Final Report

Maine Smart Chloride System

Thomas P. Ballestero

Daniel Macadam

University of New Hampshire Stormwater Center

1 August 2024

Executive Summary

Winter road maintenance introduces salt into the environment and in some locations the salt runoff pushes stream chloride concentrations to exceed acute and/or chronic water quality standards. A strategy to possibly avoid these water quality violations while continuing to use road salt is to store the road runoff and slowly let it out to receiving waters: the Smart Chloride System. Eleven ME DOT locations were initially investigated to numerically apply this strategy. Three were selected to move forward with field monitoring and numerical modeling. The three sites were: South Berwick Route 236, northbound I95 Visitor Center in Kittery, and South Hampden Route 1A.

Monitoring began June 2023 and concluded June 2024. Monitoring results show that winter road runoff routinely exceeds 2000 mg/l chloride concentration. The South Berwick and South Hampden sites both had very low ambient chloride concentrations and sufficient flow to limit exceedances of water quality criteria for the monitoring period. Both sites demonstrated higher ambient chloride concentrations in the non-winter months (when there is more groundwater inflow to streams) than in the winter months, indicating that the groundwater possesses high chloride content. For these two sites, generally the influent chloride concentration was less than the downstream concentration for the entire monitoring period. The Kittery site had I95 upstream and therefore had higher inflowing chloride concentration than outflow from the site for the entire monitoring period.

USEPA chloride criteria exist for acute and chronic concentrations. The acute concentration is that the 1-hour average chloride concentration does not exceed 830 mg/l more frequently than once every three years on the average. The chronic criteria is that the four-day average chloride concentration not exceed 230 mg/l.

The USEPA SWMM model was used to model the runoff and chloride concentration at each site. Each site was subdivided into subwatersheds. Soil and land use characteristics were downloaded from online databases. NOAA weather observations for stations closest to each site were downloaded and the period 2012 to 2023 modeled for each site (runoff, snow depth, and snowmelt). The model results demonstrated that there was no need for the Smart Chloride System at South Berwick or South Hampden because these sites already met the criteria. Employing a Smart Chloride Strategy at these sites causes the sites to fail the criteria. This is because the salt laden runoff is extended over longer periods of time thereby increasing the 1-hour and 4-day average concentrations compared to doing nothing. The Smart Chloride System did not work at the Kittery site either.

Instead of storing salt-laden runoff, another strategy was to use a source of dilution when the salt runoff occurs. Since the South Berwick and South Hampden sites already meet the criteria, a dilution strategy will be successful at those sites. At the Kittery site, dilution flows of 2,000 to 5,000 gpm would be capable of site runoff meeting criteria. It is recognized that this is a very large flowrate and may not be practical.

Table of Contents

Table of Figures

Table of Tables

Introduction and Objective

Winter maintenance of Maine DOT transportation surfaces conventionally uses plowing and salt. This maintenance is important to provide the expected level of safety. Salt is contributing to impairments in Maine's receiving waters and as such, in lieu of salt reduction or salt substitution strategies, metering out salt laden runoff to receiving streams when streams are better able to dilute the salt load is one possible strategy to minimize acute and chronic chloride concentrations (the Smart Chloride Mitigation strategy). The physical way of doing this is to contain (store) saltwater runoff while monitoring both streamflow and stream salt concentration. Then allow the stored salty water to be metered out to the stream such that the fully mixed concentration is well below a target chloride concentration. Prior to specifying and designing a physical system to do this form of stormwater management, a modeling approach is proposed to assess details such as the volume of storage necessary, ambient stream salt concentrations, and real time winter melt. In Maine, there are few sites where stream conductivity is measured year-round. One objective of this study is to perform monitoring at ME DOT sites to understand salt runoff and how it impacts receiving streams.

The next project objective is to numerically model the monitored sites to understand the feasibility of the Smart Chloride Mitigation strategy and estimate how the strategy performs over a long period of record. This then will inform on the practicality of the strategy.

Site Selection

The first fundamental effort was to select sites that would be suitable for this study. ME DOT locations were selected, with the following desirable characteristics:

- Sites should be in watersheds smaller than 5 square miles in size
- Sites need to drain to a perennial stream (in order to affect runoff conductivity)
- Sites should be in watersheds with less than 10% total impervious cover
- Sites should be the dominant impervious area in the watershed (in order that offsite salt use does not obviate the ability for the Smart Chloride strategy)
- Sites should have closed drainage systems

Initially, nine sites were suggested by ME DOT. These sites, and some of the characteristics of those sites, may be found in Table 1.

Table 1: Sites Investigated to be Included in This Study

Site Name	ME DOT Characteristics	Watershed Area (sq. mi.)	Watershed % Imperviousness	Watershed % Developed	Receiving Stream
Gardiner, ME	MTA Rest Stop				
Hampden North	Route 1A	2.8	30.7	68.9	Unnamed tributary to the Penobscot R.
Hampden South	Route 1A	1.87	2.5	10.7	Reeds Brook
Kennebunk	I95 Rest Stop	0.33			
Kittery	I95 Rest Stop	0.35			Libby Brook
Portland	Park and Ride	0.08	51.1	100	Unnamed tributary to Long Creek
South Berwick	Route 236	2.1	5.2	20.5	Driscoll Brook
Farmingdale North	Route 201	2.1	6.5	29.4	Unnamed Brook, tributary to the Kennebec River
Farmingdale South	Route 201	1.4	6.3	22.9	Unnamed Brook, tributary to the Kennebec River

The MTA rest stop in Gardiner, ME was removed from consideration after some initial discussions with MTA that indicated an unwillingness to collaborate in the project. The Hampden North, and Portland sites were removed from consideration due to the very high watershed development and percent impervious cover: if there were to be other sources of chloride in watersheds, this would limit the amount of dilution possible in the receiving stream. The Kennebunk rest stop site had recently been renovated, including its stormwater management. In addition, it was not close enough to a perennial stream to afford winter dilution and was not considered further. Both Farmingdale North and Farmingdale South had a large section of I295 in their headwaters. Farmingdale North had various other local roads in its watershed. Due to concerns of other chloride sources, both Farmingdale sites were removed from further consideration.

Selected Site Descriptions

Site 1: Kittery I95 Rest Stop

Figure 1 depicts the watershed delineation of Libby Brook at the Kittery site from the downstream monitoring location 4. Figure 2 displays an aerial image of the Kittery field site and the monitoring locations. Diagonally on the left of the figure is I95.

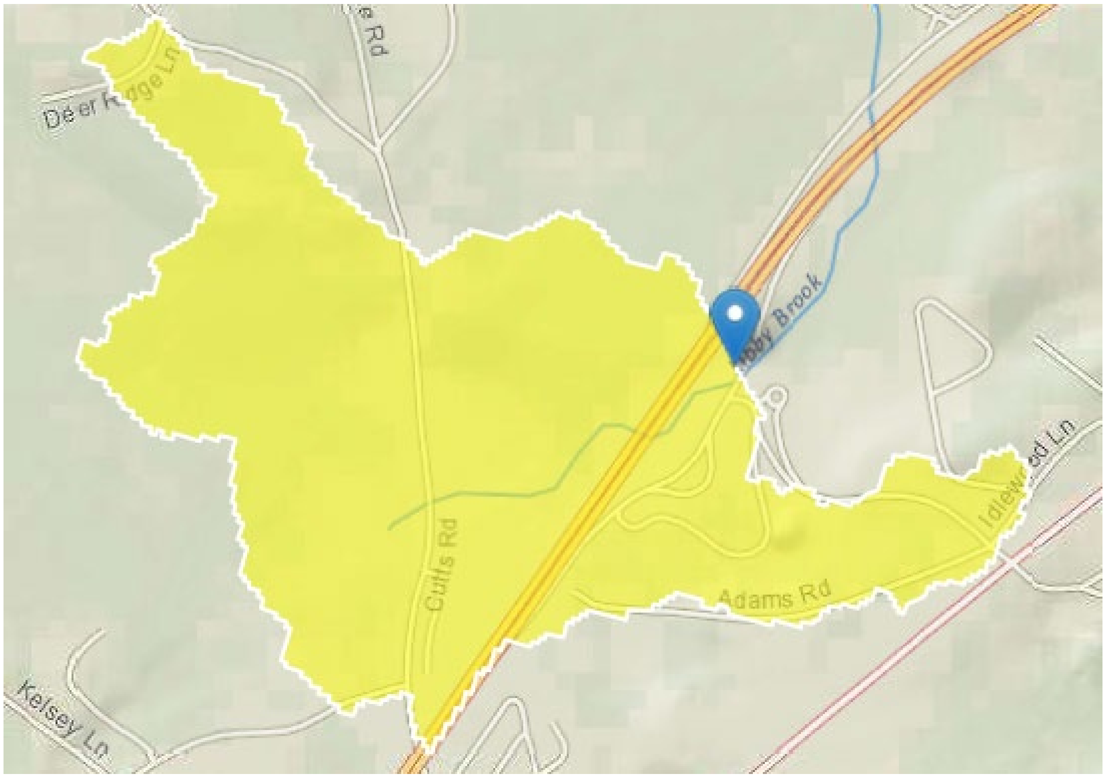

Figure 1: Watershed delineation to the downstream monitoring location Kittery site 4 (StreamStats).

In Figure 1, Libby Brook flows under I95 from the west to a swale. That swale then flows through a culvert under an entrance ramp (from Route 1) to the rest area. Kittery monitoring location 1 is just upstream of that culvert, in a wetland pool. Downstream of the entire site is monitoring location 4 in Libby Brook in the pool created by the culvert scour. During the monitoring period, the upstream location ceased to flow in the summer and winter. Location 4 flowed perennially.

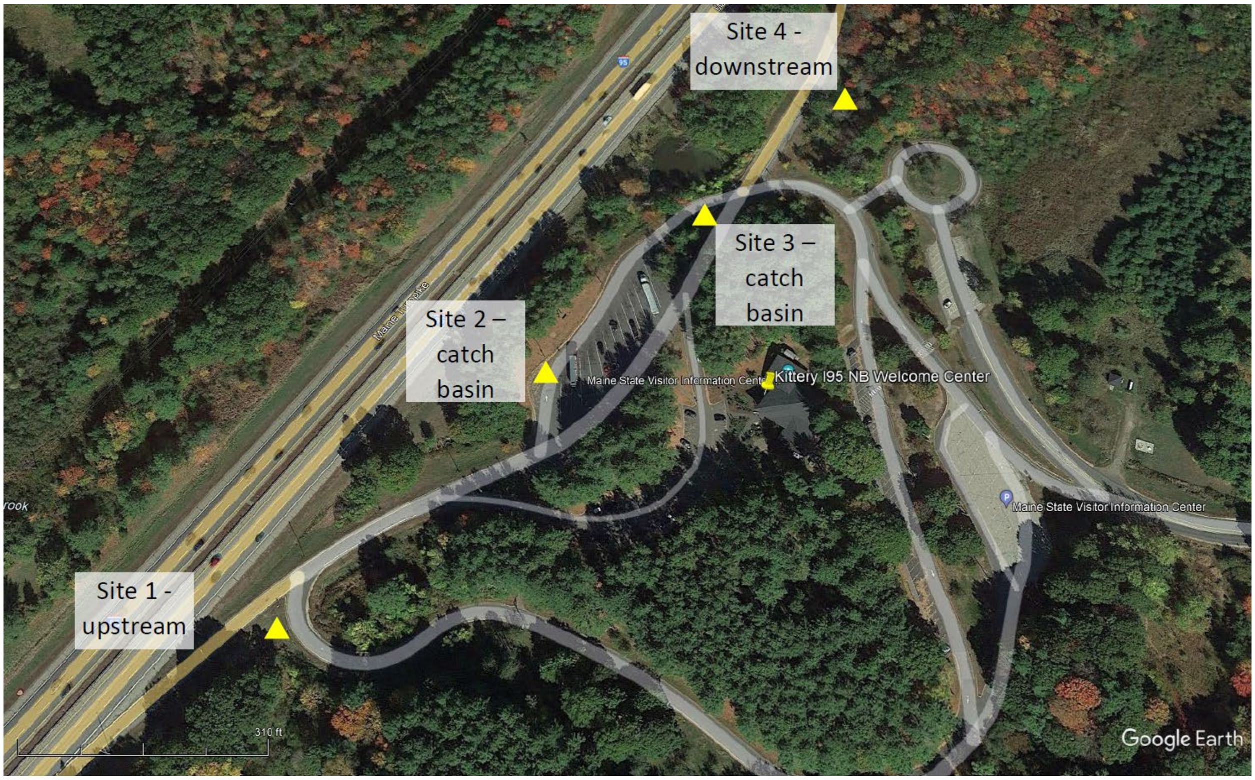

Figure 2: Kittery study site and monitoring locations

Kittery monitoring locations 2 and 3 were both located in closed drainage, inline basin catch basins: location 2 captured primarily parking lot runoff and location 3 captured primarily runoff from parking lot exit lanes.

Figure 3 depicts the closed drainage systems at the Kittery site and where the monitoring locations existed along those closed drainage systems.

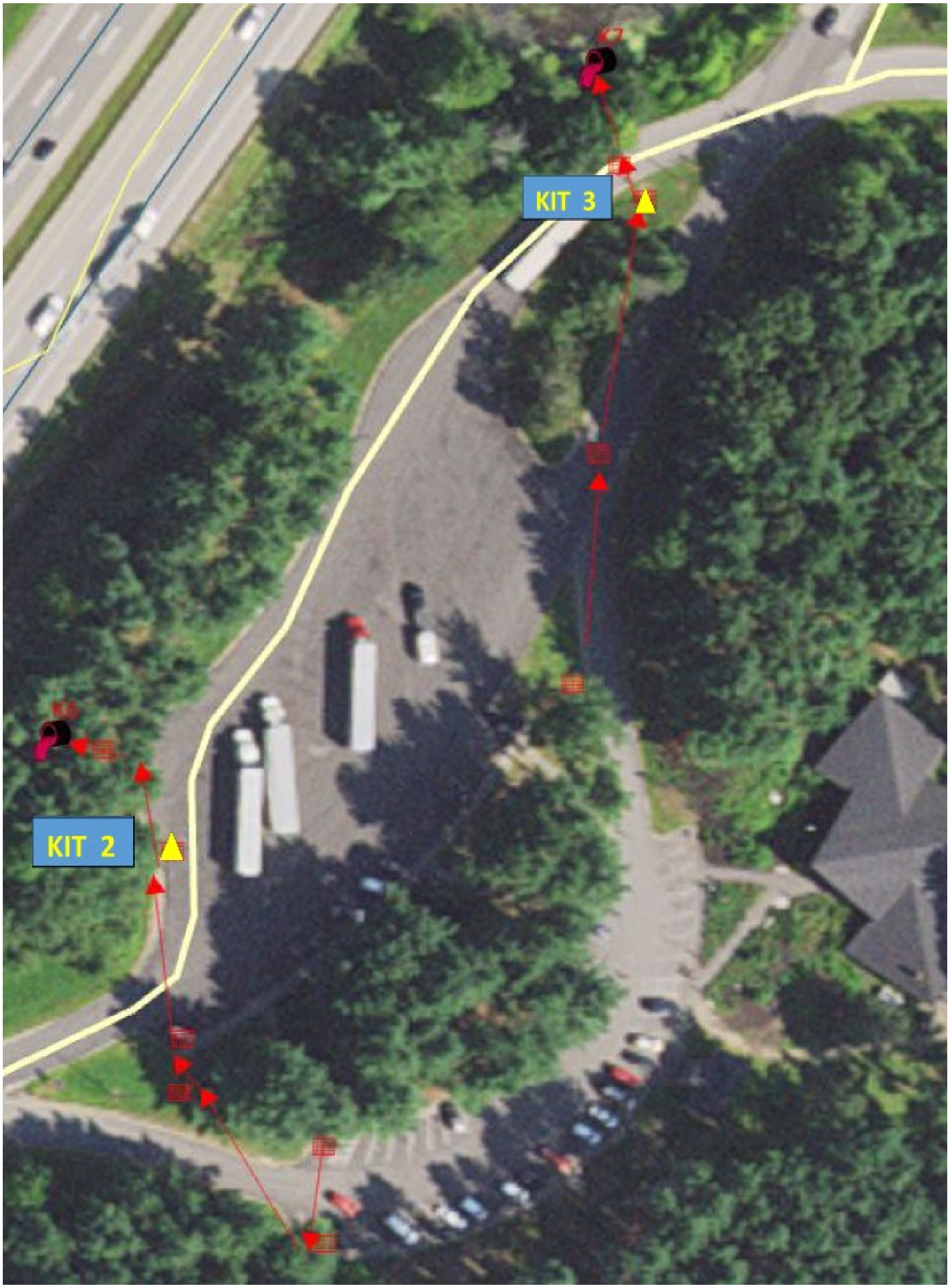

Figure 3: Kittery onsite closed drainage systems (red lines)

Site 2: South Berwick

The South Berwick site captures runoff from residential areas and state route 236 (Figure 4). Driscoll Brook flows from east to west under Route 236 before flowing into the Salmon Falls River (Figure 5): the upstream monitoring location (1) is next to the South Berwick Water District building and the downstream location (3) is approximately 50 feet downst6ream from the route 236 culvert. South Berwick monitoring location 2 is at the end of the closed, inline drainage system on the north side of route 236 (Figure 6), just before the system daylights to a swale. During the monitoring period, the closed drainage system was not always flowing. Driscoll Brook is a perennial stream.

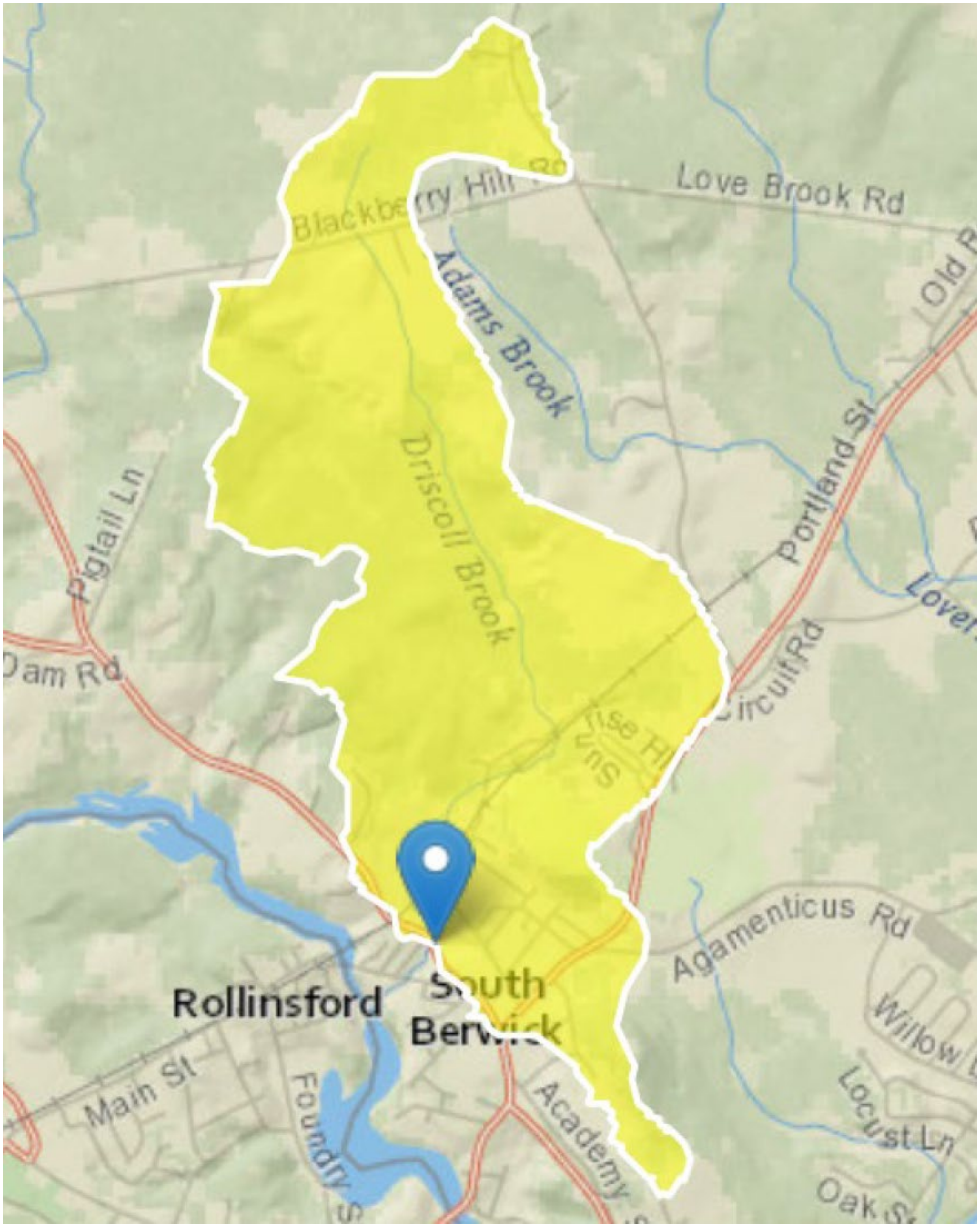

Figure 4: Driscoll Brook watershed delineation to the downstream monitoring location for the South Berwick site (StreamStats)

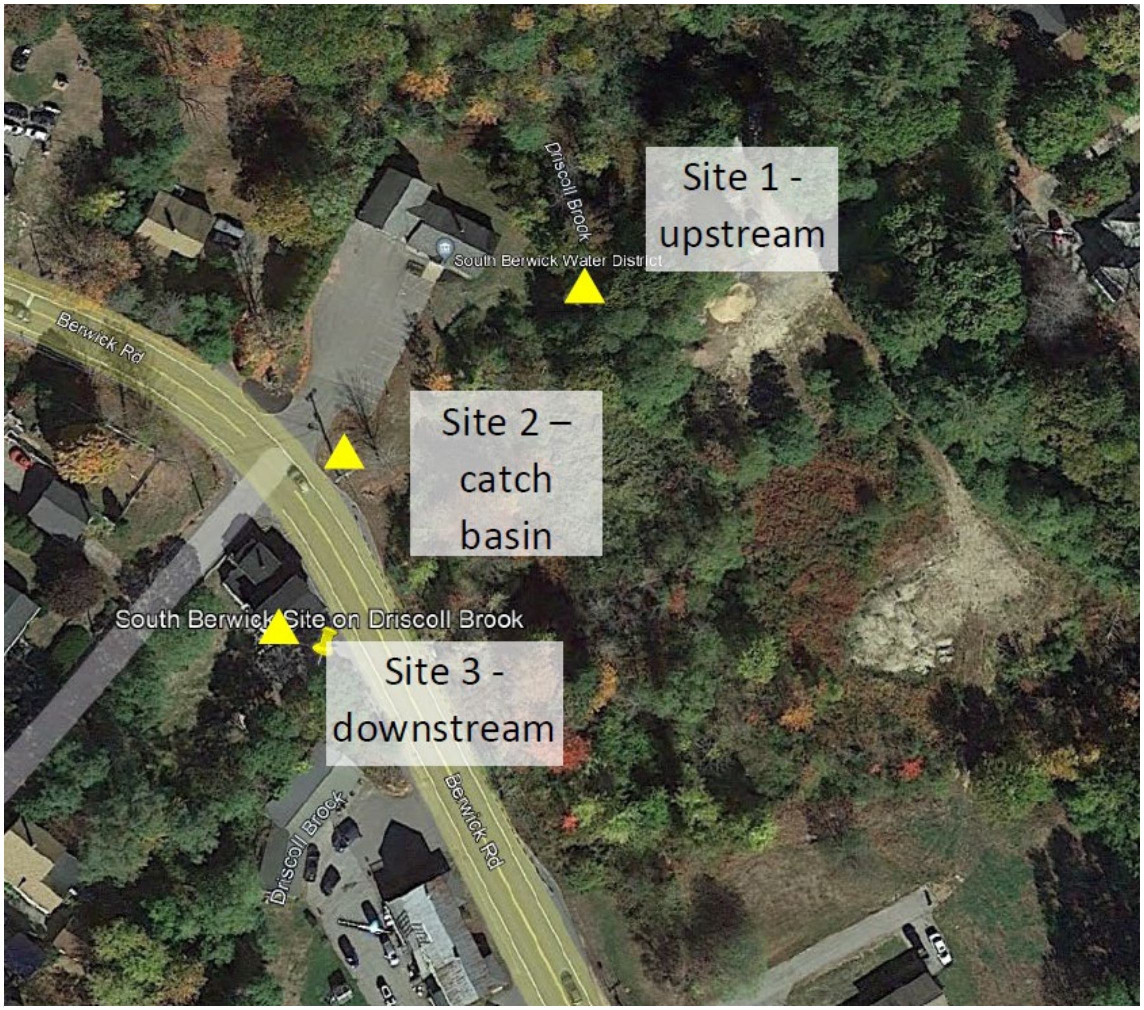

Figure 5: South Berwick monitoring locations.

Figure 6: South Berwick closed drainage system (red lines) along route 236.

Site 3: South Hampden

The South Hampden site resides on Reeds Brook. The watershed delineation to the downstream monitoring location may be found in Figure 7 and the monitoring locations in Figure 8. Monitoring location 2 is in a catch basin at the end of a long, closed, inline drainage system along the west side of route 1A (Figure 9). This catch basin flows to a pipe whose end sits about 5 feet above Reeds Brook. The upstream monitoring location (1) is approximately 60 feet upstream of route 1A. The downstream monitoring location (3) is immediately at the upstream culvert face.

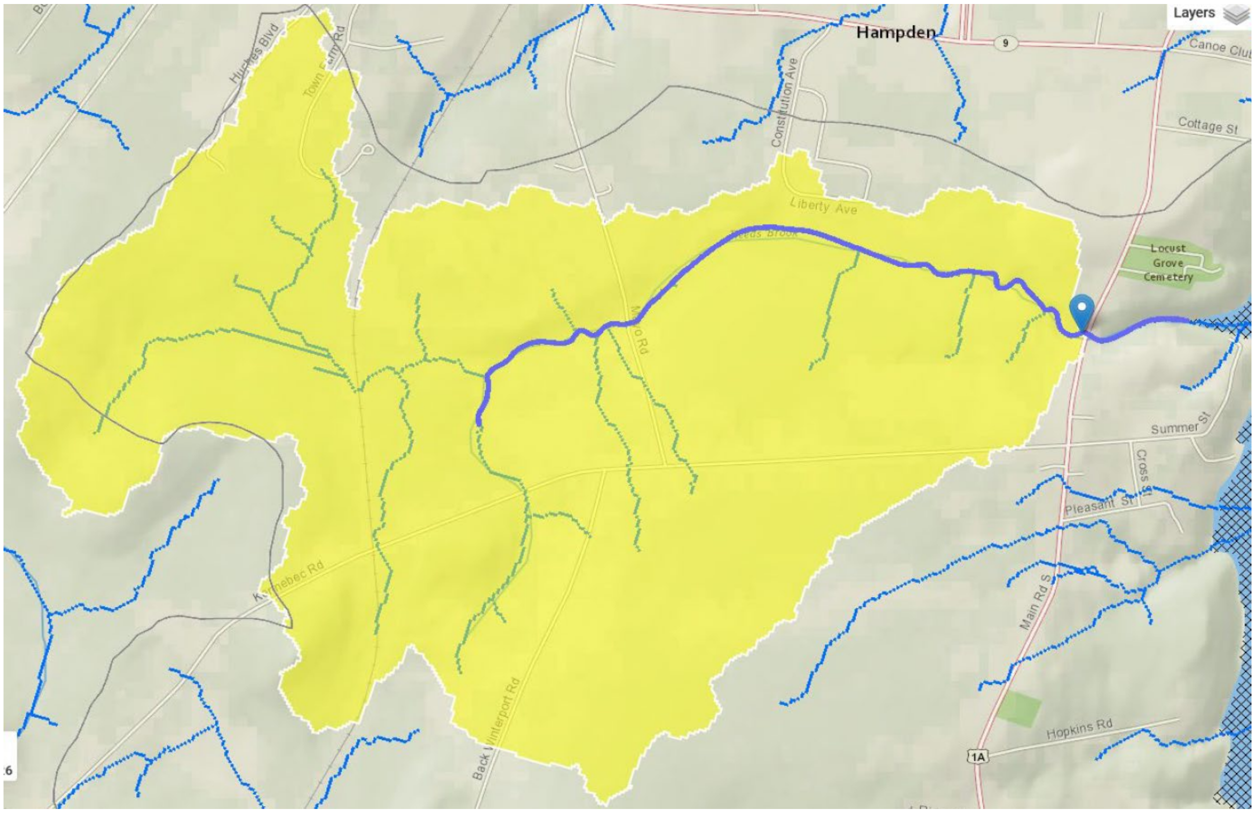

Figure 7: Reeds Brook watershed delineated to the downstream monitoring location for the South Hampden site (StreamStats)

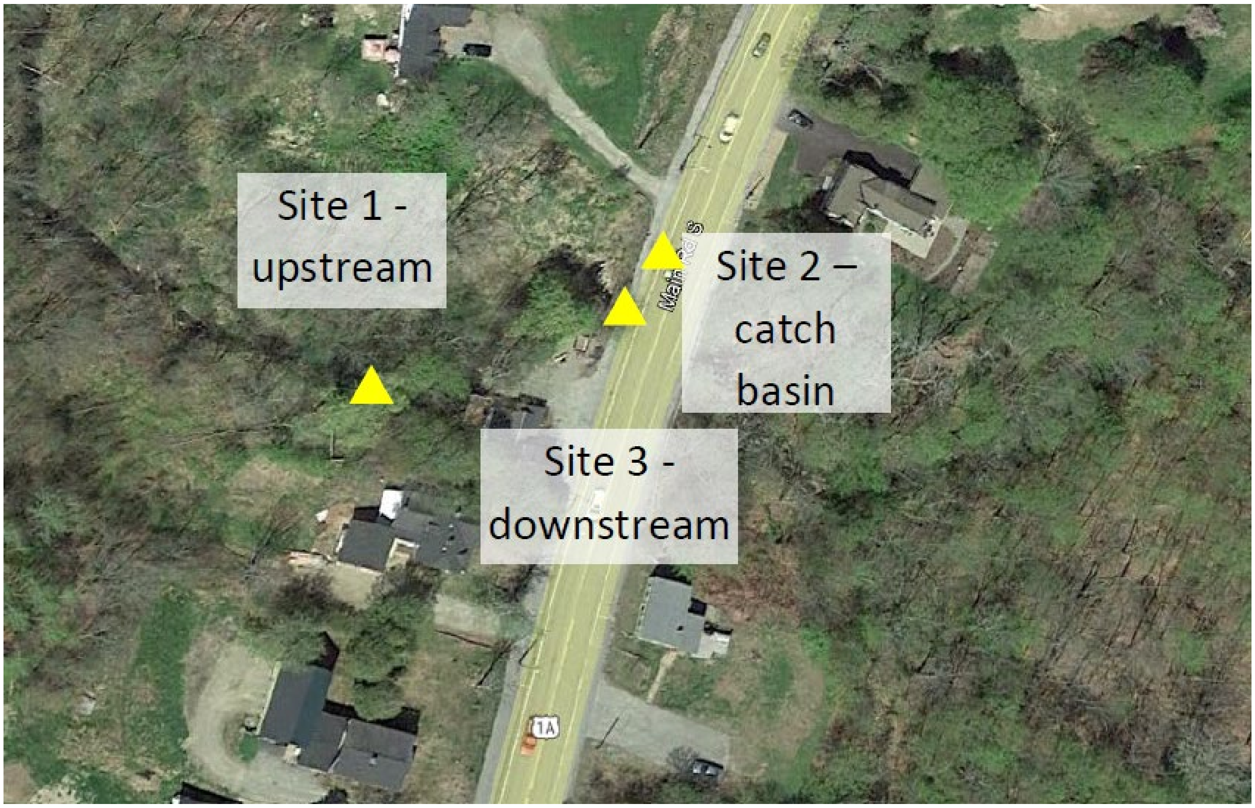

Figure 8: South Hamden monitoring locations

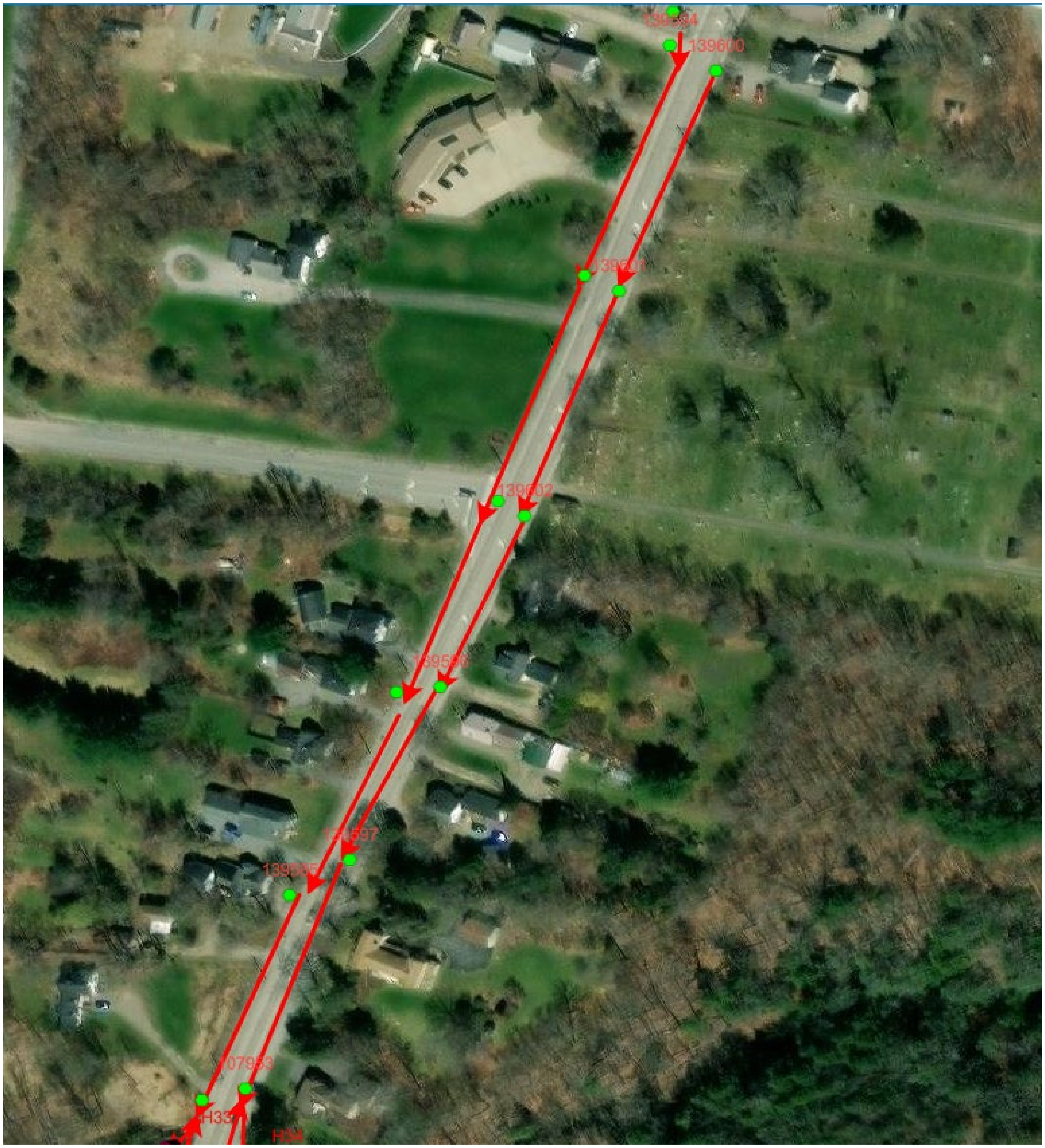

Figure 9: South Hamden closed, inline drainage system (red lines). Monitoring location 2 is at the manhole (green dot) in the lower lefthand of the figure.

Field Data Description

In order to estimate dissolved chloride concentration, HOBO conductivity probes were used (HOBO Fresh Water Conductivity Data Logger U24-001) which measure high (0 to 10,000 µS/cm) and low (0 to 1,000 µS/cm) range conductivity as well as temperature. The loggers were programmed to take a reading every 5 minutes which allowed them to continuously log data for 42 days before needing to be downloaded. The relationship between chloride concentration and specific conductivity is generally nearly linear. For the purposes of this study, the relationship is assumed to be: chloride concentration (mg/L) = 0.5 times conductivity (µS/cm).

At the Kittery and South Berwick sites, water levels were measured with HOBO water level loggers (HOBO Water Level Data Logger – U20L-04), which have a range of 0 to 13 feet. These dataloggers were also programmed to take a reading every 5 minutes at the same time as the conductivity reading. These loggers could last 72 days before needing to be downloaded. Because the water level loggers measure absolute pressures, one probe was located on the ground at the Kittery site to act as a barometer. The difference between the water level reading and the barometer is the actual depth of water over the logger.

In the streams, the loggers were lashed inside of a cinderblock and submerged in a pool. In the catch basins, the loggers were hung from strings attached to the catch basin grate, with the logger submerged in the catch basin sump.

Site 1: South Berwick Site

The South Berwick site data has some gaps when equipment was out of the water due to high water conditions that moved the upstream cinderblocks out of the water. For one monitoring period, the catch basin logger failed to record data. Figures 10 and 11 display time series plots of South Berwick conductivity (mg/l) for the monitoring period. Figure 10 includes the upstream and downstream monitoring locations and Figure 11 includes data for the catch basin. In these figures, the USEPA acute and chronic water quality criteria are included: the acute level is 830 mg/l and the chronic is 230 mg/l. The acute criteria is specifically that, "the one-hour average concentration does not exceed 830 mg/l more than once every three years on the average." The chronic criteria is specifically that, "the four-day average concentration of dissolved chloride, when associated with sodium, does not exceed 230 mg/l more than once every three years on the average."[1]

[1] USEPA, 1988, AMBIENT WATER QUALITY CRITERIA FOR CHLORIDE – 1988: OFFICE OF WATER REGULATIONS AND STANDARDS, CRITERIA AND STANDARDS DIVISION, WASHINGTON, DC, EPA 440/5-88-001, P. 8

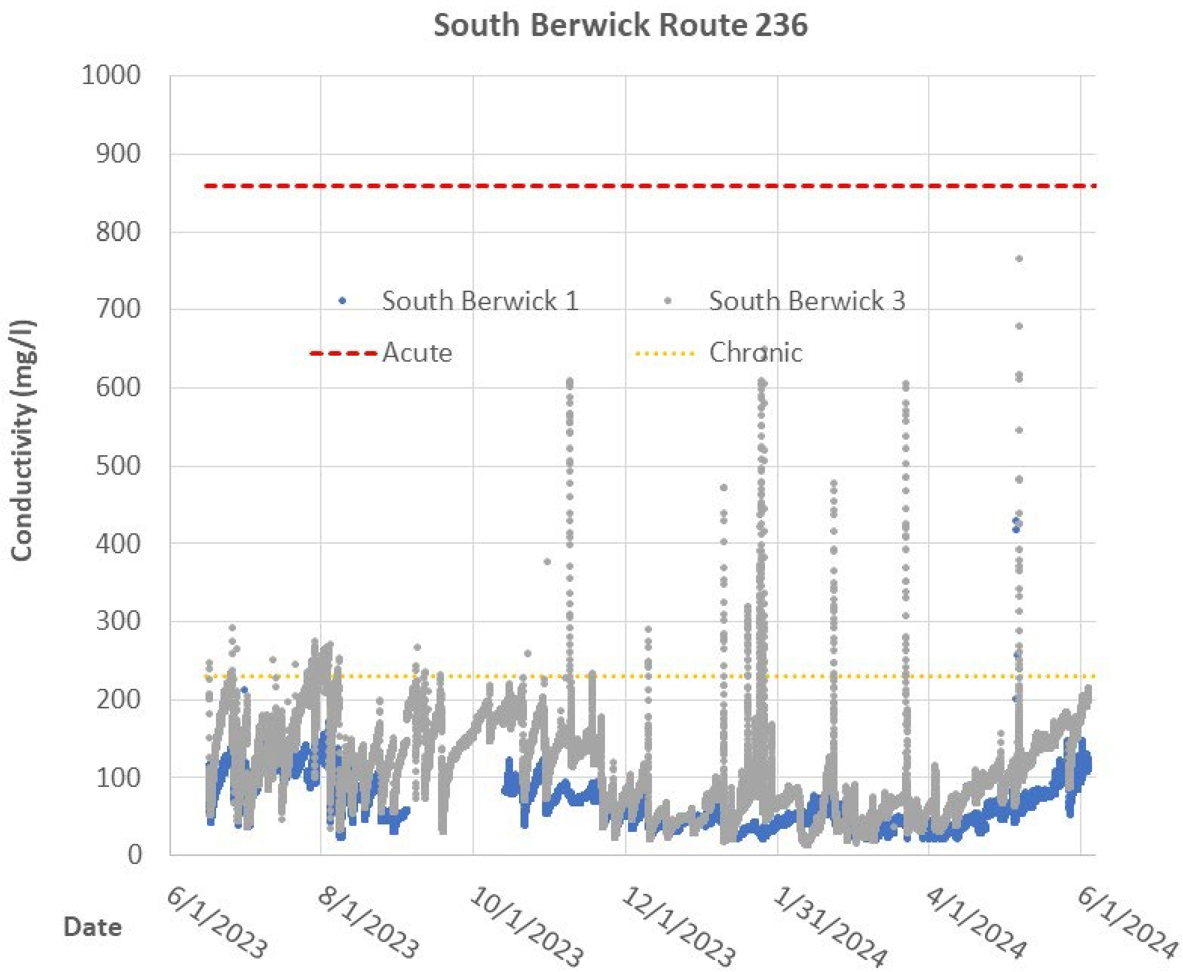

Figure 10: South Berwick upstream and downstream conductivity data for the monitoring period.

As is evident from Figure 10, stream conductivities are highest in the warmer months and lower in the winter months away from winter maintenance events. In general, the upstream conductivity is lower than the downstream conductivity.

Figure 11shows that the catch basin reflects high conductivities, with the highest peaks in the winter maintenance season.

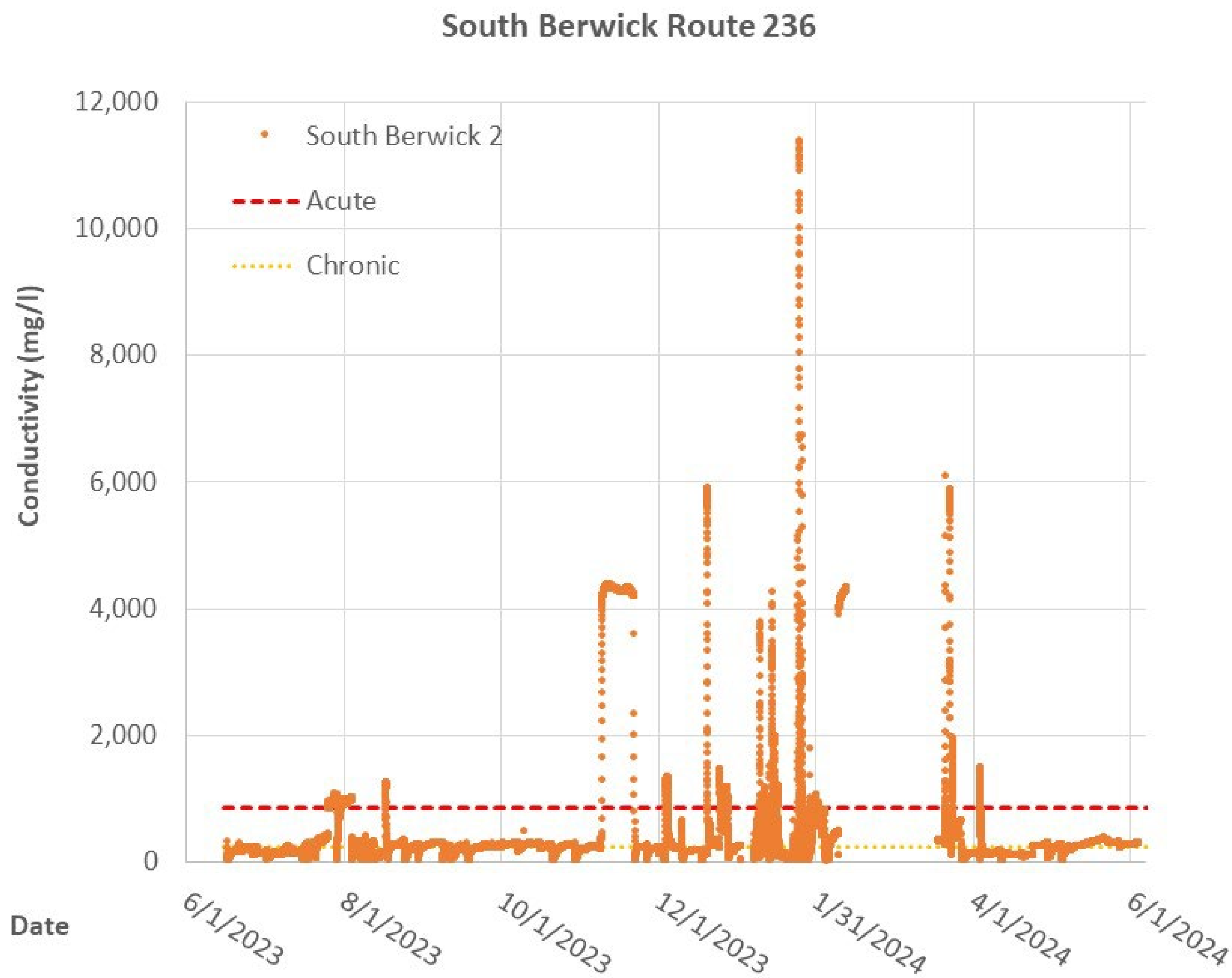

Figure 11: South Berwick catch basin conductivity for the monitoring period.

Figures 12 and 13 take the transformed (temporally average) stream data and compare the averages to acute (Figure 12) and chronic (Figure 13) criteria. Note that the vertical scales are logarithmic in order to enhance the range of the data. The Smart Chloride strategy would seem to have have potential at the South Berwick site in the winter months.

The time series data for each site was compiled into box and whisker plots (Figure 14 and 15). All South Berwick sites are in Figure 14, but due the large values from the catch basins, Figure 15 includes just the upstream and downstream Driscoll Brook data.

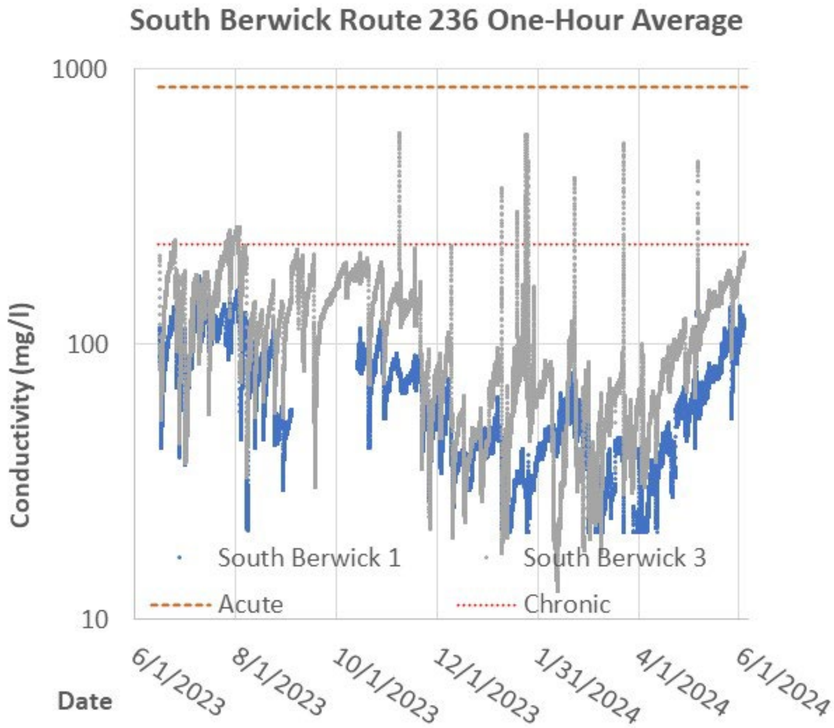

Figure 12: Comparison of South Berwick (Driscoll Brook) stream data to EPA Acute criteria

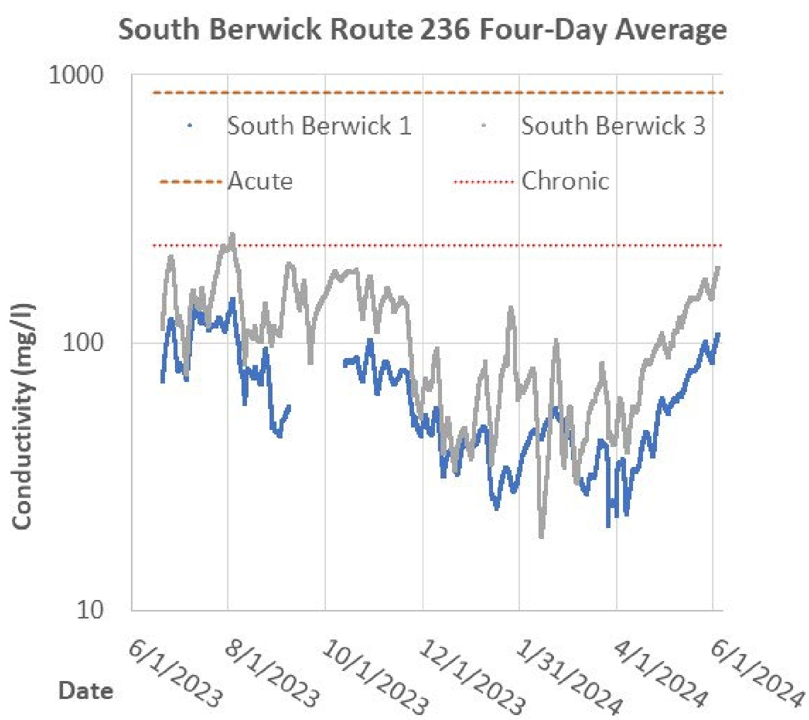

Figure 13: Comparison of South Berwick (Driscoll Brook) stream data to EPA Chronic criteria

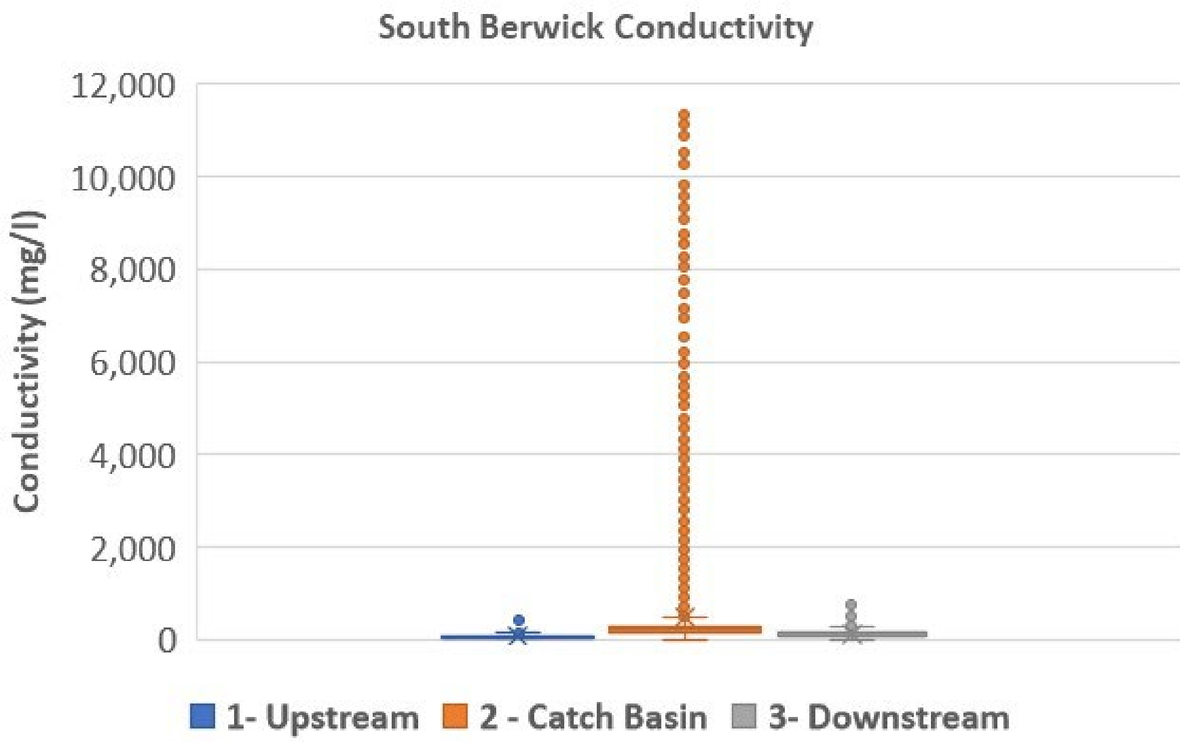

Figure 14: Box and whisker plot for all South Berwick conductivity data

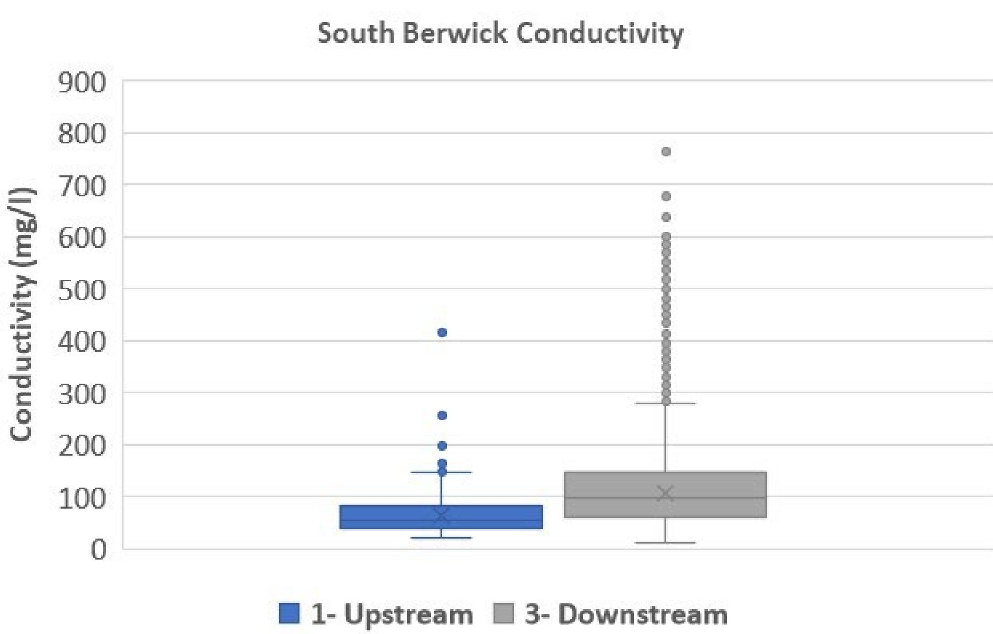

Figure 15: Box and whisker plot for upstream and downstream South Berwick conductivity data

Table 2 displays the statistics for all data from each South Berwick monitoring site. As evident from the previous figures, the upstream conductivity is generally lower than the downstream conductivity.   Upstream, Driscoll Brook meets both acute and chronic criteria, but downstream it only meets the acute criteria.

Table 2: Data statistics for South Berwick sites: All Data

	1	2	3
	Upstream	**Catch Basin**	**Downstream**
n	85,564	88,858	101,682
Mean	63.9	280.5	216.6
Median	54.6	108.1	104.2
Mode	42.8	42.8	42.8
Standard Deviation	30.2	721.7	580.8
Skew	0.875	5.453	6.930
Min	20.6	20.6	12.45
Q1	40.3	53.15	55.3
Median	54.6	108.1	104.2
Q3	83.25	233.55	185.1
Max	428	11,384	11,384

Table 3 represents the data statistics for selected events during the winter season when the catch basin conductivities frequently exceeded the chronic criteria

Table 3: Statistics for individual snowmelt events at the South Berwick sites (1 – upstream Driscoll Brook, 2 – catch basin along Route 236, and 3 - downstream Driscoll Brook)

	Event Conductivity Peaks (mg/l)		**Event Conductivity Averages (mg/l)**		
Date	**2**		**1**	**2**	**3**
9-Nov-23	4,380		74	4,279	139
5-Dec-24	1,339		40	935	61
10-Dec-23	633		55	546	170
20-Dec-23	5,895		31	5,210	37
25-Dec-23	1,458		46	1,282	45
28-Dec-23	1,164		43	1,154	50
9-Jan-24	3,771		44	2,326	218
12-Jan-24	639		29	548	46
14-Jan-24	4,260		23	2,595	46
15-Jan-24	1,977		21	1,454	50
16-Jan-24	1,199		25	999	59
24-Jan-24	5,122		28	3,644	121
26-Jan-24	6,715		32	2,628	241
29-Jan-24	1,359		30	634	121
31-Jan-24	1,060		38	747	65
21-Mar-24	6,083		44	1,741	72
23-Mar-24	1,954			1,065	40
4-Apr-24	1,485		24	821	53
average	2,805		37	1,812	91
median	1,720		32	1,218	60
std dev	2,078		13	1,374	63
max	6,715		74	5,210	241
min	633		21	546	37

Figure 16 shows an example of a winter runoff event: the catch basin conductivities exceed both acute and chronic criteria while the upstream data is all below the chronic criteria.

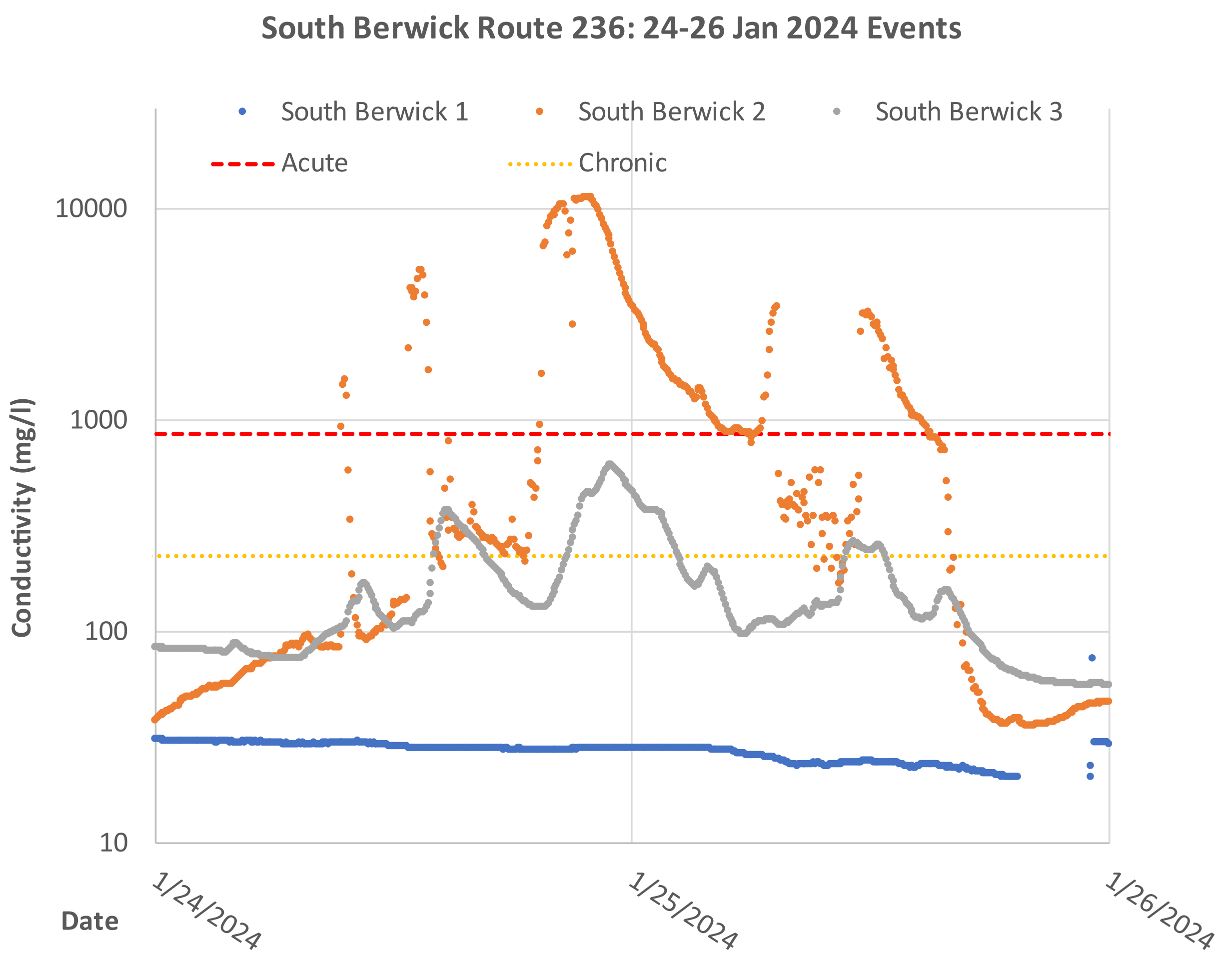

Figure 16: Individual winter runoff event conductivity at the South Berwick site

Figure 17 displays a comparison plot of coincident upstream and downstream conductivity measurements at the South Berwick (Driscoll Brook) site. The line of perfect agreement (1:1) is shown as a comparative metric. A simple linear regression line shows a slope greater than 1, meaning that in general, the upstream conductivity is less than the downstream conductivity.

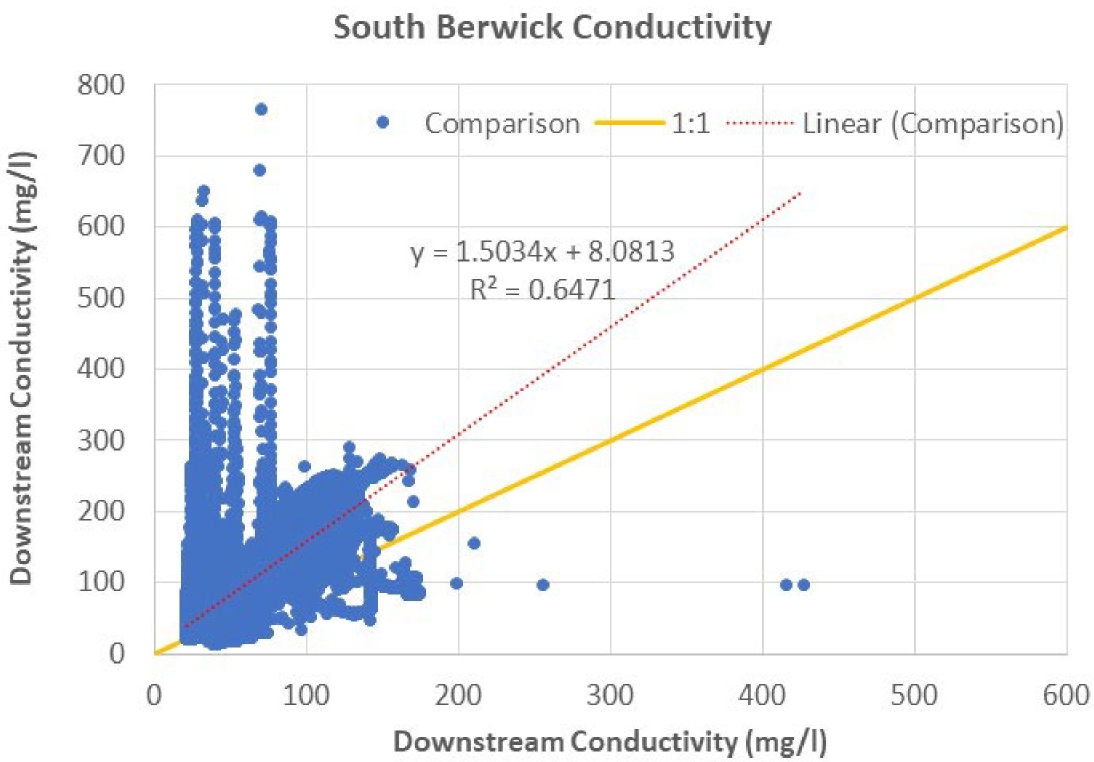

Figure 17: Comparison of all South Berwick upstream and downstream conductivity data.

Site 2: Kittery Site

The Kittery site data has some gaps when equipment was out of the water due to low water conditions. Figure 18 and Figure 19 display time series plots of conductivity (mg/l) for the monitoring period. Figure 18 includes the upstream and downstream monitoring locations and Figure 19 includes data for the two catch basins. In these figures, the USEPA acute and chronic water quality criteria are included: the acute level is 830 mg/l and the chronic is 230 mg/l.

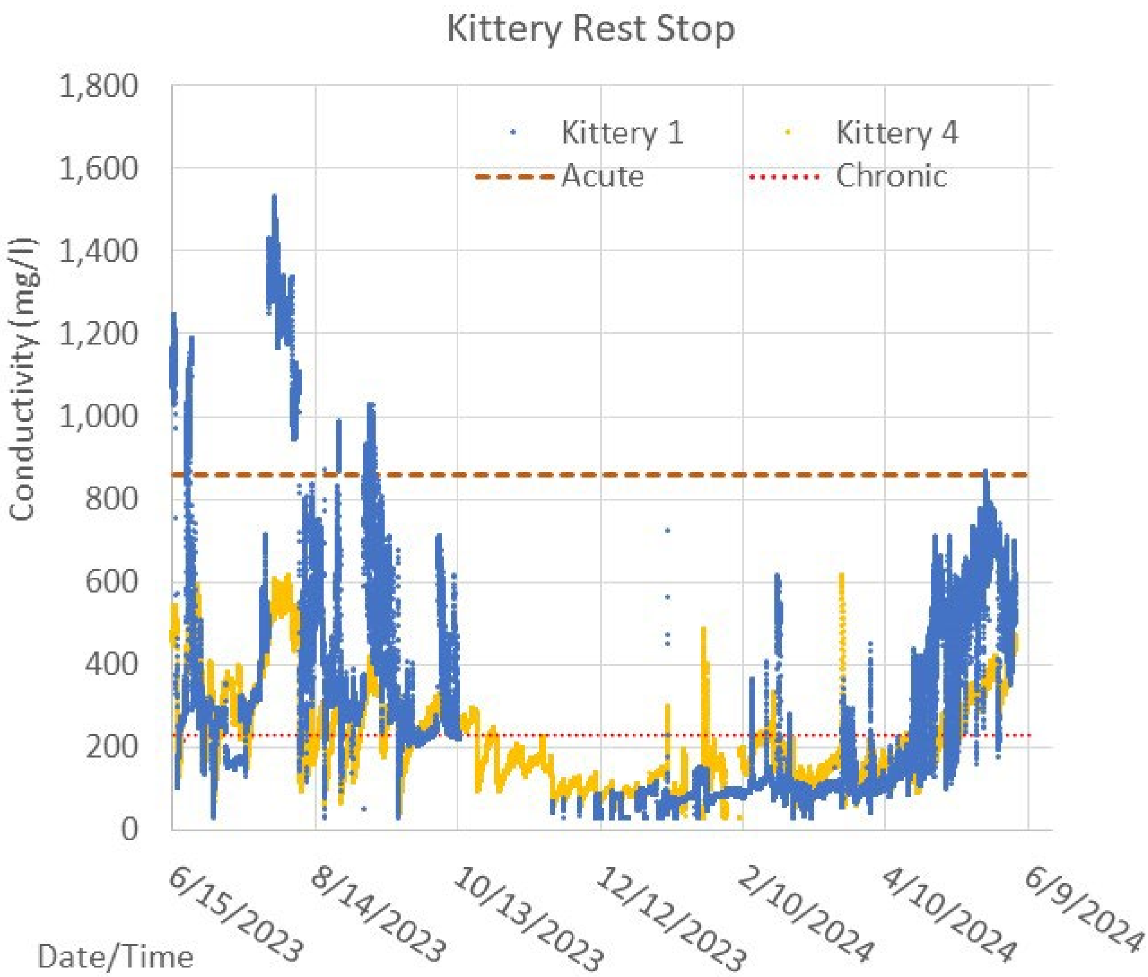

Figure 18: Upstream and downstream conductivity at the Kittery site for the monitoring period.

As is evident from Figure 18, stream conductivities are highest in the warmer months and lower in the winter months away from winter maintenance events. This more than likely is associated with the fact that I95 is immediately upstream (Figure 1) and therefore infers that significant salt remains in the watershed after the winter season.

Figure 19 shows that the two catch basins reflect high, but very different conductivities, with the highest peaks in the winter maintenance season. As a verification of the non-winter month data of Figure 18, while catch basin 2 has low conductivities in the non-winter months, catch basin 3 often exceeds 1,000 mg/l.

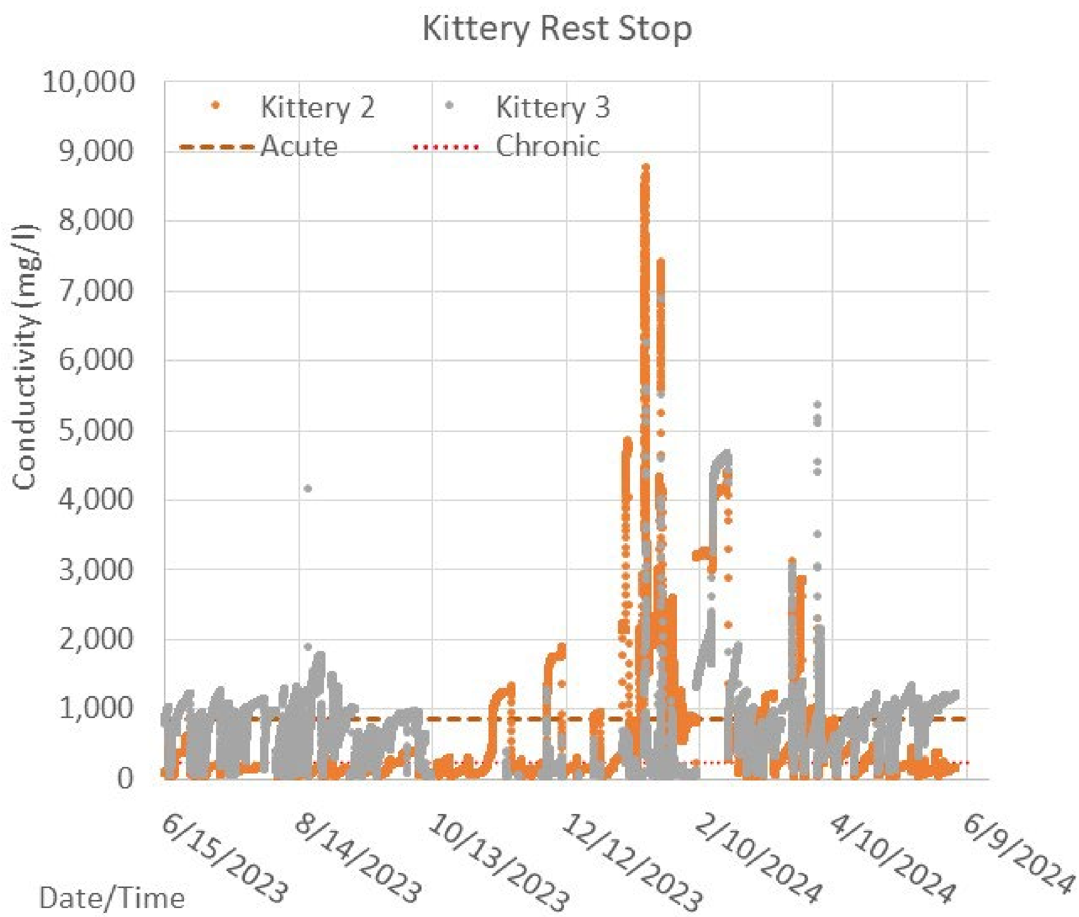

Figure 19: Conductivity measurements in the Kittery site catch basins.

