Shingle Creek Chloride TMDL Report

Wenck File #1240-34

Prepared for:

SHINGLE CREEK WATER MANAGEMENT COMMISSION
and the
MINNESOTA POLLUTION CONTROL AGENCY

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1.0 Introduction

1.1 PURPOSE

The goal of this TMDL is to quantify the pollutant reductions needed to meet the water quality standards for chloride in Shingle Creek. The Shingle Creek TMDL for chloride is being established in accordance with Section 303(d) of the Clean Water Act, because the State of Minnesota has determined waters in the Shingle Creek Watershed exceed the State established standards for chloride.

1.2 PROBLEM IDENTIFICATION

Shingle Creek has an urban/suburban watershed located in the northwestern portion of the Minneapolis metropolitan region. The Creek is heavily used for stormwater management. The drainage system is composed of Shingle Creek, which is the major waterway, several tributaries, some intermittent streams, and a few man-made ditches. The main stem of Shingle Creek begins in Brooklyn Park in northwestern Hennepin County and flows generally southeast to its confluence with the Mississippi River in Minneapolis. Shingle Creek is formed at the junction of Bass Creek and Eagle Creek, two of the minor tributaries in the watershed. The creek is approximately 11 miles long and drops approximately 66 feet from its source to its mouth. Palmer Lake is the only lake directly on Shingle Creek.

High levels of chloride can directly harm aquatic organisms by disrupting natural osmo-regulatory processes. The MPCA has been actively developing plant and invertebrate indices of biological integrity (IBIs) in depressional wetlands to be used as indicators of wetland condition Howard Markus, pers. comm.). As part of this research, standard water quality data are gathered in addition to biological data. Both the plant and invertebrate IBIs have been found to be negatively correlated with chloride concentrations (Figure 1.1), suggesting that chloride may be causing declines in wetland diversity.

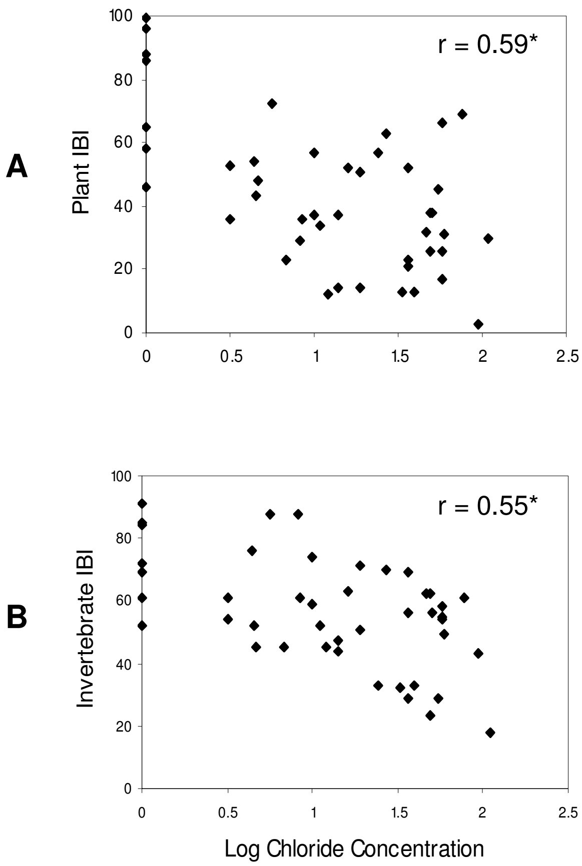


Figure 1.1. Correlations of wetland plant (A) and invertebrate (B) IBIs with chloride concentration (* = $P < 0.001$).

In 1998, Shingle Creek was listed on the Federal Clean Water Act's 303(d) list of impaired waters for exceeding the chloride standard for aquatic life. The listing of Shingle Creek as impaired resulted from a limited sampling of chloride completed in 1996 by the US Geological Survey (USGS) at their discharge monitoring station at the Queen Avenue Bridge in Minneapolis. After reviewing the USGS data from Queen Avenue, the Shingle Creek Watershed Management Commission (SCWMC) has been sampling routinely for chloride in Shingle Creek. This TMDL was developed to address the 1998 listing for the impairment of aquatic life and recreation based on chloride exceedances.

Chloride is present in road salt, which most traffic authorities in the metropolitan area use extensively in the winter for snow and ice control. A network of freeways, highways, and local roads, all of which eventually drain to the creek, crisscross Shingle Creek's watershed.

Section 303(d) of the Clean Water Act (CWA) requires the Minnesota Pollution Control Agency (MPCA) to identify waters that are not meeting State water quality standards and develop Total Maximum Daily Loads (TMDL) for those water bodies. A TMDL is the total amount of a pollutant that a water body can assimilate and still meet State water quality standards on a daily basis. Through the TMDL, pollutant loads can be distributed among the point and nonpoint sources in the watershed. These pollutant load allocations can then be used by managers to make science-based decisions on land use and management in the watershed.

In April 2002, the MPCA contracted with the Shingle Creek Watershed Management Commission, who subsequently contracted with Wenck Associates, Inc., to develop the TMDL for Chloride. The chloride TMDL included two phases: 1) field collection of data and 2) data analysis and TMDL modeling and allocation. The primary objectives pertinent to the Shingle Creek Chloride TMDL include:

- Define the spatial extent, persistence, and severity of chloride exceedances in the watershed,

- Identify and quantify the sources of chloride in Shingle Creek including point and nonpoint sources,

- Allocate Shingle Creek's assimilative capacity to both point and nonpoint sources and develop safety margins protective of State water quality standards.

Since this TMDL represents the first TMDL for chloride in Minnesota, another aspect of this TMDL was the documentation of the lessons learned during this process. The concept for the lessons learned was to develop an understanding of chloride dynamics in a representative watershed to help provide key information region wide where it is likely that widespread chloride exceedances may be occurring. The memo documenting lessons learned (Wenck 2004) was developed separately from this report.

2.0 Target Identification and Determination of Endpoints

2.1 IMPAIRED REACHES

In 1998, Shingle Creek was listed on the Federal Clean Water Act's 303(d) list of impaired waters for exceeding the chloride standard for aquatic life. Shingle Creek is considered a single assessment reach for the purposes of evaluating compliance with State water quality standards. However, several water bodies are included in the Shingle Creek watershed that may have unique hydrologic conditions. This TMDL evaluates all stream reaches in the Shingle Creek watershed including Ryan Creek, Bass Creek, and Pike Creek in addition to Shingle Creek (Hydrologic Unit Code: 07010206-506).

2.2 APPLICABLE MINNESOTA WATER QUALITY STANDARDS AND ENDPOINTS

Shingle Creek is designated as Class 2 water for the protection of Aquatic Life (Minnesota R. ch. 7050). Chloride standards for the protection of these beneficial uses include a chronic standard of 230 mg/L based on the 4-day average and an acute standard of 860 mg/L for a one-hour duration for class 2 waters (Minnesota R. ch. 7050 and 7052).

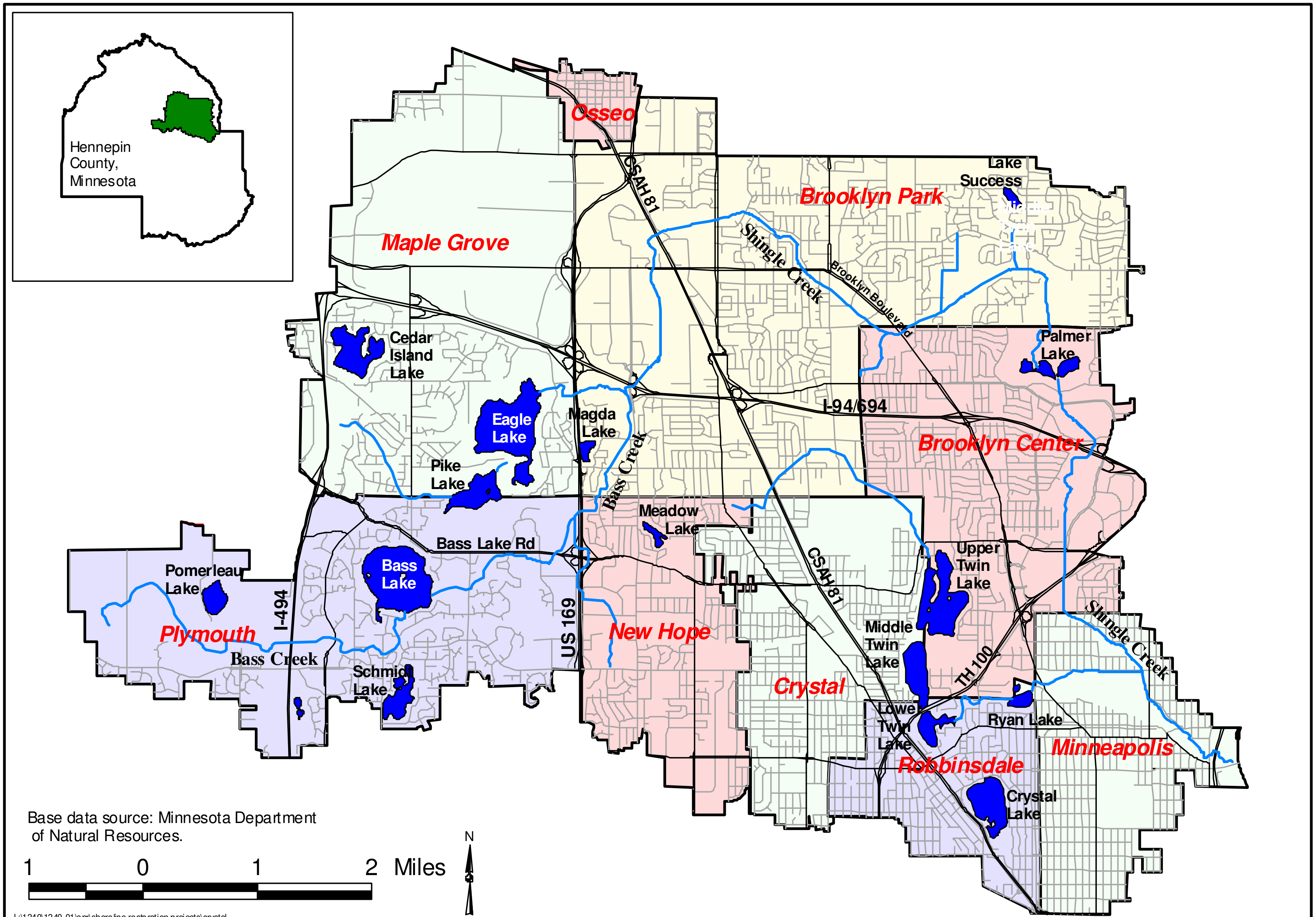
2.3 MPCA NON-DEGRADATION POLICY

An important aspect of water quality standards in Minnesota is the non-degradation policy. The fundamental concept of non-degradation is the protection of water bodies already meeting State water quality standards. A more thorough discussion of Minnesota's non-degradation policy can be found in MPCA's "Guidance Manual for Assessing the Quality of Minnesota Surface Waters" (MPCA 2003). This TMDL was prepared in compliance with the State of Minnesota's non-degradation policy.

3.0 Watershed Characterization

3.1 WATERSHED DESCRIPTION

The Shingle Creek watershed covers 44.5 square miles in east-central Hennepin County including nine municipalities (Figure 3.1). Shingle Creek begins at the junction of Bass Creek and Eagle Park in Brooklyn Park, flows easterly, then southerly for a total of 11.3 miles before discharging into the Mississippi River in Minneapolis. The nine municipalities included in the watershed are Brooklyn Center, Brooklyn Park, Crystal, Maple Grove, Minneapolis, New Hope, Osseo, Plymouth, and Robbinsdale. These entities created a joint powers organization, The Shingle Creek Watershed Management Commission (SCWMC), as required by the Metropolitan Surface Water Management Act of 1982. The SCWMC's responsibilities include controlling excessive volumes and rate runoff, stormwater management, improving water quality, preventing flooding and erosion, promoting groundwater recharge, protecting and enhancing fish and wildlife habitat, and water recreation. In addition to these municipalities, roads in the watershed are also maintained by Hennepin County and the Minnesota Department of Transportation (Mn/DOT).



SHINGLE CREEK WATERSHED MANAGEMENT COMMISSION

Watershed Base Map

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Figure 3.1

3.2 LAND USE

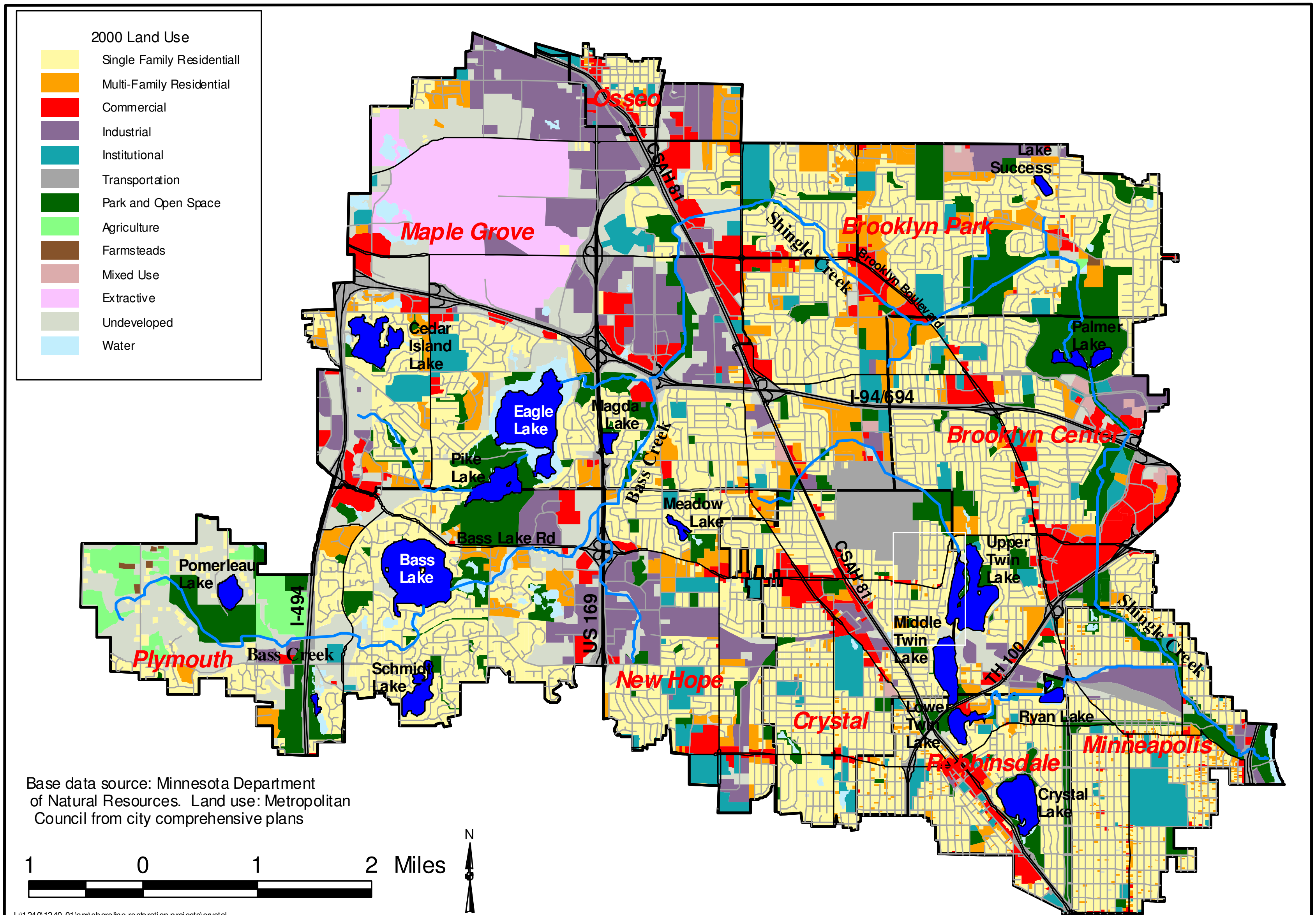
3.2.1 Current Land Use

Land use within the Shingle Creek and West Mississippi watershed has been and will be influenced by several factors, primarily proximity to Minneapolis and St. Paul and access to major transportation routes.

The predominant land uses in the southern and eastern part of the watershed are dense residential, commercial, and industrial, and in the northern and western part less dense residential, commercial, and industrial with some remaining undeveloped land (Figure 3.2; Table 3.1). All of the SCWMC except a small portion of the southwest corner of the watershed in Plymouth is within the existing Metropolitan Urban Service Area (MUSA). As such, metropolitan services and facilities including sanitary sewer are provided. Of that area of Plymouth in the SCWMC currently outside the MUSA, most lies within the MUSA 2020 expansion area. Plymouth has committed to protecting wetlands, lakes, and other natural resources within that expansion area as it develops.

Table 3.1. Land Use in the Shingle Creek Watershed

Landuse	Area (acres)	Percent
Single Family Residential	8,759	30%
Roads and Major Highway	5,205	18%
Park, Recreational or Preserve	2,486	9%
Undeveloped	2,353	8%
Industrial and Utility	2,184	8%
Multi-Family Residential	1,696	6%
Commercial	1,507	5%
Institutional	1,290	4%
Water	1,271	4%
Extractive	1,183	4%
Airport	370	1%
Agriculture	285	1%
Mixed Use	94	0.3%
Railway	72	0.3%
Farmsteads	16	0.1%
TOTAL	28,771	100%



SHINGLE CREEK WATERSHED MANAGEMENT COMMISSION

2000 Land Use

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Figure 3.2

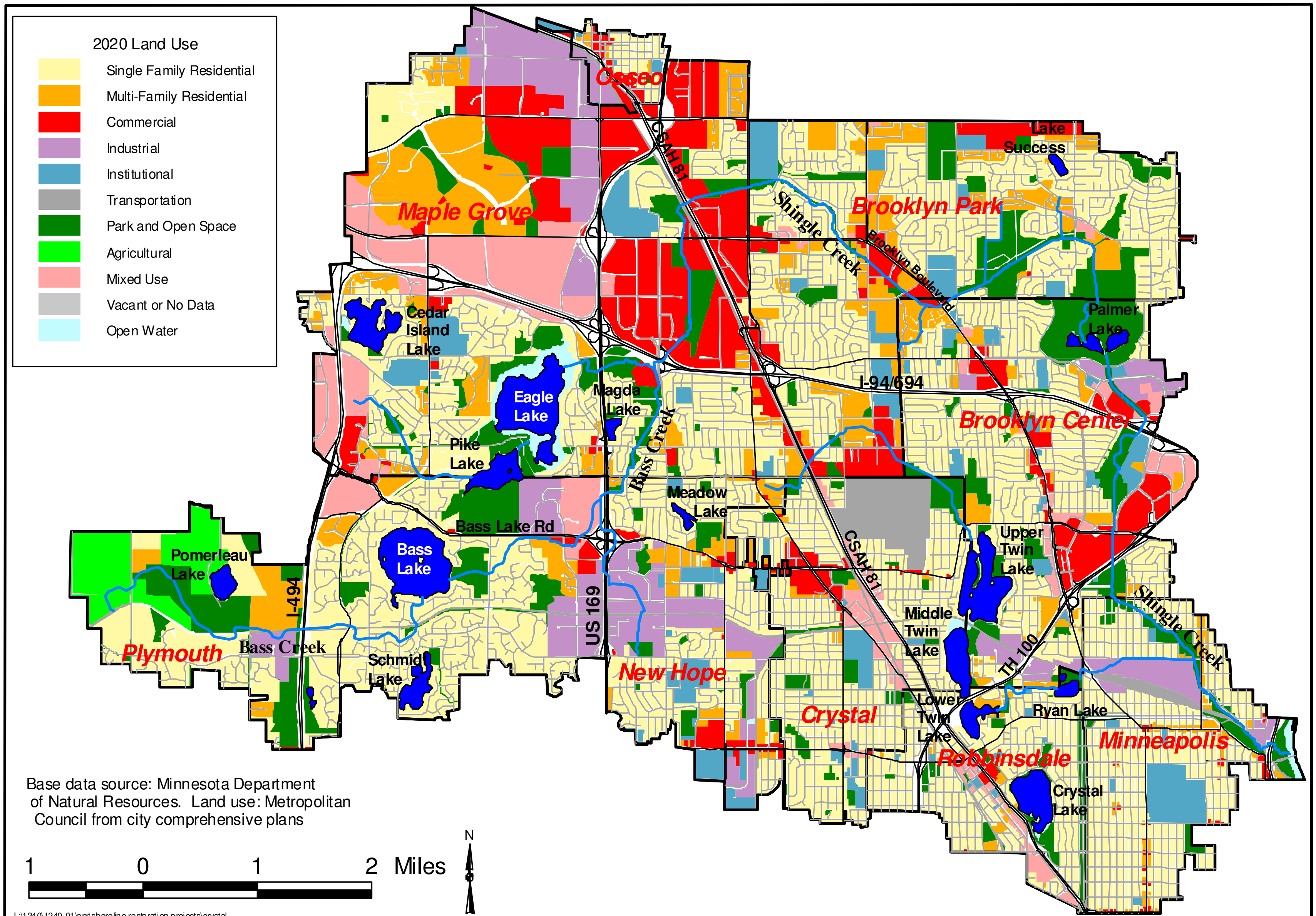
3.2.2 Population Density

In general, the central and southeastern part of the watersheds is developed, with population density increasing to the southeast. Minneapolis within the watershed is very dense, as are portions of adjacent Robbinsdale, Brooklyn Center, and Brooklyn Park. Significant areas of commercial/ industrial development cluster around major highways: TH 100, TH 169, CSAH 81, I-94.

Only three significant undeveloped or lightly developed areas of the watershed remain: northern Brooklyn Park north of 85th Avenue, now quickly developing; in Maple Grove, the area around and including part of the gravel pits, being developed as the large Arbor Lakes multi-use development; and significant tracts in northwestern Plymouth. Development will intensify in some parts of Plymouth that are currently developed at a low density. However, significant tracts that are now undeveloped or developed at very low density are intended to remain that way.

3.2.3 Future Land Use

Areas of projected urban growth are shown in Figure 3.3. These data were compiled by the Metropolitan Council from cities' most recent Comprehensive Plans, and represents cities' expected 2020 land use. Most of the currently undeveloped or lightly developed areas of northern Brooklyn Park, southeastern Maple Grove, and northwestern Plymouth are shown as expected to be developed by 2020. Growth is expected to be a mix of development at different densities, and to include residential, commercial, and industrial uses.



SHINGLE CREEK WATERSHED MANAGEMENT COMMISSION

2020 Land Use

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Figure 3.3

3.3 SOILS

Most of the watersheds' area is composed of well-drained soils. Texture is generally sandy or loamy with scattered organic or marsh soils areas. Highly to moderately permeable soils dominate the watershed, as indicated by large areas covered by soil hydrologic groups A and B. In poor permeability areas, soils are heavy textured soil groups such as clays/clay-loams and silt/silt-loams. Heavier soils can often result in reduced permeability.

3.4 GEOLOGY AND GEOMORPHOLOGY

Two major geomorphic regions are found in the Shingle Creek watershed: the Mississippi Valley Outwash area and the Emmons-Faribault moraine area. The outwash area is predominant in the eastern portion of the watersheds. The western portion of the watersheds is within the Emmons-Faribault moraine. This morainic area is characterized by a rolling topography with a relief of 20 to 30 feet. There are several lakes within this geomorphic area.

The surficial geology of the western half the watersheds ranges from areas of lacustrine sand and silt and clay and silt in the south to the sandy and loamy till in the north that characterizes the northwestern part of the county. Significant deposits of sand and gravel in the northwestern part of the watersheds are apparent in the gravel mining area of Maple Grove.

3.5 HYDROGRAPHIC DATA

Average daily flows have been monitored and reported at the USGS station at Queen Avenue since 1996. Additionally, stream flow was monitored at the outlet (Humboldt Avenue) and Zane Avenue by the SCWMC. Monthly average flows at the USGS station range from 2.77 cfs in January to 38 cfs in May. The maximum average daily flow at the USGS station was 225 cfs recorded on July 1, 1997.

3.6 METEOROLOGICAL DATA

Precipitation in the Twin Cities metropolitan area averages approximately 29 inches annually with average annual snowfall of 56 inches (State Climatology Office – Department of Natural Resources December 2000).

Chloride and discharge monitoring for the TMDL occurred from December 2002 through August 31, 2003. The winter of 2002-2003 was relatively mild with snowfall total of 36 inches (Table 3.2). However, Data was collected by the USGS at the Queen Avenue Bridge from May of 1996 to December of 1998. The winter of 1996-1997 was a heavy snow year with 72.1 inches of snowfall. The winter of 1997-1998 was slightly below the average snowfall of 56 inches at 45 inches. These data were analyzed to address annual variability.

Table 3.2. Snowfall and Precipitation in the Twin Cities Metropolitan Area for the 2002-2003 Water Year

Month	Snowfall (inches)	Twin Cities Area Precipitation or Water Equivalence (inches)	Difference from Normal[1] (inches)
September-2002	0	3.69	1.00
October-2002	0	3.80	1.69
November-2002	1.4	0.07	(1.87)
December-2002	3.0	0.28	(0.72)
January-2003	5.1	0.29	(0.75)
February-2003	10.7	0.81	0.02
March-2003	13.2	1.56	(0.30)
April-2003	1	2.61	0.30
May-2003	0	5.43	2.19
June-2003	0	3.57	(0.77)
July-2003	0	3.24	(0.80)
August-2003	0	0.69	(3.36)
Total	34.4	26	(3.37)

[1]Values in parentheses are below normal

Snow pack loss and subsequent runoff is an important process in controlling chloride movement to surface waters. Maximum daily temperatures, snow pack depth, and discharge for the TMDL monitoring period are presented in Figure 3.4.

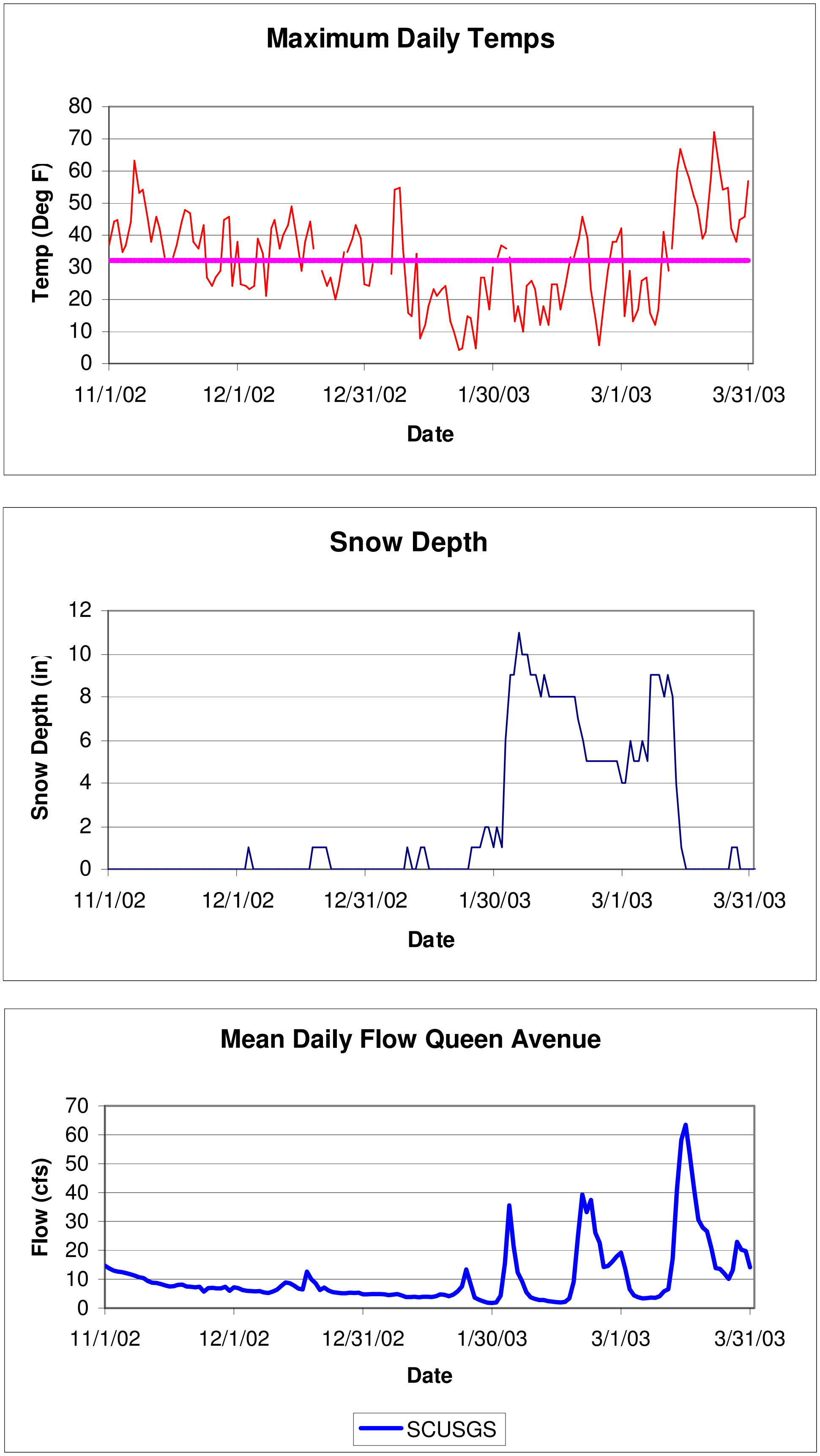

Figure 3.4. Maximum daily temperature, snow pack depth, and discharge in the Shingle Creek watershed for the winter of 2002-2003. Weather data was collected by the National Weather Service in New Hope.

Warm periods in the winter can result in melting of surface snow and increasing the snow water equivalence of the current snow pack and/or can result in a runoff event in the watershed. In general, late January and early February demonstrated an increase in snow pack depth. Following this period, snow pack depth decreased without significant runoff until about mid-February when a runoff event was recorded. This pattern demonstrates a period of snowmelt without runoff that increases the snow water equivalence.

4.0 Water Quality Monitoring Methods

In order to develop an understanding of chloride dynamics in an urban environment, monitoring of conductivity, chloride and discharge was performed from late November 2002 through August of 2003. All monitoring activities were outlined in a monitoring plan approved by the Technical Advisory Committee and MPCA (MWH, 2002). Following is a description of these activities and subsequent data processing.

4.1 STREAM SAMPLING LOCATIONS

Table 4.1 has a description of each of the stream monitoring locations. All of the sites are presented on Figure 4.1.

4.2 STREAM DISCHARGE AND CONDUCTIVITY MONITORING

Seven sites were continuously monitored for flow and conductivity (Figure 4). All sampling protocols followed an approved sampling plan (MWH 2001). Sampled was conducted from November 2002 through October of 2003. Grab samples for chloride were collected during base flow and runoff conditions at these sites to develop relationships between chloride and conductivity. Conductivity and stage were recorded every 15 minutes, and chloride samples collected biweekly and during significant runoff events. One sampling site was a storm sewer outfall that drains portions of Maple Grove. However, due to low flows, these data are not utilized in this analysis

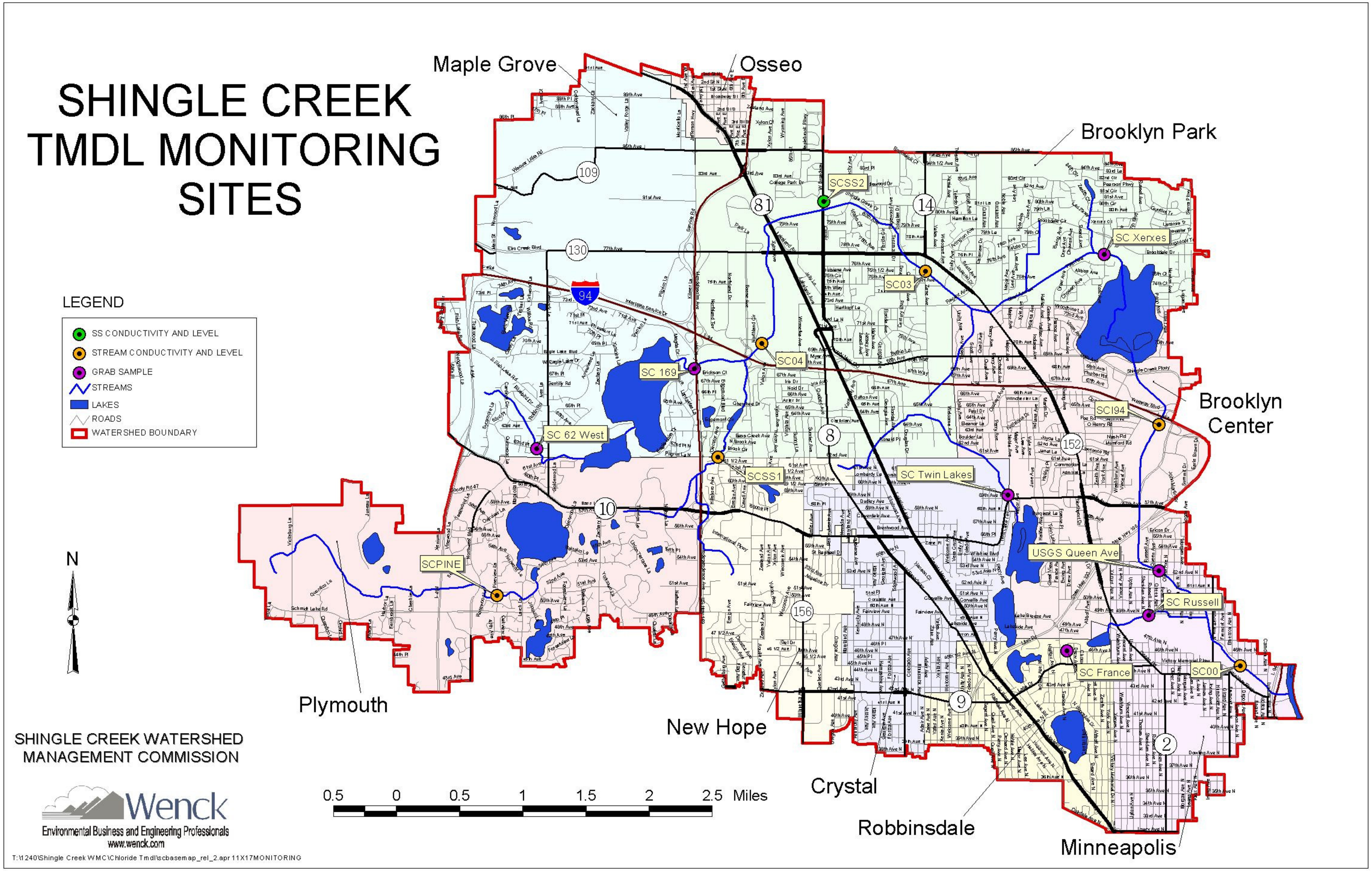
SHINGLE CREEK
TMDL MONITORING
SITES
LEGEND
SS CONDUCTIVITY AND LEVEL
STREAM CONDUCTIVITY AND LEVEL
GRAB SAMPLE
STREAMS
LAKES
ROADS
WATERSHED BOUNDARY
Maple Grove
Osseo
Brooklyn Park
Brooklyn Center
Plymouth
New Hope
Crystal
Robbinsdale
Minneapolis
SCSS2
SC Xerxes
SC03
SC04
SC 169
SC 62 West
SCSS1
SC Twin Lakes
SCI94
USGS Queen Ave
SC Russell
SC France
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Table 4.1. Stream Sampling Sites in the Shingle Creek Watershed. River Mile (RM) is given for each site.

Site Name	Stream	Location	Description
Continuous Conductivity and Flow Monitoring Sites			
SC00	Shingle Creek (RM 0.6)	Shingle Creek upstream of 45th	Shingle Creek outlet long term monitoring station.
SCI94	Shingle Creek (RM 3.3)	Shingle Creek downstream of I-94/694 Bridge	
SC03	Shingle Creek (RM 7.3)	Shingle Creek upstream of Zane	Shingle Creek Zane Avenue long term monitoring station.
SCSS2	Shingle Creek (RM 9)	West Broadway Ave N	A 60" concrete stormsewer pipe that drains to Shingle Creek. Automated conductivity measured at a manhole located just south of North Hennepin Community College and between Broadway and adjacent trail
SC04	Shingle Creek (RM 1.3)	Northland Ct N	Shingle Creek at east end of Northland Ct (The Quadrant office complex.) Sampling location is downstream of large wetland/stormwater pond.
SCSS1	Shingle Creek (RM 11.4)	Bass Creek downstream of 62nd Ave N.	Several stormsewers discharge to Bass Creek upstream of sampling location but station is below mixing zone
SCPINE	Bass Creek (RM 14)	Pineview La N	Upstream of Pineview and approximately 2000' upstream of Bass Lake
Grab Sample Sites			
Twin Lake Inlet	Ryan Creek	France Ave N	A low flow stream downstream of France between Twin Lake lower basin and Ryan Lake.
France	Ryan Creek	Bass Lake Rd	Inlet to Twin Lake upper basin: Upstream of Bass Lake Rd as it curves around Twin Lakes upper basin.
Xerxes	Shingle Creek	Xerxes Ave N	Shingle Creek downstream of Xerxes between 75th and Brookdale Dr. and adjacent to Palmer Lake Trail
62 East	Shingle Creek	US Hwy. 169	Shingle Creek downstream of Hwy. 169 and upstream of large wetland complex between Hwy. 169 and Boone Ave N.
62 West	Pike Creek	62nd Place N	Pike Creek upstream of 62nd and approximately 1500' upstream of Pike Lake

4.2.1 Stage Measurements, Rating Curves, and Discharge

Stage was monitored at four sites using SOLINST level loggers (pressure transducers). Data was collected at 15-minute intervals from late March through October 31, 2003. These data were adjusted to match a benchmark in the stream and corrected for barometric pressure. Details of the adjustments are documented in Appendix A. Stage data at Zane Ave. (SC03) and the Outlet (SC00) were collected using ISCO transducers. Stage-discharge rating curves were developed for each site. Details of rating curve development are in Appendix A.

4.2.2 Data Gaps

Although 15-minute stage data were collected at each of the monitoring sites in the watershed, there are periods where data could not be collected due to winter freeze potential (or where logger failure occurred. These data gaps were filled using regression equations relating the site with the long term USGS station at Queen Avenue. Two equations were used to fill data gaps. Summer and fall data were used to estimate winter discharge since these data are most representative of low flow periods. Spring equations were run separately since discharge in the spring is highly variable. Regression statistics are presented in Table 4.2.

Table 4.2. Regression Statistics used to Fill Hydrologic Data Gaps.

Site	Season	Slope
62 East	Winter/Summer/Fall	0.298
	Spring	0.234
SCI94	Winter/Summer/Fall	0.896
	Spring	0.839
SC04	Winter/Summer/Fall	0.735
	Spring	0.54
SCPINE	Winter/Summer/Fall	0.208
	Spring	0.179
SC00	Winter/Summer/Fall	1.17
	Spring	1.15
SC03	Winter/Summer/Fall	0.673
	Spring	0.883

4.2.3 Winter Flow Estimates

Flow in the winter is difficult to estimate due to ice conditions and equipment limitations. However, winter flow is important to understanding chloride dynamics in the winter season. Winter flow estimates were generated using the seasonal regressions described in Section 4.2.2. However, it is important to note that winter stage was measured by the USGS using a pressure transducer at the Queen Avenue location. Stage measurements from pressure transducers can be susceptible to backwater effects caused by ice on the stream and can produce some sampling error in the calculated discharge. Spot-checking the data with loss of snow pack suggests that the results provide a good approximation of runoff events in the watershed. Winter flow was compared to changes in conductivity to further verify events. Since load analysis compares loads at the same flow point, comparisons during the winter month are not sensitive to these flow errors, rather are dependent upon robust concentration estimates. Further examination of winter flows was accomplished using the XP-SWMM hydraulic model.

4.3 GRAB SAMPLES

Samples were collected biweekly and during runoff events. All sampling protocols followed an approved sampling plan (MWH 2002). Sampling was conducted from November 2002 through August of 2003. Grab sampling occurred at all continuous and grab sample sites and included field measurements of conductivity, dissolved oxygen, and temperature.

4.4 ROAD SALT APPLICATION

Another key component of the field study was documentation of salt applied for deicing purposes. GIS was used to accurately quantify road salt applied to the watershed spatially and under varied intensities. The GIS data processing is briefly described in the following sections.

4.4.1 Road Surface Evaluation

The first step in the evaluation of road surfaces was to “burn” or introduce the road surfaces into the land use coverage. Existing land use coverages do not account for road areas except for a few major right-of-ways, representing roads with an over-laid line coverage that ignores road width. To estimate road width to add to the land use coverage, twenty-seven places were chosen to measure the width of the road, including shoulders, and ramps over the Metropolitan Council 2000 1-meter digital orthophotos for the Shingle Creek Watershed. These widths were used to determine the road areas from the Minnesota Department of Transportation (Mn/DOT) alignments and DOT Basemap Roads for Hennepin County (2001 GIS data). The remaining land uses were then reduced by the corresponding area converted to roadway. The base land use coverage is from the Metropolitan Council, and is representative of the generalized land use for the year 2000. Completion of this analysis resulted in a land use coverage with actual road areas instead of lines representing roads of many different sizes. More details on this analysis can be found in Appendix B.

4.4.2 Salt Applied for Deicing

Agencies responsible for road deicing maintained records of salt applied for the winter of 2002 and 2003. All roads in the watershed were assigned one of three plow route types (Mn DOT, Hennepin County, or Municipality.) Municipality plow routes were specified by the cities in the watershed (Brooklyn Center, Brooklyn Park, Plymouth, Osseo, Robbinsdale, New Hope, Maple Grove, Crystal, and Minneapolis.) The lane miles were tabulated for each subwatershed by plow route type. The salt application data, in units of tons of salt applied per lane mile, coupled with the lane mile estimates were used to estimate the amount of salt applied to each subwatershed. For example, one subwatershed may cross three plow routes from three different applicators. Each of the applicators applies salt at a different rate for each event. The calculation assumes that in any given event, the driver is using the same application rate across the subwatershed boundaries. For example, if a driver reports using a total of 100 tons of salt for a 0.5 inch snowfall event, we assume that salt was applied evenly throughout that drivers route. Although there might be small variations in rates throughout the route, this approach provides a reasonable representation of where the salt ends up in the watershed. However, the rate is variable by event and is calculated from the reported application data provided by the drivers. - All of these records were compiled for the plow routes designated by the corresponding agency. Salt application records were then allocated to the appropriate subwatersheds using GIS on a daily time step.

NOTE: Mn/DOT uses Salt Institute research to create guidelines for Mn/DOT supervisors to determine the rates of salt application (varying between 100 to 800 lbs/mile). Mn/DOT supervisors analyze the information collected by the State’s Road Weather Information Systems (RWIS) and other sources to determine the rate of salt application that operators should use in the field. This rate guideline can also be altered by operators based on road conditions observed in the field.

4.5 SALT PILES AND RUNOFF

Salt piles in the watershed were inventoried and a site evaluation completed for each site. Site evaluations included assessment of storage area, drainage from the site, and general site information such as ground surface (i.e., gravel versus pavement). Salt piles were sampled for salt pile chemical composition. Ten representative samples from various places in the salt pile were collected with a stainless steel scoop and composited in a glass container collecting approximately one kilogram. These samples were analyzed for total and orthophosphorus. Additionally, two events were sampled from several of the sites to characterize salt pile runoff quality. Water samples were analyzed for chloride, total cyanide, free cyanide (HCN), total phosphorus, and orthophosphorus.

4.6 QUALITY CONTROL

Quality control is an important aspect of any sampling effort. Several measures were in place during the filed investigations including collecting duplicate samples and calibration analysis of field loggers.

4.6.1 Grab Samples

Twenty duplicate samples were taken representing 9% of the total samples collected. There was generally a less than 10% difference between duplicate samples collected during the field study (Figure 4.2).

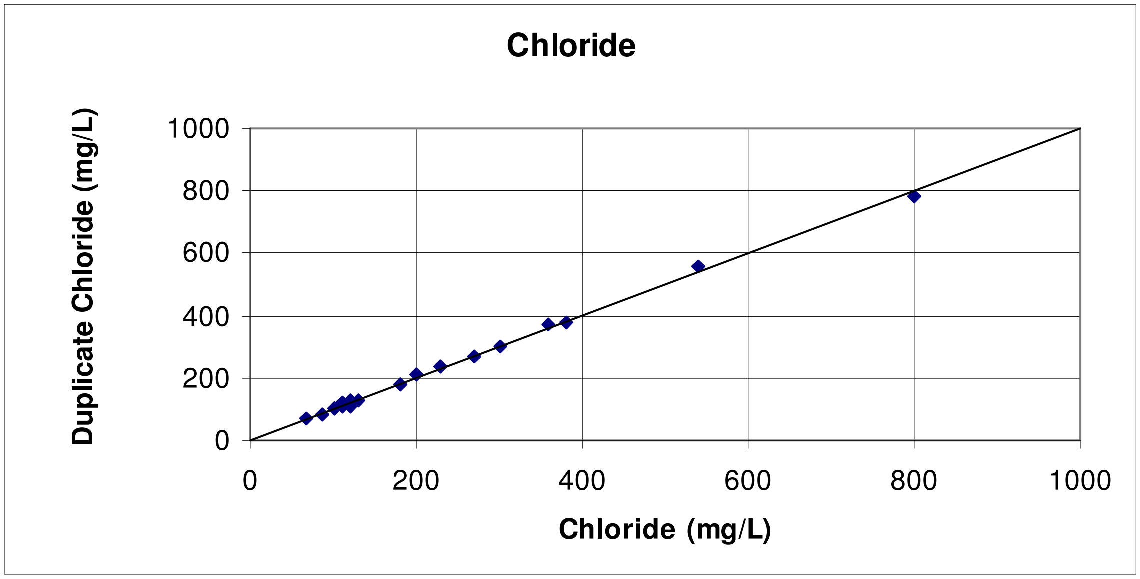


Figure 4.2. Chloride Duplicates Plotted on a 1:1 Line

4.6.2 Conductivity Loggers

Conductivity loggers were checked using both standards and an independent field conductivity meter. Conductivity loggers were evaluated and calibrated once each in April, July, and October by comparing the measured conductivity in a standard to the standard value. Evaluation of the loggers demonstrates that measurements were typically within 10% of conductivity standards with a few exceptions. The conductivity loggers performed very well.

Logged conductivity was also compared to an independent field measure of conductivity (Figure 4.3). With one exception, field and logged conductivity were typically within 10% with the median difference of less than 3%.

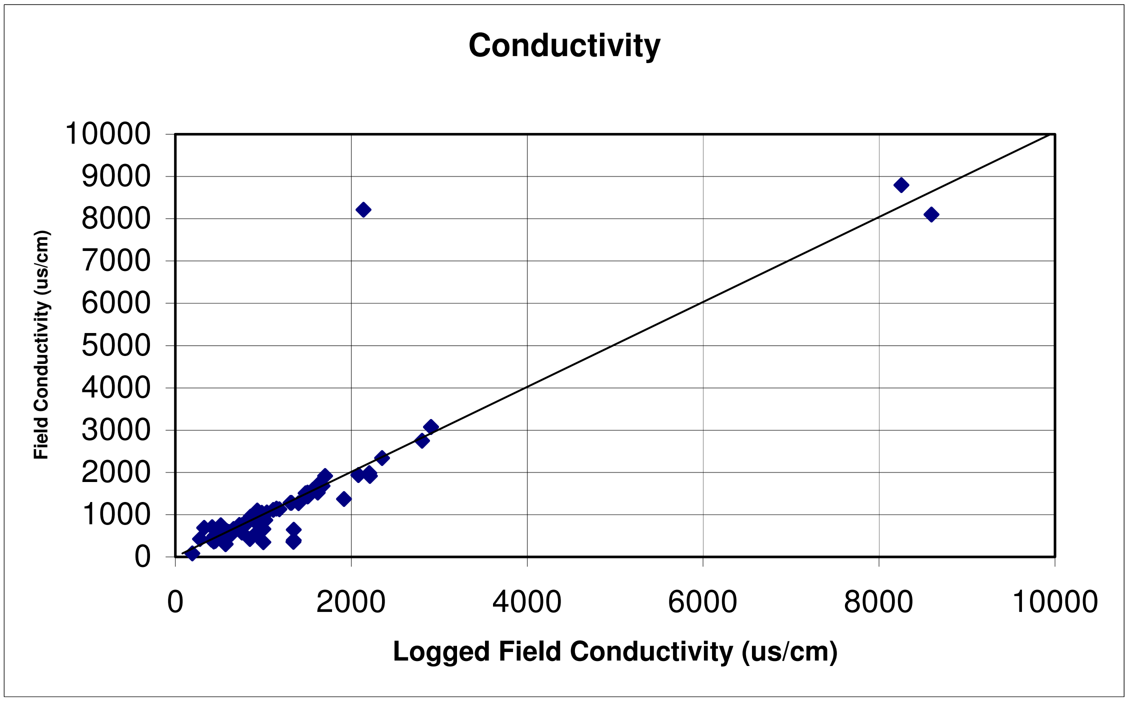


Figure 4.3. Logged and Field Measured Conductivity Plotted along a 1:1 Line.

5.0 Source Assessment

Chloride can originate from a wide range of sources including industrial wastewater discharge, municipal wastewater treatment plant effluent, runoff from road application of salt for deicing, runoff from parking lots and fertilizer applications. A detailed assessment of sources in the Shingle Creek watershed was conducted as a part of this TMDL.

5.1 POINT SOURCES

There are few point sources in the Shingle Creek watershed. There are no wastewater treatment plant effluent discharges in the watershed. NPDES permits in the watershed are listed in Table 5.1. None of the SC permits attached have chloride as a parameter of concern (Nancy Drach, MPCA pers. comm.). Consequently, the NPDES permit holders listed in Table 5.1 are all considered deminimus in regard to chloride discharges. Therefore, these discharges are consider insignificant sources and are not assigned a waste load allocation in this TMDL. The Hutchinson Technology permit lists coolant water as treated by reverse osmosis as being discharged.

Table 5.1. Industrial Discharge Permits in SCWMC

NPDES ID	Facility Name	Address	SIC Description
MNG490009	C S McCrossan	7865 Jefferson Hwy Maple Grove	Asphalt Paving Mixtures and Blocks
MNG250048	Robinson Rubber Products Co Inc	4600 Quebec Ave N New Hope	Fabricated Rubber Products
MN0002119	GAF Materials	49th Avenue Minneapolis	Asphalt Felts and Coatings
MNG490010	Tiller Corp	10633 89th Ave N Maple Grove	Asphalt Paving Mixtures and Blocks
MNG790069	Former TPI Facility - 9145	6830 Brooklyn Blvd Brooklyn Center	Gasoline Service Station
MNU000378	Universal Foods	New Hope	
MNU790130	Former Pilgrim Cleaners	Brooklyn Blvd & 69th Brooklyn Center	Dry Cleaner
MN0066699	Hutchinson Technology	5905 Trenton Plymouth	Metal Stamping
MN0066958	Mn/DOT TH 100 Project	Robbinsdale & Brooklyn Center	Highway Construction Dewatering

Source: Minnesota Pollution Control Agency

In addition to these NPDES permits in the watershed, NPDES Phase II permits for small municipal separate storm sewer systems (MS4) have been issued to the member cities in the watershed as well as Hennepin County and Mn/DOT. The City of Minneapolis has an individual NPDES permit for Stormwater – NPDES Permit # MN 0061018. The other cities, Hennepin County and MnDOT Metro District, are covered under the Phase II General NPDES Stormwater Permit – MNR040000. The unique permit numbers assigned to these cities, Hennepin County and MnDOT Metro District are as follows:

- Brooklyn Center – MS400006
- Brooklyn Park – MS400007
- Crystal – MS400012
- Maple Grove – MS400102
- New Hope – MS400039
- Osseo – MS400043
- Plymouth – MS400112
- Robbinsdale – MS400046
- Hennepin County – MS400138
- MnDOT Metro District – MS400170

EPA requires that stormwater discharges regulated under NPDES be allocated into the wasteload allocation or point source portion of the TMDL. Although the sources of chloride in the watershed are nonpoint in nature, they are allocated in the wasteload allocation in this TMDL. However, the discussion of the sources maintains the nonpoint source nature of chloride.

