenance Program Area improvements in environmental, drainage and pavement management are based on commuting the Pilot Project daily and permitting knowledge in the area. There is agreement regarding the potential of opening up tree canopy in some areas which would increase sun exposure and reduce the number of trees that can fall across the road. Regarding drainage, the Waterkeeper believes that NYSDOT should express concern about driveway and road runoff to municipal planning boards because these drainage issues are not considered by boards during the review process. This applies to the Forest Hills area as well as the Diamond Point subdivision to name a few examples. The repaving projects along Route 9N have been a tremendous improvement for snow and ice removal along the corridor. The pavement improvements along State Route 9N have been very beneficial for improved snow removal from the surface and apparent return to the desired Level of Service. However, it does not always appear this is connected to a reduction in road salt application as evident in Figures 2-11 and 2-12.

2.5.7 Tactical Working Group

NYSDOT stated Tactical Working Groups would be comprised of local stakeholders for each Pilot Project and would be sponsored by a local municipal leader. Other members would include elected officials, public works/highway departments, business leaders, landowners and local advocates as well as representatives from NYSDOT and NYSDEC. NYSDOT would coordinate agendas and meeting dates with the local municipal leader who was designed as the Chair.

NYSDOT Deputy Commissioner Sam Zhou contacted Village of Lake George Mayor Robert Blais to Chair the Tactical Working Group and the first meeting was held on August 9, 2018 at the Lake George Village Hall. NYSDOT attendees were Rob Fitch, Joe Thompson, Mike Lashmet and Kurt Korsenberg and local stakeholders included Town of Bolton Supervisor Ron Conover, Lake George Town Council member Marrisa Muratori, Bolton resident John Gaddy, Tom Guay (Sagamore Resort), Fred Vogel (Cresthaven Resort), Bolton Highway Department Superintendent Bill Sherman, and Village of Lake George DPW Superintendent Dave Harrington.

The NYSDOT gave a presentation similar to the one presented to the RSWG and referenced important and successful pilot projects they had previously implemented in the Adirondacks, such as Cascades Lakes area where a 40 percent road salt reduction was reported. Other agenda items were discussion of Level of Service goals, local training programs, recognizing the effort of the Town of Lake George Highway Department and participation in the upcoming Lake George Salt Summit. The water quality sampling agenda item was not discussed at this meeting although it had been on the agenda. It was a good outreach kickoff meeting with plenty of discussion. NYSDOT stated there was additional outreach through the Tactical Work Group such as training and calibration assistance, which was conducted with the Town of Bolton in 2019. The second and last meeting of the Tactical Working

Group was held in January 2020 at the Bolton Town Hall. This consisted of an update from NYSDOT and focused on the Town of Hague progress on brining and their salt reduction.

2.6 The NYSDOT Route 9N Pilot Program Monitoring Project and NYSDOT Data Sharing

The stated goals for the proposed environmental monitoring program were to:

> **Goal #1**: Evaluate progress towards achieving the goal of continuous and statistically significant reversals in salt loads and concentrations in surface and ground waters in the pilot areas, and
>
> **Goal #2**: Provide environmental data needed to optimize maintenance practices to achieve Goal #1.

The major objectives for conducting the monitoring were to:

> **Objective #1**: Evaluate changes in stream and groundwater chemistry in response to reduced road salt application with respect to chloride and cations (calcium, magnesium, sodium, potassium) and whether these changes are significant when compared with road salt application at un-reduced application rates, and
>
> **Objective #2**: Establish a valid field sampling protocol that can be used in the long-term monitoring of Lake George streams and groundwater to document changes in the chemical characteristics.

As discussed in the previous section, NYSDOT decided not to participate in the environmental monitoring of the proposed Route 9N Pilot Project as they felt the study needed to be completed by a neutral third party. Therefore, no agreement was made with the study team for access to the NYSDOT road salt application data. These data were necessary for any productive evaluation of a road salt reduction pilot program to determine if application rates were being reduced and to determine if there were corresponding changes in the water quality data.

In addition, we were informed at a December 11, 2018 RSWG/NYSDOT meeting that the NYSDOT legal staff advised that there could be no sharing of data or results from either pilot study road salt application rates until such time that any claims against NYSDOT regarding potential drinking well contamination were resolved.

Thus, the study team determined it would be necessary to submit Freedom Of Information Law ("FOIL") requests to the NYSDOT to obtain the road salt application data for four sections of state roads located within the four Lake George study watersheds. Highway data were requested utilizing the NYSDOT reference markers to limit the data requested to specific highway segments. Figure 2-15 is an image of a NYSDOT highway reference marker.

Figure 2-15.

The specific sections of state highways requested were:

- NYS Route 9N – Between Reference Markers 9N/1702/1265 & 9N/1702/1260
- NYS Route 9N – Between Reference Markers 9N/1702/1276 & 9N/1702/1268
- NYS Route 9 – Between Reference Markers 9/1710/2121 & 9/1710/2104
- NYS Route 9L – Between Reference Markers 9L/1701/1150 & 9L/1701/1161

The FOIL requests were broken into three groups of data requests for specific time periods:

- FOIL #1 (FMO-20-016927) – Submitted January 30, 2020 for period October 2018 through January 2020.
- FOIL #2 – Submitted November 11, 2021 for time period between January 2020 through October 2021.
- FOIL #3 – Submitted May 19, 2022 for time period between November 2021 through May 2022.

The NYSDOT response to these FOIL requests were characterized as extremely slow. FOIL #1 was received on March 24, 2021, about 14 months after the initial request. A total of six extensions were granted by the NYSDOT to itself on April 10, June 5, July 30, October 1, and November 25, 2020 and January 21, 2021. It was noted that these extensions occurred during the beginning of the COVID-19 pandemic when there were government office closures and the time extensions contained the following language "*As part of the ongoing response to the COVID-19 pandemic, some or all agency employees may be working off-site. As such, there may be delays in response to FOIL requests. If a record responsive to a request is only available in hard-copy format, that record's availability will be limited until further notice. Thank you for your patience during this extraordinary time.*"

When FOIL #1 was received and reviewed, it was determined that our request was not properly filled with the requested highway segments; instead, we received salt application data for the western portion of New York State. After several email exchanges with NYSDOT Records Access Officers, the correct data were received on April 5, 2021. The data, however, did not have coordinates for data points and did not contain any explanation of the data. After a May 2021 meeting with Tood Westhuis, NYSDOT Chief of Staff, author CN was directed to request tutorial sessions with NYSDOT to correctly understand and interpret the data and these requests started on May 5, 2021 and were re-submitted monthly to the NYSDOT Records Access Officer. In September 2021 we reached out directly to the Snow and Ice Management Department and were able to receive support regarding the data.

The FOIL #2 request proceeded in a similar delayed manner with time extensions granted by the agency to itself on December 30, 2021 and March 4, 2022. Return communications from NYSDOT on this FOIL ceased despite requests sent from the author to NYSDOT FOIL Record Assess Officers on July 5, 2022, August 12, 2022 and November 14, 2022. It was at the time of the last (November) correspondence that the NYSDOT Records Assess Officer informed me that the FOIL response was sent on April 4, 2022 but was returned since the file size was too big for our server and was resent in August and again in November 2022. It finally was determined that the server deemed the email as "Spam" and was not received. Upon review, it was determined that these data did include coordinates for individual data points to pin-point actual salt applications throughout the beat route.

FOIL #3 had a shorter delivery period with NYSDOT self-granted time extensions on July 1, 2022 and August 12, 2022. The FOIL #3 response was received on November 9, 2022.

As apparent through this FOIL process, the inability of timely delivery of FOIL requests from NYSDOT had a significant impact on the ability of this project to proceed and be completed within the initial project end date. Time extension requests had to be submitted to Lake Champlain Sea Grant on two occasions to extend the project completion date, first to December 31, 2022 and then March 31, 2023.

NYSDOT Route 9N Pilot has completed four full snow and ice seasons since it was first announced. The FOIL and this report detail the assessment of the NYSDOT Pilot Program through the 2021-2022 snow and ice season.

2.7 The NYSDOT Route 9N Road Salt Reduction Pilot Program Problems

The NYSDOT Route 9N Road Salt Reduction Pilot Program as originally designed and presented was a wonderful example of partnership and collaboration between municipal elected officials, state agencies and private stakeholders to address an issue that had significant environmental and public health concerns. The NYSDOT introduced an encouraging work-plan in May 2018 that would implement numerous proven best practices that already were being implemented locally and in other states to achieve road salt reduction that were detailed in previous sections of this Chapter. This work-plan was presented at numerous meetings as well as at the Annual Adirondack Champlain Regional Salt Summit. There were routine meetings and discussions regarding the development and implementation of the pilot programs in the early stages of the discussion with active participation from multiple state agencies and stakeholders including the development of a Group Charter.

Then, the COVID-19 pandemic occurred with a significant impact on how business was conducted, changed life for everyone, prevented any in-person meetings that were the basis of this program and resulted in a virtual-based meeting routine. The pandemic also impacted work schedules, training sessions and general human interaction.

Accepting the impact of the pandemic, there were problems arising within the pilot program that were realized before the limitations and restrictions resulting from the pandemic in March 2020. The following are problems that were encountered with the Route 9N Pilot Program:

2.7.1 Lack of Water Quality Monitoring Program

As detailed in Section 2.4, the NYSDOT retreated from committing to development of a collaborative water quality monitoring program for the Route 9N Pilot Project. Instead, The FUND for Lake George committed funding and personnel resources to develop and implement a program during summer 2018. Following the single meeting held in July 2018 with NYSDOT staff, there never was any interest from NYSDOT on monitoring water quality to determine and document the environmental benefits of road salt reduction in the Lake George basin. Early quarterly reports prepared by this report's co-authors were shared with NYSDOT and NYSDEC at RSWG meetings. At an October 2018 meeting, NYSDOT was going to rely on NYSDEC to develop monitoring plans that would only focus on the Route 86 Pilot Program in Lake Placid, with the lead being A.J. Smith. There was no interest in monitoring the Route 9N Pilot Program in Lake George and when asked about sharing plans, NYSDEC responded "We would love to have your data", referring to the data collected by The FUND/Waterkeeper.

2.7.2 Lack of Working Group Meetings

An important element of the action plan rolled out by NYSDOT in May 2018 was the solidification of the Strategic Working Group that had been discussing road salt reduction as well as the formation of Tactical Working Groups at the municipal level to provide a grass roots initiative with public and private stakeholders. It can be said that the Strategic Work Group met every quarter until the pandemic occurred, then there were sporadic virtual meetings. Although the Strategic Working Group was meeting, there was frustration with state agency representatives not having sufficient authority to disclose useful program information or the ability to make substantiative changes to winter maintenance practices. The last meeting was in-person in May 2021. However, the Tactical Working Groups held only one official meeting in August 2018 and an unofficial meeting in January 2020. The lack of meetings barred the input of local stakeholders on what was being witnessed on the roads, prevented NYSDOT from explaining the program practices and lost the critical public outreach necessary for a successful pilot program.

2.7.3 Consistent Best Practice Implementation

Road salt reduction is directly tied to the successful implementation of best practices that are proven techniques and/or equipment that maintain roads with acceptable levels of service and allow the public safe access. One of the most recognized of these practices is the prevention of the bond of snow with pavement surfaces that results in ice through the use of brine, liquid sodium chloride solution. This was listed by the NYSDOT in their Pilot Program action plan in May 2018 and is widely used throughout the state roads in Warren County, especially the Northway (Interstate 87). However, the use of brining on the Route 9N Pilot segment has been extremely limited to about once a year. It is understood there are conditions that may prevent the application of brine for anti-icing. But it is difficult to understand why brine may be applied on the Northway and its ramps that intersect 9N but not on 9N itself. It would seem these are the types of discussions that could and should occur during the specific Working Group meetings.

2.7.4 Need for Data Sharing

The use of the road salt application rates and data was a critical component of any monitoring plan to assess actual reduction of sodium and chloride and the corresponding changes in water quality. This recognized component of data sharing was included in the initial monitoring plan draft in July 2018 where it was suggested that a data sharing agreement be created between parties. Data sharing was a discussion topic at an October 15, 2018 Strategic Working Group meeting where Dan Kelting said "We need data sharing in a timely manner to correlate operations and monitoring and whatever data gets collected needs to be accessible". Language was also added to the Draft *Group Charter for Road Salt Reduction Pilot Strategic Working Group* document with the language "Data sharing: NYSDOT will share detailed Snow & Ice Operations plans in a timely manner; NYSDEC will share detailed monitoring plans in a timely manner. Non-state affiliated partners will share data analysis and study results with state partners before sharing with the press". NYSDOT representatives responded on December 11, 2018 that their legal team informed them the data should not be shared. It was then determined that working group members would have to go through the long and drawn out Freedom of Information Law process to obtain data that should be easily accessible to collaborating partners. This also was a significant problem with the extremely delayed delivery time of 15 months for the first FOIL request.

2.7.5 Data Management

When received through the FOIL process, there were problems with the NYSDOT data sets for snow and ice management. The first was the formatting of data with the second set being AVL/GIS based, data points of real-time applications, and the first and third sets being SnoMat, data based on an average application through an entire route or beat. Second was the manual input of data and inconsistent, or lack of, reporting of weather conditions, Winter Severity Index, road temperatures, etc. Third was the lack of explanation of the data sets using the inclusion of a "Read Me" page to explain all data collected with units or an explanation of terminology used in the files.

2.7.6 Self-assessment and Continuous Improvement Reporting

Another part of the NYSDOT Action Plan was that a review would be performed at the close of the season to determine the effectiveness of the pilots including safety. This was started in season 2018-19 with a brief summary during a Working Group meeting and followed up for the 2019-20 season with a brief report *NY Routes 86 and 9N S&I Material Optimization – 19//20 Seasonal wrap up*. The problem is that there has been no annual review of the Pilot Programs since 2019-2020. Additionally, there was never any information provided regarding the monitoring program, which would only have been for the Route 86 Pilot since NYSDOT never commenced monitoring for the Route 9N project.

2.8 The Adirondack Road Salt Task Force

One of the biggest successes that was produced by the Adirondack Road Salt Working Group members was the advocacy for the Adirondack Road Salt Reduction Task Force and Pilot Program legislation (S.8663a/A.8767a). This legislation, also referred to as the Randy Preston Road Salt Reduction Act, was signed by Governor Cuomo in 2021 with the purpose of creating a task force to ensure that safe passage is provided for the travelling public and clean drinking water is preserved for homeowners.

The Task Force would include representation from the NYSDOT, NYSDEC, NYSDOH and APA and consist of ten appointees from the Governor's Office who would represent various areas of expertise related to understanding environmental impacts, management, and the application of road salt and include representation of academia, law, private industry, county and local governments, and environmental advocacy. The Task Force was authorized to complete a comprehensive review of road salt contamination and snow and ice removal best management practices on roadways, parking lots, driveways and sidewalks within the Adirondack Park and to provide recommendations to reduce salt usage and its impacts, while giving due consideration to public safety of travelers in the Adirondacks.

The report was to be delivered to the State legislature by September 30, 2022, which was a deadline that was not achieved. As of the writing of this report, the Final Draft is being finalized and prepared for delivery.

2.9 Recommendations

(1) NYSDOT should continue the Route 9N Pilot Project Program in Lake George and implement the best management practices including continuous improvement based on review of pervious seasons as well as collaborate with the existing SWiM® Lake George municipal models of the Towns of Lake George and Hague and Warren County DPW.

(2) NYSDOT should partner with this study's collaborators to support the monitoring program developed to determine the environmental changes from the implementation of road salt reduction practices. This should include the formation of a team of experts from NYSDOT/NYSDEC and the study's authors to review the study and adjust and/or add to the work plan, if necessary. NYSDOT/NYSDEC should also become a funding partner to ensure sustainability of the study into the near future.

(3) NYSDOT should reconvene the Adirondack Road Salt Strategic Working Group and the Route 9N Pilot Tactical Work Group (TWG). A new chair should be selected for the TWG to replace retiring Mayor Robert Blais and a regular meeting schedule should be established. This group should include the same diversity of stakeholders to provide observations of the general public, important guidance for public outreach on the Pilot Program and the necessity to educate the traveling public on important winter driving habits.

(4) NYSDOT should make record-keeping and data publicly accessible and require reporting of dates; sources; types of materials used including anti-icing; amounts of materials applied; applications rates; treated lane miles; road conditions including temperature; and storm weather statistics. This should be made available through online and accessible database.

(5) NYSDOT should have continuous application of best practices for road salt reduction for the Route 9N segment as per their detailed Action Plan, which would include more consistent use of brine for anti-icing. NYSDOT is encouraged to collaborate with the local SWiM® certified municipalities for combined training sessions on the successful implementation of best practices for continuous improvement of snow and ice management operations.

(6) NYSDOT should base snow and ice winter operation and management decisions on data collected and analyzed in post-storm evaluations applying technology from AVL salt tracking, road-side weather stations, and road-side cameras. The analysis of these data can be used to assess and improve salt applications for specific event conditions and characteristics.

(7) New York State should utilize the Adirondack Road Salt Reduction Task Force Report to guide the state to become a national leader in sustainable snow and ice management and demonstrate the protection of vital natural resources including surface and ground water while maintaining safety winter travel for the public.

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New York State Department of Transportation Road Salt Reduction Pilot Program

Final Report for the Lake Champlain Sea Grant Program

Chapter 3

NYSDOT Route 9N Road Salt Reduction Pilot Program Monitoring Project –

Overview, Goals-Objectives-Hypothesis, Tributary Watershed Selection, and Project Data Collection

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3.0 Project Overview

The NYSDOT Road Salt Reduction Pilot Program was conceived and initiated to reduce winter deicing road salt application along the Route 9N "pilot" segment on the west side of Lake George compared with normal application rates on other state highways in the basin while maintaining winter highway safety.

3.1 Pilot Tributary Monitoring Project - Goal, Objectives, and Hypothesis

The following material was taken from the Lake Champlain Sea Grant Preproposal submitted during fall 2019 for consideration of funding. While there may be some minor adjustments necessary given the current status of the Program after four years of LGA data collection and extremely delayed receipt of the NYSDOT road salt application data, these Program tenets are repeated here for the sake of full disclosure in the final report.

Goal. The goal of this Monitoring Project was to collect water quality data to evaluate the effect of the NYSDOT Road Salt Reduction Pilot Program on the chemistry of tributaries flowing into Lake George.

Objectives. The major and secondary objectives of this Program can be stated as follows:

- Primary - Evaluate changes in tributary chemistry in response to reduced road salt application with respect to chloride and cations and determine whether these changes are significant when compared with road salt application at un-reduced normal application rates.
- Secondary - Establish a valid field sampling protocol that can be used in the long-term monitoring of Lake George tributaries to document changes in the chemical characteristics.

The fulfillment of the first objective assumes that there will be a reduced rate of road salt application along the "pilot" segment of Route 9N.

Hypothesis. The **null hypothesis** (**H_0**) being evaluated can be stated as follows:

*There will be no difference in the water chemistry response of ("**test**") tributaries within the Route 9N "pilot" reduced road salt application segment when compared with the chemistry of ("**control**") tributaries outside the Route 9N segment where normal rates of road salt application continue to occur*.

To reiterate, the incentive for development of this LGA long-term monitoring program was the NYSDOT-proposed 10 percent reduction in road salt application along the Route 9N "pilot" segment on the western shoreline of Lake George as compared with other segments of state highway that receive road salt application in the drainage basin.

3.2 The Selection of Tributary Watersheds for Investigation

The success of the effort to evaluate the NYSDOT road salt reduction program along the '***pilot***' segment of the Route 9N area is dependent upon many factors including, but not limited to, the following:

(1) the selection of suitable "**test**" tributary sites for evaluation of flow and anion-cation chemistry at ***upper*** and ***lower*** sites relative to the Route 9N segment that crosses the watershed and will undergo reduced road salt application,
(2) the selection of suitable "**control**" tributary sites for evaluation of flow and anion-cation chemistry at ***upper*** and ***lower*** sites relative to a highway segment that will experience normal rates of road salt application,
(3) the collection of reliable long-term flow and chemistry data during regular bi-weekly site visits in conjunction with loggers deployed at each ***lower*** site to collect continuous specific conductance and water level data at some pre-determined frequency and the maintenance of these loggers in good working order to minimize any loss in the continuous data records,

The components listed above that define a successful monitoring effort appear easily achieved, which has not been the case during this effort. Instead, this project definitely has been a learning experience for everyone involved, including co-author JWS who has accumulated 40+ years of water quality and stormwater monitoring experience in the Lake George drainage basin.

The site selection process began during mid-summer 2018 with the focus on suitable "test" tributary sites along the 17-mile segment of Route 9N that starts at the intersection of Route 9N-Route 9 in the Village of lake George and extends north to the intersection of Route 9N and Padanarum Road at the head of Northwest Bay and the base of the Tongue Mountain Range.

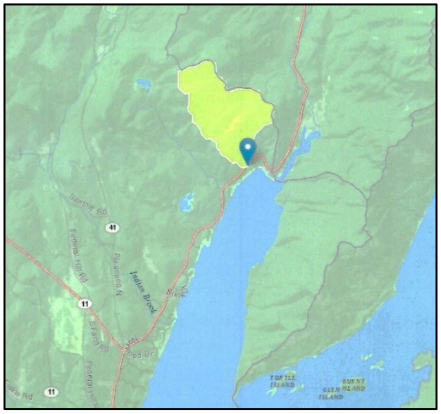
3.2.1 The "test" tributary watersheds

Initially, "***test"*** tributary site selection proved to be particularly challenging due to the extensive developed area up-gradient of the Route 9N '***pilot***' segment between the Village of Lake George and Padanarum Road. In fact, after considerable reconnaissance, there were less than 5 tributaries that flow into Lake George that were not influenced by some form of development up gradient where salt application to road surfaces during winter deicing practices could interfere with the evaluation of road salt application and reduction related to the pilot program along Route 9N.

The two ***"test"*** tributaries selected within the ***"pilot"*** segment are located along the northern extent of the Route 9N, adjacent to Northwest Bay, and include (1) Tributary 61 (**T61**) that drains Wing Pond and enters Northwest Bay near Walker Point (Figure 3-1), and (2) Tributary 63a (**T63a**) located about 0.9 miles north of T61 and is adjacent to the NYSDEC Pole Hill Pond trailhead (Figure 3-2).

Figure 3-1.

Figure 3-2.



Both tributaries drain extensive undeveloped areas of private or state-owned land up-gradient of the Route 9N 'pilot' segment where there is no anthropogenic influence of road salt application during winter deicing practices.

3.2.2 The "control" tributary watersheds

Two tributaries were selected outside the Route 9N **pilot** test area to serve as '**control**' sites where the NYSDOT would continue to apply winter road salt according to standard practices without any purposeful reduction policy.

Tributary 41 (**T41**) is a segment of English Brook that begins near the intersection of Route 9 and Somerville Road (***upper*** sampling site) and extends about 1.2 miles southwest, ending just above the area where the tributary crosses under the Interstate 87 (I-87) overpass (***lower*** sampling site) (Figure 3-3).

Tributary 36a (**T36a**) is on the east shore of Lake George at the southern end of the lake and flows across along Route 9L about 0.85 miles north of the intersection of Route 9L and Beach Road, just north of Amitola Lane (Figure 3-4).

Figure 3-3.

Figure 3-4.

T41 at the intersection of Route 9N and Somerville Road receives drainage from an extensive up-gradient forested area of private and state-owned land. The lower watershed portion receives drainage from Route 9 and also Interstate 87 (I-87), a multi-lane north-south highway that connects Albany New York with the Canadian border. All of the runoff and groundwater drainage at the lower portion of the watershed is from highway infrastructure.

T36a has no developed area up-gradient and east of the Route 9L state-maintained highway segment that crosses the watershed. In contrast to the other three watersheds selected for the current investigation, flow monitored at the lower sampling site is primarily the result of groundwater emergence from higher elevations just east of the highway.

3.3 Tributary Watershed Sampling Sites

A set of ***upper*** and ***lower*** sampling sites was selected within each tributary watershed included in the current investigation. It was important that the ***upper*** sampling sites were a sufficient distance up-gradient from the highway segment crossing the watershed to ensure that salt spray from winter highway de-icing would not affect the background levels of chloride and cations in water flowing from the higher elevations. It also was important to select placement of the ***lower*** sampling sites along the channel where all runoff and groundwater drainage from the highway segment would be recorded by installed data loggers and collected during routine monitoring.

Characteristics of the upper and lower sampling sites for each tributary watershed included in this investigation are presented later in this report in the individual watershed chapters including T63a (Chapter 5), T61 (Chapter 6), T41 (Chapter 7) and T36a (Chapter 8).

3.4 Chloride Characteristics of "Test" and "Control" Watersheds

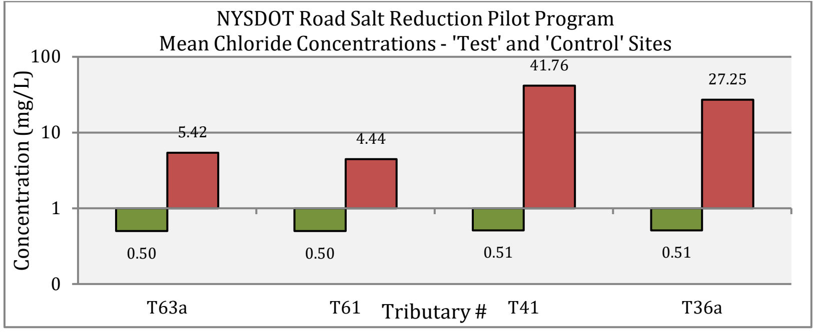
Road salt (chloride) and the potential reduction in application while maintaining highway safety by means of the 'pilot" program is the entire basis for this investigation. Chloride concentration is the most important characteristic when evaluating whether the tributary watersheds selected for the current investigation are suitable and answering the following question …

> *"is there significant difference between the chloride concentrations measured at the* ***upper*** *and* ***lower*** *watershed sampling sites that can be attributed to winter deicing practices along the subject highway segment?"*

Unless we can demonstrate this difference in chloride concentrations, then we have not done a respectable job at the watershed selection process.

The *mean* **chloride** concentrations collected from July 2018 when the monitoring program began through October 2022 at the ***upper*** and ***lower*** tributary watershed sites selected for the current investigation are summarized in Figure 3-5. The values at all ***upper*** tributary sites were < 1.0 mg Cl^-/L, which is the minimum level of detection for this anion at the DFWI Laboratory. Concentrations reported by DFWI as less than detection were stored as 0.50 mg Cl^-/L.

Figure 3-5.



The mean values at the ***lower*** tributary sites ranged from 4.44 mg Cl^-·L (at T61) to 41.76 mg Cl^-·L (at T41). For all tributaries included in the program, there was a significant difference between the ***upper*** and ***lower*** mean chloride concentrations for samples collected to date, ranging from a 9-fold difference exhibited at T61 to an 82-fold difference exhibited at T41.

3.5 The Collection of Consistent Data

The ultimate success of any large-scale environmental monitoring project such as this one depends upon the collection of dependable data which is not a trivial process because it requires total dedication and diligence throughout the entire duration of the project.

3.5.1 Project field excursions

Data collection was initiated in August 2018 at all four Project watersheds at biweekly intervals whenever possible. With a few exceptions due to inclement weather, all tributaries were sampled on the same day to minimize variability due to changing climate conditions. Each sampling excursion included visits to both ***upper*** and ***lower*** sampling stations at all four watersheds with on-site field measurements followed by the collection of raw water samples for the chemical analysis of anions and cations at the DFWI Laboratory in Bolton Landing. All data and observations at each sampling station were recorded on field sheets.

3.5.2 Sampling site data collection, sample processing and analytical protocol

Field measurements were determined *in-situ* at the sampling location and included temperature and dissolved oxygen concentration and saturation (YSI® Model 55 dissolved oxygen and temperature meter), and conductivity, total dissolved solids (TDS) and pH (Myron Ultrameter 4PII). Flow at each ***lower*** site was estimated using the current-meter cross-sectional method (Rantz 1983), dividing the total channel into equal segments of width, and measuring the depth and velocity at the centerline of each segment with the meter probe at the 0.6 depth above the stream bottom.

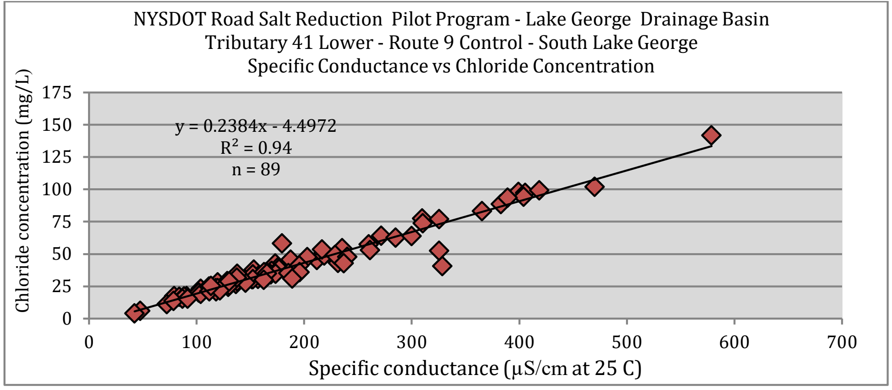
Raw water samples collected from the tributary channel were stored in PE bottles dedicated to each sampling station and processed immediately following the completion of sampling at the LGA Office and Conference Center in the Town of Lake George at the south end of the lake. Samples to be analyzed for anions (Cl, NO_3, SO_4) were filtered through a 0.2µ nitrocellulose filter and then decanted into a clean and sterile PE cup with lid. Samples to be analyzed for cations (Na, Mg, Ca, K) were decanted into a clean and sterile PE cup and then 0.5 mL of 0.1N HNO_3 was added as preservative. Processed samples then were delivered to the DFWI Laboratory in Bolton Landing (Lake George) and accompanied by a Chain of Custody form.

Chloride was determined by ion chromatography (US EPA Method 300.0, rev. 2.1) and base cations by atomic absorption spectrophotometry (US EPA Method 200).

3.6 Sampling Site Equipment Requirements

In addition to the bi-weekly chemistry samples collected at each ***lower*** watershed sampling site and analyzed for chloride, continuous chloride concentration data were measured indirectly in each tributary channel by installing a dedicated temperature-conductivity logger. It was known from previous investigations (Sutherland, unpublished data) that there is a robust relationship between instantaneous specific conductance measured in a tributary channel and the corresponding chloride concentration of water flowing through the channel at that time. An example of this relationship between specific conductance and chloride concentration is shown in Figure 3-6 for English Brook (T41) using data collected during the current investigation.

Figure 3-6.



Also, at the time that the study was initiated, it was thought that the conductance-flow relationship measured at other tributaries in Lake George (Sutherland unpublished data) could be applied to the current 'pilot' project.

3.6.1 Onset HOBO® temperature-conductivity loggers

During December 2018, Onset HOBO® (U24-001) temperature-conductivity loggers were installed at the ***lower*** sampling site on each Program tributary to continuously record conductivity in the channel at 5-minute intervals. Figure 3-7 shows the loggers prior to installation in the field and Figure 3-8 shows the logger in association with the PVC enclosure sold by Onset to protect the unit in the channel and still allow the movement of water through the enclosure so that accurate conductivity readings will occur. In Figure 3-8, the PVC enclosure is attached to a concrete half-block with straps to maintain position in the channel. Figure 3-9 shows the temperature-conductivity logger setup installed at the ***lower*** T63a channel; the entire installation is tethered to a tree on the adjacent shoreline with paracord.

Figure 3-7.

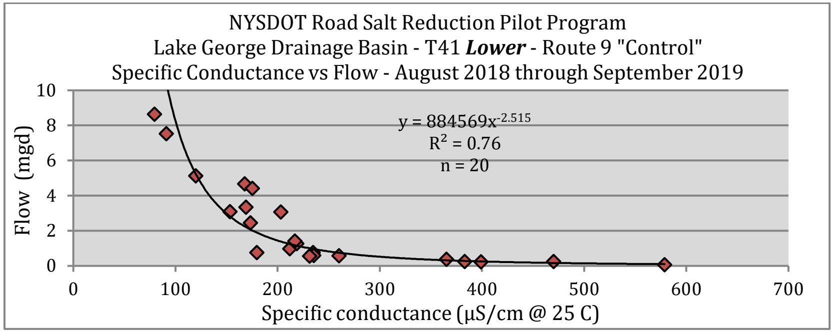
Figure 3-8.

Figure 3-9.

Following installation, the data-loggers were downloaded during each field excursion and the collected data stored in separate master Excel files for each Program tributary. The Onset software included with the logger used stored temperature values to convert conductivity to specific conductance values.

In September 2019, following a full year of data collection, report co-author Sutherland realized that, contrary to expectations, there was no accurate relationship between specific conductance and tributary flow at three of the four sites selected for investigation. Only T41 exhibited the relationship expected to occur (Figure 3-10) based upon several decades of investigation at Finkle Brook in Bolton Landing (Sutherland unpublished data).

Figure 3-10.



Even the relationship at T41 was not as significant ($R^2 = 0.76$) as had been anticipated and the other three tributaries exhibited relationships that were less significant than T41.

3.6.2 *In-Situ* water level loggers

In the absence of reliable flow data, water level data loggers had to be installed at each ***lower*** sampling sites so that continuous data could be collected and then paired with tributary gaging data collected every 2 weeks to establish a flow rating curve for each ***lower*** sampling station.

A proposal prepared and submitted to the Lake Champlain Sea Grant (LCSG) Program during fall 2019 was approved for funding and covered the period from February 1st, 2020, through January 31st, 2022. The funds from this grant were allocated to purchase water level data-loggers for the four tributaries and to compensate personal services for assistance with the field sampling, data summary and analysis and report writing associated with the Program.

Level logging instrumentation was purchased from *In-Situ* Inc. in Fort Collins, CO. Figure 3-11 is the Rugged TROLL 200 Level Logger with cable and download connection port; Figure 3-12 is Rugged Baro TROLL used to correct logger levels for local barometric pressure.

Figure 3-11.

Figure 3-12.

Figure 3-13.

Figure 3-13 is the *In-Situ* Inc. wireless TROLL.com used to download level and barometric pressure data at the sampling site using a Bluetooth connection with a cell phone.

Figure 3-14 shows the *In-Situ* level logger installation at T41 (English Brook). The logger, cable and download connector are inside the 'brown' PVC pipe mounted to two pieces of sandwiched 5/4 x 6-inch decking with the entire assembly secured to the shoreline tree with aviation cable. The Baro TROLL is secured to the top of the assembly to the 'yellow' locking cap.

Figure 3-14.

The *In-Situ* units were programmed to record tributary level at 5-minute intervals which matched the time intervals programmed on the HOBO® temperature-conductivity loggers. All 5-minute intervals were synchronized with the 5-minute clock hourly intervals.

Downloaded data are managed following the conclusion of each field excursion by correcting data files and uploading the files to the shared LGA site for use by Program cooperators.

3.7 Monitoring Project Operational Issues

An unexpected historic storm on October 31st, 2019, deposited 3 to 5 inches of precipitation in the Lake George drainage basin, resulting in extraordinary surface flows from local watersheds with ground water already saturated by precipitation earlier during that month. Flows from runoff in the four study watersheds were near record levels and resulted in two Onset HOBO® conductivity data-loggers (T-63a and T-41) becoming dislodged from their mountings in the channels, carried downstream and lost to the Program.

The Onset HOBO® T-61 logger was lost and eventually located after considerable searching and movement of debris from the area of the channel where the device had been installed. Following retrieval, however, the T-61 logger could not be downloaded and was returned to the company for service. Onset replaced the data-logger and also recovered and forwarded data stored in the unit.

The T-36a conductivity logger was unaffected by the October 2019 storm because the watershed is small, fed mostly by groundwater, and does not generate any surface runoff.

In order to keep the Program moving forward without too much loss of time, The FUND ordered two (2) replacement units for the lost data-loggers, which were installed during January 2020.

Considerable time was spent during the first two quarters of 2020 with the design, purchase of materials and supplies, construction, and installation of site enclosures for the *In-Situ* level loggers which were required to continuously record ***lower*** sampling station water levels so that chloride loading could be evaluated for each Program tributary.

Installations of the *In-Situ* equipment at the T-63a, T-61 and T-41 lower sampling sites occurred during May 2020. The installation of equipment at T-36a occurred during November 2020 following approval from the property owner for access to the property.

3.8 Summary

The preparation for a successful monitoring effort such as the one described herein has many simultaneous moving parts that require a significant dedication of time and diligence on the part of all Program cooperators. The results will reflect the total commitment of all participants and the constant effort to maintain integrity of the Program from conception to completion.

3.9 Literature Cited

Rantz, S.E. et al. 1982. Measurement and computation of streamflow: Volume 1. Measurement of stage and discharge; Volume 2. Computation of discharge. Volume 1, p. 1-284; Volume 2, p. 285-631. Water Supply Paper 2175

US EPA Methods from: US EPA, Standard Methods for Examination of Water and Wastewater, 1996. 19th Edition, American Public Health Association, Washington, DC.

New York State Department of Transportation Road Salt Reduction Pilot Program

Final Report for the Lake Champlain Sea Grant Program

Chapter 4

Pilot Program Lake George Association Monitoring Project Data Management

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4.0 Introduction

As addressed in the previous chapter, successful evaluation of the NYSDOT road salt reduction program along the Route 9N '***pilot***' segment is dependent upon (1) the selection of appropriate "**test**" tributary sites, (2) the selection of appropriate "**control**" tributary sites and, (3) the collection of reliable long-term flow and chemistry data.

In this chapter we address another critical component that determines the overall success of any program, which is (4) the proper management of considerable amounts of flow and chemistry data. Proper management includes the allocation of files, file formatting and the data calculations to determine whether discernable differences between **"test"** and **"control"** tributary watersheds occurred with regard to chloride loading and whether long-term changes in tributary chemistry could be identified using the data collected during this monitoring program.

4.1 Data Management

The collection of large amounts of reliable data from "**test**" and "**control**" watersheds is an essential intermediary step in the overall process to determine whether the proposed 10 percent road salt reduction program has been successful. In this Project, the data collection process has been facilitated by installing loggers at the ***lower*** sampling sites in each tributary watershed to collect both 5-minute flow and conductivity data. These data have been collected at all ***lower*** sampling stations since May 2020 except at T36a where the loggers were installed during November 2020.

With the regular collection of reliable data and bi-weekly field excursions to check the stations, collect samples and provide quality assurance with respect to the logger data storage, the consequent phase of data management and analysis becomes the focus of attention.

4.1.1 Major Project Excel files

All Project data are stored and summarized in Excel spreadsheet software. Table 4-1 summarizes the primary files set up to store data collected as part of this "pilot" project.

Table 4-1.

FILE NAME	# WORKSHEETS	WORKSHEETS INCLUDED IN FILE
TRIBUTARY MASTER CHEM-FIELD DATA FILE	13	(1) 'Read me' first (2) sample accession summary (3) ***upper*** station chemistry and field measurements (4) ***lower*** station chemistry and field measurements (5) interactive data summary by analyte, year; each cell updated when data entered in the upper-lower worksheets (6) summary graphs of data (7) ***lower*** site tributary flow calculations (8) ***lower*** site flow rating curve data (9) table of field & HOBO® spC, measured $[Cl^-]$ equations (10) USGS StreamStats ***upper-lower*** subwatershed data (11) site photographs (12) extra gaged flow data (13) local precipitation data
TRIBUTARY MASTER spCONDUCTANCE FILE	45	(1) 'Read me' first (2) daily summaries for each year (column data) (3) missing/bad data inventory (4) summary graphs of data (5) a separate worksheet for each month of conductivity data collected – currently December 2019 thru June 2022
TRIBUTARY TROLL 200 COMPILED DATA FILE	1	A single worksheet that includes a continuous string of 5-minute flow data beginning with the first station download
TRIBUTARY MASTER FLOW-CHLORIDE EXPORT FILE	31	(1) 'Read me' first (2) master flow and Cl^- loading tables for each year (3) flow, $[Cl^-]$ and ppt column data for each year (4) summary graphs of data (5) a separate worksheet for each month of flow and chloride loading data available – currently May 2020 through June 2022 (6) missing-bad data inventory
# of worksheets is through the end of October 2022		

This Project component requires good organization, and the entire process has gone through a period of trial-and-error to determine the best way to store data and yet make it continually accessible for update and interpretation. In addition to being used during the 'active' Project by Lake George Association and Waterkeeper personnel, it also was necessary to keep in mind during development that end users following completion of the Project should be provided with a system that affords ease of access and understanding in spite of having no familiarity with the system as originally developed.

The files highlighted in Table 4-1 files are the major files, but not the only files, included in the current data management effort. For example, during every field excursion, the HOBO® temperature-conductivity, and *In-Situ* TROLL 200 and Baro TROLL loggers at each ***lower*** site are downloaded. Following each field excursion with chemistry sample processing and submission for analysis, 12 different Excel-based logger files are checked for quality assurance and stored on a MS Office 365 Cloud-based system for access and sharing.

4.2 Data Calculations

Careful design and implementation of a suitable data management system provides ease of access and the ability to perform the calculations necessary to track flow and chloride loading in each "**test**" and "**control**" tributary on a regular basis. Individual data files downloaded in the field and transferred to the Cloud-based storage system are accessed on a regular basis and downloaded/copied to the appropriate Master file to provide an update and aid to subsequent calculations.

4.2.1 Tributary master chemistry-field data file

Table 4-2 is a portion of the ***lower*** sampling site Excel worksheet taken from the T63a master chemistry and field data file and displays only the site data collected from January 2022 through October 2022.

Table 4-2.

