NHDES-R-WD-07-40

DATA REPORT
for the
Total Maximum Daily Loads for Chloride For Waterbodies in the Vicinity of the I-93 Corridor From Massachusetts to Manchester, NH: Policy-Porcupine Brook Beaver Brook Dinsmore Brook North Tributary to Canobie Lake

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Introduction

Streams in four watersheds, including parts of Salem, Windham, Derry, Londonderry, Auburn, and Chester do not meet water quality standards for chlorides in particular segments during various times of the year (Figure 1). The largest source of chlorides in these watersheds is presumed to be road salt. Water quality monitoring from 2002 through 2005, conducted jointly by the NH Department of Environmental Services (DES), Department of Transportation (DOT), and the Environmental Protection Agency (EPA), has documented violations of the water quality standards for chloride in Beaver Brook, Dinsmore Brook, the north tributary to Canobie Lake, and Policy Brook. The violations triggered the need for a total maximum daily load (TMDL) study for chlorides in these watersheds.

The purpose of the TMDL study is to estimate chloride loads from all sources that lead to the water quality violations, determine the capacity of the water bodies to assimilate chloride without violating the standards, and to develop an implementation plan to reduce chloride loads in order to meet the water quality standards. Specifically, the study seeks to answer the following questions:

1. How frequently and by how much do chloride concentrations exceed water quality standards at the outlet of each TMDL watershed?
2. What are the critical conditions in terms of flow and seasons for chloride impairments?
3. Are there "hot spots" in the watershed with higher than average chloride concentrations where implementation actions would be most effective?
4. How much chloride is currently contributed annually by each major source category (e.g., I-93, state roads, parking lots) in the watershed?
5. What is the maximum load of chlorides that each of the impaired assessment units can assimilate without violating the water quality standards?
6. How much chloride loading should be allocated to each major source category in the watershed in order to meet water quality standards?
7. What actions are needed by state, municipal and private entities to reduce chloride loadings to the TMDL?
8. After the recommended actions are implemented, how will we know whether chloride concentrations are decreasing in the impaired assessment units?

The purpose of this report is to summarize the data collected for the TMDL study and some of the previous water quality studies. The results presented in this report will be used to generate the TMDLs for the study watersheds. This report should be considered the "Data Report" deliverable from section C2 of the Quality Assurance Project Plan (DES, 2006).

Methods

Three monitoring activities were completed for the study.

- Activity #1. Chloride Impairment Characterization Monitoring. For this activity, near-continuous (every 15 minutes) measurements of specific conductance, water temperature, and stream flow were made at six locations in the four watersheds from 7/1/06 to 6/30/07. A regression equation was used to estimate chloride concentrations in the water based on the specific conductance values. The purpose of this monitoring was to establish chloride exports from the watersheds and load duration curves.
- Activity #2. Chloride Source Identification Monitoring. For this activity, near-continuous (every 15 minutes) measurements of specific conductance and water temperature were made at 15 locations throughout the four watersheds from 1/1/07 to 3/31/07. The purpose of this monitoring was to identify concentrated sources of chlorides in the watersheds.
- Activity #3. Chloride Loading Rate Research. For this activity, the major sources of chlorides within each of the watersheds were estimated. Chloride loads from deicing, salt pile runoff, water softeners, food waste, and atmospheric deposition were considered. The study period for the load estimates was 7/1/06 to 6/30/07 to match the period of Activity #1 monitoring.

Field sampling stations and their associated subwatersheds are shown in Figures 2 and 3. Station details are provided in Table 1. Field data collection and quality assurance methods are discussed in other reports (DES, 2006; DES, 2007). The regression equation from the QAPP (DES, 2006) was used to convert specific conductance to chloride:

$$\textit{Chloride (in mg/L)} = 0.307 * \textit{Specific Conductance (in uS/cm)} - 22.00$$

Additional details of the data analysis methods are provided in the Results and Discussion section.

In this report, data and watershed characteristics are reported by station. The four watersheds for the TMDL studies have outlet stations at 09-BVR (Beaver Brook), I93-DIN-01 (Dinsmore Brook), I93-NTC-01 (North Tributary to Canobie Lake), and I93-POL-01V (Policy Brook). Therefore, for example, the land use characteristics for the whole Beaver Brook watershed are listed under station 09-BVR in the tables. All the other stations represent subwatersheds of these four study watersheds.

Some water quality data from previous studies in FY02-FY06 are provided in this report. Location information for stations from these studies is provided in Table 2.

Results and Discussion

Watershed Characteristics

The land use in watersheds was calculated from the New Hampshire Land Cover Assessment dataset. Table 3 shows the percent of each watershed in each land cover class. This dataset was completed in 2001 and is based on Landsat TM imagery collected between 1990 and 1999.

The population and number of housing units in each watershed were calculated using ArcView software from the 2000 Census block data (Table 4). For blocks that straddled a watershed divide, population density and housing unit density were considered to be uniform and applied to the portion of the block in the watershed. The census blocks were typically small (72 acres on average) compared to the size of the watersheds (3,506 acres on average). The 2000 census data was considered acceptable because the populations in Derry, Londonderry, Salem and Windham have changed only 1%, 6%, 6%, and 16%, respectively, between 2000 and 2006 (NH OEP estimates). The population change was reported for the whole town, not individual census blocks. It would not have been accurate or justified to increase the population in each census block by the average population increase for the whole town.

The percent of each watershed which is considered part of an "urbanized area" from the 2000 Census was also calculated using ArcView software (Table 4).

Water Quality Measurements

Data logger deployments to measure water quality for the TMDL study ran from 6/30/06 to 7/3/07 (Table 5). Following quality assurance checks (DES, 2007), valid water quality data from data loggers were averaged over discrete one-hour, one-day and four-day periods. One-hour averages were calculated from measurements made within the same hour (e.g., 9:00, 9:15, 9:30, and 9:45). One-day averages were calculated from measurements made during the same calendar day. Four-day averages were calculated from discrete four-calendar day periods starting on 7/1/06 and ending on 7/3/07. For example, the four-calendar day period starting on 7/1/06 comprised all the measurements made during calendar days 7/1/06, 7/2/06, 7/3/06, and 7/4/06. However, rolling four-day averages were calculated to identify water quality violations. The rolling average method differs from the calendar day method and is discussed in the next section. Discrete-period averages were used for the purpose of calculating chloride exports and load duration curves for the TMDLs.

Summary statistics for water temperature, specific conductance, and chloride inferred from specific conductance are shown in Tables 8, 9, and 10. These statistics were generated from the one-hour average values because the file size of the raw 15-minute data was too large to efficiently manipulate using Microsoft Excel. The results for grab samples for chloride analyzed by the DES Laboratory are provided in Table 11.

Time series plots for each of these parameters at the Activity #1 and Activity #2 stations are shown in Appendices A and B, respectively.

Water Quality Violations

Consistent with the 2006 surface water quality assessment process, violations of the acute and chronic standards at a station were identified by calculating rolling averages for all possible blocks of one hour and 96 hours, respectively. The time increment of the rolling average was 15 minutes; therefore, the time blocks for the rolling averages overlapped. This method was used because identification of violations by discrete calendar day averages, rather than rolling averages, can miss violations. Discrete averages involve arbitrarily splitting the time series. These arbitrary breaks can split up four-day periods and one hour periods, which would be in violation of the water quality standard if grouped together.

For violations identified by rolling averages, each independent period of violation was identified by the beginning of the time block of the first overlapping violation and the end of the time block of the last overlapping violation. For example, the time block beginning on 1/1/2007 8:00 and ending on 1/5/2007 7:45 was not considered independent of the time block beginning on 1/1/2007 8:15 and ending on 1/5/2007 8:00. However, the time block beginning on 1/5/2007 9:00 would be independent of both. The total duration of each independent period was calculated. The number of violations corresponding to each independent period was calculated by dividing the duration by one hour (for acute) or 96 hours (for chronic) and rounding to the nearest integer. The number of violations for the period of record was summed for all the independent periods of violation.

The numbers of violations of the acute and chronic water quality standards at each station between 7/1/06 and 6/30/07 (FY07) are shown in Table 13. The dates and times when the violations occurred are provided in Tables 14 and 15. Figures 4, 5 and 6 show the number of stations in violation of the acute and chronic standards over time. Note that on Figure 4 the second and third acute violations that occurred on 1/1/07 at station I93-POL-02N were excluded to avoid double counting of that station on that date.

The summary of violations provides information on critical conditions when violations occur and priority watersheds for source reduction. For the acute standard, there were two dates with multiple violations: 1/1/07 and 3/2/07. For the chronic standard, violations typically occurred in late summer and mid-winter. Aside from the watershed outlet stations, violations occurred in the I93-POLU01-01 and I93-POCU01-01 watersheds. These subwatersheds should be a priority for source identification and remediation. There were also consistent violations at I93-POL-02N. An uncovered salt-sand pile at the Salem DPW facility, which has since been removed, was the source of these violations.

For this study, DES also reviewed the readily available data for chloride from previous studies in these watersheds. For the winters ending in 2003, 2004, 2005 and 2006, DES, EPA and DOT monitored chloride in the watersheds in the vicinity if I-93. Chloride concentrations were primarily measured in winter with near continuous specific conductance measurements by data loggers. DES queried the Environmental Monitoring Database for all of the valid data for grab samples for chloride and data logger records for specific conductance from these study watersheds since 2002.

A total of 56 data logger installations with specific conductance data between 1/1/2002 and 9/30/2006 were found in the Environmental Monitoring Database (Tables 6 and 7). The datalogger records were processed to identify chronic violations using the rolling average method presented above. The data logger records were a combination of 15 minute and 1 hour frequency data. One hour averages were calculated from the 15 minute datasets so that all the datasets would have a consistent measurement frequency. Acute violations were not determined because DES assessment procedures require 15 minute datasets to determine acute violations. A summary of violations by station and the details of each violation are provided in Tables 16 and 17.

Chloride grab samples were typically collected to validate a data logger record. Therefore, those chloride samples collected at a station during a datalogger deployment were not analyzed separately. The remaining chloride samples were compiled by station and compared to the chronic and acute water quality standards (Table 12). The only station with chloride concentrations higher than the acute standard was I93-POL-02N. Multiple violations of the standards have been detected at this station from data logger deployments. The only station with chloride concentrations higher than the chronic standard which never had a data logger deployment at some point was I93-POL-04. This station is 1,800 feet downstream of I93-POL-04X. The violations at I93-POL-04X have been well documented by data loggers and should be representative of conditions at I93-POL-04 also. Therefore, no new violations of the water quality standards were found from the analysis of the chloride grab samples.

Figures 7 and 8 show the locations where water quality violations have been detected in the study watersheds in FY02 through FY07. The figures show the river reach which has been listed as impaired for chloride by DES, the location of datalogger deployments, and the locations where grab samples have been collected. The datalogger points have been plotted on top of the grab sample points because the datalogger results are more representative of actual conditions at the site. In the Beaver Brook watershed, violations were largely confined to a stretch of river on either side of I-93. However, in FY07, DES detected violations of the acute standard at stations 08-BVR and I93-BVRU03-01 farther up in the watershed. In the Policy Brook watershed, violations were detected in both Policy Brook and the Porcupine Brook. One violation occurred outside of the impaired reach. This violation at station I93-POL-06 was detected in FY06, which was after the last surface water quality assessment cycle.

Stream Flow Measurements

For the TMDL study, the U.S. Geological Survey (USGS) installed temporary stream gages at five of the six Activity #1 stations. These stations collected stream flow data for a period of record of 7/1/06 to 6/30/07. Summary statistics of the measured flows at these stations are presented in Table 18. Time series graphs of the measured stream flow values are shown in Appendix A.

Stream flow was not measured at one of the Activity #1 stations (I93-NTC-01) and at all of the Activity #2 stations. The stream flow at these stations was estimated using the drainage area ratio approach. The principle of the drainage area ratio approach is that the flow per unit of drainage area is the same for watersheds for similar size, geology, weather, and development.

Therefore, the stream flow at an ungaged station can be estimated from a gaged station by multiplying the measured flow per unit area at the gaged site by the drainage area at the ungaged site. The accuracy of the estimates is best if the ratio of the drainage areas is between 0.3 and 1.5 and the two stations are within the same watershed (Flynn, 2003).

Table 19 shows how DES used the drainage area ratio approach to estimate flows at stations without stream gages. The stream gages within each of the watersheds were used to estimate stream flow at the ungaged sites within the same watershed. The one exception to this rule was that the stream gage on Dinsmore Brook at I93-DIN-01 was also used to estimate flows at all stations with very small watersheds (<1.5 square miles). The other stream gage stations had much larger drainage areas and would not have been representative of the small watersheds. For nine of the 15 stations, the ratios of the drainage areas were between 0.3 and 1.5 as recommended by Flynn (2003). The ratios for all the stations covered a range from 0.19 to 2.5.

DES adjusted the estimated flows at I93-NTC-01 to account for large groundwater withdrawals by the W&E well field. The average stream flow at this station was estimated to be 0.37 cfs based on measured flows at I93-DIN-01 using the drainage area ratio method. In 2006, the W&E wells extracted 17 million gallons of water from north tributary to Canobie Lake watershed, which averages out to approximately 0.07 cfs. Therefore, the withdrawal was approximately 19% of the estimated flows. The water is used by homes in the region, but the watershed for the north tributary to Canobie Lake is very small so the distribution of the water is equivalent to removing it from the watershed. DES queried monthly data on water withdrawals from the W&E well field from 1/1/06 through 6/30/07. The daily average withdrawal for each month (in cfs, Table 20) was subtracted from the estimated flows for each month during the study period. If the subtraction caused the estimated flow to be negative, the flow value was set to zero.

The other major water withdrawal in the study area is the Town of Salem withdrawal from Canobie Lake. The Town of Salem sewer system discharges to the Merrimack River in Lawrence, MA. Therefore, transferring water from Canobie Lake to the Salem water supply is equivalent to removing water from the watershed. Fortunately, it was not necessary to adjust any of the estimated stream flows to account for the Canobie Lake withdrawal. The town typically operates this withdrawal during the summer months. The stream flow estimates were only needed for the winter months (1/1/07 to 3/31/07). During the rest of the time, stream gages were used to directly measure flows at the stations of interest. In the Beaver Brook watershed, the total withdrawals in 2006 were less than 1% of the stream flow at 09-BVR, which is negligible.

For this analysis, it was assumed that the geology and precipitation in all the watersheds were the same due to their proximity to each other. However, the level of development in each watershed will affect the hydrograph response. The three gaged sites for the transpositions were all heavily developed. Therefore, the resulting transpositions should be reasonably accurate for developed watersheds and less accurate for undeveloped watersheds. Summary statistics for the estimated stream flows are shown in Table 21.

Flow Duration Curves

For the TMDL study, flow duration curves are needed for the six Activity #1 stations: I93-POL-01V, I93-POL-04X, 09-BVR, 10A-BVR, I93-DIN-01 and I93-NTC-01. A flow duration curve is the relationship between a stream flow level in cubic feet per second and the percent of the time that this flow level is exceeded.

Flow duration curves were needed for three different time scales: one-hour, one-day, and four-day averages. The one-hour and four-day flow duration curves were needed to match the time scales of the chloride water quality standards. The one-day flow duration curve was calculated because historical records at the one-hour time scale do not exist. For this report, DES has assumed that the flow duration curve for one-hour is the same as for one-day (DES, 2007).

Temporary stream flow gages were installed at five of the six stations for the TMDL study (all but I93-NTC-01). The period of record for these gages is 7/1/06 to 6/30/07. This period is too short to develop a representative flow duration curve for these stations. Therefore, DES used a record extension technique to estimate historical flows using data from a permanent USGS stream gage on Beaver Brook at North Pelham (USGS Station Number 010965852).

Record extension can be performed if there is a period of overlapping data between a temporary and a long-term stream gage. The drainage areas for the two gages should be similar and the simultaneously measured values should be correlated (Nielsen, 1999).

To test for correlation, daily average flows at the five temporary stream gages were regressed against daily average flows measured at the permanent stream gage on Beaver Brook at North Pelham. The period of record for the regression was 7/1/06 to 6/30/07. The daily average values for all the stream gages were transformed by taking the natural logarithm in order to satisfy the conditions of homoscedasticity[1]. The transformed values were regressed using simple linear regression.

The parameters and error in the regressions are shown in Table 22. The correlation was excellent for 09-BVR and 10A-BVR and acceptable for I93-DIN-01, I93-POL-01V, and I93-POL-04X. The poorest correlation was observed for I93-POL-04X. The error in the linear regression ranged from 15% for 09-BVR to 70% for I93-POL-04X (note that the standard error of a ln-ln regression is equal to the percent error in the regression output).

The USGS recommends the Maintenance of Variance Extension (MOVE) type 1 for record extensions. MOVE more accurately predicts extreme high and low flows than linear regression (Nielsen, 1999; Helsel and Hirsh, 1992, p. 277). To estimate a daily average stream flow with the MOVE technique, the mean and standard deviation of the temporary and long-term gages are calculated for the period of simultaneous measurements. Then, the daily average flow from the long-term gage is adjusted according to the following formula:

[1] Homoscedasticity refers to uniform variance and residuals following a normal distribution. It is an underlying assumption required for simple linear regression.

$$\hat{Y}_i = \overline{Y} + \frac{S_y}{S_x}\left(X_i - \overline{X}\right)$$

where:

$\hat{Y}_i$ is the estimated daily average stream flow at the temporary gage,

$\overline{Y}$ is the mean stream flow at the temporary gage during the period of overlapping records,
S_y is the standard deviation of stream flow at the temporary gage during the period of overlapping records,
S_x is the standard deviation of stream flow at the long-term gage during the period of overlapping records,

$\overline{X}$ is the mean stream flow at the long-term gage during the period of overlapping records,

X_i is the measured daily average stream flow at the temporary gage,

The USGS stream gage on Beaver Brook at North Pelham has collected stream flow data since 10/1/1986. Therefore, the flow duration curves will be based on a 20 year record of daily average flows (10/1/1986 to 9/30/2006), which should be long enough to be representative of all flow conditions. The MOVE technique was used to estimate stream flows at the five temporary gages from 10/1/1986 to 6/30/2006. Measured stream flows at the five temporary gages were used for the period 7/1/06 to 9/30/06. The one-day and four-day average flow duration percentiles were calculated on the 20 year record for each of the stations (Tables 23 and 24, Figure 9).

A temporary stream gage was not installed at I93-NTC-01, therefore the historical record at this station was generated differently. For the period 10/1/1986 to 6/30/06, the drainage area ratio method was used to estimate flows at I93-NTC-01 from the historical record estimated for I93-DIN-01. A flow of 0.07 cfs was subtracted from each value to account for the average withdrawal from the W&E wellfield. Estimated values less than zero were set to zero. For the period, 7/1/06 to 9/30/06, estimated flow values based on stream flow measurements at I93-DIN-01 (as discussed in the previous section) were used. The one-day and four-day average flow duration percentiles were calculated on the 20 year record (Tables 23 and 24, Figure 9). The estimated flows at this station were zero (stagnant water) for more than 30% of the time.

To estimate the error in the estimated flow duration curves, the same technique was used to predict stream flows at the temporary gage sites between 7/1/06 and 6/30/07. Stream flow was actually measured at these sites during this period. Selected stream flow duration percentiles were calculated and compared to the same statistics calculated from measured values (Table 25). The flow statistics for the stations that had the best correlations with the long-term gage, 09-BVR and 10A-BVR, were within 9% of the correct values. Even though the correlation at I93-DIN-01 was not very good, the predicted statistics were also within 9% of the actual value. This result is probably due to the small range of flows measured at this site. The error in the statistics at I93-POL-01V and I93-POL-04X was less than 25% and 52%, respectively. This exercise shows that the process for estimating flow duration curves at the Activity #1 stations was reasonably accurate for 09-BVR, 10A-BVR, I93-DIN-01 and I93-POL-01V. There was significant error in the estimates for I93-POL-04X so this flow duration curve should be interpreted with caution. It was not possible to check the error in the flow duration curve estimate for I93-NTC-01. The low error values for the I93-DIN-01 flow statistics, which are the basis for the I93-NTC-01 values, suggest that the values for I93-NTC-01 will be acceptable. The error in the four-day average flow duration curve will be smaller than the error in the one-day flow duration curve because the range of flows will be smaller.

Chloride Imports to Study Watersheds

Chloride in the form of salt is imported to the study watersheds from several major sources: roadway deicing, food waste, water softeners, atmospheric deposition, and salt pile runoff. DES estimated the mass of salt imported from each source. Details for how these estimates were made are provided below. The import values presented in this section are expressed in terms of tons of salt. Chloride imports can be calculated from salt imports by multiplying by 0.6066 (1 ton of salt is equal to 0.6066 tons of chloride).

For the TMDL, groundwater was considered a pathway for chlorides, not an independent source. All of the chloride in the groundwater originated from one of the sources listed in the previous paragraph. The groundwater may retard the movement of chlorides through the watershed so that chloride imported to the watershed in one year is exported in another. However, to account for inputs to and outputs from the groundwater reservoir would require a detailed groundwater model which is beyond the scope of this study.

Roadway Deicing

The chloride imports for roadway deicing were estimated from the lane miles multiplied by the average salt application rate for FY07. Lane miles for roads maintained by the State and municipalities were provided by NH DOT from their roads datalayer (Table 26). Lane miles for private roads were calculated from the Plymouth State University datalayer (Sassan and Kahl, 2007). NH DOT compiled the average application rates of salt per lane mile from their patrol sheds and from municipalities in the study area for FY07 (values ranging from 4.1 to 15.7 tons NaCl/lane mile/yr). The application rate for private roads was assumed to be the average value of the municipal application rates (8.28 tons NaCl/lane mile/yr) because the deicing treatment for private roads will be more similar to municipal roads than highways. The roadway deicing loads were lumped into three groups: State roads, municipal roads, and private roads.

