Seattle Public Utilities

# Snow & Ice Control and the Aquatic Environment Report

**September 3, 2009**

**Contact for further information**

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**684-7935**

## Executive Summary

The objective of this report is to provide SDOT with information about the potential risks to the aquatic environment from SDOT's updated draft approach for snow and ice control (SDOT, 2009).

This evaluation is intended to assist SDOT in balancing environmental risks with providing the safest possible transportation system and maximum mobility for the traveling public during snow and ice conditions, within reasonable budget, product performance and environmental constraints.

Major findings of this assessment include:

1. Substantial areas of the City, including downtown, where street runoff flows to Puget Sound, to large lakes or to a wastewater treatment plant may be treated with chloride-based snow and ice control products with little or no risk of impacting aquatic organisms.
2. Use of chloride-based snow and ice control materials could have a negative impact on aquatic environments under extreme conditions. Freshwater systems with low dilution potential, such as creeks and wetlands, are most sensitive to these inputs. Salmon-bearing creeks (i.e., Major Creeks) are of special concern.
3. The risk of use of salt under expected environmental conditions is relatively low, consistent with other studies.
4. EPA has established chronic and acute threshold levels that can be used to judge when chloride levels could be harmful to aquatic life.
5. The primary value of the chloride model is to show tendencies, trends and relative risk. Numerous, conservative (i.e., tending towards worse case) assumptions were made in the model. The model allowed evaluation of potential impacts of repeated application, application rates, runoff rates and flow to show their relative significance in determining levels of chloride in specific streams. Actual chloride levels in streams can only be known through field verification and will vary considerably from one storm event to another. Output values from this modeling exercise have not been confirmed through field testing, so these values should be considered as approximations only.
6. Risk increases under certain conditions, some of which may be exclusive of one another:
    a. Accumulating amount of chloride due to repeated treatments,
    b. Rapid meltoff,
    c. Low flow conditions.
7. Thornton Creek, followed by Longfellow Creek, has the highest potential for impacts due to the density and length of Snow & Ice routes within the creek watershed.
8. Risk of impact of chloride- based treatments would be reduced with:
    a. Higher flows,
    b. Gradual meltoff,
    c. Selective use of anti-icing and deicing treatments,
    d. Use of alternative anti-icing and deicing materials.
9. Under application rates provided by SDOT, brine treatments are expected to result in lower chloride concentrations in creeks than would solid NaCl treatments due to the amount of chloride applied to the roadway per treatment.

10. Sand can have long-term degrading effects on stream habitat quality and aquatic biota.
11. Glucose has the potential of increasing demand for oxygen in receiving waters, but the levels that would be applied appear to be too low to lower dissolved oxygen levels in streams.
12. Use of products that meet Pacific Northwest Snowfighters (PNS) specifications will help to minimize risk of unintentionally introducing other pollutants.

## Introduction

The objective of this technical memo is to provide SDOT with information about the potential risks to the aquatic environment from SDOT's updated draft approach for snow and ice control (SDOT, 2009). This includes information on:

- proposed SDOT snow and ice route segments that drain to Seattle's sensitive receiving water bodies (i.e., Seattle creeks and wetlands),
- potential aquatic impacts of proposed snow and ice control materials (chloride, glucose, and sand) on Seattle's sensitive receiving water bodies, and
- snow and ice control product specifications related to environmental concerns

This memo and related attachments are intended to assist SDOT in balancing environmental risks with providing the safest possible transportation system and maximum mobility for the traveling public during snow and ice conditions, within reasonable budget, product performance and environmental constraints.

## Summary of Findings and Recommendations

<u>Sensitive Receiving Waters</u>

- Effects of anti-icing and deicing treatments proposed by SDOT are unlikely to exceed accepted threshold concentrations of chloride under conditions commonly seen in Seattle and at treatment levels projected by SDOT for these conditions.
- It is important to recognize what areas are most sensitive to winter deicing and anti-icing treatments and what environmental factors can influence potential impacts on receiving waters. Under certain extreme and unlikely conditions, snow and ice control materials proposed by SDOT could have a negative impact on aquatic environments. Freshwater systems with low dilution potential (i.e., creeks and wetlands) are most sensitive to these inputs. Salmon-bearing creeks (i.e., Major Creeks) are of special concern. (Attachment A).
- Snow and ice control procedures on roadways that drain to these sensitive waters should consider the risk factors presented in this report. SPU has provided maps which indicate Snow & Ice route segments that drain to sensitive waters (i.e., Major Creeks (salmon bearing), Minor Creeks (non-salmon bearing), and wetlands) (Attachment B).
- Snow and ice control scenarios proposed by SDOT pose little or no risk to saltwater systems and large freshwater systems due to dilution and/or salinity (Attachment B). Likewise, SDOT's deicing and anti-icing activities in areas draining to combined pipe systems in the city do not pose a risk to the aquatic environment.

<u>Salt and Potential Aquatic Risks</u>

- In freshwater systems with relatively low dilution potential (i.e. sensitive waters), chloride concentrations can be elevated as a result of snow and ice control activities involving salt. Studies on the effects of salt on receiving water bodies have mostly been undertaken in areas where severe winter conditions exist and where salt application occurs more frequently and salt accumulates over a longer period than would be encountered in Seattle. In the absence of relevant literature to Seattle, a simple, mass-balance model was developed using local data to generate estimates of chloride concentrations in specific streams. The model is only a rough estimate given the uncertainty and unlimited possibilities regarding treatment scenarios, washoff extent and duration, and creek flows – all items which are highly dependent on weather conditions, among other factors. Model results have not been field verified so it is not known how closely the model would reflect actual values. The primary value of the simple model was to show sensitivity and relative impact of changes in conditions such as flow, melt-off period, treatment and frequency of treatment.

- The simple, conservative (i.e., tending towards worst-case) model developed for the four Major Creeks (Thornton, Piper's, Longfellow and Fauntleroy creeks) that receive drainage from the Snow & Ice route roadways evaluates the risk to the aquatic environment associated with estimated chloride concentrations in the creek from various SDOT treatment scenarios at various washoff durations during typical (i.e., mean) winter stream flows (Attachments C1 & C2). Risk was evaluated by comparing estimated chloride concentrations for a scenario to acute and chronic standards (WAC 173-201A-240). Standards are not to be exceeded more than once every three years for chloride; however, the risk of a scenario occurring more than once every three years was not evaluated as part of this report. This analysis indicated that Thornton Creek, followed by Longfellow Creek, was the most sensitive to salting activities. Creek sensitivity is directly related to the density and length of Snow & Ice Routes within the creek watershed. At typical winter streamflows, the analysis also indicated:
    - Chloride concentrations were not a concern for typical deicing scenarios provided by SDOT for "light freezing conditions overnight" and "brief snowfall followed by rain."
    - Chloride concentrations were not a concern for Liquid Anti-Ice application scenarios.
    - Chloride concentrations were not a concern for the friction Sand:solid NaCl application scenarios.
    - Use of solid NaCl results in greater risk of exceeding chloride standards as the number of treatments prior to a meltoff increases. This was particularly evident for snow routes in Thornton and Longfellow creek basins.
- To evaluate how risk associated with SDOT treatment scenarios changed during extremely low and high creek flows, a sensitivity analysis was performed (Attachments C1 & C3). Extremely low flows were calculated using the minimum mean daily flow from December through February for the period of record for each creek. While these flows would be very unlikely, particularly during a meltoff event, they were used to illustrate how risk changes as flows decrease. Similarly, winter storm flows, as calculated using one-half of the maximum daily flow from December through February for the period of record, were used to illustrate the impacts of increased flow on risk of exceeding chloride thresholds. Higher flows reduce the risk of exceeding chloride thresholds. However, as flow decreases to extremely low levels, the model predicts that risks of exceeding chloride standards associated with certain scenarios and conditions could increase. Additional care may be needed at very low flows under the following scenarios:
    - Brief meltoff period, particularly in Thornton Creek.
    - Friction sand:solid NaCl application in Thornton Creek.
    - Solid NaCl applications in Thornton Creek or
    - Solid NaCl application associated with a relatively short washoff period or repeated NaCl applications in Longfellow Creek and Piper's Creek.
- To minimize salt impacts to sensitive receiving waters, it is recommended that the Snow and Ice Control Implementation Plan:

- Include consideration of the risk factors identified in this report in defining a treatment plan that balances public safety and environmental health. The use of salt for icing and deicing represents little or no risk under expected conditions and application scenarios; however, some flexibility should be maintained to respond to certain extreme conditions that would elevate risk to the aquatic environment.
- Include a recommendation to monitor at least one of the most sensitive receiving water bodies to better evaluate actual (vs. modeled) risk to aquatic habitats, and
- Specify that the least material possible should be applied that will meet snow & ice control objectives, especially in areas that drain to sensitive receiving waters. This is recommended for all materials, not just salts.