LOWER STATION

Date	Sample Set #	Sample Size (n)	Water temp (^{0}C)	DO (mg/L)	DO (% sat)	NO3-N (mg N/L)	SO4-S (mg S/L)	Cl (mg/L)	Ca (mg/L)	Na (mg/L)	Mg (mg/L)	K (mg/L)	spC (µS/cm)	TDS (ppm)	pH (s.u.)	Flow (cfs)	Flow (mgd)
1/11/2022	611	1	-0.1	14.9	101.8	0.03	1.33	2.5	2.91	2.15	0.67	0.12	44.5	30.2	6.92		
1/25/2022	620	1	0.1	14.3	98.3	0.14	1.05	1.8	5.85	1.75	0.79	0.19	48.8	32.95	8.44	0.116	0.075
2/8/2022	629	1	0.3	14.3	98.6	0.20	0.98	1.4	5.94	1.42	0.86	0.20	48.4	32.2	7.29	0.102	0.066
2/22/2022	638	1	0.1	13.5	92.8	0.07	1.03	1.6	2.70	1.57	0.47	0.38	35.0	23.2	7.85	1.144	0.739
3/15/2022	647	1	0.6	14.0	97.6	0.05	1.07	3.3	2.80	2.69	0.52	0.36	40.8	27.3	7.08	0.745	0.481
3/29/2022	657	1	0.1	14.5	99.4	0.01	0.95	2.4	1.95	2.00	0.35	0.37	20.8	31.3	7.08	0.863	0.557
4/12/2022	665	1	6.4	12.1	98.1	0.02	0.91	2.6	2.22	2.31	0.38	0.39	33.9	22.1	6.98	1.305	0.843
4/26/2022	674	1	9.1	11.2	97.2	0.03	1.04	2.4	3.19	2.39	0.05	0.11	34.7	22.5	6.94	0.675	0.436
5/10/2022	683	1	8.4	11.6	98.5	0.09	1.04	3.1	3.44	3.06	0.60	0.10	42.1	27.7	8.04	0.212	0.137
5/31/2022	692	1	15.5	9.5	95.5	0.19	0.82	2.9	3.90	3.39	0.67	0.18	45.6	29.1	8.37	0.060	0.039
6/14/2022	701	1	13.9	10.0	96.9	0.11	0.69	4.0	4.20	4.62	0.75	0.14	52.5	33.8	7.35	0.036	0.023
6/28/2022	710	1	15.1	9.8	97.9	0.16	0.71	4.8	2.79	5.54	0.77	0.20	56.0	36.0	7.41	0.042	0.027
7/12/2022	719	1	16.6	8.8	90.2	0.20	0.75	7.2	5.48	6.94	0.82	0.10	72.6	46.4	7.35	0.020	0.013
7/26/2022	728	1	16.9	9.4	96.6	0.13	0.67	4.8	5.08	4.47	0.72	0.11	60.7	38.9	7.43	0.054	0.035
8/9/2022	737	1	20.3	8.3	92.1	0.18	0.73	7.4	5.61	7.93	0.82	0.18	87.2	55.4	7.48	0.021	0.013
8/30/2022	746	1	19.4	8.6	93.7	0.20	1.97						148.3	94.4	7.35	0.026	0.017
9/13/2022	755	1	17.0	8.8	91.1	0.06	1.18	6.9					86.6	55.4	7.28	0.009	0.006
9/27/2022	764	1	12.2	10.7	99.8	0.02	1.49	2.0					46.9	30.4	7.28	0.169	0.109
10/11/2022		1	7.9	12.1	101.8	0.005	0.98	1.5					41.3	27.2	8.47	0.094	0.061
10/25/2022		1	11.0	11.1	101.0								46.2	30.0	7.32	0.457	0.295
2018 average		10	12.1	11.4	103.7	0.04	1.19	11.9	5.43	7.40	1.04	0.20	84.3	54.4	7.09	0.243	0.156
2019 average		20	9.6	12.4	106.6	0.04	1.16	3.4	4.29	3.23	0.59	0.13	43.9	29.2	7.26	0.890	0.575
2020 average		22	9.3	12.0	100.1	0.06	1.24	8.3	5.39	6.08	0.84	0.21	68.0	44.1	7.60	1.801	1.163
2021 average		22	9.4	11.6	98.5	0.06	1.06	2.3	4.82	2.41	0.60	0.14	42.4	27.5	7.14	0.607	0.392
2022 average		20	9.5	11.4	96.9	0.10	1.02	3.5	3.87	3.48	0.62	0.21	54.6	36.3	7.49	0.324	0.209
overall average		94	9.8	11.8	100.7	0.06	1.13	5.2	4.75	4.24	0.71	0.17	56.1	36.7	7.34	0.849	0.549

Data collected from 2018 through the end of 2021 are not shown; however, the annual summaries from those years are shown in the lower part of Table 2. After each excursion, field data from the T63a field sheet are entered into this data file by inserting a row and entering the date, sample bottle set #, etc.

As shown in the table, there are rows of 'averages' maintained for the individual columns for each year of data collected and an 'overall' average for all data collected. Results for anions and cations are entered into the file when received from the Darrin Fresh Water Institute Laboratory.

The *tributary flow calculations* are performed in the "flow" worksheet (#7; Table 1) and the values (cfs, mgd) are entered in the ***lower*** sampling site Excel worksheet as shown in the far-right columns in Table 4-2.

The *flow rating data* worksheet (#8; Table 1) for T63a is partially shown in Table 4-3. This table is where tributary gaging data and corresponding level readings from the T63a *In-Situ* logger are paired and used to develop an equation that defines instantaneous flow in the channel at the time that the manual gaging occurred. Instead of using a single level value to interpret instantaneous flow at the site at the time of gaging, the logger 5-minute values 1 hour *before* and 1 hour *after* download are averaged and *combined* to moderate any level differences which occasionally occur at the time of download even though the transducer portion of the logger is not disturbed during the download process.

The 'green' shading in Table 4-3 highlights extra flow gaging conducted during storm events to increase the accuracy of the rating curve.

Table 4-3.

T61 – LOWER STATION			AVERAGE IN-SITU LEVEL (ft)		
GAGING DATE	GAGING TIME	FLOW (mgd)	BEFORE DOWNLOAD	AFTER DOWNLOAD	BEFORE-AFTER COMBINED
3/9/2021	0900	0.074	0.400	0.424	0.412
3/30/2021	0835	0.394	0.625	0.646	0.636
4/13/2021	0925	0.207	0.562	0.570	0.566
4/27/2021	0910	0.233	0.576	0.581	0.579
5/5/2021	0820	0.502	0.715	0.715	0.715
5/2/5/21	1609	0.466	0.721	0.721	0.721
5/11/2021	0900	0.197	0.608	0.606	0.607
6/1/2021	0837	0.076	0.427	0.431	0.429
6/15/2021	0839	0.119	0.434	0.430	0.432
6/29/2021	0835	0.038	0.348	0.354	0.351
7/13/2021	0835	0.115	0.488	0.494	0.491
7/19/2021	0842	0.731	0.802	0.815	0.809
7/20/2021	1641	0.491	0.765	0.761	0.763
7/27/2021	1135	0.245	0.498	0.502	0.500
8/10/2021	0845	0.084	0.378	0.380	0.379
8/31/2021	0936	0.108	0.424	0.422	0.423
9/14/2021	0915	0.069	0.343	0.355	0.349
9/28/2021	0907	0.184	0.518	0.518	0.518
10/12/2021	0840	0.079	0.377	0.378	0.378

The equation for calculating instantaneous flow becomes more robust as more manual gaging and water level data are collected. After each station visit and data download, the level data are processed as shown in Table 4-3 and a new equation is generated and used to calculate 5-minute flows until the next data download.

The chloride concentrations used to calculate loadings are calculated in the tributary master chemistry and field data file (see Table 1, worksheet #9). Table 4-4 is a portion of the data stored and analyzed in example of this worksheet.

Table 4-4.

T61 - LOWER STATION			
Sampling Date-Time	**field spC (µS/cm @ 25C))**	**HOBO® spC (µS/cm @ 25C))**	**DFWI measured Cl (mg/L)**
1/12/2021 0845	33.5	32.83	1.7
1/26/2021 0855	37.0	38.34	1.9
2/9/2021 0845	34.2	39.52	1.3
2/24/2021 1330	33.3	39.03	1.0
3/9/2021 0853	40.0	38.95	2.1
3/30/2021 0835	74.0	72.64	13.8
4/13/2021 0925	60.6	56.67	8.8
4/27/2021 0910	38.0	35.39	2.9
5/11/21 0900	35.4	33.48	2.1
6/1/21 0837	34.0	33.60	1.6
6/15/21 0839	44.5	41.03	3.5
6/29/21 0835	38.3	36.12	1.6
7/13/21 0835	58.1	55.17	5.7
7/27/21 1135	22.2	33.32	1.8
8/10/21 0845	38.3	35.94	1.9
8/31/21 0936	37.62	36.92	1.6
9/14/21 0915	37.63	36.98	1.5
9/28/21 0907	36.24	34.38	1.6
10/12/21 0840	38.2	35.88	1.6
10/24/21 0833	44.6	37.75	2.3
11/16/21 0854	28.4	29.14	1.0
12/14/21 0845	33.2	32.8	2.2

The date and time of each sampling excursion is recorded in the table along with the Myron L (field) meter and the HOBO® logger specific conductance value recorded at the same date and time. As shown above, there are differences between the specific conductance measured by the two meters based upon different sensors and internal calculations for data conversions. The chloride concentration measured at the DFWI Laboratory for each collected tributary sample during each field excursion is entered in the table when the data are received. The HOBO® conductance and corresponding DFWI chloride concentrations are compared in a scatter plot and a trendline calculated along with an equation to provide chloride concentration based on HOBO® specific conductance recorded at 5-minute intervals.

4.2.2 Tributary master specific conductance file

Conductivity files downloaded from the HOBO® logger during each site visit are checked for quality assurance, then stored on the MS Office 365 cloud-based sharing system. The individual files then are copied to the Master specific conductance file (Table 4-5) which has a format similar to the HOBO files except that the specific conductance data are summarized hourly and daily (see far right columns in Table 4-5 below).

Table 4-5.

Date Time	T-61 specific conductance Full	Temp (°F)	spCONDUCTANCE	spCONDUCTANCE	spCONDUCTANCE
05/02/22 22:55	33.4	49.53	48.04		
05/02/22 23:00	33.4	49.53	48.04	48.1	
05/02/22 23:05	33.4	49.53	48.04		
05/02/22 23:10	33.4	49.53	48.04		
05/02/22 23:15	33.4	49.5	48.07		
05/02/22 23:20	33.4	49.53	48.04		
05/02/22 23:25	33.4	49.5	48.07		
05/02/22 23:30	33.4	49.5	48.07		
05/02/22 23:35	33.0	49.5	47.49		
05/02/22 23:40	33.4	49.5	48.07		
05/02/22 23:45	33.4	49.46	48.09		
05/02/22 23:50	33.4	49.48	48.08		
05/02/22 23:55	33.4	49.48	48.08		
05/03/22 00:00	33.4	49.46	48.09	48.0	47.4
05/03/22 00:05	33.4	49.48	48.08		
05/03/22 00:10	33.4	49.46	48.09		

As documented in Table 4-1, complete monthly sets of specific conductance data are stored in separate worksheets in this file in the same format as shown above and there also is a worksheet in the file where the average daily values are listed in a column along with daily precipitation data for easy access and graphing purposes.

4.2.3 Tributary TROLL 200 compiled flow data file

Data files transferred from the *In-Situ* loggers at each ***lower*** station are checked for quality assurance and then stored in the MS Office 365 cloud-based system. Table 4-6 is a portion of the TROLL 200 data file transferred to the T61 master compiled flow data file showing the time period surrounding the data download that occurred at 0840 hours.

Table 4-6.

Date and Time	BARO Corrected Depth				
05/10/22 07:30	0.340				
05/10/22 07:35	0.354				
05/10/22 07:40	0.341				
05/10/22 07:45	0.327				
05/10/22 07:50	0.328				
05/10/22 07:55	0.339				
05/10/22 08:00	0.326				
05/10/22 08:05	0.338				
05/10/22 08:10	0.327				
05/10/22 08:15	0.342				
05/10/22 08:20	0.345				
05/10/22 08:25	0.341				
05/10/22 08:30	0.340		prior average		
05/10/22 08:35	0.338		0.337		combined average
05/10/22 08:40	0.346				0.344
05/10/22 08:45	0.332		0.350		
05/10/22 08:50	0.344		post average		
05/10/22 08:55	0.338				
05/10/22 09:00	0.340				
05/10/22 09:05	0.348				
05/10/22 09:10	0.365				
05/10/22 09:15	0.342				
05/10/22 09:20	0.367				
05/10/22 09:25	0.354				
05/10/22 09:30	0.358				
05/10/22 09:35	0.350				
05/10/22 09:40	0.361				
05/10/22 09:45	0.354				
05/10/22 09:50	0.351				

The ‘yellow’ highlights include the 5-minute intervals 1 hour before and 1 hour after the download that are used to calculate average values and then used to calculate a final average value to incorporate into the rating equation. This process occurs following each field excursion, so the flow rating equation is updated bi-weekly and incorporated into the flow column of the chloride loading file.

4.2.4 Tributary master flow-chloride export file

This master file associated with each ***lower*** station tributary “subwatershed” (***lower*** station term) is the major platform where all of the important calculations are performed related to flow and chloride loading. An example of the data and formatting included in these files is presented in Table 4-7.

Table 4-7.

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9
TRIBUTARY 61 FLOW AND CHLORIDE LOADING								
APRIL 2022								
		exponential			shading here if $[Cl^-]$ <1.0 mg/L			
DATE-TIME	**TROLL 200 WATER LEVEL (ft)**	**FLOW (mgd)***	**FLOW (gallons)/ 5 min interval**	**HOBO® spC (µs/cm @ 25°C)**	**[Cl-] (mg/L)****	**Lbs Cl- per 5 min interval**	**DAILY Cl- EXPORT (lbs)**	**DAILY FLOW (mgd)**
04/01/22 23:00	0.855	0.958	3323.2	35.14	2.04	0.057		
04/01/22 23:05	0.868	1.032	3582.0	35.14	2.04	0.061		
04/01/22 23:10	0.836	0.858	2978.2	35.15	2.04	0.051		
04/01/22 23:15	0.883	1.126	3905.9	35.15	2.04	0.067		
04/01/22 23:20	0.863	1.003	3480.2	35.15	2.04	0.059		
04/01/22 23:25	0.829	0.824	2860.3	34.66	1.94	0.046		
04/01/22 23:30	0.851	0.936	3247.4	34.67	1.94	0.053		
04/01/22 23:35	0.843	0.894	3100.9	35.17	2.05	0.053		
04/01/22 23:40	0.841	0.883	3065.3	34.68	1.95	0.050		
04/01/22 23:45	0.855	0.958	3323.2	34.69	1.95	0.054		
04/01/22 23:50	0.839	0.873	3030.2	34.71	1.95	0.049		
04/01/22 23:55	0.870	1.044	3623.6	34.73	1.96	0.059		
04/02/22 00:00	0.859	0.980	3400.8	34.73	1.96	0.056	28.298	1.045
04/02/22 00:05	0.820	0.783	2715.5	34.75	1.96	0.044		
04/02/22 00:10	0.833	0.844	2927.1	34.75	1.96	0.048		
04/02/22 00:15	0.864	1.009	3500.3	34.77	1.97	0.057		

The table above is a brief snapshot from the T61 ***lower*** station master flow and chloride loading file. This table represents a single worksheet in the file for the month of April 2022. There are as many records (rows) in the file as there are 5-minute intervals during the month; 8640 rows in a 30-day month and 8928 rows in a 31-day month. The file has 1 worksheet for each month that flow and chloride data have been collected and more complete information regarding the file is presented in Table 4-1 at the beginning of this chapter.

Referring to Table 4-7 shown above, the following material describes the calculations that are performed:

- **Column 1** - stores the date and 5-minute interval copied from the *In-Situ* download file,
- Column 2 - stores the corresponding water level data (ft) copied from the *In-Situ* file,
- **Column 3** – stores the equation that calculates flow (mgd) from the *In-Situ* water levels using the latest version of the equation, which for T61 is an exponential function,
- **Column 4** - calculates the volume of flow (gallons) that passes the station during each 5-minute interval using the mgd flow calculated in **Column 3** and multiplying that value by 694 (gallons per minute per mgd), then multiplying by 5 (5-minute interval),
- **Column 5** - stores the 5-minute HOBO® logger conductivity data,
- **Column 6 -** calculates mg/L of chloride during the 5-minute interval using the equation generated from the scatter plot referenced above with regard to Table 4-4,
- **Column 7 -** calculates *pounds of chloride flowing past the station each 5-minute interval* by multiplying the corresponding **Column 6** value (*mg/L chloride*) by the *flow value* (mgd, **Column 3)**, then multiplying that value by *8.34* (weight of 1 L of water in lbs), and dividing the result by *288* (# of 5-minute intervals in 1 day), and

Column 8 and **Column 9** provide the total daily values for *pounds of chloride exported* and the *mgd volume of water* passing the station, respectively. The daily chloride values are populated in tables similar to Table 4-8, which shows the 2021 daily chloride load at T61 ***lower*** station.

Table 4-8.

2021	TRIBUTARY 61												
	DAILY CHLORIDE EXPORT AT LOWER STATION (lbs/day)												
	MONTH												
DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
1	0.73	1.29	0.80	25.18	5.25	0.87	0.68	2.83	1.40	1.41	1.88	1.47	
2	1.59	1.52	0.65	21.36	4.34	0.86	1.00	3.10	1.29	1.31	2.11	1.99	
3	2.56	1.58	0.88	24.73	4.08	2.75	0.77	2.37	1.35	1.41	2.93	2.37	
4	2.02	1.55	0.94	19.59	3.78	2.44	0.50	2.18	1.38	1.71	3.30	1.90	
5	1.89	1.54	0.87	18.15	6.24	1.64	0.45	2.11	1.37	2.16	3.73	1.75	
6	1.59	1.40	0.94	16.06	4.98	1.26	0.97	1.95	1.33	1.80	4.66	3.36	
7	1.38	1.28	0.98	15.19	3.70	1.04	0.68	1.86	1.28	1.53	4.50	3.68	
8	1.24	1.20	1.02	14.54	3.40	1.53	2.25	1.59	2.79	1.44	4.89	2.62	
9	1.16	0.93	1.29	13.83	3.23	1.47	14.36	1.42	3.23	1.34	4.86	2.20	
10	1.18	0.83	1.70	13.75	2.90	0.88	4.15	1.18	2.05	1.17	4.20	2.17	
11	1.19	1.06	8.74	13.23	2.65	0.67	2.48	1.24	1.45	1.11	2.51	24.59	
12	1.20	0.86	20.81	13.89	2.44	1.40	3.94	1.12	1.31	1.02	4.16	15.88	
13	1.11	1.00	16.45	13.24	2.15	0.79	6.26	1.36	1.21	1.06	2.15	6.44	
14	1.10	1.21	12.21	12.48	1.97	3.29	9.36	1.51	1.54	1.09	1.38	4.51	
15	1.06	1.25	8.35	28.97	2.01	2.26	11.21	1.60	4.30	1.18	1.09	3.67	
16	11.44	1.61	8.25	87.68	2.03	1.75	9.39	1.58	5.07	5.86	1.33	3.91	
17	10.21	1.39	7.86	61.40	1.79	1.66	12.32	1.88	4.34	5.65	1.90	4.05	
18	5.17	1.51	8.92	44.42	1.92	1.83	34.32	2.09	4.17	3.04	2.24	3.48	
19	3.63	5.54	8.75	35.97	2.01	1.96	21.27	9.88	3.53	2.34	2.09	2.89	
20	2.95	1.59	8.78	28.98	1.86	2.03	4.34	9.42	3.06	2.10	2.24	2.64	
21	2.65	1.43	9.67	24.69	1.82	3.48	2.06	6.01	2.86	2.15	2.14	2.59	
22	2.43	1.47	10.70	21.96	1.74	2.66	3.40	4.22	2.78	2.57	1.97	2.37	
23	2.74	1.70	12.39	20.10	1.60	1.80	2.80	3.86	2.75	2.19	1.77	1.92	
24	2.59	1.23	14.70	19.46	1.24	1.68	2.30	4.21	17.91	1.93	1.60	1.89	
25	1.85	0.52	19.72	18.10	1.13	1.59	1.72	2.88	5.63	4.40	1.59	4.79	
26	1.93	0.53	45.51	16.07	1.20	1.45	1.46	2.06	4.53	6.50	2.37	11.72	
27	1.84	0.63	31.07	14.78	1.14	1.32	2.95	1.89	3.98	1.82	16.17	5.78	
28	1.42	0.68	34.76	16.83	0.94	1.14	3.26	1.76	2.53	1.32	1.64	5.00	
29	0.95		35.41	22.53	0.74	0.94	3.96	1.76	1.61	1.57	1.43	4.41	
30	0.97		16.85	80.69	0.80	0.72	5.50	1.65	1.48	1.88	1.42	4.39	
31	1.02		13.01		0.97		2.97	1.47		8.28		5.04	ANNUAL
TOTAL	75	38	363	778	76	49	173	84	94	74	90	145	2039.81

Table 4-9 shows daily flow values for 2021 at ***lower*** station T61A.

Table 4-9.

2021	TRIBUTARY 61												
	DAILY FLOW AT LOWER STATION (mgd)												
	MONTH												
DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
1	0.178	0.063	0.067	0.281	0.706	0.070	0.046	0.111	0.075	0.093	1.477	0.142	
2	0.200	0.077	0.049	0.238	0.431	0.065	0.054	0.105	0.065	0.081	0.685	0.155	
3	0.183	0.075	0.058	0.276	0.335	0.089	0.049	0.092	0.057	0.078	0.460	0.166	
4	0.169	0.070	0.060	0.219	0.305	0.085	0.040	0.085	0.057	0.086	0.360	0.150	
5	0.155	0.069	0.054	0.203	0.373	0.074	0.038	0.078	0.050	0.093	0.305	0.146	
6	0.142	0.066	0.050	0.179	0.429	0.069	0.043	0.071	0.046	0.084	0.286	0.165	
7	0.133	0.059	0.051	0.169	0.336	0.069	0.041	0.066	0.045	0.072	0.262	0.189	
8	0.122	0.055	0.049	0.162	0.289	0.079	0.064	0.061	0.070	0.070	0.247	0.166	
9	0.117	0.056	0.059	0.154	0.265	0.076	0.153	0.058	0.077	0.066	0.239	0.156	
10	0.108	0.055	0.063	0.153	0.231	0.061	0.101	0.058	0.068	0.062	0.233	0.154	
11	0.103	0.056	0.076	0.148	0.210	0.057	0.087	0.059	0.059	0.060	0.209	0.374	
12	0.110	0.042	0.114	0.155	0.191	0.063	0.099	0.056	0.055	0.058	0.402	0.803	
13	0.110	0.043	0.128	0.148	0.182	0.052	0.107	0.056	0.053	0.057	1.063	0.490	
14	0.108	0.051	0.128	0.139	0.175	0.080	0.116	0.053	0.052	0.052	1.047	0.366	
15	0.103	0.052	0.100	0.323	0.167	0.077	0.115	0.050	0.063	0.048	0.655	0.290	
16	0.140	0.064	0.106	0.979	0.168	0.068	0.104	0.044	0.063	0.122	0.458	0.272	
17	0.146	0.055	0.108	0.685	0.154	0.064	0.121	0.047	0.057	0.173	0.351	0.231	
18	0.138	0.056	0.112	0.496	0.146	0.062	0.263	0.048	0.053	0.157	0.289	0.172	
19	0.128	0.059	0.104	0.401	0.139	0.061	0.569	0.133	0.049	0.145	0.245	0.187	
20	0.122	0.056	0.102	0.323	0.125	0.060	0.438	0.195	0.044	0.133	0.188	0.166	
21	0.118	0.049	0.105	0.276	0.117	0.069	0.443	0.191	0.039	0.127	0.178	0.166	
22	0.113	0.051	0.108	0.245	0.110	0.062	0.325	0.180	0.038	0.126	0.168	0.160	
23	0.132	0.057	0.111	0.224	0.104	0.054	0.240	0.157	0.038	0.114	0.146	0.138	
24	0.124	0.062	0.115	0.217	0.092	0.053	0.192	0.135	0.338	0.096	0.133	0.137	
25	0.088	0.064	0.120	0.202	0.083	0.052	0.171	0.124	0.206	0.139	0.137	0.168	
26	0.094	0.058	0.147	0.179	0.082	0.045	0.140	0.110	0.174	0.396	0.179	0.224	
27	0.094	0.060	0.149	0.165	0.083	0.043	0.148	0.104	0.152	0.521	1.378	0.178	
28	0.076	0.062	0.182	0.188	0.079	0.046	0.135	0.100	0.137	0.293	0.161	0.190	
29	0.052		0.233	0.251	0.068	0.046	0.136	0.098	0.117	0.219	0.152	0.182	
30	0.052		0.195	0.901	0.073	0.042	0.152	0.087	0.102	0.201	0.144	0.183	
31	0.054		0.191		0.073		0.116	0.080		2.344		0.189	ANNUAL
TOTAL	3.713	1.641	3.295	8.681	6.320	1.892	4.843	2.892	2.498	6.364	12.237	6.857	61.23

The yellow color-coded cells in Tables 4-8 and 4-9 identify days during 2021 when high flow at the ***lower*** station resulted in the chloride concentration decreasing below detection (1.0 mg/L) for a period of time.

Evaluation of these data are explained in a subsequent section of this report.

The daily chloride and flow data summarized in Tables 4-8 and 4-9 also are stored in column format with daily precipitation data in a separate worksheet with one row for each day of the year. This method of data storage facilitates the easy generation of graphs that summarize the data.

4.2.5 Defining the winter period of tributary subwatershed monitoring data

Except at T36a, the lower stations of the "**test**" and "**control**" subwatersheds have been fully instrumented since May 2020 to monitor specific conductance and water level, the data required to conduct a thorough evaluation of chloride loading from each subwatershed. The data collected from 2020, however, have limited usefulness because water level loggers were not installed at the ***lower*** subwatershed sampling stations during the first four months of the year.

Using 12-month calendar periods (January through December) to calculate the annual chloride loading of individual subwatersheds was not realistic for this particular Project because during late October-early November each year, local temperatures decline, and road salt is applied to the "test" and "control" highway surfaces in anticipation of certain forecast storm events. Continuing to monitor "calendar year" specific conductance and water level during this period means that chloride loading values will include contributions from a different "winter period" than the monitoring that occurred from January through October.

Based upon this information, it was decided to use October 31st each year as the date to terminate the chloride load and flow data collection for the "winter period" under investigation unless other information was available from the NYSDOT to indicate that road salt application was delayed beyond that date. Accordingly, it also was valid to start the "winter period" on November 1st and use October 31st the following year as the end date. So, for example, the flow and chloride monitoring data for "Winter Period 2020-2021" would start on November 1st, 2020, and end on October 31st, 2021. It was decided to use "road salt application period" to form the acronym RSAP to denote the period that begins on November 1st and end on October 31st.

Flow and chloride monitoring data are complete for the "RSAP 2020-2021" and "RSAP 2021-2022" and these data will be presented for the watersheds currently under investigation in the report chapters that follow.

4.3 Summary

This chapter has presented the Pilot Program Data Management process in great detail starting with an explanation of specific Excel files and required formatting to the tedious process of calculating chloride loads over time using 5-minute flow values and 5-minute specific conductance concentrations collected at each lower sampling site. It has taken considerable effort to achieve the long-term data records that currently exist for each watershed under investigation and all of the Project cooperators are to be acknowledged for their part in this successful outcome.

4.4 Literature Cited

No literature cited in the text of this chapter.

New York State Department of Transportation Road Salt Reduction Pilot Program

Final Report for the Lake Champlain Sea Grant Program

Chapter 5

Tributary 63a "Test" Watershed and the Pilot Monitoring Project

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5.0 Watershed Characteristics. "Test" tributary 63a (T63a) is an unnamed tributary located near the end of Northwest Bay on the west side of Lake George, about 3 miles south of the Route 9N-Padanarum Road intersection, which is the northern extent of the Route 9N "**pilot**" segment. The tributary was sampled at an ***upper*** site located about 200 feet above Route 9N and a ***lower*** site about 150 feet below Route 9N.

The ***upper*** and ***lower*** sub-watersheds of T63a are shown in Figure 5-1 and 5-2, respectively. The T63a ***upper*** sub-watershed is undeveloped except for a well-traveled hiking trail. The ***lowe***r sampling site was selected so that storm runoff and groundwater movement from Route 9N are the only developed area drainage sampled at this location.

Watershed characteristics of the ***upper*** and ***lower*** sampling sites are summarized in Table 5-1.

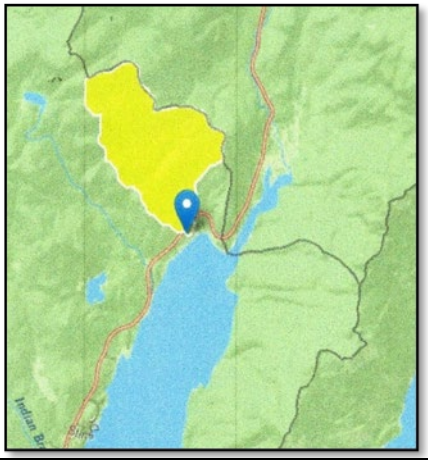
Tributary 63a Watershed Characteristics	
Figure 5-1.	**Figure 5-2.**
Watershed Configuration at *Upper* Site	**Watershed Configuration at *Lower* Site**
	

Table 5-1. Tributary 63a Watershed Characteristics

	Sampling Site	Sampling Site
Category	***Upper***	***Lower***
Latitude of sampling site	43.61567	43.61411
Longitude of sampling site	-73.62194	-73.62175
Watershed area @ sampling site (mile^2)	0.76	0.80
Length of main channel to basin divide (miles)	1.94	2.07
Mean watershed slope at sampling site (feet/mile)	990	986
% of watershed > 1200 feet in elevation	15.7	15
% of area with storage (lakes, ponds, wetlands)	1.86	1.77
% of area covered by forests	98.1	98.2
Mean annual runoff (inches)	18.2	18.2
50th percentile of seasonal max snow depth (inches)	20.4	20.4
Mean annual precipitation (inches)	37	36.9
% of area with Hydrologic Soil Type B	62.4	61.9
% of area with Hydrologic Soil Type A	0	0
Average % impervious area	0.0004	0.0168
% of developed (urban) land	0.0404	0.88
% of watershed impacted by road salt	0.0	to be determined

T63a at the ***lower*** station has the second largest drainage of the four watersheds under investigation at 512 acres and the third largest highway segment at 0.45 acres, or 0.27 lane miles. The sampling station at the ***lower*** sub-watershed is located about 150 feet east of Route 9N and about 60 feet lower in elevation than the highway surface.

5.1 *Lower* Site Equipment Installation. Figure 5-3 is a photograph of the T63a ***lower*** sampling site, looking northwest and showing the PVC assembly situated in a deep pool in the channel. The PVC assembly is free-standing and surrounded by a pile of numerous channel boulders and rocks to secure placement and prevent movement during potential catastrophic flows, although there is a paracord connection between the assembly and an adjacent tree. The assembly purposely was placed outside the direct line of flow in the channel path.

The PVC housing contains the *In-Situ* logger and the site Baro TROLL is mounted to the top of the assembly. The Onset HOBO® specific conductance and temperature logger is enclosed in a PVC housing which is mounted to a concrete block and positioned in the channel adjacent to the *In-Situ* installation (Figure 5-4).

Figure 5-3.

Figure 5-4.

5.2 Field Measurements, Analytical Chemistry and Tributary Flow. Tables 5-2 and 5-3 summarize the field measurements, analytical chemistry results from the DFWI Laboratory and flow gaging measurements that have been collected at the ***upper*** and ***lower*** stations of T63a, respectively, from 2018 through October 2022.

Table 5-2.

T63a ***UPPER*** STATION													
Sample Size (n)	Water temp (C)	DO (mg/L)	DO (% sat)	NO3-N (mg N/L)	SO4-S (mg/L)	Cl (mg/L)	Ca (mg/L)	Na (mg/L)	Mg (mg/L)	K (mg/L)	spC (µS/cm @ 25 C)	TDS (ppm)	pH (s.u.)
94	9.6	11.6	98.6	0.06	1.03	0.52	4.16	0.78	0.62	0.15	32.3	20.9	7.40

Table 5-3.

T63a ***LOWER*** STATION														
Sample Size (n)	Water temp (C)	DO (mg/L)	DO (% sat)	NO3-N (mg N/L)	SO4-S (mg S/L)	Cl (mg/L)	Ca (mg/L)	Na (mg/L)	Mg (mg/L)	K (mg/L)	spC (µS/cm @ 25 C)	TDS (ppm)	pH (s.u.)	Flow (mgd)
96	9.7	11.8	100.8	0.06	1.13	5.18	4.76	4.33	0.72	0.18	55.7	36.4	7.37	0.551

A complete set of all field measurements, analytical chemistry results from the DFWI Laboratory and gaged tributary flow will be uploaded to the Lake Champlain Sea Grant Program shared data website following release of this report.

5.3 Specific Conductance and Chloride Concentrations. A summary of select analyte data with respect to road salt application are presented in Table 5-4 including chloride and specific conductance concentrations, flow, and number of samples (n) collected each calendar year that the Program has been in effect.

Table 5-4.

	Upper	***Lower***	***Upper***	***Lower***	***Lower***	***Upper***	***Lower***
	Cl (mg/L)	**Cl (mg/L)**	**spC (µS/cm)**	**spC (µS/cm)**	**Flow (mgd)**	**Sample Size (n)**	**Sample Size (n)**
mean 2018 samples	**0.58**	**11.88**	**36.4**	**84.3**	**0.156**	**10**	**10**
mean 2019 samples	**0.51**	**3.39**	**29.2**	**43.9**	**0.575**	**20**	**20**
mean 2020 samples	**0.50**	**8.30**	**30.5**	**68.0**	**1.163**	**20**	**22**
mean 2021 samples	**0.50**	**2.31**	**33.5**	**42.4**	**0.392**	**22**	**22**
mean 2022 samples	**0.50**	**3.48**	**32.3**	**45.4**	**0.267**	**23**	**23**
mean all samples	**0.52**	**5.18**	**32.3**	**55.7**	**0.551**	**94**	**96**

The values presented in Table 5-4 are *mean* values for samples collected during a particular *calendar year* and not during the *road salt application period* (RSAP) which covers the period from November 1st through October 31st of the following year. The difference in *average* chloride concentration between ***upper*** and ***lower*** stations is apparent when comparing the annual summaries with each other; the *mean* value of all 94 ***upper*** samples collected to date is

0.52 versus 5.18 mg Cl$^-$/L for the ***lower*** samples, a 10-fold difference. A similar difference between ***upper*** and ***lower*** sites occurs with the overall *mean* specific conductance concentrations, 32.3 and 55.7 µS/cm @ 25C, respectively, a 1.7-fold difference.

Figures 5-5 and 5-6 present the relationship between field specific conductance and DFWI chloride concentration and the Onset HOBO® specific conductance logger and chloride concentration, respectively, measured since mid-summer 2018 at the T63a ***lower*** site.

Figure 5-5.

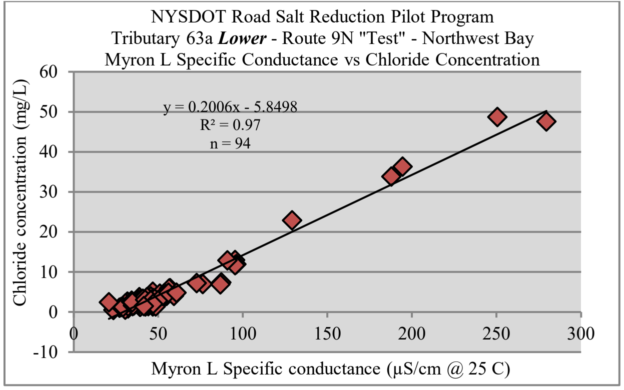
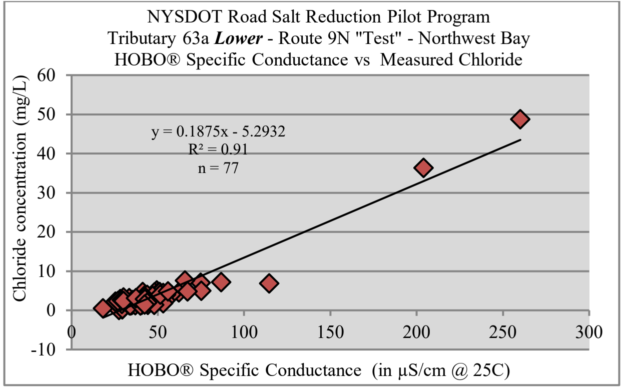


Figure 5-6.

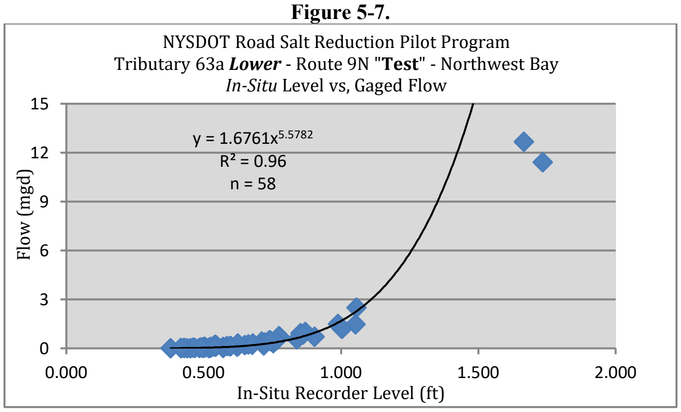


Field specific conductance is measured on-site with the Myron L muti-function meter and the HOBO logger 5-minute readings are stored internally until retrieved at each download. The relationship between specific conductance and the chloride concentration at the T63a ***lower*** site is very robust as noted by the high R^2 values (0.97, 0.91), regardless of which measurement is used. Based upon the equation shown in Figure 5-6 for the HOBO® logger, it is possible to construct chloride concentrations in the channel with ~91 percent accuracy using the 5-minute specific conductance values recorded with the Onset HOBO® logger.

The equation in Figure 5-6 is updated and entered into the Tributary Master Flow-Chloride Loading File every time the HOBO® values are downloaded during the field excursions and chloride data are received from DFWI for samples submitted for analysis. As of the writing of this report, a total of **77** pairs of specific conductance and chloride concentration values have been used to define this relationship.

5.4 Tributary Flow. A strong relationship also is exhibited by the rating curve developed between T63a tributary flow, calculated after each manual gaging, and the corresponding *In-Situ* TROLL 200 water level readings stored by the data logger installed in the tributary channel. Since the beginning of the current investigation, there have been 58 pairings of gaged flow and water level which provide a very robust (R^2 = 0.96) relationship between the two sets of data. Figure 5-7 presents a graphical summary of T63a flow rating data.

Figure 5-7.



The equation in Figure 5-7 that describes the relationship between gaged flow and data logger water level is defined by a ‘power’ function that provides the best fit for all of the data points. The flow rating curve and the accompanying equation are updated following each field excursion when the manual tributary gaging and data downloads occur.

5.5 Tributary RSAP Data Summaries. Each NYSDOT Road Salt Reduction Pilot-T#-Master Flow-Chloride Export file had a worksheet dedicated to RSAP data summarized in a ‘string’ of columns where daily data were stored including headers: *Date, Daily Chloride Exported, Cumulative Daily Chloride Exported, Daily Flow (million gallons), Cumulative Daily Flow, Daily Precipitation (inches), Daily Precipitation (mm)*, and *Cumulative Daily Precipitation*. The column header from the T63a Excel file spreadsheet summarizing RSAP 2020-2021 on a daily basis is below:

ROAD SALT APPLICATION PERIOD (RSAP) 2020-2021							
Date	Daily Cl^- Exported (lbs)	Cumulative Daily Cl^- Exported (lbs)	Daily Flow (mg)	Cumulative Daily Flow (mg)	Daily Precipitation (inches)	Daily Precipitation (mm)	Cumulative Daily Precipitation (mm)

These daily data summaries then can be plotted as line graphs like Figure 5-8 and 5-9 below which are daily chloride exported, flow, and precipitation data summarized for RSAP 2020-2021 and 2021-2022, respectively.

Figure 5-8.

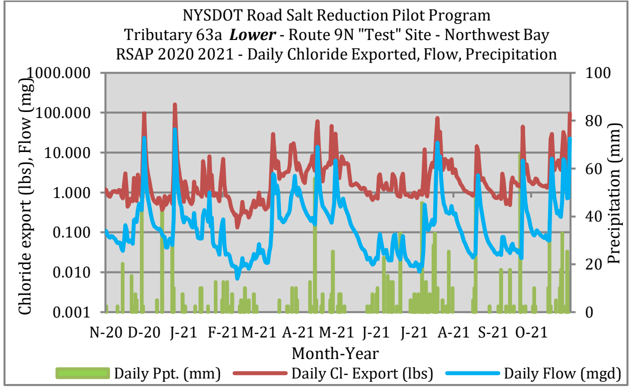
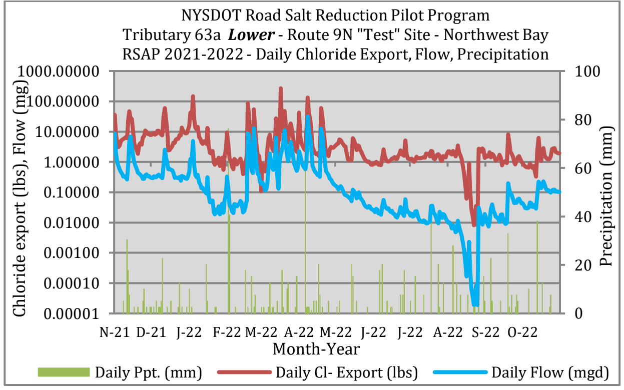


Figure 5-9.



The above figures are an effective way to visually summarize the daily data for general comparisons during portions of the 12-month period. For example, we can see the different flow pattern for RSAP 2021-2022 from about May 2022 through September 2022 when the flow values steadily dropped to below 0.0001 mgd (10 gallons /day), while there was no similar occurrence for RSAP 2020-2021 during the period. Other, more detailed comparisons between RSAPs are difficult if impossible to decipher because of the scale of the data (daily) during the entire period.

The following tables summarize monthly chloride export (lbs), tributary flow (mg = million gallons), chloride export/mg of flow, and precipitation (inches and mm) during road salt application period (RSAP) 2020-2021 (Table 5-5) and RSAP 2021-2022 (Table 5-6).

Table 5-5.

ROAD SALT APPLICATION PERIOD 2020-2021 DATA SUMMARY												
Parameter	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Chloride Exported (lbs)	42	340	50	19	164	290	82	42	253	75	96	289
Flow (mg)	5.683	79.483	5.616	0.738	19.519	36.087	8.191	1.102	40.699	7.521	10.479	52.410
Chloride Exported/mg Flow	7.4	4.3	8.8	26.2	8.4	8.0	10.0	38.4	6.2	9.9	9.1	5.5
Precipitation (inches)	4.1	3.8	1.8	2.8	1.4	4.9	1.3	5.1	8.4	2.9	4.5	6.9
Precipitation (mm)	104.1	96.5	45.7	71.1	35.6	124.5	33.0	129.5	213.4	73.7	114.3	175.3
# of days	30	31	31	28	31	30	31	30	31	31	30	31

Table 5-6.

ROAD SALT APPLICATION PERIOD 2021-2022 DATA SUMMARY												
Parameter	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Chloride Exported (lbs)	309	328	370	228	507	417	83	44	46	41	51	33
Flow (mg)	38.062	15.080	11.345	37.039	59.187	86.455	2.471	0.781	0.508	0.199	1.192	2.192
Chloride Exported/mg Flow	8.1	21.7	32.6	6.2	8.6	4.8	33.4	56.7	91.1	204.3	42.9	15.1
Precipitation (inches)	3.40	2.80	1.70	6.50	3.60	4.65	2.00	3.20	4.00	4.10	3.60	2.80
Precipitation (mm)	86.36	71.12	43.18	165.10	91.44	118.11	50.80	81.28	101.60	104.14	91.44	71.12
# of days	30	31	31	28	31	30	31	30	31	31	30	31

The chloride export, flow, and precipitation monthly summaries for RSAP 2020-2021 and 2021-2022 presented in Tables 5-5 and 5-6, respectively, also can be displayed graphically to provide a better visual interpretation and means of comparing the monthly data summarized during each road salt application period. Figures 5-10 and 5-11 are column graphs/charts of the monthly chloride export and tributary flow data for RSAPs 2020-2021 and 2021-2022 summarized in Tables 5-5 and 5-6, respectively.