Parking Lot Deicing

The chloride imports for deicing parking lots were estimated by multiplying the surface area of parking lots by an average application rate of 6.4 tons of salt per acre per year. The total surface area of parking lots was calculated from the Plymouth State University parking lot datalayer (Sassan and Kahl, 2007). The area of parking lots in each watershed was calculated using ArcView software (Table 26). Parking lot driveways mapped by Plymouth State University were also clipped the watersheds and their surface area calculated by assuming that each driveway had two lanes and each lane was 12 feet wide. The average application rate of 6.4 tons of salt per acre per year was derived by Sassan and Kahl (2007) after researching typical practices in New Hampshire and other states. This value, once converted to tons salt per lane mile per year (9.3, assuming each lane mile is 12 feet wide) is approximately equal to the average application rate for municipal roadways (8.28 tons salt per lane mile per year). The application rate was multiplied by the combined area of parking lots and parking lot driveways to estimate the total load.

Food Waste and Sewage

Food waste and human sewage contains chloride from salt added to foods. Chloride from this source would be added to the watershed through septic systems and wastewater treatment facility outfalls. The total imports from this source were estimated by multiplying the population producing sewage in each watershed by a typical per capita rate of chloride excretion.

Population estimates for each watershed were generated from 2000 Census block data as described in a previous section (Table 4).

The typical concentration of chloride in raw wastewater is 50 mg/L (Metcalf and Eddy, 1991). Assuming domestic water usage of 75 gallons per person per day (DES septic system requirements), each person would contribute 12 pounds of chloride per year. Hall (1975) estimated per capita chloride loads of 4 to 7 pounds per year. Hall's estimates do not include chloride added to wastewater from household chemicals and industrial discharges. Therefore, for source loading, DES will use the upper bound estimate of 12 pounds of chloride per person per year (20 pounds of salt per person per year). The typical concentration of chloride in raw wastewater does not include any chloride introduced by water softeners. This source will be discussed separately in the next section.

A portion of the households in the TMDL watersheds are sewered. The wastewater treatment facility discharges for these sewer systems are outside of the TMDL watersheds. Therefore, chloride loads from the sewered households do not contribute to the overall chloride load of the TMDL watersheds. DES did not conduct a detailed analysis of municipal sewer service areas for this study. Instead, DES conservatively estimated that 50% of the households in each watershed were sewered. This percentage will undoubtedly be low for some watersheds and high for others. However, the estimated value provides a means to estimate the relative importance of this source. Furthermore, the effects of food waste sources from transient populations who enter the watershed for business cannot be reliably estimated. If this source is determined to be critical, DES can conduct additional research to refine this estimate.

Water Softeners

Water softeners contribute chloride to the watershed when the systems are back flushed and the brine is discharged to septic systems or wastewater treatment facilities. DES estimated the total load from water softeners in the study area by multiplying the number of water softener units by the average salt load per year from a unit.

The number of water softener units was estimated from the number of households in the study area. The 2000 Census block data was queried to calculate the number of housing units in each watershed as was discussed in a previous section (Table 4). The percent of private wells with water softeners was estimated from an evaluation of all the private wells that were tested between 1/1/01 and 3/1/05 in the NHDES Laboratory Database. For the towns of Windham, Salem, Derry, and Londonderry, the average percentage of wells tested with softeners was 25%. Finally, it was recognized that a portion of the households in the watersheds are served by town water and sewer systems. As with the food waste load estimates, DES assumed that 50% of the households were on town services. Therefore, the number of water softener units that discharge to the watershed was assumed to be 12.5% (50% of 25%) of the housing units in each watershed.

The rate of salt discharge per water softener was estimated from a DES survey of public water supply systems in 2004. The survey gathered information from public water supplies in the I-93 expansion corridor in southern New Hampshire. The average salt use per gallon of treated water from the survey was 0.006 pounds per gallon. For a typical household consisting of 2.3 people using 75 gallons per person per day (DES septic system requirements), each water softener should generate 378 pounds of salt per year.

Only one public water supply in the TMDL watersheds has a water softener. The W&E well field, operated by Pennichuck Corporation, is in the North Tributary to Canobie Lake watershed. The brine from this water softener started to be diverted to a holding tank and trucked to the Nashua wastewater treatment facility in September 2005. Therefore, this water softener unit did not contribute to the chloride loads during the study period.

Atmospheric Deposition

The chloride load from atmospheric deposition was calculated from the area of each watershed multiplied by the annual wet deposition rate from the closest station from the National Atmospheric Deposition Program (http://nadp.sws.uiuc.edu/). DES calculated the watershed areas using ArcView software. The National Atmospheric Deposition Program measured the wet deposition rate of chloride in Middlesex MA (Site MA13) in CY2006 to be 6.69 Kg Cl/Ha. The chloride deposition rate was divided by 0.6066 to convert it to NaCl (11.01 kg NaCl/Ha).

Salt piles

During the winter of FY07, Plymouth State University mapped all of the parking lots in the four TMDL watersheds. As part of this mapping, PSU also noted salt storage locations in the watersheds. Each location was photographed (if possible) and the coordinates recorded. DES also asked DPWs from the municipalities to send in salt pile information. All the salt piles were cross checked for duplicates.

A total of 17 piles of salt or salt-sand mixture were mapped in the watershed. Four of the piles were managed by NH DOT or municipalities. The other 13 piles were managed by private organizations. Several other salt piles were identified by PSU or municipal officials but were found to be outside the study watersheds.

The salt piles were divided into two groups: (1) Large, deicing patrol yards managed by NH DOT or municipalities; and (2) Small salt piles managed by private organizations. The methods used to estimate salt loads from each of these types of salt piles are described below.

For the large, deicing piles, DES compiled information on the storage practices and estimated the salt loss. If the salt piles were completely covered by a structure, it was assumed that no salt was lost. Only one of the large, deicing salt-sand piles was uncovered. The Town of Salem operated a facility where a 600 cubic yard pile of salt-sand mixture (4:1 ratio) was stored uncovered up until February 2007. The pile is close to Policy Brook, upstream of the Salem Rest Area (Figure 10). Salt lost from this pile discharges to Policy Brook near the rest area through a small stream and groundwater. To estimate the salt loss from this pile, DES measured the chloride export in Policy Brook upstream of the pile at I93-POL-03 and downstream of the pile at I93-POL-01V. Continuous measurements of chloride export were made at these two stations between 1/1/07 and 3/31/07. The difference in chloride export values for this period was 253 tons of chloride per year (417 tons salt per year). Assuming this period is representative of annual conditions, 417 tons of salt are discharged to the brook in the 0.5 mile stretch of river between I93-POL-03 and I93-POL-04X. Figure 10 shows the watershed area for the stretch of river between the two stations. The salt load from other sources to this area can be estimated from the difference between the salt loads for the I93-POL-03 and the I93-POL-01V watersheds. For all other sources besides salt piles, this difference was 104 tons of salt per year. Therefore, the salt pile can be assumed to contribute 313 tons of salt per year.

The DES estimate of salt losses from the former Salem DPW salt-sand pile value is supported by a field study conducted by the U.S. Geological Survey in the fall of 2006 (Harte, 2007). The USGS report shows that chloride concentrations were not uniform but were high at the point of salt pile discharge and between the rest area and I-93. Two methods were used to estimate the salt load from groundwater in this reach. The salt pile was major source of salt to the groundwater during the time of the study because winter deicing activities had not begun. The residual method subtracted the observed load at I93-POL-03 and two small tributaries from the observed load at I93-POL-02 (just upstream of I93-POL-01V). The outcome of this method was an estimate of 139 tons of chloride per year (229 tons of salt per year) for the day of the observation (November 7, 2006). The USGS also used the darcy-flow method to estimate groundwater flux from piezometers and multiplied it by the shallow groundwater chloride concentration. The outcome of this method was an estimate of 548 tons of chloride per year (903 tons of salt per year). The USGS considered the two methods to bracket the range of possible loads. The DES estimate falls in the middle of the two USGS estimates.

For the small, privately managed salt piles, DES reviewed the photographs to estimate the volume of the pile to the nearest 10 cubic yards. All salt-sand piles were assumed to be 20% salt (4:1 mixture by volume). Only one pile of straight salt was identified (Rockingham Park). The rate of salt loss was determined from the mass of salt in the pile (product of volume and salt-sand mixture) and the loss rate from Environment Canada (EC, 2000). A study in New Brunswick measured the leachate from an uncovered salt-sand pile and found that 33% of the salt in the original pile was lost. From the photographs, DES determined whether the piles were completely covered, partially covered or uncovered. If the pile was covered by shed or other structure, it was assumed that none of the pile was exposed. If the pile was covered by a tarp or was inadequately covered by a shed, it was assumed that 20% of the pile was exposed. If the pile was uncovered, it was assumed that 100% of the pile was exposed. The fraction of salt lost from the pile was calculated as the product of the percent of the pile that was exposed and the assumed loss rate of 33%. Therefore, a completely covered pile was assumed to lose 0% of its salt (0%*33%). A partially covered pile was assumed to lose 6.7% of its salt (20%*33%). An uncovered pile was assumed to lose 33% of its salt (100%*33%).

An inventory of the salt piles in the study area and their estimated salt losses is provided in Table 27.

Total Salt Loads

The salt imports to each watershed by source are shown in Table 28 and Figure 11. In Table 29, the application rates for each of the sources have been summarized. Pie charts for the Policy Brook, Beaver Brook, Dinsmore Brook and North Tributary to Canobie Lake watersheds are provided in Figures 12 through 17. Approximately 90% of the salt imports to the study watersheds were from roadway and parking lot deicing.

Chloride Exports from Study Watersheds

The chloride exports from watersheds were calculated by multiplying the near continuous measurements of chloride concentrations and stream flow. Chloride export is useful for determining the mass balance of salt in the watersheds. The export calculation was made with chloride concentration in units of mg/L and flow in units of cfs with a conversion factor of 0.9837 to produce units of tons of chloride per year. With these units, the average chloride export for the year is the same value as the total chloride export during the year. For example, the average export for station I93-POL-01V for the period 7/1/06 to 6/30/07 was 1,563 tons of chloride per year, which means that 1,563 tons of chloride were exported from the watershed over this period.

The chloride export calculation was only performed for stations which had at least 80% data completeness between 7/1/06 and 6/30/07 so that the results would be comparable between stations. The results for each station are provided in Table 30.

Chloride Mass Balance in Study Watersheds

The mass balance of any conservative material in a watershed is simply:

$$\textit{Imports - Exports = Change in storage}$$

Chloride import and export data are available for the Activity #1 watersheds. The chloride import, export, and the apparent change in storage are shown in Table 31 and Figure 18. The same results, normalized by the watershed area, are provided in Table 32 and 19.

The import and export values calculated for the Beaver Brook and Canobie Lake tributary watersheds were almost equal (+/- 20%). In contrast, the import values for the Policy Brook watershed (I93-POL-01V, I93-POL-04X) were much higher than the export values. These data suggest that approximately 50% of the chloride import to the watershed in FY07 was retained (1,357 tons Cl/year, 2,238 tons salt/year).

The large retention of chloride in the Policy Brook watershed raised concerns that either the import or export estimates (or both) are inaccurate. However, analysis of the underlying data did not discover any obvious errors. The component of the salt import values with the most uncertainty is the salt application rate to parking lots (6.4 tons salt/year/acre). In the Policy Brook watershed, there are 379 acres of parking lots, which amounts to 2,426 tons of salt imports per year. The application rate on parking lots would have to be reduced to almost zero to eliminate the large difference between imports and exports. Therefore, it does not appear that the parking lot salt application rate is the reason for the difference. The rest of the salt import estimates are either based on well researched numbers or are small contributors to the total. The salt export values via Policy Brook are based on empirical measurements of chloride concentrations and streamflow which should be very accurate. Finally, the relatively good correspondence between salt imports and exports in the Beaver Brook watershed indicates that the method for estimating salt imports and exports is sound.

One explanation for the lower export values compared to import values is that water is leaving the Policy Brook by pathways other than Policy Brook. The annual average stream flow per square mile in the Policy Brook watershed (1.54 cfsm) is 38% lower than for the Beaver Brook watershed (2.13 cfsm). Two watersheds experiencing the same weather and having similar geology should have similar stream flow yields. Some water is removed for the Policy Brook watershed by a withdrawal from Canobie Lake for the Town of Salem drinking water supply. In 2006, this withdrawal amounted to 0.15 cfsm, which is not enough to explain the difference between the two watersheds. Water might also be leaving the Policy Brook watershed through shallow groundwater flow. If the stream flow yield for the two watersheds were equal, the chloride export from Policy Brook would only be 26% less than the import value, which is similar to the ratio observed in Beaver Brook.

Chloride Concentrations and Export Relative to Hydrologic Condition

EPA recommends the use of load duration curves for TMDLs for which stream flow is significantly correlated with water quality (EPA, 2007). Chloride concentrations in streams are largely controlled by stream flow because chloride does not degrade and is conservatively transported through the environment. Load duration curves can be used to identify critical hydrologic conditions when violations of the water quality standard occur.

In Appendix C, the chloride concentrations have been plotted against flow exceedence percentile. The flow exceedences percentile was determined by matching the measured stream flow to the flow duration curves developed in a previous section.

The flow exceedences percentiles are typically grouped into five hydrologic conditions (EPA, 2007): High flows (0-10%); Moist conditions (10-40%), Mid-Range flows (40-60%), Dry conditions (60-90%), and Low flows (90-100%). Summary statistics for the daily average chloride concentrations and chloride export in each of these hydrologic conditions are presented in Tables 33 and 34. The same statistics for four day average values are shown in Tables 35 and 36. Chronic water quality standards were the basis for the targets in the tables because there were far more exceedences of the chronic water quality standard than the acute water quality standard in the study watersheds.

The figures and tables both indicate that the majority of the violations of the water quality standard occur during dry conditions. No measurements were made during low flows but it would be expected that violations would occur in this hydrologic condition as well. The violations occurred in both summer and winter. Therefore, the critical condition for water quality violations depends exclusively on stream flow. Please note that the hydrologic condition classification is based exclusively on stream flow, not precipitation. A small runoff or melt event during a period of low stream flow would still be considered "dry conditions".

Percent Reduction Goals

Two methods were used to estimate the percent reduction goals to meet water quality targets in each hydrologic condition. The results for each of these methods are shown in Table 37.

The first method was to calculate the percent reduction goal for each day (or 4 day period) based on the measured chloride export and the target corresponding to the measured flows. The target was set at 90% of the chronic water quality standard multiplied by the daily (or 4 day) average flow with an appropriate conversion factor. If the chloride export was below the target, no value was calculated. The statistics shown on Table 37 are the 90th percentile of the individual percent reduction goals within each hydrologic condition class. If there were less than five individual percent reduction goals in a hydrologic condition, the statistic was not calculated due to small sample size. This method for calculating the percent reduction goal was originally described in the QAPP (DES, 2006).

The second method calculated the percent reduction goal for each class based on the summary statistics for chloride concentrations within each class. Specifically, the difference between the 90th percentile chloride concentration in the class and the target (90% of the chronic water quality standard) was considered the percent reduction goal. This approach differs from the previous method because concentrations that did not exceed the target were included in the sample for the statistics.

For both methods, the percent reduction goal (PRG) was calculated with the following equation:

$$PRG = \left(\frac{Value - Target}{Value}\right) \times 100\%$$

The percent reduction goals in Table 37 confirm that the dry conditions are the critical conditions for all stations. The goals calculated from individual export PRGs and the chloride concentrations group by condition were in agreement. The results were also similar regardless of whether the daily average or 4-day average values were used.

The percent reduction goals for station I93-NTC-01 ranged from 37.8% to 41.2%. The percent reduction goals for I93-POL-01V and I93-POL-04X were 24.7-26.4% and 34.0-40.2%, respectively. No percent reduction goals were calculated for the stations in the Beaver Brook watershed. No violations of water quality standards occurred at these stations during the TMDL study, although violations have been documented in 2004 and 2005. The percent reduction goals calculated in this report are relevant to the conditions from 7/1/06 to 6/30/07, which was a mild winter with a relatively low deicing load.

Water Quality Violations Relative to Chloride Imports

The percent reduction goals from the previous section will be helpful for establishing TMDLs for the study watersheds; however, they are watershed-specific and cannot be applied to other watersheds. One of the expected benefits of the investment in monitoring for this TMDL study was to develop tools which could be applied to other watersheds in the state.

Figure 20 shows the relationship between chloride imports to the Activity #1 watersheds and the number of chronic water quality violations which occurred in the same year. The relationship is not linear but it does illustrate a threshold for chloride imports of approximately 140 tons Cl per year per square mile above which water quality violations occur. If the salt imports to other watersheds are known, this threshold could be used to identify watersheds where water quality violations are likely to occur.

While it is possible to estimate the salt imports to any watershed using the methods outlined in this report, it would be better to express the threshold in terms of land use characteristics which are readily available. Salt imports to the study watersheds were shown to be well correlated with the percent of developed land in the watershed (r^2=0.83, Figure 21). Using this linear relationship, the threshold of 140 tons Cl per year per square mile corresponds to approximately 6% of the watershed being developed (+/-2.5%, one standard deviation). This value is in agreement with other watershed studies which have shown that water quality problems typically occur after impervious surfaces cover 10% of the watershed (CWP, 2003; Deacon et al., 2005).

Summary

In this report, the data collected for the chloride TMDL studies has been summarized and analyzed. The statistics from this report will be used to establish TMDLs for the study watersheds.

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Table 1: Monitoring Stations for the TMDL Study

Activity	Station	Station Name	Town	Latitude (D M S)	Longitude (D M S)
#1	09-BVR	BEAVER BROOK AT KENDALL POND OUTLET	LONDONDERRY	42 50 23.04	-71 20 58.26
#1	10A-BVR	BEAVER BROOK AT FORDWAY EXT. BRIDGE	DERRY	42 52 21.14	-71 19 46.06
#1	I93-DIN-01	DINSMORE BROOK BEHIND CASTLETON BANQUET HALL	WINDHAM	42 48 22.98	-71 16 26.22
#1	I93-NTC-01	UNNAMED TRIB TO WEST BAY OF CANOBIE LAKE AT WEST SHORE RD	WINDHAM	42 48 5.61	-71 15 58.92
#1	I93-POL-01V	POLICY BK AT SALEM REST AREA OFF RAMP FROM I93	SALEM	42 45 13.28	-71 13 12.98
#1	I93-POL-04X	POLICY BROOK BEHIND KOHLS DEPT. STORE	SALEM	42 46 1.851	-71 13 22.7
#2	03-SHB	SHIELDS BK AT RTE 102	DERRY	42 52 43.2	-71 19 48.3
#2	04-WRB	WEST RUNNING BK AT RTE 28 BYP	DERRY	42 52 52.4	-71 18 9
#2	06-SHB	SHIELDS BK AT MADDEN RD	DERRY	42 53 22.9	-71 19 54.9
#2	08-SHB	SHIELDS BK AT COTEVILLE RD	LONDONDERRY	42 53 36.4	-71 20 23.7
#2	I93-BVRU03-01	UNNAMED TRIB TO BEAVER BK AT RTE 102	DERRY	42 53 21.3	-71 18 48
#2	I93-DIN-05	DINSMORE BK AT D/S FROM CONVENT	WINDHAM	42 48 33.9	-71 16 .5
#2	I93-POC-02	PORCUPINE BROOK AT S. POLICY ROAD	SALEM	42 45 48.5	-71 13 54.8
#2	I93-POCU01-01	TRIBUTARY OF PORCUPINE BROOK D/S SE SALEM BUSINESS PARK	SALEM	42 46 11.5	-71 14 21.7
#2	I93-POL-02N	SALEM DPW DRAINAGE DITCH TO POLICY BROOK	SALEM	42 45 23	-71 13 25.9
#2	I93-POL-03	POLICY BROOK AT KELLY ROAD	SALEM	42 45 35.1	-71 13 22.6
#2	I93-POL-06	PLEASANT ST	SALEM	42 46 35.6	-71 13 51.7
#2	I93-POLU01-01	BETWEEN RR TRACKS AND RTE 28, UPSTRM OF I-93 AND MALL	SALEM	42 46 26.6	-71 13 27.6
#2	I93-POLU02-02	RTE 97 (BROOKS PLAZA)	SALEM	42 46 56.1	-71 13 33.9
#2	I93-STB-02	SOUTH TRIB TO BEAVER BK NEAR RR TRACKS	DERRY	42 52 9.4	-71 19 19.1
#2	I93-WLPU-01	RTE 102, WHEELER POND OUTLET	LONDONDERRY	42 52 20	-71 20 12.2