Sand and Potential Aquatic Impacts

- Fine sediment associated with road sanding can have negative impacts on aquatic ecosystems. Therefore, the use of sand should be minimized on roads that drain to sensitive aquatic ecosystems. Additionally, sand should be removed from road surface via street sweeping or other methods as soon as feasible after snow and ice conditions end (Attachment D).

Glucose and Potential Aquatic Impacts

- Glucose has the potential to increase demand for oxygen in receiving waters. The levels that would be applied in scenarios evaluated appear to be too low to lower dissolved oxygen levels in streams (Attachment E).

Product Specification – Environmental Attributes

- Snow and ice control materials often include additives or impurities which can be a concern to the aquatic environment. It is recommended that SDOT use Pacific Northwest Snowfighters (PNS) qualified products. Alternatively, SDOT should have an established quality testing process that utilizes PNS or similar specifications for environmental contaminants of concern (Attachment F).

Findings and recommendations presented above are based on analysis and background information summarized in the follow attachments to this memo:

**Attachment A**. **Aquatic Impacts of Snow & Ice Control Methods -** brief review of relevant literature

**Attachment B. Major Creeks, Minor Creeks, and Wetlands Drainage Basins and Snow & Ice Routes**

**Attachment C. Salt and Potential Aquatic Impacts**

**C1. Conservative Chloride Analysis – Typical Scenarios**

**C2. Conservative Chloride Analysis - Various Scenarios – Typical Conditions**

**C3. Conservative Chloride Analysis - Various Scenarios – Sensitivity Analysis**

**Attachment D. Sand and Potential Aquatic Impacts**

**Attachment E. Glucose and Potential Aquatic Impacts**

**Attachment F. Product Specification – Environmental Attributes**

## References

Seattle Department of Transportation (SDOT), 2009. Draft Memo: Alternative Scenarios, SDOT ANTI_ICING & DEICING PRACTICES. From Paul Roberts, SDOT Street Maintenance Manager. June 16, 2009. 1 p.

**Attachment A. Aquatic Impacts of Snow and Ice Control Methods** – Brief Review of Relevant Deicing Literature

Roadway runoff from deicing activities may impact freshwater streams, lakes and wetlands in Seattle. The biggest concern for Seattle's waterways is the potential impact on salmon and trout species in Thornton, Piper's, Longfellow, Fauntleroy and Taylor creeks. Deicing activities pose little risk to saltwater systems and large freshwater systems due to the existing salinity and high dilution potential of these receiving waters.

Chloride is present in salt-based deicing compounds. Elevated chloride concentrations may interfere with aquatic organism survival, growth or reproduction. Sand used on roads as a friction agent may also impact freshwater communities by decreasing habitat quality. Other additives in deicing compounds may also impact freshwater organisms. The following issues and references on this subject were found to be pertinent to the evaluation of chloride on Seattle's freshwater systems.

*What is known about the impact of salting roadways on freshwater life?*

The impacts of road deicing activities on instream organisms are well documented in the literature. Most freshwater organisms can tolerate some changes in chloride concentrations. However, aquatic life including salmon, trout and macroinvertebrates that live in Seattle's streams could be impacted by road deicing applications, if chloride concentrations in receiving waters are high enough. In general, fish eggs, embryos and fry are the most sensitive life history stages to salt (James et al. 2003, Environment Canada 2001). For salmon, these life stages may be present in Seattle's creeks during the months when deicing is most likely. Trout spawn in the spring and are less likely to be affected.

Sporadic, low-level or short-term deicing activities generally have not been found to impact fish or macroinvertebrate communities. The chronic toxicity threshold for chloride is 230 mg/L for a 4-day average concentration not to be exceeded more than once every three years on the average. The acute threshold is 860 mg/l for a 1-hour average concentration not to be exceeded more than once every three years on the average (WAC 173-201A-240).[1]

Volume, flow, runoff and receiving water flushing are important in the ability of a system to receive chloride runoff without harming aquatic organisms (NCHRP 2007). For example, short-term exposure to road salt from deicing processes did not significantly affect stream macro-invertebrate communities (e.g., Blasius and Merrit 2002). A creek adjacent to Highway 97 in eastern Washington was studied after a liquid deicer was applied to the roadway. The study revealed that no degradation in water chemistry or macroinvertebrate communities occurred (Yonge and Marcoe 2001). Furthermore, Montana Department of Transportation (MDT) testing in three streams adjacent to highways where deicing materials were applied showed increased chloride in the creeks (MDT 2004). However, 36 mg/l chloride was the highest level found in streams adjacent to deiced highways, and levels were most frequently under 15 mg/l (MDT

[1] These numbers were established and verified through toxicity testing on several aquatic organisms. See New Hampshire DES 2007 for more details.

2004). These levels were well below the chloride thresholds for chronic or acute toxicity. A Michigan DOT study found deicer runoff could be toxic to aquatic organisms in streams with very low flow or extensive wetlands and ponds (as cited in MDT 2004). However, in urban areas that use salt extensively to manage heavy snowfall and where the majority of runoff occurs in spring, the chloride thresholds can be exceeded. Shingle Creek, in Minneapolis, Minnesota, is listed as impaired for chloride and has a TMDL (Wenck 2006).

The effects of salt use for anti-icing and deicing are influenced by the amounts of chloride entering receiving waters and the dilution effect of the receiving waters. Concentration thresholds have been established and serve as reference levels for evaluating the risk of applying salt on roadways to aquatic organisms. Most studies on the effects of salt occur where salt application occurs more frequently due to severe winter weather conditions. In these areas, deicing salt also accumulates over a longer period than would be encountered in Seattle.

*What is known about the impact of sanding roadways on freshwater life?*

In some situations, sanding may be more harmful to freshwater communities than chemical deicers. As sand moves into streams from roadways, it can degrade instream habitat, increase turbidity and may transport other pollutants to receiving waters. Sand blocks interstitial spaces within stream substrates interfering with egg incubation and macroinvertebrate habitat.. Sand was cited as being of greater concern to the Montana DEQ than deicers are (MDT 2004). The MDT (2004) found decreases in the diversity and productivity of aquatic ecosystems at some sites with inflow of highway runoff containing sediment (Buckler and Granato 1999). Particle sizes less than two mm can block movement of oxygen into streambed gravels (where salmon and trout eggs are). NCHRP (2007) reports that sand runoff to streams can result in partial or complete burial of invertebrate leaf packs, which impacts invertebrate activity, colonization and feeding. Three sand application guidelines help to reduce the negative impacts of sanding on streams: reduce application, recover the sand through street sweeping and capture the runoff using structural treatment facilities (BMPs) that may already be in place (MDT 2004).

*What is known about the impact of other deicing chemicals on freshwater communities?*

When a deicer contains product that is high in carbon content, such as molasses, there is the potential to have high biochemical oxygen demand (BOD) in receiving waters. An increase in BOD in receiving waters can cause low-oxygen conditions for aquatic organisms (NCHRP 2007**.** Yonge and Marco (2001) found that BOD associated with a liquid deicer did not increase to levels that would impact aquatic life. However, dilution is important. High BOD is most likely in deep pools, ponds or lakes, where mixing is minimal (NCHRP 2007).

## References

Blasius, B. J. and R. W. Merritt. 2002. Field and laboratory investigations on the effects of road salt (NaCl) on stream macroinvertebrate communities. Environmental Pollution 120: 219–231.

Buckler and Granato 1999. Assessing biological effects from highway-runoff constituents: U.S. Geological Survey Open File Report 99-240, 45 p. http://ma.water.usgs.gov/fhwa/products/ofr99-240.pdf

Environment Canada. 2001. Priority Substances List Assessment Report: Road Salts. 170 p. http://www.hc-sc.gc.ca/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/contaminants/psl2-lsp2/road_salt_sels_voirie/road_salt_sels_voirie-eng.pdf

Idaho Department of Environmental Quality (IDEQ). 2008. A Preliminary Evaluation of Road Deicing Chemical Concentrations in North Idaho Streams Adjacent to Interstate 90 That Drain Fourth of July Pass. 39 p.

