SUNNYSIDE BROOK CHLORIDE TMDL

Waterbody ID: VT08-02.08

Draft for Public Comment – February 2024

VERMONT DEPARTMENT OF ENVIRONMENTAL CONSERVATION
WATERSHED MANAGEMENT DIVISION

Contents

Introduction

Section 303(d) of the Federal Clean Water Act requires each state to identify waters not attaining water quality standards, and to establish total maximum daily loads (TMDLs) for these waters for the pollutant of concern. The TMDL establishes the allowable pollutant loading from all contributing sources at a level necessary to attain the applicable water quality standards. TMDLs must account for seasonal variability and include a margin of safety that accounts for uncertainty of how pollutant loadings may impact the receiving water's quality. Once the public has had an opportunity to review and comment on the TMDL, it is submitted to the U.S. Environmental Protection Agency (USEPA) for approval. Upon approval, the TMDL is incorporated into the state's water quality management plan.

This TMDL establishes a scientifically based water quality target for Sunnyside Brook that, when attained, will allow the stream to meet or exceed the established Vermont Water Quality Standards (VTWQS, 2022) for which it is impaired. This TMDL has been established in accordance with Section 303(d) of the Federal Clean Water Act, implementing regulations (40 CFR §130) regarding TMDL development, and other relevant USEPA guidance documents.

Watershed Description

Watershed Description and Identification

Located in the town of Colchester, VT within Chittenden County, Sunnyside Brook is a small tributary of the lower Winooski River basin (Figure 1). The TMDL monitoring point drains a 0.57 square mile area. This is slightly smaller than what would be the natural topographic drainage area due to stormwater diversions in the upper portion of the watershed.

Topography

The elevation of the watershed ranges from 163 to 441 ft. above mean sea level, and the topography is somewhat varied. The southern portion of the watershed is relatively level with pebbly marine sands of the Champlain Sea and contains much of the commercial and industrial development with some forest and wetlands. The western edge of the watershed is made up of a prominent hill with various commercial and office buildings. The lower outlet of the watershed contains forested ridge and valley terrain of a fluvially eroded dissected plateau.

Soils

The western upland area makes up about a third of the watershed and is a bedrock exposure with mostly thin, rocky loam soils of the poor draining type D hydrologic group. The remaining lower portion of the watershed consists mostly of pebbly marine sand of the Champlain Sea deposit, classified as either fine sandy loam or loamy sand of the well-draining type A hydrologic soil group, with some type D.

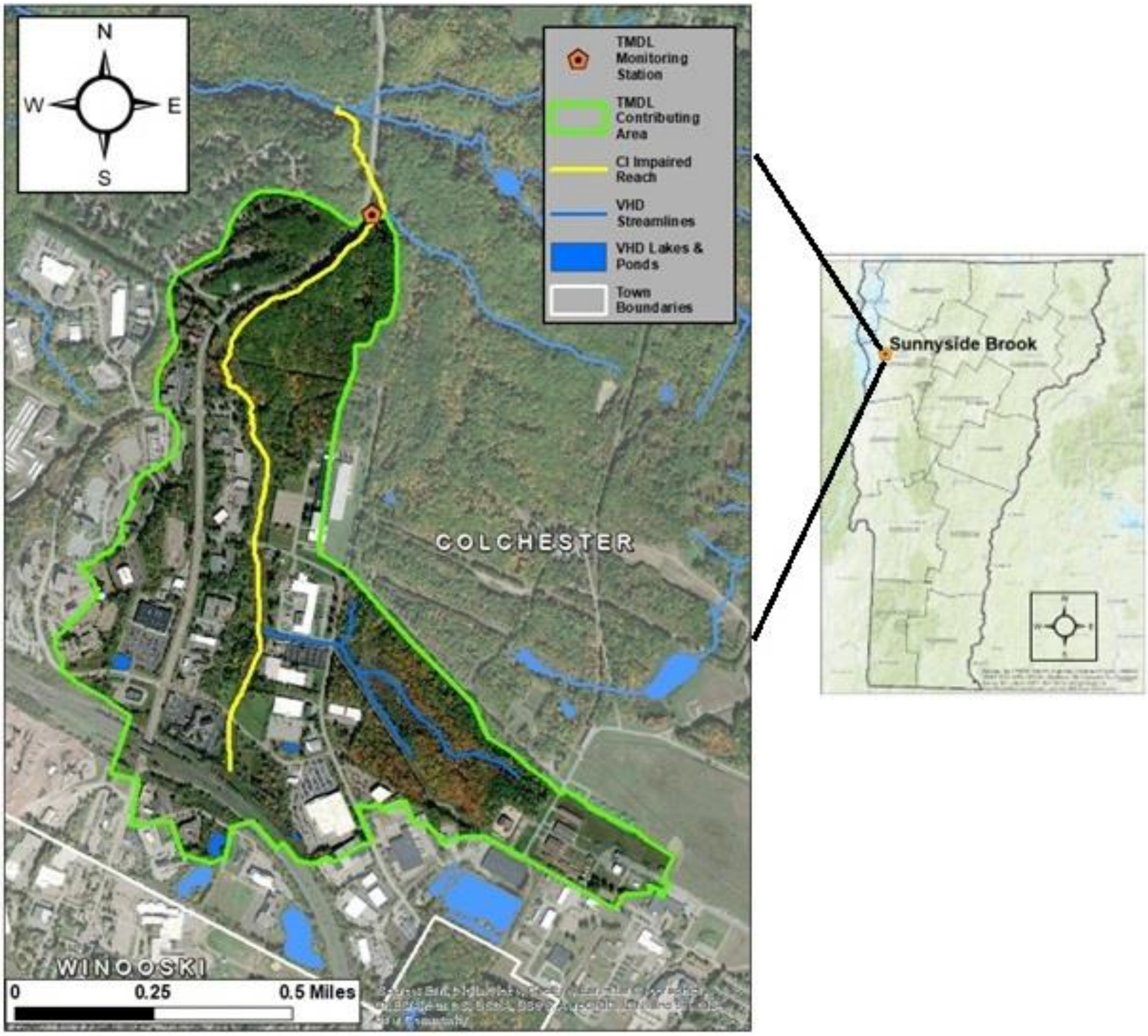


FIGURE 1: MAP OF SUNNYSIDE BROOK TMDL WATERSHED

Land Use Land Cover

Table 1 shows the different land cover types and respective areas within the watershed, as derived from 2016 remote sensing data (Univ. of Vermont SAL, 2016) and minor manual edits based on more recent aerial imagery. Of the 0.57 square miles, 27.1% is wetland and forest while 72.6% has been developed to varying degrees. Table 1 includes the relative areas of impervious surface within the developed portion of the watershed, which accounts for 31% of the total drainage area. The majority of impervious is classified as "other paved", being mostly parking lots. Buildings and roads make up approximately equal share of the remaining impervious surface. The State of Vermont owns and maintains the largest area of road surface, followed by the Town of Colchester and private entities. A very small portion of road is on property of the United States Army. The total impervious area assumed to receive deicing maintenance is 88.7 acres, or 24.3% of the watershed.

Table 1: Landcover Classes within Sunnyside Brook TMDL watershed: a) All landcover classes; b) Impervious surface by type and road owner.

A) ALL LANDCOVER CLASSES

Land Use/Land Cover Type	Area (acres)	Area (percent of watershed)
Developed, Open Space	73.8	20.2
Developed, Low Intensity	59.8	16.3
Developed, Medium Intensity	83.2	22.7
Developed, High Intensity	48.9	13.4
Barren Land	0.2	0.1
Deciduous Forest	50.5	13.8
Evergreen Forest	4.4	1.2
Mixed Forest	5.3	1.5
Shrub/Scrub	0.2	0.1
Hay/Pasture	0.7	0.2
Woody Wetlands	37.8	10.3
Emergent Herbaceous Wetlands	1.1	0.3

B) IMPERVIOUS SURFACE BY TYPE AND ROAD OWNER

Impervious Surface Type	Area (acres)	Area (percent of watershed)	Area (percent of total impervious)
Buildings	24.4	7	21.6
Other Paved	67.8	19	59.9
All Roads	20.9	6	18.5
State roads	*11.5*	*3*	*10.2*
Municipal roads	*6.3*	*2*	*5.6*
Private roads	*0.5*	*<1*	*0.4*
US Army road	*2.6*	*1*	*2.3*

The Sunnyside Brook watershed's developed land is a mix of commercial and industrial properties, with only a small portion being residential. Publicly available data from the Town of Colchester indicate that residentially zoned parcels include only a few single-family dwellings and two parcels with multi-family dwelling complexes (CAI Technologies, 2022). Notable developed features include the I-89 interstate and associated on/off ramps, State Route 7 highway, as well as some large industrial buildings, supermarkets, big box retailers, hotels, and office parks. The watershed includes a small portion of the Camp Johnson military base.

Weather/climate

The climate at Sunnyside Brook is classified as humid continental (Kottek et al., 2006 https://www.weather.gov/jetstream/climate_max), with cold winters, warm summers, and precipitation distributed relatively evenly throughout the year. Current climate normal data from 1991-2020 show July as the month with the highest average precipitation of 4.45 inches, while February is the lowest averaging 1.84 inches (PRISM, 2021). Annual average precipitation is 40.02 inches. July also has the highest average temperature of 70.9 °F with January being the coldest at 18.8 °F. Annual average temperature is 46.1 °F. It is common for this area to receive snow from October through April. The average total seasonal snow depth is 85.9 inches.