Table 2: Monitoring Stations for Water Quality Studies in FY02 to FY06

Station	Station Name	Town	Latitude (D M S)	Longitude (D M S)
01-WRB	WEST RUNNING BK AT DERRY TOWN PARK	DERRY	42 52 43.9	-71 18 49.8
01X-SHB	SHIELDS BK D/S FROM SOUTH AVE	DERRY	42 52 34.2	-71 19 39.6
09J-BVR	BEAVER BK OFF OF REED ST	LONDONDERRY	42 50 49.2	-71 20 46.8
10-BVR	HARDY/GILCREST RD BRIDGE	LONDONDERRY	42 51 27.5	-71 20 10.1
12-BVR	BEAVER BK AT BIRCH ST	DERRY	42 55 42.1	-71 19 39.6
13-BVR	RTE 28 BRIDGE	DERRY	42 53 28.2	-71 18 40.6
I93-DIN-02	GOV. DINSMORE RD	WINDHAM	42 48 52.9	-71 16 38.2
I93-EAY-01	EAYERS RANGE BK AT EAYERS RANGE RD	LONDONDERRY	42 51 12.6	-71 21 3.3
I93-HDPU-00	TRIBUTARY TO HOODS POND AT MADDEN RD	DERRY	42 53 18.8	-71 19 50.2
I93-HDPU-01	RTE 28	LONDONDERRY	42 54 8	-71 21 42.2
I93-HDPU-02	STONEHENGE RD.	LONDONDERRY	42 54 5.8	-71 21 51.3
I93-NETC-01	RTE 111A NEAR SEARLES RD	WINDHAM	42 48 34.1	-71 15 24
I93-NETC-02	DOWNSTREAM FROM RTE 111	WINDHAM	42 48 5.3	-71 15 55.3
I93-NTB-01	GAMACHE RD OFF KENDALL PND RD	DERRY	42 51 0.2	-71 19 0.5
I93-NTC-02	RTE 111A IN NB AND SB LANES	WINDHAM	42 48 5.8	-71 16 4.6
I93-POC-05D	MUTUAL MART GAS STAT-UPSTRM OF I-93	SALEM	42 45 58.5	-71 14 39.9
I93-POC-05P	PORCUPINE BK AT QUILL LN	SALEM	42 45 48	-71 15 9.8
I93-POC-06	PORCUPINE BK AT PELHAM RD	SALEM	42 46 21.5	-71 15 21.2
I93-POC-07	BRADY AVE	SALEM	42 45 49.2	-71 15 34.2
I93-POC-08	BROOKDALE AVE	SALEM	42 46 25.3	-71 16 0.1
I93-POL-02	POLICY BROOK U/S FROM SALEM REST AREA ON RAMP TO I93	SALEM	42 45 13.4	-71 13 13.3
I93-POL-02T	CULVERT FROM I-93 TO POLICY BK ON I-93N RAMP AT REST AREA	SALEM	42 45 18.7	-71 13 24.6
I93-POL-04	CLUFF RD	SALEM	42 45 44.3	-71 13 21.4
I93-POL-07	SO. POLICY RD	SALEM	42 46 41.3	-71 14 19.5
I93-POL-10	BROOKDALE RD	SALEM	42 47 18.4	-71 14 51.9
I93-STB-09	S. TRIB TO BEAVER BK OFF FORDWAY EXT	DERRY	42 51 37.6	-71 19 7.6
I93-STC-01	WEST SHORE RD	WINDHAM	42 47 22.7	-71 16 2.3
I93-STC-02	SQUIRE ARMOUR RD	WINDHAM	42 47 10.1	-71 16 35.1
I93-WLPU-02	LONDONDERRY RD	LONDONDERRY	42 52 32.7	-71 20 22.1
I93-WLPU-03	TROLLEY CAR LANE	LONDONDERRY	42 53 12.8	-71 21 13.7

Table 3: Land Use in Study Watersheds

Station	Agriculture (%)	Cleared (%)	Developed (%)	Forested (%)	Transport-ation (%)	Wetland (%)	Area (Sq. Miles)
03-SHB	1.89	24.16	7.57	50.53	10.60	5.25	6.34
04-WRB	16.77	16.65	2.96	51.94	8.44	3.26	1.07
06-SHB	1.60	22.98	5.58	55.41	8.95	5.47	5.71
08-SHB	1.31	21.42	2.82	59.09	8.60	6.76	4.52
09-BVR	5.91	22.27	6.87	48.10	11.23	5.62	30.33
10A-BVR	5.93	21.25	6.09	50.98	9.88	5.86	23.97
I93-BVRU03-01	19.67	21.80	17.76	27.61	13.09	0.07	0.45
I93-DIN-01	4.19	10.53	6.68	60.64	14.78	3.18	0.55
I93-DIN-05	13.88	12.20	13.70	39.40	15.38	5.44	0.17
I93-NTC-01	7.85	19.15	2.99	38.93	18.84	12.24	0.20
I93-POC-02	4.41	18.29	14.39	48.00	11.54	3.36	4.53
I93-POCU01-01	1.99	18.16	14.33	52.09	10.11	3.33	3.70
I93-POL-01V	3.47	18.77	18.13	34.97	14.83	9.81	10.18
I93-POL-03	3.52	18.80	17.83	35.07	14.79	9.99	10.03
I93-POL-04X	2.99	19.33	17.74	26.15	17.33	16.47	5.04
I93-POL-06	2.87	14.61	10.43	32.49	14.36	25.24	2.95
I93-POLU01-01	1.02	29.68	21.13	20.41	23.78	4.00	1.76
I93-POLU02-02	0.85	32.59	13.78	22.88	25.64	4.26	0.85
I93-STB-02	0.29	20.70	4.74	52.23	9.57	12.47	0.75
I93-WPLU-01	2.14	18.96	7.50	51.97	18.04	1.38	1.36

* Cross walk between NH Land Cover Assessment classifications and groups

Group	NHLCA Classification
Agriculture	Hay/Rotation/Permanent Pasture
Agriculture	Row Crops
Cleared	Cleared/Other Open
Developed	Disturbed
Developed	Residential/Commercial/Industrial
Forested	Beech/Oak
Forested	Forested Wetland
Forested	Fruit Orchards
Forested	Hemlock
Forested	Mixed Forest
Forested	Other Hardwoods
Forested	Paper Birch/Aspen
Forested	White/Red Pine
Transportation	Transportation
Wetland	Non-forested Wetland
Wetland	Open Water

Table 4: Demographics in Study Watersheds

Station	Population	Housing Units	Population Density (people per sq.mile)	Percent "Urbanized Area" Census Classification
03-SHB	6,448	2,503	1,016	79.2%
04-WRB	403	155	377	10.6%
06-SHB	4,636	1,750	813	76.8%
08-SHB	2,917	956	645	70.8%
09-BVR	29,895	11,525	986	66.0%
10A-BVR	24,135	9,387	1,007	56.9%
I93-BVRU03-01	1,222	554	2,742	100.0%
I93-DIN-01	103	30	186	28.6%
I93-DIN-05	33	9	198	44.4%
I93-NTC-01	38	15	191	100.0%
I93-POC-02	2,023	761	446	100.0%
I93-POCU01-01	1,515	569	409	99.9%
I93-POL-01V	10,463	4,310	1,027	98.4%
I93-POL-03	10,234	4,218	1,021	98.4%
I93-POL-04X	6,421	2,586	1,274	96.8%
I93-POL-06	2,146	851	728	94.6%
I93-POLU01-01	4,062	1,639	2,302	100.0%
I93-POLU02-02	2,148	828	2,522	100.0%
I93-STB-02	1,049	354	1,401	39.6%
I93-WPLU-01	475	178	349	100.0%

Table 5: Data Logger Deployments for Water Quality Measurements in FY07 for the TMDL Study

Activity	Station	InstallationID	Start Date	End Date
1	09-BVR	I93T001	6/30/06	4/12/07
		I93T033	4/12/07	5/24/07
		I93T034	5/24/07	7/3/07
	10A-BVR	I93T002	6/30/06	4/12/07
		I93T032	4/12/07	7/3/07
	I93-DIN-01	I93T004	6/30/06	4/11/07
		I93T028	4/11/07	7/3/07
	I93-NTC-01	I93T003	6/30/06	4/11/07
		I93T029	4/11/07	7/3/07
	I93-POL-01V	I93T005	6/30/06	4/12/07
		I93T030	4/12/07	7/3/07
	I93-POL-04X	I93T006	6/30/06	10/31/06
		I93T035	10/31/06	4/12/07
		I93T031	4/12/07	7/3/07
2	03-SHB	I93T016	12/21/06	4/11/07
	04-WRB	I93T020	1/11/07	4/11/07
	06-SHB	I93T018	12/22/06	2/1/07
		I93T022	2/1/07	3/7/07
		I93T027	3/7/07	4/11/07
	08-SHB	I93T017	12/22/06	4/11/07
	I93-BVRU03-01	I93T019	12/22/06	2/8/07
		I93T023	2/8/07	3/7/07
		I93T026	3/7/07	4/11/07
	I93-DIN-05	I93T011	12/6/06	4/13/07
	I93-POC-02	I93T010	12/6/06	4/12/07
	I93-POCU01-01	I93T008	11/30/06	4/12/07
	I93-POL-02N	I93T009	12/6/06	4/12/07
	I93-POL-03	I93T007	11/30/06	4/12/07
	I93-POL-06	I93T014	12/6/06	2/1/07
		I93T036	2/8/07	4/13/07
	I93-POLU01-01	I93T012	12/6/06	4/13/07
	I93-POLU02-02	I93T013	12/6/06	2/21/07
		I93T037	3/1/07	4/13/07
	I93-STB-02	I93T021	12/22/06	4/12/07
	I93-WLPU-01	I93T015	12/21/06	4/12/07

Table 6: Data Logger Deployments for Water Quality Measurements in FY02-FY06 for Water Quality Studies in the Beaver Brook Watershed

Station	InstallationID	ProjectID	Start Date	End Date	Recording Interval (min)
01-WRB	I93DES19	I93CHLOR	12/28/05	04/26/06	15
01X-SHB	I93DES17	I93CHLOR	12/28/05	04/26/06	15
09J-BVR	I93DOT20	I93CHLOR	12/19/05	05/02/06	15
10A-BVR	I93DOT03	I93CHLOR	12/17/03	04/15/04	15
10A-BVR	I93DOT07	ARMP	01/20/05	01/26/05	60
10A-BVR	I93DOT07	I93CHLOR	01/20/05	01/26/05	60
10A-BVR	I93DOT08	I93CHLOR	03/11/05	04/08/05	60
10A-BVR	I93DES16	I93CHLOR	12/28/05	03/15/06	15
10A-BVR	I93DES22	I93CHLOR	03/16/06	04/26/06	15
10-BVR	I93EPA02	ARMP	01/10/03	01/31/03	15
10-BVR	I93EPA02	I93CHLOR	01/10/03	01/31/03	15
10-BVR	I93DOT02	I93CHLOR	12/28/03	03/11/04	15
10-BVR	I93EPA22	I93CHLOR	12/17/04	03/25/05	60
12-BVR	I93DES18	I93CHLOR	12/28/05	04/26/06	15
13-BVR	I93DES20	I93CHLOR	12/28/05	02/01/06	15
13-BVR	I93DES21	I93CHLOR	02/02/06	04/26/06	15
13-BVR	13-BVR	RIVPERI	08/09/06	08/14/06	15
I93-EAY-01	I93DOT19	I93CHLOR	12/19/05	05/02/06	15
I93-HDPU-00	I93EPA26	I93CHLOR	12/20/04	04/12/05	60
I93-HDPU-00	I93DOT21	I93CHLOR	12/19/05	03/31/06	15
I93-HDPU-01	I93DOT18	I93CHLOR	12/19/05	01/05/06	15

Table 7: Data Logger Deployments for Water Quality Measurements in FY02-FY06 for Water Quality Studies in the Policy Brook, Dinsmore Brook and North Tributary to Canobie Lake Watersheds

Station	InstallationID	ProjectID	Start Date	End Date	Recording Interval (min)
I93-DIN-01	I93DOT04	I93CHLOR	12/17/03	04/15/04	15
I93-DIN-01	I93DOT09	I93CHLOR	12/09/04	04/15/05	15
I93-DIN-01	I93DOT16	I93CHLOR	11/18/05	05/02/06	15
I93-DIN-05	I93DOT17	I93CHLOR	11/18/05	05/02/06	15
I93-NTC-01	I93EPA03	I93CHLOR	08/24/04	10/05/04	15
I93-POC-02	I93EPA05	I93CHLOR	12/17/03	03/26/04	15
I93-POC-02	I93DOT11	I93CHLOR	12/09/04	04/15/05	15
I93-POC-05D	I93DOT05	I93CHLOR	12/17/03	04/22/04	15
I93-POC-05D	I93DOT10	I93CHLOR	12/09/04	04/15/05	15
I93-POC-05P	I93EPA21	I93CHLOR	12/15/05	04/13/06	60
I93-POC-06	I93EPA20	I93CHLOR	12/15/05	04/13/06	60
I93-POCU01-01	I93EPA06	I93CHLOR	06/04/04	08/06/04	15
I93-POL-02	I93DES02	I93CHLOR	12/11/02	04/30/03	15
I93-POL-02	I93EPA09	I93CHLOR	12/17/03	01/30/04	15
I93-POL-02	I93EPA10	I93CHLOR	02/02/04	03/26/04	15
I93-POL-02	I93EPA11	I93CHLOR	04/16/04	08/27/04	60
I93-POL-02	I93EPA12	I93CHLOR	09/10/04	11/12/04	60
I93-POL-02	I93EPA32	I93CHLOR	12/17/04	04/12/05	60
I93-POL-02	I93EPA13	I93CHLOR	11/05/05	12/12/05	15
I93-POL-02	I93EPA15	I93CHLOR	12/12/05	02/16/06	60
I93-POL-02	I93EPA16	I93CHLOR	02/16/06	05/19/06	15
I93-POL-02T	E0806041	I93CHLOR	08/06/04	08/24/04	15
I93-POL-02T	I93EPA14	I93CHLOR	11/08/05	01/06/06	15
I93-POL-02T	I93EPA17	I93CHLOR	01/06/06	05/19/06	60
I93-POL-04X	I93EPA07	I93CHLOR	12/17/03	01/30/04	15
I93-POL-04X	I93EPA08	I93CHLOR	01/30/04	03/26/04	15
I93-POL-04X	I93EPA31	I93CHLOR	09/10/04	12/17/04	60
I93-POL-04X	I93DOT13	I93CHLOR	09/15/04	11/01/04	60
I93-POL-04X	I93DOT15	I93CHLOR	11/01/04	04/15/05	15
I93-POL-06	I93EPA18	I93CHLOR	12/12/05	01/20/06	15
I93-POL-06	I93EPA19	I93CHLOR	01/20/06	04/13/06	60
I93-POLU01-01	I93DOT06	I93CHLOR	12/17/03	04/15/04	15
I93-POLU01-01	I93DOT12	I93CHLOR	09/15/04	11/01/04	60
I93-POLU01-01	I93DOT14	I93CHLOR	11/01/04	04/15/05	15
I93-POLU01-01	I93DOT22	I93CHLOR	12/12/05	05/02/06	15

Table 8: Summary Statistics of Water Temperature Measured by In-Situ Dataloggers in FY07

Station	Period of Record	Number of measurements	Minimum (deg C)	Average (deg C)	Maximum (deg C)
09-BVR	7/1/06-6/30/07	35,002	-0.23	11.03	29.73
10A-BVR	7/1/06-6/30/07	34,709	-0.21	11.33	29.30
I93-DIN-01	7/1/06-6/30/07	34,997	0.07	9.19	23.73
I93-NTC-01	7/1/06-6/30/07	33,148	-0.07	9.79	26.46
I93-POL-01V	7/1/06-6/30/07	34,985	0.01	10.75	26.22
I93-POL-04X	7/1/06-6/30/07	33,747	-0.08	10.53	27.10
03-SHB	1/1/07-3/31/07	8,581	-4.94	2.04	15.98
04-WRB	1/1/07-3/31/07	8,488	-0.50	0.44	9.41
06-SHB	1/1/07-3/31/07	6,026	-0.69	0.86	8.33
08-SHB	1/1/07-3/31/07	8,617	-0.50	0.61	8.67
I93-BVRU03-01	1/1/07-3/31/07	7,993	-0.11	1.90	9.41
I93-DIN-05	1/1/07-3/31/07	8,627	-0.06	1.66	9.01
I93-POC-02	1/1/07-3/31/07	8,620	0.01	1.14	8.37
I93-POCU01-01	1/1/07-3/31/07	8,625	-0.06	1.31	11.65
I93-POL-02N	1/1/07-3/31/07	5,272	-0.35	2.54	7.56
I93-POL-03	1/1/07-3/31/07	8,614	0.53	1.60	9.30
I93-POL-06	1/1/07-3/31/07	6,960	-0.02	1.13	10.36
I93-POLU01-01	1/1/07-3/31/07	7,611	-0.07	0.80	9.55
I93-POLU02-02	1/1/07-3/31/07	7,858	-1.76	0.77	11.28
I93-STB-02	1/1/07-3/31/07	8,626	-0.10	1.56	10.36
I93-WLPU-01	1/1/07-3/31/07	5,787	1.01	2.83	6.94

Table 9: Summary Statistics of Specific Conductance Measured by In-Situ Dataloggers in FY07

Station	Period of Record	Number of measurements	Minimum (uS/cm)	Average (uS/cm)	Maximum (uS/cm)
09-BVR	7/1/06-6/30/07	35,002	135.24	291.79	992.00
10A-BVR	7/1/06-6/30/07	34,707	119.43	253.61	1098.75
I93-DIN-01	7/1/06-6/30/07	34,997	149.90	591.64	2302.45
I93-NTC-01	7/1/06-6/30/07	33,148	41.45	567.54	2322.83
I93-POL-01V	7/1/06-6/30/07	34,985	67.13	602.65	2065.75
I93-POL-04X	7/1/06-6/30/07	33,747	60.25	605.44	3369.50
03-SHB	1/1/07-3/31/07	8,622	184.23	311.59	1,190.00
04-WRB	1/1/07-3/31/07	8,488	84.28	172.77	272.20
06-SHB	1/1/07-3/31/07	6,026	108.63	306.29	1,542.25
08-SHB	1/1/07-3/31/07	8,617	49.33	227.12	6,604.75
I93-BVRU03-01	1/1/07-3/31/07	7,993	183.58	490.53	3,164.50
I93-DIN-05	1/1/07-3/31/07	8,593	213.20	621.24	1,927.83
I93-POC-02	1/1/07-3/31/07	8,620	224.25	468.77	1,007.50
I93-POCU01-01	1/1/07-3/31/07	8,625	281.75	1,129.38	2,284.25
I93-POL-02N	1/1/07-3/31/07	5,272	400.60	5,001.12	13,543.40
I93-POL-03	1/1/07-3/31/07	8,614	252.25	568.65	1,580.75
I93-POL-06	1/1/07-3/31/07	6,818	109.73	636.88	3,837.50
I93-POLU01-01	1/1/07-3/31/07	7,611	302.40	893.44	1,977.98
I93-POLU02-02	1/1/07-3/31/07	5,344	151.18	546.06	3,498.08
I93-STB-02	1/1/07-3/31/07	8,626	162.25	273.02	869.25
I93-WLPU-01	1/1/07-3/31/07	5,329	271.25	402.81	2,216.25

Table 10: Summary Statistics of Chloride Concentrations Calculated from Specific Conductance Measured by In-Situ Dataloggers in FY07

Station	Period of Record	Number of measurements	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)
09-BVR	7/1/06-6/30/07	35,001	19.52	67.58	282.55
10A-BVR	7/1/06-6/30/07	34,707	14.66	55.86	315.32
I93-DIN-01	7/1/06-6/30/07	25,117	24.02	114.34	684.86
I93-NTC-01	7/1/06-6/30/07	33,135	1.07	152.27	691.11
I93-POL-01V	7/1/06-6/30/07	34,975	7.66	163.02	612.19
I93-POL-04X	7/1/06-6/30/07	33,737	0.72	163.89	1012.44
03-SHB	1/1/07-3/31/07	8,622	34.56	73.66	343.33
04-WRB	1/1/07-3/31/07	8,488	3.88	31.04	61.57
06-SHB	1/1/07-3/31/07	6,026	11.35	72.03	451.47
08-SHB	1/1/07-3/31/07	8,574	0.04	47.97	2,005.66
I93-BVRU03-01	1/1/07-3/31/07	7,993	34.36	128.59	949.50
I93-DIN-05	1/1/07-3/31/07	8,593	43.45	168.72	569.84
I93-POC-02	1/1/07-3/31/07	8,620	46.85	121.91	287.31
I93-POCU01-01	1/1/07-3/31/07	8,625	64.50	324.72	679.26
I93-POL-02N	1/1/07-3/31/07	5,272	100.99	1,513.34	4,135.83
I93-POL-03	1/1/07-3/31/07	8,614	55.44	152.58	463.29
I93-POL-06	1/1/07-3/31/07	6,818	11.69	173.52	1,156.12
I93-POLU01-01	1/1/07-3/31/07	7,611	70.84	252.29	585.24
I93-POLU02-02	1/1/07-3/31/07	5,343	24.41	145.65	1,051.91
I93-STB-02	1/1/07-3/31/07	8,626	27.81	61.82	244.86
I93-WLPU-01	1/1/07-3/31/07	5,329	61.27	101.66	658.39

Table 11: Summary Statistics of Chloride Concentrations from Grab Samples in FY07

Station	Period of Record	Number of samples	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)
09-BVR	6/30/06-7/3/07	20	41	63	95
10A-BVR	6/30/06-7/3/07	20	36	54	85
I93-DIN-01	6/30/06-7/3/07	21	79	126	210
I93-NTC-01	6/30/06-7/3/07	20	64	165	400
I93-POL-01V	6/30/06-7/3/07	21	72	157	320
I93-POL-04X	6/30/06-7/3/07	21	69	155	330
03-SHB	12/21/06-4/11/07	7	44	82	180
04-WRB	12/22/06-4/11/07	7	24	31	36
06-SHB	12/22/06-4/11/07	7	33	55	73
08-SHB	12/22/06-4/11/07	7	33	49	62
I93-BVRU03-01	12/21/06-4/11/07	7	65	117	240
I93-DIN-05	10/4/06-4/13/07	8	110	148	190
I93-POC-02	12/21/06-4/12/07	7	64	96	140
I93-POCU01-01	12/21/06-4/12/07	7	120	257	360
I93-POL-02N	12/21/06-4/12/07	6	520	1,260	1,900
I93-POL-03	12/21/06-4/12/07	7	83	133	210
I93-POL-06	12/20/06-4/13/07	7	89	141	220
I93-POLU01-01	12/20/06-4/13/07	7	100	174	280
I93-POLU02-02	12/20/06-4/13/07	7	87	2,835	14,000
I93-STB-02	12/22/06-4/12/07	7	43	54	73
I93-WLPU-01	12/21/06-4/12/07	7	52	79	95

Table 12: Summary Statistics of Chloride Concentrations from Grab Samples in FY02-FY06

Watershed	Station	Number of Samples	Average Chloride Conc. (mg/L)	Max Chloride Conc. (mg/L)	Number of Samples >230 mg/L	Number of Samples >860 mg/L
Beaver Brook	10A-BVR	16	93.19	180.00	0	0
	10-BVR	18	92.50	200.00	0	0
	I93-HDPU-00	1	62.00	62.00	0	0
	I93-HDPU-01	12	71.17	99.00	0	0
	I93-HDPU-02	12	61.08	80.00	0	0
	I93-NTB-01	9	54.56	86.00	0	0
	I93-STB-09	13	95.54	130.00	0	0
	I93-WLPU-01	12	133.17	180.00	0	0
	I93-WLPU-02	5	117.60	141.00	0	0
	I93-WLPU-03	12	106.83	130.00	0	0
Dinsmore Brook	I93-DIN-01	13	151.00	220.00	0	0
	I93-DIN-02	12	14.08	22.00	0	0
North Trib. To Canobie	I93-NTC-01	27	207.96	340.00	11	0
	I93-NTC-02	4	102.00	110.00	0	0
Policy Brook	I93-NETC-01	12	68.33	88.00	0	0
	I93-NETC-02	11	198.18	230.00	0	0
	I93-POC-02	8	108.75	173.00	0	0
	I93-POC-05D	1	77.00	77.00	0	0
	I93-POC-07	12	108.08	200.00	0	0
	I93-POC-08	5	34.20	37.00	0	0
	I93-POCU01-01	11	388.27	529.00	9	0
	I93-POL-02	7	155.57	193.00	0	0
	I93-POL-02N	15	1,155.20	2,360.00	14	10
	I93-POL-02T	2	403.00	425.00	2	0
	I93-POL-04	10	174.50	250.00	2	0
	I93-POL-04X	3	157.33	280.00	1	0
	I93-POL-06	10	208.40	329.00	3	0
	I93-POL-07	10	152.10	210.00	0	0
	I93-POL-10	10	79.30	163.00	0	0
	I93-POLU01-01	1	290.00	290.00	1	0
	I93-POLU02-02	10	205.80	330.00	2	0
	I93-STC-01	17	78.06	220.00	0	0
	I93-STC-02	17	32.12	72.00	0	0

*Does not include grab samples collected during data logger deployments.