James, K.R., B. Cant, and T. Ryan. 2003. Responses of freshwater biota to rising salinity levels and implications for saline water management: a review. Australian Journal of Botany 51: 703–713.

Montana Department of Transportation (MDT). 2004. Recommendations for Winter Traction Materials Management on Roadways Adjacent to Bodies of Water. 88 p. http://www.mdt.mt.gov/research/docs/research_proj/traction/final_report.pdf

National Cooperative Highway Research Program (NCHRP). 2007. Guidelines for the Selection of Snow and Ice Control Materials to Mitigate Environmental Impacts. NCHRP Report 577. Washington DC. 211 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_577.pdf

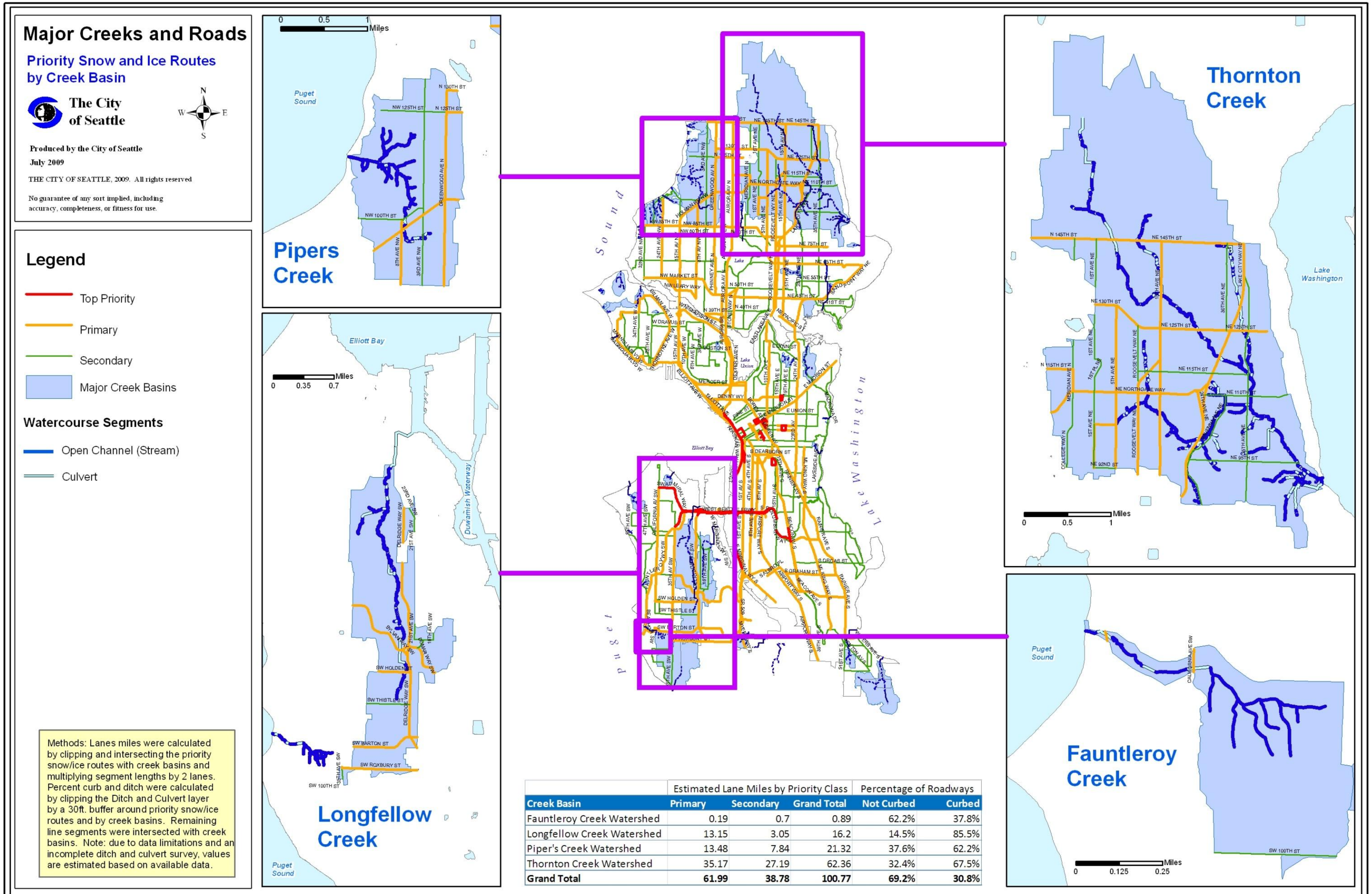
New Hampshire Department of Environmental Services (DES). 2007. Hazard Identification for Human and Ecological Effects of Sodium Chloride Road Salt. 15 p. http://www.rebuildingi93.com/documents/environmental/Chloride%20TMDL%20Toxicological%20Evaluation.pdf

Novotny, V., D. W. Smith, D. A. Kuemmel, J. Mastriano and A. Bartosova. 1999. Urban and Highway Snowmelt. Minimizing the Impact on Receiving Water. Water Environment research Foundation Project 94-IRM-2.

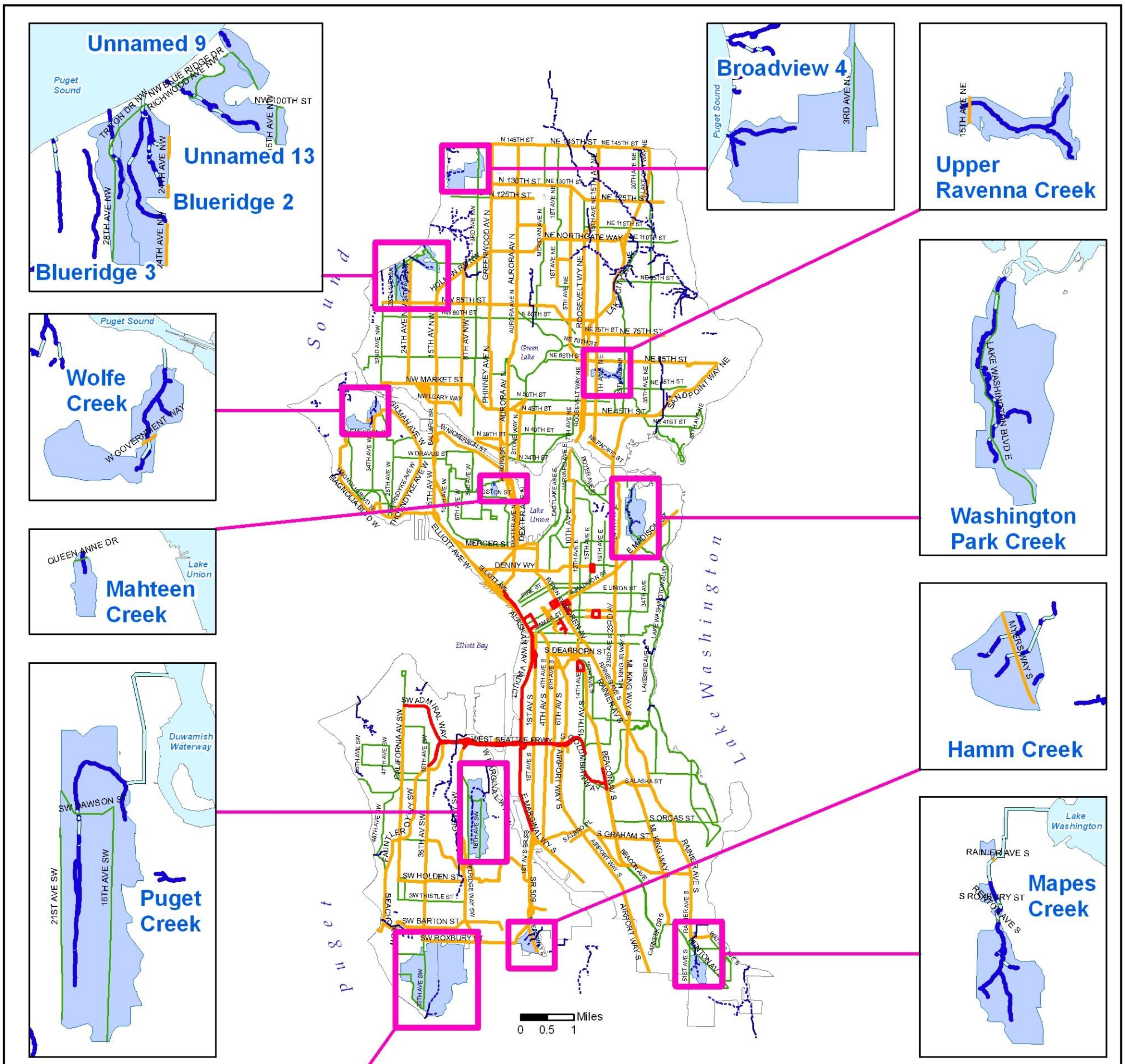
Wenck Associates, Inc., 2006. Shingle Creek Chloride TMDL Report. Prepared for: Shingle Creek Water Management Commission and Minnesota Pollution Control Agency. Wenck File #1240-34. December 2006. 83pp. http://www.pca.state.mn.us/publications/wq-iw8-02g.pdf