5.2 NON-POINT SOURCES

The majority of chloride in the Shingle Creek watershed is derived from nonpoint sources including road deicing, commercial and industrial deicing, and fertilizer application. Most fertilizer application occurs in the spring, summer, and fall suggesting that the chloride generated from this source either infiltrates into the groundwater or runs off during spring and summer storms.

5.2.1 Salt Piles

Salt piles are a potential source of chloride in the Single Creek watershed. Salt piles or road salt storage facilities are used to store road salt before application to roads for snow and ice removal. Table 5.2 lists the salt piles in the Shingle Creek watershed along with some general characteristics of the storage facility. There are eight salt piles in the Shingle Creek watershed.

Several factors can affect the amount of chloride that can enter stream systems from a road salt storage facility. In general, covered road salt piles with an impervious surface will generate less runoff and infiltration of chloride-laden water. Two of the salt piles in the watershed were only covered by a tarp and one of these was on a gravel surface. The drainage route can also affect the amount of chloride discharge to surface waters. Direct connections through storm pipes provide a direct route to surface waters whereas discharge to a pond can offer some retention and dilution of salt storage facility runoff. Most of the facilities drained to a pond or wetland and then directly to a storm sewer. Runoff chloride, phosphorus and cyanide concentrations were measured for several of these salt storage facilities.

Table 5.2. Salt Storage and Maintenance Facilities in the Shingle Creek Watershed

Operator	Location	Storage Facility	Pile Composition	Drainage Surface	Drainage Route
Hennepin County Osseo	West of Hwy 81	Unknown	Unknown	Unknown	Unknown
Maple Grove	Forestview La. N.	Covered with plastic tarp on asphalt	Salt	Asphalt	Surface drainage to wetland 50 ft from pile; discharge from wetland to storm sewer
Brooklyn Park	Noble Ave. N. north of 83rd Ave N.	Enclosed	Salt	Asphalt	Surface drainage to pond 300 ft from pile; discharge from pond to storm sewer
Brooklyn Center	Shingle Creek Pkwy. east of Shingle Creek	Enclosed	Salt	Asphalt	Surface drainage to storm sewer to pond
Robbinsdale	Toledo Ave. north of 45th Ave. N.	Covered with plastic tarp on gravel	Salt/sand mixture	Gravel	Surface drainage to ditch adjacent to property; ditch drains to storm sewer
New Hope	International Pkwy. south of Research Center Rd. E.	Enclosed	Salt	Asphalt	Surface drainage to storm sewer
Osseo	Broadway Ave. west of Hwy. 169	Covered with plastic tarp on asphalt	Salt/sand mixture	Asphalt	Surface drainage to storm sewer
Crystal	41st Ave N. east of Douglas Dr. N.	Enclosed	Salt	Asphalt	Surface drainage to pond south of property

Spillage of road salt and deicing materials can also increase the amount of chloride in runoff from salt storage facilities. Spillage outside of covered areas makes the road salt available for dissolution and runoff during precipitation events.

Another potential source of chloride from road salt storage facilities is the washing of the maintenance vehicles. Wash water that enters the storm sewer system ultimately ends up in surface waters. Although this source is potentially small in comparison to other sources in the watershed, it is worth noting.

Runoff from salt piles in the watershed was sampled on March 20, March 28 and April 17, 2003. Samples were analyzed for ortho and total phosphorus as well as chloride and total and free cyanide (weak acid dissociable). Results of these sampling events are presented in Table 5.3.

Table 5.3. Runoff Characteristics (Average) from Several Salt Storage Facilities in the Shingle Creek Watershed.

Operator	Area (ac)	Drainage Route	Chloride (mg/L)	Free Cyanide (mg/L)	Total Cyanide (mg/L)	Total Phosphorus (mg/L)
Hennepin County Osseo	0.10	Unknown	1,270	ND	0.078	0.219
Maple Grove	0.07	Surface drainage to wetland 50 ft from pile; discharge from wetland to storm sewer	12,800	0.014	0.904	0.119
Brooklyn Park	0.27	Surface drainage to pond 300 ft from pile; discharge from pond to storm sewer	824	ND	0.103	0.175
Brooklyn Center	0.32	Surface drainage to storm sewer to pond	--	--	--	--
Robbinsdale	0.06	Surface drainage to ditch adjacent to property; ditch drains to storm sewer	1,038	ND	0.016	0.162
New Hope	0.16	Surface drainage to storm sewer	19	ND	ND	0.070
Osseo	0.05	Surface drainage to storm sewer	1,285	ND	0.037	0.257
Crystal	0.20	Surface drainage to pond south of property	17	ND	ND	0.137

5.2.2 Road Deicing

One of the primary sources of chloride in the watershed is the application of road salt or road salt alternatives in the watershed. The predominant chloride salt used for deicing in North America is sodium chloride (Environment Canada 1999). Substances potentially present in road salt include phosphorus (14-26 mg/kg), nitrogen (6.8-4,200 mg/kg), copper (0-14 mg/kg), and zinc (0.02 – 0.68 mg/kg) (MDOT 1993). Additives often include sodium ferrocyanide and ferric ferrocyanide used as anti-caking agents. These additives are of some concern because these compounds can photolyse and release free cyanide ions which are toxic to aquatic organisms. Runoff concentrations from salt piles in the Shingle Creek watershed only found one detection of free cyanide (Table 5.3) and several grab samples collected from Shingle Creek were non-detects as well.

Table 5.4 presents results from salt pile sampling in the Shingle Creek watershed. Salt piles were sampled at 10 different locations vertically and then composited and analyzed for total and orthophosphorus. Total phosphorus concentrations ranged from 6.3 to 28 ppm.

Table 5.4. Phosphorus results from salt pile sampling for salt storage areas that supply salt for use in the Shingle Creek Watershed.

Salt Pile	Ortho P (mg/kg)	Total P (mg/kg)
MNDOT Golden Valley	4.24	6.33
MNDOT Maple Grove	ND	ND
Hennepin County Osseo	--	--
Plymouth	ND	ND
Maple Grove	ND	6.77
Brooklyn Park	ND	ND
Brooklyn Center	ND	ND
Robbinsdale	ND	28
New Hope	ND	19.5
Osseo	1.16	13.4
Crystal	ND	ND

Roads in the Shingle Creek watershed are maintained by Mn/DOT, Hennepin County and the respective cities (Table 5.5). Hennepin County and Brooklyn Park maintain the largest proportion of roads comprising 37% of all the lane miles in the watershed.

Table 5.5. Lane Miles by Maintenance Official in the Shingle Creek Watershed.

Owner	Lane Miles	Percent
Hennepin County	259.9	19%
Brooklyn Park	243.2	18%
Mn DOT	155.9	11%
Brooklyn Center	139.1	10%
Crystal	112.0	8%
Minneapolis	105.7	8%
Plymouth	92.8	7%
Robbinsdale	87.8	6%
Maple Grove	86.9	6%
New Hope	73.5	5%
Osseo	18.7	1%
Total	1375.5	100%

Road salt applied in the watershed was typically sodium chloride applied in rock or brine form, often as a part of a mixture of salt and sand (Table 5.6).

Table 5.6. General deicing policies for road maintenance officials in the watershed.

Road Authority	De-icing Substances Used	Comments
Brooklyn Center	100% salt	Salt-sand used as necessary
Brooklyn Park	100% salt	Salt-sand used as necessary
Crystal	4:1 sand/salt	
Maple Grove	100% salt	Have tried molasses product in past but had trouble with application – too sticky
Minneapolis	100% salt 5:1 sand/salt	
New Hope	2:1 sand/salt	
Osseo	1:1 sand/salt	Had good luck with "Clear Lane" MgCl/molasses product instead of salt in 2003-04 and will likely continue in the future
Plymouth	3:1 sand/salt	Occasional 100% salt
Robbinsdale	4:1 sand/salt	
Hennepin County	100% Salt Sand/salt mix	5:1, 10:1 salt/sand as necessary. Has tried prewetting with mixed results. Have a potassium acetate test site outside of SC watershed on CR 135.
Mn/DOT	100% salt Sand/salt mix Some calcium chloride and magnesium chloride	Salt/sand of various mixes used as necessary.
CP Railroad Yard	Some sand/salt mix on rails and walkways as necessary	Some CaCl used in Feb-Mar to deice and dry out

Road salt application rates in the winter of 2002 and 2003 by maintenance entity is presented in Figure 5.1. Application rates were normalized to present rates in tons applied per lane mile by month and entity. Application occurs on some major highway shoulders to provide access for busses and mass transit. These lane miles were not included in these calculations. Application rates varied by maintenance entity, with the highest application rates associated with those entities responsible for major highways.

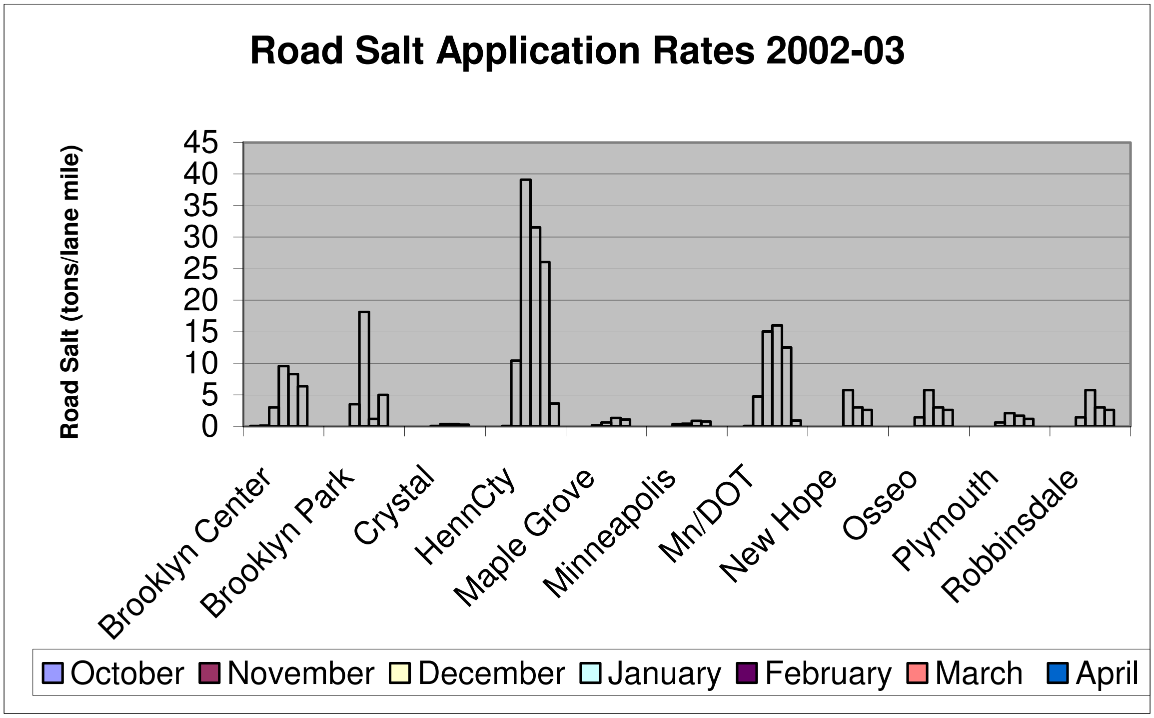


Figure 5.1. Road Salt Application Rates for each Month of the 2002-2003 Winter Season.

Approximately 8,701 tons of road salt (5,308 tons chloride) were applied to the watershed during the winter of 2002 and 2003 (Table 5.7). The heaviest application occurred in January and February, corresponding to the months with the greatest amount of snowfall. It is important to note that the winter of 2002-2003 was a below normal snow fall year for the Twin Cities metropolitan area. Snowfall was around 36 inches while the long-term average is approximately 56 inches. Data is not available for specific application amounts in the Shingle Creek watershed for other years. Consequently, we must assume that the rates in the monitored year are indicative of relative agency application rates. Stream data is available for 1996 through 1998 from the USGS and is used to assess interannual variability.

Table 5.7. Tons of Road Salt and Associated Chloride applied to the Shingle Creek Watershed during the Winter of 2002-2003 for Road Deicing.

Month	Total Road Salt (tons)	Total Chloride (tons)
October	1	0
November	6	3
December	773	471
January	3,414	2,083
February	2,360	1,440
March	2,026	1,236
April	122	75
TOTAL	8,701	5,308

5.2.3 Private Industrial and Residential Deicing

Private contractors, industry, and agencies such as port authorities and airports use salt as a deicer. Limited data were available for parking lots, industrial, commercial, and other private properties. Cheminfo (1999) estimated that commercial and industrial consumers represented approximately 5 to 10% of the road salt market. In quantifying total road salt application in Canada, Environment Canada used the midpoint of these data (7.5%) to represent commercial and industrial road salt application (Environment Canada 1999).

5.2.4 Natural Sources

Natural sources of chloride salts (calcium, potassium, sodium, and magnesium) can occur as a result of rock weathering, soil erosion, and atmospheric precipitation. Atmospheric precipitation is typically only important in coastal maritime regions. Local precipitation monitoring only identifies trace amounts of chloride in precipitation (NADP 2002). Few, if any, rock outcrops occur in the watershed. Consequently, any input from geologic sources would be groundwater sources.

5.2.5 Groundwater Discharge

Although groundwater sources are not directly addressed in this report, they can be important since much of what enters the groundwater can end up in the stream channel. Natural sources of chloride in groundwater are primarily geologic. Anthropogenic sources to groundwater can include septic leachate, landfill leachate, infiltration from fertilizers (potassium chloride), and infiltration of chloride rich runoff from deicing activities.

5.2.5.1 Water Softeners and Septic Systems

There is little information available for septic systems in the Shingle Creek watershed since most of the watershed is sewered. However, some septic systems do exist in the watershed. Typical chloride concentrations in untreated domestic wastewater range from 30 to 100 mg/L (Metcalf and Eddy 1991). Much of this discharge would ultimately end up in groundwater through infiltration and not in surface waters.

Water softeners have also been mentioned as a potential source of chloride to surface waters. Concerns arise when the water softening system recharges resin with salt brine and discharge the wastewater rich in chloride. Most softened water is discharged to sanitary sewer systems and ultimately ends up in wastewater treatment plant effluent. Some may end up in septic systems. It is unlikely that this is a significant source in the Shingle Creek Watershed. Few septic systems exist in the watershed and there are no wastewater treatment plant discharges in the watershed. Of the septic systems that do exist, it is unclear as to the proportion that use water softeners.

5.2.5.2 Landfills

There are a few permitted and unpermitted landfills or dumps in the Shingle Creek watershed. Although these would be considered groundwater sources and are not addressed directly as a part of this TMDL, they are worth noting.

Several permitted and unpermitted solid waste and dumpsites are located in the Maple Grove Gravel Pits Area. Permitted sites include: North Hennepin Yard Waste site, Recycling Transfer Station, and Solid Waste Transfer Station. Unpermitted sites include: the Osseo/Maple Grove Pay Dump north of 85th and the Sonny Link Dump south of 85th, and an NSP fly ash dump between Jefferson Highway and TH 169, north of 83rd.

An unpermitted cement washings dump is on Shingle Creek south of Brooklyn Boulevard, west of CR 81. The old Brooklyn Park dump stood where Brooklyn Park Central Park is now located, south of 85th between Noble and Regent Avenues.

The old Brooklyn Center dump was located on 65th Avenue west of Brooklyn Boulevard.

More information can be found at:
http://pca-gis04.pca.state.mn.us/website/mes/mesfin/entry.htm

5.2.5.3 Fertilizers

Fertilizers used on lawns and landscaping often contain potassium chloride as a potassium source for plants. Consequently, fertilizers represent a potential source of chloride in the watershed. Much of the fertilizer would be applied in the spring, summer, and fall months to coincide with the growing season. Ultimately, chloride from fertilizers would enter surface waters as a result of runoff events soon after application or enter groundwater as a result of infiltration. Because of the timing of fertilizer application, it is unlikely that it represents a significant source during the most sensitive times for chloride (winter flow). The greatest potential for fertilizer chloride to reach surface waters is through ground water. Chloride from fertilizer application is considered a groundwater source in this TMDL.

5.2.5.4 Infiltration

Infiltration of surface water can also be a major source of chloride to groundwater. Infiltration water may be rich in chloride as a result of road application for deicing or fertilizer application.

5.2.6 Railway and Airport Deicing

Aviation activity at the Crystal Airport is sharply reduced in winter, and deicing of aircraft is not performed. Planes are typically grounded during inclement weather. Urea is used in a limited manner on runways in the winter with an estimated use less than 500 pounds per year. Some sand is used as an abrasive. However, no salt is used due to corrosive effects on aircraft.

The railways do apply a small amount of salt and sand, primarily to walkways in the Soo Line Humboldt switching yards. Some CaCl is used at the yards, primarily in February through March to deice and also to dry out the rail area. Salt, sand and CaCl are applied as needed and where needed, although there is no written or unwritten policy. There are no records of applications. Very little ice control is done in the rail corridor to the west. They do plow at the yards and the snow is stockpiled on site.

6.0 Assessment of Water Quality Data and Monitoring Results

6.1 HISTORIC DATA AND CAUSE FOR LISTING

The listing of Shingle Creek as impaired resulted from a limited sampling of chloride completed in 1996 by the US Geological Survey (USGS) at the Queen Avenue Bridge in Minneapolis. After reviewing the USGS data from Queen Avenue, the Shingle Creek WMO has been sampling routinely for chloride in Shingle Creek.

6.2 EXTENT OF CHLORIDE EXCEEDANCES

One of the primary goals of this TMDL was to determine the spatial extent, severity and duration of chloride exceedances in the Shingle Creek watershed. To define the extent of chloride exceedances in the watershed, both grab samples and logged conductivity data were collected at numerous sites throughout the watershed (Figure 4.1). Conductivity can act as a surrogate measure for chloride. Chloride is a charged ionic species that makes water conductive. As chloride concentrations increase, the conductivity of a solution increases; therefore, specific conductance and chloride are directly related. By utilizing conductivity as a surrogate for chloride and developing chloride-conductivity relationships, more robust data sets can be developed to increase the accuracy of load estimations and decrease the need for some manual data-collection activities. Additionally, the chronic standard is based on a four-day exposure to chloride concentrations. This is difficult to measure with grab samples unless data is collected daily. Logging specific conductance allows for the calculation of a four-day average to identify both the severity and duration of the exceedance.

6.2.1 Grab Samples

As expected, grab samples throughout the watershed demonstrated both chronic and acute exceedances. Stream grab sample concentrations ranged from 16 to 12,000 mg/L (Table 6.1). In box plots (Figure 6.1 and 6.2), the upper and lower ends of the box represent the 75th and 25th percentile while the line in the box represents the median value. Median values were higher at the three lowest sites in the watershed than the three higher sites. Bass Creek did not demonstrate any acute exceedances but the maximum of the grab samples did exceed the chronic standard.

Table 6.1. Grab Sample Results for the Shingle Creek Watershed.

			Chloride (mg/L)			
Creek	**Site**	**N**	**Mean**	**Median**	**Min**	**Max**
Shingle Creek	SCSS1	17	793	180	55	8,200
	SC04	18	180	125	66	700
	SC03	27	308	150	16	2,900
	Xerxes	19	297	210	68	1,200
	SCI94	15	224	200	64	570
	SC00	30	297	170	68	2,200
Bass Creek	SCPINE	13	120	100	33	420
Ryan Creek	Twin Lake	13	1069	150	64	12,000
	France	15	575	84	51	3,400
	Russell	6	85	76	35	170
Pike Creek	169	17	111	87	74	350
	62 West	17	1031	260	67	7,400
Storm Sewer	SCSS2	16	3197	205	14	35,000

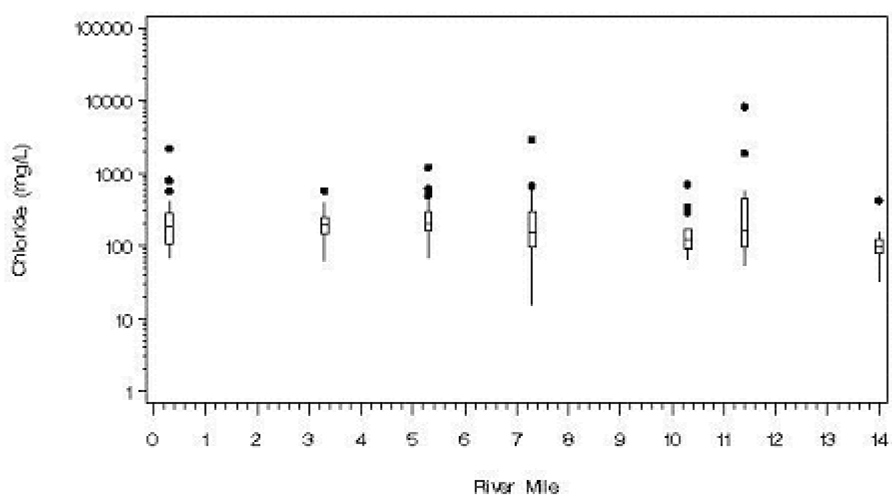


Figure 6.1. Box Plot of Grab Samples Collected from Shingle Creek

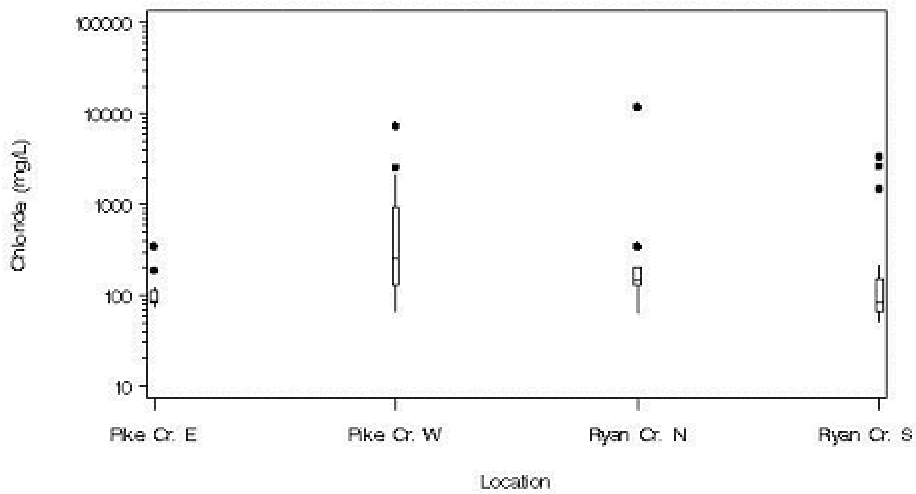


Figure 6.2. Box Plot of Grab Samples Collected from Tributaries to Shingle Creek

6.2.2 Chloride and Conductivity Relationships

Specific conductance was logged at a 15-minute interval at six sites in the watershed. At each of these sites, grab samples were also collected for chloride to develop a relationship between specific conductance and chloride concentrations for each site. Conductivity-chloride relationships are presented in Figures 6.3a and 6.3b. For all of the regression equations, the intercepts were forced through zero so that no negative values would be predicted. This stands to reason since natural streams in Minnesota would have some chloride and zero conductance would relate to water with no dissolved solids including chloride. These relationships were used to predict daily chloride concentrations at these sites.

Thorough examination of the regressions resulted in the identification of a few trends that need to be addressed, the first of which was the examination of the effects of outliers. Several extreme measurements occurred during the development of the relationships Table 6.2. Extreme values can have a disproportionate effect of a regression relationship causing an over or under prediction of the predicted variable. Since our analyses focuses on values around the standard concentrations of 230 mg/L and 860 mg/L, these extreme values were excluded from the relationships used to predict chloride concentrations.

Table 6.2. Extreme Conductivity and Chloride Values

River Mile	Site	Conductivity (µs/cm)	Chloride (mg/L)
0.6	SC00	8,210	2,200
7.3	SC03	8,255	2,900
11.4	SCSS1	26,800	8,200
11.4	SCSS1	5,750	1,900

Secondly, relationships between chloride and conductivity were examined seasonally to evaluate potential differences in the relationship that may result from changes in the proportion of the total dissolved solids represented by chloride. Our results indicate that winter runoff conductivity is most likely driven by deicing salt high in chloride whereas total dissolved solids in groundwater that may have proportionally less chloride contributing to the ionic balance may drive summer low flow conductivity. Once the outliers were removed and the seasonal variations taken into account, the relationships for the winter/spring period and summer period were significantly different with a summer slope for each of the sites around 0.15 and winter/spring slope around 0.21 in Table 6.3. The only exception was the Bass Creek site (Pineview; RM 14) where some of the weakest relationships occurred. It may be that this site is affected by groundwater during a greater portion of the year.

Table 6.3. Conductivity – Chloride Relationships in the Shingle Creek Watershed

River Mile	Site	Summer		Winter/Spring	
		Slope	**r-square**	**Slope**	**r-square**
	All	0.15	0.86	0.21	0.78
0.6	SC00	0.15	0.83	0.22	0.82
3.3	SCI94	0.14	0.99	0.18	0.77
7.3	SC03	0.16	0.81	0.22	0.84
10.3	SC04	0.16	0.9	0.22	0.82
11.4	SCSS1	0.15	0.97	0.24	0.76
14	Pineview	0.09	0.91	0.17	0.75
Standard Deviation		0.025	--	0.028	--

The slope values in Table 6.3 were used to predict chloride concentrations for each of the sites. Since there were only three points on the summer relationship at all of the sites except RM 0.6 and 7.3, predicted summer concentrations were based on the combined relationship of all of these sites combined (slope =0.15) except for RM 14.

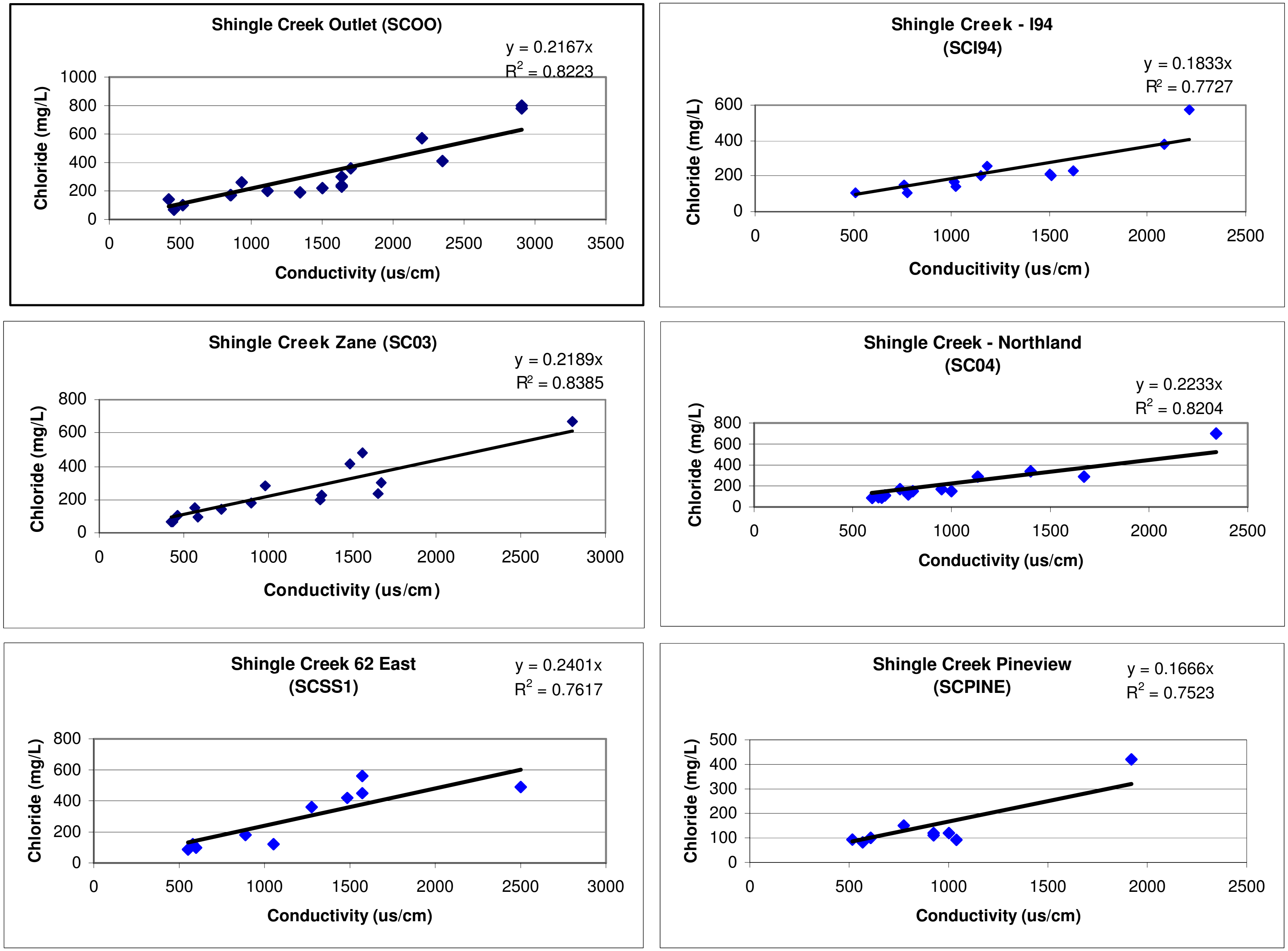
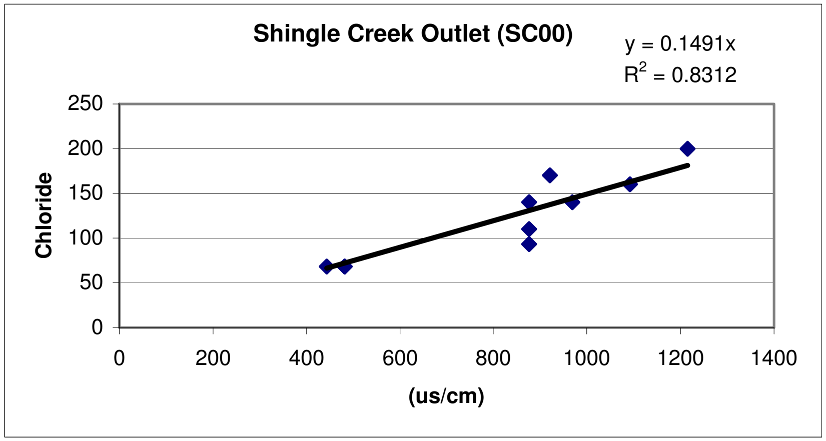
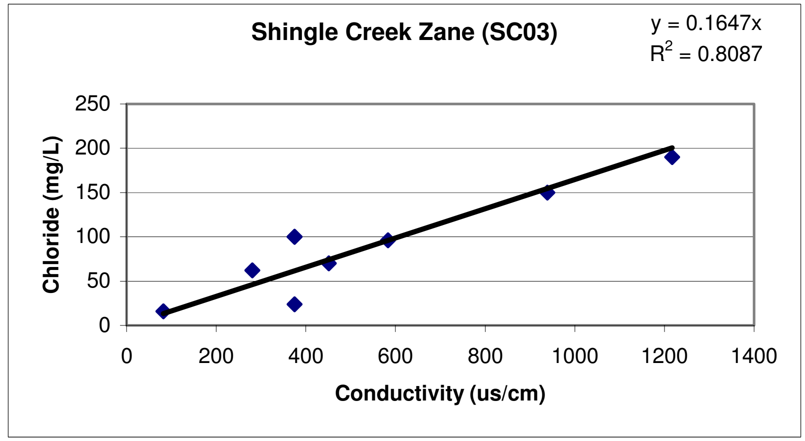


Figure 6.3a. Chloride-Conductivity Relationships for Samples Collected in the Winter and Spring of 2002-03.





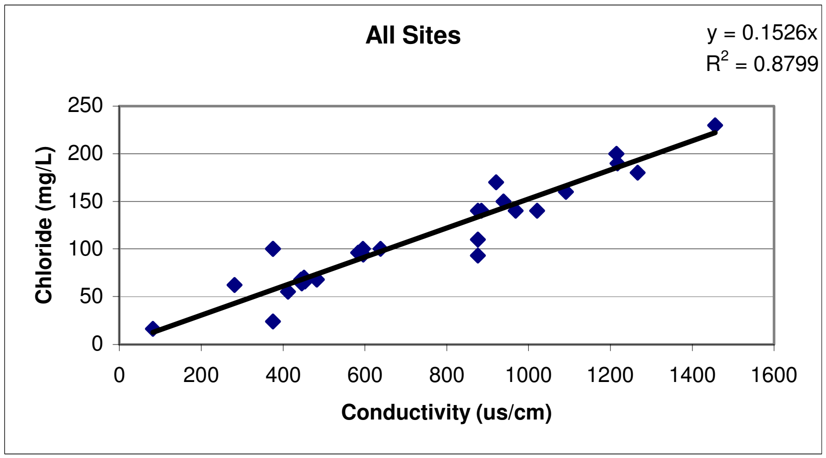


Figure 6.3b. Chloride-Conductivity Relationships for Samples Collected in the Summer of 2002-03.

The USGS also collected data at the Queen Avenue Bridge from May of 1996 to December of 1998. These data were used to develop chloride-conductivity relationships for the Queen Avenue site. After separating the data into winter and spring/summer/fall sets and forcing the intercept through zero, the slope values align with the data previously presented (Figure 6.4).

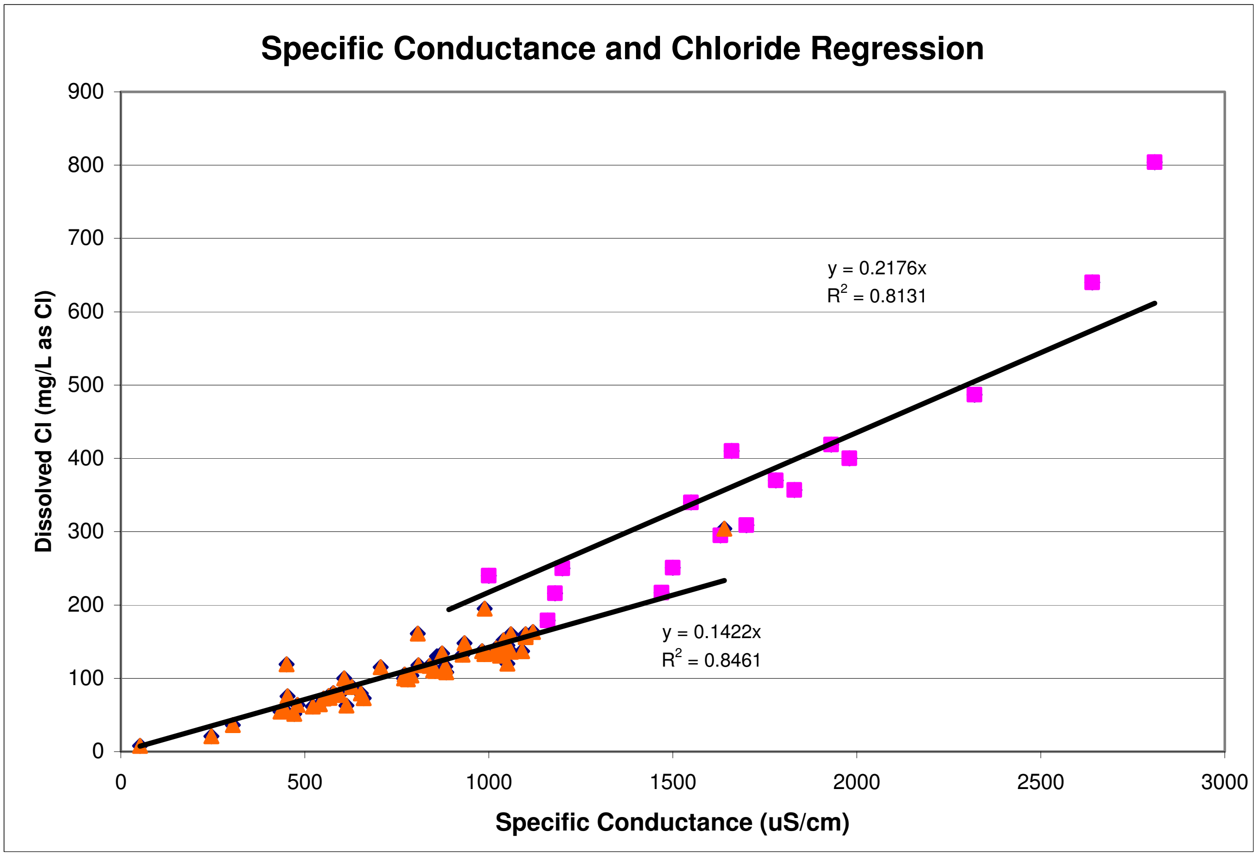


Figure 6.4. Chloride Conductivity relationship at the Queen Avenue Bridge. Data was collected by the USGS. The triangles represent summer/spring/fall data and the squares represent winter data.

6.2.2 Conductivity and Chloride Time Series

Time series were generated for chloride concentrations based on the logged conductivity. Two series were generated. The first was four-day average chloride concentrations with flow and grab chloride samples included on the plots. The second set of plots includes the daily maximum chloride concentration to assess acute exceedances.

6.2.2.1 Chronic Exceedances

A box plot of chloride concentrations based on measured conductivity by river mile is presented in Figure 6.5.

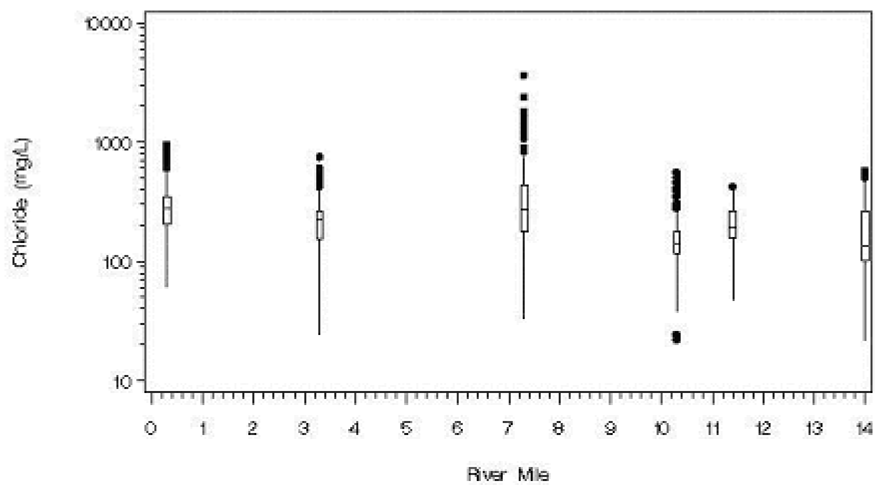


Figure 6.5. Box Plot of Conductivity Estimated Chloride Concentrations in the Shingle Creek Watershed

Figure 6.6 presents four-day average chloride concentrations based on the chloride conductivity relationships at six sites in the Shingle Creek watershed. All of the sites demonstrated exceedances during the winter months. Concentrations at River Mile 14 (Pineview Lane) did not demonstrate the same variability associated with runoff that the other sites demonstrated. Additionally, field visits to the site found the stream channel completely frozen. We believe monitoring during this period represents a pool of water below the ice during the winter.

Summer concentrations occur at River Miles 0.6 through 7.3 and River Mile 11.4. River mile 10.3 sits downstream of a wetland complex. Water stored and subsequently discharged from the wetland may be diluting concentrations at this site during base flow.

Four day average concentration time series for each for the six logged sites are presented in Appendix C.

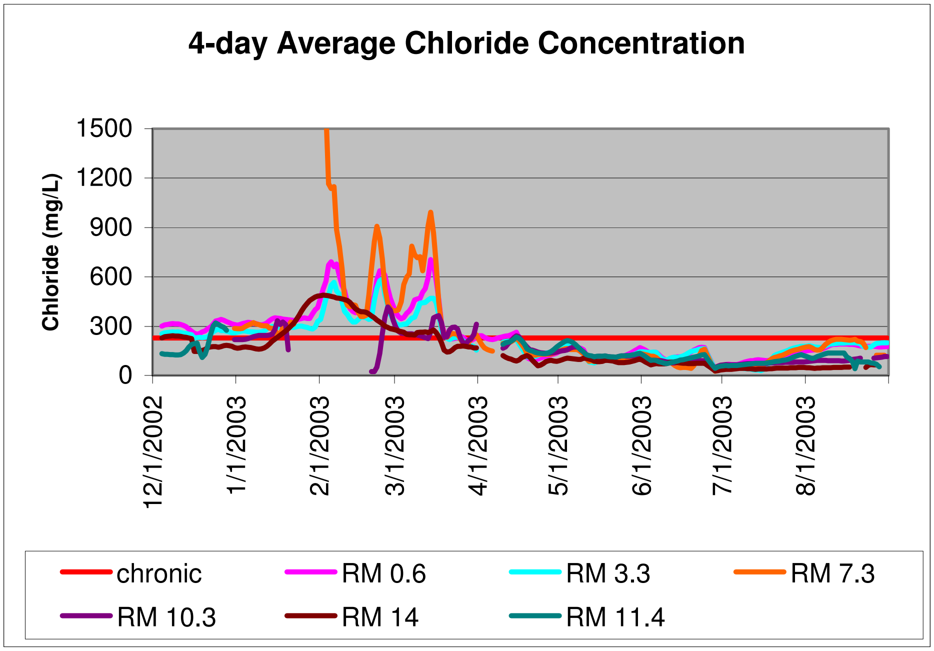


Figure 6.6. Four Day Average Chloride Concentrations Based on Conductivity Chloride Relationships.

6.2.2.2 Acute Exceedances

Figure 6.7 presents daily maximum concentrations at the six logged sites. Only two sites demonstrated acute exceedances including Zane (RM 7.3) and the outlet (RM 0.3). Zane Avenue had long durations above the acute standard in the winter, lasting thorough mid-March. Acute violations did not occur after spring rains arrived and snow pack was lost from the watershed. Four day average concentration time series for each for the six logged sites are presented in Appendix C.

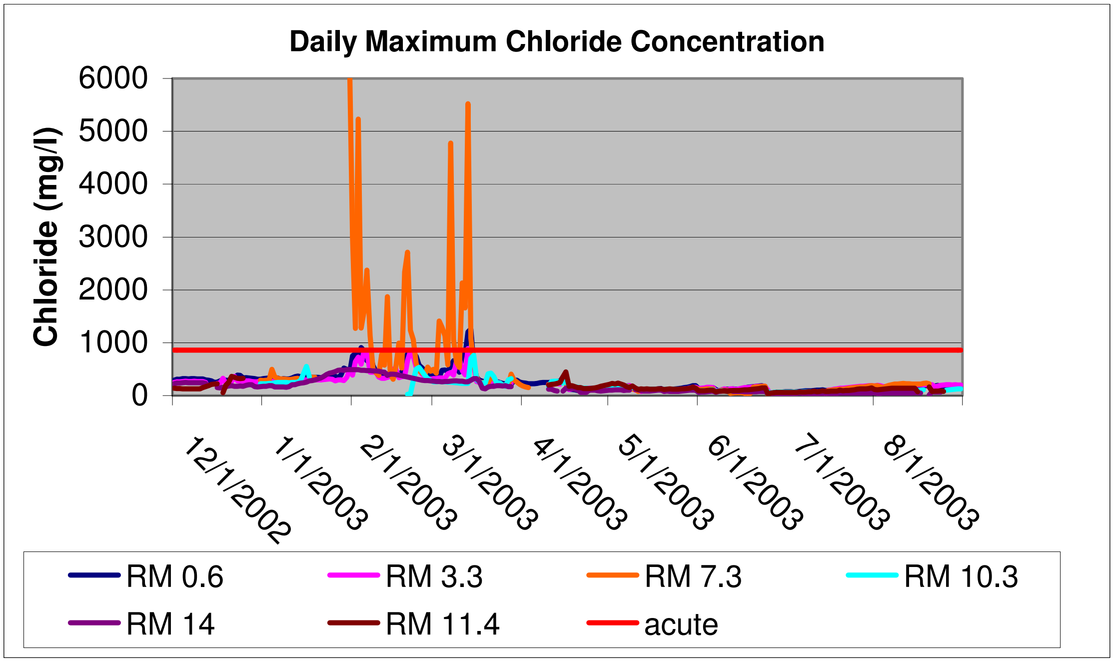


Figure 6.7. Daily Maximum Chloride Concentrations Based On The Conductivity Chloride Relationships.

6.3 GROUND WATER QUALITY

Ground water contributions to surface waters can constitute a significant portion of surface water loads for dissolved substances such as total dissolved solids or chloride. However, groundwater interactions with surface waters in the Shingle Creek watershed have not been thoroughly studied. The USGS completed a water quality assessment of groundwater quality in the Shingle Creek watershed and surrounding areas in 1996 (Andrews et al. 1996). Thirty shallow groundwater wells were installed, sampled and analyzed for 240 compounds including chloride. Chloride concentrations ranged from 4.3 to greater than 370 mg/L. Prior samples taken residential areas of the Anoka Sand Plain reported a substantially less median concentration of 26 mg/L (Anderson 1993). The spatial distribution of chloride concentrations in groundwater in the Shingle Creek watershed is presented in Figure 6.8.

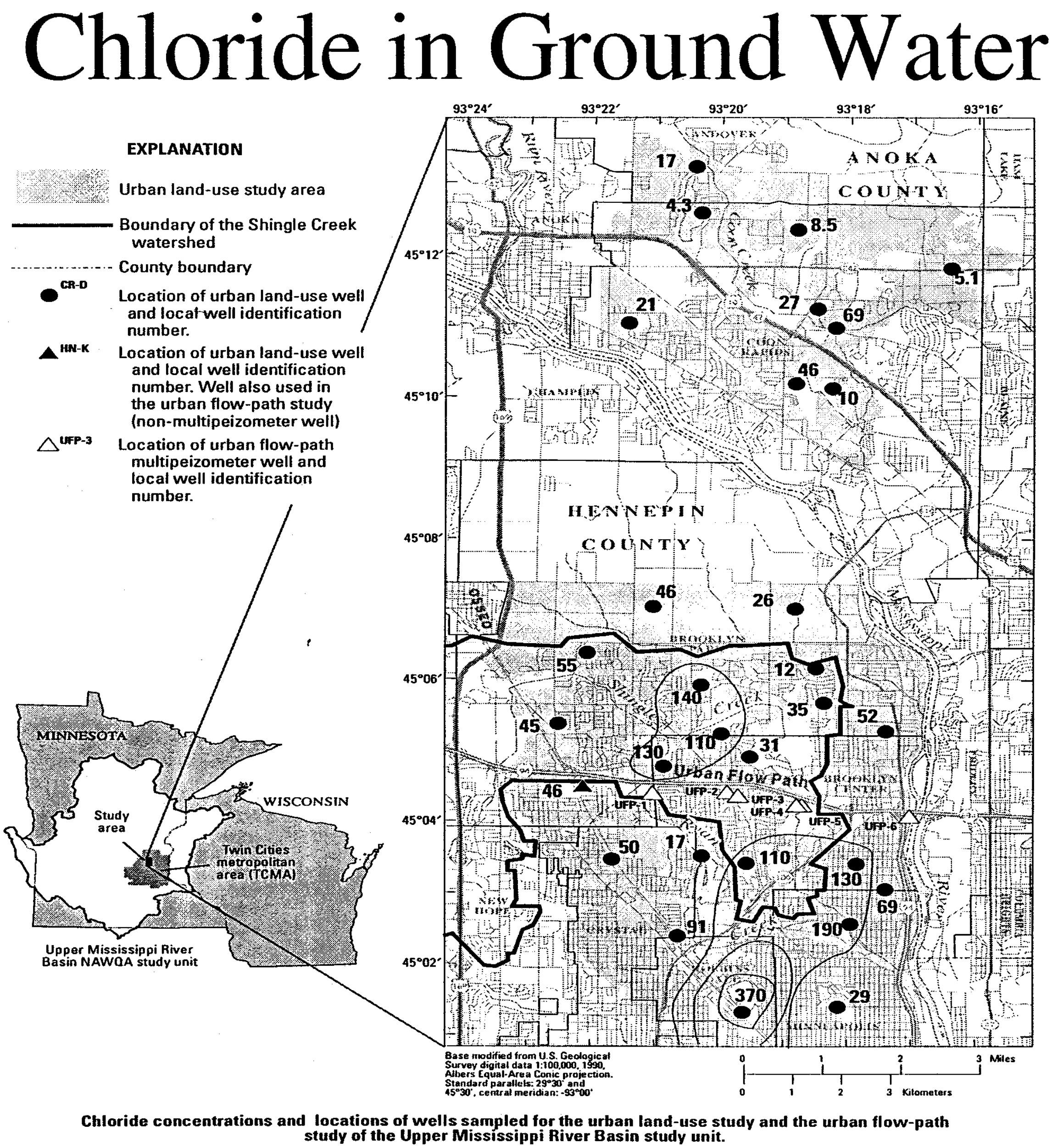


Figure 6.8. Chloride Concentrations in Groundwater Wells in the Shingle Creek Watershed and Surrounding Areas. Figure was adapted from Andrews 1996.

To assess loads to source waters, base flows were determined using the flow record. Once base flows were determined, concentrations were selected from each monitoring site during those flow periods after a long dry period. Incremental inflows and associated concentrations are presented in Table 6.4. Stream concentrations chosen were from grab samples collected on August 8, 2003.

Table 6.4. Incremental Inflow and Associated Concentrations and Daily Loads

Site	Incremental Inflow (cfs)	Stream Concentration (mg/L)	Inflow Concentration (mg/L)	Inflow Load (tons/day)
Pineview	0.5	42	42	0.06
SCSS1	0.5	140	238	0.32
SC04	1	100	80	0.22
SC03	1	190	280	0.75
SCI94	2	180	175	0.94
SC00	0.7	200	257	0.48
Total	5.7	--	--	2.8

Some portion of the groundwater chloride is likely the result of natural sources including rock mineralization. Background conditions are difficult to identify but several studies may shed some light on the issue. The USGS sampled 992 wells in the Upper Mississippi River watershed where chloride concentrations ranged from 1-50 mg/L (Andrews et al, 1996). Chloride concentrations measured in groundwater wells in residential areas of the Anoka Sand Plain had a median concentration of 26 mg/L. Concentrations in ground water around Shingle Creek were higher than reported values in either of these two studies.

7.0 Linking Water Quality Targets and Sources

7.1 INTRODUCTION

A key aspect of a TMDL is the development of an analytical link between loading sources and receiving water quality. This analysis involves the solution of the equation for loading capacity as a function of wasteload allocation (WLA), load allocation (LA), margin of safety (MOS), and seasonal variation (SV).