Table 13: Violations of Chloride Water Quality Standards* from In-Situ Datalogger Deployments in FY07

Station	Period of Record	Number of Violations of Acute Standard (1 hour rolling average)	Number of Violations of Chronic Standard (4 day rolling average)
09-BVR	7/1/06-6/30/07	0	0
10A-BVR	7/1/06-6/30/07	0	0
I93-DIN-01	10/12/06-6/30/07	0	0
I93-NTC-01	7/1/06-6/30/07	0	17 (68.1 d)
I93-POL-01V	7/1/06-6/30/07	0	22 (87.7 d)
I93-POL-04X	7/1/06-6/30/07	3 (2.5 hr)	16 (66.0 d)
03-SHB	1/1/07-3/31/07	0	0
04-WRB	1/1/07-3/31/07	0	0
06-SHB	1/1/07-3/31/07	0	0
08-SHB	1/1/07-3/31/07	4 (3.5 hr)	0
I93-BVRU03-01	1/1/07-3/31/07	1 (1.3 hr)	0
I93-DIN-05	1/1/07-3/31/07	0	3 (13.2 d)
I93-POC-02	1/1/07-3/31/07	0	0
I93-POCU01-01	1/1/07-3/31/07	0	23 (92.0 d)
I93-POL-02N	1/1/07-3/31/07	1,147 (1,147 hr)	16 (59.7 d)
I93-POL-03	1/1/07-3/31/07	0	0
I93-POL-06	1/1/07-3/31/07	7 (6.8 hr)	6 (23.3 d)
I93-POLU01-01	1/1/07-3/31/07	0	13 (53.0 d)
I93-POLU02-02	1/1/07-3/31/07	4 (3.8 hr)	2 (8.0 d)
I93-STB-02	1/1/07-3/31/07	0	0
I93-WLPU-01	1/1/07-3/31/07	0	0

1. From Env-Ws 1703.21, chloride concentrations should not exceed 860 mg/L for acute exposures (1 hour duration) or 230 mg/L for chronic exposures (4 day duration).

2. Rolling averages were calculated for all possible blocks of 1 hour or 96 hours. The time blocks overlapped. The 1 hour average value was calculated if four specific conductance measurements were made within the hour at 15 minute increments. The 96 hour average value was calculated if 365 specific conductance measurements were made with the four day period (95% data completeness).

3. For violations identified by rolling averages, each independent period of violation was identified by the beginning of the period of the first overlapping violation and the end of the period of the last overlapping violation. The total duration of each independent period was calculated. The number of violations corresponding to each independent period was calculated by dividing the duration by 1 hour or 96 hours and rounding to the nearest integer. The number of violations for the period of record was summed for all the independent periods of violation. The total amount of time in violation of the water quality standard is shown in parentheses.

4. Periods of violation occasionally overlap the beginning of the study period because averages were calculated on a trailing edge basis. All stations were treated equally so this practice does not introduce bias.

Table 14: Periods in Violation of the Acute Water Quality Standard from Water Quality Monitoring in FY07

Station	Violation Episode	Start Time	End Time	Duration (hours)	Number of Violations
I93-POL-04X	1	3/2/07 10:00	3/2/07 12:30	2.5	3
08-SHB	1	3/2/07 12:00	3/2/07 15:30	3.5	4
I93-BVRU03-01	1	1/1/07 6:30	1/1/07 7:45	1.2	1
I93-POL-02N	1	12/31/06 23:00	1/1/07 14:00	15.0	15
	2	1/1/07 15:30	1/1/07 18:45	3.2	3
	3	1/1/07 19:30	1/1/07 22:30	3.0	3
	4	1/2/07 4:30	1/8/07 7:00	146.5	146
	5	1/8/07 9:45	1/11/07 9:45	72.0	72
	6	1/11/07 10:45	1/15/07 8:30	93.8	94
	7	1/16/07 0:30	1/31/07 11:15	370.7	371
	8	2/28/07 15:00	3/3/07 16:00	73.0	73
	9	3/4/07 6:30	3/6/07 17:30	59.0	59
	10	3/16/07 12:45	3/18/07 4:15	39.5	40
	11	3/19/07 4:15	3/19/07 7:30	3.2	3
	12	3/20/07 19:45	3/31/07 23:45	268.0	268
I93-POL-06	1	1/1/07 6:00	1/1/07 7:30	1.5	2
	2	1/15/07 7:30	1/15/07 9:15	1.7	2
	3	1/19/07 0:45	1/19/07 2:00	1.3	1
	4	3/2/07 9:30	3/2/07 11:45	2.3	2
I93-POLU02-02	1	1/27/07 2:15	1/27/07 4:15	2.0	2
	2	3/2/07 10:00	3/2/07 11:45	1.8	2

Table 15: Periods in Violation of the Chronic Water Quality Standard from Water Quality Monitoring in FY07

Station	Violation Episode	Start Time	End Time	Duration (days)	Number of Violations
I93-NTC-01	1	7/3/06 2:00	8/11/06 21:45	39.8	10
	2	10/3/06 2:00	10/7/06 20:45	4.8	1
	3	1/30/07 4:15	2/22/07 16:30	23.5	6
I93-POL-01V	1	7/27/06 13:15	8/21/06 13:30	25.0	6
	2	9/8/06 17:45	9/22/06 14:00	13.8	3
	3	10/6/06 3:45	10/12/06 10:30	6.3	2
	4	1/27/07 11:15	2/12/07 4:45	15.7	4
	5	2/13/07 23:15	3/4/07 3:30	18.2	5
	6	6/22/07 7:30	6/30/07 23:45	8.7	2
I93-POL04X	1	8/9/06 1:15	8/16/06 0:45	7.0	2
	2	1/15/07 10:15	3/5/07 2:15	48.7	12
	3	3/17/07 2:00	3/22/07 0:00	4.9	1
	4	6/25/07 12:45	6/30/07 23:45	5.5	1
I93-DIN-05	1	2/6/07 6:15	2/19/07 10:00	13.2	3
I93-POCU01-01	1	12/28/06 0:00	1/8/07 16:30	11.7	3
	2	1/10/07 8:00	3/13/07 16:15	62.3	16
	3	3/14/07 0:00	3/31/07 23:45	18.0	4
I93-POL-02N	1	12/28/06 0:00	1/31/07 16:00	34.7	9
	2	2/28/07 10:15	3/6/07 22:15	6.5	2
	3	3/13/07 10:00	3/31/07 23:45	18.6	5
I93-POL-06	1	1/15/07 2:00	1/27/07 9:15	12.3	3
	2	2/21/07 10:15	3/4/07 9:00	10.9	3
I93-POLU01-01	1	1/16/07 0:30	3/4/07 17:30	47.7	12
	2	3/17/07 2:00	3/22/07 8:00	5.3	1
I93-POLU02-02	1	1/19/07 9:00	1/27/07 9:00	8.0	2

Table 16: Violations of Chloride Water Quality Standards from In-Situ Datalogger Deployments in FY02-FY06

Station	Number of Violations of Chronic Standard (4 day rolling average)
01-WRB	0
01X-SHB	0
09J-BVR	0
10A-BVR	2 (10.1 d)
10-BVR	1 (5.9 d)
12-BVR	0
13-BVR	0
I93-DIN-01	5 (19.0 d)
I93-DIN-05	0
I93-EAY-01	0
I93-HDPU-00	0
I93-HDPU-01	0
I93-NTC-01	11 (42.0 d)
I93-POC-02	3 (13.5 d)
I93-POC-05D	0
I93-POC-05P	19 (77.1 d)
I93-POC-06	0
I93-POCU01-01	16 (62.6 d)
I93-POL-02	37 (148.8 d)
I93-POL-04X	31 (128.8 d)
I93-POL-06	8 (31.1 d)
I93-POLU01-01	56 (221.8 d)

Table 17: Periods in Violation of the Chronic Water Quality Standard from Water Quality Monitoring in FY02-FY06

Station	Violation Episode	Start Time	End Time	Duration (days)	Number of Violations
10A-BVR	1	2/3/04 10:00	2/8/04 22:00	5.5	1
	2	1/20/05 9:00	1/25/05 0:00	4.6	1
10-BVR	1	2/3/04 8:00	2/9/04 6:00	5.9	1
I93-DIN-01	1	1/31/04 13:00	2/11/04 23:00	11.4	3
	2	3/9/05 13:00	3/17/05 3:00	7.6	2
I93-NTC-01	1	8/24/04 12:00	10/5/04 13:00	42.0	11
I93-POC-02	1	2/1/04 2:00	2/14/04 14:00	13.5	3
I93-POC-05P	1	12/19/05 13:00	12/27/05 19:00	8.3	2
	2	1/3/06 18:00	1/14/06 23:00	11.2	3
	3	1/20/06 14:00	2/1/06 17:00	12.1	3
	4	2/24/06 9:00	3/14/06 13:00	18.2	5
	5	3/16/06 0:00	4/6/06 20:00	21.8	5
	6	4/7/06 21:00	4/13/06 9:00	5.5	1
I93-POCU01-01	1	6/4/04 12:00	7/22/04 6:00	47.8	12
	2	7/22/04 13:00	8/6/04 10:00	14.9	4
I93-POL-02	1	12/11/02 14:00	12/16/02 14:00	5.0	1
	2	1/5/03 16:00	1/14/03 10:00	8.8	2
	3	1/30/03 2:00	2/6/03 11:00	7.4	2
	4	2/7/03 9:00	2/26/03 5:00	18.8	5
	5	3/12/03 19:00	3/18/03 4:00	5.4	1
	6	1/21/04 9:00	1/29/04 5:00	7.8	2
	7	2/2/04 10:00	3/1/04 11:00	28.0	7
	8	3/16/04 22:00	3/23/04 19:00	6.9	2
	9	7/2/04 1:00	7/15/04 13:00	13.5	3
	10	7/20/04 11:00	7/24/04 20:00	4.4	1
	11	7/29/04 13:00	8/5/04 17:00	7.2	2
	12	8/5/04 20:00	8/14/04 13:00	8.7	2
	13	9/13/04 1:00	9/18/04 5:00	5.2	1
	14	1/9/05 17:00	1/16/05 0:00	6.3	2
	15	2/1/05 12:00	2/10/05 22:00	9.4	2
	16	2/26/06 0:00	3/4/06 3:00	6.1	2
I93-POL-04X	1	1/2/04 10:00	1/9/04 23:00	7.5	2
	2	1/22/04 12:00	3/4/04 7:00	41.8	10
	3	3/5/04 16:00	3/26/04 11:00	20.8	5
	4	12/19/04 12:00	12/24/04 8:00	4.8	1
	5	1/5/05 16:00	2/15/05 0:00	40.3	10
	6	3/10/05 23:00	3/16/05 15:00	5.7	1
	7	3/21/05 4:00	3/29/05 1:00	7.9	2
I93-POL-06	1	12/12/05 12:00	12/19/05 6:00	6.8	2
	2	2/22/06 1:00	3/11/06 6:00	17.2	4
	3	3/28/06 0:00	4/4/06 4:00	7.2	2

Table 17 (cont.)

Station	Violation Episode	Start Time	End Time	Duration (days)	Number of Violations
I93-POLU01-01	1	1/6/04 8:00	3/4/04 4:00	57.8	14
	2	3/5/04 19:00	3/27/04 6:00	21.5	5
	3	9/21/04 12:00	10/30/04 16:00	39.2	10
	4	1/6/05 16:00	1/17/05 1:00	10.4	3
	5	2/1/05 12:00	2/14/05 19:00	13.3	3
	6	2/19/05 13:00	3/19/05 14:00	28.0	7
	7	3/23/05 14:00	3/28/05 20:00	5.3	1
	8	12/13/05 19:00	12/20/05 11:00	6.7	2
	9	1/2/06 12:00	1/13/06 17:00	11.2	3
	10	1/23/06 8:00	1/30/06 13:00	7.2	2
	11	2/11/06 3:00	2/18/06 2:00	7.0	2
	12	2/23/06 1:00	3/9/06 8:00	14.3	4

Table 18: Summary Statistics of Stream Flow Measured by the U.S. Geological Survey

Station	Period of Record	Number of measurements	Minimum (cfs)	Average (cfs)	Maximum (cfs)
09-BVR	7/1/06-6/30/07	35036	4.80	64.66	1455.00
10A-BVR	7/1/06-6/30/07	35036	2.75	51.07	1097.50
I93-DIN-01	7/1/06-6/30/07	35036	0.04	1.00	57.25
I93-POL-01V	7/1/06-6/30/07	35036	0.35	15.72	337.00
I93-POL-04X	7/1/06-6/30/07	35036	0.08	6.12	94.75

Table 19: Watershed Areas and Drainage Area Ratio Factors for Stream Flow Estimates

Station	Watershed Area			Reference Flow Gage for Transposition	Transposition Factor
	Acres	Hectares	Square Miles		
09-BVR	19,410	7,855	30.33	None	
10A-BVR	15,340	6,208	23.97	None	
I93-DIN-01	346	140*	0.54	None	
I93-NTC-01	127	52	0.20	I93-DIN-01	0.368 minus withdrawals
I93-POL-01V	6,518	2,638	10.18	None	
I93-POL-04X	3,225	1,305	5.04	None	
03-SHB	4,061	1,643	6.34	10A-BVR	0.265
04-WRB	684	277	1.07	I93-DIN-01	1.979
06-SHB	3,651	1,478	5.71	10A-BVR	0.238
08-SHB	2,896	1,172	4.52	10A-BVR	0.189
I93-BVRU03-01	285	115	0.45	I93-DIN-01	0.825
I93-DIN-05	107	43	0.17	I93-DIN-01	0.309
I93-POC-02	2,900	1,174	4.53	I93-POL-04X	0.899
I93-POCU01-01	2,368	958	3.70	I93-POL-04X	0.734
I93-POL-02N	10	4	0.02	None - too small	
I93-POL-03	6,417	2,597	10.03	I93-POL-01V	0.985
I93-POL-06	1,886	763	2.95	I93-POL-04X	0.585
I93-POLU01-01	1,129	457	1.76	I93-POL-04X	0.350
I93-POLU02-02	545	221	0.85	I93-DIN-01	1.576
I93-STB-02	479	194	0.75	I93-DIN-01	1.386
I93-WPLU-01	872	353	1.36	I93-DIN-01	2.520

* Note that the watershed area for I93-DIN-01 is for the stream gage station, which is slightly smaller than for the water quality station (143.1 Ha)

Table 20: Measured Groundwater Withdrawals in the Vicinity of I93-NTC-01

WU ID	Facility	Year	Month	Monthly Withdrawal (1000 gallons)	Average Daily Withdrawal (cfs)
20347-S01	W & E COMMUNITY WS	2006	JANUARY	1,748.3	0.09
20347-S01	W & E COMMUNITY WS	2006	FEBRUARY	1,734.2	0.10
20347-S01	W & E COMMUNITY WS	2006	MARCH	1,793.3	0.09
20347-S01	W & E COMMUNITY WS	2006	APRIL	1,668.2	0.09
20347-S01	W & E COMMUNITY WS	2006	MAY	1,147.7	0.06
20347-S01	W & E COMMUNITY WS	2006	JUNE	1,007.0	0.05
20347-S01	W & E COMMUNITY WS	2006	JULY	1,193.9	0.06
20347-S01	W & E COMMUNITY WS	2006	AUGUST	1,124.6	0.06
20347-S01	W & E COMMUNITY WS	2006	SEPTEMBER	751.8	0.04
20347-S01	W & E COMMUNITY WS	2006	OCTOBER	1,580.7	0.08
20347-S01	W & E COMMUNITY WS	2006	NOVEMBER	1,567.1	0.08
20347-S01	W & E COMMUNITY WS	2006	DECEMBER	1,711.3	0.09
20347-S01	W & E COMMUNITY WS	2007	JANUARY	1,769.3	0.09
20347-S01	W & E COMMUNITY WS	2007	FEBRUARY	2,014.6	0.11
20347-S01	W & E COMMUNITY WS	2007	MARCH	2,123.7	0.11
20347-S01	W & E COMMUNITY WS	2007	APRIL	2,088.0	0.11
20347-S01	W & E COMMUNITY WS	2007	MAY	2,282.0	0.11
20347-S01	W & E COMMUNITY WS	2007	JUNE	2,326.3	0.12

Table 21: Summary Statistics of Stream Flow Estimated by the Drainage Area Ratio Method

Station	Period of Record	Number of measurements	Minimum (cfs)	Average (cfs)	Maximum (cfs)
I93-NTC-01	7/1/06-6/30/07	35,036	0.00	0.28	20.99
03-SHB	1/1/07-3/31/07	8,636	2.36	11.90	35.08
04-WRB	1/1/07-3/31/07	8,636	0.50	1.97	17.55
06-SHB	1/1/07-3/31/07	8,636	2.12	10.70	31.54
08-SHB	1/1/07-3/31/07	8,636	1.68	8.49	25.01
I93-BVRU03-01	1/1/07-3/31/07	8,636	0.22	0.82	7.32
I93-DIN-05	1/1/07-3/31/07	8,636	0.08	0.31	2.74
I93-POC-02	1/1/07-3/31/07	8,636	0.40	4.29	26.10
I93-POCU01-01	1/1/07-3/31/07	8,636	0.30	3.50	21.30
I93-POL-02N	1/1/07-3/31/07	8,636	1.98	14.48	65.35
I93-POL-03	1/1/07-3/31/07	8,636	1.98	14.34	64.75
I93-POL-06	1/1/07-3/31/07	8,636	0.26	2.79	16.96
I93-POLU01-01	1/1/07-3/31/07	8,636	0.15	1.67	10.15
I93-POLU02-02	1/1/07-3/31/07	8,636	0.40	1.52	13.70
I93-STB-02	1/1/07-3/31/07	8,636	0.40	1.38	12.28
I93-WLPU-01	1/1/07-3/31/07	8,636	0.70	2.50	22.38

Table 22: Statistics from Linear Regression of Daily Average Flows at the Temporary Stream Gages versus the USGS Gage on Beaver Brook at North Pelham (7/1/06-6/30/07)

Station	Number of Observations	Slope	Intercept	R Square	Standard Error
09-BVR	365	0.941	-0.157	0.975	0.153
10A-BVR	365	0.994	-0.649	0.960	0.209
I93-DIN-01	365	0.998	-4.691	0.794	0.519
I93-POL-01V	365	1.115	-2.551	0.829	0.518
I93-POL-04X	365	1.231	-4.209	0.764	0.699

Table 23: Daily Average Flows for Selected Flow Duration Percentiles

Percent Exceeding	09-BVR	10A-BVR	I93-DIN-01	I93-POL-01V	I93-POL-04X	I93-NTC-01
99%	1.43	0.87	0.01	0.10	0.02	0.00
95%	2.63	1.67	0.02	0.23	0.04	0.00
90%	4.52	2.98	0.04	0.45	0.09	0.00
80%	9.39	6.48	0.10	1.15	0.27	0.00
75%	12.13	8.96	0.13	1.60	0.42	0.00
70%	16.18	11.55	0.18	2.32	0.60	0.00
60%	22.82	16.66	0.28	3.61	0.99	0.03
50%	32.62	24.36	0.42	5.71	1.68	0.08
40%	42.91	32.61	0.59	8.12	2.52	0.15
30%	55.61	42.97	0.80	11.32	3.70	0.22
25%	63.79	49.73	0.94	13.51	4.52	0.27
20%	73.78	58.05	1.11	16.28	5.61	0.34
10%	110.12	88.90	1.77	27.22	10.13	0.58
5%	151.76	124.64	2.58	40.93	16.19	0.88
1%	287.08	246.43	5.47	93.17	41.69	1.94

Table 24: Four Day Average Flows for Selected Flow Duration Percentiles

Percent Exceeding	09-BVR	10A-BVR	I93-DIN-01	I93-POL-01V	I93-POL-04X	I93-NTC-01
99%	1.49	0.91	0.01	0.11	0.02	0.00
95%	2.72	1.74	0.02	0.24	0.04	0.00
90%	5.03	3.33	0.05	0.52	0.11	0.00
80%	10.05	6.98	0.11	1.27	0.30	0.00
75%	12.96	9.14	0.14	1.78	0.44	0.00
70%	16.51	11.81	0.19	2.40	0.63	0.01
60%	23.45	17.17	0.29	3.77	1.06	0.04
50%	33.27	24.88	0.44	5.89	1.77	0.09
40%	44.35	33.78	0.61	8.50	2.66	0.16
30%	56.62	43.88	0.82	11.66	3.84	0.23
25%	65.82	51.52	0.97	14.12	4.79	0.29
20%	75.37	59.56	1.15	17.00	6.00	0.35
10%	109.67	88.59	1.78	27.40	10.44	0.59
5%	147.65	121.49	2.51	39.88	15.83	0.85
1%	273.85	234.46	5.18	87.87	39.30	1.84

Table 25: Observed and Predicted Flow Percentiles for 7/1/06 to 6/30/07. Values Predicted Using MOVE.1 Technique.