Yonge, D. and N. Marcoe. 2001. An Evaluation of the Impacts of Highway Deicers on Peshastin Creek. Washington State Transportation Center (TRAC), Washington State University. Research Project T1804-2. April. 93 p. http://www.wsdot.wa.gov/research/reports/fullreports/500.1.pdf

**Attachment B. Major Creeks, Minor Creeks, and Wetlands Drainage Basins and Snow & Ice Routes**




| | Estimated Lane Miles by Priority Class | | | Percentage of Roadways | |
|---|---|---|---|---|---|
| **Creek Basin** | **Primary** | **Secondary** | **Grand Total** | **Not Curbed** | **Curbed** |
| Fauntleroy Creek Watershed | 0.19 | 0.7 | 0.89 | 62.2% | 37.8% |
| Longfellow Creek Watershed | 13.15 | 3.05 | 16.2 | 14.5% | 85.5% |
| Piper's Creek Watershed | 13.48 | 7.84 | 21.32 | 37.6% | 62.2% |
| Thornton Creek Watershed | 35.17 | 27.19 | 62.36 | 32.4% | 67.5% |
| **Grand Total** | **61.99** | **38.78** | **100.77** | **69.2%** | **30.8%** |





| | Estimated Lane Miles by Priority Class | | | Percentage of Roadways | |
|---|---|---|---|---|---|
| **Creek Basin** | **Primary** | **Secondary** | **Grand Total** | **Not Curbed** | **Curbed** |
| Blue Ridge 2 Watershed | 0.7 | 0.34 | 1.04 | 57.7% | 42.3% |
| Blue Ridge 3 Watershed | 0 | 1.29 | 1.29 | 54.5% | 45.5% |
| Broadview 4 Watershed | 0 | 1.02 | 1.02 | 42.0% | 58.0% |
| Hamm Creek Watershed | 0.89 | 0 | 0.89 | 67.2% | 32.8% |
| Mahteen Creek Watershed | 0 | 0.13 | 0.13 | 0.0% | 100.0% |
| Mapes Creek Watershed | 0 | 0.03 | 0.03 | 0.0% | 100.0% |
| Puget Creek Watershed | 0 | 4.62 | 4.62 | 21.3% | 78.7% |
| Ravenna (Upper) Creek Watershed | 0.24 | 0 | 0.24 | 100.0% | 0.0% |
| Seloa Beach Creek | 0 | 4.42 | 4.42 | 43.6% | 56.4% |
| Unnamed 13 Watershed | 0 | 1.39 | 1.39 | 64.1% | 35.9% |
| Unnamed 9 Watershed | 0 | 0.31 | 0.31 | 87.0% | 13.0% |
| Washington Park Watershed | 0 | 2.26 | 2.26 | ~ 0% | ~ 100%* |
| Wolfe Creek Watershed | 0.14 | 0 | 0.14 | 0.0% | 100.0% |
| **Grand Total** | **1.97** | **15.81** | **17.78** | **57.0%** | **43.0%** |

* Washington Park contains Lake Washington Blvd, a priority snow/ice route which is mostly but not completely "hard" edge.
Note: Madrona Creek Watershed contains .0019 of secondary priority lane miles, but was not included in this map.

## Minor Creeks and Roads

**Priority Snow and Ice Routes by Creek Basin**

The City of Seattle

Produced by the City of Seattle
July 2009



**Legend**

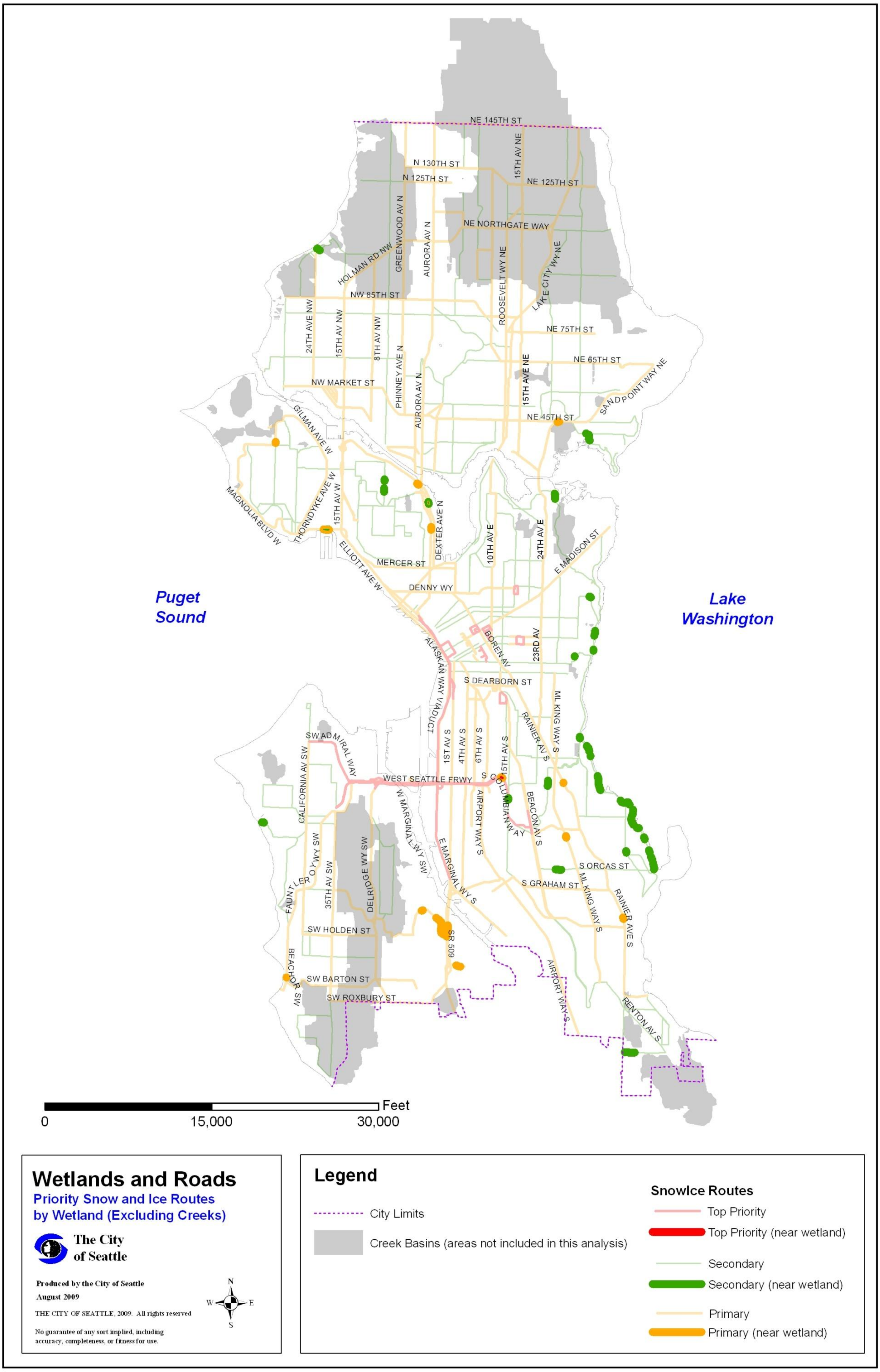
**Priority Snow and Ice Routes**
- Top Priority
- Primary
- Secondary

**Watercourse Segments**
- Open Channel (Stream)
- Culvert

Insets Scale: 0 0.25 0.5 Miles

Minor Creek Basins Containing Priority Roads

Methods: Lanes miles were calculated by clipping and intersecting the priority snow/ice routes with creek basins and multiplying segment lengths by 2 lanes. Percent curb and ditch were calculated by clipping the Ditch and Culvert layer by a 30ft. buffer around priority snow/ice routes and by creek basins. Remaining line segments were intersected with creek basins. Note: due to data limitations and an incomplete ditch and culvert survey, values are estimated based on available data.