Figure 20 and Figure 21 take the transformed (temporally averaged) stream data and compare the averages to acute (Figure 20) and chronic (Figure 21) criteria. The Smart Chloride strategy would appear to have potential for the Kittery site in the winter months. However, the ambient, non-winter conductivities do not now meet EPA criteria.

The time series data for each site was compiled into box and whisker plots (Figure 22 and Figure 23). All Kittery sites are in Figure 22, but due the large range of values from the catch basins, Figure 23 includes just the upstream and downstream data.

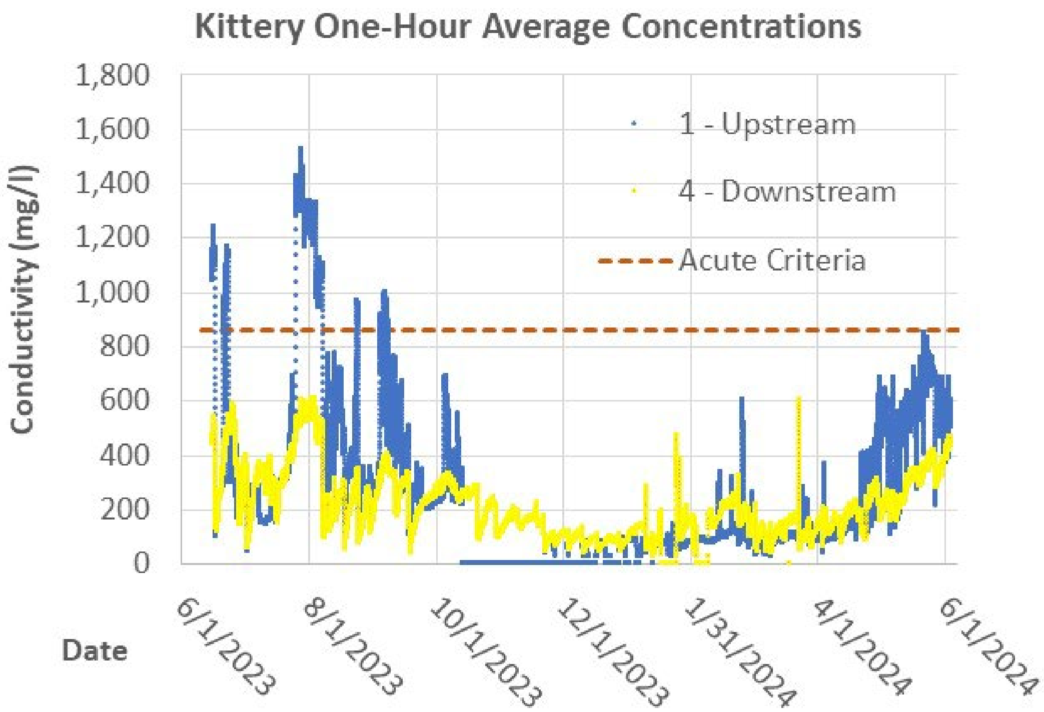

Figure 20: Comparison of Kittery stream data to EPA Acute criteria

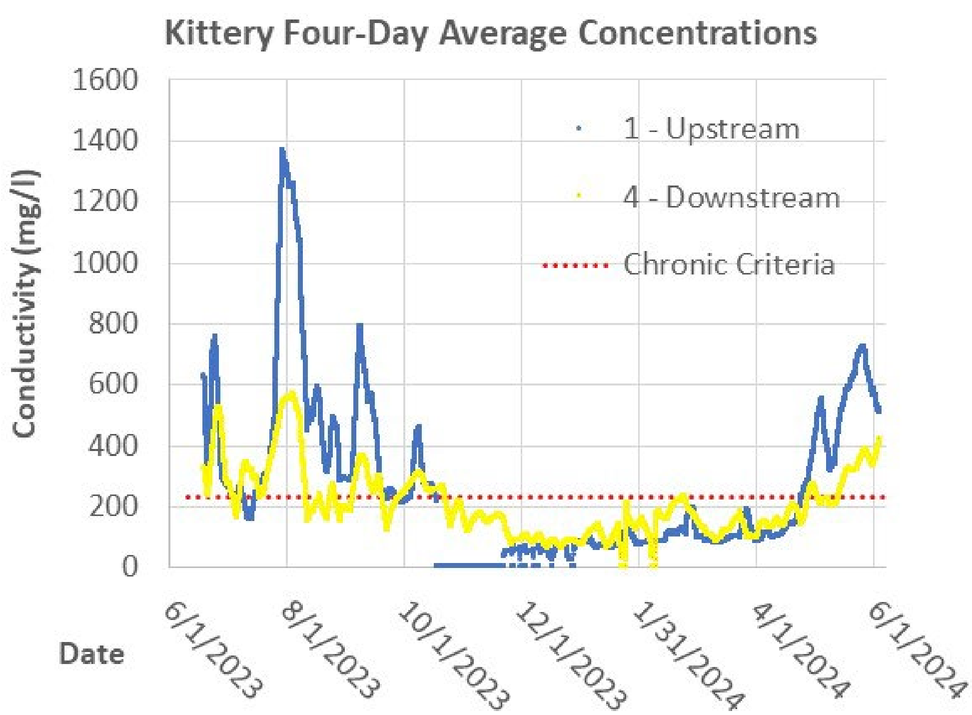

Figure 21: Comparison of Kittery stream data to EPA Chronic criteria

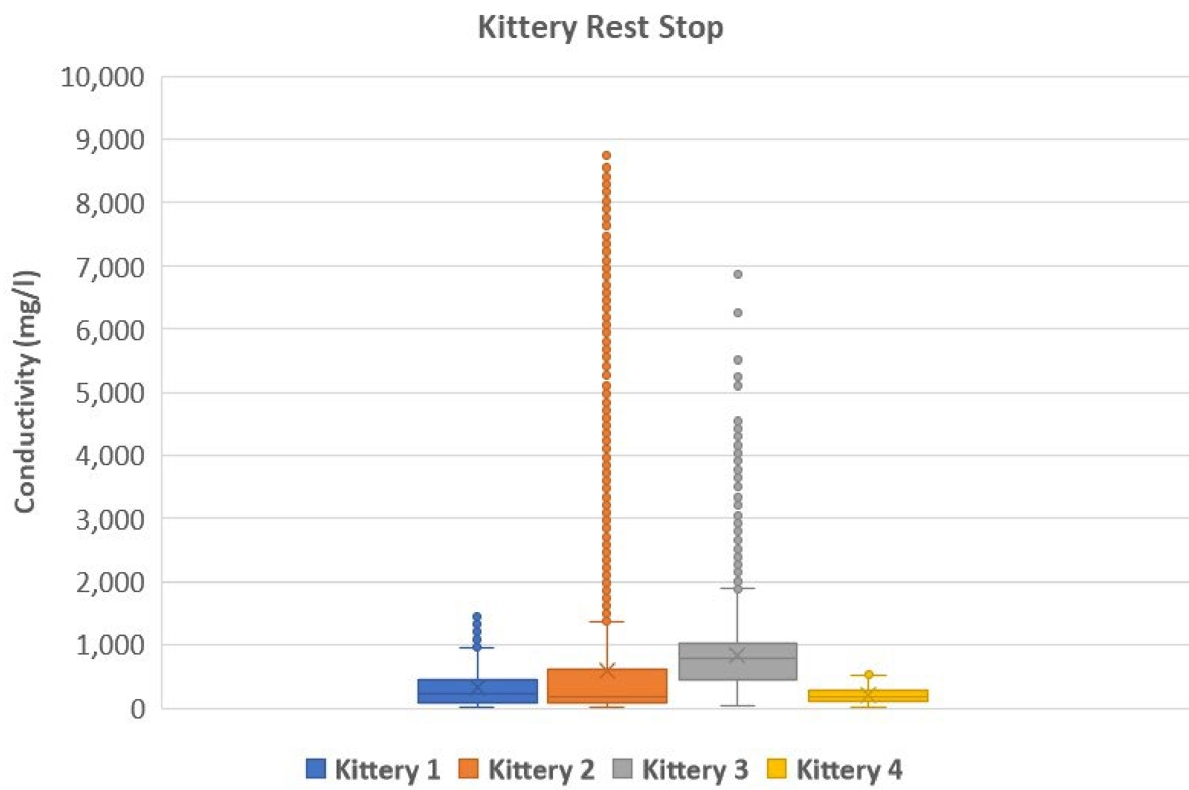

Figure 22: Box and whisker plots for all Kittery data

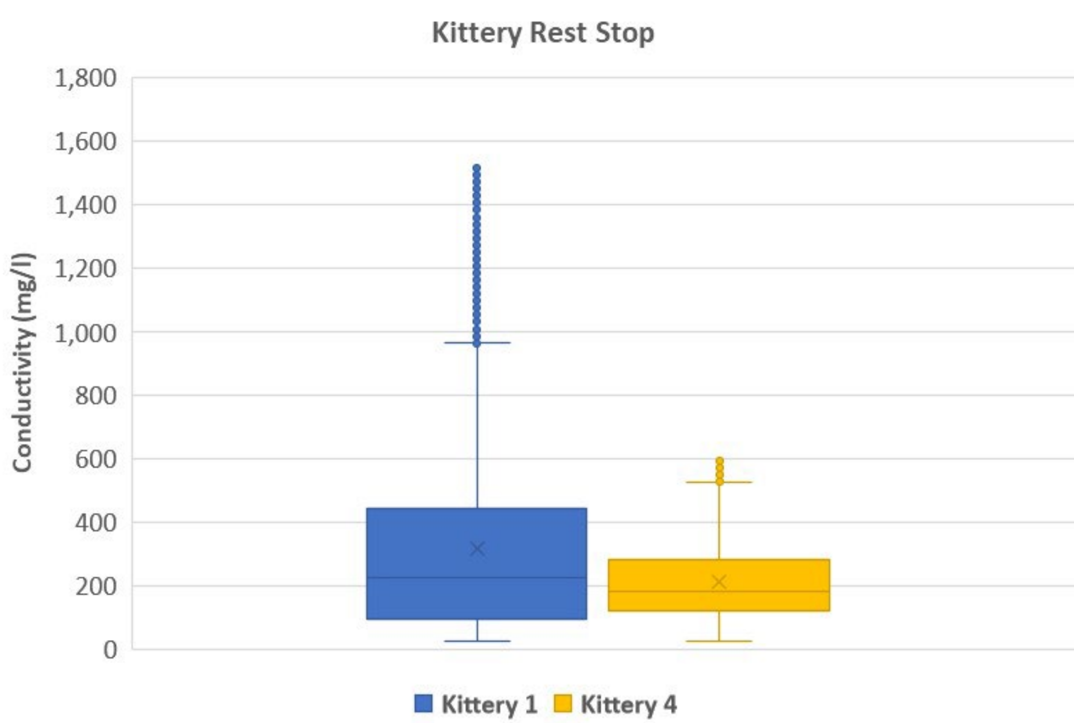

Figure 23: Box and whisker plots for upstream and downstream Kittery data

Table 4 displays the statistics for all data from each Kittery monitoring site. As evident from previous figures, the upstream conductivity is generally higher than the downstream conductivity.

Table 4: Data statistics for Kittery sites: All Data

	1	2	3	4
	Upstream	**Catch basin**	**Catch basin**	**Downstream**
n	81,487	96,597	76,810	98,542
Mean	317	591	842	212
Median	224	174	791	182
Mode	79	4,144	4,547	116
Standard Deviation	298	977	732	120
Skew	1.70	3.06	3.25	1.03
Min	23	22	25	22
Q1	94	94	455	119
Median	224	174	791	182
Q3	441	607	1,028	282
Max	1,528	8,749	6,861	611

Table 5 represents the data statistics for selected events during the winter season when the catch basin conductivities frequently exceeded the chronic criteria

Table 5: Statistics for individual snowmelt events at the Kittery site

	Event Conductivity Peaks (mg/l)			Event Conductivity Averages (mg/l)			
date	2	3		1	2	3	4
18-Nov-23	2,591	730			1,104	81	159
4-Dec-23	2,520	2,422		56	1,237	134	61
10-Dec-23	3,767	2,526			1,720	143	99
28-Dec-23	1,846	1,103			894	63	86
3-Jan-24	313			84	210		
8-Jan-24	2,361	673		50	2,117	486	138
9-Jan-24	4,844	606		85	4,569	375	131
10-Jan-24	814	255		85	408	83	212
17-Jan-24	8,749	6,247		70	4,572	667	126
24-Jan-24	7,394	6,861		127	6,259	1,006	
26-Jan-24	2,508	538		74	1,888	119	107
14-Feb-24	4,392	4,650		116	4,107	4,497	222
25-Feb-24	1,004	1,890		216	672	1,575	183
28-Feb-24	585	1,239		107	379	999	138
3-Mar-24	547	999		92	443	796	98
7-Mar-24	967	795		89	885	641	102
10-Mar-24	1,191	946		84	1,130	689	106
23-Mar-24	3,099	3,042		85	1,890	2,267	229
24-Mar-24	2,840	1,360		183	1,826	979	96
29-Mar-24	2,292	5,355		87	885	641	128
4-Apr-24	1,746	2,139		125	964	903	165
7-Apr-24	837	548		100	754	388	146
average	2,600	2,139		101	1,769	835	137
median	2,327	1,239		87	1,117	641	129
std dev	2,173	1,988		41	1,630	999	47
max	8,749	6,861		216	6,259	4,497	229
min	313	255		50	210	63	61

Figure 24 shows an example of a winter runoff event: the catch basin conductivities exceed both acute and chronic criteria while the stream data is all below the chronic criteria.

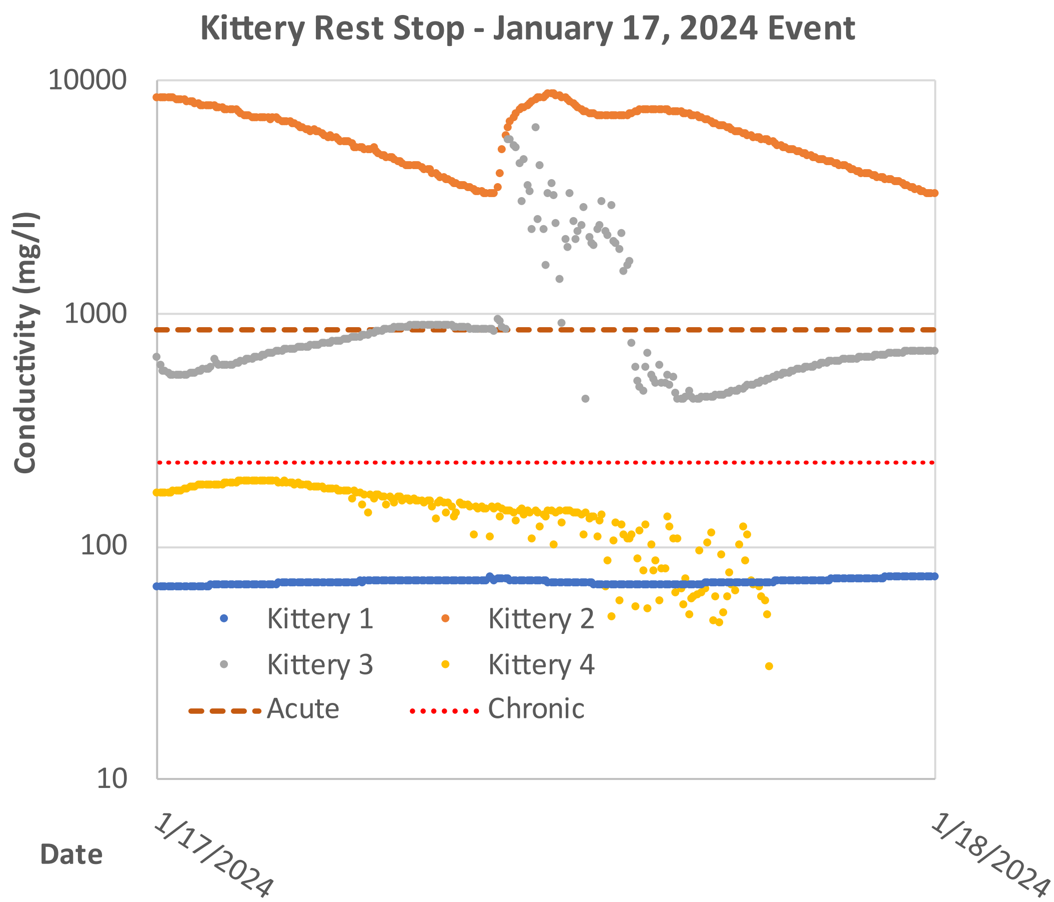

Figure 24: Individual winter runoff event conductivity at the Kittery site

Figure 25 displays a comparison plot of coincident upstream and downstream conductivity measurements at the Kittery site. The line of perfect agreement (1:1) is shown as a comparative metric. A simple linear regression line shows a slope less than 1, meaning that in general, the upstream conductivity is greater than the downstream conductivity.

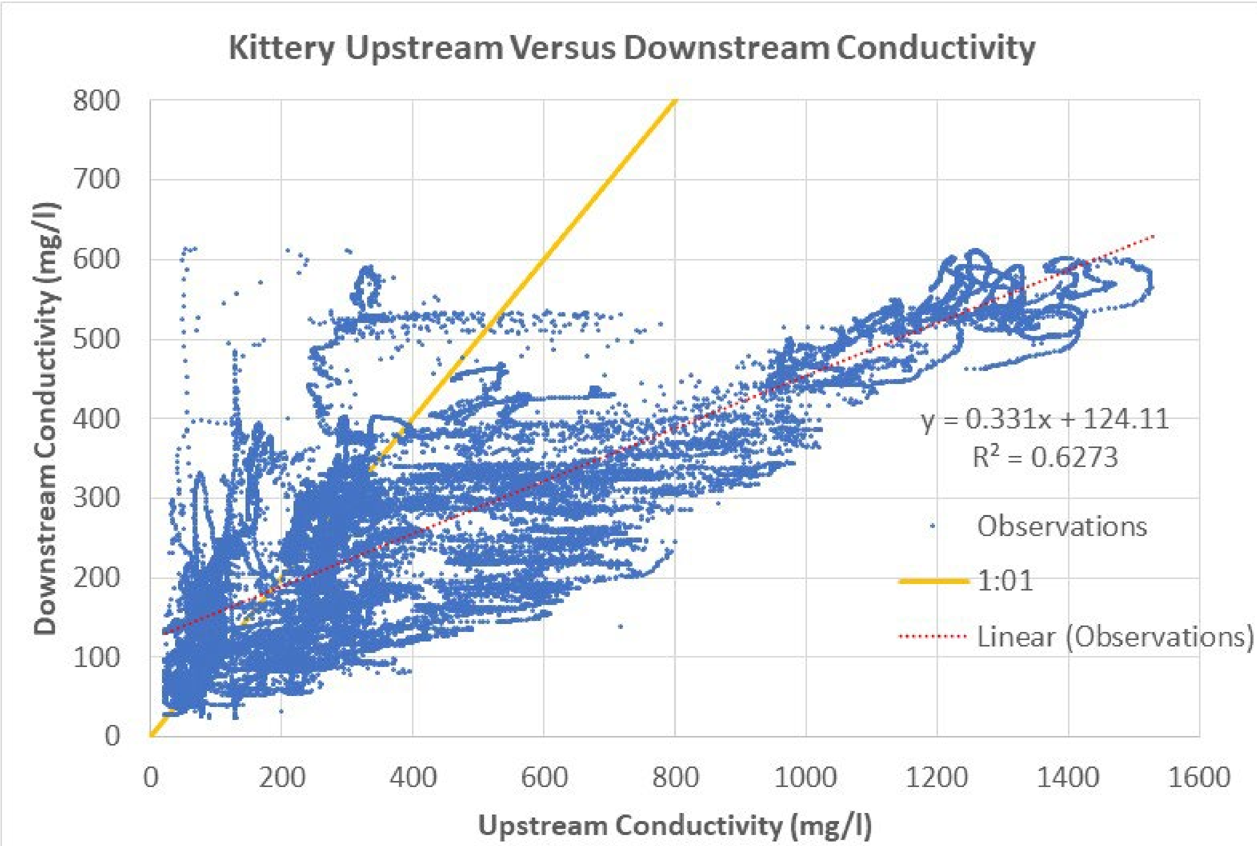

Figure 25: Comparison of all Kittery upstream and downstream conductivity data.

Site 3: South Hampden

The South Hampden site data has gaps when equipment was out of the water due to very low water conditions in Reeds Brook or when equipment failed to log. Figure 26 and Figure 27 display time series plots of South Hampden conductivity (mg/l) for the monitoring period. Figure 26 includes the upstream and downstream monitoring locations and Figure 27 includes data for the catch basin. In these figures, the USEPA acute and chronic water quality criteria are included: the acute level is 830 mg/l and the chronic is 230 mg/l.

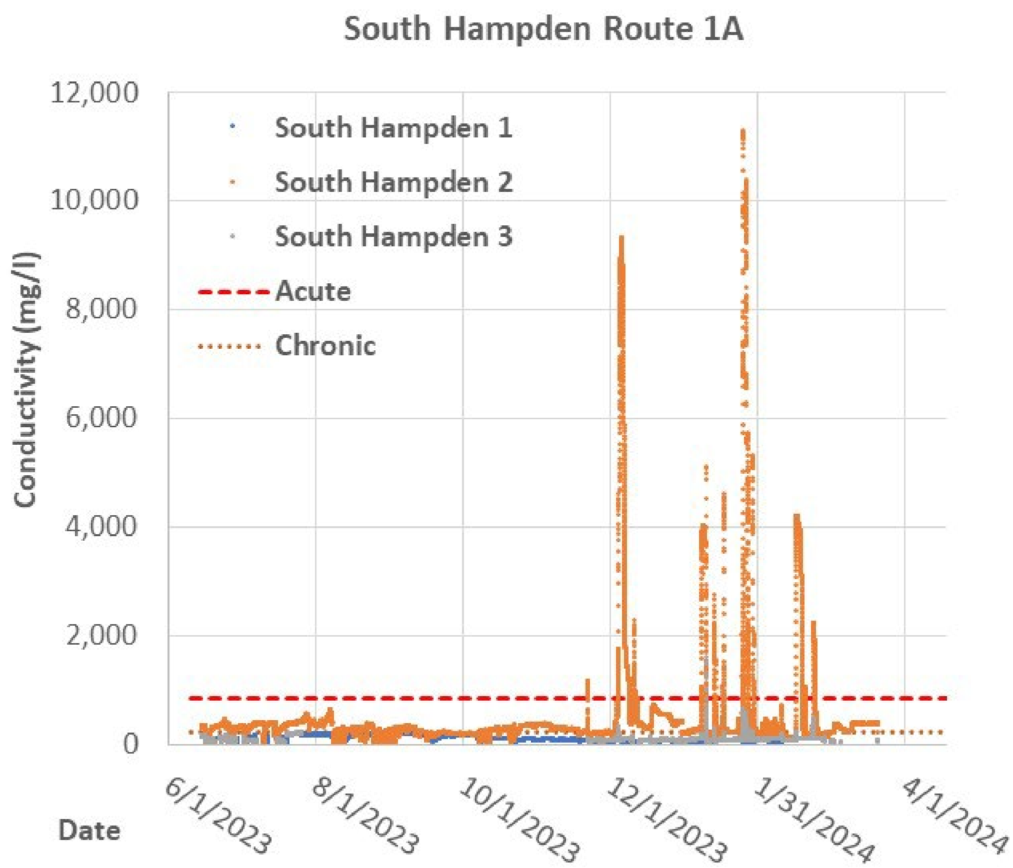

Figure 26: Time series plot of all South Hampden conductivity data for the monitoring period

As is evident from Figure 27, stream conductivities are highest in the warmer months and lower in the winter months away from winter maintenance events. In general, the upstream conductivity is lower than the downstream conductivity.

Figure 26 shows that the catch basin reflects high conductivities, with the highest peaks in the winter maintenance season.

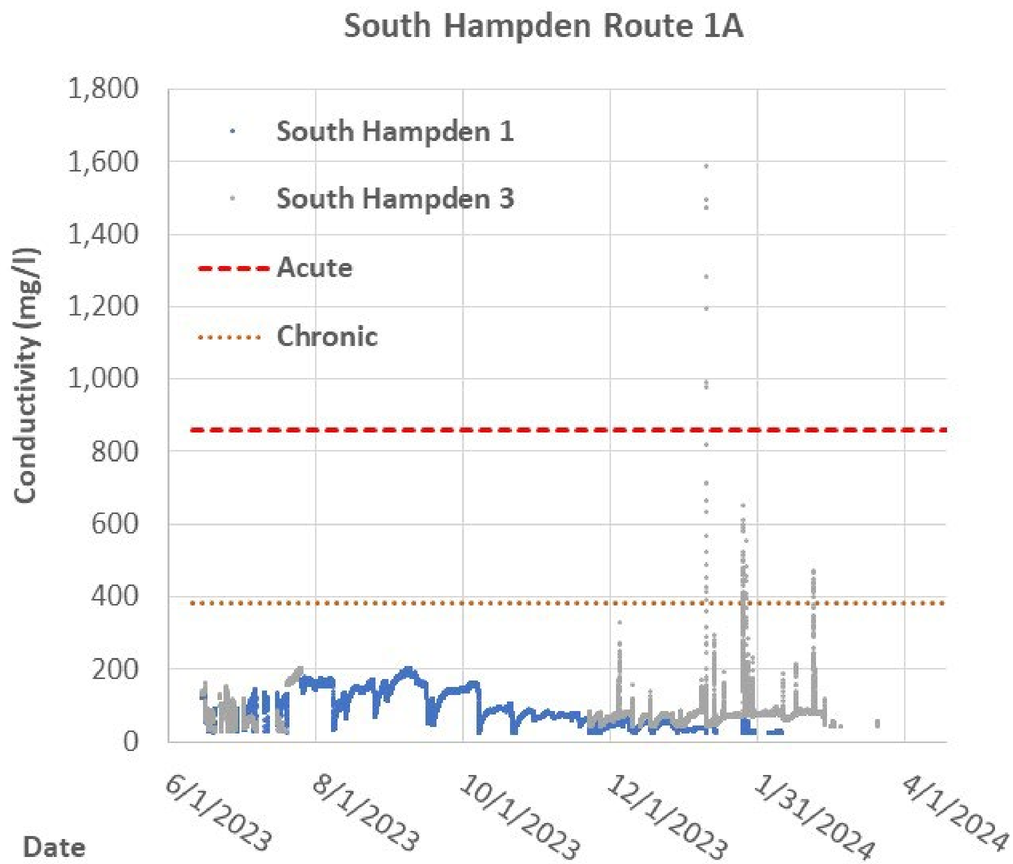

Figure 27: Time series plot of upstream and downstream South Hampden conductivity data for the monitoring period

Figure 28 and Figure 29 take the transformed (temporally averaged) Reeds Brook data and compare the averages to acute (Figure 28) and chronic (Figure 29) criteria. The Smart Chloride strategy would seem to have potential at the South Hampden site in the winter months.

The time series data for each site was compiled into box and whisker plots (Figure 30 and Figure 31). All South Hampden sites are in Figure 30, but due the large range of values from the catch basins, Figure 31 includes just the upstream and downstream Reeds Brook data.

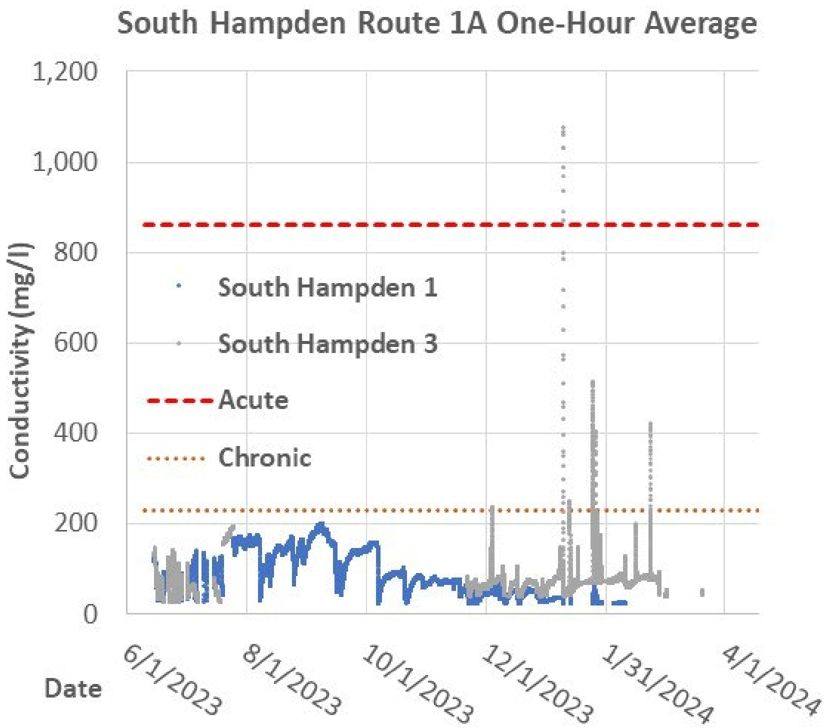

Figure 28: Comparison of South Berwick (Driscoll Brook) stream data to EPA Acute criteria

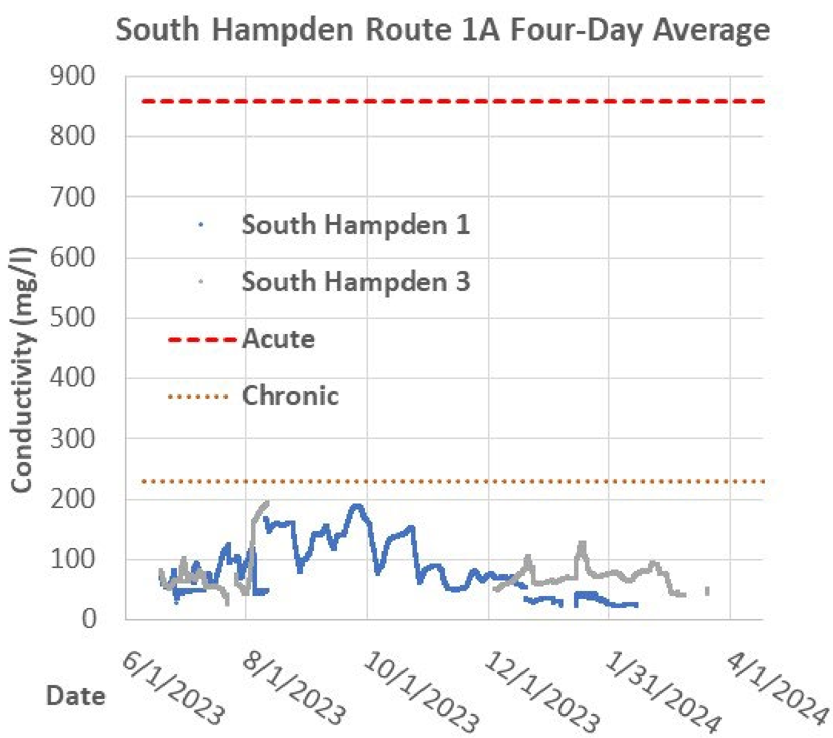

Figure 29: Comparison of South Hampden (Reeds Brook) stream data to EPA Chronic criteria

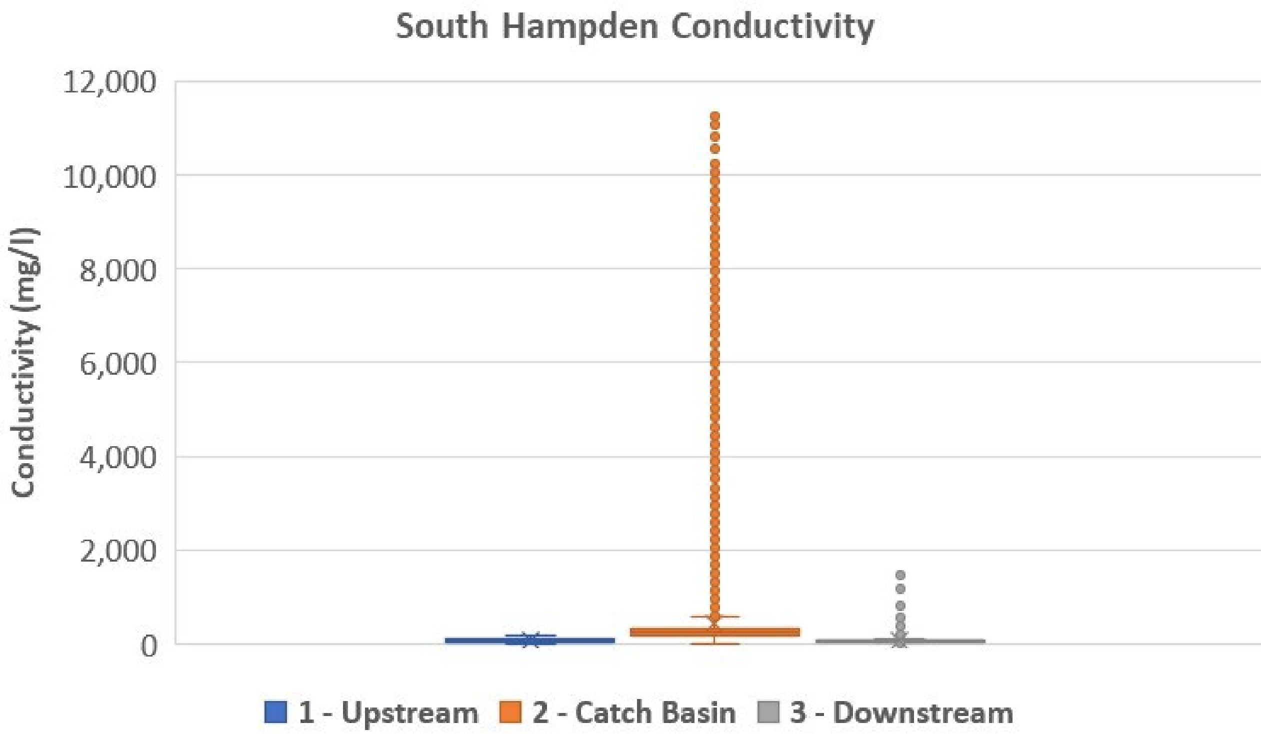

Figure 30: Box and whisker plot for all South Hampden conductivity data

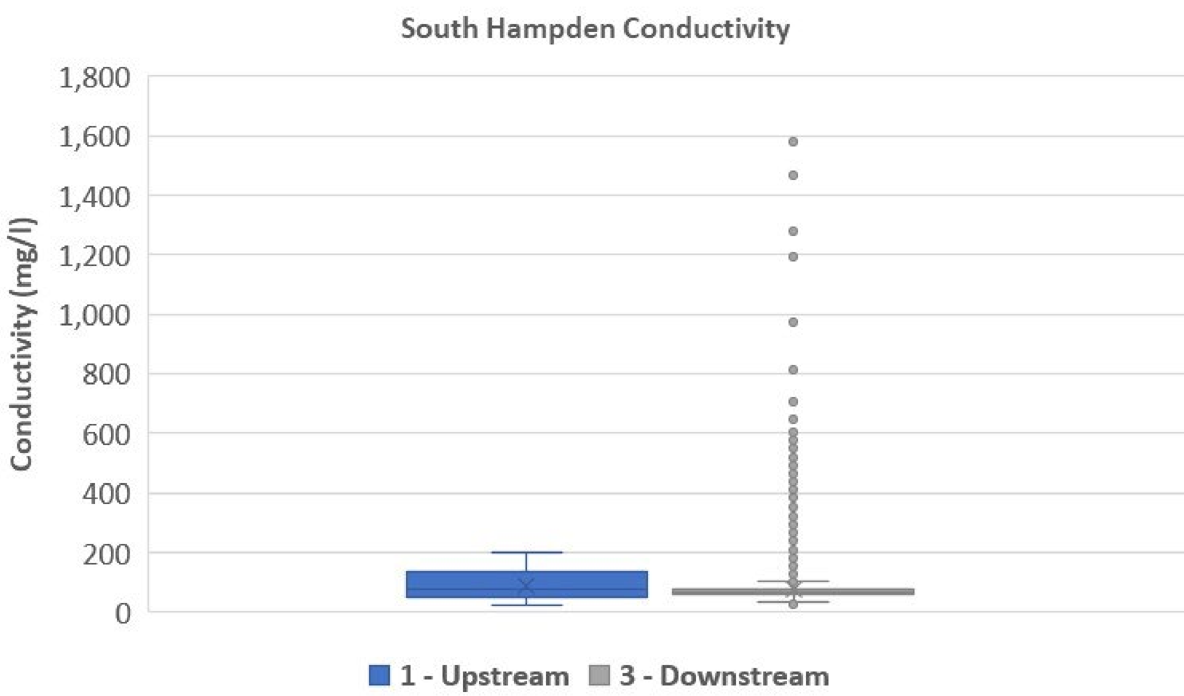

Figure 31: Box and whisker plot for upstream and downstream South Hampden conductivity data

Table 6 displays the statistics for all data from each South Hampden monitoring site. Caution should be taken in comparing these statistics as there are very little concurrent measurements between upstream and downstream locations. Upstream, Reeds Brook meets both acute and chronic criteria, but downstream only meets the acute criteria.

Table 6: Data statistics for South Hampden sites: All Data

	1	2	3
	Upstream	Catch Basin	Downstream
n	53,463	80,088	33,084
Mean	88.6	441.3	74.3
Median	75.1	257.1	68.1
Mode	21.8	361.4	66.6
Standard Deviation	47.7	1006.8	42.1
Skew	0.399	6.681	9.858
Min	21.75	22.35	23.05
Q1	48.35	184.75	58.85
Median	75.05	257.05	68.05
Q3	136.1	349.1	76.3
Max	198	11,278	1,582

Table 7 represents the data statistics for selected events during the winter season when the catch basin conductivities frequently exceeded the chronic criteria

Table 7: Statistics for individual snowmelt events at the South Hampden site (1 – upstream Reeds Brook, 2 – catch basin along Route 236, and 3 - downstream Reeds Brook)

Date	**Event Conductivity Peaks (mg/l)**		**Event Conductivity Averages (mg/l)**		
	2		**1**	**2**	**3**
22-Nov-23	1,151		59	964	
4-Dec-23	1,734		56	1,163	91
5-Dec-23	9,305		55	4,633	76
11-Dec-23	2,272		29	883	
18-Dec-23	690		44	562	63
8-Jan-24	5,080		33	3,224	113
13-Jan-24	2,732		27	1,616	173
17-Jan-24	4,580			2,191	99
23-Jan-24	449			336	69
25-Jan-24	11,278		40	4,443	264
26-Jan-24	10,365		35	7,703	148
28-Jan-24	5,697		24	2,388	120
29-Jan-24	5,298		23	4,182	96
2-Feb-24	357			251	70
3-Feb-24	431			234	70
4-Feb-24	401			227	72
5-Feb-24	194		22	179	72
6-Feb-24	366		22	226	74
7-Feb-24	432		22	250	77
8-Feb-24	349		23	245	79
9-Feb-24	257		23	209	77
10-Feb-24	690		22	212	79
16-Feb-24	1,045			779	75
20-Feb-24	1,039			751	78
23-Feb-24	2,213			1,493	114
average	2,736		33	1,574	98
median	1,045		27	779	78
std dev	3,339		13	1,904	45
max	11,278		59	7,703	264
min	194		22	179	63

Figure 32 shows an example of winter maintenance events and subsequent days of snowmelt: the catch basin conductivities exceed both acute and chronic criteria while the upstream data is all below the chronic criteria.

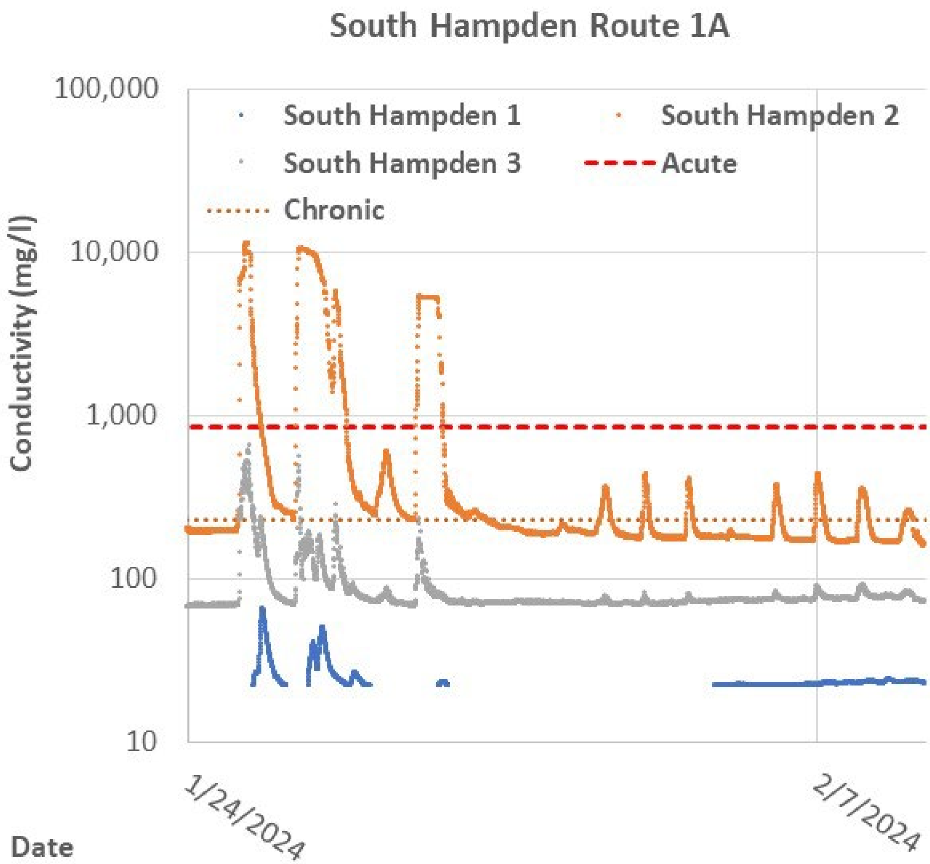

Figure 32: Individual winter runoff event conductivity at the South Hampden site

Figure 33 displays a comparison plot of coincident upstream and downstream conductivity measurements at the South Hampden (Reeds Brook) site. The line of perfect agreement (1:1) is shown as a comparative metric. A simple linear regression line shows a slope of nearly zero with very low correlation. There may be a few interpretations for this. For example, that the downstream conductivity varies much more than the upstream conductivity or that Route 1A runoff strongly effects the downstream conductivity readings.

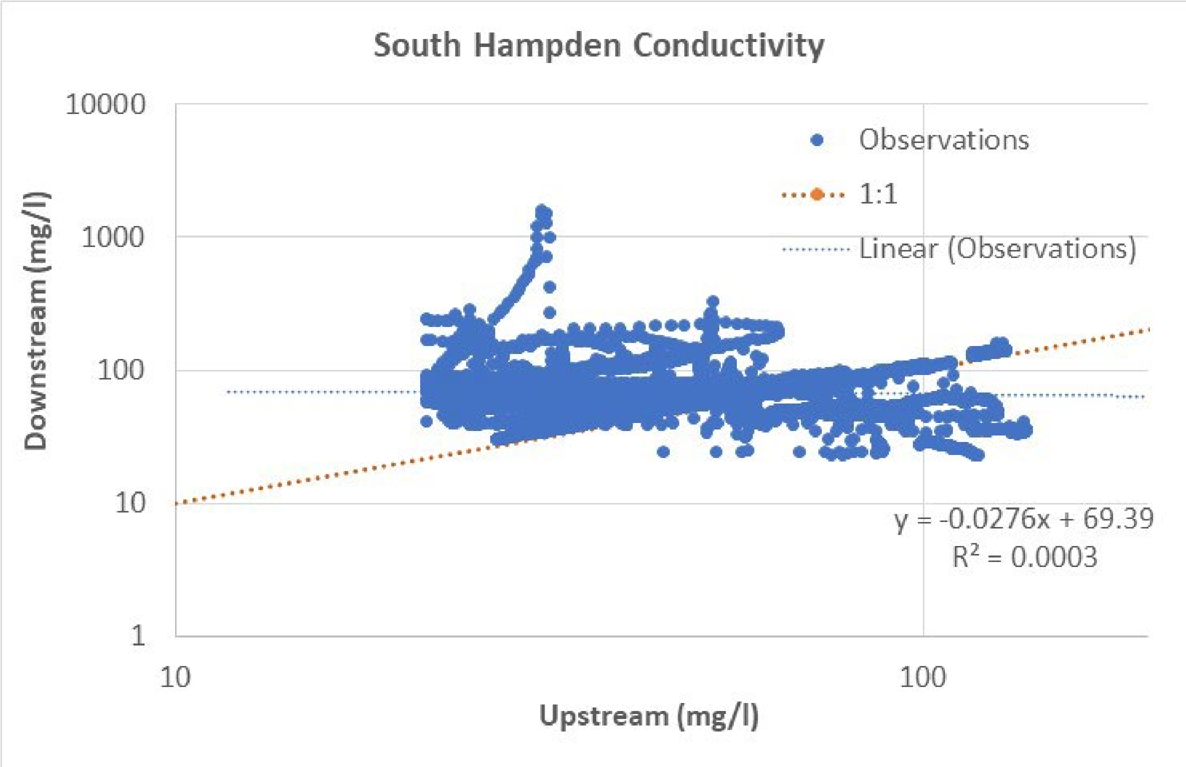

Figure 33: Comparison of all South Hampden upstream and downstream conductivity data.

Site Modeling

For all modeling steps that follow, the following abbreviations were given to the sites:

Site 1 South Berwick: 1SB
Site 2 Kittery: 2K
Site 3 Hampden South: 3HS

Note that the terms watershed and catchment are used interchangeably in the Modeling section as well as subwatershed and subcatchment. The use may depend on the context; for example, SWMM uses the term "subcatchment" exclusively while other processes do not have such requirements.

The goal of the modeling process was to determine whether proposed strategies such as storage of salty runoff or dilution of the runoff using a well pump would reduce the chloride levels in the receiving waters to below the criteria for acute and chronic chloride concentrations. This modeling was performed in the free modeling software SWMM (Stormwater Management Model) developed by the EPA for stormwater runoff modeling. The model for each site was calibrated to monitored data from UNHSC (for chloride) and climatic data from NOAA (for snow depth). The subcatchment characteristics (area, width, percent impervious cover, etc.) were obtained by GIS analysis of the sites using publicly available data layers from Maine Geolibrary, USGS StreamStats, and NRCS Web Soil Survey.

StreamStats

The initial watershed and stream flow statistics were obtained from USGS StreamStats. The downstream monitoring location was selected as the point of analysis for each site. StreamStats provides a free report (.pdf file) of the watershed's topographic and hydrological characteristics. The other helpful output is a vector layer (.shp file) of the watershed boundary. While this is later refined through the terrain analysis, it is used initially to start the analysis. The summary reports are in Appendix A: StreamStats Reports.

Some relevant summary statistics from the StreamStats reports are shown in Table 8.

Table 8: StreamStats summary of the percentiles and mean daily flow (cfs) for the three sites.

Site	Area (sq. mi.) [ac]	Mean Slope	Mean Impervious	Mean Annual Flow (cfs)	Mean August baseflow (cfs)
1SB	2.09 [1338]	5.3%	5.2%	4.67	0.74
2K	0.36 [230]	4.4%	10.4%	1.05	0.21
3HS	1.87 [1197]	4.9%	2.5%	4.13	0.33

The mean annual flow and percentile flows from the reports were used for calibration and are shown in Table 9.

Table 9: StreamStats summary of the percentiles and mean daily flow (cfs) for the three sites.

	Flow (cfs)		
Statistic	**1SB**	**2K**	**3HS**
1%	0.0053	0.094	0.003
5%	0.0336	0.124	0.02
10%	0.0965	0.185	0.07
25%	0.538	0.331	0.4
50%	1.96	0.633	1.7
75%	5.04	1.289	4
90%	11.2	2.721	10
95%	17.7	4.742	16
99%	46.2	13.633	43
Mean	4.67	1.256	4.1

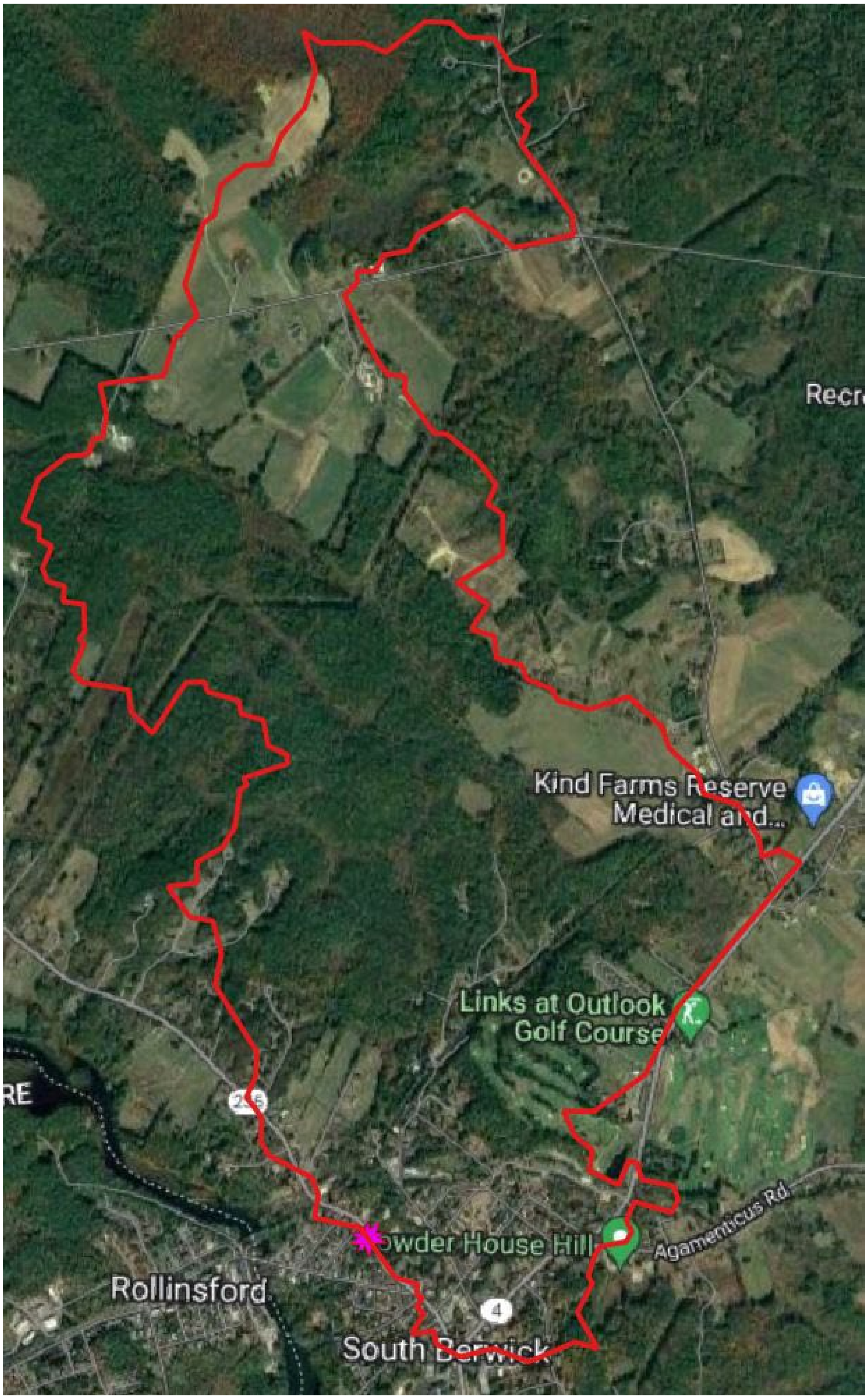

Figure 34: 1SB. The watershed boundary output from StreamStats overlayed on Google Maps satellite view for reference. The purple star indicates the POA.

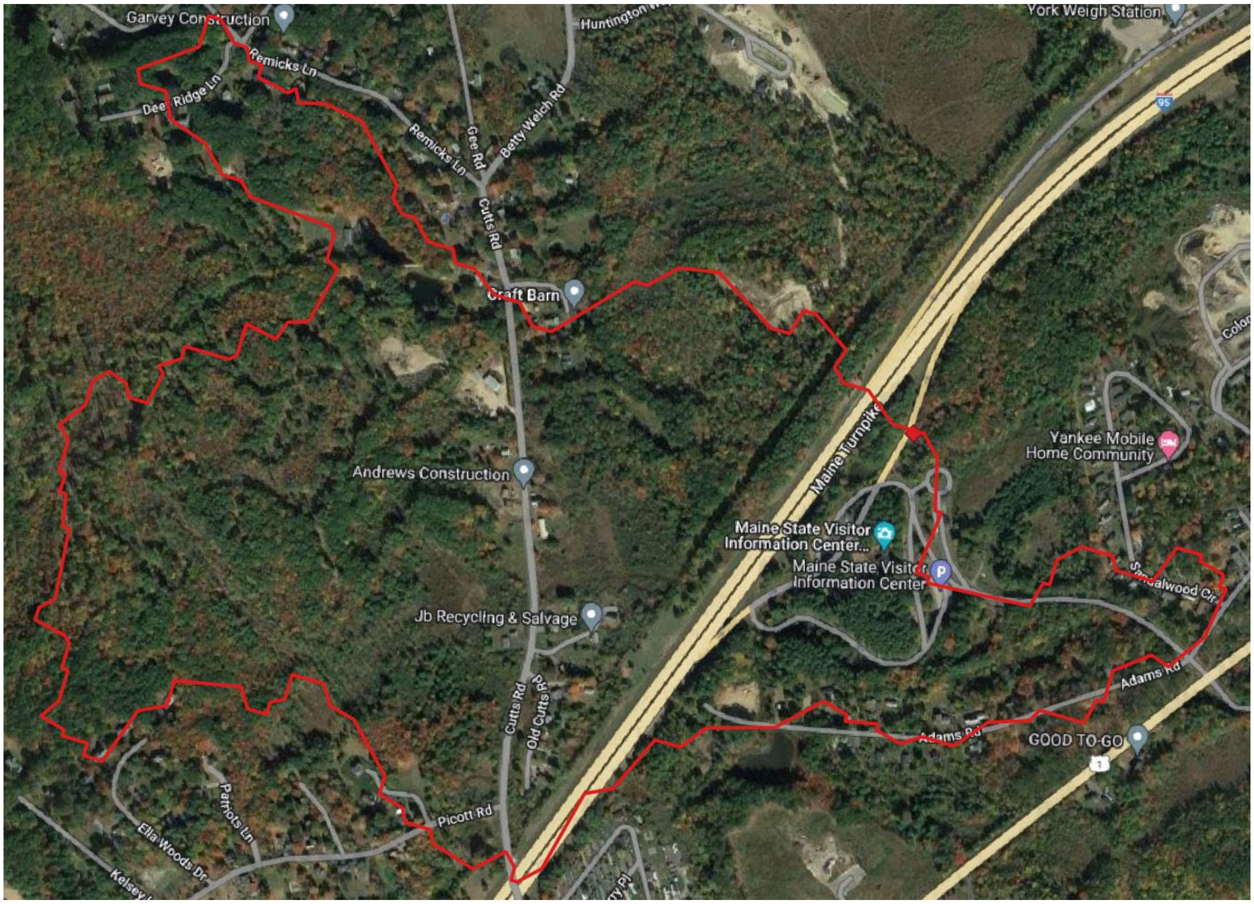

Figure 35: 2K. The watershed boundary output from StreamStats overlayed on Google Maps satellite view for reference.

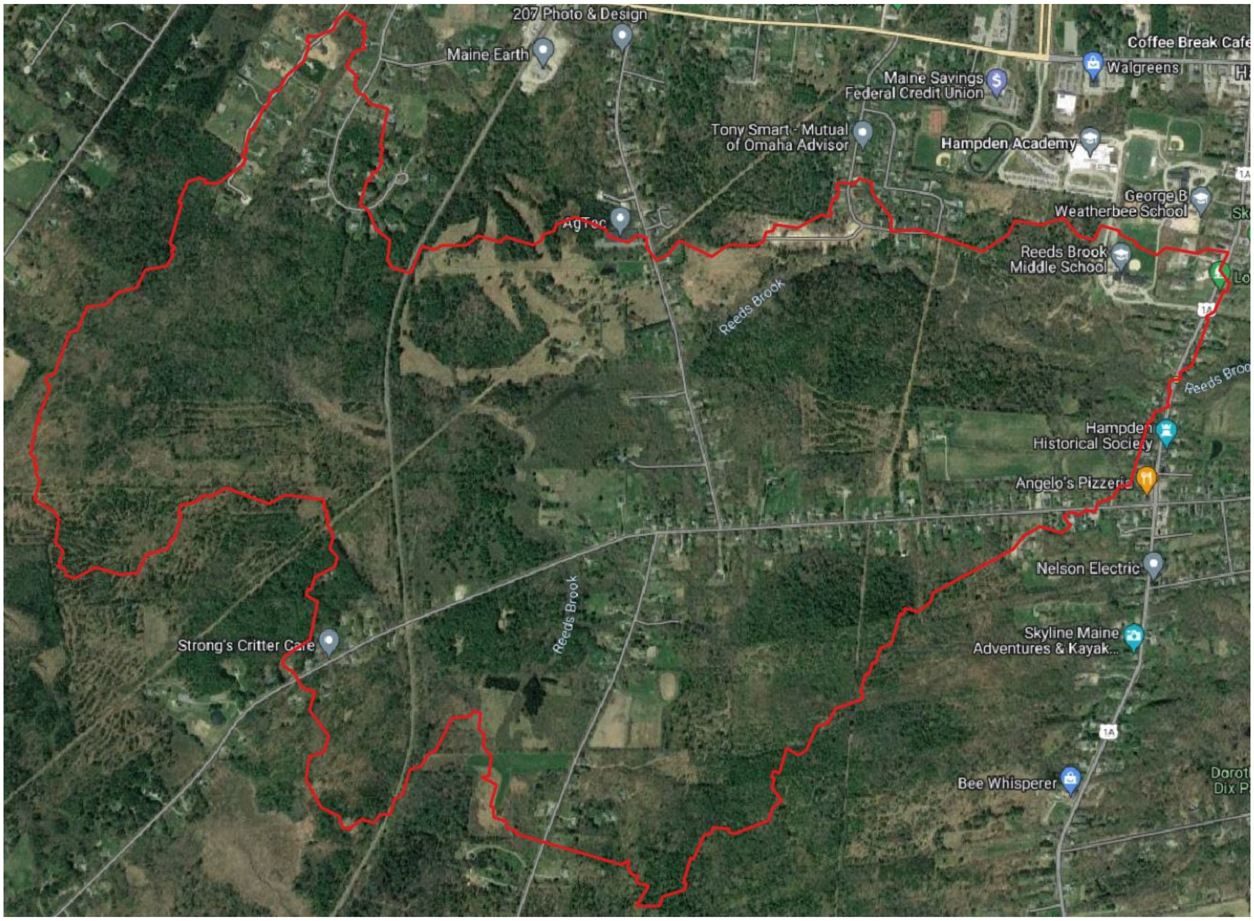

Figure 36: 3HS. The watershed boundary output from StreamStats overlayed on Google Maps satellite view for reference.

GIS

The watersheds were divided into subwatersheds to be used in the SWMM model using elevation, land use, and soil layers. The software used for the analysis was QGIS 3.34.6-Prizren. The summary of the GIS layer data sources is shown in Table 10.

Table 10: GIS data sources

Description	Data Type	Source	URL
Watershed	Vector	StreamStats	https://streamstats.usgs.gov/ss/
Elevation	Raster	Maine Geolibrary	https://www.maine.gov/geolib/catalog.html
Land Use (CCAP)	Raster	Maine Geolibrary	https://www.maine.gov/geolib/catalog.html
Soil (SSURGO)	Vector	Maine Geolibrary	https://www.maine.gov/geolib/catalog.html

Infrastructure

The GIS data for the infrastructure was provided through the Maine Office of GIS with access to the DOT infrastructure. The provided data included the outfall locations, culverts and pipes, and catch basins. These points were used to further refine the watershed into subcatchments and dictate how catchments were delineated for the SWMM model. The maps provided the infrastructure that was imported into the GIS model. All of the GIS data is in Appendix B: GIS DOT Infrastructure. The following figures show the data for Site 1 only as an example.

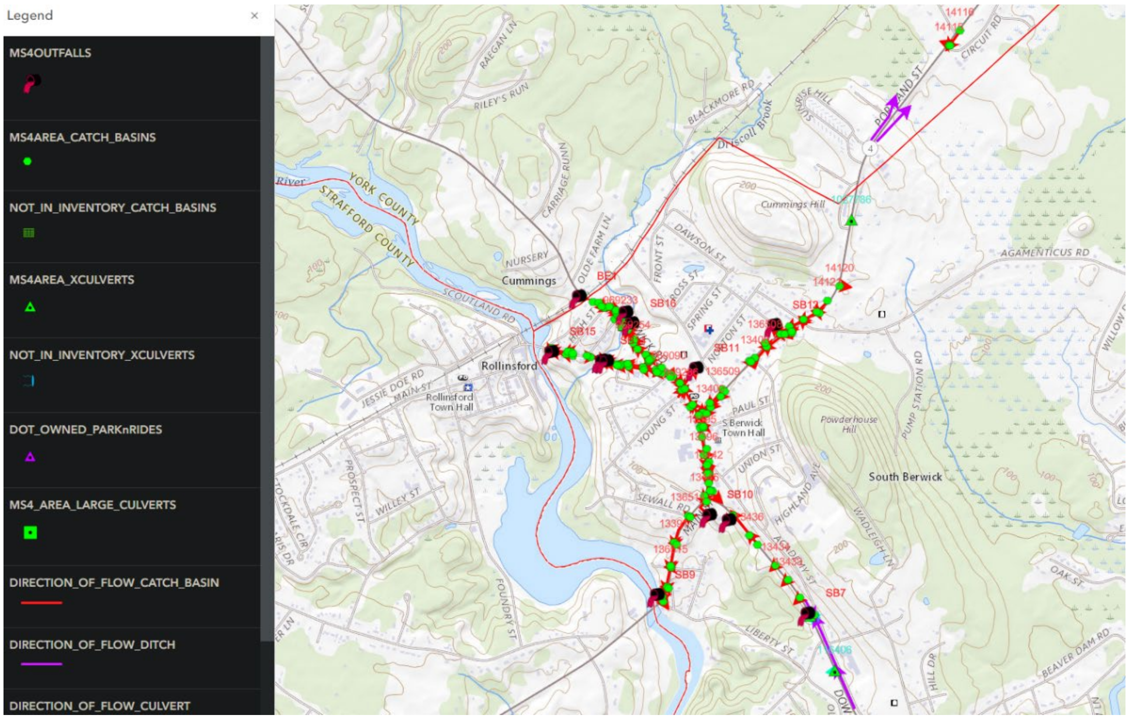

Figure 37: 1SB. This screenshot shows the locations of DOT outfalls, catch basins, and culverts.

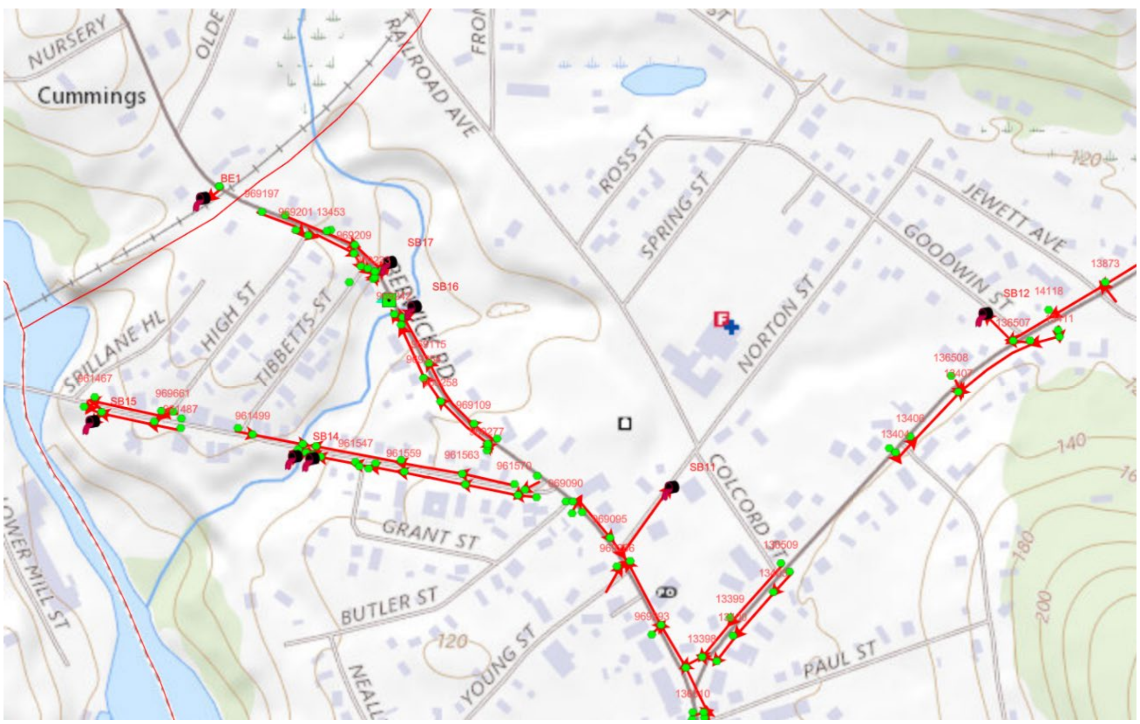

Figure 38: 1SB. This screenshot shows the locations of DOT outfalls, catch basins, and culverts near the POA.

Land Use

The land use for the subcatchments were determined from an analysis of the NOAA NLCD land use raster available from Maine Geolibrary. The general land uses used for categorization were wetland, agricultural, open space, residential, urban, and commercial/industrial. The categorized land use raster was overlayed onto the subcatchments, and the areas of each were calculated to use in the SWMM models. All of the watershed land use data is in Appendix C: GIS Land Use. The following Figure 39 shows the data for Site 1 only as an example.

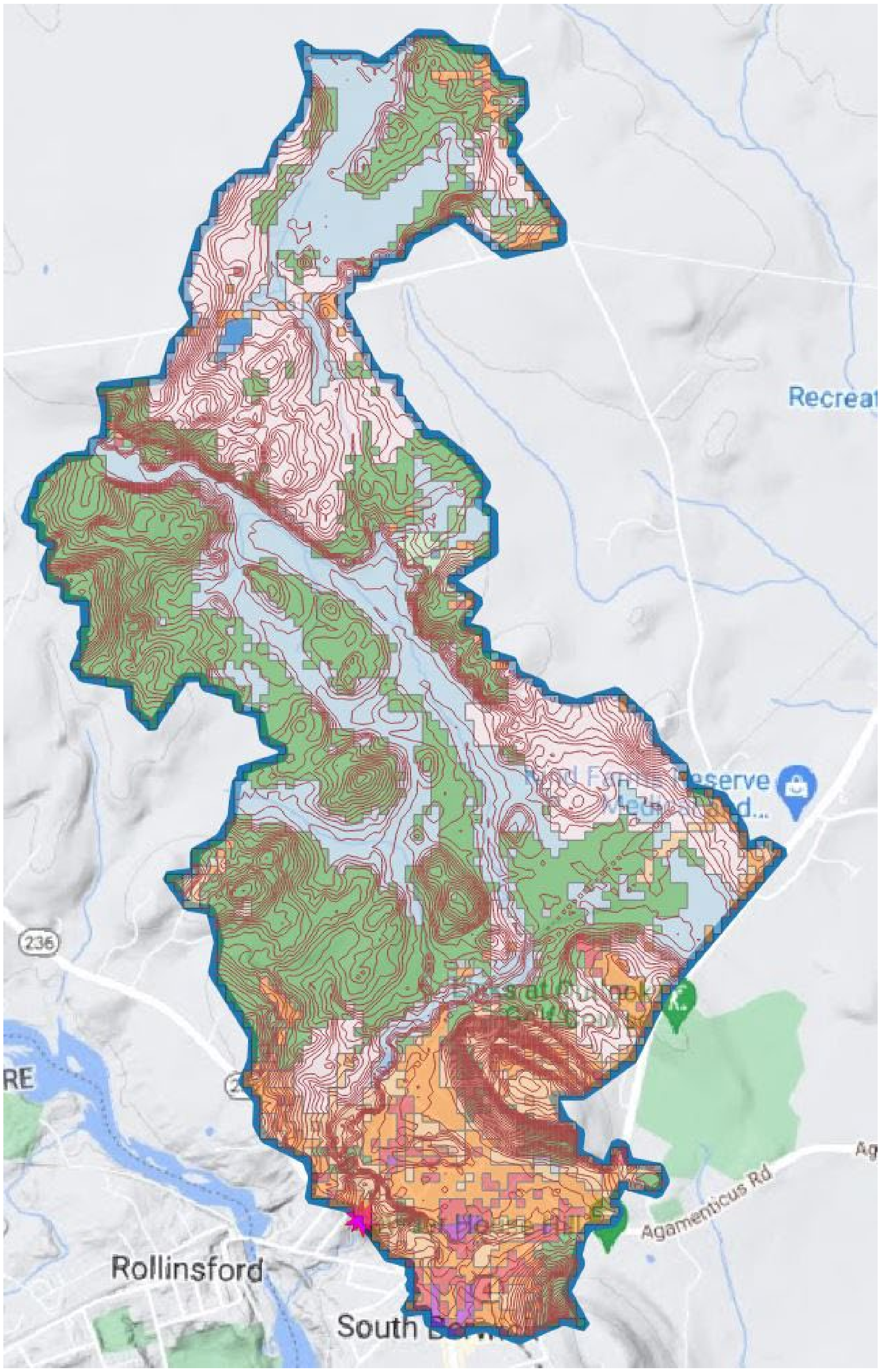

Figure 39: 1SB. Land Use from CCAP 2016 overlayed on 1-meter contour lines. Generally, blue indicates wetlands, green is forested, white is open space, orange is developed/impervious, and red is highly developed.

Soils

The soil GIS data (SSURGO) were analyzed to determine the hydrologic soil group (HSG) of the subcatchments. The HSG corresponds to the saturated hydraulic conductivity (K_{sat}) which determines the infiltration rate in SWMM. The soils vector layer (SSURGO) was available from Maine Geolibrary. The soils vector was grouped by HSG, and the areally weighted K_{sat} was calculated per subcatchment. All the Web Soil Survey reports are in Appendix D: Web Soil Survey Reports. Figure 40 shows the data for Site 1 only as an example. The annotations are of the soil name which have corresponding characteristics including HSG and K_{sat}.