Population and Households

No permanent population data specific to the Sunnyside Brook TMDL watershed could be identified. 2020 housing data from the Chittenden County Regional Planning Commission (CCRPC, 2021) show 22 residential buildings within the watershed, 13 of which are single family homes while 9 are multifamily buildings. 2020 census data indicate an average of 2.3 persons per household in Chittenden County (U.S. Census, 2021). Estimating between 2-6 units per multifamily dwelling, an estimated resident population for this watershed is approximately 71-154 people. The daily transient population is much higher owing to the several large hotels, supermarkets, office parks and industrial buildings. Exact estimates of this are hard to derive, though it is likely in the thousands on a typical weekday.

Sewer

The entirety of the Sunnyside Brook watershed is within the Town of Colchester wastewater collection system. However, collected wastewater is pumped to the South Burlington Airport Parkway wastewater treatment facility (permit # 3-1278) and discharged to the Winooski River.

Applicable Water Quality Standards

Vermont Water Quality Standards (VTWQS) establish designated uses, management objectives, and minimum water quality criteria necessary to support those designated uses. The standards applicable to the impairments in Sunnyside Brook are discussed below.

Designated Uses

The designated uses are aquatic biota and wildlife, aquatic habitat, aesthetics, swimming, boating, fishing, public water source, and irrigation. Surface waters may be classified for individual designated uses and the criteria that support them vary according to the class - A(1), A(2), B(1), and B(2).

Sunnyside Brook is classified B(2) for all designated uses. The aquatic biota and wildlife use in the Vermont Water Quality Standards (29A-306(a)(3)) is stated as:

> (A) Management Objectives. Waters shall be managed to achieve and maintain good biological integrity.
>
> (B) Biological Criteria. Change from the natural condition for aquatic macroinvertebrate and fish assemblages not exceeding moderate changes in the relative proportions of taxonomic, functional, tolerant, and intolerant aquatic organisms.

Aquatic Biota and Wildlife Use

To directly assess the aquatic biota use in wadeable streams, the VTDEC uses macroinvertebrate and in some cases, fish, community data. Raw abundance data from samples identified in the VTDEC laboratory are converted to eight aggregate community 'metrics', and thresholds in those metrics determine whether the biological condition meets minimum aquatic life use standards (ALUS). Identifying which specific metrics fail to achieve these minimum thresholds can also provide important information on stressors that may be altering the community. Metrics and thresholds can vary depending on stream type, including whether the reach is identified as high, moderate, or low gradient. More detailed information on the development and application of these biocriteria is available in Appendix G of the VTWQS.

Water Quality Criteria

Chloride is identified as a toxic substance in excess concentrations in the VTWQS. In §29A-303(7)(A) as General Criteria Applicable to all Waters, the Standards state:

> Waters shall be managed to prevent the discharge of toxic substances in concentrations, quantities, or combinations that exceed…(iii) Acute or chronic toxicity to aquatic biota or wildlife.

Appendix C of the VTWQS gives the numeric criteria for toxic substances for the protection of aquatic biota, for which the chloride concentrations are 860 mg/L and 230 mg/L for acute and chronic exposures, respectively. Application of the chloride criteria is found in Chapter Three of the Vermont Surface Water Assessment and Listing Methodology.

Impairment Listing and Current Status

Sunnyside Brook was initially listed as impaired in 2016 based on multiple years of failing to meet the minimum biocriteria for macroinvertebrates and is listed on the 2022 303(d) List (Table 2).

Table 2. 2022 Sunnyside Brook 303(d) listing

WBID	Waterbody Name	Impaired use(s)	Pollutant	Problem	TMDL Priority
VT08-02	Sunnyside Brook (Trib #8 to Sunderland Brook) (1.2 mi.)	Aquatic biota	Chloride	Elevated chloride levels due to road salt	High

Biomonitoring

Macroinvertebrate sampling occurred on Sunnyside Brook, river mile 0.2, eight times since 2002. Seven of the most recent sampling events resulted in overall community assessments less than “good” which indicate noncompliance with the VTWQS for a Class B(2) stream (Figure 2).

FIGURE 2 MACROINVERTEBRATE SAMPLING RESULTS AT RIVER MILE 0.2.

Location:	Sunnyside Brook	**Location ID:**	501965
Town:	Colchester	**Bio Site ID:**	490208000002
Description:	Located above and adjacent to Route 2 crossing, and above confluence with Trib # 1 or Camp Johnson	**WBID:**	VT08-02
Stream Type:	Warm Water Medium Gradient		

Date	Density	Richness	EPT Richness	PMA-O	B.I.	Oligo.	EPT/EPT + Chiro	PPCS-F	Community Assessment
10/9/2002	1688	35.0	16.0	67.1	2.74	2.84	0.85	0.52	Good
10/31/2005	1773	42.5	15.0	48.6	2.84	1.27	0.89	0.39	G-Fair
10/3/2006	1077	41.0	9.0	51.5	4.90	3.06	0.51	0.39	Fair
10/5/2010	2368	43.0	14.0	66.0	4.56	2.37	0.88	0.52	G-Fair
10/19/2011	859	34.0	15.5	58.4	3.66	1.81	0.93	0.40	G-Fair
10/11/2012	1567	35.0	10.0	60.3	3.49	0.66	0.79	0.37	Fair
10/9/2014	1173	36.0	10.0	57.3	4.28	0.77	0.70	0.45	Fair
9/17/2020	389	35.0	7.0	57.3	4.63	0.00	0.74	0.56	Fair
Full Support	≥ 300	≥ 30	≥ 16	≥ 45	≤ 5.4	≤ 12	≥ 0.45	≥ 0.4	
Indeterminate	≥ 250	≥ 28	≥ 15	≥ 40	≤ 5.65	≤ 14.5	≥ 0.43	≥ 0.35	
Non-Support	< 250	< 28	< 15	< 40	> 5.65	> 14.5	< 0.43	< 0.35	

*Scoring Guidelines for Stream Type WWMG and WQ Class B(2).

Chloride concentrations

For the initial listing in 2016, in addition to biomonitoring data chloride data was utilized to confirm impairments in conjunction with the chloride numeric criteria. Continuous conductivity monitoring data, converted to chloride concentrations, were collected for the calendar year 2014 that showed nearly continuous exceedance of the numeric chronic criterion (230 mg/L) and several exceedances of the acute criterion (860 mg/L). More recent continuous conductivity/chloride data obtained by VTDEC during 2020 also show consistent criteria exceedances, as described below in the TMDL Development section.

Review of the Evidence that Chloride is a Stressor of the Biological Community

In urban areas with high amounts of development and impervious surface, the combined effects of increased stormwater and high groundwater chloride concentrations can have significant effects on macroinvertebrate communities. This can best be seen by the loss of abundance and diversity of sensitive taxa, which can be replaced by more tolerant species. Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa are generally very diverse in Vermont reference streams, and most of these species are sensitive to high chloride concentrations. Because of this, among all metrics used in Vermont to assess biological condition, EPT richness is the primary response variable in urban streams that fails to meet minimum B(2) criteria. While Trichoptera (caddisflies) and Plecoptera (stoneflies) exhibit notable declines in response to elevated chloride, some species from these groups can persist under high chloride conditions. This is not necessarily true for Ephemeroptera (mayflies), which can be quickly eliminated as conditions become more toxic. A recent analysis by VTDEC shows an average of only two Ephemeroptera taxa in small streams (< 25 km^2 watershed) with chloride greater than 100 mg/l, a value that is significantly lower than mayfly richness in streams with chloride less than 60 mg/l.

These biological patterns are evident in Sunnyside Brook, which has chloride concentrations routinely above the 230 mg/l chronic criteria. In eight macroinvertebrate assessments since 2002, the community has failed to fully meet minimum B(2) biocriteria in the most recent seven years. EPT richness has routinely been the limiting metric that causes aquatic biota to fail, and values appear to have declined over the last decade. EPT richness was lowest in 2020, when Vermont experienced a statewide drought and low flows were observed to be correlated with increased chloride concentrations. Among all eight sampling events, Ephemeroptera was highest in 2002 when the stream last met B(2) criteria (relative abundance = 4%, richness = 2). In the seven assessments since then, Ephemeroptera were completely absent five times. One mayfly individual of one taxa (Baetis tricaudatus) was found in both 2011 and 2014. This pattern in EPT richness (and in mayflies specifically) strongly suggests that the deterioration of biological condition is because of urban development and toxic chloride concentrations. It should be noted that the State's functional feeding group metric (PPCS-F), which relates observed distribution of groups to an expected reference model, was at or below the B(2) threshold (i.e. 'indeterminate') on four occasions. On each of these occurrences, a different feeding group was found to be dominant. This variability in the community is likely another consequence of the destabilization caused by the loss of sensitive species rather than a direct result of increased chloride. The community is also likely transitional between the small high gradient (SHG) and warm-water moderate gradient (WWMG) stream types. The PPCS-F metric values as shown represent the WWMG expectations, but the stream would meet SHG thresholds for all sampling events.

TMDL Development

The goals of this analysis are to further characterize continuous instream flow and water quality conditions in Sunnyside Brook, as well as guide TMDL target setting. Specifically, this study aimed to:

1. Identify the frequency and degree of violations of chloride water quality standards
2. Determine the maximum chloride loading capacity of Sunnyside Brook across all flow conditions
3. Assess loading targets against observed data
4. Examine critical conditions and seasons for impairments, with load reductions needed at various flow categories from high to low.