Figure 5-10.

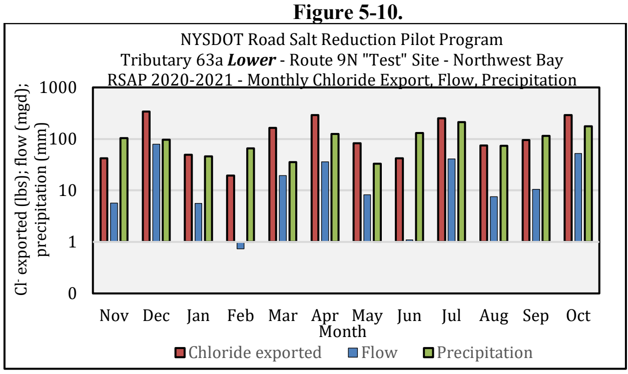
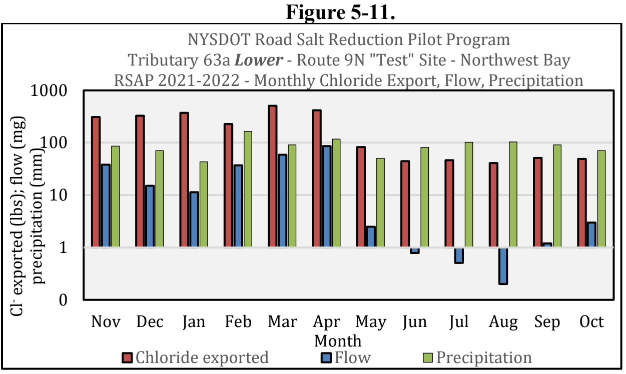


Figure 5-11.



Note: The *y-axis* in Figures 5-10 and 5-11 is logarithmic scale. We see "peaks and valleys" with all three parameters and using the logarithm scale makes it difficult to accurately interpret the relationship among the parameters. Some important observations during RSAP 2020-2021 and 2021-2022 include (1) the highest chloride exports during RSAP 2020-2021 occurred during five months spread throughout the year, while in RSAP 2021-2022, the highest exports occurred from November through April, and (2) RSAP 2021-2022 flows were <1.0 mgd in July-August.

Using the monthly data summaries provided so far, we can evaluate whether a relationship exists between flow and chloride for the RSAP 2020-2021 and RSAP 2021-2022 data. Figures 5-12 and 5-13 present scatterplots of these data for both road salt application years.

Figure 5-12.

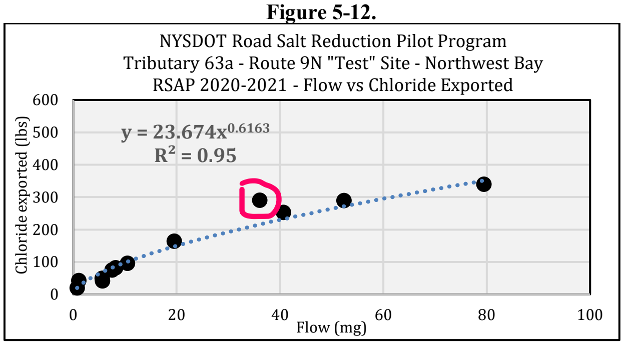
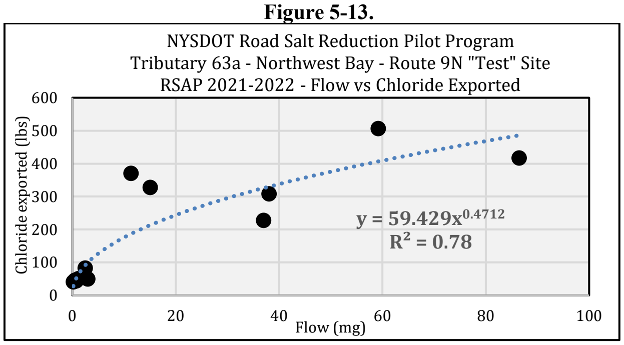


Figure 5-13.



The RSAP 2020-2021 scatterplot has a very robust relationship (R^2 = 0.95) between flow and chloride export explained by a power function, with only one point (red circle in Figure 5-12) falling away from the trendline as a result of runoff flow (36.087 mg) and chloride exported (290 lbs.) during April 2021 (see Table 5-5). The RSAP 2021-2022 scatterplot is far less robust (R^2= 0.78) with many points lying above and below the trendline (Figure 5-13).

The 'cumulative' format graphs that show the daily progression of the variables of interest as they accumulate during the 12-month period are presented in Figures 5-14 (RSAP 2020-20921) and Figure 5-15 (RSAP 2021-2022).

Figure 5-14.

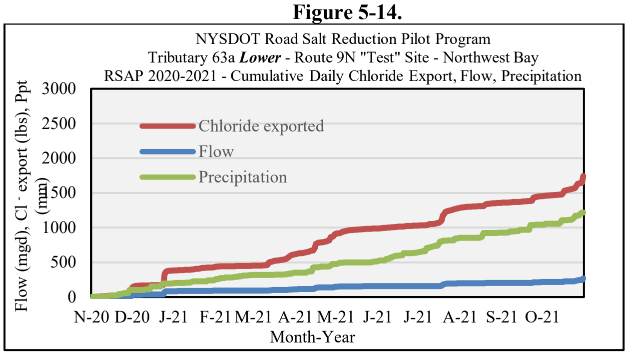
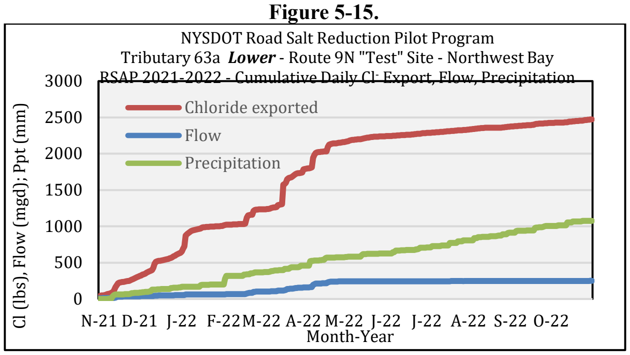


Figure 5-15.



These graphs provide a certain convenience when comparing different RSAPs, and Figures 5-14 and 5-15 are good examples to compare. The different slope patterns exhibited by the flow and chloride load trendlines tell the story of how the two RSAPs differed. Looking at RSAP 2020-2021, flow progressed through the year in a stepwise fashion and chloride exported responded accordingly to each "step" and "plateau". RSAP 2021-2022 was totally different, reaching almost maximum annual values of flow and chloride export during April-May 2022 and then levelling off for the remainder of the period due to very dry low flow conditions in the watershed.

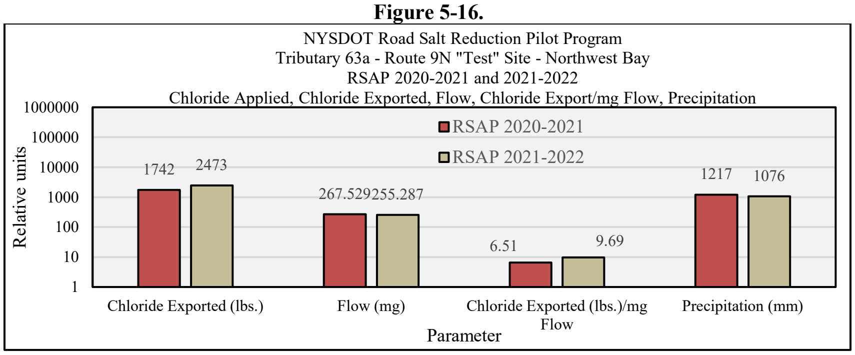
Detailed flow and chloride export information have been collected from the T63a watershed for the previous two road salt application cycles (RSAPs). Now is the time to summarize the extensive data collected so that evaluations can be achieved using the NYSDOT road salt application data received for this particular "pilot" segment of Route 9N. Table 5-7 summarizes and compares the RSAP 2020-2021 and RSAP 2021-2022 "Annual" parameter values from the Table 5-5 and Table 5-6 datasets above.

Table 5-7.

	RSAP ANNUAL	
	2020-2021	2021-2022
Chloride Export (lbs)	1741.79	2472.73
Flow (mg)	267.529	255.287
Chloride exported/mg Flow	6.51	9.69
Precipitation (mm)	1216.66	1075.7

RSAP 2021-2022 had a greater chloride export than RSAP 2020-2021 (2473 vs 1742 lbs., respectively), even though the total annual flow was less during RSAP 2021-2022 than during 2020-2021 (255.29 vs 267.53 mgd, respectively). Figure 5-16 summarizes and compares the RSAP 2020-2021 and RSAP 2021-2022 "Annual" parameter values provided in Table 5-7 (*y-axis* in logarithm scale).

Figure 5-16.



A comparison of the two RSAP parameters in Figure 5-16 reveals that (1) chloride export was 42 percent greater in 2021-2022 (2473 lbs.) than in 2020-2021 (1742 lbs.), (2) flow at the ***lower*** site was 5 percent less in 2021-2022 (255.287 mgd) than in 2020-2021 (267.529 mgd), (3) chloride export per million gallons (mg) of flow was 49 percent greater in 2021-2022 (9.7 lbs.) than in 2020-2021 (6.5 lbs.), and (4) total precipitation was 12 percent less during 2021-2022 (1076 mm) than in 2020-2021 (1217 mm).

At this time, the summarized RSAP 2020-2021 and 2021-2022 chloride export, flow and precipitation data can be used to populate a table that contains some of the watershed characteristics that define T61 (Table 5-8).

Table 5-8.

							Chloride load in lbs			
Program ID	Watershed Area (ac)	Highway Area (ac)	Lane Miles	RSAP	Period Ppt (mm)	Annual flow (mg)	Annual Cl Export	Cl^- Export/ LM	Cl^- Export/ million gals	Cl^- Export/ mm Ppt
Trib 63a	512	0.45	0.27	2020-2021	1217	268	1742	6452	6.5	1.43
				2021-2022	1076	255	2473	9159	9.7	2.29

Each of the following three chapters (6, 7, and 8) presents information from the remaining three watersheds under investigation similar to the material presented in this chapter. Chapter 9 will compile all of this watershed and collected data information into a single place so that comparisons can be made. Chapter 10 describes the challenges, understanding, evaluation and problems associated with the NYSDOT road salt application data, while Chapter 11will compare the data collected by the LGA monitoring program with the road salt application data provided by the NYSDOT to determine whether an evaluation of the 10 percent reduction program could be accomplished.

5.6 Literature Cited

No literature cited in the text of this chapter.

New York State Department of Transportation Road Salt Reduction Pilot Program

Final Report for the Lake Champlain Sea Grant Program

Chapter 6

Tributary 61 “Test” Watershed and the Pilot Monitoring Project

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6.0 Watershed Characteristics. Tributary 61 (T61) is located about 1 mile south of Tributary 63a, has Wing Pond outlet as its source and flows into Northwest Bay. The tributary ***upper*** site was located about 100 yards west of Route 9N and the ***lower*** site about 100 yards below (east of) Route 9N. The watershed characteristics are summarized below.

Tributary 61 (Wing Pond Outlet) Watershed Characteristics	
Figure 6-1.	**Figure 6-2.**
Watershed Configuration at *Upper* Site	**Watershed Configuration at *Lower* Site**
	

Table 6-1. Tributary 61 (Wing Pond Outlet) Watershed Characteristics

	Sampling Site	**Sampling Site**
Category	***Upper***	***Lower***
Latitude of sampling site	43.60454	43.60314
Longitude of sampling site	-73.63286	-73.63277
Watershed area @ sampling site (mile^2)	0.28	0.30
Length of main channel to basin divide (miles)	0.82	0.92
Mean watershed slope at sampling site (feet/mile)	448	495
% of watershed > 1200 feet in elevation	0	0
% of area with storage (lakes, ponds, wetlands)	9.55	8.68
% of area covered by forests	88.9	89.9
Mean annual runoff (inches)	18	18
50th percentile of seasonal max snow depth	20.4	20.4
Mean annual precipitation (inches)	36.8	36.8
% of area with Hydrologic Soil Type B	68.2	69
% of area with Hydrologic Soil Type A	0	0
Average % impervious area	0	0.0427
% of developed (urban) land	0	1.74
% of watershed impacted by road salt	0	to be determined

T61 at the ***lower*** station has the second smallest drainage of the four watersheds under investigation at 192 acres and the smallest highway segment at 0.37 acres, or 0.22 lane miles. The sub-watershed at the lower sampling site is 90 percent forested, 1.74 percent developed, and 0.04 percent impervious. The sampling station at the ***lower*** sub-watershed is located about 250 feet east of Route 9N and about 30-40 feet lower in elevation than the highway surface.

6.1 *Lower* Site Equipment Installation

Figures 6-3 and 6-4 are photographs of the T61 ***lower*** site location showing the *In-Situ* water level data logger and the Onset HOBO specific conductance and temperature logger located in the tributary channel, respectively. The channel is very bony and irregular above the site with large boulders and rocks along the tributary length above the station as well as fallen trees in the area and across the channel. The Onset HOBO specific conductance and temperature logger is checked during each visit to make certain that there is sufficient water depth above the installation.

The PVC housing contains the *In-Situ* logger and is mounted on 5/4 deck lumber attached to the tree on the shoreline with aviation cable. The Baro TROLL is attached to the top of the PVC installation. The Onset HOBO® unit is mounted with metal straps on a concrete block situated in the channel visible in Figure 6-4 (red circle).

Figure 6-3.

Figure 6-4.

There are certain times during the winter when access to the Onset HOBO® unit is precluded because the unit is encased in extremely thick channel ice which prevents gaining access to the logger for download purposes.

6.2 Field Measurements, Analytical Chemistry and Flow. Tables 6-2 and 6-3 below summarize the field measurements, analytical chemistry results from the DFWI Laboratory and flow gaging measurements that have been collected at the ***upper*** and ***lower*** stations of T61, respectively, from 2018 through October 2022.

Table 6-2.

T61 ***UPPER*** STATION													
Sample Size (n)	Water temp (ºC)	DO (mg/L)	DO (% sat)	NO3-N (mg N/L)	SO4-S (mg S/L)	Cl (mg/L)	Ca (mg/L)	Na (mg/L)	Mg (mg/L)	K (mg/L)	spC (µS/cm)	TDS (ppm	pH (s.u.)
93	10.7	11.2	97.6	0.06	0.93	0.50	3.37	0.81	0.59	0.18	28.9	18.7	7.30

Table 6-3.

T61 ***LOWER*** STATION														
Sample Size (n)	Water temp (ºC)	DO (mg/L)	DO (% sat)	NO3-N (mg N/L)	SO4-S (mg S/L)	Cl (mg/L)	Ca (mg/L)	Na (mg/L)	Mg (mg/L)	K (mg/L)	spC (µS/cm)	TDS (ppm)	pH (s.u.)	Flow (mgd)
93	10.5	11.5	100.1	0.08	0.98	4.44	3.76	3.96	0.66	0.22	47.7	32.1	7.28	0.166

A complete set of all field measurements, analytical chemistry results from the DFWI Laboratory and gaged tributary flow will be uploaded to the Lake Champlain Sea Grant Program shared data website following release of this report.

6.3 Specific Conductance and Chloride Concentration. A summary of select analyte data important to this particular study with respect to road salt application is presented in Table 6-4 and includes chloride and specific conductance concentrations, flow, and number of samples (n) collected for each calendar year that the Program has been in effect. The specific conductance and chloride data highlight the difference in chemistry between the ***upper*** and ***lower*** sampling stations and the suitability of the watershed to be included in this investigation.

Table 6-4.

	Upper **Cl (mg/L)**	***Lower*** **Cl (mg/L)**	***Upper*** **spC (µS/cm)**	***Lower*** **spC (µS/cm)**	***Lower*** **Flow (mgd)**	***Upper*** **Sample Size (n)**	***Lower*** **Sample Size (n)**
avg 2018 samples	**0.52**	**8.95**	**31.1**	**67.4**	**0.093**	**9**	**9**
avg 2019 samples	**0.51**	**3.85**	**27.2**	**43.1**	**0.204**	**20**	**20**
avg 2020 samples	**0.50**	**5.75**	**28.8**	**54.1**	**0.188**	**22**	**22**
avg 2021 samples	**0.50**	**2.89**	**28.8**	**39.9**	**0.195**	**22**	**22**
avg 2022 samples	**0.50**	**3.19**	**29.6**	**44.9**	**0.099**	**20**	**20**
Avg all samples	**0.50**	**4.43**	**28.9**	**47.7**	**0.165**	**95**	**95**

The values in Table 6-4 are *mean* values for samples collected during a particular *calendar year* and not during the RSAPs described earlier which include the period from November 1st through October 31st the following year. The difference in *mean* chloride concentration between the ***upper*** and ***lower*** stations at T61 is apparent when comparing the annual summaries; the *mean* value of all 95 samples collected to date is 0.50 versus 4.44 mg Cl^-/L, a 9-fold difference overall. The same difference occurs between T61 ***upper*** and ***lower*** sites with respect to overall *mean* specific conductance concentrations, 28.9 and 47.7 µS/cm @ 25 C, respectively, a 1.7-fold difference.

Figures 6-5 and 6-6 present the relationship between field specific conductance and chloride concentration and the Onset HOBO® specific conductance logger and chloride concentration, respectively, measured since mid-summer 2018 at the T63a ***lower*** site.

Figure 6-5.

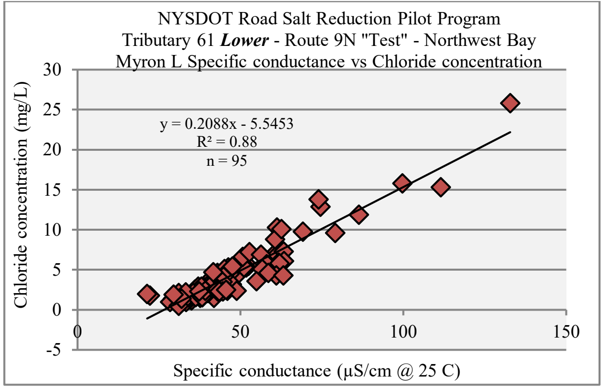
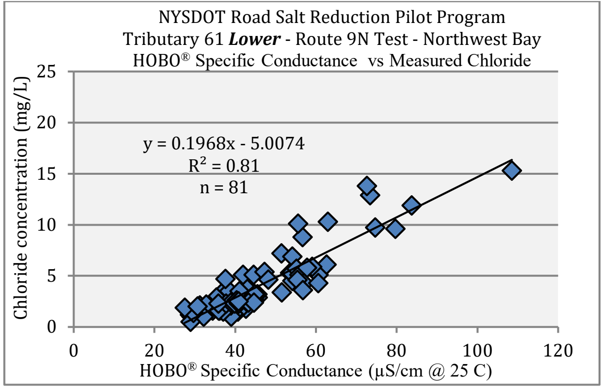


Figure 6-6.

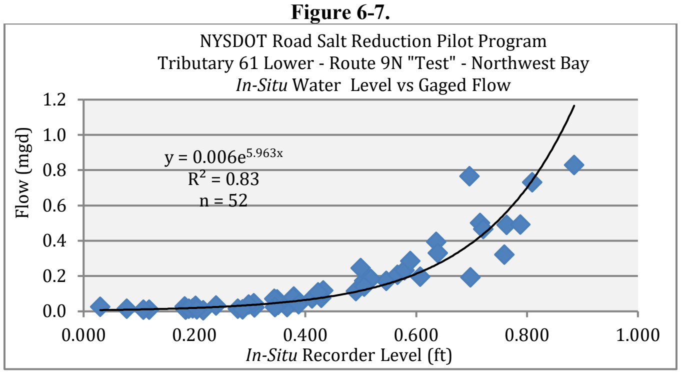


Field specific conductance is measured on-site with the Myron L muti-function meter and the HOBO® logger 5-minute readings are stored internally until retrieved at each download. The relationship between the HOBO® specific conductance and the chloride concentration at the T61 ***lower*** site is modest as noted by the R^2 value (0.81). Based upon the equation shown in Figure 6-6 for the HOBO® logger relationship, it is possible to construct chloride concentrations in the channel with ~81 percent accuracy using the 5-minute specific conductance values recorded with the installed Onset HOBO® logger.

The equation in Figure 6-5 is modified and entered into the Tributary Master Flow-Chloride Loading File every time the HOBO® files are downloaded during the field excursions and chloride data are received from DFWI for samples submitted for analysis. The relationship has become even more robust as specific conductance data and chloride analytical results are added to the data set. As of the writing of this report, a total of 81 pairs of specific conductance and chloride concentration values have been used to define this relationship.

6.4 Tributary Flow. A modest relationship ($R^2 = 0.83$) also is exhibited by the flow rating curve developed between the T61 tributary flow calculated after each manual gaging and the corresponding *In-Situ* TROLL 200 water level readings stored by the data logger installed in the tributary channel at the ***lower*** sampling station. Since the beginning of the current investigation, there have been 52 pairings of these data and the equation is refreshed after each field excursion and data download. Figure 6-7 is a summary of these data.

Figure 6-7.



The equation in Figure 6-7 defines the 'best fit' relationship between the manually gaged flow and the *In-Situ* data logger water level is an 'exponential' function. The constant "*e*" in the equation equals 2.71828182845908, the base of the natural logarithm and, in this case, is raised to the 5.963**x* power, where *x* is the corresponding 5-minute water level value stored by the *In-Situ* data logger. The flow rating equation is updated following each field excursion when manual tributary gaging and data downloads occur.

6.5 Tributary RSAP Data Summaries. Each NYSDOT Road Salt Reduction Pilot-T##-Master Flow-Chloride Export file has a separate worksheet dedicated to RSAP data summarized in columns where ‘strings’ of daily data, one row for each day of the year, were stored under the following headers: *Date, Daily Chloride Export, Cumulative Daily Chloride Export, Daily Flow (million gallons), Cumulative Daily Flow, Daily Precipitation (inches), Daily Precipitation (mm)*, and *Cumulative Daily Precipitation*. The column header from the T61 Excel file spreadsheet summarizing RSAP 2020-2021 on a daily basis is presented below:

ROAD SALT APPLICATION PERIOD (RSAP) 2020-2021							
Date	Daily Cl^- Export (lbs.)	Cumulative Daily Cl^- Export (lbs.)	Daily Flow (mg)	Cumulative Daily Flow (mg)	Daily Precipitation (inches)	Daily Precipitation (mm)	Cumulative Daily Precipitation (mm)

These ‘string of daily data’ summaries then can be plotted as line graphs as provided in Figure 6-8 and Figure 6-9 below which present T61 daily chloride export, flow, and precipitation data summarized for RSAP 2020-2021 and 2021-2022, respectively.

Figure 6-8.

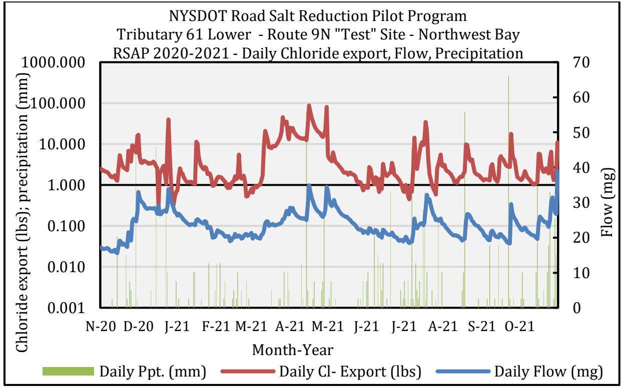
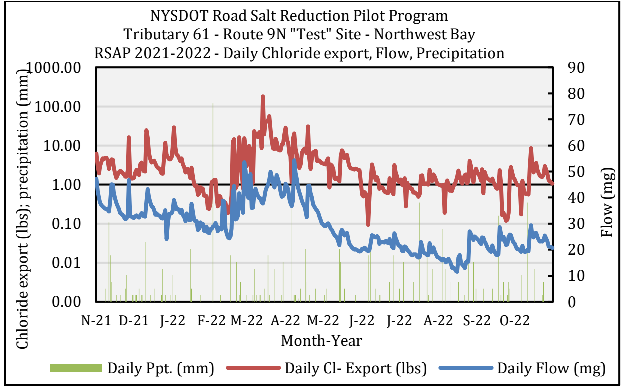


Figure 6-9.



Summaries of data formatted monthly also are a convenient way to present data for comparisons. The following tables summarize monthly chloride export (lbs.), tributary flow (mg = million gallons), chloride export per mg of tributary flow, and precipitation (inches, millimeters) during RSAP 2020-2021 (Table 6-5) and RSAP 2021-2022 (Table 6-6).

Table 6-5.

RSAP 2020-2021												
Parameter	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Chloride Export (lbs.)	114	143	75	38	363	778	76	49	165	84	94	77
Flow (mg)	1.587	9.920	3.713	1.641	3.295	8.681	6.320	1.892	4.843	2.892	2.498	6.364
Chloride export/mg Flow	72	14	20	23	110	90	12	26	34	29	37	12
Precipitation (inches)	4.1	3.8	1.8	2.8	1.4	4.9	1.3	5.1	8.4	2.9	4.5	6.9
Precipitation (mm)	104.1	96.5	45.7	71.1	35.6	124.5	33.0	129.5	213.4	73.7	114.3	175.3
# of days	30	31	31	28	31	30	31	30	31	31	30	31

Table 6-6.

RSAP 2021-2022												
Parameter	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Chloride Export (lbs.)	100	145	102	90	680	244	98	33	33	43	38	56
Flow (mg)	12.237	6.857	4.759	11.040	14.777	19.506	1.582	1.012	0.614	0.551	1.029	1.070
Chloride export/mg Flow	8	21	21	8	46	13	62	33	54	78	37	52
Precipitation (inches)	3.3	2.9	1.70	6.50	3.70	4.65	2.0	3.2	4.0	4.1	3.6	2.8
Precipitation (mm)	83.8	73.7	43.2	165.1	94.0	118.1	50.8	81.3	101.6	104.1	91.4	71.1
# of days	30	31	31	28	31	30	31	30	31	31	30	31

Monthly summaries are helpful for storing the data in a format that reduces daily data to a more manageable system and allows some simple comparisons between individual months in both RSAP datasets. However, more complicated comparisons and evaluation are difficult when using tabular format and for that reason these data also can be displayed graphically in column format to provide a better visual interpretation.

Figures 6-10 and 6-11 are separate column graphs of the RSAP 2020-2021 and RSAP 2021-2022 monthly chloride export, flow, and precipitation data, respectively, presented in the Tables 6-5 and 6-6 above.

Figure 6-10.

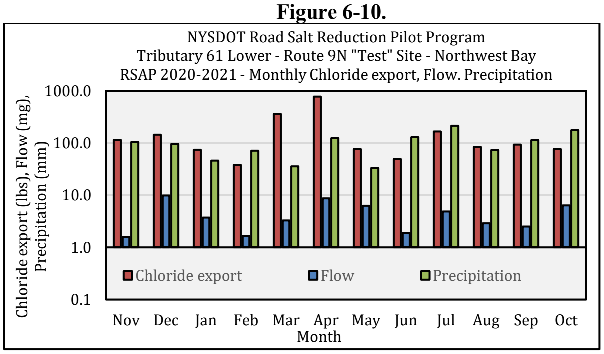
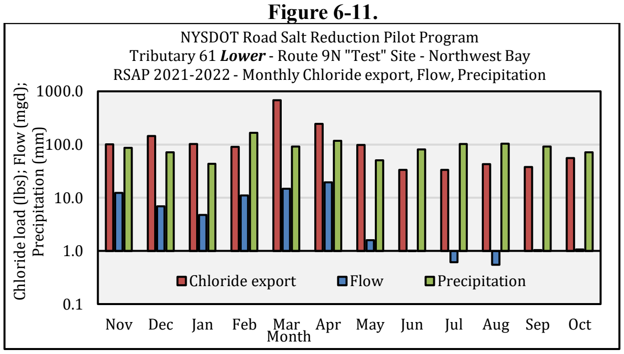


Figure 6-11.



<u>**Note**</u>: The *y-axis* in Figures 6-10 and 6-11 is in logarithmic scale to better display the wide range of values. We see "peaks and valleys" with all three parameters and using the logarithm scale makes it difficult to accurately interpret the relationship among the parameters. Some important observations during RSAP 2020-2021 and 2021-2022 include (1) March and April were the months with the highest salt export during the 12-month periods (period of spring runoff), and (2) RSAP 2021-2022 flows dropped below 1.0 mg in July and August (but not in 2020-2021).

Using the monthly data summaries provided so far, we can evaluate whether a relationship exists between flow and chloride for the RSAP 2020-2021 and RSAP 2021-2022 data. Figures 6-12 and 6-13 present scatterplots of these data for both road salt application years.

Figure 6-12.

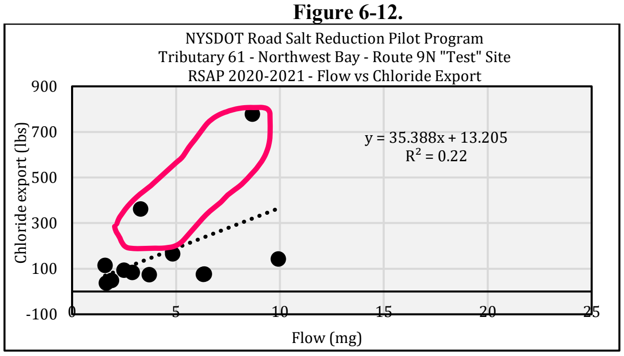
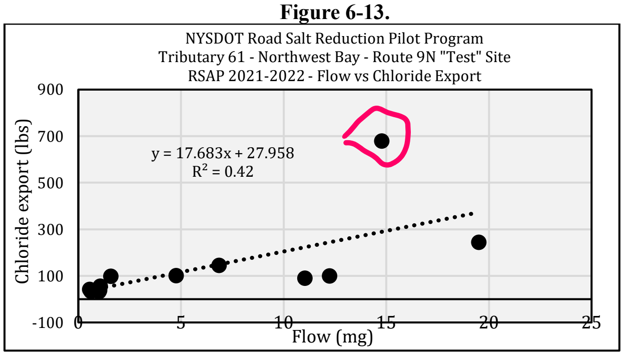


Figure 6-13.



Neither scatterplot indicates a good relationship between flow and chloride export at T61; the relationship is less robust during RSAP 2020-2021 ($R^2 = 0.22$) than during RSAP 2021-2022 ($R^2 = 0.42$). It is clear from both figures that a few high flows during each RSAP contributed to the poor R^2 value. For example, the red circled values in Figure 6-12 and the red circled value in Figure 6-13. All of these aberrant points represent periods of spring runoff.

The best visual data representation occurs when the RSAP data are shown in a 'cumulative' format that presents, in line graph format, the daily sequence of the three variables as they accrue during the 12-month period. The data in daily cumulative format are presented in Figure 6-14 (RSAP 2020-2021) and Figure 6-115 (RSAP 2021-2022).

Figure 6-14.

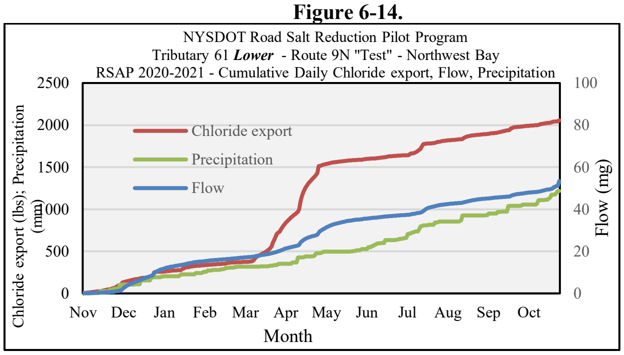
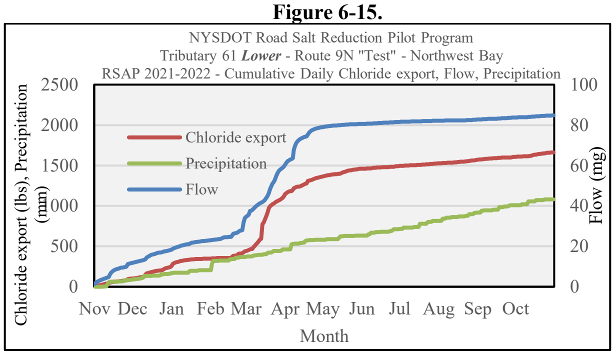


Figure 6-15.



It is easy to look at these graphs and determine differences between the two RSAPs by noticing where each of the variable lines intersects the y-axis scale at the end of the RSAP (October 31st). In addition, the steep slope of the lines in some areas provides information related to rapid variable change while any level or plateau in each line indicates slight or minor change in the variable under examination.

Detailed flow and chloride export information were collected from the T61 watershed for the previous two road salt application cycles. The extensive data has been summarized so that evaluations can be achieved using the NYSDOT road salt application data received for this “pilot” segment of Route 9N. Table 6-7 summarizes and compares the RSAP 2020-2021 and RSAP 2021-2022 “Annual” parameter values provided in Table 6-5 and Table 6-6 above.

Table 6-7.

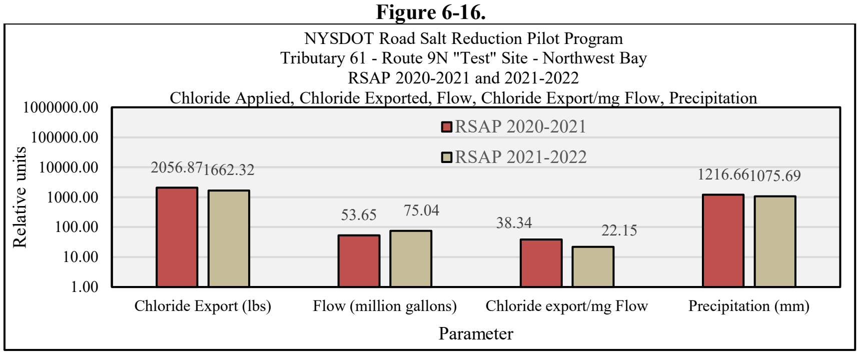
	RSAP ANNUAL VALUES	
	2020-2021	2021-2022
Chloride Export (lbs.)	2056.87	1662.32
Flow (mg)	53.646	75.035
Chloride export/million gallons Flow	38.34	22.15
Precipitation (mm)	1216.66	1075.69
Precipitation (inches)	47.90	42.45

0

As shown above, RSAP 2020-2021 had a greater chloride export than RSAP 2021-2022 (2057 lbs. vs 1662 lbs., respectively), even though the total annual flow was less during RSAP 2020-2021 than during 2021-2022 (53.646 mg vs 75.035 mg, respectively). The fact that RSAP 2021-2022 had greater total flow in spite of less total annual precipitation (1078.2 mm vs 1216.7 mm) can be explained by differing annual amounts and cycles of precipitation and accompanying groundwater storage levels that contributes to down-gradient channel flow.

Figure 6-16 summarizes and compares RSAP 2020-2021 and 2021-2022 “Annual” parameter values in Table 6-7.

Figure 6-16.



The *y-axis* in Figure 6-16 is in logarithm scale to display the wide range of “annual” parameters summarized. A comparison of the two RSAPs reveals that (1) chloride export was 19 percent less in 2021-2022 (1662 lbs.) than in 2020-2021 (2057 lbs.), (2) flow at the ***lower*** site was 40 percent greater in 2021-2022 (75.035 mgd) than in 2020-2021 (53.646 mgd), (3) chloride export per million gallons of flow was 42 percent less in 2021-2022 (22 lbs.) than in 2020-2021 (38 lbs.), and (4) l precipitation was 12 percent less during 2021-2022 (1078 mm) than in 2020-2021 (1217 mm).

The discrepancy between sub-watershed flow and total precipitation that occurred during the two RSAPs was explained above and relates to differing annual amounts and cycles of precipitation and accompanying groundwater storage levels that contributes to down-gradient channel flow.

At this time, the summarized RSAP 2020-2021 and 2021-2022 chloride load, flow and precipitation data can be used to populate a table that contains some of the watershed characteristics that define T61 (Table 6-8).

Table 6-8.

							Cl^- in lbs			
Program ID	Watershed Area (ac)	Highway Area (ac)	Lane Miles	RSAP	Period Ppt (mm)	Annual flow (mg)	Annual Cl Export (lbs.)	Cl^- Export/ LM	Cl^- Export/ mg	Cl^- Export/ mm Ppt
Trib 61	192	0.37	0.22	2020-2021	1217	54	2,057	9350	38.3	1.69
				2021-2022	1076	75	1,662	7555	22.2	1.54

Each of the following two chapters (7 and 8) presents information from the remaining two watersheds under investigation similar to the material presented in this chapter. Chapter 9 will compile all of this watershed and collected data information into a single place so that comparisons can be made. Chapter 10 describes the challenges, understanding, evaluation and problems associated with the NYSDOT road salt application data, while Chapter 11 will compare the data collected by the LGA monitoring program with the road salt application data provided by the NYSDOT to determine whether an evaluation of the 10 percent reduction program could be accomplished.

6.6 Literature Cited.

No literature cited in the text of this chapter.

New York State Department of Transportation Road Salt Reduction Pilot Program

Final Report for the Lake Champlain Sea Grant Program

Chapter 7

Tributary 41 “Control” Watershed and the Pilot Monitoring Project

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7.0 Watershed Characteristics. "Control" tributary 41 (T41), also known as English Brook, is located on the west side of Lake George, has the sixth largest watershed in the Lake George drainage basin, and flows into the lake about one mile from the south end. This tributary is particularly interesting because it flows adjacent to Route 9, a major highway corridor between the Village of Lake George and Warrensburg, from the basin divide near the intersection of Route 9 and Somerville Road to the Exit 22 Interchange of Interstate 87 (I-87), a distance of about 4 miles.

The ***upper*** and ***lower*** sub-watersheds of T41 are shown in Figure 7-1 and Figure 7-2, respectively. The T41 ***upper*** sub-watershed is undeveloped except for a dirt logging road that goes to higher elevations in the watershed and a small portion of Route 9 as it crosses over the basin divide to Warrensburg. Watershed characteristics of the ***upper*** and ***lower*** sampling sites are summarized in Table 7-1.

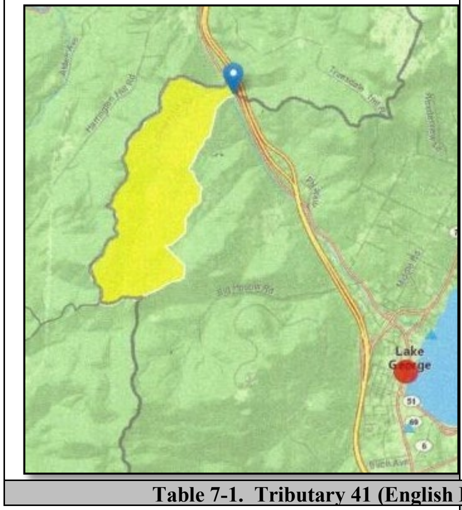
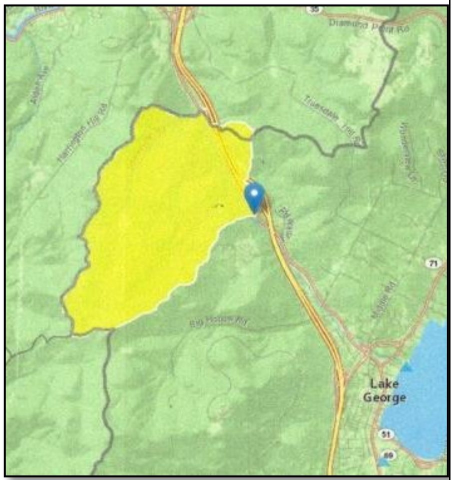
Tributary 41 (English Brook) Watershed Configuration	
Figure 7-1.	**Figure 7-2.**
Watershed Configuration at *Upper* Site	**Watershed Configuration at *Lower* Site**
	

Table 7-1. Tributary 41 (English Brook) Watershed Characteristics

Category	Sampling Site *Upper*	Sampling Site *Lower*
Latitude of sampling site	43.46946	43.45522
Longitude of sampling site	-73.7488	-73.73882
Watershed area @ sampling site (mile^2)	1.78	2.95
Length of main channel to basin divide (miles)	3.5	4.84
Mean watershed slope at sampling site (feet/mile)	363	187
% of watershed > 1200 feet in elevation	90.2	78.5
% of area with storage (lakes, ponds, wetlands)	0	0
% of area covered by forests	99.7	97.7
Mean annual runoff (inches)	19.9	19.7
50th percentile of seasonal max snow depth	20.2	20.2
Mean annual precipitation (inches)	39.2	39
% of area with Hydrologic Soil Type B	66.6	59.7
% of area with Hydrologic Soil Type A	1.24	4.4
Average % impervious area	0.0956	0.63
% of developed (urban) land	0.78	5.7
% of watershed impacted by road salt	0	to be determined

T41 at the ***lower*** station has the largest drainage at 1,888 acres and the largest highway segment at 10.74 acres, or 5.51 lane miles, which includes both Route 9 and Interstate 87 (I-87). The sampling station at the ***lower*** sub-watershed is located about 1,000 ft above the area where I-87 crosses over Route 9; from this station to the intersection of Somerville Road is a total distance of about 1.2 miles and English Brook and Route 9 are within about 50 feet of each other along most of this segment.

7.1 *Lower* Site Equipment Installation. Figure 7-3 is a photograph of the T41 ***lower*** site location, looking south and showing the PVC assembly mounted on the east shoreline of the channel to a tree with aviation cable. This photograph (courtesy of Jim Sutherland) was taken on September 30th 2020 during a period of high flow following a storm event. The PVC housing contains the *In-Situ* logger and is mounted on a piece of 5/4 deck lumber which is attached to the tree on the eastern shoreline in two separate locations. The Baro TROLL is attached to the top of the

PVC installation. The concrete block with the attached Onset HOBO specific conductance and temperature logger is located on the bottom of the tributary channel (Figure 7-4, red circle), adjacent to the water level recording assembly.

Figure 7-3.

Figure 7-4.

At this ***lower*** sampling station location, the Route 9 highway surface is about 15 feet to the left (east) of the station assembly. All highway runoff from the mid-point of the road surface drains toward the tributary between here and the ***upper*** sampling station which is ~1.25 miles north of the ***lower*** location.

7.2 Field Measurements, Analytical Chemistry and Flow. Tables 7-2 and 7-3 summarize the field measurements, analytical chemistry results from the DFWI Laboratory and flow that have been collected at the ***upper*** and ***lower*** stations of T41, respectively, since 2018.