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

7.2 SELECTION OF MODELS AND TOOLS

An empirical approach was used to develop the chloride TMDL for Shingle Creek. The first step in the load allocation was using the analytical data collected in the watershed to identify flow conditions and seasons where the greatest occurrence of exceedances occurred. Target and measured loads were used to empirically develop load and wasteload allocations needed to meet water quality standards for chloride in Shingle Creek.

7.3 STREAM LOADS

7.3.1 Monitoring Year (2002-2003)

To assess stream loads, daily flow and load duration curves were developed for each of the sites with conductivity and flow data from December 1, 2002 to August 31, 2003. Flow duration curves are used to describe the frequency and occurrence of specific flow rates over a period of time. For example, a discharge of 5 cfs at an 80% flow interval tells us that the stream had a flow rate of 5 cfs or greater, 80% of the time. This results in breaking down the flow intervals from flood conditions (<1% interval) to dry conditions (90% interval). The real advantage to this approach is that data is presented across all the flow regimes and not restricted to a design flow criteria. This is essential since nonpoint source pollution is driven by runoff events and needs to be evaluated across all flow regimes.

Figure 7.1 presents the flow duration curve for the outlet of the watershed (RM 0.3). Flows ranged from approximately 2 cfs to over 600 cfs. All flow duration curves are presented in Appendix D.

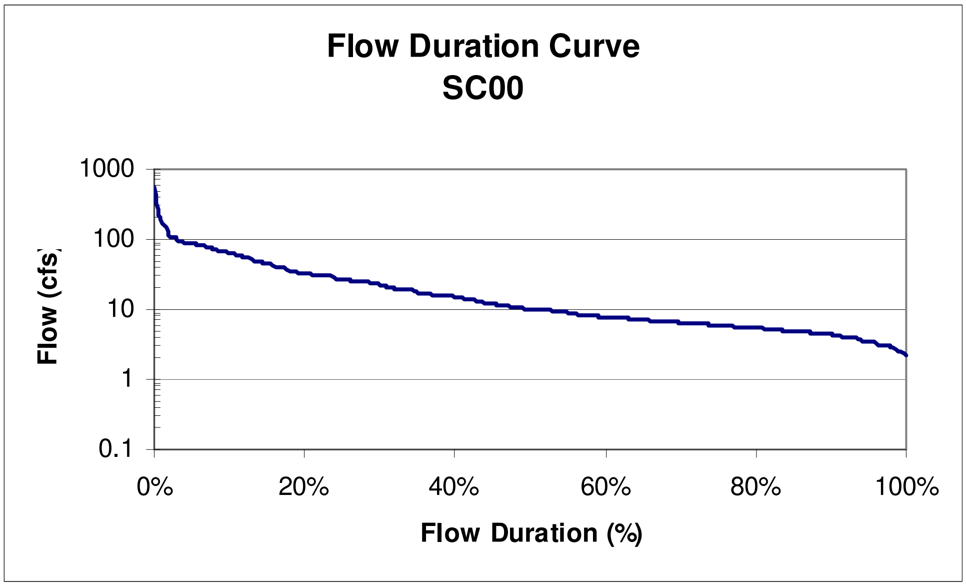


Figure 7.1. Flow Duration Curve for the Outlet of the Watershed (RM 0.3).

These data are then used to develop a load duration curve for chloride (Figure 7.2). Flow intervals are described on the figure as ranging from dry to very high runoff conditions. Load violations occurred over the entire flow regimes at the outlet except at very high flows. Load duration plots for all sites can be found in Appendix D.

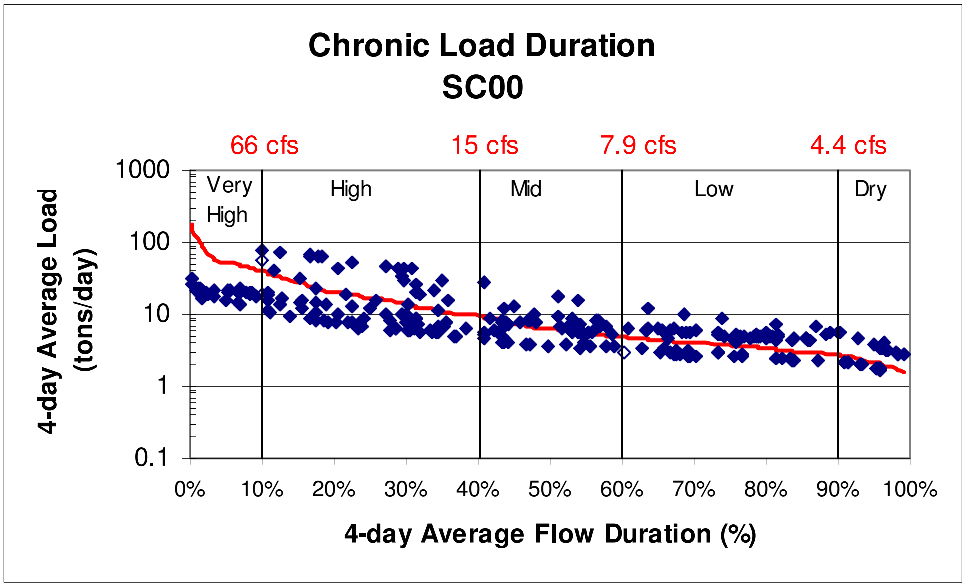


Figure 7.2. Load Durations for the Shingle Creek Outlet (RM 0.3).

Load durations can be plotted seasonally to better understand violations on a seasonal basis across flow regimes. Seasonal load duration plots for all sites can be found in Appendix D.

Winter (December 1 through March 31) load violations (December 1 through March 31) occurred across all of the flow regimes (Figure 7.3).

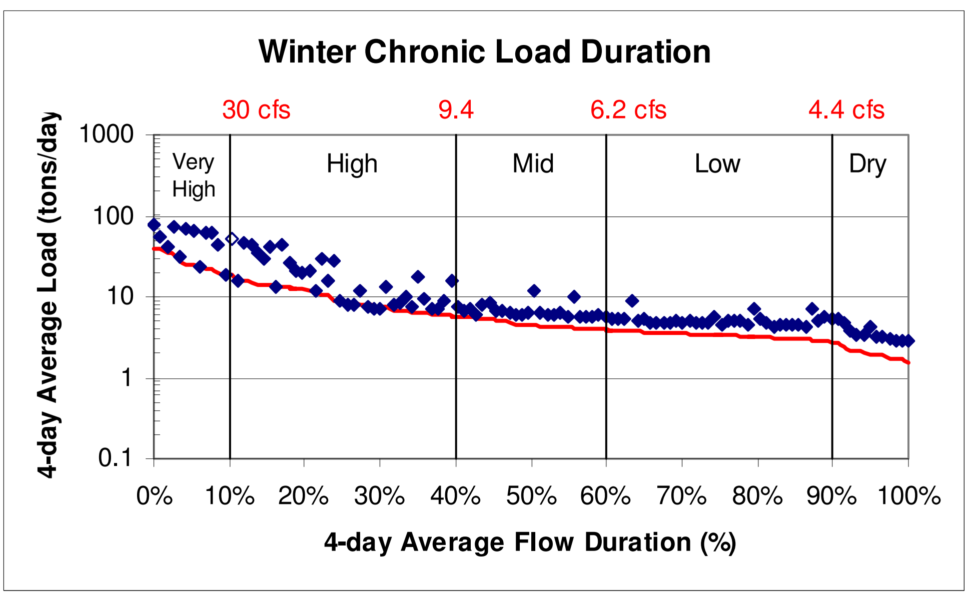


Figure 7.3. Winter (December 1 through March 31) Load Durations for the Shingle Creek Outlet (RM 0.3).

Spring (April and May) load violations occurred during the low flows (Figure 7.4). High flows offered enough dilution capacity or were late enough that the salt sources were depleted.

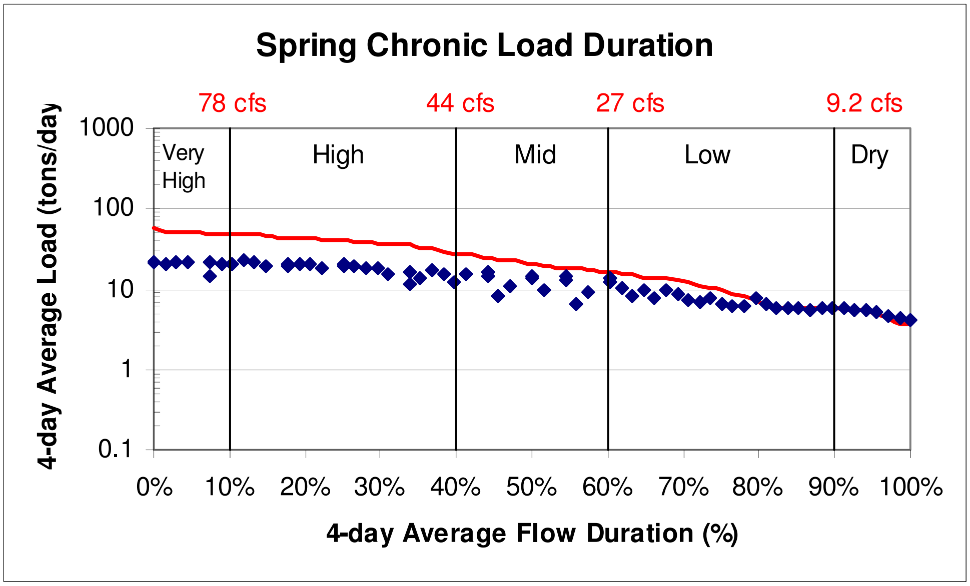


Figure 7.4. Spring (April and May) Load Durations for the Shingle Creek Outlet (RM 0.3).

Summer (June 1 through August 31) load violations did not occur (Figure 7.5). However, very dry periods had loads approaching the standard suggesting that ground water is close to the standard concentration of 230 mg/L.

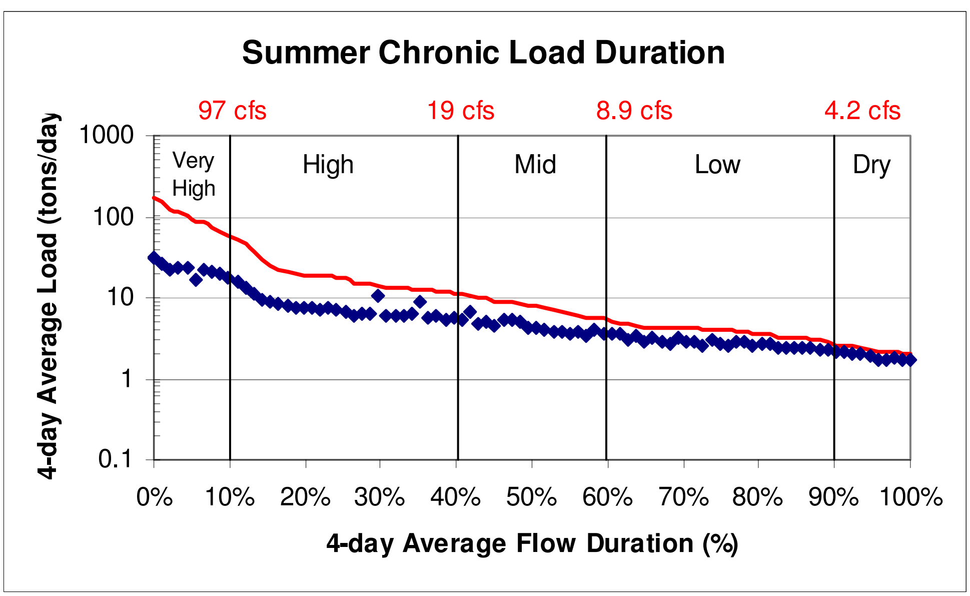


Figure 7.5. Summer (June 1 through August 31) Load Durations for the Shingle Creek Outlet (RM 0.3).

Seasonal violation occurrences across the flow regimes are summarized in Table 7.1.

Table 7.1. Summary of Exceedance Occurrences under Varied Flow Regimes.

Site	Winter			Spring			Summer		
	Low Flow	Medium Flow	High Flow	Low Flow	Medium Flow	High Flow	Low Flow	Medium Flow	High Flow
SC00	Yes	Yes	Yes	No	No	No	No	No	No
SCI94	Yes	Yes	Yes	No	No	No	No	No	No
SC03	Yes	Yes	Yes	No	No	Yes	No	No	No
SC04	Yes	Yes	Yes	No	No	Yes	No	No	No
SCSS1	--	Yes	No	No	Yes	No	No	No	No
SCPine	Yes	Yes	Yes	No	No	No	No	No	No

7.3.2 USGS Data

Additionally, we analyzed data collected by the USGS at the Queen Avenue Bridge from May of 1996 to December of 1998. The winter of 1996-1997 was a heavy snow year with 72.1 inches of snowfall. Exceedances still occurred across the entire winter except for the extremely high flows which probably represent late spring snowmelt (Figure 7.6).

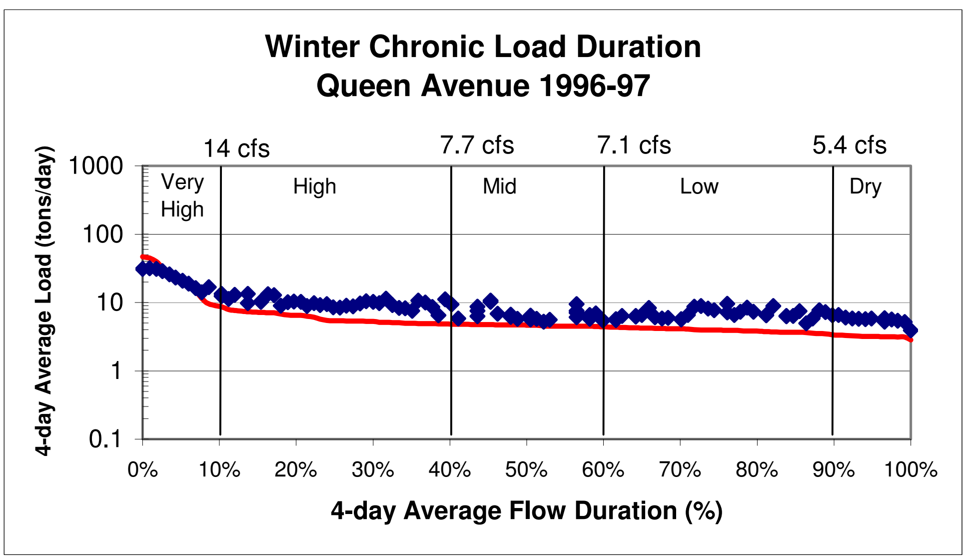


Figure 7.6. Winter (December 1996 through March 31, 1997) Load Durations for Shingle Creek at the Queen Avenue Bridge.

The winter of 1997-1998 was slightly below the average snowfall of 56 inches at 45 inches. Once again, the same pattern emerges where exceedances occur over the entire monitoring period (Figure 7.7). During this winter sampling period, high flows also demonstrated exceedances.

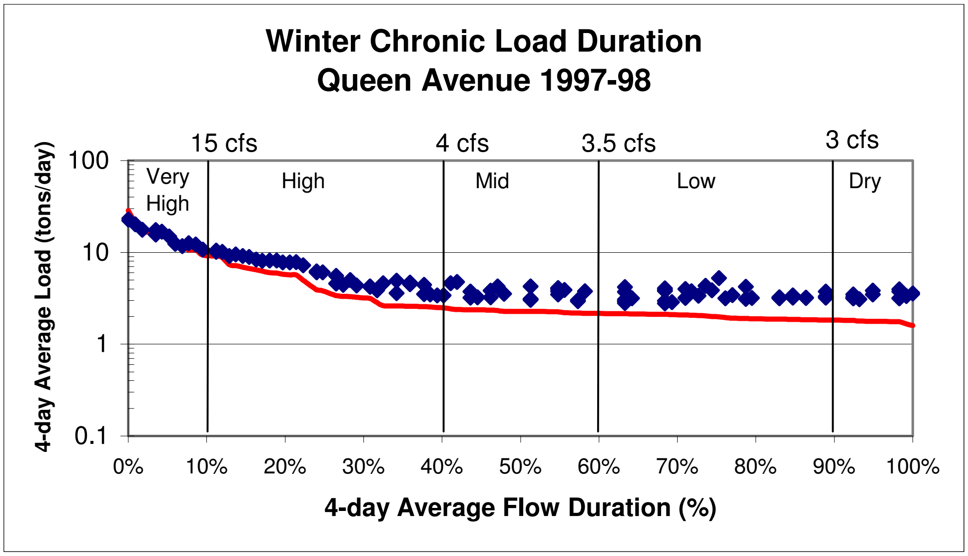


Figure 7.6. Winter (December 1997 through March 31, 1998) Load Durations for Shingle Creek at the Queen Avenue Bridge.

7.3.3 Reductions

Another way to analyze the data includes assessing the reductions needed for each daily load to reach the standard. The reductions needed to meet the standard during the monitoring year of 2002-2003 had a maximum of 72% and occurred during high flow periods (Figure 7.7). All flow categories had loads that required a reduction greater than 60%.

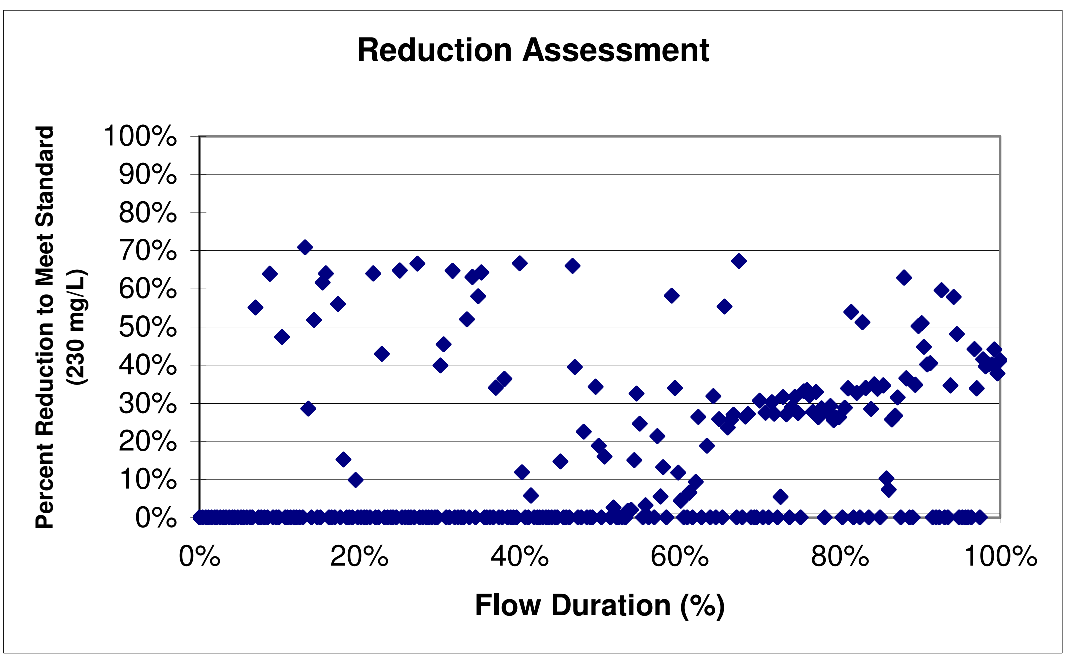


Figure 7.7. Percent Reductions Identified to Bring Individual Loads Below the Standard.

For comparison purposes, we also analyzed data collected at the Queen Avenue station by the USGS during the 1996-1997 and 1997-1998 winters. The winter of 1996-1997 was a heavy snow year with 72.1 inches of snowfall. Necessary reductions were as high as 59% (Figure 7.8). The winter of 1997-1998 was slightly below the average snowfall of 56 inches at 45 inches and required reductions as high as 62% with the greatest needed reductions in the 40% to 100% flow categories (Figure 7.9).

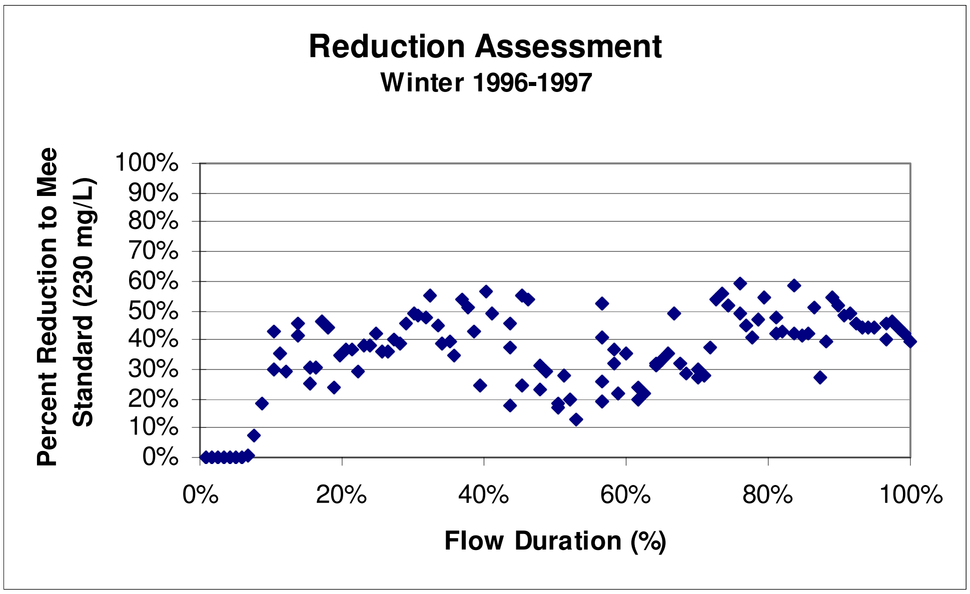


Figure 7.8. Percent Reductions Identified to Bring Individual Loads Below the Standard.

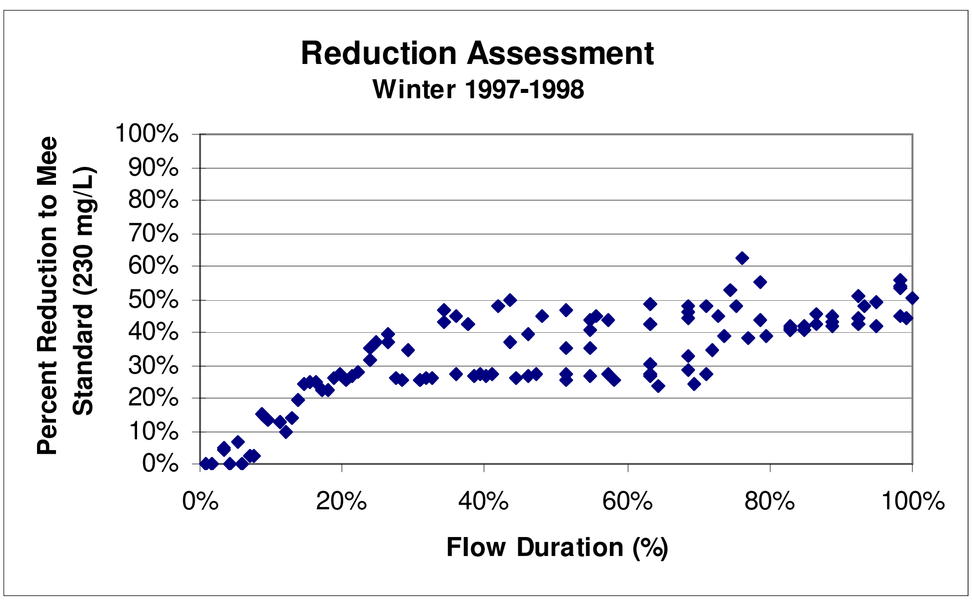


Figure 7.9. Percent Reductions Identified to Bring Individual Loads Below the Standard.

In our case, the monitored year turned out to be a worst-case year in that the amount of salt used compared to the precipitation was high resulting in a lowered dilution capacity because less water was on the watershed in the form of snow pack. This is demonstrated by the greatest load reductions needed in the lightest snow year. The largest snow year required the smallest percent reductions.

8.0 TMDL Allocation

8.1 TMDL

Critical conditions defined for the load and wasteload allocations were defined as all winter flow conditions. However, because the chloride loading functions as a non-point source issue in the Shingle Creek watershed, it is inappropriate to define the TMDL as a single number since the TMDL as developed is entirely dependant on the daily flow and concentration, which is highly dynamic. To this effect, the TMDL is represented by an allowable daily load across all flow regimes as is demonstrated in Figure 8.1. To determine acceptable loads under the critical flow regimes, chronic standard concentrations were multiplied by the flow at each interval.

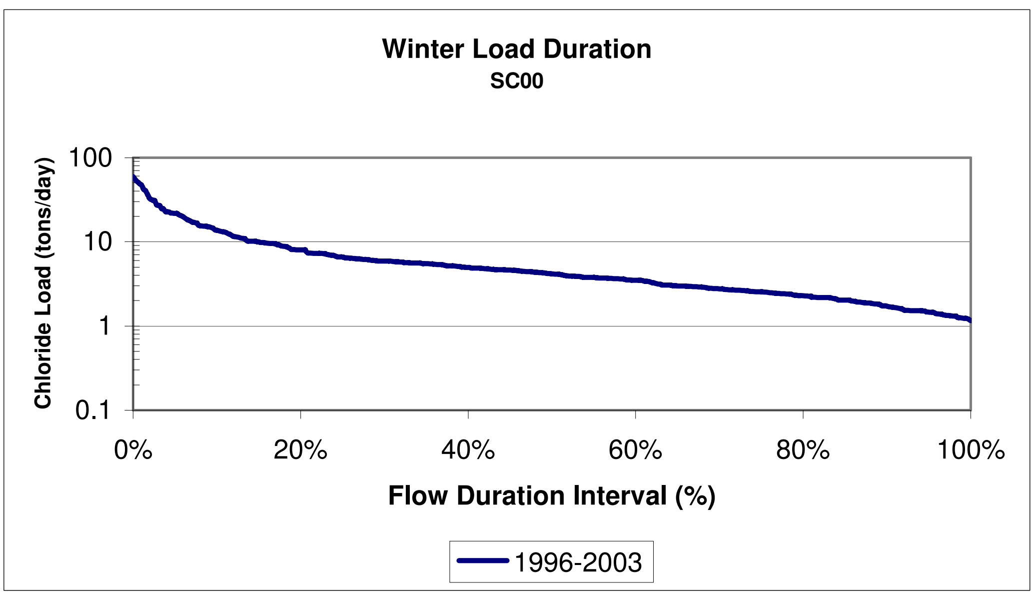


Figure 8.1. Total Maximum Daily Load Across Flow Exceedances for Shingle Creek. Data used to calculate the load duration curve was from December 1996 thorough March 2003.

To better facilitate implementation, TMDL guidance suggests that alternate expressions of the TMDL can be applied where appropriate. In this case, the TMDL is represented as a percent reduction across the flow regimes needed to meet the standard (Table 8.1). The TMDL is set such that all of the loads would come into compliance. In other words, the reduction is set to the highest required reduction based on the monitoring data.

Table 8.1. TMDL for Chlorides in Shingle Creek as Represented by a Percent Reduction.

Critical Condition[1]	Wasteload Allocation (percent reduction)	Load Allocation (percent reduction)	Margin of Safety (percent reduction)	TMDL (percent reduction)
Winter Low Flow (60 to 100%)	60%	3% [1]	Implicit	63%
Winter Runoff (60% to 0%)	67%	4% [1]	Implicit	71%

[1]Assumed groundwater reductions with reductions of surface application of chloride (37% and 52% respectively). Total load reduction was based on an assumed stream load share of 8%. For example, a 37% load reduction on 8% of the load results in a 3% reduction of the entire load.

The TMDL can also be expressed as a set of daily equations derived from the load duration curve. Table 8.2 represents the TMDL for the 5th, 25th, 50th, 75th, and 95th flow duration intervals.

Table 8.2. TMDL for Chlorides in Shingle Creek as Represented by Daily Loads.

Load Duration Interval	Wasteload Allocation (tons/day)	Load Allocation (tons/day)	Margin of Safety (tons/day)	TMDL (tons/day)
5%	23.2	1.6	Implicit	24.8
25%	7.2	1.6	Implicit	8.8
50%	2.9	1.6	Implicit	4.5
75%	1.8	1.6	Implicit	3.4
95%	0.3	1.6	Implicit	1.9

[1]Assumed groundwater reductions with reductions of surface application of chloride (45% reduction).

8.2 LOAD ALLOCATION (LA) AND WASTELOAD ALLOCATION (WLA)

Because stormwater discharges are regulated under NPDES Phase II, allocations of chloride reductions are considered wasteloads and must be divided among permit holders. Although the cities hold individual permits, they are combined here to reflect their participation in the SCWMC.

To support determination of source load reductions needed to meet the standard, a thorough inventory of chloride sources was conducted. Table 8.3 outlines the sources and their overall contribution to chloride in the watershed.

Table 8.3. Chloride Sources in the Shingle Creek Watershed.

Assumed Sources	Total Chloride (tons)	Daily Load (tons/day)	Percent of Total
Road Salt Cities	2,790	23.1	43%
Road Salt Hennepin County	1,660	13.7	26%
Road Salt MnDOT	858	7.1	13%
Road Salt Storage Facilities	290	2.4	5%
Private Application	463	3.8	7%
Residential	53	0.4	1%
Groundwater	335	2.8	5%
TOTAL	6,449	50.5	100%

[1]Reduction based on groundwater returning to natural background levels of <50 mg/L

Using the information provided, a stakeholder process was used to determine load allocations among users in the watershed. The stakeholders in the watershed agreed to work collectively to achieve a 71% reduction in chloride use to achieve the standard understanding that each stakeholder was working under unique financial, public safety and perception, and feasibility limitations. However, each stakeholder agreed to implement BMPs to the maximum extent practicable. This collective approach allows for greater reductions for some agencies and less for those with greater constraints. The collective approach is to be outlined in an implementation plan developed by the Shingle Creek Watershed Management Commission.

8.3 RATIONALE FOR LOAD AND WASTELOAD ALLOCATIONS

8.3.1 Rationale for Load and Wasteload Allocations

The allocations are based on evaluation of chloride and flow monitoring in Shingle Creek during 2002 and 2003. Monitoring, using conductivity as a surrogate measure of chloride, provided daily loads of chloride in the Shingle Creek watershed. Measured daily loads were then compared to acceptable loads across the suite of flows that occur in Shingle Creek providing the basis for the load allocations.

To determine acceptable loads under the critical flow regimes, the chronic standard concentration was multiplied by the flow at each interval. Measured loads can then be compared to standard loads to determine the percent difference between the values and ultimately the percent reduction needed to meet the standard. To develop the load allocations, critical flow period were identified on the flow duration curve, which included to 10% to 60% duration interval and the 60% to 90% duration interval. Load reductions are presented on Figure 8.2.

The load allocation represents the groundwater portion of the stream chloride load. To determine groundwater load reductions, we assumed groundwater chloride was reduced linearly with surface reductions to a minimum of 50 mg/L, which is the assumed background chloride concentration. For example, a 51% reduction in chloride sources to groundwater would reduce the groundwater source by 37% since the reduction is only applied to the assumed non-background chloride load. The total load reduction was based on an assumed stream load share of 8%. A 37% load reduction on 8% of the entire load results in a 3% reduction of the entire load. It is also important to note that this reduction is considered a long-term effect since groundwater flushing will take many years to purge prior chloride additions.

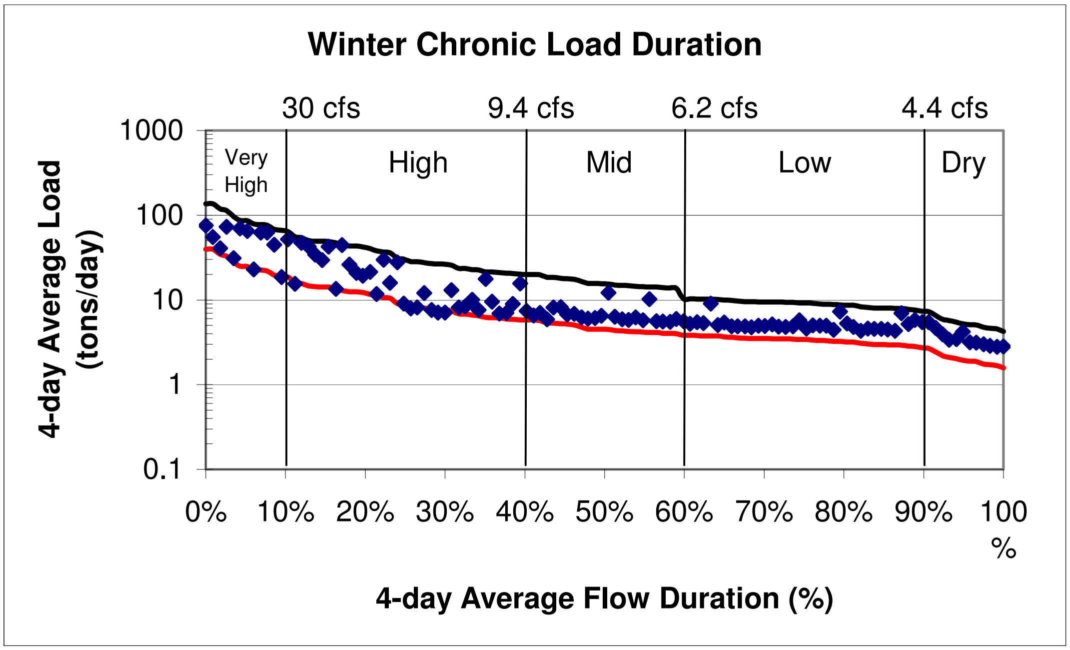


Figure 8.2 TMDL Applied to the 2002-2003 Monitoring Season. The red line represents the TMDL. The black line represents the loads across flow durations where the allocated load reductions would result in all of the measured loads meeting the standard.

8.3.2 Margin of Safety

The Margin of Safety - MOS - is implicit. The TMDL calls for a 71% reduction of chloride during all conditions. Much of the runoff results from the melting of roadside snow from previous snowfall events and therefore previous road salt applications. The 71% reduction was determined based upon the highest single exceedance of the WQS. This 71% is not the direct result of a 71% excessive application of chloride, rather, it represents the cumulative impact of multiple events. However, since the cumulative impacts cannot be quantified at this time, MPCA believes using the 71% target is a conservative assumption that overestimates the chloride reduction needed to achieve WQSs.

As the overall 71% reduction is achieved, the salt burden held in the accumulated roadside snow from previous snows will be significantly reduced over the conditions that existed during the TMDL development winters. This compounding reduction (71% during all conditions) should ensure achieving water quality standards during future critical conditions (winter snowmelt and runoff).

8.4 SEASONAL AND ANNUAL VARIATION

8.4.1 Seasonal Variation

Conductivity and chloride data analyzed for this TMDL were collected from December 2002 through August 31, 2003. Data were analyzed seasonally including winter (December 1 through March 31), Spring (April 1 through May 31) and summer (June 1 through August 31). These periods reflect differences in the mass of chloride available since road salt is applied only during the snow and ice season. Fall will act much the same as summer since no application of chloride (road salt) occurs and the chloride source is groundwater. Winter and spring were evaluated separately since runoff is produced through different processes during these seasons. Winter runoff is primarily snowmelt resulting from warm periods and high sun intensity. Spring is primarily precipitation events. Since snow accumulates in snow piles adjacent to the roads, snowmelt can deliver runoff extremely high in chloride concentrations. These differences have been accounted for in the identification of the critical periods and allocations for each of the critical periods.

8.4.2 Annual Variation

Load allocations for this TMDL are based on monitoring from December 2002 through August 31, 2003. The better understand annual variability, load durations based on the chloride standard of 230 mg/L were compared for winter months for both the long-term record and analysis year

(Figure 8.3). The two curves are almost identical. There is a difference in the 80 to 100% flow duration categories with the analysis year allowable load lower than the long-term allowable load. This is most likely due to utilizing data from a light snow/precipitation year where low flows were lower than normal. This could also be caused by an extended dry summer/fall period where groundwater contributions are less during the following winter.

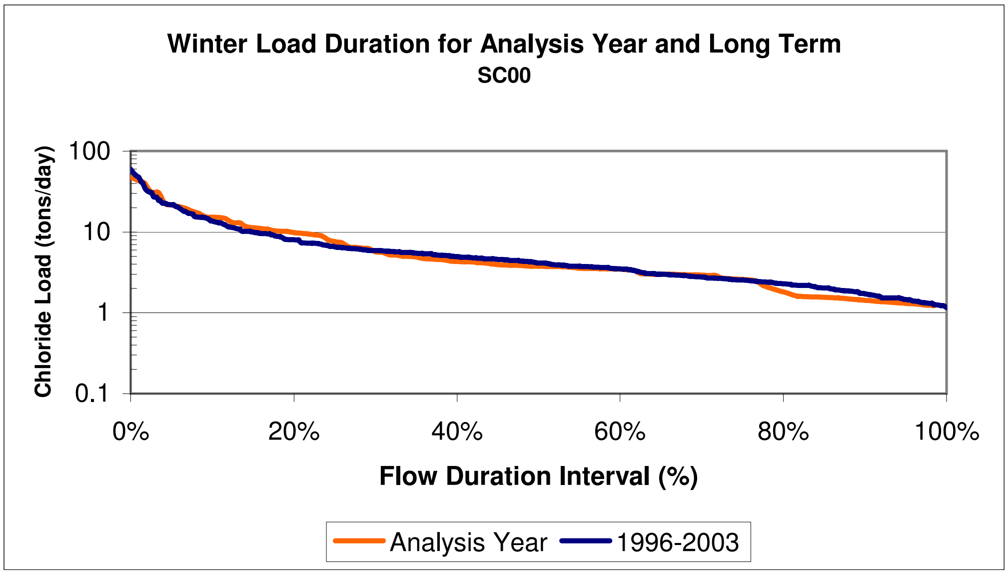


Figure 8.3. Flow Duration Curves for the Long-Term Data Set at the Watershed Outlet and the Analysis Year (2002-03).

To illustrate that the proposed reductions are protective of the standard in all years, we analyzed data collected by the USGS at the Queen Avenue Bridge from May of 1996 to December of 1998. The winter of 1996-1997 was a heavy snow year with 72.1 inches of snowfall. The winter of 1997-1998 was slightly below the average snowfall of 56 inches at 45 inches. These two years required a maximum reduction of 59% and 62% respectively (Figures 7.8 and 7.9). Based on this analysis the current TMDL would be protective of the standard in more average snow years. Additionally, TMDLs are often set to the most sensitive conditions or the "critical conditions". In our case, the monitored year turned out to be a critical condition in that the amount of salt used compared to the precipitation was high resulting in a lowered dilution capacity because less water was on the watershed in the form of snow pack. Consequently, the TMDL appears to be protective of the critical conditions of the watershed.

8.5 FUTURE GROWTH

Most of the currently undeveloped or lightly developed areas of northern Brooklyn Park, southeastern Maple Grove, and northwestern Plymouth are expected to be developed by 2020. Growth is expected to include residential, commercial, and industrial development. Invariably, some of this development will include roads and ultimately increased amounts of chloride based deicer use in the watershed. Areas of northern Brooklyn Park that will be developed are mostly outside of the watershed and drain directly to the Mississippi River. Increases in development are expected to be relatively small since the watershed is essentially fully developed. Expected development in Maple Grove would impact Shingle Creek directly while expected development in Plymouth would impact Bass Creek.

Since the changes are relatively small and the majority of roads associated with this development would be low speed, residential roads, only small increases in chloride use would be expected. Any policies or BMPs prescribed by this TMDL would be implemented on the new roads and developed areas. Consequently, provisions for new growth is built into the TMDL as a part of the adaptive management approach.

9.0 Public Participation

9.1 INTRODUCTION

As a part of the strategy to achieve implementation of the necessary allocations, the SCWMC sought stakeholder and public engagement and participation regarding their concerns, hopes, and questions regarding the development of the TMDL. Specifically, meetings were held for a Technical Advisory Committee representing key stakeholders and local experts. Additionally, the SCWMC held a series of stakeholder meetings focused on implementation of the TMDL requirements.

The SCWMC maintains an interactive website. The TMDL and all related material were posted on this website. Stakeholder and other public meeting notices were posted on this website. The NBC News affiliate, KARE 11, did a news piece on road salt (chloride) featuring Shingle Creek. This news piece reached an audience of approximately 1.5 million households. The news piece is/was posted on SCWMC's website.

9.2 TECHNICAL ADVISORY COMMITTEE

A technical advisory committee was established so that interested stakeholders could be involved in key decisions in developing the TMDL. Stakeholders represented on the Technical Advisory Committee include the 10 local cities, Hennepin County, Mn/DOT, Minnesota DNR, the Metropolitan Council, the USGS and the Minnesota Pollution Control Agency. All meetings were open to interested individuals and organizations. Technical Advisory committee meetings were held at regular intervals during the development of the TMDL.

9.3 STAKEHOLDER MEETINGS

A detailed stakeholder process was conducted for the Shingle Creek Chloride TMDL that included meetings and work sessions to identify activities (BMPs) that may be implemented to address chloride exceedances in Shingle Creek. The stakeholder process focused on the agencies responsible for winter road maintenance and included member cities of the SCWMC, Mn/DOT, and Hennepin County. The stakeholder process focused on these groups because of the inherent need to address both public safety and the environmental concerns of deicing activities. The necessary reductions in chloride will be implemented primarily by these agencies and will ultimately change the way roads are maintained for winter snow and ice conditions. Additionally, a vast amount on knowledge resides in this group concerning the newest technologies, the feasibility of implementing BMPs, and the extent of service required to protect public safety. Stakeholder meetings were held on the following dates:

February 4, 2005
February 25, 2005
April 1, 2005
May 6, 2005

9.4 PUBLIC MEETINGS

The SCWMC maintains an interactive website. The TMDL and all related material were posted on this website. Stakeholder and other public meeting notices were posted on this website. The NBC News affiliate, KARE 11, did a news piece on road salt (chloride) featuring Shingle Creek. This news piece reached an audience of approximately 1.5 million households. The news piece is/was posted on SCWMC's website.

The TMDL was noticed on the State of Minnesota's register with a 30-day public comment period.

10.0 Implementation

10.1 DEVELOPMENT OF THE IMPLEMENTATION PLAN

The activities and BMPs identified in the implementation plan are the result of a series of stakeholder working-meetings led by the Shingle Creek Watershed Management Commission. The meetings focused on the discussion of the TMDL requirements, BMPs and technologies available to address chloride, public safety, and the feasibility of implementing the activity.

Additionally, MnDOT developed a “Best Available Technologies” report outlining the state of BMPs in six categories. That report is attached as appendix H. The MnDOT report and the stakeholder discussions during the load reduction/implementation development, identified BMPs ranked the smallest level of implementation to the greatest level of implementation. The ranking was as follows:

No BMP<Minimum BMP<Maximum Extent Practicable<Best Available Technology

The load allocations in this TMDL represent aggressive goals for chloride reductions with the added challenge of addressing public safety and expectation. Consequently, implementation will be conducted using adaptive management principles. Adaptive management is appropriate because it is difficult to predict the chloride reduction that will occur from implementing strategies with the paucity of information available to demonstrate expected reductions. Continued monitoring and “course corrections” responding to monitoring results are the most appropriate strategy for attaining the water quality goals established in this TMDL while maintaining required levels of public safety.

10.2 IMPLEMENTATION FRAMEWORK

Member cities of the SCWMC, Mn/DOT, and Hennepin County have all agreed to identify and implement BMPs focused on reducing chloride use in the Shingle Creek watershed. Stakeholder meetings focused on the Cities' current activities and identification of activities that can be added to address the needed load reductions in the Chloride TMDL. The topics for the meeting included:

1. Product Application Equipment and Decisions
2. Product Stockpiles
3. Product Type and Quality
4. Operator Training
5. Clean-up and Snow Stockpiling
6. Ongoing Research into Salt Alternatives

During the stakeholder process, each of the cities discussed their current methodologies and practices for winter road maintenance and identified those areas where improvements could be achieved in each of the six identified categories. Results of these discussions are included in Table H1 through H6 in Appendix I. The following section is a general summary of the activities to be implemented under each of the six categories.

10.3 IDENTIFIED REDUCTION STRATEGIES

The SCWMC will work through the above framework to encourage implementation of the following strategies. Although the SCWMC will be the lead on the implementation of the Chloride TMDL, individual stakeholders will be ultimately responsible for implementing the identified BMPs. These activities will be tracked by the MPCA as part of the NPDES Phase II Permits that all of the stakeholders hold. The NPDES Phase II permits are BMP based calling for BMPs at the Maximum Extent Practicable (MEP) level to achieve applicable water quality standards. Mn/DOT's reduction strategies are covered in the BAT Report included in Appendix H.

10.3.1 Product Application Equipment and Decisions

In many cases, less road salt can be used without compromising public safety. To avoid over application, standards can be established for application rates that account for pavement temperature ranges and timing. Newer technologies such as pre-wetting and anti-icing can result in the same results while using significantly less product. Pre-wetting of salt refers to applying water, or some other liquid agent such as magnesium chloride, to the salt either prior to or during application of the material. Pre-wetting reduces the amount of scatter and loss of material, ultimately reducing the usage amounts. To this end, the stakeholders in the watershed have agreed to incorporate the following practices:

1. Annually calibrate spreaders
2. Use the Road Weather Information Service (RWIS) and other sensors such as truck mounted or hand held sensors to improve application decisions such as the amount and timing of application
3. Evaluate new technologies such as prewetting and anti-icing as equipment needs to be replaced. These technologies will be adopted where feasible and practical.
4. Investigate and adopt new products (such as Clear Lane, a commercially available pretreated salt) where feasible and cost effective

The estimated cost of implementing this activity will vary based on the technologies. Some examples include:

- Dry tailgate spreader: $3,000
- Prewetting: $6,000
- Spreader: $9,000
- Epoke spreaders: $60,000
- Brine storage system: $25,000
- Salt: $34/ton; Clear Lane: $39/ton + $5/ton delivery

10.3.2 Deicer Stockpiles

Another source of chloride is runoff from salt storage facilities. The stakeholders agreed to cover all product stockpiles and store them on impervious surfaces. Additionally, stakeholders will maintain general good-housekeeping policies associated with the handling of road salt to minimize the potential for wash-off of excess or spilled salt. There is no additional cost expected for this activity.

10.3.3 Operator Training

Stakeholders identified operator training as a primary area that could result in significant reductions in road salt use. One aspect of the training is to discuss the environmental concerns with the public safety issues to reinforce the concept of using the least amount of product necessary to maintain public safety. The stakeholders agreed to have annual training that may include outside support such as LTAP (Local Technical Assistance Program) or vendor training on the appropriate use of technologies or products. The estimated cost of this activity is $1,000 for staff time annually per LGU.

10.3.4 Cleanup and Snow Stockpiling

Snow disposal can be a concern, especially in areas where snow cannot be pushed off the side of the road. Snow plowed directly streamside can leak high concentrations of chloride into the stream. This is of special concern during base flow resulting in increased chloride concentrations. Although little snow hauling occurs in the Shingle Creek watershed, the stakeholders agreed to stockpile snow away from sensitive areas. A sensitive area is defined as directly streamside, on slopes greater than 6%, or near a wetland or storm sewer inlet. All stakeholders also agreed to sweep City streets as soon as possible in late winter to remove as much residual product as possible. There is no additional cost expected for this activity.

10.3.5 Ongoing Research into Salt Alternatives

Technologies associated with winter road maintenance are constantly changing based on the needs of the industry. Due to the changing technologies, there is a need to keep informed on new practices, technologies, and products that can ultimately protect public safety and the environment. All of the stakeholders will evaluate the technologies on an annual basis and implement the most appropriate technologies where feasible. The estimated cost of this activity is $2,000 for staff time annually per LGU, plus the cost of any technologies implemented.

10.3.6 SCWMC Activities

The SCWMC has agreed to take the lead on public education and private applicator education. The following activities will be conducted by the SCWMC.

Coordinate an Annual Commercial Applicator Workshop

The purpose of the workshop is to discuss salt usage, application techniques, and storage issues, product type and alternatives, and other technologies so that commercial applicators are informed. The estimated cost of this activity is $1,000 annually.

Private Applicator Education

Education of private applicators (commercial, industrial, and residential) and homeowners can help reduce chloride based deicer use in the watershed. Some educational materials have been developed by Canadian agencies regarding private use of chloride-based deicers. Private applicator education will include development of brochures, newsletters, website pieces, and presentations to educate private applicators on chloride issues in the watershed. The estimated cost of this activity is $1,500 annually.

Permit Requirements

The commission will incorporate private (commercial) snow management rules for reducing chloride use and include chloride reduction in the Commission's project review program. One requirement may be the development of a salt management plan for individual commercial properties. The commission will develop a template for the salt management plan. The estimated cost of this activity is $2,000.

Conduct Official Education

There is a need for City, County, and State officials to understand the TMDL and the proposed implementation activities so that they can effectively balance the public safety issues with the environmental risks. The SCWMC will inform the appropriate officials with the necessary information. The estimated cost of this activity is $1,000 annually.

Monitoring

Monitoring of chloride and conductivity at two locations is already incorporated into the Commission's annual monitoring activities. The estimated cost of this activity is $3,000 annually.

Public Education and Outreach

One measure that may allow for reductions in usage of deicing chemicals is to increase public knowledge of the environmental effects of road salt and ultimately gain public acceptance in lowering driving speeds during icy conditions. Another effect education can have is lowering public expectations for snow removal and deicing. This task will educate the public to help manage expectations and identify the need for chloride reductions. Activities may include newsletter articles, brochures, website pieces and presentations. The estimated cost of this activity is $3,000 annually.

Annual Report on Monitoring and Activities

An annual report on salt reduction activities is necessary under the adaptive management guidelines established in the TMDL. This report will provide the Cities' with necessary information for their annual NPDES reports. The report will track BMP scheduling, implementation, O & M and environmental condition monitoring data to evaluate activity effectiveness. The estimated annual cost of this activity is $5,000.

City Salt Management Plans

The implementation plan asks the Cities to develop and maintain a City Salt Management Plan. Many Cities already have these, but a template is needed to easily compare activities between Cities. A template will reduce the Cities' workload and provide an easily amendable plan for reducing salt use. The SCWMC will develop a template for the City Salt Management Plans at an estimated cost of $3,000.

10.3.7 Monitoring Implementation of Policies and BMPs

The SCWMC will evaluate progress toward meeting the goals and policies outlined in the Second Generation Plan in their Annual Report. Success will be measured by completion of policies and strategies, or progress toward completion of policies and strategies. The Annual Report will be presented to the public at the Commission's annual public meeting. The findings of the Annual Report and the comments received from the member cities and the public will be used to formulate the work plan, budget, Capital Improvement Program (CIP) and specific measurable goals and objectives for the coming year as well as to propose modifications or additions to the management goals, policies, and strategies.

10.3.8 Follow-up Monitoring

The SCWMC monitors water quality at two stations in the watershed (Zane Ave. and Humboldt Ave. near the outlet). Upon the initiation of this TMDL study, the SCWMC has increased monitoring at these two stations to include grab samples of chloride and collection of conductivity at 15-minute intervals. These data will be used to track effectiveness of BMP implementation. Results will be included in the Commission's annual water quality monitoring report.

The SCWMC has agreed to take the lead on monitoring and tracking the effectiveness of activities implemented to reduce chloride in Shingle Creek.