Application of Load Duration Method to Sunnyside Brook Chloride TMDLs

The chloride TMDL for Sunnyside Brook was developed using the load duration method. As recommended by the EPA (U.S. EPA, 2007) and implemented in several previous chloride TMDLs across the country (Trowbridge, 2008; ICPRB, 2017), the load duration approach is particularly suited for flow-driven water quality conditions, like chloride loading, to determine loading capacities, allocations, margins of safety, and seasonal variations. With this approach, a representative flow duration curve (FDC) is developed for the impaired stream which shows the full range of observed or modeled streamflow, from lowest to highest on the y-axis and the corresponding percent of time they are equaled or exceeded on the x-axis. For example, a modeled record of daily average streamflow spanning ten years may show that a stream has flows of 1 $ft.^3$/sec. that are equaled or exceeded eighty percent of the time while flows greater than or equal to 10 $ft.^3$/sec. only five percent of the time.

The FDC is translated into a load duration curve (LDC) by multiplying each individual streamflow data point (in units of volume/time) by the applicable chloride concentration standard (in units of mass/volume). The result is a curve showing the loads of chloride on the y-axis (in units of mass/time) that meet water quality standards across the full range of expected streamflow conditions, with the corresponding exceedance probability on the x-axis. Continuing the hypothetical of a ten-year period of modeled streamflow and using a water quality standard of chloride concentrations not to exceed 230 mg/L, after various unit conversions the stream's chloride loading capacity would be greater than or equal to 6.20 tons/day five percent of the time and greater than or equal to 0.62 tons/day eighty percent of the time. For both streamflow conditions these loading values meet the water quality standard concentration of 230 mg/L.

For any streamflow condition within this ten-year period from the very lowest to the very highest, a mass load of chloride at or below the LDC would be within the loading capacity of the stream. In this way the curve can be used to determine the target chloride load for any streamflow for any time of year, during the most critical conditions as well as on a daily or annual basis. LDCs are often developed based on values of streamflow and concentration on a daily timestep. In this instance the maximum daily load for a given streamflow that meets water quality standards can be directly determined from the LDC. Total maximum loads for longer periods such as an annual load may then be calculated by multiplying the average of the daily loads used to construct the curve by number of days in the period of interest.

The hydrologic nature of water quality conditions can be further characterized by dividing the duration curve into distinct zones of hydrologic condition, or "wetness". EPA (2007) suggests defining five categories of flow magnitude, each centered on the 5^{th}, 25^{th}, 50^{th}, 75^{th} and 95^{th} percentile as shown with observed Sunnyside Brook data in Figure 12. Each zone represents hydrologic conditions of "high", "moist", "mid-range", "dry" and "low", respectively. Plotting observed loads against the target LDC with defined zones helps identify differences in exceedances based on wet vs. dry conditions. Percent load reductions needed to meet target loads can then be calculated for each category.

To customize this approach to a Sunnyside Brook TMDL, a representative FDC was developed for Sunnyside Brook. The numeric chloride criteria from the VTWQS were then applied to determine the target annual chloride load within the capacity of the stream. Further details on data collection and analysis are included in the Methodology section.

Methodology

Site specific monitoring data near the mouth of Sunnyside Brook were collected to facilitate developing a load duration curve and TMDL for chloride. A monitoring station was sited and established in a small pool immediately adjacent to Vermont State Route 2, which runs parallel to Sunnyside Brook just before the confluence with the mainstem of the larger Sunderland Brook (Figure 1). Data collection included water level, streamflow, specific conductivity and samples of chloride concentration.

Specific Conductivity and Chloride

A conductivity sensor was deployed to log continuous specific conductivity (SpC) at 15-minute intervals, from December 2019 through November 2020. Eight periodic water quality grab samples were collected during this deployment and later analyzed for chloride concentration at the Vermont Environmental and Agricultural Laboratory, according to its approved methods and quality control systems (VAEL 2021; VAEL 2023). Paired data points of specific conductivity and chloride were included in a dataset of 44 additional water quality samples collected from Sunnyside Brook periodically from 2003-2014 (Figure 3). A site-specific SpC-Chloride regression equation was developed from these 52 paired data points to predict chloride concentrations from SpC (Figure 3). This equation was then used to derive a 15-minute time series of estimated chloride concentration for the 12-month monitoring period. Monitoring data are presented in the Results section below.

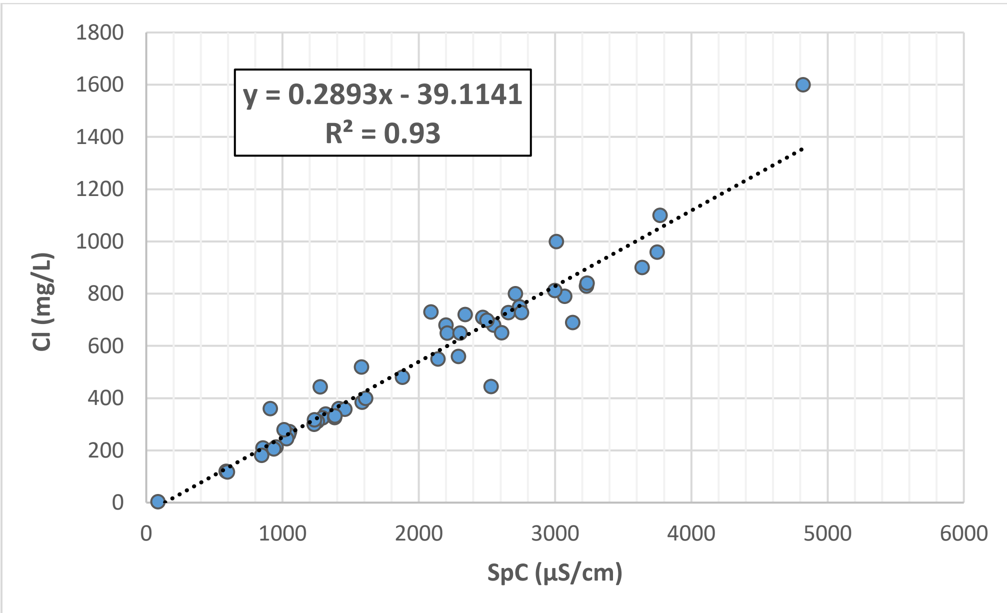


FIGURE 3: RELATIONSHIP BETWEEN SPECIFIC CONDUCTIVITY AND CHLORIDE AT SUNNYSIDE BROOK BASED ON VTDEC SAMPLE DATA, WITH REGRESSION EQUATION PREDICTING CHLORIDE CONCENTRATION FROM SPECIFIC CONDUCTIVITY MEASUREMENTS.

Streamflow

A temporary streamflow gage was established near the mouth of Sunnyside Brook in April 2020 to get a better record of local streamflow and to derive a representative FDC. The climate of northern Vermont presents substantial technical challenges for gaging small streams through the winter, so streamflow was only monitored during the non-winter months of April to November 2020. Gaging procedures followed those of Rantz et al. (1982), Turnipseed and Sauer (2010) and U.S. EPA (2014) to the extent possible. The station was equipped with water level loggers recording stage to the nearest 0.01 ft. (± 0.015 ft), every 15 minutes. Stage data were compared to reference water levels established via local benchmarks and elevation surveys during site visits, and the logged values adjusted as needed. Discharge measurements were collected periodically over a range of flows to develop a stage-discharge rating curve and estimate streamflow from 15-minute stage data. Five discharge measurements were collected to produce the stage-discharge rating curve in Figure 4. The rating equation was then applied to each stream stage measurement to estimate streamflow at 15-minute intervals for duration of the flow gaging period.

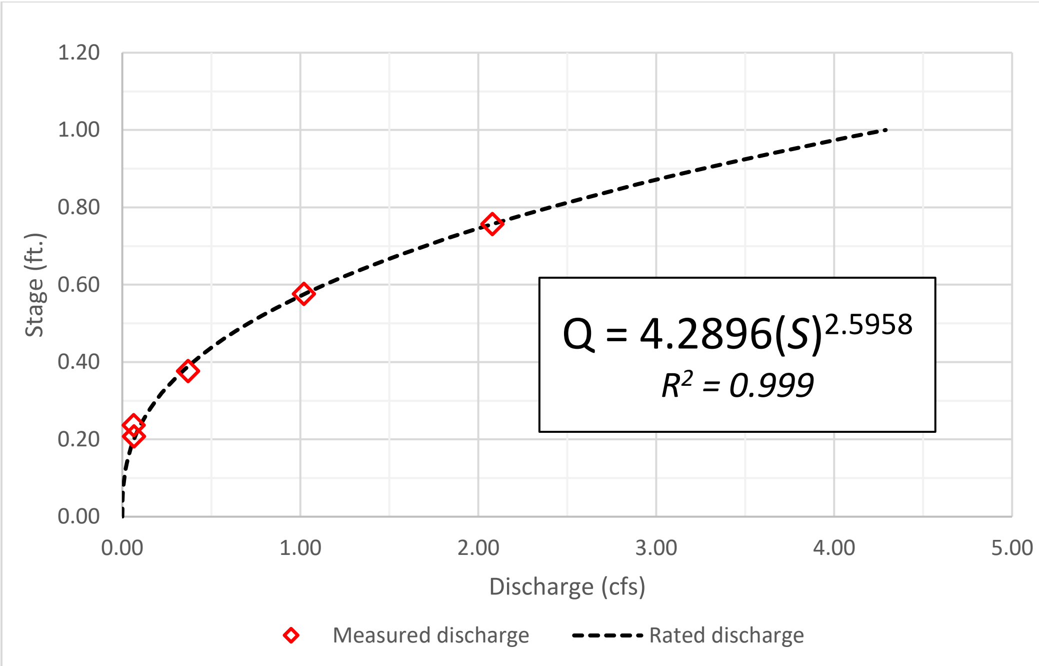


FIGURE 4: STAGE-DISCHARGE RATING FOR THE SHORT-TERM VTDEC STREAMFLOW GAGE AT SUNNYSIDE BROOK.