Table 7-2.

T41 ***UPPER*** STATION

Sample Size (n)	Water temp (C)	DO (mg/L)	DO (% sat)	NO3-N (mg/L)	SO4-S (mg/L)	Cl (mg/L)	Ca (mg/L)	Na (mg/L)	Mg (mg/L)	K (mg/L)	spC (µS/cm @ 25 C)	TDS (ppm)	pH (s.u.)	Flow (mgd)
95	9.8	11.8	101.7	0.08	0.78	0.51	4.82	1.10	0.87	0.24	35.0	22.7	7.55	2.140

Table 7-3.

T41 ***LOWER*** STATION

Sample Size (n)	Water temp (C)	DO (mg/L)	DO (% sat)	NO3-N (mg/L)	SO4-S (mg/L)	Cl (mg/L	Ca (mg/L	Na (mg/L)	Mg (mg/L)	K (mg/L)	spC (µS/cm @ 25 C)	TDS (ppm	pH (s.u.)	Flow (mgd)
95	9.7	11.8	100.9	0.09	1.11	41.39	8.49	23.70	1.79	0.42	191.2	127.7	7.42	3.353

A complete set of field measurements, analytical chemistry results from the DFWI Laboratory and gaged tributary flow will be uploaded to the Lake Champlain Sea Grant Program shared data website following release of this report.

7.3 Specific Conductance and Chloride Concentration. Some select analyte data important to this particular study with respect to road salt application are presented in Table 7-4 and include chloride and specific conductance concentrations, flow, and the number of samples (n) collected each calendar year that the Program has been active.

Table 7-4.

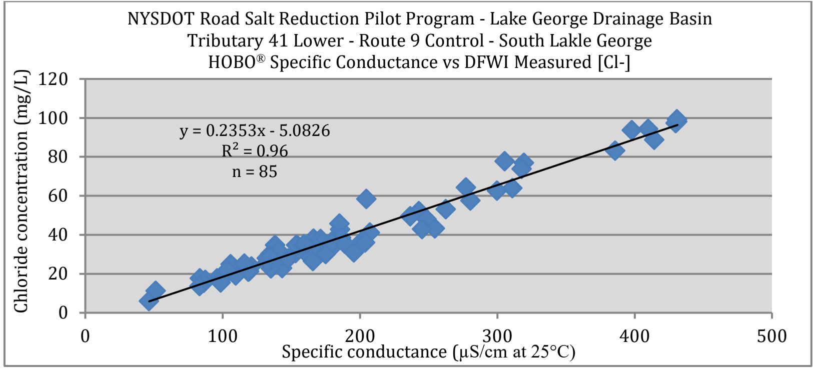
	Upper	***Lower***	***Upper***	***Lower***	***Lower***	***Upper***	***Lower***
	Cl (mg/L)	**Cl (mg/L)**	**spC (µS/cm)**	**spC (µS/cm)**	**Flow (mgd)**	**Sample Size (n)**	**Sample Size (n)**
avg 2018 samples	**0.51**	**65.83**	**40.3**	**290.0**	**1.460**	**9**	**9**
avg 2019 samples	**0.53**	**44.67**	**30.6**	**193.2**	**3.278**	**20**	**20**
avg 2020 samples	**0.50**	**47.99**	**36.7**	**213.0**	**4.596**	**22**	**22**
avg 2021 samples	**0.50**	**29.59**	**31.0**	**146.7**	**4.008**	**22**	**22**
avg 2022 samples	**0.50**	**35.18**	**39.0**	**179.3**	**2.114**	**22**	**22**
avg all samples	**0.51**	**41.39**	**35.0**	**191.2**	**3.353**	**95**	**95**

The specific conductance and chloride data highlight the difference in chemistry between the ***upper*** and ***lower*** sampling stations and the suitability of the watershed to be included in this investigation. As a reminder, the values presented in Table 7-4 are *mean* values for samples collected during a particular *calendar year* and not during the *road salt application periods* (RSAP) described earlier which include the period from November 1st through October 31st the following year.

The difference in *mean* chloride concentration between the ***upper*** and ***lower*** sampling stations at T41 is apparent when comparing the annual summaries with each other; the *mean* value of all 95 samples collected to date is 0.51 versus 41.39 mg Cl^-/L, an 81-fold difference overall. A similar difference between ***upper*** and ***lower*** sites is apparent with respect to the overall *mean* specific conductance concentrations, 35.0 and 191.2 µS/cm @ 25 C, respectively, a 5-fold difference in concentration.

The T41 ***lower*** sampling station exhibited a strong relationship ($R^2 = 0.96$) between specific conductance recorded by the Onset HOBO® data logger and the chloride concentrations measured on raw water samples collected and submitted to the Darrin Fresh Water Institute for analysis. The current relationship is shown in scatterplot Figure 7-5.

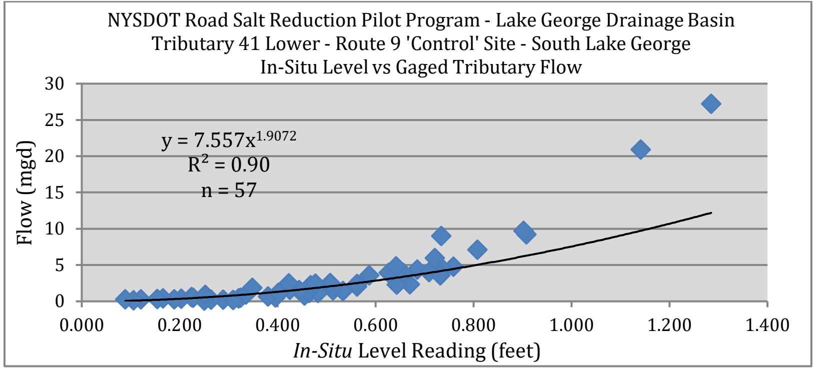
Figure 7-5.



The relationship has become more robust as additional specific conductance data and analytical chloride results are added to the data set. The equation shown in Figure 7-5 is entered into the Tributary Master Flow-Chloride Loading File every time the HOBO values are downloaded during the field excursions and chloride data are received from DFWI for samples submitted for analysis. As of the writing of this report, a total of 85 pairs of values for specific conductance and chloride concentration have been used to define this relationship.

7.4 Tributary Flow. A strong relationship also was exhibited by the flow rating curve developed between T41 tributary flow, calculated after each manual gaging, and the corresponding *In-Situ* TROLL 200 5-minute water level reading stored by the data logger installed in the tributary channel. Since the beginning of the current investigation in 2018, there have been 57 pairings of these data which provide a robust relationship ($R^2 = 0.90$). Figure 7-6 presents a scatterplot summary of tributary flow rating data.

Figure 7-6.



The equation shown in Figure 7-6 that calculates T41 tributary flow (*y*) is referred to as a 'power' function and uses the manual tributary gaging value (in mgd) and the corresponding 5-minute water level readings (*x*) stored by the *In-Situ* level logger which is raised to the 1.9072 power.

The equation in Figure 7-6 is updated to a new version following each field excursion and data download and used for the station flow calculation until the subsequent field excursion and the manual flow gaging and data download.

7.5 Tributary RSAP Data Summary. Each NYSDOT Road Salt Reduction Pilot-T##-Master Flow-Chloride Export file has a separate worksheet dedicated to RSAP data summarized in columns where ‘strings’ of daily data, one row for each day of the year, were stored under the following headers: *Date, Daily Chloride Export, Cumulative Daily Chloride Export, Daily Flow (million gallon), Cumulative Daily Flow, Daily Precipitation (inches), Daily Precipitation (mm)*, and *Cumulative Daily Precipitation*. The column header from the T41 Excel file spreadsheet summarizing RSAP 2020-2021 on a daily basis is presented below:

ROAD SALT APPLICATION PERIOD (RSAP) 2020-2021							
Date	Daily Cl^- Export (lbs.)	Cumulative Daily Cl^- Export (lbs.)	Daily Flow (mg)	Cumulative Daily Flow (mg)	Daily Precipitation (inches)	Daily Precipitation (mm)	Cumulative Daily Precipitation (mm)

These ‘string of daily data’ summaries then can be plotted as line graphs as shown in Figure 7-7 and Figure 7-8 below which present T41 daily chloride export, flow, and precipitation data summarized for RSAP 2020-2021 and 2021-2022, respectively.

Figure 7-7.

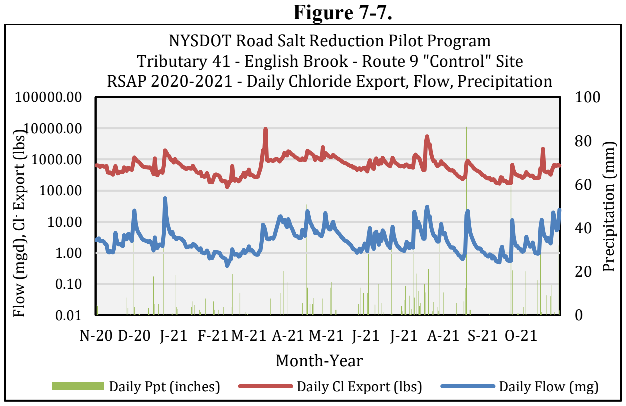
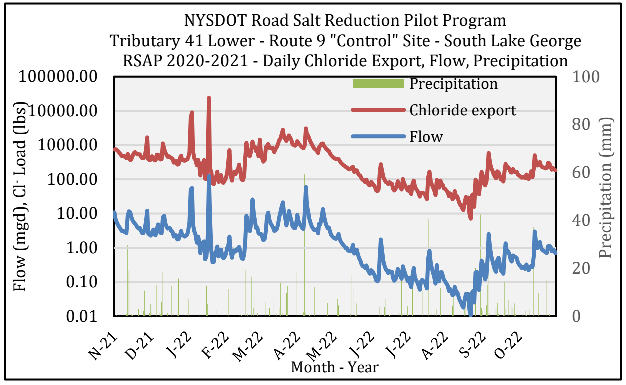


Figure 7-8.



Summaries of data formatted monthly are a convenient way to present data for comparative purposes. The following tables summarize monthly chloride export (lbs.), tributary flow (mg = million gallons), chloride export per million gallons of tributary flow, and precipitation (inches, millimeters) during RSAP 2020-2021 (Table 7-5) and RSAP 2021-2022 (Table 7-6).

Table 7-5.

RSAP 2020-2021												
Parameter	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Salt Export (lbs.)	14,940	23,976	15,283	7,323	35,643	39,589	26,096	22,405	36,747	14,673	7,747	14,076
Salt Export (tons)	7.47	11.99	7.64	3.66	17.82	19.79	13.05	11.20	18.37	7.34	3.87	7.04
Flow (mg: million gallons)	75.3	189.8	54.9	24.7	151.3	202.8	109.5	82.7	211.6	97.2	41.0	144.3
Salt Export (lbs.)/mg Flow	198.3	126.3	278.2	297.0	235.6	195.2	238.4	270.8	173.7	151.0	189.0	97.5
Precipitation (inches)	4.33	2.98	2.02	2.24	2.10	4.73	2.60	4.61	8.11	5.09	4.65	6.76
Precipitation (mm)	110.0	75.7	51.3	56.9	53.3	120.1	66.0	117.1	206.0	129.3	118.1	171.7
# of days	30	31	31	28	31	30	31	30	31	31	30	31

Table 7-6.

RSAP 2021-2022												
Parameter	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Salt Export (lbs.)	16,867	13,710	45,931	11,855	35,631	30,921	6,571	2,511	1,885	1,208	5,186	4,670
Salt Export (tons)	8.43	6.86	22.97	5.93	17.82	15.46	3.29	1.26	0.94	0.60	2.59	2.34
Flow (mg: million gallons)	157.6	107.5	281.3	93.4	196.5	227.1	29.5	8.2	5.4	2.2	16.0	16.8
Salt Export (lbs.)/mg Flow	107.0	127.6	163.3	126.9	181.3	136.1	222.5	304.5	346.4	539.0	324.0	278.0
Precipitation (inches)	3.23	3.14	1.13	2.69	3.68	4.32	1.92	2.42	3.69	3.68	4.16	2.74
Precipitation (mm)	82.04	79.76	28.70	68.33	93.47	109.73	48.77	61.47	93.73	93.47	105.66	69.60
# of days	30	31	31	28	31	30	31	30	31	31	30	31

The “salt export” values in Tables 7-5 and 7-6 are presented both in lbs. and tons because the amount exported in this tributary is so high compared with the other tributaries under investigation.

The monthly summary of RSAP 2020-2021 and RSAP 2021-2022 chloride export, flow and precipitation data presented in Tables 7-5 and 7-6, respectively, are helpful for storing the data in a format that reduces daily data to a more manageable system and allows some simple comparisons between individual months in the two RSAP datasets.

More complicated comparisons and evaluations are difficult in table format and can be shown graphically in columns to give a better visual interpretation of the data set collected during the two winter periods. Figures 7-9 and 7-10 are individual column graphs of the monthly chloride load, flow and precipitation data shown in Tables 7-5 and 7-6.

Figure 7-9.

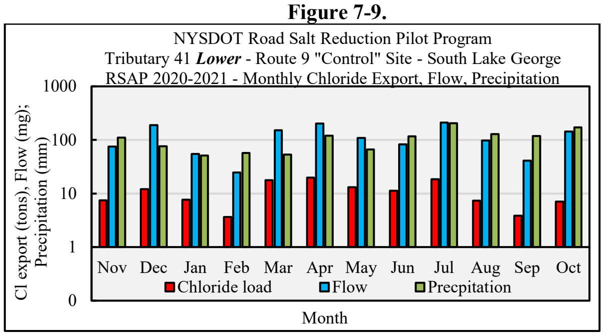
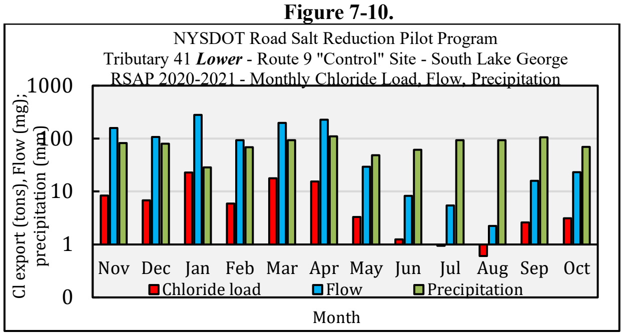


Figure 7-10.



Chloride export in the above figures is in units of "*tons*" not "*lbs*." as was the case with the other tributaries reported herein. There are "peaks and valleys" with all of the parameters throughout each RSAP and the y-axis logarithm scale makes it difficult to interpret relationships among the parameters. Some important observations during RSAP 2020-2021 and RSAP 2021-2022 include (1) the highest chloride export occurred from November through April each period, and (2) flows during the same period were in excess of 100 mgd each month, while (3) chloride export dropped below one ton during July and August each year when the monthly flows in the tributary were less than 1 mgd.

Using the data presented so far, we can evaluate whether a relationship exists between flow and chloride for the RSAP 2020-2021 and RSAP 2021-2022 data. Figures 7-11 and 7-12 present scatterplots of these data for both road salt application years; chloride export in these two figures is in lbs.

Figure 7-11.

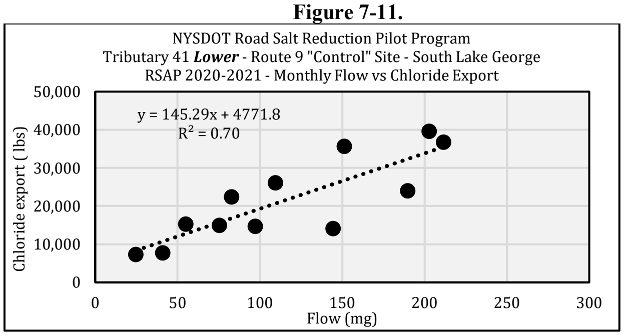
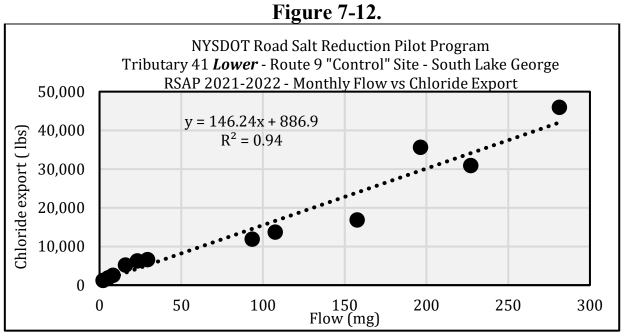


Figure 7-12.



The relationship between flow and chloride export at this site is linear and was more robust during RSAP 2021-2022 ($R^2 = 0.94$) than RSAP 2020-2021 ($R^2 = 0.70$) which was modest. Some insights regarding the differences in linearity between these two RSAPs will be provided later.

The chloride export, flow and precipitation data for RSAPs 2020-2021 and 2021-2022 at T41 are presented in cumulative daily format in Figures 7-13 and 7-14, respectively.

Figure 7-13.

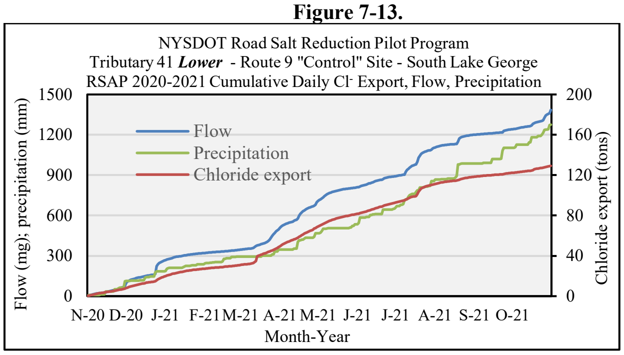
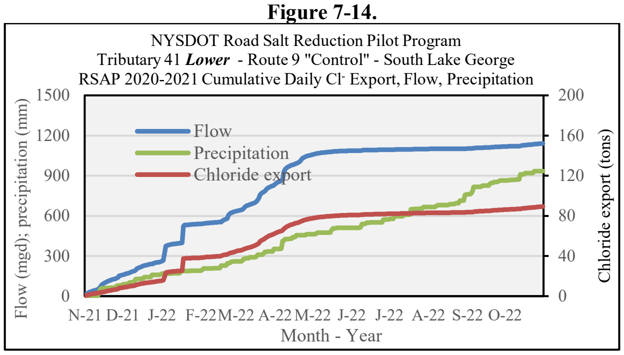


Figure 7-14.



Figures 7-13 and 7-14 both have a secondary *y-axis* which is used to track changes in chloride export (in tons). As with the other watersheds under investigation, it is easy to look at the figures above and notice differences in the slope and endpoint of the lines representing the parameters of interest from November 1st through October 31st of the following year. The slopes of the trendlines, whether exhibiting a sharp increase or plateau, as they progress from November 1st through October 31st, give valuable information about the types of changes that occur at the site.

Detailed flow and chloride export information were collected from the T41 watershed for the previous two road salt application cycles. The extensive data set has been summarized so that evaluations can be performed using the NYSDOT road salt application data for this "pilot" segment of Route 9N. Table 7-7 summarizes and compares the RSAP 2020-2021 and RSAP 2021-2022 "Annual" parameter values provided in Table 7-5 and Table 7-6 above.

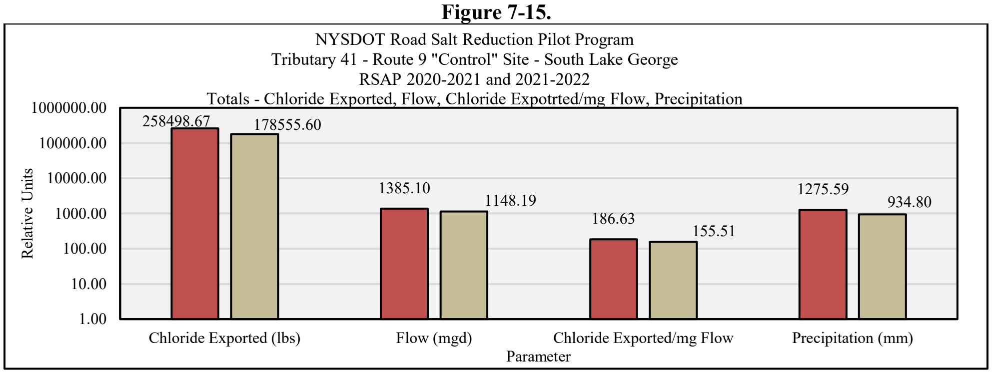
Table 7-7.

	RSAP ANNUAL	
	2020-2021	2021-2022
Chloride Exported (lbs.)	258499	178556
Flow (mg: million gallons)	1385	1148
Chloride exported/mg Flow	187	156
Precipitation (mm)	1276	935

As shown above, (1) RSAP 2020-2021 had a greater chloride export than RSAP 2021-2022 (258,499 lbs. vs 178,556 lbs., respectively), (2) the total annual flow was greater during RSAP 2020-2021 than during 2021-2022 (1385 mg vs 1148 mg, respectively), and (3) the chloride export per mgd was greater during RSAP 2020-2021 than 2021-2022 (187 lbs. vs 156 lbs., respectively)

Figure 7-15 summarizes and compares RSAP 2020-2021 and 2021-2022 "Annual" parameter values in Table 7-7.

Figure 7-15.



The *y-axis* in Figure 7-15 is in logarithm scale to display the wide range of "annual" parameter values summarized from RSAP 2020-2021 and 2021-2022. A comparison of the two RSAP parameters in Figure 7-9 reveals that (1) chloride export was 31 percent less in 2021-2022 (178,556 lbs.) than in 2020-2021 (258,499 lbs.), (2) flow at the ***lower*** site was 17 percent less in 2021-2022 (1148 mg) than in 2020-2021 (1385 mg), (3) chloride exported per million gallons of flow was 17 percent less in 2021-2022 (156 lbs.) than in 2020-2021 (187 lbs.), and (4) total precipitation was 26 percent less during 2021-2022 (935 mm) than in 2020-2021 (1271 mm).

At this time, the summarized RSAP 2020-2021 and 2021-2022 chloride load, flow and precipitation data can be used to populate a table that contains some of the watershed characteristics that define T41 (Table 7-8).

Table 7-8.

							Cl^- in lbs			
Program ID	Watershed Area (ac)	Highway Area (ac)	Lane Miles	RSAP	Period Ppt (mm)	Annual flow (mg)	Annual Cl Export (lbs.)	Cl^- Export/ LM	Cl^- Export/ million gallons	Cl^- Export/ mm Ppt
T41	1888	10.74	5.51*	2020-2021	1276	1385	258499	46915	186.6	202.6
				2021-2022	935	1148	178556	32406	155.5	191.0

- = LM includes 2.33 of Route 9 + 3.18 of I-87

The following chapter (8) presents information from the T36a watershed under investigation similar to the material presented here. Chapter 9 compiles all of the watershed and other data into a single place so that comparisons can be made. Chapter 10 describes the challenges, understanding, evaluation and problems associated with the NYSDOT road salt application data. Chapter 11 compares the data collected by the LGA monitoring program with the road salt application data to determine whether an evaluation of the 10 percent reduction program could be accomplished.

7.6 Literature Cited

No literature cited in the text of this chapter.

New York State Department of Transportation Road Salt Reduction Pilot Program

Final Report for the Lake Champlain Sea Grant Program

Chapter 8

Tributary 36a “Control” Watershed and the Pilot Monitoring Project

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8.0 Watershed Characteristics. Tributary 36a is located on the east side of Lake George at the end of the south basin about 1 mile northeast of the intersection of State Route 9L and Beach Road. This tributary is derived from groundwater emerging at higher elevations to the east on French Mountain. The watershed characteristics up-gradient of the sampling sites are summarized below with maps showing the watershed configurations.

The ***upper*** and ***lower*** sub-watersheds of T36a are shown in Figure 8-1 and Figure 8-2, respectively. The T36a ***upper*** sub-watershed is undeveloped.

Tributary 36a Watershed

Figure 8-1.

Watershed Configuration at *Upper* Site

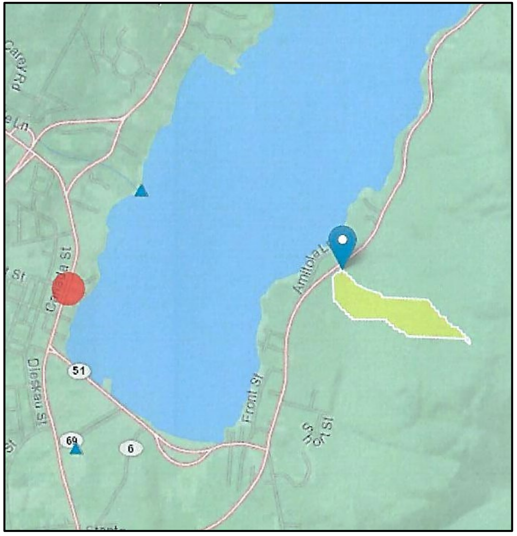


Figure 8-2.

Watershed Configuration at *Lower* Site

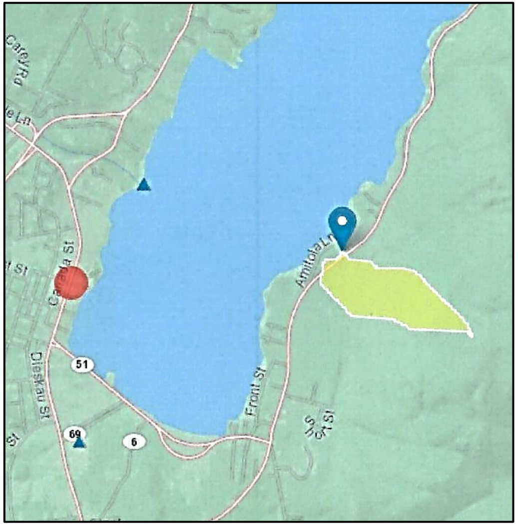


Table 8-1. Tributary 36a Watershed Characteristics

	Sampling Site	Sampling Site
Category	***Upper* Route 9L**	***Lower* Route 9L**
Latitude of sampling site	43.42671	43.42865
Longitude of sampling site	-73.69114	-73.69153
Watershed area @ sampling site (mile^2/acres)	0.0492/31.490	0.21/134.4
Length of main channel to basin divide (miles)	0.22	0.83
Mean watershed slope at sampling site (feet/mile)	184	956
% of watershed > 1200 feet in elevation	1.4	19.1
% of area with storage (lakes, ponds, wetlands)	0	0
% of area covered by forests	100	99.7
Mean annual runoff (inches)	18.2	18.2
50th percentile of seasonal max snow depth (inches)	19.9	19.9
Mean annual precipitation (inches)	37.5	37.4
% of area with Hydrologic Soil Type B	82.7	53.4
% of area with Hydrologic Soil Type A	7.46	13.7
Average % impervious area	0	0.19
% of developed (urban) land	0	7.01
% of watershed impacted by road salt	0	to be determined

T36a at the ***lower*** station has the smallest watershed at 134 acres and the second largest highway segment at 0.59 acres, or 0.35 lane miles, which is Route 9L, that traverses the watershed. This highway segment is maintained for winter deicing by NYSDOT trucks out of Warrensburg as is the segment of Route 9 adjacent to T41 (English Brook).

8-1. *Lower* Site Equipment Installation. Figure 8-3 is a photograph of the T36a ***lower*** site installation showing the PVC assembly which is mounted on the east shoreline of the narrow channel. This photograph (courtesy of Brea Arvidson) was taken on November 2nd 2020 following setup of the equipment. The PVC housing contains the *In-Situ* logger and is mounted on a piece of 5/4 deck lumber which is attached to a metal fence post pounded into the sand. The Baro TROLL is attached to the top of the PVC installation. The concrete block with the attached Onset HOBO specific conductance and temperature logger is located on the bottom of the tributary channel, adjacent to the water level recording assembly near the log in Figure 8-4.

Figure 8-3.

Figure 8-4.

At this ***lower*** sampling location, the shoulder of Route 9L is about 30 feet east of the station and about 5-8 feet higher in elevation.

8-2. Field Measurements, Analytical Chemistry and Flow. Tables 8-2 and 8-3 summarize the field measurements, analytical chemistry results from the DFWI Laboratory and flow data that have been collected at the ***upper*** and ***lower*** stations of T36a, respectively, since 2018.

Table 8-2.

T41 ***UPPER*** STATION													
Sample Size (n)	Water temp (C)	DO (mg/L)	DO (% sat)	NO3-N (mg N/L)	SO4-S (mg S/L)	Cl (mg/L)	Ca (mg/L)	Na (mg/L)	Mg (mg/L)	K (mg/L)	spC (µS/cm	TDS (ppm)	pH (s.u.)
96	9.1	11.1	95.2	0.02	1.42	0.52	13.85	1.25	5.52	0.24	115.9	75.8	7.51

Table 8-3.

T41 ***LOWER*** STATION														
Sample Size (n)	Water temp (C)	DO (mg/L)	DO (% sat)	NO3-N (mg N/L)	SO4-S (mg S/L)	Cl (mg/L)	Ca (mg/L)	Na (mg/L)	Mg (mg/L)	K (mg/L)	spC (µS/cm @ 25 C)	TDS (ppm)	pH (s.u.)	Flow (mgd
71	9.2	9.5	81.9	0.06	1.76	26.27	20.39	18.53	6.62	0.32	250.9	167.1	7.57	0.062

A complete set of all field measurements, analytical chemistry results from the DFWI Laboratory and gaged tributary flow will be uploaded to the Lake Champlain Sea Grant Program shared data website following release of this report.

8-3. Specific Conductance and Chloride Concentration. A summary of selected analyte data important to this study with respect to road salt application collected at the ***upper*** and ***lower*** sites is presented in Table 8-4 and includes chloride and specific conductance concentrations, flow, and the number of samples (n) for each calendar year that the Program has been active.

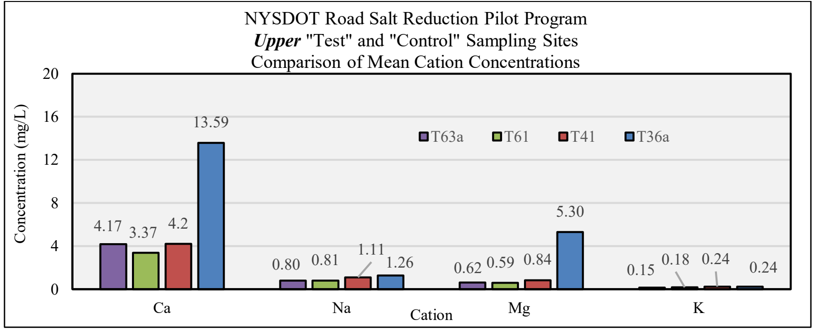
Table 8-4.

	Upper **Cl (mg/L)**	***Lower*** **Cl (mg/L)**	***Upper*** **spC (µS/cm)**	***Lower*** **spC (µS/cm)**	***Lower*** **Flow (mgd)**	***Upper*** **Sample Size (n)**	***Lower*** **Sample Size (n)**
avg 2019 samples	**0.52**	**19.45**	**102.7**	**233.5**	**0.033**	**21**	**6**
avg 2020 samples	**0.50**	**30.72**	**113.7**	**255.0**	**0.061**	**22**	**22**
avg 2021 samples	**0.50**	**27.74**	**116.7**	**269.1**	**0.072**	**22**	**22**
avg 2022 samples	**0.55**	**22.03**	**117.9**	**233.3**	**0.060**	**22**	**22**
avg all samples	**0.52**	**26.27**	**115.9**	**250.9**	**0.062**	**87**	**72**

The specific conductance and chloride data summarized above highlight the difference in chemistry between the ***upper*** and ***lower*** sampling stations and the suitability of the watershed to be included in this investigation. The values presented in Table 8-4 are *mean* values for samples collected during each *calendar year* and not during the *winter road salt application periods* (RSDAPs) described earlier which include the time from November 1st through October 31st of the following year.

The difference in *mean* chloride concentration between the ***upper*** and ***lower*** sampling stations at T36a is most apparent when comparing the annual summaries with each other; the *mean* value of all samples collected to date is 0.52 versus 26.27 mg Cl^{-}/L, a difference of 51-fold overall. There also is a difference between ***upper*** and ***lower*** sites with respect to the overall *mean* specific conductance concentrations, 115.9 and 250.9 µS/cm @ 25 C, respectively, although the difference in concentration only is 2-fold. The reason for a smaller difference between *mean* specific conductance and chloride concentration is attributed to the high concentrations of the cations calcium (Ca) and magnesium (Mg) in the groundwater flowing from the upper region of the watershed. Figure 8-5 summarizes the *mean* cation concentrations at the four ***upper*** sub-watershed stations (sodium is denoted by "Na" and potassium is denoted by "K").

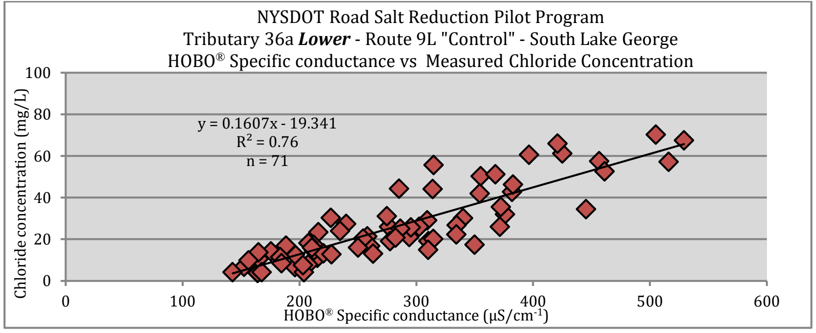
Figure 8-5.



The extremely high calcium (Ca) and magnesium (Mg) concentrations at T36a relative to the other three watersheds under investigation are apparent from Figure 8-5. These elevated concentrations of Ca and Mg in flow from the ***upper*** watershed in T36a add (1) concentration (ions) to the ***lower*** sub-watershed specific conductance, and (2) variability to the specific conductance readings based upon groundwater level (flow) and recent precipitation.

With reference to the cation information presented above, and in contrast to the other three watersheds included in this investigation for the reduction of road salt application,T36a only had a moderate relationship ($R^2 = 0.76$) between specific conductance recorded by the Onset HOBO® data logger and the chloride concentrations measured on raw water samples collected and submitted to the Darrin Fresh Water Institute for analysis. The current relationship is shown in Figure 8-6.

Figure 8-6.

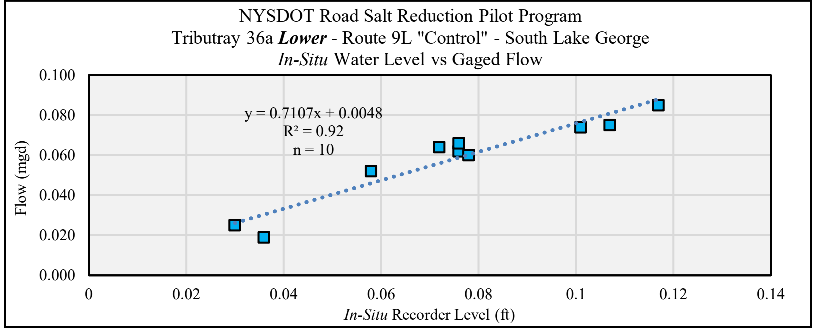


The relationship between these two variables has become less robust over time, with $R^2 = 0.86$ early in the investigation and $R^2 = 0.76$ as of November 2022. As presented and discussed above, the reason for this anomaly in variability is due to high concentrations of the cations calcium (Ca) and magnesium (Mg) in groundwater seepage from higher elevations in the sub-watershed.

8-4. Tributary Flow. Tributary 36a presented the greatest challenge for the development of a flow rating curve based upon manual gaging at the ***lower*** site during each field excursion and the corresponding level data recorded by the station *In-Situ* logger. As previously shown in Figure 8-3, the channel at the ***lower*** sampling site was narrow, consisted mostly of very porous sand, was not well defined, and the main issue that affected rating curve development was the extremely low water levels and the variability of the *In-Situ* logger data to measure these low water levels accurately.

An analysis of the 64 manual ratings conducted at the ***lower*** station found that the highest flow was 0.170 mgd, the lowest flow was 0.018 mgd and the *average* flow was 0.062 mgd. Given the hydrologic conditions described at this site, 10 pairs of manual gaging data and corresponding *average* daily *In-Situ* logger readings were used to develop the sub-watershed rating curve which is shown in Figure 8-7.

Figure 8-7.



The equation shown above describes the relationship between gaged flow and water level and calculates flow (*y*) is a 'linear' function that exhibits a strong relationship ($R^2 = 0.92$).

8-5. Tributary RSAP Data Summaries. Each NYSDOT Road Salt Reduction Pilot-T#-Master Flow-Chloride Export file had a worksheet dedicated to RSAP data summarized in a 'string' of columns where daily data were stored including headers: *Date, Daily Chloride Export, Cumulative Daily Chloride Export, Daily Flow (million gallons), Cumulative Daily Flow, Daily Precipitation (inches), Daily Precipitation (mm)*, and *Cumulative Daily Precipitation*. The column header from the T36a Excel file spreadsheet summarizing RSAP 2020-2021 on a daily basis is below:

ROAD SALT APPLICATION PERIOD (RSAP) 2020-2021							
Date	Daily Cl^- Export (lbs.)	Cumulative Daily Cl^- Export (lbs.)	Daily Flow (mg)	Cumulative Daily Flow (mg)	Daily Precipitation (inches)	Daily Precipitation (mm)	Cumulative Daily Precipitation (mm)

These daily data summaries then can be plotted as line graphs like Figure 8-8 and 8-9 below which are daily chloride loading, flow, and precipitation data summarized for RSAP 2020-2021 and 2021-2022, respectively.

Figure 8-8.

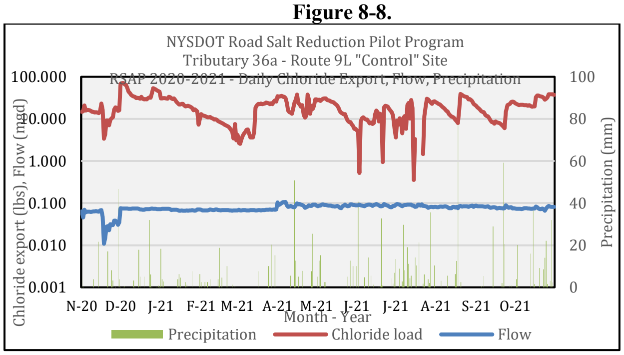
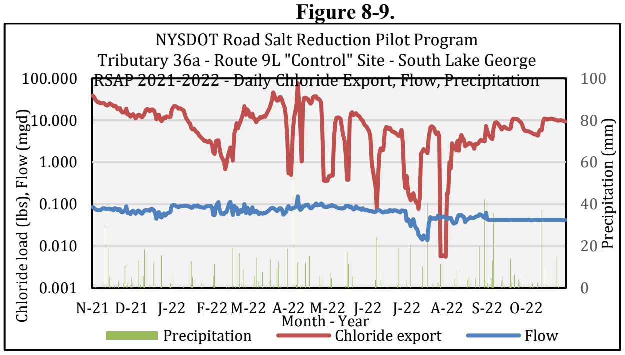


Figure 8-9.



The above figures are an effective way to visually summarize the daily and make general comparisons during portions of the 12-month period. For example, we can see the different flow pattern for RSAP 2021-2022 from about July 2022 through the end of August 2022 when the flow values steadily declined to dropped to ~0.01 mgd (10,000 gallons /day), while there was no similar occurrence during the same period in RSAP 2020-2021. Other, more detailed comparisons between RSAPs are difficult to decipher because of the scale of the data (daily) during the entire period.

The following tables summarize monthly chloride export (lbs.), tributary flow (mg = million gallons), chloride export/million gallons of flow, and precipitation (inches, mm) during road salt application period (RSAP) 2020-2021 (Table 8-5) and RSAP 2021-2022 (Table 8-6).

Table 8-5.

ROAD SALT APPLICATION PERIOD 2020-2021 DATA SUMMARY												
Parameter	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Salt Export (lbs)	421	1329	1207	242	452	716	607	333	405	558	357	772
Flow (mg)	1.428	2.266	3.371	1.903	2.119	2.710	2.692	2.644	2.703	2.140	2.071	2.123
Salt Export (lbs)/mg Flow	295	586	358	127	213	264	225	126	150	261	173	364
Precipitation (inches)	4.33	2.98	2.02	2.24	1.50	5.33	2.60	4.61	8.11	5.09	4.65	6.76
Precipitation (mm)	110.0	75.7	51.3	56.9	38.1	135.4	66.0	117.1	206.0	129.3	118.1	171.7
# of days	30	31	31	28	31	30	31	30	31	31	30	31

Table 8-6.

ROAD SALT APPLICATION PERIOD 2021-2022 DATA SUMMARY												
Parameter	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Salt Export (lbs.)	676	420	317	154	605	642	239	107	48	84	223	251
Flow (mg)	2.218	1.979	2.749	2.129	2.135	2.715	2.570	2.046	0.805	1.477	1.275	1.275
Salt Export (lbs.)/mg Flow	305	212	115	72	284	236	93	52	60	57	175	197
Precipitation (inches)	3.23	3.14	1.13	2.69	2.94	5.06	1.92	2.42	3.69	3.68	4.16	2.74
Precipitation (mm)	82.0	79.8	28.7	68.3	74.7	128.5	48.8	61.5	93.7	93.5	105.7	69.7
# of days	30	31	31	28	31	30	31	30	31	31	30	31

The chloride export, flow, and precipitation monthly summaries for RSAP 2020-2021 and 2021-2022 presented in Tables 8-5 and 8-6, respectively, also can be displayed graphically to provide a better visual interpretation and means of comparing the monthly data summarized during each road salt application period.

Figures 8-10 and 5-11 are column graphs/charts of the monthly chloride export and tributary flow data for RSAPs 2020-2021 and 2021-2022 summarized in Tables 8-5 and 8-6, respectively.

Figure 8-10.

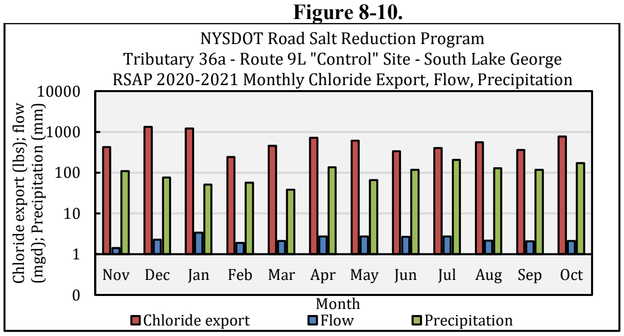
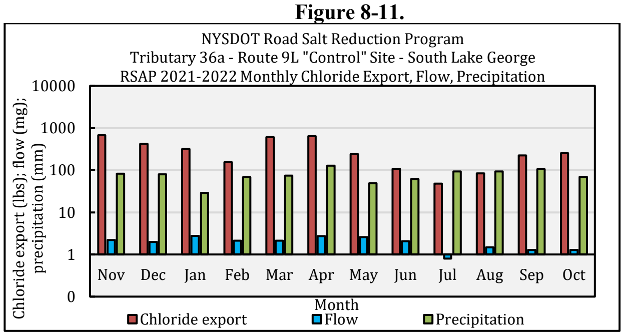


Figure 8-11.