11.0 Reasonable Assurance

11.1 INTRODUCTION

When establishing a TMDL, reasonable assurances must be provided demonstrating the ability to reach and maintain water quality endpoints. Several factors control reasonable assurances including a thorough knowledge of the ability to implement BMPs as well as the overall effectiveness of the BMPs. This TMDL is unique in that it requires maintaining a balance between protecting the beneficial use of the water body and public safety. Additionally, the scientific understanding of BMP effectiveness for chloride is still young and research must account for changes in public safety. To address these issues, adaptive management will be implemented to protect water quality without sacrificing public safety. As research and understanding on the potential BMPs begin to solidify our understanding of their ability to maintain public safety and protect the beneficial uses of the water body, actions and management plans will be changed to incorporate these advances. However, there are some BMPs and policies that can be addressed now to improve water quality conditions in Shingle Creek. Additionally, there is a need to begin implementation and monitor the effectiveness of these BMPs in meeting the load allocations.

11.2 THE SHINGLE CREEK WATERSHED MANAGEMENT COMMISSION

The Shingle Creek Watershed Management Commission was formed in 1984 using Joint Powers Agreements developed under authority conferred to the member communities by Minnesota Statutes 471.59 and 103B.201 through 103B.251. The Commissions' purpose is to preserve and use natural water storage and retention in the Shingle Creek watershed to meet Surface Water Management Act goals.

The Shingle Creek and West Mississippi Watershed Management Commissions – briefly explain that these two have cooperated to plan and act.

The Metropolitan Surface Water Management Act (Chapter 509, Laws of 1982, Minnesota Statute Section 473.875 to 473.883 as amended) establishes requirements for preparing watershed management plans within the Twin Cities Metropolitan Area. The law requires the plan to focus on preserving and using natural water storage and retention systems to:

- Improve water quality.
- Prevent flooding and erosion from surface flows.
- Promote groundwater recharge.
- Protect and enhance fish and wildlife habitat and water recreation facilities.
- Reduce, to the greatest practical extent, the public capital expenditures necessary to control excessive volumes and rate of runoff and to improve water quality.
- Secure other benefits associated with proper management of surface water.

Minnesota Rules Chapter 8410 requires watershed management plans to address eight management areas and to include specific goals and policies for each. Strategies and policies for each goal were developed to serve as a management framework. To implement these goals, policies, and strategies, the Commission has developed the Capital Improvement Program and Work Plan discussed in detail in the Second Generation Plan (SCWMC 2004).

The philosophy of the Joint Powers Agreement is that the management plan establishes certain common goals and standards for water resources management in the watersheds, agreed to by the ten cities having land in the watersheds, and implemented by those cities by activities at both the Commission and local levels. TMDLs developed for water bodies in the watershed will be used as guiding documents for developing appropriate goals, policies, and strategies and ultimately sections of the Capital Improvement Program and Work Plan.

The SCWMC is committed to improving water quality in the Shingle Creek watershed. To this end, the SCWMC has recently completed a water quality management plan. The Shingle Creek and West Mississippi Watershed Management Commissions' Water Quality Plan (WQP) is intended to help achieve a Second Generation Management Plan goal of protecting and improving water quality. A number of activities are proposed in the Management Plan over the next ten years, including developing individual management plans for major water resources. One specific activity identified in the plan was the completion and implementation of the chloride TMDLs for Shingle Creek.

The Shingle Creek Water Quality Plan (WQP) is intended to:

- Set forth the Commissions' water quality goals, standards, and methodologies in more detail than the general goals and policies established in the Second Generation Management Plan.
- Provide philosophical guidance for completing water resource management plans and TMDLs; and
- Provide direction for the ongoing water quality monitoring programs that will be essential to determining if the TMDLs and implementation program are effectively improving water quality.

The Shingle Creek and West Mississippi Watershed Commissions' Water Quality Implementation Plan is composed of four parts:

- A monitoring plan to track water quality changes over time;
- Detailed management plans for each resource to lay out a specific plan of action for meeting water quality goals;
- A capital improvement plan; and
- An education and public outreach plan.

This Implementation Plan charts the course the Commissions will take to meet their Second Generation Management Plan goals to protect and improve water quality and meet Commission and State water quality standards. While the Plan lays out a series of activities and projects, implementation will occur as the Commissions' and cities' budgets permit.

The Commissions have received significant grant funding from the Minnesota Pollution Control Agency, the Board of Water and Soil Resources, the Metropolitan Council, and the Department of Natural Resources to undertake planning and demonstration projects. The Commissions intend to continue to solicit funds and partnerships from these and other sources to supplement the funds provided by the ten cities having land in the two watersheds. It is expected that the Commissions will continuously update their annual Capital Improvement Programs (CIPs) as a part of their annual budget process.

11.3 NPDES MS4 STORMWATER PERMITS

NPDES Phase II stormwater permits are in place for each of the member cities in the watershed as well as Hennepin County and Mn/DOT. Under the stormwater program, permit holders are required to develop and implement a Stormwater Pollution Prevention Program (SWPPP; MPCA, 2004). The SWPPP must cover six minimum control measures:

- Public education and outreach;
- Public participation/involvement;
- Illicit discharge, detection and elimination;
- Construction site runoff control;
- Post-construction site runoff control; and
- Pollution prevention/good housekeeping.

The permit holder must identify BMPs and measurable goals associated with each minimum control measure. The EPA requires that stormwater sources of a pollutant addressed in a TMDL must be treated as a wasteload allocation (i.e., a point source). Under the NPDES provisions, the permit will require addressing load allocations as either an effluent limit or as BMPs or other similar requirements. Stormwater loads in this TMDL are allocated among the permit holders while combining the cities. Combination of the cities maintains the watershed approach of the Shingle Creek Watershed Management Commission.

11.4 EFFICACY OF BEST MANAGEMENT PRACTICES

Source reduction strategies and BMPs are starting to be implemented in the Snow Belt region and have shown promise in reducing chloride loads while maintaining public safety. These practices and policies are adoptable by local resource managers and stakeholders.

Improved Equipment

Improved technologies have demonstrated reductions in road salt usage and ultimately reduced costs in acquiring material. Prewetting material has been linked to reductions of up to 30% (www.saltinstitute.org).

Deicing Alternatives

Numerous deicing alternatives exist, however the majority of these carry other water quality impacts. Most of the alternatives include chloride based deicers and are often more toxic than sodium chloride. Other, "organic" alternatives typically have a high BOD. Shingle Creek is currently impaired due to low oxygen. Consequently, deicers that increase BOD are not a feasible alternative at this time in the Shingle Creek watershed.

11.5 MONITORING

The SCWMC has agreed to take the lead on monitoring and tracking the effectiveness of activities implemented to reduce chloride in Shingle Creek. The monitoring effort is a key aspect of adaptive management in that an annual evaluation of chloride data from Shingle Creek provides for an assessment of BMP effectiveness. Evaluation of the monitoring data will be included in the Shingle Creek Annual Monitoring Report.

12.0 References

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Shingle Creek Chloride TMDL

Appendix A
Stream Rating Curves

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E-mail: wenckmp@wenck.com

MEMORANDUM

TO: Joe Bischoff

FROM: Todd Shoemaker

DATE: May 27, 2004

SUBJECT: Shingle Creek TMDL Rating Curve Development

This memorandum summarizes the methods taken to determine the discharge rating curves for six monitoring sites during the summer of 2003. A rating curve is a mathematical expression used to relate water depth to discharge in an open channel. For each site, the method of data collection, assumptions, data corrections, and final rating curve will be described.

The Manning equation expresses flow in a channel as a function of water depth. The six rating curves developed for this study will be presented as a mathematical power function to simulate the discharge predicted by the Manning equation.

The sites are described below in descending order by their position in the watershed.

Pineview

Nine flow and depth measurements were taken between March 26 and June 30, 2003 to determine the rating curve at the Pineview site. These measurements are listed in Table 1 and plotted in Figure 1.

Table 1. Pineview flow and depth measurements.

Date	Flow (cfs)	Depth (ft)
3/26/2003	0.74	0.98
3/28/2003	1.94	1.22
4/3/2003	0.65	1.1
4/10/2003	0.45	0.89
4/11/2003	3.64	1.34
4/17/2003	12.12	2.6
4/21/2003	7.65	2.27
6/25/03	94.97	5.4
6/30/2003	6.27	2.00

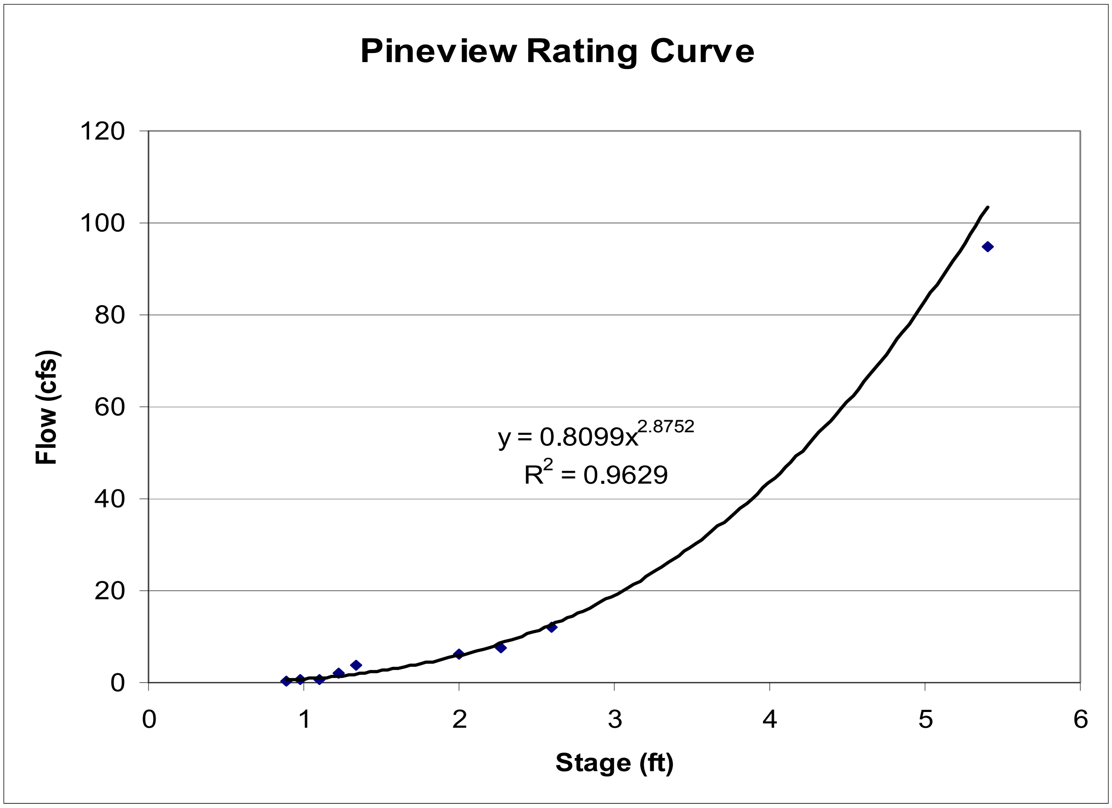


Figure 1. Raw Pineview site rating curve based on 9 depth and flow measurements.

Figure 1 indicates that there is effectively no flow in the channel below a depth of 0.7 feet and that the three highest flows appear to follow a different curve than the lower flows. Therefore, the raw data was corrected to account for these issues.

First, a depth of 0.7 feet was subtracted from all depth measurements to account for the depth of stagnant water in the channel. Secondly, the data were separated into two rating curves. One rating curve was developed for flows less than 1.8 feet (after subtraction of 0.7 feet) and a different curve for greater than 1.8 feet. The corrected data are plotted below in Figure 2.

<u>Pineview Rating Curves</u>

Water depth < 1.8 feet:	Flow = 4.4916 (water depth – 0.7)$^{1.4543}$
Water depth > 1.8 feet:	Flow = 2.7524 (water depth – 0.7)$^{2.2896}$

Water depth at the Pineview site was recorded from March 28 to October 27, 2003. A Solinst 3001 Levelogger was installed at the site and programmed to record a depth measurement in the channel at 15-minute intervals. Figure 3 shows the water depths recorded by the Levelogger. Figure 3 also shows water depth measurements recorded by Wenck Associates, Inc. personnel during the monitoring period.

Due to discrepancies between the recorded water depths by the Levelogger and Wenck personnel, corrections were made to the Levelogger record. Between April 16 and July 4, a constant of 0.768 feet was added to the recorded Levelogger depths because

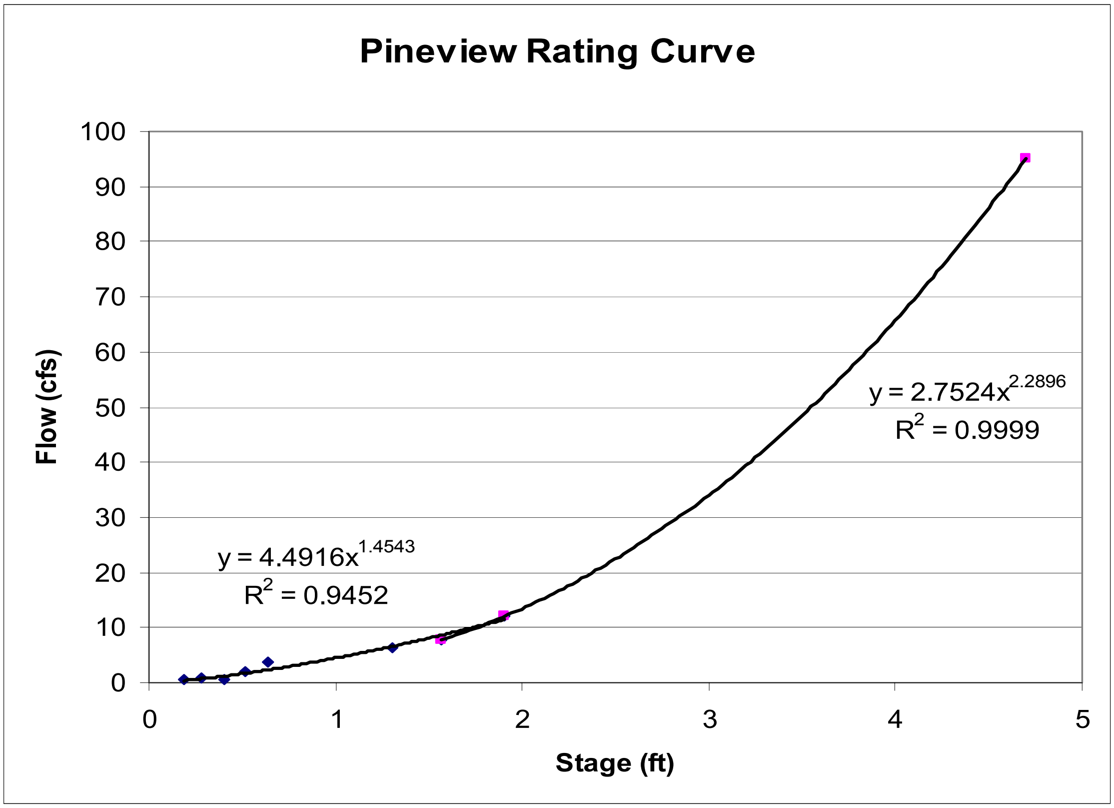


Figure 2. Corrected Pineview site rating curve based on 9 depth and flow measurements.

measured data showed the water depth in the channel was greater than that recorded by the Levelogger. Similarly, a constant of 0.88 feet was added to the recorded Levelogger depths between August 14 and September 12. Wenck Associates, Inc. measured the water depth on October 2 higher than what was recorded by the Levelogger. However, a correction was not made for this time period because there was only one depth measurement. It was also more conservative to underestimate flow since it was the end of the water year. Figure 3 shows the corrected water depths that were used to determine the flow in the channel for the period of record.

The hydrograph for the Pineview site and measured flows from Table 1 are shown in Figure 4. It is the result of the corrected rating curve and corrected water depth record discussed above.

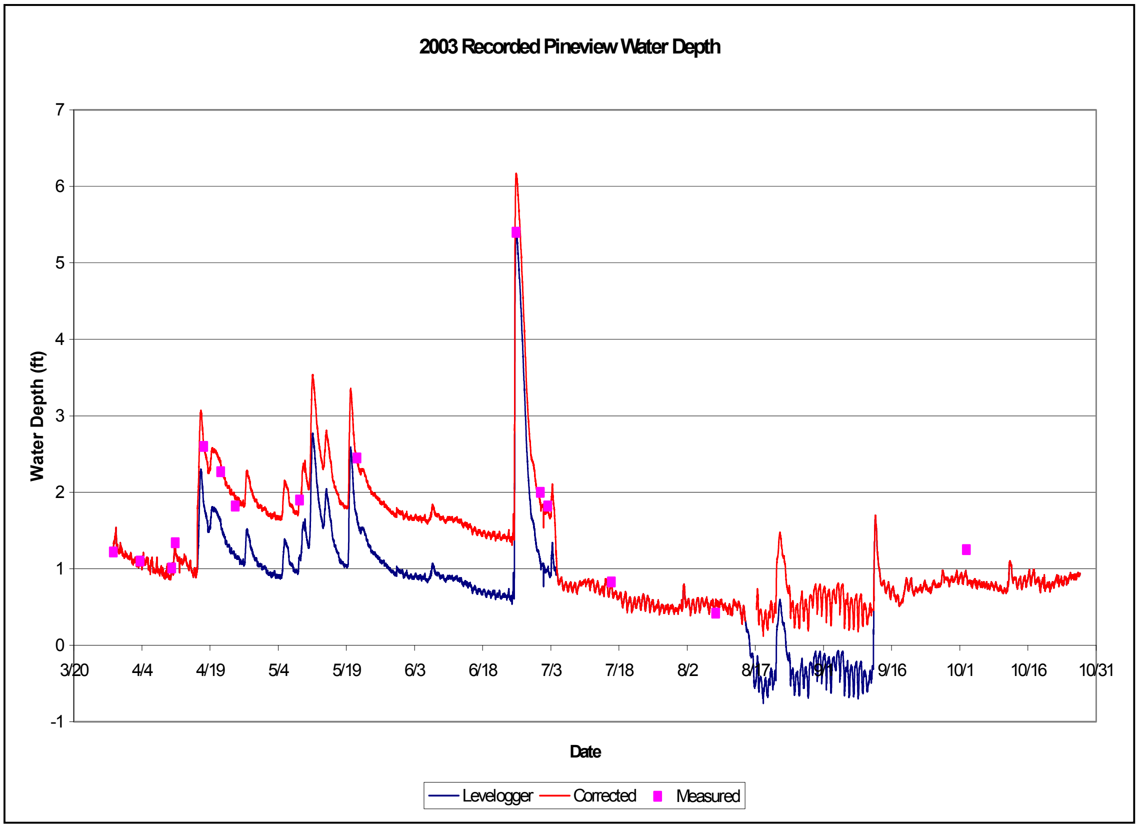


Figure 3. Raw, measured and corrected Pineview site water depth data.

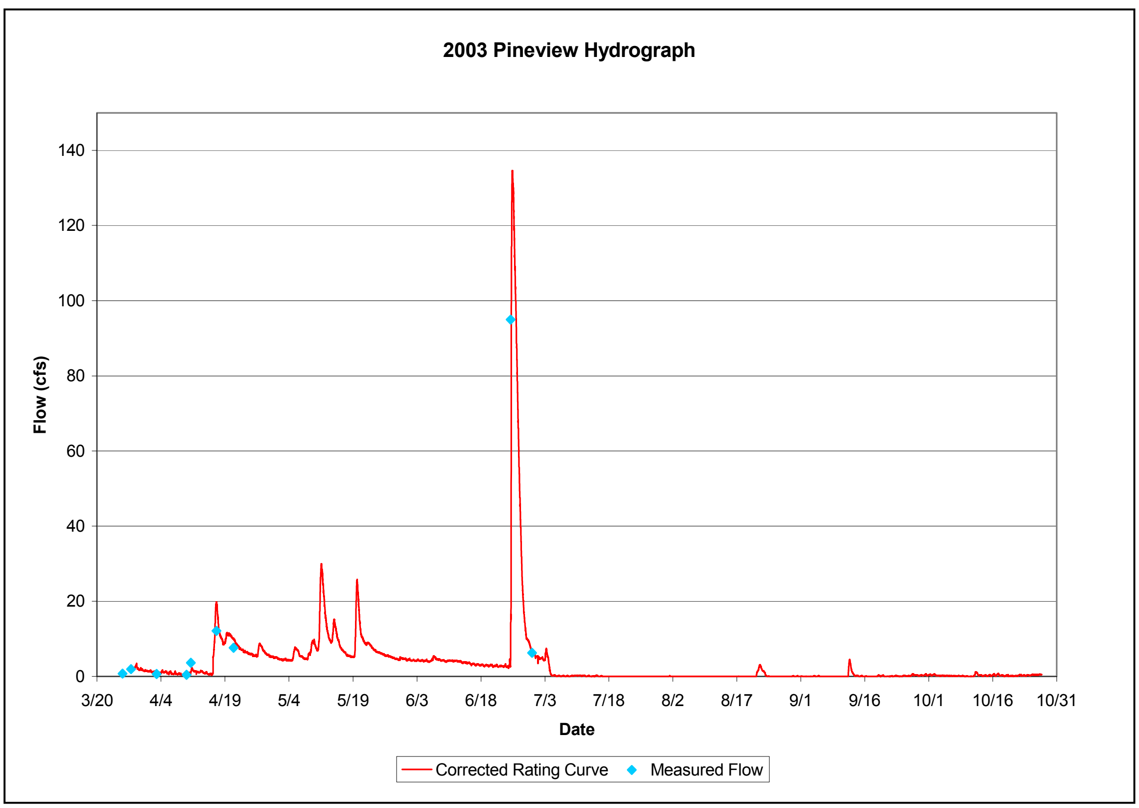


Figure 4. Hydrograph and measured flows for the Pineview site.

62 East

Eight flow and depth measurements were taken between March 26 and June 30, 2003 to determine the rating curve at the 62 East site. These measurements are listed in Table 2. Similar to the Pineview site, a correction of 0.6 feet was subtracted from the depth corresponding to each flow to account for the depth of stagnant water in the channel. Figure 5 shows the corrected rating curve.

Table 2. 62 East flow and depth measurements.

Date	Flow (cfs)	Depth (ft)
3/26/2003	1.28	1.5
3/28/2003	4.29	1.85
4/3/2003	2.27	2.00
4/10/2003	1.04	1.87
4/17/2003	11.6	2.25
4/21/2003	16.65	2.42
6/25/03	256.71	6.5
6/30/2003	35.16	3.2

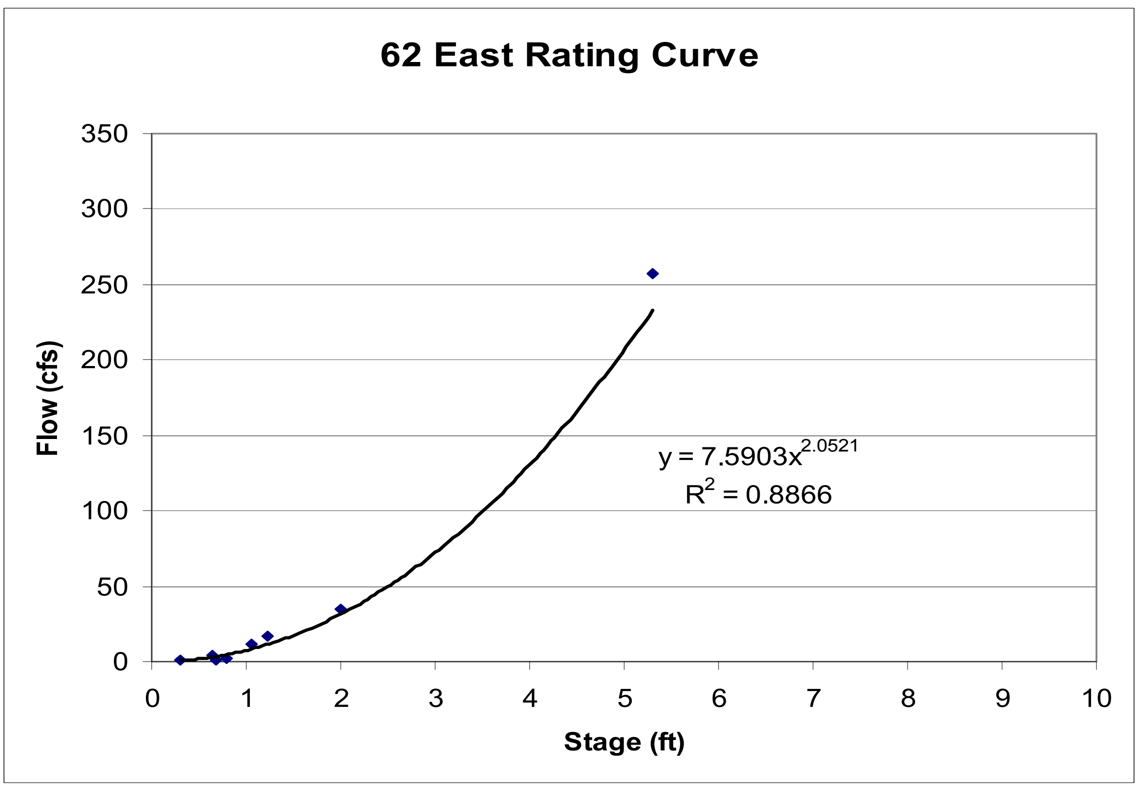


Figure 5. Corrected rating curve for the 62 East site.

<u>62 East Rating Curve</u>

For all water depths: $\text{Flow} = 7.5903\,(\text{water depth} - 0.6)^{2.0521}$

Water depth at the 62 East site was recorded from March 28 to October 27, 2003. A Solinst 3001 Levelogger was installed at the site and programmed to record a depth measurement in the channel at 15-minute intervals. Figure 6 shows the water depths recorded by the Levelogger. Figure 6 also shows water depth measurements recorded by Wenck personnel during the monitoring period.

Due to discrepancies between the recorded water depths by the Levelogger and Wenck personnel, corrections were made to the Levelogger record. Between March 28 and August 9, a constant of 0.71 feet was subtracted from the recorded Levelogger depths because measured data showed the water depth in the channel was less than that recorded by the Levelogger. Measurements by Wenck personnel after August 9 indicated that a correction to the recorded Levelogger data was not necessary. Figure 6 shows the corrected water depths that were used to determine the flow in the channel for the period of record.

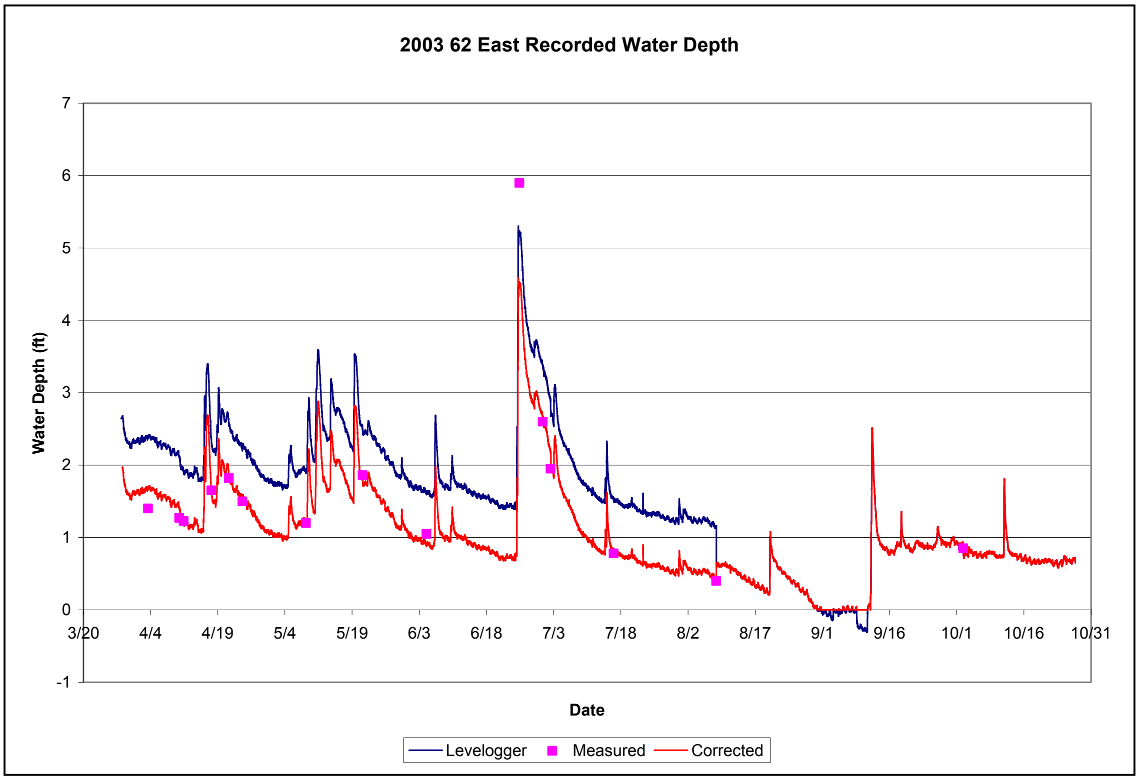


Figure 6. Raw, measured and corrected 62 East site water depth data.

The hydrograph for the 62 East site and measured flows from Table 2 are shown in Figure 7. It is the result of the corrected rating curve and corrected water depth record discussed above. The difference between the measured and predicted flow on June 25 is not of great concern. For safety reasons, estimated the flow by measuring the surface velocity.

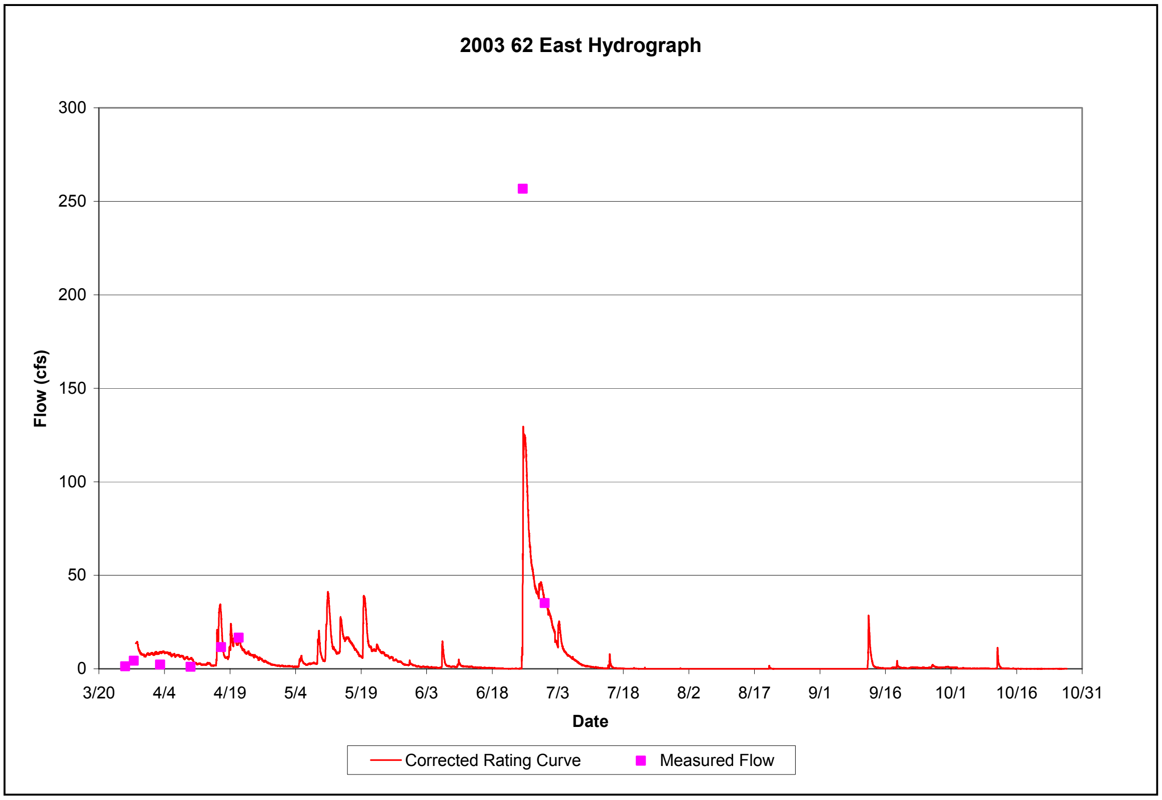


Figure 7. Hydrograph and measured flows for the 62 East site.

Northland

Eight flow and depth measurements were taken between March 26 and June 30, 2003 to determine the rating curve at the Northland site. These measurements are listed in Table 3. Site conditions indicated that there were no downstream obstructions that could cause stagnant water in the channel. Therefore, unlike the previous two sites, a correction was not applied to the measured depths.

Table 3. Northland flow and depth measurements.

Date	Flow (cfs)	Depth (ft)
3/26/2003	6.31	1.13
3/28/2003	12.02	1.68
4/3/2003	7.38	1.25
4/10/2003	2.96	0.84
4/17/2003	32.98	2.85
4/21/2003	27.26	2.26
6/25/03	219.4	5.5
6/30/2003	65.0	3.85

Similar to the Pineview rating curves, two rating curves were developed for the Northland site. Figure 8 shows the flow and depth measurements from Table 3. The red line indicates the rating curve for all of the data; it has an R-squared value of 0.9865. The dark blue line indicates the rating curve for flow measurements with depths less than 2.0 feet; the R-squared value is 0.9813. The light blue line indicates the rating curve for flow measurements with depths greater than 2.0 feet. Two rating curves were developed for this site for two reasons: the red and dark blue lines are essentially the same for depths less than 2.0 feet and the light blue line better approximates high flows than does the red line.

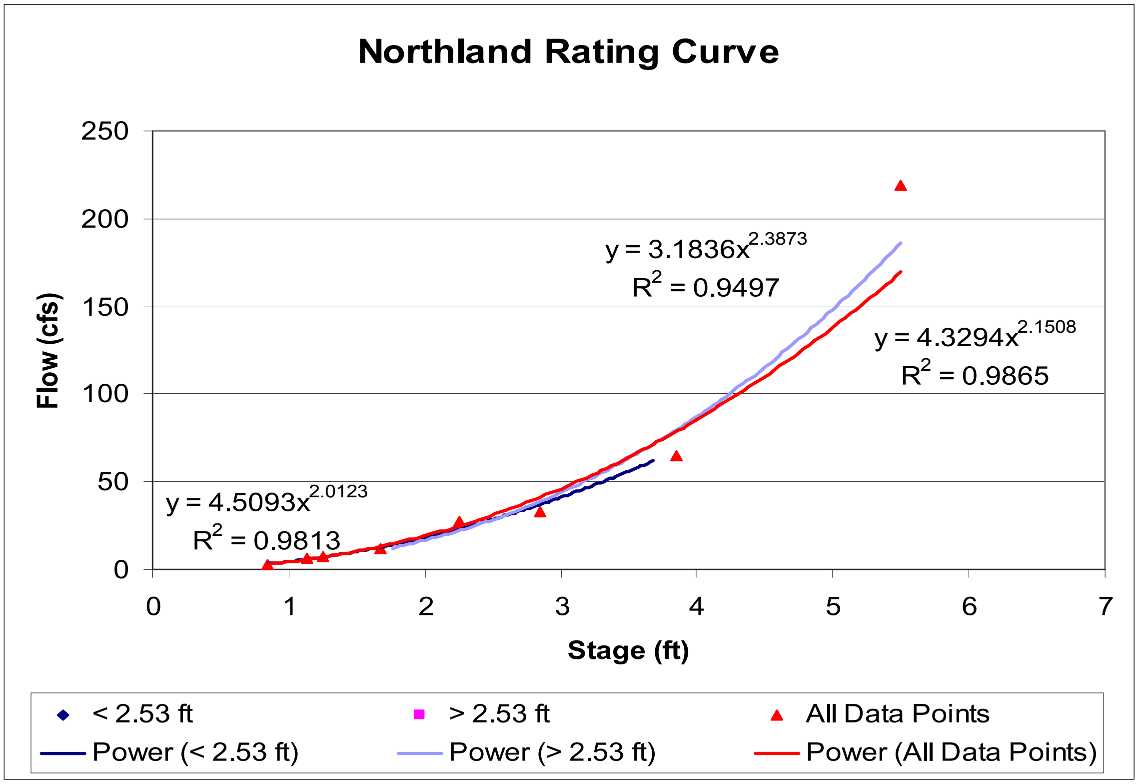


Figure 8. Raw and corrected rating curves for the Northland site.

As shown by the channel cross-section survey in Figure 9, a significant floodplain exists at the site location adjacent to the main channel. Based on the survey, the floodplain will carry flow above a depth of approximately 2.2 feet. Equating the dark and light blue rating curves, the change in flow occurs at a depth of 2.53 feet.

Northland Rating Curves

Water depth < 2.53 feet: Flow = 4.5093 (water depth)$^{2.0123}$

Water depth > 2.53 feet: Flow = 3.1836 (water depth)$^{2.3873}$

Water depth at the Northland site was recorded from March 29 to October 27, 2003. A Solinst 3001 Levelogger was installed at the site and programmed to record a depth measurement in the channel at 15-minute intervals. Figure 10 shows the water depths recorded by the Levelogger. Figure 10 also shows water depth measurements recorded by Wenck personnel during the monitoring period. Measured depths closely matched the depths recorded by the Levelogger; therefore, no correction was applied to the recorded water depths for the Northland site.

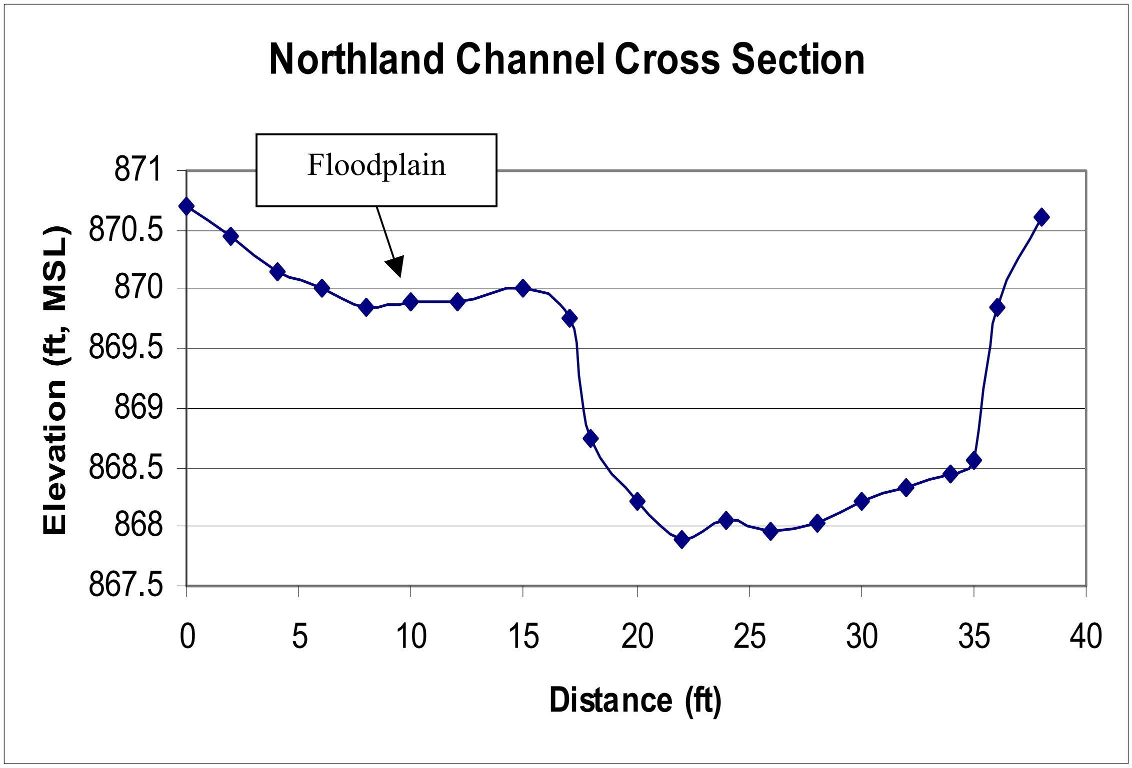


Figure 9. Channel cross-section survey for the Northland site (looking downstream).

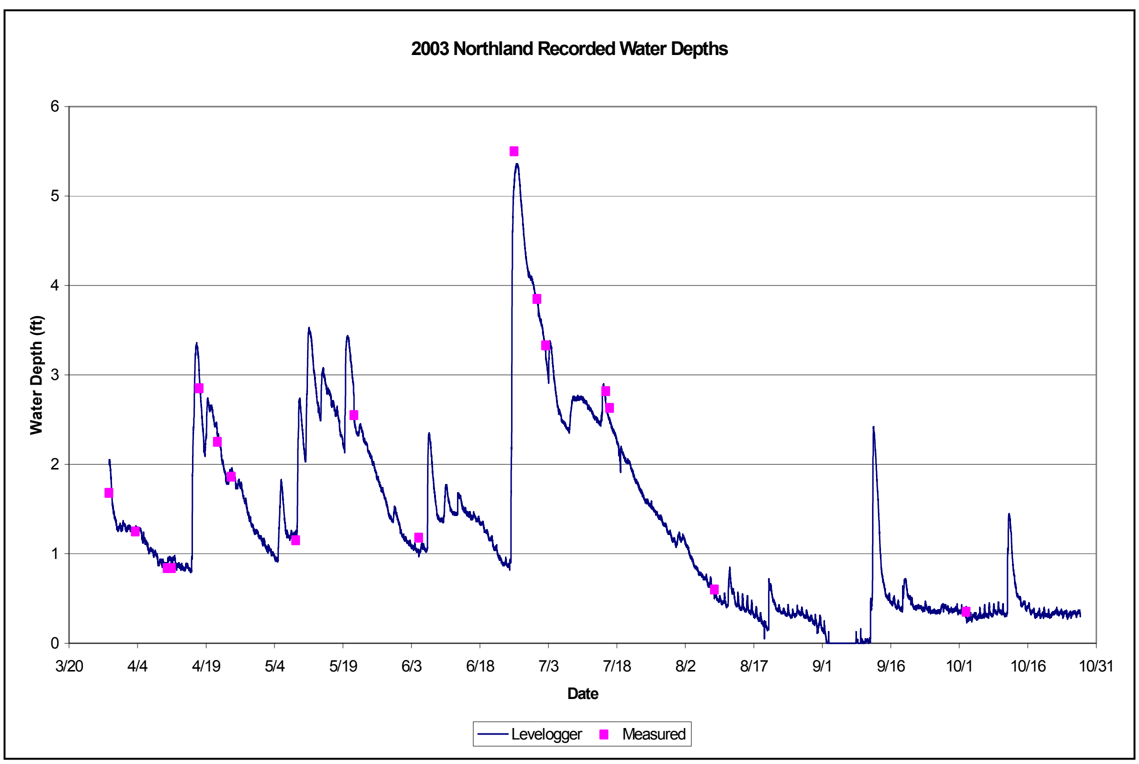


Figure 10. Raw and measured Northland site water depth data.

The hydrograph for the Northland site and measured flows from Table 3 are shown in Figure 11. It is the result of the rating curve and water depth record discussed above.

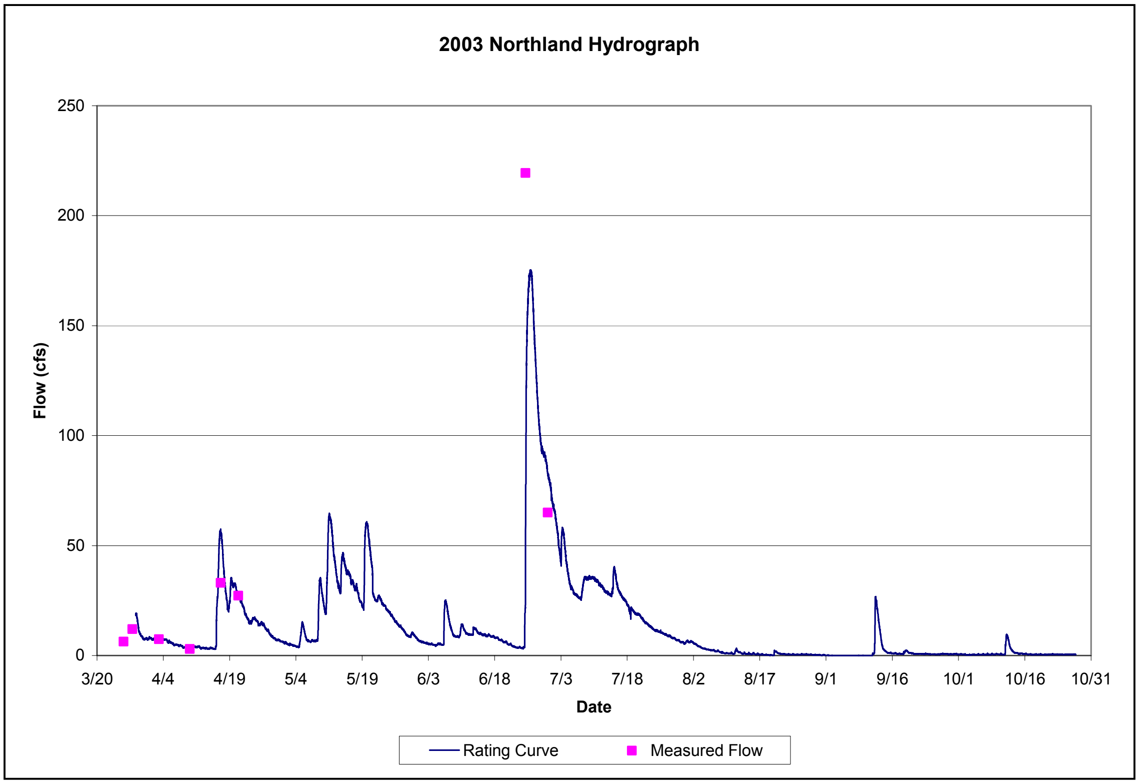


Figure 11. Hydrograph and measured flows for the Northland site.

<u>Zane</u>

Nineteen flow and depth measurements were taken between March 2002 and June 30, 2003 to determine the rating curve at the Zane site. For brevity, these measurements will not be listed in a table but are plotted in Figure 12. Similar to the Pineview and 62 East sites, a correction of 0.2 feet was subtracted from the depth corresponding to each flow to account for the depth of stagnant water in the channel. The corrected rating curve is shown in Figure 12.

<u>Zane Rating Curve</u>

For all water depths: $\text{Flow} = 7.6835\ (\text{water depth})^{2.4099}$

Water depth at the Zane site was recorded from March 27 to October 27, 2003. An Isco 4120 Submerged Probe Flow Meter was installed at the site and programmed to record a depth measurement in the channel at 15-minute intervals. Figure 13 shows the water depths recorded by the 4120 unit. Figure 13 also shows water depth measurements recorded by Wenck personnel during the monitoring period. Measured depths closely matched the depths recorded by the 4120 unit; therefore, no correction was applied to the recorded water depths for the Zane site.

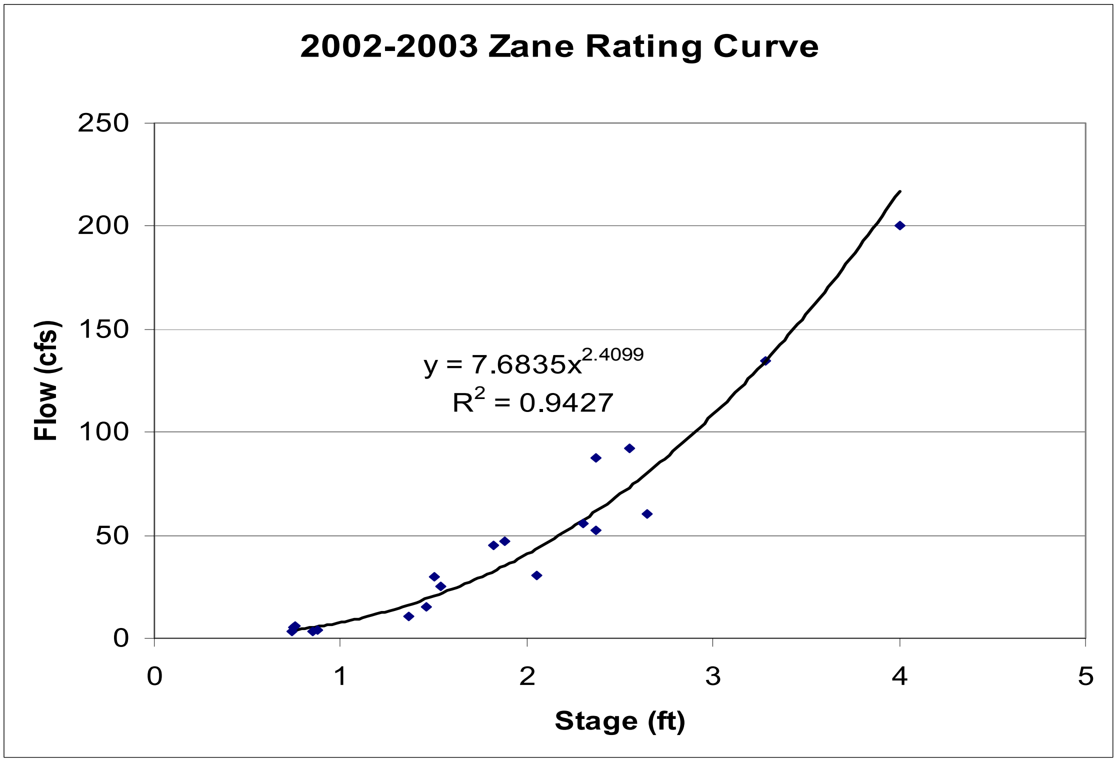


Figure 12. Corrected rating curve for the Zane site.

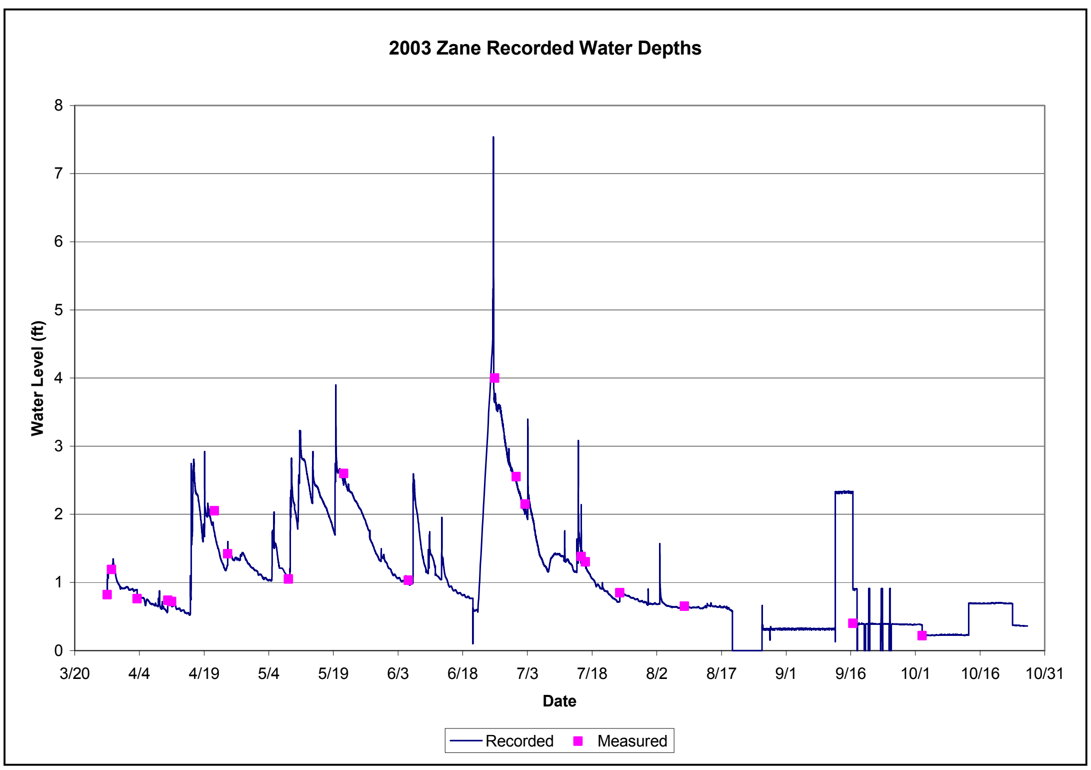


Figure 13. Raw and measured Zane site water depth data.