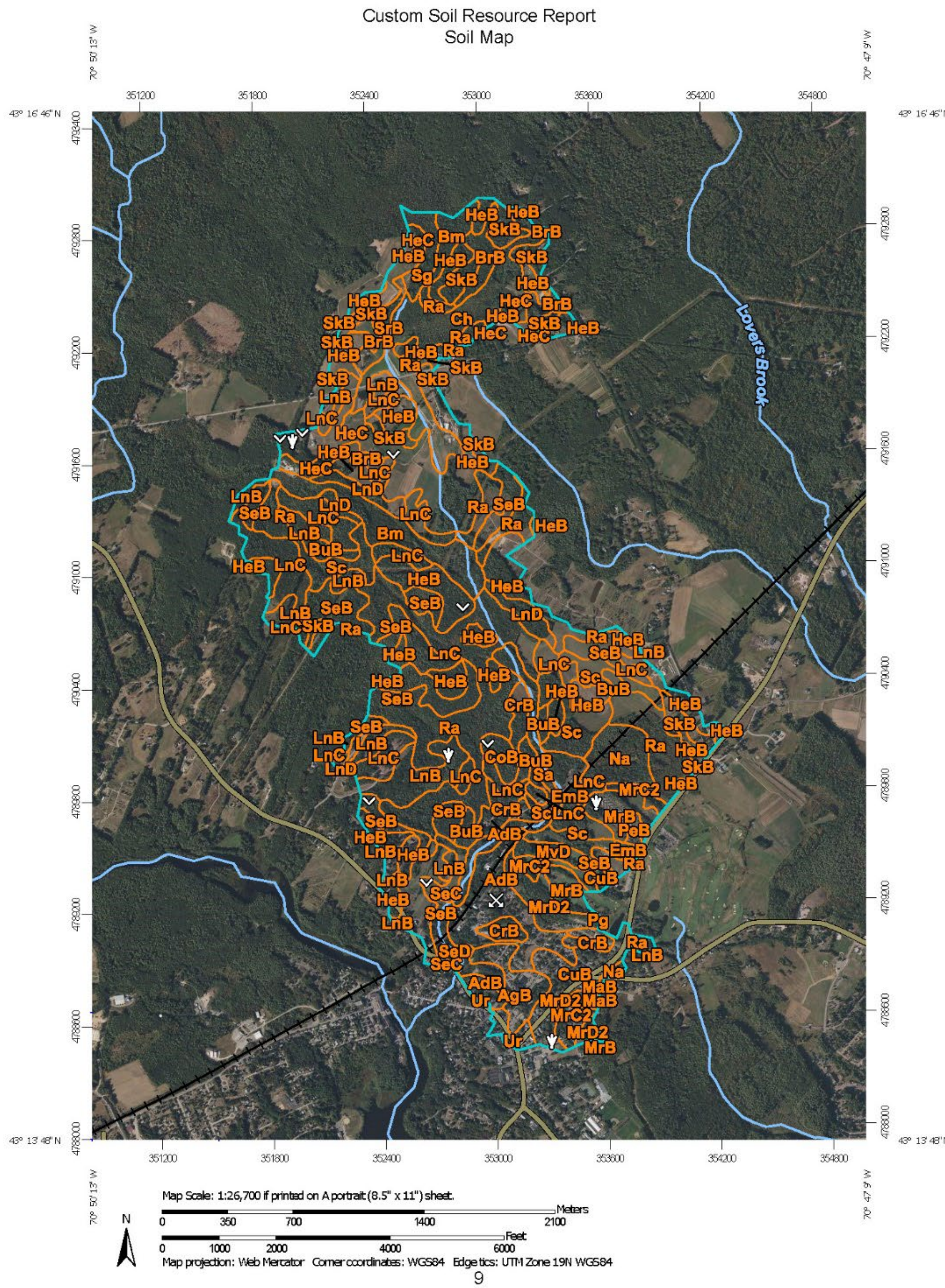

Figure 40: 1SB. Soil map from NRCS Web Soil Survey. This data was imported into GIS to find the areally-weighted K_{sat} per subcatchment.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
AdB	Adams loamy sand, 0 to 8 percent slopes	57.0	4.2%
AgB	Adams-Urban land complex, 0 to 8 percent slopes	19.3	1.4%
Bm	Biddeford mucky peat, 0 to 3 percent slopes	49.6	3.7%
BrB	Brayton and Westbury fine sandy loams, 0 to 8 percent slopes	17.9	1.3%
BuB	Buxton silt loam, 3 to 8 percent slopes	20.4	1.5%
Ch	Chocorua peat	40.9	3.0%
CoB	Colton gravelly sandy loam, 0 to 8 percent slopes	8.2	0.6%
CrB	Croghan loamy fine sand, 0 to 8 percent slopes, wooded	22.1	1.6%
CuB	Croghan-Urban land complex, 0 to 8 percent slopes	35.1	2.6%
EmB	Elmwood fine sandy loam, 0 to 8 percent slopes	21.9	1.6%
HeB	Hermon sandy loam, 3 to 8 percent slopes	215.2	16.0%
HeC	Hermon sandy loam, 8 to 15 percent slopes	26.2	2.0%
LnB	Lyman loam, 3 to 8 percent slopes, rocky	67.5	5.0%
LnC	Lyman loam, 8 to 15 percent slopes, rocky	102.6	7.6%
LnD	Lyman loam, 15 to 25 percent slopes, rocky	24.1	1.8%
MaB	Madawaska fine sandy loam, 0 to 8 percent slopes	0.1	0.0%
MrB	Marlow fine sandy loam, 3 to 8 percent slopes	26.2	2.0%
MrC2	Marlow fine sandy loam, 8 to 15 percent slopes	15.0	1.1%
MrD2	Marlow fine sandy loam, 15 to 25 percent slopes	29.0	2.2%
MvD	Marlow fine sandy loam, 15 to 25 percent slopes, very stony	9.0	0.7%
Na	Naumburg sand	33.7	2.5%
PeB	Peru fine sandy loam, 3 to 8 percent slopes	3.5	0.3%
Pg	Pits, gravel	0.1	0.0%

Terrain

The bare Earth digital elevation model (DEM) raster available from Maine Geolibrary was used for multiple GIS analyses. The elevation was the basis for flow calculations, delineating subcatchments, and calculating stream cross-sections (transects) for routing the SWMM mode.

Elevation

This section shows the bare Earth DEM data using the hillshade tool for visualization.

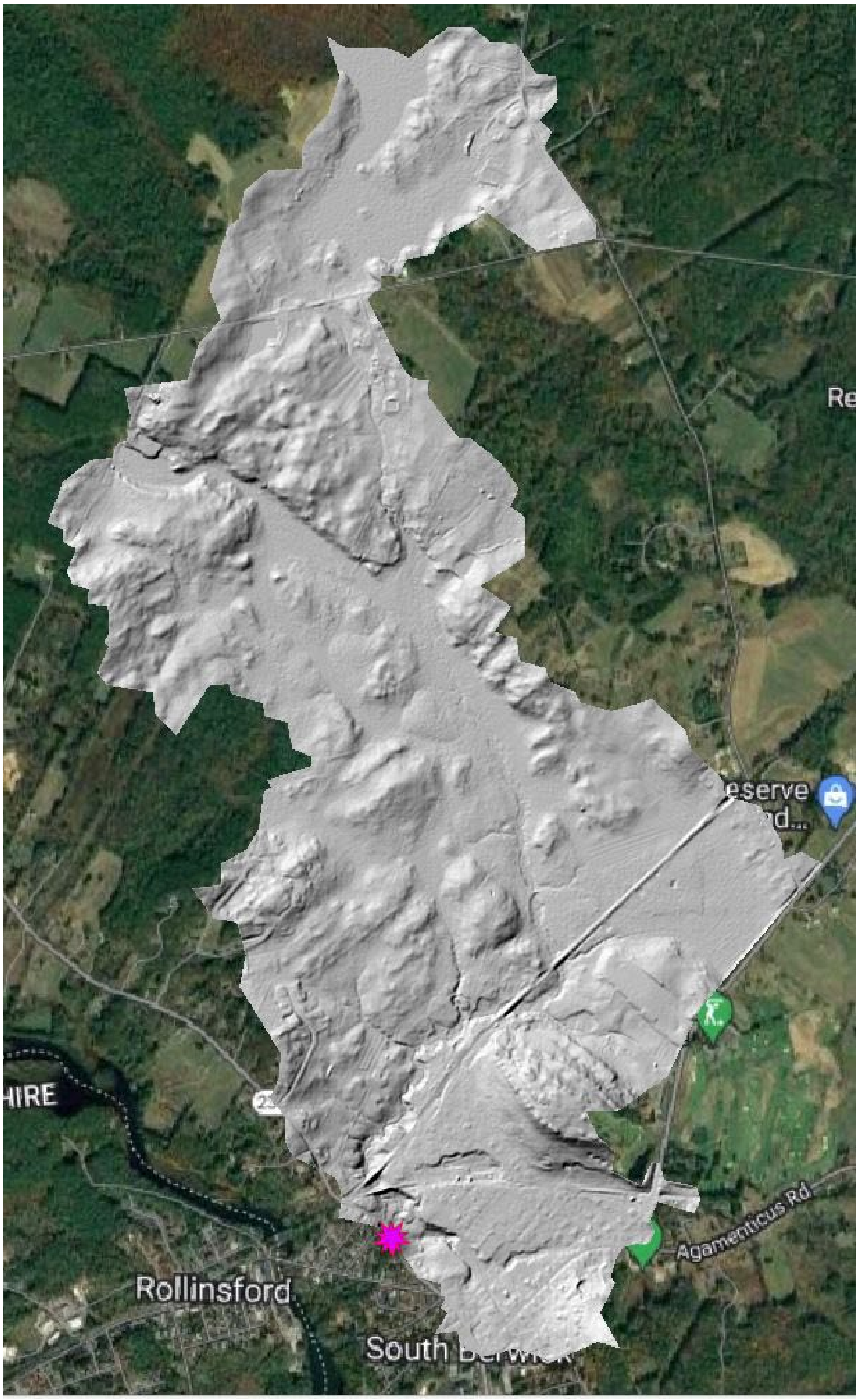

Figure 41: 1SB. Elevation is rendered using the Hillshade visualization for the watershed. The purple star indicates the POA.

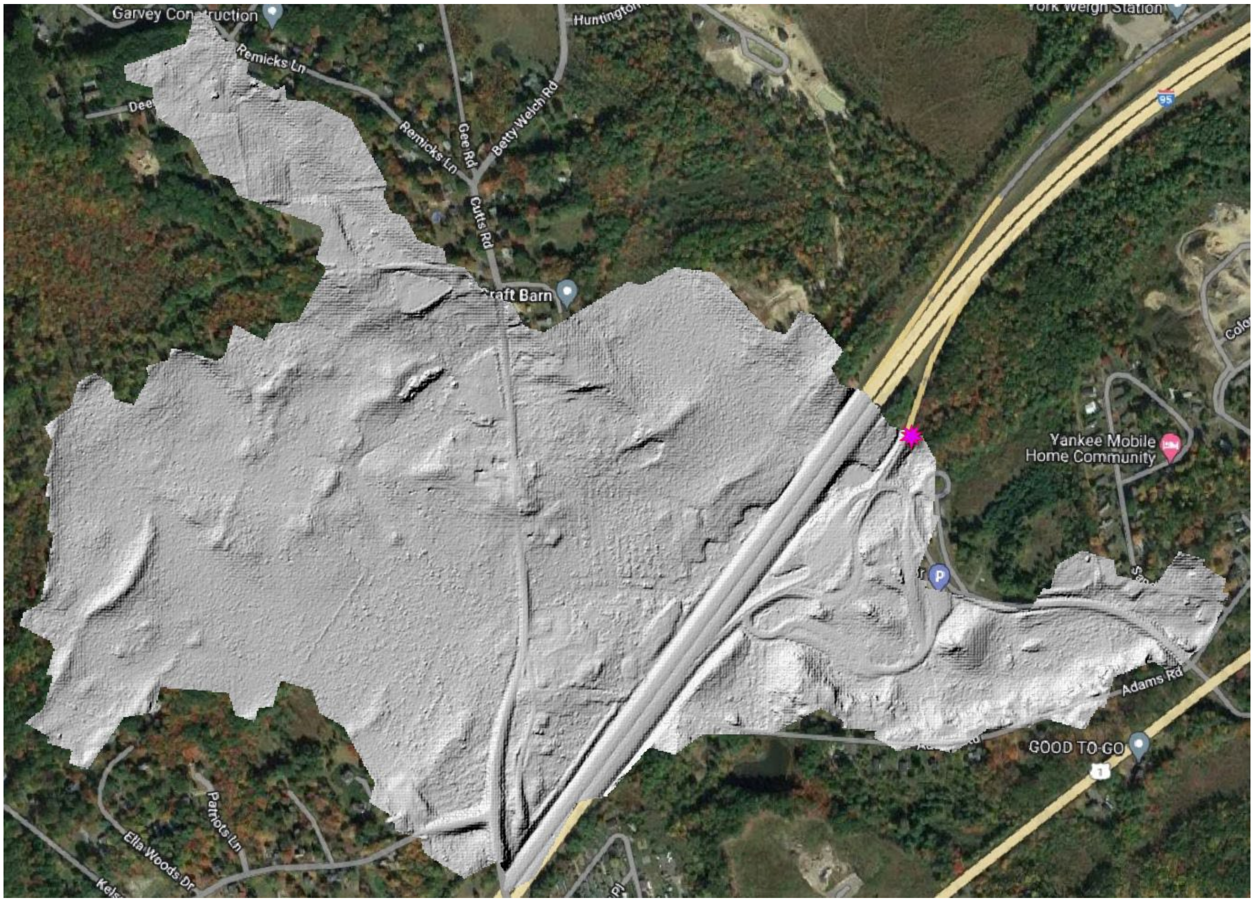

Figure 42: 2K. Elevation is rendered using the Hillshade visualization for the watershed. The purple star indicates the POA.

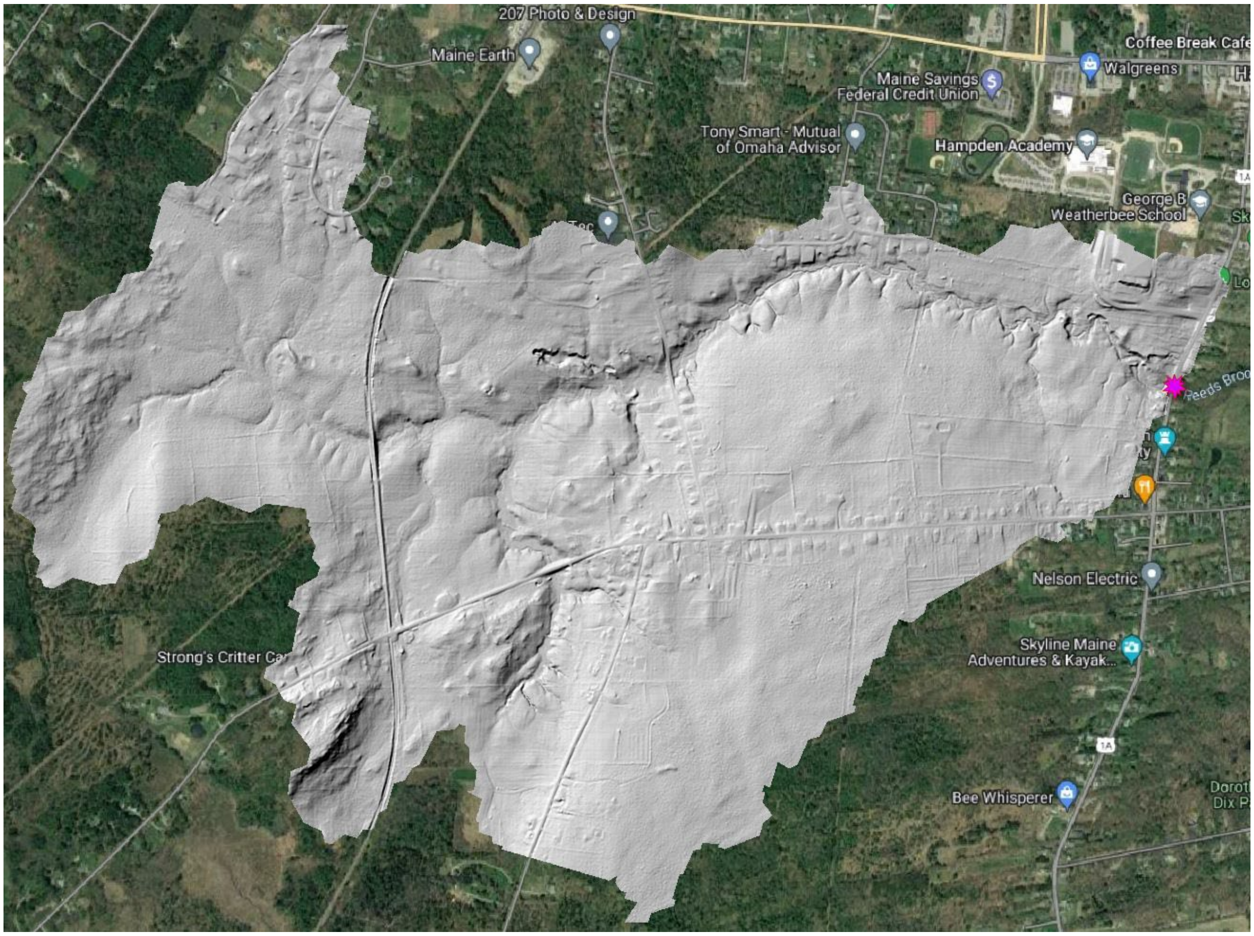

Figure 43: 3HS. Elevation is rendered using the Hillshade visualization for the watershed. The purple star indicates the POA.

Flow Accumulation

The DEM data was passed to the r.watershed tool which among other useful outputs, calculates a raster file of flow accumulation in each cell. This map can be helpful to manually delineate subcatchments and to check the automatic output of the calculated basins. Figure 44 through Figure 46 show the flow accumulation (white to black lines) and the automatically calculated subbasins.

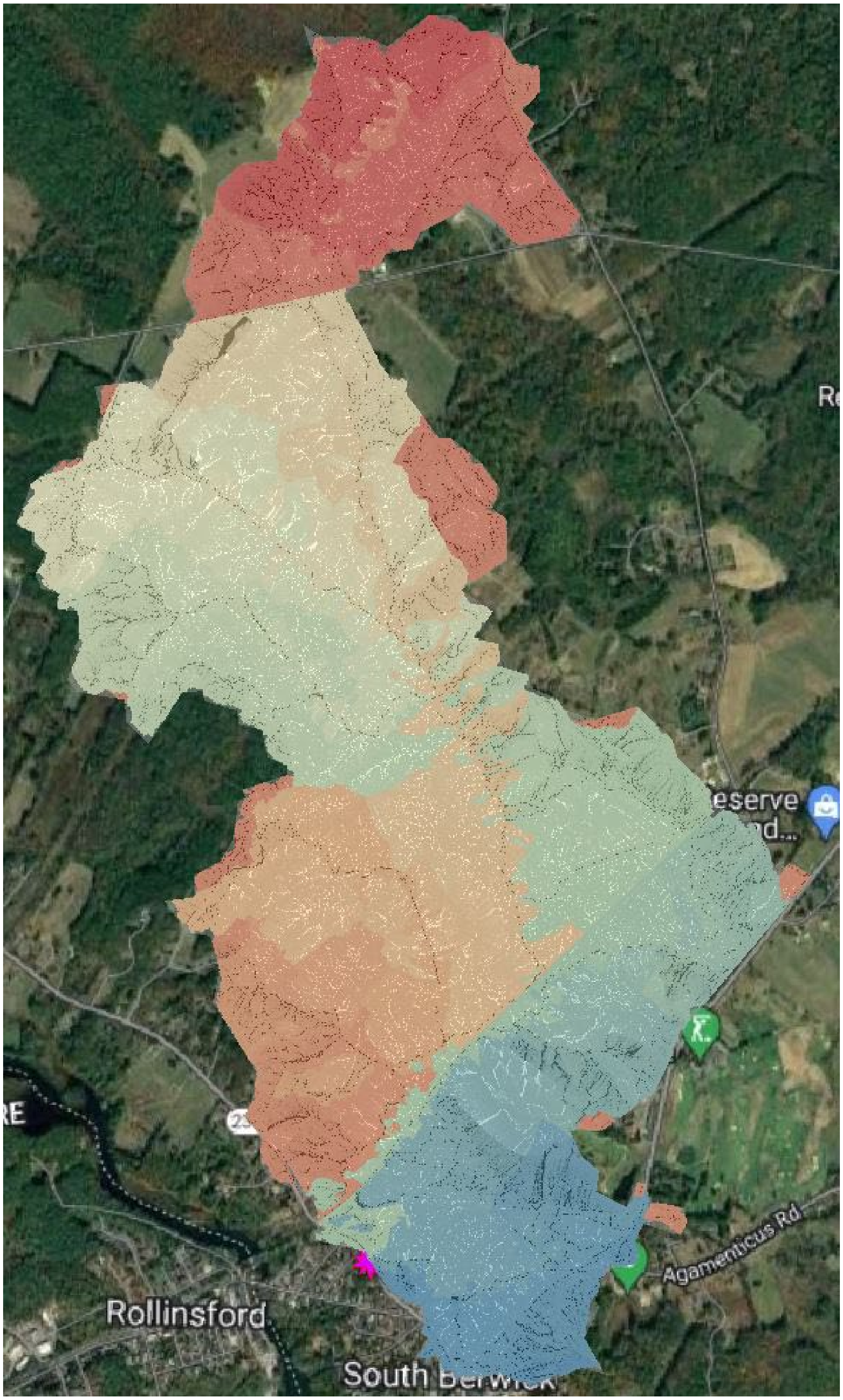

Figure 44: 1SB. Flow accumulation (black and white lines) and subcatchments (colors) were calculated with the r.watershed tool. The purple star indicates the POA.

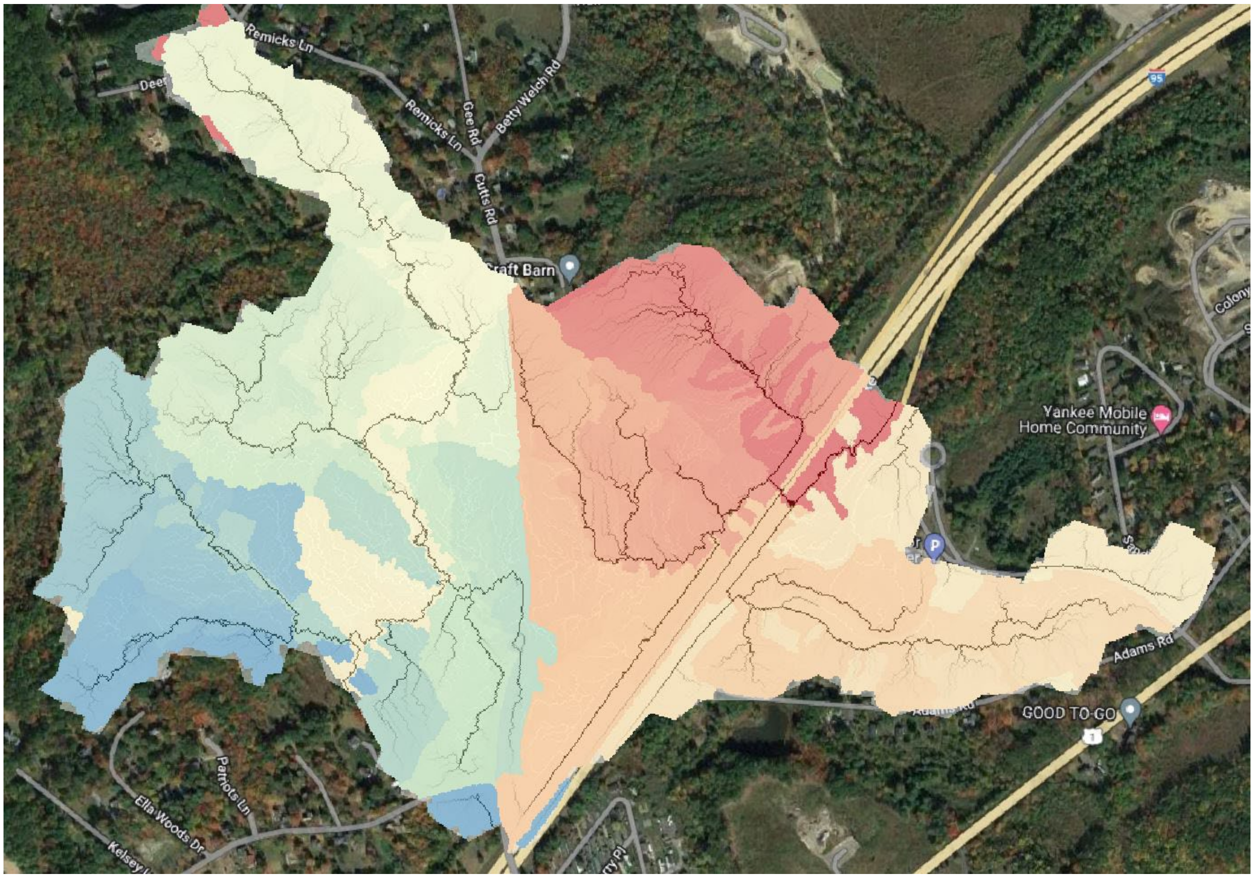

Figure 45: 2K. Flow accumulation (black and white lines) and subcatchments (colors) were calculated with the r.watershed tool. The purple star indicates the POA.

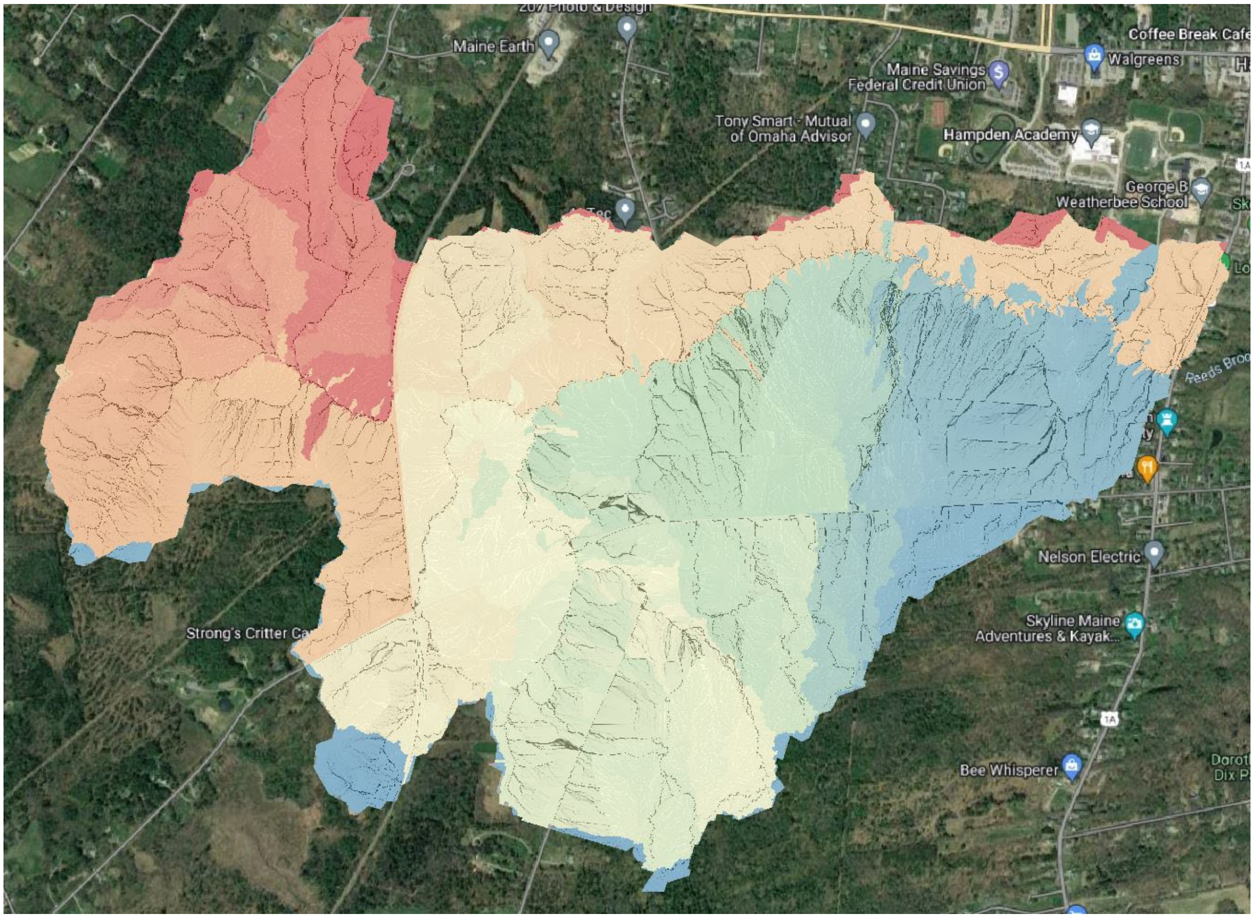

Figure 46: 3HS. Flow accumulation (black and white lines) and subcatchments (colors) were calculated with the r.watershed tool. The purple star indicates the POA.

Subcatchments

The calculated subbasins from the r.watershed tool were aggregated by land use to make fewer subcatchments that would be relatively homogeneous for modeling rainfall/runoff in SWMM. The following maps in Figure 47 through Figure 49 were the final subcatchments to be modeled in SWMM. They are numbered ascending from upstream to downstream (the POA). The DOT roads were separated into their own subcatchments to reflect the runoff observed from the monitoring data as well as for adequate modeling of the existing and future conditions in SWMM.

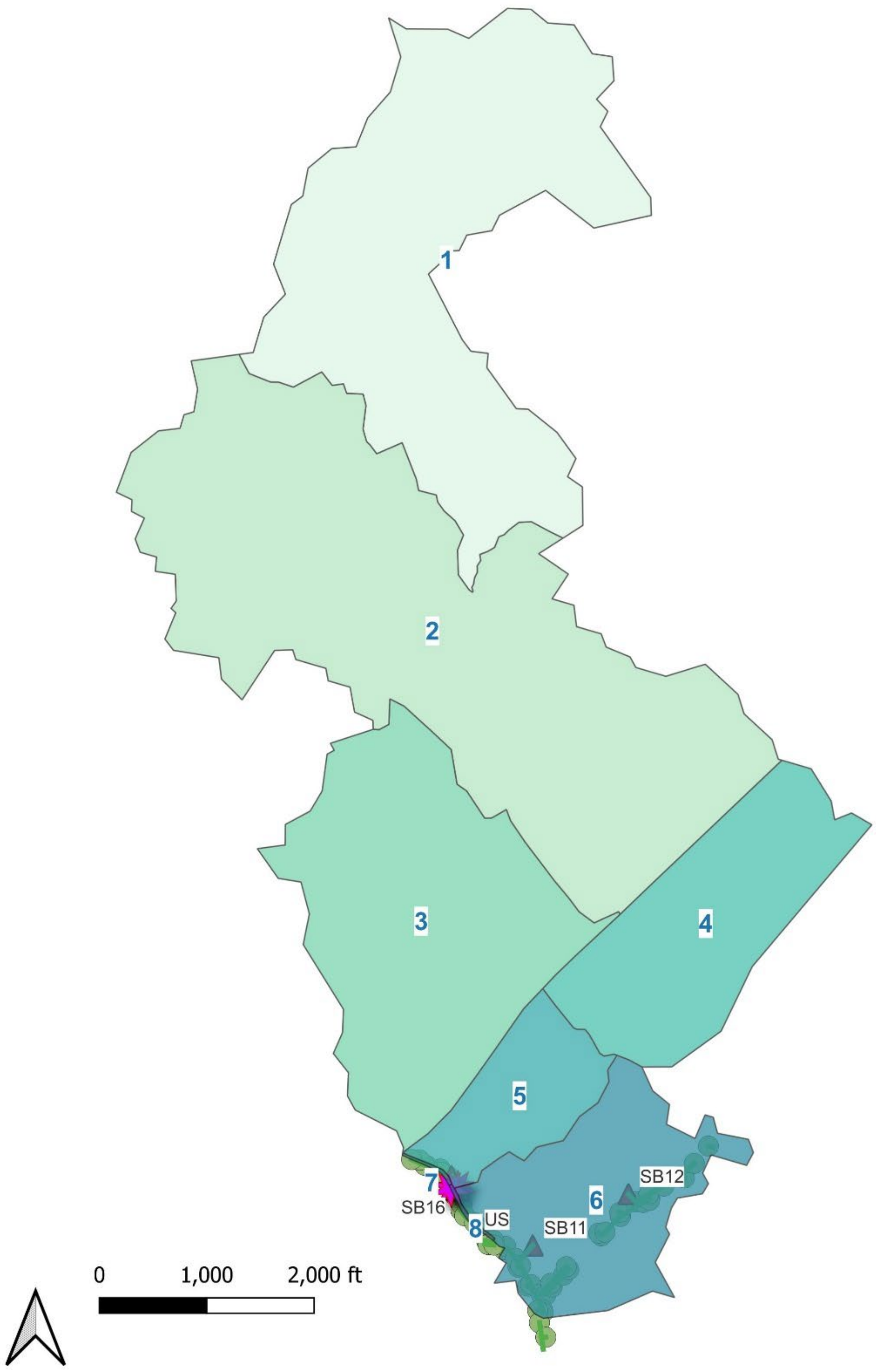

Figure 47: 1SB. The final subcatchments numbered from upstream to downstream from GIS were then imported to SWMM for modeling.

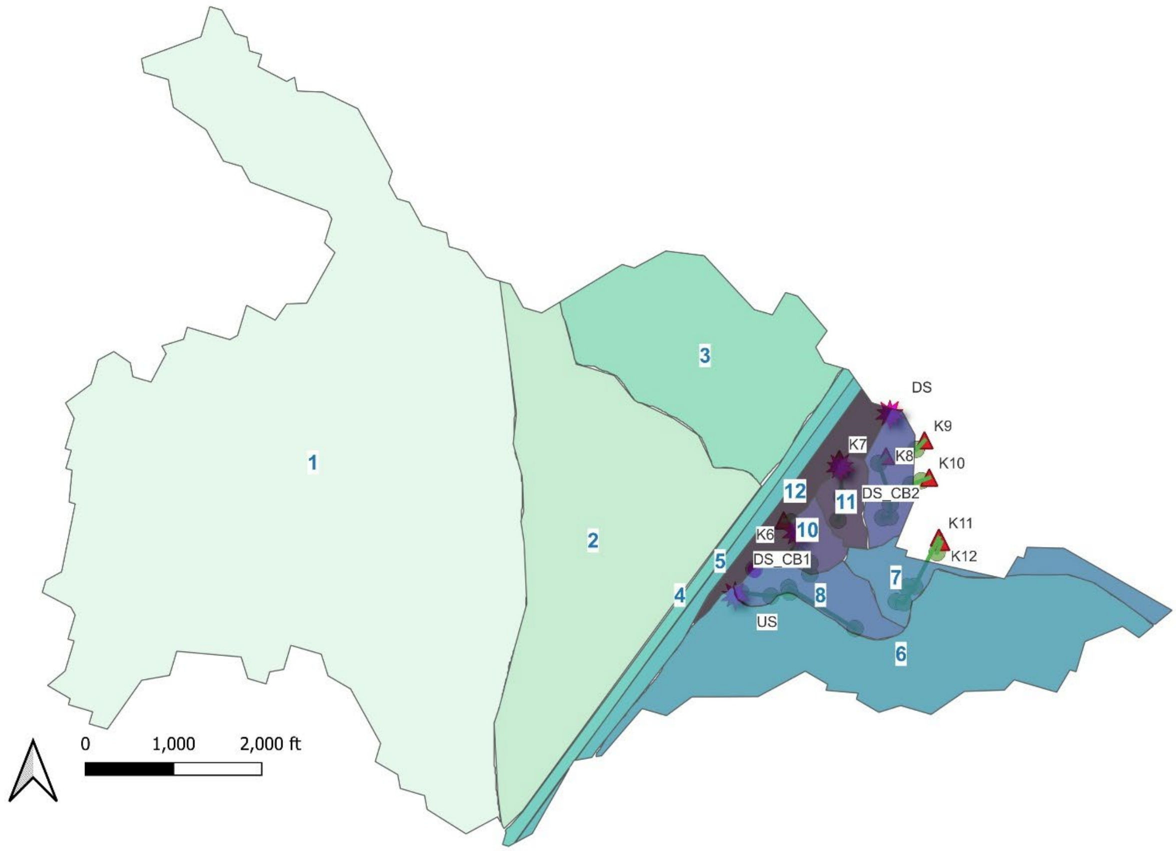

Figure 48: 2K. The final subcatchments numbered from upstream to downstream from GIS were then imported to SWMM for modeling.

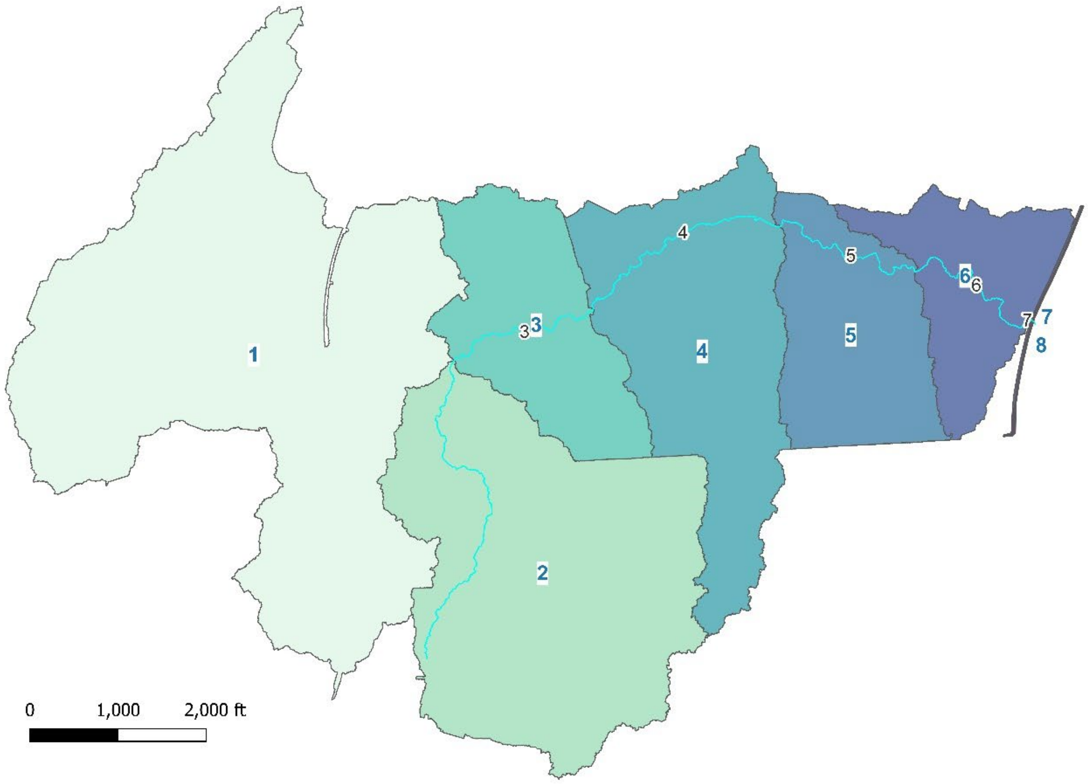

Figure 49: 3HS. The final subcatchments numbered from upstream to downstream from GIS were then imported to SWMM for modeling.

Transects

The transects (stream cross-section) through the subcatchments were found for the average cross-section of each subcatchment using the QGIS plugin Profile tool and Terrain Profile. All units are in meters and shown looking downstream such that x = 0 is on the left bank. The y-axis shows the elevation (meters). The transect name (e.g. "Transect 1") generally corresponds to the subcatchment in which the cross-section is found. Figure 50 shows an example of a transect used to create a conduit in SWMM for routing the runoff downstream. See Appendix E: GIS Transects for all of the transects. The transects are used in SWMM to route runoff to a point further downstream. For this model, for example, Transect 1 would route runoff from S1 through S2 to its outlet and add it to the hydrograph of S2, then route the combined flow to Transect 2, etc.

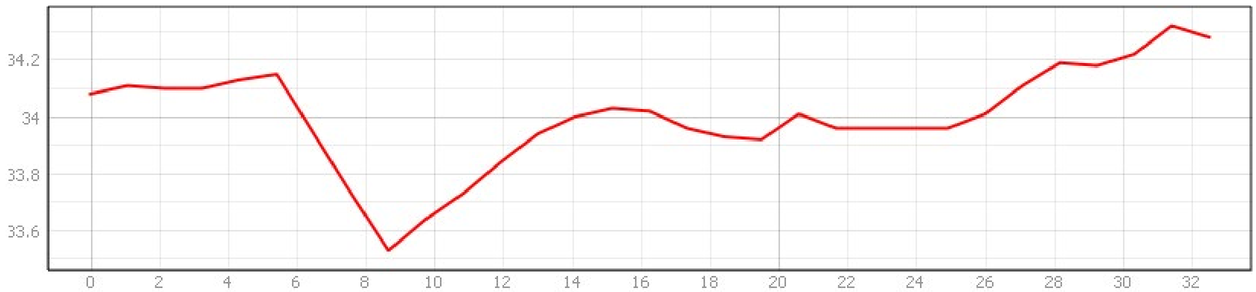

Figure 50: 1SB. An example of a transect (cross-section) of the stream used to route runoff downstream.

Watershed Characteristics for Modeling

The result of the GIS analysis is shown for each site and subcatchment in Table 11. The Pollutant – Percent of IC column is the percent of the impervious cover that contributes the pollutant (chloride). In other words, it's the percent of salted roads.

Table 11: Summary of all subcatchment characteristics from GIS analyses for modeling.

		Subcatchment				Snow	Infiltration		Groundwater			Pollutant
Site	**Subcatch-ment**	**Area (ac)**	**Imperv (%)**	**Width (ft)**	**Slope (%)**	**SnowPack**	**Suction Head Ψ (in)**	**Hydraulic Conductivity K_{sat} (in/hr)**	**Surface Elevation (ft)**	**Aquifer Bottom (ft)**	**Initial Water Table (ft)**	**Percent of IC**
1SB	1	323.81	3.09	1,800	6.69	Res	2.40	1.20	122.48	117.06	119.35	1.55
	2	473.75	0.91	2,628	8.24	Res	3.86	0.61	108.80	103.48	105.41	0.45
	3	236.79	5.13	1,775	9.17	Res	4.00	0.56	84.45	79.30	80.87	2.56
	4	135.76	5.55	1,591	9.20	Res	3.50	0.75	108.35	103.48	105.35	2.78
	5	57.43	17.35	1,102	11.93	Res	2.38	1.31	84.51	79.30	78.95	8.67
	6	115.70	30.89	1,470	9.30	Res	2.37	1.37	77.51	72.01	73.10	15.44
	7	0.55	93.83	41	6.22	DOT	5.93	0.32	78.58	72.01	76.57	93.83
	8	0.74	89.17	44	1.29	DOT	2.40	1.18	78.58	72.01	73.34	89.17

Site	Subcatch-ment	Area (ac)	Imperv (%)	Width (ft)	Slope (%)	SnowPack	Suction Head Ψ (in)	Hydraulic Conductivity K_{sat} (in/hr)	Surface Elevation (ft)	Aquifer Bottom (ft)	Initial Water Table (ft)	Percent of IC
2K	1	132.04	3.47	2,253	4.84	Res	4.56	0.41	33.90	28.40	31.75	1.58
	2	40.81	6.51	780	6.67	Res	7.08	0.08	26.08	20.36	24.91	5.95
	3	22.72	0.11	545	5.67	Res	6.24	0.24	26.13	20.36	24.20	0.66
	4	4.11	83.07	78	2.96	DOT	8.92	0.04	26.83	20.36	26.15	28.46
	5	3.99	87.51	100	3.84	DOT	9.77	0.03	29.58	23.02	29.01	32.76
	6	26.39	9.33	518	10.41	Res	4.84	0.11	29.32	25.78	25.11	5.45
	7	4.90	29.05	497	7.31	DOT	3.65	0.69	31.12	25.55	27.43	35.09
	8	3.96	15.23	215	6.43	DOT	5.13	0.20	32.33	25.78	31.15	19.10
	9	3.30	23.58	179	8.63	DOT	3.41	0.79	32.12	25.55	29.11	43.47
	10	1.67	64.93	247	3.77	DOT	2.48	1.15	29.59	23.02	25.56	52.40
	11	2.05	41.91	200	7.88	DOT	2.47	1.15	24.80	18.24	20.62	37.08
	12	4.45	12.02	142	11.06	Res	9.85	0.03	24.80	18.24	24.07	23.44

Site	Subcatch-ment	Area (ac)	Imperv (%)	Width (ft)	Slope (%)	SnowPack	Suction Head Ψ (in)	Hydraulic Conductivity K_{sat} (in/hr)	Surface Elevation (ft)	Aquifer Bottom (ft)	Initial Water Table (ft)	Percent of IC
3HS	1	420.54	2.20	3,054	6.92	Res	6.64	0.26	141.96	137.74	139.76	0.72
	2	264.55	3.27	2,088	6.84	Res	3.58	0.13	139.87	137.74	138.63	1.08
	3	102.54	5.94	2,221	7.19	Res	4.86	0.19	136.23	132.66	135.12	2.03
	4	169.32	4.14	1,790	6.50	Res	3.52	0.13	125.11	122.21	124.07	1.24
	5	96.48	4.16	1,284	6.93	Res	4.51	0.17	117.54	114.70	116.31	1.22
	6	75.82	9.00	1,249	7.40	Res	5.08	0.38	97.93	94.73	96.61	5.14
	7	1.06	100.00	33	2.59	DOT	4.17	0.49	97.39	94.73	95.06	100.00
	8	1.32	90.53	41	2.00	DOT	4.91	0.39	91.67	89.29	89.57	100.00

Climatology

All climatic data was obtained from the NOAA Local Climatological Data (LCD) website. The nearest stations to each site as well as the available period of record (POR) is shown in Table 12. The data was available at 1-hour intervals for precipitation, temperature, and wind speed. Snow depth was recorded at daily intervals and was only available at Site 3: Hampden.

Table 12: NOAA stations used for climatological data for each site, their distances apart, and period of records.

Site	Station	Distance to Site (mi)	POR
1SB	Rochester Skyhaven	6.7	2006 – 2024
2K	Portsmouth Pease AFB	6.3	2010 – 2024
3HS	Bangor	5.1	2010 – 2024

Figure 51, Figure 52, and Figure 53 show the downloaded data from NOAA LCD stations at hourly intervals for precipitation (in), air temperature (°F), and wind speed (mph). These data are formatted and used in the SWMM model to generate rainfall from precipitation, snowfall from the precipitation and air temperature, and areal depletion (evaporation) from the air temperature and windspeed.

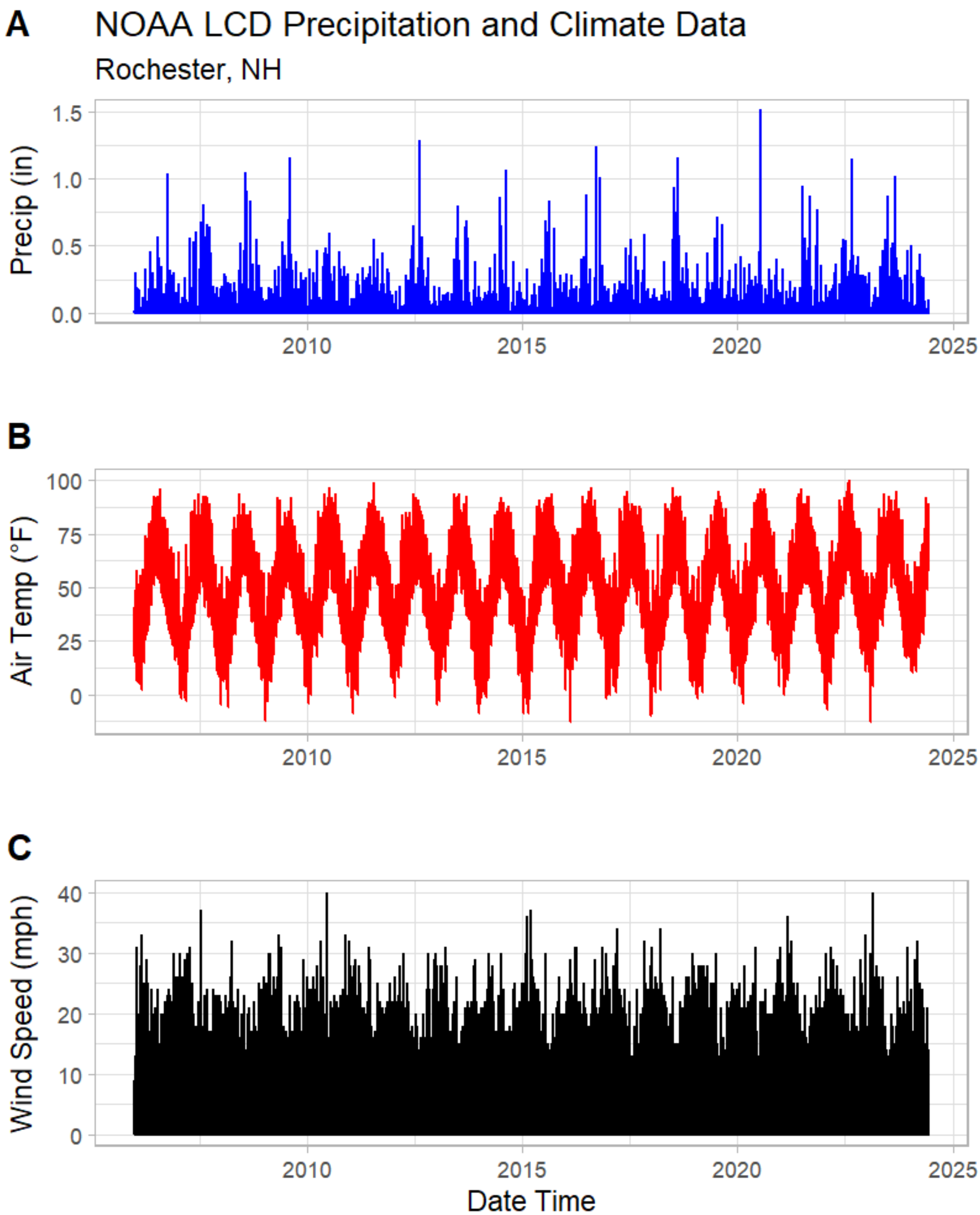

Figure 51: 1SB. NOAA LCD climatological data from the station at Rochester Skyhaven airport, Rochester, NH. All data is shown at 1-hour intervals.

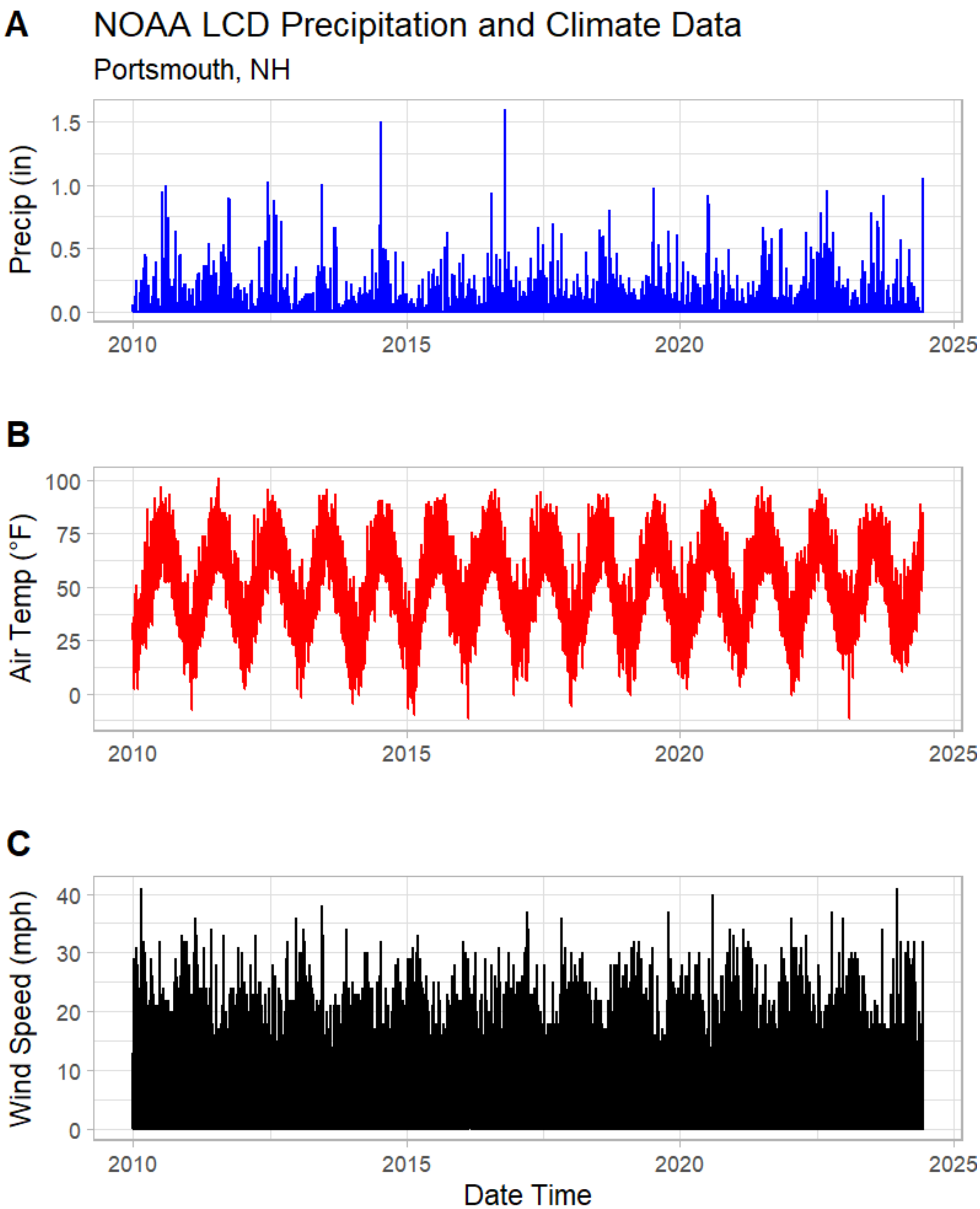

Figure 52: 2K. NOAA LCD climatological data from the station at Portsmouth Pease AFB, Portsmouth, NH. All data is shown at 1-hour intervals.

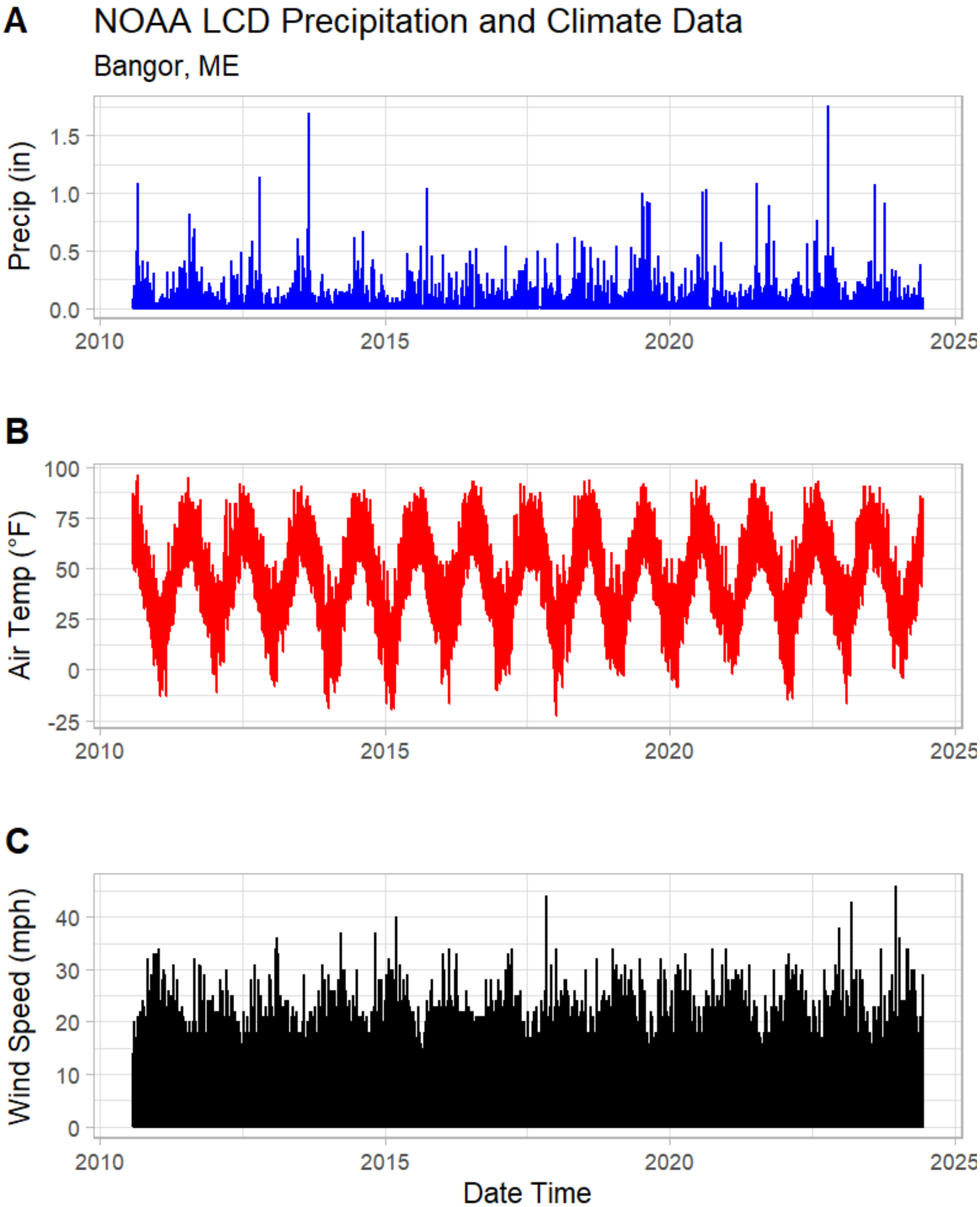

Figure 53: 3HS. NOAA LCD climatological data from the station at Bangor airport, Bangor, ME. All data is shown at 1 hour intervals.

SWMM

Input Files

The rainfall, climatic data, and observed monitoring data were converted to *.dat* files in the formats specified by the SWMM manual. Generally, SWMM requires tab-separated values (tsv) files and each measurement is on its own line. Lines that start with the semicolon (;) start a comment for the user.

Rainfall

SWMM manual section 11.3 describes the required format for rainfall data. Multiple stations may be included in a single file and the station applicable to model is specified in the gage properties. The header is not included in the rainfall.dat file used in SWMM but is shown in Table 13 for clarity. All rainfall values of zero (0) are removed from the file. The data is shown as a table in this report, but the required format for SWMM is a tab-separated *.dat* file.

Table 13: Example rainfall data format for input into SWMM projects.

Station	Year	Month	Day	Hour	Minute	Rainfall (in)
(Header shown for clarity, the rainfall.dat file starts below)						
Rochester	2006	1	1	2	51	0.01
Rochester	2006	1	1	3	11	0.01
Rochester	2006	1	1	3	34	0.01
Portsmouth	2010	1	1	16	55	0.02
Portsmouth	2010	1	1	23	55	0.01
Portsmouth	2010	1	2	0	55	0.01
Bangor	2010	8	3	3	53	0.01
Bangor	2010	8	3	8	37	0.04
Bangor	2010	8	3	8	53	0.04

Climatology

SWMM manual section 11.4 describes the required format for climatic data. Only one station may be included per file. The header is not included in the climate.dat file used in SWMM but is shown in Table 14 for clarity. Climatic data are shown on a daily interval. Where values are missing for any parameter, it is replaced with an asterisk for SWMM to skip that value. This was the case for the evaporation rate as that data was not available from NOAA LCD. The Wind Speed is the average daily value. The data is shown as a table in this report, but the required format for SWMM is a tab-separated *.dat* file.

Table 14: Example climatic data format for input into SWMM projects.

Station	**Year**	**Month**	**Day**	**Max. Temp. (°F)**	**Min. Temp. (°F)**	**Evaporation Rate (in/hr)**	**Wind Speed (mph)**
(Header shown for clarity, the climate.dat file starts below)							
Rochester	2006	1	1	25	18	*	4.6
Rochester	2006	1	2	41	21	*	2.2
Rochester	2006	1	3	34	22	*	8.1
Rochester	2006	1	4	31	17	*	4.7
Rochester	2006	1	5	32	26	*	0.2

Calibration Data

SWMM manual section 11.5 describes the required format for calibration data. Each category of object (subcatchment, node, conduit, etc.) in the model requires its own file, but many objects of the same category may have data in a single file. Headers are allowed in calibration files and are started by a semicolon. Each object starts a new line with the object ID and its data starts on the following line. The units must match the units of the object being calibrated. For example, if the flow is modeled in SWMM in cfs, the calibration file values must be in cfs. Calibration data may be supplied to SWMM at any interval. The calibration data is not used for calibration in SWMM but can be graphed over simulated results for visual inspection by the user. The data is shown as a table in this report, but the required format for SWMM is a tab-separated *.dat* file.

Table 15: Example calibration data formats for various object types for input into SWMM projects.

File 1: calibration_snow_depth.dat

```
;Subcatchment      Date         Time        Snow Pack Depth (in)
;-------------------------------------------------------------------
     S1
                11/27/2010    0:00:00             1
                11/28/2010    0:00:00             1
                12/06/2010    0:00:00             6
                12/07/2010    0:00:00             6
```

File 2: calibration_chloride_sub.dat

```
;Subcatchment   Date            Time        Chloride (mg/L)
;-------------------------------------------------------------------
     S7
                06/17/2023    11:00:00           390.7
                06/17/2023    11:05:00           243.45
                06/17/2023    11:10:00           250.55
                06/17/2023    11:15:00           151.9
```

File 3: calibration_chloride_node.dat

```
;Node          Date          Time        Chloride (mg/L)
;--------------------------------------------------------------------
     J5
               06/17/2023    11:00:00         139.55
               06/17/2023    11:05:00         140.2
               06/17/2023    11:10:00         140.5
               06/17/2023    11:15:00         141.15
     O1
               06/17/2023    11:00:00         247.05
               06/17/2023    11:05:00         248.45
               06/17/2023    11:10:00         247.35
               06/17/2023    11:15:00         248.1
```

Model Overviews

The simulations for the three sites were run using 30-second routing steps, and 1-minute wet and dry runoff steps, and were reported at 5-minute intervals. The figures in the Results section were resampled to hourly intervals (or daily for snow) for plotting purposes. All conclusions and results are based on the 5-minute reporting step from SWMM. The kinematic wave routing equations were used because the relatively simple models did not warrant dynamic wave routing, and the kinematic routing was significantly faster (about 3-minute runtime). For the detailed input files, see Appendix F: SWMM Input Files.

Site 1: South Berwick

Existing Conditions

Figure 54 shows the map overview of the model of the subcatchments drawn from Figure 47 from the GIS output. The detailed view of the outlet map is shown in Figure 55. Junction J5 was the upstream monitoring location, subcatchment S7 was the catch basin (CB) monitoring location, and the downstream location was at the outfall O1.

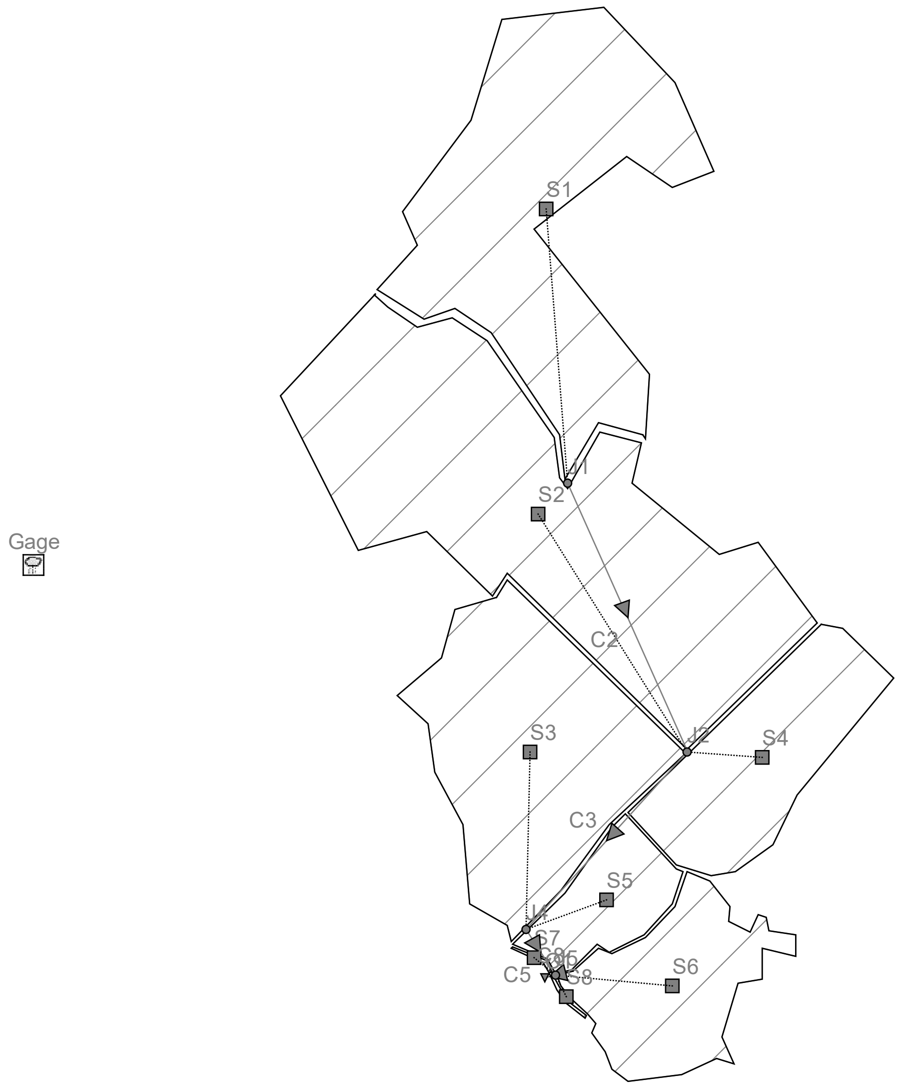

Figure 54: 1SB. SWMM model overview of the existing conditions. There are 8 subcatchments, 4 junctions, 4 conduits (3 transects and 1 culvert), and 1 outfall.

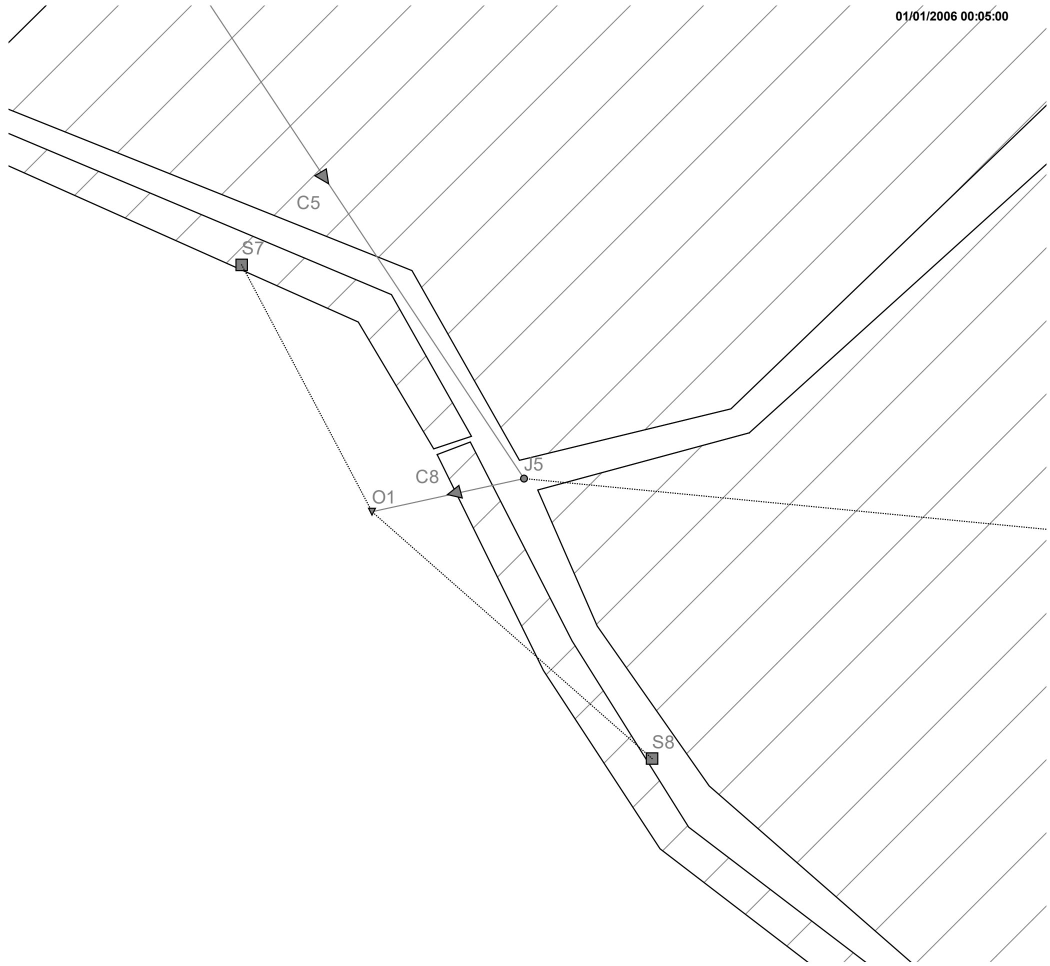

Figure 55: 1SB. Close-up of the outfall SWMM model of the existing conditions. J5 is the upstream node, S7 and S8 are the DOT-owned roads, and O1 is the downstream outfall.

Proposed Conditions: Storage

Figure 56 shows the modifications near the outfall in the proposed storage scenarios. The DOT subcatchments S7 and S8 (the road) are routed to a storage unit that has an orifice control outlet draining to the outfall. Note that the x-y location of the storage unit has no bearing on the model's hydraulics. In the proposed storage scenarios, the size of the storage unit did not change and had a large footprint, and the orifice diameter varied from 1-inch, 3-inch, 6-inch, and 12-inch. The area was kept constant with a large footprint to model the effects of the orifice only and not have significant influence by the driving head from a small storage unit. This is not a realistic depiction for construction, but it easily distinguishes the modeled effects between the depth in storage and the orifice size. The 1-inch result is not shown in the later figures, however, because it did not improve the solution and cluttered the figures. In these scenarios, J5 is still the upstream location, S7 is still the CB, and O1 is the downstream location as before.

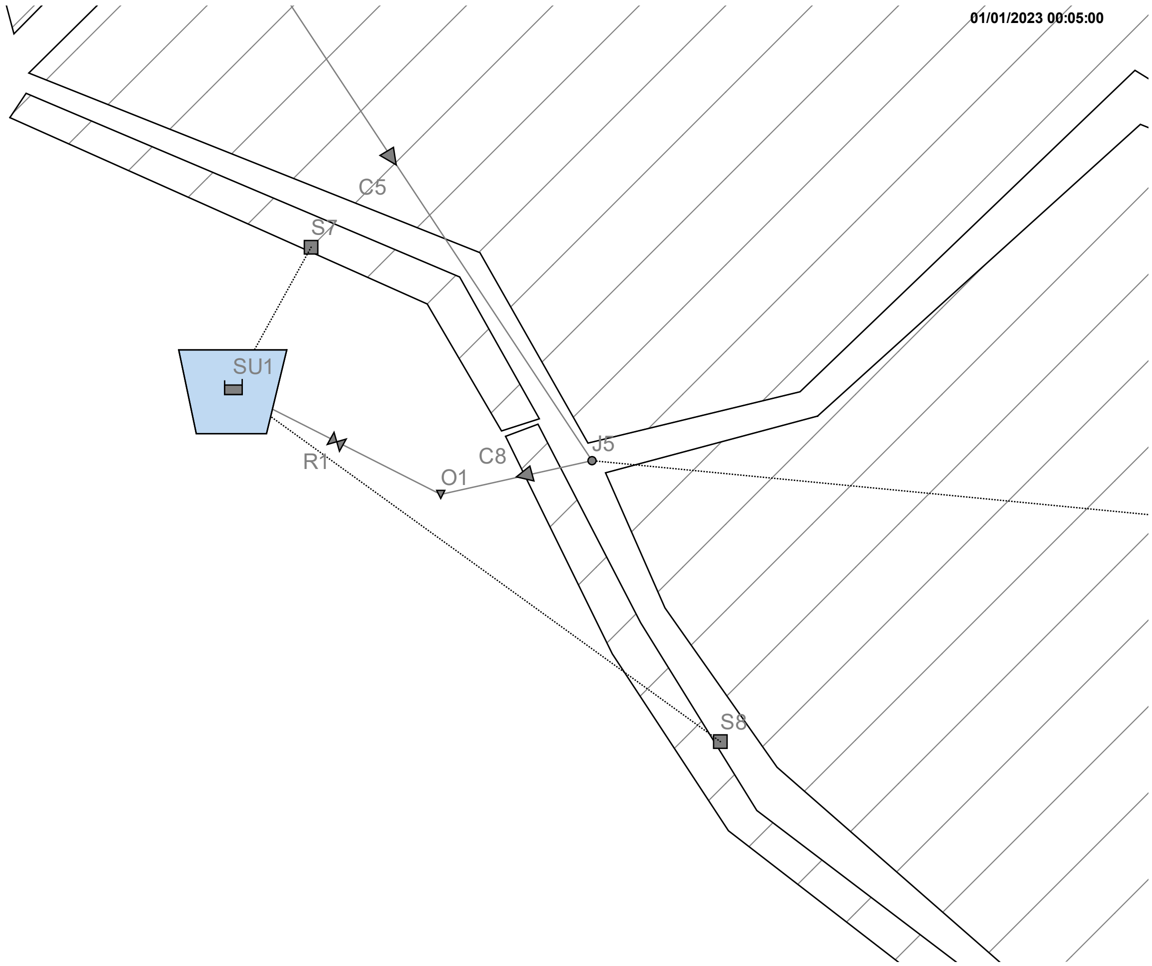

Figure 56: 1SB. Close-up of the outfall for the proposed storage simulation. The DOT roads S7 and S8 are routed to storage (SU1) which has an orifice control (R1) release to the outfall.