Note: The *y-axis* in Figures 8-10 and 8-11 is logarithmic scale. We see "peaks and valleys" with all three parameters and using the logarithm scale makes it difficult to accurately interpret the relationship among the parameters. Some important observations during RSAP 2020-2021 and 2021-2022 include (1) with only two exceptions, chloride export ranged between 100-1000 lbs. each month, while (2) July 2022 was the only month during which the total flow at the ***lower*** site dropped below 1.0 mgd.

We can evaluate whether a relationship exists between flow and chloride for the RSAP 2020-2021 and RSAP 2021-2022 data. Figures 8-12 and 8-13 present scatterplots of these data for both road salt application years.

Figure 8-12.

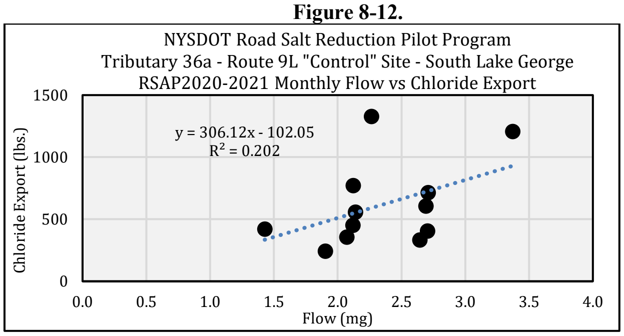
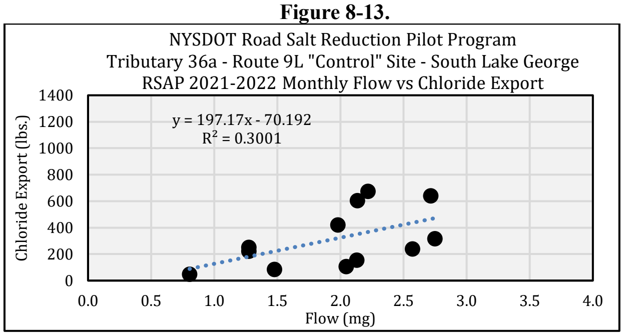


Figure 8-13.



The relationship between flow and chloride export at this site was poor for both RSAPs although the relationship for RSAP 2021-2022 ($R^2 = 0.30$) was slightly better than the RSAP for 2020-2021 ($R^2 = 0.20$). The nature of this site made it difficult to collect accurate flow data because the levels always were extremely low and not directly influenced by runoff from storm events. All flow through the ***lower*** station data collection installation was from groundwater emerging at higher elevations in the watershed.

The chloride export, flow and precipitation data for RSAPs 2020-2021 and 2021-2022 at T36a are presented in cumulative daily format in Figures 8-14 and 8-15, respectively.

Figure 8-14.

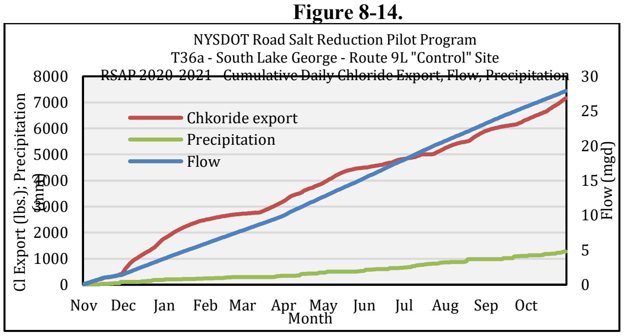
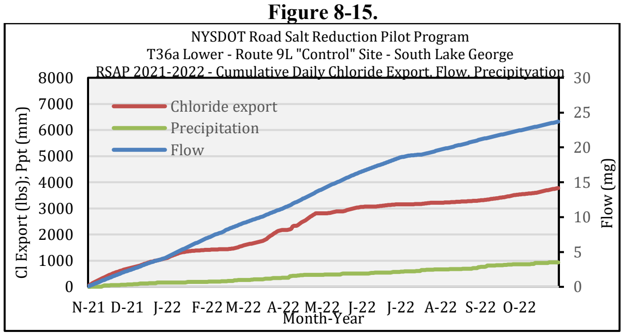


Figure 8-15.



Figures 8-14 and 8-15 both have a secondary *y-axis* which is used to track changes in flow (mgd). The slopes of the trendlines, whether exhibiting a sharp increase or plateau, as they progress from November 1st through October 31st, give valuable information about the types of changes that occur at the site. For example, in Figure 8-15, we see that although the total flow (23.372 mgd) during RSAP 2021-2022 was only 17 percent less than the total flow (28.170 mgd) during RSAP 2020-2021, the total salt export (3766 lbs.) during RSAP 2021-2022 was only about 50 percent of the total salt load (7399 lbs.) during RSAP 2021-2022.

Now is the time to summarize the extensive data collected so that evaluations can be achieved using the NYSDOT road salt application data received for this particular "pilot" segment of Route 9N. The RSAP 2020-2021 and RSAP 2021-2022 "Annual" parameter values provided in Table 8-5 and Table 8-6 are summarized in Table 8-7.

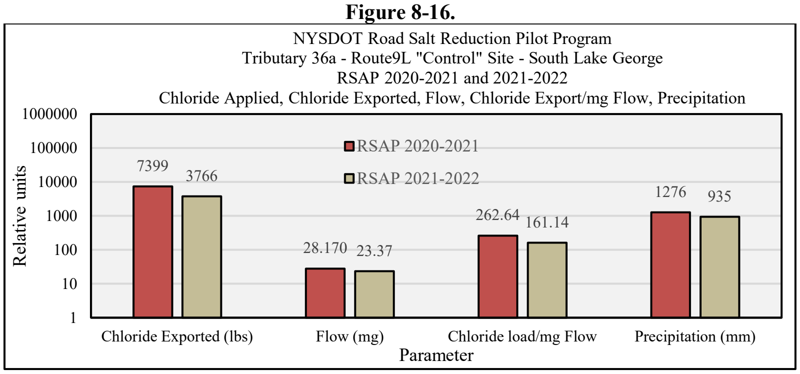
Table 8-7.

	RSAP ANNUAL	
	2020-2021	2021-2022
Chloride Load (lbs.)	7399	3766
Flow (mg)	28.170	23.372
Chloride load/mgd Flow	262.6	161.1
Precipitation (mm)	1276	935

As summarized above, (1) RSAP 2020-2021 had a greater chloride export than RSAP 2021-2022 (7399 lbs. vs 3766 lbs., respectively, (2) the total annual flow was great during RSAP 2020-2021 than during 2021-2022 (28 mg vs 23 mg, respectively), and (3) the chloride export per million gallons of flow was greater during RSAP 2020-2021 than RSAP 2021-2022 (263 lbs. vs 161 lbs., respectively).

Figure 8-16 summarizes and compares the RSAP 2020-2021 and RSAP 2021-2022 "Annual" parameter values presented in Table 8-7.

Figure 8-16.



The *y-axis* in Figure 8-16 is logarithm scale to display the wide range of "annual" parameter values summarized from RSAP 2020-2021 and 2021-2022. A comparison of the two RSAP parameters in Figure 8-16 reveals that (1) chloride export was 49 percent less in 2021-2022 (3766 lbs.) than in 2020-2021 (7399 lbs.), (2) flow at the ***lower*** site was 18 percent less in 2021-2022 (23 mg) than in 2020-2021 (28 mg), (3) chloride export per mg of flow was 39 percent less in 2021-2022 (161 lbs.) than in 2020-2021 (263 lbs.), and (4) total precipitation was 27 percent less during 2021-2022 (935 mm) than in 2020-2021 (1271 mm).

At this time, the summarized RSAP 2020-2021 and 2021-2022 chloride export, flow and precipitation data can be used to populate a table that contains some of the watershed characteristics that define T36a (Table 8-8).

Table 8-8.

							Cl^- in lbs.			
Program ID	Watershed Area (ac)	Highway Area (ac)	Lane Miles	RSAP	Period Ppt (mm)	Flow (mg)	Annual Cl^- Export	Cl^- Export/ LM	Cl^- Export/ million gallons	Cl^- Export/ mm Ppt
T36a	134	0.59	0.35	2020-2021	1276	28.170	7399	21140	262.6	5.80
				2021-2022	935	23.372	3766	10760	161.1	4.03

The following chapter (9) will compile all of this watershed and collected data in a single place so that comparisons can be made. Chapter 10 describes the challenges, understanding, evaluation and problems associated with the NYSDOT road salt application data, while Chapter 11 will compare the data collected by the LGA monitoring program with the road salt application data provided by the NYSDOT to determine whether an evaluation of the 10 percent reduction program could be accomplished.

8.6 Literature Cited

No literature cited in the text of this chapter.

New York State Department of Transportation Road Salt Reduction Pilot Program

Final Report for the Lake Champlain Sea Grant Program

Chapter 9

Summary and Evaluation of Lake George Association Tributary Watershed Monitoring Data

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9.0 Introduction

The ***lower*** stations of the T63a, T61, and T41 “test” and “control” subwatersheds have been fully instrumented since May 2020 to monitor specific conductance and water level, the data required to conduct a thorough evaluation of chloride loading from each subwatershed. Tributary watershed T36a was fully instrumented during November 2020. The logger data collected from most of 2020 have limited usefulness, however, because water level data were not collected during the first four months of the year.

As explained earlier in this report, using the 12-month calendar (January through December) to calculate the annual chloride loading of individual subwatersheds was not realistic for this Program because during late October-early November each year, local basin temperatures decline, and road salt is applied to the “test” and “control” highway surfaces in anticipation of predicted/potential impending storm events. Continuing to monitor ‘calendar year’ specific conductance and water level during this period meant that the calculated chloride loading values will include contributions from a different “winter” period than the monitoring that occurred from November through October.

Based upon this information, October 31st each year was selected as the date to terminate the chloride load and flow data collection for each “road salt application period” (RSAP) under investigation unless other information was available from the NYSDOT to indicate that road salt application was delayed beyond that date. Consequently, November 1st was chosen as the date to begin each RSAP. So, for example, the flow and chloride monitoring data for RSAP 2020-2021” would start on November 1st, 2020, and end on October 31st, 2021.

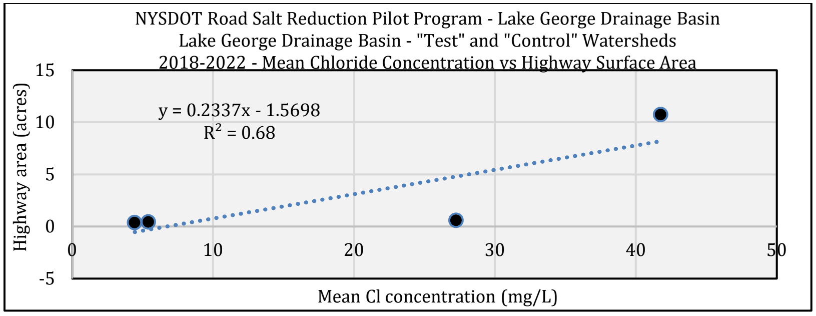
9.1 The Difference between *Upper* and *Lower* Tributary Monitoring Sites

The goal of this monitoring program is to evaluate the 10 percent road salt reduction “pilot” Program implemented by the NYSDOT. The selection of suitable Program “test” sites proved to be difficult due to the fact that most of the upland area above Route 9N along the west side of the lake from the Village of Lake George to the north end of Northwest Bay is developed and influences any tributaries that drain these areas before they cross under Route 9N. In fact, T61 and T63a proved to be the only suitable tributaries for this particular investigation because their upland areas were comprised of either private or state-owned undeveloped land.

The selection of the two “control” watersheds was less troublesome because of the existence of other State operated highways systems beside Route 9N within the Lake George drainage basin where the 10 percent road salt reduction Program would not be in effect. Thus, T41 (English Brook) along a segment of Route 9 that runs between Lake George Village and Warrenburg and T36a along a segment of Route 9L which runs from Route 9 in the Town of Lake George along the eastern shore of Lake George to the Town of Fort Ann, were selected.

The suitability of each tributary subwatershed for the current investigation was demonstrated earlier in this report when the difference between the ***upper*** and ***lower*** mean chloride concentrations was presented using the extensive dataset collected since 2018 when the Program was initiated. In fact, as shown in Figure 9-1, even with only four watersheds under investigation, there was a modest relationship between the mean chloride concentration calculated at each ***lower*** site and the surface area of highway that drains to that site on each tributary.

Figure 9-1.



An earlier study in the Lake George drainage basin reported the direct relationship between mean chloride concentration in a tributary and the amount of highway/road surface area (Swinton et al. 2015).

In each tributary subwatershed selected for this investigation, the only source of chloride measured at each ***lower*** site above background levels (< 1.0 mg Cl^-/L) is due to road salt (NaCl) added to the highway segment. If there was no influence of highway segment on the chloride concentration measured at each ***lower*** site, the mean concentration of chloride would be the same as the mean concentration measured at each ***upper*** site (< 1.0 mg Cl^-/L).

9.2 Summary of "Test" and "Control" *Lower* Subwatershed Characteristics

Previous chapters in this report have documented (1) the justification for including the "test" and "control" watersheds in the present investigation, (2) the important characteristics of the individual "test" and "control" watersheds, and (3) summaries of the road salt, flow and precipitation data collected from the watersheds. In this section of the report, we begin to assemble and compare characteristics and collected data from the 'test' and 'control' ***lower*** subwatersheds. In particular, we focus on (1) the characteristics that define each subwatershed, (2) the specific features used to determine chloride load along highway segments within each lower subwatershed and (3) how the chloride load values will compare with the NYSDOT road salt application rates within these subwatersheds.

A first step in the Program data evaluation process is to present a collective summary of the "test" and "control" watershed characteristics with some basic information so that some point of reference is available once we begin analyzing flow and chloride data. Table 9-1 compares some important characteristics for the ***lower*** subwatersheds under investigation including surface area, highway surface area (in acres and lane miles), channel length to the watershed divide from the lower sampling station, and percent forested, developed and impervious area. For the purposes of data presentation and discussion in this report, a "lane mile" is 63,360 ft^2 (1.45 acres).

Table 9-1.

Watershed Type	Program ID	Watershed Area (ac)	Highway Area (ac)	Highway Lane Miles	Channel length to divide (miles)	% forested	% developed	% impervious
"Test"	Trib 63a	512	0.45	0.27	2.07	98.2	0.88	0.0168
	Trib 61	192	0.37	0.22	0.92	89.9	1.74	0.0427
"Control"	Trib 41	1888	10.74	5.51	4.84	97.7	5.7	0.63
	Trib 36a	64	0.59	0.35	0.73	100	6.07	0.0791

Some noteworthy observations from the data summarized in the above table include the following:

- Subwatershed surface areas at the ***lower*** stations range from 64 acres (T36a) to 1888 acres (T41),
- Highway surface area that drains to the ***lower*** stations ranges from 0.37 (T61) to 10.74 acres (T41),
- Highway lane miles that drain to each ***lower*** station ranges from 0.22 (T61) to 5.51 (T41),
- Channel length from the ***lower*** station to top of the divide ranges from 0.73 (T36a) to 4.84 miles (T41),
- All ***lower*** subwatersheds are 90 percent forested or greater and range from 90 (T61) to 100 percent (T36a),
- Percent developed area in each ***lower*** subwatershed ranges from 0.88 (T63a) to 6.07 percent (T36a), and
- Percent impervious area in the ***lower*** subwatersheds ranges from 0.0168 (T63a) to 0.63 percent (T41).

In each of the ***lower*** subwatersheds, all of the percent developed and percent impervious consists of the highway surface that crosses the drainage area.

9.3 Determining Subwatershed Precipitation and Snowpack.

With a complete set of daily flow and daily chloride load data for RSAPs 2020-2021 and 2021-2022, the next tasks in the evaluation process were to (1) document local annual precipitation on a daily basis and (2) gain some insight into the weather severity of each RSAP by evaluating local snowpack in the basin at the location of each ***lower*** subwatershed sampling site. This information would be compared with the NYSDOT *S&I Event Code* (explained in Chapter 10), if the full set of requested road salt application data were acquired, to determine if there was any agreement between the two different sets of weather forecasting data. Instead, the local precipitation and snowpack data would be critical to the overall evaluation if the NYSDOT road salt application data was not provided at all.

Instead of documenting precipitation data for just the two RSAPs mentioned above with a complete set of daily flow and daily chloride load data, we decided to go back to the earliest winter period starting with 2018-2019 and calculating precipitation and snowpack for each interval to provide a larger sample size to compare our winter severity indices with any indices provided by the NYSDOT with their road salt application data if and when received.

9.3.1 Local precipitation

Records of local daily precipitation data collected at the Village of Lake George and Town of Bolton Wastewater Treatment Plants (WWTPs) during the previous decade have been entered into Excel format, summarized, and stored for use when two separate water quality studies were conducted at both facilities and Final Reports issued (Sutherland and Navitsky 2015, 2017). Both facilities produce significant wastewater discharge and have individual operating permits issued under the State Pollutant Discharge Elimination System (SPDES) permit program which is mandated and administered by the New York State Department of Environmental Conservation (NYSDEC). SPDES permits may incorporate current water quality standards, effective implementation of best management practices (BMPs) by permitted facilities, and timely sampling, analysis, and reporting to NYSDEC on the quality of wastewater discharged under the SPDES permit.

A unique feature of the SPDES program is the requirement for 'significant' permittees to submit monitoring data to the NYSDEC on a monthly Discharge Monitoring Report (DMRs). The DMRs contain a variety of data collected during plant operation and the NYSDEC processes this information to help direct its compliance assurance activities.

The collection and recording of daily precipitation data on the DMRs is one of the SPDES monitoring reporting requirements. Based upon the availability of these daily precipitation data from 2017 through the present time, it was decided to use the daily precipitation data recorded at the Bolton and Village of Lake George (VLG) Wastewater Treatment Plants due to the proximity of these facilities to the "**test**" and "**control**" watersheds under investigation.

Daily precipitation data received from both WWTPs at the end of each month when the DMRs are completed are entered into the Excel Master Precipitation file, the Master spConductance file and Tributary Master Flow and Chloride Loading file for each subwatershed under investigation and are used for subsequent data evaluation.

We considered it necessary to segregate the annual precipitation data for the "**test**" and "**control**" watersheds for several reasons including (1) their ~10-mile distance from each other in the drainage basin (south end of the lake versus Northwest Bay), (2) the difference in topography between the watersheds in Northwest Bay and areas in south Lake George, and (3) the noticeable increase during the previous decade of intense, localized rain and thunderstorms which do not impact the entire distance between the south end of the lake and the western shore area around Bolton Landing, thus leading to discrepancies in amounts of precipitation that occur in these regions.

In addition, it seemed important to take the analysis of local precipitation data one step further and separate out the amounts that occurred during the "winter" and "non-winter" portions of the overall 12-month period. The primary reason for this segmentation of the data was that only rain events would occur during the "non-winter" period of the year and that snow, sleet and rain could occur during the "winter" period of the year. Thus, for the purposes of this investigation, the 12-month period from November 1st thru October 31st was broken down as follows:

- November 1st through April 30th was considered the "winter" period of the 12-month cycle, and
- May 1st through October 31st was considered the "non-winter" period of the cycle.

Each period was six months in duration even though winters during recent decades in the northeastern US and particularly upstate New York seem to begin during late November-early December and finish by mid-to-late March.

Bolton Wastewater Treatment Plant (Bolton WWTP). The two "**test**" watersheds (T61 and T63a) in Northwest Bay are located to the north and within four and five miles of the Bolton WWTP, respectively. The monthly Bolton precipitation data compiled for the four RSAPs are summarized in Table 9-2 in units of inches and millimeters.

Table 9-2.

		these data were used for "test" watersheds T61 and T63a												
BOLTON	units	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Annual
2017-2018	inches	1.70	3.30	2.50	5.70	2.70	5.80	2.00	3.70	3.95	4.60	5.10	4.2	45.3
	millimeter	43.18	83.8	63.5	144.7	68.5	147.3	50.8	93.9	100.3	116.8	129.5	106.68	1149.4
2018-2019	inches	8.70	5.10	5.60	5.20	2.50	7.00	5.30	4.90	2.10	3.70	2.00	11.10	63.2
	millimeter	221.0	129.	142.	132.1	63.5	177.8	134.	124.	53.3	94.0	50.8	281.9	1605.3
2019-2020	inches	3.40	3.05	2.70	3.60	3.40	4.20	1.70	4.00	2.60	6.50	2.70	2.90	40.8
	millimeter	86.4	77.5	68.6	91.4	86.4	106.7	43.2	101.	66.0	165.1	68.6	73.7	1035.1
2020-2021	inches	4.1	3.8	1.8	2.8	1.4	4.9	1.3	5.1	8.4	2.9	4.5	6.9	47.9
	millimeter	104.4	96.6	45.7	71.1	35.6	124.4	33.0	129.	213.3	73.7	114.3	175.3	1216.7
2021-2022	inches	3.4	2.8	1.7	3.8	3.6	4.7	2.0	3.2	4.0	4.1	3.6	2.8	42.5
	millimeter	86.4	71.1	43.2	96.5	91.4	118.1	50.8	81.3	101.6	104.1	91.4	71.1	1075.7

Among the five consecutive RSAPs analyzed for the Bolton WWTP precipitation data, there was a 22.4 in (569 mm) difference between the 'wettest' RSAP (2018-2019; 63.2 in; 1605.3 mm) and the 'driest' RSAP (2019-2020; 40.8 in; 1035.1 mm), with the other three RSAPs falling near the low end of the range for total precipitation.

Figure 9-2 presents the annual summaries (inches, mm) for the five RSAPs while Figure 9-3 presents monthly summaries (in inches) for the five RSAPs.

Figure 9-2.

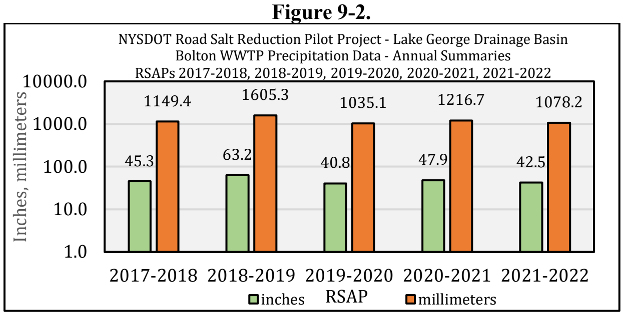
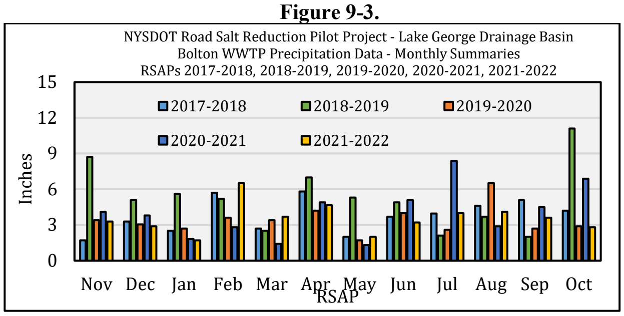


Figure 9-3.



The next step was to segment the 12-month precipitation data into the "winter" and "non-winter" periods as described above, and these data are summarized the five RSAPs in Table 9-3.

Table 9-3.

	Bolton WWTP Precipitation Data for "Test" Watersheds T61, T63a		
RSAP	units	Nov-Apr (winter)	May-Oct (non-winter)
2017-2018	inches	21.70	23.55
	millimeters	551.2	598.2
2018-2019	inches	34.10	29.10
	millimeters	866.1	739.1
2019-2020	inches	20.35	20.40
	millimeters	516.9	518.2
2020-2021	inches	18.80	29.10
	millimeters	477.5	739.1
2021-2022	inches	22.75	19.70
	millimeters	577.9	500.4

The Bolton data summarized in Table 9-3 also are shown in Figures 9-4 (in) and 9-5 (mm) to show the difference (1) between "winter" and "non-winter" RSAP period and (2) among RSAPs within "winter" and "non-winter".

Figure 9-4.

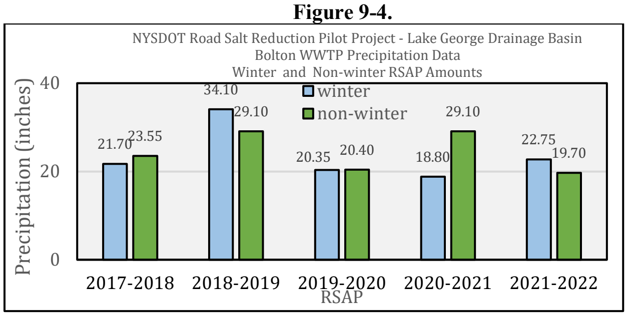
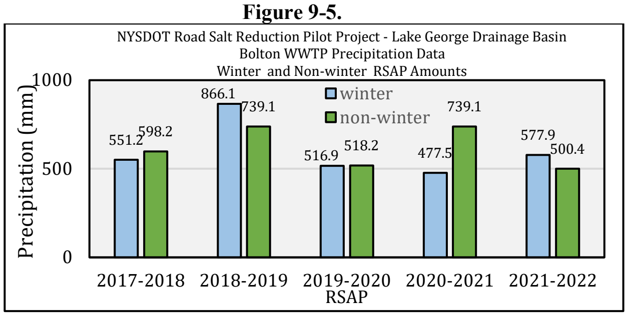


Figure 9-5.



The similarity between "winter" and "non-winter" periods for the Bolton RSAPs summarized above was variable. The order of most similar to least similar RSAPs were as follows: 2019-2020 (0.05 in; 1.3 mm difference), 2021-2022 (3.05 in; 77.5 mm difference), 2018-2019 (5.0 in; 127 mm), 2020-2021 (10.3 in; 261.6 mm).

<u>Village of Lake George Wastewater Treatment Plant (VLG WWTP)</u>. "**Control**" watershed T36a is located 2.0 miles northeast of the VLG WWTP, while "**control**" watershed T41 is located ~4.5 miles northwest of the facility. The monthly precipitation data compiled for the RSAPs are summarized in Table 9-4 (in and mm).

Table 9-4.

		these data were used for "test" watersheds T36a and T41												Annual
VLG	units	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
2017-2018	inches	1.94	2.74	3.18	2.09	2.25	6.09	1.2	4.56	3.58	3.56	4.46	3.46	39.1
	millimeters	49.3	69.6	80.8	53.1	57.2	154.7	30.5	115.8	90.9	90.4	113.3	87.9	993.4
2018-2019	inches	8.10	4.83	2.96	2.46	1.30	5.76	3.95	4.61	2.00	2.92	1.05	9.79	49.7
	millimeters	205.7	122.7	75.2	62.5	33.0	146.3	100.3	117.1	50.8	74.2	26.7	248.7	1263.1
2019-2020	inches	1.98	2.83	2.36	1.31	2.65	4.06	2.17	1.44	2.43	5.33	2.85	2.31	31.7
	millimeters	50.3	71.9	59.9	33.3	67.3	103.1	55.1	36.6	61.7	135.4	72.4	58.7	805.7
2020-2021	inches	4.33	2.98	2.02	2.24	2.10	4.73	2.60	4.61	8.11	5.09	4.65	6.76	50.2
	millimeters	110.0	75.7	51.3	56.9	53.3	120.1	66.0	117.1	206.0	129.3	118.1	171.7	1275.6
2021-2022	inches	3.23	3.14	1.13	2.69	3.68	4.32	1.92	2.42	3.69	3.68	4.16	2.74	36.8
	millimeters	82.0	79.8	28.7	68.3	93.5	109.7	48.8	61.5	93.7	93.5	105.7	69.6	934.8

Figure 9-6 presents the annual summaries (in, mm) for the five RSAPs while Figure 9-7 presents monthly summaries (in units of inches) for the five RSAPs.

Figure 9-6.

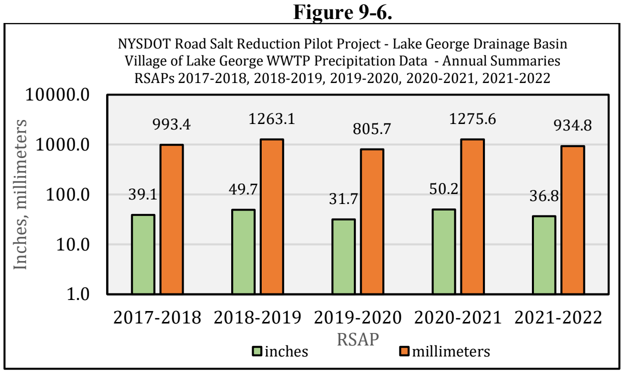
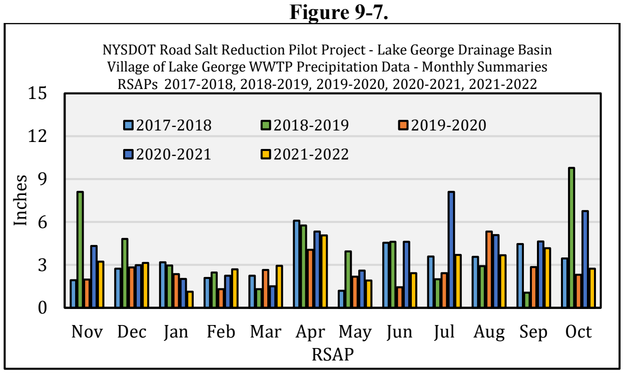


Figure 9-7.



Segmentation of the 12-month precipitation record into the "winter" and "non-winter" was conducted similar to the process with the Bolton data above and the results are summarized for all five RSAPs in Table 9-5

Table 9-5.

	VLG WWTP Precipitation Data - "Control" Watersheds T36a, T41		
RSAP	units	Nov-Apr (winter)	May-Oct (non-winter)
2017-2018	inches	18.29	20.82
	millimeters	464.6	528.8
2018-2019	inches	25.41	24.32
	millimeters	645.4	617.7
2019-2020	inches	15.19	16.53
	millimeters	385.8	419.9
2020-2021	inches	18.40	31.82
	millimeters	467.4	808.2
2021-2022	inches	18.19	18.61
	millimeters	462.0	472.8

The WWTP data in Table 9-5 are graphed in Figures 9-8 (in) and 9-9 (mm) to show the difference between "winter" and "non-winter" periods for the RSAPs and the differences among the RSAPs within "winter" and "non-winter".

Figure 9-8.

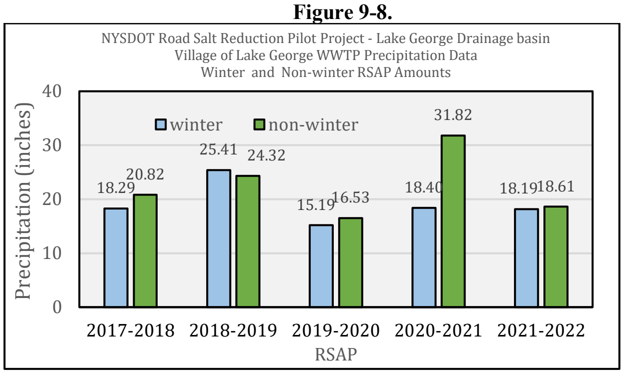
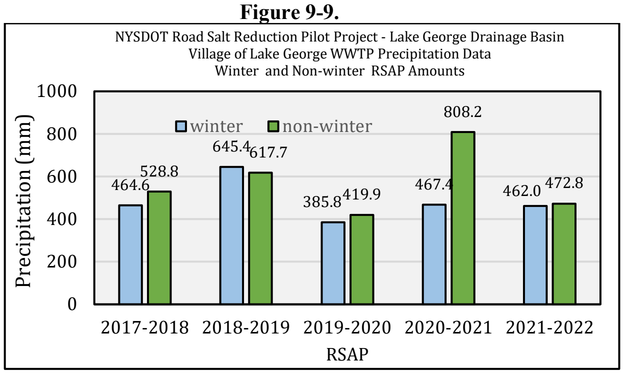


Figure 9-9.



All "winter" and "non-winter" RSAPs for the Village of Lake George summarized above were within 1.5 in of each other except RSAP 2020-2021 where the "non winter" period had 13 in (330 mm) more precipitation than the "winter" period. If winter severity can be equated with relative amounts of precipitation, then the winter of 2018-2019 was the most severe (25.42 in), followed by 2020-2021 (18.4 in), 2017-2018 (18.29 in), 2021-2022 (18.19 in) and finally 2019-2020 (15.19 in).

Comparison of Bolton and Village of Lake George "Winter" Period Precipitation. The next step in the precipitation evaluation process was to compare the amount of precipitation recorded at both facilities for the five "winter" period RSAPs of interest. The result of this analysis is summarized in Table 9-6.

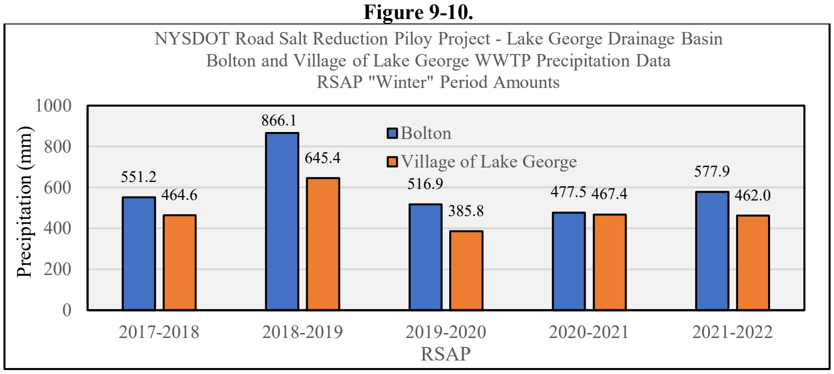
As shown below, all five RSAP "winter" periods at the "test" watersheds in close proximity to the Bolton WWTP had more precipitation than the corresponding "winter" periods measured at the Village of Lake George WWTP where the "control" watersheds were located. The greatest difference occurred during RSAP 2018-2019 when the Bolton facility measured 221 mm (8.7 in) more precipitation than the Village of Lake George facility. The order of decreasing difference for the remaining "winter" periods was as follows: RSAP 2019-2020 (131 mm/5.2 in), RSAP 2021-2022 (116 mm/4.6 in), and RSAP 2020-2021 (11 mm/0.4 in).

Table 9-6.

Bolton, Village of Lake George "Winter" Period Total Amounts (mm)			
RSAP	Location	Nov-Apr (winter)	± difference (mm/inches)
2017-2018	Bolton	551	+86/3.4
	Village of Lake George	465	-86/3.4
2018-2019	Bolton	866	+ 221/8.7
	Village of Lake George	645	-221/8.7
2019-2020	Bolton	517	+131/5.2
	Village of Lake George	386	-131/5.2
2020-2021	Bolton	478	+11.0/0.4
	Village of Lake George	467	-11.0/0.4
2021-2022	Bolton	578	+116/4.6
	Village of Lake George	462	-116/4.6

The RSAP "winter" period precipitation data for the Bolton and the Village of Lake George WWTPs summarized in Table 9-10 also are plotted in a column chart shown in Figure 9-6.

Figure 9-10.



With successful segmentation of the local precipitation data segmented into "winter" and "non-winter" periods for both the "test" and "control" watersheds under investigation, the next step in the evaluation process was to analyze potential severity of the RSAP "winter" periods by analyzing winter snowpack in the Lake George drainage basin.

9.3.2 Local snowpack

Our preliminary analysis used the "*Interactive Snow Information*" page, accessed within the National Operational Hydrologic Remote Sensing Center (NOHRSC), on the National Oceanic and Atmospheric Administration (NOAA) website (https://www.nohrsc.noaa.gov/). Figure 9-11 is a screenshot of the NOHRSC interactive page.

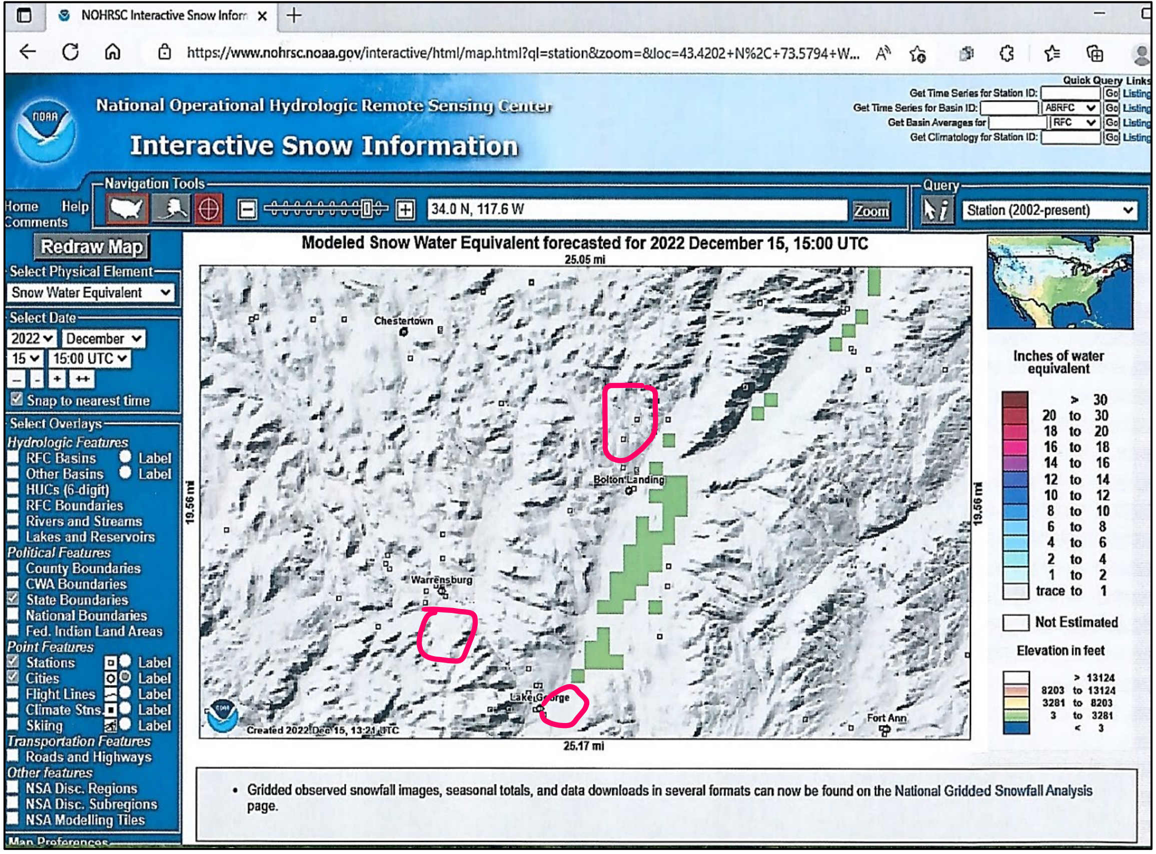
Figure 9-11 shows the site overlay menu on the left side, the map of the Lake George drainage basin area of interest in the center location and the color-coded chart (far right side) used to interpret the water equivalent of snowpack for pixelated areas in the "test" and "control" watersheds (circled in red). The resolution of the map used to interpret water content of the snowpack typically was 19.29 miles wide by 14.96 miles high (450 x 800 pixels).

The map of Lake George in the screenshot center area depicts the color-coded water content of the local snowpack in the "**test**" and "**control**" watersheds on December 15th 2022. Both basin areas where the "test" and "control" watersheds are located are clearly visible for the color-coded interpretation of snowpack water content which is "trace to 1" (inch) in the case of this map date.

It seemed important to evaluate the snowpack water content for the "control" watersheds T41 and T36a separately due to (1) elevation differences between the two sites (the ***lower*** site of T41 was situated at 790 ft [AMSL = above mean sea level] while the ***lower*** site of T36a was situated at 360 ft [AMSL]), and (2) the 3^+-mile distance between the two sites. The level of Lake George on USGS 15-minute quadrangle maps is 320 ft (AMSL). The ***lower*** sites of T61 and T63a are about the same elevation (340 ft (AMSL).

The watershed snowpack evaluation involved color-code interpretation of screens similar to Figure 9-11 of the Lake George local area snowpack for RSAPs 2018-2019, 2019-2020, 2020-2021 and 2021-2022 beginning on November 1st and repeating the process every seven days through the end of April. Data interpreted as equivalent inches of snowpack water content from the maps were converted to millimeters (mm) of water, and the individual values interpreted for each month were used to calculate a mean "winter" season value.

Figure 9-11.



- Gridded observed snowfall images, seasonal totals, and data downloads in several formats can now be found on the National Gridded Snowfall Analysis page.

The monthly RSAP data were summarized in tabular form according to the three separate basin areas of investigation and then plotted in column graph format as shown in Figure 9-12 (RSAP 2018-2019), Figure 9-13 (RSAP 2019-2020), Figure 9-14 (RSAP 2020-2021) and Figure 9-15 (RSAP 2021-2022).

Figure 9-12.

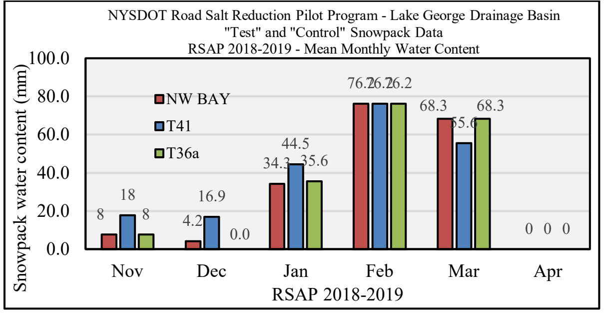


Figure 9-13.

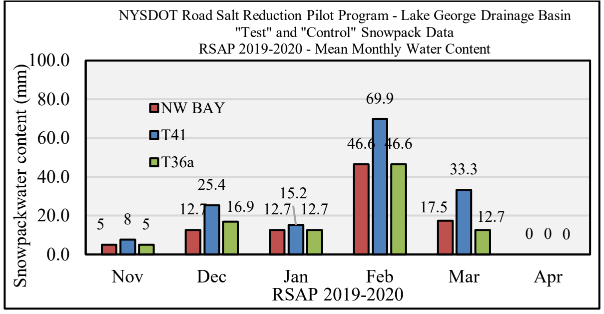


Figure 9-14.