Following September 12, the water depths measured by the 4120 unit were unreliable. The pressure transducer within the submerged probe was not able to accurately sense the one to three inches of water in the channel caused by the near drought conditions in the region. Therefore, based on field experience, a water depth of 0.15 feet was assumed for the site from September 12 through October 27, 2003.

The hydrograph and measured flows for the Zane site are shown in Figure 14. It is the result of the corrected rating curve and water depth record discussed above.

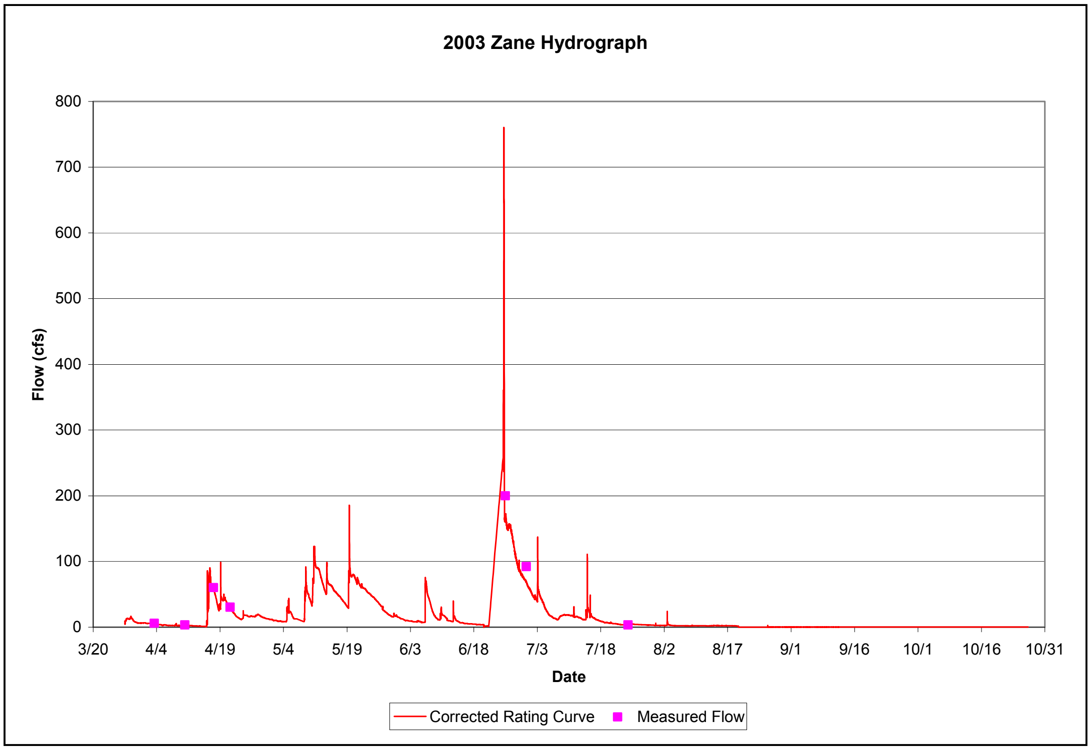


Figure 14. Hydrograph and measured flows for the Zane site.

I-94

Five flow and depth measurements were taken between April 11 and June 30, 2003 to determine the rating curve at the I-94 site. These measurements are listed in Table 4. Similar to previous sites, a correction of 2.35 feet was subtracted from the depth corresponding to each flow to account for the depth of stagnant water in the channel. Figure 15 shows the corrected rating curve.

Table 4. I-94 flow and depth measurements.

Date	Flow (cfs)	Depth (ft)
4/11/2003	3.25	2.47
4/17/2003	81.25	3.45
4/21/2003	35.58	3.11
6/25/03	197.28	4.8
6/30/2003	101.0	3.9

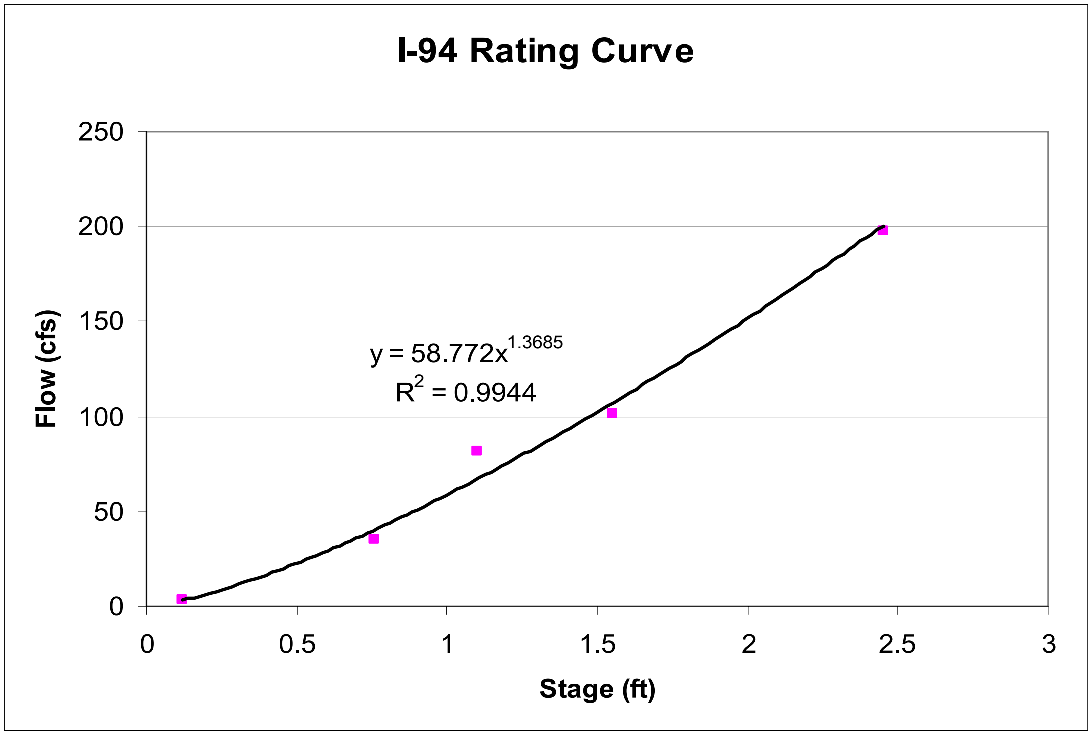


Figure 15. Corrected rating curve for the I-94 site.

<u>I-94 Rating Curve</u>

For all water depths: Flow = 58.772 (water depth – 2.35)$^{1.3685}$

Water depth at the I-94 site was recorded from March 29 to October 27, 2003. A Solinst 3001 Levelogger was installed at the site and programmed to record a depth measurement in the channel at 15-minute intervals. Figure 16 shows the water depths recorded by the Levelogger. Figure 16 also shows water depth measurements recorded by Wenck personnel during the monitoring period.

Due to discrepancies between the recorded water depths by the Levelogger and Wenck personnel, corrections were made to the Levelogger record. A constant of 0.13 feet was subtracted from the recorded Levelogger depths because measured data showed the water depth in the channel was less than that recorded by the Levelogger. Figure 16 shows the corrected water depths that were used to determine the flow in the channel for the period of record.

The hydrograph for the I-94 site and measured flows from Table 4 are shown in Figure 17. It is the result of the corrected rating curve and corrected water depth record discussed above.

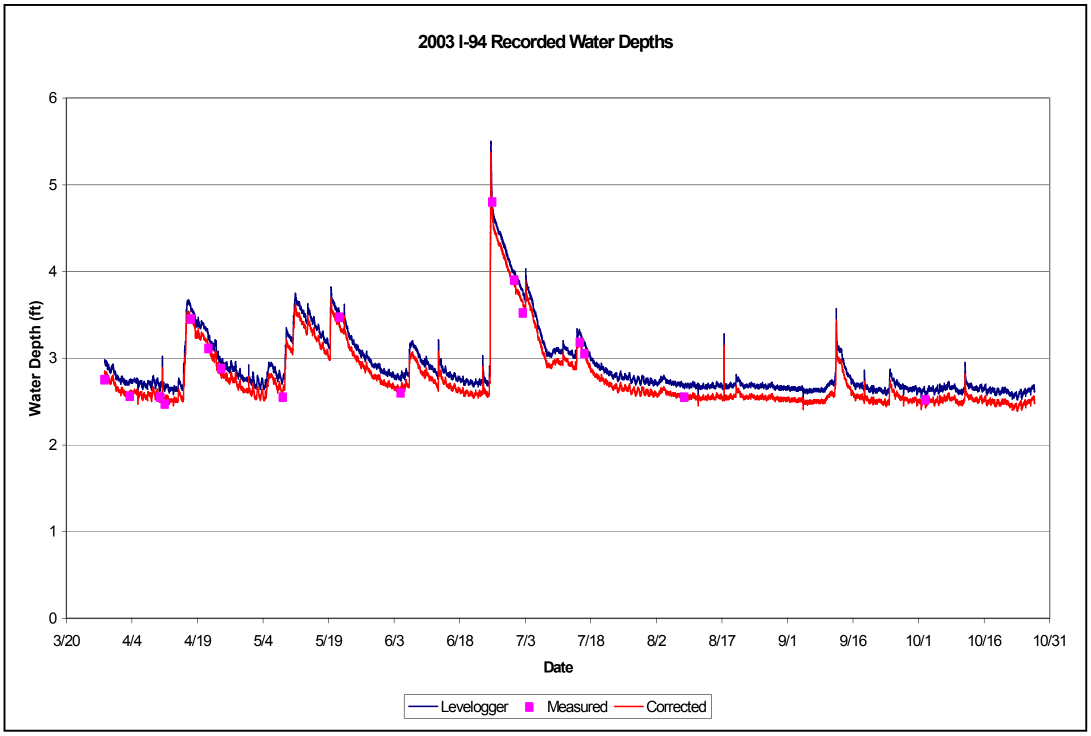


Figure 16. Raw, corrected and measured I-94 site water depth data.

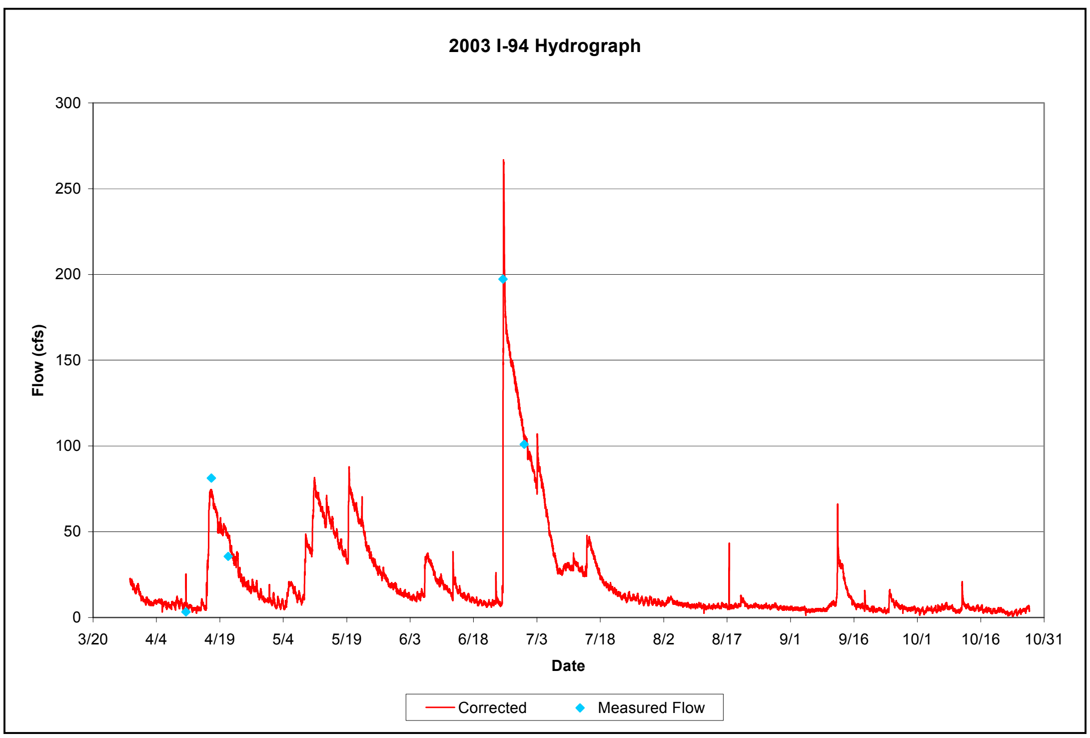


Figure 17. Corrected and measured flows for the I-94 site.

Outlet

Six flow and depth measurements were taken between March 26 and June 30, 2003 to determine the rating curve at the Outlet site. These measurements are listed in Table 5. Site conditions indicated that there were no downstream obstructions that caused stagnant water in the channel. Therefore, similar to the Northland site, a correction was not applied to the measured depths. The rating curve is shown in Figure 18.

Table 5. Outlet flow and depth measurements.

Date	Flow (cfs)	Depth (ft)
3/26/2003	10.97	0.95
4/3/2003	9.52	1.04
4/10/2003	5.66	0.96
4/21/2003	52.15	1.65
6/25/03	303.22	3.3
6/30/2003	110.33	2.15

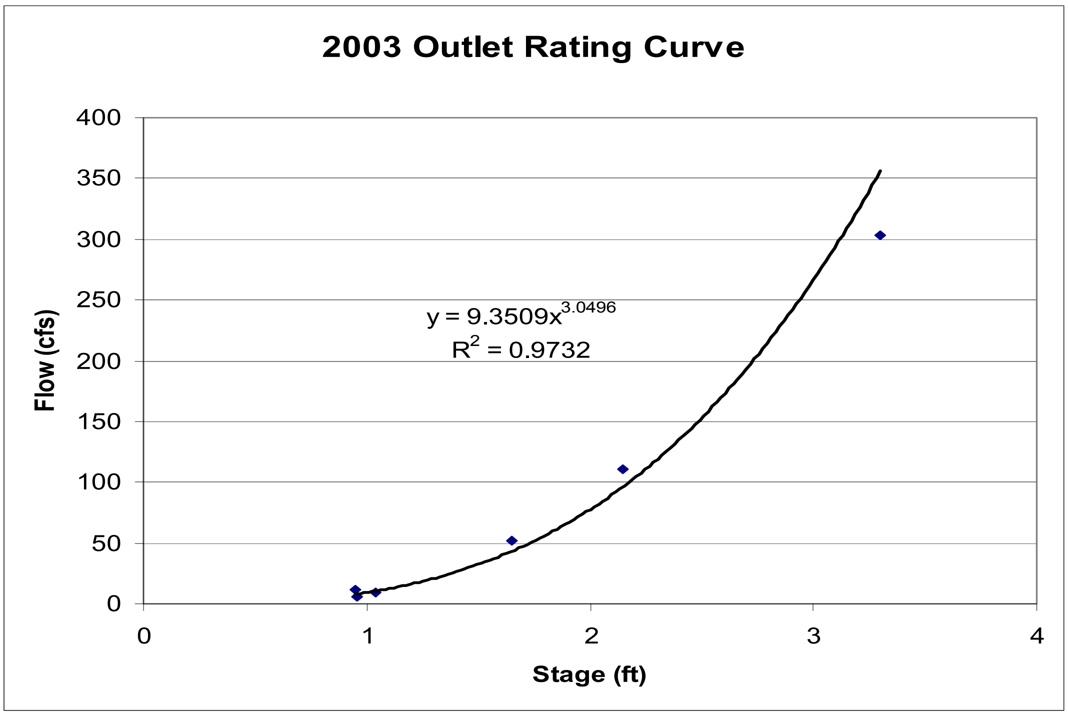


Figure 18. Raw rating curve for the Outlet site.

<u>Zane Rating Curve</u>

For all water depths: Flow = 7.6835 (water depth)$^{2.4099}$

Water depth at the Outlet site was recorded from March 26 to October 27, 2003. An Isco 4150 Bubbler Flow Meter was installed at the site and programmed to record a depth measurement in the channel at 15-minute intervals. Figure 19 shows the water depths recorded by the 4150 unit. Figure 19 also shows water depth measurements recorded by Wenck personnel during the monitoring period. Measured depths closely matched the depths recorded by the 4150 unit; therefore, no correction was applied to the recorded water depths for the Outlet site.

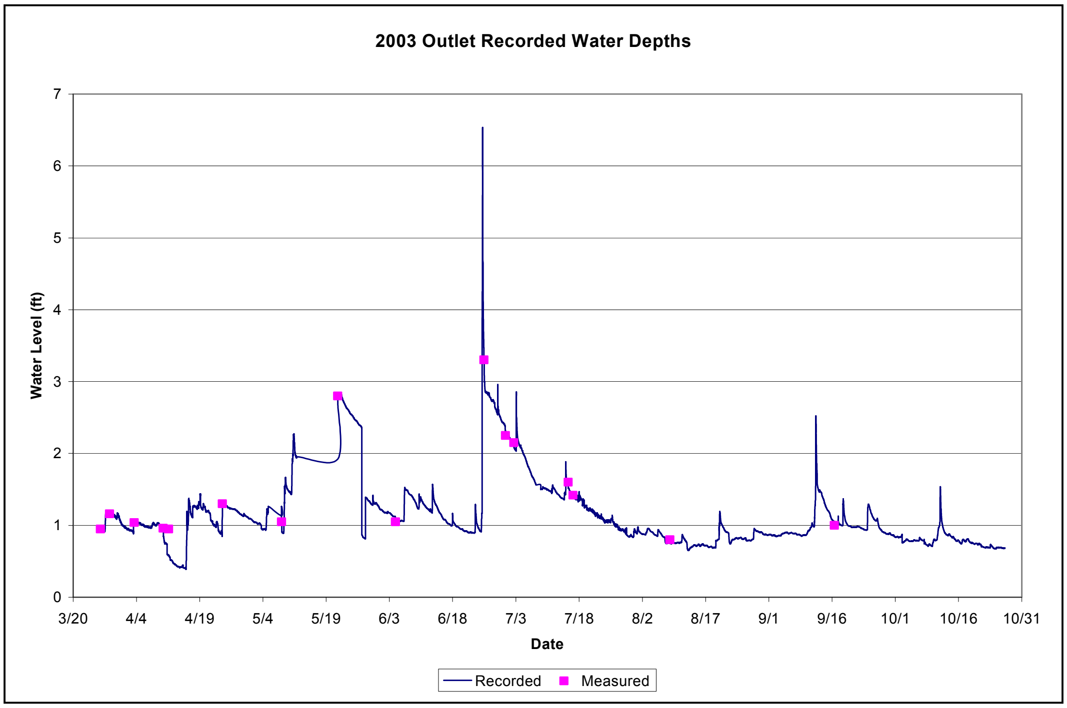


Figure 19. Raw and measured Outlet site water depth data.

The hydrograph for the Outlet site and measured flows from Table 5 are shown in Figure 20. It is the result of the rating curve and water depth record discussed above.

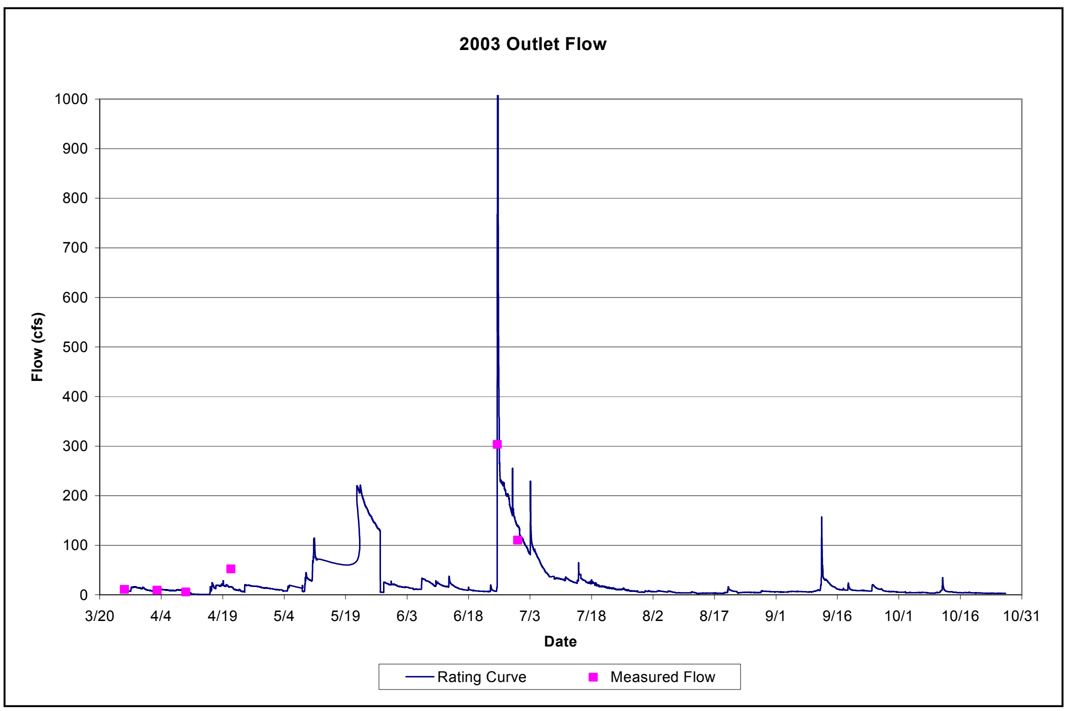


Figure 20. Hydrograph and measured flows for the Outlet site.

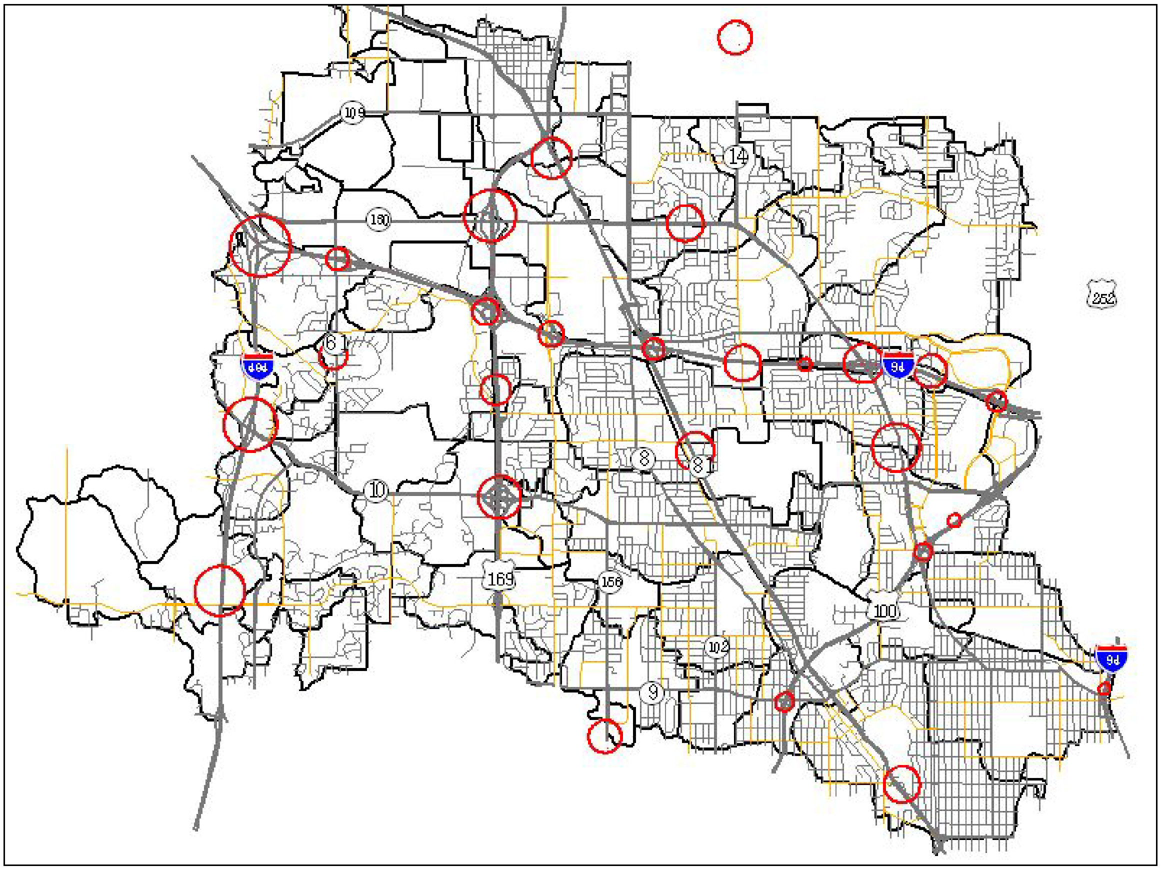
Shingle Creek Chloride TMDL

Appendix B Road Surface Analysis

B.1 Lane Mile Evaluation

Twenty-seven places (shown as circles in Figure A) were chosen to measure the width of the road, including shoulders, and ramps over the Metropolitan Council 2000 1-meter digital orthophotos for the Shingle Creek Watershed.

Figure A: Buffer Width Measurement Locations



These widths, summarized in Table B-1, were used to buffer the road lines from the Minnesota Department of Transportation (Mn DOT) survey and mapping DOT Basemap Roads for Hennepin County (Jan-01 most current update). The base landuse coverage is from the Metropolitan Council, and is representative of the generalized landuse for the year 2000. By removing the buffered roads from the landuse coverage, a reasonable estimate of non-transportation corridor landuse could be made for each subcatchment, based on published percent impervious values.

Table B-2 presents "Typical Percentage Imperviousness by Landuse", of acceptable published ranges for percent impervious by landuse. This table represents the starting point of establishing the percent imperviousness estimates for the modeled subcatchment for the Shingle Creek Watershed. This table also sets the bounds of reasonable calibrated percent imperviousness. If the final calibrated imperviousness percentages fall outside of this reasonable range, further investigation will be required to determine exactly why the value falls outside of the reasonable range. These published values were applied to the generalized landuse for the year 2000 to determine the initial subcatchment percent impervious values using geoprocessing routines in ArcView.

Table B-1. Road Widths.

Average Width (ft)	Count	Standard Deviation	Location
66.1	6	4.2	94 north-western section
45.2	16	4.1	I-494 running south of intersection with 94
47.5	33	4.3	section of 94
48.7	18	4.4	Hwy 169 width
48.9	3	3.0	county Rd 61
64.2	3	0.6	county Rd 156
72.7	6	4.0	three lanes
58.2	2	0.5	
60.1	11	6.0	section of 94
75.8	8	7.5	I-94 SE subwatershed
40.9	16	5.5	Hwy 100 width
36.1	16	7.6	average of wider areas North & Middle (8 measurements) and more narrow Southern (8 measurements)
40.2	22	6.6	county road 152
49.0	3	15.1	average of county roads 14, 156, 61, widths used for all county roads, except 14, 156, 61, and 81 and 156
34.0	10	4.7	county road 14
35.4	48	9.6	I 94, 494 ramps
32.6	23	12.7	169 ramps
24.4	6	2.2	100 ramps

Table B-2.

Typical Percentage Imperviousness by Landuse (published)	Total IMP (%)	Starting IMP (%)
Low Density Residential	20 – 35	27.5
Medium Density Residential	30 – 50	40
High Density Residential	40 – 60	50
Commercial	60 – 90	75
Light Industrial	40 – 70	65
Heavy Industrial	60 – 90	65
Institutional/Public	50 – 70	50
Parks/Green Spaces	0 – 10	5

Special Note On Mn/DOT Reported Lane Miles

The ArcView shape file for roads shows multi-lane as a single line. Using information provided by Norm Ashfeld (Mn/DOT), a lane mile factor was calculated to properly estimate the correct lane miles, for various corridors as summarized below:

	Hwy between:	Mn DOT Reported Lane Miles	Lane Mile Factor	Length of Digitized Line (miles)
TP5H2261	I94 from 252 to TH55	61.5	5.35	11.49
TP5E1669	TH100 from 694 to TH55	45.9	3.21	14.30
TP5E1671	I94 from 81 to 252	41.1	4.51	9.11
TP5B1251	I94 from Wright/Hennepin County line to 252	108.4	---	
---	I94 from Wright/Hennepin County line to 81	67.3	2.21	39.57
---	I94 from 81 to 252	41.1	4.51	9.11

Other lane mile factors were determined by class of road, as summarized below:

Road Class	Road Class Description	Lane Mile Factor
22	Mn/DOT (Ramp)	1
2	Mn/DOT (U.S. Trunk Highway) TH169	3.21[(a)]
3	Mn/DOT (Minnesota Trunk Highway) TH100	3.21[(a)]
4	County State Aid Highway	See table below
5, 7	Municipal State Aid Street, County Road	2
10	Municipal Street	2
8, 23	Township Road, Private Jurisdictional Road	2
Portion of 1	Mn/DOT (Interstate Trunk Highway) I494	2.21[(b)]
Portion of 1	Mn/DOT (Interstate Trunk Highway) I694 (east of I94 and 152)	4.51[(c)]

Notes: (a): Assume the same factor as TH100 from 694 to TH55
(b): Assume the same factor as I94 from Wright/Hennepin County line to 81
(c): Assume the same factor as I94 from 81 to 252

County Plow Route	County Lane Miles	Lanes per digitized line	Digitized Line (miles)	Ramps ArcView (miles)
43-44	20.1	2.64	7.62	0
45-46	7.3	3.29	2.22	0
47-48	45.7	2.80	16.35	0.0662
49-50	37.9	2.67	14.18	0.3303
51-52	16	5.65	2.83	0
53-54	40.5	2.99	13.56	0.1079
55-56	27.2	4.28	6.36	0.1329
57-58	1.9	4.12	0.46	0
59-60	11.4	2.13	5.34	0.0286
63-64	15.2	3.39	4.49	0
67-68-69	36	3.69	9.75	

B.3 Road Salt Application

All roads in the subwatershed were assigned one of three plow route types (Mn DOT, Hennepin County, or Municipality.) Municipality plow routes were specified by the cities in the watershed (Brooklyn Center, Brooklyn Park, Plymouth, Osseo, Robbinsdale, New Hope, Maple Grove, Crystal, and Minneapolis.) The lane miles by plow route type were tabulated for each subwatershed. The salt application data, in units of tons of salt applied per lane mile, coupled with the lane mile estimates were used to estimate the amount of salt applied to each subwatershed.

Shingle Creek Chloride TMDL

Appendix C
Time Series of Logged Data

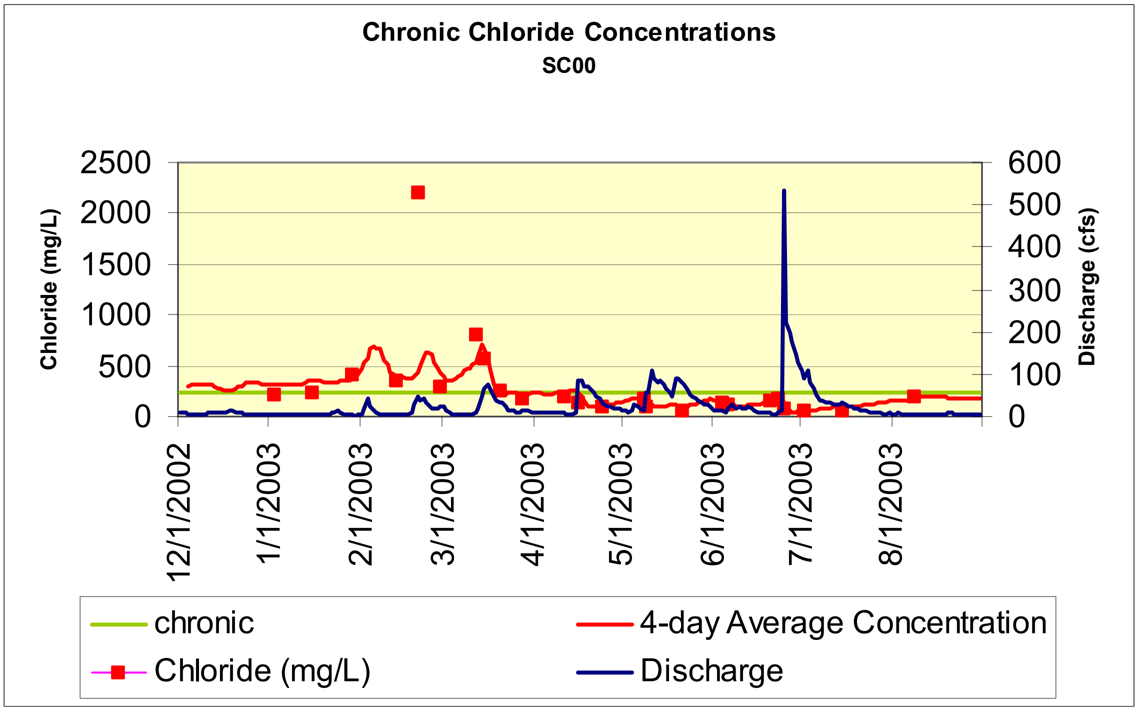


Figure C.1 Average (4-day) chloride concentrations and flow at the watershed outlet (RM 0.6). The blocks represent grab samples and the average chloride concentrations are based on the conductivity –chloride relationship.

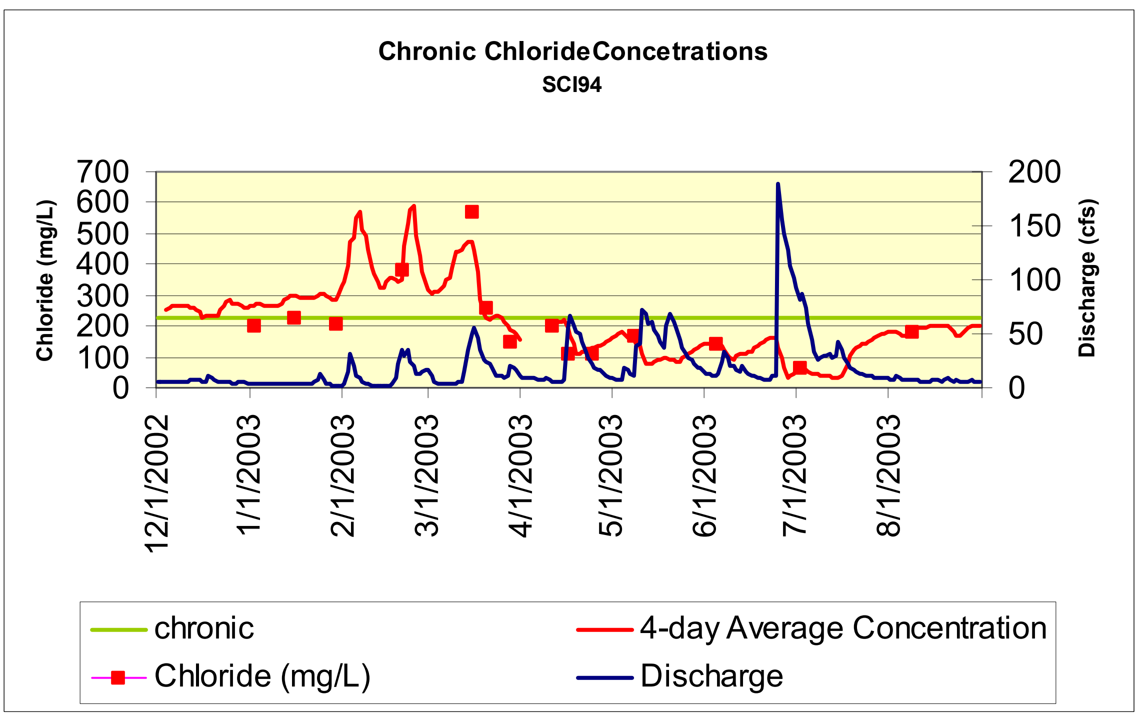


Figure C.1 Average (4-day) chloride concentrations and flow at RM 3.3. The blocks represent grab samples and the average chloride concentrations are based on the conductivity –chloride relationship.

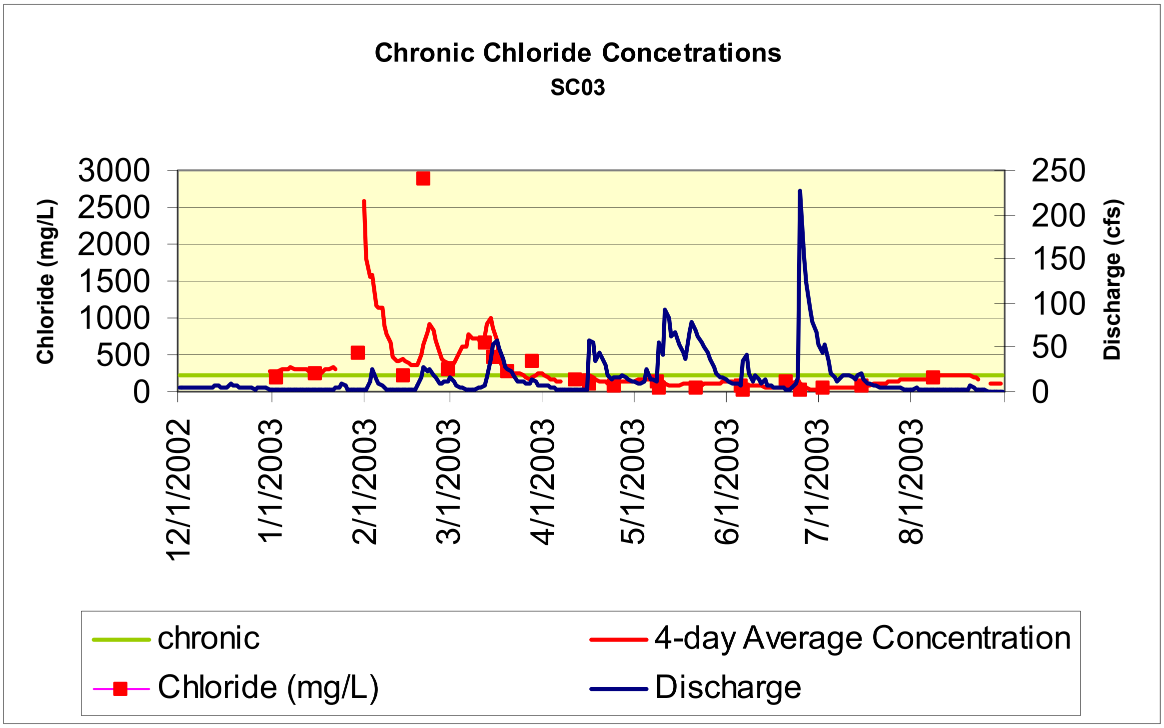


Figure C.1 Average (4-day) chloride concentrations and flow at RM 7.3. The blocks represent grab samples and the average chloride concentrations are based on the conductivity –chloride relationship.

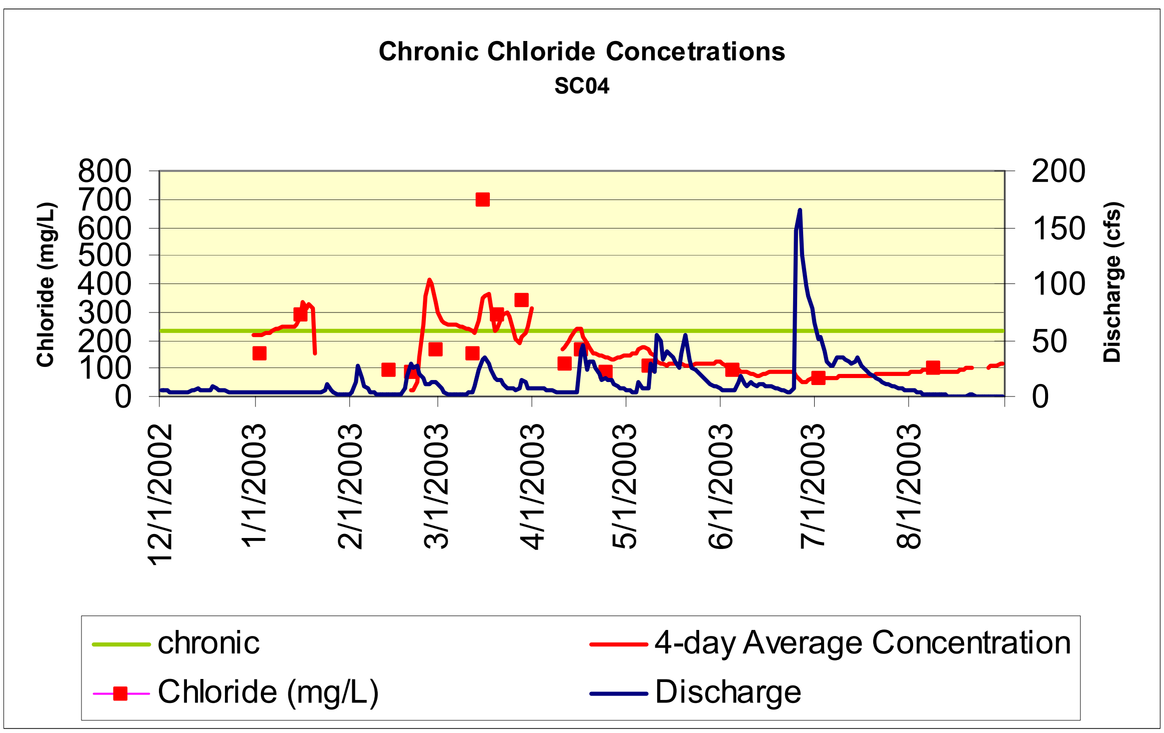


Figure C.1 Average (4-day) chloride concentrations and flow at RM 10.3. The blocks represent grab samples and the average chloride concentrations are based on the conductivity –chloride relationship.

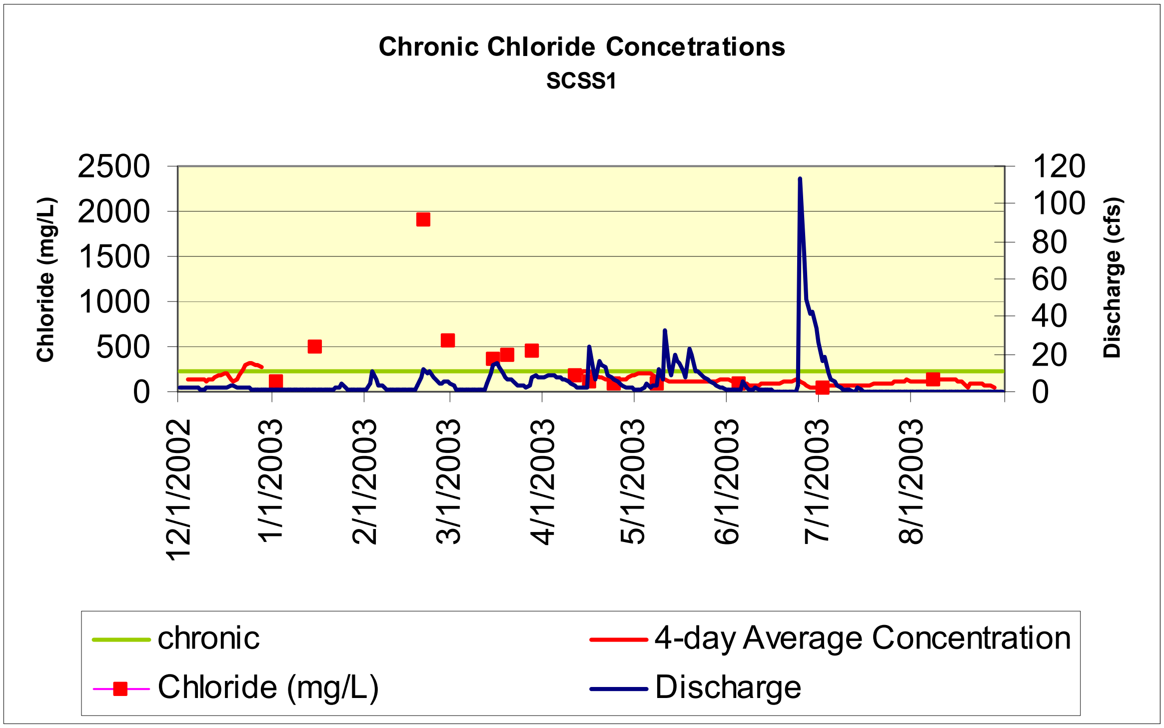


Figure C.1 Average (4-day) chloride concentrations and flow at RM 11.4. The blocks represent grab samples and the average chloride concentrations are based on the conductivity –chloride relationship.

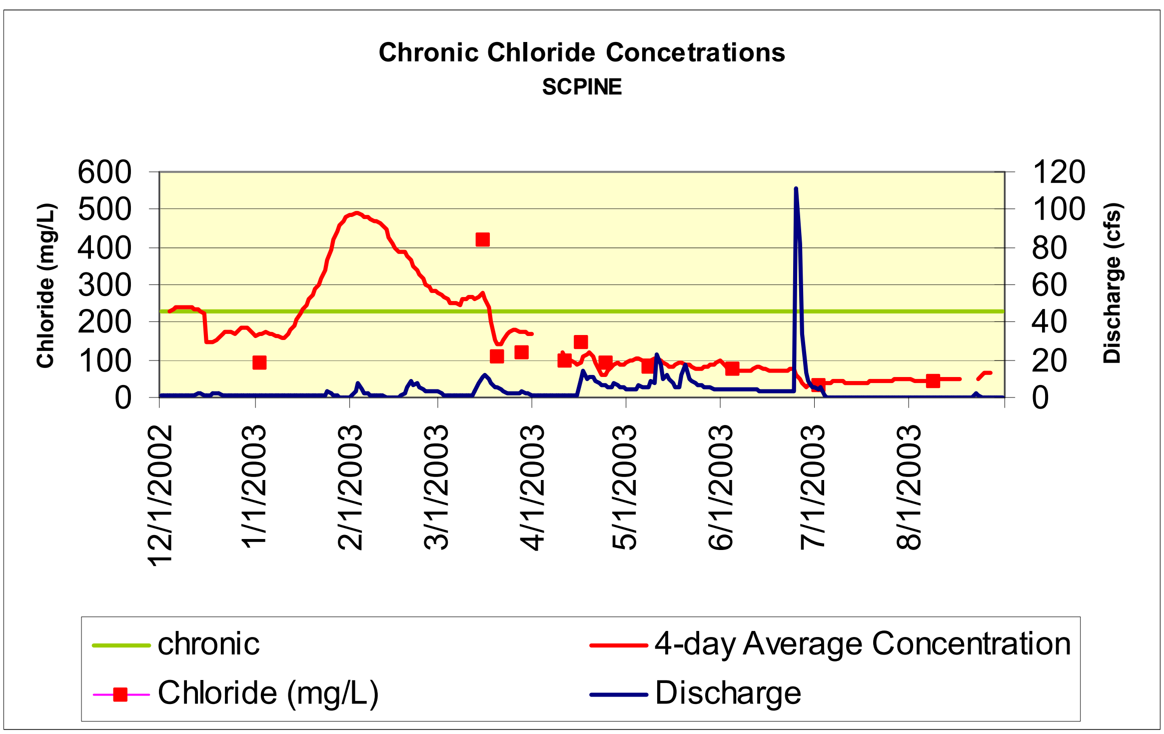
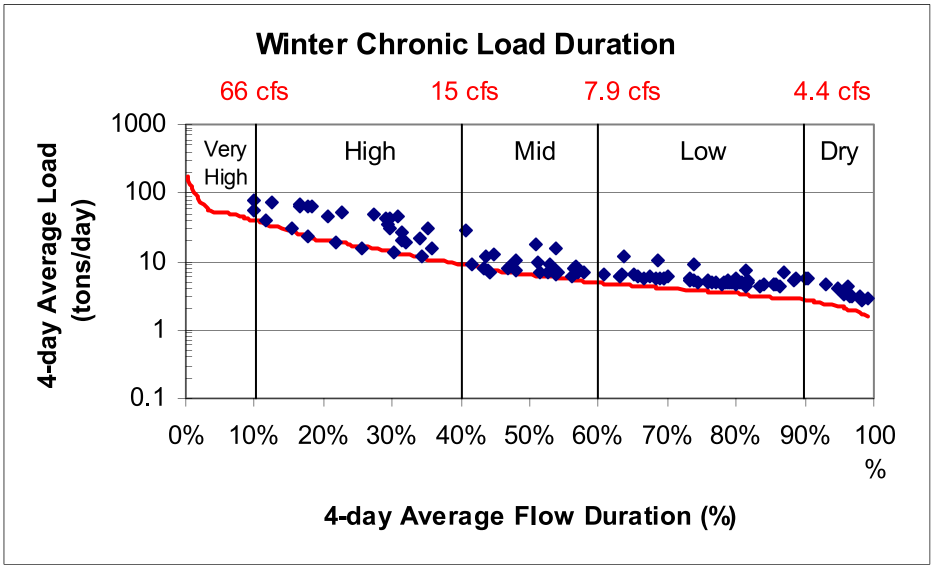
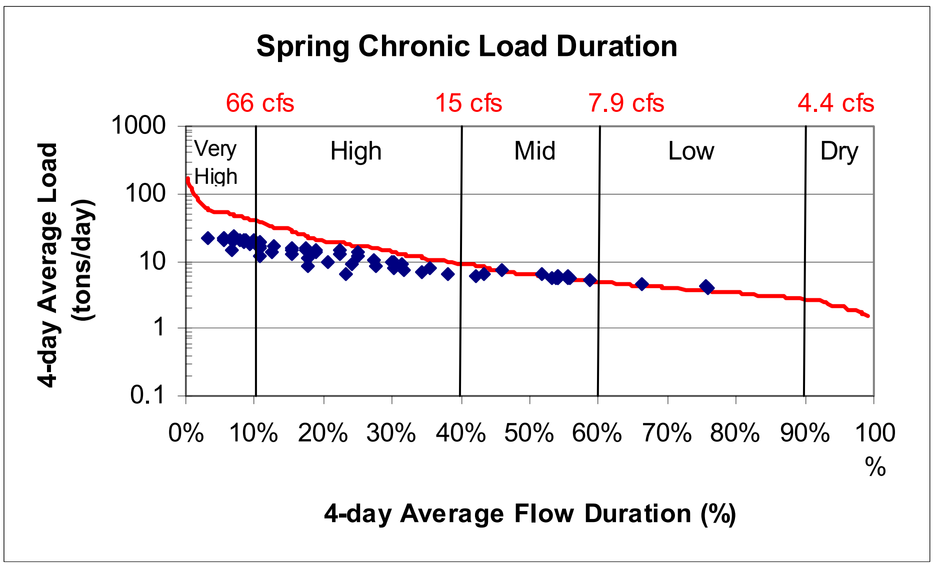


Figure C.1 Average (4-day) chloride concentrations and flow at RM 14. The blocks represent grab samples and the average chloride concentrations are based on the conductivity –chloride relationship.