Proposed Conditions: Dilution

Figure 57 shows the modifications near the outfall in the proposed dilution scenarios. The DOT subcatchments S7 and S8 (the road) are routed to a junction (like a CB) in the model which has constant inflow to simulate a well pumping fresh groundwater into the junction which drained to the outfall. Note that the x-y location of the pumping junction has no bearing on the model hydraulics. In proposed dilution scenarios, the pump had flows of 0.1, 1, 10, 100, and 1000 gpm. The 0.1 gpm result is not shown in the later figures, however, because it did not improve the solution and cluttered the figures. In these scenarios, J5 is still the upstream location, J6 is still the CB with dilution, and O1 is the downstream location as before.

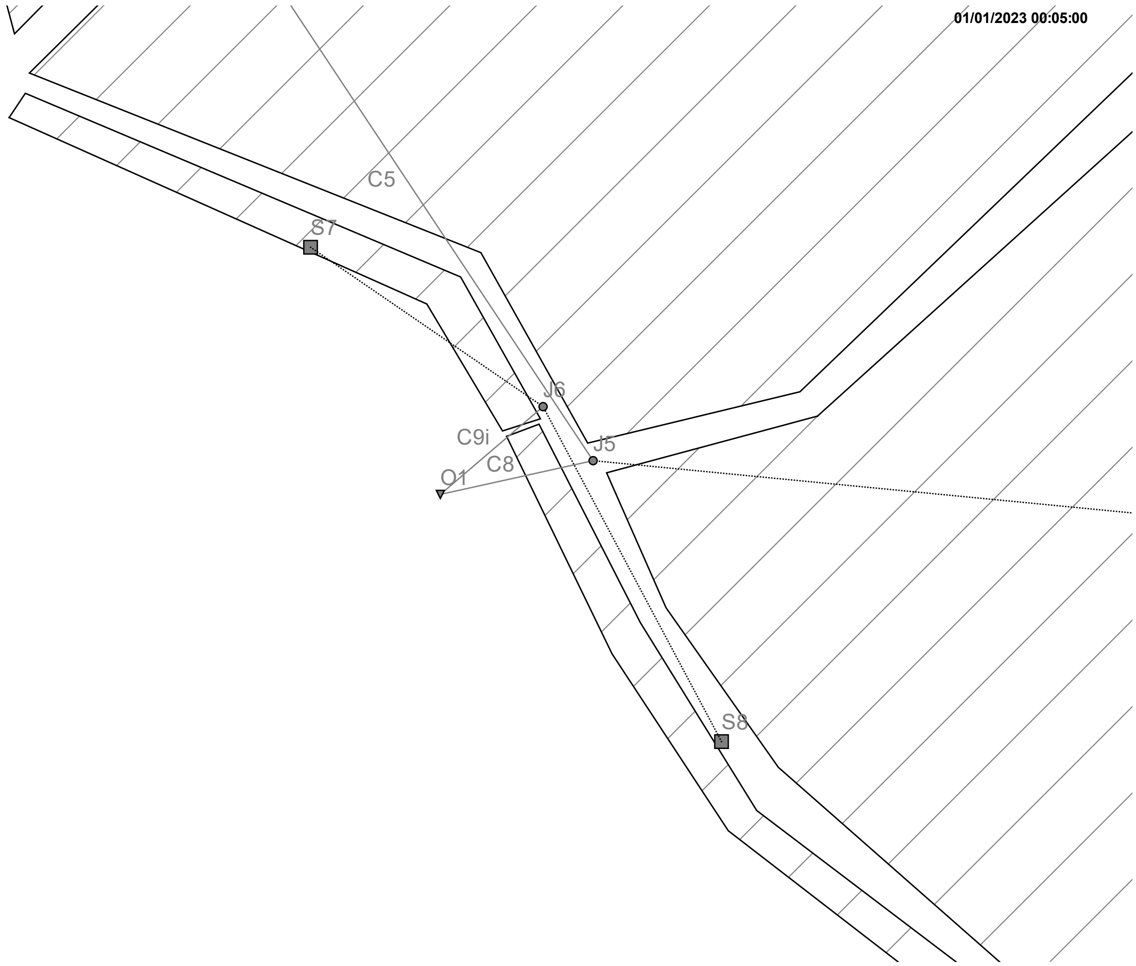

Figure 57: 1SB. Close-up of the outfall for the proposed dilution simulation. The DOT roads S7 and S8 are routed to junction J6 which has a constant flow of freshwater. The mixed runoff is routed back to the outfall.

Site 2: Kittery

Existing Conditions

Figure 58 shows the map overview of the model of the subcatchments drawn from Figure 48 from the GIS output. The detailed view of the outlet map is shown in Figure 59. Subcatchment S6 was the upstream monitoring location, subcatchments S10 and S11 were the catch basin (CB1 and CB2) monitoring location, and the downstream location was at the outfall O1. Note that O2 is the modeled outfall that drains the eastern pavement of S7 and S9 but does not connect to the monitored outfall of this study.

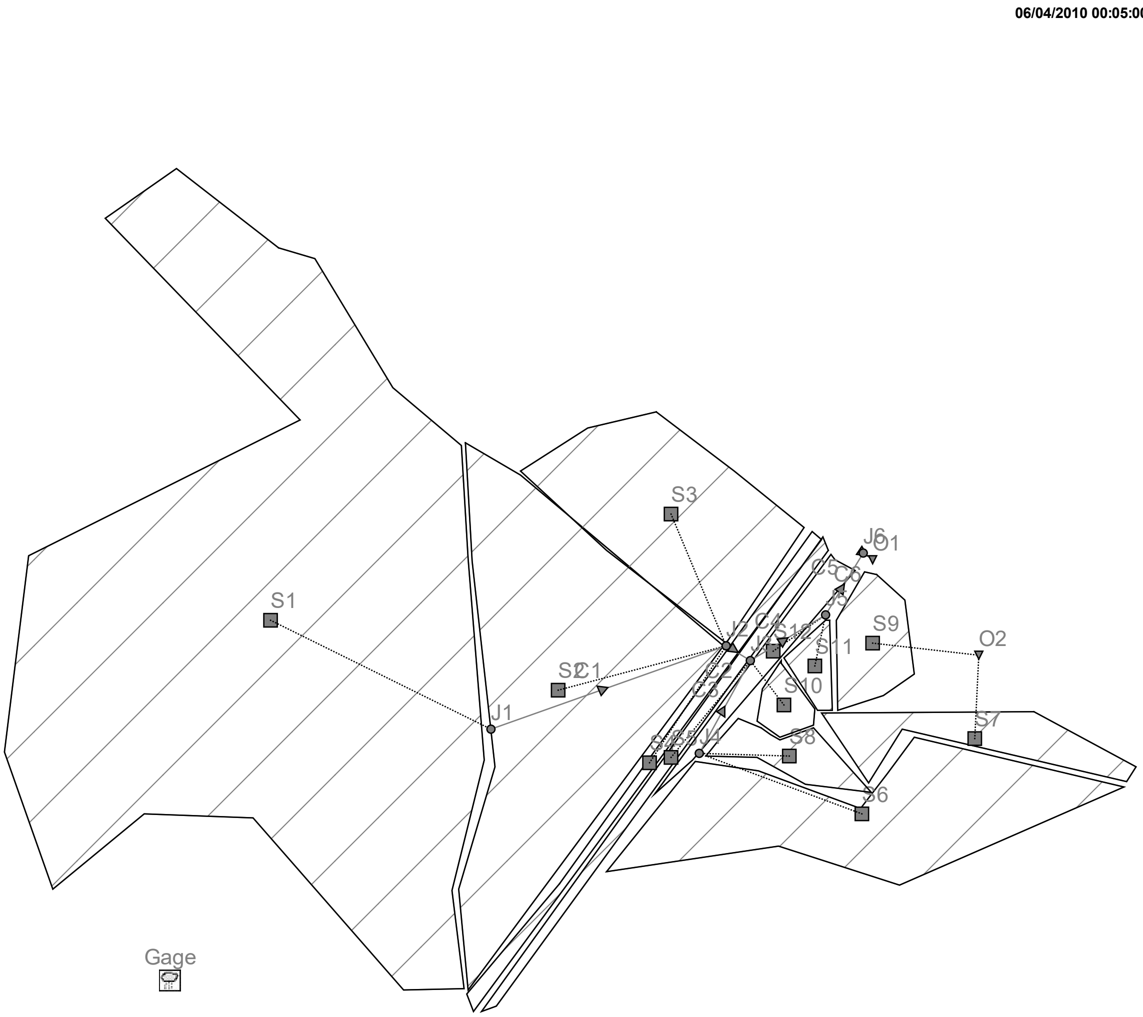

Figure 58: 2K. SWMM model overview of the existing conditions. There are 12 subcatchments, 6 junctions, 6 conduits (4 transects and 2 culverts), and 2 outfalls.

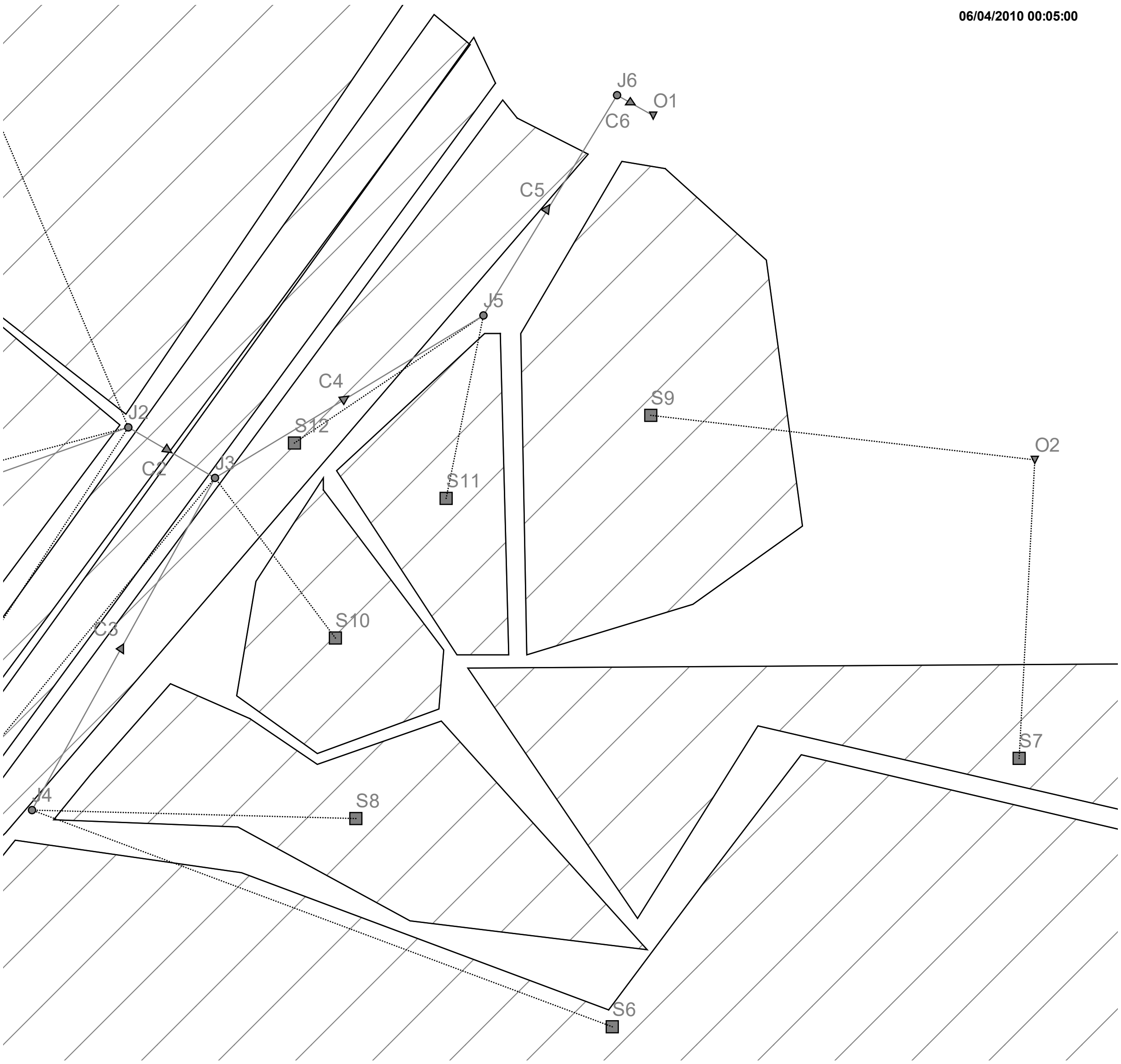

Figure 59: 2K. Close-up of the outfall SWMM model of the existing conditions. S6 is the upstream subcatchment, S8-S11 are the DOT-owned roads/parking lots, and O1 is the downstream outfall. O2 is an outfall that is downstream of the POA.

Proposed Conditions: Storage

Figure 60 shows the modifications near the outfall in the proposed storage scenarios. The DOT subcatchments S8 and S10 are routed to a storage unit that has an orifice control outlet draining to the swale near the Northbound highway routing toward the outfall. Note that the x-y location of the storage unit has no bearing on the model's hydraulics. In the proposed storage scenarios, the size of the storage unit did not change, but the orifice diameter varied from 1-inch, 3-inch, 6-inch, and 12-inch. The 1-inch result is not shown in the later figures, however, because it did not improve the solution and cluttered the figures. In these scenarios, S6 is still the upstream location, S10 and S11 are still the CBs, and O1 is the downstream location.

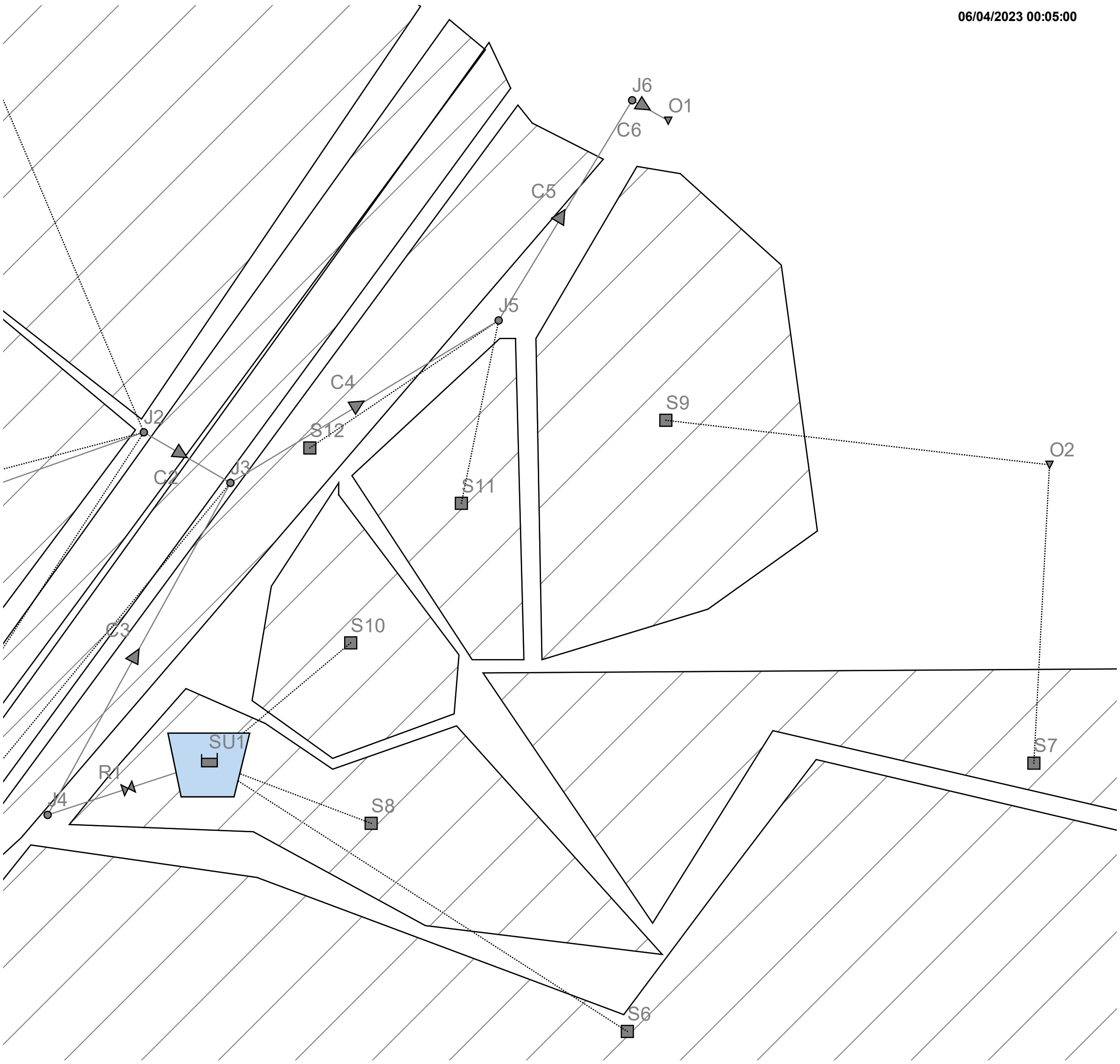

Figure 60: 2K. Close-up of the outfall for the proposed storage simulation. The DOT subcatchments S8 and S10 (and upstream S6) are routed to storage (SU1) which has an orifice control (R1) release to the swale at J4.

Proposed Conditions: Dilution

Figure 61 shows the modifications near the outfall in the proposed dilution scenarios. The map here does not change compared to the existing conditions due to the specific configuration of the site. All flows are routed identically to the existing conditions. The final junction J6 in the model has constant inflow to simulate a well pump (or other fresh water source) pumping fresh groundwater into the junction which drained to the catch basins. Note that the x-y location of the pumping junction has no bearing on the model hydraulics. In proposed dilution scenarios, the pump had flows of 0.1, 1, 10, 100, and 1000 gpm. The 0.1 gpm result is not shown in the later figures, however, because it did not improve the solution and cluttered the figures. In these scenarios, S6 is still the upstream location, S10 and S11 are still the CB1 and CB2, J6 is the well pump junction, and O1 is the downstream location as before.

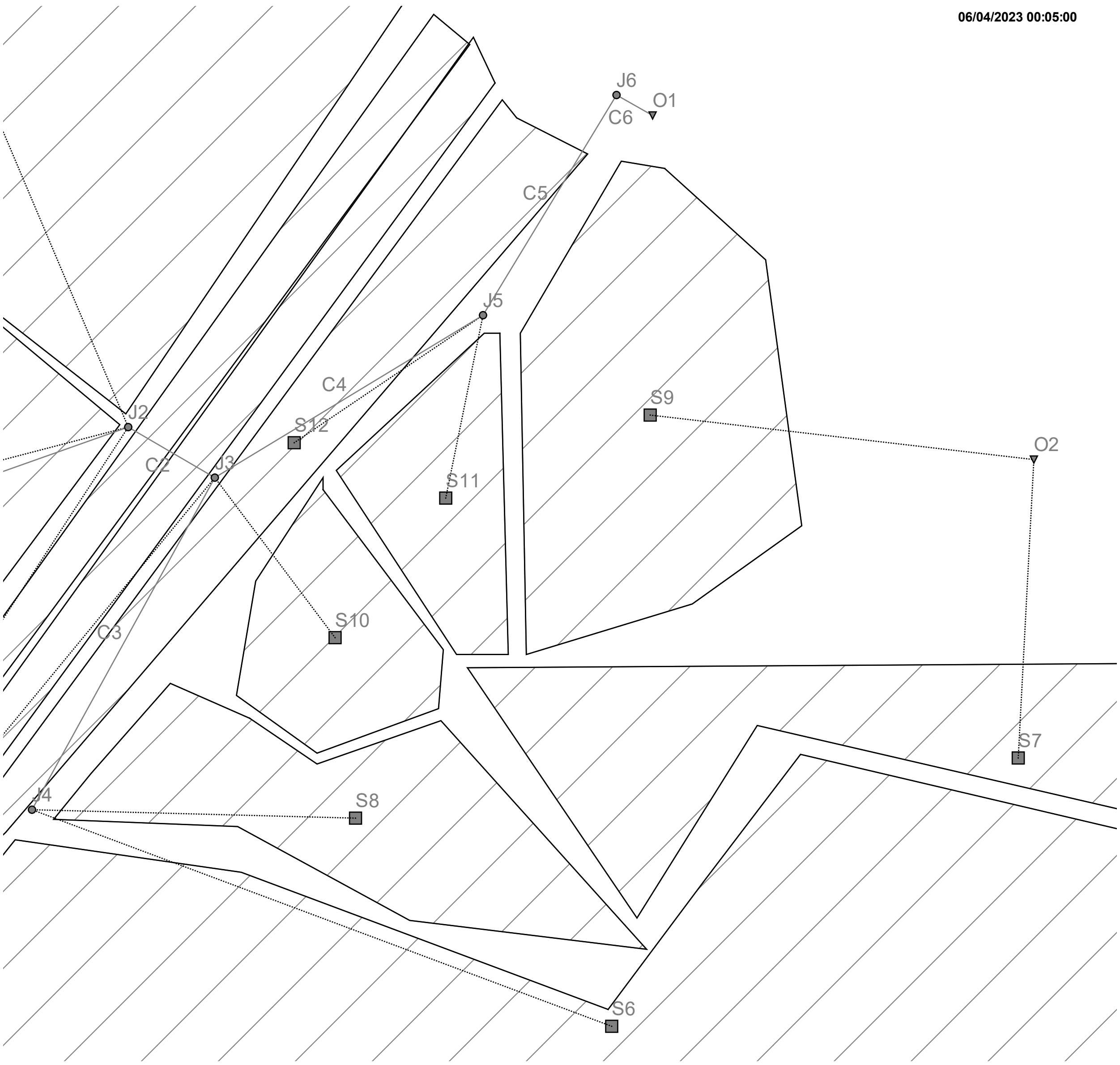

Figure 61: 2K. Close-up of the outfall for the proposed dilution simulation. The junction J7 nearest the outfall has a constant flow of freshwater. The mixed runoff is routed to the outfall O1.

Site 3: Hampden South

Existing Conditions

Figure 62 shows the map overview of the model of the subcatchments drawn from Figure 49 from the GIS output. The detailed view of the outlet map is shown in Figure 63. Junction J6 was the upstream monitoring location, subcatchment S7 was the catch basin (CB) monitoring location, and the downstream location was at junction J7. O1 is the final outfall, but junction J7 matches the location of the monitored "downstream" which excludes the eastern half of the road (S8).

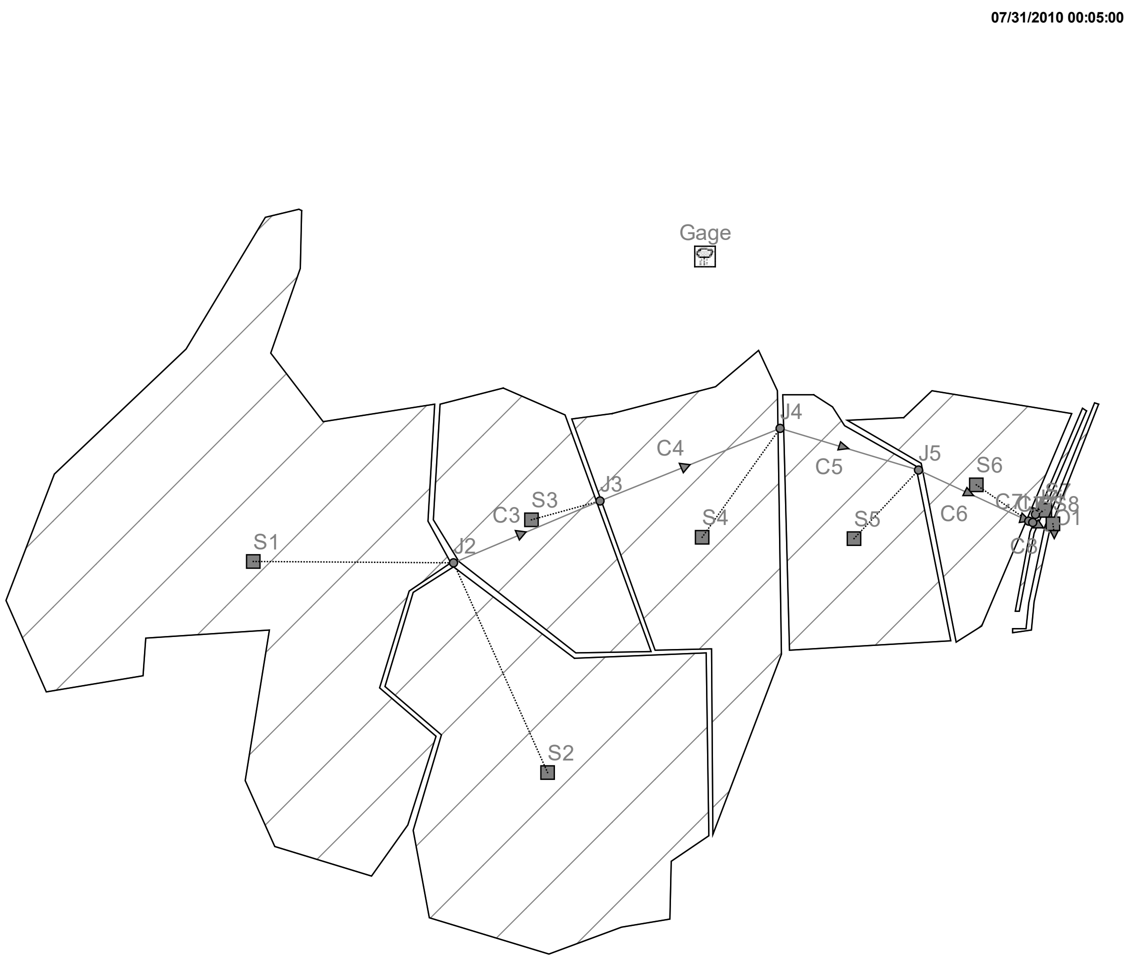

Figure 62: 3HS. SWMM model overview of the existing conditions. There are 8 subcatchments, 7 junctions, 7 conduits (5 transects and 2 culverts), and 1 outfall.

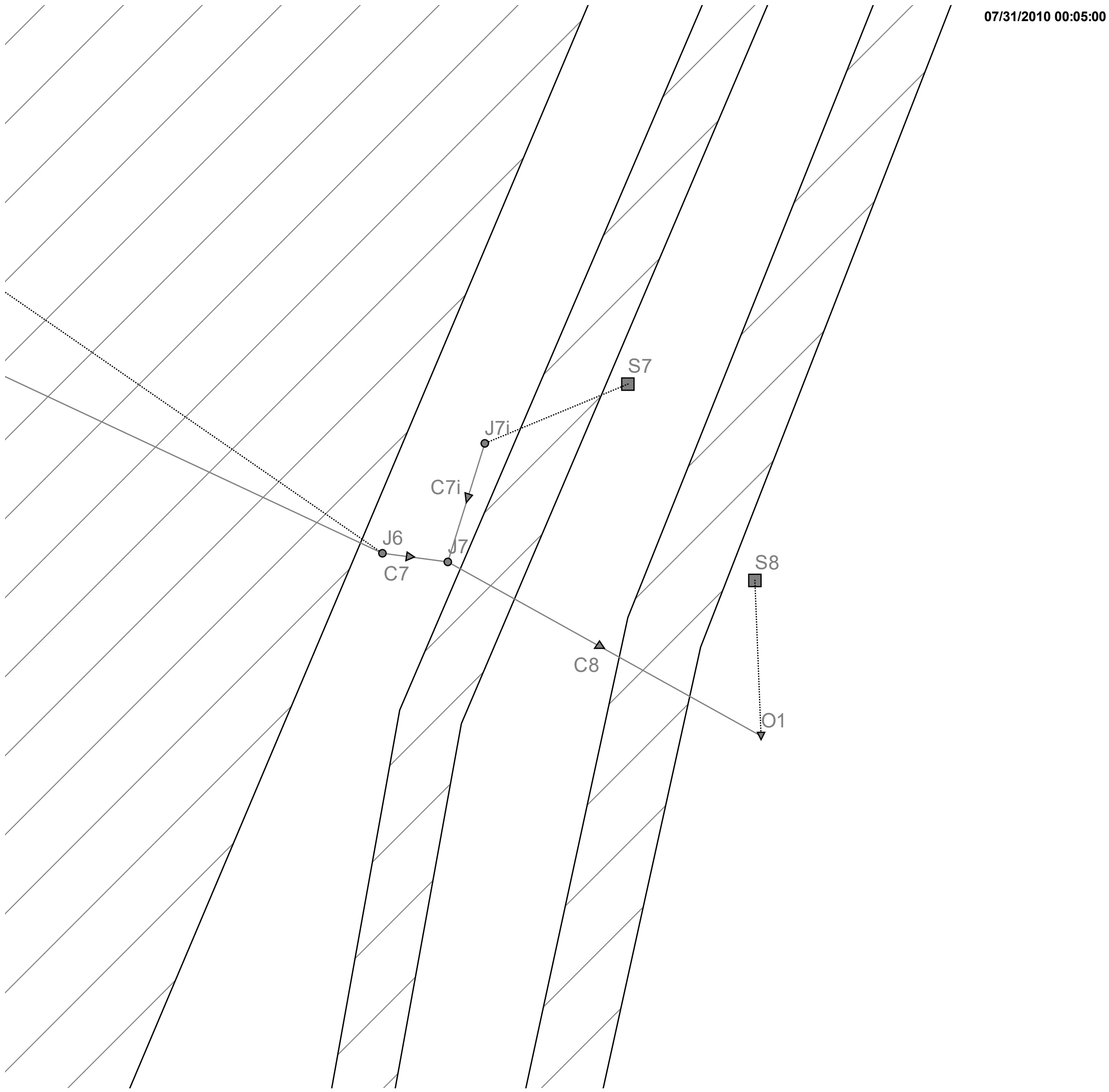

Figure 63: 3HS. Close-up of the outfall SWMM model of the existing conditions. J6 is the upstream node, S7 and S8 are the DOT-owned roads, and O1 is the downstream outfall.

Proposed Conditions: Storage

Figure 64 shows the modifications near the outfall in the proposed storage scenarios. The DOT subcatchments S7 and S8 (the road) would be routed to a storage unit that has an orifice control outlet draining to the outfall. Note that the x-y location of the storage unit has no bearing on the model's hydraulics. In the proposed storage scenarios, the size of the storage unit did not change, but the orifice diameter varied from 1-inch, 3-inch, 6-inch, and 12-inch. The 1-inch result is not shown in the later figures, however, because it did not improve the solution and cluttered the figures. In these scenarios, J6 is still the upstream location, S7 is still the CB, and O1 is the downstream location.

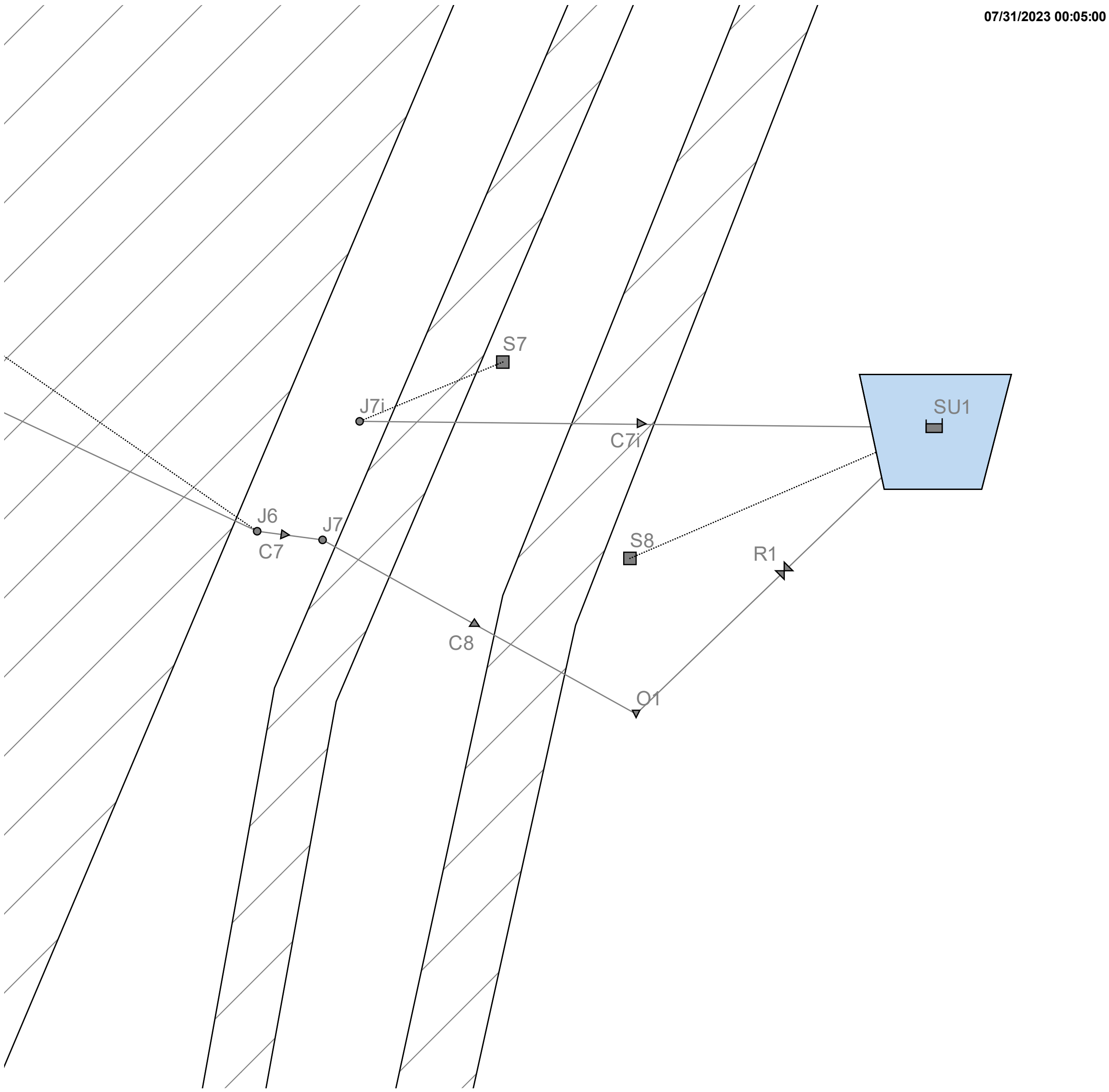

Figure 64: 3HS. Close-up of the outfall for the proposed storage simulation. The DOT roads S7 and S8 are routed to storage (SU1) which has an orifice control (R1) release to the outfall.

Proposed Conditions: Dilution

Figure 65 shows the modifications near the outfall in the proposed dilution scenarios. The DOT subcatchments S7 and S8 (the road) are routed to junction J8i (like a CB) in the model which had constant inflow which simulates a well pump pumping fresh groundwater into the junction which drained to the outfall. Note that the x-y location of the pumping junction has no bearing on the model hydraulics. In proposed dilution scenarios, the pump had flows of 0.1, 1, 10, 100, and 1000 gpm. The 0.1 gpm result is not shown in the later figures, however, because it did not improve the solution and cluttered the figures. In these scenarios, J6 is still the upstream location, S7 is still the CB, junction J8i is the new junction with dilution, and O1 is the downstream location.

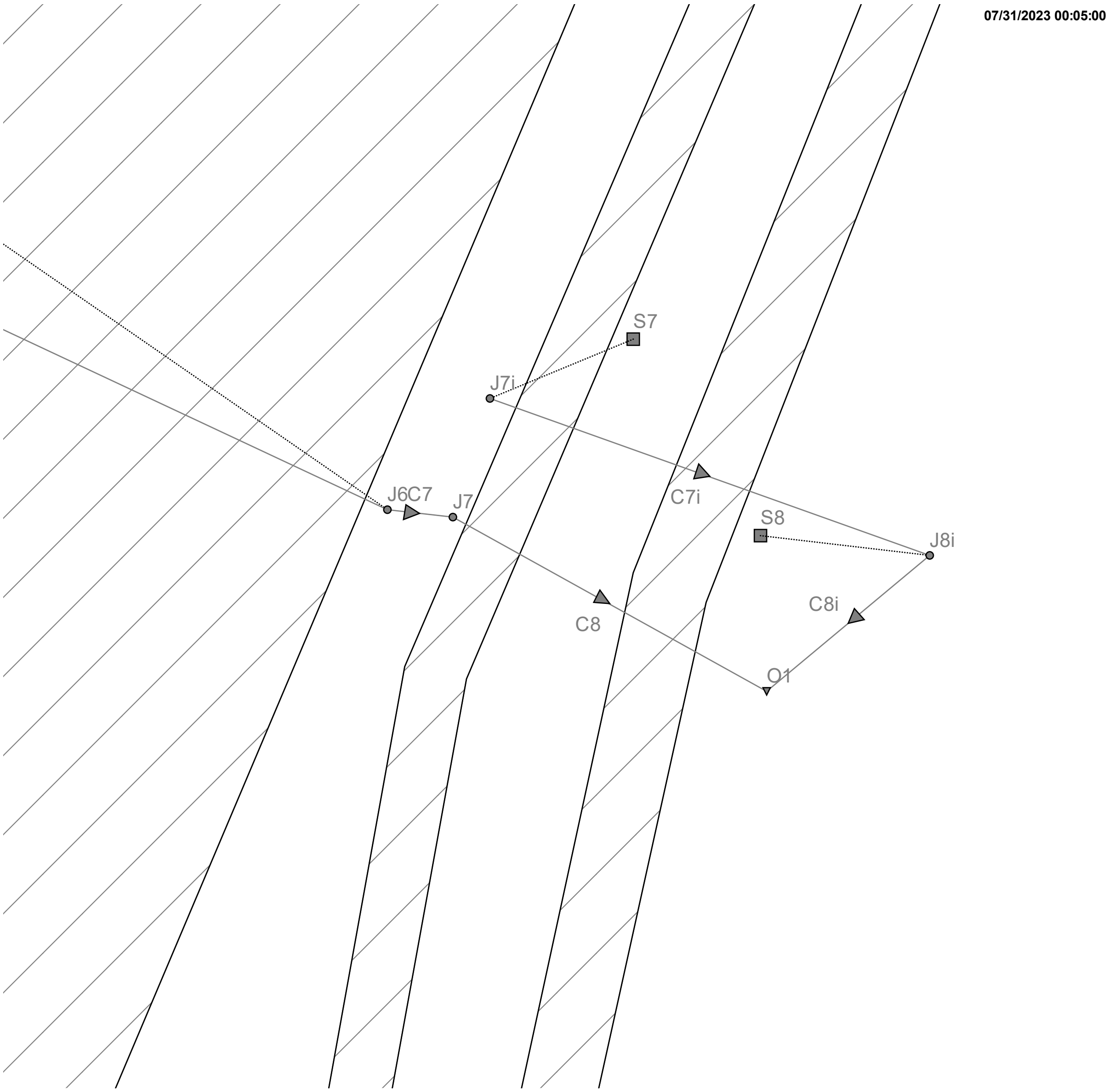

Figure 65: 3HS. Close-up of the outfall for the proposed dilution simulation. The DOT roads S7 and S8 are routed to junction J8i which has a constant flow of freshwater. The mixed runoff is routed back to the outfall.

Model Calibration

The models of the existing conditions were calibrated using observed data where available. This included the daily snow depth at 3HS from NOAA, average and percentile flows at all three sites from StreamStats, and monitored data for chloride for the upstream, CBs, and downstream locations for all three sites from UNHSC. While SWMM does have an option to input calibration files, there is no native calibration tool for the model parameters. The calibration files within SWMM only show the calibration data in the graphs and tables.

In order to calibrate the many parameters for the snow pack, aquifers, and chloride buildup and washoff, an external Python program was written using the *swmm-api* package to read and run the SWMM files and the *scipy.optimize* tool. One benefit of using a dedicated optimization package and the open-source Python language was that the optimization trials were run in parallel to dramatically decrease the runtime by utilizing 12 logical processors rather than just 1; this was accomplished using the *joblib* library the *Parallel* tool.

The general procedure for calibration was to: open the SWMM input file (.inp extension), modify the desired parameters using the *swmm-api SwmmInput* tool within a function, save the temporary input file for the trial, run the file through the SWMM executive file with *swmm5_run*, read the output with the *read_out_file* and *SwmmOutput* tools, and calculate the Kling-Gupta Efficiency (KGE) to compare the observed and simulated data. These steps were combined into a function and passed to the optimizer which always has a goal of minimization. Because the range for KGE is negative infinity to 1, the inverse of the function was passed to the optimization to try to reach a KGE value of 1 by minimizing negative KGE. The optimization algorithm used was the *direct* algorithm which always converged to a global solution. Other local multivariate and global optimization algorithms were tested but were unsuccessful at converging; these included *Nelder-Mead*, *Powell*, *BFGS*, *Newton-CG*, *L-BFGS-B, TNC, COBYLA , SLSQP , basinhopping*, differential_evolution, *dual_annealing*, and *shgo*. The *minimize_parallel* function from the *optimparallel 0.1.3* package, which is a parallelized version of *scipy.optimize.minimize* and *L-BFGS-B* algorithm, was attempted but would not successfully run without errors. Additional potentially faster methods like the OSTRICH-SWMM package and swarm algorithms were attempted without success.

The calibration results of the snow depth at 3HS is shown in Figure 66, and the outfall flows at all three sites are shown in Figure 67, Figure 68, and Figure 69.

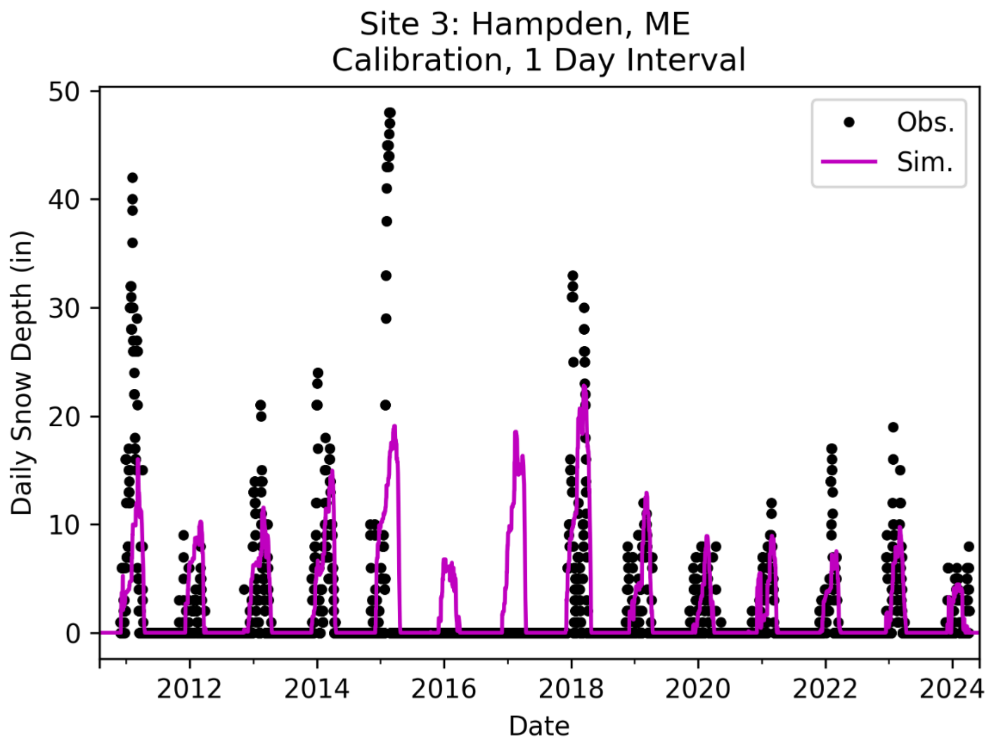

Figure 66: 3HS. Calibration results of the existing conditions overlayed on the observed snow depth from the NOAA station. Results are shown as the daily total value.

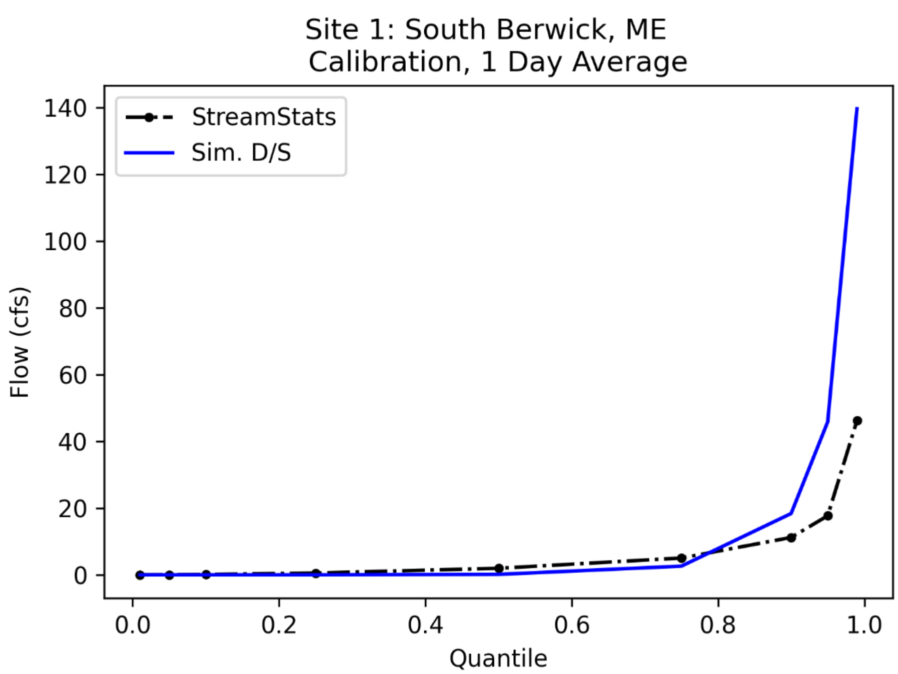

Figure 67: 1SB. Calibration results of the downstream flow with existing conditions overlayed on the StreamStats quantile flows.

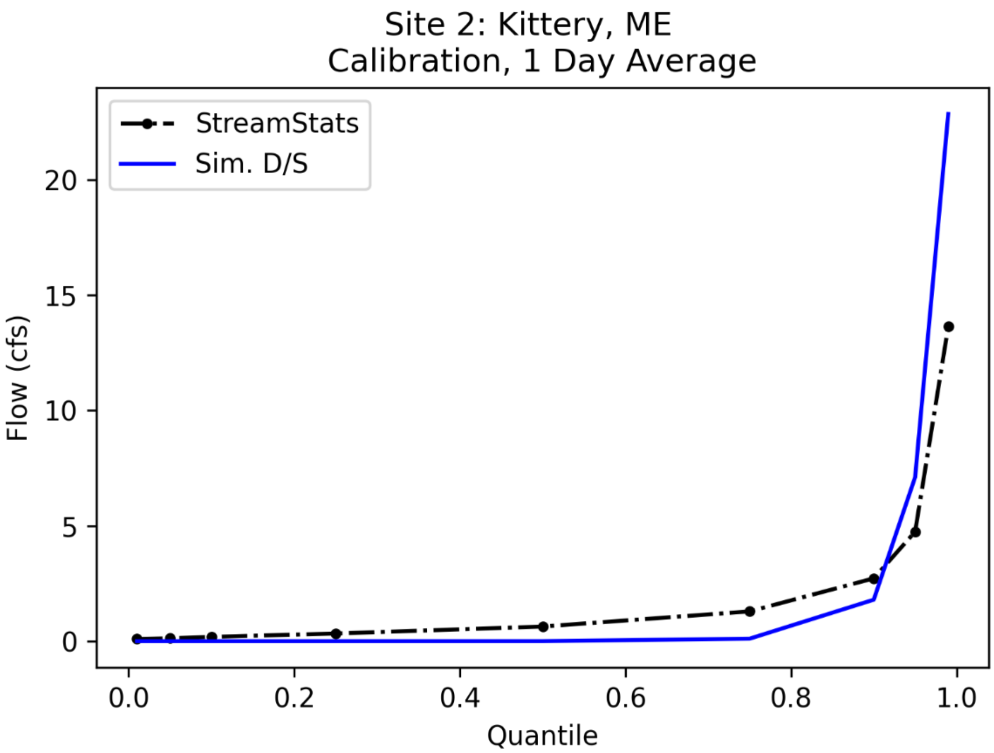

Figure 68: 2K. Calibration results of the downstream flow with existing conditions overlayed on the StreamStats quantile flows.

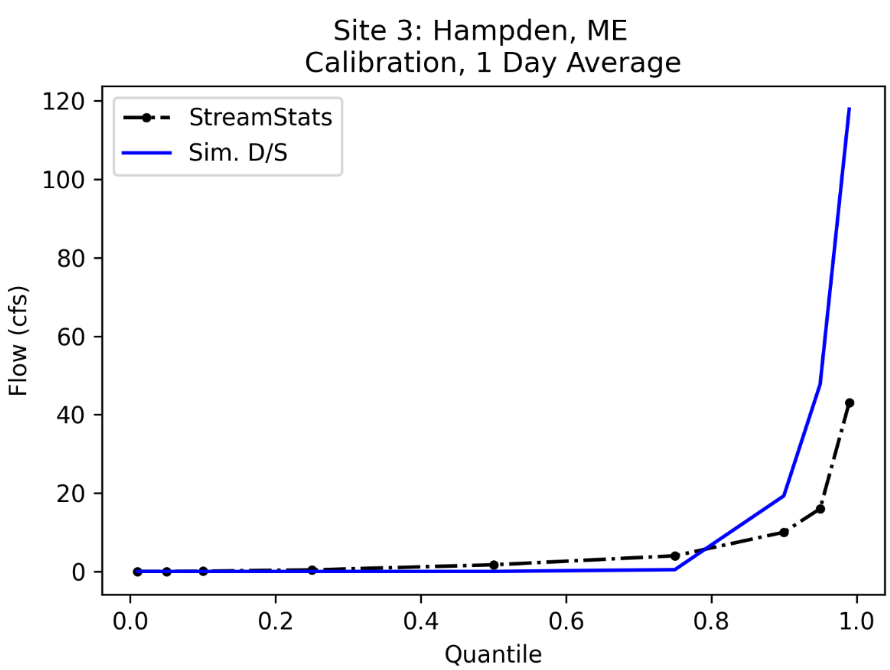

Figure 69: 3HS. Calibration results of the downstream flow with existing conditions overlayed on the StreamStats quantile flows.

Results

The results for the three sites are shown in the following figures as the raw output of the simulations resampled to 1-hour averages (to better visualize the graph), and as the 4-day average values which are used for the comparison to the acute (230 mg/L) and chronic (860 mg/L) criteria for stream chloride concentrations, respectively. The simulation results are first shown for the current (existing) conditions at all the locations matching the monitoring locations (upstream, CB, and downstream), then two proposed design scenarios are shown. The first scenario is the “Storage” scenario which has a large storage unit collecting the DOT-runoff in storage and slowly releasing it back into the stream via a simple orifice control ranging in size of 3 to 12-inches. The second design scenario is the “Dilution” scenario which had groundwater wells pumping into the runoff to dilute the salty runoff before it enters the stream. The pumping/dilution option ranged from 0.1 to 1000 gpm. While the simulation was run with constant flows, smart controls could be installed to reduce the pumping volume during the off-season and between runoff events when the runoff concentrations would be below the acute and chronic criteria.

Site 1: South Berwick

Existing Conditions: 1-Day Simulation Results

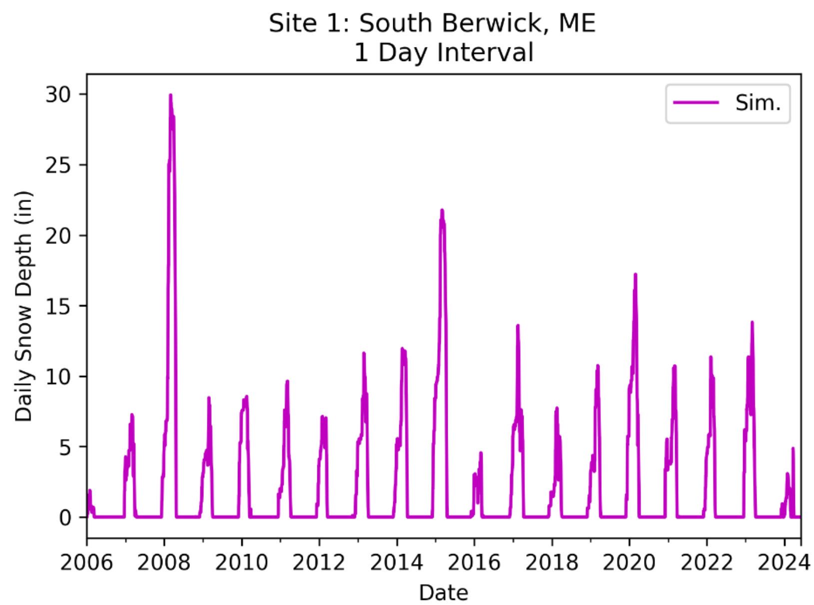

Figure 70: 1SB. Simulation results of the existing conditions. Results are shown as the daily total value.

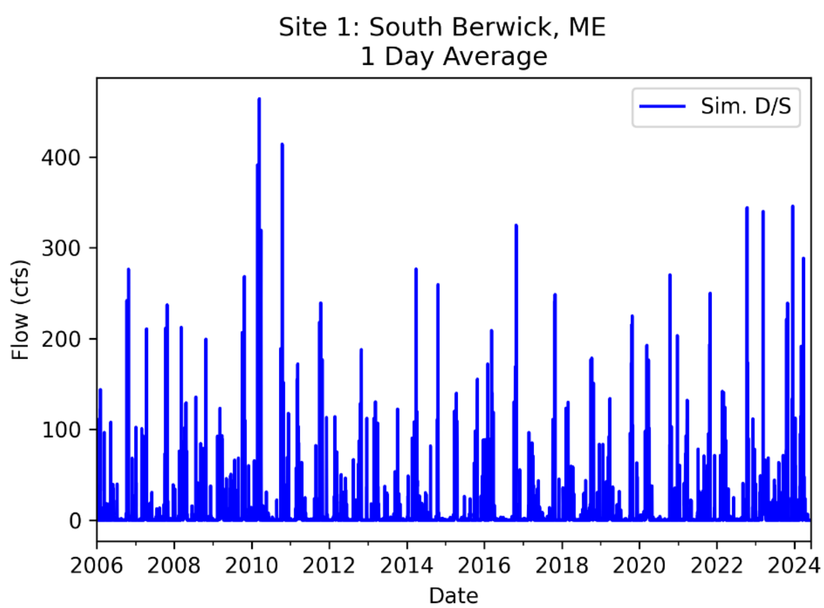

Figure 71: 1SB. Simulation results of the existing conditions at the outfall (farthest downstream). Results are shown as the daily mean value. This interval aligns with the comparison to the StreamStats flows.

Existing Conditions: 1-Hour Simulation Results

This section shows the simulation results as is. While not used for analysis, this output data is shown to visualize the scales and responses of the model.

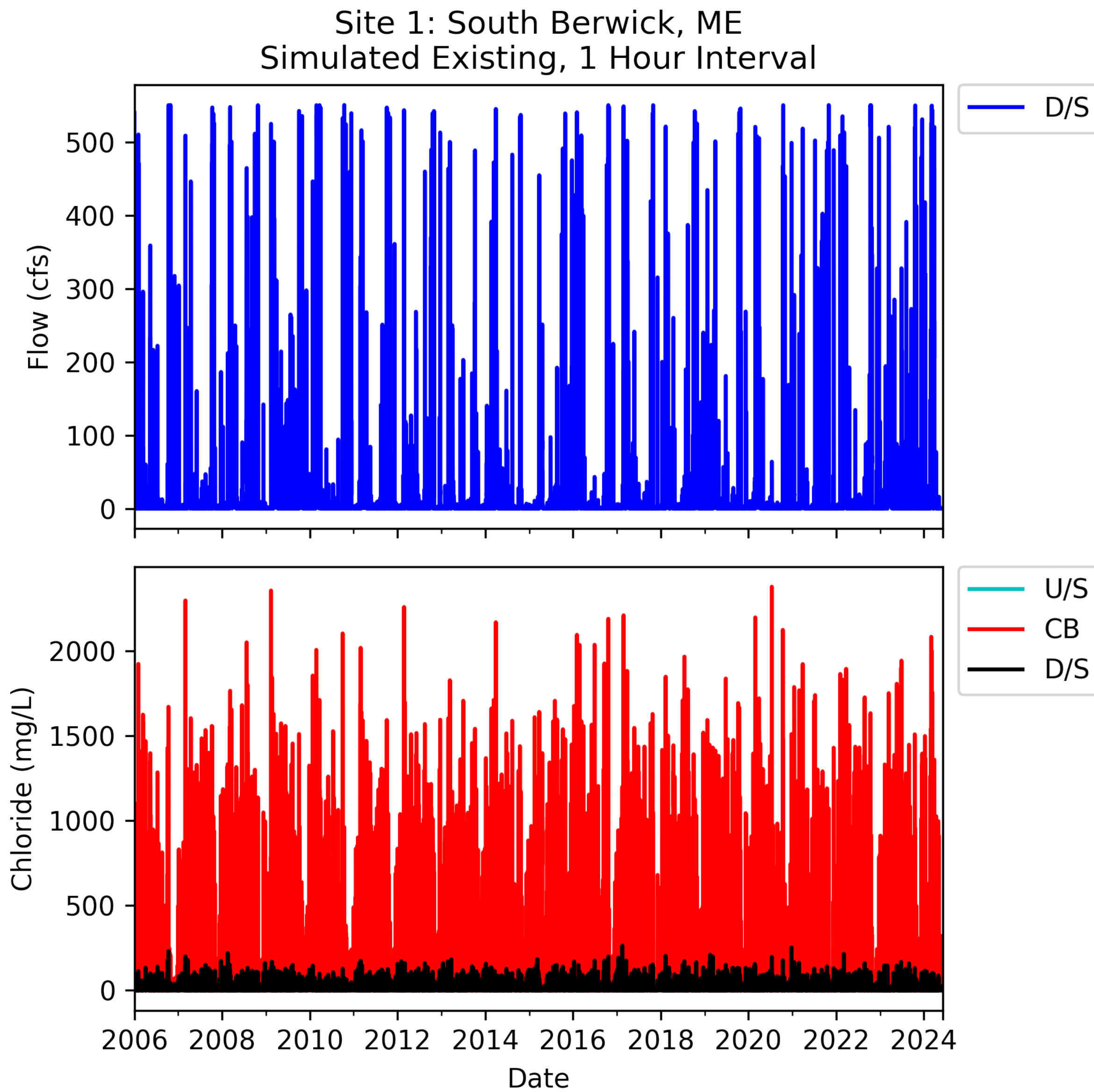

Figure 72: 1SB. Simulation results are shown at 1-hour intervals of the existing conditions at the monitored locations for POR. The upper subplot shows flow at the downstream outfall, and the lower subplot shows the concentration of chloride upstream (U/S), in the catch basin (CB), and at the downstream outfall (D/S).

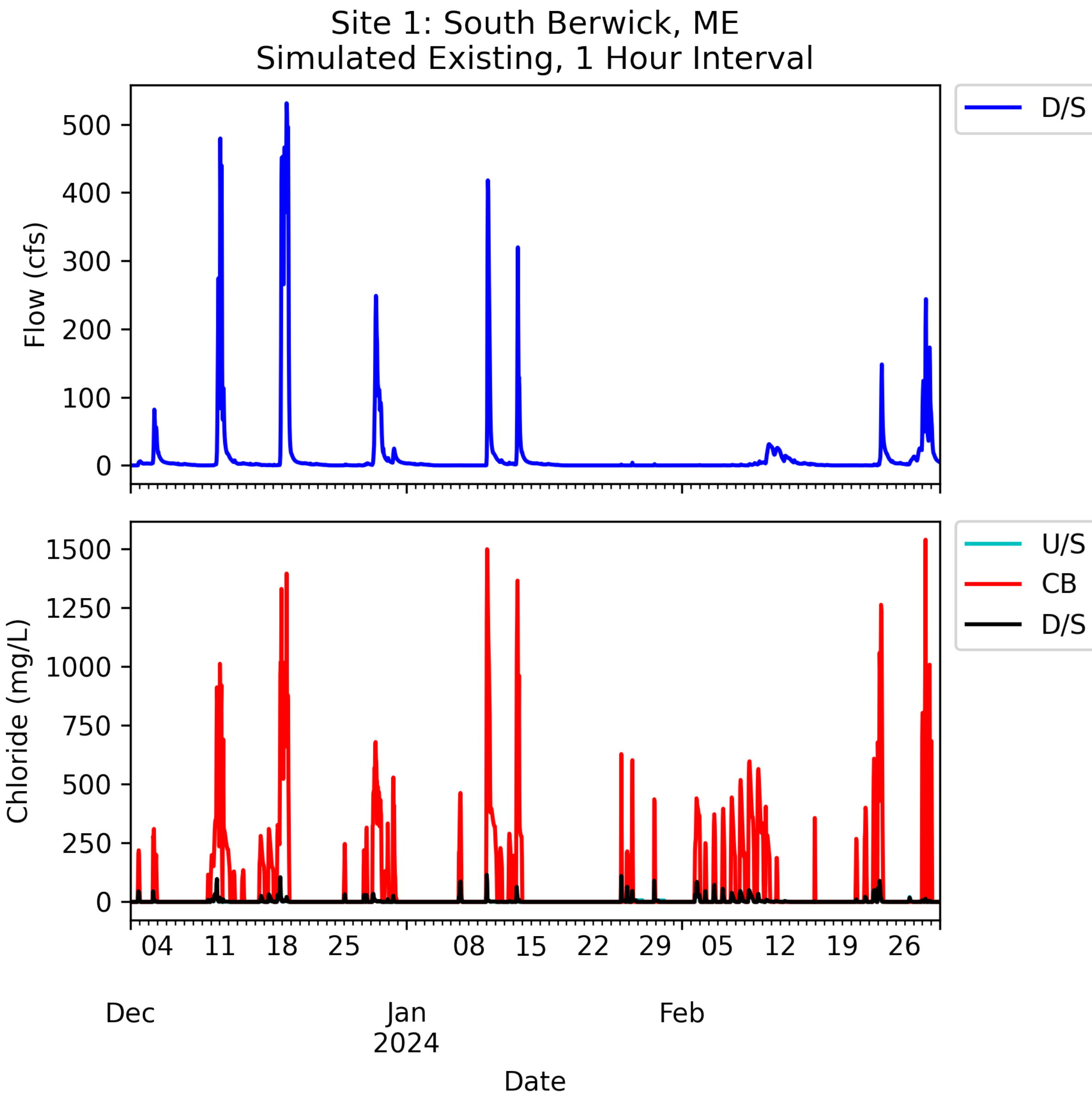

Figure 73: 1SB. A three-month sample of the simulation results is shown at 1-hour intervals of the existing conditions at the monitored locations. The upper subplot shows flow at the downstream outfall, and the lower subplot shows the concentration of chloride upstream (U/S), in the catch basin (CB), and at the downstream outfall (D/S).

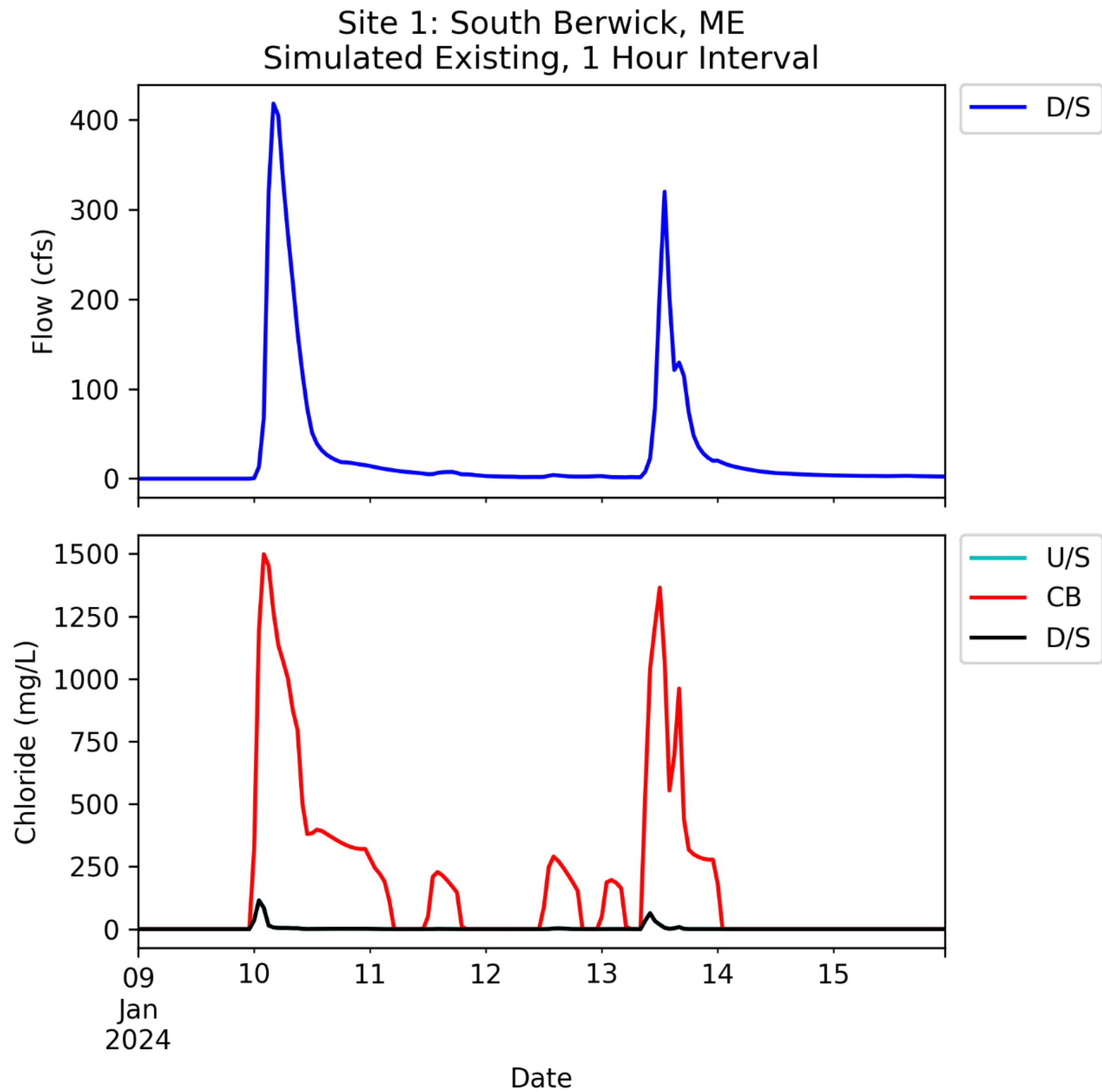

Figure 74: 1SB. A sample of two runoff events of the simulation results is shown at 1-hour intervals of the existing conditions at the monitored locations. The upper subplot shows flow at the downstream outfall, and the lower subplot shows the concentration of chloride upstream (U/S), in the catch basin (CB), and at the downstream outfall (D/S).

Existing Conditions: 4-Day Mean Simulation Results

This section and the following show the 4-day means (average). The 4-day average chloride concentrations are used for comparison to the chronic criteria.

The subplots with chloride concentrations show the reference acute and chronic criteria at 230 mg/L and 860 mg/L, respectively. The goal for the stream health is to not have the 4-day mean concentration exceed the criteria more than once every three years on average.

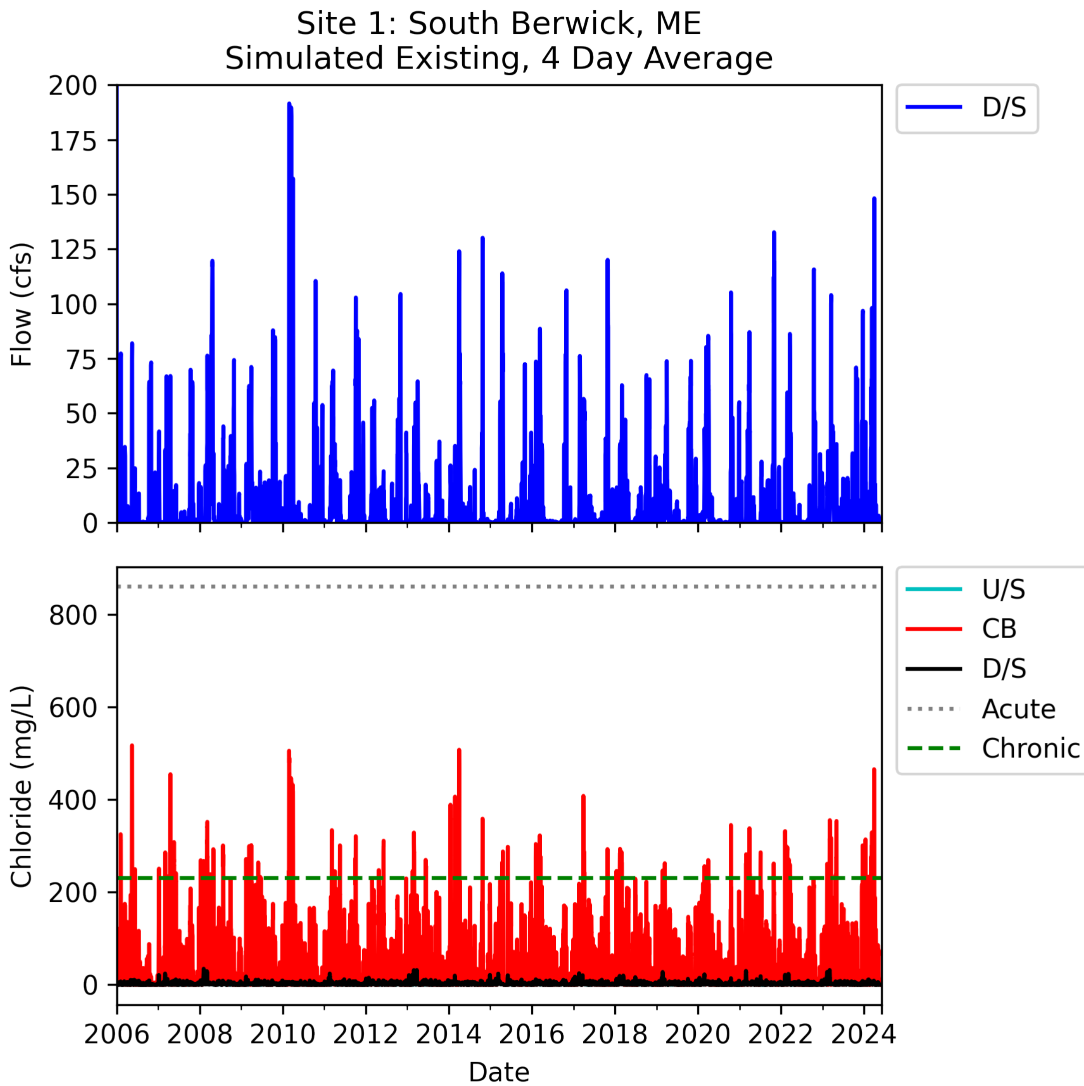

Figure 75: 1SB. Simulation results are shown as the 4-day average of the existing conditions at the monitored locations for POR. The upper subplot shows flow at the downstream outfall, and the lower subplot shows the concentration of chloride upstream (U/S), in the catch basin (CB), and at the downstream outfall (D/S).