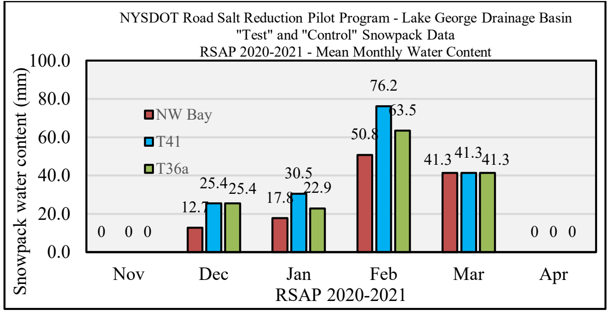
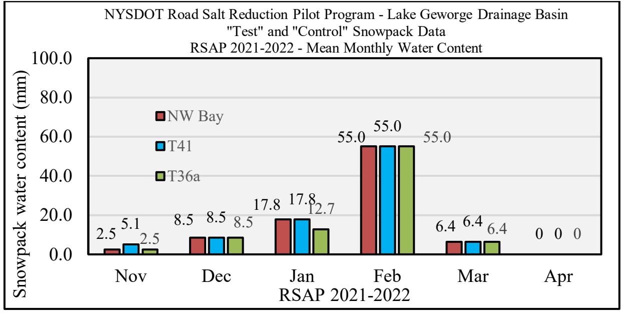


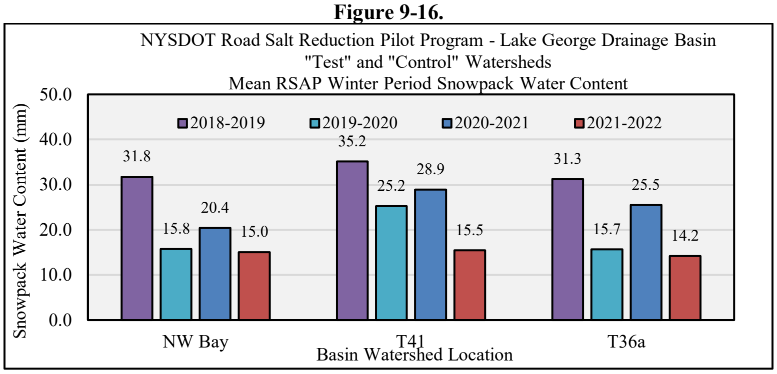
Figure 9-15.



A visual comparison of the snowpack water content data presented in the figures above suggests that within the Lake George basin RSAP 2018-2019 may have been the most severe winter in terms of weather conditions while RSAP 2021-2022 may have been the least severe. And, upon further inspection, RSAP 2020-2021 may have been slightly more severe than RSAP 2019-2020. This ranking of RSAPs, however, is based strictly upon the snowpack water content documented in the area of each watershed under investigation and may not reflect the actual conditions on the basis of individual storm events.

One last step in the evaluation of precipitation in the basin was to summarize the individual watersheds with respect to each other across all four of the "winter period" RSAPs where data were available. This was accomplished by summarizing the monthly data for each location in the basin and reporting the snowpack water content values as a seasonal average. The results of this analysis are presented in Figure 9-16.

Figure 9-16.



With this plot we are able to evaluate individual RSAPs for each watershed under investigation. For example, RSAP 2018-2019 was the most severe of the four RSAPs under consideration in all three watershed locations based strictly on the water content reported in Figure 9-12. Continued ranking using this technique would suggest that RSAP 2020-2021 was the next most severe winter, followed by RSAP 2019-2020 and 2021-2022, although both of these RSAPs are close to each other in terms of average seasonal snowpack water content.

As a reminder, this entire precipitation evaluation process was conducted because it was not certain whether the NYSDOT would provide road salt application data for the time period requested and whether these data would include any sort of storm event severity index to catalog individual events based upon some set of criteria. Without any input from the NYSDOT, then the process conducted and explained above would be the only reference available with regard to winter severity in the Lake George drainage basin.

9.4 Summary of Data Collected for Road Salt Application Periods 2020-2021 and 2021-2022

To date, the collection of continuous 5-minute flow and chloride data are complete only for RSAPs 2020-2021 and 2021-2022; all data for both RSAPs have been entered in their respective data files and summarized from the beginning of November through the end of October. Table 9-7 presents a summary of these data collected from the four watersheds under investigation along with other essential information that will be used for the evaluation process.

Table 9-7.

								Total Cl^- Exported (lbs.)		
Watershed Type	Program ID	Watershed Area (ac)	Lane Miles (ac)	RSAP*	Total Chloride Exported (lbs.)	Total flow #(mg)	Total Period Precipitation (mm)	Per Lane Mile	Per **mg	Per mm Precipitation
"Test"	Trib 63a	512	0.27	2020-2021	1,742	268	1,217	6452	6.5	1.43
				2021-2022	2,473	255	1,078	9159	9.7	2.29
	Trib 61	192	0.22	2020-2021	2,057	54	1,217	9350	38.3	1.69
				2021-2022	1,662	75	1,078	7555	22.2	1.54
"Control"	Trib 41	1888	5.51#	2020-2021	258,499	1,385	1,276	46915	186.6	202.59
				2021-2022	178,556	1,148	935	32406	155.5	190.97
	Trib 36a	64	0.35	2020-2021	7,399	28	1,276	21140	262.6	5.80
				2021-2022	3,766	23	935	10760	161.1	4.03

* RSAP = the 12-month period from November 1st during any year through October 31st of the following year.
** = million gallons
\# = includes Route 9 (2.33 LM) + I-87 (3.18 LM)

Some important observations from the data summarized above include the following:

- The total chloride export measured at T41 during each RSAP was several orders of magnitude greater than the total chloride load measured at the other watersheds under investigation,
- T63a was the only watershed under investigation that had a smaller total chloride export during RSAP 2020-2021 (1,742 lbs.) than in RSAP 2021-2022 (2,473 lbs.),
- T61 was the only watershed that exhibited greater flow during RSAP 2021-2022 (75 mg) than during RSAP 2020-2021 (54 mg), and
- In spite of having the smallest watershed surface area (64 acres) and traversing highway lane miles (0.35) only slightly larger than T61 (0.22) and T63a (0.27), T36a had the largest total chloride exported per mgd during RSAP 2020-2021 (262.6 lbs.) and RSAP 2021-2022 (161.1 lbs.) than any other watershed under investigation because of the extremely low total flow.

The most incomprehensible part of the data summary is the astonishing magnitude of the total chloride export measured at site T41 during RSAP 2020-2021 (258,499 lbs. = 129 tons) and RSAP 2021-2022 (178,556 lbs. = 89 tons) that entered Lake George during a two-year period, particularly when one remembers that there are numerous other road and highway systems in the basin that are in close proximity to tributaries that flow into the lake.

9.5 The Presentation of Data for the Remainder of the Report

The acquisition, challenges, understanding, evaluation, and problems associated with the NYSDOT road salt application data will be explained in the next chapter (10) of this report. With a complete set of flow and chloride load data for RSAPs 2020-2021 and 2021-2022, the process of evaluating road salt application reduction along the “pilot” segment of Route 9N, which includes “Test” watersheds T61 and T63a, and “Control” watersheds T36a and T41 adjacent to Route 9L and Route 9,respectively, will be presented and discussed in the Chapter 11 of this report. Data for RSAPs 2020-2021 and 2021-2022 for each “Test” and “Control” watershed will be presented separately and evaluated to the best of our ability with the road salt application data provided by the NYSDOT.

9.6 Literature Cited

Sutherland, J.W. and C. Navitsky. 2015. Final Report. Village of Lake George Wastewater Treatment Plant – A Monitoring Program to Document Current Treatment Efficiencies. Prepared for The Village of Lake George. 129 pp. + appendices.

Sutherland, J.W. and C. Navitsky. 2017. *Final Report. Bolton Bay (Lake George, Warren County) Water Quality Assessment. A Monitoring Program to Evaluate Current Water Quality Issues*. Prepared for The Fund for Lake George and the Town of Bolton. 150 pp. + appendices.

Swinton M.W., L.W. Eichler, and C.W. Boylen. 2015. Road salt application differentially threatens water resources in Lake George, New York. Lake Reserv Manage. 31:20–30. DOI: 10.1080/10402381.2014.983583

New York State Department of Transportation Road Salt Reduction Pilot Program

Final Report for the Lake Champlain Sea Grant Program

Chapter 10

New York State Department of Transportation Road Salt Application Data – Acquisition, Challenges, Interpretation, Evaluation and Problems

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10.0 Purpose of NYSDOT Road Salt Application Data Review

Obtaining the road salt application data from the NYSDOT was necessary for the successful analysis of the Route 9N Pilot Program. This dataset, along with the stream monitoring data, are the two major datasets required for this study, and allows for loading analysis which was not covered in the NYSDOT workplan for the Pilot Program. Understanding the loading helps determine the environmental benefits of such an application reduction initiative.

When the Pilot Project was first announced in May 2018, a proposed work plan was presented to NYSDOT at an opening meeting between the report authors and NYSDOT personnel. Data were a primary topic at the meeting: how it was going to be collected, what tracking equipment would be used, how it would be transferred, and how it would be shared. It was conveyed that the necessary information for analysis would include road salt application rates recorded through an Automatic Vehicle Location (AVL) system with GPS coordinates for the specific highway segments within the study area. It was assumed that a data sharing agreement would be established between the parties; however, this agreement did not occur, necessitating data acquisition through other means.

10.1 Terminology and Definitions

Application Event – The documentation of road treatment during a winter storm event that is comprised of one or more passes. Multiple application events can occur during a single winter storm event.

AVL – Acronym, Automatic Vehicle Locator. Onboard data management system used for real-time, GPS tracking of trucks and collecting data pertaining to salt applications at specific time intervals.

Application Rate – the amount of deicing material applied per Lane Mile.

Beat – A defined section of road as determined by NYSDOT Route Numbers and Mile Markers based on travel distance from a maintenance facility, length of road and amount of material capacity of trucks. Used to identify and assign sections of roads, and in respect of this project, specifically for salt applications. Beats typically are assigned to specific operators who acquire local knowledge of specific conditions of road.

Blasting – The act of applying an elevated quantity of treatment material to a section of road due to known or anticipated conditions, resulting in a high application rate. Blasting is not captured entirely in the SnoMat data format but can be noted in the AVL data format.

ClearLane® – Specific de-icing material comprised of sodium chloride with a solution additive containing magnesium chloride and used by NYSDOT for winter storm event road treatment. The pre-wet solution additive promotes enhanced activation, works at colder temperatures than standard sodium chloride and reduces scatter on the road during application (Cargill 2023).

FOIL – Acronym, Freedom of Information Law. Designed to ensure public access to government records. “Under FOIL, an agency must make records available for public inspection and copying, except to the extent that records or portions thereof fall within one or more grounds for denial.” (NYSDOT)

Lane Mile – Abbrev. LM. Mileage of single lane width present within a stretch of roadway, e.g., a mile of a two-way road would be considered two lane miles. Synonym of Spread Miles.

Pass – When a section of road is treated. Multiple passes can be made on a section of road during a documented application event. This information is captured in 10-second intervals by AVL but is not captured by SnoMat.

SnoMat – Operator-run data management system used for tracking trucks and data pertaining to salt applications. Roads are assigned to Beats by NYSDOT and do not utilize GPS. Operators/Supervisors manually input data into spreadsheets.

Winter Period – Referring to the date extent of treatments pertaining to a “snow & ice season” starting in the late season of calendar year and continuing into the following year. As an example: Winter 2020 is comprised of treatments starting in November 2020 and ending in April 2021. In this report, also referred to as ‘RSAP.’

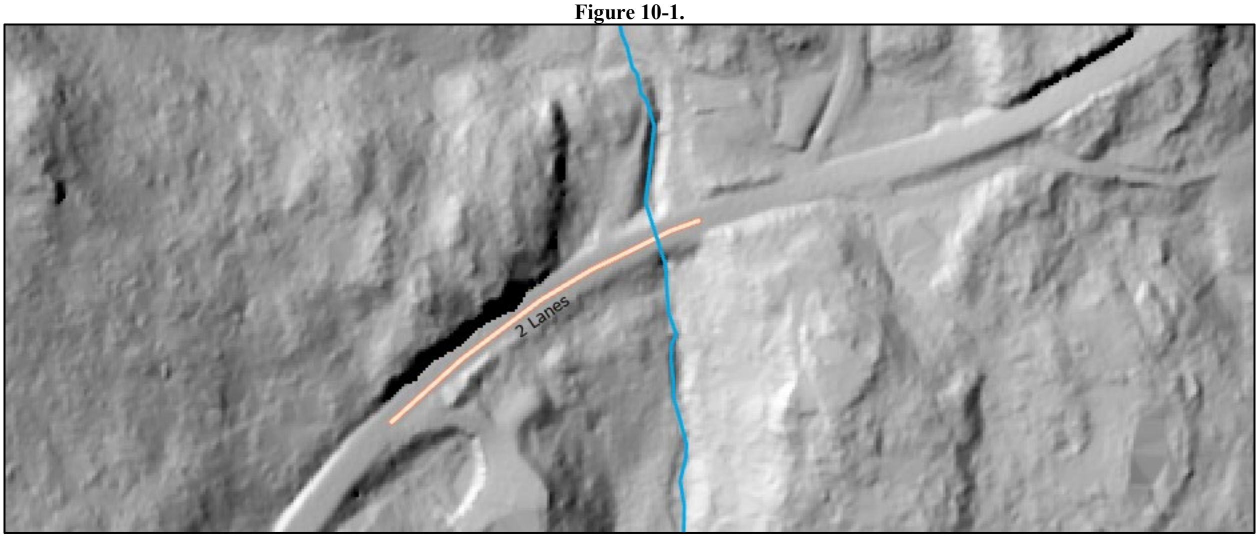
Winter Storm Event – The duration of precipitation requiring road treatment. Depending on the storm severity and duration, multiple application events can occur during a single winter storm event.

10.2 Study Area Road Lengths Determination

Road measurements of state routes (Route 9, Route 9N, and Route 9L) within the watershed for each lower site were necessary for two purposes: 1) by understanding the section of road included in the watershed, we could provide specific DOT Reference Markers, including Route Numbers and Mile Marker data, within our request for information to specify and simplify the data processing from NYSDOT, and 2) knowing the road lengths within each watershed allowed us to calculate the road salt material load applied to the lower sites.

Using watersheds derived from USGS StreamStats (USGS 2020), estimated road endpoints were located for T36a, T41, T61, and T63a. Figure 10-1 displays study tributary T61 (blue line) mapped in ArcGIS Pro with two lanes (orange line) of Route 9N that influence the T61 ***lower*** sampling site.

Figure 10-1.



By physically walking the respective sections of road, any culvert and stormwater practice drainage was noted, and road endpoints were confirmed or updated. Road lengths for all ***lower*** sites aside from T41 were determined with this methodology; T41 road surface determination needed additional investigation due to an unknown influence from I-87 in addition to Route 9.

The T41 watershed and lane miles were determined using ArcGIS Pro (version 2.9), 2015 LiDAR data* (2m contours and hillshade dataset), 2022 aerial photo imagery*, and DOT plat maps in addition to field observations and Google Street View (*NYS GIS Clearinghouse). The plat maps, which show locations of existing culverts, were reviewed to determine flow paths under I-87 and Route 9. The boundaries of the watershed over I-87 and Route 9 roadways were determined utilizing a combination of field observations, Google Street View, and elevation contours.

To obtain Lane Miles, a GIS DOT roadway inventory dataset (milepost2020) was clipped to the newly determined drainage area (NYS GIS Clearinghouse). The DOT dataset contained information on each road segment including the number of lanes and length. Each watershed Lane Mile of crossing highway was calculated as follows:

$$\textbf{Lane Miles} = \textbf{(Road Length (}\textbf{\textit{ft}}\textbf{) / 5280 ft/mile) * \# of Lanes}$$

For example: **T61**

$$\begin{aligned} \textit{Lane Miles} &= (575\ (ft) / 5280\ ft/mile) * 2 \\ &= 0.22 \text{ LM} \end{aligned}$$

Lane Mile calculations for each watershed are listed in Table 10-1 below.

Table 10-1.

Watershed	Route	Lane Miles (LM)
T63a	RT 9N	0.27
T61	RT 9N	0.22
T41	RT 9 & I-87	5.51 (2.33 RT 9 + 3.18 I-87)
T36a	RT 9L	0.35

10.3 Acquisition of NYSDOT Road Salt Application Data

Per New York State, public access to government records is obtained through the Freedom of Information Law (FOIL), set forth in Article 6 of the Public Officers Law (Section 84-90). This law states the people's right to know the process of government decision-making and the ability to review the documents and statistics leading to determinations is basic to our society.

The FOIL process was required for this study as data would not be shared by NYSDOT outside of the legal process. Three FOIL requests for winter road salt application data were submitted to NYSDOT starting in 2020. The following FOIL responses encompassed data from Winter Periods 2017-2018 through 2021-2022.

(1) FMO-20-016927 (FOIL 1)
  - Submitted February 5th 2020 requesting data for winters 2017-2018, 2018-2019, 2019-2020
  - Received April 5th 2021 after five extensions determined by NYSDOT and an incorrect dataset supplied on March 23rd 2021. Data included winters 2017-2018, 2018-2019, and partial data for 2019-2020 (through December 2019).

(2) FMO-21-019116 (FOIL 2)
  - Submitted March 2021 requesting data for Winters 2019-2020 and 2020-2021
  - Received November 15th 2022. Data included winter 2020-2021 and partial data for 2021-2022 (through February 2022). A second set of data was also provided in a different format - Automatic Vehicle Location (AVL) data – for winters 2019-2020 (partial, starting January 2020) and 2020-2021 (full).

(3) FMO-22-019955 (FOIL 3)
  - Submitted December 2021 requesting data for winter 2021-2022
  - Received November 8th 2022. Data included winter 2021-2022.

Each FOIL request detailed the specific section of highway that was determined in Section 10.2, along with DOT Reference Marker locations. It was initially anticipated that the FOILs would be processed through the smaller Regional Office, specifically Region 1 for the Capitol District. Unfortunately, the requests were forwarded to the Central Headquarters located in Albany and assigned tracking numbers which extended the acquisition process. The troubles encountered in obtaining the data were detailed in Chapter 2. In summary, four issues were encountered:

- The extremely long delay in the receipt of the data from the NYSDOT.
- Receipt of incorrect data, e.g., receiving the entire western half of NY State in response to our first request.
- The data spreadsheets were received without "Read Me" files to explain data collected, formatting, etc., and,
- The inconsistent formatting between the data management and responses.

Specific to the T41 ***lower*** site, the determination of influence from I-87 was not confirmed until 2022. Considering NYSDOT's turn-around time for FOIL requests and study timeline, a FOIL request was not submitted for additional treatment data for I-87 and therefore, our calculations for T41 totals include an estimated quantity for I-87 based off of a 10% increase from the Route 9 application rates as per guidance standards provided by NYSDOT personnel.

10.4 Data Format Interpretation and Processing

Two data formats were received from NYSDOT for road salt application data extending from Winter Periods 2017-2018 through 2021-2022 including SnoMat and Automatic Vehicle Locator (AVL). Both formats required additional conversations and meetings with NYSDOT representatives to review and identify material used as well as understand data terminology, abbreviations, reference codes, units, and overall data formatting. The data spreadsheet interpretation and processing pertain to solid material applied; while both formats include columns for brine applications, no application data were provided due to a lack of brine applications and tracking equipment.

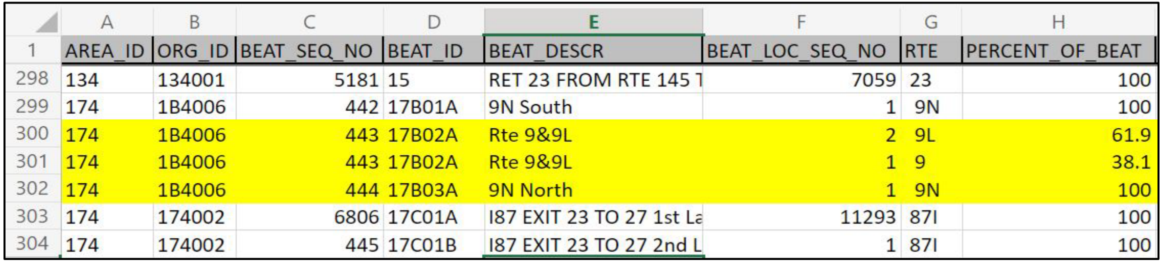
10.4.1 SnoMat Data Management System

The NYSDOT responses to all FOILs provided data extracted from the SnoMat data management system, an on-board application tracking system that requires manual input from truck operators or supervisors. SnoMat data were provided for all Winter Periods; however, Winter Periods 2019-2020 and 2020-2021 were incomplete datasets. NYSDOT stated that they only utilized AVL, another tracking management system, for calendar year 2020 and part of 2021. The SnoMat data files include two parts:

(1) The identification of 'Beats,' identified as **BEAT_ID** in **Column D** in Figure 10-2 received from DOT: Each Beat is a section of road defined by NYSDOT **Route Marker** (**RM**) and **Mile Markers** (**MM**), as

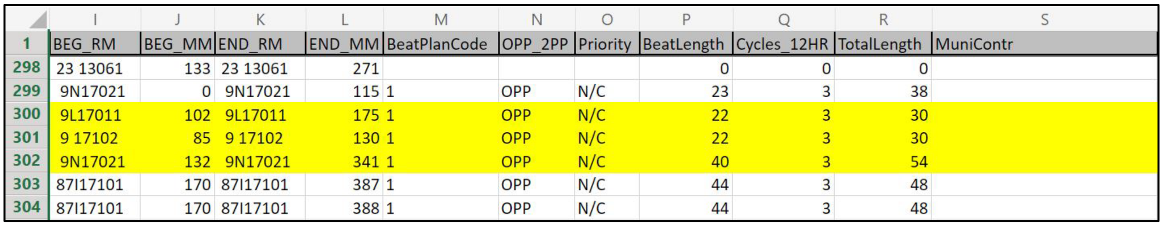
seen in **Columns I-L** in Figure 10-3 below. Of the locational data provided for each Beat, only the Beat ID is carried over into the salt application information (Part 2 of the dataset received). This is unfortunate since Beat **Location Sequence Number** (**Column F**) would provide further specificity for treatment location information.

Figure 10-2.



	A	B	C	D	E	F	G	H
1	AREA_ID	ORG_ID	BEAT_SEQ_NO	BEAT_ID	BEAT_DESCR	BEAT_LOC_SEQ_NO	RTE	PERCENT_OF_BEAT
298	134	134001	5181	15	RET 23 FROM RTE 145 T	7059	23	100
299	174	1B4006	442	17B01A	9N South	1	9N	100
300	174	1B4006	443	17B02A	Rte 9&9L	2	9L	61.9
301	174	1B4006	443	17B02A	Rte 9&9L	1	9	38.1
302	174	1B4006	444	17B03A	9N North	1	9N	100
303	174	174002	6806	17C01A	I87 EXIT 23 TO 27 1st La	11293	87I	100
304	174	174002	445	17C01B	I87 EXIT 23 TO 27 2nd L	1	87I	100

Figure 10-3.



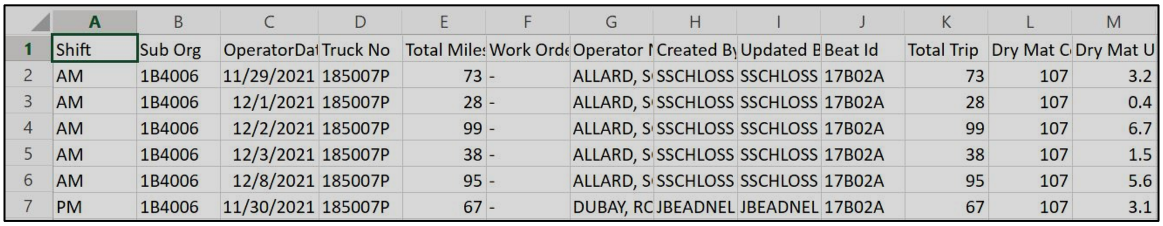
	I	J	K	L	M	N	O	P	Q	R	S
1	BEG_RM	BEG_MM	END_RM	END_MM	BeatPlanCode	OPP_2PP	Priority	BeatLength	Cycles_12HR	TotalLength	MuniContr
298	23 13061	133	23 13061	271				0	0	0	
299	9N17021	0	9N17021	115	1	OPP	N/C	23	3	38	
300	9L17011	102	9L17011	175	1	OPP	N/C	22	3	30	
301	9 17102	85	9 17102	130	1	OPP	N/C	22	3	30	
302	9N17021	132	9N17021	341	1	OPP	N/C	40	3	54	
303	87I17101	170	87I17101	387	1	OPP	N/C	44	3	48	
304	87I17101	170	87I17101	388	1	OPP	N/C	44	3	48	

Using Route Marker and Mile Marker data columns, we manually discerned that two Beats were pertinent to our study, highlighted in yellow in the tables above: 17B02A includes the watersheds for T36a ***lower*** and T41 ***lower*** and 17B03A includes the watersheds for T63a ***lower*** and T61 ***lower***.

By identifying the Beats covering the study area, all Application Event data for Beats 17B02A and 17B03A could be extracted from the second part of the data, explained below.

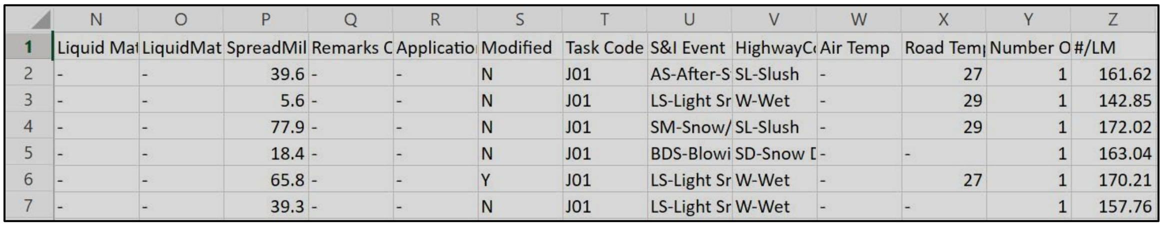
(2) Application Event data received from NYSDOT, broken up by date, in Figures 10-4 and 10-5 below.

Figure 10-4.



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Shift	Sub Org	OperatorDat	Truck No	Total Miles	Work Orde	Operator N	Created By	Updated B	Beat Id	Total Trip	Dry Mat C	Dry Mat U
2	AM	1B4006	11/29/2021	185007P	73	-	ALLARD, S	SSCHLOSS	SSCHLOSS	17B02A	73	107	3.2
3	AM	1B4006	12/1/2021	185007P	28	-	ALLARD, S	SSCHLOSS	SSCHLOSS	17B02A	28	107	0.4
4	AM	1B4006	12/2/2021	185007P	99	-	ALLARD, S	SSCHLOSS	SSCHLOSS	17B02A	99	107	6.7
5	AM	1B4006	12/3/2021	185007P	38	-	ALLARD, S	SSCHLOSS	SSCHLOSS	17B02A	38	107	1.5
6	AM	1B4006	12/8/2021	185007P	95	-	ALLARD, S	SSCHLOSS	SSCHLOSS	17B02A	95	107	5.6
7	PM	1B4006	11/30/2021	185007P	67	-	DUBAY, RC	JBEADNEL	JBEADNEL	17B02A	67	107	3.1

Figure 10-5.



	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1	Liquid Mat	LiquidMat	SpreadMil	Remarks C	Applicatio	Modified	Task Code	S&I Event	HighwayC	Air Temp	Road Temp	Number O	#/LM
2	-	-	39.6	-	-	N	J01	AS-After-S	SL-Slush	-	27	1	161.62
3	-	-	5.6	-	-	N	J01	LS-Light Sr	W-Wet	-	29	1	142.85
4	-	-	77.9	-	-	N	J01	SM-Snow/	SL-Slush	-	29	1	172.02
5	-	-	18.4	-	-	N	J01	BDS-Blowi	SD-Snow [	-	-	1	163.04
6	-	-	65.8	-	-	Y	J01	LS-Light Sr	W-Wet	-	27	1	170.21
7	-	-	39.3	-	-	N	J01	LS-Light Sr	W-Wet	-	-	1	157.76

The following information was pertinent to the study: **Date** (**Column C**), **Beat ID** (**Column J**), **Dry Material Used** (**Column M**), and **Spread Miles** (**Column P**).

Each Application Event is tracked by Beat and not by the physical location (latitude-longitude or DOT RM or MM) of the treatment. Based on the data provided, it is not possible to determine specific sections of the Beat where road salt is applied, not applied, or Blasted within the SnoMat format. Only the Application Rate for each Application Event can be determined (**Column Z**), and this calculation is shown in Section 10.5.2.

S&I Event Code (**Column U**) and **Liquid Material Used** (**Column O**) would be beneficial, but insufficient data were provided. The **S&I Event Code** is a label for the type of winter event determined by the operator. While intentions appear properly oriented, the labels are arbitrary and do not correlate to a storm severity scale. **Liquid Material Used** (pre-wetting material or brine) was simply not tracked either due to type of solid material, failure to implement or insufficient equipment.

10.4.2 AVL Data Management System

The NYSDOT response to FMO-21-019116 (FOIL 2) included data extracted from AVL, an on-board treatment tracking system that records real-time information at specific set intervals (every 10 seconds). NYSDOT provided all treatments (labeled Truck 185015P) from January 2020 through February 2021. This AVL dataset replaced some of the missing SnoMat data for Winter Period 2019 (November 2019-March 2020) and supplements the SnoMat data for Winter Period 2020 (November 2020–March 2021).

Of the 44 columns of data, pertinent information included date and time, latitude, longitude, application rate, and vehicle distance. The rest of the data columns provided were either not tracked (i.e., liquid application information) or not immediately useful (i.e., speed). While AVL provides high-accuracy treatment information, reformatting was required to extract data relevant to our study areas and for compatibility with the SnoMat data format. The following manipulations were made for incorporation into a master data workbook:

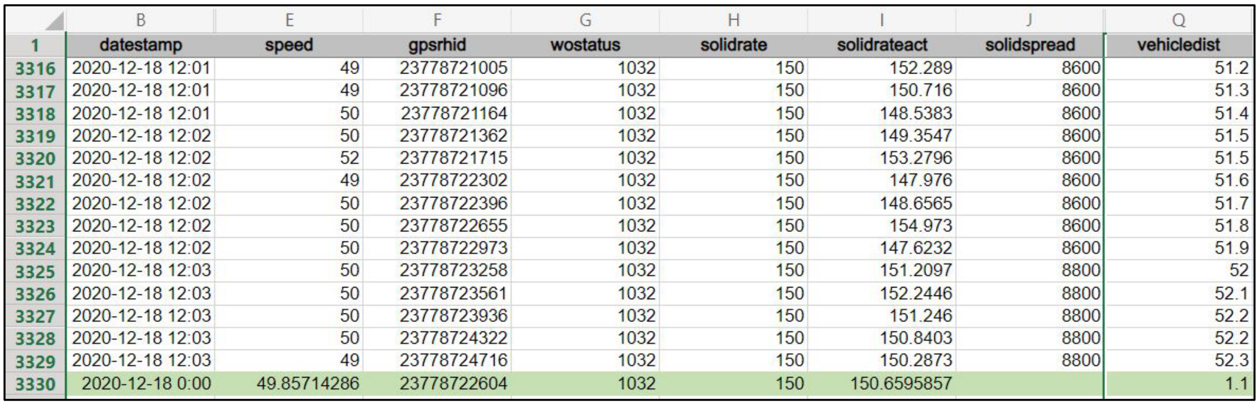
- The entire data file was uploaded into ArcGIS Pro, where the road lengths within the study areas were used to select and extract relevant data into an Excel file for further processing. Figure 10-6 displays a map of the application data relevant to the study (yellow) that was extracted from the provided dataset (red).

Figure 10-6.

- With data extracted for each study area, each treatment interval was consolidated into a single-lane Pass using **date and time** (**Column B**), **average application rate** (**Column I**) and **vehicle distance** (**Column Q**). Figure

10-7 displays the consecutive treatment intervals (white rows) averaged into data for a single-lane Pass (green row). This process was required for compatibility with the SnoMat data format, consumed a considerable amount of time, and was completed for all study areas.

Figure 10-7.



	B	E	F	G	H	I	J	Q
1	datestamp	speed	gpsrhid	wostatus	solidrate	solidrateact	solidspread	vehicledist
3316	2020-12-18 12:01	49	23778721005	1032	150	152.289	8600	51.2
3317	2020-12-18 12:01	49	23778721096	1032	150	150.716	8600	51.3
3318	2020-12-18 12:01	50	23778721164	1032	150	148.5383	8600	51.4
3319	2020-12-18 12:02	50	23778721362	1032	150	149.3547	8600	51.5
3320	2020-12-18 12:02	52	23778721715	1032	150	153.2796	8600	51.5
3321	2020-12-18 12:02	49	23778722302	1032	150	147.976	8600	51.6
3322	2020-12-18 12:02	50	23778722396	1032	150	148.6565	8600	51.7
3323	2020-12-18 12:02	50	23778722655	1032	150	154.973	8600	51.8
3324	2020-12-18 12:02	50	23778722973	1032	150	147.6232	8600	51.9
3325	2020-12-18 12:03	50	23778723258	1032	150	151.2097	8800	52
3326	2020-12-18 12:03	50	23778723561	1032	150	152.2446	8800	52.1
3327	2020-12-18 12:03	50	23778723936	1032	150	151.246	8800	52.2
3328	2020-12-18 12:03	50	23778724322	1032	150	150.8403	8800	52.2
3329	2020-12-18 12:03	49	23778724716	1032	150	150.2873	8800	52.3
3330	2020-12-18 0:00	49.85714286	23778722604	1032	150	150.6595857		1.1

10.5 Calculation of Winter Period Road Salt Application and Loading

The purpose of the analyzing the NYSDOT road salt data was two-fold including to determine (1) whether the NYSDOT is achieving the stated goals of the road salt reduction pilot program of 10 percent reduction in application, and 2) the loading of road salt into local tributaries and ultimately Lake George.

10.5.1 Road Salt Application Workbook

For ease of data processing, relevant data from all FOILs were collated into a singular master Excel workbook. A READ ME file is provided as the first worksheet and discusses the contents of each of the following 11 worksheets. Each worksheet is labeled as follows:

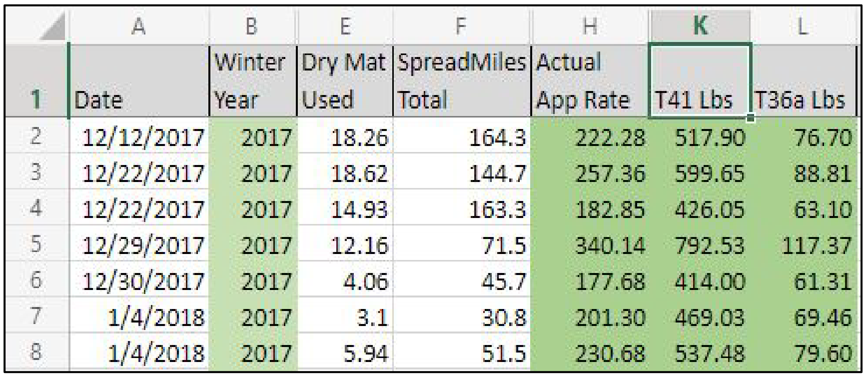
- Summary Tables & Graphs: displays summarized application information for all sites across all Winter Periods, including chloride application totals, average application rates, and application events,
- Sheets #1-4: collate estimated salt totals for 2017-2021 winter seasons. Data are segregated by site and comprised of pertinent application data from all FOILs,
- Sheets #5 & 6: collate SnoMat data, segregated by Beat, and
- Sheets #7-10: collate AVL data extracted from FOIL 2. Data are segregated by site.

10.5.2 Calculation of Total Material Applied

Winter de-icing material application can be estimated for all study areas by combining the previously detailed data formats provided by NYSDOT using a three-step process.

1. SnoMat, Sheets #5 & 6 (Figure 10-8): Dividing the **Dry Material Used** (**Column E**) by the **Spread Miles** (**Column F**) calculates the **Application Rate** (**Column H**), which is then multiplied by the **Road**

Figure 10-8.

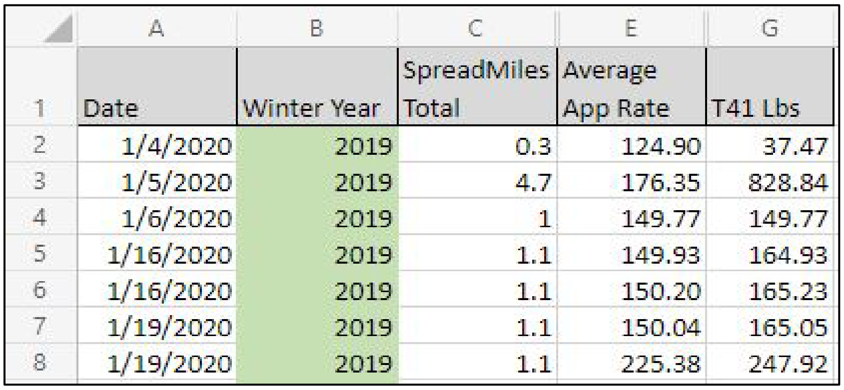


	A	B	E	F	H	K	L
1	Date	Winter Year	Dry Mat Used	SpreadMiles Total	Actual App Rate	T41 Lbs	T36a Lbs
2	12/12/2017	2017	18.26	164.3	222.28	517.90	76.70
3	12/22/2017	2017	18.62	144.7	257.36	599.65	88.81
4	12/22/2017	2017	14.93	163.3	182.85	426.05	63.10
5	12/29/2017	2017	12.16	71.5	340.14	792.53	117.37
6	12/30/2017	2017	4.06	45.7	177.68	414.00	61.31
7	1/4/2018	2017	3.1	30.8	201.30	469.03	69.46
8	1/4/2018	2017	5.94	51.5	230.68	537.48	79.60

Length for each study watershed, as detailed in 10.2. This equation calculates the **Estimated Material Applied** (**Column K and L**) for each Application Event and can be summed for each Winter Period.

2. AVL, Sheets #7-10 (Figure 10-9): Multiply the **Average Application Rate** (**Column E**) by **Spread Miles** (**Column C**) to calculate the **Estimated Material Applied** (**Column G**).

Figure 10-9.



	A	B	C	E	G
1	Date	Winter Year	SpreadMiles Total	Average App Rate	T41 Lbs
2	1/4/2020	2019	0.3	124.90	37.47
3	1/5/2020	2019	4.7	176.35	828.84
4	1/6/2020	2019	1	149.77	149.77
5	1/16/2020	2019	1.1	149.93	164.93
6	1/16/2020	2019	1.1	150.20	165.23
7	1/19/2020	2019	1.1	150.04	165.05
8	1/19/2020	2019	1.1	225.38	247.92

3. Sheets #1-4: The data from SnoMat and AVL were combined by date. During this process, duplicate Application Events for winter 2020-2021 between the SnoMat and AVL data were noted and addressed by removing respective SnoMat data in favor of the accuracy of the treatment tracking provided by the AVL system.
4. Calculation of **Number of Application Events**. It is important to note the difference in timing resolution of the application events between AVL and SnoMat formats, especially in order to calculate the number of **application events** for each Winter Period. The date and time stamp (yyyy-mm-dd hh:mm) of the AVL dataset, as shown in Figure 10-7, has a higher resolution than the SnoMat dataset, which tracks application events by beat and date. Understanding that an AVL application event consisted of two individual lane treatments to cover the entire Lane Miles (two lane widths) for each watershed, the number of passes can be calculated for the AVL data; this is reciprocal of the calculation of application events from the AVL data. Since SnoMat tracks application events by beat and date, pass information is not available and, thus, each entry must be accepted as a single application event. With this method, total application events can be calculated for each Winter Period. This information is especially important for Winter Periods 2019-2020 and 2020-2021 which have application event data from both AVL and SnoMat formats.

The total road salt applied at each site (in lbs.) for each Winter Period is summarized below in Table 10-2:

Table 10-2.

Winter	T36a	T41	T61	T63a
2017-2018	1665.84	27738.59	1612.76	1979.30
2018-2019	1232.34	20520.30	892.55	1095.41
2019-2020	194.47	26345.82	3881.22	4559.22
2020-2021	2692.85	71430.82	3513.02	4241.29
2021-2022	4413.01	73483.00	3748.26	4600.14
cell values for watersheds are in lbs.				

As explained in Section 10.2 and as summed in Table 10-2, the application rate to I-87 within the T41 ***lower*** watershed was estimated at 10% greater than that of State Route 9. Totals for T41 ***lower*** were calculated as follows:

Multiply Rt 9 Application Rate (lbs./LM) by 110% = I-87 Application Rate (lbs./LM)
I-87 Application Rate (lbs./LM) *x* 3.18 LM + Rt 9 Application Rate (lbs,/LM) x 2.33 LM = T41 Material Applied (lbs.)

10.5.3 Chloride Calculation for ClearLane®

Since ClearLane® is the preferred de-icing material applied by NYSDOT as part of their Best Practice Action Plan for the Route 9N Pilot Program, chloride loading calculations from the total applications for each Winter Period were performed as follows:

ClearLane® is comprised of 95.9% road salt (sodium chloride, NaCl) and 4.1% of pre-wetting agent, which contains 29% magnesium chloride (Cargill 2023). Using molecular weight of the constituents, the percentage of chloride in the material applied is calculated in Table 10-3 below:

Table 10-3.

NaCl		$MgCl_2$	
Molecular weight Cl^-	35.45	Molecular weight Cl^-	70.9
Molecular weight Na^+	22.9897	Molecular weight Mg^{+2}	24.305
% Cl^- of weight	60.67%	% Cl^- of weight	74.47%

The chloride loading per 100 lbs ClearLane® is calculated as follows:

95.9 lbs NaCl x 60.67% Cl = 58.18 lbs Cl^- in NaCl per 100lbs ClearLane®

1.189 lbs $MgCl_2$ x 70.9% Cl = 0.84 lbs Cl^- in pre-wetting agent per 100 lbs ClearLane®

TOTAL Cl WEIGHT = 59.02 LBS. PER 100 LBS CLEARLANE® or 59.02% of each application event.

10.5.4 Winter Period 2017-2018 through 2021-2022 Total Chloride Calculation

By using the calculations explained in Sections 10.5.2 and 10.5.3, total Cl^- can be estimated for all sites for all Winter Periods as summarized in Table 10-4 below, converted from lbs. to tons.

Table 10-4.

Winter Period	T36a	T41	T61	T63a
2017-2018	0.49	8.19	0.48	0.58
2018-2019	0.36	6.06	0.26	0.32
2019-2020	0.06	7.77	1.15	1.35
2020-2021	0.79	21.08	1.04	1.25
2021-2022	1.30	21.68	1.11	1.36

10.6 Issues and Resulting Assumptions from NYSDOT Road Salt Application Data Management

Multiple issues were presented throughout the integration of the datasets for analysis from the SnoMat and AVL data management systems. Thus, assumptions must be made in order for analysis of the Pilot Program to occur.