Shingle Creek Chloride TMDL

Appendix D
Load Duration





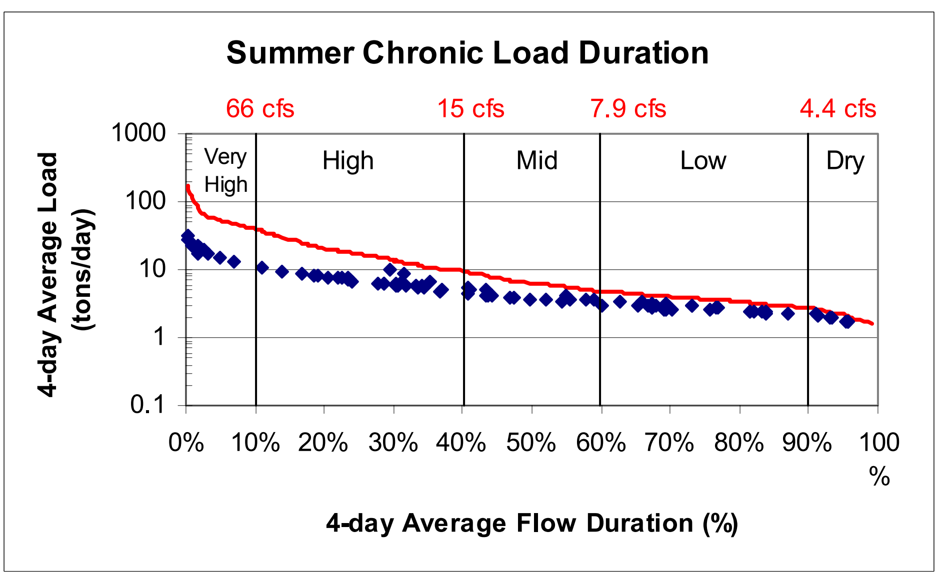
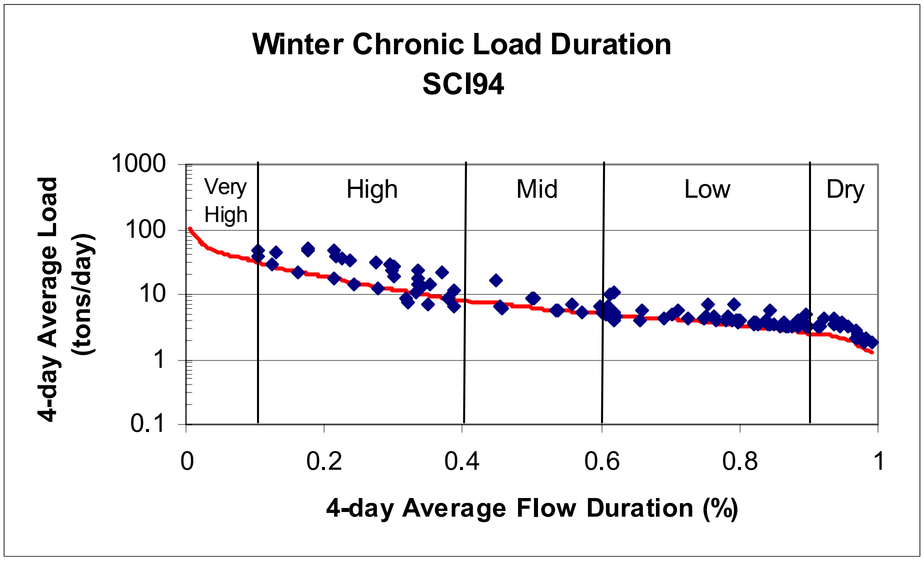
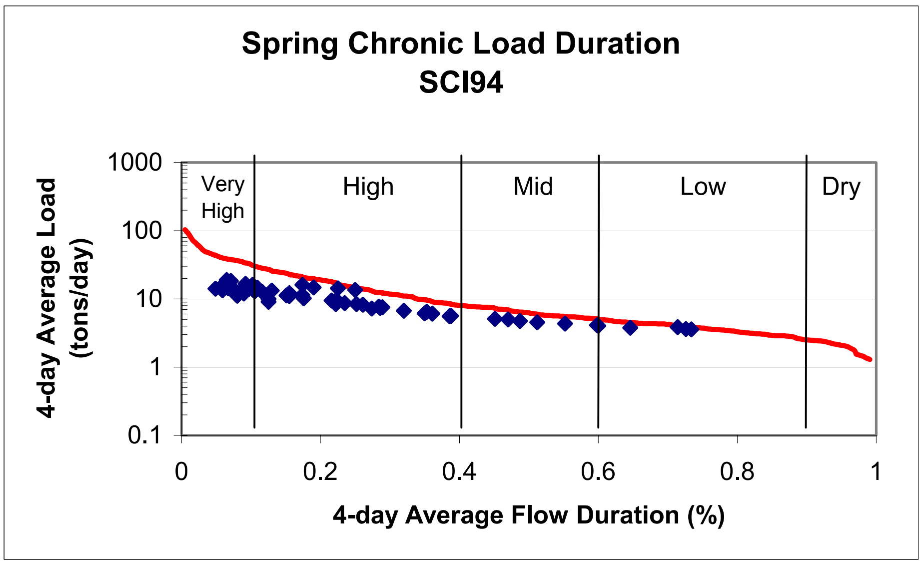


Figure D.1 Seasonal load duration curves for River Mile 0.3





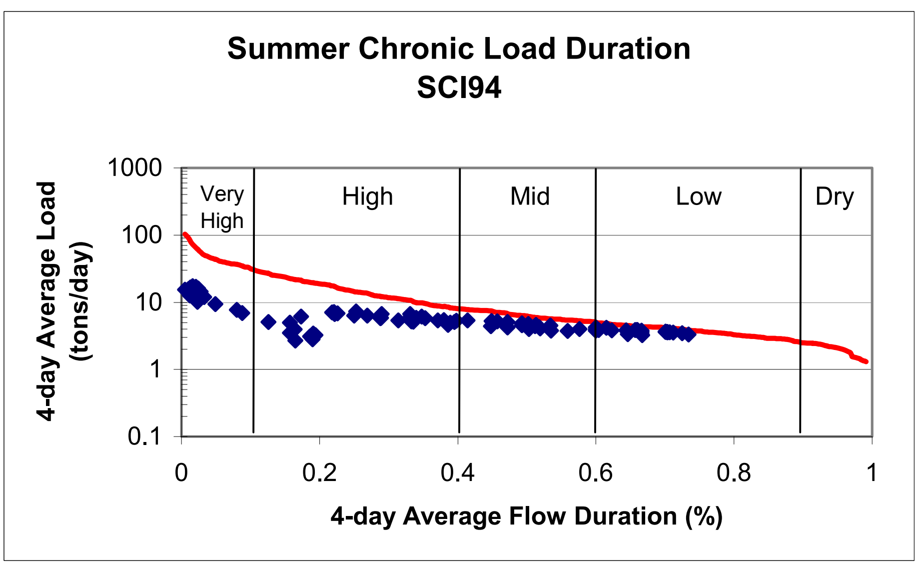
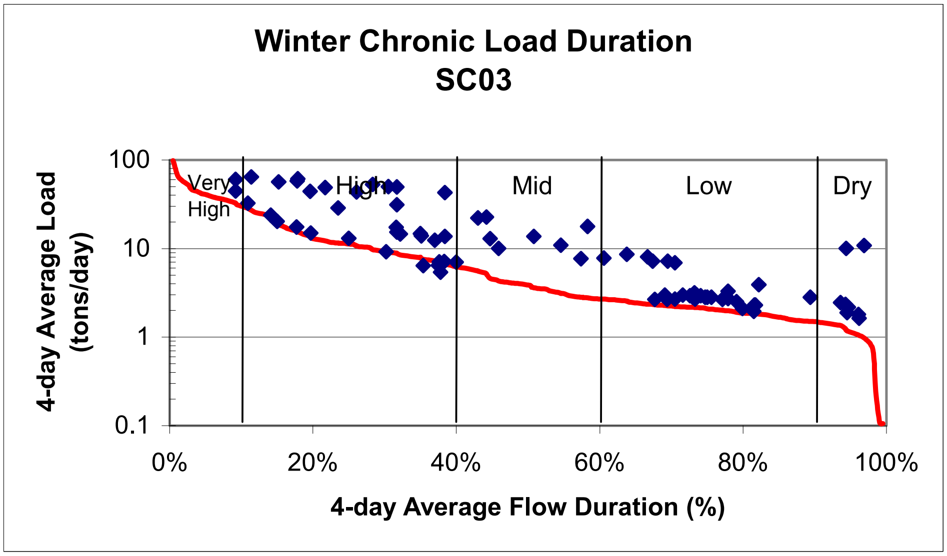
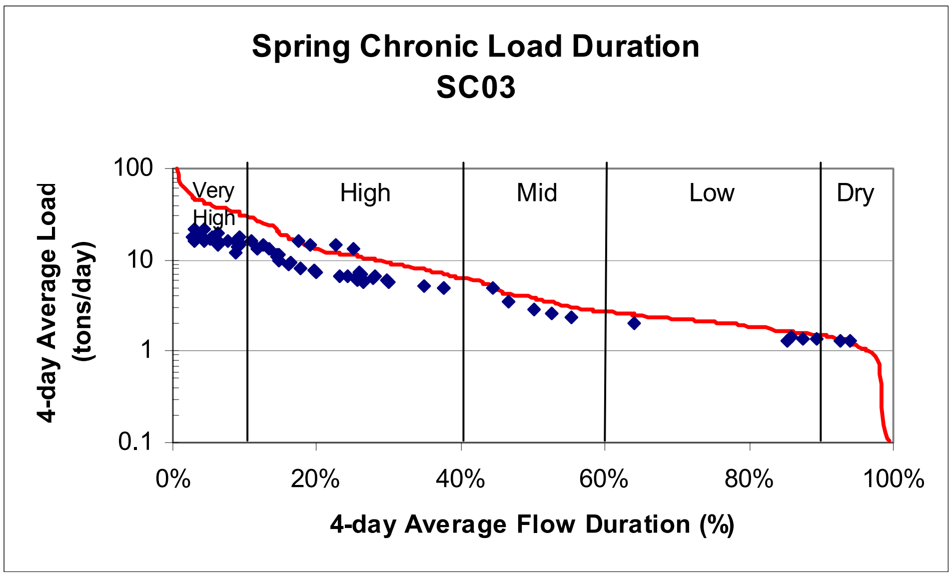


Figure D.2 Seasonal load duration curves for River Mile 3.3





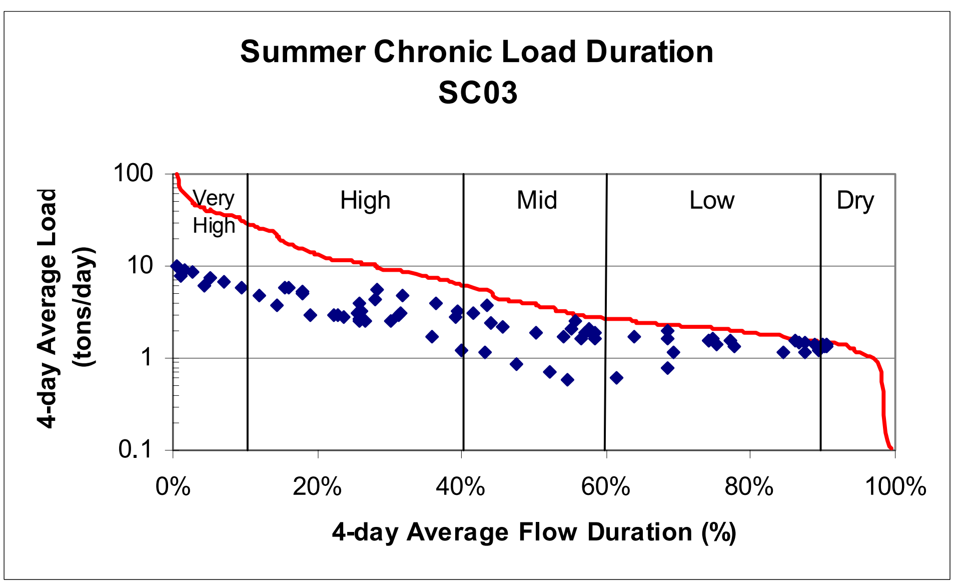
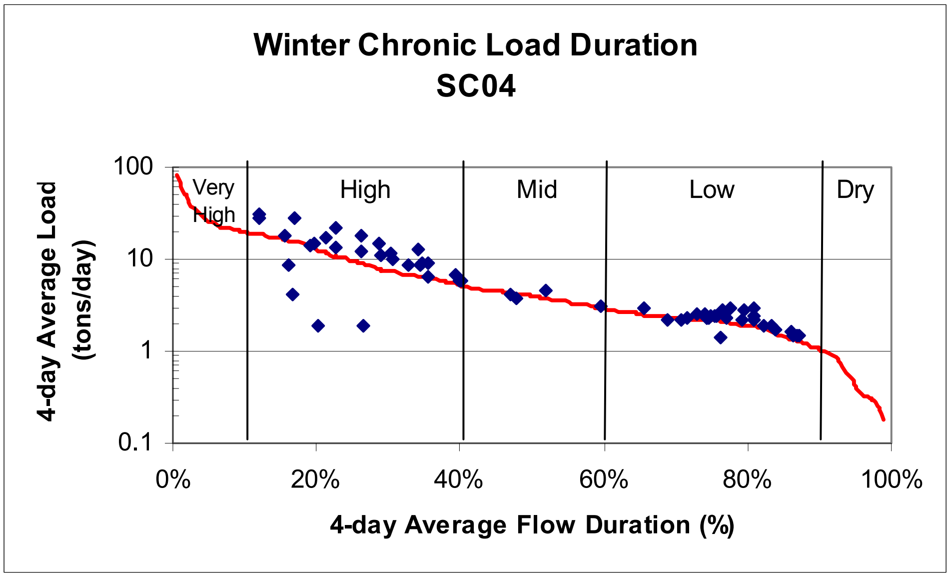
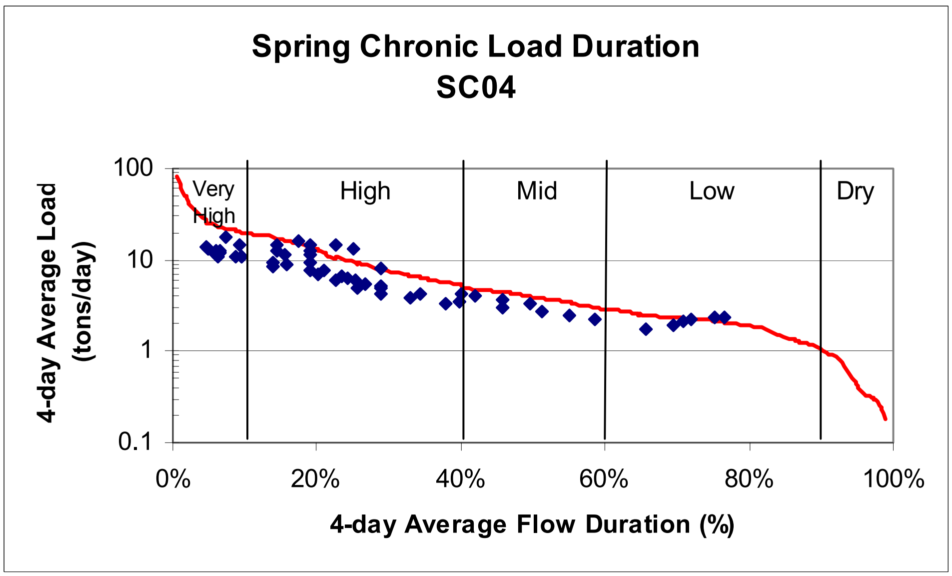


Figure D.3 Seasonal load duration curves for River Mile 7.3





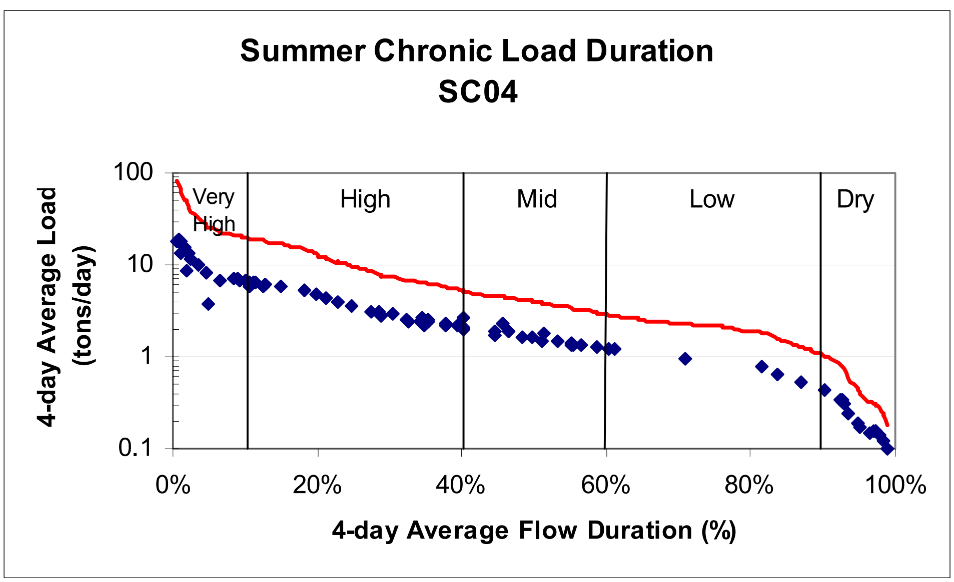


Figure D.4 Seasonal load duration curves for River Mile 10.3

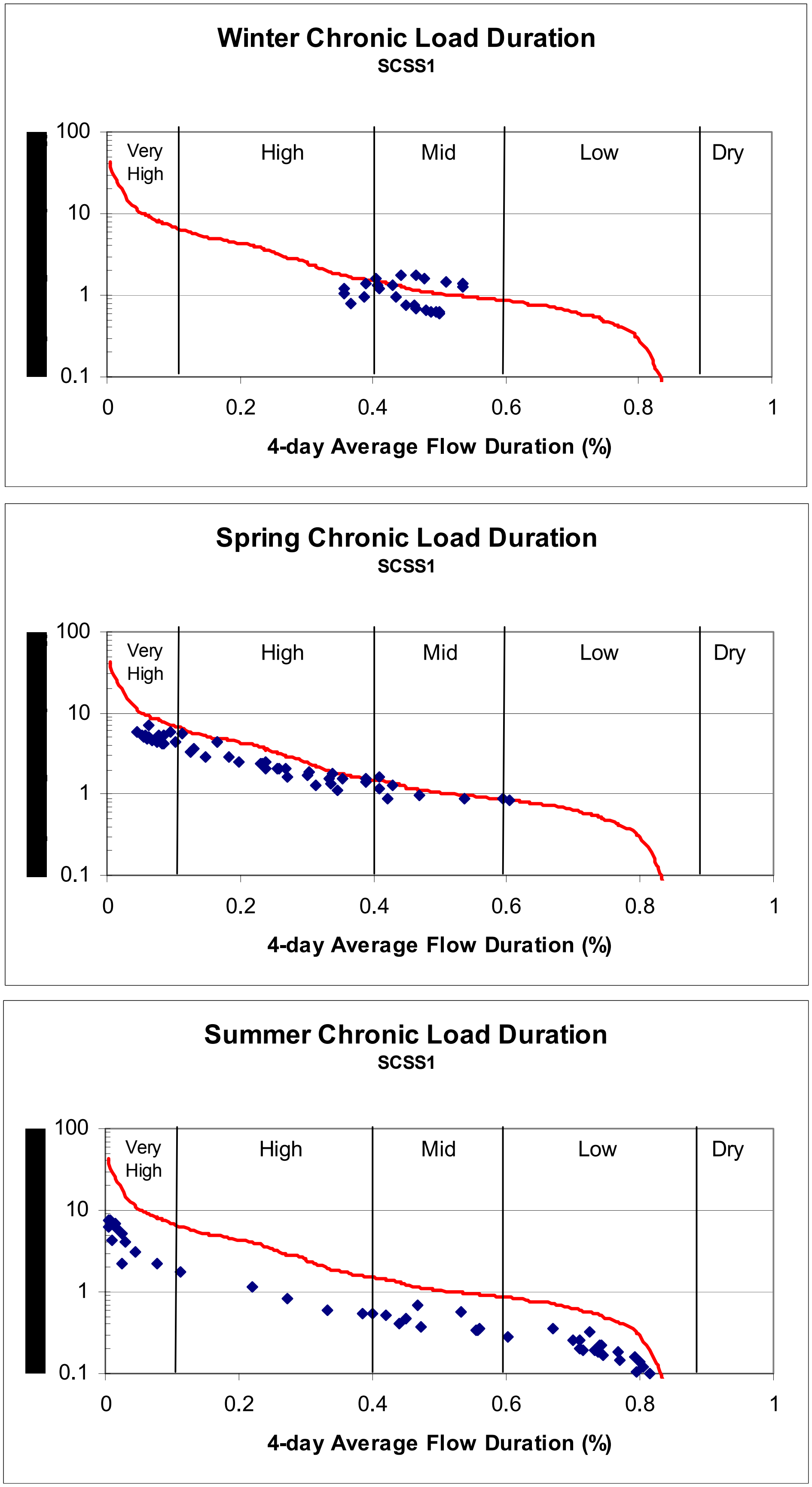
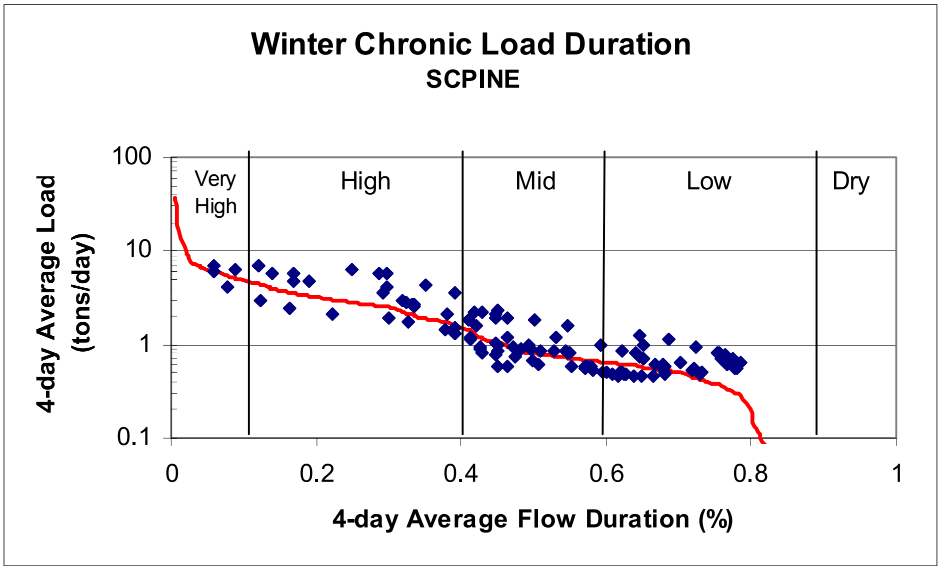
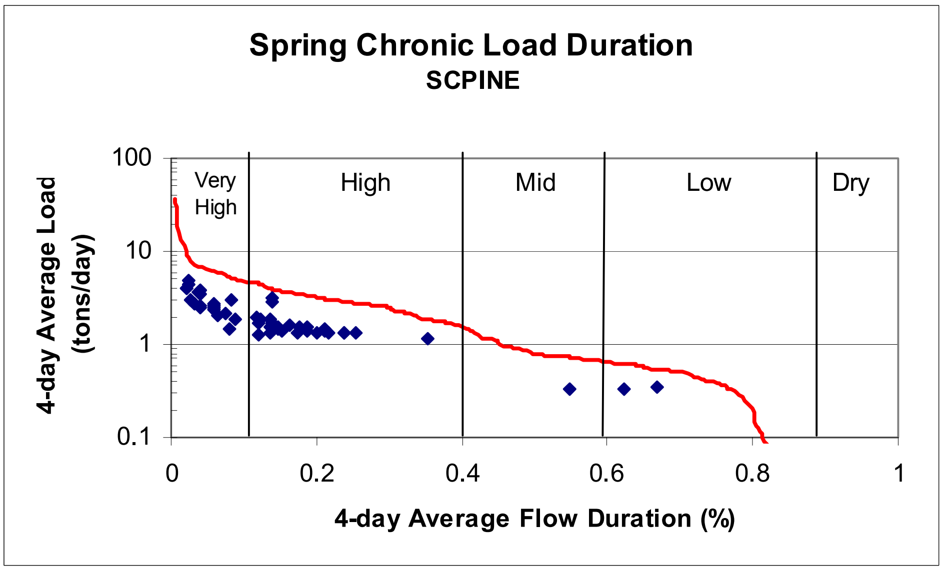


Figure D.5 Seasonal load duration curves for River Mile 11.4





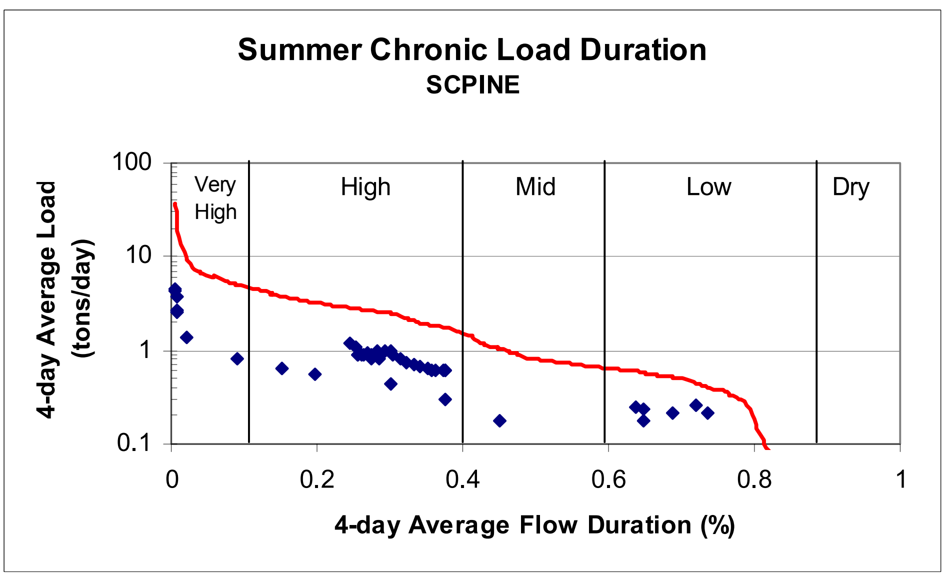


Figure D.6 Seasonal load duration curves for River Mile 14

Shingle Creek Chloride TMDL

Appendix E XP-SWMM Model Inputs

Table E.1. Subwatershed Land Use, Watershed Slope

Subwatershed ID	Non-Road Area (ac)	Non-Road Percent Impervious (%)	Non-Road Area (ac)	Watershed Width (ft)	Watershed Slope (ft/ft)
1-1	920.8	36.4	317.8	12281	0.0119
2-1	729.3	33.2	248.4	10912	0.0063
3-1	123.1	65.0	36.2	3730	0.0022
3-2	304.0	32.0	58.9	7702	0.0054
3-3	559.7	40.0	166.6	9906	0.0024
3-4	424.8	32.0	130.2	5849	0.0023
3-5	463.9	35.9	98.8	7306	0.0035
4-1	239.8	53.4	53.4	7231	0.0044
4-2	1077.4	24.0	177.1	10627	0.0131
4-3	138.3	41.0	67.3	2365	0.0030
5-1	872.2	36.8	197.6	10572	0.0038
5-2	687.5	29.1	118.6	11567	0.0131
5-3	161.6	34.5	30.8	4380	0.0021
5-4	261.9	26.1	43.0	3939	0.0083
6-1	50.1	49.3	8.9	3249	0.0060
6-2	195.7	42.0	42.4	4841	0.0076
7-10	439.2	39.6	119.4	8405	0.0113
7-11	41.7	37.3	11.6	2379	0.0011
7-2	285.5	41.3	110.6	6003	0.0034
7-3	298.8	48.0	82.4	6266	0.0040
7-4	291.8	58.3	33.8	5449	0.0053
7-5	753.7	37.5	221.5	5312	0.0167
7-6	205.4	49.2	30.4	5047	0.0111
7-7	412.3	41.2	101.1	5922	0.0044
7-8	66.5	53.9	10.1	2543	0.0067
7-9	221.1	34.2	61.6	5486	0.0007
8-1	103.3	29.4	9.7	2445	0.0023
8-2	423.1	41.1	32.5	4766	0.0028
8-3	292.3	40.6	62.2	9792	0.0050
8-4	529.4	32.2	124.6	6571	0.0131
9-1	100.1	64.6	6.0	2294	0.0019
9-10	122.3	31.2	11.4	3303	0.0051
9-11	240.0	58.6	13.8	4475	0.0131
9-12	332.8	50.5	24.0	5551	0.0131
9-13	133.5	48.2	37.8	5082	0.0131
9-14	689.1	51.0	121.5	19312	0.0131
9-15	243.1	58.3	30.0	3823	0.0131
9-16	64.9	74.7	2.3	2561	0.0131
9-2	451.6	43.5	120.3	5534	0.0139
9-3	554.7	39.1	105.6	12900	0.0131
9-4	108.4	51.0	24.2	1563	0.0131
9-5	481.8	49.4	143.5	9879	0.0074
9-6	221.7	59.5	25.2	5641	0.0106
9-7	321.6	50.4	21.6	3631	0.0131
9-8	274.9	50.0	0.9	4771	0.0131
9-9	342.4	51.6	8.6	6867	0.0131
9-9a	79.4	50.9	2.9	2549	0.0133
10-1	82.8	34.1	32.9	2019	0.0043
11-1	128.2	30.9	33.1	5331	0.0095
11-2	177.5	27.0	60.3	7310	0.0048
11-3	130.7	66.7	20.4	3710	0.0136
11-4	44.7	42.1	17.7	2432	0.0131

Subwatershed ID	Non-Road Area (ac)	Non-Road Percent Impervious (%)	Non-Road Area (ac)	Watershed Width (ft)	Watershed Slope (ft/ft)
12-1	822.7	55.6	108.9	12102	0.0160
12-2	188.5	51.0	12.7	3277	0.0167
12-3	197.1	37.9	37.7	4238	0.0095
12-4	497.1	46.3	144.7	12256	0.0083
12-5	71.3	42.1	21.9	2580	0.0103
12-6	422.4	33.2	31.0	8177	0.0089
13-1	100.1	36.5	18.1	2967	0.0026
13-2	175.0	41.5	30.4	4108	0.0074
13-3	166.3	48.9	35.1	3775	0.0032
14-1	59.3	32.2	20.2	2504	0.0049
14-10	117.5	27.7	32.3	4633	0.0133
14-11	200.5	41.2	31.1	6977	0.0056
14-12	81.2	34.2	12.6	3051	0.0028
14-13	239.7	49.7	32.7	3794	0.0067
14-14	203.1	38.6	53.4	4087	0.0197
14-2	310.6	40.4	66.8	4849	0.0067
14-3	81.3	59.8	24.5	2955	0.0333
14-4	122.7	49.4	22.1	3421	0.0143
14-5	99.7	38.0	21.3	4245	0.0061
14-6	90.1	27.5	27.3	3997	0.0143
14-7	38.1	51.2	16.6	1803	0.0105
14-8	534.8	47.1	67.0	11473	0.0074
14-9	557.3	51.4	71.5	9366	0.0131
15-1	90.4	42.1	19.4	2937	0.0070
15-2	413.6	23.5	34.6	8715	0.0088
15-3	287.1	41.0	5.8	4431	0.0083
15-4	650.6	31.1	35.3	15873	0.0131
15-5	248.1	31.9	35.0	5897	0.0119
16-1	32.3	49.4	6.3	1820	0.0063
16-2	21.3	40.3	4.0	1747	0.0022

Shingle Creek
Chloride TMDL

Appendix F
Conductivity

Memorandum

1800 Pioneer Creek Center, Maple Plain, MN 55359
Phone: 763-479-4200 Fax: 763-479-4242

To: Shingle Creek Chloride TMDL TAC

From: Todd Shoemaker
Joe Bischoff

Date: April 14, 2003

Subject: Assessment of Geoscientific Electrode Conductivity Recorder (model 6536) calibration for five monitoring sites

---

This memo summarizes the results of the work performed on April 10, 2003 for the Shingle Creek Chloride TMDL project. The purpose was to evaluate the calibration of the 6536 Conductivity Recorders that were initially installed on November 25, 2002.

Assessment protocol:

1) Remove and clean the conductivity probe
2) Dry the probe
3) Immerse probe in distilled water
4) Dry the probe
5) Record the measured conductivity of open air from the Starlog computer program
6) Immerse probe in 1413 µS/cm standard conductivity solution
7) Record the measured conductivity from the Starlog computer program
8) Immerse probe in distilled water
9) Immerse probe in 12880 µS/cm standard conductivity solution
10) Record the measured conductivity from the Starlog computer program

All recorded conductivity measurements were corrected for temperature. Therefore, a perfectly calibrated instrument should measure the exact value of the standard solution.

November 25, 2002 Calibration Assessment

Site	Standard Solution (µS/cm)	Measured Conductivity (µS/cm)	Percent Difference	Open Air (µS/cm)
Outlet	1413	1415	0.14	0
I-94	1413	1413	0.00	0
Zane	1413	1410	0.21	0
Broadway	1413	1412	0.07	0
Northland	1413	1413	0.00	0
62 East	1413	1413	0.00	0
Pineview	1413	1414	0.07	0

April 10, 2003 Calibration Assessment

Site	Standard Solution (µS/cm)	Measured Conductivity (µS/cm)	Percent Difference	Open Air (µS/cm)
Outlet	1413	1482	4.9	0.42
I-94*	1413	N/A	N/A	N/A
Zane	1413	1230	13.0	0.72
Broadway**	1413	N/A	N/A	N/A
Northland	1413	1650	16.8	0.00
62 East	1413	1550	9.7	0.00
Pineview	1413	1550	9.7	1.30
Outlet	12880	13500	4.8	Same as above
I-94	12880	N/A	N/A	
Zane	12880	11800	8.4	
Broadway	12880	N/A	N/A	
Northland	12880	14300	11.0	
62 East	12880	13650	6.6	
Pineview	12880	13810	7.2	

*The calibration of the I-94 site was not evaluated due to site conditions. The Shingle Creek channel at this location is approximately four feet deep. Therefore, removal and re-installation of the probe was not practical.

**The probe at the Broadway site is located at the bottom of a 66" CMP, which is considered a confined space. Therefore, the calibration of the instrument was not evaluated since this site requires two people to access the probe.

The above results were discussed with Stephen Biduk (Technical Specialist for Geoscientific) on April 14, 2003. Mr. Biduk advised that the 6536 Conductivity Recorders should be recalibrated because the anticipated drift is approximately 40 µS/cm. Conductivity loggers were recalibrated accordingly.

Memorandum

1800 Pioneer Creek Center, Maple Plain, MN 55359
Phone: 763-479-4200 Fax: 763-479-4242

To: Joe Bischoff

From: Todd Shoemaker

Date: July 16, 2003

Subject: Recalibration of 6536 Electrode Conductivity Recorders

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This memo summarizes the methods and results of the recalibration of the conductivity recorders installed for the Shingle Creek TMDL.

Recalibration of the instruments took place on July 16, 2003. Six of the seven instruments installed for the study were evaluated. Five units were recalibrated according to the specifications provided by Geoscientific Environmental Instruments, Inc. The Broadway site was not recalibrated because it is installed in a storm sewer. (Two people are required for entry into a confined space such as a storm sewer.) The Northland site was not recalibrated because the initial evaluation yielded a conductivity of 1413 μS/cm in 1411 μS/cm solution.

Methods
Each unit was first evaluated to determine if recalibration was necessary. The evaluation consisted of measuring the conductivity of a 1411 μS/cm standard solution. The evaluation results are presented in the table below. As noted above, all units required recalibration except for the Northland site.

A three-point calibration was then performed for the five units at low, medium and high levels. A low standard conductivity solution was not available, so all units were calibrated to zero with distilled water. The medium standard solution was 1411 μS/cm, and the high standard was 12880 μS/cm.

Results
Following recalibration all units were within 30 μS/cm of the 1411 μS/cm standard solution.

Site	Standard Solution (μS/cm)	Measured Conductivity Before Calibration (μS/cm)	Percent Difference	Open Air (μS/cm)
Outlet	1411	1497	6.1	2.71
I-94	1411	1506	6.7	3.56
Zane	1411	1357	-3.8	8.14
Broadway	1411	NA	NA	NA
Northland	1411	1413	0.1	0.32
62 East	1411	1317	-6.7	3.77
Pineview	1411	1367	-3.1	4.08

Memorandum

1800 Pioneer Creek Center, Maple Plain, MN 55359
Phone: 763-479-4200 Fax: 763-479-4242

To: Joe Bischoff

From: Todd Shoemaker

Date: October 29, 2003

Subject: Evaluation of 6536 Electrode Conductivity Recorders

This memo summarizes the methods and results of the evaluation of the conductivity recorders installed for the Shingle Creek TMDL.

Evaluation of the instruments took place on October 2, 2003. Six of the seven instruments installed for the study were evaluated. The unit installed in the storm sewer on Broadway was not accessible because it is located in a confined space.

Methods
Each unit was evaluated to compare conductivity measurements to that of a hand-held Geotech MultiLine P4 unit. The evaluation consisted of comparing the conductivity measured by the Geotech unit and the 6536 units. The probes attached to the 6536 units were then cleaned, and the conductivity was measured again. The evaluation results are presented in the table below.

Site	Geotech MultiLine P4 (µS/cm)	Measured Conductivity Before Cleaning (µS/cm)	Percent Difference Before Cleaning	Measured Conductivity After Cleaning (µS/cm)	Percent Difference After Cleaning
Outlet	1246	1284	3.0	1286	3.2
I-94	1343	1320	-1.7	1320	-1.7
Zane	1345	1446	7.5	1463	8.7
Broadway	NA	NA	NA	NA	NA
Northland	706	752	6.5	745	5.5
62 East	812	841	3.5	841	3.5
Pineview	533	399	25	531	0.4

Results
Following recalibration all units were within 40 µS/cm of the 1411 µS/cm standard solution except for the Zane site. This site was not recalibrated because the percent difference was within 10%.

Shingle Creek Chloride TMDL

Appendix G
Modeling

G1.1 INTRODUCTION

A key aspect of a TMDL is the development of an analytical link between loading sources and receiving water quality. This analysis involves the solution of the equation for loading capacity as a function of wasteload allocation (WLA), load allocation (LA), margin of safety (MOS), and seasonal variation (SV).

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

The watershed model is designed to provide a tool that will define maximum allowable loads, based upon land use and management practices.

G1.2 SELECTION OF MODELS AND TOOLS

A two-step approach was used to develop the TMDL for Shingle Creek. The first step in the load allocation was using the analytical data collected in the watershed to identify flow conditions and seasons where the greatest occurrence of exceedances occurred (section 6.2.4). Target and measured loads were used to empirically develop load and wasteload allocations needed to meet water quality standards for chloride in Shingle Creek. The second step was to investigate land management practices, specifically road deicing practices, needed to achieve the required NPS load reductions identified in the load allocations. The model chosen was the XP-SWMM model. XP-SWMM was used to better define linkages between salt applied to the watershed and in-stream chloride concentrations.

XP-SWMM is a graphics based Wastewater and Stormwater decision support system. XP-SWMM performs hydrology, hydraulics and quality analysis of stormwater and wastewater drainage systems including sewage treatment plants, water quality control devices and Best Management Practices (BMP's). Typical XP-SWMM applications include predicting combined sewer overflows (CSO's) and sanitary sewer overflows

(SSO's), interconnected pond analysis, open and closed conduit flow analysis, major/minor flow analysis, design of new developments, and analysis of existing stormwater and sanitary sewer systems.

XP-SWMM has three layers. There is a stormwater layer for hydrology and water quality generation, a wastewater layer for generation of wastewater flows including Storage/Treatment for BMP and water quality routing, and a hydrodynamic hydraulics layer for the hydraulic simulation of open and closed conduit wastewater or stormwater systems. A Global Database contains design and measured storm events, infiltration data, pollutant data and other data required to run XP-SWMM. The different layers of XP-SWMM are connected to the global data required for the simulation.[1]

1 XP-SWMM Software, Technical Description, 2004.

G1.3 MODELING OBJECTIVES

The objective of the modeling was to provide a tool that could be used during the implementation phase of this project and evaluate annual differences in snowfall. The primary modeling objectives for this TMDL include:

- Evaluation of deicing salt application rates required meeting load allocations and reductions;
- Provide a better understanding linkages between chloride sources and in-stream chloride concentrations; and
- Evaluation of a normal snowfall year since the monitored year was below normal in snowfall totals

Ultimately, the XP-SWMM model provides a tool to the Shingle Creek Watershed Management Commission and other local authorities that can be used to evaluate changes in road ice and snow management and selected BMPs or deicing alternatives. However, in this TMDL, the XP-SWMM model is used to estimate loads in a normal precipitation year and evaluate deicing loads necessary to meet load allocations and associated load reductions.

G1.4 CRITICAL CONDITIONS

TMDLs must be developed to ensure compliance with water quality standards during critical conditions including seasonal and flow variations. Consequently, load allocations must be set to account for variations in both flow and season. Annual variation may play a large role in chloride concentrations since application rates are highly dependent upon weather conditions. Chloride is highly episodic, dependent upon wash-off from the watershed through snowmelt or rain events. Additionally, chloride is applied to the watershed in a highly seasonal manner with heavy winter application occurring with road and walkway deicing. To account for these variations in flow, season and annual weather patterns, we selected several critical conditions in the watershed.

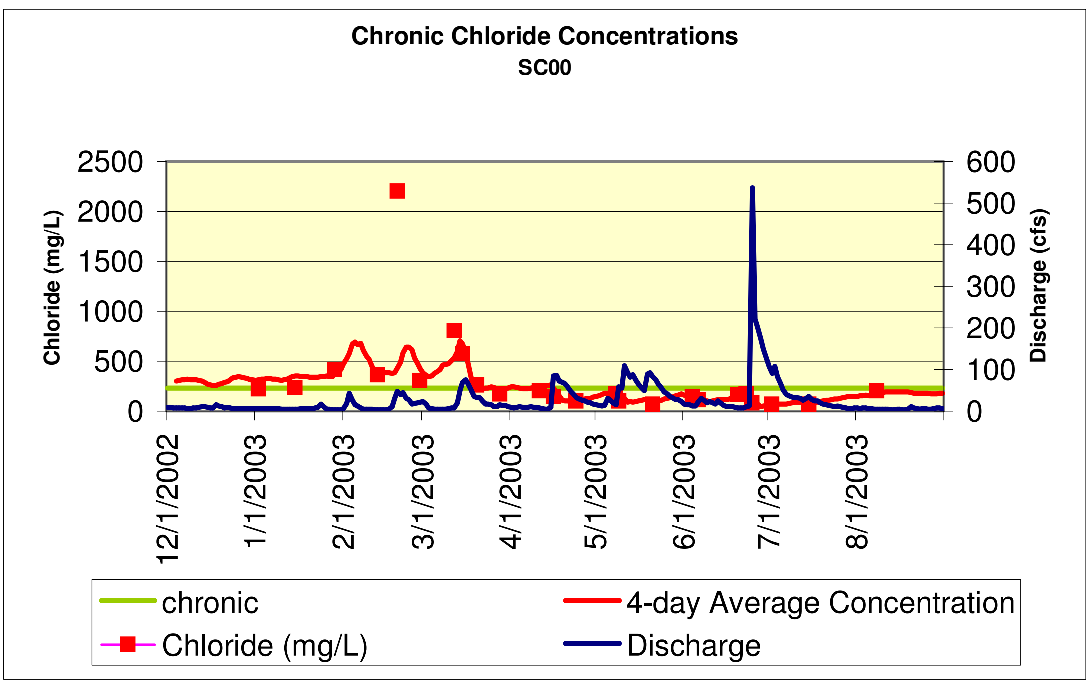


Figure 7.1 Average (4-day) chloride concentrations and flow at the watershed outlet (RM 0.6).

Runoff during each of the seasons seems to play a different role in terms of chloride loading to the stream (Figure 7.1). During the winter, runoff events are typically small until late season and associated with snowmelt events. During these runoff events, chloride concentrations in the stream increased. Dry periods or no runoff periods typically demonstrated lower chloride concentrations. Winter runoff events are transporting large concentrations of road salt to the streams. Once the spring and summer rains arrive, runoff has a markedly different effect on in-stream chloride concentrations. Runoff during the spring has a dilutional affect on the stream concentrations resulting in low chloride concentrations. During the summer and spring low flow, chloride concentrations again increase. These data suggest that runoff during the winter when the heaviest application of chloride to the roads is occurring; runoff is a significant source of chloride. During the spring and summer, runoff actually dilutes chloride concentrations in the stream.

Critical conditions are based the occurrence of flow violations during seasons and across flow regimes. These were defined using the load duration analysis and time series of chloride concentrations. The primary critical conditions identified for this TMDL includes all winter flow conditions. Winter runoff are controlled primarily by snowmelt whereas summer low flow is primarily a base flow issue.

It is important to note that although critical conditions are outlined in this TMDL, dynamic modeling of chloride reductions was used to determine the effectiveness of proposed load reductions on a daily time step. Dynamic modeling reduces the need for design flows and critical conditions for assessment of meeting water quality criteria on a daily basis because it calculates changes over time rather than for one selected set of environmental conditions. For this TMDL, critical conditions provide a better understanding of processes affecting chloride runoff from roads and the subsequent in-stream concentrations.

G1.5 MODELING CHLORIDE USING XP-SWMM

G1.5.1 Hydrologic Model Construction

An XP-SWMM hydrologic and hydraulic model was constructed for the Shingle Creek watershed as a part of this project. Following is a description of the key components of the model.

G1.5.1.1 Subwatersheds

The 80 subwatersheds for the TMDL utilized delineations completed as part of existing hydrologic study of the watershed with slight modifications to represent monitoring stations. Watershed boundaries were verified with current Municipal Stormwater Management Plans (SWMP). The existing model for the watershed had been calibrated in 1999 and provided a reliable source of subwatershed boundaries for the model.

Watershed boundaries were adjusted if monitoring stations were not located at the outlet of an existing watershed. Drainage areas to the station were delineated with Municipal SWMP and verified with USGS topographical maps. It was critical to the project to have contributing watershed areas know for each monitoring station properly represented for load analysis.

G1.5.1.2 Pipes

Pipe attribute information used in the model was collected from City Stormwater Management Plans, Municipality HydroCAD models, and the Shingle Creek Profile study completed in 2000 (MWH 2000). Information utilized by the model assumed the Shingle Creek Profile Study as the most current data, unless City Stormwater Management Plans were more recent.

G1.5.1.3 Shingle Creek Channel

Channel cross sectional information was taken from the Shingle Creek Profile Study. Channel cross-sections were surveyed at approximately 1000’ intervals. Cross Sections for tributaries to Shingle Creek were modeled based on City Stormwater Management Plans and Municipality HydroCAD models.

G1.5.1.4 Land Use

Land use data for the hydrologic calibration was based on the 2000 land use coverage provided by Metropolitan Council. Land use classifications were separated for the watershed and assigned a representative percent impervious according to typical literature values (Table 7.1).

Table 7.1 Land use categorizations with percent impervious

2000 Generalized Land Use type	Assigned %imp
Agriculture	2
Farmsteads	20
Single Family Residential (Seasonal/Vacation)	27.5
Single Family Residential (Single Family Detached)	27.5
Multi-Family Residential (Single Family Attached)	40
Multi-Family Residential (Apartments, etc.)	50
Commercial (Retail and Other Commercial)	75
Commercial (Office)	75
Mixed Use Residential	40
Mixed Use Industrial	65
Mixed Use Commercial and Other	75
Industrial and Utility	65
Extractive	50
Institutional	50
Park, Recreational or Preserve	5
Golf Course	5
Major Highway	98
Railway	50
Airport	50
Undeveloped	50
Water	100

Subwatershed land use breakdown was then used to develop a composite percent impervious for each subwatershed.

When calculating composite percent impervious for each subwatershed, road land use was separated from all non-road land uses. All road subwatersheds were assumed to be 98% impervious. Separation of road and non-road areas was completed to allow for the model to have separate chloride application rates for roads and non-road areas.

Watershed slopes were calculated using an average travel length and corresponding elevation difference within each subwatershed from USGS topographical maps. Watershed width was computed as the watershed area divided by the average travel length. Watershed width and slope were assumed to be the same for both road and non-road land uses. Appendix E provides a summary of percent impervious for road and non-road areas, watershed slope, and watershed width for each subwatershed

G1.5.2 Hydrologic Calibration of XP-SWMM

Hydrologic calibration was completed for two periods of record 12/1/02 to 4/1/03 and 4/1/03 to 9/1/03. The calibration was broken up to allow for winter conditions and summer conditions to be modeled separately given the difference in runoff characteristics of the watershed for the given seasons. Calibration results (described below) demonstrate the model provides an accurate representation of the watershed hydrology and hydraulics.

G1.5.2.1 Meteorologic Data for Hydrologic Calibration

Meteorologic data used for the calibration was from the National Weather Service New Hope Station #215838 from 12/1/02 to 9/1/03. Verification model used precipitation records from 4/1/03 to 9/1/03. Winter precipitation is reported in rainfall equivalents. Data was collected on a daily time step for the duration of the modeling; this time step was considered sufficient for modeling on a seasonal basis. Precipitation values are summarized below (Table 7.2 and Figure 7.2).

Table 7.2 Precipitation data from the New Hope National Weather Service Station used in model calibration and verification.

Date	Precipitation (in)
Summer Calibration 4/1/03-9/1/03	23.9
Verification 4/1/03-9/1/03	31.8
Winter Rainfall Equivalents from NWS 12/1/02-4/1/03	3.33
Winter Calibration Model Total Rainfall Equivalents	2.13

The difference in the winter precipitation can be explained by evaporation of snow pack during the winter and minor losses due to infiltration, which was assumed equal to zero over the winter period. A large rainfall event in late March where 0.6 in of precipitation was recorded did not show a corresponding runoff volume, so it appears that the rainfall may have been over-estimated increasing the difference in total precipitation.