Streamflow record extension

A FDC that is representative of the flow regime for a specific location necessitates several years of streamflow record, generally 10 to 25 years. Lacking prior data for this portion of Sunnyside Brook precludes assessing the representativeness of 2020 monitoring period. A record extension is one way to address this limitation, where the short-term flow dataset is regressed against one or more contemporaneous datasets of nearby streams with longer periods of record. With a strong enough correlation for the overlapping period, a regression model can then be developed to generate a longer-term streamflow dataset at the short-term site of interest for those periods when the long-term gage(s) have additional flow data. Alternative approaches include a full watershed rainfall runoff model; however, this requires a substantial amount of streamflow, precipitation, and land cover data, including several distinct periods for model calibration and validation. A record extension was identified as the preferred approach for this work due to its simplicity and feasibility with available data.

Four nearby streamflow gages were considered in the record extension analysis (Table 3). They were selected for having a period of record overlap with the temporary VTDEC Sunnyside Brook gage and physiographic similarities (e.g., proximity, smaller drainage areas, elevation, etc.). A best subset regression analysis ranked adjusted R-square performance of all combinations of models using one or more of these gages in a multiple linear regression model. The model using daily streamflow for Allen, Englesby, and Potash Brooks ranked the best (adj. R^2 = 0.662), though would only result in a final Sunnyside flow dataset of four years. The second ranking model of Potash and Englesby Brooks (adj. R^2 = 0.661) was similar and could provide a flow dataset of almost ten full years for Sunnyside, so was ultimately chosen for use in record extension. It should be noted that in many circumstances a higher correlation between short- and long-term streamflow datasets would be desired for use in streamflow record extensions. Recognizing this, the regression model was still considered the best alternative given the limited available local streamflow data. A full watershed model producing runoff response and streamflow would also depend on the same limited data and would be likely to produce performance metrics equal to or even worse than our selected record extension model. Additionally, because the end-use of an extended time-series of daily streamflow here is to produce a FDC representing the possible range of flows and associated probabilities, it was not necessary to reconstruct actual sequence of flows of over one or more years or even an actual runoff event. Thus, the resource requirements of more elaborate watershed model development were not warranted.

TABLE 3: NEARBY LONGER-TERM STREAMFLOW DATASETS CONSIDERED FOR USE IN RECORD EXTENSION OF THE SHORT-TERM SUNNYSIDE BROOK STREAMFLOW DATASET.

Streamflow Gaging Station	Drainage Area (sq. mi.)	Period of Record*	Operator
ALLEN BROOK AT VT 2A, NEAR ESSEX JUNCTION, VT	9.9	Sep. 2005 – Oct. 2013; Jan. 2017- Dec. 2020	USGS; Stone Environmental
ENGLESBY BROOK AT BURLINGTON, VT	0.9	Oct. 1999 -Sep. 2010; Jan. 2017- Dec. 2020	USGS; Stone Environmental
POTASH BR @ QUEEN CITY PARK RD, NR BURLINGTON, VT	7.2	Aug. 2004 -Sep. 2011; Jan. 2017-Dec. 2020	USGS; Stone Environmental
MILL RIVER AT GEORGIA SHORE RD, NR ST ALBANS, VT	22.3	Nov. 2010 – Dec. 2020	USGS

*Available at the time of analysis.

Monitoring Results

Chloride and Water Quality Standard Exceedances

Figure 5 shows chloride concentration results dating back to 2005 for periodic grab sampling at this location by VTDEC. Nearly all samples are above the chronic chloride standard of 230 mg/L, and more recent results approach the acute standard of 860 mg/L. The more recent data in Figure 5 appear to show elevated chloride levels when compared to earlier samples; however, a statistical test of this is complicated by the irregular and unsystematic sampling dates. What these data do not show are how chloride concentrations vary throughout a year with changing streamflow conditions.

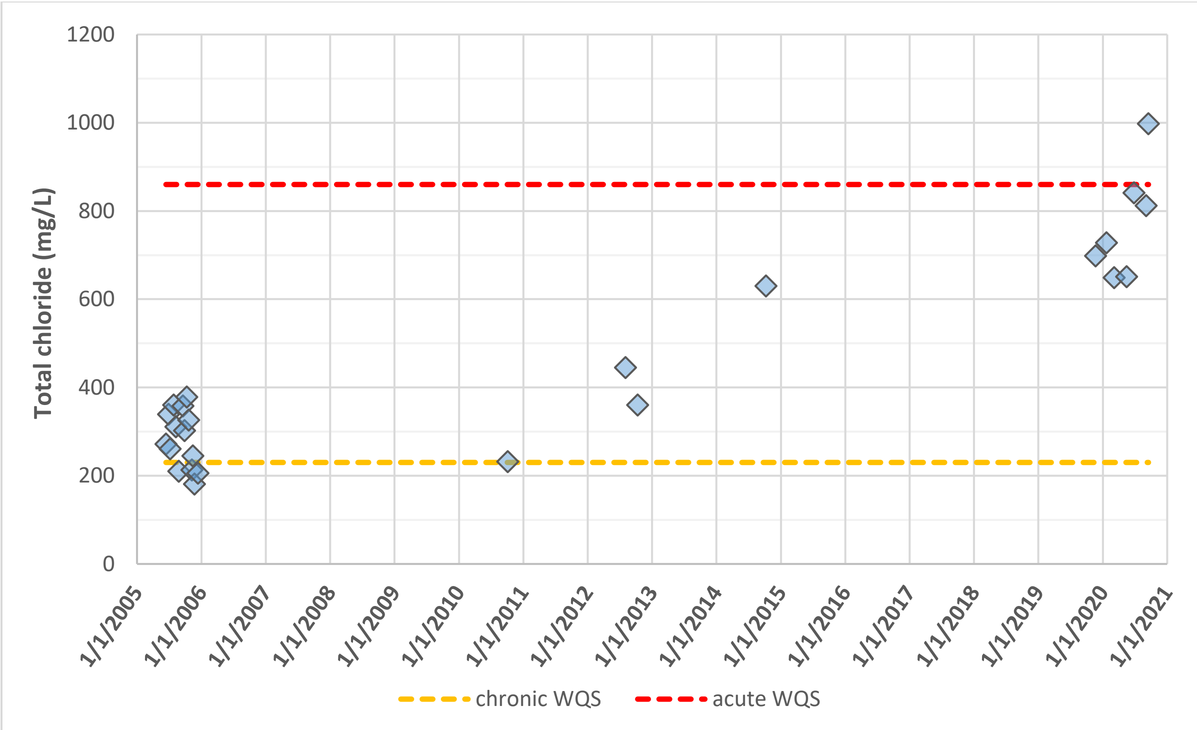
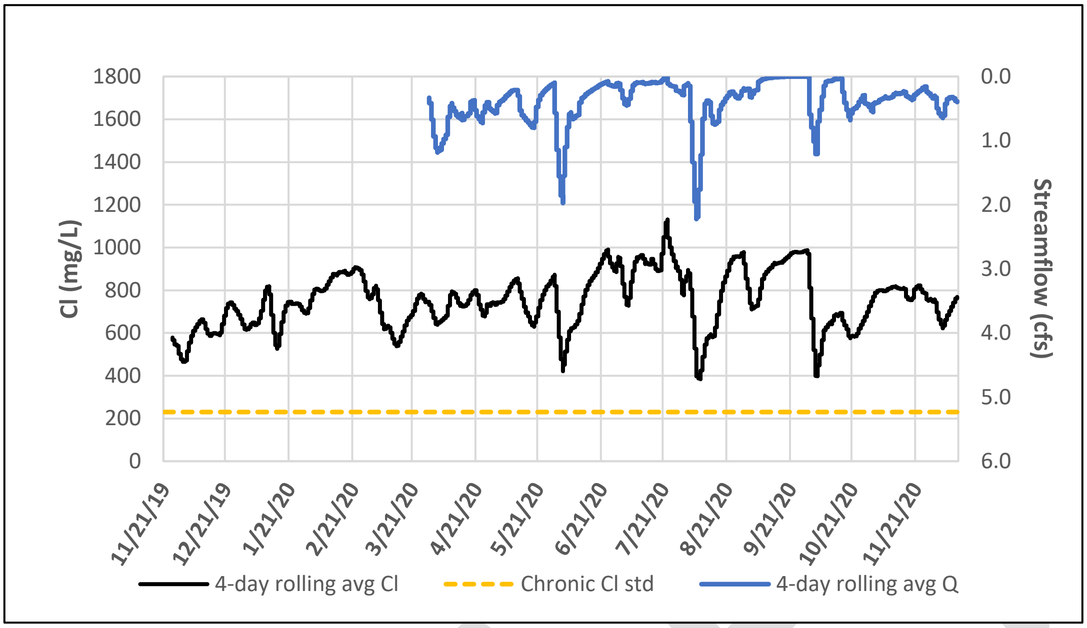


FIGURE 5: VTDEC CHLORIDE CONCENTRATION GRAB SAMPLE RESULTS, 2005-2021

Figures 6a and 6b show continuous observed chloride concentration as both hourly and four-day rolling averages to reflect the temporal criteria for the acute and chronic standards. Four-day rolling average chloride concentrations remained well above the chronic standard, not just during the winter deicing months or during summer low flows but for the entirety of the monitoring period. Hourly average chloride showed a similar fluctuation pattern throughout the period and often exceeded the acute standard during February and much of June through September. Summary chloride concentration statistics are presented in Table 4. Plotted with daily average streamflow we see that the spikes in daily average chloride levels often coincide with periods of decreased streamflow and concentrations drop with high flow dilution. This negative chloride-streamflow relationship is evident in Figures 6 and 7.