The 4-day average chloride concentration at the downstream (D/S) node never exceeded either acute or chronic criteria in the POR as shown in Figure 75. While the CB concentration exceeded the chronic criteria very often (most runoff events), when the catch basin runoff mixed into the stream, the catch basin concentration was dramatically reduced due to the low upstream (U/S) concentration.

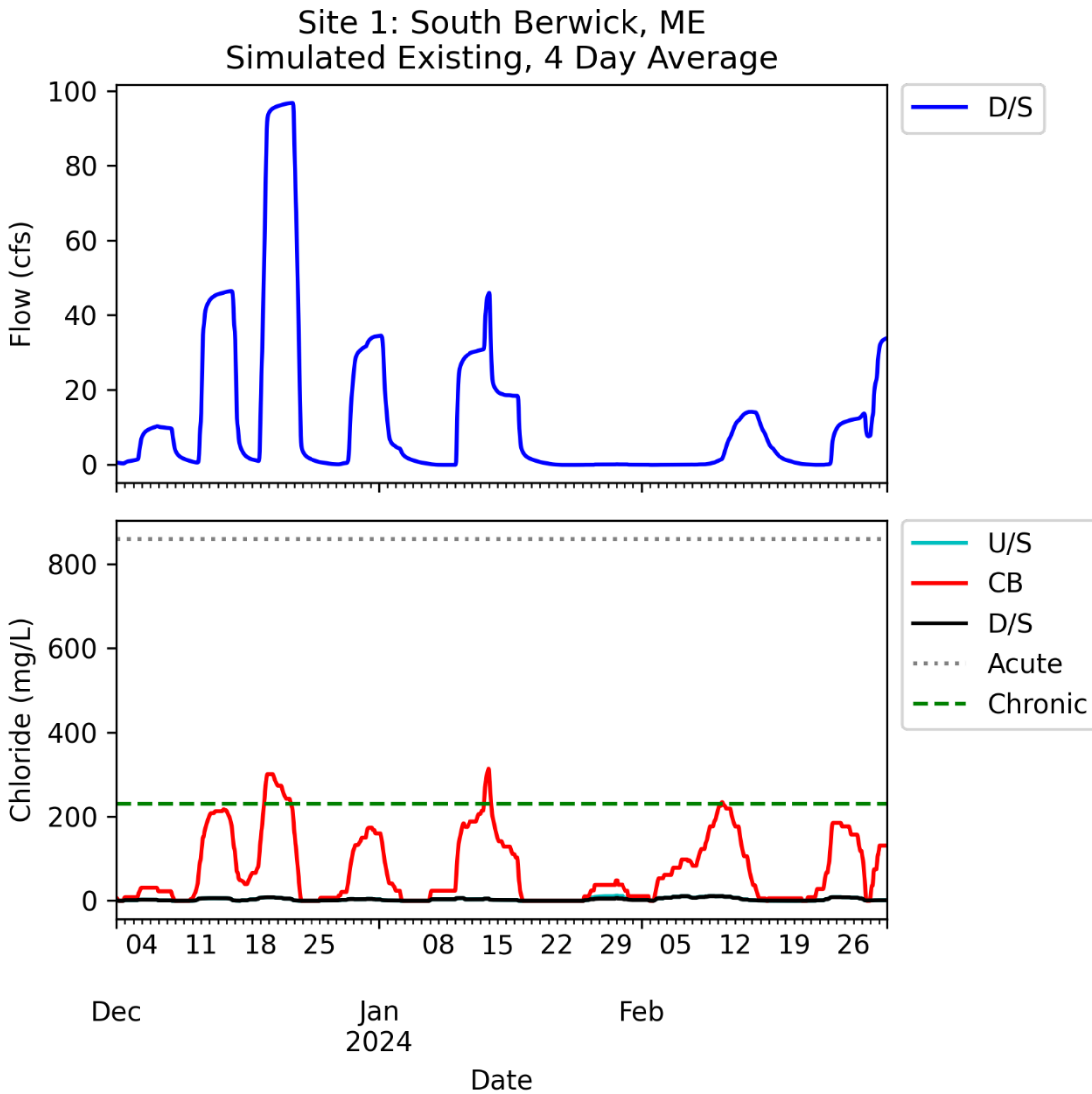

Figure 76: 1SB. A three-month sample of the simulation results is shown as the 4-day average of the existing conditions at the monitored locations for POR. The upper subplot shows flow at the downstream outfall, and the lower subplot shows the concentration of chloride upstream (U/S), in the catch basin (CB), and at the downstream outfall (D/S).

The 4-day average chloride concentration at the downstream (D/S) never exceeded either acute or chronic criteria in this three-month sample. While the CB concentration exceeded the chronic criteria often during runoff events, when the runoff mixed into the stream, the concentration was dramatically reduced due to the low upstream (U/S) concentration.

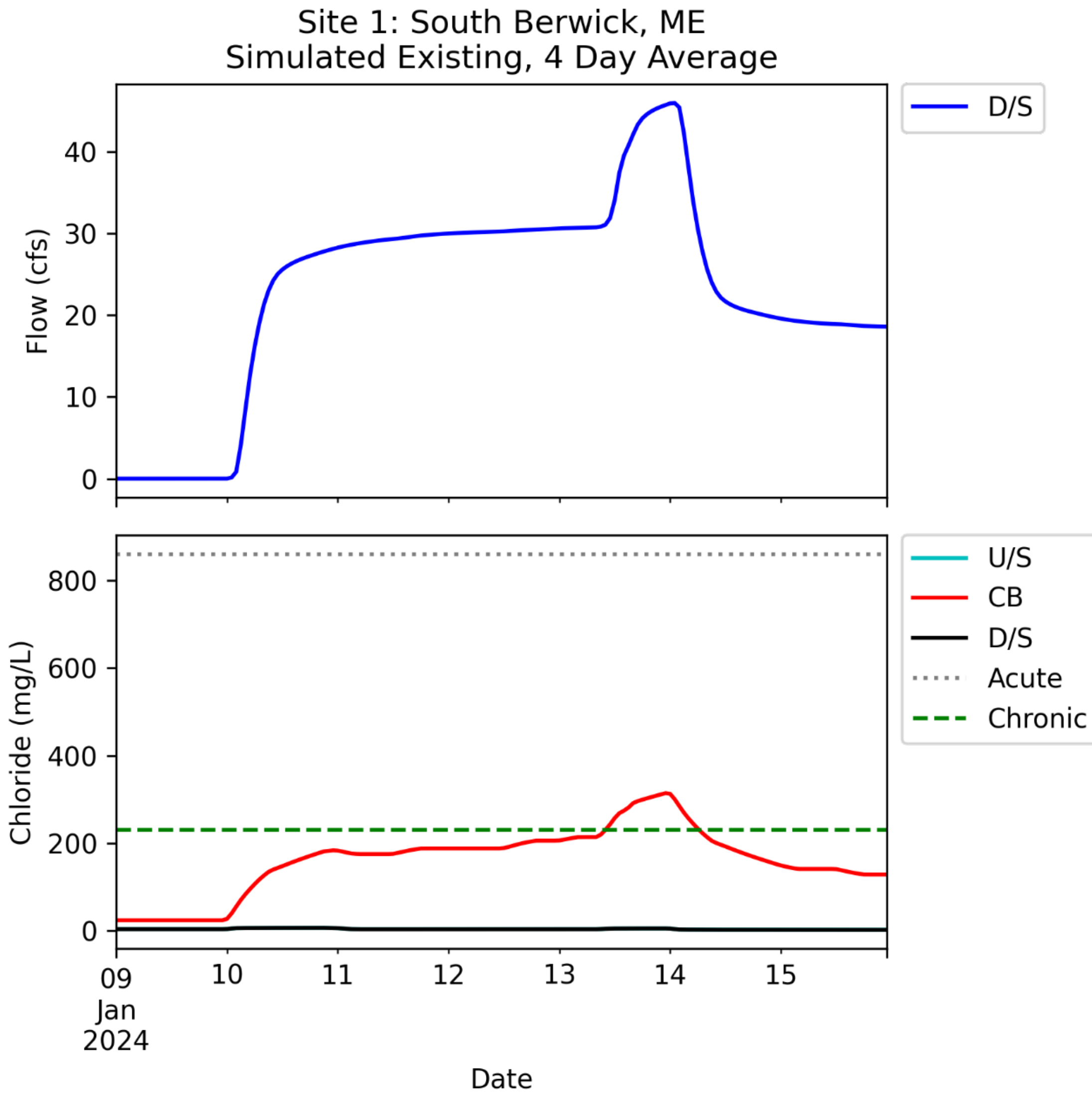

Figure 77: 1SB. A sample of two runoff events of the simulation results is shown as the 4-day average of the existing conditions at the monitored locations for POR. The upper subplot shows flow at the downstream outfall, and the lower subplot shows the concentration of chloride upstream (U/S), in the catch basin (CB), and at the downstream outfall (D/S).

Proposed Conditions: 4-Day Mean Simulation Results of Storage Scenarios

This section shows the same figures as above but for the storage scenarios and the full modeling period. The storage scenarios use the same storage unit sizes, and the outlet orifice sizes are varied which cause the storage depth to increase as well as control the outflow of high chloride concentration runoff into the stream. All the chloride concentrations are shown at the outfall for comparison of the existing conditions and the proposed storage designs.

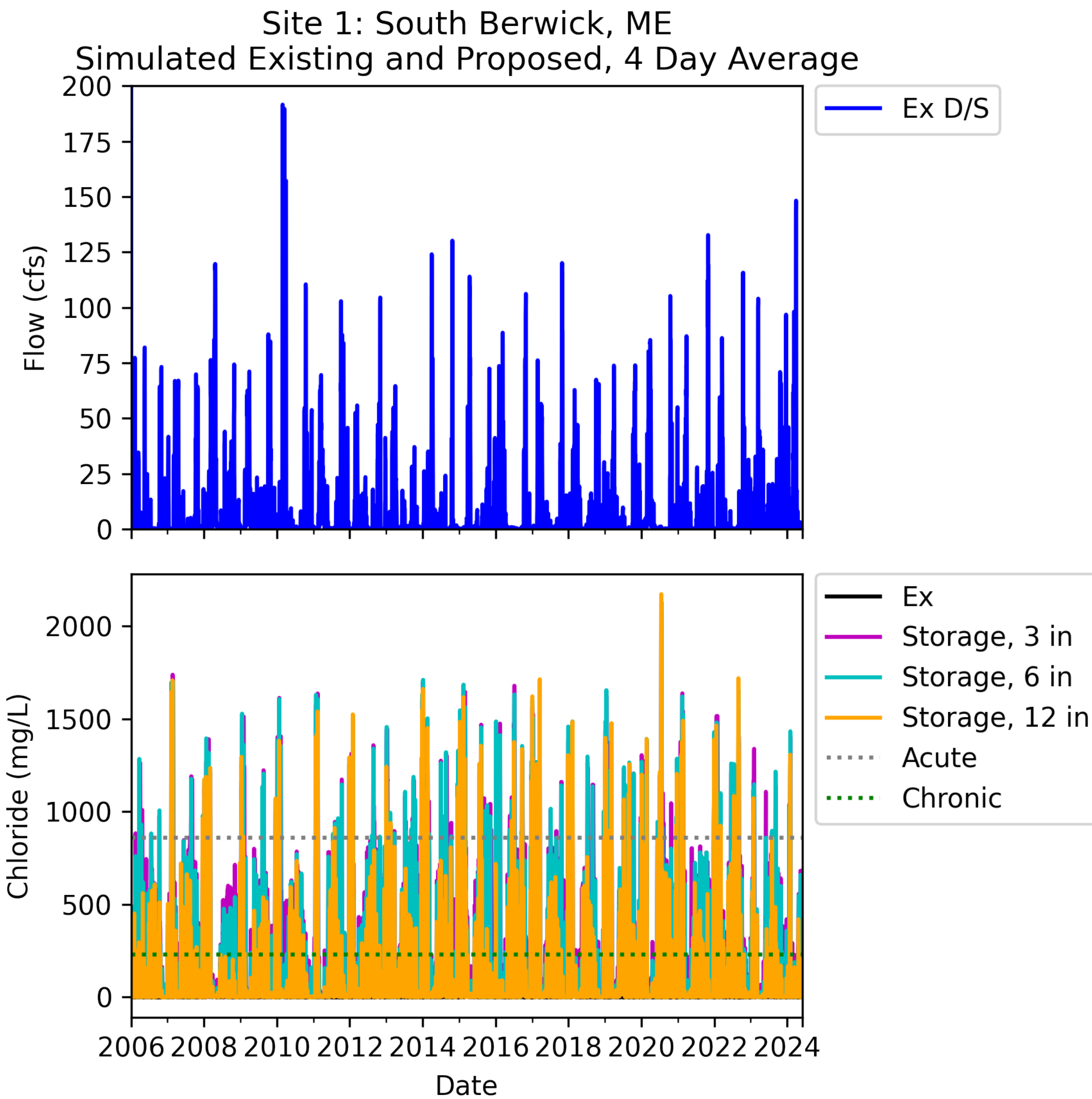

Figure 78: 1SB. Simulation results are shown as the 4-day average of the proposed storage designs at downstream outfall for the POR. The upper subplot shows flow at the downstream outfall flow, and the lower subplot shows the concentration of chloride for the existing conditions (black), and the storage designs with 3-, 6-, and 12-inch orifices.

For the proposed storage designs, the 4-day average chloride concentration at the downstream (D/S) node exceeded the chronic criteria almost all runoff events and the acute criteria during most runoff events for the POR.

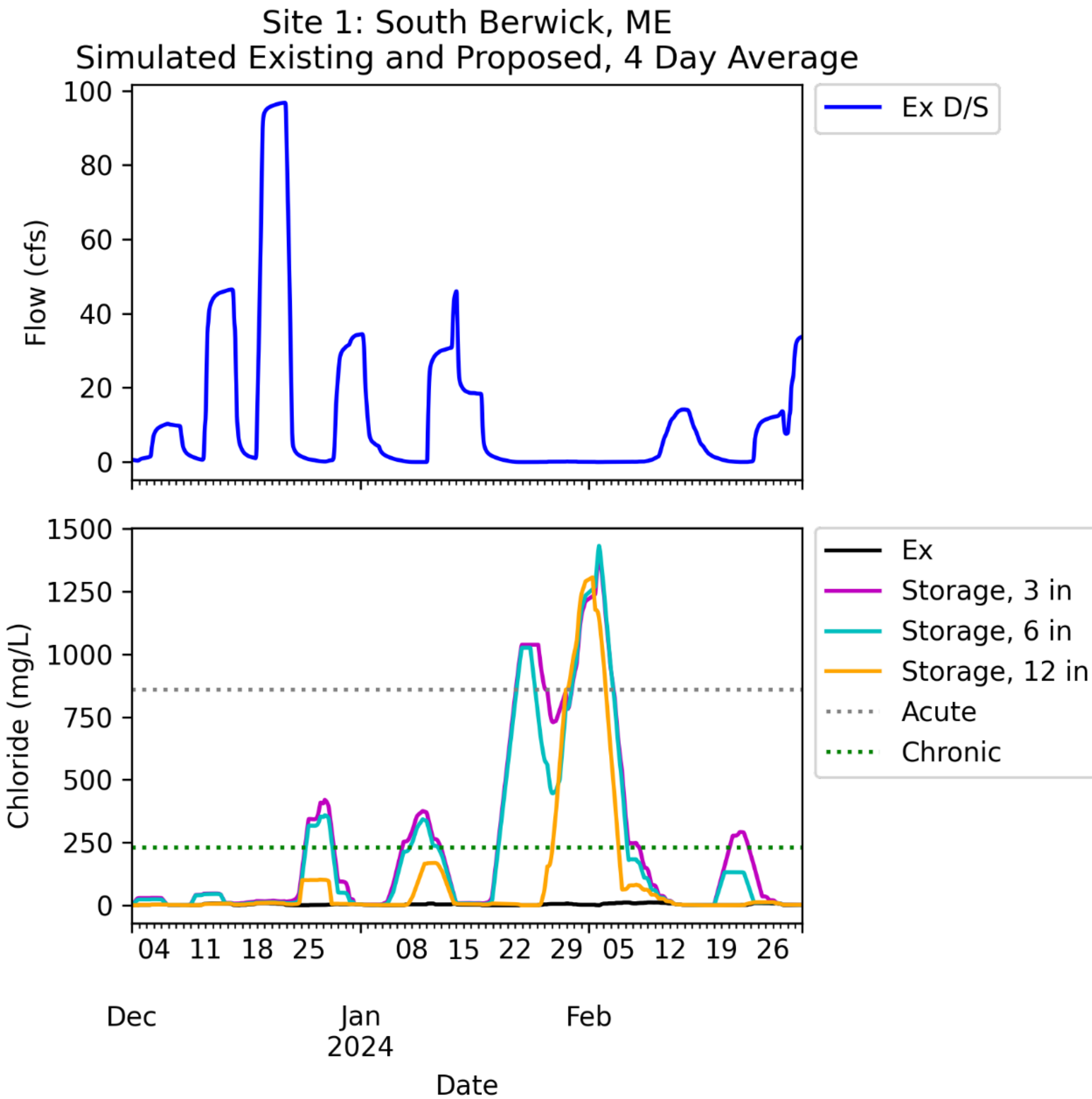

Figure 79: 1SB. A three-month sample of the simulation results is shown as the 4-day average of the proposed storage designs at the downstream outfall. The upper subplot shows flow at the downstream outfall flow, and the lower subplot shows the concentration of chloride for the existing conditions (black), and the storage designs with 3-, 6-, and 12-inch orifices.

Figure 79 shows a three-month sample for the proposed storage designs, 4-day average chloride concentration at the downstream (D/S) node. The general trend for the storage scenarios is that the concentrations tend to increase higher than the existing conditions during low-flow times which follow runoff events. One might accept the slow release of high-concentration runoff into the stream to decrease the downstream concentration. While there is a lag in the chloride concentrations from the runoff event, the reason the concentrations increase is because of flows in the stream are so low that the relative concentration increases. Concentration is mass / volume (mg/L), so the release of chloride (mass) is extended into low flow times, and the small flow (or volume in L) therefore increases the concentrations.

Generally, the smaller the orifice diameter, the larger the stream concentrations were during low-flow times. This is due to the extended release time of the salty runoff past the runoff events. The largest (12-inch) orifice most closely resembles the existing condition by passing the majority of the salty runoff volume to the stream close to the event while providing some storage. However, Figure 78 shows that all proposed designs exceed both criteria much more than once every 3 years.

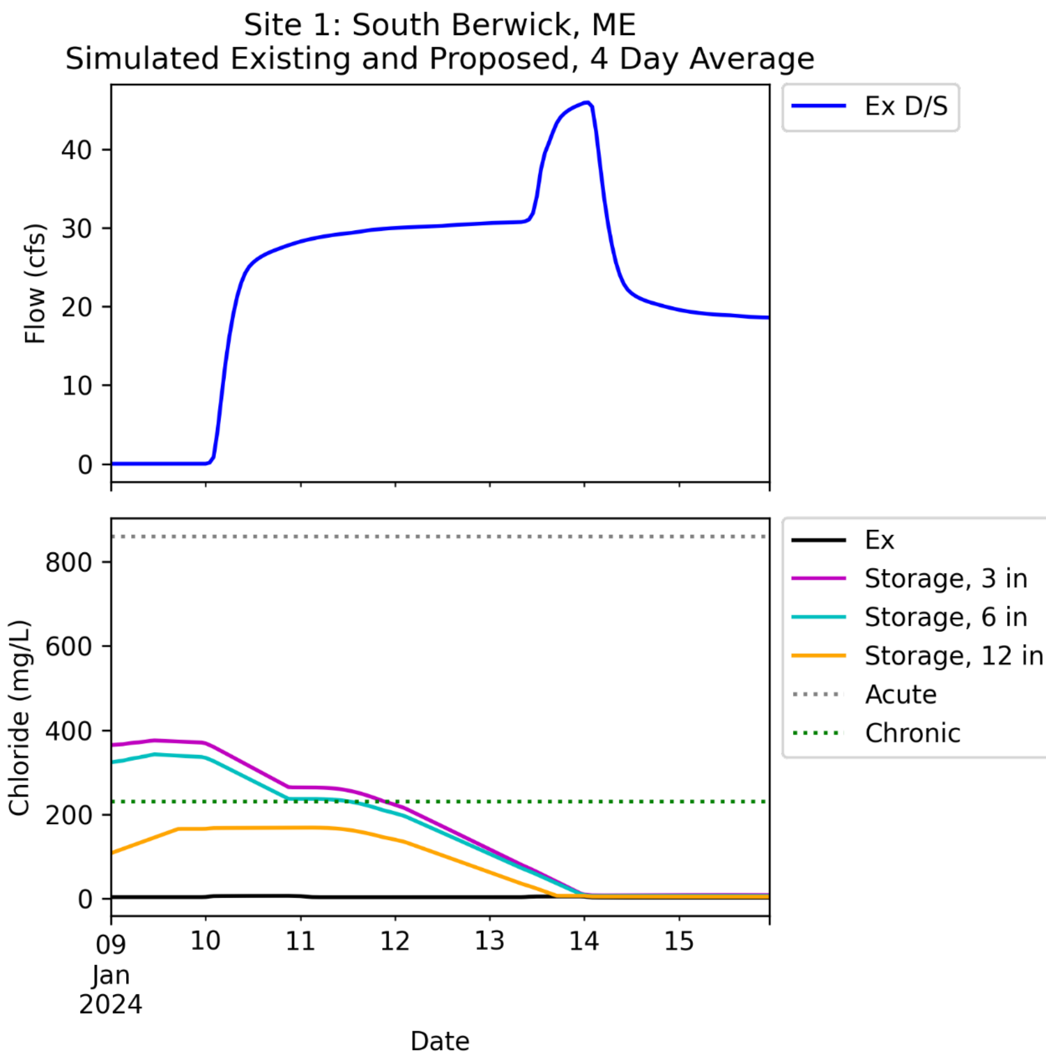

Figure 80: 1SB. A sample of two runoff events of the simulation results is shown as the 4-day average of the proposed storage designs at the downstream outfall. The upper subplot shows flow at the downstream outfall flow, and the lower subplot shows the concentration of chloride for the existing conditions (black), and the storage designs with 3-, 6-, and 12-inch orifices.

Figure 80 illustrates the point further looking at two runoff events. Before the event at the start of the plot, the concentrations in the storage scenarios are high. Once the flow begins during the runoff events, the concentrations decrease with the increase in water volume (or flow) in the stream.

Proposed Conditions: 4-Day Mean Simulation Results of Dilution Scenarios

This section shows the same figures as previously but for the well pump, dilution scenarios. The junctions downstream of the salty runoff received constant-volume pumping at 1, 10, 100, and 1000 gpm. The diluted runoff was then routed to the downstream outfall. All the chloride concentrations are shown at the outfall for comparison of the existing conditions and the proposed dilution designs.

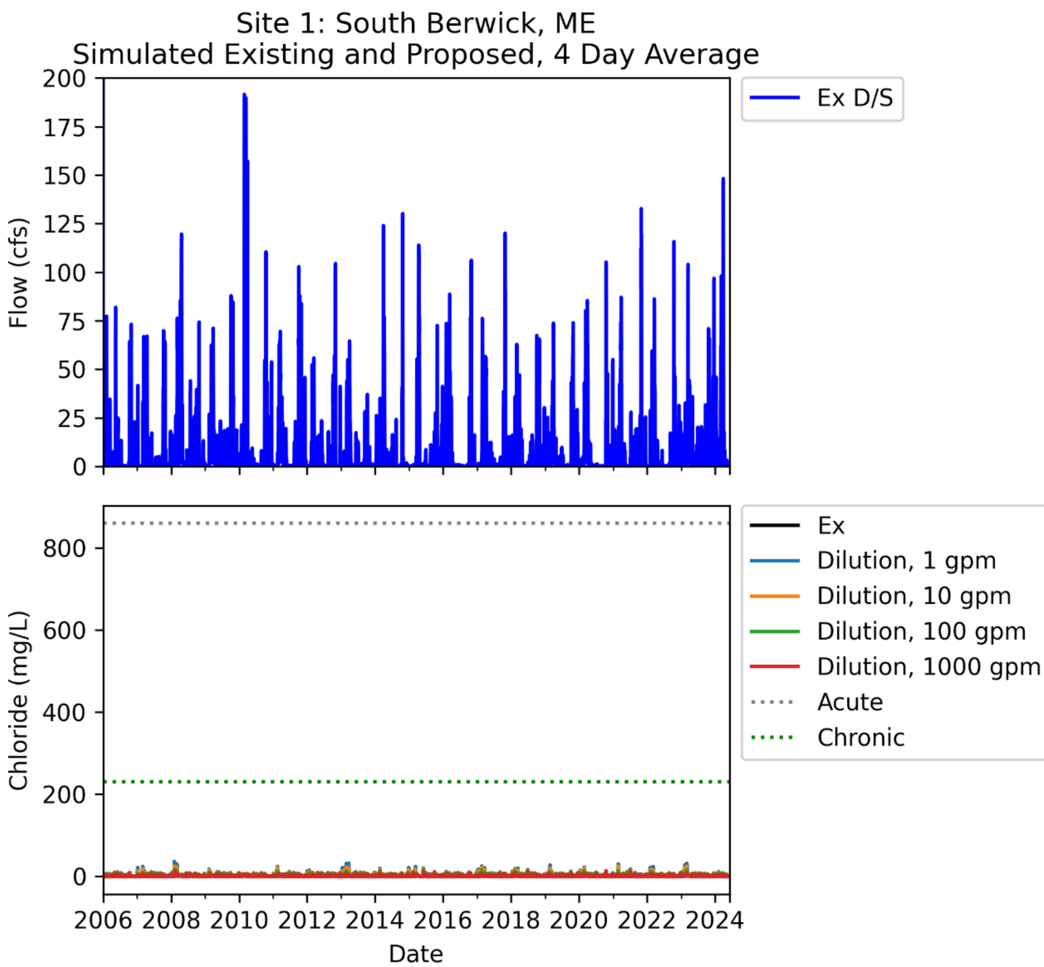

Figure 81: 1SB. Simulation results are shown as the 4-day average of the proposed dilution designs at downstream outfall for the POR. The upper subplot shows flow at the downstream outfall flow, and the lower subplot shows the concentration of chloride for the existing conditions (black), and the pumping rates of 1, 10, 100, and 1000 gpm.

For the proposed dilution designs, the 4-day average chloride concentration at the downstream (D/S) node never exceeded either the chronic or acute criteria during any runoff events for the POR.

Figure 82 and Figure 83 show the trend of the dilution scenarios at Site 1. The concentrations tend to be less than the already low existing conditions due to the relatively large flows and lower runoff concentrations of the watershed.

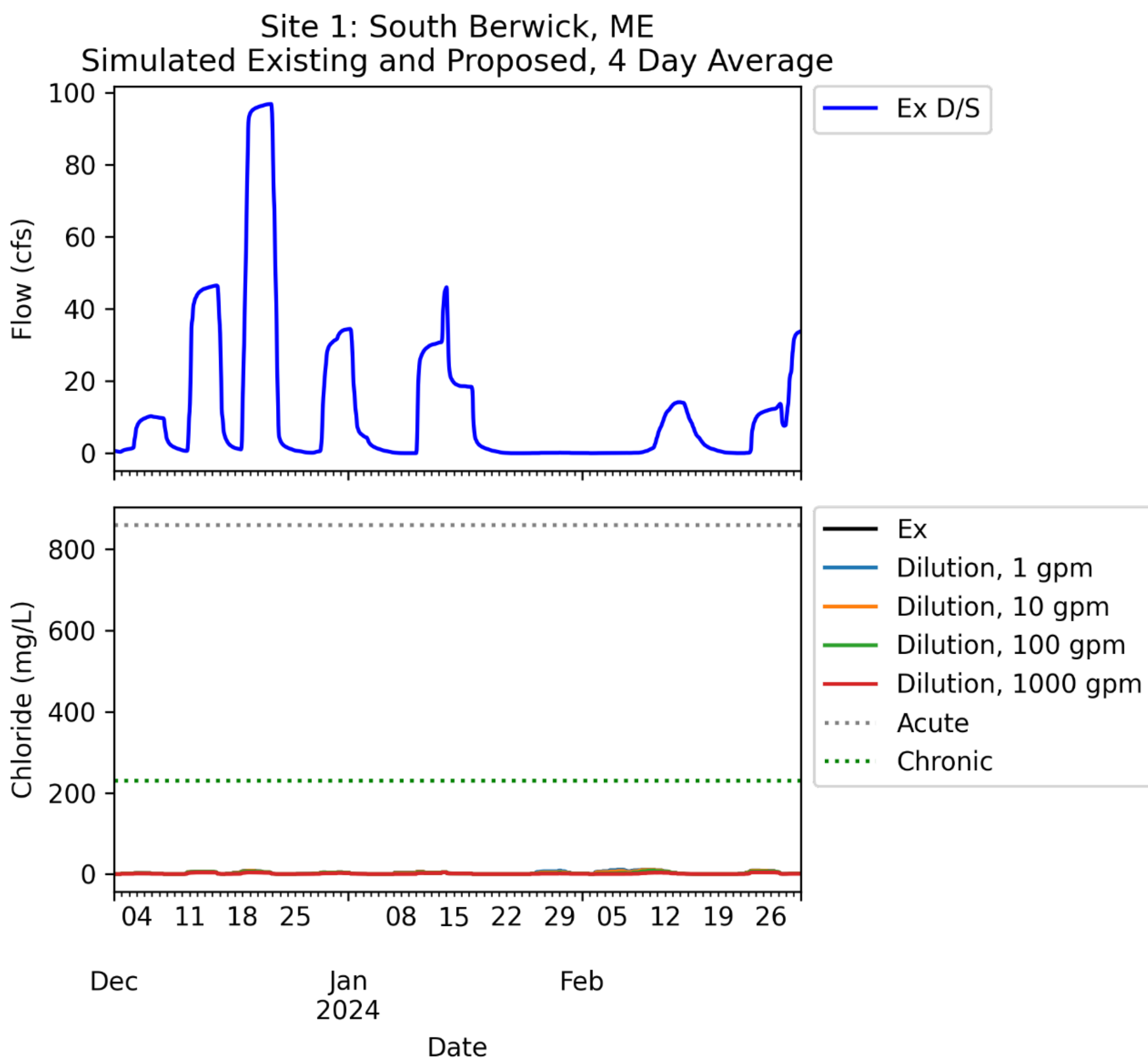

Figure 82: 1SB. A three-month sample of the simulation results is shown as the 4-day average of the proposed dilution designs at the downstream outfall. The upper subplot shows flow at the downstream outfall flow, and the lower subplot shows the concentration of chloride for the existing conditions (black), and the pumping rates of 1, 10, 100, and 1000 gpm.

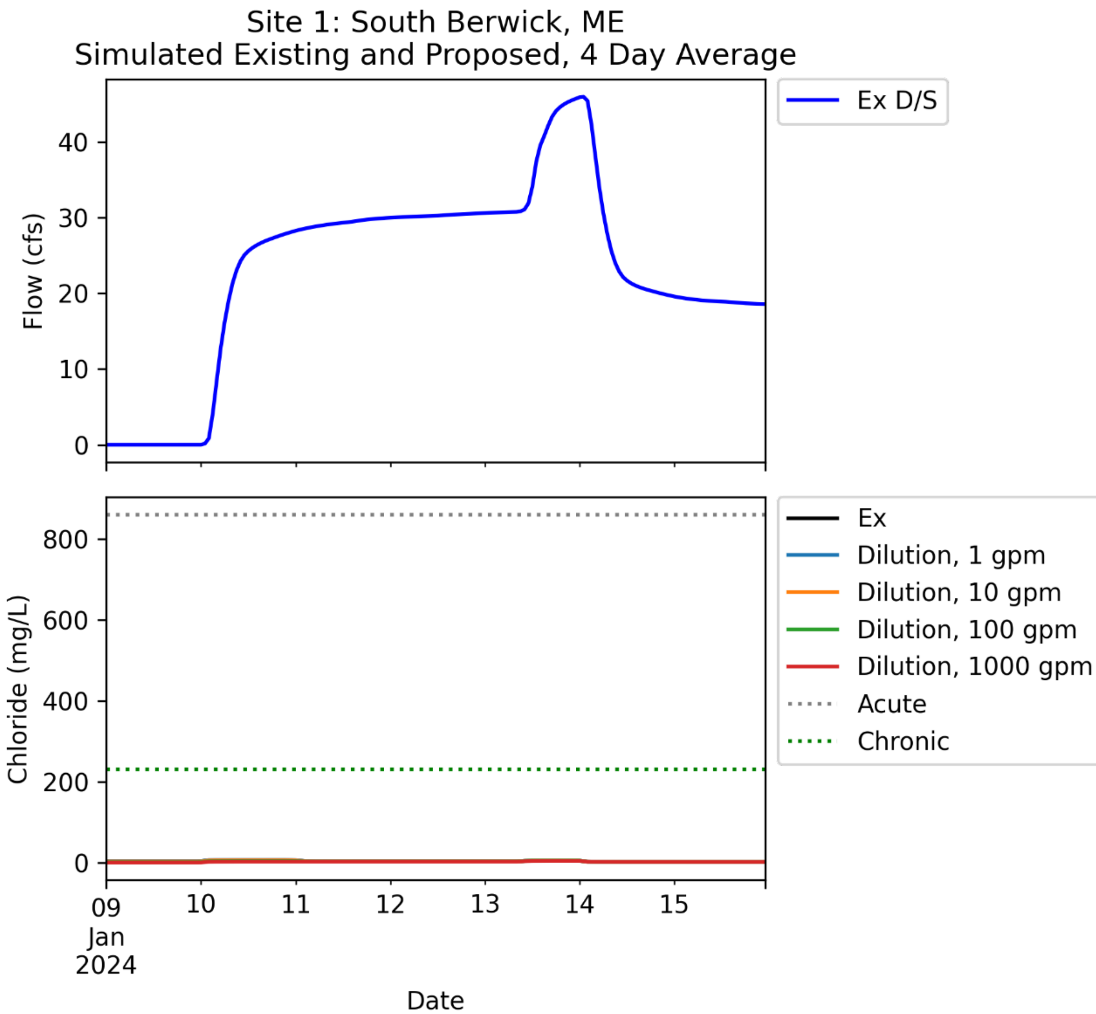

Figure 83: 1SB. A sample of two runoff events of the simulation results is shown as the 4-day average of the proposed dilution designs at the downstream outfall. The upper subplot shows flow at the downstream outfall flow, and the lower subplot shows the concentration of chloride for the existing conditions (black), and the pumping rates of 1, 10, 100, and 1000 gpm.

Site 2: Kittery

Existing Conditions: 1-Day Simulation Results

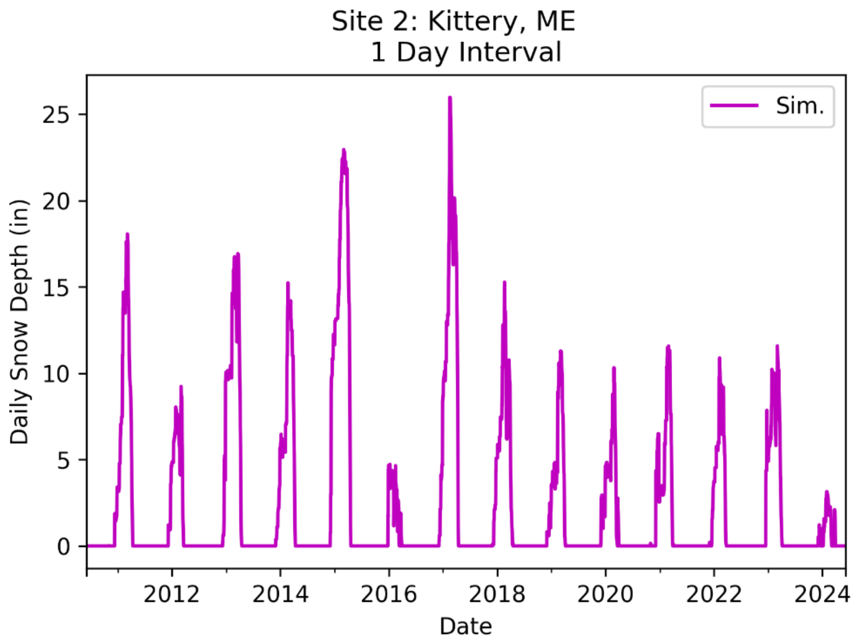

Figure 84: 2K. Simulation results of the existing conditions. Results are shown as the daily total value.

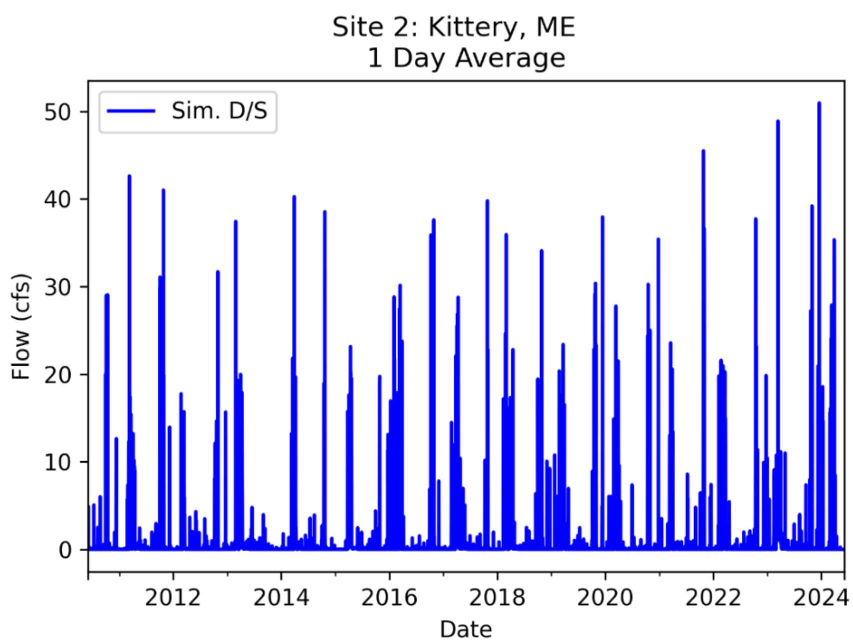

Figure 85: 2K. Simulation results of the existing conditions at the outfall (farthest downstream). Results are shown as the daily mean value. This interval aligns with the comparison to the StreamStats flows.

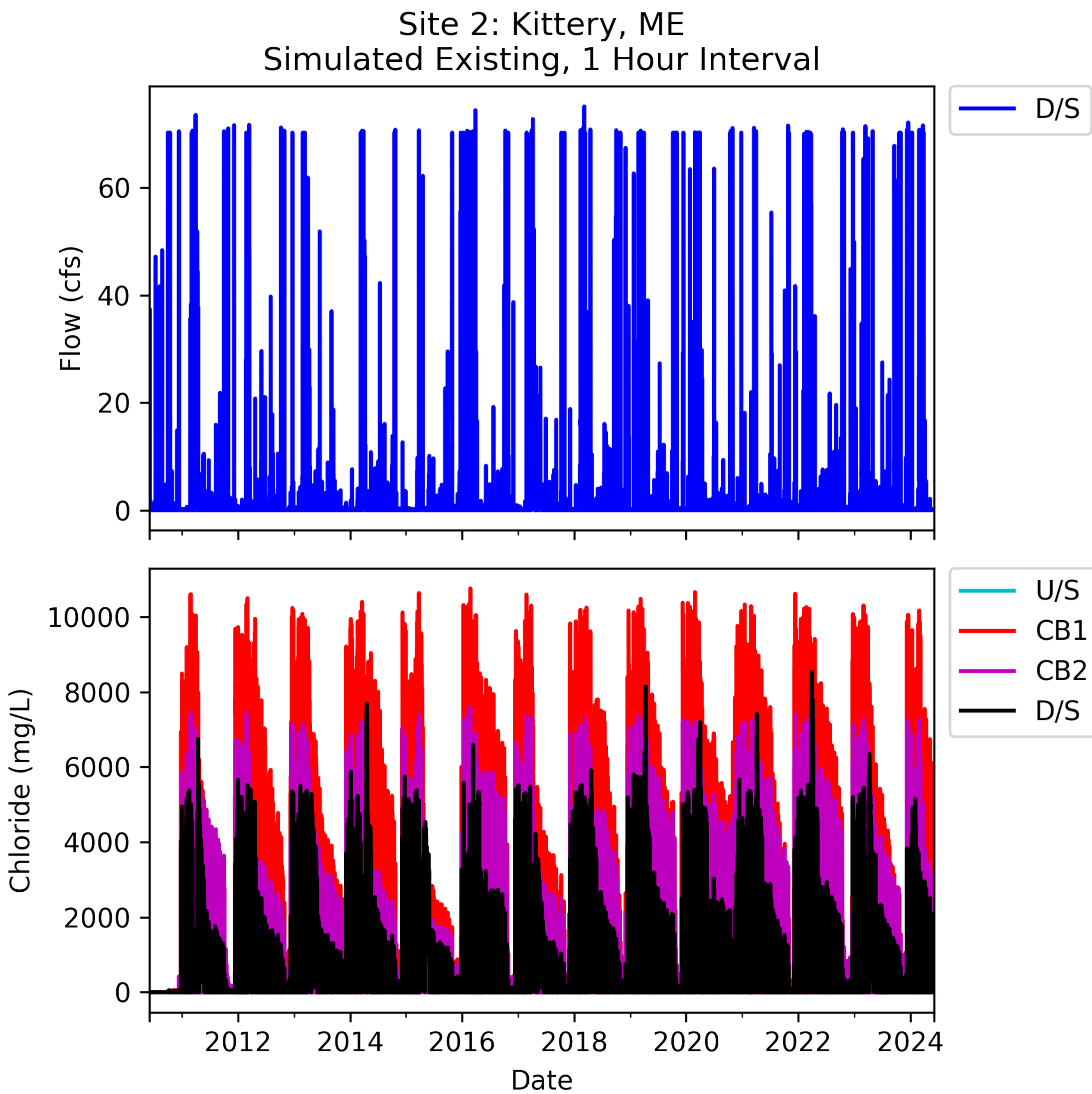

Figure 86: 2K. Simulation results are shown at 1-hour intervals of the existing conditions at the monitored locations for POR. The upper subplot shows flow at the downstream outfall, and the lower subplot shows the concentration of chloride upstream (U/S), in the two catch basins (CB1, CB2), and at the downstream outfall (D/S).

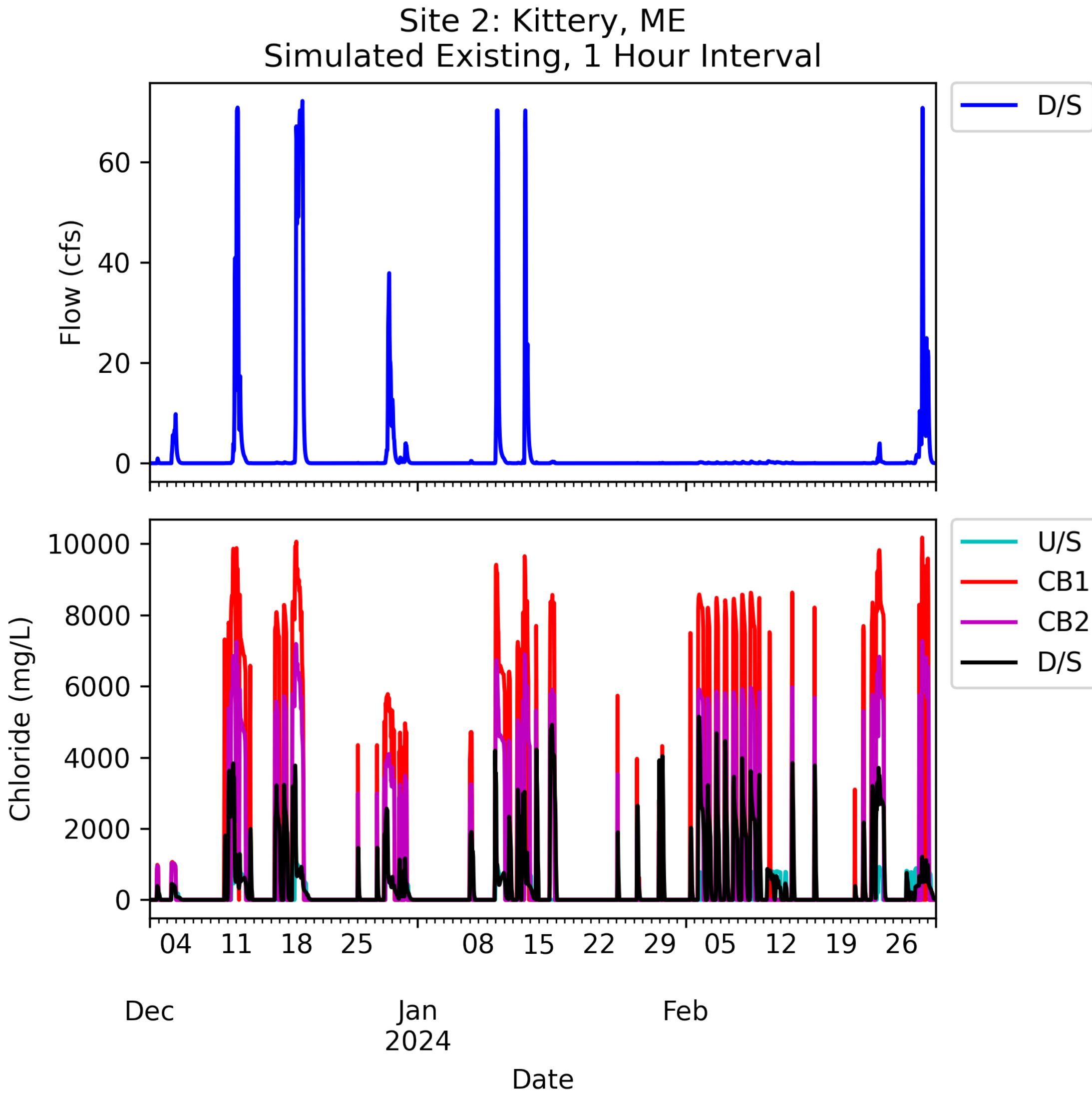

Figure 87: 2K. A three-month sample of the simulation results is shown at 1-hour intervals of the existing conditions at the monitored locations. The upper subplot shows flow at the downstream outfall, and the lower subplot shows the concentration of chloride upstream (U/S), in the catch basins (CB1, CB2), and at the downstream outfall (D/S).

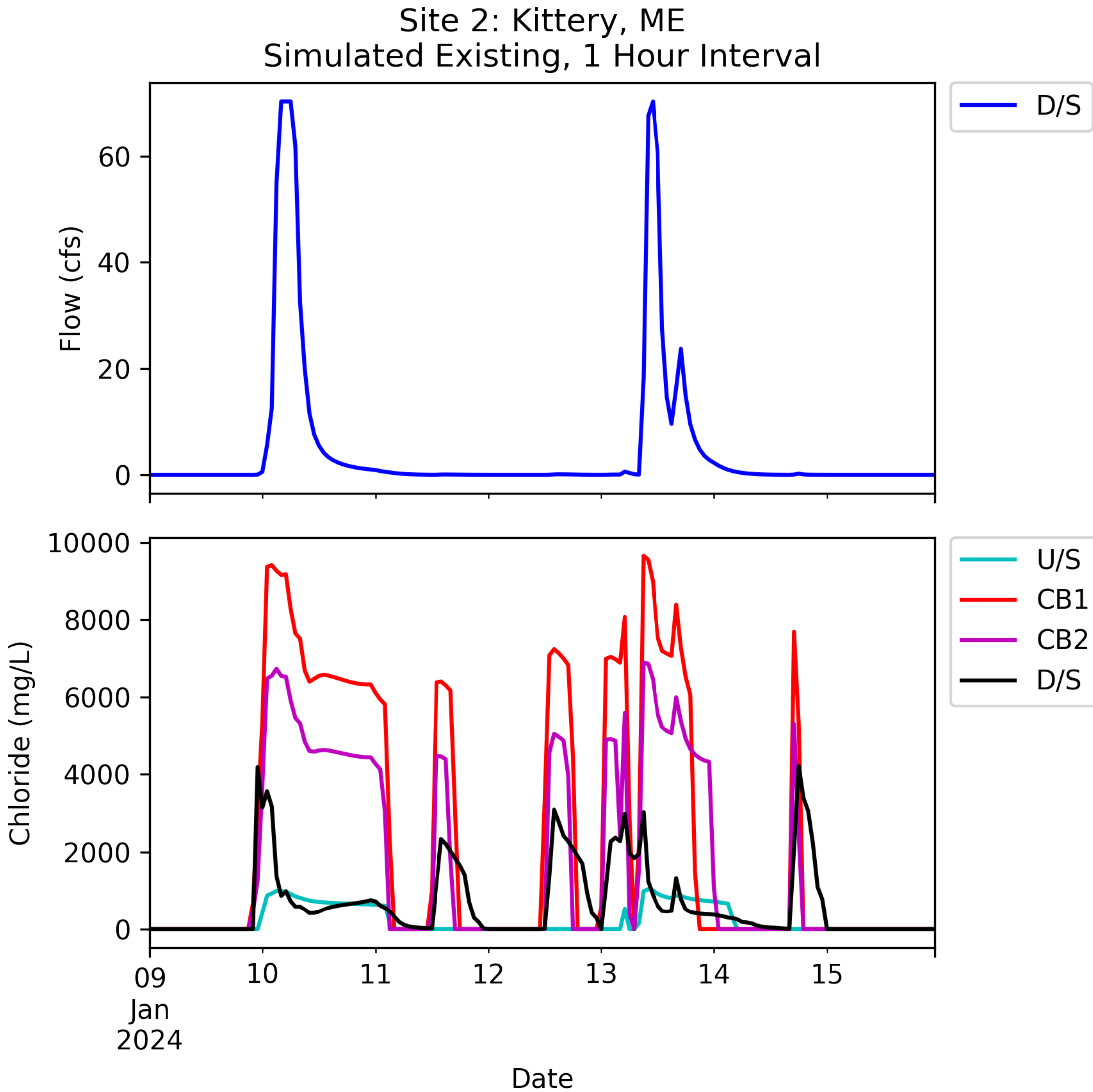

Figure 88: 2K. A sample of two runoff events of the simulation results is shown at 1-hour intervals of the existing conditions at the monitored locations. The upper subplot shows flow at

the downstream outfall, and the lower subplot shows the concentration of chloride upstream (U/S), in the catch basins (CB1, CB2), and at the downstream outfall (D/S).

Existing Conditions: 4-Day Mean Simulation Results

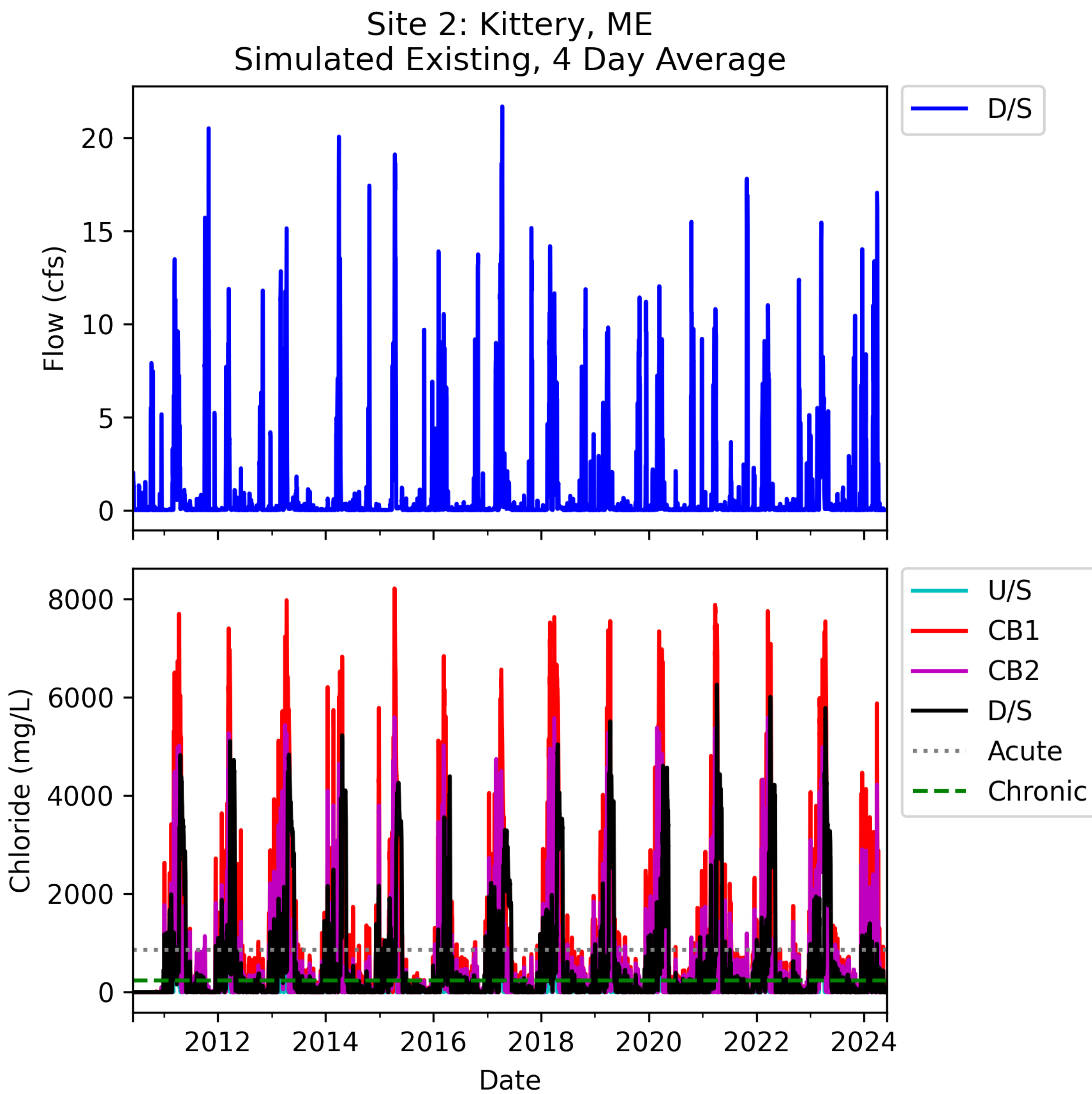

Figure 89: 2K. Simulation results are shown as the 4-day average of the existing conditions at the monitored locations for POR. The upper subplot shows flow at the downstream outfall, and the lower subplot shows the concentration of chloride upstream (U/S), in the catch basins (CB1, CB2), and at the downstream outfall (D/S).

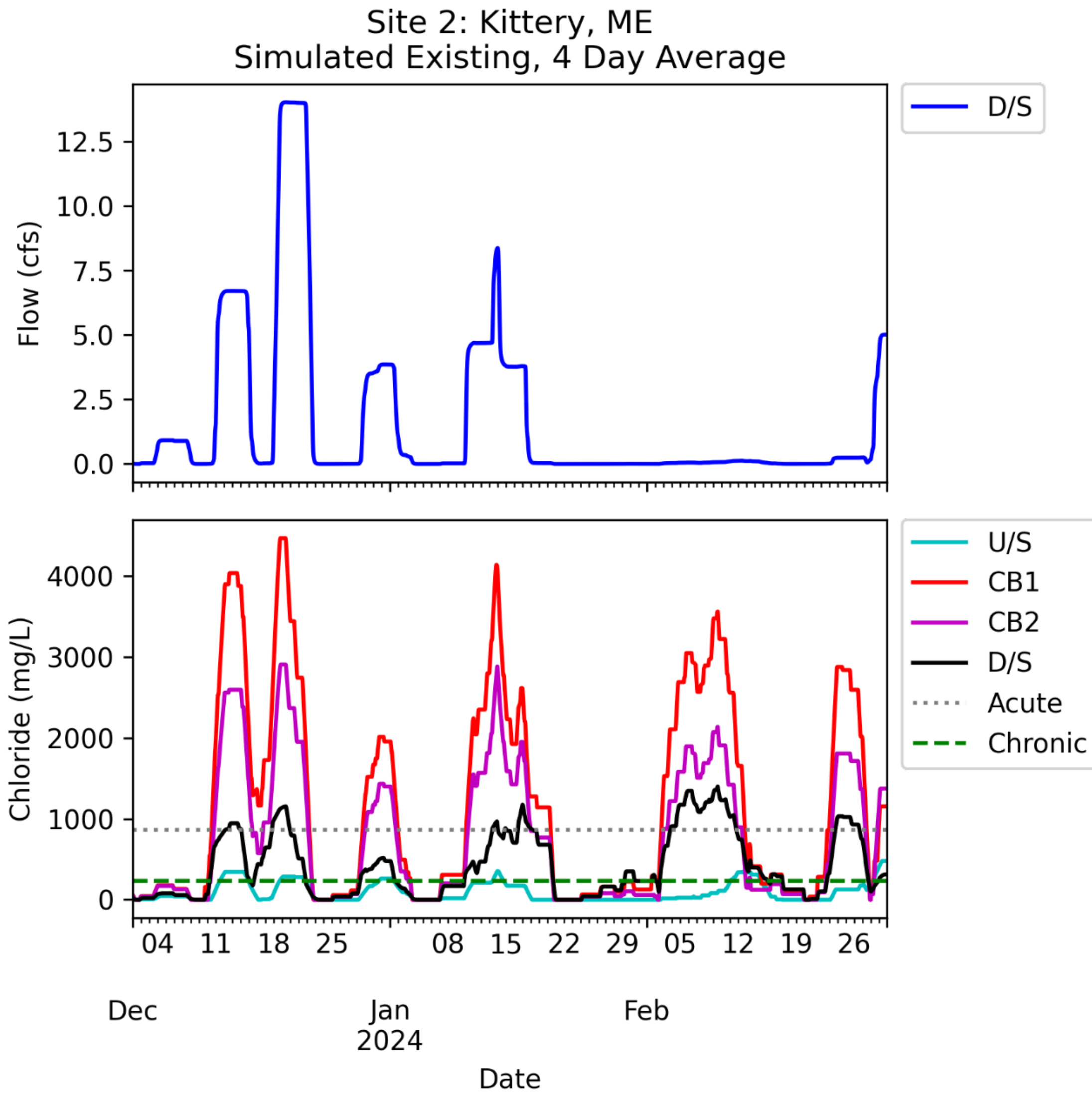

Figure 90: 2K. A three-month sample of the simulation results is shown as the 4-day average of the existing conditions at the monitored locations for POR. The upper subplot shows flow at the downstream outfall, and the lower subplot shows the concentration of chloride upstream (U/S), in the catch basins (CB1, CB2), and at the downstream outfall (D/S).

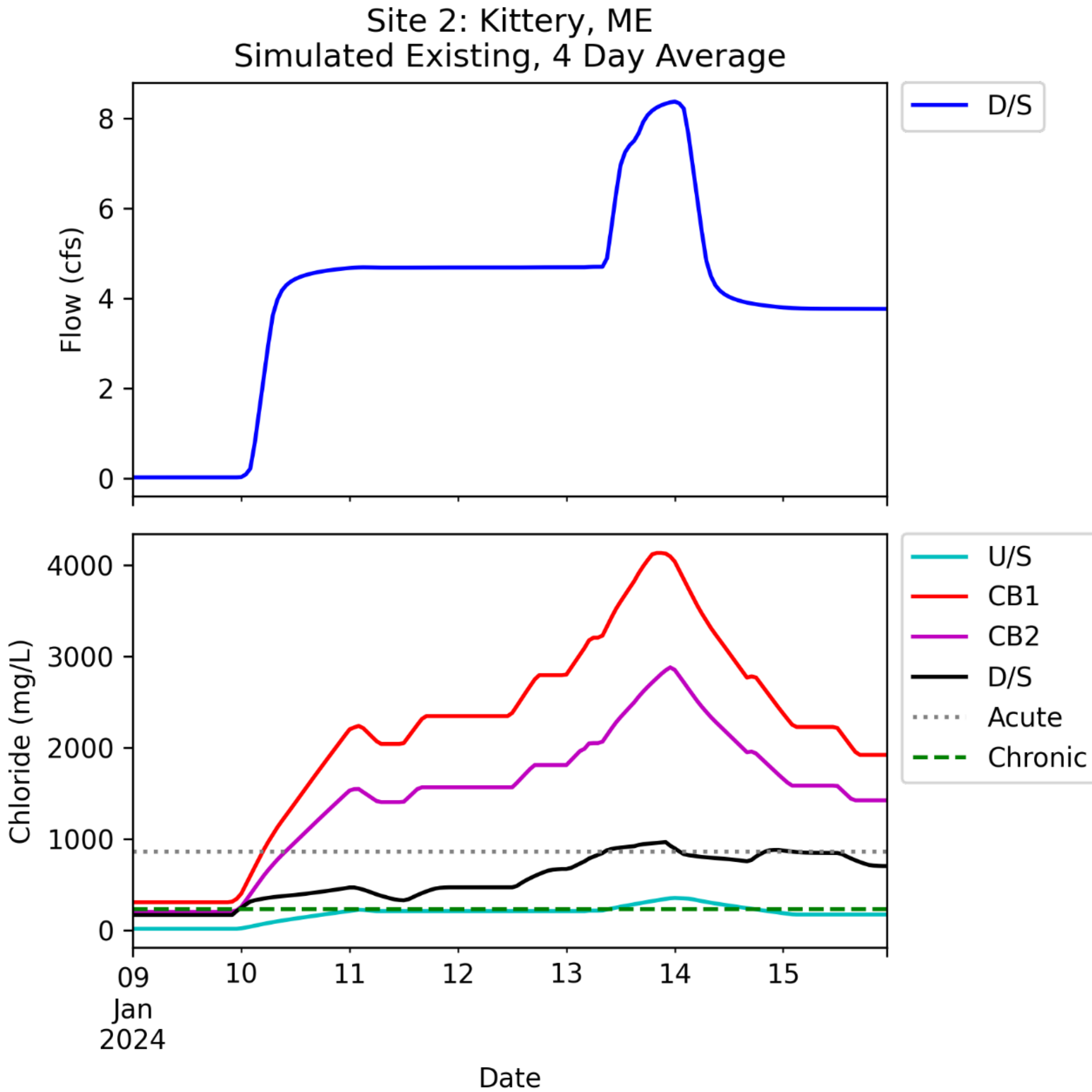

Figure 91: 2K. A sample of two runoff events of the simulation results is shown as the 4-day average of the existing conditions at the monitored locations for POR. The upper subplot shows flow at the downstream outfall, and the lower subplot shows the concentration of chloride upstream (U/S), in the catch basins (CB1, CB2), and at the downstream outfall (D/S).

Proposed Conditions: 4-Day Mean Simulation Results of Storage Scenarios

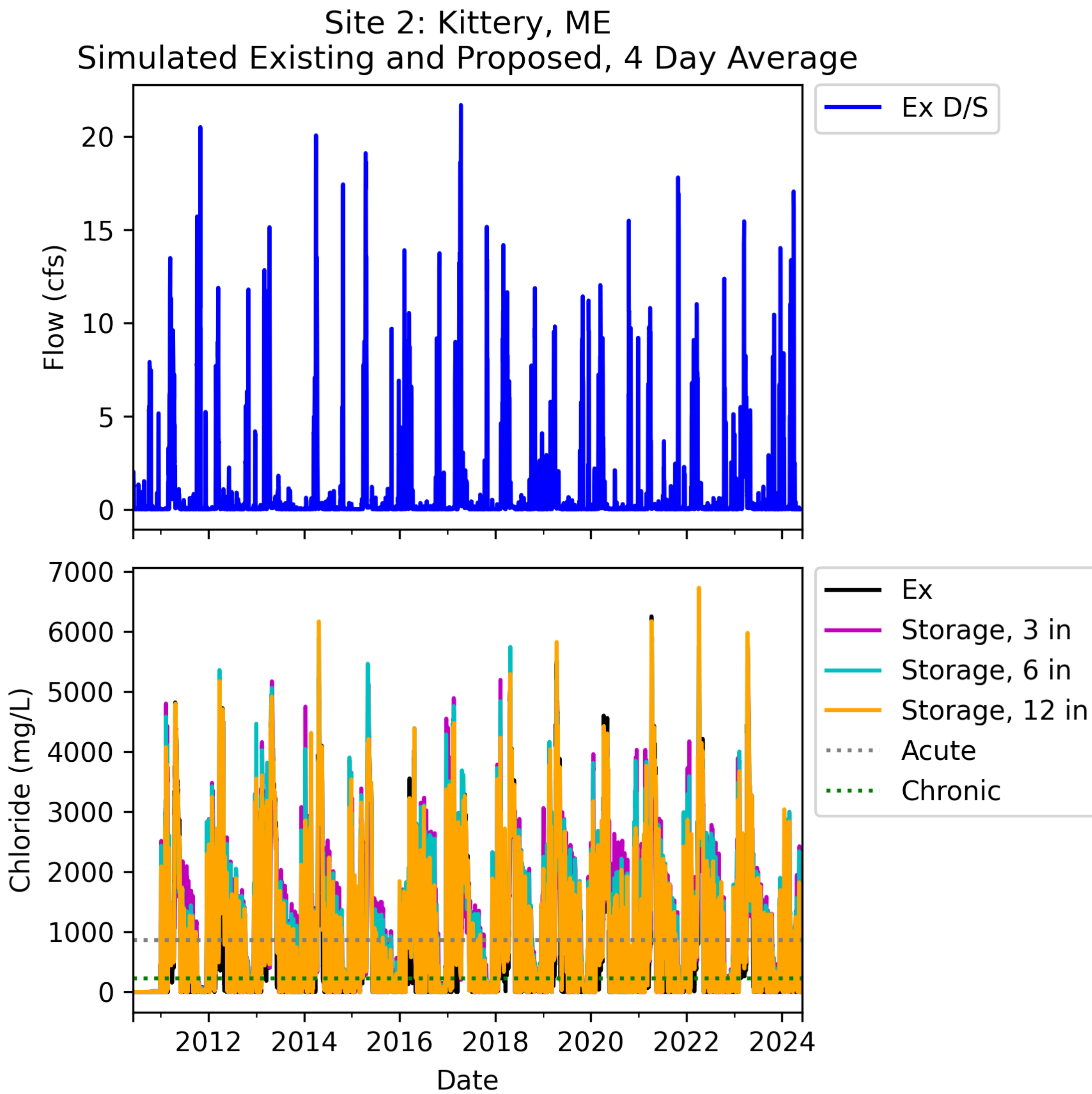

Figure 92: 2K. Simulation results are shown as the 4-day average of the proposed storage designs at downstream outfall for the POR. The upper subplot shows flow at the downstream outfall flow, and the lower subplot shows the concentration of chloride for the existing conditions (black), and the storage designs with 3-, 6-, and 12-inch orifices.

For the proposed storage designs, the 4-day average chloride concentration at the downstream (D/S) node exceeded the chronic criteria almost all runoff events and the acute criteria during most runoff events for the POR.

Generally, the smaller the orifice diameter, the larger the concentrations were during low-flow times. This is due to the extended-release time of the salty runoff past the runoff events. The largest 12-inch orifice most closely resembles the existing condition by passing the majority of the salty runoff volume to the stream close to the event while providing some storage. However,

Figure 92 shows that all proposed designs exceed both criteria much more than once every 3 years. As with the South Berwick site, the storage strategy results in higher 1-hour and 4-day average concentrations than not using the strategy.

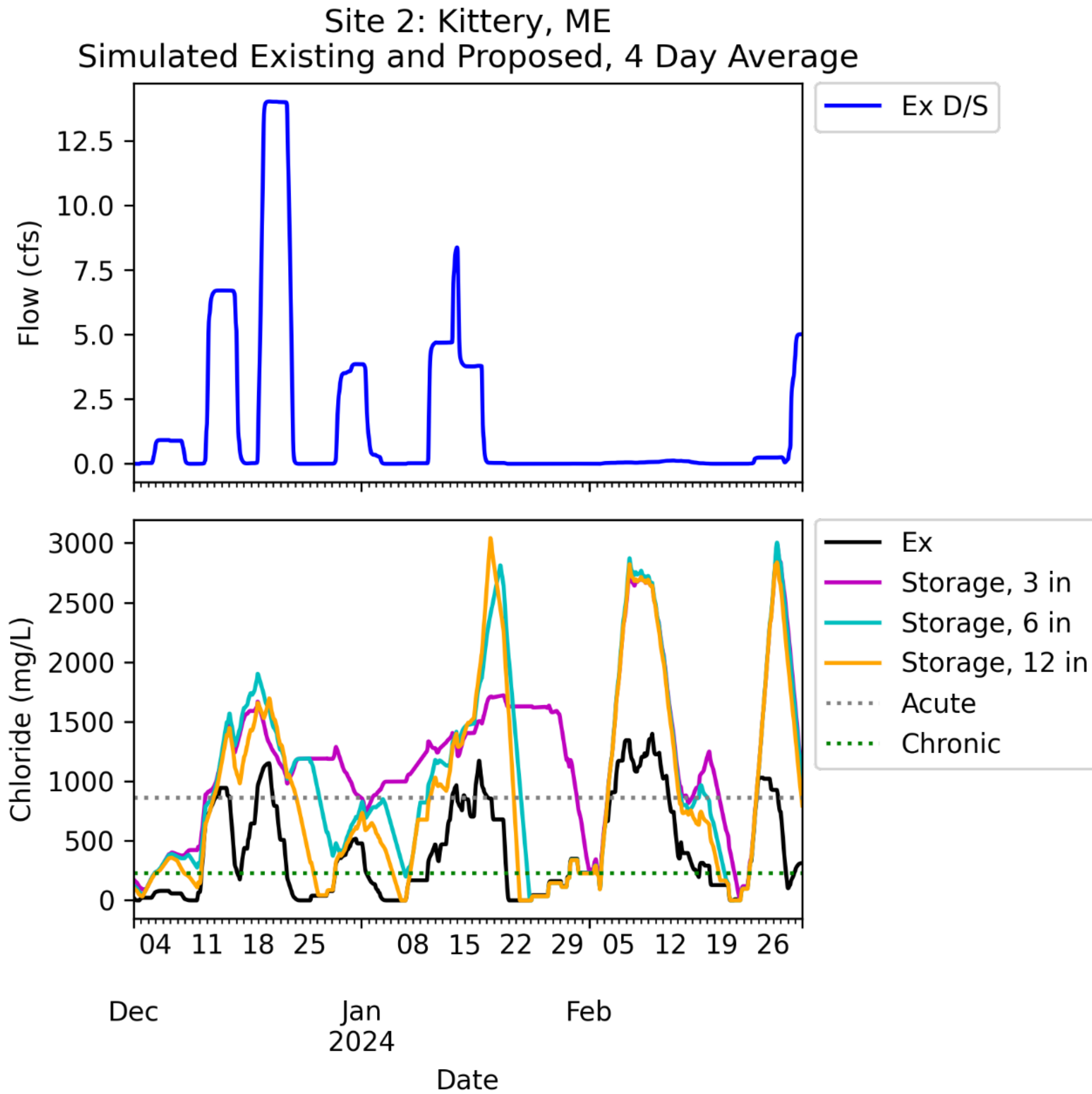

Figure 93: 2K. A three-month sample of the simulation results is shown as the 4-day average of the proposed storage designs at the downstream outfall. The upper subplot shows flow at the downstream outfall flow, and the lower subplot shows the concentration of chloride for the existing conditions (black), and the storage designs with 3-, 6-, and 12-inch orifices.