Station	Type	Percentile				
		5th	25th	50th	75th	95th
09-BVR	Obs	7.6	18.2	42.2	83.8	158.5
	Pred	7.3	18.7	43.2	87.9	146.0
	RPD	4%	-3%	-2%	-5%	8%
10A-BVR	Obs	5.2	13.1	32.5	65.6	130.7
	Pred	5.0	13.5	32.8	70.0	120.0
	RPD	5%	-3%	-1%	-6%	9%
I93-DIN-01	Obs	0.1	0.2	0.6	1.3	2.7
	Pred	0.1	0.2	0.6	1.4	2.5
	RPD	3%	9%	1%	-8%	8%
I93-POL-01V	Obs	1.0	2.7	7.3	19.3	50.1
	Pred	0.8	2.8	8.2	20.4	39.1
	RPD	15%	-4%	-12%	-5%	25%
I93-POL-04X	Obs	0.3	0.7	2.1	6.2	26.0
	Pred	0.2	0.7	2.5	7.3	15.4
	RPD	39%	-13%	-17%	-16%	51%

Table 26: Summary of Paved Surfaces in Study Watersheds

Watershed	Source Type	Value	Units
Beaver Brook (09-BVR)	STATE ROADS	53.21	LANEMILES
	MUNICIPAL ROADS	295.60	LANEMILES
	PRIVATE ROADS	38.45	LANEMILES
	PARKING LOTS	461.88	ACRES
Dinsmore Brook (I93-DIN-01)	STATE ROADS	5.97	LANEMILES
	MUNICIPAL ROADS	0.98	LANEMILES
	PRIVATE ROADS	4.15	LANEMILES
	PARKING LOTS	6.79	ACRES
North Tributary to Canobie Lake (I93-NTC-01)	STATE ROADS	2.81	LANEMILES
	MUNICIPAL ROADS	1.03	LANEMILES
	PRIVATE ROADS	0.00	LANEMILES
	PARKING LOTS	0.36	ACRES
Policy Brook (I93-POL-01V)	STATE ROADS	33.44	LANEMILES
	MUNICIPAL ROADS	115.55	LANEMILES
	PRIVATE ROADS	15.09	LANEMILES
	PARKING LOTS	379.13	ACRES

Table 27: Inventory of Salt Piles in the Study Area

Location	ID	Watershed	Coverage	Comments	Volume (CY)	Salt Loss (tons NaCl/yr)
State/Municipal Salt Piles						
NH DOT PS 528	BEA500	Beaver Brook	Building	Completely covered		0.00
Salem DPW Salt-Sand Pile	POL215	Policy Brook	None	Pile was moved and covered after Feb 07	600	313.00
Salem DPW Salt Shed	POL215	Policy Brook	Building	Completely covered		0.00
Derry DPW Town Shed	BEA122	Beaver Brook	Building	Completely covered		0.00
Private Salt Piles						
Groundhog Landscaping	BEA013	Beaver Brook	Unknown	Assume no coverage	10	0.64
Wal Mart	BEA076	Beaver Brook	Shelter	Completely covered	10	0.00
Hood Commons	BEA100	Beaver Brook	Tarp	Poorly covered	10	0.13
Derry Country Club Estates	BEA166	Beaver Brook	Tarp	Mostly covered	10	0.13
Pinkerton Academy	BEA271	Beaver Brook	Building	Completely covered	10	0.00
Market Basket/Sears Essentials	BEA758	Beaver Brook	None		10	0.64
DeLahunty Nursery	POL035	Policy Brook	Building	Completely covered	10	0.00
Flightline Shuttle Service	POL052	Policy Brook	Shelter	Completely covered	10	0.00
Raymond Park	POL139	Policy Brook	Tarp	Poorly covered	10	0.13
Rockingham Park Racetrack (100% salt)	POL220	Policy Brook	Building	Poorly covered	20	1.28
Boston Equipment and Supplies	POL239	Policy Brook	Building	Completely covered	10	0.00
Rockingham Mall Shopping Plaza	POL257	Policy Brook	None	Though storage tent is present, material is stored in the open beside tent.	10	0.64
Mall at Rockingham Park	POL323	Policy Brook	Tarp	Poorly covered	10	0.13

Table 28: Annual Salt Imports to Watersheds (tons salt per year) in FY07 (7/1/06-6/30/07)

Watershed	State Roads	Municipal Roads	Private Roads	Parking Lots	Salt Piles	Water Softeners	Food Waste	Atm. Deposi-tion	Total
03-SHB	156.7	405.6	61.7	1,123.4	0.9	59.1	32.2	19.9	1,859.6
04-WRB	35.1	41.1	9.2	18.0	0.0	3.7	2.0	3.4	112.4
06-SHB	152.6	292.5	47.4	812.4	0.8	41.3	23.2	17.9	1,388.1
08-SHB	129.6	219.4	25.6	239.8	0.6	22.6	14.6	14.2	666.4
09-BVR	668.7	1,901.1	318.4	2,956.0	1.5	272.3	149.5	95.1	6,362.6
10A-BVR	398.0	1,522.9	244.6	1,932.4	0.9	221.8	120.7	75.2	4,516.4
I93-BVRU03-01	5.7	35.5	17.1	122.6	0.0	13.1	6.1	1.4	201.6
I93-DIN-01	81.7	4.0	34.3	43.4	0.0	0.7	0.5	1.7	166.5
I93-DIN-05	28.1	0.0	28.7	36.9	0.0	0.2	0.2	0.5	94.5
I93-NTC-01	38.8	4.2	0.0	2.3	0.0	0.4	0.2	0.6	46.5
I93-POC-02	268.9	326.0	36.0	992.7	0.1	18.0	10.1	14.2	1,666.1
I93-POCU01-01	147.9	279.0	34.2	888.6	0.1	13.4	7.6	11.6	1,382.4
I93-POL-01V	456.1	1,305.7	124.9	2,426.4	315.2	101.8	52.3	31.9	4,814.3
I93-POL-03	437.2	1,287.5	120.7	2,367.1	2.2	99.7	51.2	31.5	4,396.9
I93-POL-04X	142.2	854.2	69.5	921.4	1.9	61.1	32.1	15.8	2,098.3
I93-POL-06	127.4	265.7	45.2	364.4	0.0	20.1	10.7	9.2	842.8
I93-POLU01-01	0.0	541.9	14.9	390.9	0.0	38.7	20.3	5.5	1,012.3
I93-POLU02-02	0.0	262.1	0.0	62.2	0.0	19.6	10.7	2.7	357.3
I93-STB-02	46.1	34.5	21.7	0.7	0.0	8.4	5.2	2.3	119.0
I93-WPLU-01	136.9	59.6	0.3	157.5	0.0	4.2	2.4	4.3	365.1

Table 29: Summary of Salt Application Rates for Salt Import Calculations

Source Type	Source	Application Rate	Units
STATE ROADS	STATE PS 508	15.24	TONS NACL/LANEMILE/YEAR
	STATE PS 512	9.16	TONS NACL/LANEMILE/YEAR
	STATE PS 513	15.71	TONS NACL/LANEMILE/YEAR
	STATE PS 514	13.03	TONS NACL/LANEMILE/YEAR
	STATE PS 528	13.99	TONS NACL/LANEMILE/YEAR
MUNICIPAL ROADS	AUBURN	12.00	TONS NACL/LANEMILE/YEAR
	CHESTER	12.36	TONS NACL/LANEMILE/YEAR
	DERRY	6.84	TONS NACL/LANEMILE/YEAR
	LONDONDERRY	4.82	TONS NACL/LANEMILE/YEAR
	SALEM	12.30	TONS NACL/LANEMILE/YEAR
	WINDHAM	4.11	TONS NACL/LANEMILE/YEAR
PRIVATE ROADS		8.28	TONS NACL/LANEMILE/YEAR
PARKING LOTS	DRIVEWAYS	6.4	TONS NACL/ACRE/YEAR
	LOTS	6.4	TONS NACL/ACRE/YEAR
SALT PILES		See Text	
WATER SOFTENERS		378	LB NACL/HSE/YEAR
FOOD WASTE		20	LB NACL/PERSON/YEAR
ATMOSPHERIC DEPOSITION		11.01	KG NACL/HA/YEAR

Table 30: Summary Statistics of Chloride Export for the Period 7/1/06 to 6/30/07 Calculated from Specific Conductance and Stream Flow

Station	Period of Record	Number of measurements	Minimum (tons Cl/yr)	Average (tons Cl/yr)	Maximum (tons Cl/yr)
09-BVR	7/1/06-6/30/07	35,001	471.36	3,328.25	36,693.07
10A-BVR	7/1/06-6/30/07	34,707	230.04	2,181.99	19,800.86
I93-NTC-01	7/1/06-6/30/07	33,135	0.00	26.15	1,393.41
I93-POL-01V	7/1/06-6/30/07	34,975	113.65	1,562.83	18,154.69
I93-POL-04X	7/1/06-6/30/07	33,737	9.28	608.31	15,312.09

*Chloride export only calculated for stations with 80% data completeness.

Table 31: Chloride Mass Balance in Study Watersheds

Station	Period of Record	Chloride Imports (tons Cl/yr)	Chloride Exports (tons Cl/yr)	Net Chloride Gain or Loss (tons Cl/yr)	Percent of Cl Imports Retained
09-BVR	7/1/06-6/30/07	3,859.56	3,328.25	531.31	14%
10A-BVR	7/1/06-6/30/07	2,739.63	2,181.99	557.64	20%
I93-NTC-01	7/1/06-6/30/07	28.22	26.15	2.07	7%
I93-POL-01V	7/1/06-6/30/07	2,920.36	1,562.83	1,357.53	46%
I93-POL-04X	7/1/06-6/30/07	1,272.82	608.31	664.51	52%

Table 32: Chloride Mass Balance in Study Watersheds Normalized by Watershed Area

Station	Period of Record	Drainage Area (sq.mile)	Chloride Imports (tons Cl/yr/sq.mi)	Chloride Exports (tons Cl/yr/sq.mi)	Chloride Storage (tons Cl/yr/sq.mile)
09-BVR	7/1/06-6/30/07	30.33	127.26	109.74	17.52
10A-BVR	7/1/06-6/30/07	23.97	114.30	91.03	23.27
I93-NTC-01	7/1/06-6/30/07	0.20	141.72	131.33	10.39
I93-POL-01V	7/1/06-6/30/07	10.18	286.76	153.46	133.30
I93-POL-04X	7/1/06-6/30/07	5.04	252.57	120.71	131.86

Table 33: Summary Statistics for Daily Average Chloride Concentrations (mg/L) by Hydrologic Condition Class

Station	Statistic	High	Moist	Mid Range	Dry	Low
09-BVR	N	49	129	76	111	0
	50th %ile	42.1	55.9	67.1	87.9	
	90th %ile	56.1	75.2	79.2	98.1	
	Target	207	207	207	207	207
10A-BVR	N	50	132	70	113	0
	50th %ile	35.0	45.7	55.2	71.0	
	90th %ile	49.0	66.3	63.5	81.3	
	Target	207	207	207	207	207
I93-NTC-01	N	50	126	68	105	0
	50th %ile	82.2	99.8	171.2	211.5	
	90th %ile	131.9	157.4	**247.5**	**346.0**	
	Target	207	207	207	207	207
I93-POL-01V	N	67	100	76	122	0
	50th %ile	89.0	116.6	153.1	**230.6**	
	90th %ile	124.7	161.3	201.6	**279.5**	
	Target	207	207	207	207	207
I93-POL-04X	N	62	102	72	121	0
	50th %ile	88.3	126.9	151.7	203.0	
	90th %ile	135.9	186.6	**248.3**	**313.6**	
	Target	207	207	207	207	207

* Concentrations greater than the target (90% of the chronic water quality standard) are shown in **bold**.

Table 34: Summary Statistics for Daily Average Chloride Loads (tons Cl/day) by Hydrologic Condition Class

Station	Statistic	High	Moist	Mid Range	Dry	Low
09-BVR	N	49	129	76	111	0
	50th %ile	17.97	10.06	6.01	3.08	
	90th %ile	29.25	15.98	7.22	4.36	
	Target	84.55	35.54	18.18	6.76	1.47
10A-BVR	N	50	132	70	113	0
	50th %ile	12.36	6.65	3.62	1.74	
	90th %ile	20.79	11.49	4.63	2.54	
	Target	69.44	27.70	13.57	4.99	0.93
I93-NTC-01	N	50	126	68	105	0
	50th %ile	0.174	0.075	0.033	0.000	
	90th %ile	0.339	0.132	**0.053**	**0.014**	
	Target	0.490	0.153	0.047	0.000	0.000
I93-POL-01V	N	67	100	76	122	0
	50th %ile	10.09	4.19	2.51	**1.15**	
	90th %ile	19.74	6.69	3.13	**2.00**	
	Target	22.80	7.52	3.18	0.89	0.13
I93-POL-04X	N	62	102	72	121	0
	50th %ile	4.77	1.43	0.77	**0.25**	
	90th %ile	9.09	2.77	**1.12**	**0.54**	
	Target	9.02	2.52	0.94	0.24	0.02

* Loads greater than the target (90% of the chronic water quality standard times flow) are shown in **bold**.
* No flow was predicted for I93-NTC-01 at the 75% and 95% exceedence percentile, which results in a target export of zero for dry and low flow conditions.

Table 35: Summary Statistics for 4-Day Average Chloride Concentrations (mg/L) by Hydrologic Condition Class

Station	Statistic	High	Moist	Mid Range	Dry	Low
09-BVR	N	12	35	16	29	0
	50th %ile	42.0	57.2	65.4	87.7	
	90th %ile	61.5	73.9	76.1	95.6	
	Target	207	207	207	207	207
10A-BVR	N	13	34	16	29	0
	50th %ile	35.5	44.8	58.1	71.7	
	90th %ile	52.4	63.7	61.9	81.8	
	Target	207	207	207	207	207
I93-NTC-01	N	11	36	17	27	0
	50th %ile	82.2	100.1	165.0	**210.3**	
	90th %ile	116.2	160.2	**244.4**	**332.6**	
	Target	207	207	207	207	207
I93-POL-01V	N	14	33	15	30	0
	50th %ile	98.7	124.5	160.4	**229.8**	
	90th %ile	123.7	159.3	**213.1**	**274.7**	
	Target	207	207	207	207	207
I93-POL-04X	N	14	33	16	29	0
	50th %ile	102.2	127.5	157.0	195.9	
	90th %ile	133.1	182.6	**228.3**	**317.0**	
	Target	207	207	207	207	207

* Concentrations greater than the target (90% of the chronic water quality standard) are shown in **bold**.

Table 36: Summary Statistics for 4-Day Average Chloride Loads (tons Cl/day) by Hydrologic Condition Class

Station	Statistic	High	Moist	Mid Range	Dry	Low
09-BVR	N	49	129	76	111	0
	50^{th} %ile	16.79	10.46	6.14	3.40	
	90^{th} %ile	26.62	15.70	7.80	4.25	
	Target	82.26	36.67	18.54	7.22	1.52
10A-BVR	N	50	132	70	113	0
	50^{th} %ile	12.07	6.71	3.93	1.82	
	90^{th} %ile	17.11	11.06	5.03	2.38	
	Target	67.69	28.70	13.86	5.09	0.97
I93-NTC-01	N	50	126	68	105	0
	50^{th} %ile	0.165	0.077	0.031	0.001	
	90^{th} %ile	0.281	0.128	0.046	**0.018**	
	Target	0.476	0.161	0.051	0.000	0.000
I93-POL-01V	N	67	100	76	122	0
	50^{th} %ile	11.15	4.36	2.57	**1.33**	
	90^{th} %ile	15.90	6.75	3.11	**2.00**	
	Target	22.22	7.87	3.28	0.99	0.13
I93-POL-04X	N	62	102	72	121	0
	50^{th} %ile	5.09	1.38	0.77	**0.26**	
	90^{th} %ile	8.45	2.65	**1.16**	**0.59**	
	Target	8.82	2.67	0.98	0.25	0.02

* Loads greater than the target (90% of the chronic water quality standard times flow) are shown in **bold**.
* No flow was predicted for I93-NTC-01 at the 75% and 95% exceedence percentile, which results in a target export of zero for dry and low flow conditions.

Table 37: Percent Reduction Goals for Each Hydrologic Condition

Station	Averaging Period*	Method**	High	Moist	Mid Range	Dry	Low
09-BVR	1 day	90th %ile of individual PRGs					No data
		90th %ile of conc. vs target	0.0	0.0	0.0	0.0	No data
	4 day	90th %ile of individual PRGs					No data
		90th %ile of conc. vs target	0.0	0.0	0.0	0.0	No data
10A-BVR	1 day	90th %ile of individual PRGs					No data
		90th %ile of conc. vs target	0.0	0.0	0.0	0.0	No data
	4 day	90th %ile of individual PRGs					No data
		90th %ile of conc. vs target	0.0	0.0	0.0	0.0	No data
I93-NTC-01	1 day	90th %ile of individual PRGs	NC	NC	29.8	41.2	No data
		90th %ile of conc. vs target	0.0	0.0	16.4	40.2	No data
	4 day	90th %ile of individual PRGs	NC	NC	NC	39.6	No data
		90th %ile of conc. vs target	0.0	0.0	15.3	37.8	No data
I93-POL-01V	1 day	90th %ile of individual PRGs	NC	NC	16.7	26.4	No data
		90th %ile of conc. vs target	0.0	0.0	0.0	25.9	No data
	4 day	90th %ile of individual PRGs	NC	NC	NC	24.5	No data
		90th %ile of conc. vs target	0.0	0.0	2.9	24.7	No data
I93-POL-04X	1 day	90th %ile of individual PRGs	NC	24.5	32.1	40.2	No data
		90th %ile of conc. vs target	0.0	0.0	16.6	34.0	No data
	4 day	90th %ile of individual PRGs	0.0	0.0	9.3	34.7	No data
		90th %ile of conc. vs target	NC	NC	NC	39.7	No data

NC - Not calculated. If there were less than 5 individual percent reduction goals for a hydrologic condition, the 90th percentile statistic was not calculated due to small sample size.

* Averaging Period: The length of time period used to calculate average chloride concentrations and chloride export values.

** Method: The “90th %ile of individual PRGs” is the 90th percentile of all the individual percent reduction goals calculated for days or 4 day periods within the hydrologic condition class. The individual PRG is calculated if the daily or 4 day average chloride export was higher than the target (90% of the chronic water quality standard). The “90th percentile of conc. vs target” was calculated from the 90th percentile concentrations measured within each hydrologic condition class on Tables 33 and 35 and the target (90% of the chronic water quality standard).