10.6.1 SnoMat Data Management System

The SnoMat data format presents the following issues:

1. (1) SnoMat is dependent on operator/supervisor input and not as accurate or as high resolution as real-time AVL tracking.
2. (2) Beats consist of larger stretches of road than the road lengths in the study watersheds.
    - Due to the nature of Application Event documentation in SnoMat, road salt applications may or may not have occurred within our study watersheds. For example, if a treatment is documented for 17B02A, we must assume that treatment occurred on road lengths within both T41 ***lower*** and T36a ***lower*** watersheds.
    - Since application rates relate to a Beat rather than for specific road locations, we cannot account for locations with specific road salt application, locations with no road salt application, altered application rates due to site conditions or additional passes that may have occurred.
    - Our "control" sites T41 and T36a appear to be included within the same Beat, 17B02A, and therefore no distinction can be made between the applications and loading rates for the two watersheds.
    - Information such as Storm Event Code, Highway Conditions, and Road Temperature, was either inconsistent across entries or could not be substantiated. Specifically, Storm Event Code would have been useful if the codes could be ranked by storm severity and based on a consistent standard.
3. (3) S&I Event Code data has the potential to relate storm severity, but the code is determined by the operator, does not correlate to a storm severity scale, and is only included for SnoMat (not AVL).
4. (4) While liquid data columns are present in the dataset, brining operations are not included and cannot be substantiated for inclusion into this study.

10.6.2 AVL Data Management System

The AVL data format and the incorporation of the AVL data into the dataset present the following issues:

(1) The AVL and SnoMat data management system do not communicate without extensive processing as shown in the sections above.
(2) AVL data were provided only for parts of winter 2019-2020 (November-December 2019) and 2020-2021 (November 2020-February 2021)
(3) Only AVL data were provided for the calendar year 2020.
(4) Overlap between the two data management systems occurred from December 2020-February 2021 (winter 2020-2021), and inconsistencies for application events and rates between AVL and SnoMat were apparent.
(5) A potential error occurred at Truck Number input, as the dataset indicates only a single truck applied the entire extent of the applications.
  - It is possible that road salt applications from other trucks are missing from this dataset.
  - If Truck Numbers are missing, identifying duplicate data between AVL and SnoMat data for January-February 2021 is not possible.
(6) While columns are present in the dataset, brining operations are not included and cannot be substantiated for inclusion into this study.

10.6.3 Data Calculation Assumptions

The data format and documentation issues require this study to depend on multiple assumptions:

1) The calculations from this chapter reveal the least amount of chloride applied by NYSDOT
2) ClearLane® is the only material applied in the study areas.
3) Brining applications did not occur within the study area.
4) Road salt application rates for I87 were 10% greater than Route 9.
5) Per SnoMat, road salt application occurred for an entire Beat at an average rate and only one Pass was made during the Application Event.
6) Per SnoMat, the road salt application rate was consistent for the entire treatment event.
7) Per SnoMat, the same Application Events and road salt application rates occurred for T41 and T36a
8) Per SnoMat, the same Application Events and road salt application rates occurred for T63a and T61
9) Per AVL, applications from only one truck were tracked from January 2020 through February 2021
10) Per AVL, T36a only received four Application Events including January 2020-March 2020 vs. the 37 treatment events that occurred for T41, 108 treatment events for T61, and 109 treatment events for T63a.

10.7 Literature Cited

Cargill 2023. Technical Information: ClearLane Enhanced Deicer. Last revised September 2015 (revision 11). https://www.cargill.com/doc/1432076001160/clearlane-technical-data-sheet.pdf

NYS GIS Clearinghouse https://gis.ny.gov/

NYSDOT. Freedom of Information Law (FOIL). https://www.osc.state.ny.us/help/foil. Accessed March 15, 2023.

U.S. Geological Survey 2020. The StreamStats Program. https://streamstats.usgs.gov/ss/ Accessed 2020-2023.

New York State Department of Transportation Road Salt Reduction Pilot Program

Final Report for the Lake Champlain Sea Grant Program

Chapter 11

NYSDOT Road Salt Application Data and the Lake George Association Tributary Monitoring Cl^- Export Data

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11.0 Introduction

Chapter 9 of this report (1) reiterated several important concepts germane to the discussion and evaluation road salt application reduction, and (2) presented some new watershed material including the following:

- The description and rationale of defining the "road salt application period" (RSAP) as the calendar date starting November 1st of any given year and ending on October 31st of the following year,
- The suitability and differences between the ***upper*** and ***lower*** tributary monitoring sites in the watersheds currently under investigation,
- A summary of "test" and "control" ***lower*** sub-watershed development characteristics such as surface area, highway surface area, and percent forested, developed and impervious,
- An explanation and evaluation of sub-watershed precipitation and snowpack for RSAPs 2020-2021 and 2021-2022 using precipitation data from the Bolton and Village of Lake George Wastewater Treatment Plants for watersheds T-61/T-63a and T-36a/T-41, respectively, and
- A final table (9-7) in the chapter summarized chloride export and precipitation data for RSAPs 2020-2021 and 2021-2022 in the four watersheds under investigation.

RSAPs 2020-2021 and 2021-2022 are the only complete export periods when the ***lower*** stations in each sub-watershed were fully instrumented for water level (converted to tributary flow) and conductivity (converted to chloride concentration). There are abundant data for all of the watersheds prior to that time dating back to mid-summer 2018; however, full instrumentation was required to calculate chloride export accurately.

Chapter 10 of this report explained in step-by-step detail the process of interpreting and evaluating the NYSDOT road salt application data. These data were eventually received following several FOIL requests and extensive delays that postponed completion of this final report far beyond a reasonable time period in relation to the contract period with the Lake Champlain Sea Grant Program. There also was considerable time spent communicating back-and-forth with NYSDOT staff regarding the road salt application data received to be confident that we fully understood the formatting and were able to conduct the interpretation, evaluation, and assessment in an appropriate manner.

The final products of the data interpretation process described in Chapter 10 included the following information for the five RSAPs (2017-2018, 2018-2019, 2019-2020, 2020-2021, and 2021-2022) in the road salt application database:

- Total chloride export (in tons) for each "test" and "control" highway segment under investigation,
- Average chloride application rate (in lbs./lane mile) for each highway segment under investigation, and
- The total number of road salt application events for each highway segment under investigation.

The data described in "bullet" #1 above were presented in Tables 10-2 and 10-4 in Chapter 10 for the five RSAPs. The data described in "bullets" #2 and #3 above are presented in this chapter.

Here, in Chapter 11, we consider all of the summary information assembled from the road salt application data provided by the NYSDOT in an attempt to

- document a proposed 10 percent difference in road salt application between "test" and "control" watersheds,
- determine how the amount of road salt applied during RSAPs 2020-2021 and 2021-2022 compare with the total chloride loads calculated from flow and conductivity data collected from each tributary, and
- determine whether a 10 percent reduction could be realized in the tributary water chemistry of the "test" watersheds under investigation.

All aspects of the evaluation process are considered herein including the 'bulleted' data summaries itemized above as well as some additional information. In the evaluation process that follows, each ***lower*** sub-watershed will be presented and discussed separately to provide complete transparency of the data evaluation process.

11.1 RSAPs, Non-winter-Winter Periods, and NYSDOT Start-Stop Dates for Road Salt Application

We decided it was important to verify the months that we selected for the RSAPs and the 'non-winter'/'winter' periods, because the information was available in the application data that we received from the NYSDOT. We confirmed our choices by extracting the "start" and "stop" dates each year for the road salt applications in the files received from the NYSDOT. A summary of these data is presented in Table 11-1 below for each of the five RSAPS for T63a and T61 combined, T41 and T36a. The two Northwest Bay tributary watersheds were combined because of their proximity to each other and because these segments of Route 9N are on the same ‘beat’ of truck-delivered road salt.

Table 11-1.

	T63a, T61		T41		T36a	
RSAP	Start Date	Stop Date	Start Date	Stop Date	Start Date	Stop Date
2017-2018	Dec 11th	Mar 13th	Dec 12th	Mar 17th	Dec 12th	Mar 17th
2018-2019	Nov 15th	Mar 10th	Nov 9th	Mar 3rd	Nov 9th	Mar 3rd
2019-2020	Nov 11th	Mar 24th	Nov 18th	Mar 24th	Nov 18th	Feb 29th
2020-2021	Nov 3rd	Mar 2nd	Nov 3rd	Mar 18th	Dec 9th	Mar 18th
2021-2022	Nov 26th	Apr 19th	Nov 29th	Mar 28th	Nov 29th	Mar 28th

Early-to-mid November was the most frequent period when road salt application started in all three geographical areas, while most ‘end’ dates were in March; an April end date only occurred at the T63a/T61 sites during RSAP 2021-2022. Based upon these data, our selection of November 1st through October 31st for the RSDAP each year is justified as well as the “winter” (November 1st through April 30th) and the “non-winter” periods (May 1st through October 31st).

Before examining the results of the road salt application analysis, we will present and evaluate the NYSDOT road salt application “event” data, beginning with RSAP 2017-2018 and compare the inventory of events when road salt was applied with the local NOAA Interactive snow information used to interpret winter severity as reported in Chapter 9.

11.2 NYSDOT Application Events and Local NOAA Interactive Snowpack Data

Once the complete set of road salt application data and associated material was received from the NYSDOT, we focused on the spreadsheet information relevant to our tributary watershed study including (1) the road salt application data for the different ‘beats’ that included the highway segments that traversed the current tributary watersheds under investigation, and (2) the S&I Event Code information which refers to the type of storm event that determined the need for road salt application. With respect to the S&I Event Code, it was determined that categorizing storm events was a subjective process and that the criteria that defined the driver-created record were not known or explained in the files. Subsequently, we learned after receiving data from the last FOIL request, that the S&I Event Code information was not documented on a regular basis, so it could not be used to determine storm event severity.

Thus, we were not able to compare NYSDOT storm event severity information with our own analysis that used the “*Interactive Snow Information*” page, within the National Operational Hydrologic Remote Sensing Center (NOHRSC), on the National Oceanic and Atmospheric Administration (NOAA) website. We decided, therefore, to query the road salt application database and extract the number of application events for each ‘beat,’ using this information as an indication of weather severity within the RSAPs under investigation.

Table 11-2 provides a summary of the total road salt application events in the four watersheds during the five RSAPs.

Table 11-2.

	Tributary Watershed #				Mean # RSAP Events
RSAP	T63a	T61	T41	T36a	
2017-2018	30	30	21	21	26
2018-2019	21	21	19	19	20
2019-2020	109	108	37	4	85
2020-2021	105	108	84	41	85
2021-2022	93	93	70	70	82
Total	358	360	231	155	
##	= the number of road salt application events within each watershed during each RSAP				
🟧	= missing data in NYSDOT database; not used in Mean # RSAP Events calculation				

It is noted here that road salt application data and associated material for T36a during RSAP 2019-2020 was missing in the database versions received from the NYSDOT. And, in spite of repeated requests to acquire this missing information, the data never were made available, which leads us to believe that those data never were stored in the NYSDOT database during RSAP 2019-2020.

As summarized in Table 11-2, there are some interesting similarities and differences among the five RSAPs and the four watersheds under investigation with respect to the number of application events including:

- The *mean* number of RSAP events in the far-right column of Table 11-2 indicate that 2019-2020 and 2020-2021 were equal as the most severe winters followed by 2021-2022, 2017-2018 and finally, 2018-2019. This was the simplest method of ranking winter severity since differences among the watersheds and RSAPs were substantial.

- The proximity of T61 and T63a translates to similar numbers of road salt application events within any RSAP, and among all five RSAPs, there were only two more applications in T61 than in T63a, and
- The winter severity at T41/T36a is less severe than T63a/T61 within each RSAP.

Based upon this more thorough examination of the individual cell data summarized in Table 11-2 and some of the similarities and differences revealed above, it became evident that winter severity, the number of road salt application events, and the local NOAA Interactive Snowpack Data need to be considered collectively in the context of each physical watershed location within the Lake George drainage basin, except for T63a and T61 as explained below.

11.2.1 Tributaries T63a and T61

These two ***"test"*** tributaries within the ***"pilot"*** segment are located along the northern extent of the Route 9N, adjacent to Northwest Bay, and cross Route 9N within ~0.9 miles of each other; T63a is the northern-most watershed. The proximity of these two watersheds makes it difficult to imagine that different weather conditions would occur between these areas and the similarity of total 'event' road salt applications summarized in Table 11-2 is based on the fact that both watersheds are located within the same 'beat' for truck-delivered road salt applications during storm events.

In spite of their similarities, Figures 11-1 and 11-2 summarize the number of road salt application events for T63a and T61, respectively, for the five RSAPs under consideration are presented below.

Figure 11-1.

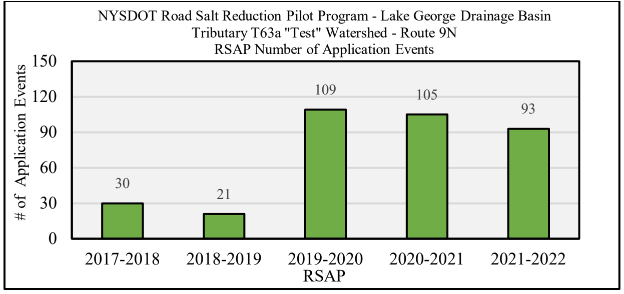
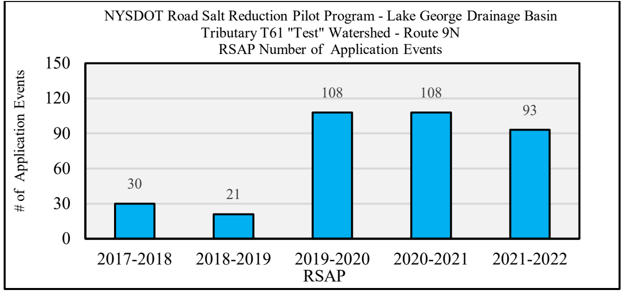


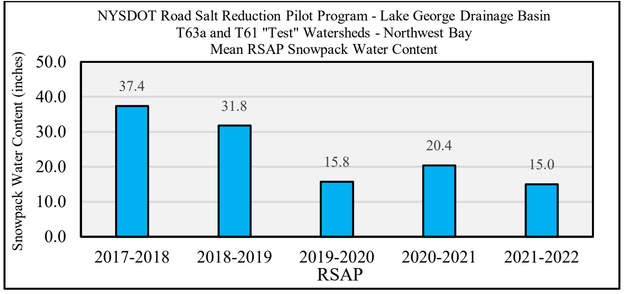
Figure 11-2.



The order of winter severity for these two "test" watersheds is similar to the ranking presented above for the initial generic analysis of all sites and RSAPs, that is, 2019-2020, followed by 2020-2021, then 2021-2022, 2017-2018 and finally 2018-2019. The difference between RSAP 2017-2018 and 2018-2019 (9 applications) is the smallest in the dataset and these were the least severe winter periods in the set of five RSAPs analyzed.

Figure 11-3 presents a summary of winter severity in the T63a/T61 Northwest Bay area based upon the mean RSAP snowpack water content collected from the NOAA website.

Figure 11-3.

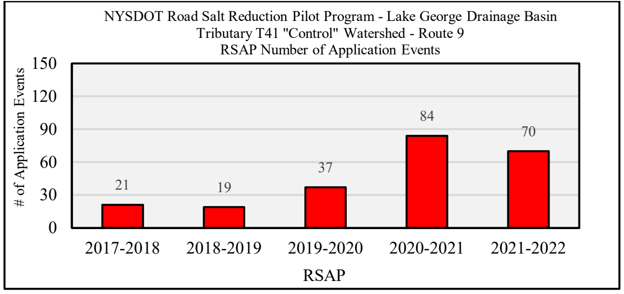


This method of predicting winter severity is not useful in our road salt application evaluation. RSAP 2019-2020 was the most significant severe winter based upon the number of applications in the NYSDOT database but is the least significant severe winter based upon mean water content of the snowpack. Furthermore, RSAPs 2017-2018 and 2018-2019 were the least severe winters in the data base and are the most severe in the snowpack water content analysis.

11.2.2 Tributary T41

Figure 11-4 summarizes the winter severity in the area of the T41 ***lower*** sampling station based upon the number of road salt application events gleaned from the NYSDOT database. In direct contrast to the information presented above for T63a/T61, the ranking order of winter severity at the T41 location was RSAP 2020-2021, followed by 2021-2022, 2019-2020, 2017-2018, and finally 2018-2019. The relative difference in application events among the five RSAPs at T41 is less than the differences observed for the T63a/T61 watersheds in Northwest Bay.

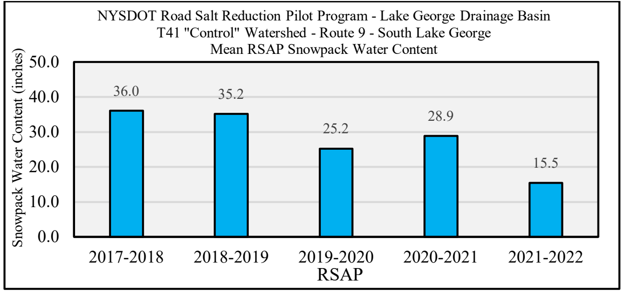
Figure 11-4



A problematic number in Figure 11-4 is the '37' application events reported during RSAP 2019-2020 when, during the same period, the number of application events at T63a/T61 was 3-fold greater. It is possible that the value reported is an error and occurred due to staff changeover during winter 2019-2020 when COVID-19 broke out and different protocols had to be followed, or there was a problem with the SnoMat system, and several application events were combined on the same date. It is hard to imagine that the weather at T41 would be so much less severe than at T63a/T61 based strictly on the difference in elevation (~780 ft at T41 vs ~350 ft at T63a/T61).

Figure 11-5 presents a summary of winter severity in the T41 ***lower*** station area based upon the mean RSAP snowpack water content collected from the NOAA website.

Figure 11-5.

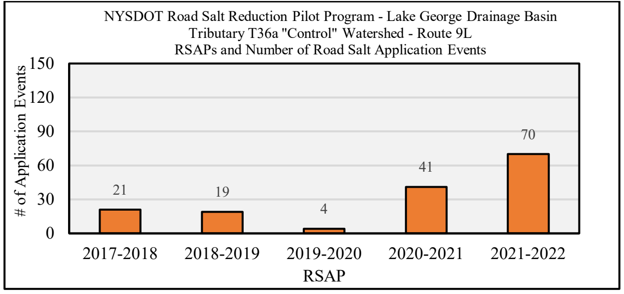


It is immediately obvious that this method of predicting winter severity has no application in our road salt application evaluation. RSAPs 2017-2018 and 2018-2019 were the most severe according to the snowpack information; however, these RSAPs were labelled the least severe among all RSAPs according to the NYSDOT application event inventory.

11.2.3 Tributary T36a

Figure 11-6 summarizes the winter severity in the area of the T36a ***lower*** sampling station based upon the number of road salt application events extracted from the NYSDOT database.

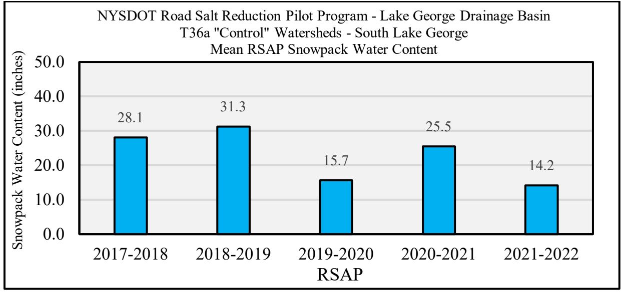
Figure 11-6.



There is missing information in Figure 11-6, i.e., the number of application events for RSAP 2019-2020 is incomplete. Based upon the available data, however, we can prioritize the RSAP winter severity as follows (decreasing order): 2021-2022, 2020-2021, 2017-2018, 2018-2019, and 2019-2020 which is the incomplete set of data. This sequence of RSAP winter severity is completely different than any of the other watersheds discussed so far.

Figure 11-7 presents a summary of winter severity in the T36a ***lower*** station area based upon the mean RSAP snowpack water content collected from the NOAA website.

Figure 11-7.



As with the other watersheds under investigation, there is no correlation of snowpack water content (Figure 11-7) with winter severity based upon road salt application events (Figure 11-6) in T36a. The interpretation of Figure 11-7 results in the following decreasing RSAP priority: 2018-2019, 2017-2018, 2020-2021, 2019-2020, and 2021-2022.

As a result of the above exercise conducted within the four watersheds under investigation, we are able to clearly and confidently state that the best indication of winter severity along any highway segment within the Lake George drainage basin is the number of road salt applications that have occurred in that area.

11.3 NYSDOT Chloride Application Amounts and the LGA Tributary Monitoring Cl^- Export Data

In this section we compare the chloride application data calculated from the NYSDOT files as described in Chapter (10) with the chloride data calculated from our detailed 5-minute flow and conductivity data collected at the four ***lower*** watershed stations under investigation. These station data were presented in individual chapters previously as follows:

- Chapter 5 – Tributary T63a – Route 9N – Northwest Bay
- Chapter 6 – Tributary T61 – Route 9N – Northwest Bay
- Chapter 7 – Tributary T41 – Route 9 – South Lake George
- Chapter 8 – Tributary T36a – Route 9L – South Lake George

The data collected and calculated from the installed instrumentation and the data calculated from the NYSDOT files will be presented in this section by addressing each watershed studied in this investigation.

The NYSDOT maintains all highway surfaces within the Lake George drainage basin with the winter deicing product ClearLane™ Enhanced Deicer (Cargill, Lansing, NY) which contains the components included in Table 11-3.

Table 11-3.

ClearLane™ Enhanced Deicer	
component	**%**
sodium chloride	95.9
pre-wetting agent[1]	4.1
[1]water	67-70 of 4.1%
[1]magnesium chloride	26-29 of 4.1%
[1]sodium gluconate	0.25-0.35 of 4.1%
[1]xanthan gum	0.2-0.4 of 4.1%
[1]colorant blend	0.01-0.06 of 4.1%

The method used to calculate chloride (Cl^-) from the composition of ClearLane™ Enhanced Deicer was presented in Chapter 10. A summary of the tributary watershed Cl^- application amounts calculated from the road salt application data provided by the NYSDOT for RSAPs 2017-2018 through 2021-2022 are summarized in Table 11-4.

Table 11-4.

	Lake George Drainage Basin Watershed			
RSAP	T63a	T61	T41	T36a
2017-2018	0.58	0.48	8.19	0.49
2018-2019	0.32	0.26	6.06	0.36
2019-2020	1.35	1.15	7.77	0.06
2020-2021	1.25	1.04	21.08	0.79
2021-2022	1.36	1.11	21.68	1.30

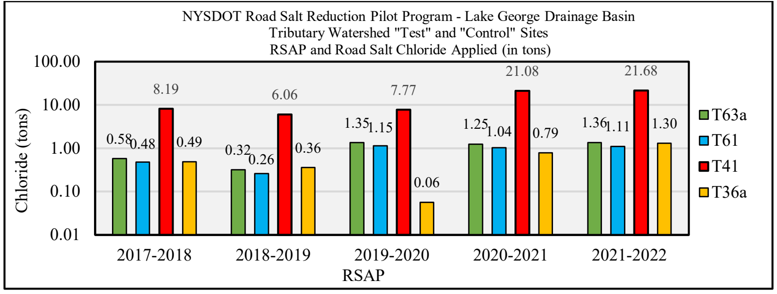
T41 = Route 9 + I87 at a 10% greater application rate

Cl^- application values are in tons

#.## = road salt application data missing

The tributary watershed RSAP chloride application amounts summarized in Table 11-4 are shown in Figure 11-8.

Figure 11-8.



The watershed Cl⁻ application data in Figure 11-8 are from the respective columns in Table 11-4; see table legend for explanation of how data were derived. The following material is an examination of chloride load and the individual tributary watersheds included in the current investigation.

11.3.1 Tributary T63a

Tributary 63a is the northern-most "test" watershed in the current investigation. Extensive information regarding this tributary watershed and its instrumentation was provided in Chapter 5 and a summary table (5-8) at the end of that chapter provided important information including watershed area (512 acres), Route 9N surface area (0.45 acres), lane miles (0.27) and detailed RSAP 2020-2021 and 2021-2022 information for flow (in mgd), chloride export (in lbs.), and precipitation (in mm). The RSAP information from Table 5-8 has been entered in Table 11-5 below along with the NYSDOT Cl⁻ application data evaluated in Chapter 10 and presented in Table 11-4.

Table 11-5.

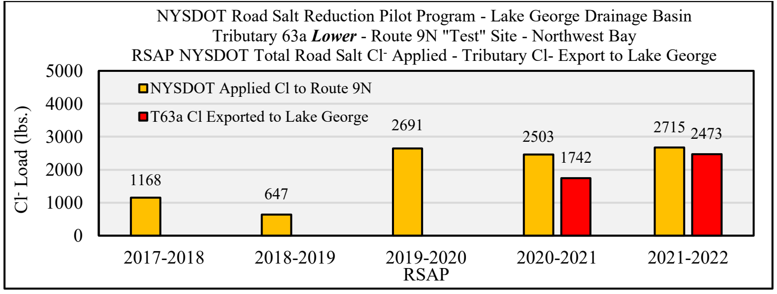
				Cl⁻ in lbs				
Program ID	RSAP	Annual flow (mg)	Period Ppt (mm)	Annual Cl⁻ Applied to Route 9N	Annual Cl⁻ Export to Lake George	Cl⁻ Export/ LM	Cl⁻ Export/ million gals	Cl⁻ Export/ mm Ppt
T63a	2017-2018	-	1149	1168	-	-	-	-
	2018-2019	-	1605	647	-	-	-	-
	2019-2020	-	1035	2691	-	-	-	-
	2020-2021	268	1217	2503	1742	6452	6.5	1.43
	2021-2022	255	1078	2715	2473	9159	9.7	2.29

"-" = missing data; mm = millimeters; LM = lanes miles.

The information in Table 11-5 for RSAPs 2017-2018, 2018-2019, and 2019-2020 is incomplete because the station was not fully instrumented for flow until 2019, and continuous 5-minute flow and specific conductance data (converted to chloride concentration) are required to calculate Cl⁻ export.

The data for *annual Cl⁻ applied to Route 9N* and the *annual Cl⁻ exported to Lake George* from Table 11-5 are plotted in Figure 11-9.

Figure 11-9.



For the two RSAPs where the *Cl⁻ input-Cl⁻ output* data are complete, we see that 70 percent of the *Cl⁻* applied during the RSAP 2020-2021 "winter" period (2503 lbs.) was exported by T63a tributary flow (1742 lbs.) into Lake George. For RSAP 2021-2022, the total *Cl⁻* applied was 2715 lbs. and 91 percent (2473 lbs.) was exported to Lake George.

There are several assumptions built into our Lake George tributary flow and chloride 'loading model' that can result in some inconsistencies within the database and the results calculated by the database including the following:

- The October 31st end date of the road salt application period (RSAP) is artificial and was selected to separate one “winter” road salt application periods, i.e., not all Cl^- applied during a winter period will get exported to Lake George in local tributary flow before the October 31st end date,
- Whether chloride movement is ‘fast’ or ‘slow’ through the groundwater is entirely dependent upon the local precipitation cycle, i.e., timing through the annual cycle and amount, and
- There are areas where the depth to bedrock is extensive, allowing considerable storage of groundwater containing chloride from winter road salt application. The movement of chloride applied during a certain period of time will be delayed even more than in areas where depth to local bedrock is shallow.

Because the ‘loading model’ is not perfect, it results in a ‘grey area’ where chloride from different winter application periods can get ‘blended’ when traveling with the groundwater before eventually reaching the tributary channel and being exported to Lake George. The only way to improve upon this situation would be to “label” the different winter period chloride components of the road salt with different ‘markers’ to distinguish between the chloride applications.

We can surmise that there was either insufficient time or insufficient precipitation/groundwater movement that caused less Cl^- exported to Lake George than was applied to Route 9N during RSAP 2020-2021 and 2021-2022.

Figures 11-10 and 11-11 are time series plots of chloride concentration and flow measured at about bi-weekly intervals in T63a during RSAPs 2020-2021 (Figure 11-10) and RSAP 2021-2022 (Figure 11-11).

Figure 11-10.

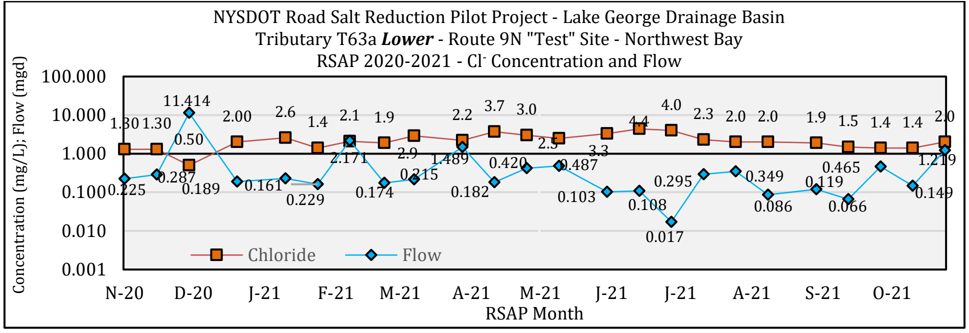
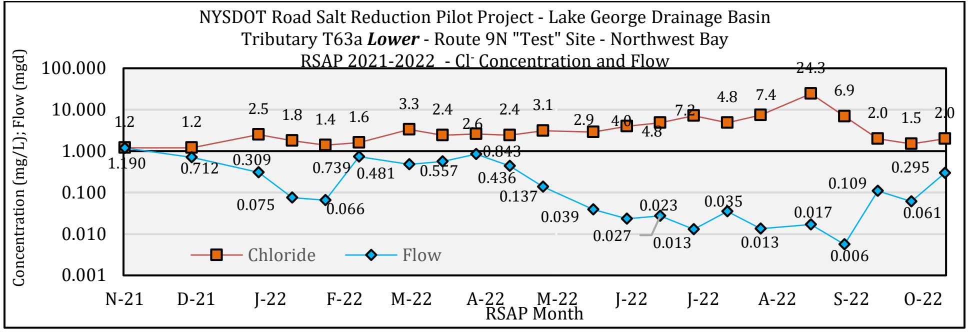


Figure 11-11.



In both RSAPs, the Cl^- concentration during September and most of October was decreasing and approaching a level of 1.0 mg Cl^-/L, the lower level of laboratory detection, which would indicate that all stored Cl^- had been flushed from the watershed. The Cl^- ‘loading model’ is not perfect, and there likely was Cl^- contamination among different RSAPs which makes deciphering Cl^- movement even more difficult to determine.

11.3.2 Tributary T61

T61 is the other “test” tributary and its watershed is located on the western side of Lake George adjacent to Northwest Bay; the tributary crosses Route 9N about one mile south of the T63a tributary crossing at Route 9N. Extensive information regarding this tributary watershed and its instrumentation was provided in Chapter 6 and a summary table (6-8) at the end of that chapter provided important information including watershed area (192 acres), Route 9N surface area (0.37 acres), lane miles (0.22) and detailed RSAP 2020-2021 and 2021-2022 information for flow (in mgd), chloride export (in lbs.), and precipitation (in mm).

The RSAP information in Table 6-8 for Tributary T61 has been incorporated into Table 11-6 along with the NYSDOT chloride application data evaluated in Chapter 10 and presented in Table 11-4.

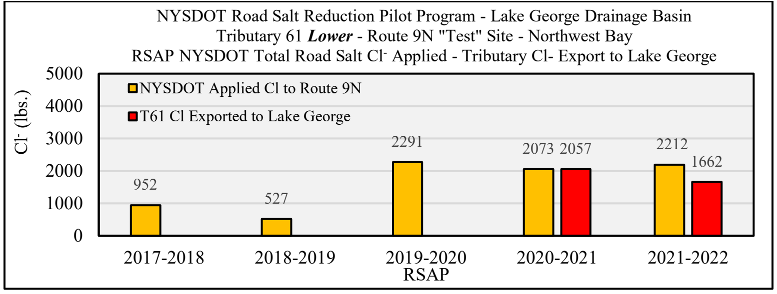
Table 11-6.

				Cl^- in lbs				
Program ID	RSAP	Annual flow (mg)	Period Ppt (mm)	Annual Cl^- Applied to Route 9N	Annual Cl^- Export to Lake George	Cl^- Export/ LM	Cl^- Export/ million gals	Cl^- Export/ mm Ppt
T61	2017-2018	-	1149	952	-	-	-	-
	2018-2019	-	1605	527	-	-	-	-
	2019-2020	-	1035	2291	-	-	-	-
	2020-2021	54	1217	2073	2057	9350	38.1	1.69
	2021-2022	75	1078	2212	1662	7555	22.2	1.54

"-" = missing data; mm = millimeters; LM = lane miles.

The T61 data for *annual Cl^- applied to Route 9N* and the *annual Cl^- exported to Lake George* from Table 11-6 are plotted in Figure 11-12. 99 percent of the Cl^- applied during the RSAP 2020-2021 "winter" period (2073 lbs.) was exported by T61 flow (2057 lbs.) into Lake George. For RSAP 2021-2022, the total Cl^- applied was 2212 lbs. and 75 percent (1662 lbs.) was exported to Lake George. The precipitation/groundwater conditions were appropriate for complete flushing of applied Cl^- during RSAP 2020-2021 but not in 2021-2022.

Figure 11-12.



The T61 results in Table 11-6 are supported by the Cl^- concentration and flow data presented in annual plots for RSAP 2020-2021 (Figure 11-13) and 2021-2022 (Figure 11-14).

Figure 11-13.

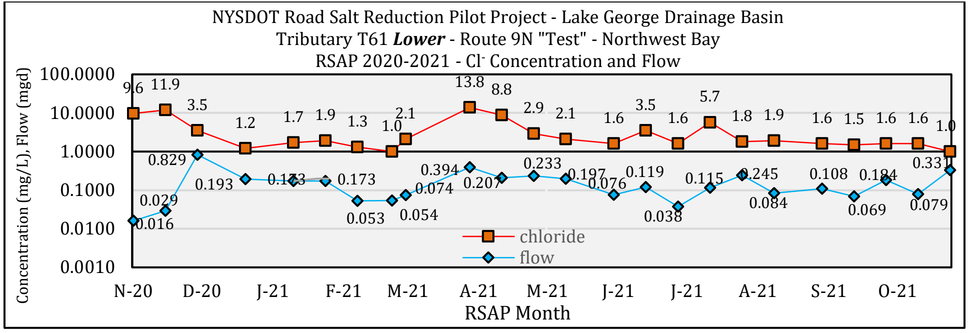
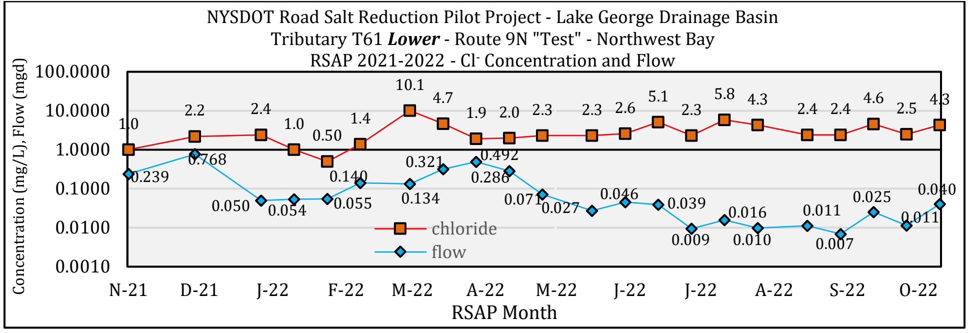


Figure 11-14.



The Cl^- concentration during RSAP 2020-2021 (Figure 11-13) decreased steadily from April after snowmelt/spring runoff through October, reaching 1.0 mg Cl^-/L on the last sampling date. In contrast, the Cl^- concentration during the latter portion of September-October 2022 was averaging ~4.0 mg Cl^-/L, indicating sufficient residual Cl^- remaining in the soil. Another interesting point is that RSAP 2021-2022 was a particularly low precipitation year, which is evident when comparing the flow trend in Figures 11-13 and 11-14 from about May through the end of October.

11.3.3 Tributary T41

T41 is a "control" tributary on the west side and south end of the lake near the basin divide with Warrensburg (Hudson River drainage). Chapter 7 had a summary table (7-8) that provided information including watershed area (1888 acres), Route 9N and Interstate 87 surface area (10.74 acres), lane miles (5.51) and detailed RSAP 2020-2021 and 2021-2022 information for flow (in mgd), chloride export (in lbs.), and precipitation (in mm).

The T41 RSAP information in Table 7-8 has been incorporated into Table 11-7 along with the NYSDOT Cl^- application data evaluated in Chapter 10 and presented in Table 11-4. Road salt application data were not provided for Interstate 87 which is within the drainage of the T41 lower sampling site. The specific amount of road salt applied to this section of highway was calculated using a technique recommended by NYSDOT staff (see Table 11-4 legend).

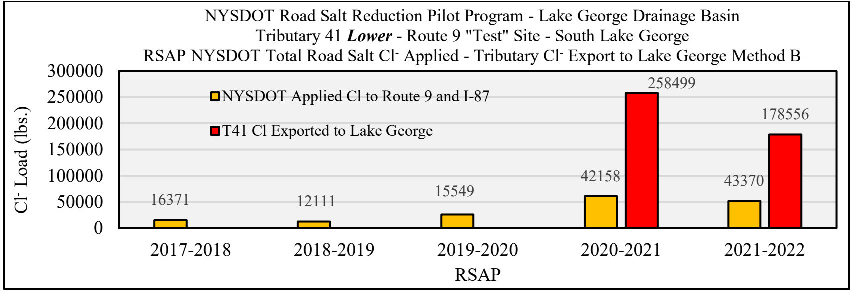
Table 11-7.

				Cl^- in lbs				
Program ID	RSAP	Annual flow (mg)	Period Ppt (mm)	Annual Cl^- Applied to Route 9, I-87	Annual Cl^- Export to Lake George	Cl^- Export/ LM	Cl^- Export/ million gals	Cl^- Export/ mm Ppt
T41	2017-2018	-	993	16371	-	-	-	-
	2018-2019	-	1263	12111	-	-	-	-
	2019-2020	-	806	15549	-	-	-	-
	2020-2021	1385	1276	42158	258499	46915	186.6	202.6
	2021-2022	1148	935	43370	178556	32406	155.5	191.0

"-" = missing data; mm = millimeters; LM = lane miles.

The T41 data for *annual Cl^- applied to Route 9* and the *annual Cl^- exported to Lake George* by T41 from Table 11-7 are plotted in Figure 11-15.

Figure 11-15.



Cl^- exported by T41 during RSAP 2020-2021 (258499 lbs.) was 6.1-fold greater than the amount applied (42158 lbs.), while the RSAP 2021-2022 amount exported (178556 lbs.) was 4.1-fold greater than the amount applied (43370 lbs.).

The Cl^- concentration and flow data presented in annual plots for RSAP 2020-2021 (Figure 11-16) and 2021-2022 (Figure 11-17) confirm the results summarized in Table 11-7 and Figure 11-15 for the extraordinary amounts of Cl^- exported by T41 during RSAP 2020-2021 and 2021-2022.

Figure 11-16.

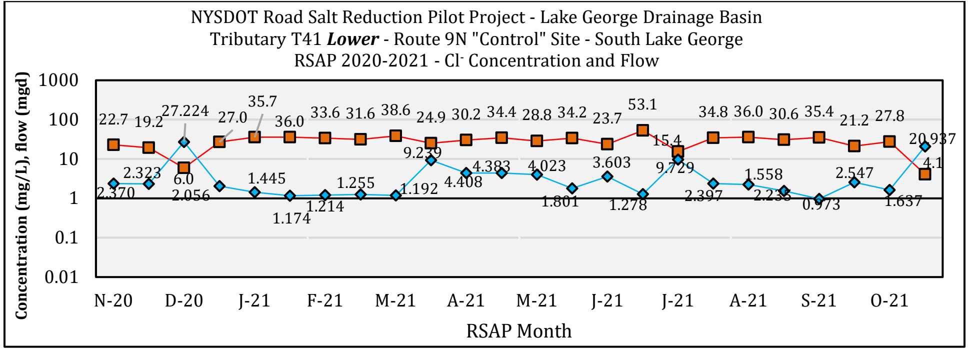
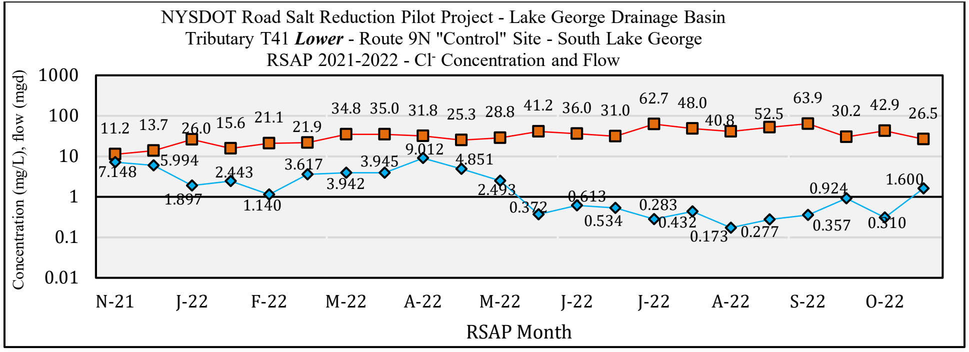


Figure 11-17.



In both figures above, there is no indication that the Cl^- concentration is trending toward the lower detection level (1.0 mg/L) near the end of each RSAP (September-October); the mean concentration during the last two months of 2020-2021 is 22.1 mg Cl^- /L and the mean concentration during the same period in 2021-2022 is 40.9 mg Cl^- /L.

This astonishing phenomenon in exhibited in T41 is only possible if there is an extensive area between I-87 and T41 where depth to bedrock is considerable and available for storing groundwater and accumulating Cl^- from the road salt applied to these highway segments. Most of the Cl^- would have to come from I-87 because Route 9 is within 15-25 feet of T41, and any road salt applied to this highway segment would enter the tributary almost immediately.

11.3.4 Tributary T36a

Tributary 36a is a "control" watershed located on the east side near the south end of the lake basin about one mile from the Route 9L-Beach Road intersection. Watershed characteristics and equipment installation were described in Chapter 8. A summary table (8-9) near the end of Chapter 8 provided valuable information including watershed area (134 acres), Route 9L surface area (0.59 acres), lane miles (0.35) and detailed RSAP 2020-2021 and 2021-2022 information for flow (in mgd), chloride export (in lbs.), and precipitation (in mm).

Some of the T36a RSAP information in Table 8-8 has been incorporated into Table 11-8 (below) along with the NYSDOT chloride application data evaluated in Chapter 10 and earlier herein (Table 11-4).

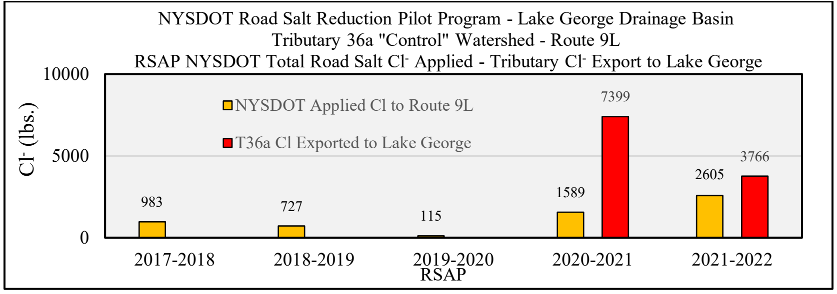
Table 11-8.