Wetlands and Roads
Priority Snow and Ice Routes
by Wetland (Excluding Creeks)
The City of Seattle
Produced by the City of Seattle
August 2009
THE CITY OF SEATTLE, 2009. All rights reserved
No guarantee of any sort implied, including accuracy, completeness, or fitness for use.
N
W
E
S
Legend
City Limits
Creek Basins (areas not included in this analysis)
SnowIce Routes
Top Priority
Top Priority (near wetland)
Secondary
Secondary (near wetland)
Primary
Primary (near wetland)
Feet
0
15,000
30,000
Puget Sound
Lake Washington
NE 145TH ST
N 130TH ST
N 125TH ST
NE 125TH ST
15TH AV NE
NE NORTHGATE WAY
GREENWOOD AV N
AURORA AV N
HOLMAN RD NW
LAKE CITY WY NE
ROOSEVELT WY NE
NW 85TH ST
NE 75TH ST
24TH AVE NW
15TH AV NW
8TH AV NW
PHINNEY AVE N
NE 65TH ST
SANDPOINT WAY NE
15TH AVE NE
NW MARKET ST
AURORA AV N
NE 45TH ST
GILMAN AVE W
MAGNOLIA BLVD W
THORNDYKE AVE W
15TH AV W
DEXTER AVE N
10TH AV E
24TH AV E
E MADISON ST
ELLIOTT AVE W
MERCER ST
DENNY WY
ALASKAN WAY VIADUCT
BOREN AV
23RD AV
S DEARBORN ST
ML KING WAY S
RAINIER AV S
SW ADMIRAL WAY
1ST AV S
4TH AV S
6TH AV S
15TH AV S
CALIFORNIA AV SW
WEST SEATTLE FRWY
S COLUMBIAN WAY
W MARGINAL WY SW
AIRPORT WAY S
BEACON AV S
DELRIDGE WY SW
E MARGINAL WY S
S ORCAS ST
S GRAHAM ST
ML KING WAY S
RAINIER AVE S
FAUNTLEROY WY SW
35TH AV SW
SW HOLDEN ST
SR 509
BEACH DR SW
SW BARTON ST
SW ROXBURY ST
AIRPORT WAY S
RENTON AV S

**Attachment C1. Conservative Chloride Analysis – Typical Scenarios**

**Method**

A simple, spreadsheet model was developed to roughly estimate conservative (i.e., tending toward worse case) chloride concentrations for the four Major Creeks that receiving drainage from the Snow & Ice Route roadways (i.e., Thornton, Longfellow, Piper's, and Fauntleroy creeks). The model helps evaluate the risk to the aquatic environment associated from salting activities by providing conservative estimates of chloride concentrations in the creek from typical SDOT treatment scenarios at various washoff durations. Estimated chloride concentrations are compared to EPA's acute and chronic standards for chloride (WAC 173-201A-240) listed below:

**Acute Standard,** a 1-hour average concentration not to be exceeded more than once every three years on the average = 860 mg/L;

**Chronic Standard,** a 4-day average concentration not to be exceeded more than once every three years on the average = 230 mg/L.

Chloride concentrations were considered a potential concern if they were greater than the acute standard or greater than the chronic standard concentration for a washoff period of four days. The model did not consider whether the scenario was likely to occur more than once every three years.

The model estimated chloride concentrations by calculating the chloride load accumulated on the roadway in the creek drainage basin as a result of SDOT snow & ice control material for that scenario. Chloride load accumulated was based on the number of applications, application rate, and application routes for the snow and ice control material. This chloride volume was then diluted by the volume of water that passed through the creek during the washoff duration. The volume of water passing through the creek was determined by multiplying the creek flow rate by the washoff duration.

**Inputs**

**Snow and Ice Control - Typical Scenarios**

SDOT provided two typical application scenarios for evaluation: a scenario for "light freezing conditions overnight" and "brief snowfall followed by rain." The first scenario consisted of one application of 20 gallons (gal)/lane mile (LM) of liquid anti-ice on high priority and primary routes. The second scenario consisted of one application of solid NaCl (75 lbs/LM) prewet with liquid anti-ice (4 gal/LM). Chloride concentrations in snow and ice control materials were calculated from MSDS sheets or SDOT-provided information.

**Assumptions**

**Creek Flow Rates**

As part of the simple model, the following creek flow rates were evaluated:

**Winter Mean Flow** = Average mean daily flow from December through February for the period of record. This is intended to represent typical winter flows.

**Winter Minimum Flow** = Minimum mean daily flow from December through February for the period of record. This extremely low flow is intended to represent the unlikely worst case scenario.

**One-half Winter Maximum Flow** = One-half of the maximum mean daily flow from December through February for the period of record. This is intended to represent flow during larger winter storm events.

Creek flow estimates are based on the daily average of continuous 5-min flow data from December through February during the period of record for SPU data recorders that represent flow near the mouth of the creek. Amount of data varies between creeks. See Attachments C1, C2 and C3 for further information.

**Washoff Extent and Duration**

Several simple, conservative assumptions were made regarding washoff extent and duration. It was assumed that chloride load accumulated on the roadway until the washoff period. It was assumed that 80% of the chloride load applied to the roadway was washed off into the creek. The remaining 20% was assumed to be retained on the road, in vegetated areas, or in the drainage system. It was assumed that the chloride load washed off uniformly throughout the washoff duration. It was assumed that typical washoff durations for the Seattle area were between 6 and 96 hours.

**Results**

Model results are shown in two tables for each creek in this section.

**Discussion**

Model results from this conservative analysis indicate:

- At typical winter stream flows, chloride concentrations were not a concern for typical deicing scenarios provided by SDOT for “light freezing conditions overnight” and “brief snowfall followed by rain” (Tables C1-A through C1-H).
- During extremely low flow conditions, chloride concentrations may be a concern for typical deicing scenarios provided by SDOT for “light freezing conditions overnight” and “brief snowfall followed by rain” associated with a relatively short washoff period in Thornton Creek (Tables C1-A and C1-B).

Note that concern (“risk”) associated with chloride concentrations was assessed by comparing conservative estimates of chloride concentrations in the creek to acute and chronic water quality standards. These standards are not to be exceeded more than once every three years on the average. The average three year frequency is not considered in the model but may be a factor for SDOT when evaluating approaches to infrequent storm events.

# Conservative[1] Analysis of Typical SDOT Deicing Scenarios

## Thornton Creek

| | | |
|---|---|---|
| Lane Miles (LM) Sand and Ice | 62 | **WDOE WQ Standards:** |
| Lane Miles (LM) Friction | 18.2 | Chronic: 230 mg/L. A 4-day average concentration not to be exceeded more than once evey three years on the average |
| Lane Miles (LM) High | 0 | |
| Lane Miles (LM) Primary | 35.2 | Acute: 860 mg/L. A 1-hour average concentration not to be exceeded more than once evey three years on the average (WAC 173-201A-240). |
| Lane Miles (LM) Secondary | 27.2 | |
| Percent of salt runoff to reach receiving water | 80% | |

| Winter Mean Flow | Winter Minimum Flow | 1/2 Winter Maximum Flow |
|---|---|---|
| Average mean daily flow from Dec-Feb for period of record. | Minimum mean daily flow from Dec-Feb for period of record. | One-half of the maximum mean daily flow from Dec-Feb for period of record. |
| cfs | cfs | cfs |
| **Flow:** 8.0 | **Flow:** 0.6 | **Flow:** 47.8 |

**Volume Calculations**

| Flow (cfs) | Baseflow (L/hr) | 1 h volume (L) |
|---|---|---|
| **0.6** | **57,495** | **57,495** |
| **8.0** | **820,141** | **820,141** |
| **47.8** | **4,876,586** | **4,876,586** |

| Legend |
|---|
| Over acute standard |
| Over chronic standard |
| Over chronic concentration, but for fewer than 4 days |
| Below chronic and acute standards |

[1] Tending towards worst-case.