Figure 1: Study Area for the Chloride TMDLs

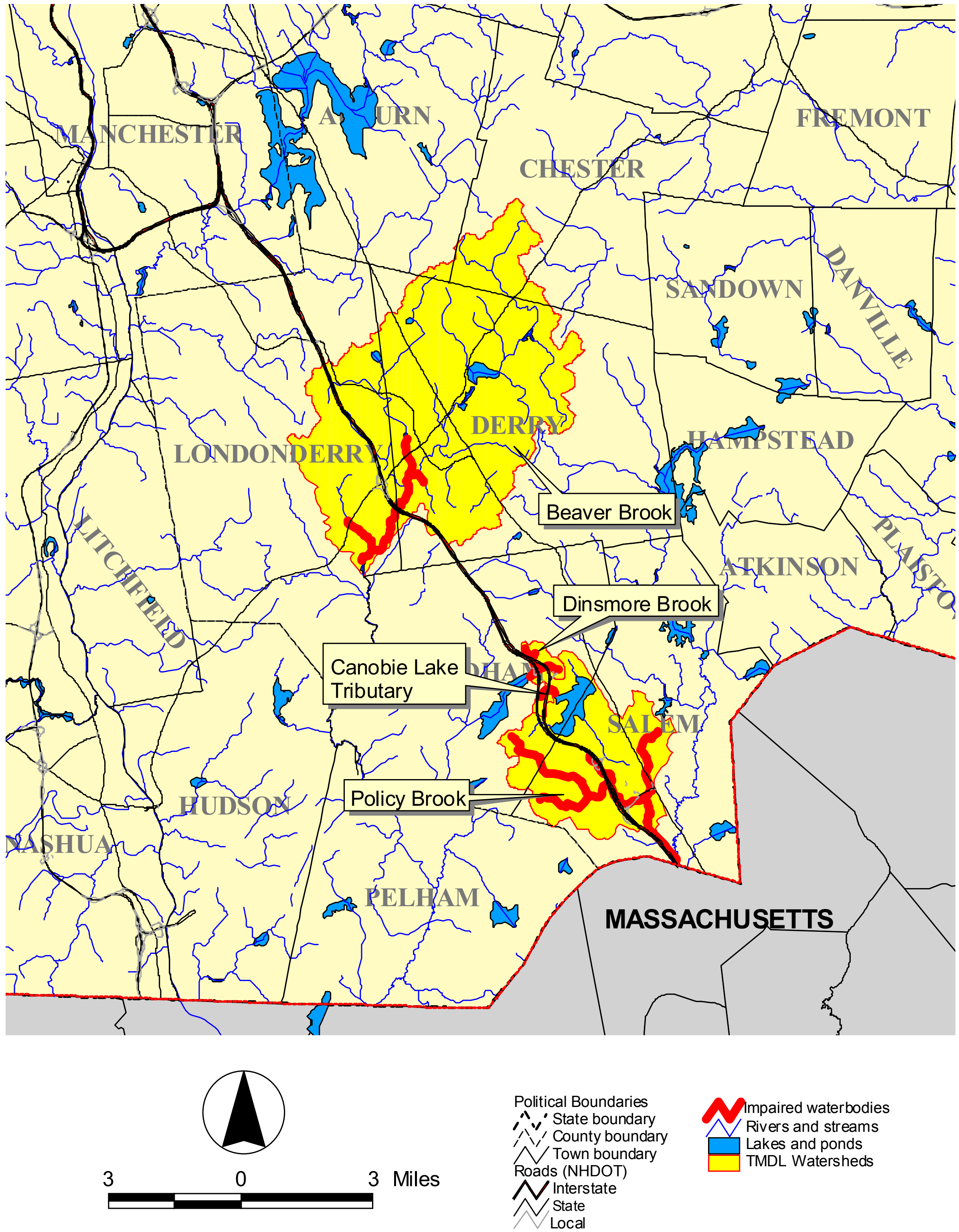

Figure 2: Study Area for the Policy Brook, Dinsmore Brook, and North Tributary to Canobie Lake Watersheds

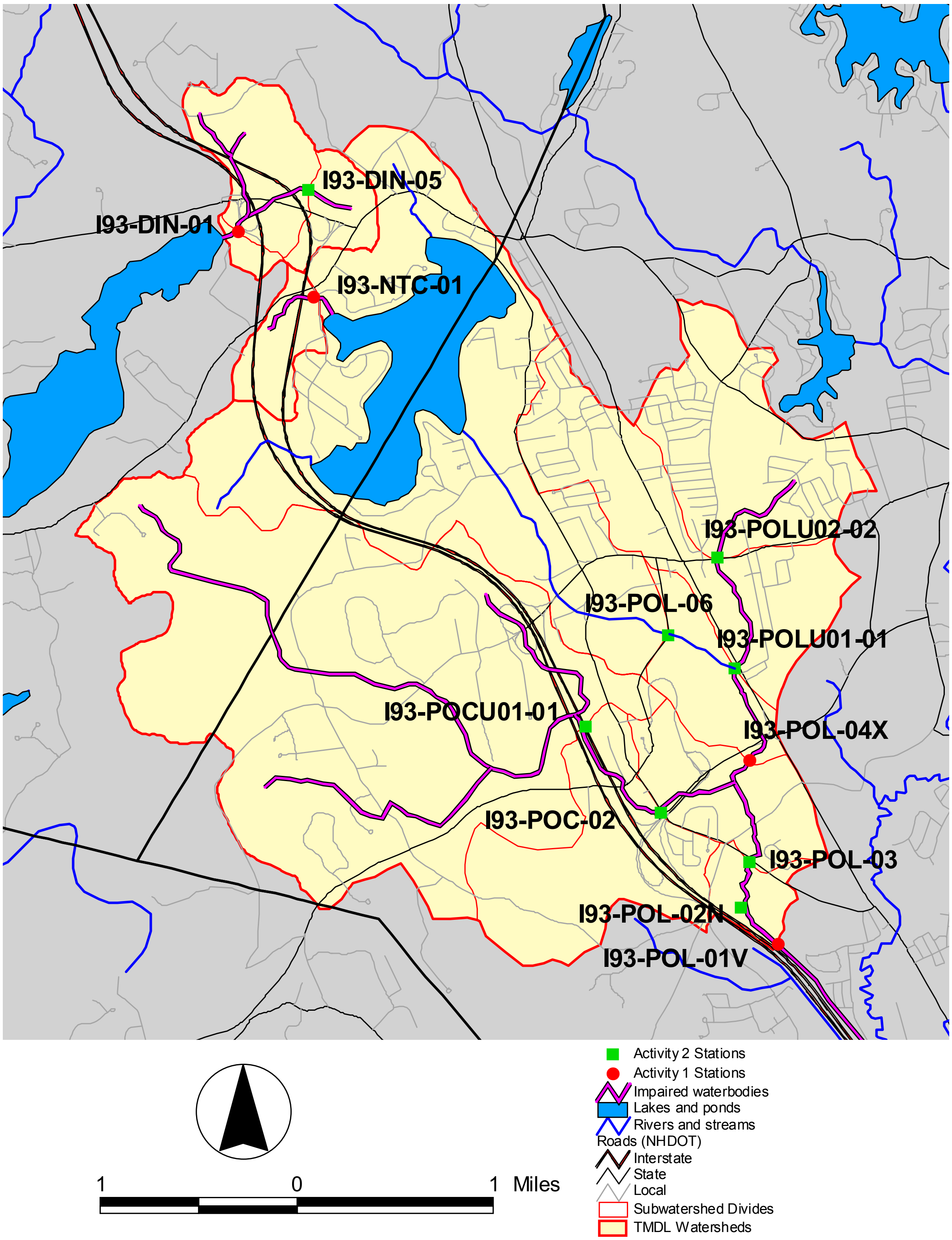

Figure 3: Study Area for the Beaver Brook Watershed

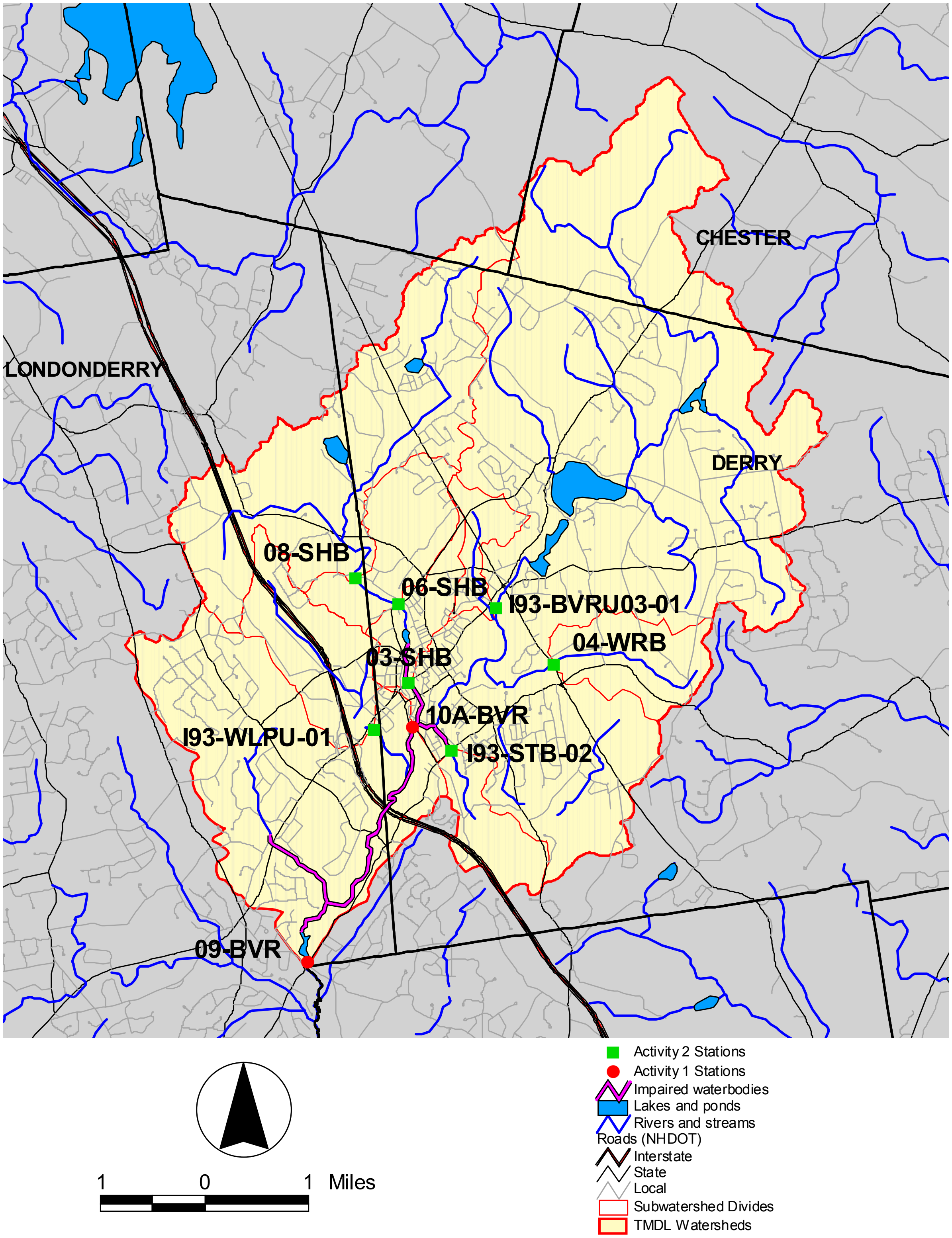

Figure 4: Number of Stations in Violation of the Acute Water Quality Standard between 1/1/07 and 3/31/07 (Activity #1 and Activity #2 stations)

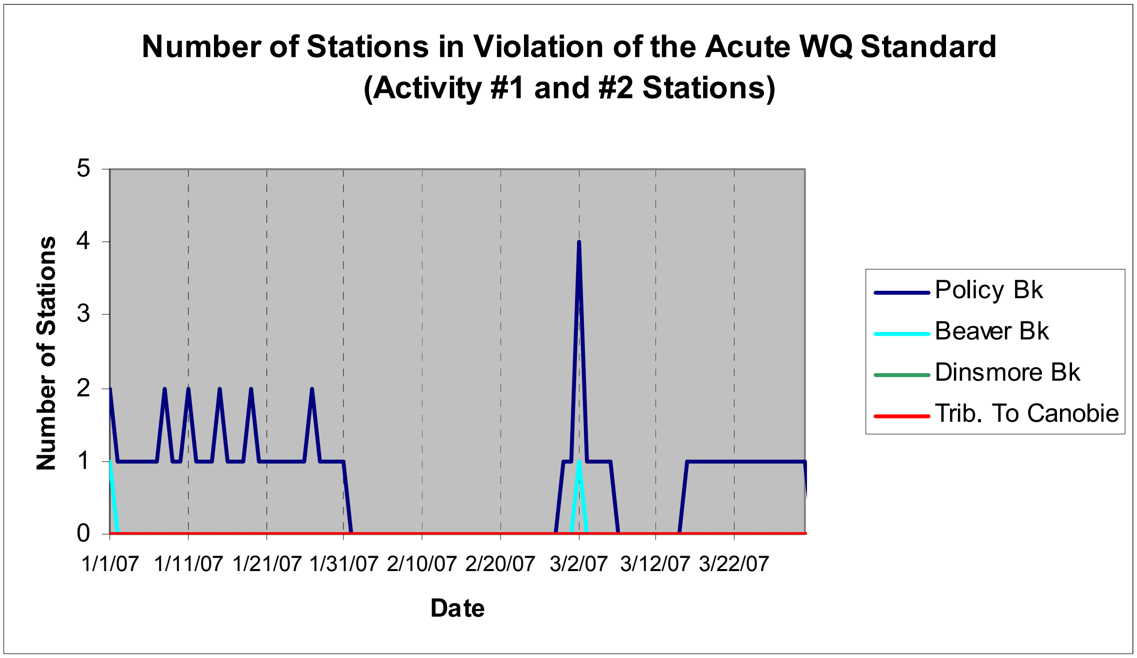

Figure 5: Number of Stations in Violation of the Chronic Water Quality Standard between 1/1/07 and 3/31/07 (Activity #1 and Activity #2 stations)

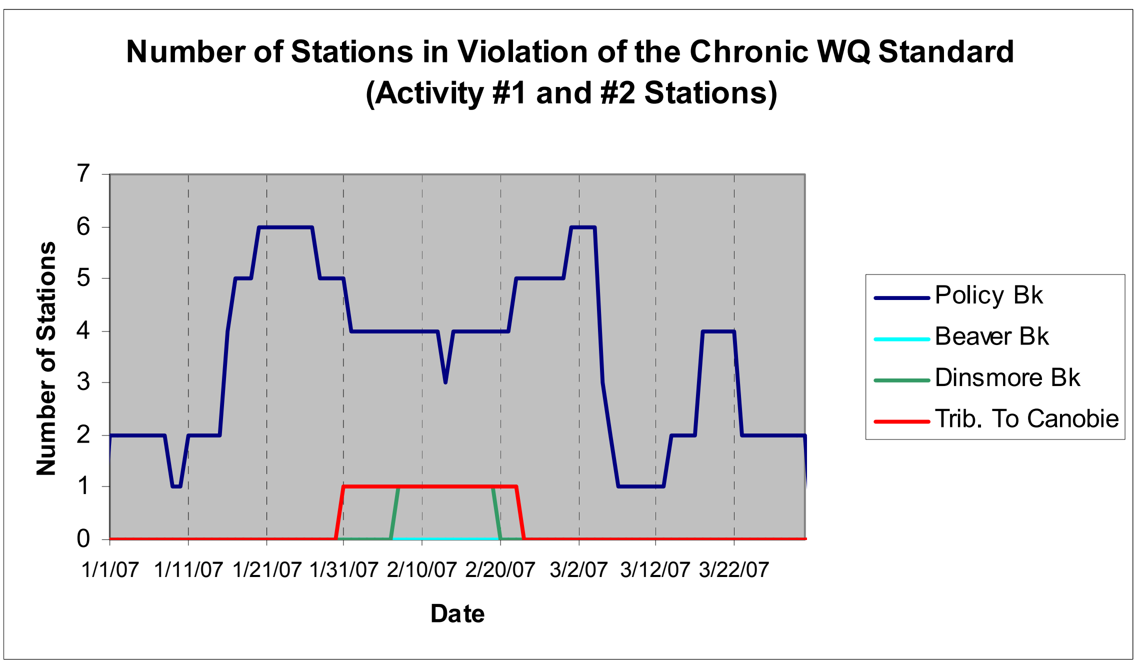

Figure 6: Number of Stations in Violation of the Chronic Water Quality Standard between 7/1/06 and 6/30/07 (Activity #1 stations only)

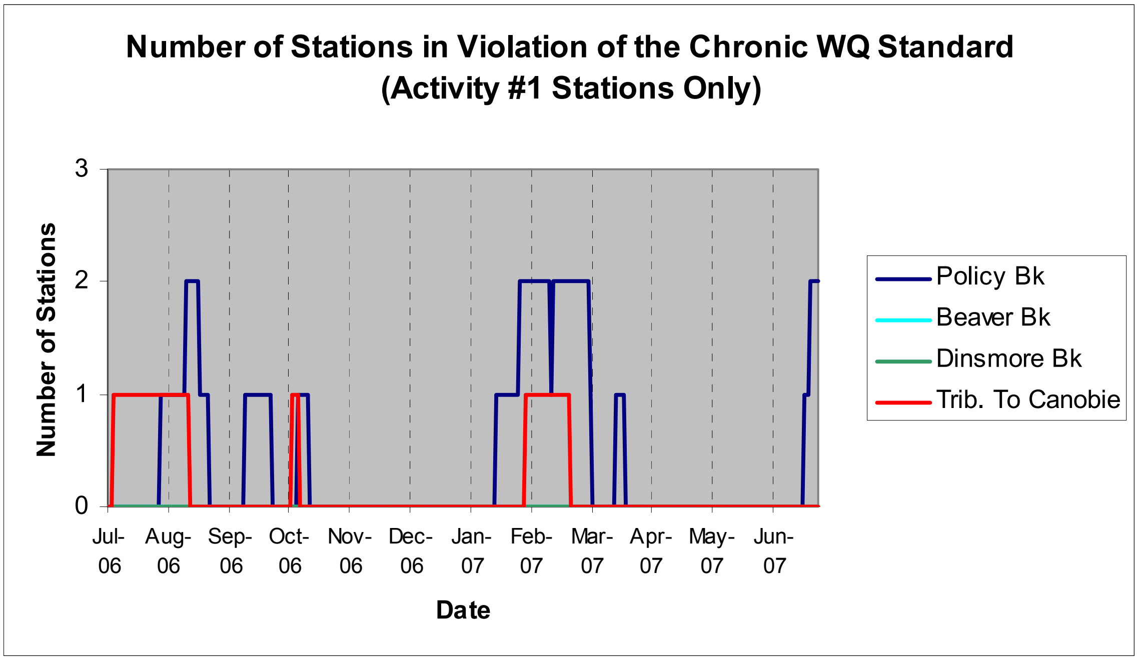

Figure 7: Locations of Water Quality Violations in the Policy Brook, Dinsmore Brook, and North Tributary to Canobie Lake Watersheds