It is difficult to quantify the number of individual violations of water quality standards during the monitoring period due to the challenge in differentiating one incident from the next, although it is clear there are many. A useful characterization is the percent of time conditions in Sunnyside Brook were at or above the State standards. This is presented in Table 4, which shows that concentrations exceeded the acute standard about half of the time or more during the months of February and June-September. Again, the chronic chloride standard was exceeded 100% of the time. Because of this persistent occurrence, maintenance of the chronic standard will be the basis for developing a chloride TMDL for Sunnyside Brook. Achievement of the lower concentration standard is also expected to nearly eliminate the exceedances of the acute standard.

a)



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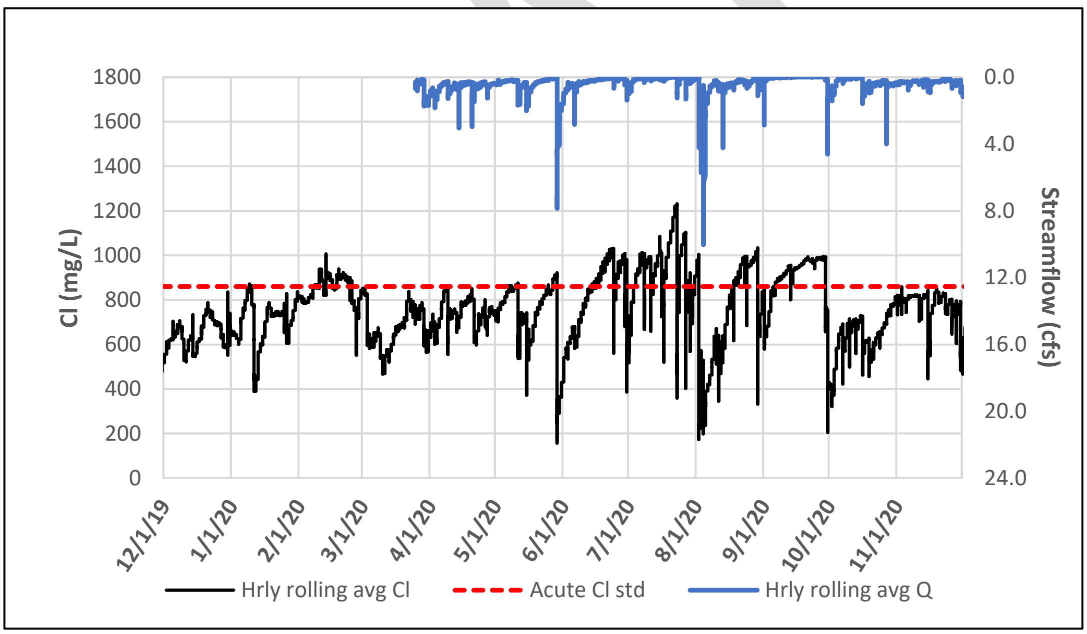

Figure 6: Continuous chloride and streamflow data for the 2019-2020 monitoring period at Sunnyside Brook. A): Four-day rolling average concentration compared to chronic standard, and B): Hourly rolling average compared to the acute standard.

TABLE 4: CHLORIDE CONCENTRATION AND WATER QUALITY STANDARD EXCEEDANCES AT SUNNYSIDE BROOK DURING 2019-2020 MONITORING PERIOD.

Year:	*2019*	*2020*	*2020*	*2020*	*2020*	*2020*	*2020*	*2020*	*2020*	*2020*	*2020*	*2020*
Month:	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov
Ave Cl (mg/L)	642	701	847	674	734	743	810	911	739	893	633	787
Max Cl (mg/L)	879	871	1025	852	879	923	1032	1231	1033	994	815	862
Min Cl (mg/L)	518	387	549	466	530	102	307	333	93	202	295	395
Acute exceedences (% of time)	***0.0%***	***1%***	***46%***	***0%***	***0%***	***13%***	***45%***	***70%***	***40%***	***78%***	***0%***	***0%***
Chronic exceedences (% of time)	***100%***	***100%***	***100%***	***100%***	***100%***	***100%***	***100%***	***100%***	***100%***	***100%***	***100%***	***100%***

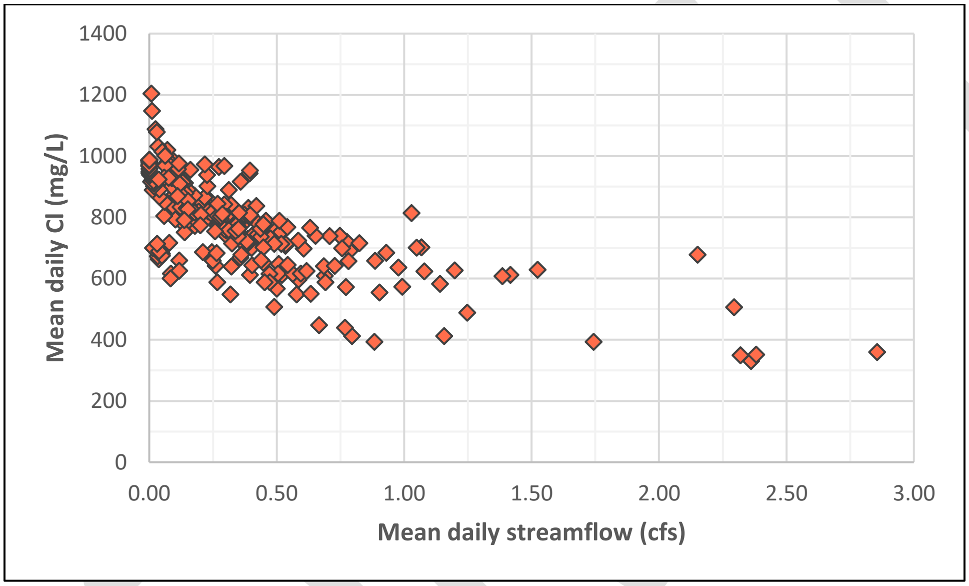

FIGURE 7: MEAN DAILY STREAMFLOW VS. MEAN DAILY CHLORIDE CONCENTRATION DURING THE 2019-2020 MONITORING PERIOD AT SUNNYSIDE BROOK.

Streamflow and Flow Duration Curve

Figure 8 shows the hydrograph of instantaneous streamflow for Sunnyside Brook, gaged from 03/26/2020 through 12/10/2020. Rated peak flow during this period reached 10.4 cfs, while periods of zero flow occurred during much of September. Average flow for the monitoring period was 0.39 cfs.

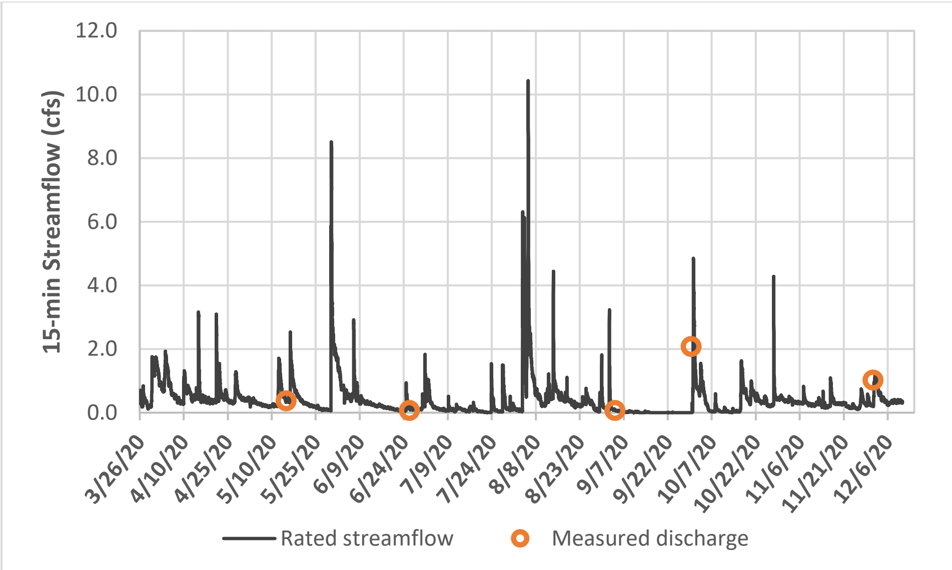

FIGURE 8: OBSERVED INSTANTANEOUS (15-MINUTE) STREAMFLOW HYDROGRAPH FOR THE 2020 MONITORING PERIOD AT SUNNYSIDE BROOK.

As previously mentioned, a record extension using multiple linear regression produced a combination modeled and observed dataset of daily average streamflow from January 2005 through December 2009, and January 2011 through December 2020. Streamflow for 2010 was omitted due to missing data from the long-term gages for a substantial portion of that year. Modeled maximum daily average streamflow for this period is 14.8 cfs, with minimum streamflows of 0.0 cfs. Average streamflow is 0.60 cfs. Figure 9 shows the modeled FDC using our four-day rolling average streamflow dataset. This FDC was used to derive the chloride LDC and TMDL targets to reflect the four-day average concentration duration of Vermont's chronic chloride standard. High flow events are not shown to be common, with almost 90-percent of 4-day average flows below 1 cfs. There are relatively few occurrences of flows above 2 cfs as indicated by the very steep nature of the curve at low exceedance probabilities. The 2020 observed FDC shows generally lower flows than the longer representative FDC, especially in the higher flow range. Moderate flows were similar to longer term patterns and lower flows slightly less.