**Scenario:** Light freezing conditions overnight

Trace to 2" of accumulation
**2.b** Liquid Anti-Ice

| | mg Cl per cycle | Prewet. gal/LM | Gallons per LM |
|---|---|---|---|
| High and Primary | 336,738,503 | | 20 |

**Table C1-A**

| Duration of washoff (hrs) | Winter Flow: Mean | Minimum | 1/2 Max |
|---|---|---|---|
| 6 | 68 | 976 | 12 |
| 12 | 34 | 488 | 6 |
| 24 | 17 | 244 | 3 |
| 36 | 11 | 163 | 2 |
| 48 | 9 | 122 | 1 |
| 72 | 6 | 81 | 1 |
| 96 | 4 | 61 | 1 |

**Scenario:** Brief snowfall followed by rain

Trace to 2" of accumulation
**2.b** Liquid Anti-Ice
**2.c** Solid/prewet

| | mg Cl per cycle | Gal/LM | Lbs per LM |
|---|---|---|---|
| High | - | 20 | 0 |
| Primary | 651,221,302 | 4 | 75 |

**Table C1-B**

| Duration of washoff (hrs) | Winter Flow: Mean | Minimum | 1/2 Max |
|---|---|---|---|
| 6 | 132 | 1,888 | 22 |
| 12 | 66 | 944 | 11 |
| 24 | 33 | 472 | 6 |
| 36 | 22 | 315 | 4 |
| 48 | 17 | 236 | 3 |
| 72 | 11 | 157 | 2 |
| 96 | 8 | 118 | 1 |

**Model Input**
Scenarios provided by SDOT. Cl- concentrations in snow and ice control materials calculated from MDS sheets or SDOT-provided information.
**Model Assumptions**
- Flow estimates based on daily average of continuous 5-min flow data from December through February during the period of record for SPU data recorders in the receiving water.
  - Winter Mean Flow = Average mean daily flow from Dec-Feb for period of record. This is intended to represent typical winter flows.
  - Winter Minimum Flow = Minimum mean daily flow from Dec-Feb for period of record. This extremely low flow is intended to represent the unlikely worst case scenario.
  - One-half Winter Maximum Flow = One-half of the maximum mean daily flow from Dec-Feb for period of record. This is intended to represent flow during larger winter storm events.
- Duration of runoff ranges from 6 to 96 hours.
- 80% of Cl- load applied to roadways in the drainage basin is diluted by the total creek flow.
- Cl- uniformly washes off throughout the runoff duration.

See accompanying text for more information.

# Conservative[1] Analysis of Typical SDOT Deicing Scenarios

## Piper's Creek

| | |
|---|---|
| Lane Miles (LM) Sand and Ice | 21 |
| Lane Miles Friction | 2.2 |
| Lane Miles (LM) High | 0 |
| Lane Miles (LM) Primary | 13.5 |
| Lane Miles (LM) Secondary | 7.8 |
| Percent of salt runoff to reach receiving water | 80% |

**WDOE WQ Standards:**
Chronic: 230 mg/L. A 4-day average concentration not to be exceeded more than once evey three
Acute: 860 mg/L. A 1-hour average concentration not to be exceeded more than once evey three years on the average (WAC 173-201A-240).

| Winter Mean Flow | Winter Minimum Flow | 1/2 Winter Maximum Flow |
|---|---|---|
| Average mean daily flow from Dec-Feb for period of record. | Minimum mean daily flow from Dec-Feb for period of record. | One-half of the maximum mean daily flow from Dec-Feb for period of record. |
| **cfs** | **cfs** | **cfs** |
| **Flow:** 2.5 | **Flow:** 1.3 | **Flow:** 5.6 |

**Volume Calculations**

| Flow (cfs) | Baseflow (L/hr) | 1 h volume (L) |
|---|---|---|
| **1.3** | **134,562** | **134,562** |
| **2.5** | **250,386** | **250,386** |
| **5.6** | **575,557** | **575,557** |

| Legend |
|---|
| Over acute standard |
| Over chronic standard |
| Over chronic concentration, but for fewer than 4 days |
| Below chronic and acute standards |

[1] Tending towards worst-case.

**Scenario:** Light freezing conditions overnight

Trace to 2" of accumulation

**2.b** Liquid Anti-Ice

| | mg Cl per cycle | Prewet. gal/LM | Gallons per LM |
|---|---|---|---|
| High and Primary | 129,065,539 | | 20 |

**Table C1-C**

| Duration of washoff (hrs) | Winter Flow: Mean | Minimum | 1/2 Max |
|---|---|---|---|
| 6 | 86 | 160 | 37 |
| 12 | 43 | 80 | 19 |
| 24 | 21 | 40 | 9 |
| 36 | 14 | 27 | 6 |
| 48 | 11 | 20 | 5 |
| 72 | 7 | 13 | 3 |
| 96 | 5 | 10 | 2 |

**Scenario:** Brief snowfall followed by rain

Trace to 2" of accumulation

**2.b** Liquid An Prewet with Liquid Anti Ice

**2.c** Solid/prewet

| | mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|---|
| High | - | 20 | 0 |
| Primary | 249,600,886 | 4 | 75 |

**Table C1-D**

| Duration of washoff (hrs) | Winter Flow: Mean | Minimum | 1/2 Max |
|---|---|---|---|
| 6 | 166 | 309 | 72 |
| 12 | 83 | 155 | 36 |
| 24 | 42 | 77 | 18 |
| 36 | 28 | 52 | 12 |
| 48 | 21 | 39 | 9 |
| 72 | 14 | 26 | 6 |
| 96 | 10 | 19 | 5 |

**Model Input**
Scenarios provided by SDOT. Cl- concentrations in snow and ice control materials calculated from MDS sheets or SDOT-provided information.
**Model Assumptions**

- Flow estimates based on daily average of continuous 5-min flow data from December through February during the period of record for SPU data recorders in the receiving water.
  - o Winter Mean Flow = Average mean daily flow from Dec-Feb for period of record. This is intended to represent typical winter flows.
  - o Winter Minimum Flow = Minimum mean daily flow from Dec-Feb for period of record. This extremely low flow is intended to represent the unlikely worst case scenario.
  - o One-half Winter Maximum Flow = One-half of the maximum mean daily flow from Dec-Feb for period of record. This is intended to represent flow during larger winter storm events.
- Duration of runoff ranges from 6 to 96 hours.
- 80% of Cl- load applied to roadways in the drainage basin is diluted by the total creek flow.
- Cl- uniformly washes off throughout the runoff duration.

See accompanying text for more information.

# Conservative[1] Analysis of Typical SDOT Deicing Scenarios

## Longfellow Creek
### Winter Base Flow

| | |
|---|---|
| Lane Miles (LM) Sand and Ice | 16 |
| Lane Miles Friction | 10.1 |
| Lane Miles (LM) High | 0 |
| Lane Miles (LM) Primary | 13.2 |
| Lane Miles (LM) Secondary | 3.1 |
| Percent of salt runoff to reach receiving water | 80% |

**WDOE WQ Standards:**
Chronic: 230 mg/L. A 4-day average concentration not to be exceeded more than once evey three years on the
Acute: 860 mg/L. A 1-hour average concentration not to be exceeded more than once evey three years on the average (WAC 173-201A-240).

| Winter Mean Flow | | Winter Minimum Flow | | 1/2 Winter Maximum Flow | |
|---|---|---|---|---|---|
| Average mean daily flow from Dec-Feb for period of record. | | Minimum mean daily flow from Dec-Feb for period of record. | | One-half of the maximum mean daily flow from Dec-Feb for period of record. | |
| **cfs** | | **cfs** | | **cfs** | |
| **Flow:** | 2.1 | **Flow:** | 0.7 | **Flow:** | 37.5 |

**Volume Calculations**

| Flow (cfs) | Baseflow (L/hr) | 1 h volume (L) |
|---|---|---|
| **0.7** | **66,669** | **66,669** |
| **2.1** | **209,012** | **209,012** |
| **37.5** | **3,822,061** | **3,822,061** |

| Legend |
|---|
| Over acute standard |
| Over chronic standard |
| Over chronic concentration, but for fewer than 4 days |
| Below chronic and acute standards |

[1] Tending towards worst-case.