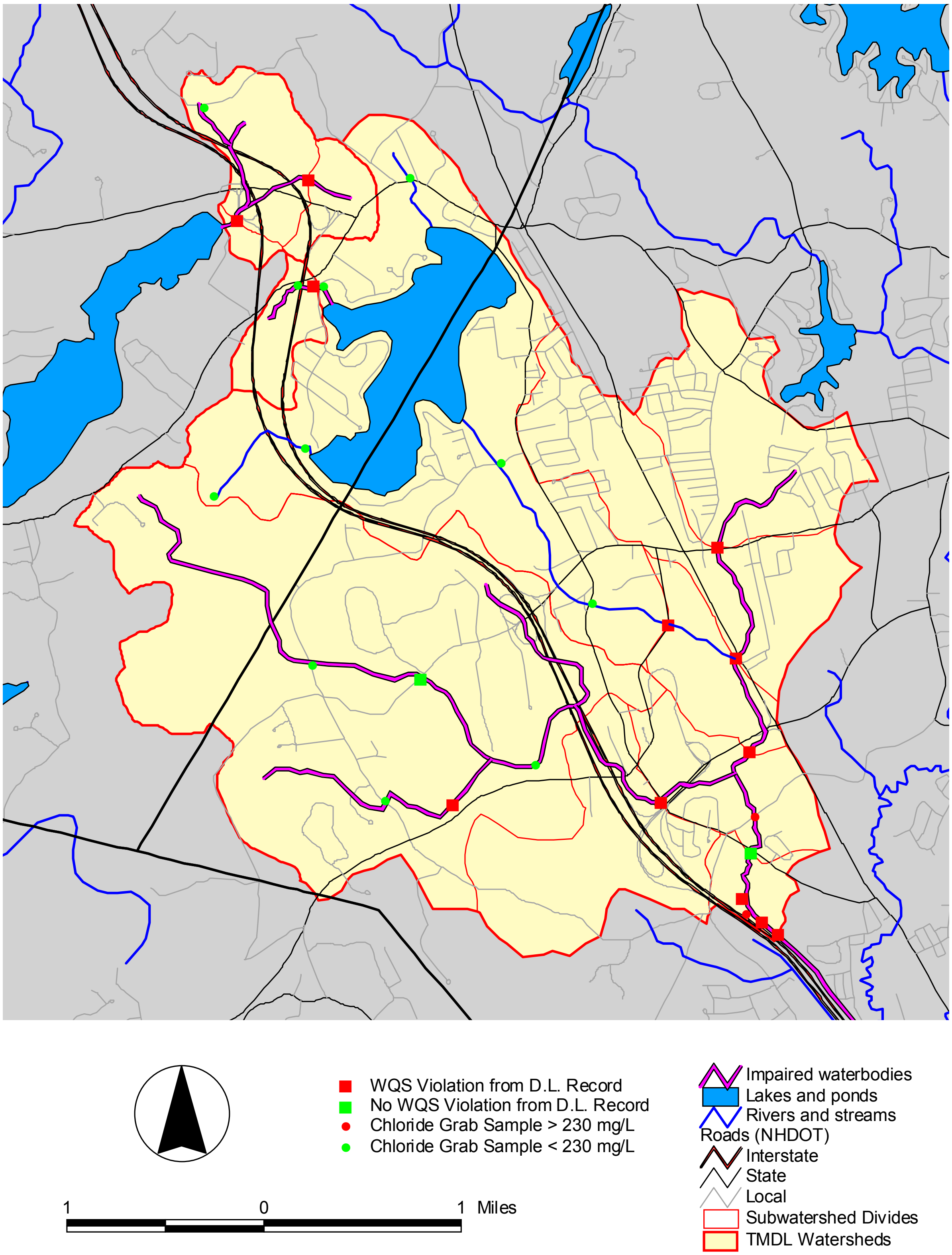

Figure 8: Locations of Water Quality Violations in the Beaver Brook Watershed

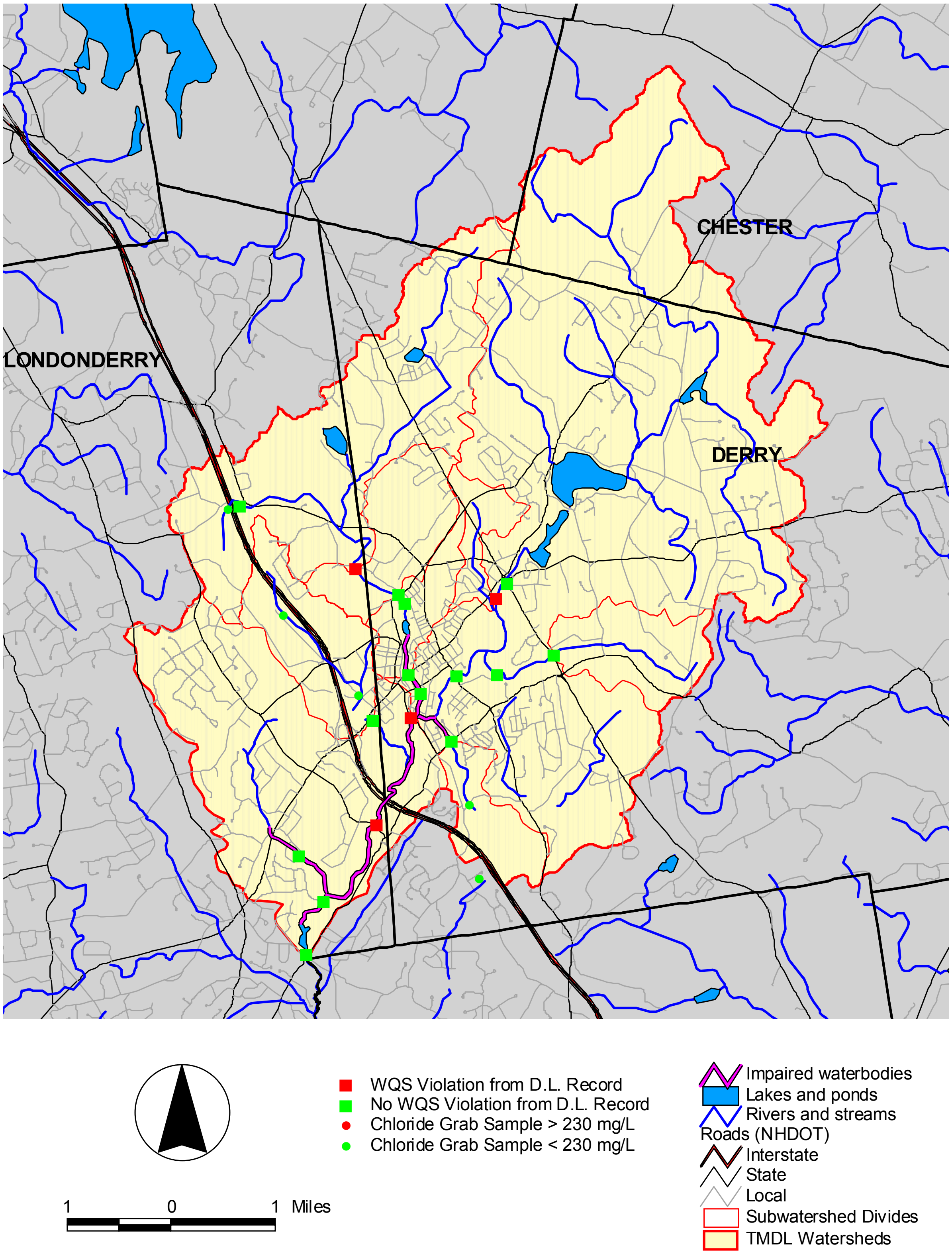

Figure 9: Daily Average Flow Duration Curves for Activity #1 Stations

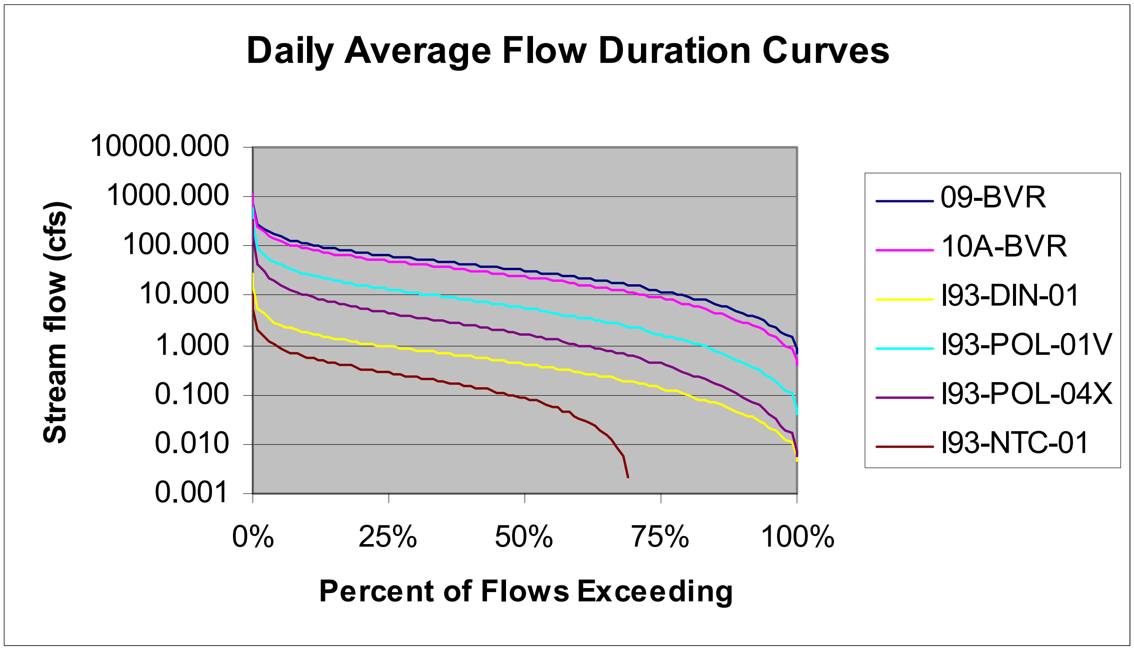

Figure 10: Watershed Area near the Former Salem DPW Salt-Sand Pile

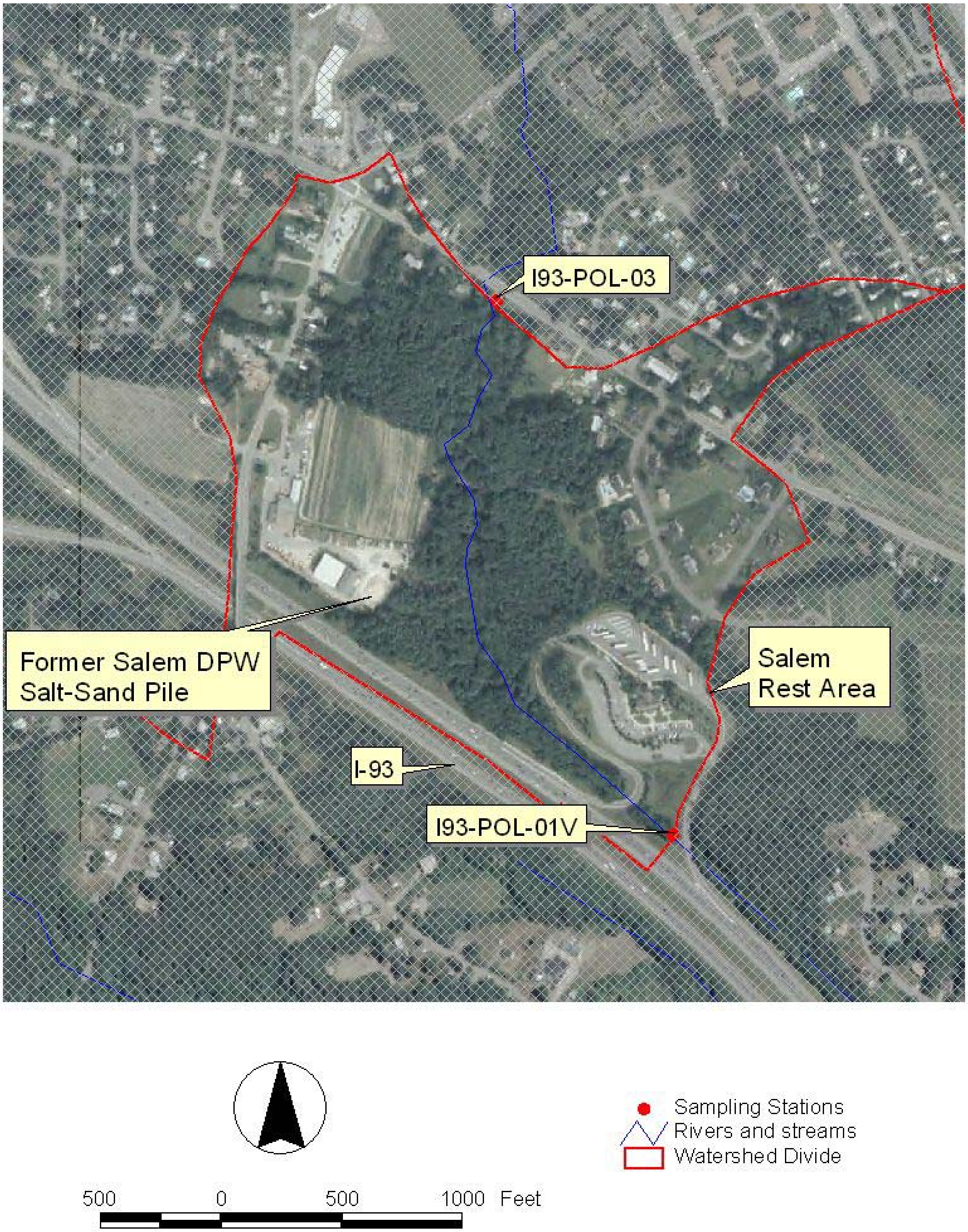

Figure 11: Annual Salt Imports to Study Watersheds

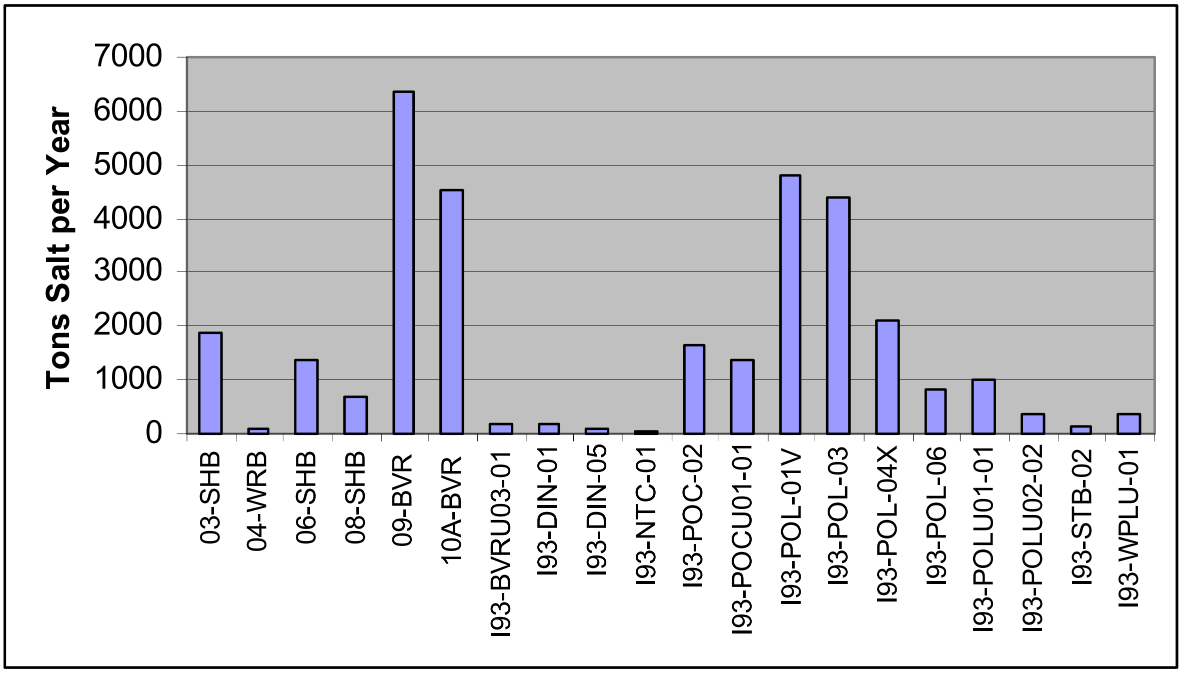

Figure 12: Percent of Total Salt Imports for Each Source for the 09-BVR Watershed

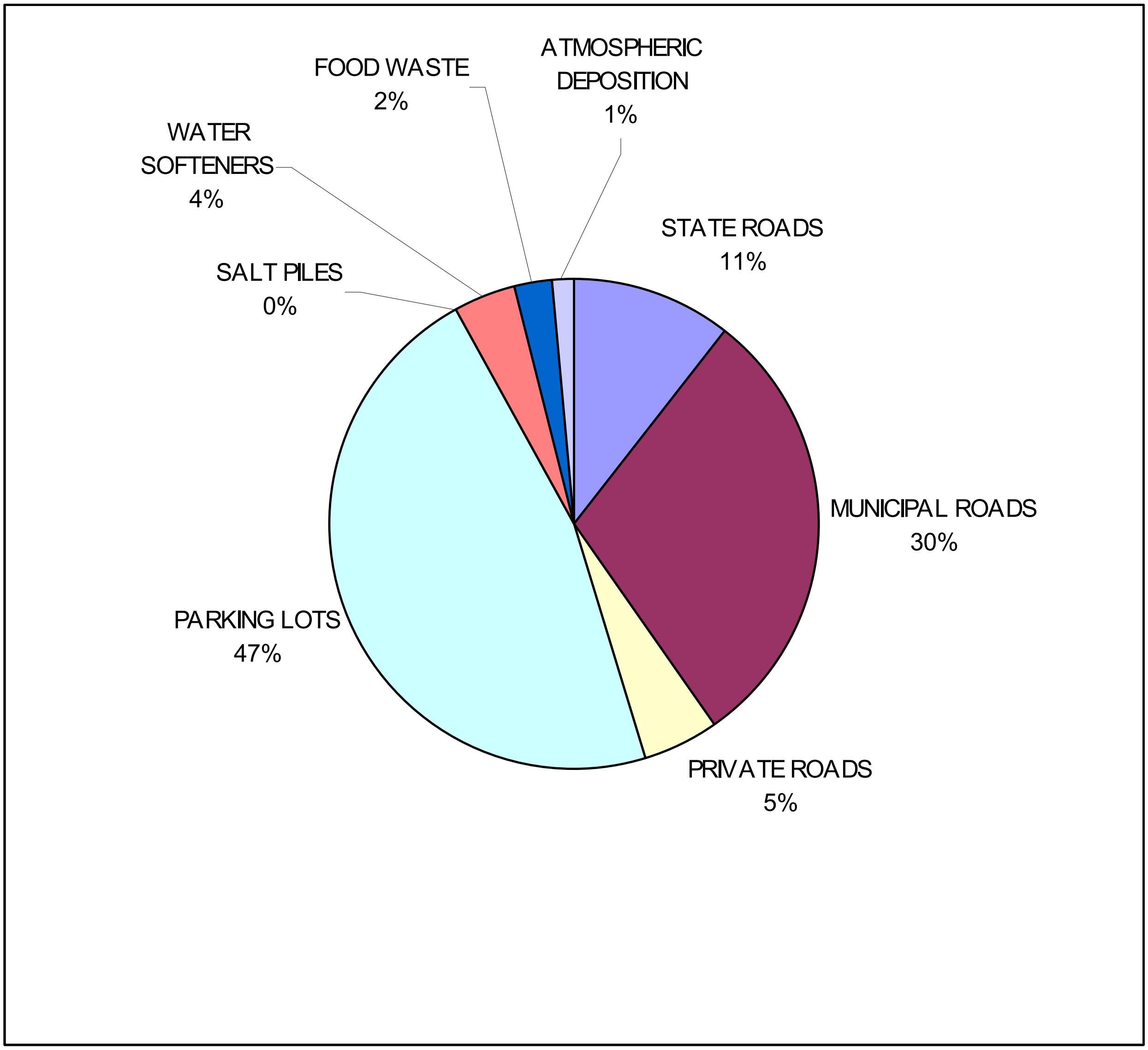

Figure 13: Percent of Total Salt Imports for Each Source for the 10A-BVR Watershed

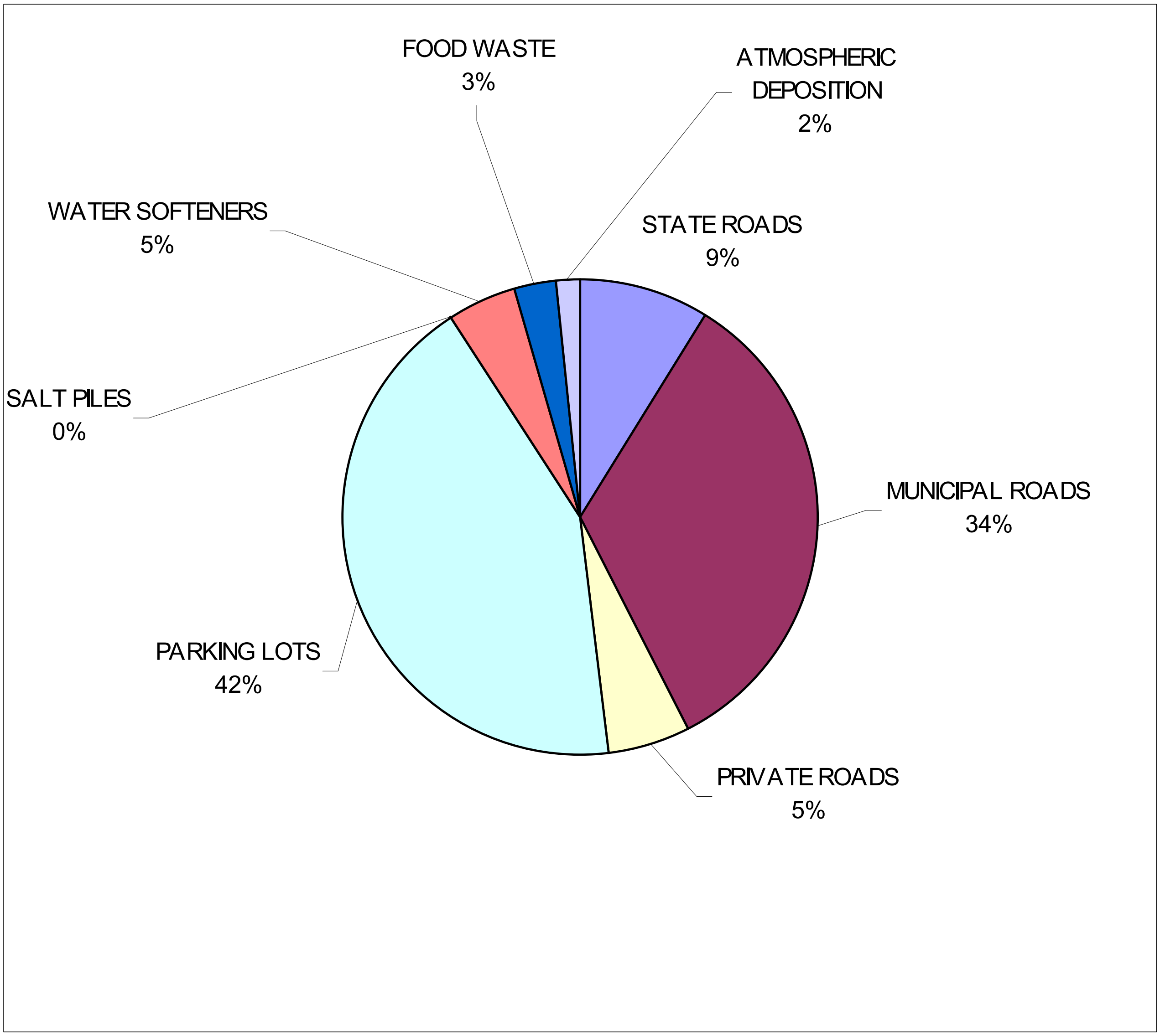

Figure 14: Percent of Total Salt Imports for Each Source for the I93-NTC-01 Watershed