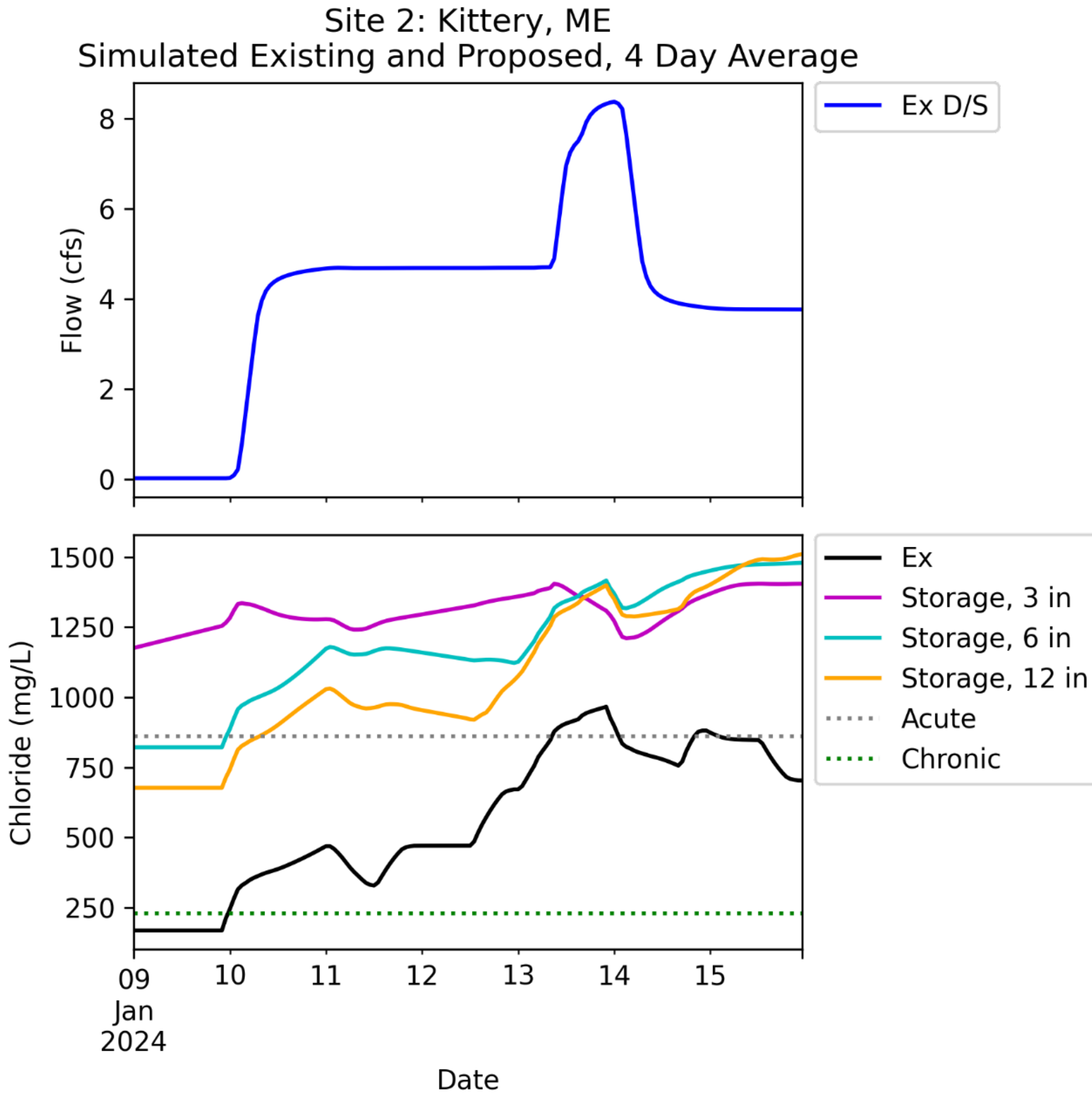

Figure 94: 2K. A sample of two runoff events of the simulation results is shown as the 4-day average of the proposed storage designs at the downstream outfall. The upper subplot shows flow at the downstream outfall flow, and the lower subplot shows the concentration of chloride for the existing conditions (black), and the storage designs with 3-, 6-, and 12-inch orifices.

Proposed Conditions: 4-Day Mean Simulation Results of Dilution Scenarios

This section shows the same figures as above but for the well pump, dilution scenarios. The junctions downstream of the salty runoff received constant-volume pumping at 1, 10, 100, and 1000 gpm. The diluted runoff was then routed to the downstream outfall. All the chloride concentrations are shown at the outfall for comparison of the existing conditions and the proposed dilution designs.

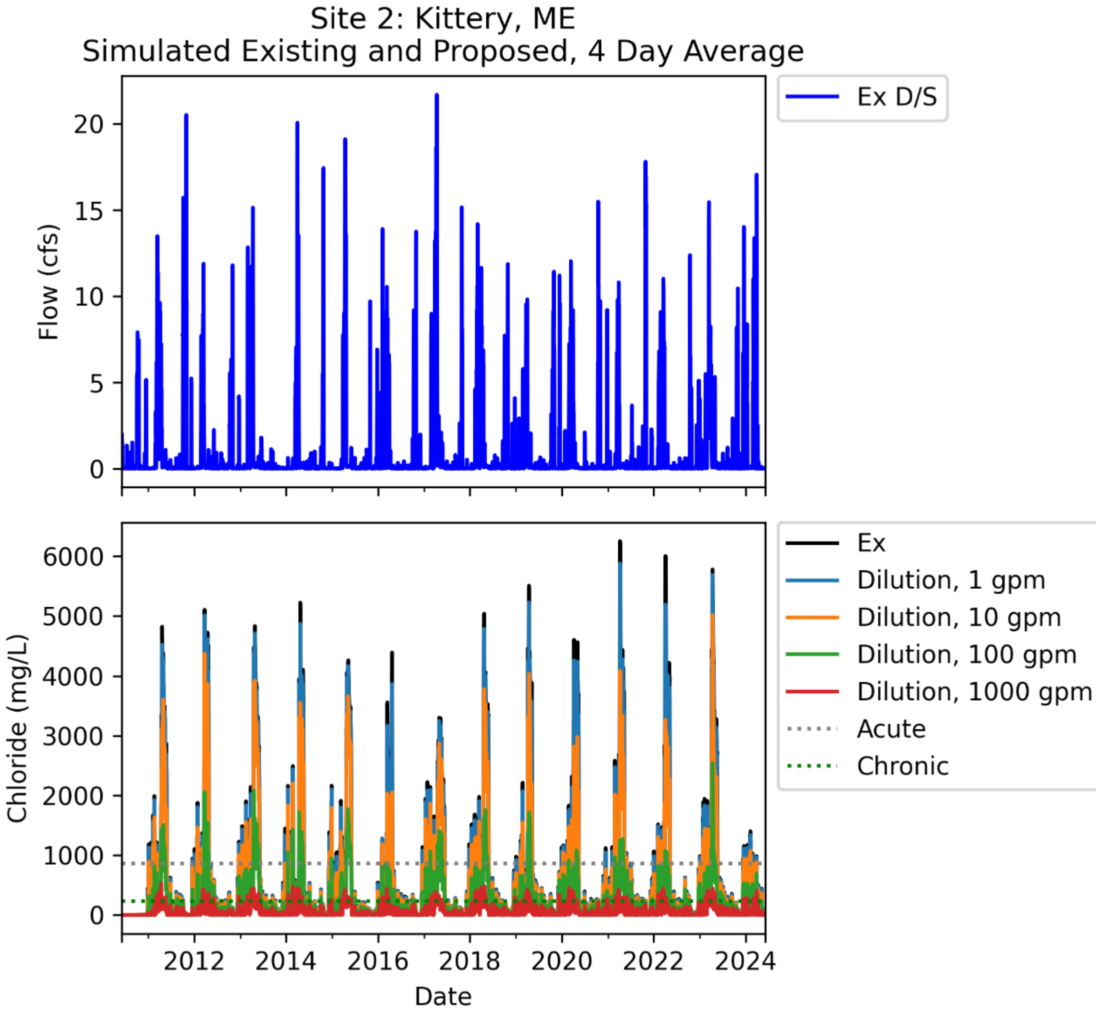

Figure 95: 2K. Simulation results are shown as the 4-day average of the proposed dilution designs at downstream outfall for the POR. The upper subplot shows flow at the downstream outfall flow, and the lower subplot shows the concentration of chloride for the existing conditions (black), and the pumping rates of 1, 10, 100, and 1000 gpm.

For the proposed dilution designs, the 4-day average chloride concentration at the downstream (D/S) node did exceed chronic and acute criteria during most runoff events for the POR. The 1000 gpm design never exceeded the acute criterium and did not excessively exceed the chronic criterium.

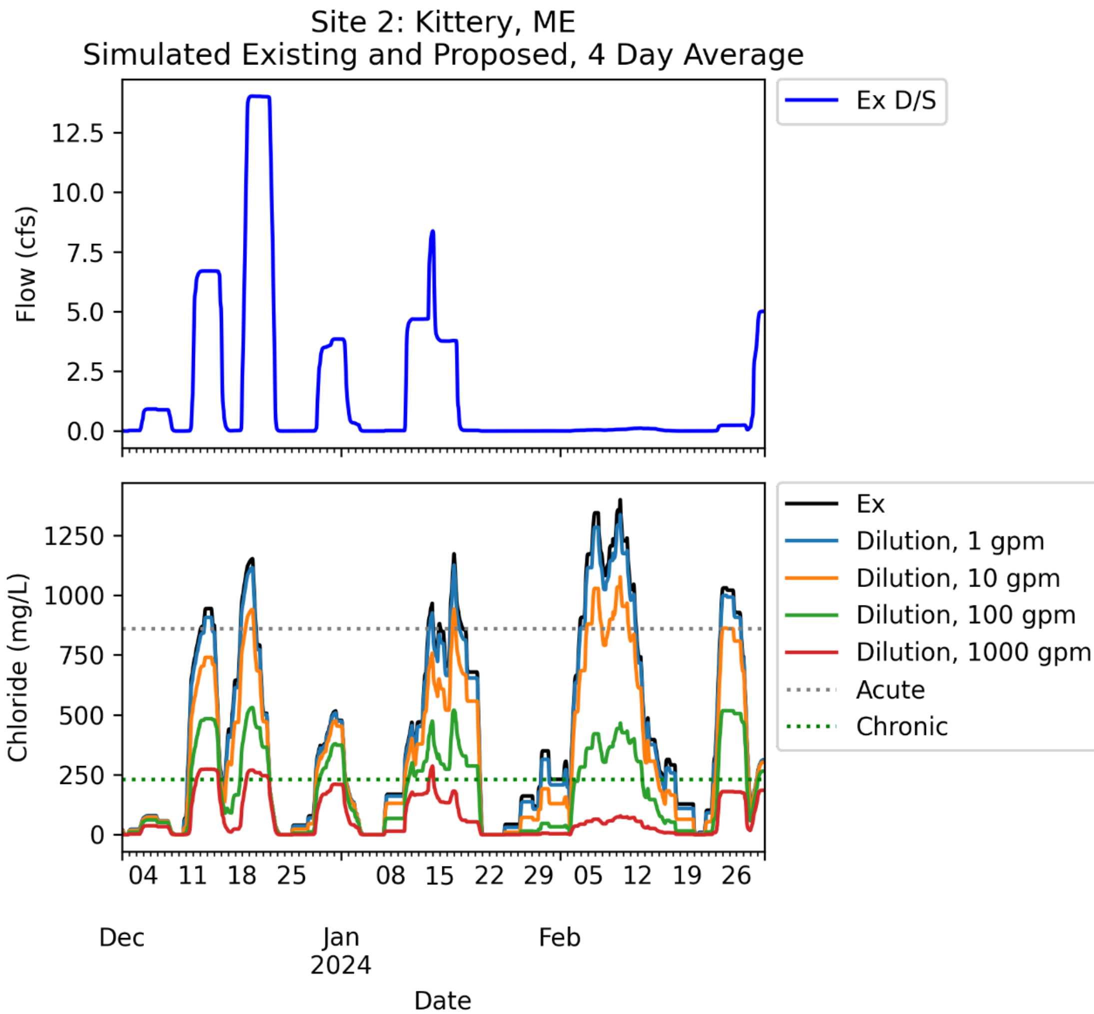

Figure 96: 2K. A three-month sample of the simulation results is shown as the 4-day average of the proposed dilution designs at the downstream outfall. The upper subplot shows flow at the downstream outfall flow, and the lower subplot shows the concentration of chloride for the existing conditions (black), and the pumping rates of 1, 10, 100, and 1000 gpm.

Figure 96 shows the general trend of the peak concentrations decreasing as the pumping rate increases. The 1000 gpm rate is near, but often just above the chronic criterium. A higher rate of about 2000-5000 gpm should be sufficient to bring it to below the chronic criteria.

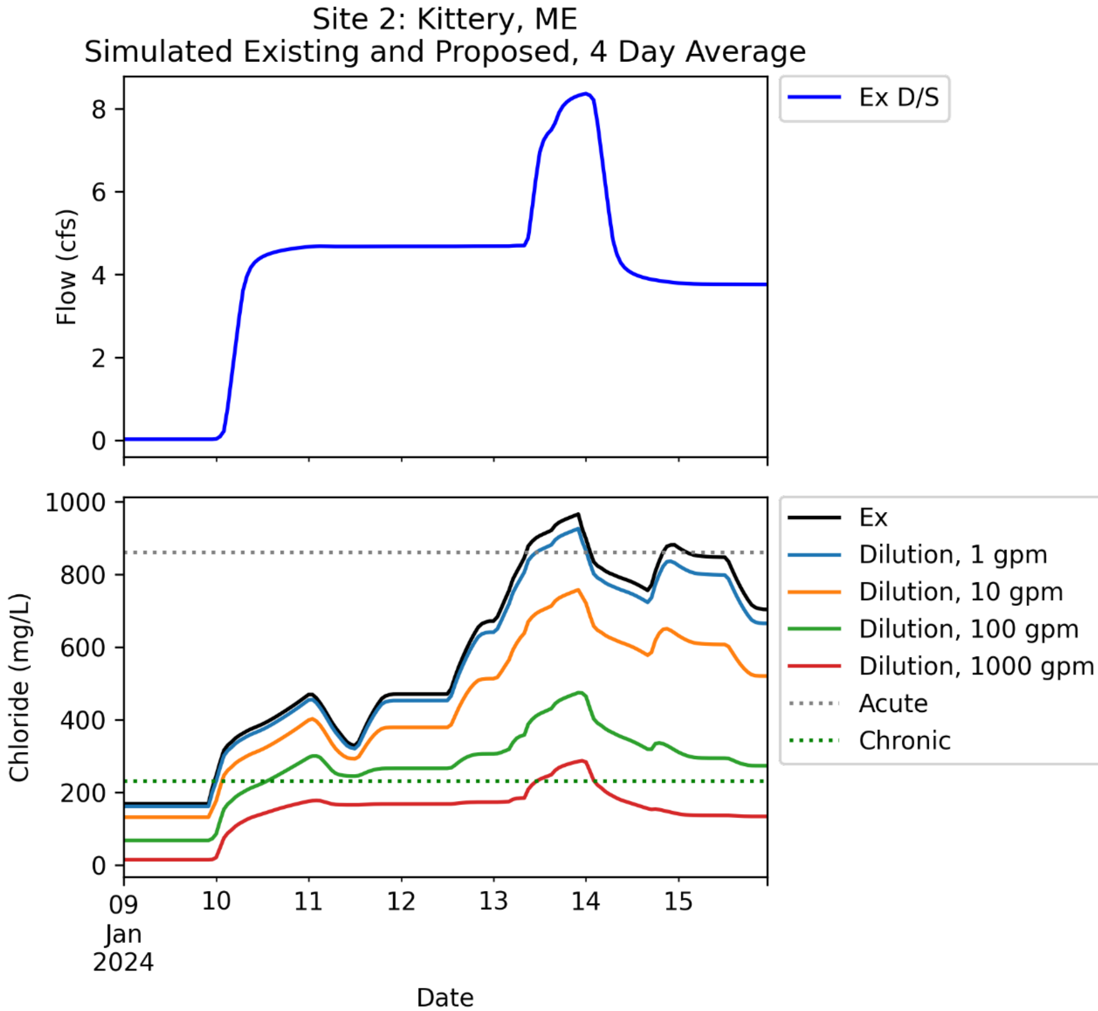

Figure 97: 2K. A sample of two runoff events of the simulation results is shown as the 4-day average of the proposed dilution designs at the downstream outfall. The upper subplot shows flow at the downstream outfall flow, and the lower subplot shows the concentration of chloride for the existing conditions (black), and the pumping rates of 1, 10, 100, and 1000 gpm.

In contrast to the storage scenarios where the concentration remains high during low-flow and decreases during the runoff events where flows increase, the opposite is seen in the dilution scenarios in Figure 97. When the runoff events and dilution flows begin, the delivery of salty runoff decrease the downstream concentrations. The highest pumping design of 1000 gpm (2.23 cfs) is about half of the flow of the first runoff event and about a quarter of the second. This relatively small dilution ratio during the peak of the runoff is not enough to dilute the runoff to less than the chronic criterium.

Site 3: Hampden South

Existing Conditions: 1-Day Simulation Results

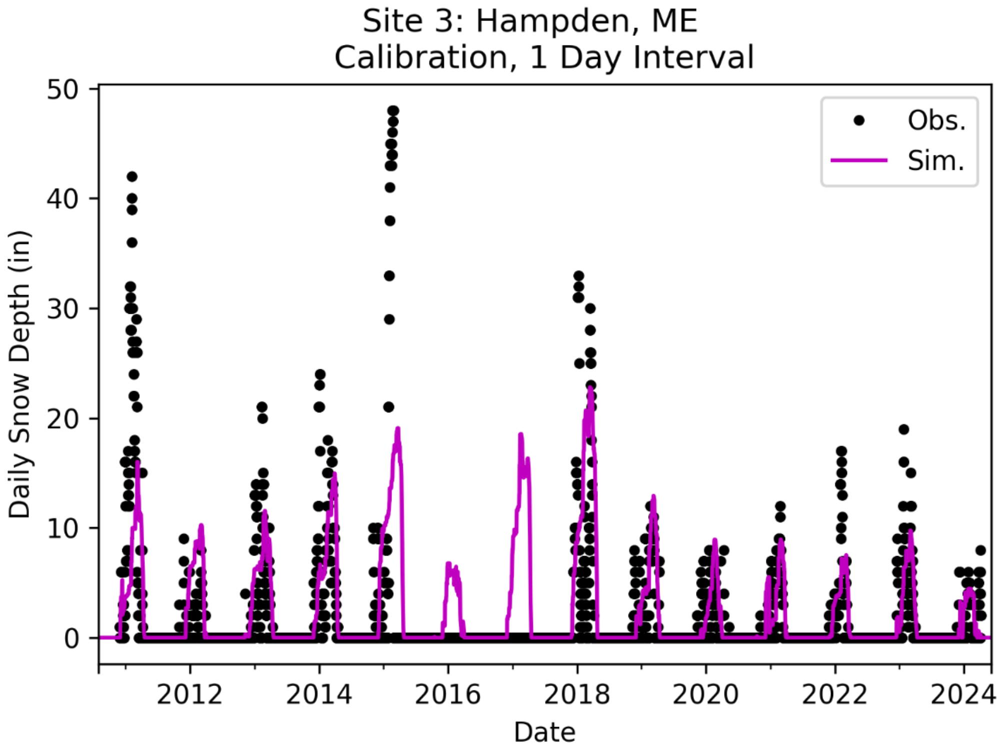

Figure 98: 3HS. Simulation results of the existing conditions overlayed on the observed snow depth from the NOAA station. Results are shown as the daily total value.

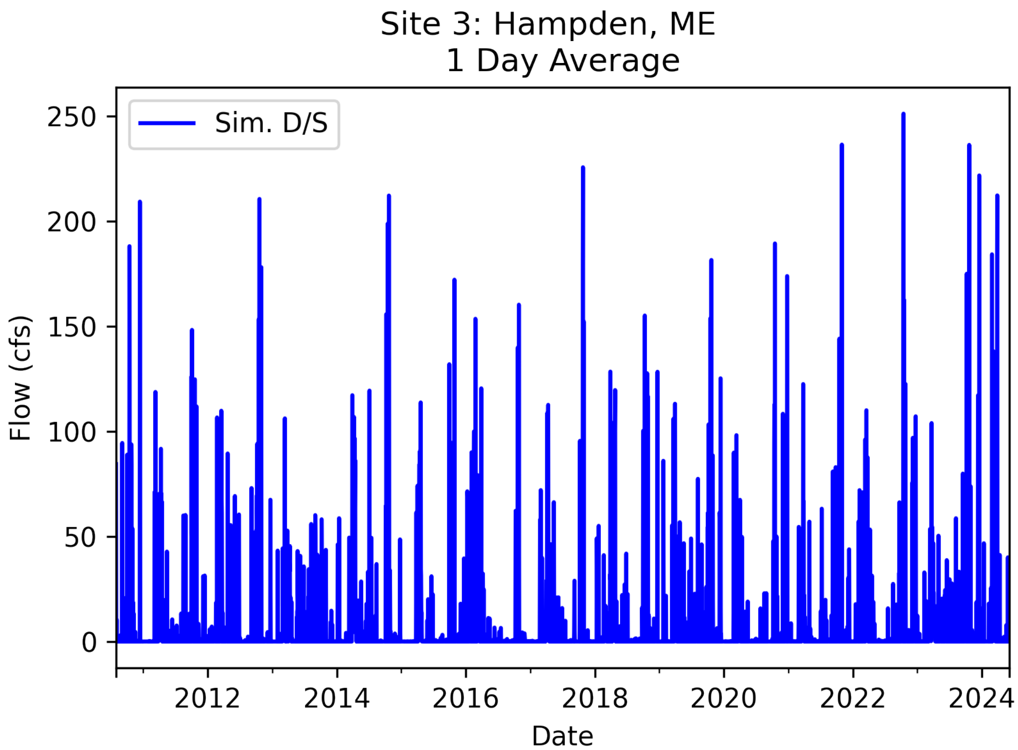

Figure 99: 3HS. Simulation results of the existing conditions at the outfall (farthest downstream). Results are shown as the daily mean value. This interval aligns with the comparison to the StreamStats flows.

Existing Conditions: 1-Hour Simulation Results

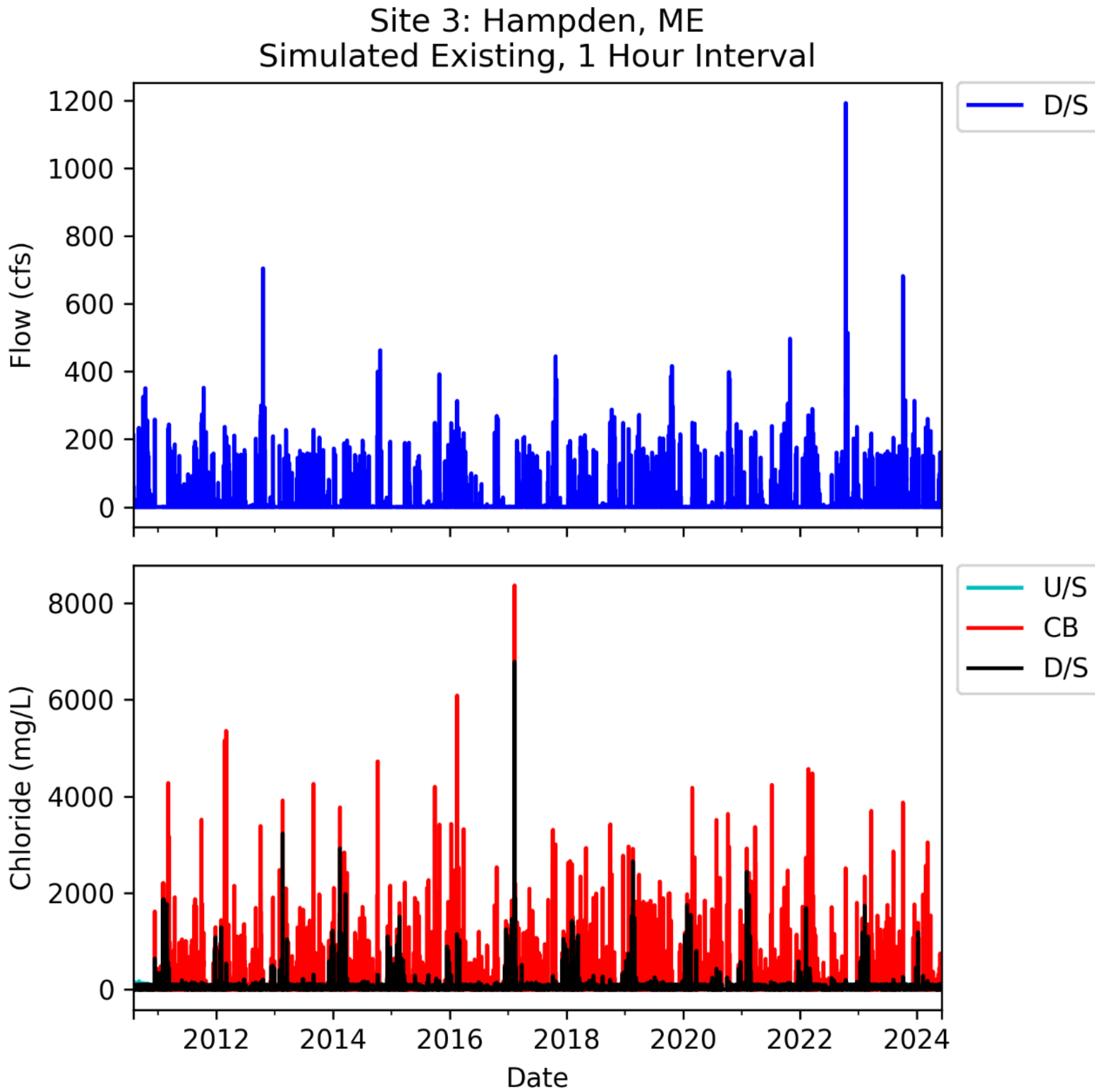

Figure 100: 3HS. Simulation results are shown at 1-hour intervals of the existing conditions at the monitored locations for POR. The upper subplot shows flow at the downstream outfall, and the lower subplot shows the concentration of chloride upstream (U/S), in the catch basin (CB), and at the downstream outfall (D/S).

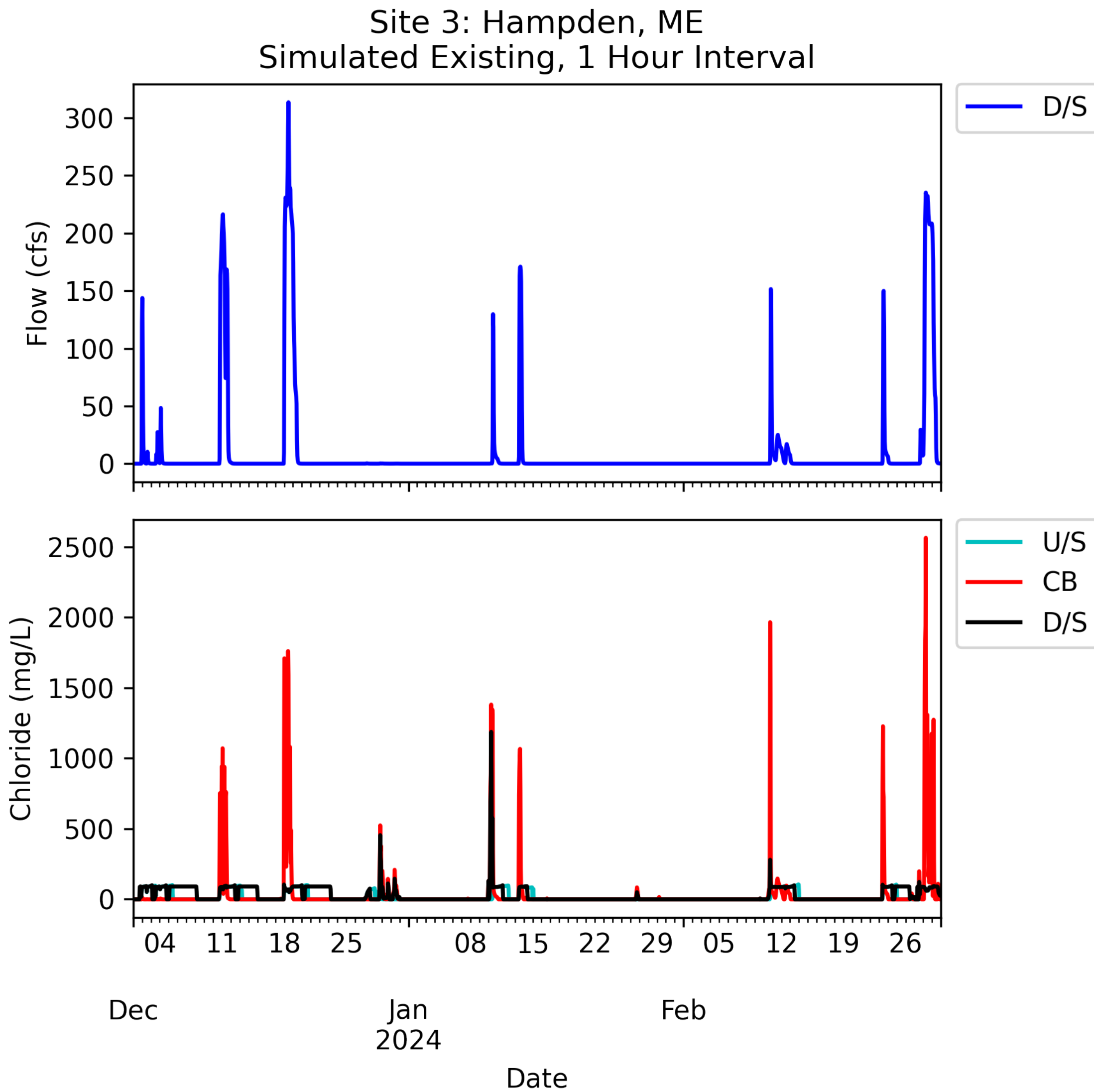

Figure 101: 3HS. A three-month sample of the simulation results is shown at 1-hour intervals of the existing conditions at the monitored locations. The upper subplot shows flow at the downstream outfall, and the lower subplot shows the concentration of chloride upstream (U/S), in the catch basin (CB), and at the downstream outfall (D/S).

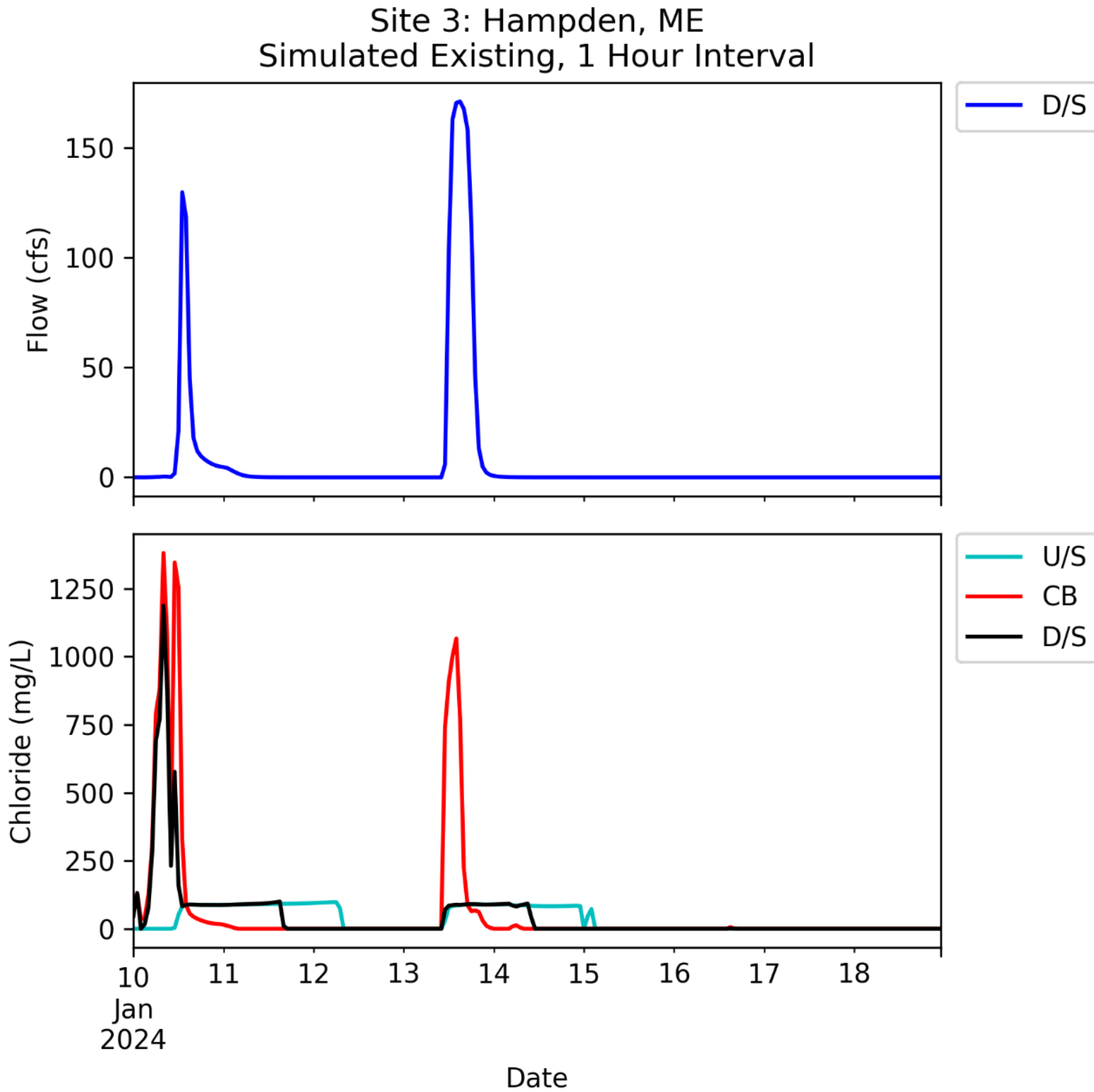

Figure 102: 3HS. A sample of two runoff events of the simulation results is shown at 1-hour intervals of the existing conditions at the monitored locations. The upper subplot shows flow at the downstream outfall, and the lower subplot shows the concentration of chloride upstream (U/S), in the catch basin (CB), and at the downstream outfall (D/S).

Existing Conditions: 4-Day Mean Simulation Results

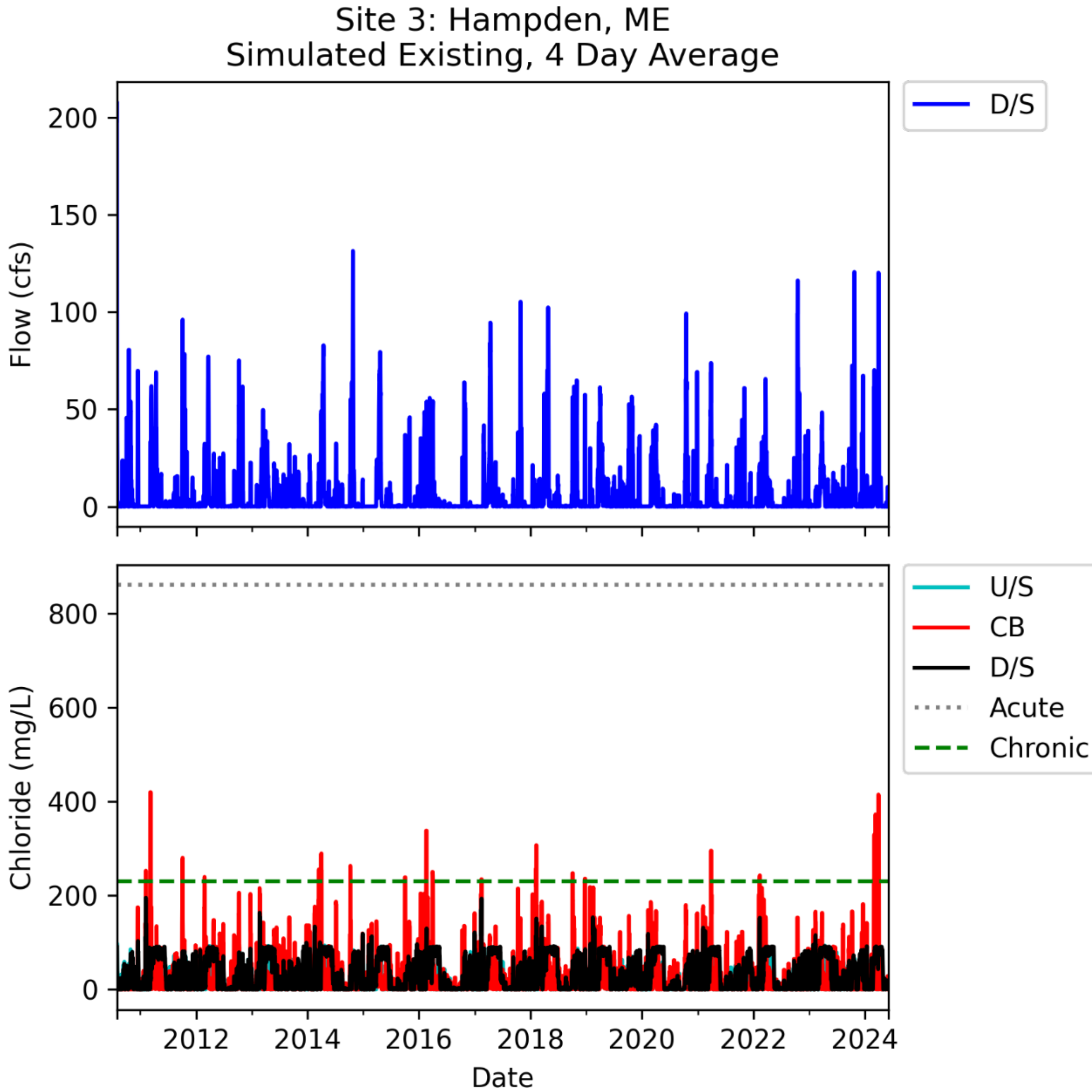

Figure 103: 3HS. Simulation results are shown as the 4-day average of the existing conditions at the monitored locations for POR. The upper subplot shows flow at the downstream outfall, and the lower subplot shows the concentration of chloride upstream (U/S), in the catch basin (CB), and at the downstream outfall (D/S).

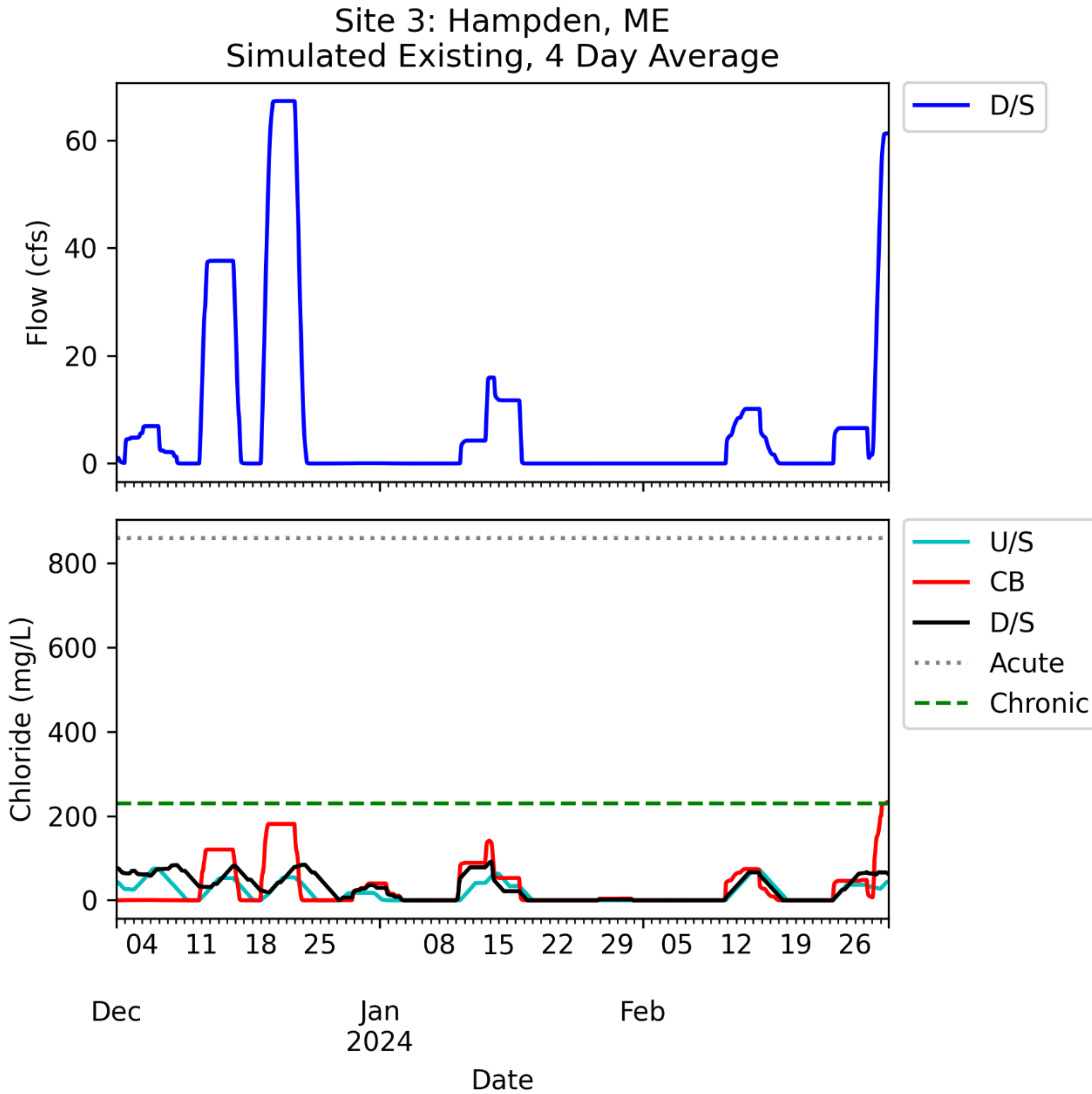

Figure 104: 3HS. A three-month sample of the simulation results is shown as the 4-day average of the existing conditions at the monitored locations for POR. The upper subplot shows flow at the downstream outfall, and the lower subplot shows the concentration of chloride upstream (U/S), in the catch basin (CB), and at the downstream outfall (D/S).

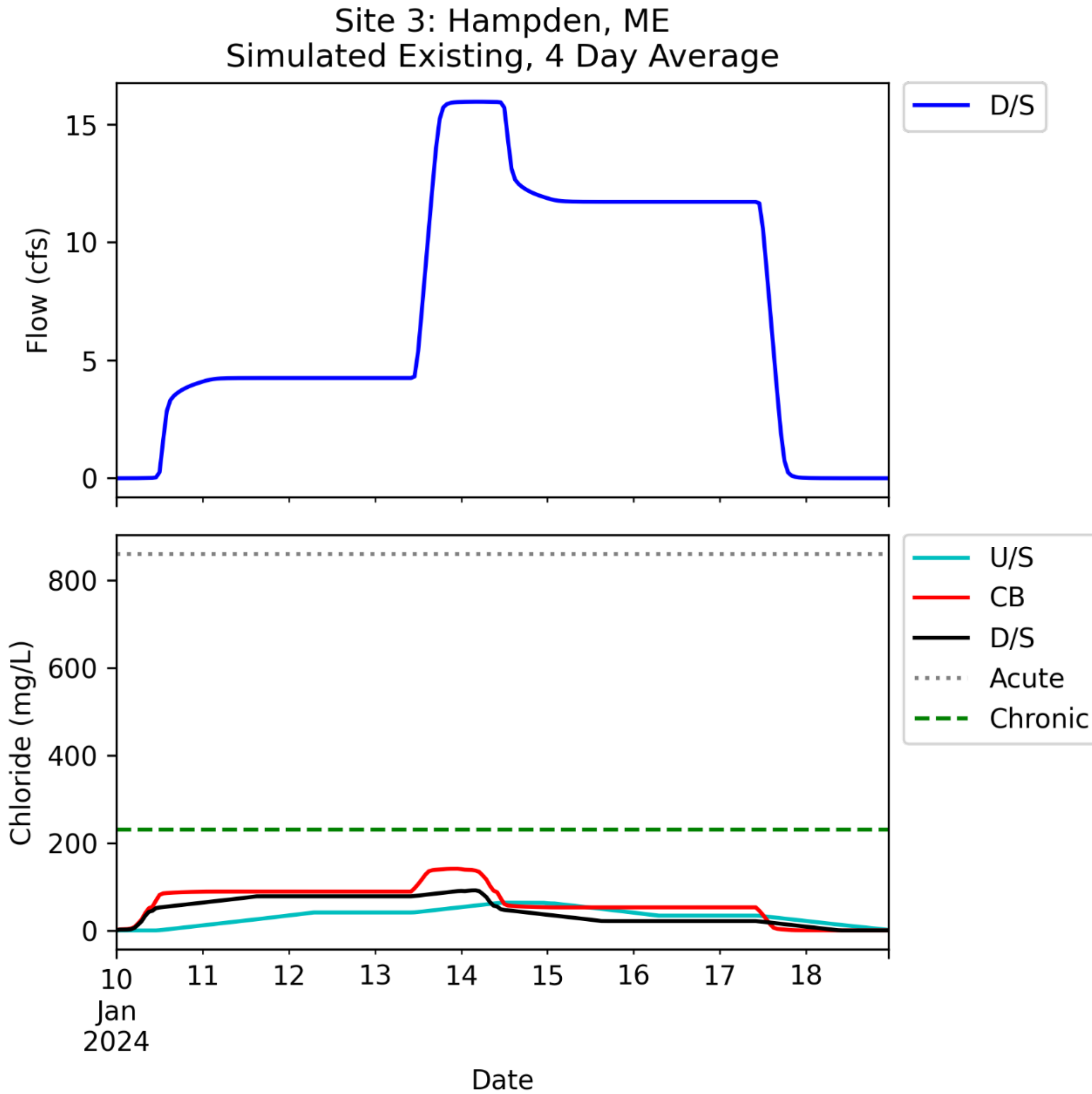

Figure 105: 3HS. A sample of two runoff events of the simulation results is shown as the 4-day average of the existing conditions at the monitored locations for POR. The upper subplot shows

flow at the downstream outfall, and the lower subplot shows the concentration of chloride upstream (U/S), in the catch basin (CB), and at the downstream outfall (D/S).

Proposed Conditions: 4-Day Mean Simulation Results of Storage Scenarios

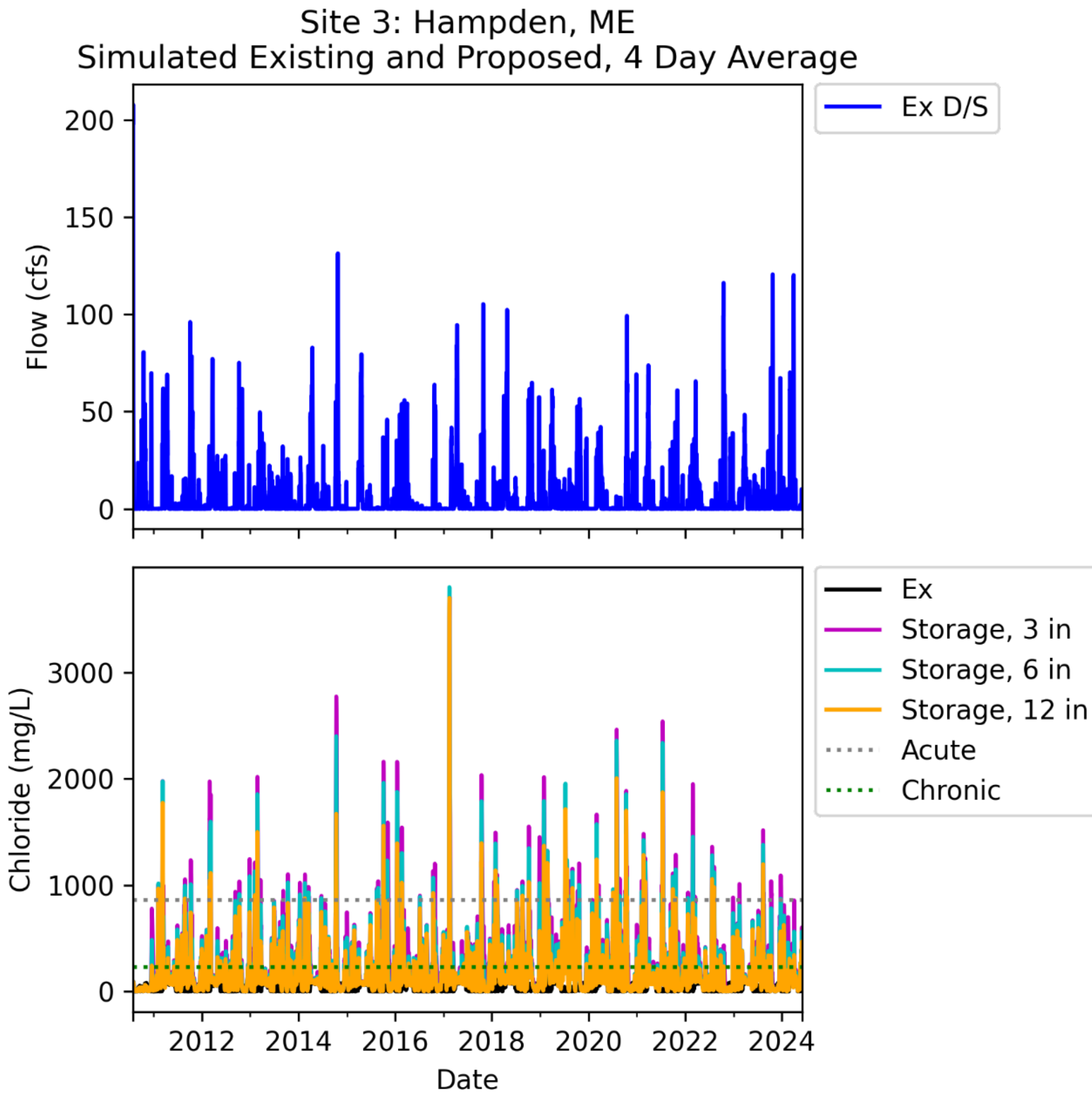

Figure 106: 3HS. Simulation results are shown as the 4-day average of the proposed storage designs at downstream outfall for the POR. The upper subplot shows flow at the downstream outfall flow, and the lower subplot shows the concentration of chloride for the existing conditions (black), and the storage designs with 3-, 6-, and 12-inch orifices.

For the proposed storage designs, the 4-day average chloride concentration at the downstream (D/S) node exceeded the chronic criteria almost all runoff events and the acute criteria during most runoff events for the POR.

Generally, the smaller the orifice diameter, the larger the concentrations were during low-flow times. This is due to the extended-release time of the salty runoff past the runoff events. The largest 12-inch orifice most closely resembles the existing condition by passing the majority of the salty runoff volume to the stream close to the event while providing some storage. However, Figure 106 shows that all proposed designs exceed both criteria much more than once every 3 years.

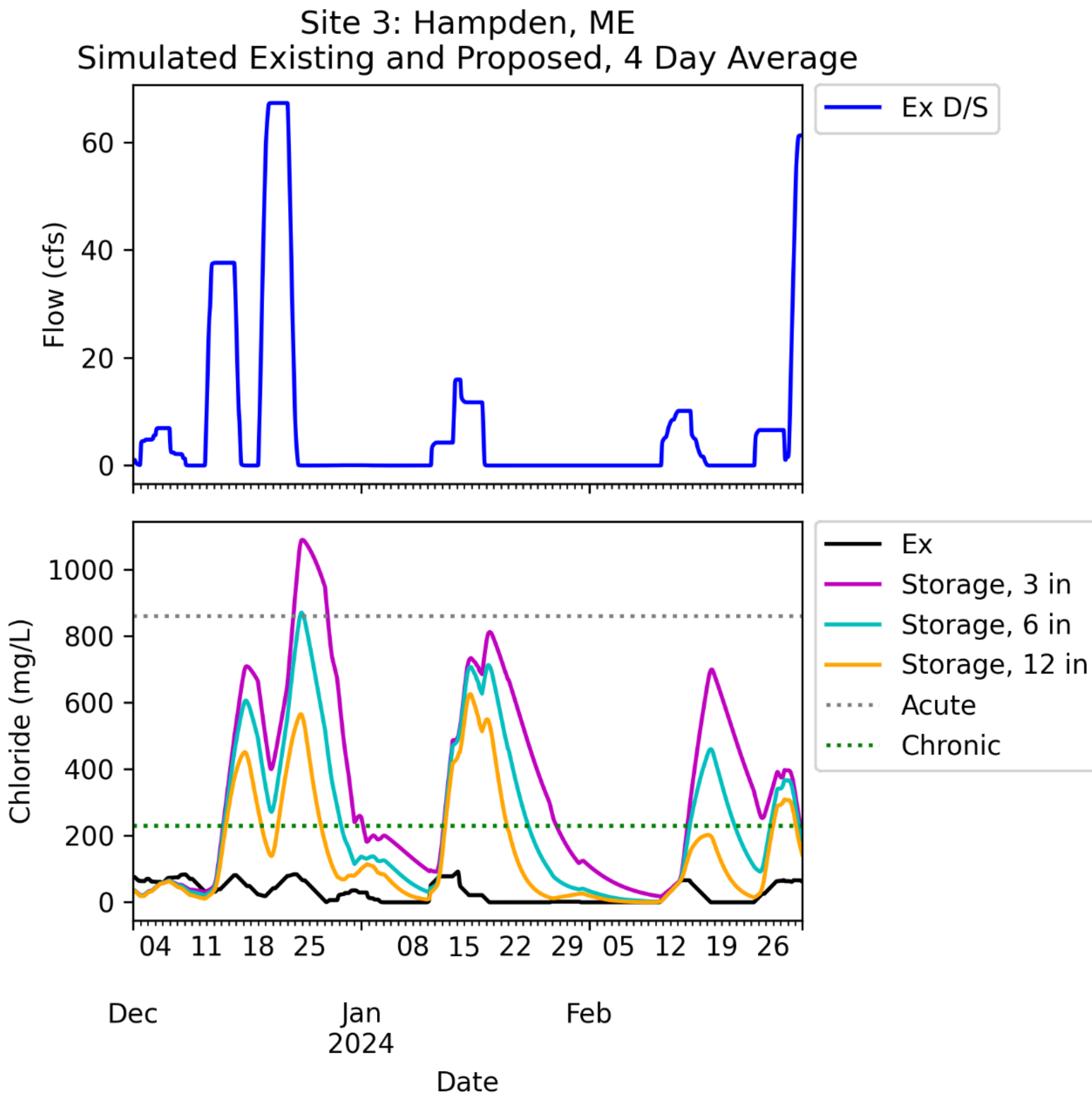

Figure 107: 3HS. A three-month sample of the simulation results is shown as the 4-day average of the proposed storage designs at the downstream outfall. The upper subplot shows flow at the downstream outfall flow, and the lower subplot shows the concentration of chloride for the existing conditions (black), and the storage designs with 3-, 6-, and 12-inch orifices.

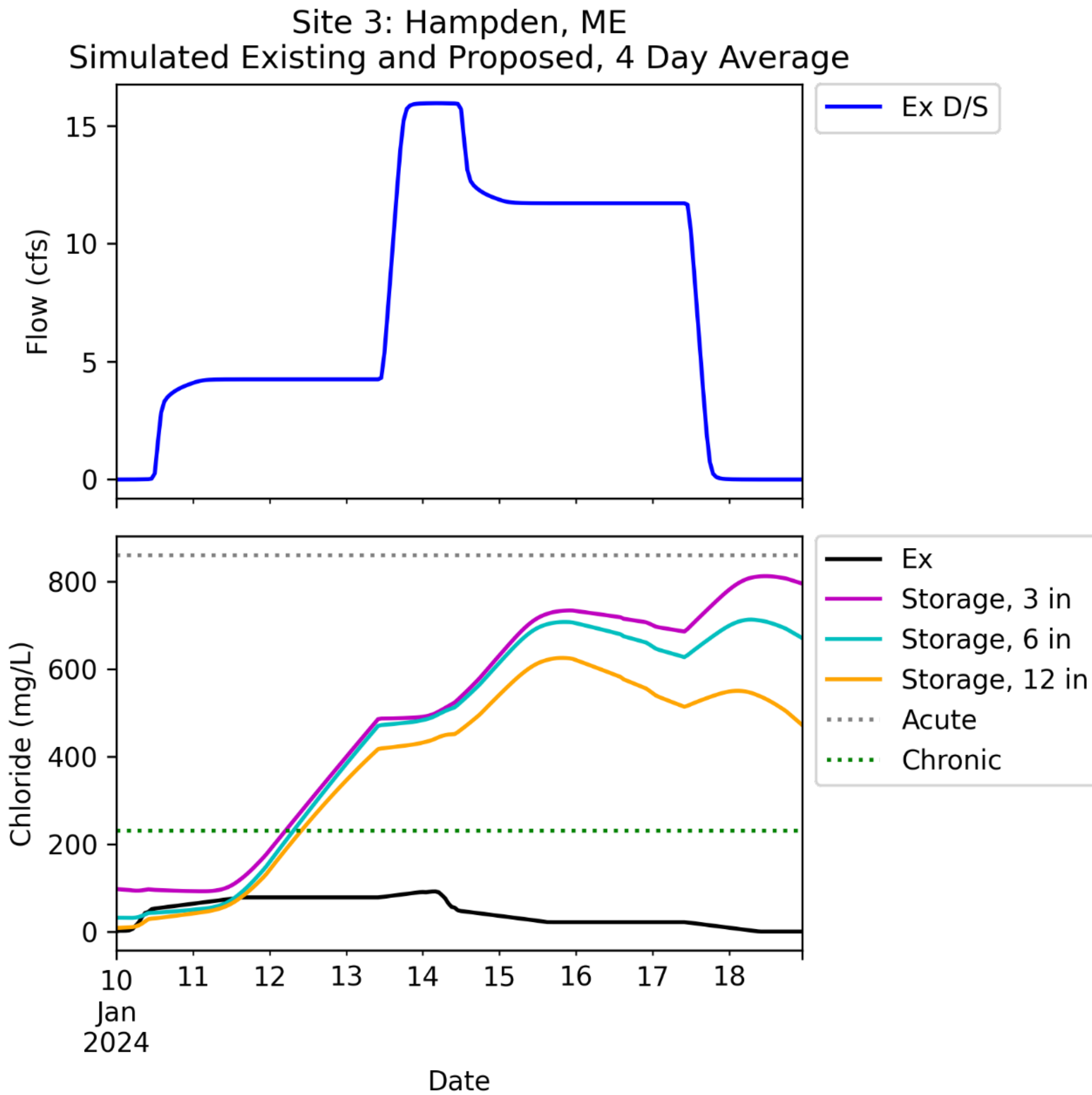

Figure 108: 3HS. A sample of two runoff events of the simulation results is shown as the 4-day average of the proposed storage designs at the downstream outfall. The upper subplot shows flow at the downstream outfall flow, and the lower subplot shows the concentration of chloride for the existing conditions (black), and the storage designs with 3-, 6-, and 12-inch orifices.

Proposed Conditions: 4-Day Mean Simulation Results of Dilution Scenarios

This section shows the same figures as above but for the well pump, dilution scenarios. The junctions downstream of the salty runoff received constant-volume pumping at 1, 10, 100, and 1000 gpm. The diluted runoff was then routed to the downstream outfall. All the chloride concentrations are shown at the outfall for comparison of the existing conditions and the proposed dilution designs.

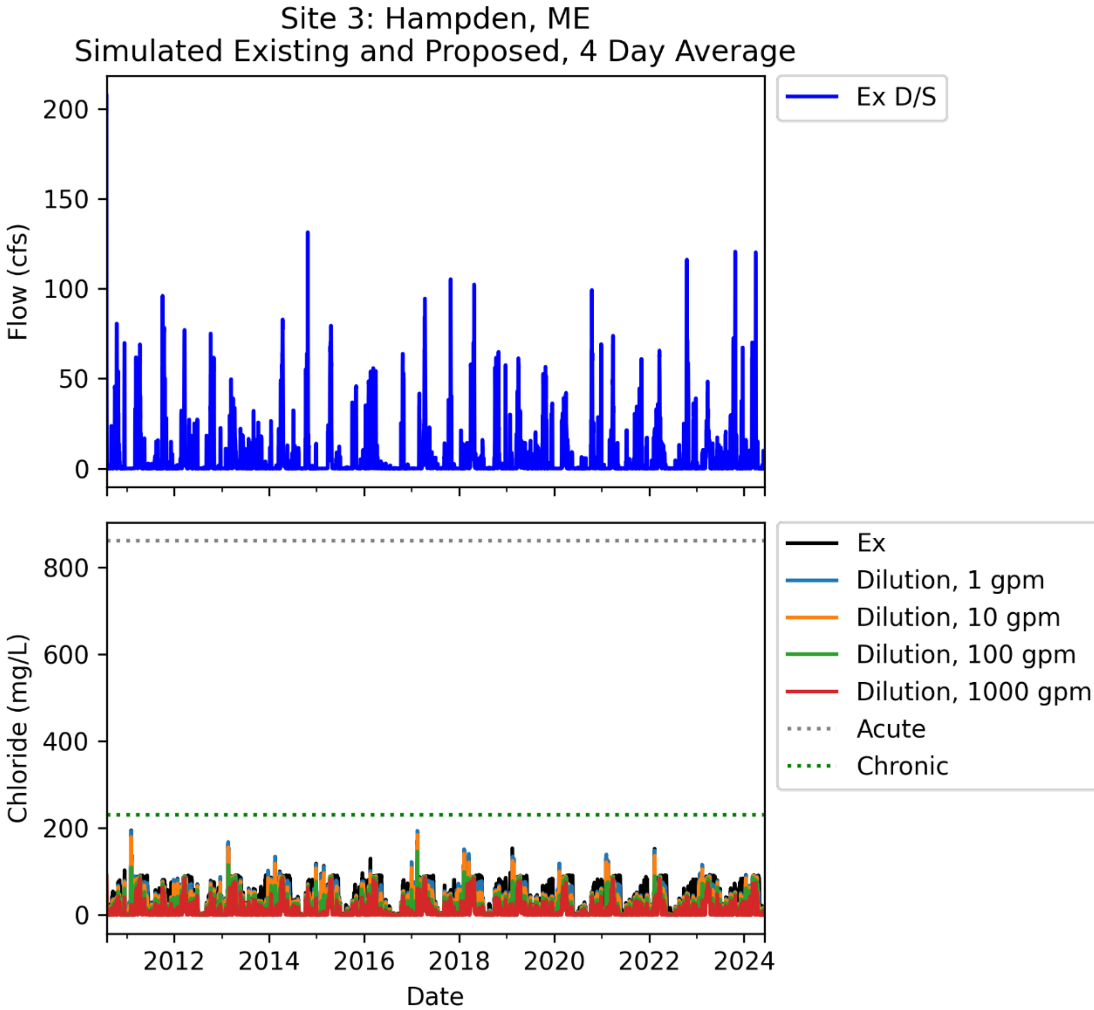

Figure 109: 3HS. Simulation results are shown as the 4-day average of the proposed dilution designs at downstream outfall for the POR. The upper subplot shows flow at the downstream outfall flow, and the lower subplot shows the concentration of chloride for the existing conditions (black), and the pumping rates of 1, 10, 100, and 1000 gpm.

For the proposed dilution designs, the 4-day average chloride concentration at the downstream (D/S) node never exceeded either the chronic or acute criteria during any runoff events for the POR.

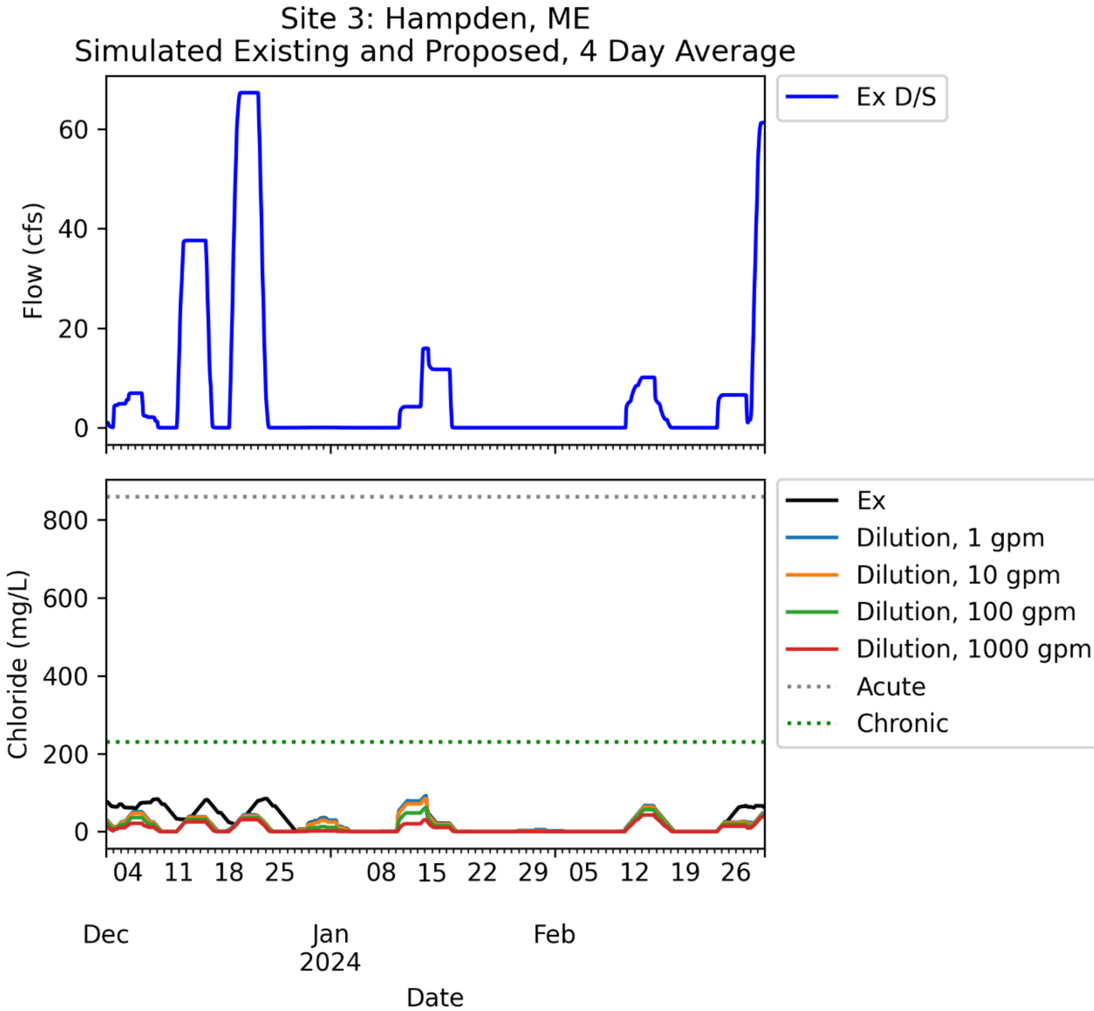

Figure 110: 3HS. A three-month sample of the simulation results is shown as the 4-day average of the proposed dilution designs at the downstream outfall. The upper subplot shows flow at the downstream outfall flow, and the lower subplot shows the concentration of chloride for the existing conditions (black), and the pumping rates of 1, 10, 100, and 1000 gpm.

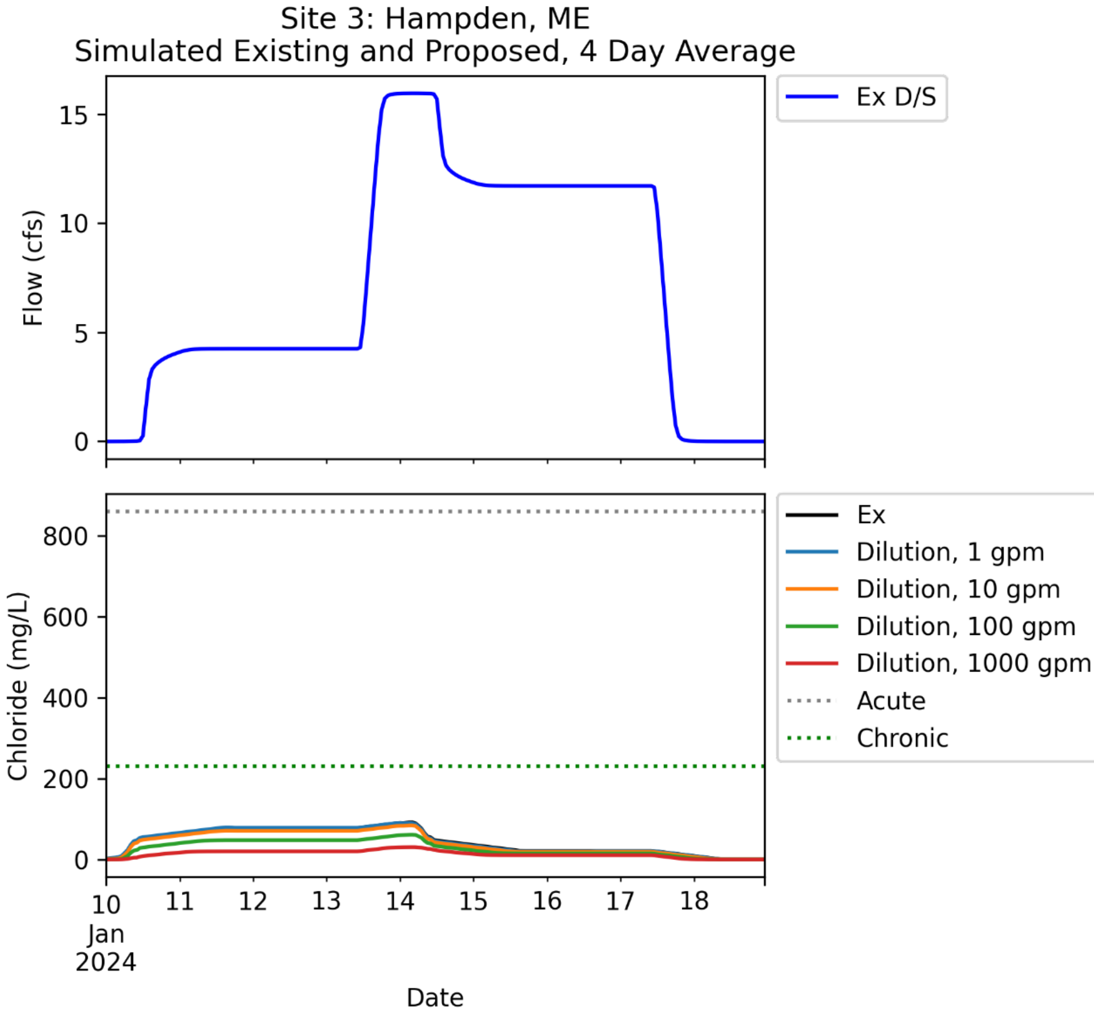

Figure 111: 3HS. A sample of two runoff events of the simulation results is shown as the 4-day average of the proposed dilution designs at the downstream outfall. The upper subplot shows flow at the downstream outfall flow, and the lower subplot shows the concentration of chloride for the existing conditions (black), and the pumping rates of 1, 10, 100, and 1000 gpm.