**Scenario:** Light freezing conditions overnight
Trace to 2" of accumulation
**2.b** Liquid Anti-Ice

| | mg Cl per cycle | Prewet. gal/LM | Gallons per LM |
|---|---|---|---|
| High and Primary | 157,382,404 | | 25 |

**Table C1-E**

| Duration of washoff (hrs) | Winter Flow Mean | Winter Flow Minimum | Winter Flow 1/2 Max |
|---|---|---|---|
| 6 | 125 | 393 | 7 |
| 12 | 63 | 197 | 3 |
| 24 | 31 | 98 | 2 |
| 36 | 21 | 66 | 1 |
| 48 | 16 | 49 | 1 |
| 72 | 10 | 33 | 1 |
| 96 | 8 | 25 | 0 |

**Scenario:** Brief snowfall followed by rain
Trace to 2" of accumulation
**2.b** Liquid Anti-Ic Prewet with Liquid Anti Ice
**2.c** Solid/prewet

| | mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|---|
| High | - | 20 | 0 |
| Primary | 243,490,478 | 4 | 75 |

**Table C1-F**

| Duration of washoff (hrs) | Winter Flow Mean | Winter Flow Minimum | Winter Flow 1/2 Max |
|---|---|---|---|
| 6 | 194 | 609 | 11 |
| 12 | 97 | 304 | 5 |
| 24 | 49 | 152 | 3 |
| 36 | 32 | 101 | 2 |
| 48 | 24 | 76 | 1 |
| 72 | 16 | 51 | 1 |
| 96 | 12 | 38 | 1 |

**Model Input**
Scenarios provided by SDOT. Cl- concentrations in snow and ice control materials calculated from MDS sheets or SDOT-provided information.
**Model Assumptions**
- Flow estimates based on daily average of continuous 5-min flow data from December through February during the period of record for SPU data recorders in the receiving water.
  - Winter Mean Flow = Average mean daily flow from Dec-Feb for period of record. This is intended to represent typical winter flows.
  - Winter Minimum Flow = Minimum mean daily flow from Dec-Feb for period of record. This extremely low flow is intended to represent the unlikely worst case scenario.
  - One-half Winter Maximum Flow = One-half of the maximum mean daily flow from Dec-Feb for period of record. This is intended to represent flow during larger winter storm events.
- Duration of runoff ranges from 6 to 96 hours.
- 80% of Cl- load applied to roadways in the drainage basin is diluted by the total creek flow.

# Conservative[1] Analysis of Typical SDOT Deicing Scenarios

## Fauntleroy Creek

| | |
|---|---|
| Lane Miles (LM) Sand and Ice | 1 |
| Lane Miles Friction | 0.8 |
| Lane Miles (LM) High | 0 |
| Lane Miles (LM) Primary | 0.2 |
| Lane Miles (LM) Secondary | 0.7 |
| Percent of salt runoff to reach receiving water | 80% |

**WDOE WQ Standards:**
Chronic: 230 mg/L. A 4-day average concentration not to be exceeded more than once evey three
Acute: 860 mg/L. A 1-hour average concentration not to be exceeded more than once evey three years on the average (WAC 173-201A-240).

| Winter Mean Flow | Winter Minimum Flow | 1/2 Winter Maximum Flow |
|---|---|---|
| Average mean daily flow from Dec-Feb for period of record. | Minimum mean daily flow from Dec-Feb for period of record. | One-half of the maximum mean daily flow from Dec-Feb for period of record. |
| **cfs** | **cfs** | **cfs** |
| **Flow:** 0.5 | **Flow:** 0.4 | **Flow:** 5.6 |

**Volume Calculations**

| Flow (cfs) | Baseflow (L/hr) | 1 h volume (L) |
|---|---|---|
| **0.4** | **44,752** | **44,752** |
| **0.5** | **48,432** | **48,432** |
| **5.6** | **575,557** | **575,557** |

| Legend |
|---|
| Over acute standard |
| Over chronic standard |
| Over chronic concentration, but for fewer than 4 days |
| Below chronic and acute standards |

[1] Tending towards worst-case.

**Scenario:** **2.b** Trace to 2" of accumulation

Liquid Anti-Ice

| | mg Cl per cycle | Prewet. gal/LM | Gallons per LM |
|---|---|---|---|
| High and Primary | 2,273,966 | 0 | 25 |

**Table C1-G**

| Duration of washoff (hrs) | Winter Flow: Mean | Minimum | 1/2 Max |
|---|---|---|---|
| 6 | 8 | 8 | 1 |
| 12 | 4 | 4 | 0 |
| 24 | 2 | 2 | 0 |
| 36 | 1 | 1 | 0 |
| 48 | 1 | 1 | 0 |
| 72 | 1 | 1 | 0 |
| 96 | 0 | 1 | 0 |

**Scenario:** **2.bc** Trace to 2" of accumulation

Liquid Anti-Ice

Solid NaCl Prewet with Liquid Anti Ice

| | mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|---|
| High | 0 | 20 | 0 |
| Primary | 3,518,113 | 4 | 75 |

**Table C1-H**

| Duration of washoff (hrs) | Winter Flow: Mean | Minimum | 1/2 Max |
|---|---|---|---|
| 6 | 12 | 13 | 1 |
| 12 | 6 | 7 | 1 |
| 24 | 3 | 3 | 0 |
| 36 | 2 | 2 | 0 |
| 48 | 2 | 2 | 0 |
| 72 | 1 | 1 | 0 |
| 96 | 1 | 1 | 0 |

**Model Input**

Scenarios provided by SDOT. Cl- concentrations in snow and ice control materials calculated from MDS sheets or SDOT-provided information.

**Model Assumptions**

- Flow estimates based on daily average of continuous 5-min flow data from December through February during the period of record for SPU data recorders in the receiving water.
  - Winter Mean Flow = Average mean daily flow from Dec-Feb for period of record. This is intended to represent typical winter flows.
  - Winter Minimum Flow = Minimum mean daily flow from Dec-Feb for period of record. This extremely low flow is intended to represent the unlikely worst case scenario.
  - One-half Winter Maximum Flow = One-half of the maximum mean daily flow from Dec-Feb for period of record. This is intended to represent flow during larger winter storm events. Due to the short period of record for Fauntleroy Creek, this value was estimated by using flow data from Piper's Creek.
- Duration of runoff ranges from 6 to 96 hours.
- 80% of Cl- load applied to roadways in the drainage basin is diluted by the total creek flow.
- Cl- uniformly washes off throughout the runoff duration.

See accompanying text for more information.

**Attachment C2. Conservative Chloride Analysis – Various Scenarios - Typical Conditions**

**Method**

The same simple, spreadsheet model used to evaluate typical SDOT snow & ice control scenarios was used to evaluate various other, potentially less typical, SDOT snow & ice control scenarios during typical stream flow conditions. Refer to method description in Attachment C1. The model was expanded to look at additional snow & ice control materials and repeated applications prior to washoff and to deemphasize unlikely scenarios. These scenarios were applied to the four Major Creeks that have snow and ice routes within their basins.

**Inputs**

**Snow and Ice Control – Various Scenarios**

SDOT provided a draft list of SDOT 14 anti-icing and de-icing practices at a range of application rates for evaluation (Source: DRAFT SDOT memo, Alternative Scenarios, SDOT ANTI-ICING & DEICING PRACTICES, June 16, 2009). All the practices relied on one of the following three snow & ice control materials at the following range of application rates:

- Liquid anti-ice, 23.3% NaCl salt-brine with 5% MgCl, 15–30 gal/lane mile (LM).
- Solid NaCl, 50-200[2] lbs/LM prewet with liquid anti-ice (4 gal/LM)
- Sand:solid NaCl (3:1 or 5:1 ratio) (271 lbs/LM) prewet with liquid anti-ice (4 gal/LM) applied in friction areas only.

To focus on worst case scenarios, the following high-end application rates were evaluated using the simple model:

- Liquid anti-ice (25 gal/LM)
- Solid NaCl (100 lbs/LM) prewet with liquid anti-ice (4 gal/LM)
- Solid NaCl (200 lbs/LM) prewet with liquid anti-ice (4 gal/LM)
- Sand:solid NaCl (3:1 ratio) (271 lbs/LM) prewet with liquid anti-ice (4 gal/LM)

Chloride concentrations in snow and ice control materials were calculated from MSDS sheets or SDOT-provided information. The model evaluated up to ten applications cycles of each material prior to washoff.