				Cl^- in lbs				
Program ID	RSAP	Annual flow (mg)	Period Ppt (mm)	Annual Cl^- Applied to Route 9L	Annual Cl^- Export to Lake George	Cl^- Export/ LM	Cl^- Export/ million gals	Cl^- Export/ mm Ppt
T36a	2017-2018	-		983	-	-	-	-
	2018-2019	-		727	-	-	-	-
	2019-2020	-		115	-	-	-	-
	2020-2021	28.170	1276	1589	7399	21140	262.6	5.80
	2021-2022	23.372	935	2605	3766	10760	161.1	4.03

"-" = missing data; mm = millimeters; LM = lane miles; #.## = incomplete data

The 36a data for *annual chloride applied to Route 9L* and the *annual chloride exported to Lake George* by T36a from Table 11-8 are plotted in Figure 11-18.

Figure 11-18.



Cl^- exported to Lake George by T36a during RSAP 2020-2021 (7399 lbs.) was 4.7-fold greater than the amount applied (1589 lbs.) by NYSDOT road salt application, while the RSAP 2021-2022 amount exported (3766 lbs.) was 1.4-fold greater than the amount applied (2605 lbs.).

The Cl^- concentration and flow data presented in annual plots for RSAP 2020-2021 (Figure 11-19) and 2021-2022 (Figure 11-20) confirm the results summarized in Table 11-8 and Figure 11-17 for the extraordinary amounts of Cl^- exported by T36a during RSAP 2020-2021 and 2021-2022.

Figure 11-19.

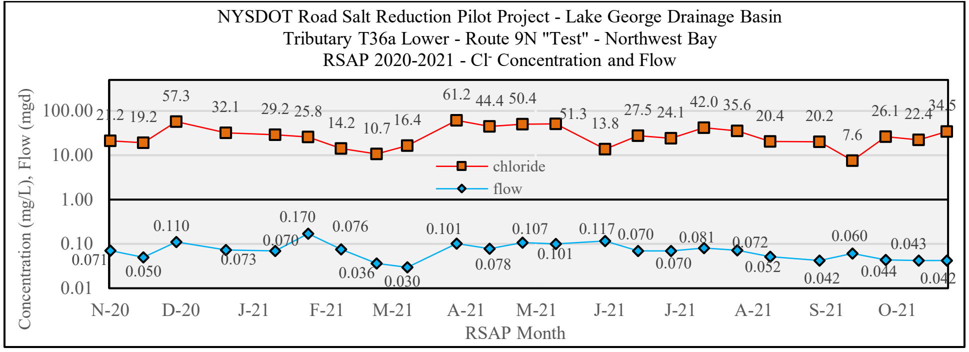
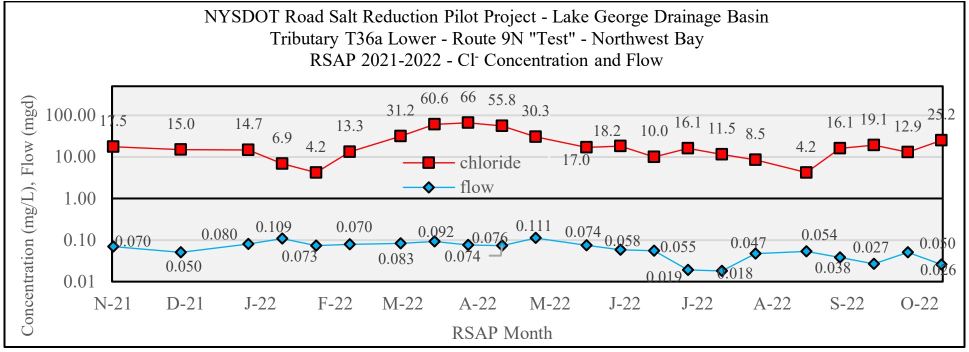


Figure 11-20.



There is no indication in either figure above that the Cl^- concentration is trending toward the lower detection level (1.0 mg/L) near the end of each RSAP (September-October). The mean concentration during the last two months of 2020-2021 was 22.7 mg Cl^- /L and the mean concentration during the same period in 2021-2022 was 18.3 mg Cl^- /L.

Here again, as with T41, the phenomenon of excessive Cl^- export into Lake George has occurred and only is possible if there is an extensive area within the T36a watershed where the depth to bedrock is considerable and available for storing groundwater and accumulating Cl^- from road salt applied to Route 9L. There is no obvious area in this small watershed traversed by Route 9L that would be able to store such an astonishing amount of Cl^-.

11.4 NYSDOT Road Salt Application Rates

The NYSDOT Road Salt Reduction Pilot Program proposed a 10 percent reduction in application rate between the "test" segment of Route 9N and other state-maintained highways within the Lake George drainage basin. In theory and in practice, the only way to achieve this proposed 10 percent reduction would be to adjust the road salt application rate accordingly. While it also would be possible to realize a 10 percent decrease by reducing the number of application events, this would not be prudent in terms of public safety.

The road salt application rate is the amount of material applied (in lbs.) per lane mile (LM). The calculation of lane miles and application rates was explained in Chapter 10. The application rates calculated for the four watersheds across the five RSAPs are summarized in Table 11-9.

Table 11-9.

	Watershed included in investigation			
RSAP	T63a	T61	T41 (Rt 9/I87)	T36a
2017-2018	244.36	244.36	226.64/249.31	226.64
2018-2019	193.19	193.19	185.32/203.85	185.32
2019-2020	165.60	170.59	162.07/178.28	153.54
2020-2021	154.22	157.91	146.69/161.36	188.23
2021-2022	183.20	183.20	180.12/198.14	180.12
values are in lbs./lane mile (LM)				

There are some interesting similarities and differences among the four watersheds under investigation and the five RSAPs with respect to road salt application rates summarized above including the following:

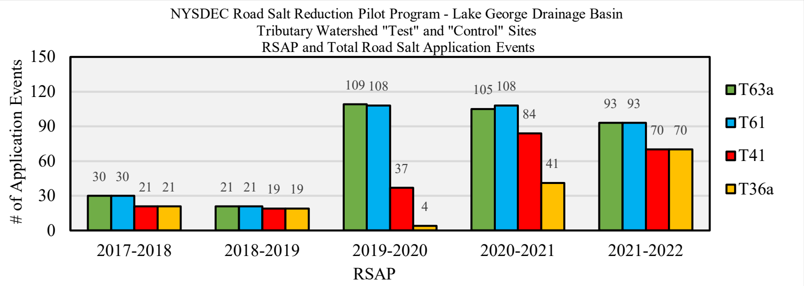
(1) With the exception of T36a during RSAP 2020-2021, application rates were fairly consistent among the four watersheds within each RSAP,
(2) The highest application rate in each watershed occurred during RSAP 2017-2018, then decreased through RSAP 2020-2021, except in watershed T36a, then increased in RSAP 2021-2022,
(3) The decrease in application rate between RSAP 2017-2018 and 2018-2019, when the reduction program was initiated, was 21 percent in the T63a/T61 watersheds and 18 percent in the T41/T35a watersheds,
(4) The application rate during RSAPs 2019-2020 and 2020-2021 continued to decrease, except in T36a where the RSAP 2020-2021 increased,
(5) There was no 10 percent difference between the application rates documented for "test" watersheds T63a/T61 and the application rates documented for "control" watersheds T41/T36a.

The application rates summarized in Table 11-9 show that the NYSDOT initiated the road salt reduction "pilot" program during the winter of 2018-2019 instead of late during the winter of 2017-2018 as originally planned, and that the reduction program occurred throughout the Lake George basin, and not just on the Route 9N pilot segment.

11.5 NYSDOT Road Salt Cl^- Applied

Looking more closely at the data provided by the NYSDOT suggests that an 'actual' reduction of road salt may not have occurred in the Lake George basin. We refer here to Figure 11-21 which is a plot of the number of application events that occurred during each RSAP within each watershed as summarized in Table 11-2.

Figure 11-21.



Application events were consistent during RSAP 2017-2018 and 2018-2019 and then increased dramatically during RSAP 2019-2020 with a 3.6-fold increase in events within T63a/T61 and a 2.6-fold increase in T41 (data from T36a were incomplete). From RSAP 2020-2021 and beyond, the number of application events continued to be significantly higher than the application events that occurred during RSAPs 2017-2018 and 2018-2019.

The data in Table 11-10 summarize the amount of Cl^- (in lbs.) applied to state-maintained highways within the Lake George basin watersheds included in this investigation.

Table 11-10.

	Tributary Watershed #			
RSAP	T63a	T61	T41	T36a
2017-2018	1168	952	16371	983
2018-2019	647	527	12111	727
2019-2020	2876	2392	20627	127
2020-2021	2580	2214	42384	1594
2021-2022	2715	2212	43370	2605

individual cell values in lbs. = amt of Cl^- applied based on *application rates* in Table 11-9 x *number of application events* in Table 11-2 x LM x 0.5902 Cl^- conversion for ClearLane®composition

The individual cell values in Table 11-10 were calculated as follows:

Cell value = the *number of application events* (Table 11-2) *X* the *application rate* (from Table 11-9 corresponding cell) *X* watershed *Lane Miles (LM)* value *X 0.5902* (Cl amount per unit weight of ClearLane®

From the data summarized above (Table 11-10), *the reduction of road salt applied* during RSAP 2018-2019 resulted in reduced amounts of Cl^- applied to state-maintained highways within the Lake George watersheds under investigation. The reduced amounts of Cl^- ranged from 45 percent in the T63a/T61 watersheds to 26 percent in the

T41/T36a watersheds. Thereafter, however, *the reduction of road salt application rates* combined with *the increased number of road salt application events* resulted in an increased amount of Cl^- added to the basin highways starting in RSAP 2019-2020. The increased Cl^- amounts were significant within each watershed and across all RSAPs, ranging from 300-350 percent in the T63a/T61 watersheds and 70-260 percent in the T41/T36a watersheds.

11.6 Summary

Table 11-11 is a final summary of some basic characteristics of the "test" and "control" watersheds and their amounts of Cl^- highway application and tributary export during RSAP 2020-2021 and RSAP 2021-2022.

Table 11-11.

							Cl^- in lbs				
Watershed Type	Project ID	Watershed Area (ac)	Lane Miles	RSAP	Total flow (mg)	Total Precipitation (mm)	Applied to Highway	Exported to Lake George	Exported/ Lane Mile	Exported/ million gals	Exported/ mm Precipitation
"Test"	T63a	512	0.27	2020-2021	268	1,217	2503	1,742	6452	6.5	1.43
				2021-2022	255	1,078	2715	2,473	9159	9.7	2.29
	T61	192	0.22	2020-2021	54	1,217	2073	2,057	9350	38.3	1.69
				2021-2022	75	1,078	2212	1,662	7555	22.2	1.54
"Control"	T41	1888	5.51	2020-2021	1,385	1,276	42158	258,499	46915	186.6	202.59
				2021-2022	1,148	935	43370	178,556	32406	155.5	190.97
	T36a	64	0.35	2020-2021	28	1,276	1589	7,399	21140	262.6	5.80
				2021-2022	23	935	2605	3,766	10760	161.1	4.03

Some interesting features of the data summarized above are as follows:

- There were two instances where the total Cl^- applied and total Cl^- exported were in good agreement at the end of the RSAP, i.e., "test" T63a during RSAP 2021-2022 and "test" T61 during RSAP 2020-2021,
- Otherwise, "test" T63a and T61 exported less Cl^- than applied during RSAP 2020-2021 and 2021-2022, respectively,
- Both "control" tributaries exported total amounts of Cl^- that were in several fold greater than the Cl^- applied during the "winter period" in RSAP 2020-2021 and 2021-2022, which indicates extensive areas in the watershed where groundwater and elevated concentrations of Cl^- occur,
- T41 wins an award for the astounding amount of Cl^- exported to Lake George from a 1.2-mile segment of Route 9 and adjacent segment of I-87 which included 129 tons during RSAP 2021-2022 and 89 tons during RSAP 2021-2022,
- T36a has the lowest annual flow of all the tributaries in this investigation and surpassed T41 for the amount of Cl^- exported per mgd of flow during RSAP 2020-2021 and RSAP 2021-2022,
- The 1.2-mile segment of T41 adjacent to Route 9 and I-87 during RSAP 2020-2021 and 2021-2022 consistently exported ~0.1 tons of Cl^- per mm of precipitation, an astounding amount, and
- Collectively, these four tributary watersheds exported 135 tons and 93 tons of Cl^- to Lake George during RSAP 2020-2021 and RSAP 2021-2022, respectively.

These observations should be of great concern to everyone with regard to the annual loading of Cl^- to Lake George. An earlier study of all tributaries and stormsewers flowing in the Lake George basin (Sutherland et al. 2001) found that (1) English Brook (T41) contributed about 5.5-8.0 percent of the total flow entering the lake, and that (2) about 60 percent of the 109 tributaries flowing into the lake at the time of the study (141 total; only 109 with flow) had road/highway systems traversing their watersheds. All of the major tributaries including East, West, Finkle, Indian, Northwest Bay, and Hague Brooks are included in the category with networks of road systems that receive winter deicing products. While the total amount is unknown, the export of Cl^- from these watersheds into Lake George on an annual basis must be staggering given the amount of Cl^- exported to the lake by the four watersheds investigated!

11.7 Findings and Conclusions

The following conclusions are offered following the presentation and discussion of material related to the application of road salt in the Lake George drainage basin associated with the NYSDOT Road Salt Reduction Pilot Program:

- The assignment of Road Salt Application Periods (RSAPs) with a 'start' date of November 1st and a 'stop' date of October 31st the following year was confirmed as a valid concept by the actual NYSDOT 'start' and 'stop' dates documented during the five RSAPs.

- The Lake George basin road salt reduction pilot program began during the winter period (RSAP) 2018-2019 and *the reduced road salt application* on local highways ranged from ~45 percent in the T63a/T61 watersheds to ~26 percent in the T41/T36a watersheds.
- Thereafter, however, *the reduction of road salt application rates* combined with an increase in *the number of road salt application events* resulted in increased amounts of road salt (Cl^-) added to Lake George basin state-maintained highways, with the amount dependent upon which RSAP and watershed was queried.
- Increased amounts of Cl^- added to state-maintained highways beginning during RSAP 2019-2020 ranged from 300-350 percent in the T63a/T61 watersheds and from 70-258 percent in the T41 watershed. T36a had increases of 119 percent for RSAP 2020-2021 and 258 percent for RSAP 2021-2022.
- Although the *number of road salt application events* was interpreted initially as an indication of 'winter severity,' it appears that the increased number of *application events* following winter 2018-2019 was in response to the reduced *rate of road salt application* in the subject watersheds to ensure 'clear' roads.
- With regard to the above conclusion, the interpretation of local snowpack data using the "*Interactive Snow Information*" page, within the National Operational Hydrologic Remote Sensing Center (NOHRSC), on the National Oceanic and Atmospheric Administration (NOAA) website to document winter severity may be valid and requires further investigation.
- Based upon the analysis of data provided by the NYSDOT during the five RSAPs, the application rates per lane mile were reduced on all state-maintained highways throughout the Lake George basin and not just on the "pilot" segment of Route 9N.
- Starting in winter period (RSAP) 2019-2020, the NYSDOT increased the number of application events to compensate for the reduced road salt application rates.
- According to the data received from the NYSDOT and several follow-up communications, winter period 2019-2020 application data were missing from the T36a watershed worksheet. This situation reveals 'human error' introduced into the data transfer process which supports the adoption of a 'standard protocol' for future winter periods using AVL technology to remove the possibility of error.

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New York State Department of Transportation Road Salt Reduction Pilot Program

Final Report for the Lake Champlain Sea Grant Program

Chapter 12

Background, 2018-2022 Pilot Program Monitoring Project, Discussion, Summary, Conclusions and Recommendations

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12.0 Introduction

The use of road salt for winter deicing is essential for driver safety and for sustaining a successful business economy during winter months in snow belt regions. Sodium chloride (NaCl, road salt) first was used as a deicing compound by New Hampshire during the winter of 1941-1942 (Kelly et al. 2010). Seven decades later, during the winters of 2013-2017, an annual average of ~23.2 million tons of road salt were applied to US roads (Riley 2015).

Widespread salinization of lakes throughout North America and Europe has resulted from the increasing use of road salt to mitigate winter icing in temperate regions (Novotny et al. 2008; Muller and Gachter 2011). An investigation of 371 freshwater lakes in North America found that most urban lakes and rural lakes located in the Midwest and Northeast North America surrounded by > 1 percent impervious land cover show increasing chloride trends (Dugan et al. 2017a). Based upon these results, it was estimated that at least 7,770 US lakes may be at risk for elevated Cl^- concentrations from winter highway deicing (Dugan et al. 2017b).

Sustained applications of road salt cause accumulation of Na^+ and Cl^- in watershed soil and soil water where ion-exchange processes alter the cation composition of runoff into receiving waters and ecosystems (Norrstrom and Bergstedt 2001, Rosfjord et al. 2007, Rhodes and Guswa 2016). In a recent evaluation of long-term road salt application data from the Lake George, New York (USA) region, it was shown that salt loading displaced cations from exchange sites in basin soils and that the desorbed cations follow a simple ion-exchange model, with lower sodium and higher calcium, magnesium, and potassium fluxes in local runoff (Sutherland et al. 2018).

The long-term effects of road salt application can cause mortality of forest vegetation from direct impact of aerosols and changes of chemical and physical properties of soil that are in close proximity to treated highways (Fleck et al. 1988; Langen et al. 2006; Kelting and Laxson 2010). Increased salinity in lakes can affect a phytoplankton community composition shift toward cyanobacteria (Tonk et al. 2007; Pade and Hagemann 2015), and alter circulation and water column overturn (Bubeck et al. 1989; Ramakrishna and Viraraghavan 2005; Novotny et al., 2008; Sibert et al., 2015).

Excess Na^+ in drinking water is a health concern due to hypertension for individuals on low sodium diets. The US EPA requires monitoring of drinking water for Na^+ and suppliers of public water to report concentrations above 20 mg/L to local health authorities (US EPA, 2003). Recent results from a bench-scale experiment showed that increased chloride concentration in water increased galvanic corrosion and dezincification of plumbing materials, resulting in increased metal leaching and pipe wall thinning (Pieper et al. 2018). Furthermore, spatial analysis of data in the same study suggested that 2 percent of private well users in New York State could potentially be impacted by road salt storage facilities and 24 percent could potentially be impacted by road salt application. Another recent study showed that chloride concentrations in wells increased as the percentage of impervious surface cover within a 25-m radius around wells increased ($r^2 = 0.87$, $p <0.01$) and declined with increasing distance to the nearest road ($r^2 = 0.76$, $p < 0.01$) (Kelly et al. 2018).

At a regional level in New York, recent scientific reports have documented that (1) significant salinization of lakes and ponds in the Adirondacks has occurred from road salting (Kelting et al. 2012), and that (2) the majority of lakes, ponds and streams in the Adirondacks are susceptible to road salt pollution by virtue of the hydrologic connection between surface waters and paved roads (Regalado and Kelting 2015). Given the hydraulic connection of winter-maintained roads and highways with ground water and surface water, it also is likely that sodium and chloride concentrations in private wells receiving runoff from paved roads are significantly higher than concentrations in private wells not receiving runoff from paved roads.

While environmental and public health concerns about adverse effects from road salt may stimulate efforts to reduce salt loading in watersheds, salt accumulated in roadside soils, and altered concentrations of exported cations will continue to impact streams and lakes following reductions of salt input. The recovery time in down-gradient receiving waters in response to reductions has received little investigation and is poorly understood. Meanwhile, salt loading from winter de-icing has been increasing for up to six decades in many watersheds (Jackson and Jobbagy, 2005) and drainage basins, including Lake George, New York (USA), where the lake salt concentration has increased by about 3.4 percent/y since 1980 (Boylen et al., 2014), and has been raised by a factor of ~30 since the early 1940s (Sutherland et al. 2018 (inferred from Lipka and Aulenbach, 1976); NADP, 2017).

12.1 Lake George Water Quality and Chloride Concerns

The NYSDOT Road Salt Reduction Pilot Program was developed following the realization that (1) the chloride concentration in Lake George increased about 3-fold from 5.8 mg Cl L^{-1} in 1980 to 15.9 mg Cl L^{-1} in 2009 (Boylen et al. 2014), primarily from winter road de-icing applications, and that (2) significant efforts were required to focus on the reduction of road salt application without jeopardizing public safety. As described and modeled in Sutherland et al. 2018, continued salt loading in the Lake George drainage basin at 2009 application rates eventually could affect lake water column circulation dynamics, alter phytoplankton community composition, and have adverse effects on public health through sensitivity to sodium in drinking water taken from the lake.

A leading local advocacy organization, The FUND for Lake George, responded to the road salt crisis, termed the "acid rain of our time," by leading a basin-wide signing by local officials of a Memorandum of Understanding (MOU) that detailed the case, provisions, and recommendations for an aggressive salt reduction program in the lake basin. In addition to this initial action, the FUND became even more proactive and organized a series of local Salt Summits, held annually since 2015 to inform and empower the systematic pursuit of road salt reduction on a basin-wide level. The FUND also partnered with the international Snow and Ice Management Association (SIMA) to demonstrate the practices and procedures to reduce salt application by instrumenting local trucks with live-edge plows, web-linked sensors, and computerized salt applicators. To date, the effort has been extremely successful, with 28 trucks equipped within the drainage basin, 100 different roads covered, and 350 lane miles monitored for salt application.

During 2018, the FUND entered into discussions with the New York State Department of Transportation (NYSDOT) regarding a Pilot Program in the Lake George basin where reduced salt application would occur on a State road and environmental monitoring would be conducted to evaluate the effects of the reduced application on tributaries that discharge to Lake George. Specific details regarding the entire process that led to the Lake George Pilot Program were presented in Chapter 2. The NYSDOT Road Salt Reduction Pilot Program was initiated late during 2018 along the segment of Route 9N that extends from the intersection of Route 9N-Route 9 in the Village of Lake George to the intersection of Route 9N-Pandanarum Road adjacent to the Tongue Mountain range, a total distance of ~17 miles. It was clear at that time, however, that the NYSDOT had no intentions of conducting or participating in any sort of tributary monitoring.

In addition to a 3-fold increase in sodium chloride concentrations in Lake George since 1980, soils in basin watersheds with roads receiving winter road salt exhibit elevated chloride concentrations as do the tributaries that drain these developed areas and discharge to the lake (Sutherland et al. 2018). A long-term study conducted in the Finkle Brook watershed (Town of Bolton) showed that a significant 236-fold chloride concentration factor can be attributed to development in the watershed, primarily due to the extensive road network that is adjacent to the tributary channel (Sutherland and Navitsky, 2016). Water leaving Edgecomb Pond, above the developed area in the Finkle Brook watershed, exhibits an average chloride concentration of ~0.58 mg Cl/L, while the annual flow-weighted fall base-flow concentrations of chloride entering Sawmill Bay increased from ~20-30 mg Cl/L in 1995 to ~137 mg Cl/L in 2014 (Sutherland, unpublished data). Other findings pointed to the retention of chloride in watershed soils and the exchange of sodium ions with calcium ions in the upper soil complexes as ground water moved down-gradient toward Lake George (Sutherland et al. 2018).

The awareness that tributary watersheds throughout the Lake George basin were more seriously impacted by NaCl from winter de-icing practices than the lake itself made it critical to determine how quickly stream chemistry would respond to reduced salt application and then, how the lake would respond to these reductions in application. The FUND for Lake George (now the Lake George Association [LGA]) decided to sponsor a monitoring project that would focus specifically on tributary watersheds traversed by the "pilot" segment of Route 9N to evaluate potential changes in water chemistry in response to a reduced application of winter deicing road salt.

12.2 The LGA Route 9N Road Salt Reduction Pilot Program Monitoring Project

The Monitoring Project was initiated on June 5th and July 10th, 2018, with local reconnaissance and sampling, respectively, to identify potential candidates for the sampling effort. Regular bi-weekly sampling at all four tributaries was initiated on August 1st, 2018, and has occurred on a regular basis since that time with over 100 sampling excursions as of the writing of this report.

Four (4) tributaries were monitored on a routine basis during this Project; two tributaries were '***test***' sites located along the "pilot" segment of Route 9N, and two tributaries were selected outside the proposed pilot route to serve as '***control***' sites where road salt application would continue without a 10 percent reduction. The two "test" tributaries (**T61** and **T63a**) inside the pilot area are located along the northern extent of the Route 9N corridor, flow into Northwest Bay, and were sampled previously by the FUND (Keppler 2008, 2009). The two '***control***' tributaries are located at the south end of Lake George; one (**T36a**) drains a small watershed on the east side and crosses Route 9L prior to discharging to Lake George; the second tributary is a 1.2-mile segment of English Brook (**T41**) between Somerville Road at the northern extent of the watershed and a site just north of the stream crossing under Interstate 87 with the channel adjacent to Route 9 the entire distance.

The major objectives for conducting the proposed monitoring of these Lake George tributaries were to:

- *Evaluate changes in tributary chemistry in response to reduced road salt application with respect to chloride and cations (calcium, magnesium, sodium, and potassium) and whether these changes are significant when compared with road salt application at previous un-reduced application rates.*
- *Establish a valid field sampling protocol that can be used in the long-term monitoring of Lake George tributaries to document changes in chemical characteristics.*

The null hypothesis **(H_0)** tested in the proposed work-plan can be stated as follows:

- *There will be no difference in the chemical response of tributaries within the reduced road salt application zone when compared with tributaries outside the zone of reduced road salt application.*

The two 'control' tributaries outside the Route 9N Pilot Program area are critical components of the monitoring program and absolutely necessary to evaluate the effects of the reduced road salt application.

Each tributary was sampled at **upper** and **lower** sites relative to the zone where the highway influences the channel. Sites are sampled as close to a bi-weekly frequency as possible. All tributaries were sampled on the same day to minimize variability due to changing weather and discharge conditions, with samples processed immediately thereafter and submitted for analysis at the Darrin Fresh Water Institute (DFWI) Laboratory in Bolton Landing.

Every sampling excursion includes manual flow gaging, collection of field measurements (specific conductance, total dissolved solids, temperature, dissolved oxygen concentration/percent saturation), collection of water samples for analysis of anions/cations and the downloading of data-loggers. Field measurements are determined on-site and recorded on field sheets. Water samples for chemistry are collected mid-stream and stored on ice until processing. Collected samples were processed at The Lake George Association office and conference center in the Town of Lake George and then delivered along with a completed Chain of Custody form to the DFWI Laboratory for analysis.

Program chemistry samples are analyzed for anions (chloride, nitrate-nitrogen, and sulfate) and cations (sodium, calcium, magnesium, and potassium). All Program data were stored in a series of master Excel files for each tributary formatted specifically for this monitoring program (see Chapter 4 for a more detailed description).

12.3 Acquisition, Processing and Evaluation of NYSDOT Road Salt Application Data

The Freedom of Information Law (FOIL) process was required for successful completion of this study because NYSDOT would not share data outside of the legal process. Three separate FOIL requests were submitted beginning in February 2020; the final group of requested data was received from NYSDOT in November 2022.

Two data formats were received from NYSDOT for road salt application data that we requested through five different winter periods including SnoMat and Automatic Vehicle Locator (AVL) data. Both formats required additional conversations and meetings with NYSDOT representatives to review and identify material used as well as understand data terminology, abbreviations, reference codes, units, and overall data formatting.

SnoMat data were provided for all winter periods; however, the data for winter periods 2019-2020 and 2020-2021 were incomplete and had to be supplemented with data from the AVL tracking system. Integrating the data from the two different data management systems into an effective system was tedious and extremely time-consuming which added to the frustration already associated with the process following the unreasonable FOIL request delays.

The process of data evaluation is explained in step-by-step detail in Chapter 10 and even includes 'sceenshots' of the Excel file where different worksheets were set up to accommodate the various calculations performed to 'blend' the two application data formats into material applied during each winter period within the four tributary watersheds under investigation.

Numerous issues were presented throughout the integration of the datasets for analysis from the SnoMat and AVL data management systems in Chapter 10. The primary problems were the lack of any consistency in data management systems used within and among different winter periods. As a result, assumptions had to be made and were stated quite clearly in order for the analysis of the NYSDOT road salt application database to occur. A very extensive list of issues and assumptions that resulted from the data analysis process are presented at the end of Chapter 10 and also in Attachment 1 at the end of this report.

12.4 NYSDOT Road Salt Application Data and LGA Tributary Monitoring Cl^- Export Data

Three basic types of data were extracted from the road salt application information once it was compiled and reformatted from the different versions received including (1) the amount of road salt applied, (2) the number of application events, and (3) the average road salt application rates. Each data type was obtained for each tributary watershed included in the present monitoring project and for each winter period beginning with 2017-2018.

We attempted to use local Lake George basin snowpack information to determine the severity of winter weather for the five winter periods but concluded that the NYSDOT recorded number of application events for each watershed was a better indicator. In general, the order of winter severity from most to least severe was determined from the application events and was as follows: 2019-2020, 2020-2021, 2021-2022, 2017-2018, and 2018-2019.

There was good agreement between the annual amount of Cl^- applied to highway surfaces versus the annual amount of Cl^- exported to Lake George only in the two “test” watersheds and the amount of precipitation and groundwater levels were key factors in this regard. In the “control” watersheds, there was more Cl^- exported to the lake than applied to the affected highway surfaces indicating significant areas of soil depth to bedrock where storage could occur. In the case of T41, the export of Cl^- to Lake George was about 4-fold greater than the amount applied during each of the winter periods where flow and Cl^- data were complete.

Based upon road salt application rates for each watershed and each winter period, we determined that the NYSDOT initiated the full road salt reduction “pilot” program during the winter of 2018-2019 and that the program occurred on all state-maintained highways in the Lake George basin, not just on the Route 9N pilot segment.

And finally, it was shown through an exercise of some simple calculations that the amount of road salt applied to Lake George highway systems actually has increased significantly since winter period 2019-2020 due to an increased number of application events within each tributary watershed.

12.5 Discussion

During 2018 when the tributary monitoring program was initiated, our intentions were to (1) conduct rigorous monitoring of four selected tributaries at about bi-weekly intervals so that we could (2) have sufficient data to evaluate any potential changes in water chemistry between “test” and “control” based upon a 10 percent reduction in road salt application.

Following 12 months of data collection, we were faced with the realization that the four ***lower*** stations had to be instrumented for continuous flow (water level) instrumentation because the anticipated relationship between specific conductance and flow did not exist when the lower station data were analyzed. Then the historic October 31st 2019 storm occurred, and three specific conductivity data-loggers were either lost or damaged. Full instrumentation of the ***lower*** stations subsequently occurred during 2020. The point of all this detail is that in spite of initiating monitoring during 2018, we currently have complete sets of flow and specific conductivity data for only two complete winter periods, 2020-2021 and 2021-2022.

Imagine our frustration and disappointment after filing three FOIL requests and waiting over two years to receive all of the data, and then realizing that we had to spend an inordinate amount of time ‘piecing’ together road salt application data from different data management systems because the NYSDOT never adopted a standard protocol prior to initiating the road salt reduction “pilot” program on Route 9N. And there were portions of the dataset that obviously were incomplete in spite of being assured that we had all of the information.

Then, upon deciphering the essential information, we realized that the “reduction” in road salt application actually occurred basin-wide and was not restricted to just Route 9N. In addition, since inception of the reduced application rate during the winter period 2018-2019, there was a significant increase in the number of “application events’ on basin roads and a series of simple calculations showed that road salt application actually **increased** in the Lake George basin since the winter period of 2018-2019!

The ”test” watersheds adjacent to Northwest Bay responded to the *Cl^- applied to highway/ Cl^- exported to Lake George* in the manner expected, and the ‘flushing’ process in both watersheds was dependent upon the amount and cycle of local precipitation and the impact on groundwater moving through the area.

The “control” watersheds, however, both responded in an astonishing manner by exporting Cl^- in amounts many-fold greater than the Cl^- applied during any winter cycle. The primary example occurred in T41 (English Brook) where 129 and 89 tons of Cl^- were exported to Lake George from application in winter periods 2020-2021 and 2021-2022, respectively! The lesson learned here is that either natural or man-made areas exist throughout the basin where the depth to bedrock is significant and allows pockets of groundwater and Cl^- to be stored for release either continually or when conditions are favorable.

As a result of our monitoring efforts and the increased application of road salt within the Lake George basin during winter deicing periods, we were not able to demonstrate any water quality improvements with respect to Cl^- contamination. Smaller watersheds similar to the "test" areas selected for this investigation are able to maintain their level of quality in spite of continued applications as long as precipitation cycles in the area do not change significantly. Other areas, similar to our "control" sites, will receive, export, and also store Cl^- to the extent that these watersheds (even small ones) will be a constant source of excess Cl^- export to Lake George.

We openly admit in our discussions in Chapter 11 that our Cl^- loading model is not perfect in its analytical ability. It did work well enough, however, to reveal the massive amounts of chloride entering Lake George from just a few tributary watersheds under investigation.

12.6 Summary

The observations highlighted in Chapter 11 should be of great concern to everyone with regard to the annual loading of Cl^- to Lake George. An earlier study of all tributaries and stormsewers flowing in the Lake George basin (Sutherland et al. 2001) found that (1) English Brook (T41) contributed about 5.5-8.0 percent of the total flow entering the lake, and that (2) about 60 percent of the 109 tributaries flowing into the lake at the time of the study (141 total; only 109 with flow) had road/highway systems traversing their watersheds. All of the major tributaries including East, West, Finkle, Indian, Northwest Bay, and Hague Brooks are included in the category with networks of road systems that receive winter deicing products. While the total amount is not known, the export of Cl^- from these watersheds into Lake George on an annual basis must be staggering amount given the amount of Cl^- exported to the lake by the four watersheds under investigation and reported in this Final Report.

It was not possible to either prove or dis-prove the null hypothesis **(H_0)** for the following reasons:

- The NYSDOT reduced the road salt *application rate* on all state-maintained highways in the Lake George basin and not just the "pilot" segment of Route 9N, and
- The NYSDOT did not reduce the total amount of road salt applied to the "pilot" segment of Route 9N during the five winter periods (RSAPs) under consideration in the current investigation reported herein.

In other words, the NYSDOT altered the original design of the Route 9N Road Salt Reduction "Pilot" Program without communicating this key factor to other interested groups such as the LGA.

12.7 Conclusions

The following conclusions are presented in the order of chapter sequence in the Final Report and are not listed in any ranking of priority indicating importance.

Chapter 2:

- The NYSDOT did not exhibit interest in any aspect of a water quality monitoring program (participating, reviewing, funding) for the Lake George Drainage Basin Route 9N Pilot Project.
- The NYSDOT did not establish consistent stakeholder working group meetings throughout the entire project, especially during and after the COVID pandemic, more so relating to the Tactical Working Group but with the Strategic Work Group as well.
- NYSDOT needs to improve implementation of best management practices that are proven to reduce road salt applications, specifically the use of brine as anti-icing on Route 9N.
- NYSDOT needs to improve interested user access to data related to winter maintenance record keeping that should include road salt application rates, brine application rates and a winter storm severity index.
- NYSDOT should implement year-end self-assessment reporting for the winter maintenance activity goals of the Pilot Program and use the assessment to guide continuous improvement of the Program.

Chapter 10:

- Multiple issues were described throughout the integration of the datasets for analysis from the SnoMat and AVL data management systems which required that assumptions had to be made in order for analysis of the Pilot Program data to occur. The list of these issues is too extensive to be presented here and is located at the end of Chapter 10 and in Attachment 1 at the end of this report.

- According to the data received from the NYSDOT and several follow-up communications, winter period 2019-2020 application data were missing from the T36a watershed. This situation reveals 'human error' introduced into the data transfer process which supports the adoption of a 'standard protocol' for future winter periods using AVL technology to remove the possibility of human error.

Chapter 11:

- The NYSDOT Road Salt Reduction Pilot Program was initiated during winter 2018-2019 instead of later during winter 2017-2018 as originally proposed.
- Based upon the analysis of data provided by the NYSDOT during the five RSAPs, the application rates per lane mile were reduced on all state-maintained highways throughout the Lake George basin and not just on the "pilot" segment of Route 9N.
- The reduction of *road salt application rates* combined with the increase in the *number of road salt application events* during winter period (RSAP) 2019-2020 and beyond resulted in an increase in the amount of road salt added to Lake George basin highways, with the amount dependent upon which RSAP and watershed was queried. Amounts ranged from 300-354 percent increase in the T63a/T61 watersheds and 70-258 percent increase in the T41 watershed. T36a had increases of 119 percent for RSAP 2020-2021 and 258 percent for RSAP 2021-2022.
- Our assessment of local winter severity using NOAA snowpack data may be valid because the NYSDOT increased the number of winter period road salt *application events* (at reduced *application rates*) to maintain public safety on basin roads and not necessarily in response to local storm conditions.

Chapter 12:

- Based upon the information received following three separate FOIL requests and extensive associated delays, it is apparent that the NYSDOT has not exercised consistency in terms of the data management system related to the Lake George Route 9N Road Salt Reduction Pilot Program, which has resulted in extensive problems and assumptions regarding interpretation and evaluation of the database.
- It was not possible to either prove or dis-prove the null hypothesis (**H_0**) because the NYSDOT did not reduce the total amount of road salt applied to highways in the "test" watersheds.

12.8 Recommendations

The following recommendations are presented in the order of chapter sequence in the Final Report and are not listed in any ranking of priority indicating importance.

Chapter 2:

- The NYSDOT should continue the Route 9N Road Salt Reduction Pilot Program in Lake George and implement the best practices including continuous improvement based on review of previous seasons as well as collaboration with the existing SWiM® Lake George municipal models of the Towns of Lake George and Hague, and the Warren County DPW.
- The NYSDOT should partner with this study's investigators to support the monitoring program developed to determine the potential water quality changes from the implementation of road salt reduction practices.
- The NYSDOT should reconvene the Adirondack Road Salt Strategic Working Group and the Route 9N Pilot Tactical Work Group (TWG).
- The NYSDOT should make record-keeping and data publicly accessible and require reporting of dates, sources, types of materials used including anti-icing, amounts of materials applied, applications rates, treated lane miles, road conditions including temperature, and storm weather statistics.
- The NYSDOT should continuously apply best practices for road salt reduction for the Route 9N segment as per their detailed Action Plan, which would include more consistent use of brine for anti-icing.
- The NYSDOT should base snow and ice winter operation and management decisions on data collected and analyzed in post-storm evaluations applying technology from AVL salt tracking, road-side weather stations, and road-side cameras.
- New York State should utilize the Adirondack Road Salt Reduction Task Force Report to guide the state to become a national leader in sustainable snow and ice management and demonstrate the protection of vital natural resources including surface and ground water while maintaining public winter travel safety.

Chapter 10 and Chapter 12:

- Based upon our experience described herein with extracting, compiling, and re-formatting the NYSDOT road salt application data, it is clear that the agency needs to adopt a standard protocol for the road salt reduction pilot program currently on-going in the Lake George basin with input from others familiar with the current status of the data management systems currently in use.

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New York State Department of Transportation Road Salt Reduction Pilot Program

Final Report for the Lake Champlain Sea Grant Program

Attachment 1

Issues and Resulting Assumptions from NYSDOT Road Salt Application Data Management

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10.6 Issues and Resulting Assumptions from NYSDOT Road Salt Application Data Management

Multiple issues were presented throughout the integration of the datasets for analysis from the SnoMat and AVL data management systems. Thus, assumptions must be made in order for analysis of the Pilot Program to occur.

10.6.1 SnoMat Data Management

The SnoMat data format presents the following issues:

(1) SnoMat is dependent on operator/supervisor input and not as accurate as real-time AVL tracking.
(2) Beats consist of larger stretches of road than the road lengths in the study watersheds.
  - Due to the nature of Application Event documentation in SnoMat, road salt applications may or may not have occurred within our study watersheds. For example, if a treatment is documented for 17B02A, we must assume that treatment occurred on road lengths within both T41 ***lower*** and T36a ***lower*** watersheds.
  - Since application rates relate to a Beat rather than for specific road locations, we cannot account for locations with specific road salt application, locations with no road salt application, altered application rates due to site conditions or additional passes that may have occurred.
  - Our "control" sites T41 and T36a appear to be included within the same Beat, 17B02A, and therefore no distinction can be made between the applications and loading rates for the two watersheds.
  - Information such as Storm Event Code, Highway Conditions, and Road Temperature, was either inconsistent across entries or could not be substantiated. Specifically, Storm Event Code would have been useful if the codes could be ranked by storm severity and based on a consistent standard.
(3) S&I Event Code data has the potential relate storm severity, but the code is determined by the operator, does not correlate to a storm severity scale, and is only included for SnoMat (not AVL).
(4) While liquid data columns are present in the dataset, brining operations are not included and cannot be substantiated for inclusion into this study.

10.6.2 AVL Data Management System

The AVL data format and the incorporation of the AVL data into the dataset present the following issues:

(1) The AVL and SnoMat data management system do not communicate without extensive processing as shown in the sections above.
(2) AVL data were provided only for parts of winter 2019-2020 (November-December 2019) and 2020-2021 (November 2020-February 2021)
(3) Only AVL data were provided for calendar year 2020.
(4) Overlap between the two data management systems occurred from December 2020-February 2021 (winter 2020-2021), and inconsistencies for application events and rates between AVL and SnoMat were apparent.
(5) A potential error occurred at Truck Number input, as the dataset indicates only a single truck applied the entire extent of the applications.
  - It is possible that road salt applications from other trucks are missing from this dataset.
  - If Truck Numbers are missing, identifying duplicate data between AVL and SnoMat data for January-February 2021 is not possible.
(6) While columns are present in the dataset, brining operations are not included and cannot be substantiated for inclusion into this study.

10.6.3 Data Calculation Assumptions

The data format and documentation issues require this study to depend on multiple assumptions:

(1) The calculations from this chapter reveal the least amount of chloride Applied by NYSDOT
(2) ClearLane® is the only material applied in the study areas.
(3) Brining applications did not occur within the study area.
(4) Road salt application rates for I87 were 10% greater than Route 9.
(5) Per SnoMat, road salt application occurred for an entire Beat at an average rate and only one Pass was made during the Application Event.
(6) Per SnoMat, the road salt application rate was consistent for the entire treatment event.
(7) Per SnoMat, the same Application Events and road salt application rates occurred for T41 and T36a

(8) Per SnoMat, the same Application Events and road salt application rates occurred for T63a and T61

(9) Per AVL, applications from only one truck were tracked from January 2020 through February 2021

(10) Per AVL, T36a only received two Application Events including January 2020-March 2020 vs. the 47 treatment events that occurred for T41, 193 treatment events for T61, and 191 treatment events for T63a.