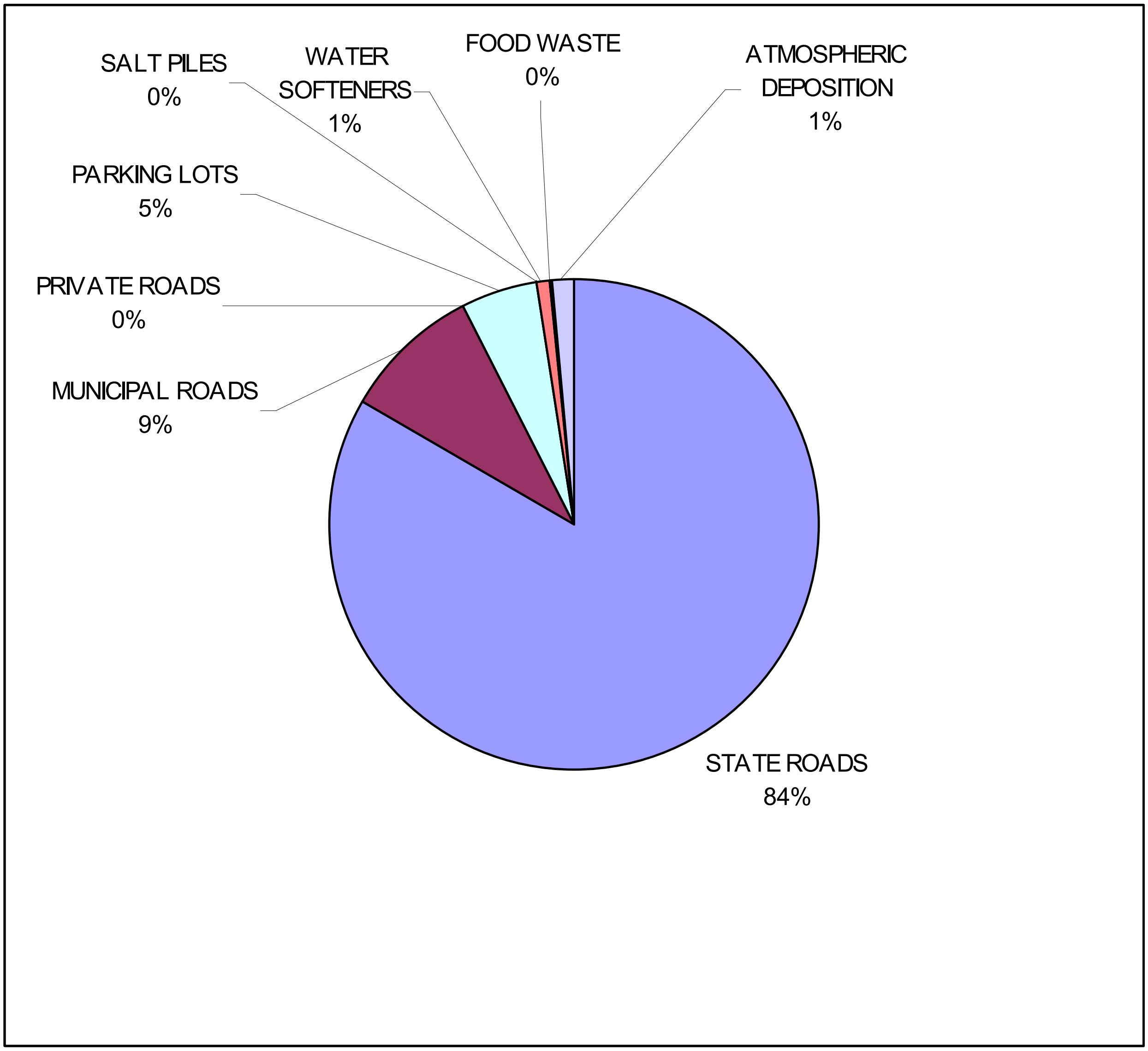

Figure 15: Percent of Total Salt Imports for Each Source for the I93-DIN-01 Watershed

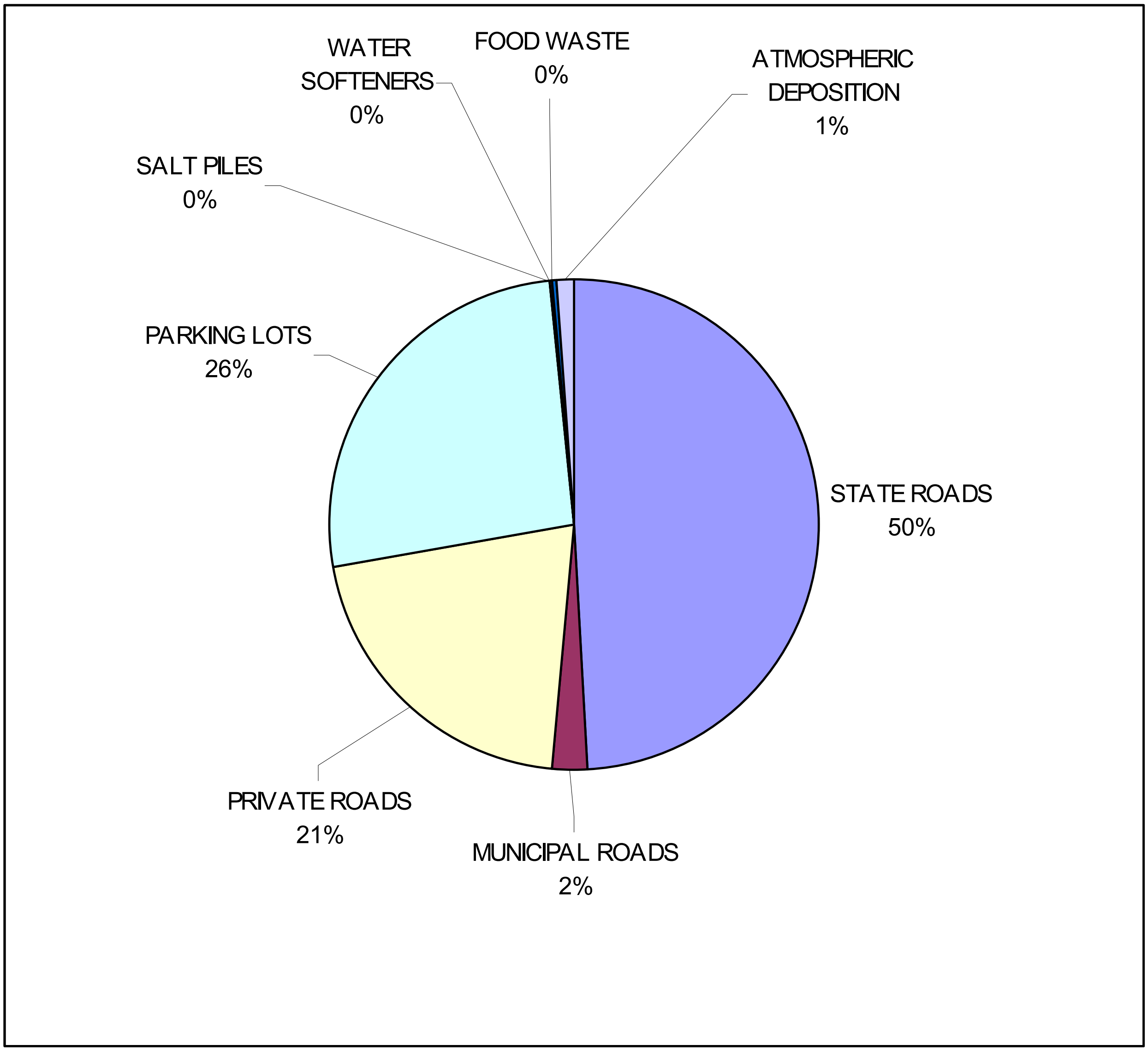

Figure 16: Percent of Total Salt Imports for Each Source for the I93-POL-01V Watershed

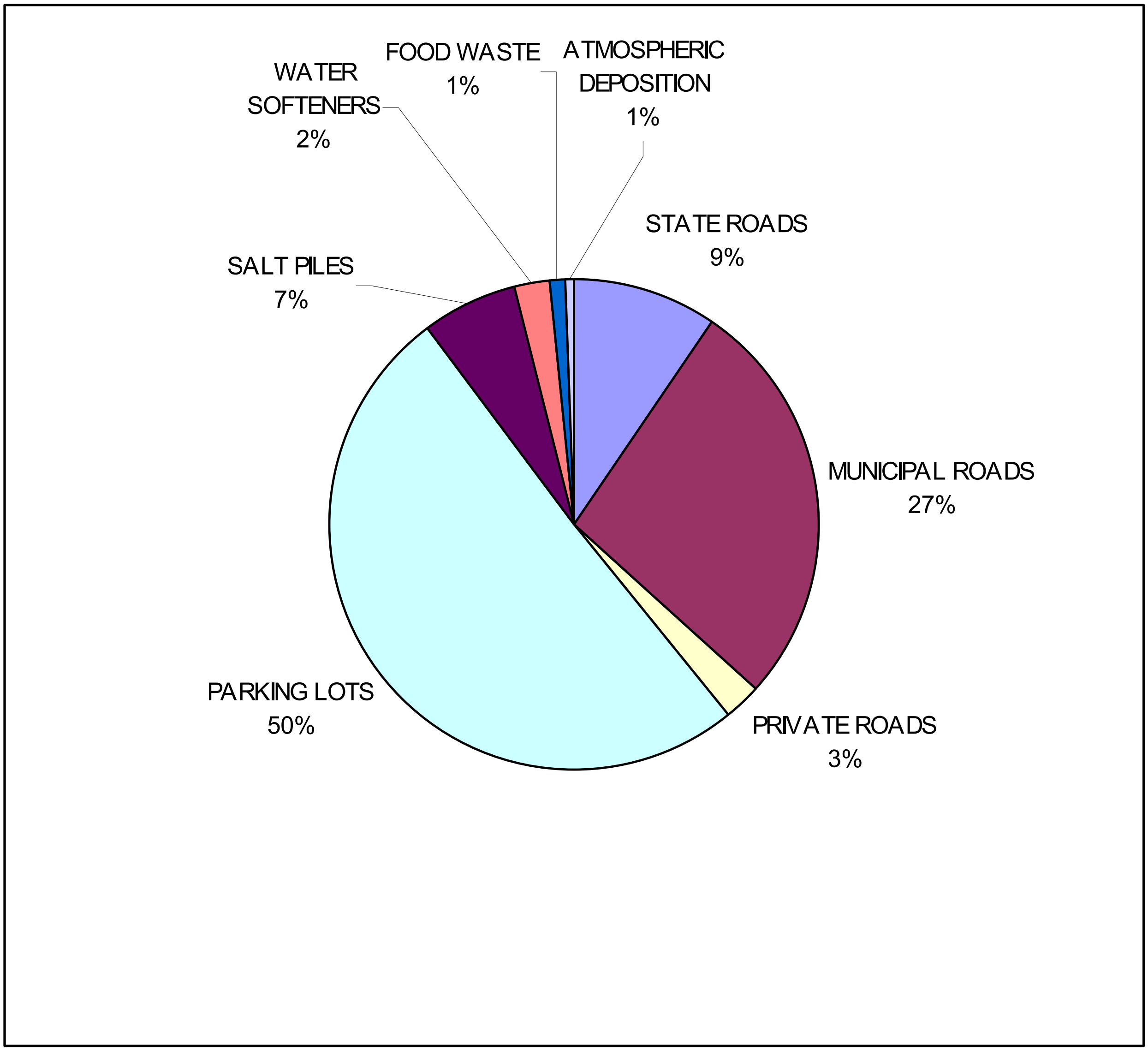

Figure 17: Percent of Total Salt Imports for Each Source for the I93-POL-04X Watershed

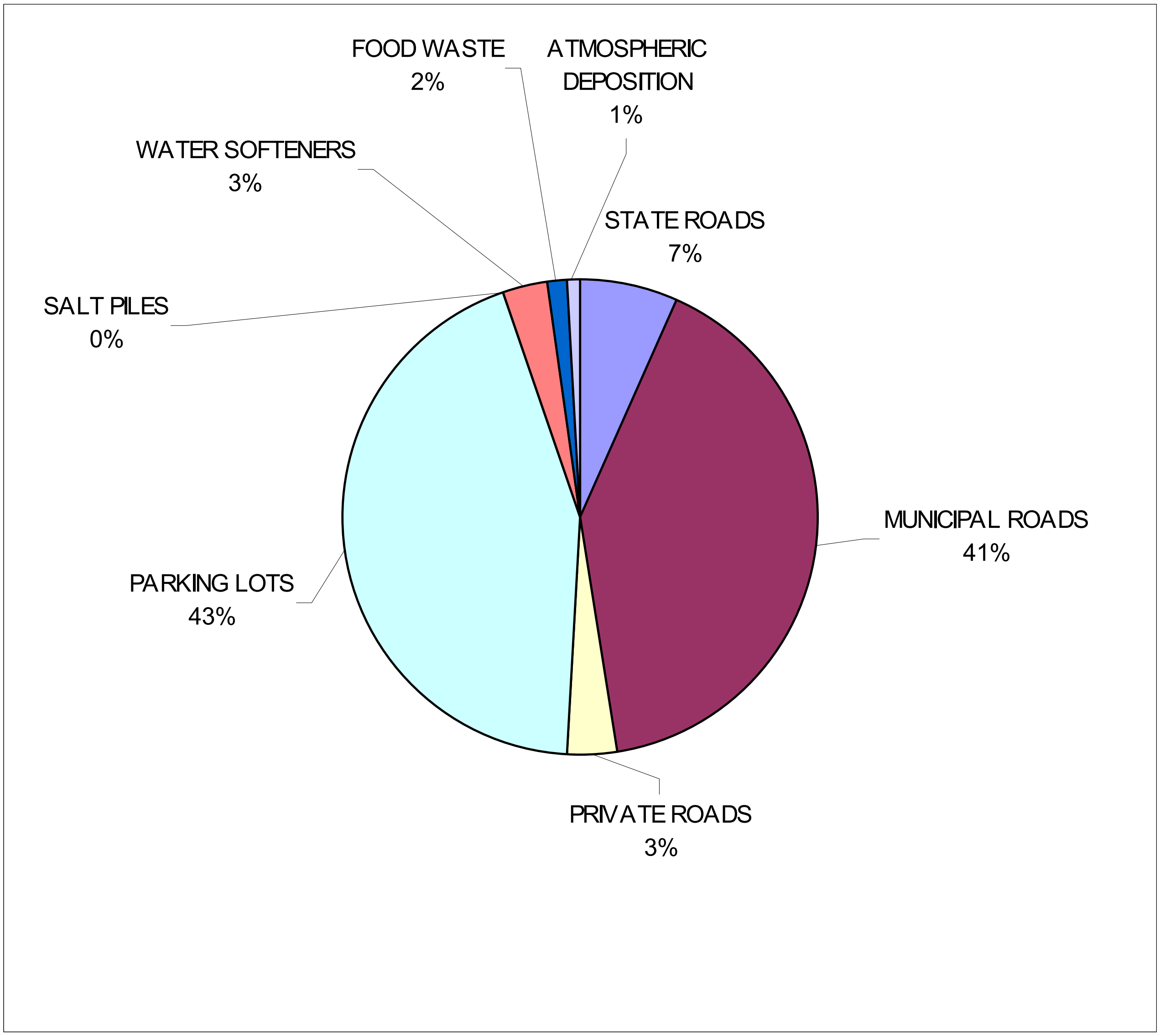

Figure 18: Chloride Mass Balance in Study Watersheds

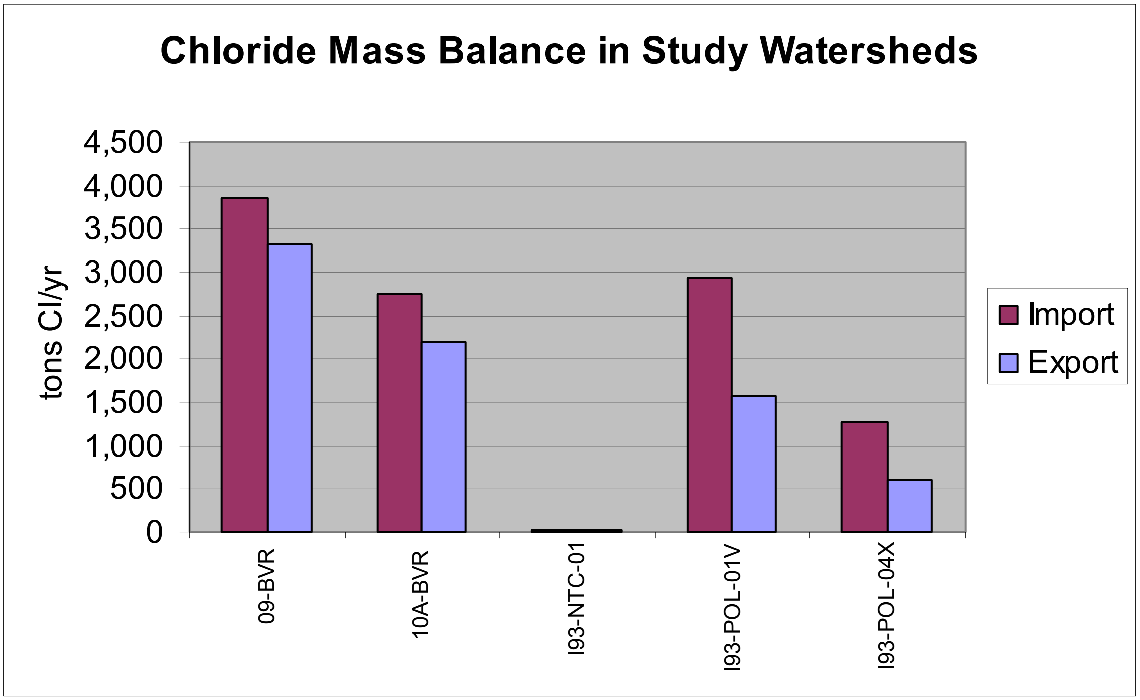

Figure 19: Chloride Mass Balance in Study Watersheds Normalized by Drainage Area

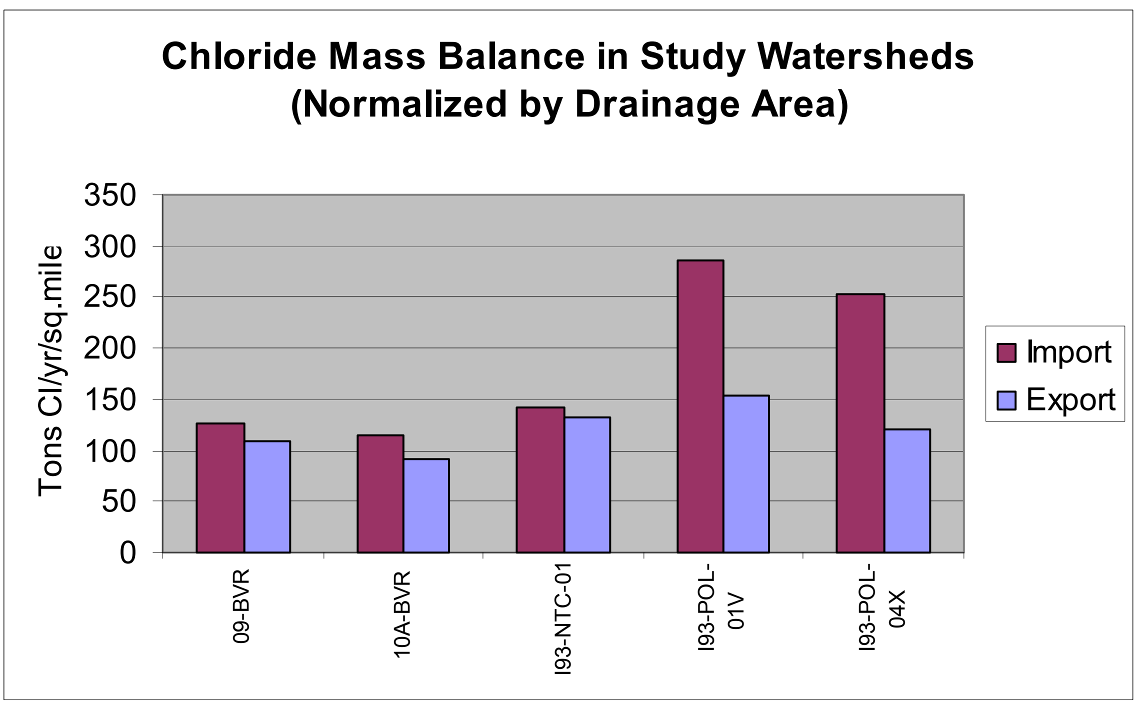

Figure 20: Relationship between Chloride Imports to Activity #1 Watersheds and Violations of the Chronic Water Quality Standard

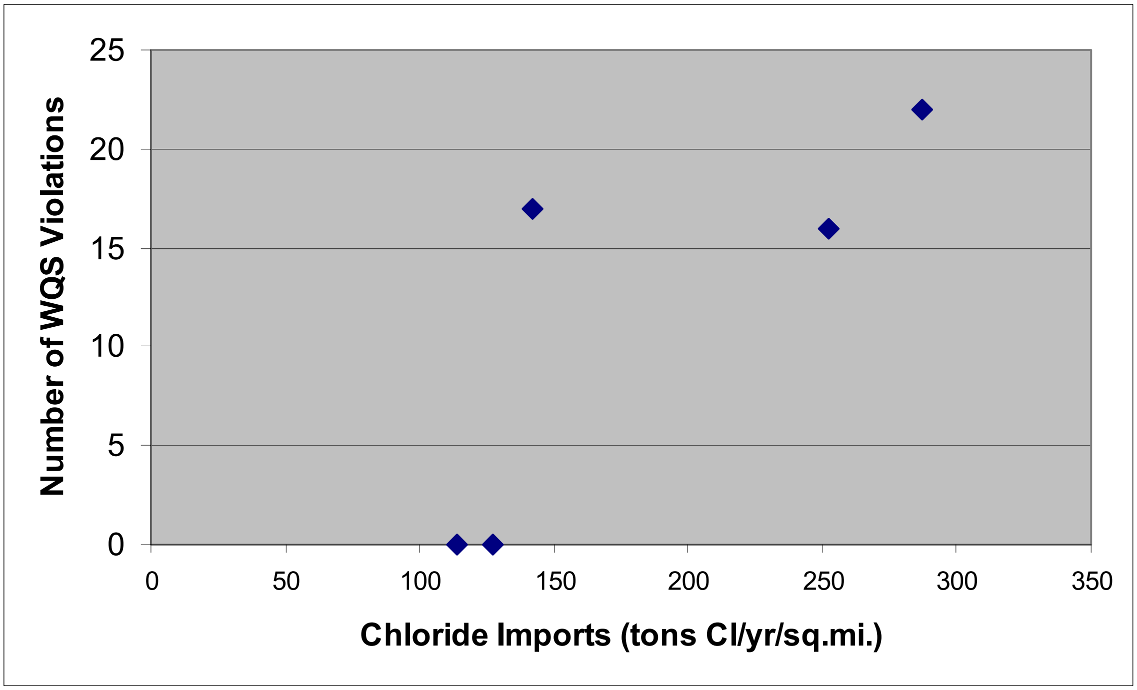

Figure 21: Relationship between Chloride Imports to Study Watersheds and the Percent of Developed Land in the Watershed