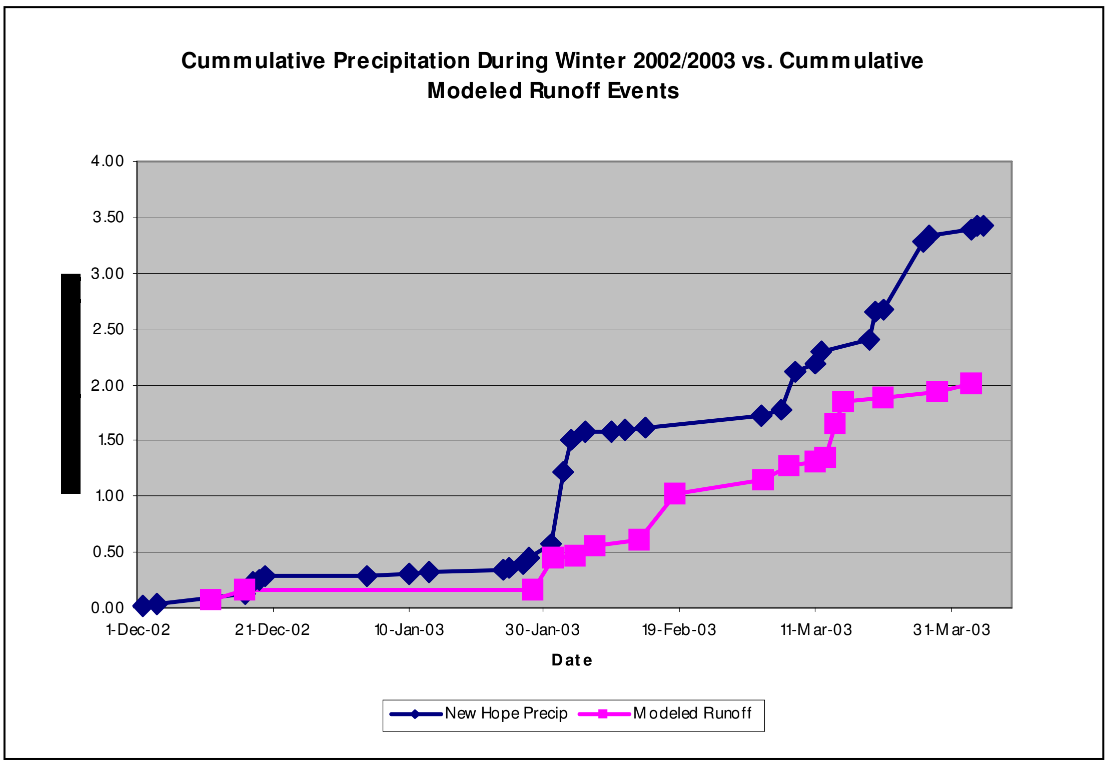


Figure 7.2. Cumulative precipitation and modeled runoff for the model calibration period.

G1.5.2.2 Point Source Data for Hydrologic Calibration

Salt storage areas were the only point sources modeled. Salt storage areas were identified in the watershed and were specified in the model as a specific node. Runoff from each storage area was assigned event mean concentrations based on grab sample data.

G1.5.2.3 Initial Parameters for Hydrologic Model

Parameters quantified for calibration were percent impervious, watershed width, watershed slope, and evaporation. All of the parameters have been shown above except evaporation and infiltration. Evaporation values for the model used monthly pan evaporation values recorded by the University of Minnesota St. Paul Climatological Observatory. Pan evaporation rates were corrected using a pan coefficient of 0.74 (Minnesota Hydrology Guide, NRCS).

Infiltration was only utilized during the non-winter simulations and calibration runs. The Green Ampt equation was used to represent infiltration. This method is recommended for long-term continuous model calibrations for it’s ability to track soil moisture conditions. Loam to Sandy loam soils were represented in the infiltration input parameters which are the dominant soil types in the watershed.

Stream cross section information was obtained from topographic surveys of the Shingle Creek Stream Profile Study completed by SCWMC 2000. Stormwater conveyance information was obtained from Municipality stormwater management plans and from a previously-existing hydrologic model for the watershed

G1.5.2.4 Summer Calibration

Hydrologic and hydraulic calibration was completed for the winter season (12/1/02 to 4/1/03) and the summer season (4/1/02 to 9/1/03).

Calibration was completed for volume and peak flow at each monitoring station by adjusting impervious percentage (0% to –10%), evaporation (+5%), base flow contributions (-20%), and watershed width (0% to +15%). Table 7.3 below provides calibration volume results and monitored data. The calibration for the USGS monitoring station at Queen Ave. is shown on Figure 7.3.

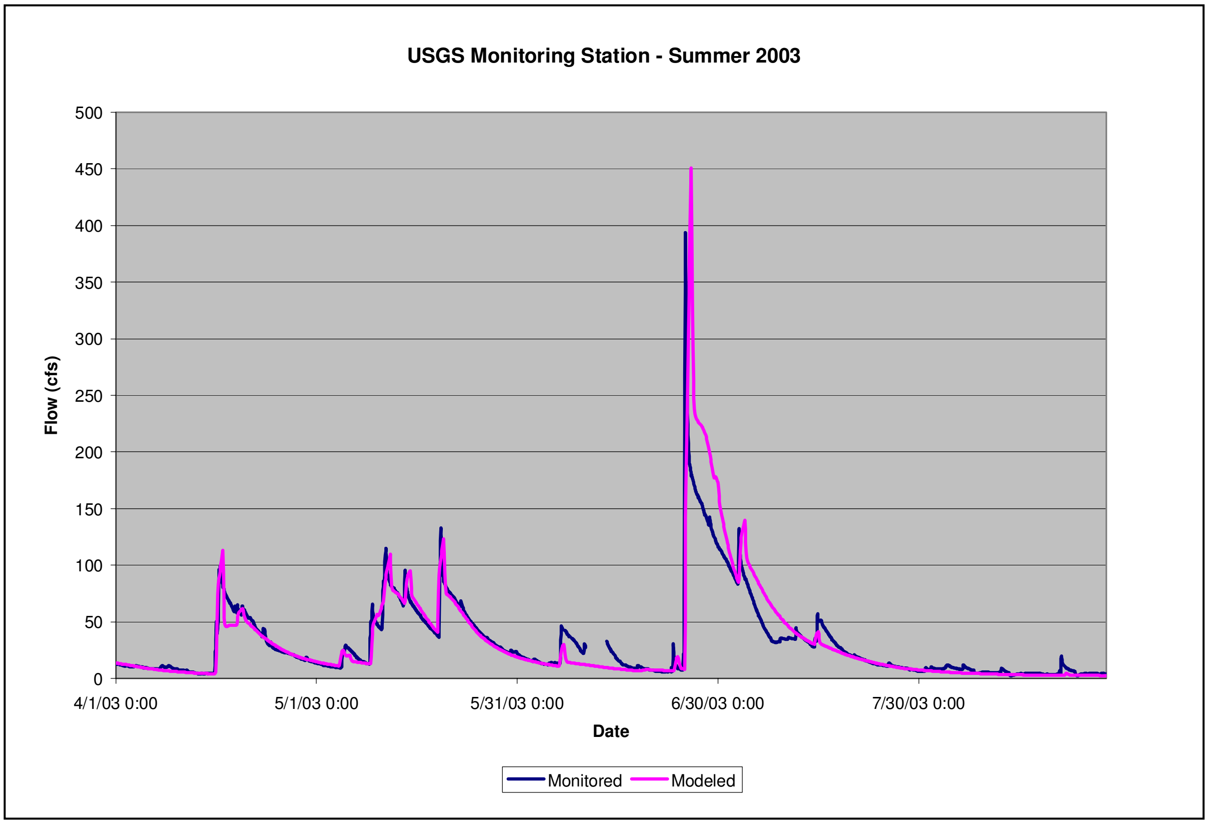


Figure 7.3 Summer modeled and monitored flows at the USGS station, Queen Avenue.

Table 7.3: Summer Calibrated Model Flow Volume Results

Station	Monitored Volume (ac-ft)	Modeled Volume (ac-ft)	Percent Difference (%)
Pineview	1478	1205	-18%
62E	1901	2624	+38%
Northland	5558	3637	-35%
Zane	6487	6777	+4%
I-94	8065	8692	+8%
Queen Ave	9098	9831	+8%
Outlet	10543	11937	+13%

The extreme rainfall event that occurred on 6/28/03 (Figure 7.3) was a 4.53” rainfall event which is equal to the 25-year event for the watershed. Rating curve measurements at several stations did not extend to these high discharges and flows were estimated by extrapolation of the curves; this is the likely reason for the discrepancy in flows following 6/28/03.

Verification of the model was completed at the Queen Ave monitoring station, for the same time period (4/1-9/1) in 2002. Table 7.4 and Figure 7.4 compare the volume and hydrographs.

Table 7.4: Summer Verification Run Flow Volume Results

Station	Monitored Volume (ac-ft)	Modeled Volume (ac-ft)	Percent Difference (%)
Queen Ave	15,616	16422	+5%

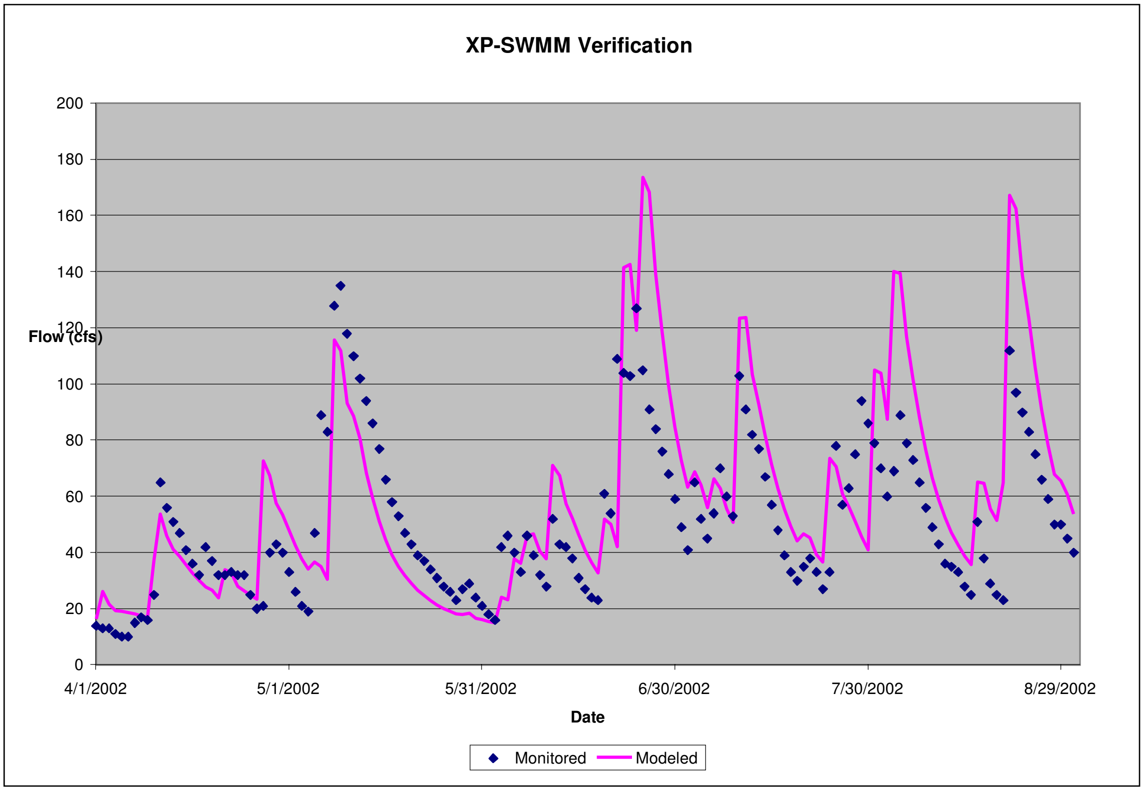


Figure 7.4. Monitored flow at USGS Queen Ave. vs Verification Run in XP-SWMM Model

G1.5.2.5 Winter Calibration

Winter calibration was completed by utilizing snow-pack snow-melt data from the New Hope station, flow records from the USGS Monitoring station, and chloride concentration from monitoring stations located along Shingle Creek. Snow melt/runoff events were modeled based on monitoring data demonstrating an increase in chloride concentrations, then correlated to a decrease in snow pack and verified with a change in stream flow from base flow conditions (Table 7.5; Figure 7.5).

Table 7.5: Winter Calibrated Model Flow Volume Results

Station	Monitored Volume (ac-ft)	Modeled Volume (ac-ft)	Percent Difference (%)
Queen Ave	2709	3217	+19%

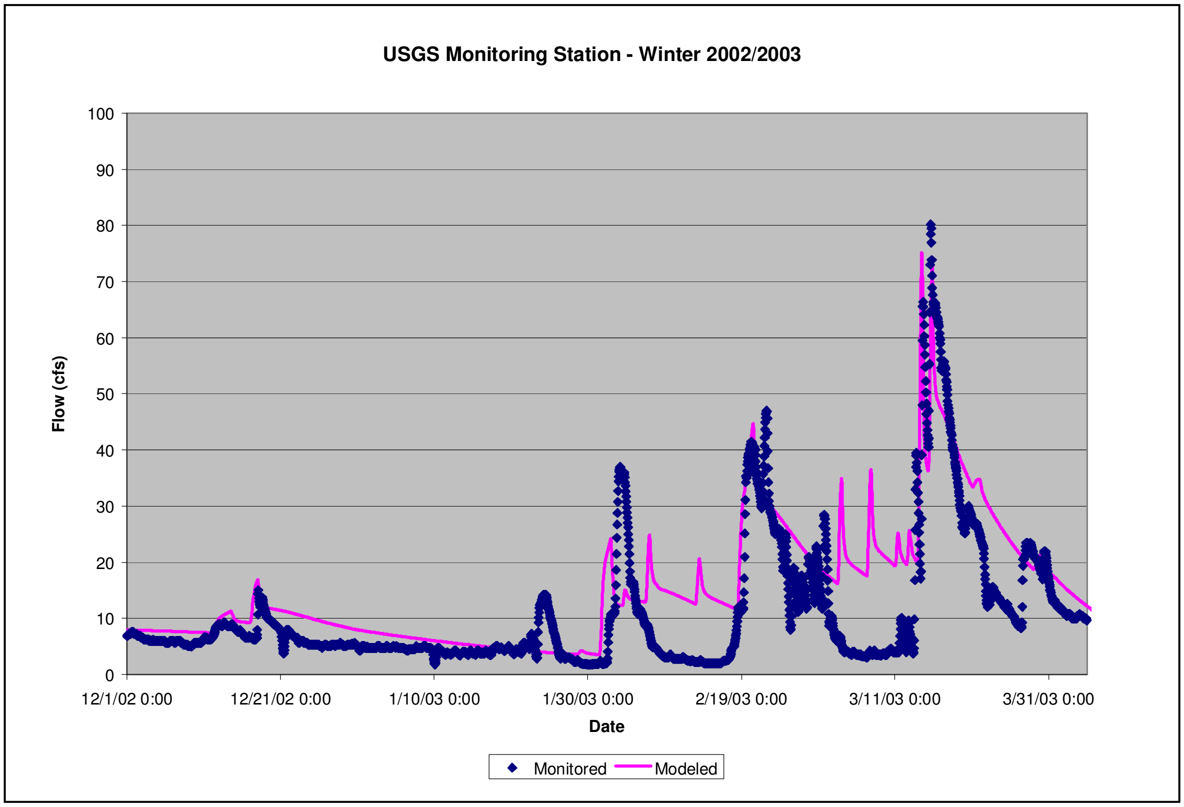


Figure 7.5 Monitored flow at USGS Queen Ave. vs Winter Calibration Run in XP-SWMM Model

Low flow conditions where ice cover would occur at the monitoring stations limited the data quality during low flow conditions and are attributed to the difference in flow.

The discharge calibration was judged to be reasonable in view of the uncertainty of the flow records during winter (ice and ice cover) conditions.

G1.5.3 Water Quality Calibration for Chloride

Calibration of the XP-SWMM model was completed using continuous monitoring data from each monitoring station from December 2002 to April 2003. The calibrated hydrologic and hydraulic model for the winter season was used as the base for the winter chloride calibration.

Chloride loads were developed for the model on a subwatershed basis. Plow records supplied by local agencies allowed for loads and application rates to be developed on a daily time step. Application of chloride was assumed to be applied to road and commercial/industrial land uses in the model.

G1.5.3.1 Road Surface Data

Road surfaces were "burned" into the land use coverage (see section 4.6.1) so road salt could be applied directly to road surfaces in the model.

G1.5.3.2 Road Salt Application Data

Maintenance officials in the Shingle creek watershed recorded road salt application rates and total applied. These rates were then compiled by subwatershed for input into the XP-SWMM model. XP-SWMM only accepts a constant mass loading over the watershed, so rates needed to be adjusted to match measured application rates in the watershed. To accomplish this task, we divided the XP-SWMM model into three segments where application rates were relatively uniform (Figure 7.6).

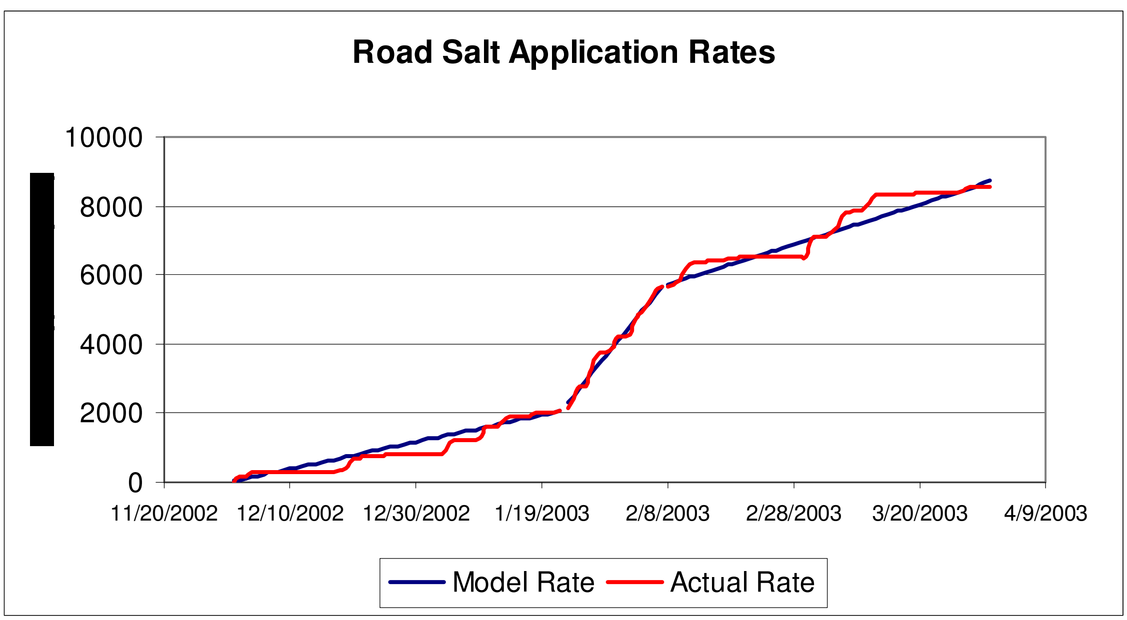


Figure 7.6. Cumulative road salt mass applied to the Shingle Creek watershed during the winter of 2002-2003

G1.5.3.3 Initial Parameters for Chloride Calibration

Chloride buildup/application was calculated on a daily time step based on road salt application records provided by agencies within the watershed. Road salt loading was reduced to chloride loading by computing the ratio of chloride to road salt (NaCl) based on molecular weight. The application rate of chloride was further broken down by subwatershed based on application records. Buildup of chloride was applied at a rate of lb/acre/day basis. Commercial and Industrial land uses were assumed to have an application rate equal to 7.5% of the road application (lbs/acre/day) for the subwatershed.

The winter calibration was broken up into three seasons to represent the different road salt application rates in the watershed. Each subwatershed was therefore assigned a chloride application rate for each season. Buildup rates were specific to each subwatershed allowing for a more accurate spatial representation of chloride buildup on the watershed based on monitored chloride application data. Chloride was assumed to build up linearly (daily) based on rates. Chloride was then runoff using a rating curve equation with a runoff coefficient multiplied by the runoff depth to a power.

G1.5.3.4 Chloride Calibration Results

Chloride concentrations were calibrated versus monitoring data. Results from the calibration demonstrate chloride concentration trends are sufficiently represented with the modeling results (Figure 7.7 and 7.8).

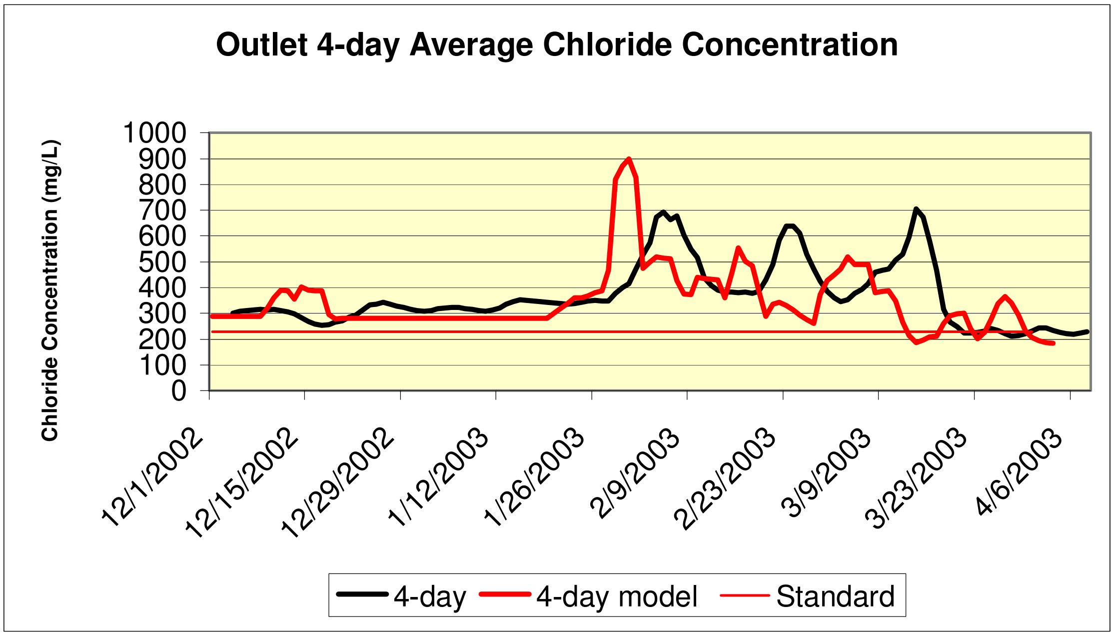


Figure 7.7. Modeled 4-day average chloride concentrations at the outlet.

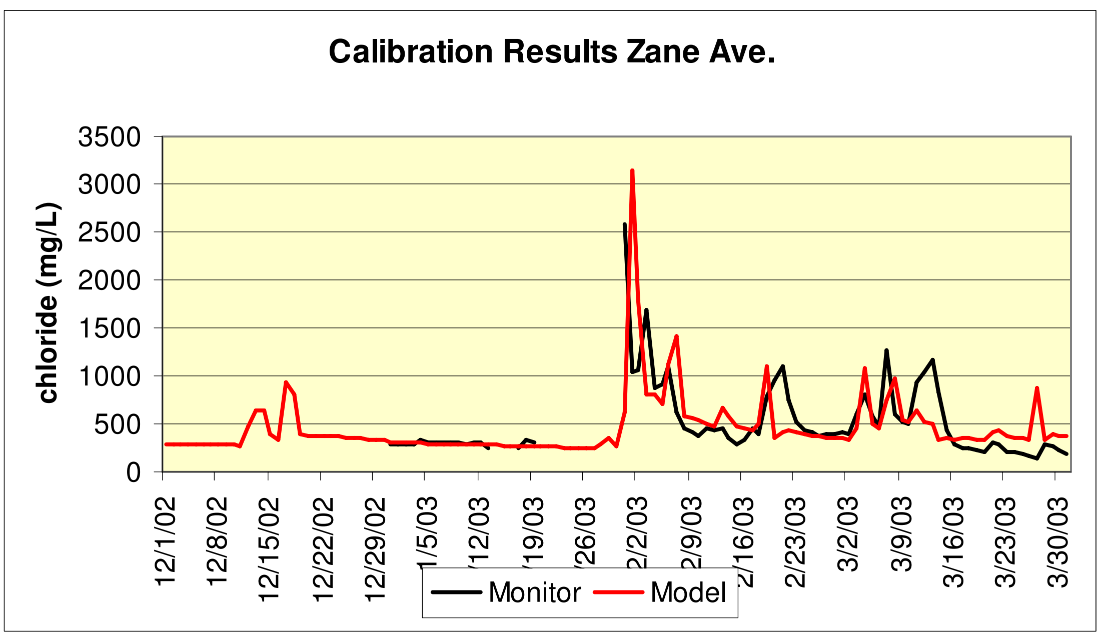


Figure 7.8. Modeled 4-day average chloride concentrations at the Zane Avenue station.

G1.5.4 Model Results

G1.5.4.1 Average Precipitation year

To mimic a normal precipitation winter, two factors needed to be addressed including selection of a typical precipitation year and estimating road salt use during that winter. The winter of 1995 and 1996 was selected as representative of a typical precipitation year. This winter (1995-96) had a total snowfall amount of 56 inches.

To estimate road salt applied, data supplied to the SCWMC was utilized to determine the relationship between snowfall totals and road salt applied for deicing. The total road salt used by agency including areas outside of the Shingle Creek watershed demonstrates the relationship between snowfall totals and road salt application (Table 7.6).

Table 7.6. Road salt usage by agencies that maintain roads in and out of the Shingle Creek watershed and snowfall totals for 1996 through 2000.

Year	Snowfall (inches)	Road Salt (tons)	Road Salt per Inch of Snowfall (tons/inch)
99-00	36.2	19,815	547
98-99	56.5	21,166	375
97-98	45	26,382	586
96-97	72.1	39,282	545
Predicted 95-96	56	28,327	506

All of the years demonstrated a linear relationship with snowfall except for 1998-99 (Figure 7.10).

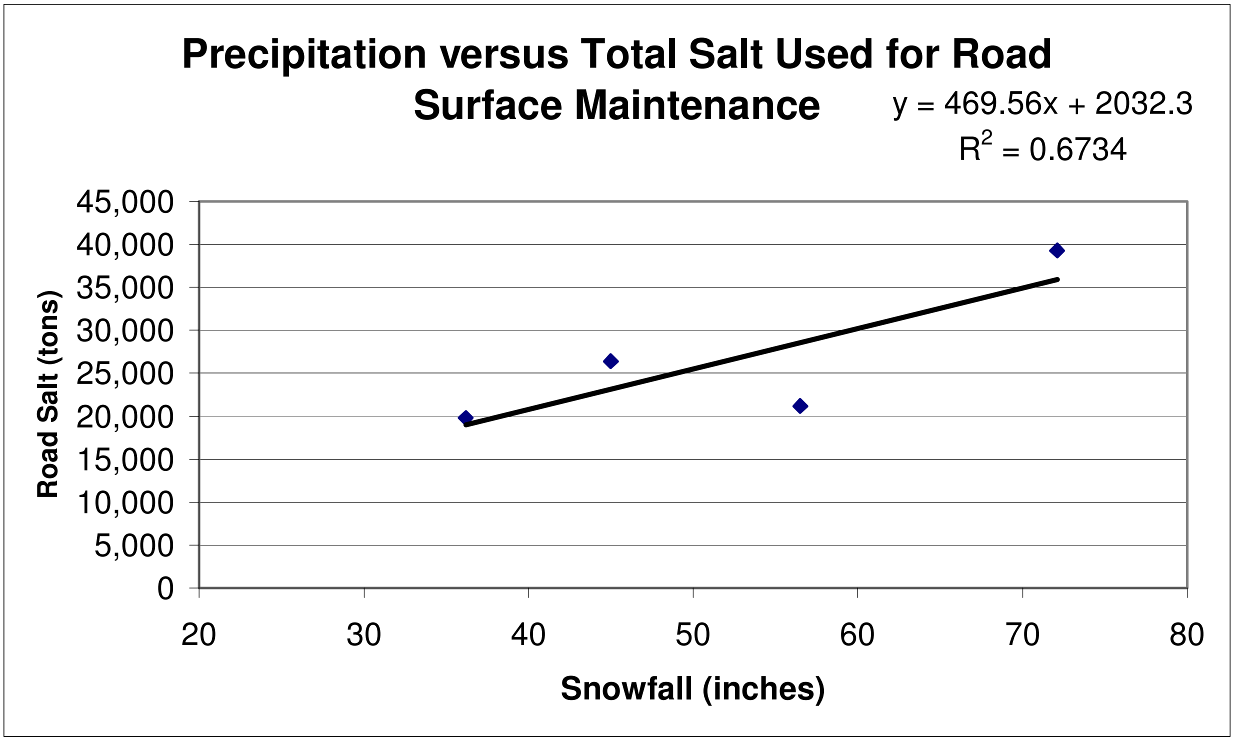


Figure 7.10. Total road salt used by local agencies (local cities and Hennepin County) for all roads including those outside of Shingle Creek's watershed plotted with snowfall totals.

Utilizing this relationship, it was determined that 1995-96 would have resulted in a 56% increase in road salt usage based on differences in snowfall totals, totaling 13,639 tons of road salt applied to the watershed. It is important to recognize that the data used in the relationship included areas outside of the Shingle Creek Watershed. As a result, the percent increase was utilized to estimate road salt usage in the Shingle Creek watershed.

Patterns of road salt application in 2002-03 followed the cumulative snowfall totals in the watershed (Figure 7.11). Road salt was applied to the watershed based on precipitation totals in the average year so that application timing was properly accounted for in the model.

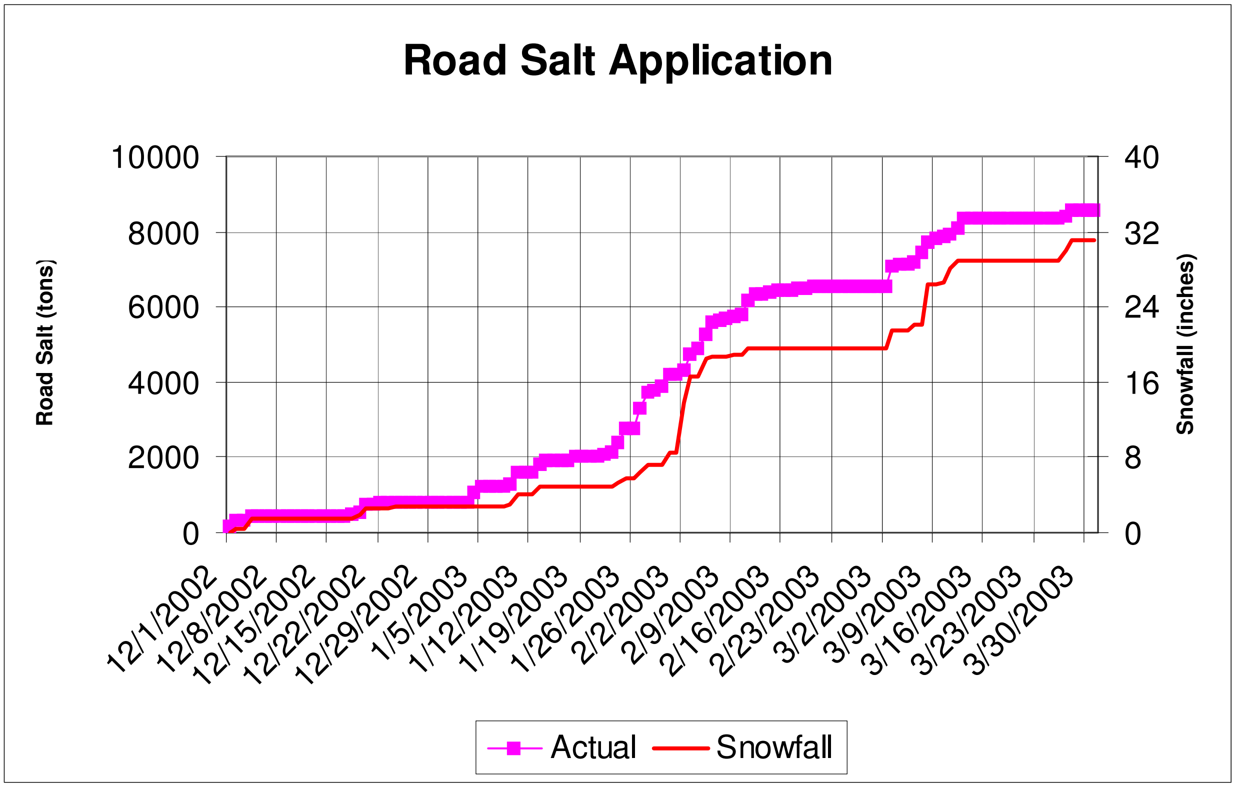


Figure 7.11. Cumulative road salt application and snowfall during the 2002-03 winter monitoring period.

The average year and analysis year data from the model are presented in Figure 7.12. The average year demonstrates higher base flow concentrations for much of the winter.

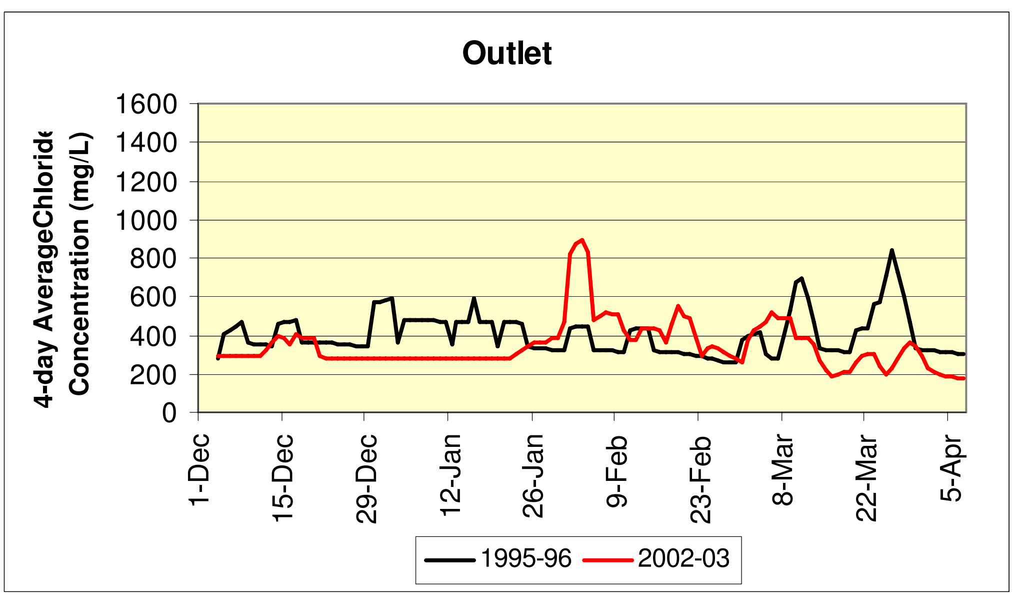


Figure 7.12. 4-day average chloride concentrations for the 1995-96 and 2002-03 winter.

Overall, average year runs suggests that both the peak and baseline concentrations would be higher in an average year as a result of higher road salt usage.

G1.5.4.2 Changes in Deicing Loads in the Watershed

Another factor addressed by the model was the need to test the assumption that load reductions prescribed by the TMDL would result in compliance with the chloride standard. Model output for both the Zane Ave. station and the outlet are presented in Figures 7.13 and 7.14. Two scenarios were run including a 75% reduction in deicer application across all sources with current groundwater concentrations and the same reduction including groundwater at 50 mg/L. Using 50 mg/L assumes groundwater returns to background conditions with the reductions in road salt usage.

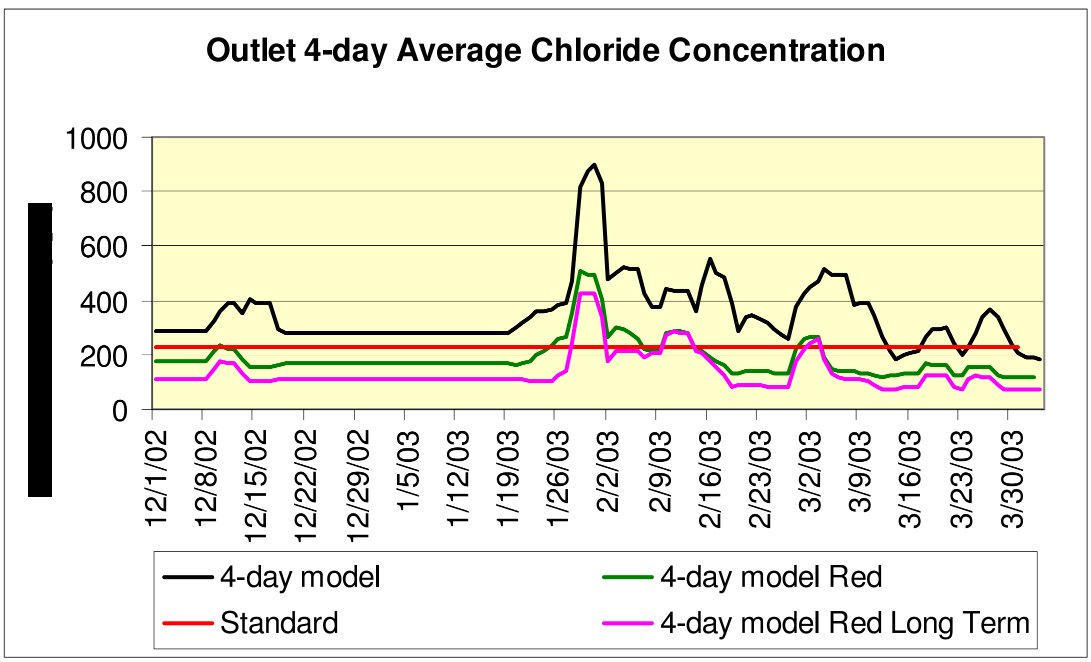


Figure 7.13 Modeled 4-day average chloride concentrations for the two scenarios at the outlet.

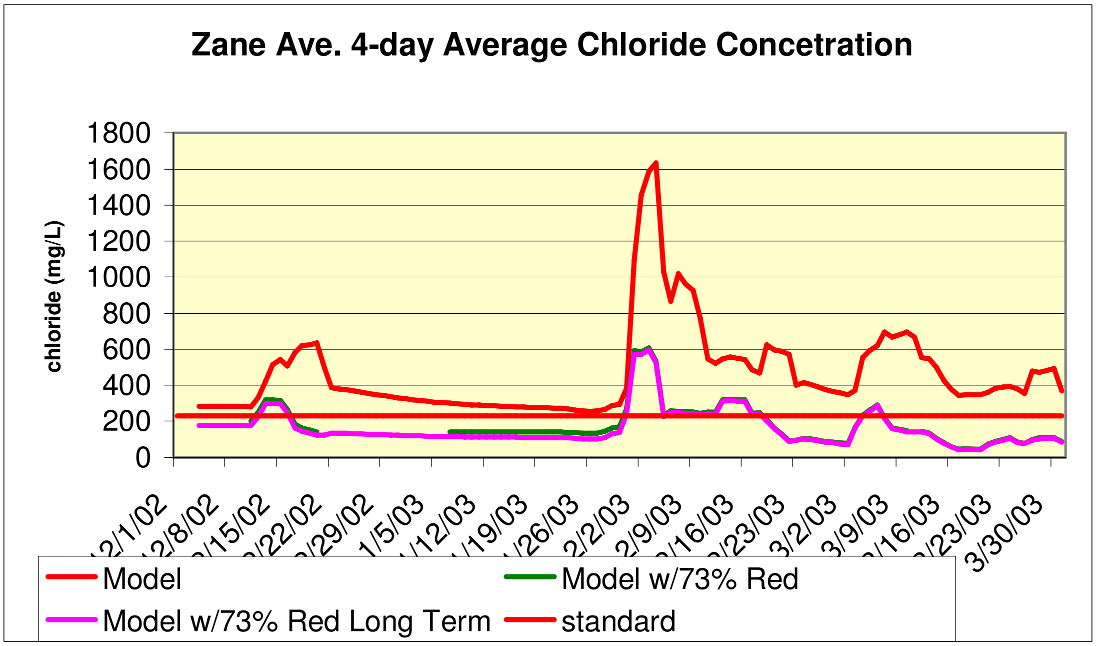


Figure 7.14 Modeled 4-day average chloride concentrations for the two scenarios at the Zane Avenue station.

Seventy five percent reductions in deicer application across all sources reduced both the baseline concentrations and peak concentrations. However, some runoff conditions do result in violations. These violations point to the importance of controlling winter runoff events to protect in-stream concentrations. It is likely that any salt usage would result in violations during peak winter runoff events since salt will be readily transported by small runoff events and stream flows are low with little capacity for assimilating pollutants. Controlling the runoff load to meet load allocations would result in compliance with the water quality standard. Barring the elimination of road salt usage for deicing, runoff controls must be included in BMPs to meet water quality standards.

Shingle Creek Chloride TMDL

Appendix H
Final BAT Report

Best Available Technology Report

A Review of Mn/DOT Metro District Salt Management Practices in the Shingle Creek Watershed

July 31, 2006

Table of Contents

1. Introduction

In May, 2004 the Shingle Creek Watershed Management Commission (SCWMC) completed an analysis of the chloride loadings to Shingle Creek in their report titled "(DRAFT) Chloride TMDL Report." The monitoring and analysis contained in this report was in response to Shingle Creek being identified as an impaired water with a concentration of chloride that is greater than the standard to support aquatic life. The specific goals of the study were to define the levels of chloride in Shingle Creek, identify the sources of the chloride load, and allocate reductions necessary to return Shingle Creek to water quality standards.

The SCWMC TMDL report concludes that 87% of the chloride load to Shingle Creek is related to application and storage of road salt by public entities (Table 1). The remaining 13% was attributed to commercial, residential and groundwater sources.

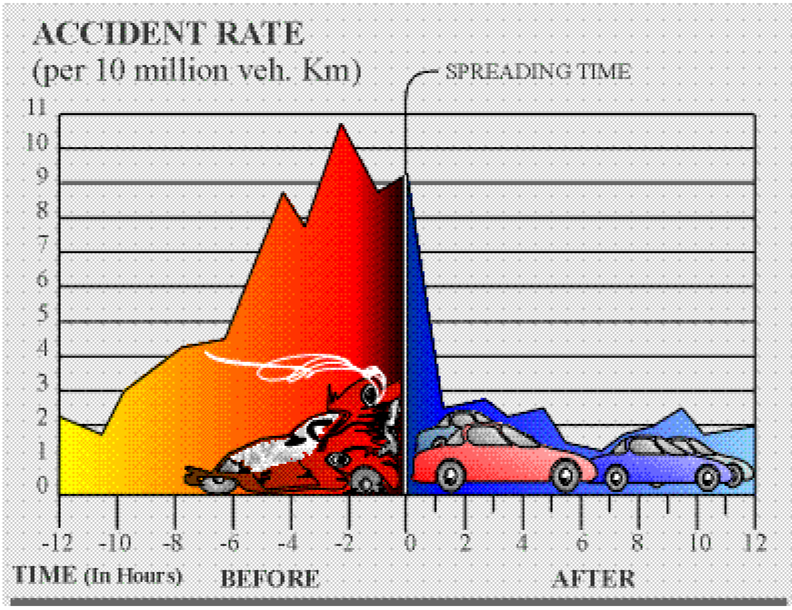
Table 1 Sources of chloride loads to Shingle Creek per SCWMC TMDL report.

Source	Share of Stream Load (%)
All Cities	43
Hennepin County	26
Mn/DOT	13
Road Salt Storage Facilities	5
Commercial Application	7
Residential	1
Groundwater	5
Total	**100**

A long term goal of 71% reduction in total chloride loading was set to bring chloride concentrations down to recommended standards for Shingle Creek (per the Sept 2005 SCWMC TMDL report).

According to the Salt Institute, salt is used as the principal de-icer because it is the most cost effective de-icer available. It is estimated that annual salt de-icer usage totals 15 million tons in the United States and about 4 to 5 million in Canada. Salt is used to prevent and break a bond from forming between the pavement and the ice, thus preventing the build-up of ice. Maximum safety, measured in injury accident rates, is a key goal for winter road maintenance. A study by Marquette University Department of Civil and Environmental Engineering, illustrated graphically by the Salt Institute in Figure 1, concludes that the vehicle accident rate decreases sharply after deicing.

Figure 1 - Road accident rates before and after deicing. (The Salt Institute)



The goal of any deicing program is to create the safest roadway with the least impact to the environment. In 1998, prior to initiation of the SCWMC study, the Minnesota Department of Transportation (Mn/DOT) implemented their Salt Solutions Program, aimed at improved efficiencies in road salt application and management. Practices implemented include improved operator training and monitoring to ensure operators are meeting state guidelines. Through this program, Mn/DOT has achieved much of the road salt usage reduction recommended for the public road entities affected by the recommendations for Shingle Creek.

For purposes of assessment, Mn/DOT's road salt management practices have been sorted into the following categories in this report:

- Salt storage and handling
- Operator training
- Product application – equipment
- Product application – decision
- Ongoing research
- Other practices

The remainder of this report will classify Mn/DOT's road salt management practices in terms of Best Available Technology (BAT). This term has its roots in the Federal Clean Water Act, and is generally defined as being that technology which is the best, but not most cost effective for pollution control. It is a concept that is presently applied to air and water quality technologies but not typically used to meet TMDL goals.

Subsequent sections of this report detail Mn/DOT's practices and highlight areas where additional equipment or efficiencies would bring Mn/DOT practices to Best Available Technology. For each category a graphic was created that represents the range of management practices available, from no management practice to the Best Available Technology. Best Available Technologies identified in this report were determined through a review of existing research on salt management practices and in consultation with the Minnesota Pollution Control Agency.

2. History of Mn/DOT Salt Management Practices

Timeline

1970s	Mn/DOT adds ground-oriented controls to spreaders
1980s	Storage and/or loading facilities covered Pre-wetting equipment first purchased
1998	Switched to pure salt application in the Metro Area and stopped using approximately 130,000 tons of sand annually
1998	Implemented Salt Solutions Program
2004	First trucks equipped with equipment that electronically tracks salt application rates
2015	All Mn/DOT trucks equipped with pre-wetting equipment (projected)

3. Storage & Handling

Current Mn/DOT Practices

All Mn/DOT salt storage facilities and most loading sites within the seven-county metro area are covered.

Three loading facilities are used by Mn/DOT operators to cover routes in the Shingle Creek Watershed (Figure 2). The loading area at the Maple Grove site is uncovered and could potentially contribute chloride to Shingle Creek via overland flow. Sites in Minneapolis and Golden Valley are outside the watershed and are unlikely to contribute chloride to Shingle Creek via overland flow.

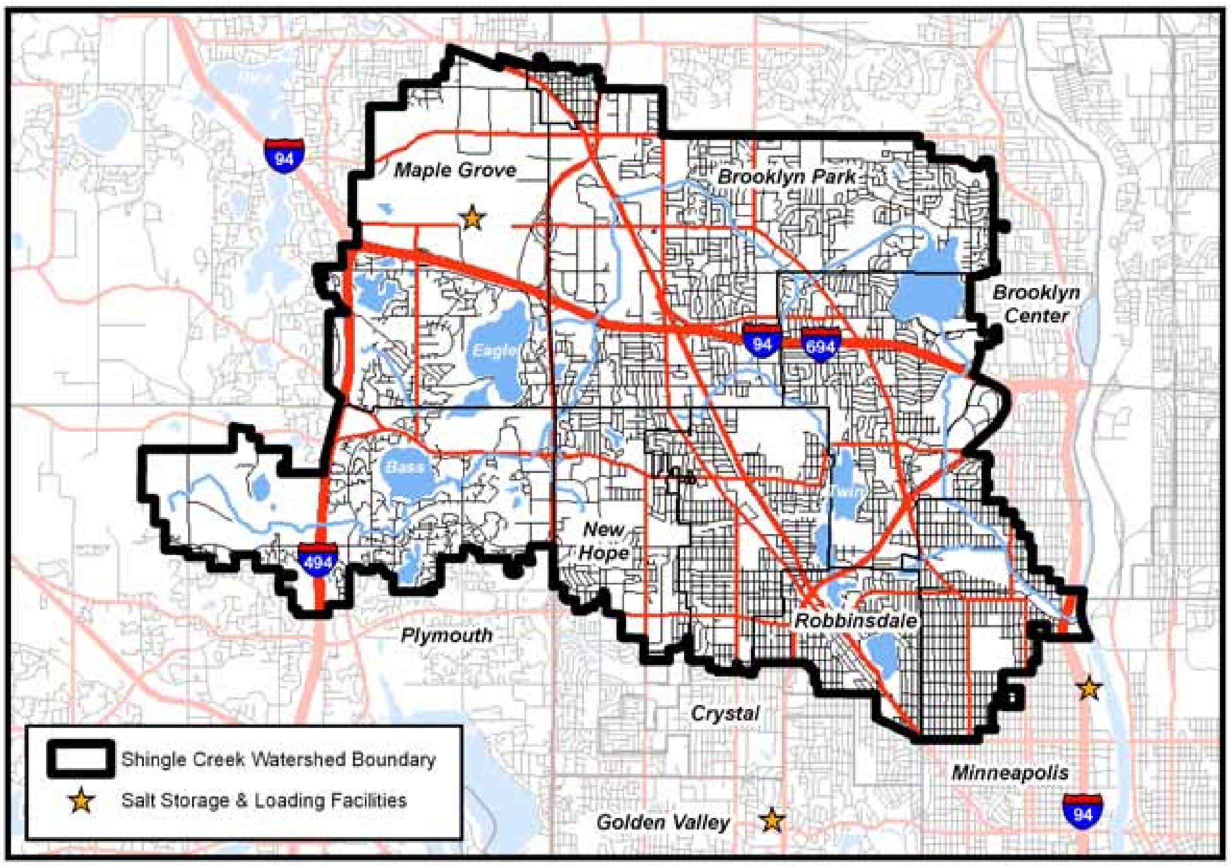
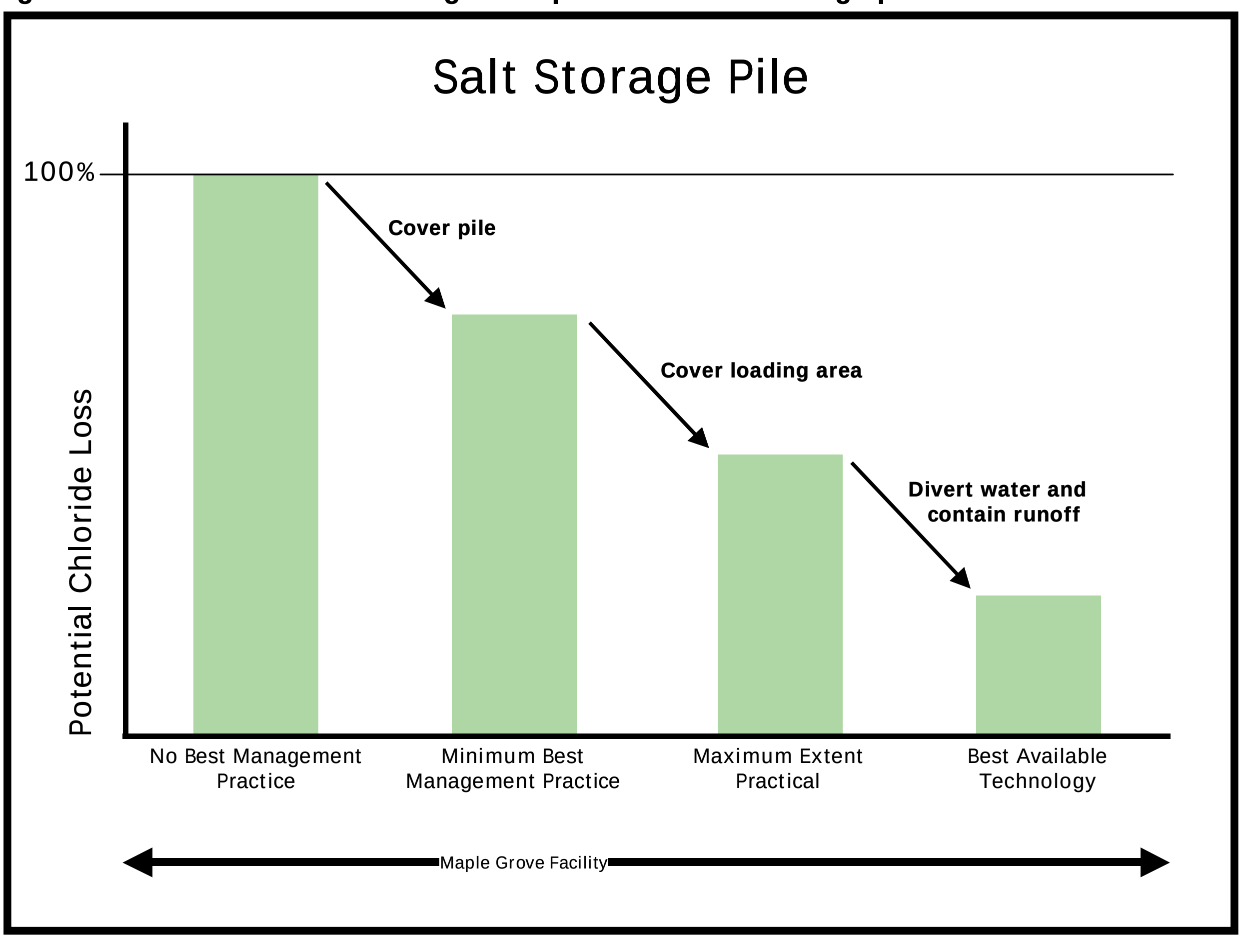


Figure 2 - Location of Mn/DOT salt storage facilities in or near the Shingle Creek Watershed

Best Available Technology – Salt Storage and Handling

Figure 3 shows the continuum of management practices for the storage of salt piles. Covering the salt pile will result in reduction of potential chloride lost via surface water flow. Covering areas where salt is loaded onto trucks will result in additional reductions in the amount of chloride that could potentially be lost. The best available technology for salt storage piles would involve covering both the storage and loading areas, diverting surface water runoff away from loading and storage piles, and containing any runoff that does come in contact with the salt pile. The majority of Mn/DOT salt storage facilities in the metro area have covered storage piles and loading areas. The only Mn/DOT storage facility in the Shingle Creek Watershed, located in Maple Grove, has a covered salt pile but does not have a covered loading area. Mn/DOT is seeking capital improvement funding to relocate and build a new facility; land is currently available and site planning has been done.