Storage Summary

The maximum storage observed in the storage scenarios was calculated for each water year (WY) of the simulations and plotted along with the annual snow depth.

Site 1: South Berwick

Figure 112, Figure 113, and Figure 114 show the annual snow depth and maximum storage reached per water year for the storage scenarios with a 3-, 6-, and 12-inch orifices, respectively.

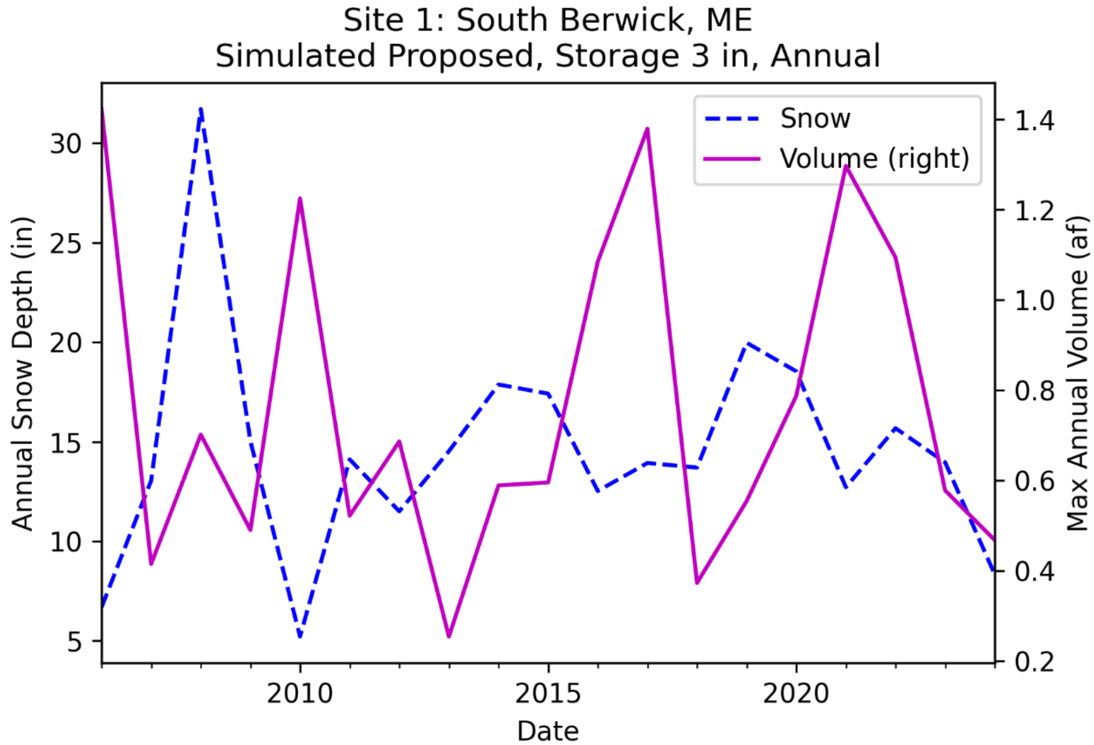

Figure 112: 1SB. Summary of the simulation results shown for the 4-day average of the proposed storage design at the downstream outfall. The left axis shows the annual snow depth (in), and the right-axis shows the maximum annual volume required for storage for the design with the 3-inch orifice.

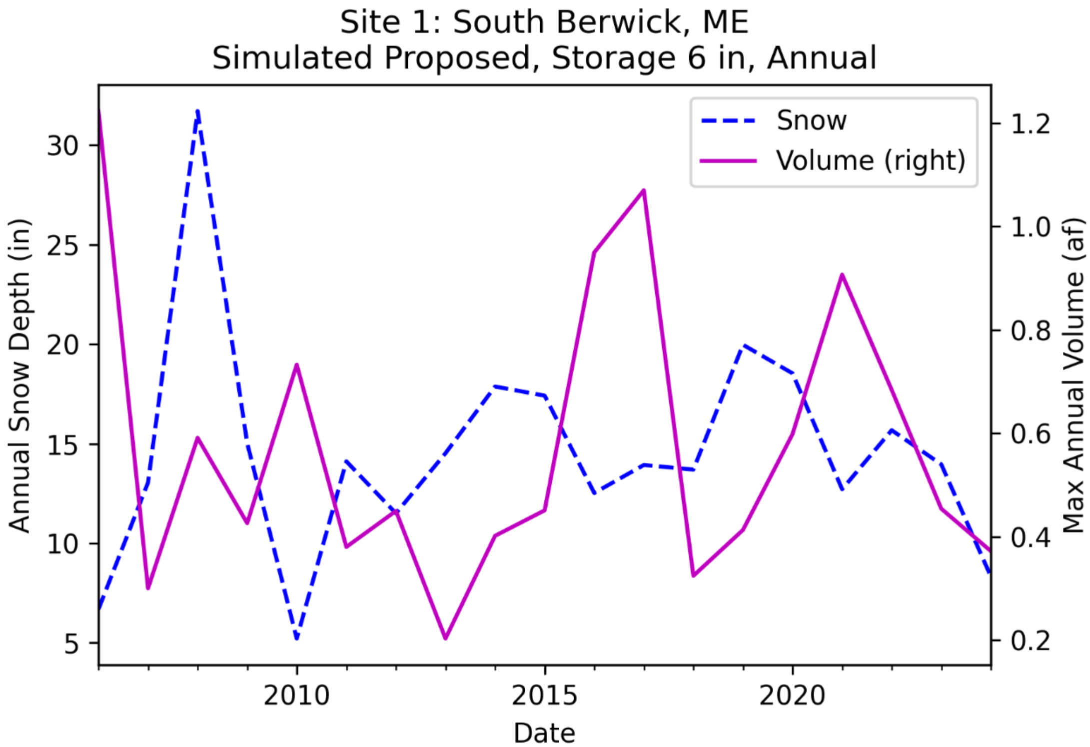

Figure 113: 1SB. Summary of the simulation results shown for the 4-day average of the proposed storage design at the downstream outfall. The left axis shows the annual snow depth (in), and the right-axis shows the maximum annual volume required for storage for the design with the 6-inch orifice.

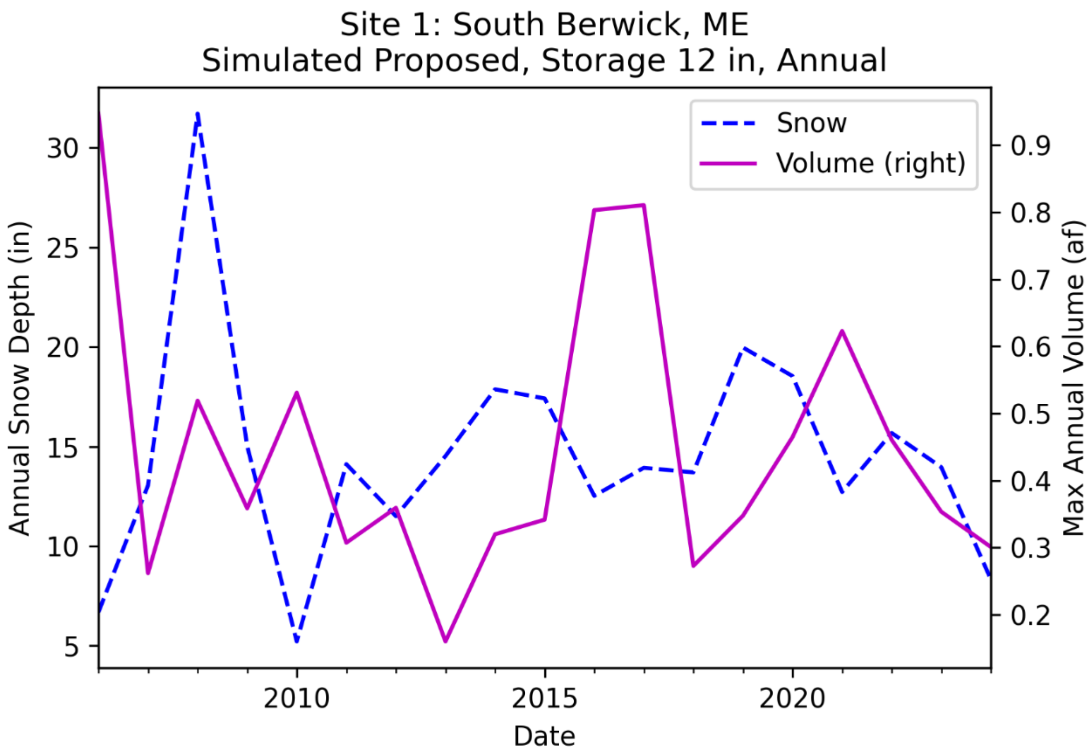

Figure 114: 1SB. Summary of the simulation results shown for the 4-day average of the proposed storage design at the downstream outfall. The left axis shows the annual snow depth (in), and the right-axis shows the maximum annual volume required for storage for the design with the 12-inch orifice.

Figure 115 shows the maximum concentration of chloride per water year for the existing conditions and all the storage design scenarios along with the acute and chronic criteria.

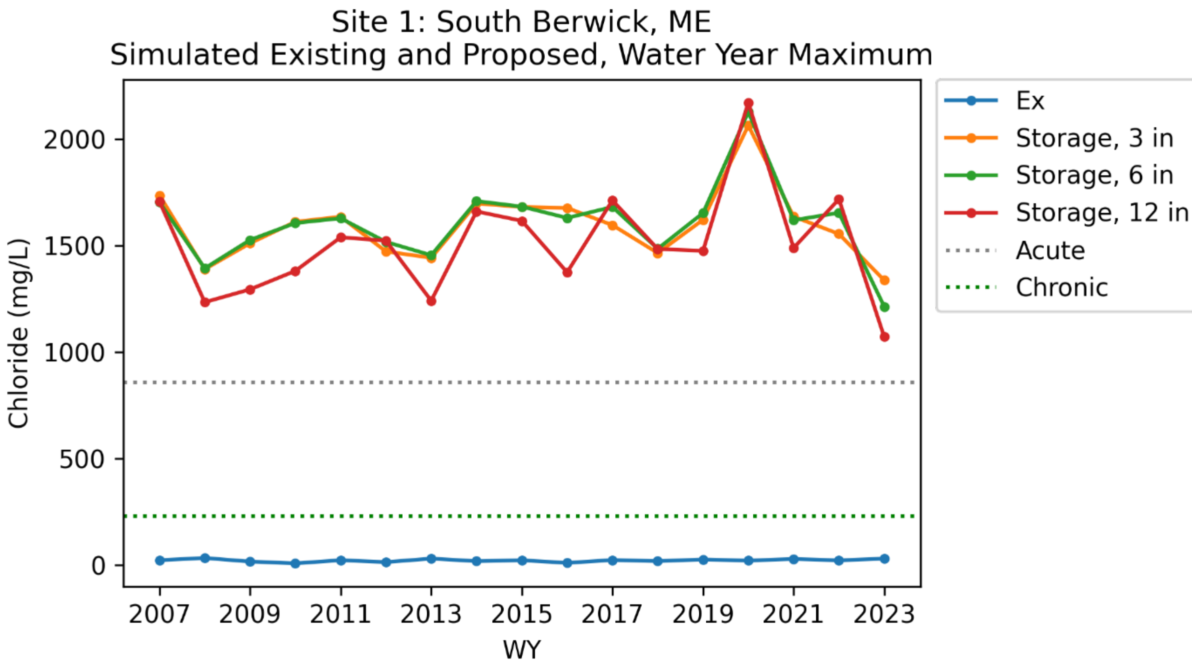

Figure 115: 1SB. Summary of the simulation results shown for the proposed storage design at the downstream outfall. The maximum chloride concentration per water year (WY) was calculated from the 4-day average time series.

Figure 115 summarizes the effectiveness of the storage design scenarios: the storage strategy increases the chloride concentrations such that both the acute and chronic criteria are exceeded every year.

Site 2: Kittery

Figure 116, Figure 117 ,Figure 118 Figure 112show the annual snow depth and maximum storage reached per water year for the storage scenarios with a 3-, 6-, and 12-inch orifices, respectively.

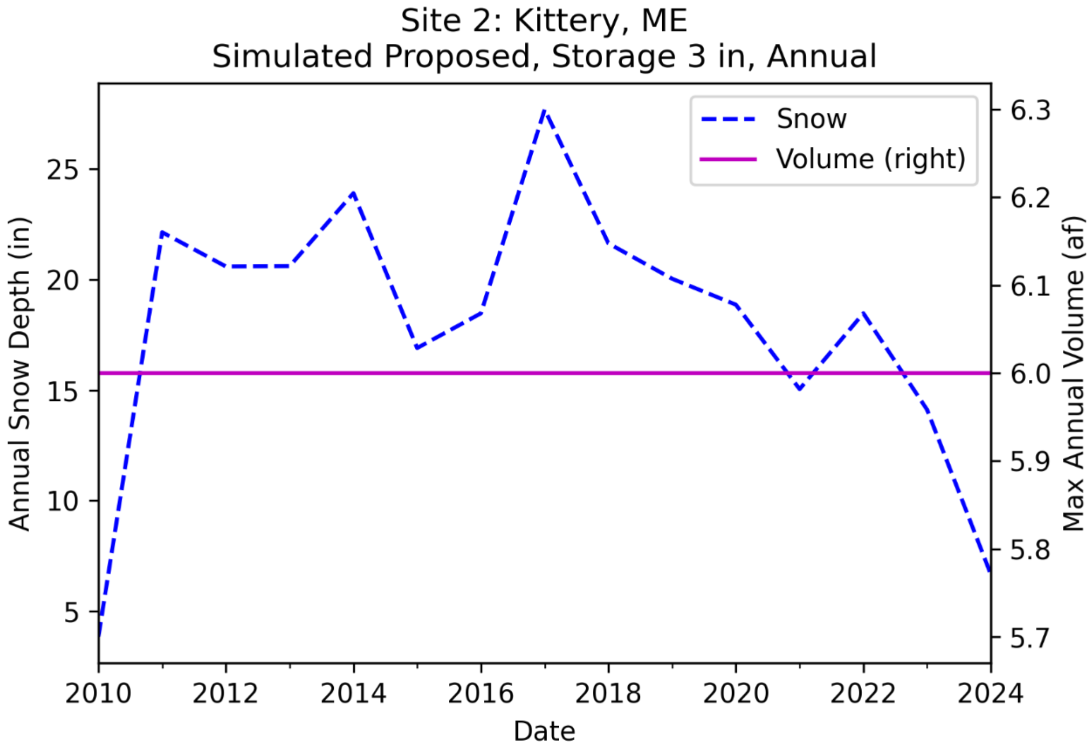

Figure 116: 2K. Summary of the simulation results shown for the 4-day average of the proposed storage design at the downstream outfall. The left axis shows the annual snow depth (in), and the right-axis shows the maximum annual volume required for storage for the design with the 3-inch orifice.

Note that the maximum volume is a straight line at 6 acre-feet (af). This is because the maximum allowable depth of the storage was set at 6 ft in the model setup, and the simulation met the maximum depth every water year. The max. allowable depth was estimated from the GIS elevations and from a site visit to keep a free-flowing inlet and outlet of the storage unit from the culverts to the swale.

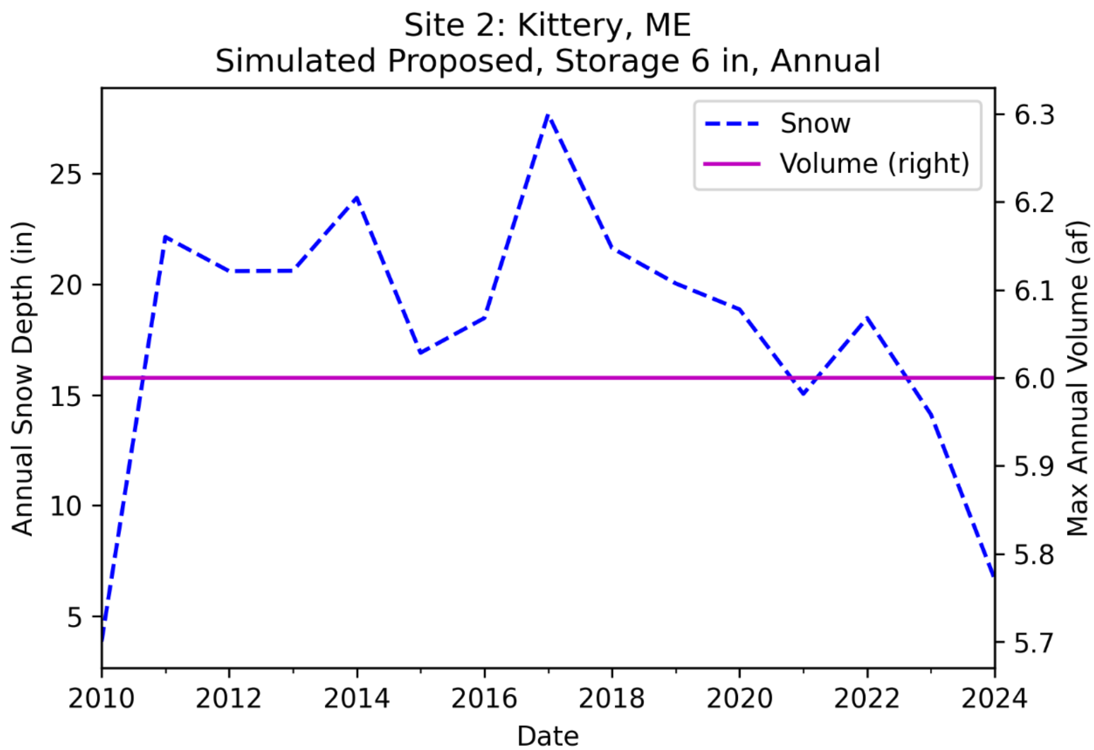

Figure 117: 2K. Summary of the simulation results shown for the 4-day average of the proposed storage design at the downstream outfall. The left axis shows the annual snow depth (in), and the right-axis shows the maximum annual volume required for storage for the design with the 6-inch orifice.

Note that the maximum volume is a straight line at 6 acre-feet (af). This is because the maximum allowable depth of the storage was set at 6 ft in the model setup, and the simulation met the maximum depth every water year. The max. allowable depth was estimated from the GIS elevations and from a site visit to keep a free-flowing inlet and outlet of the storage unit from the culverts to the swale.

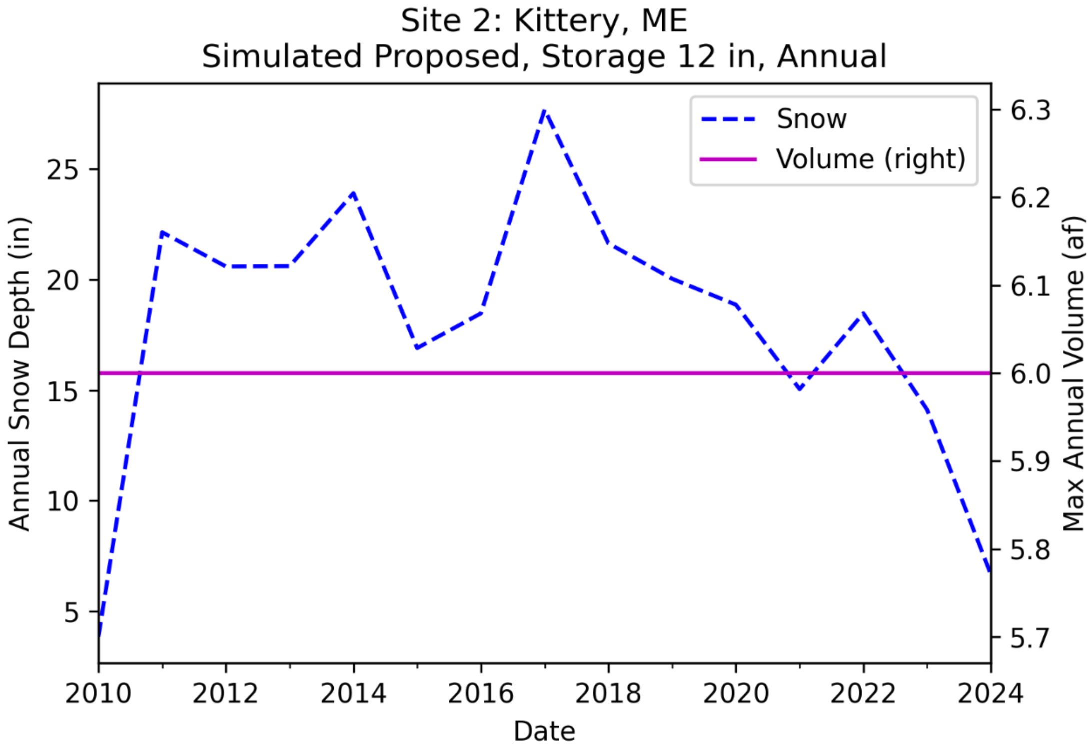

Figure 118: 2K. Summary of the simulation results shown for the 4-day average of the proposed storage design at the downstream outfall. The left axis shows the annual snow depth (in), and the right-axis shows the maximum annual volume required for storage for the design with the 12-inch orifice.

Note that the maximum volume is a straight line at 6 acre-feet (af). This is because the maximum allowable depth of the storage was set at 6 ft in the model setup, and the simulation met the maximum depth every water year. The max. allowable depth was estimated from the GIS elevations and from a site visit to keep a free-flowing inlet and outlet of the storage unit from the culverts to the swale.

Figure 119 shows the maximum concentration of chloride per water year for the existing conditions and all the storage design scenarios along with the acute and chronic criteria.

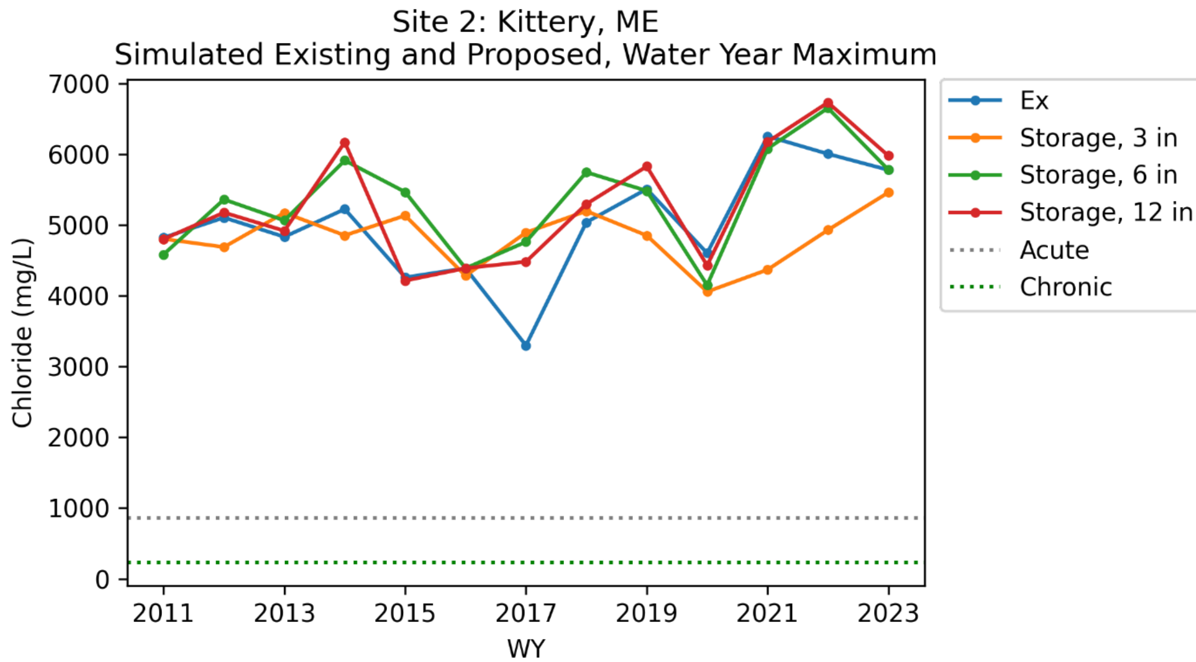

Figure 119: 2K. Summary of the simulation results shown for the proposed storage design at the downstream outfall. The maximum chloride concentration per water year (WY) was calculated from the 4-day average time series.

Figure 119 summarizes the effectiveness of the storage design scenarios: the storage strategy increases the chloride concentrations such that both the acute and chronic criteria are exceeded every year.

Site 3: Hampden South

Figure 120, Figure 121, and Figure 122 show the annual snow depth and maximum storage reached per water year for the storage scenarios with a 3-, 6-, and 12-inch orifices, respectively.

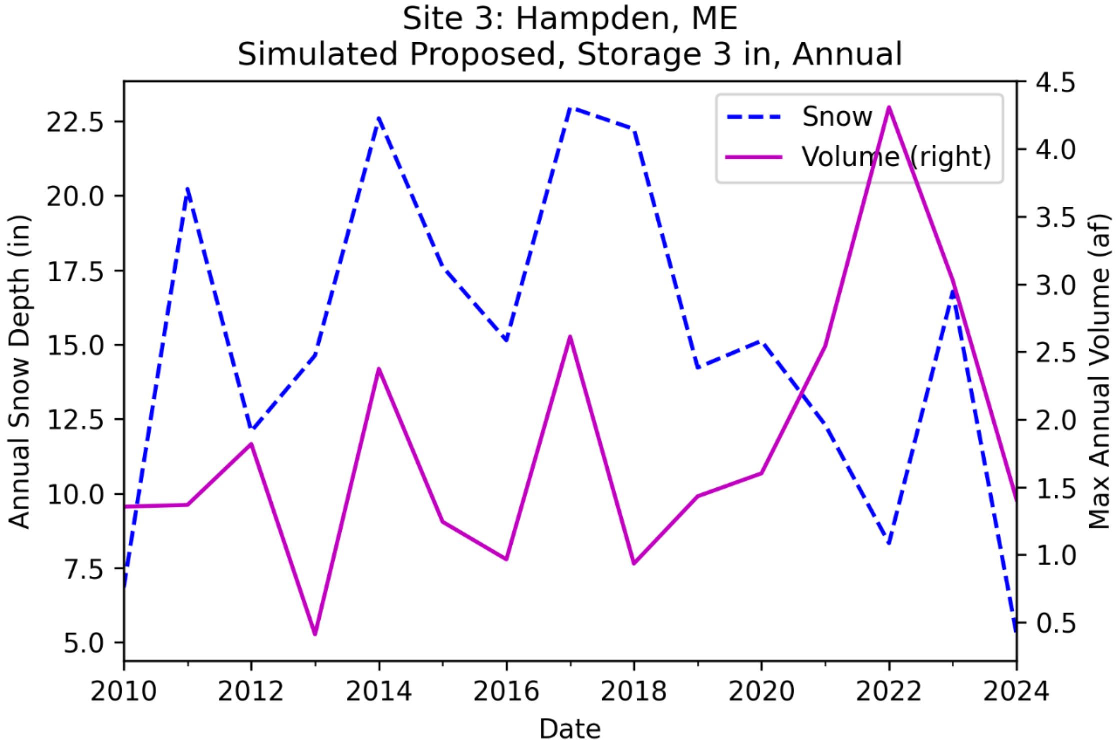

Figure 120: 3HS. Summary of the simulation results shown for the 4-day average of the proposed storage design at the downstream outfall. The left axis shows the annual snow depth (in), and the right-axis shows the maximum annual volume required for storage for the design with the 3-inch orifice.

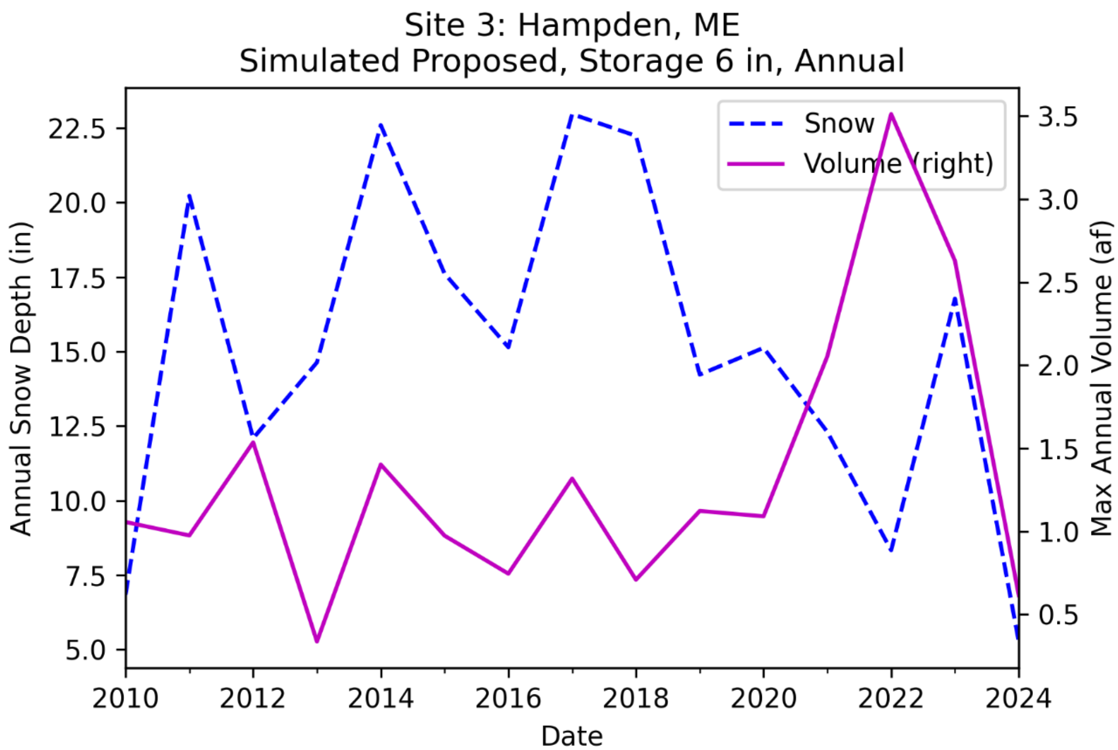

Figure 121: 3HS. Summary of the simulation results shown for the 4-day average of the proposed storage design at the downstream outfall. The left axis shows the annual snow depth (in), and the right-axis shows the maximum annual volume required for storage for the design with the 6-inch orifice.

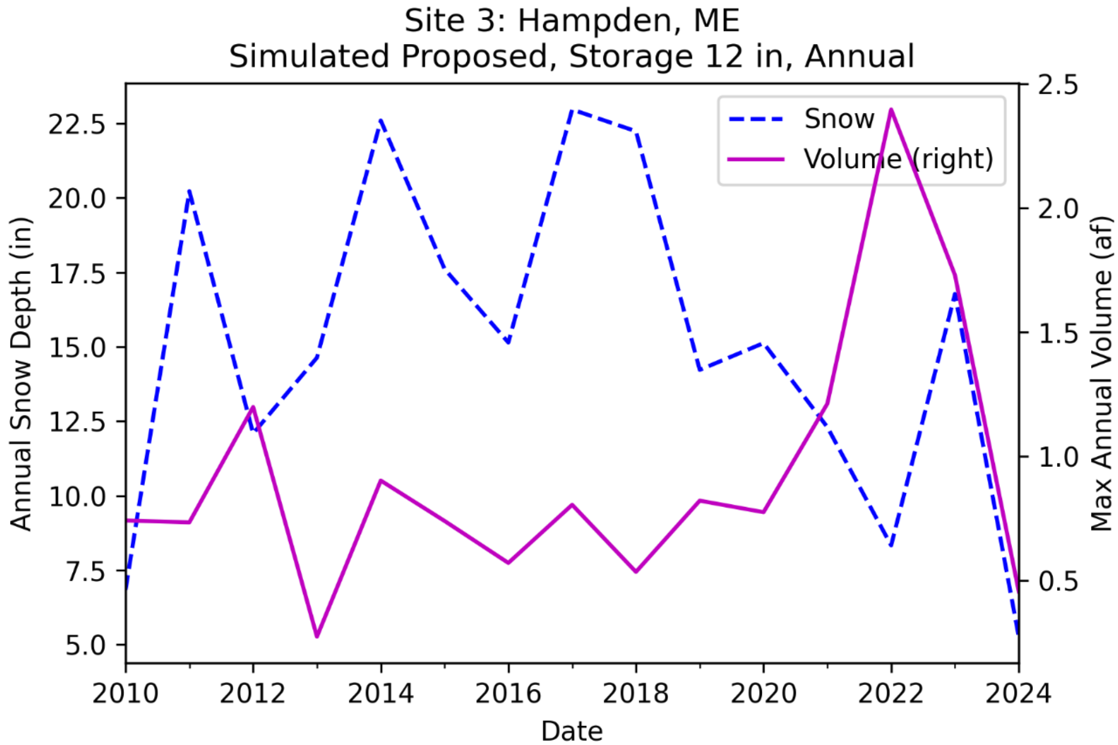

Figure 122: 3HS. Summary of the simulation results shown for the 4-day average of the proposed storage design at the downstream outfall. The left axis shows the annual snow depth (in), and the right-axis shows the maximum annual volume required for storage for the design with the 12-inch orifice.

Figure 123 shows the maximum concentration of chloride per water year for the existing conditions and all the storage design scenarios along with the acute and chronic criteria.

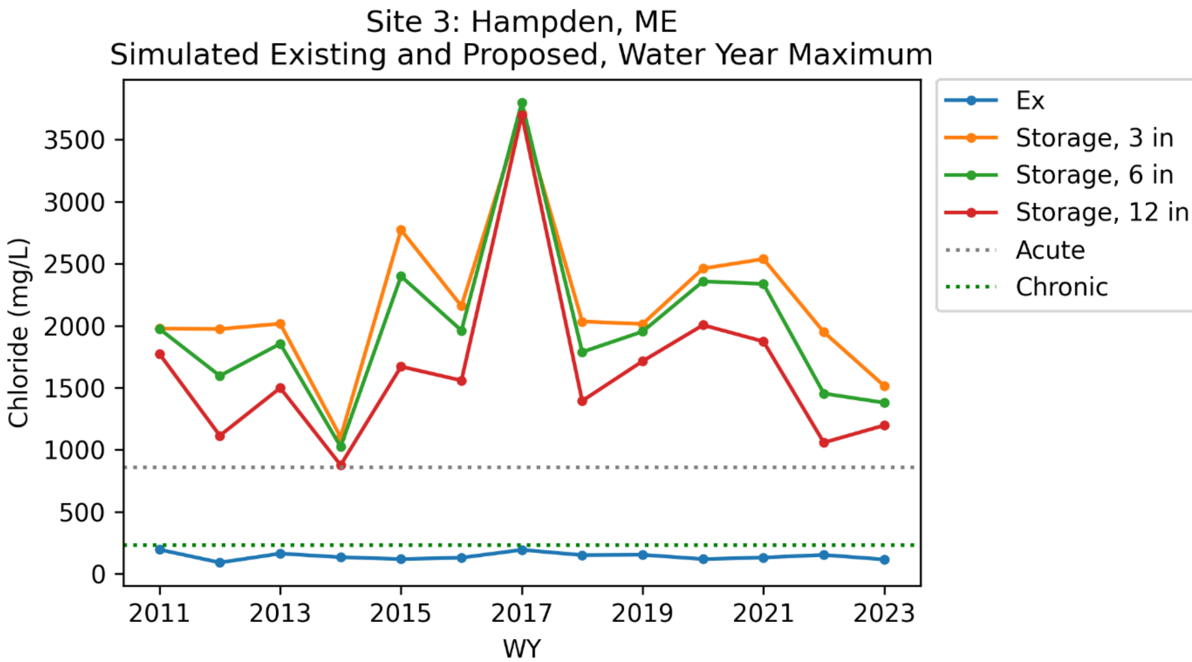

Figure 123: 3HS. Summary of the simulation results shown for the proposed storage design at the downstream outfall. The maximum chloride concentration per water year (WY) was calculated from the 4-day average time series.

Figure 123 summarizes the effectiveness of the storage design scenarios: the storage strategy increases the chloride concentrations such that both the acute and chronic criteria are exceeded every year.

Dilution Summary

Figure 124, Figure 125, and Figure 126 show Figure 115the maximum concentration of chloride per water year for the existing conditions and all the well pump dilution design scenarios along with the acute and chronic criteria.

Site 1: South Berwick

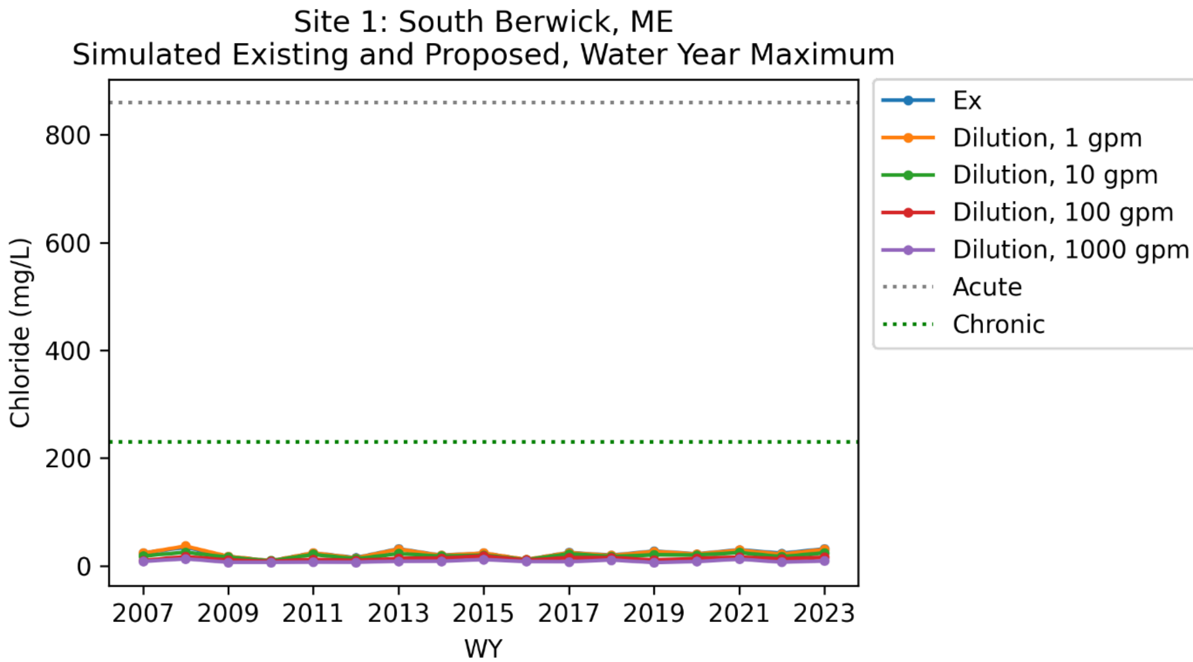

Figure 124: 1SB. Summary of the simulation results shown for the proposed dilution design at downstream outfall. The maximum chloride concentration per water year (WY) was calculated from the 4-day average time series.

Figure 124 summarizes the effectiveness of the dilution design scenarios: the dilution strategy decreases the chloride concentrations such that neither the acute nor chronic criteria are exceeded any year for all pumping rates from 1-1000 gpm.

Site 2: Kittery

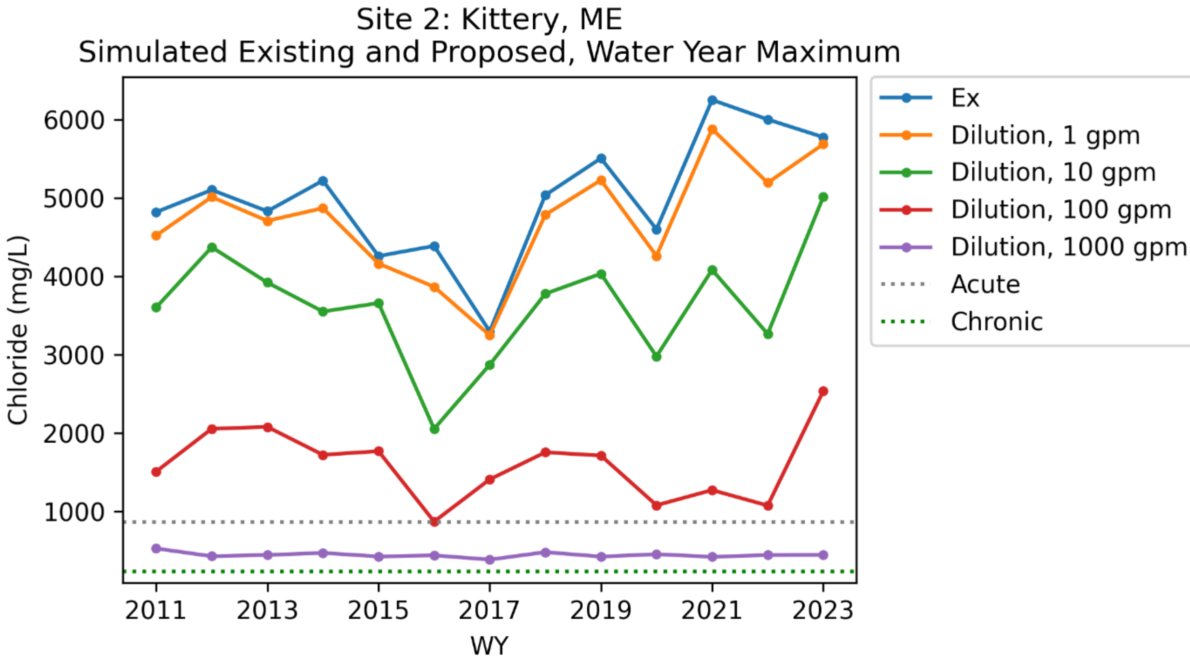

Figure 125: 2K. Summary of the simulation results shown for the proposed dilution design at downstream outfall. The maximum chloride concentration per water year (WY) was calculated from the 4-day average time series.

Figure 125 summarizes the effectiveness of the dilution design scenarios: the dilution strategy for pumping rates less than 1000 gpm increases the chloride concentrations such that both the acute and chronic criteria are exceeded every year.

The dilution strategy for the pumping rates of 1000 gpm shows the chloride concentrations between the acute and chronic criteria every year. Higher pumping rates may further decrease the concentrations to below the chronic criteria.

Site 3: Hampden South

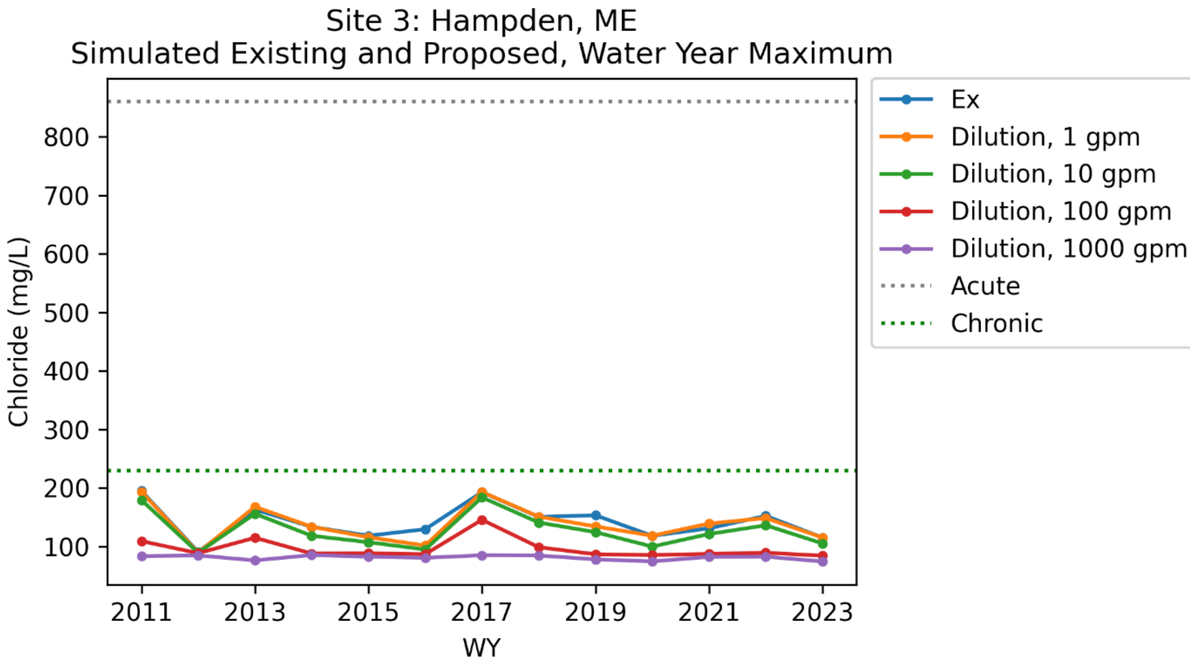

Figure 126: 3HS. Summary of the simulation results shown for the proposed dilution design at downstream outfall. The maximum chloride concentration per water year (WY) was calculated from the 4-day average time series.

Figure 126 summarizes the effectiveness of the dilution design scenarios: the dilution strategy decreases the chloride concentrations such that neither the acute nor chronic criteria are exceeded any year for all pumping rates from 1-1000 gpm.

Conclusions

Proposed Storage

Figure 115, Figure 119, and Figure 123 summarize the effectiveness of the storage design scenarios for all three sites: the storage strategy increases the 4-day average, downstream chloride concentrations such that both the acute and chronic criteria are exceeded every year. These sites have either intermittent flows and/or low winter flows. The storage scenarios which slowly release the salty runoff via the orifice control into no to low flows in the streams yield higher concentrations of chloride in the stream due to the increased release of mass of chloride and low flow in the streams.

Proposed Dilution

Figure 124 and Figure 126 summarize the effectiveness of the dilution design scenarios for Site 1: South Berwick and Site 3: Hampden, respectively: the dilution strategy decreases the 4-day average, downstream chloride concentrations such that neither the acute nor chronic criteria are exceeded any year for all pumping rates from 1-1000 gpm. In contrast to the conclusion of the storage strategies, the dilution strategy increases the flow in the stream during low flow runoff events when the salt runs off, thus lowering the concentration.

Figure 125 summarizes the effectiveness of the dilution design scenarios at Site 2: Kittery: the dilution strategy for pumping rates less than 1000 gpm increases the 4-day average, downstream chloride concentrations such that both the acute and chronic criteria are exceeded every year. The dilution strategy for the pumping rates of 1000 gpm shows the 4-day average, downstream chloride concentrations between the acute and chronic criteria every year. Higher pumping rates may further decrease the concentrations to below the chronic criteria.

Appendices

Appendix A: StreamStats Reports

In the interest of keeping this document file size small and more manageable, the reports for this appendix are attached as separate PDF files with the name “Appendix A_StreamStats Report_[site].pdf”

Appendix B: GIS DOT Infrastructure

The GIS data for the infrastructure was provided through the Maine Office of GIS with access to the DOT infrastructure. The provided data included the outfall locations, culverts and pipes, and catch basins. These points were used to further refine the watershed into subcatchments and dictate how catchments were delineated for the SWMM model. The following figures show the maps provided of the infrastructure that was imported into the GIS model.

Site 1: South Berwick

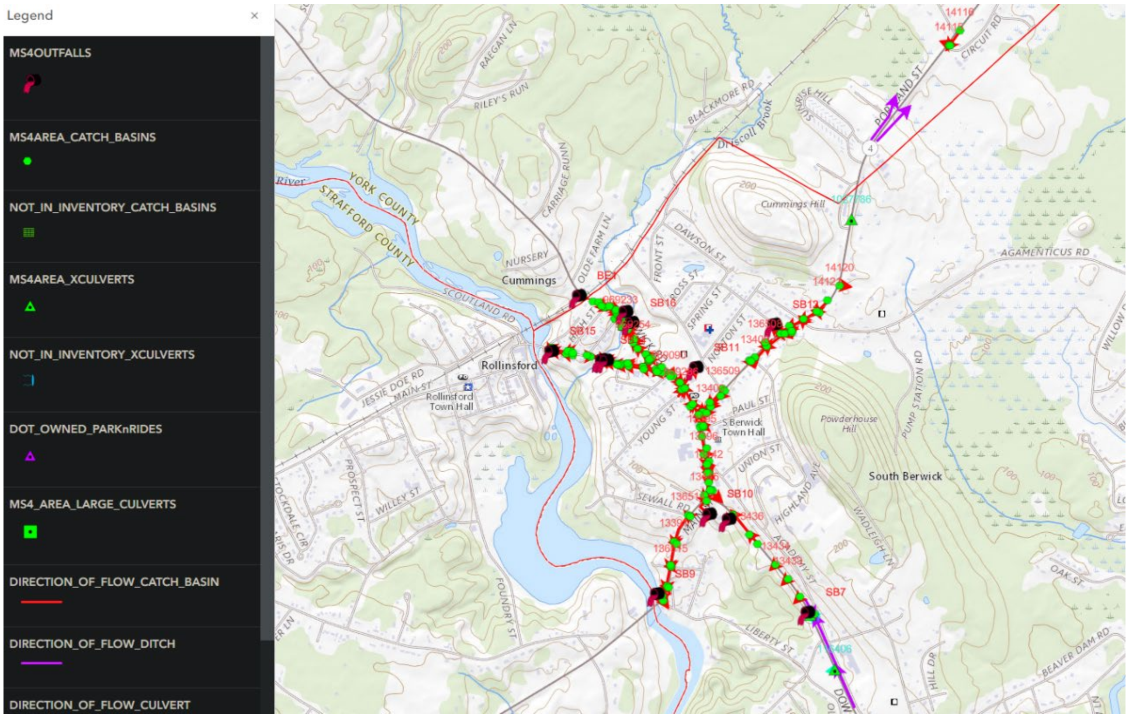

Figure 127: 1SB. This screenshot shows the locations of DOT outfalls, catch basins, and culverts.

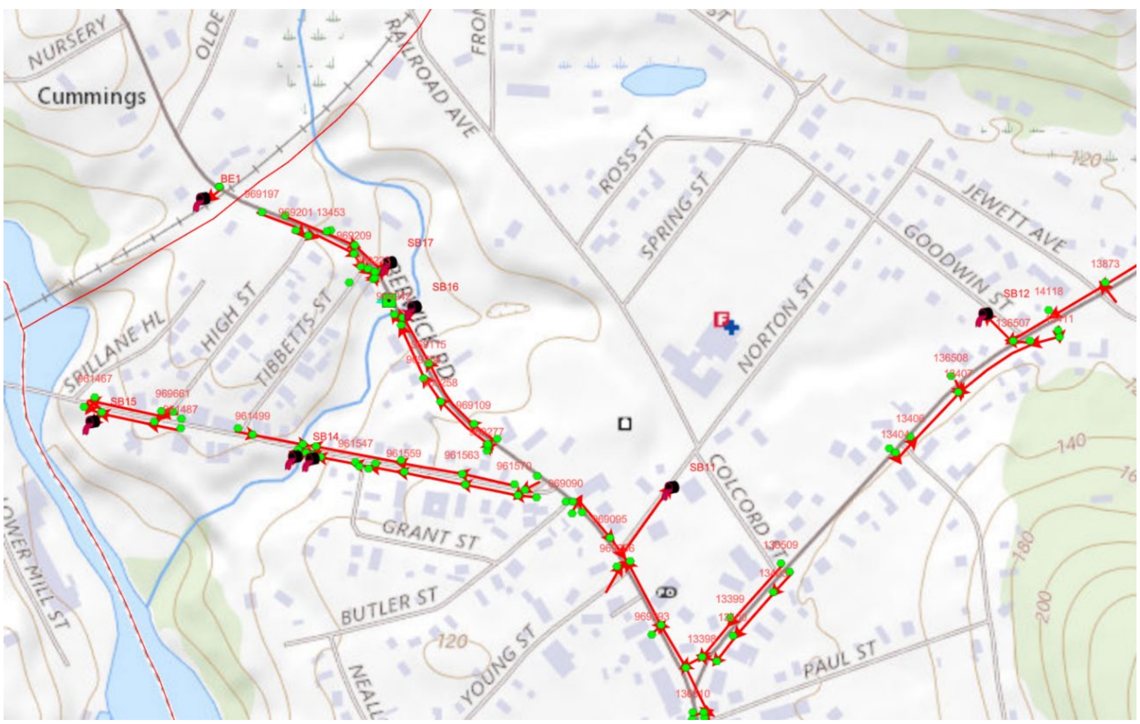

Figure 128: 1SB. This screenshot shows the locations of DOT outfalls, catch basins, and culverts near the POA.

Figure 129: 1SB. This screenshot shows the locations of DOT catch basins and the salted areas (blue).

Site 2: Kittery

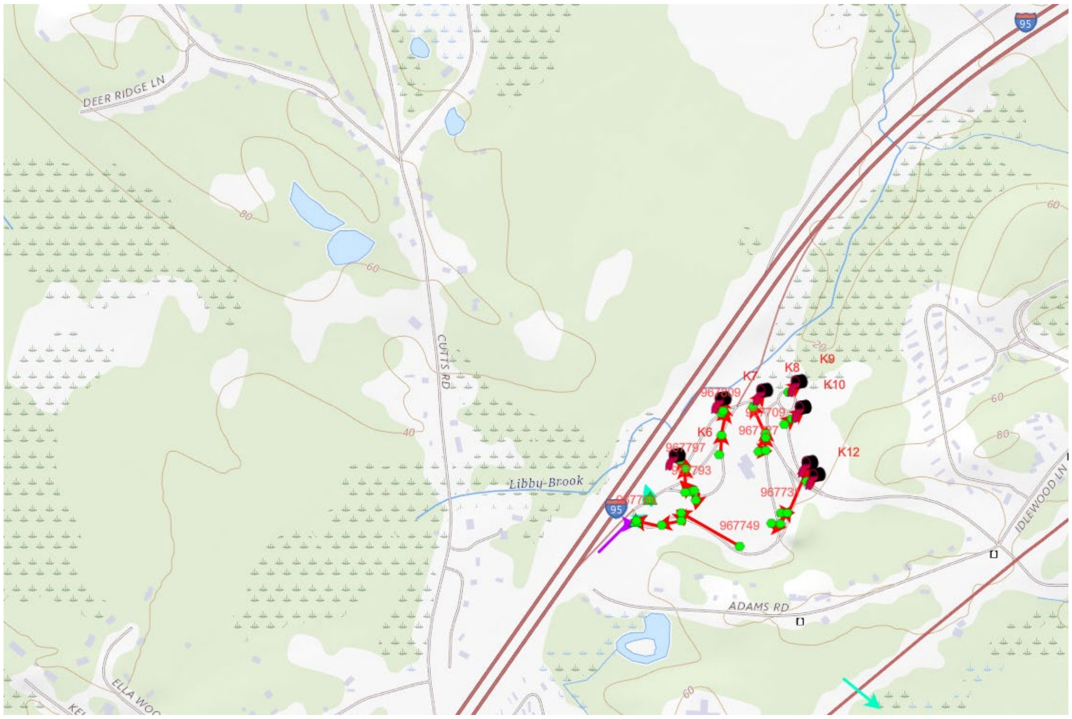

Figure 130: 2K. This screenshot shows the locations of DOT outfalls, catch basins, and culverts.

Figure 131: 2K. This screenshot shows the locations of DOT outfalls, catch basins, and culverts near the POA.

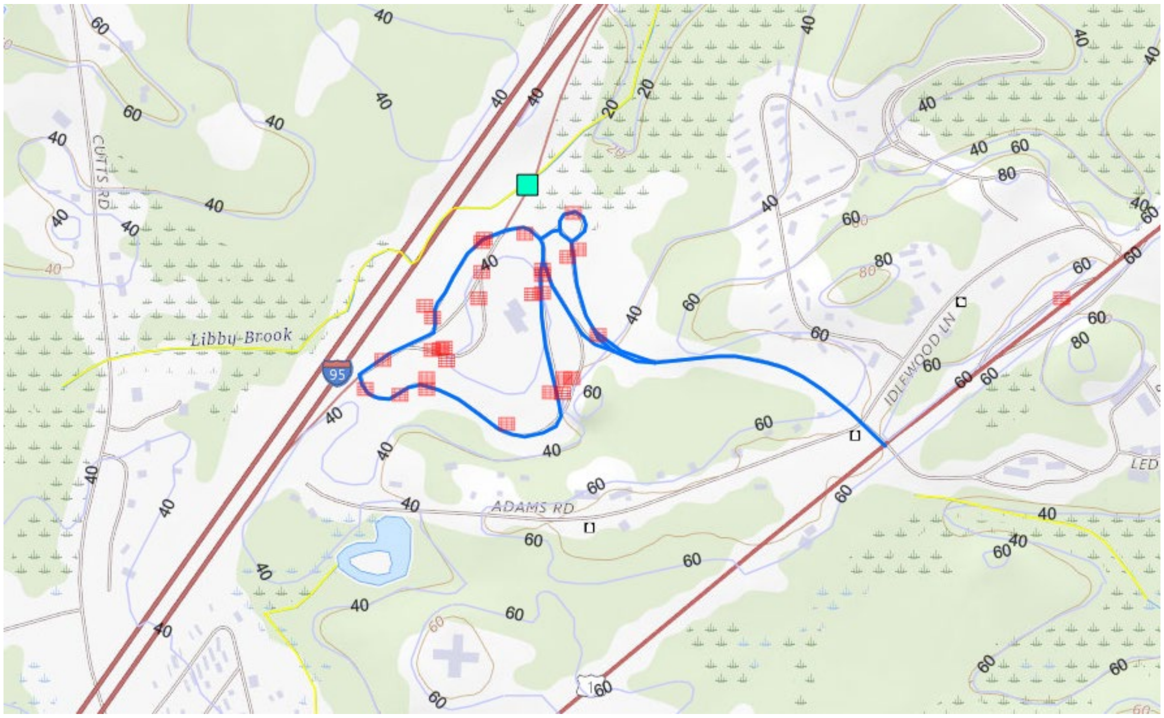

Figure 132: 2K. This screenshot shows the locations of DOT catch basins and the salted areas (blue).

Site 3: Hampden South

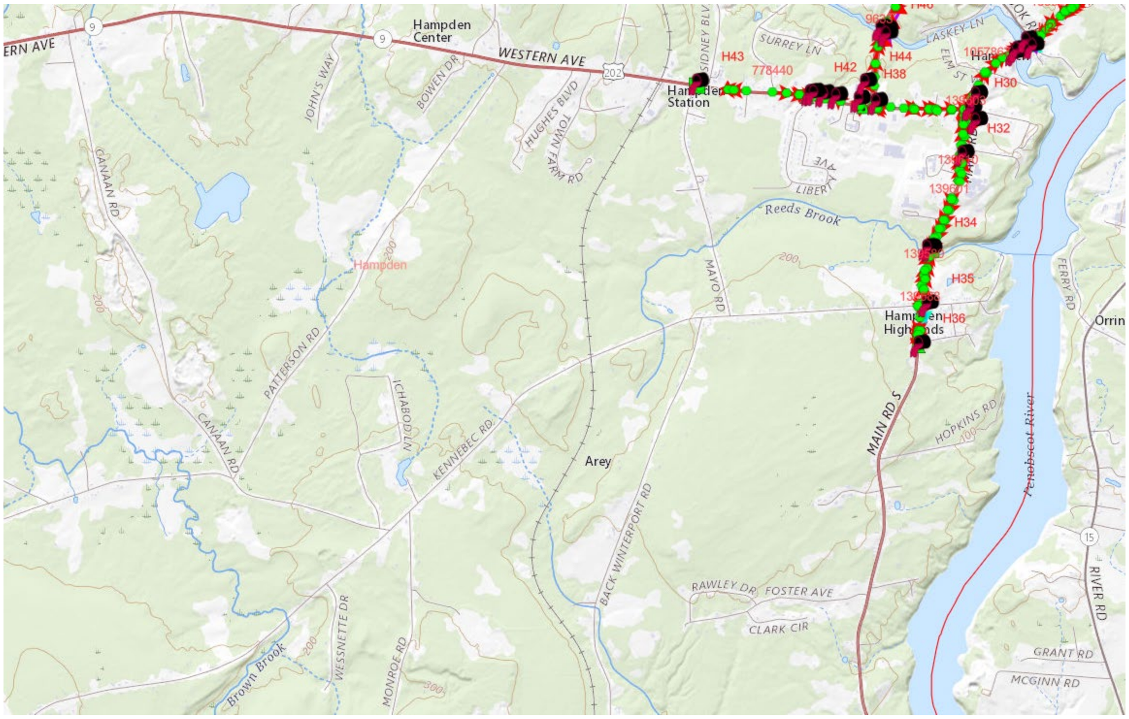

Figure 133: 3HS. This screenshot shows the locations of DOT outfalls, catch basins, and culverts.

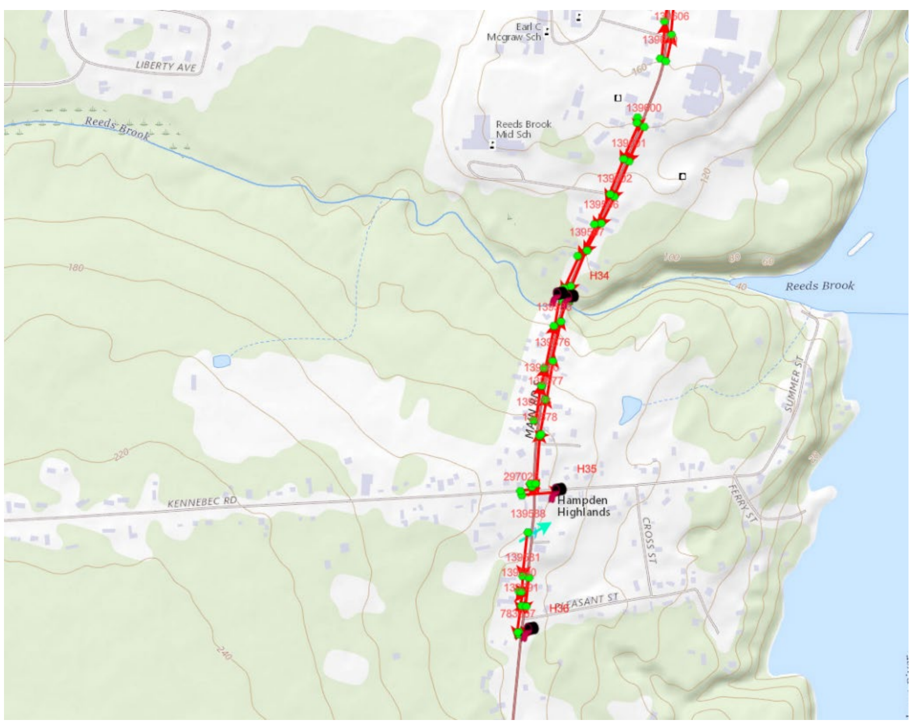

Figure 134: 3HS. This screenshot shows the locations of DOT outfalls, catch basins, and culverts near the POA.

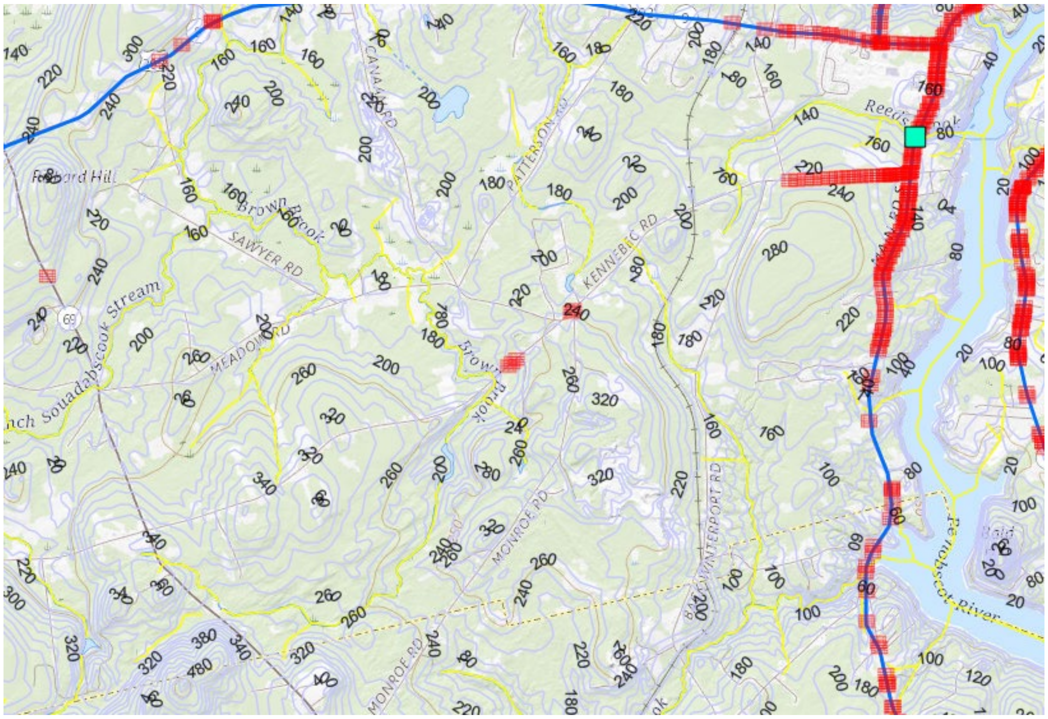

Figure 135: 3HS. This screenshot shows the locations of DOT catch basins and salted areas (blue).

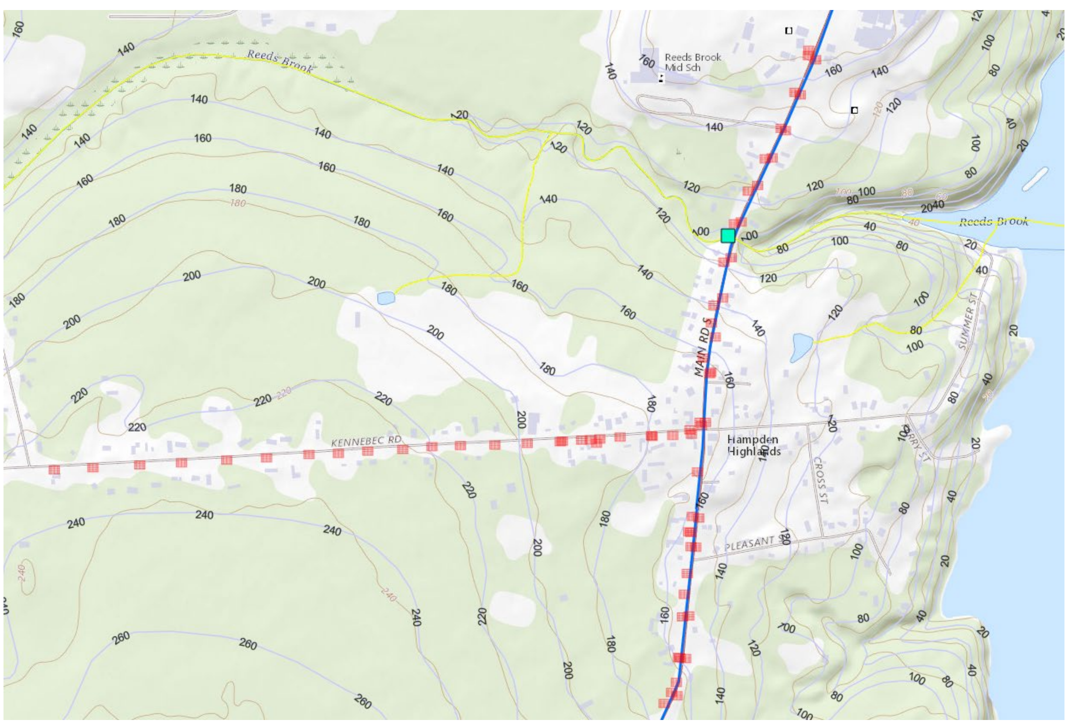

Figure 136: 3HS. This screenshot shows the locations of DOT catch basins and salted areas (blue).

Appendix C: GIS Land Use

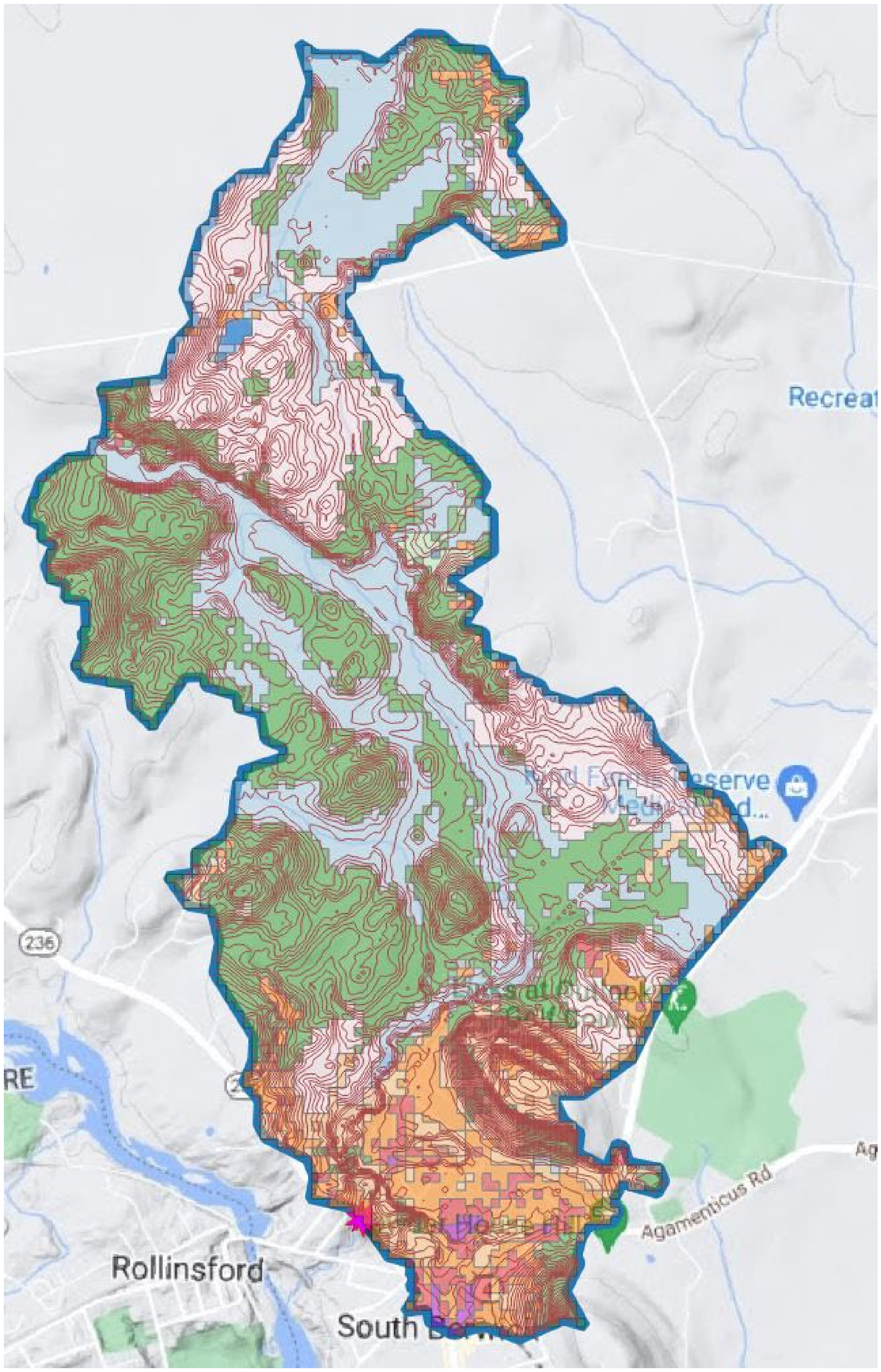

Figure 137: 1SB. Land Use from CCAP 2016 overlayed on 1-meter contour lines. Generally, blue indicates wetlands, green is forested, white is open space, orange is developed/impervious, and red is highly developed.