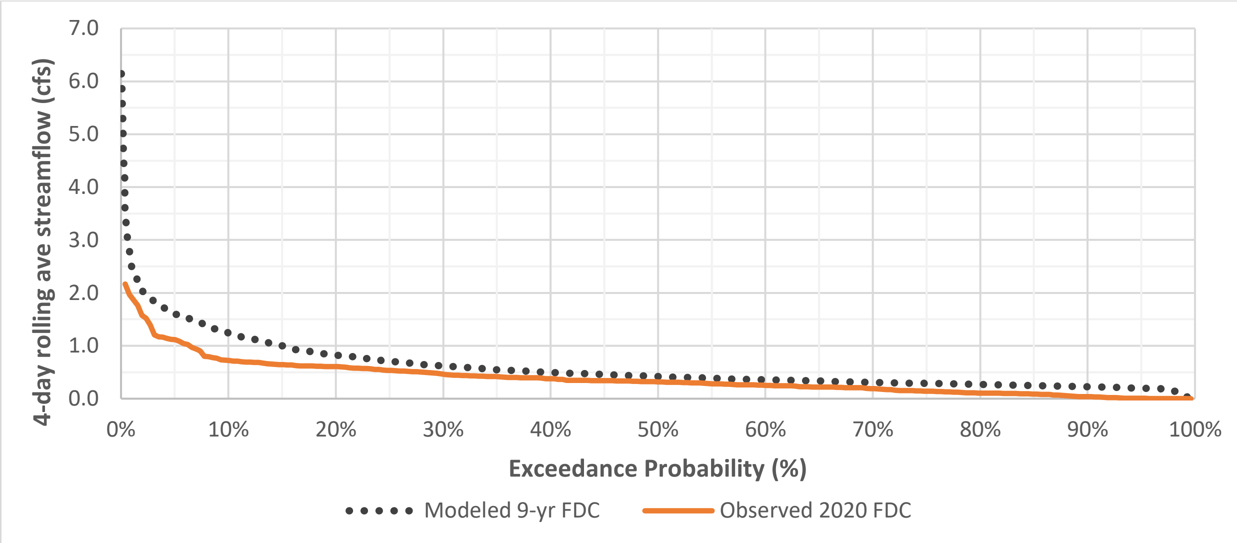

FIGURE 9: OBSERVED AND MODELED FLOW DURATION CURVES BASED ON FOUR-DAY AVERAGE STREAMFLOW.

Seasonality and Critical Conditions

Duration curves are useful for identifying patterns in water quality associated with seasonality as well as during critical streamflow conditions. Figure 10 shows chloride concentration for the period when flow data was collected, with observed daily average chloride concentration on the y-axis and the corresponding exceedance probability of daily streamflow for each day of the monitoring period. Note, exceedance percentiles here are relative to flow data collected at Sunnyside Brook from March 26, 2020, through December 10, 2020, and not the extended dataset used to derive the LDC. When plotted by season we see that exceedances of both the chronic and acute criteria occur in all seasons. Here spring is defined as March through April, summer June through August, and fall the remainder of the year. In the case of chloride in Sunnyside Brook, critical conditions are during low flows where the least dilution is available, resulting in the highest instream chloride concentrations. Figure 10 reflects this with a seasonal influence, where flows of lower exceedance probability (i.e., higher flows) diluting chloride and flows of higher exceedance probability (i.e., lower flows) produce higher chloride concentrations. As would be expected, spring flows in Vermont are generally higher and resulted in generally lower chloride concentrations; however, acute exceedances still occurred in spring. More exceedances were observed in the typically lower summer and fall flows, though there were several days with higher streamflow and chloride concentrations less than 860 mg/L.

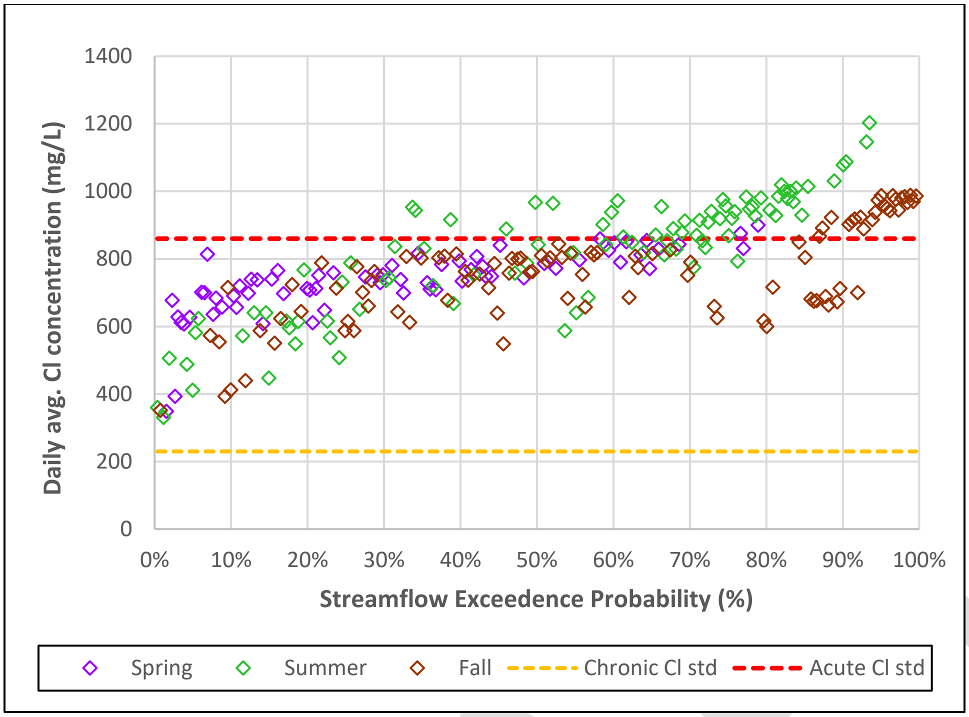

FIGURE 10: OBSERVED DAILY AVERAGE CHLORIDE CONCENTRATION FOR THE 2020 STREAMFLOW MONITORING PERIOD AT SUNNYSIDE BROOK. COLORS INDICATE SEASONS: MAR. - MAY = SPRING, JUN. - AUG. = SUMMER AND SEP. - NOV. = FALL. WINTER DATA ARE EXCLUDED AS THERE WERE NO CONCURRENT CHLORIDE AND STREAMFLOW MONITORING.

Load Duration Curve and Chloride Load Targets

The target LDC in Figure 11 was derived by multiplying each four-day average streamflow of our nine-year modeled dataset by 207 mg/L, or 90% of the chronic water quality standard for chloride. This 10% reduction in target chloride load represents an explicit margin of safety for this TMDL. Included in Figure 12 are actual four-day average chloride loads from the 2020 monitoring period, which are all well above the target LDC save for the lowest of streamflows (and therefore loads). A line of best fit through observed chloride loads can be used to quantify the percent reduction needed to meet the target load. Percent reductions are similar across all five flow conditions, ranging from 63% to 74%. These percent reductions are not the ultimate TMDL target, which is described below, but can be useful for understanding patterns, target certain flow conditions and guide implementation strategies.

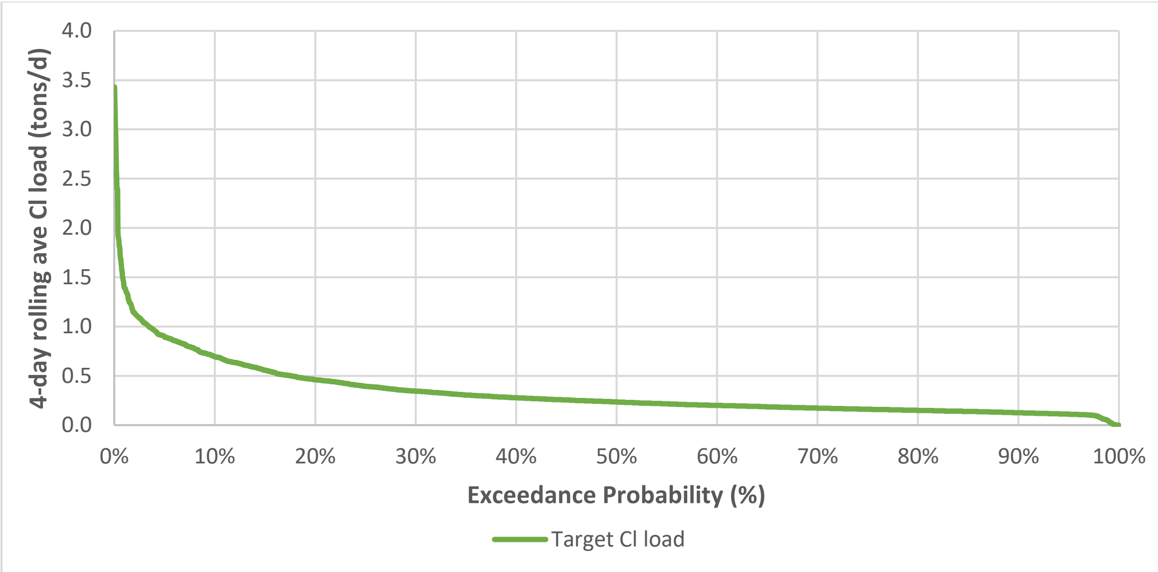

FIGURE 11: TARGET LOAD DURATION CURVE FOR SUNNYSIDE BROOK, DERIVED FROM FOUR-DAY ROLLING AVERAGE CHLORIDE LOADS BASED ON 90% OF THE VERMONT CHRONIC CHLORIDE WATER QUALITY STANDARD.