Figure 3 - Continuum of best management practices for salt storage piles.



4. Operator Training

Current Mn/DOT Practices

Mn/DOT believes training is a crucial component to optimal salt application. As a result, Mn/DOT Operators go through a rigorous and thorough training program to prepare for snowplow and salt application. When operators report for duty during a winter storm event, they are given recommended application rates by their supervisors. These rates are based on information obtained through the Road Weather Information Systems (RWIS) and other sources. Additional description of the RWIS system is detailed on page 12 of this report. Operators have the authority to alter these recommended application rates based on conditions in the field. To do so in a responsible manner requires thorough understanding of how salt works to melt snow and the detrimental effects that chloride has on the environment. To gain this understanding, Mn/DOT operators go through an initial training program comprised of several training sessions for new operators and an annual refresher course.

Initial Training

The initial training for new operators covers basic equipment operation and maintenance, snow and ice equipment operation and maintenance, chemical characteristics, and various weather and traffic proper applications. This initial two week session in combination with other training includes documenting and reporting salt usage.

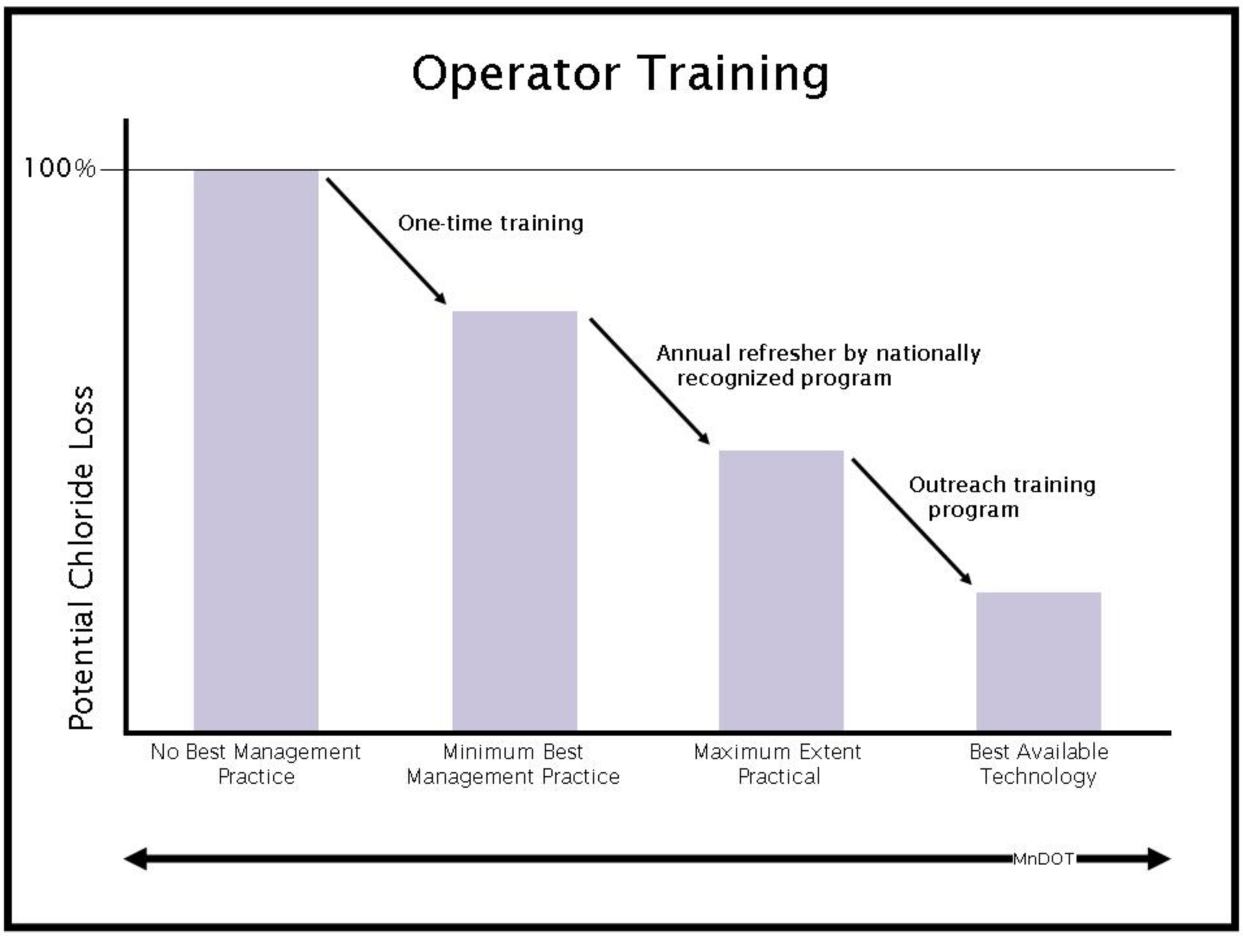
Salt Solutions Program

The annual refresher course is done using the Salt Solutions Program, a nationally recognized program created by Mn/DOT. The program was created in 1998 and is based on a Federal Highway Administration (FHWA) program and tailored to weather conditions in Minnesota. After examining conditions in Minnesota, Mn/DOT found that FHWA guidelines for salt application are higher than necessary to ensure safe roadways. As a result, the Salt Solutions Program trains Mn/DOT operators to apply salt in lower amounts than what is recommended by the FHWA. The program also reviews the different types of chemicals, equipment, and application methods. The training covers pre-wetting, anti-icing, de-icing, and sensible salt and sand usage and also includes computer-based training on Road Weather Information Systems (RWIS, Mn/DOT, 2005).

Best Available Technology – Operator Training

Figure 4 shows the continuum of management practices available for operator training. Training is crucial to minimizing chloride lost through misapplication. An initial training program with many sessions will increase operator understanding of the relationship between environmental damage and over application of salt and help to limit excess application of chloride. Annual refresher programs, like the Salt Solutions program, will reinforce this link and help ensure that optimum application of de-icing chemicals continues beyond the initial training. Additionally, making these training programs available to local operators can help to ensure that other agencies are also working to reduce the amount of chloride that could be lost through misapplication. This could potentially lead to a reduction in the amount of chloride applied on all highways in the Shingle Creek Watershed, not just those highways maintained by Mn/DOT.

Figure 4 - Continuum of best management practices for operator training.



5. Product Application - Equipment

Current Mn/DOT Practices

Calibrating the spreader

Mn/DOT trucks are equipped with a spreader for applying de-icers. A spinning circular plate distributes the de-icing material in a semi-circle onto the road surface (Figure 5). Calibration of spreading equipment is done when a new truck enters service. Until recently Mn/DOT calibrated the spreading equipment on its trucks annually but has found that equipment does not usually become “uncalibrated” until major work is performed on the truck.

Ground-oriented controls

Equipping spreaders with automatic or ground-oriented controls can help operators apply the optimal amount of product. Ground-oriented controls automatically (Figure 5) regulate application rates as truck speeds fluctuate, freeing the operator from having to adjust spreader controls. Mn/DOT trucks have been equipped with ground-oriented controls since the mid-1970s.

Figure 5 – Mn/DOT truck equipped with epoke, state of the art equipment for prewetting and anti-icing applications.

Recording rate of product application

Beginning in 2004, all new trucks will be equipped with a Dickey John brand controller that both controls and electronically records the rate of salt application. The Dickey John controller is calibrated to the speed of the truck and the target rate of application (pounds of product per lane mile). The existing fleet will not be retrofitted with this equipment. The existing fleet has the capability to calibrate and control rate of application, but it is not electronically recorded.

Pre-wetting

Pre-wetting is a strategy that aims to decrease the amount of dry product that is lost due to wind action, material bounce or traffic dispersion. Wet salt is more able to adhere to the pavement and less likely to bounce or be blown off the road by traffic. It is estimated that pre-wetting can reduce wasted salt by 20% to 30% (Road Management Journal, 1997). Pre-wetting may also result in faster melting action because it provides the moisture necessary to activate the dry chemical.

In the metro area, about 35 percent of trucks are outfitted with pre-wetting equipment (Figure 6). That percentage increases by about 10% each year. As weather conditions warrant, these trucks will pre-wet dry salt with a liquid de-icing product. This product is usually a sodium choloride brine solution.

Figure 6 – Mn/DOT truck equipped with pre-wetting equipment.

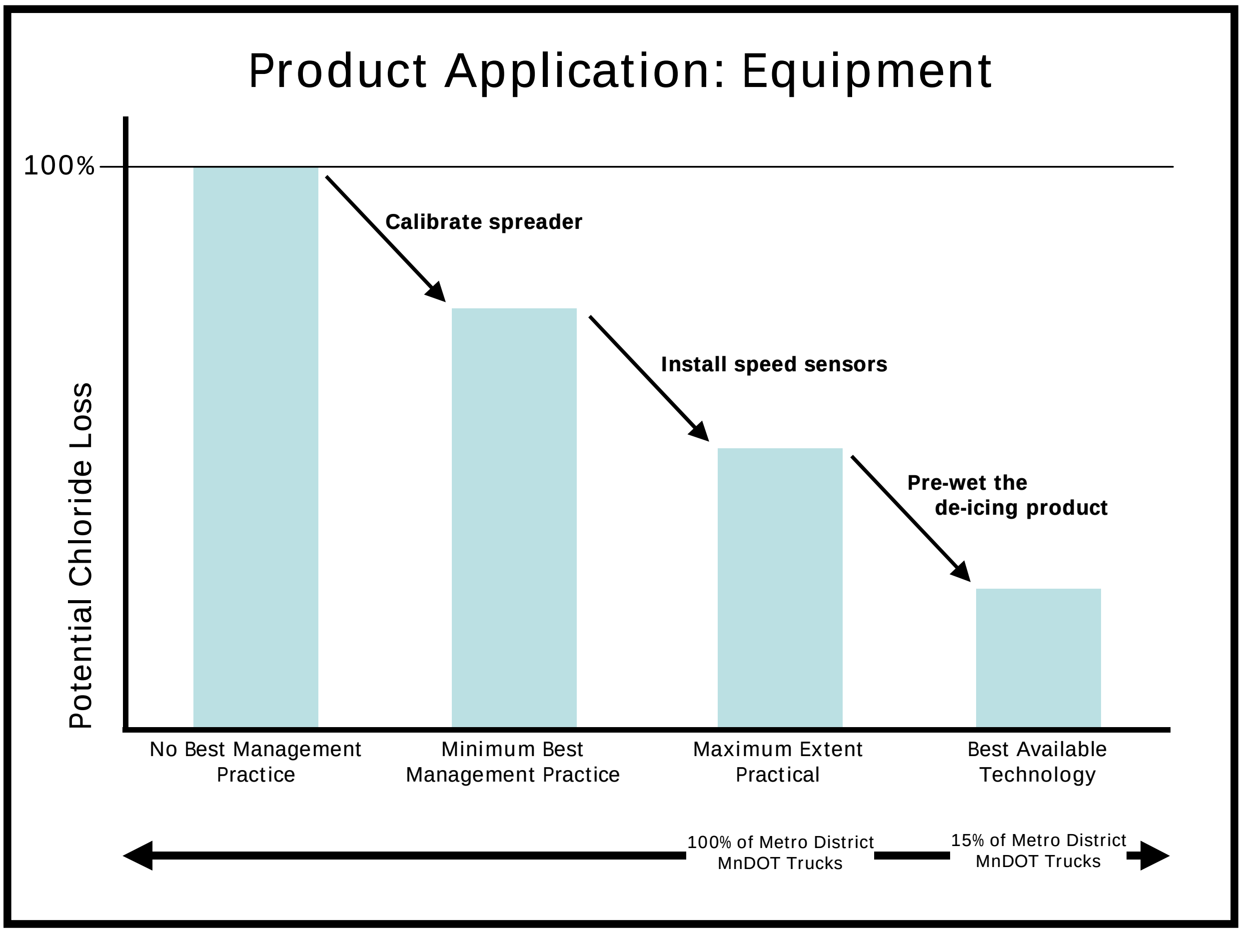
Planned equipment upgrades – Pre-wetting equipment

Mn/DOT staff has prepared a proposal to update all metro area equipment with pre-wetting and anti-icing equipment by 2015 (See Appendix A1 for the Metro District Prewet/Anti-icing 10 Year Implementation Plan). The department is also investigating equipment that would monitor and track salt usage electronically. This plan will be implemented providing that funding becomes available.

Best Available Technology – Product Application - Equipment

Figure 7 shows the best available technology continuum for equipment used to apply anti-icing and de-icing products. Calibrating the spreader that distributes the anti-icing or de-icing product results in a significant reduction in the amount of misapplied product. Installing speed sensors or ground-oriented controls results in further reductions in the amount of misapplied product. All Mn/DOT trucks in the metro area are currently equipped with ground-oriented controls. Trucks purchased after 2004 will be fitted with controllers that also record the amount of material applied. Fifteen percent of those trucks are also outfitted with pre-wetting equipment. Pre-wetting equipment can reduce the amount of misapplied product by up to 30 percent over trucks that are equipped with only ground-oriented spreaders.

Figure 7 - Continuum of best management practices for de-icing equipment



6. Product Application - Decision

Current Mn/DOT Practices

Use of Road Weather Information Systems (RWIS)

The surface temperature of a snow or ice-covered road is used to determine de-icing chemical application rates. It is important to have an accurate measure of pavement temperatures because the effectiveness of de-icing chemicals can decrease with small changes in pavement temperature. As pavement temperature decreases, the amount of de-icing chemical needed to melt a given quantity of ice increases significantly. For example, salt can melt five times as much ice at 30° F as it can at 20° F (Road Management Journal, 1997).

In order to accurately measure road temperatures, Mn/DOT has a network of 90 sensors embedded in roadways around the state. There are 8 RWIS sites in the metro area. There are usually 4 sensors to a site. Mn/DOT supervisors can also make use of sensors in other parts of the state to see weather that is approaching the Metro area. This information is used to help determine optimal rates of application.

Information collected by Mn/DOT's RWIS is available to city and county officials via the Mn/DOT website.

Determining Rate of Salt Application (range 100-800 lbs/mile)

Mn/DOT uses Salt Institute research to create guidelines for Mn/DOT supervisors to determining the rates of salt application. Mn/DOT supervisors analyze information collected by the state's RWIS and other sources to determine the rate of salt application that operators should use in the field. This rate guideline can be altered by operators based on road conditions observed in the field.

De-Icing

Clearing winter roads to the bare pavement usually requires de-icing chemicals. The most commonly used chemical is sodium chloride but calcium and magnesium chlorides are also occasionally used. De-icing chemicals work by lowering the freezing point of water (Road Management Journal, 1997).

Dry de-icing chemical must dissolve into a brine solution in order to begin melting ice. The moisture needed to convert the dry chemical into brine can come from snow on the road surface or from water vapor in the air (Road Management Journal, 1997). Pre-wetting with brine solutions previously discussed also initiates this action.

Anti-Icing

Anti-icing is a road maintenance strategy that tries to keep the bond between ice and the pavement surface from forming. It involves applying ice control chemicals before or at the very beginning of the storm. Using this strategy can reduce total chemical use and maximize service to the traveling public (Road Management Journal, 1997).

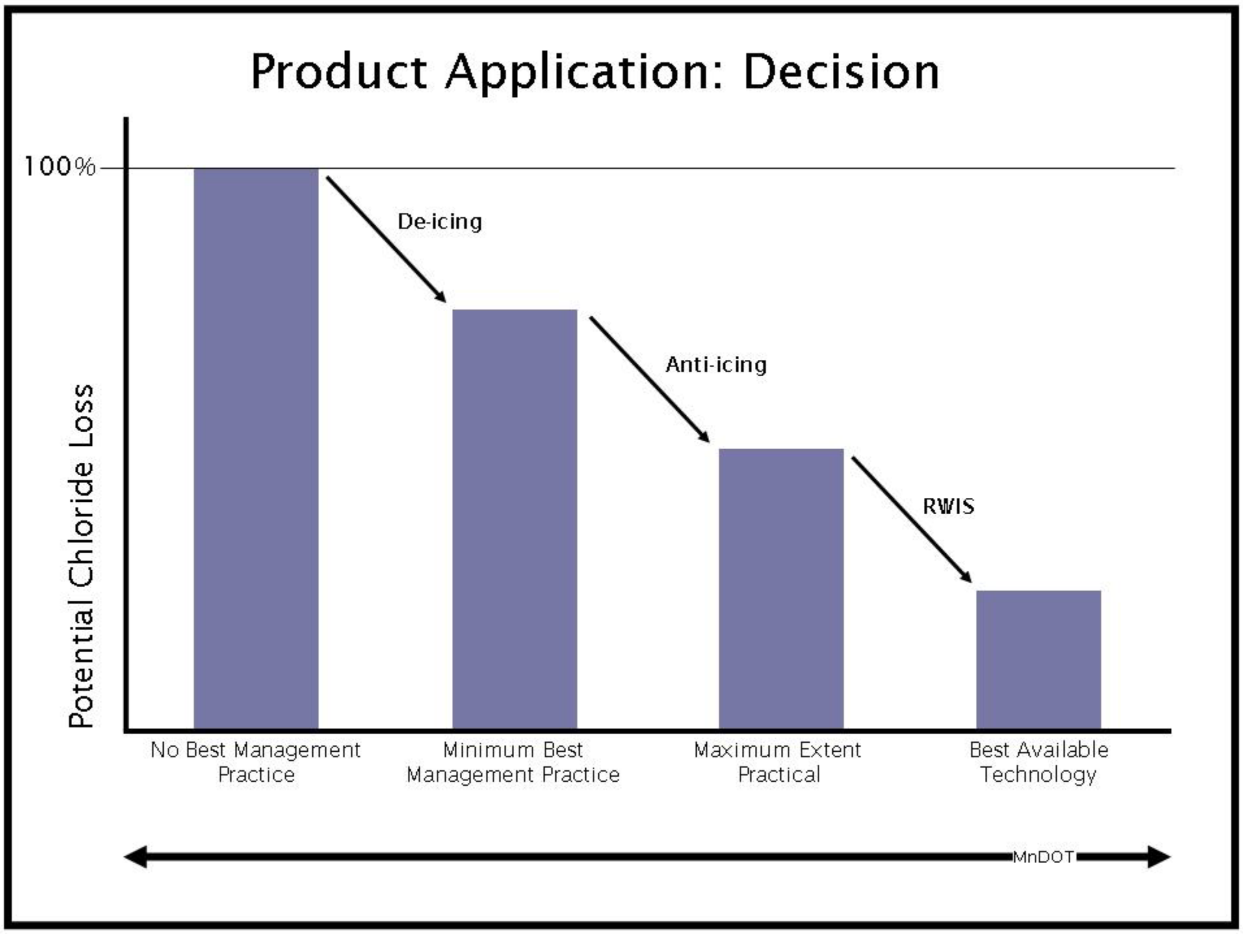
Mn/DOT has two anti-icing strategies to minimize chloride loss, a “just in time” strategy and a routine strategy. A “just in time” strategy aims to apply the anti-icing product just prior to a major snowfall to maximize the effectiveness of the chemical. Routine anti-icing is done twice a week. An anti-icing product is applied to areas that tend to freeze first. Bridge decks and curves are examples of such areas. Temperature and anticipated weather are also considered when determining how often routine anti-icing is done. Mn/DOT guidelines to operators on when to use anti-icing strategies are included in Appendix A2.

Mn/DOT has anti-icing equipment dedicated to application of magnesium chloride to bridges and other surfaces subject to rapid accumulation of ice, such as bridge decks. Anti-icing in the metro area is done selectively because of the cost and the potential impact to the environment if timed incorrectly. Mn/DOT applies a liquid anti-icing chemical because too much salt is lost in anti-icing applications using dry chemicals. Mn/DOT currently uses a magnesium chloride solution but is also testing the effectiveness of sodium chloride solutions. Magnesium chloride is used because of its ability to attract moisture to reactivate the dry chemical and prevent icing. Presently bridges in the Shingle Creek watershed are treated by operators applying an anti-icing chemical. Although used elsewhere in Minnesota, automatic bridge anti-icing equipment is not installed in the Shingle Creek watershed.

Best Available Technology – Product Application - Decision

Figure 8 shows how the continuum of best available technology for the decision making process applies to anti-icing and de-icing techniques. Making use of a Road Weather Information System can play a significant role in an agency's ability to accurately determine application rates for de-icing and anti-icing products. Additionally, information collected by the state's RWIS is available to other organizations via Mn/DOT's web site at http://rwis.dot.state.mn.us. This makes it possible for other county and city officials to increase the accuracy with which they determine application rates. This has the potential to lead to a reduction in the amount of chloride used on all roads in the Shingle Creek watershed, not just those maintained by Mn/DOT.

Figure 8 - Continuum of best management practices for de-icing equipment.



7. On-Going Research

Current Mn/DOT Practices

Mn/DOT Office of Maintenance and Research

Mn/DOT has an in-house research department that pre-tests chemicals before they go into road tests. Mn/DOT has developed a testing, evaluation and approval process for all chemicals used for anti-icing and de-icing during winter maintenance on Minnesota highways. This process was developed in order to address questions surrounding the environmental impact, personal and public safety, corrosion properties, and other factors regarding chemical usage (Mn/DOT Office of Maintenance and Research).

Before any new de-icing chemicals are used on highways and freeways maintained by Mn/DOT, they must go through a screening process. The process involves:

1. A Mn/DOT employee proposes that a specific new material be tested and identifies the reasons the new chemical should be evaluated.
2. If approved for prescreening, the Mn/DOT employee fills out a check list that demonstrates that specific information has been obtained from the supplier of the new material. This checklist includes information on the human health effects, environmental effects and properties of the chemical proposed for evaluation. This check list is included in Appendix A3.
3. If approved for evaluation, a lab evaluation is conducted which will determine if the chemical performs in the manner stated by the vendor
4. Once the new chemical makes it through the pre-screening process, field evaluation begins on carefully selected road sections.

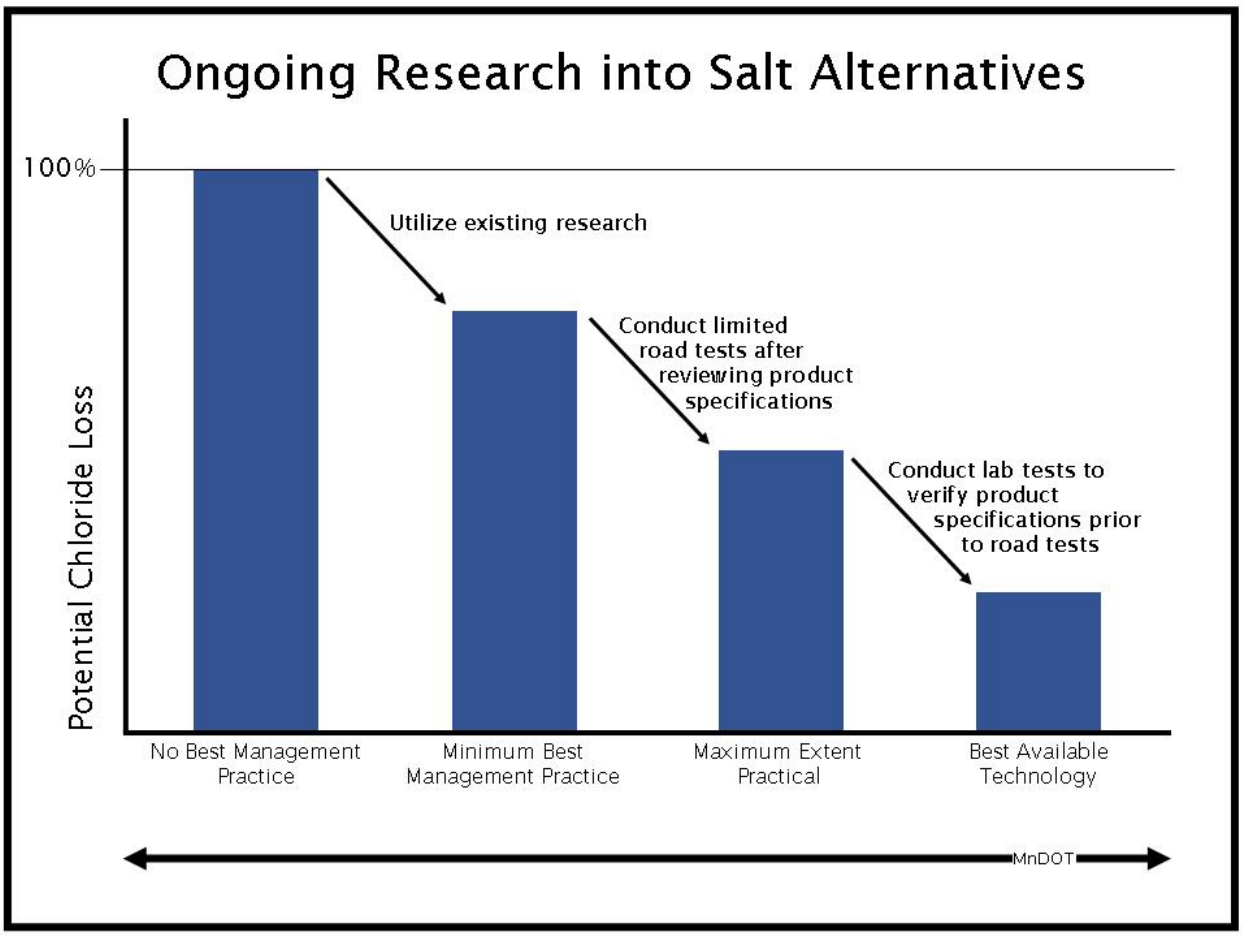
Alternative liquid de-icing chemicals

Mn/DOT is currently road testing two alternative liquid de-icing chemicals that have lower levels of chlorides. Corn salt combines salt brine with a corn by-product. Magnesium acetate was being tested in the Shingle Creek Watershed on State Highway 169 in Maple Grove.

Best Available Technology – On-going research

Figure 9 shows the continuum of the ways in which research into anti-icing and de-icing products can reduce the amount of chlorides that can potentially be lost to the surrounding environment. Making use of research conducted at the Salt Institute or another nationally recognized institution can help agencies and operators stay abreast of new products or methods that can reduce the amount of chloride lost to the surrounding environment. Conducting limited road tests can also help determine how new products or techniques can replace or reduce the amount of chloride used to keep roadways free of ice and snow. Mn/DOT conducts its own lab tests prior to road testing to verify that the chemical is capable of performing as stated by the vendor. These lab tests help to assess any additional impacts the chemical might have on the environment or personal and public safety.

Figure 9 - Continuum of best management practices for on-going research.



8. Effectiveness

To gauge the effectiveness of each salt management practice, existing research into practices designed to reduce salt use was reviewed. The available research focuses on reducing road salt use while still maintaining safe roadways. The studies reviewed used various combinations of salt management practices to reduce salt usage, including anti-icing, pre-wetting, Road Weather Information Systems and training. Reductions in salt usage were measured in the amount of materials used, the amount of chloride lost to the environment, and/or in annual costs (Table 2). Information on these case studies can be found on the Environment Canada website http://www.ec.gc.ca/nopp/roadsalt/cStudies/en/index.cfm.

Table 2 – Range of percent savings for various combinations of salt management practices

	Practice				**% Savings**		
Case Study	*Anti-icing*	*Pre-wetting*	*RWIS*	*Training*	*Materials*	*Chloride*	*Annual Cost*
Cypress Bowl (Canada)	✓	✓				73	34
Nova Scotia (Canada)		✓	✓		10		
Kamloops (Canada)	✓	✓	✓		58		
Otterburn Park (Canada)		✓		✓	73		
Toronto (Canada)				✓	7		
Funen County (Denmark)	✓				30		

9. Conclusion

Through on-going research and implementation of the Salt Solutions Program, Mn/DOT has achieved efficiencies in winter road management that should be a standard for local road agencies to follow. Mn/DOT has achieved a level of Best Available Technology (the highest level available) in the following categories of salt management:

- Operator Training
- Product Application: Decision
- Ongoing Research into Salt Alternatives

Mn/DOT has achieved a level of Maximum Extent Practical (the level used by the EPA in its' NPDES MS4 Program) in the following categories of salt management:

- Salt Storage Piles
- Product Application: Equipment

Further improvements could be made by following these recommendations:
Covering the loading area at the existing Maple Grove salt storage facility or relocating the salt storage facility has the potential to reduce the amount of chloride entering the creek. Equipping trucks with pre-wetting equipment has the potential to further reduce Mn/DOT's salt usage. Pre-wetting equipment can reduce the amount of misapplied product by up to 30 percent over trucks that are equipped with only ground-oriented spreaders. Equipping 100% of trucks in the Metro area with pre-wetting equipment could further reduce Mn/DOT's chloride contribution to Shingle Creek.

It is recommended that Mn/DOT seek funding to retrofit pre-wetting equipment to the entire fleet of Metro District trucks as planned in Appendix A and relocate the Maple Grove truck station facility as soon as capital improvement funding is obtained.

10. References

Environment Canada. 2005. Case studies on implementing better road salt practices. Retrieved March 10, 2005 from http://www.ec.gc.ca/nopp/roadsalt/cStudies/en/index.cfm.

Fonnesbech, JK, Knodsen, F. 2002. Optimization of Salt Sprinkling Method To Minimize Its Consumption. XIth International Winter Road Congress: New Challenges for Winter Road Service, Japan.

Mn/DOT Office of Maintenance and Research. 2005. Retrieved January 10, 2005 from http://www.dot.state.mn.us/maint/research-chemical.html

Road Management Journal. 1997. Retrieved January 10, 2005 from http://www.usroads.com/journals/p/rmj/9712/rm971202.htm.

Appendix A

Mn/DOT Metro District Prewet/Anti-icing 10 Year Implementation Plan

DRAFT

Metro District Prewet / Anti-icing 10 Year Implementation Plan

01/06/2005 developed by– Norm Ashfeld

Year of Implementation	Prewet Equipment	Units to Retrofit	Anti-icing Equipment	Support Equipment	Needed funds per year
2005-2006	18 units @ $63,000	4 units @ $14,000	Tanker with controls @ $35,000	Storage tank @$10,500	**$123,000**
2006-2007	18 units @ $67,000	4 units @ $15,000	1st Response @ $35,000	Storage tank @ $11,025	**$128,000**
2007-2008	18 units @ $69,000	4 units @ $15,000		Storage tank @ $11,576	**$96,000**
2008-2009	18 units @ $73,000	4 units @ $16,000		Storage tank @ $12,155	**$101,000**
2009-2010	18 units @ $76,000	4 units @ $17,000		Storage tank @ $12,762	**$106,000**
2010-2011	18 units @ $80,000	4 units @ $18,000	Replace 5 units @ 10K ea. = $65,000	Storage tank @ $13,400	**$176,000**
2011-2012	18 units @ $84,000	4 units @ $19,000		Storage tank @ $14,071	**$117,000**
2012-2013	18 units @ $88,000	4 units @ $20,000		Storage tank @ $14,775	**$123,000**
2013-2014	18 units @ $93,000	4 units @ $21,000		Storage tank @ $15,513	**$130,000**
2014-2015	18 units @ $97,000	4 units @ $22,000	Replace 5 units @ 10K ea. = $78,000	Storage tank @ $16,289	**$213,000**

NOTE: Calculations are based on purchasing 18 units, (9 Tandems, 9 Single axle trucks), and retrofitting 4 units, (2 tandems, 2 single axle trucks per year. All calculations are also based on a 5% inflation indexed per year, rounded to the nearest 000's. Total funds needed over the 10 year period is $1,313,000; price of pre-wet does not include the cost of the truck equipped with snow plow etc) Subject to change based on funding.

Appendix B

Mn/DOT Guidelines For Anti-icing

Guidelines For Anti-icing

INTRODUCTION

The Mn/DOT Anti-icing Committee has formulated this booklet to assist with the introduction of anti-icing to the arsenal of winter storm fighting tools. The committee is made up of various employees and management involved with the use and implementation of anti-icing practices throughout the State of Minnesota. The information contained herein is intended as a basic guideline only. This in no way constitutes a specific numbered process or procedure for the use of anti-icing material, chemicals, or equipment. The successful use of anti-icing is a learning process of which knowledge through experience is gained. The use of anti-icing can be a very beneficial tool when used in conjunction with other best practices and methods for snow and ice control.

The Mn/DOT Anti-icing Committee

For questions or comments contact the Metro Maintenance Enginners Office at:

Mn/DOT Metro Waters Edge 651-582-1643

MN/DOT ANTI-ICING GUIDELINES

A. DEFINITIONS:

Anti-Icing: The application of liquid chemicals* to prevent the formation of frost or the bonding of snow or ice to pavement. Initial applications can be made either as a pre-treatment in advance of a storm event, or as an early storm period treatment.

Black Ice: Popular term for a very thin coating of clear ice which forms on a pavement or bridge deck surface.

Working Temperature: Range of pavement temperatures at which chemical will effectively melt ice.
*In rare instances solids may be used.

B. WHEN TO APPLY:

1. Application Schedule: Regularly scheduled applications twice per week on bridge decks and critical areas or on black ice and routes prior to events.

2. Residual effect can remain for up to five days after application if the precipitation does not dilute the initial application. Refreezing of the surface can occur when precipitation or moisture in the air dilutes the chemical on the surface.

3. Magnesium Chloride: pavement temperature –10 degrees F to + 30 degrees F.

4. May be used at lower temperatures with high traffic volume roads.

5. Application - preferred times are during off peak ADT hours.

6. Other chemicals may be applied at different pavement temperature (see Appendix A.)

C. APPLICATION RATES:

	Mag	Brine
1. Regularly Scheduled Applications	15 to 20 Gal/LM	20-35 Gal/LM
2. Prior to Frost or Black Ice Event	15 to 20 Gal/LM	20-35 Gal/LM
3. Prior to Light or Moderate Snow*	15 to 20 Gal/LM	20-50 Gal/LM

*Used as bond breaking agent

D. WHEN NOT TO ANTI-ICE:

1. Prior to predicted rain.

2. During heavy snow (1 inch/hour events). Heavy snows will cause the rapid dilution of chemicals and require frequent reapplication of liquid. During this time a snow fighter may need to switch to de-icing methods (may include liquids) for their area.

3. Under blowing or drifting snow conditions.

4. After the bond between in the snow and the pavement has occurred.

E. PRECAUTIONS:

1. Use caution especially with higher rates

2. Refreezing of bridge deck or pavement surfaces can occur if the applied chemical is significantly diluted or pavement temperature decreases. Need to know the lowest working temperature of applied chemical to determine minimum freezing point depression (See Appendix A.).

3. Pavement slipperiness with the use of liquid magnesium chloride and calcium chloride is possible after application under certain temperature and humidity condition. (Example: temperature above 30 F and humidity level greater than 40%).

4. When blowing and drifting snow conditions exist. Anti-icing chemicals on a dry pavement or bridge deck may cause blowing snow to stick and create slippery conditions.

5. Corrosion inhibitors that reduce material corrosion to 70% less than sodium chloride are to be used with liquid magnesium and calcium chloride.

6. Buildup of oils and rubber residues on pavement surfaces and bridge decks may become slippery after the application of liquid anti-icing chemicals. If no significant precipitation has occurred within seven days, assure that these conditions do not exist prior to application.

F. BENEFITS OF ANTI-ICING:

1. Accident Reduction.
2. More rapid bare lane regain times.
3. Reduce de-icing material, labor, and de-icer residue.
4. Reduce winter clean-up work and costs.
5. Reduce accumulation of sand in drainage structures and beneath guardrails.

G. NOZZLE RECOMMENDATIONS:

1. Eight holes minimum
2. Solid Stream
3. Bar height 12-14 inches

H. QUESTION AND ANSWER

Q: Does MgCL need to dry to be effective?
A: No, It is still effective when wet.

REFERENCES

Pacific Northwest Snowfighters
http://www.wsdot.wa.gov/partners/pns/default.htm

AASHTO “Guide for snow and ice control”, 1999

FHWA “Manual of Practice for an Effective Anti-icing Program” Publication No. FHWA-RD-95-202, June 1996

A Guide for Selecting Anti-icing Chemicals Version 1.0 by Wilfrid A. Nixon and Anissa D. Williams, University of Iowa, IIHR Technical Report No. 420, October, 2001

Office of Maintenance Operations and Research
395 John Ireland Blvd., MS 722
St. Paul, MN 55155-1899
Fax: 651-296-6758

Appendix C

Mn/DOT Liquid Anti and De-ice Chemicals (including additives) Vendor Checklist for Preliminary Screening

Liquid Anti and De-ice Chemicals (including additives)
Vendor Checklist for Preliminary Screening

Minnesota Department of Transportation

Submitted by____

Date___________

Company ____

Address ____

Contact Person ______________________________Phone ( ) ______________________

To insure that chemicals for de-icing and anti-icing are evaluated for use by Mn/DOT, certain specific information is required. The following checklist has been formulated to insure that the vender and or manufacturer supply the required information. Mn/DOT intends to prescreen materials based on the information submitted prior to doing any laboratory or field evaluation. Other information may be required after the preliminary evaluation is started.

Do Not Submit Product Samples with the Pre-screen Packet, and please label any proprietary information submitted.

The following information is required both for finished products and for additives intended to enhance the performance or provide benefit to existing de-ice and anti-ice chemicals. The information received will be sent for review to the Mn/DOT Chemical Laboratory, Mn/DOT Safety Office, and the Mn/DOT Office of Environmental Services for pre-screen evaluation. **Upon request only,** a 1 gallon liquid sample or 2 pounds of the dry chemical will be made available for testing purposes.

Deicer tests will be: freezing point, solubility, ice melting capacity, ice penetration, ice undercutting, corrosive effects on metals, rapid evaluation on concrete, and frictional characteristics.

Anti-icer tests will be: freezing point, solubility, ice melting capacity, corrosive effects on metals, rapid evaluation on concrete, and frictional characteristics.

NOTE: ALL INFORMATION REQUESTED BELOW MUST BE SUPPLIED BEFORE THE PROCESS FOR PRELIMINARY SCREENING CAN BEGIN. Place a checkmark in the box when the information is placed in the preliminary test packet. Not supplying all information below will **immediately disqualify** the request for preliminary screening and further evaluation. When completed include this form in the prescreen packet.

Udated 3/15/04
1
Name of chemical/product for prescreen:
____
(**Note: A separate checklist must be completed for each product submitted. Liquid chemicals will be tested as they are received.)**

Written certification that no detectable quantities of the following chemicals are contained in the product:
Dioxins
Furans
Polychlorinated Biphenyls (PCBs)
Octachlorostyrene
Hexavalent Chromium
Polyaromatic Hydrocarbons,
Radioactive materials
Registered Pesticides

The following analyses for information purposes for liquid products or solid products that will be converted into a liquid product for application purposes. Testing of the following parameters shall be done in accordance with the testing methodology listed in the Pacific Northwest Snowfighters specifications.

Ammonia – Nitrogen
Total Kjeldahl Nitrogen
Nitrate and Nitrate as Nitrogen
Biological Oxygen Demand
Chemical Oxygen Demand
Frictional Analysis
Toxicity Testing:
Rainbow Trout or Fathead Minnow Toxicity Test
Ceriodaphnia Dubia Reproductive and Survival Bioassay
Selenastrum capricornutum Algal Growth
List of chemical constituents in product - identification and quantification

Product Data Sheet

Most recent Material Safety Data Sheet for product

Most recent Material Safety Data Sheet for corrosion inhibitor (if applicable)

Status on the Pacific Northwest Snowfighters Qualified Products List.

Recommended field application rates and application technique in chart form if available (e.g. dilution rate, pretreatment technique, etc.).

List of agencies currently using the product.

pH data (liquid products only)

No product shall be submitted unless it is at least 70% less corrosive than sodium chloride (excluding additives to salt brine) using the National Association of Corrosion Engineers (NACE) Standard TM-01-69 (1995 rev.), modified to use 30ml of a 3% chemical product solution per square inch of coupon surface area. Test data and certification that the material meets corrosion criteria must be included.

Data that states that the following concentrations are not exceeded in the finished product (If product to be purchased is premixed with salt brine, provide the following concentrations for both the salt brine alone and the finished premixed product):

Phosphorus	25.00 ppm	(Based on a 1:100 solution)
Cyanide	0.20 ppm	ppm = mg/L
Arsenic	5.00 ppm	
Copper	0.20 ppm	
Lead	1.00 ppm	
Mercury	0.05 ppm	
Chromium	0.50 ppm	
Cadmium	0.50 ppm	
Barium	10.00 ppm	
Selenium	5.00 ppm	
Zinc	10.00 ppm	

Return this form along with required information to:

Minnesota Department of Transportation
Maintenance Operations Engineer
Mail Stop 722
395 John Ireland Blvd.
St. Paul, Minnesota 55155-1899
(651) 282-2281

Shingle Creek Chloride TMDL

Appendix I
Implementation Table

TABLE I1. PRODUCT APPLICATION EQUIPMENT AND DECISIONS

CITY	CURRENT ACTIVITIES	PROPOSED BMPS/ACTIVITIES
Brooklyn Center	Dry Salt. Calibrate spreaders annually. Weather dependent decisions. Use MnDOT pavement sensors (RWIS) and hand held sensor. Turnover = 11 years.	Annual/on-going process. Investigate alternatives such as Clear Lane. Evaluate prewetting in sensitive areas. Implement if funds available.
Brooklyn Park	Dry salt. Calibrate spreaders annually Weather dependent application. Monitor Mn/DOT pavement sensors. Turnover = 15 years	Investigate alternatives such as prewetting. Improve driver training.
Crystal	3:1 dry sand/salt mixture. <0 degrees for Clear Lane. Turnover = 14 years.	
Maple Grove		
Minneapolis	3:1 dry salt/sand mixture on residential, curves, intersections, and hills. Anti-ice mix, Clear Lane, Salt. Turnover = 15 years.	Research into new products and appropriate BMPs.
Minneapolis Parks	Use straight sand on walking paths and parking lots. Rely on City of Minneapolis for salt when necessary.	Considering pilot project to test anti-icing materials.
New Hope	2:1 salt/sand. Computerized sanders. Truck temperature sensors - air and pavement. Turnover = 12 years.	Annual calibration of spreaders. Continued research.
Osseo	2:1 salt/sand. Use Clear Lane in mixture applied at all intersections, curves and slight inclines. Operators use judgment based on current and future weather conditions. Turnover when Council deems necessary.	Annual calibration of spreaders.
Plymouth	Prewetted on most trucks. $MgCl_2$ on bridges. One hand-held temp sensor. Follow MnDOT temp guidance. Turnover = 14 years.	All trucks prewetting in 10 years. Add a couple of brine units/year. Try treated salt (Clear Lane) Calibrate annually.
Robbinsdale	Dry salt/sand mixture. Turnover = 7 years. Not calibrated.	Interested in EPOKE. May recommend as part of capital budget. Calibrate spreaders annually. Review CIP for salt storage and application technologies.
Hennepin County	Snow and Ice Control Manual used to set policy for: 1. Use of straight salt, treated salt, or salt sand mix dependent upon ADT volumes, temperature, and weather conditions. 2. Rates of product and ratio of salt/sand mixture to be used for given ADT volumes, temperature and weather conditions. 3. Level of service based on end of storm. Equipment consists of tandem and single axle trucks equipped with tailgate or hopper sanders Foreman and Supervisors' trucks and select plowing equipment are equipped with ambient and pavement temperature sensors	Begin an anti-icing program for bridges and select roadway areas. Money budgeted for 2006, use to occur on third shift. Purchase of 2- 2,500 to 3,000 gallon tanker trucks for anti-icing application. Equip all application trucks with AVL and ability for automated data capture. Fleet turnover 10 years

TABLE I2. PRODUCT STOCKPILES
How stored and maintained? What improvements can be made?

CITY	CURRENT ACTIVITIES	PROPOSED BMPS
Brooklyn Center	Enclosed bldg on impervious surface; drains to pond.	At MEP.
Brooklyn Park	Enclosed bldg on impervious surface, minimal runoff - goes to pond, spillage pushed back into bldg.	At MEP.
Crystal	Enclosed bldg, half of runoff goes to drainage pond.	Future, improve runoff detention w/better pond facility. Working on it now.
Maple Grove	Covered on asphalt.	
Minneapolis		
Minneapolis Parks	Use City of Minneapolis' stockpiles.	
New Hope	Enclosed bldg on impervious surface, detention pond.	At MEP.
Osseo	No salt storage in watershed. Covered on asphalt. Spillage pushed back into shed.	Hennepin County is building a new facility in 2005 where the City will store the bulk of its material.
Plymouth	Facility is outside watershed	
Robbinsdale	Salt and sand piles on impervious surface, tarped.	Salt shed in 2005 budget.
Hennepin County	All storage areas are in enclosed buildings with impervious floors Runoff from loading area goes to storm sewer connections Loading area spills are pushed back into building	

TABLE I3. OPERATOR TRAINING
Current training practices? How to improve?

CITY	CURRENT ACTIVITIES	PROPOSED BMPS
Brooklyn Center	Annual driver training. Review application procedures with drivers after each event.	Consider outreach training (LTAP) if funds available.
Brooklyn Park	Attend annual snow plow/ice control meeting. Talk to drivers who use more salt.	Provide additional training.
Crystal		
Maple Grove		
Minneapolis	Vendors, Mn/DOT, LTAP, and internal trainers review, bring to and discuss practices and methods or material applications with the work force.	Additional training is always a need as equipment and material practices change.
Minneapolis Parks		Annual operator training. Establish in-house written procedures.
New Hope	Operators use their own judgment. Have sensors in truck. Need to retrain and calibrate every year	
Osseo	None.	Provide additional training.
Plymouth		Improve driver training. Need training by vendors. Remind drivers how much salt they're using.
Robbinsdale		
Hennepin County	Annual driver training with equipment vendors for proper calibration of equipment. Operators attend annual snow and ice control district meetings. Management reviews application data with operators that appear to be using the product incorrectly	Automate the gathering of data through the use of AVL Develop additional annual training with MnDot, and LTAP

TABLE I4. CLEAN-UP / SNOW STOCKPILING
How is snow handled? What changes proposed in future?

CITY	CURRENT ACTIVITIES	PROPOSED BMPS
Brooklyn Center	Plow ASAP, No hauling unless problematic. Sweep ASAP in spring and fall.	Evaluate annually.
Brooklyn Park	Plow ASAP, no hauling. Sweep ASAP in spring	Evaluate annually.
Crystal	Plow ASAP. Haul from some cul-de-sacs - goes to old field at airport. Little/no salt content. Sweep 5-6 times annually, in spring ASAP.	Evaluate annually.
Maple Grove	Haul snow. Vacuum sweep 2x/year. Other sweeping thru-out year including winter.	Evaluate annually.
Minneapolis	Arterials plowed immediately, residential next day. Spring/fall comprehensive sweeping. Actually sweep 5-6 times/year. Parkways on 11 to15-day cycle. Watersheds on 30-day cycle. Critical watersheds regenerative sweeper. Tier system.	Evaluate annually.
Minneapolis Parks	No hauling and no stockpiling. Vacuum sweep all year long. Sweep along parkway if city can't.	Evaluate annually.
New Hope	Plow ASAP. Minimal hauling. Sweep spring & fall, early window in spring (contracted).	Evaluate annually.
Osseo	Plow ASAP. Haul snow off of Central and intersections along 81. Piled on field behind Elementary School. Sweep streets 5-6 times a year. Central done ASAP in Spring and then monthly.	Evaluate annually.
Plymouth	Plow ASAP. Plows active during storms. No hauling. Sweep ASAP, annually. Broom works all year long after storms. Vacuum-assisted sweeping.	May have to haul downtown. Evaluate annually.
Robbinsdale	Plow ASAP; have two areas for stockpiling. Sweep 4x/year.	Evaluate annually.
Hennepin County	Plow ASAP No hauling unless requested by city Will clear bridge decks of snow but dispose of on roadside area Annually sweep all needed roadway areas Clean silt traps in various catch basins	Evaluate annually

TABLE I5. ONGOING RESEARCH RE SALT ALTERNATIVES

How is new technology tracked?

CITY	CURRENT ACTIVITIES	PROPOSED BMPS
Brooklyn Center	Network w/other organizations re new products. Monitor new products/equipment - Clear Lane.	Continue monitoring of new products and equipment for effectiveness (Mn/DOT, MSSA, Vendors)
Brooklyn Park	Try new products/equipment - Clear Lane. Shed for prewetting.	
Crystal	Check out electronic controls on sanders.	
Maple Grove	Has tried several new products. Future: No change.	
Minneapolis	Mn/DOT does deep research, City actively researches. Has limited lab. Research Clear Lane – Current research= does the product do what it claims -- determine if better/worse than what we're currently doing/using. Determine where to do BMPs -- is it giving us bang for the buck? Looking to partner w/St. Paul. $MgCl_2$ truck.	Continue research department. Research Clear Lane.
Minneapolis Parks	Use City of Minneapolis' research.	Considering pilot project to test anti-icing materials.
New Hope	Investigate new products, equipment, and methods.	Will probably try Clear Lane next year.
Osseo	None.	Investigate and monitor new products, equipment, and methods.
Plymouth	Investigate new products, equipment, and methods.	Try new products as feasible.
Robbinsdale		Monitor new products/equipment.
Hennepin County	Attend conferences to stay current on technology and monitor technical publications and trade journals Investigate and try new products, equipment and methods Network with other agencies	