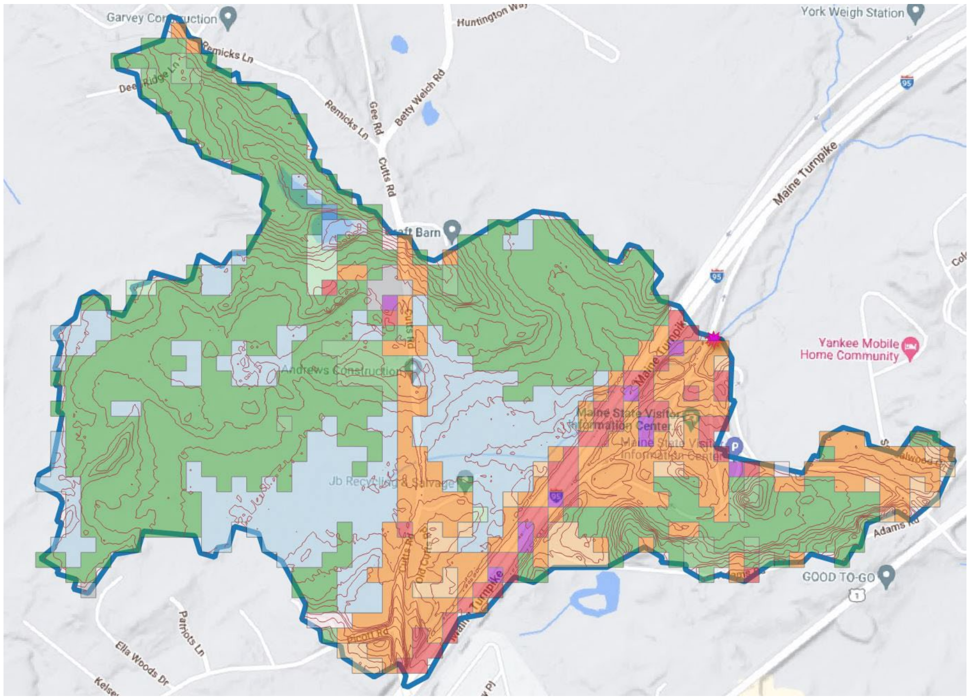

Figure 138: 2K. Land Use from CCAP 2016 overlayed on 1-meter contour lines. Generally, blue indicates wetlands, green is forested, white is open space, orange is developed/impervious, and red is highly developed.

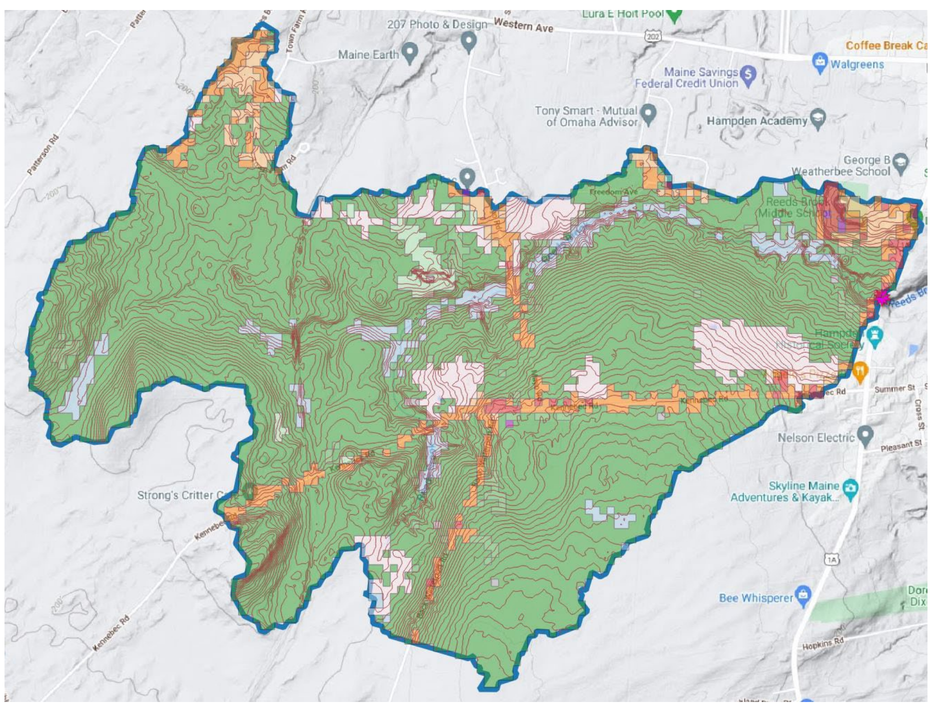

Figure 139: 3HS. Land Use from CCAP 2016 overlayed on 1-meter contour lines. Generally, blue indicates wetlands, green is forested, white is open space, orange is developed/impervious, and red is highly developed.

Appendix D: Web Soil Survey Reports

In the interest of keeping this document file size small and more manageable, the reports for this appendix are attached as separate PDF files with the name "Appendix B_Web Soil Survey_[site].pdf"

Appendix E: GIS Transects

The following transects through the subcatchments were found for the average cross-section of each subcatchment using the QGIS plugin Profile tool and Terrain Profile. All units are in meters and shown looking downstream such that x = 0 is on the left bank. The y-axis shows the elevation (meters). The transect name (e.g. "Transect 1") generally corresponds to the subcatchment in which the cross-section is found. SWMM uses the transects to route the runoff as a "conduit" from one an inlet to an outlet. For example, Transect 1 routes the runoff from Subcatchment 1 (S1) through S2 to the outlet of S2 where the routed S1 hydrograph is added to the runoff hydrograph of S2. For more detail, see the SWMM user's manual.

Site 1: South Berwick

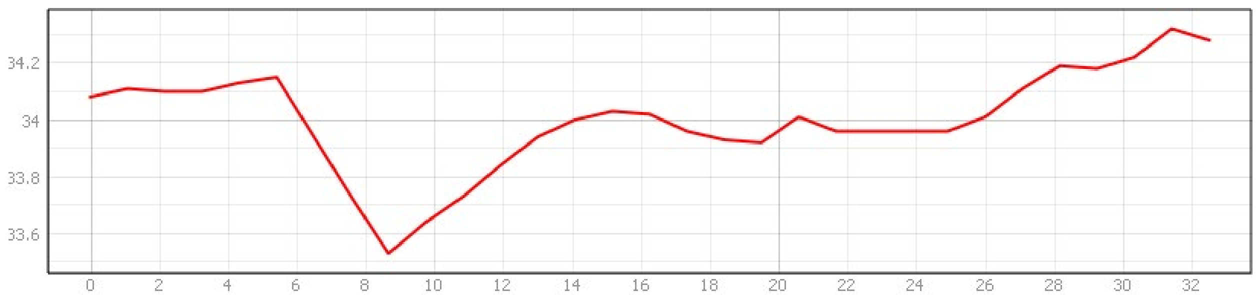

Figure 140: 1SB. Transect 1.

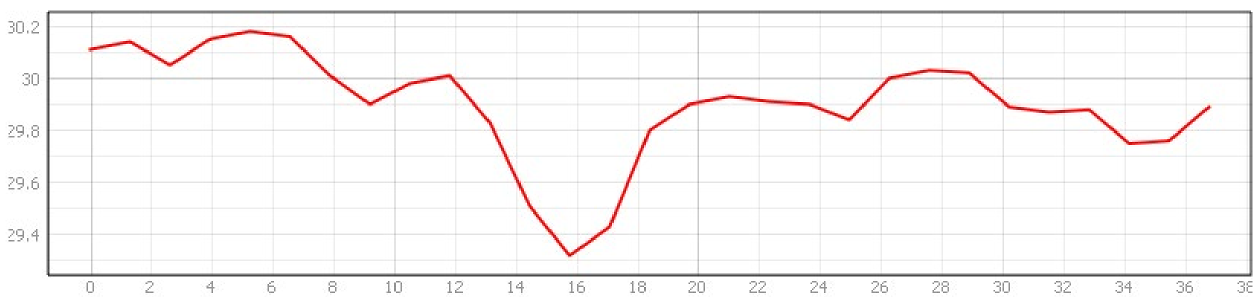

Figure 141: 1SB. Transect 3.

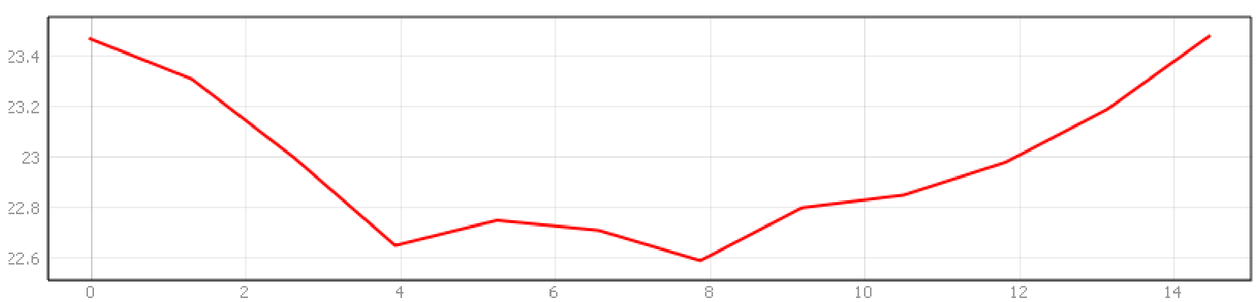

Figure 142: 1SB. Transect 5.

Site 2: Kittery

Figure 143: 2K. Transect 1.

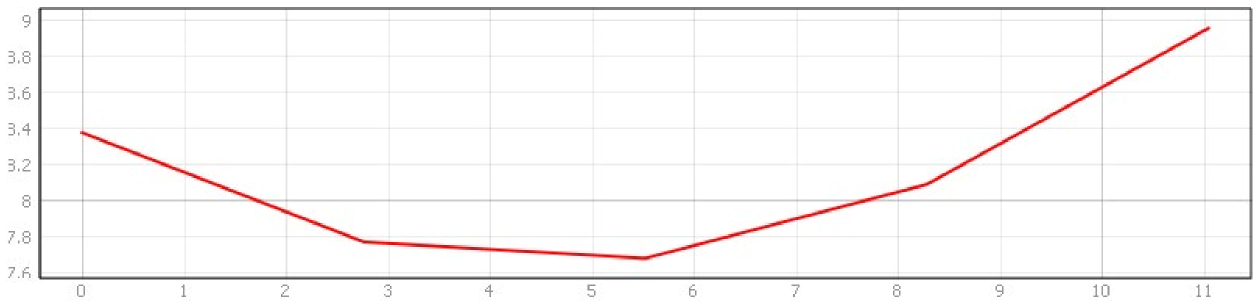

Figure 144: 2K. Transect 3.

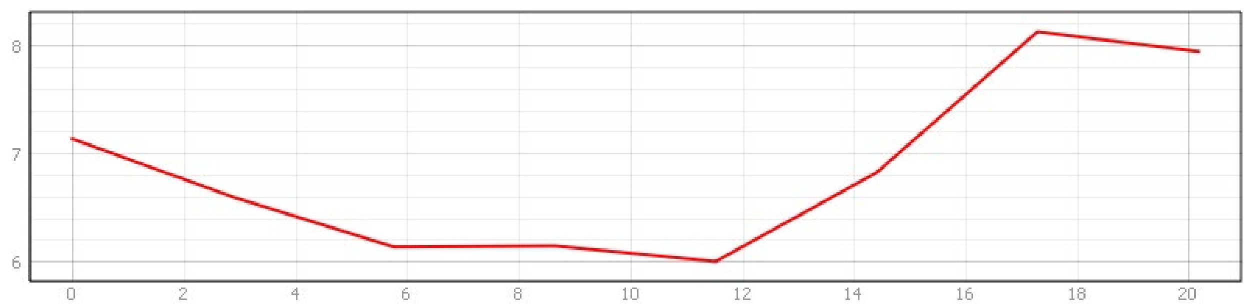

Figure 145: 2K. Transect 4.

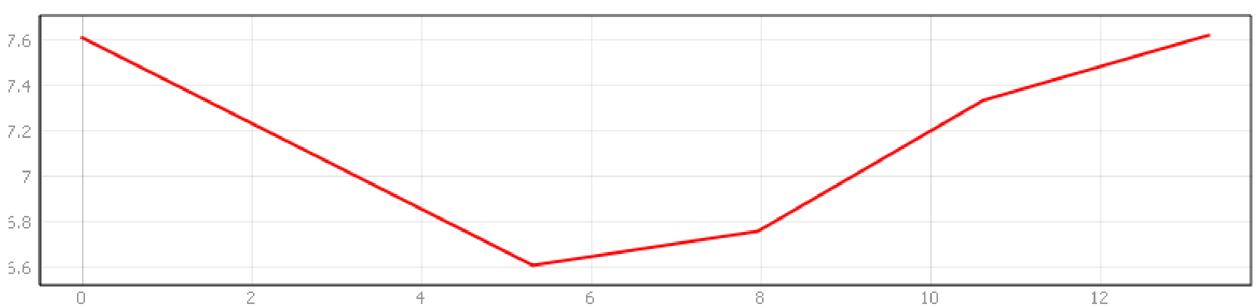

Figure 146: 2K. Transect 5.

Site 3: Hampden South

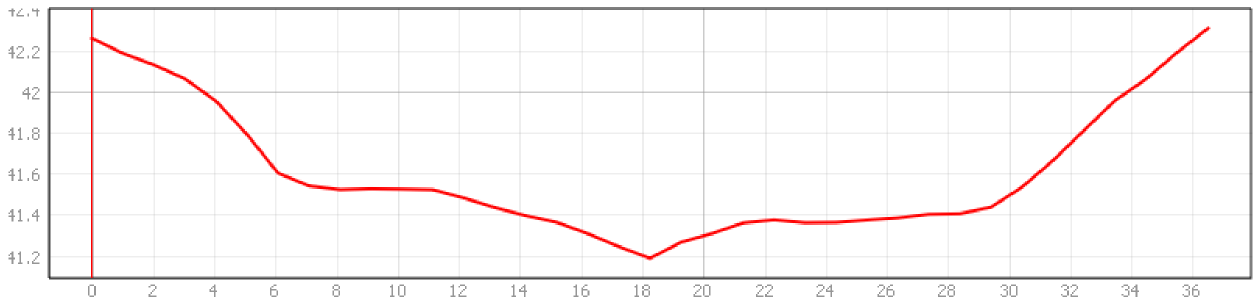

Figure 147: 3HS. Transect 3.

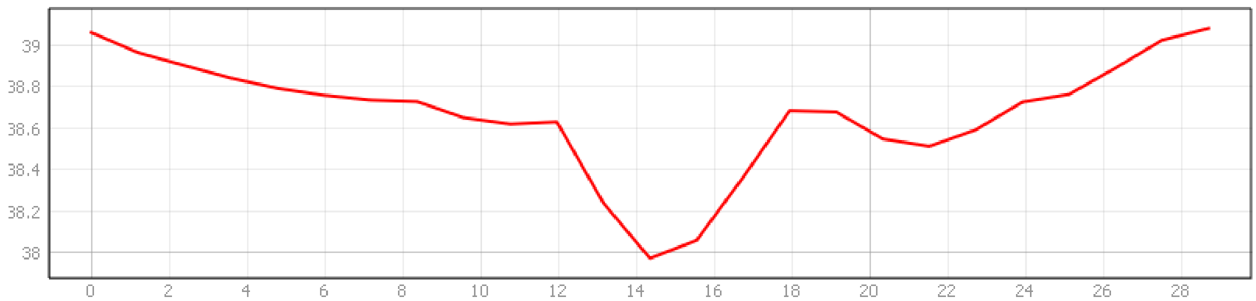

Figure 148: 3HS. Transect 4.

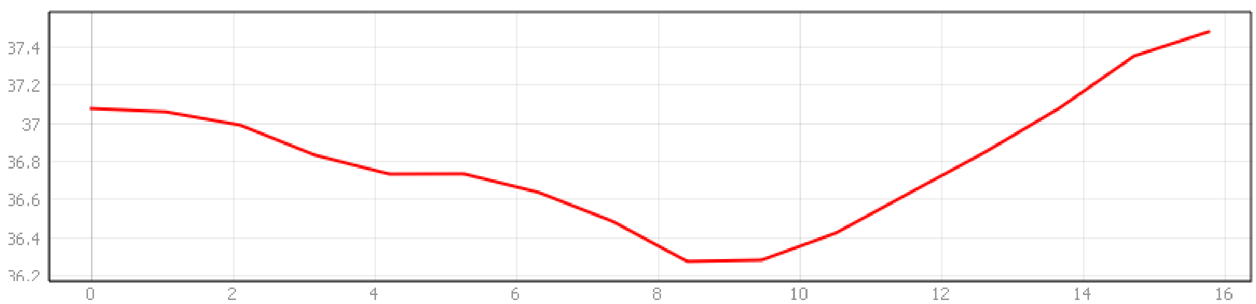

Figure 149: 3HS. Transect 5.

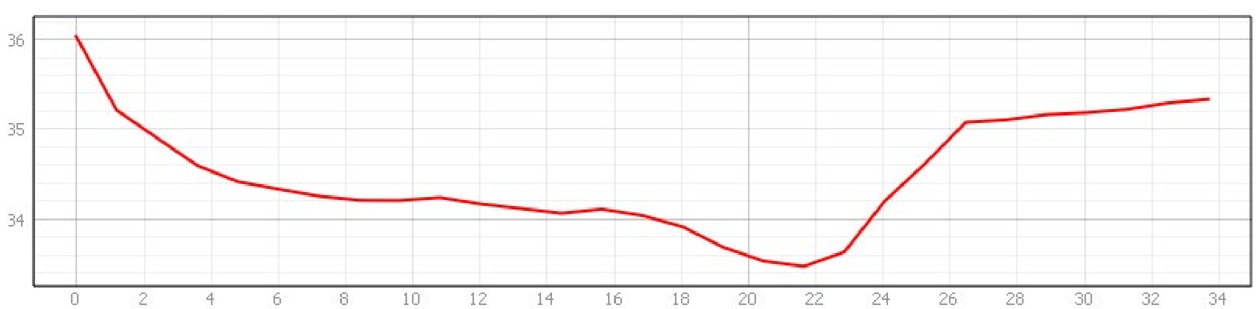

Figure 150: 3HS. Transect 6.

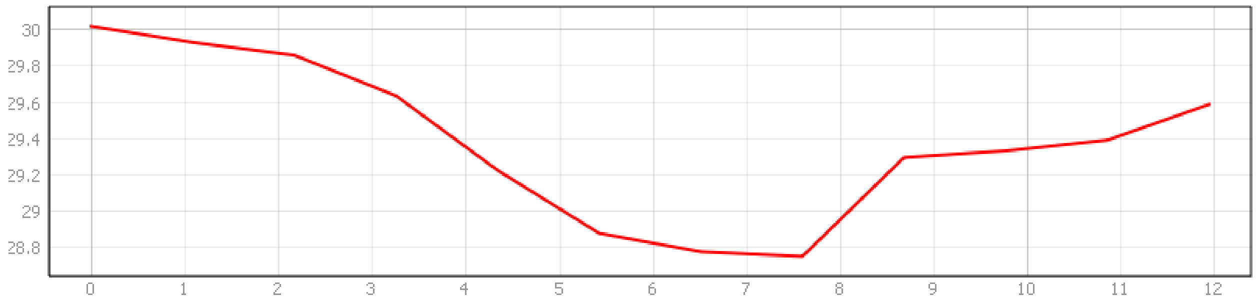

Figure 151: 3HS. Transect 7.

Appendix F: SWMM Input Files

The following files are input files (.inp) for the existing conditions.

Site 1: South Berwick

```
[TITLE]
;;Project Title/Notes
ME DOT Chloride
Site 1, Driscoll Brook, South Berwick, ME
Existing Conditions
5/24/2024
Daniel Macadam
UNH Stormwater Center

[OPTIONS]
;;Option             Value
FLOW_UNITS           CFS
INFILTRATION         MODIFIED_GREEN_AMPT
FLOW_ROUTING         KINWAVE
LINK_OFFSETS         ELEVATION
MIN_SLOPE            0
ALLOW_PONDING        NO
SKIP_STEADY_STATE    NO

START_DATE           01/01/2006
START_TIME           00:00:00
REPORT_START_DATE    01/01/2006
REPORT_START_TIME    00:00:00
END_DATE             06/05/2024
END_TIME             00:00:00
SWEEP_START          01/01
SWEEP_END            12/31
DRY_DAYS             0
REPORT_STEP          00:05:00
WET_STEP             00:01:00
DRY_STEP             00:01:00
ROUTING_STEP         0:00:30
RULE_STEP            00:00:00

INERTIAL_DAMPING     PARTIAL
NORMAL_FLOW_LIMITED  BOTH
FORCE_MAIN_EQUATION  H-W
VARIABLE_STEP        0.75
LENGTHENING_STEP     0
MIN_SURFAREA         12.566
MAX_TRIALS           8
```

```
HEAD_TOLERANCE         0.005
SYS_FLOW_TOL           5
LAT_FLOW_TOL           5
MINIMUM_STEP           1
THREADS                11

[EVAPORATION]
;;Data Source          Parameters
;;--------------   ----------------
TEMPERATURE
DRY_ONLY               YES

[TEMPERATURE]
;;Data Element         Values
FILE             "C:\R_to_SWMM_climate_Rochester.dat"    *      F
WINDSPEED FILE
SNOWMELT         34     0.57    0.21    88.74   43.23804     0
ADC IMPERVIOUS          0.1     0.35    0.53    0.66    0.75    0.82    0.87    0.92    0.95
        0.98
ADC PERVIOUS     0.1    0.35    0.53    0.66    0.75    0.82    0.87    0.92    0.95    0.98

[RAINGAGES]
;;Name           Format          Interval        SCF             Source
;;--------------   ---------------   ------   ----------
Gage             VOLUME          1:00    1       FILE
        "C:\R_to_SWMM_rainfall_Rochester.dat"    Rochester    IN

[SUBCATCHMENTS]
;;Name           Rain Gage       Outlet          Area    %Imperv         Width           %Slope
        CurbLen          SnowPack
;;--------------   ----------------   ----------------   -------- -------- -------- -------- -------- ----------------
S1               Gage            J1              323.812         3.094           1800.368        6.694
        0        Res
S2               Gage            J2              473.745         0.91    2628.481        8.243
        0        Res
S3               Gage            J4              236.788         5.128           1775.183        9.174
        0        Res
S4               Gage            J2              135.757         5.552           1590.871        9.197
        0        Res
S5               Gage            J4              57.43           17.346          1101.888        11.934
        0        Res
S6               Gage            J5              115.701         30.885          1470.015        9.299
        0        Res
```

S7 Gage J5 0.552 93.834 40.729 6.216
0 DOT
S8 Gage J5 0.739 89.174 43.801 1.288
0 DOT

[SUBAREAS]
;;Subcatchment N-Imperv N-Perv S-Imperv S-Perv PctZero
RouteTo PctRouted
;;-------------- ---------- ---------- ---------- ---------- ---------- ---------
- ----------
S1 0.01 0.1 0.05 0.05 25
OUTLET
S2 0.01 0.1 0.05 0.05 25
OUTLET
S3 0.01 0.1 0.05 0.05 25
OUTLET
S4 0.01 0.1 0.05 0.05 25
OUTLET
S5 0.01 0.1 0.05 0.05 25
OUTLET
S6 0.01 0.1 0.05 0.05 25
OUTLET
S7 0.01 0.1 0.05 0.05 25
OUTLET
S8 0.01 0.1 0.05 0.05 25
OUTLET

[INFILTRATION]
;;Subcatchment Param1 Param2 Param3 Param4 Param5
;;-------------- ---------- ---------- ---------- ---------- ----------
S1 2.4 1.2 0.25
S2 3.86 0.61 0.25
S3 4 0.56 0.25
S4 3.5 0.75 0.25
S5 2.38 1.31 0.25
S6 2.37 1.37 0.25
S7 5.93 0.32 0.25
S8 2.4 1.18 0.25

[AQUIFERS]
;;Name Por WP FC Ksat Kslope Tslope ETu ETs Seep Ebot Egw
Umc ETupat

```
;;--------------	------	------	------	------	------	------	------	------	------	------	------
	------	------
Aq1		0.3	0.15	0.25	0.85	10	15	0.35	14	0.002	72.01	73.1
	0.3

[GROUNDWATER]
;;Subcatchment	Aquifer	Node		Esurf	A1	B1	A2	B2	A3
	Dsw	Egwt	Ebot	Wgr	Umc
;;--------------	----------------	----------------	------	------	------	------	------	------	------
	------	------	------	------
S1		Aq1		J1		122.48	5	0.5	5	0.5	0.2778	0
	0	117.06	119.35	0.3
S2		Aq1		J2		108.8	5	0.5	5	0.5	0.2778	0
	0	103.48	105.41	0.3
S3		Aq1		J4		84.45	5	0.5	5	0.5	0.2778	0
	0	79.3	80.87	0.3
S4		Aq1		J2		108.35	5	0.5	5	0.5	0.2778	0
	0	103.48	105.35	0.3
S5		Aq1		J4		84.51	5	0.5	5	0.5	0.2778	0
	0	79.3	78.95	0.3
S6		Aq1		J5		77.51	5	0.5	5	0.5	0.2778	0
	0	72.01	73.1	0.3
S7		Aq1		J5		78.58	5	0.5	5	0.5	0.2778	0
	0	72.01	76.57	0.3
S8		Aq1		J5		78.58	5	0.5	5	0.5	0.2778	0
	0	72.01	73.34	0.3

[SNOWPACKS]
;;Name		Surface		Parameters
;;--------------	----------	----------
Res		PLOWABLE	0.001		0.005		32		0.1		0
	0	0.25
Res		IMPERVIOUS		0.001		0.005		32		0.1
	0	0	1
Res		PERVIOUS	0.001		0.005		32		0.1		0
	0	6
Res		REMOVAL	1	0	0	0.2		0.1813		0
DOT		PLOWABLE	0.001		0.005		32		0.1		0
	0	0.9
DOT		IMPERVIOUS		0.001		0.005		32		0.1
	0	0	1
DOT		PERVIOUS	0.001		0.005		32		0.1		0
	0	6
```

```
DOT              REMOVAL     1        0        0        0.2              0.1813          0

[JUNCTIONS]
;;Name           Elevation        MaxDepth         InitDepth        SurDepth         Aponded
;;-------------- ----------       ----------       ----------       ----------       ----------
J1               117.06           8        0        0        0
J2               103.478          8        0        0        0
J4               79.298           8        0        0        0
J5               72.014           8        0        0        0

[OUTFALLS]
;;Name           Elevation        Type             Stage Data       Gated            Route To
;;-------------- ----------       ----------       ---------------- -------- ----------------
O1               71.85            FREE                              NO

[CONDUITS]
;;Name           From Node                To Node          Length           Roughness        InOffset
        OutOffset        InitFlow         MaxFlow
;;-------------- ---------------- ---------------- ----------       ----------       ----------       ---------
-       ----------       ----------
C2               J1               J2               4845.801         0.035            *        *        0
        0
C3               J2               J4               3244.751         0.035            *        *        0
        0
C5               J4               J5               1079.396         0.035            *        *        0
        0
C8               J5               O1               45               0.013            *        *        0
        0

[XSECTIONS]
;;Link           Shape            Geom1            Geom2            Geom3            Geom4            Barrels
        Culvert
;;-------------- ------------     ---------------- ----------       ----------       ----------       ---------
-       ----------
C2               IRREGULAR        t2
C3               IRREGULAR        t3
C5               IRREGULAR        t5
C8               ARCH             6.667            9.583            0        0        1

[TRANSECTS]
;;Transect Data in HEC-2 format
;
NC      0.07     0.07     0.035
```

```
X1      t2              31      17.77           88.86           0.0     0.0     0       0       0
GR      111.81          0       111.91          3.55    111.88          7.11    111.88          10.66
        111.98          14.22
GR      112.04          17.77           111.35          21.33           110.66          24.88
        110.01          28.44           110.37          31.99
GR      110.66          35.55           111.02          39.1    111.35          42.66           111.55
        46.21           111.65          49.76
GR      111.61          53.32           111.42          56.87           111.32          60.43
        111.29          63.98           111.58          67.54
GR      111.42          71.09           111.42          74.65           111.42          78.2    111.42
        81.76           111.58          85.31
GR      111.91          88.86           112.17          92.42           112.14          95.97
        112.27          99.53           112.6   103.08
GR      112.47          106.64
;
NC      0.07    0.07    0.035
X1      t3              29      38.8    86.22           0.0     0.0     0       0       0
GR      98.79           0       98.88           4.31    98.59           8.62    98.92           12.93
        99.02           17.24
GR      98.95           21.56           98.46           25.87           98.1    30.18           98.36
        34.49           98.46           38.8
GR      97.87           43.11   96.82           47.42           96.19           51.73           96.56
        56.04           97.77           60.36
GR      98.1    64.67           98.2    68.98           98.13           73.29           98.1    77.6
        97.9    81.91
GR      98.43           86.22           98.52           90.53           98.49           94.84
        98.06           99.16           98      103.47
GR      98.03           107.78          97.6    112.09          97.64           116.4   98.06
        120.71
;
NC      0.07    0.07    0.035
X1      t5              12      8.62    38.81           0.0     0.0     0       0       0
GR      77      0       76.48           4.31    75.46           8.62    74.31           12.94
        74.64           17.25
GR      74.51           21.56           74.11   25.87           74.8    30.19           74.97
        34.5    75.39           38.81
GR      76.08           43.12           77.03           47.44

[POLLUTANTS]
;;Name         Units   Crain           Cgw             Crdii           Kdecay          SnowOnly
        Co-Pollutant            Co-Frac         Cdwf            Cinit
;;-------------- ------  ----------      ----------      ----------      ----------      ----------
        ---------------- ----------      ----------      ----------
```

```
Chloride        MG/L  0       0       98.1481       0       YES             *               0
        0       98.1481

[LANDUSES]
;;              Sweeping        Fraction        Last
;;Name          Interval        Available       Swept
;;--------------  ----------      ----------      ----------
Road            0       0       0

[COVERAGES]
;;Subcatchment          Land Use        Percent
;;--------------  ----------------  ----------
S1              Road            1.55
S2              Road            0.45
S3              Road            2.56
S4              Road            2.78
S5              Road            8.67
S6              Road            15.44
S7              Road            93.83
S8              Road            89.17

[LOADINGS]
;;Subcatchment          Pollutant       Buildup
;;--------------  ----------------  ----------

[BUILDUP]
;;Land Use      Pollutant       Function        Coeff1          Coeff2          Coeff3          Per
Unit
;;--------------  ----------------  ----------      ----------      ----------      ----------      ---------
-
Road            Chloride        EXP             9268.333        0.0935          1       AREA

[WASHOFF]
;;Land Use      Pollutant       Function        Coeff1          Coeff2          SweepRmvl
        BmpRmvl
;;--------------  ----------------  ----------      ----------      ----------      ----------      ---------
-
Road            Chloride        EXP             0.0717          1.3943          0       0

[REPORT]
;;Reporting Options
AVERAGES   YES
SUBCATCHMENTS  ALL
```

```
NODES          ALL
LINKS ALL

[ADJUSTMENTS]
;;Parameter     Subcatchment        Monthly Adjustments
TEMPERATURE                         -5.2824        -0.1012        0.0807 0.1169 0.0     0.0
        0.0     0.0     0.0     2.4704 -4.0539      -6.2525
RAINFALL                            1.369   4.6939 3.6218 1.0386 1.0     1.0     1.0     1.0
        1.0     6.3332 0.1834 2.7507

[TAGS]

[MAP]
DIMENSIONS          350397.265     4788141.900   354468.000     4793226.100
Units           Meters

[COORDINATES]
;;Node          X-Coord             Y-Coord
;;--------------  ----------------------------------
J1              352877.000          4790947.000
J2              353394.300          4789793.000
J4              352697.600          4789029.000
J5              352827.500          4788833.000
O1              352777.100          4788822.000

[VERTICES]
;;Link          X-Coord             Y-Coord
;;--------------  ----------------------------------
C2              353397.700          4789782.000

[Polygons]
;;Subcatchment          X-Coord             Y-Coord
;;--------------  ----------------------------------
S1              353199.600          4791153.000
S1              353199.600          4791153.000
S1              353199.600          4791153.000
S1              353013.700          4791206.000
S1              352865.100          4790967.000
S1              352843.900          4791158.000
S1              352546.600          4791594.000
S1              352392.600          4791700.000
S1              352259.900          4791652.000
S1              352058.200          4791779.000
```

S1	352228.000	4791971.000
S1	352164.300	4792114.000
S1	352461.600	4792507.000
S1	352594.300	4792942.000
S1	353035.000	4792995.000
S1	353337.600	4792671.000
S1	353507.500	4792289.000
S1	353327.000	4792220.000
S1	353130.500	4792353.000
S1	352732.400	4792040.000
S1	353231.400	4791418.000
S1	353215.500	4791137.000
S2	352047.500	4791758.000
S2	352047.500	4791758.000
S2	352105.900	4791705.000
S2	352105.900	4791705.000
S2	352228.000	4791620.000
S2	352228.000	4791620.000
S2	352382.000	4791657.000
S2	352530.600	4791562.000
S2	352822.600	4791142.000
S2	352843.900	4790972.000
S2	352875.700	4790925.000
S2	353019.100	4791169.000
S2	353194.200	4791121.000
S2	353157.100	4790946.000
S2	353534.000	4790643.000
S2	353698.600	4790691.000
S2	353953.400	4790346.000
S2	353390.700	4789805.000
S2	352615.600	4790558.000
S2	352551.900	4790463.000
S2	352270.500	4790739.000
S2	351973.200	4790659.000
S2	351638.800	4791323.000
S2	352052.800	4791763.000
S3	352571.800	4790458.000
S3	352391.400	4790405.000
S3	352333.100	4790198.000
S3	352144.700	4790031.000
S3	352274.700	4789912.000
S3	352303.900	4789705.000
S3	352428.600	4789480.000

S3	352455.100	4789135.000
S3	352616.900	4789044.000
S3	352635.500	4788975.000
S3	352850.400	4789193.000
S3	353060.000	4789480.000
S3	353386.300	4789787.000
S3	352619.600	4790533.000
S4	353972.600	4790339.000
S4	354062.700	4790320.000
S4	354282.900	4790108.000
S4	353866.400	4789607.000
S4	353760.300	4789389.000
S4	353601.200	4789275.000
S4	353497.700	4789257.000
S4	353343.800	4789304.000
S4	353136.900	4789530.000
S4	353967.200	4790334.000
S5	353070.000	4789468.000
S5	352865.800	4789185.000
S5	352640.400	4788962.000
S5	352790.200	4788902.000
S5	352826.000	4788839.000
S5	352896.300	4788856.000
S5	353007.600	4788963.000
S5	353059.300	4788931.000
S5	353206.500	4789006.000
S5	353331.100	4789136.000
S5	353373.500	4789277.000
S5	353348.300	4789287.000
S5	353125.600	4789523.000
S6	352902.200	4788848.000
S6	352832.000	4788829.000
S6	352851.800	4788784.000
S6	352888.900	4788731.000
S6	352964.200	4788665.000
S6	352999.900	4788623.000
S6	352981.400	4788583.000
S6	353037.000	4788503.000
S6	353071.500	4788425.000
S6	353139.100	4788373.000
S6	353371.100	4788400.000
S6	353519.600	4788473.000
S6	353593.800	4788448.000

```
S6              353542.100          4788566.000
S6              353609.700          4788794.000
S6              353714.400          4788816.000
S6              353718.400          4788946.000
S6              353858.900          4788912.000
S6              353860.300          4789002.000
S6              353747.600          4789020.000
S6              353734.300          4789077.000
S6              353697.200          4789093.000
S6              353661.400          4789014.000
S6              353572.600          4789061.000
S6              353577.900          4789125.000
S6              353491.700          4789238.000
S6              353392.400          4789274.000
S6              353340.700          4789126.000
S6              353212.100          4788995.000
S6              353069.000          4788921.000
S6              353009.500          4788945.000
S7              352633.900          4788947.000
S7              352772.600          4788885.000
S7              352797.400          4788843.000
S7              352810.000          4788847.000
S7              352783.500          4788894.000
S7              352639.200          4788955.000
S8              352798.700          4788841.000
S8              352834.100          4788769.000
S8              352872.500          4788710.000
S8              352955.600          4788646.000
S8              352960.600          4788657.000
S8              352882.100          4788717.000
S8              352843.400          4788779.000
S8              352809.600          4788845.000

[SYMBOLS]
;;Gage          X-Coord             Y-Coord
;;--------------  ------------------------------------
Gage            350582.295          4790590.228


[PROFILES]
;;Name          Links
;;--------------  ----------
"path1          " C3       C4       C5       C6       C7
```

"path1 "	C8	C3	C4	C5	C6
"path1 "	C7	C8			
"SU1 "	352725.967	4788869.572	352719.045	4788842.081	352695.945
"SU1 "	4788842.081	352695.945	4788842.081	352690.171	4788869.511

Site 2: Kittery

```
[TITLE]
;;Project Title/Notes
ME DOT Chloride
Site 2, Libby Brook, Kittery, ME

Existing Conditions
5/24/2024

Daniel Macadam
UNH Stormwater Center

[OPTIONS]
;;Option             Value
FLOW_UNITS           CFS
INFILTRATION         MODIFIED_GREEN_AMPT
FLOW_ROUTING         KINWAVE
LINK_OFFSETS         ELEVATION
MIN_SLOPE            0
ALLOW_PONDING        NO
SKIP_STEADY_STATE    NO

START_DATE           06/04/2010
START_TIME           00:00:00
REPORT_START_DATE    06/04/2010
REPORT_START_TIME    00:00:00
END_DATE             06/05/2024
END_TIME             00:00:00
SWEEP_START          01/01
SWEEP_END            12/31
DRY_DAYS             0
REPORT_STEP          00:05:00
WET_STEP             00:01:00
DRY_STEP             00:01:00
ROUTING_STEP         0:00:30
RULE_STEP            00:00:00

INERTIAL_DAMPING     PARTIAL
NORMAL_FLOW_LIMITED  BOTH
FORCE_MAIN_EQUATION  H-W
VARIABLE_STEP        0.75
LENGTHENING_STEP     0
```

```
MIN_SURFAREA            12.566
MAX_TRIALS        8
HEAD_TOLERANCE          0.005
SYS_FLOW_TOL            5
LAT_FLOW_TOL            5
MINIMUM_STEP            1
THREADS           11

[EVAPORATION]
;;Data Source           Parameters
;;--------------    ----------------
TEMPERATURE
DRY_ONLY          YES

[TEMPERATURE]
;;Data Element          Values
FILE        "C:\R_to_SWMM_climate_Portsmouth.dat" *        F
WINDSPEED FILE
SNOWMELT          34      0.57    0.21    135     44.74   0
ADC IMPERVIOUS          0.1     0.35    0.53    0.66    0.75    0.82    0.87    0.92    0.95
      0.98
ADC PERVIOUS      0.1     0.35    0.53    0.66    0.75    0.82    0.87    0.92    0.95    0.98

[RAINGAGES]
;;Name        Format        Interval        SCF           Source
;;--------------    ---------------    ------    ----------
Gage          VOLUME      1:00    1       FILE
      "C:\R_to_SWMM_rainfall_Portsmouth.dat" Portsmouth     IN

[SUBCATCHMENTS]
;;Name        Rain Gage     Outlet          Area    %Imperv       Width         %Slope
      CurbLen       SnowPack
;;--------------    ----------------    ----------------    -------- -------- -------- -------- -------- ----------------
S1            Gage          J1              132.036         3.472           2253.289        4.836
      0       Res
S2            Gage          J2              40.807          6.514           779.556         6.671
      0       Res
S3            Gage          J2              22.722          0.112   544.545         5.668
      0       Res
S4            Gage          J2              4.111   83.07           78.195          2.961
      0       DOT
S5            Gage          J3              3.989           87.508          100.49          3.841
      0       DOT
```

```
S6              Gage        J4          26.389      9.326       518.303     10.406
        0       Res
S7              Gage        O2          4.899       29.047      496.542     7.305
        0       DOT
S8              Gage        J4          3.957       15.228      215.292     6.433
        0       DOT
S9              Gage        O2          3.298       23.578      179.482     8.627
        0       DOT
S10             Gage        J3          1.673       64.931      246.781     3.769
        0       DOT
S11             Gage        J5          2.051       41.914      200.272     7.879
        0       DOT
S12             Gage        J5          4.454       12.02       141.829     11.062
        0       Res

[SUBAREAS]
;;Subcatchment       N-Imperv    N-Perv      S-Imperv    S-Perv      PctZero
        RouteTo     PctRouted
;;--------------    ----------  ----------  ----------  ----------  ----------  ---------
-       ----------
S1              0.01        0.1         0.05        0.05        25
        OUTLET
S2              0.01        0.1         0.05        0.05        25
        OUTLET
S3              0.01        0.1         0.05        0.05        25
        OUTLET
S4              0.01        0.1         0.05        0.05        25
        OUTLET
S5              0.01        0.1         0.05        0.05        25
        OUTLET
S6              0.01        0.1         0.05        0.05        25
        OUTLET
S7              0.01        0.1         0.05        0.05        25
        OUTLET
S8              0.01        0.1         0.05        0.05        25
        OUTLET
S9              0.01        0.1         0.05        0.05        25
        OUTLET
S10             0.01        0.1         0.05        0.05        25
        OUTLET
S11             0.01        0.1         0.05        0.05        25
        OUTLET
```

```
S12             0.01            0.1             0.05            0.05            25
        OUTLET

[INFILTRATION]
;;Subcatchment         Param1          Param2          Param3          Param4          Param5
;;--------------       ----------      ----------      ----------      ----------      ----------
S1              4.56            0.41            0.25
S2              7.08            0.08            0.25
S3              6.24            0.24            0.25
S4              8.92            0.04            0.25
S5              9.77            0.03            0.25
S6              4.84            0.11            0.25
S7              3.65            0.69            0.25
S8              5.13            0.2             0.25
S9              3.41            0.79            0.25
S10             2.48            1.15            0.25
S11             2.47            1.15            0.25
S12             9.85            0.03            0.25

[AQUIFERS]
;;Name          Por     WP      FC      Ksat    Kslope  Tslope  ETu     ETs     Seep    Ebot    Egw
        Umc     ETupat
;;--------------  ------  ------  ------  ------  ------  ------  ------  ------  ------  ------  ------
        ------  ------
Aq1             0.3     0.15    0.25    0.25    10      15      0.35    14      0.002   93      96
        0.3

[GROUNDWATER]
;;Subcatchment         Aquifer         Node            Esurf   A1      B1      A2      B2      A3
        Dsw     Egwt    Ebot    Wgr     Umc
;;--------------  ----------------  ----------------  ------  ------  ------  ------  ------  ------  ------
        ------  ------  ------  ------
S1              Aq1             J1              33.9    1.6667  0.463   5       0.5     0.537   0
        0       28.4    31.75   0.3
S2              Aq1             J2              26.08   1.6667  0.463   5       0.5     0.537   0
        0       20.36   24.91   0.3
S3              Aq1             J2              26.13   1.6667  0.463   5       0.5     0.537   0
        0       20.36   24.2    0.3
S4              Aq1             J2              26.83   1.6667  0.463   5       0.5     0.537   0
        0       20.36   26.15   0.3
S5              Aq1             J3              29.58   1.6667  0.463   5       0.5     0.537   0
        0       23.02   29.01   0.3
```

```
S6              Aq1             J4              29.32   1.6667 0.463   5       0.5     0.537   0
        0       25.78   25.11   0.3
S7              Aq1             O2              31.12   1.6667 0.463   5       0.5     0.537   0
        0       25.55   27.43   0.3
S8              Aq1             J4              32.33   1.6667 0.463   5       0.5     0.537   0
        0       25.78   31.15   0.3
S9              Aq1             O2              32.12   1.6667 0.463   5       0.5     0.537   0
        0       25.55   29.11   0.3
S10             Aq1             J3              29.59   1.6667 0.463   5       0.5     0.537   0
        0       23.02   25.56   0.3
S11             Aq1             J5              24.8    1.6667 0.463   5       0.5     0.537   0
        0       18.24   20.62   0.3
S12             Aq1             J5              24.8    1.6667 0.463   5       0.5     0.537   0
        0       18.24   24.07   0.3

[SNOWPACKS]
;;Name          Surface         Parameters
;;--------------  ----------    ----------
Res             PLOWABLE        0.001           0.005           32              0.1             0
        0       0.25
Res             IMPERVIOUS      0.001           0.005           32              0.1
        0       0       1
Res             PERVIOUS        0.001           0.005           32              0.1             0
        0       6
Res             REMOVAL         1       0       0       0.2             0.0185          0
DOT             PLOWABLE        0.001           0.005           32              0.1             0
        0       0.9
DOT             IMPERVIOUS      0.001           0.005           32              0.1
        0       0       1
DOT             PERVIOUS        0.001           0.005           32              0.1             0
        0       6
DOT             REMOVAL         1       0       0       0.2             0.0185          0

[JUNCTIONS]
;;Name          Elevation       MaxDepth        InitDepth       SurDepth        Aponded
;;--------------  ----------    ----------      ----------      ----------      ----------
J1              28.402          8       0       0       0
J2              25.361          8       0       0       0
J3              23.025          0       0       0       0
J4              25.784          0       0       0       0
J5              18.238          0       0       0       0
J6              17.16           0       0       0       0
```

```
[OUTFALLS]
;;Name          Elevation       Type            Stage Data      Gated           Route To
;;--------------  ----------      ----------      ----------------  -------- ----------------
O1              16.28           FREE                            NO
O2              25.554          FREE                            NO

[CONDUITS]
;;Name          From Node               To Node         Length          Roughness       InOffset
        OutOffset       InitFlow        MaxFlow
;;--------------  ----------------  ----------------  ----------      ----------      ----------      ---------
-       ----------      ----------
C1              J1              J2              1630.577428     0.035           *       *       0
        0
C2              J2              J3              180.4461942     0.013           *       *       0
        0
C3              J4              J3              360.8923885     0.035           *       *       0
        0
C4              J3              J5              495.4068241     0.035           *       *       0
        0
C5              J5              J6              413.3858268     0.035           *       *       0
        0
C6              J6              O1              30              0.013           *       *       0
        0

[XSECTIONS]
;;Link          Shape           Geom1           Geom2           Geom3           Geom4           Barrels
        Culvert
;;--------------  ------------    ----------------  ----------      ----------      ----------      ---------
-       ----------
C1              IRREGULAR       t1
C2              RECT_OPEN       6               9       0       0       1
C3              IRREGULAR       t3
C4              IRREGULAR       t4
C5              IRREGULAR       t5
C6              CIRCULAR        2.5             0       0       0       1

[TRANSECTS]
;;Transect Data in HEC-2 format
;
NC      0.07    0.07    0.035
X1      t1              14      33.72           67.43           0.0     0.0     0       0       0
GR      25.42           0       25.57           6.74    25.77           13.49           25.62
        20.23           25.84           26.97
```

```
GR      24.89           33.72           24.75           40.46           24.27           47.2    24.51
        53.94           24.75           60.69
GR      24.98           67.43           24.97           74.17           24.59           80.92
        25.47           87.66
;
NC      0.07    0.07    0.035
X1      t3              5       9.06    27.18           0.0     0.0     0       0       0
GR      27.48           0       25.5    9.06    25.2    18.12           26.54           27.18
        29.38           36.24
;
NC      0.07    0.07    0.035
X1      t4              8       9.46    47.28           0.0     0.0     0       0       0
GR      23.42           0       21.65           9.46    20.14           18.91           20.17
        28.37           19.7    37.82
GR      22.4    47.28           26.68           56.74           26.08           66.19
;
NC      0.07    0.07    0.035
X1      t5              6       8.71    34.86           0.0     0.0     0       0       0
GR      24.96           0       23.32           8.71    21.68           17.43           22.17
        26.14           24.06           34.86
GR      24.99           43.57

[POLLUTANTS]
;;Name          Units   Crain           Cgw             Crdii           Kdecay          SnowOnly
        Co-Pollutant            Co-Frac         Cdwf            Cinit
;;--------------  ------  ----------      ----------      ----------      ----------      ----------
        ----------------  ----------      ----------      ----------
Chloride        MG/L    0       196.2963        0       0       YES             *               0
        0       196.2963

[LANDUSES]
;;              Sweeping        Fraction        Last
;;Name          Interval        Available       Swept
;;--------------  ----------      ----------      ----------
Road            0       0       0

[COVERAGES]
;;Subcatchment          Land Use        Percent
;;--------------  ----------------  ----------
S1              Road            1.578717471
S2              Road            5.945076904
S3              Road            0.659663089
S4              Road            28.46043457
```

```
S5		Road		32.76349049
S6		Road		5.452597549
S7		Road		35.087326
S8		Road		19.09604696
S9		Road		43.46546299
S10		Road		52.3981974
S11		Road		37.0758251
S12		Road		23.43506962

[LOADINGS]
;;Subcatchment		Pollutant		Buildup
;;--------------	----------------	----------

[BUILDUP]
;;Land Use	Pollutant	Function	Coeff1		Coeff2		Coeff3		Per
Unit
;;--------------	----------------	----------	----------	----------	----------	---------
-
Road		Chloride	EXP		68521.6667	0.6485		1	AREA

[WASHOFF]
;;Land Use	Pollutant	Function	Coeff1		Coeff2		SweepRmvl
	BmpRmvl
;;--------------	----------------	----------	----------	----------	----------	---------
-
Road		Chloride	EXP		0.0717		1.062		0	0

[REPORT]
;;Reporting Options
AVERAGES	YES
SUBCATCHMENTS	ALL
NODES		ALL
LINKS	ALL

[ADJUSTMENTS]
;;Parameter	Subcatchment		Monthly Adjustments
TEMPERATURE				-5.2824		-0.1012		0.0807 0.1169 0.0	0.0
	0.0	0.0	0.0	2.4704 -4.0539		-6.2525
RAINFALL				1.369	4.6939 3.6218 1.0386 1.0	1.0	1.0	1.0
	1.0	6.3332 0.1834 2.7507

[TAGS]
```

```
[MAP]
DIMENSIONS          358971.400     4775941.000   360916.100     4777389.000
Units               Meters

[COORDINATES]
;;Node              X-Coord              Y-Coord
;;--------------    ----------------------------------
J1                  359820.500           4776447.000
J2                  360188.000           4776577.000
J3                  360225.900           4776555.000
J4                  360146.100           4776410.000
J5                  360342.800           4776626.000
J6                  360401.200           4776722.000
O1                  360416.800           4776713.000
O2                  360583.000           4776563.000

[VERTICES]
;;Link              X-Coord              Y-Coord
;;--------------    ----------------------------------

[Polygons]
;;Subcatchment      X-Coord              Y-Coord
;;--------------    ----------------------------------
S1                  359487.100           4777199.000
S1                  359544.400           4777183.000
S1                  359667.000           4776981.000
S1                  359774.200           4776891.000
S1                  359784.300           4776715.000
S1                  359809.300           4776400.000
S1                  359759.100           4776196.000
S1                  359777.700           4776043.000
S1                  359684.300           4776041.000
S1                  359447.300           4776309.000
S1                  359277.800           4776315.000
S1                  359135.900           4776197.000
S1                  359059.800           4776411.000
S1                  359097.800           4776719.000
S1                  359521.700           4776930.000
S1                  359217.200           4777245.000
S1                  359327.900           4777323.000
S2                  359779.400           4776896.000
S2                  359865.900           4776844.000
S2                  360184.200           4776578.000
```

S2	359783.300	4776040.000
S2	359768.600	4776197.000
S2	359826.600	4776388.000
S2	359789.600	4776710.000
S3	360078.700	4776943.000
S3	360199.800	4776851.000
S3	360308.800	4776763.000
S3	360186.800	4776583.000
S3	360001.500	4776728.000
S3	359865.900	4776851.000
S3	359971.400	4776918.000
S4	359927.100	4776206.000
S4	360321.200	4776757.000
S4	360337.200	4776744.000
S4	359792.400	4776007.000
S4	359782.600	4776034.000
S5	360347.900	4776727.000
S5	359827.200	4776016.000
S5	359805.800	4776007.000
S5	360338.500	4776747.000
S6	360397.300	4776323.000
S6	360439.400	4776379.000
S6	360481.500	4776434.000
S6	360809.800	4776357.000
S6	360457.400	4776204.000
S6	360269.100	4776264.000
S6	360000.700	4776224.000
S6	360138.300	4776397.000
S6	360237.100	4776383.000
S7	360668.200	4776474.000
S7	360827.700	4776389.000
S7	360812.300	4776366.000
S7	360462.700	4776447.000
S7	360410.000	4776363.000
S7	360335.900	4776472.000
S8	360241.100	4776450.000
S8	360255.800	4776440.000
S8	360270.500	4776430.000
S8	360324.600	4776449.000
S8	360414.000	4776349.000
S8	360310.500	4776362.000
S8	360235.800	4776403.000
S8	360155.100	4776406.000

```
S8              360171.800          4776426.000
S8              360206.500          4776465.000
S9              360422.000          4776690.000
S9              360466.000          4776650.000
S9              360482.000          4776534.000
S9              360434.000          4776500.000
S9              360361.900          4776478.000
S9              360359.300          4776618.000
S9              360403.300          4776693.000
S10             360273.200          4776550.000
S10             360325.200          4776480.000
S10             360323.200          4776454.000
S10             360270.500          4776435.000
S10             360235.100          4776460.000
S10             360243.800          4776510.000
S10             360273.200          4776555.000
S11             360349.900          4776618.000
S11             360353.900          4776478.000
S11             360331.200          4776478.000
S11             360278.500          4776558.000
S11             360343.200          4776618.000
S12             360357.300          4776712.000
S12             360388.600          4776696.000
S12             360134.400          4776400.000
S12             360075.700          4776346.000
S12             360351.200          4776720.000

[SYMBOLS]
;;Gage          X-Coord             Y-Coord
;;--------------   -----------------------------------
Gage            359319.700          4776052.000


[PROFILES]
;;Name          Links
;;--------------   ----------
"path1         " C3      C4      C5      C6      C7
"path1         " C8      C3      C4      C5      C6
"path1         " C7      C8
```

Site 3: Hampden South

```
[TITLE]
;;Project Title/Notes
ME DOT Chloride
Site 3, Reed Brook, Hampden, ME

Existing Conditions
5/24/2024

Daniel Macadam
UNH Stormwater Center

[OPTIONS]
;;Option             Value
FLOW_UNITS           CFS
INFILTRATION         MODIFIED_GREEN_AMPT
FLOW_ROUTING         KINWAVE
LINK_OFFSETS         ELEVATION
MIN_SLOPE            0
ALLOW_PONDING        NO
SKIP_STEADY_STATE    NO

START_DATE           07/31/2010
START_TIME           00:00:00
REPORT_START_DATE    07/31/2010
REPORT_START_TIME    00:00:00
END_DATE             06/05/2024
END_TIME             00:00:00
SWEEP_START          01/01
SWEEP_END            12/31
DRY_DAYS             0
REPORT_STEP          00:05:00
WET_STEP             00:01:00
DRY_STEP             00:01:00
ROUTING_STEP         0:00:30
RULE_STEP            00:00:00

INERTIAL_DAMPING     PARTIAL
NORMAL_FLOW_LIMITED  BOTH
FORCE_MAIN_EQUATION  H-W
VARIABLE_STEP        0.75
LENGTHENING_STEP     0
MIN_SURFAREA         12.566
```

```
MAX_TRIALS        8
HEAD_TOLERANCE          0.005
SYS_FLOW_TOL            5
LAT_FLOW_TOL            5
MINIMUM_STEP            1
THREADS           11

[EVAPORATION]
;;Data Source           Parameters
;;--------------   ----------------
TEMPERATURE
DRY_ONLY          YES

[TEMPERATURE]
;;Data Element          Values
FILE        "C:\R_to_SWMM_climate_Bangor.dat"      *       F
WINDSPEED FILE
SNOWMELT          34    0.57  0.21  135   44.74 0
ADC IMPERVIOUS          0.1   0.35  0.53  0.66  0.75  0.82  0.87  0.92  0.95
      0.98
ADC PERVIOUS      0.1   0.35  0.53  0.66  0.75  0.82  0.87  0.92  0.95  0.98

[RAINGAGES]
;;Name        Format        Interval        SCF           Source
;;--------------   ---------------   ------   ----------
Gage        VOLUME      1:00  1     FILE
      "C:\R_to_SWMM_rainfall_Bangor.dat"      Bangor      IN

[SUBCATCHMENTS]
;;Name        Rain Gage     Outlet        Area  %Imperv     Width       %Slope
      CurbLen     SnowPack
;;--------------   ----------------   ----------------   -------- -------- -------- -------- -------- ----------------
S1          Gage        J2          420.536     2.198       3054.428    6.921
      0     Res
S2          Gage        J2          264.546     3.267       2088.229    6.844
      0     Res
S3          Gage        J3          102.543     5.936       2220.998    7.187
      0     Res
S4          Gage        J4          169.316     4.141       1789.828    6.502
      0     Res
S5          Gage        J5          96.479      4.164       1283.523    6.926
      0     Res
```

```
S6          Gage        J6          75.819      9.004       1248.947    7.403
     0      Res
S7          Gage        J7i         1.063       100   33.062      2.589
     0      DOT
S8          Gage        O1          1.315       90.525      41.172      1.998
     0      DOT

[SUBAREAS]
;;Subcatchment     N-Imperv    N-Perv      S-Imperv    S-Perv      PctZero
     RouteTo       PctRouted
;;--------------   ----------  ----------  ----------  ----------  ----------  ---------
-    ----------
S1          0.01        0.1         0.05        0.05        25
     OUTLET
S2          0.01        0.1         0.05        0.05        25
     OUTLET
S3          0.01        0.1         0.05        0.05        25
     OUTLET
S4          0.01        0.1         0.05        0.05        25
     OUTLET
S5          0.01        0.1         0.05        0.05        25
     OUTLET
S6          0.01        0.1         0.05        0.05        25
     OUTLET
S7          0.01        0.1         0.05        0.05        25
     OUTLET
S8          0.01        0.1         0.05        0.05        25
     OUTLET

[INFILTRATION]
;;Subcatchment     Param1      Param2      Param3      Param4      Param5
;;--------------   ----------  ----------  ----------  ----------  ----------
S1          6.64        0.26        0.25
S2          3.58        0.13        0.25
S3          4.86        0.19        0.25
S4          3.52        0.13        0.25
S5          4.51        0.17        0.25
S6          5.08        0.38        0.25
S7          4.17        0.49        0.25
S8          4.91        0.39        0.25

[AQUIFERS]
```

```
;;Name          Por    WP     FC     Ksat   Kslope Tslope ETu    ETs    Seep   Ebot   Egw
       Umc    ETupat
;;-------------- ------ ------ ------ ------ ------ ------ ------ ------ ------ ------ ------
       ------ ------
Aq1             0.3    0.15   0.25   0.21   10     15     0.35   14     0.002  89.29  89.57
       0.3

[GROUNDWATER]
;;Subcatchment         Aquifer          Node             Esurf  A1     B1     A2     B2     A3
       Dsw    Egwt   Ebot   Wgr    Umc
;;-------------- ---------------- ---------------- ------ ------ ------ ------ ------ ------ ------
       ------ ------ ------ ------
S1              Aq1              J2               141.96 1.6667 0.1667 1.6667 0.1667 0.9815 0
       0      137.74 139.76 0.3
S2              Aq1              J2               139.87 1.6667 0.1667 1.6667 0.1667 0.9815 0
       0      137.74 138.63 0.3
S3              Aq1              J3               136.23 1.6667 0.1667 1.6667 0.1667 0.9815 0
       0      132.66 135.12 0.3
S4              Aq1              J4               125.11 1.6667 0.1667 1.6667 0.1667 0.9815 0
       0      122.21 124.07 0.3
S5              Aq1              J5               117.54 1.6667 0.1667 1.6667 0.1667 0.9815 0
       0      114.7  116.31 0.3
S6              Aq1              J6               97.93  1.6667 0.1667 1.6667 0.1667 0.9815 0
       0      94.73  96.61  0.3
S7              Aq1              J7i              97.39  1.6667 0.1667 1.6667 0.1667 0.9815 0
       0      94.73  95.06  0.3
S8              Aq1              O1               91.67  1.6667 0.1667 1.6667 0.1667 0.9815 0
       0      89.29  89.57  0.3

[SNOWPACKS]
;;Name          Surface          Parameters
;;-------------- ----------       ----------
Res             PLOWABLE  0.001         0.005         32            0.1           0
       0      0.25
Res             IMPERVIOUS       0.001         0.005         32            0.1
       0      0      1
Res             PERVIOUS  0.001         0.005         32            0.1           0
       0      6
Res             REMOVAL   1      0      0      0.2           0.0185        0
DOT             PLOWABLE  0.001         0.005         32            0.1           0
       0      0.9
DOT             IMPERVIOUS       0.001         0.005         32            0.1
       0      0      1
```

```
DOT             PERVIOUS    0.001           0.005           32              0.1             0
        0       6
DOT             REMOVAL     1       0       0       0.2             0.0185          0

[JUNCTIONS]
;;Name          Elevation       MaxDepth        InitDepth       SurDepth        Aponded
;;--------------  ----------      ----------      ----------      ----------      ----------
J2              137.74          8       0       0       0
J3              132.661         8       0       0       0
J4              122.211         8       0       0       0
J5              114.698         8       0       0       0
J6              94.734          8       0       0       0
J7i             94.73           8       0       0       0
J7              93.802          8       0       0       0

[OUTFALLS]
;;Name          Elevation       Type            Stage Data      Gated           Route To
;;--------------  ----------      ----------      ----------------  --------  ----------------
O1              89.295          FREE                            NO

[CONDUITS]
;;Name          From Node               To Node         Length          Roughness       InOffset
        OutOffset       InitFlow        MaxFlow
;;--------------  ----------------  ----------------  ----------      ----------      ----------      ---------
-       ----------      ----------
C3              J2              J3              2181.759        0.035           *       *       0
        0
C4              J3              J4              3061.024        0.035           *       *       0
        0
C5              J4              J5              2276.903        0.035           *       *       0
        0
C6              J5              J6              2296.588        0.035           *       *       0
        0
C7              J6              J7              20              0.035           *       *       0
        0
C7i             J7i             J7              20              0.013           *       *       0
        0
C8              J7              O1              60              0.013           *       *       0
        0

[XSECTIONS]
;;Link          Shape           Geom1           Geom2           Geom3           Geom4           Barrels
        Culvert
```

```
;;--------------   ------------    ----------------  ----------    ----------    ----------    ---------
-     ----------
C3          IRREGULAR     t3
C4          IRREGULAR     t4
C5          IRREGULAR     t5
C6          IRREGULAR     t6
C7          IRREGULAR     t7
C7i         CIRCULAR      2          0     0     0     1
C8          RECT_OPEN     6          9     0     0     1

[TRANSECTS]
;;Transect Data in HEC-2 format
;
NC    0.07    0.07    0.035
X1    t3              28     49.67        69.54        0.0    0.0    0     0     0
GR    137.12          16.56         136.49       19.87         136.27        23.18
      136.27          26.49         136.26       29.8
GR    136.24          33.11  136.23        36.42        136.1         39.73         135.95
      43.05           135.82        46.36
GR    135.71          49.67         135.53       52.98         135.33        56.29
      135.23          59.6   135.4         62.91
GR    135.53          66.22         135.7        69.54         135.75        72.85
      135.71          76.16         135.71       79.47
GR    135.75          82.78         135.78       86.09         135.84        89.4   135.99
      92.71           135.95        96.03
GR    136.28          99.34         136.7        102.65        137.18        105.96
;
NC    0.07    0.07    0.035
X1    t4              25     31.55        59.16        0.0    0.0    0     0     0
GR    128.56          0      127.83        3.94   127.62        7.89   127.43        11.83
      127.24          15.78
GR    127.16          19.72         127.08       23.66         126.92        27.61
      126.8           31.55         126.7        35.5
GR    126.24          39.44         125.46       43.39         124.59        47.33
      124.87          51.27         125.86       55.22
GR    126.91          59.16         126.89       63.11  126.64        67.05         126.64
      70.99           126.64        74.94
GR    127.05          78.88         127.49       82.83         127.58        86.77
      128.02          90.71         128.65       94.66
;
NC    0.07    0.07    0.035
X1    t5              17     23.06        44.35        0.0    0.0    0     0     0
```

GR 121.55 0 121.62 3.29 121.55 6.59 121.29 9.88
120.84 13.17
GR 120.52 16.47 120.43 19.76 120.52 23.06
120.21 26.35 119.71 29.64
GR 119.02 32.94 119.04 36.23 119.51 39.52
120.2 42.82 120.52 44.35
GR 120.89 46.11 121.65 49.4
;
NC 0.07 0.07 0.035
X1 t6 20 41.98 67.18 0.0 0.0 0 0 0
GR 114.27 0 113.3 4.2 112.77 8.4 112.64 12.6 112.35
16.79
GR 112.19 20.99 112.14 25.19 112.17 29.39
112.19 33.59 112.4 37.79
GR 112.47 41.98 111.8 46.18 110.86 50.38 110.15
54.58 110.03 58.78
GR 110.54 62.98 112.41 67.18 114.12 71.37
114.74 75.57 115.09 79.77
;
NC 0.07 0.07 0.035
X1 t7 16 17.62 35.24 0.0 0.0 0 0 0
GR 98.82 0 98.49 3.52 98.19 7.05 97.96 10.57
97.46 14.09
GR 95.88 17.62 94.74 21.14 94.41 24.67
94.41 28.19 95.38 31.71
GR 96.11 35.24 96.23 38.76 96.35 42.28 97.07
45.81 98.55 49.16
GR 100.23 52.52

[POLLUTANTS]
;;Name Units Crain Cgw Crdii Kdecay SnowOnly
Co-Pollutant Co-Frac Cdwf Cinit
;;-------------- ------ ---------- ---------- ---------- ---------- ----------
---------------- ---------- ---------- ----------
Chloride MG/L 0 90.7407 0 0 YES * 0
0 90.7407

[LANDUSES]
;; Sweeping Fraction Last
;;Name Interval Available Swept
;;-------------- ---------- ---------- ----------
Road 0 0 0

```
[COVERAGES]
;;Subcatchment     Land Use     Percent
;;--------------   ----------------   ----------
S1              Road            0.72
S2              Road            1.08
S3              Road            2.03
S4              Road            1.24
S5              Road            1.22
S6              Road            5.14
S7              Road            100
S8              Road            100

[LOADINGS]
;;Subcatchment     Pollutant     Buildup
;;--------------   ----------------   ----------

[BUILDUP]
;;Land Use      Pollutant       Function        Coeff1          Coeff2          Coeff3          Per
Unit
;;--------------   ----------------   ----------     ----------     ----------     ----------     ---------
-
Road            Chloride        EXP             9268.333        0.0565          1       AREA

[WASHOFF]
;;Land Use      Pollutant       Function        Coeff1          Coeff2          SweepRmvl
        BmpRmvl
;;--------------   ----------------   ----------     ----------     ----------     ----------     ---------
-
Road            Chloride        EXP             0.195           2.0218          0       0

[DWF]
;;Node          Constituent     Baseline        Patterns
;;--------------   ----------------   ----------     ----------
J7i             FLOW            0.002
J7i             Chloride        200

[REPORT]
;;Reporting Options
AVERAGES   YES
SUBCATCHMENTS  ALL
NODES          ALL
LINKS ALL
```

```
[ADJUSTMENTS]
;;Parameter     Subcatchment          Monthly Adjustments
TEMPERATURE                           -5.2824         -0.1012         0.0807 0.1169 0.0       0.0
          0.0       0.0       0.0       2.4704 -4.0539         -6.2525
RAINFALL                              1.369   4.6939 3.6218 1.0386 1.0       1.0       1.0       1.0
          1.0       6.3332 0.1834 2.7507

[TAGS]

[MAP]
DIMENSIONS          508762.300     4951875.000   513073.000     4954922.000
Units               Meters

[COORDINATES]
;;Node              X-Coord                Y-Coord
;;--------------    ------------------------------------
J2                  510597.700             4953506.000
J3                  511101.600             4953723.000
J4                  511726.700             4953974.000
J5                  512208.900             4953827.000
J6                  512587.100             4953650.000
J7i                 512611.200             4953676.000
J7                  512602.400             4953648.000
O1                  512676.300             4953607.000

[VERTICES]
;;Link              X-Coord                Y-Coord
;;--------------    ------------------------------------

[Polygons]
;;Subcatchment          X-Coord                Y-Coord
;;--------------    ------------------------------------
S1                  510069.700             4954726.000
S1                  510064.000             4954527.000
S1                  509962.800             4954235.000
S1                  510144.900             4953998.000
S1                  510531.100             4954056.000
S1                  510508.900             4953654.000
S1                  510586.900             4953507.000
S1                  510442.400             4953412.000
S1                  510341.300             4953076.000
S1                  510537.800             4952909.000
S1                  510439.500             4952600.000
```

S1	510312.400	4952423.000
S1	509977.300	4952525.000
S1	509873.300	4952756.000
S1	509957.100	4953273.000
S1	509529.500	4953247.000
S1	509520.800	4953117.000
S1	509185.700	4953062.000
S1	509047.000	4953377.000
S1	509214.600	4953813.000
S1	509671.100	4954246.000
S1	509942.600	4954706.000
S1	510061.100	4954732.000
S2	511017.400	4953177.000
S2	511473.800	4953198.000
S2	511479.600	4952562.000
S2	511349.600	4952473.000
S2	511343.800	4952276.000
S2	511179.100	4952247.000
S2	510924.900	4952155.000
S2	510511.800	4952279.000
S2	510457.500	4952581.000
S2	510555.700	4952914.000
S2	510359.300	4953079.000
S2	510454.600	4953404.000
S2	510598.400	4953495.000
S3	510768.900	4954111.000
S3	510982.700	4954021.000
S3	511280.300	4953201.000
S3	511020.300	4953198.000
S3	510616.300	4953513.000
S3	510526.800	4953658.000
S3	510548.500	4954056.000
S4	511147.400	4954024.000
S4	511502.700	4954119.000
S4	511653.000	4954244.000
S4	511716.500	4954102.000
S4	511733.900	4953192.000
S4	511492.600	4952569.000
S4	511488.300	4953209.000
S4	511296.300	4953203.000
S4	511005.800	4954007.000
S5	511843.600	4954088.000
S5	511910.100	4954050.000

S5	511953.400	4953981.000
S5	512196.100	4953842.000
S5	512317.400	4953238.000
S5	511759.900	4953203.000
S5	511735.200	4954089.000
S6	512155.700	4954012.000
S6	512253.900	4954105.000
S6	512739.200	4954024.000
S6	512427.200	4953287.000
S6	512337.700	4953235.000
S6	512216.300	4953854.000
S6	511960.400	4954003.000
S7	512787.600	4954036.000
S7	512605.600	4953610.000
S7	512556.600	4953339.000
S7	512542.100	4953340.000
S7	512591.200	4953613.000
S7	512776.000	4954043.000
S8	512829.700	4954057.000
S8	512662.200	4953628.000
S8	512605.900	4953374.000
S8	512597.300	4953273.000
S8	512533.800	4953264.000
S8	512532.300	4953279.000
S8	512580.000	4953281.000
S8	512587.200	4953368.000
S8	512644.900	4953635.000
S8	512816.700	4954063.000

[SYMBOLS]

;;Gage	X-Coord	Y-Coord
;;--------------	------------------------------------	
Gage	511473.800	4954564.000

[PROFILES]

;;Name	Links				
;;--------------	----------				
"path1 "	C3	C4	C5	C6	C7
"path1 "	C8				