The source of chloride in the Sunnyside Brook watershed is almost entirely from deicing salts imported annually into the watershed and applied to the landscape during a specific portion of the year. Other typical chloride sources associated with either municipal or industrial wastewater are not relevant in Sunnyside Brook because the entire watershed is sewered and collected wastewater is treated and discharged outside the watershed. Our monitoring data show the impacts on instream water quality throughout the year, but it is the annual nature of deicing management that is the focus of target setting. The target of this TMDL is therefore the annual mass load of chloride that can be imported into the watershed, which our data suggest can still maintain water quality standards. This annual mass of chloride would remain within the stream's daily assimilative capacity.

The annual assimilative capacity is calculated by determining the area below the LDC. With arithmetically scaled axes, the area under the LDC is equal to the average of the daily chloride loads (or in this case, rolling 4-day average) used to construct the curve. Using our target chronic concentration of 207 mg/L with our streamflow dataset, the total mass chloride load for the 9-year period that meets the water quality standards was 1,100.5 tons. Dividing by the number of data points (i.e., days) that results in an average target loading of 0.3354 tons/day. To produce an annual target, we multiply by 365.25 days for a final TMDL of 122.5 tons of chloride per year. Because this approach uses streamflow at the watershed outlet this target load represents the mass of chloride leaving the watershed; however, for the TMDL it is assumed to equal mass of chloride imported into the watershed. This TMDL target is based on daily 4-day rolling average values used to construct the LDC as this is in-line with the applicable duration of the chronic water quality standard. The difference in results when compared to an analysis of 1-day average values is negligible, 122.4 tons per year versus 122.5 tons per year.

The most common deicing substance used in Vermont is rock salt, or NaCl. NaCl has a molar mass of 58.44 g/mol, 35.45 g/mol (60.7%) of which is chloride (NIH, 2022). This translates to an annual import target of 201.8 tons of rock salt. For a typical liquid deicing solution of 23% NaCl, or 2.3 lbs of NaCl per gallon of final solution (FWHA, 1996), the chloride target is equivalent to annual application of 175,478 gallons of deicing solution.

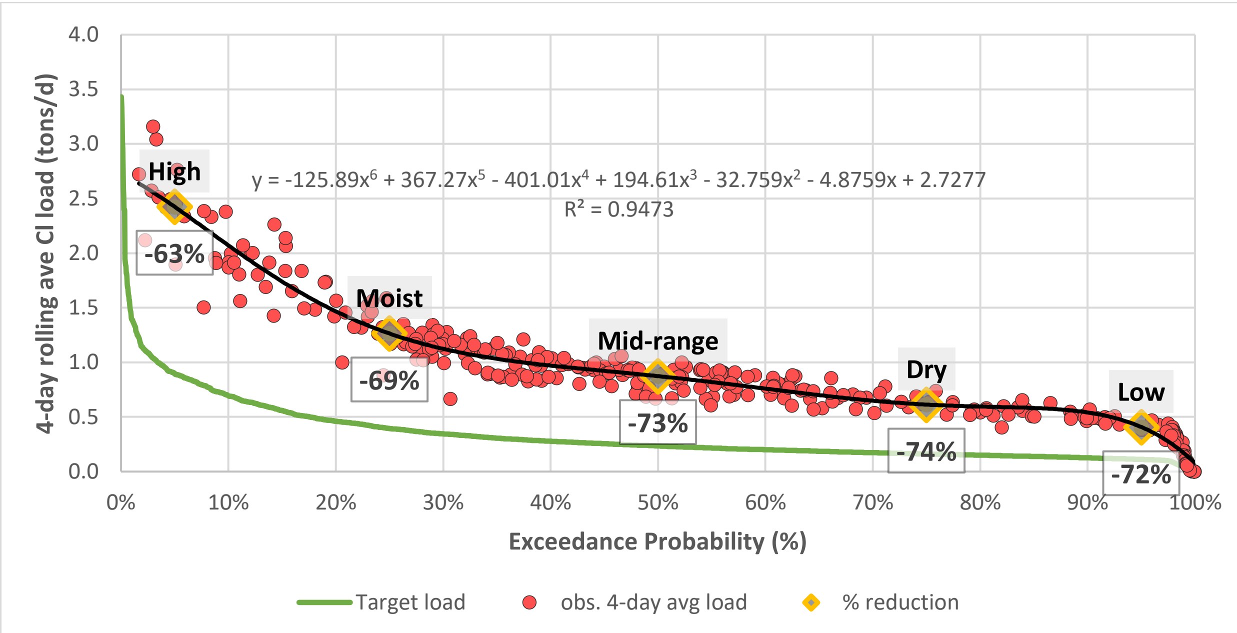

FIGURE 12: OBSERVED AND TARGET CHLORIDE LOAD DURATION CURVES FOR SUNNYSIDE BROOK BASED ON FOUR-DAY ROLLING AVERAGES, INCLUDING PERCENT REDUCTIONS CALCULATED FOR THE PERCENTILE MID-POINT OF THE HIGH, MOIST, MID-RANGE, DRY AND LOW STREAMFLOW CATEGORIES.

Summary of TMDL Development

The major tasks completed during the development of a chloride TMDL for Sunnyside Brook and detailed in this report are summarized below.

1) Confirm impairment via biomonitoring and Vermont Assessment and Listing process.

   Result: Non-support for EPT richness in 5 of 8 years of biomonitoring, including the last three in 2012, 2014, and 2020.

2) Conduct short-term conductivity and chloride monitoring to characterize continuous water quality conditions at Sunnyside Brook. Developed a regression equation to estimate chloride concentrations from continuous specific conductivity monitoring data.

   Result: A 15-minute in-stream specific conductivity time series from December 2019 – November 2020. Chloride concentration was above the acute standard 23% of the time and in 7 of the 12 months, and above the chronic standard 100% of the time.

3) Conduct short-term streamflow monitoring to characterize continuous hydrological conditions at Sunnyside Brook.

Result: A 15-minute time series of streamflow from April 2020 – November 2020. There is a negative relationship between streamflow and chloride concentrations, with the highest concentrations during low-flow periods, especially in the summer months.

4) Develop a long-term daily streamflow dataset to derive a representative chloride load duration curve (LDC).

   Result: Conducted a record extension via multiple linear regression with concurrent streamflow datasets at two nearby long-term gages. Resulted in a nine-year dataset of daily streamflow.

5) Multiply daily flows in the streamflow dataset by 90% of VT chronic chloride standard to establish a target load duration curve.

   Result: A daily dataset of target 4-day average chloride loads covering all seasons and streamflow conditions including critical conditions. For any 4-day average streamflow condition the applicable loading target meets VT Water Quality Standards.

6) Establish an annual chloride TMDL target by calculating the area under the target LDC.

   Result: An annual chloride TMDL target of 122.5 tons per year for the Sunnyside Brook watershed. Assumes imports of chloride equal exports of in-stream chloride loads for a given year.

TMDL Allocations

A TMDL is the amount of pollutant a waterbody can assimilate and still meet water quality standards. According to EPA regulations (CFR 130.2, 130.7), the TMDL must be assigned or allocated among regulated and non-regulated sources, according to the following equation:

$TMDL = \Sigma WLA + \Sigma LA + MOS$

Where:

WLA = Wasteload Allocation, which is the portion of the TMDL assigned to regulated or permitted sources.

LA = Load Allocation, which is the portion of the TMDL assigned to non-regulated sources

MOS = Margin of Safety

Each of the components of the TMDL is discussed in more detail below.

Margin of Safety

A margin of safety (MOS) is necessary to account for any uncertainty in the relation between pollutant loading rates and water quality. The MOS can be implicit or explicit. An implicit MOS is based on conservative assumptions used to determine the TMDL while an explicit MOS reserves a portion of the TMDL to the MOS.

The margin of safety provided for in this TMDL is an explicit 10% reduction in the estimated loading capacity. Based on the perceived variability in accuracy of TMDL development (flow record extension), future chloride accounting and tracking (recording how much chloride applied to surfaces in the watershed), and instream monitoring (conductivity/chloride relationship), a MOS of 10% is considered generous and appropriate. When developing the target LDC for Sunnyside Brook, 90% of the chronic chloride criterion, 207 mg/L, was used rather than the actual criterion of 230 mg/L. This effectively lowers the allocated chloride loading target and reserves 10% of the load as MOS. As an annual mass of chloride, this equates to 13.6 tons/yr.

Wasteload Allocation

EPA interprets 40 C.F.R. § 130.2(h) to mean that allocations for point source discharges subject to the NPDES permit program must be included in the WLA portion of the TMDL (Wayland and Hanlon, 2002). The NPDES program permits relevant to Sunnyside Brook are included above in the “Permitted Facilities” section.

The transport of chloride from anti-icing and de-icing agents spread throughout the watershed to Sunnyside Brook is driven by brief and intermittent rainstorm and snowmelt events and is highly variable in quantity from one event to the next. Monitoring chloride loading in stormwater runoff events is extremely difficult and resource intensive which makes it very difficult to assign loading limits from every pathway from which chloride is delivered to the stream. Because of these monitoring difficulties it was not technically feasible to separate the allocations for stormwater sources requiring NPDES permits from the allocations for other stormwater nonpoint and non-NPDES regulated point source categories based on land use. EPA guidance states that NPDES-regulated stormwater discharges may either be expressed as individual wasteload allocations (for each source, for example) or as a single categorical allocation for all NPDES-regulated stormwater discharges when data are insufficient to assign each source an individual wasteload allocation (Wayland and Hanlon, 2002; Sawyers and Best-Wong, 2014). The 2002 guidance also explains that stormwater discharges from stormwater point sources not currently subject to NPDES regulations may also be included in the wasteload allocation portion of a TMDL.

The NPDES stormwater-related chloride sources are aggregated into the WLA category of developed land sources because these are the only areas that receive anti-icing and deicing products (e.g., sidewalks, roads, driveways, parking lots). This category also includes runoff from non-NPDES regulated point source and nonpoint sources such as residential areas since it is not technically feasible to distinguish loads among the various sources and accurately separate the allocations into WLAs and LAs. Additionally, some stormwater discharges from developed land may in the future become subject to NPDES permits (through the exercise of residual designation, for example), and including the loads within the WLA now is reasonable and consistent with EPA’s guidance discussed above.

The overall WLA for Sunnyside Brook is 122.5 tons of chloride per year. For practical purposes, the WLA is presented based on mapped areas that tend to receive de-icing salt such as roads and parking areas. This breakdown is given as the relative proportion of de-iced surfaces as shown in Table 4. Some categories can be identified and defined by a single permitted entity such as state roads (TS4) and municipal roads (MS4). Other categories have not been further defined at this time such as private roads or other paved areas such as parking lots.

TABLE 5. DISTRIBUTION OF WASTELOAD ALLOCATION AMONG DE-ICED SURFACES

Impervious Surface Type	Area (acres)	Area (% of de-iced surfaces)	Chloride – as % of total de-iced area (tons/yr)	NaCl Equivalent of chloride (tons/yr)
All Roads	**20.9**	**24**	**28.9**	**47.5**
State roads	11.5	13	15.9	26.2
Municipal roads	*6.3*	*7*	*8.7*	*14.3*
Private roads	*0.5*	*1*	*0.7*	*1.1*
US Army road	*2.6*	*3*	*3.6*	*5.9*
Other Paved	***67.8***	***76***	**93.6**	**154.3**
Total	***88.7***	***100***	**122.5**	**201.8**

Load Allocation

Based on the discussion above, no Load Allocations are provided for in this TMDL.

TMDLs Expressed as Daily Loads

Though the chloride target is presented as an annual mass, the maximum daily load that meets water quality standards can be determined for any given day from the LDC and the 4-day rolling average streamflow for that day. For example, our FDC shows that a day with a 4-day rolling average streamflow of 0.29 cfs has an exceedance probability of 75-percent which is the mid-point of the “dry” hydrologic condition category. The LDC can then be used to show that the maximum daily load of chloride that is within the assimilative capacity of the stream in this dry condition is 0.16 tons, including the margin of safety.

TMDL Summary

According to USEPA TMDL guidance, the components of a TMDL are contained within the equation:

$$TMDL = \Sigma WLA + \Sigma LA + MOS$$

In this equation, the “TMDL” term is the maximum loading capacity to the waterbody since it includes the MOS. The allocation terms, WLA and LA, are the only part of the chloride loading capacity that can be applied to the watershed while still maintaining the MOS set-aside.

For the purposes of this TMDL, the daily expression of the TMDL has been described above, however, a more practical way of describing the TMDL is on an annual basis of gross annual tonnage (tons/yr.) of chloride as expressed below:

$$136.1 = 122.5 + 0 + 13.6$$

Assuming that all chloride is derived from de-icing salt, and all deicing salt is road salt (sodium chloride), the TMDL equation can be expressed in term of gross tonnage of road salt:

224.2 = 201.8 + 0 + 22.4

TMDL Implementation

The application of chloride-based materials such as road salt and brine are the primary means of preventing icy conditions and deicing roadways, parking lots and sidewalks throughout Vermont. VTrans (Vermont Transportation Agency), town municipalities, and some proportion of commercial operations and residents apply chloride-based products to provide an economical solution for winter safety. These products are ubiquitous where paved surfaces are found, and therefore with this level of usage, are often found at elevated levels in surface waters across the state.

Sunnyside Brook is not unique in that it contains elevated levels of chloride, although its levels show that it is consistently elevated to such a degree that its impaired, other streams have similar chloride problems. In all cases, however, the source of excessive chloride and even impairment in some streams, all likely stem from the same source, the application of chloride-based materials used for winter safety.

Since chloride is a "conservative" substance in that does not form complexes under most groundwater conditions, is not sorbed onto mineral surfaces, and is not involved in many significant biochemical reactions so therefore flows, largely unmitigated, to surface water. Because of its conservative nature, traditional stormwater runoff practices required through the various impervious runoff permits designed to reduce sediment and nutrients are generally ineffective at reducing chloride either in runoff or groundwater. Therefore, VTDEC envisions the solution to the significant impacts of chloride on surface waters will be through source reduction actions rather than by runoff treatment via infrastructure investments.

At the time of this TMDL development, no new mandatory chloride control measures or permits are proposed. As with other TMDLs in Vermont, loading targets are first set before the appropriate remediation/implementation measures can be sought.

Current Permits

Applicable discharge permits in the Sunnyside Brook watershed that relate to chloride discharges associated with deicing practices include the Municipal Separate Storm Sewer System (MS4) and the Transportation Separate Storm Sewer System (TS4) general permits. Since these are general permits, conditions apply to all areas subject to these permits where they have been issued across the state.

MS4 General Permit, Town of Colchester

As stated in the 2018 MS4 General Permit 3-9014, and as stated unchanged in the 2023 MS4 permit, for discharges to impaired waters with and approved TMDL, the permittee shall control discharges consistent with the assumptions and requirements of any wasteload allocation (WLA) applicable to the permittee in the TMDL. Also, the permittee shall describe in the Storm Water Management Plan (SWMP) all measures that are being used to address this requirement.

To comply with similar requirements with discharges to impaired waters prior to TMDL development, the Town of Colchester has developed and submitted to VTDEC chloride response plans in its SWMP.

TS4 General Permit, VTrans

As stated in the General Permit 3-9007 for Stormwater Discharges from the State Transportation Separate Storm Sewer System (TS4), for any discharge from the TS4 to impaired waters with an approved TMDL, VTrans shall control discharges consistent with the assumptions and requirements of any wasteload allocation (WLA) applicable to VTrans in the TMDL. VTrans shall describe in the Storm Water Management Plan (SWMP) all measures that are being used to address this requirement.

To comply with similar requirements with discharges to impaired waters prior to TMDL development, VTrans has developed and submitted to VTDEC chloride response plans in its SWMP.

Since the 2021-2022 winter season, VTrans has employed truck-based GPS technology linked to salt and brine dispersal to record the amounts of chloride-based products it spreads on its roadways in the Sunnyside Brook watershed. This system provides an accurate accounting of salt application in the watershed and is used to calculate the mass of chloride that is dispersed in a given season and tracked from year to year.

Implementation Gaps

Chloride Application Accounting

The primary information gap to better understand the magnitude of chloride impacts is the lack of accounting for chloride applied in the watershed by the various entities using it. As noted above, VTrans has recently employed salt application accounting technologies which account for approximately 55% of the roads and 13% of all paved areas in the watershed. However, for other salt applicators such as the Town of Colchester, commercial operations, residents, and Camp Johnson, the mass of chloride applied is unknown. With a better understanding of the source excess chloride usage related to water quality conditions, better targeted reductions strategies can be employed. Additionally, a better accounting of salt usage in the watershed would allow a better understanding of the timing between application and resultant instream conditions, interannual variability, and tracking reductions toward the TMDL target and ultimate stream recovery.

Reduction Strategies

While some of the paved areas in the watershed fall under either of the two permits described above (20% of total paved) where there is some level of chloride reduction planning required, the vast majority (80%) of the paved area falls outside the jurisdiction of these permits. There currently is a lack of sufficient incentivization of non-MS4 and TS4 sectors to decrease chloride application in Sunnyside Brook or in other impacted watersheds.

Water Quality Monitoring

To track impairment status of the aquatic biota condition and to track chloride reduction impacts in Sunnyside Brook, two types of stream monitoring are essential, both chemical and biological.

Chemical monitoring for chloride would likely consist of deployment of an instream, continuous conductivity sensor and data logger to track short frequency values (15 minute to 1 hour) over the course of several weeks or months. The conductivity data can be converted to chloride concentrations using a site-specific regression equation as used in the 2020 study. The critical period for Sunnyside Brook appears to be low flow conditions in late-summer and fall so deployment of a sensor in that time of year gives the best indication of critical condition chloride concentrations. However, until there is reason to believe a change in chloride loading to the brook is occurring, resources are not available at VTDEC to perform continuous monitoring. When a chloride reduction strategy is developed and implemented in the watershed, a robust monitoring plan can be developed to track resultant conditions in the stream.

Biological monitoring is the method that will ultimately detail a full recovery of the stream. This is a direct measure of the biological community present in the stream performed according to standard procedures that define whether the aquatic biota use is impaired or in attainment. Currently Sunnyside Brook is not a high priority for ongoing biological monitoring. Like chemical monitoring, when there is evidence of substantial and consistent chloride reduction efforts implemented in the watershed, a higher prioritization to initiate biomonitoring will occur.

Public Participation

[Documentation of public notification, informational meetings, comment solicitation and comment responses will be summarized in this section following the 30-day public comment period, prior to submittal to EPA for final approval.]

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