**Assumptions**

**Creek Flow Rates**

To reflect typical stream flow conditions during typical small winter storms, the following creek flow rate was evaluated:

**Winter Mean Flow** = Average mean daily flow from Dec-Feb for period of record. This is intended to represent typical winter flows.

[2] Maximum was revised by SDOT to 200 lbs/LM.

Creek flow estimates are based on the daily average of continuous 5-min flow data from December through February during the period of record for SPU data recorders that represent flow near the mouth of the creek.

**Washoff Extent and Duration**

Washoff extent and duration assumptions were the same as used for Typical Scenarios. These are outlined in Attachment C1, Conservative Chloride Analysis – Typical Scenarios.

**Unlikely Scenarios**

Some scenarios included in the analysis seemed unlikely due to either conditions under which a deicing practice is used or likelihood that a flow condition occurred. For example, it is unlikely that SDOT would do 10 applications of any deicing practice, runoff would occur over a six hour period, and it would be extremely low flow conditions. The following rules were used for deemphasizing unlikely scenarios:

**Rule 1.** If the scenario is for 2" or over of accumulation (Scenarios 3a and 3c)...

**Rule 1a.** runoff in 6 hrs or less is unlikely (because will likely take greater than 6 hrs for over 2" accumulation to melt off)

**Rule 2.** If 5 or greater applications of any scenario...

**Rule 2a.** runoff in 12 hrs or less is unlikely (because more applications indicate more accumulation which would likely take more than 12 hrs to meltoff)

**Rule 3.** If the scenario is for trace to 2" of accumulation (Scenario 2c)...

**Rule 3a.** runoff in 72 or more is unlikely (because accumulation of less than 2" is unlikely to take 3 or more days to runoff)

**Rule 4.** If 3 or less applications of any scenario...

**Rule 4a.** runoff in 72 hrs or more is unlikely (because fewer applications indicate less accumulation which is unlikely to take 3 days to runoff)

Note that Rules 1 and 2 refer to unlikely high concentration scenarios and Rules 3 and 4 refer to unlikely low concentration scenarios. Situations resulting in these conditions are shaded out in the C2 tables.

**<u>Results</u>**

Model results are shown in four tables for each Major Creek in the attached tables.

**<u>Discussion</u>**

Model results from this conservative analysis indicate:

- Thornton Creek, followed by Longfellow Creek, is the most sensitive to salting activities. Creek sensitivity is directly related to the density of Snow & Ice Routes within the creek watershed.
- At typical winter stream flows, chloride concentrations were not a concern for liquid anti-ice application scenarios (Tables C2-A, C2-E, C2-I and C2-M).

- At typical winter stream flows, chloride concentrations were not a concern for the friction Sand:solid NaCl application scenarios (Tables C2-D, C2-H, C2-L and C2-P).
- At typical winter stream flows, chloride concentrations may be a concern for repeated solid NaCl applications prior to washoff in Thornton and Longfellow Creek basins (Tables C2-B, C2-C, C2-J and C2-K).

Note that concern ("risk") associated with chloride concentrations was assessed by comparing conservative estimates of chloride concentrations in the creek to acute and chronic water quality standards. These standards are not to be exceeded more than once every three years on the average. The average three year frequency is not considered in the model but may be a factor for SDOT when evaluating approaches to infrequent storm events.

# Conservative[1] Analysis of Various SDOT Deicing Scenarios - Typical Winter Flow

## Thornton Creek

Winter Mean Flow - Average mean daily flow from Dec-Feb for period of record.

| | |
|---|---|
| Lane Miles (LM) Sand and Ice | 62 |
| Lane Miles Friction | 18.2 |
| Percent of salt runoff to reach receiving water | 80% |
| Flow: cfs | 8.0 |

| WDOE WQ Standards: | Legend |
|---|---|
| Chronic: 230 mg/L. A 4-day average concentration not to be exceeded more than once evey three years on the | Over acute standard |
| | Over chronic standard |
| Acute: 860 mg/L. A 1-hour average concentration not to be exceeded more than once evey three years on the average (WAC 173-201A-240). | Over chronic concentration, but for fewer than 4 days |
| | Below chronic and acute standards |
| | Unlikely scenarios |

**Volume Calculations**

| Flow (cfs) | up/down (cfs) | Baseflow (L/hr) | up/down (L/hr) | 1 h volume (L) |
|---|---|---|---|---|
| **8.0** | **0** | **820,141** | **-** | **820,141** |

[1] Tending towards worst-case.

**Scenario:** **3.a** 2" and over of accumulation
Liquid Anti-Ice

| mg Cl per cycle | Prewet. gal/LM | Gallons per LM |
|---|---|---|
| 746,339,673 | | 25 |

**Table C3-A**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 152 | 303 | 455 | 607 | 758 | 910 | 1,062 | 1,213 | 1,365 | 1,517 |
| 12 | 76 | 152 | 228 | 303 | 379 | 455 | 531 | 607 | 683 | 758 |
| 24 | 38 | 76 | 114 | 152 | 190 | 228 | 265 | 303 | 341 | 379 |
| 36 | 25 | 51 | 76 | 101 | 126 | 152 | 177 | 202 | 228 | 253 |
| 48 | 19 | 38 | 57 | 76 | 95 | 114 | 133 | 152 | 171 | 190 |
| 72 | 13 | 25 | 38 | 51 | 63 | 76 | 88 | 101 | 114 | 126 |
| 96 | 9 | 19 | 28 | 38 | 47 | 57 | 66 | 76 | 85 | 95 |

**Scenario:** **2.c** Trace to 2" of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 1,499,771,007 | 4 | 100 |

**Table C2-B**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 305 | 610 | 914 | 1,219 | 1,524 | 1,829 | 2,133 | 2,438 | 2,743 | 3,048 |
| 12 | 152 | 305 | 457 | 610 | 762 | 914 | 1,067 | 1,219 | 1,372 | 1,524 |
| 24 | 76 | 152 | 229 | 305 | 381 | 457 | 533 | 610 | 686 | 762 |
| 36 | 51 | 102 | 152 | 203 | 254 | 305 | 356 | 406 | 457 | 508 |
| 48 | 38 | 76 | 114 | 152 | 190 | 229 | 267 | 305 | 343 | 381 |
| 72 | 25 | 51 | 76 | 102 | 127 | 152 | 178 | 203 | 229 | 254 |
| 96 | 19 | 38 | 57 | 76 | 95 | 114 | 133 | 152 | 171 | 190 |

**Scenario:** **3.c** 2" and over of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 2,880,127,667 | 4 | 200 |

**Table C2-C**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 585 | 1,171 | 1,756 | 2,341 | 2,926 | 3,512 | 4,097 | 4,682 | 5,268 | 5,853 |
| 12 | 293 | 585 | 878 | 1,171 | 1,463 | 1,756 | 2,049 | 2,341 | 2,634 | 2,926 |
| 24 | 146 | 293 | 439 | 585 | 732 | 878 | 1,024 | 1,171 | 1,317 | 1,463 |
| 36 | 98 | 195 | 293 | 390 | 488 | 585 | 683 | 780 | 878 | 975 |
| 48 | 73 | 146 | 219 | 293 | 366 | 439 | 512 | 585 | 658 | 732 |
| 72 | 49 | 98 | 146 | 195 | 244 | 293 | 341 | 390 | 439 | 488 |
| 96 | 37 | 73 | 110 | 146 | 183 | 219 | 256 | 293 | 329 | 366 |

**Scenario:** **4.b** 3:1 Sand:Solid NaCl
Prewet with Liquid Anti Ice
Friction Areas Only

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 264,410,686 | 4 | 271 |

**Table C2-D**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 54 | 107 | 161 | 215 | 269 | 322 | 376 | 430 | 484 | 537 |
| 12 | 27 | 54 | 81 | 107 | 134 | 161 | 188 | 215 | 242 | 269 |
| 24 | 13 | 27 | 40 | 54 | 67 | 81 | 94 | 107 | 121 | 134 |
| 36 | 9 | 18 | 27 | 36 | 45 | 54 | 63 | 72 | 81 | 90 |
| 72 | 4 | 9 | 13 | 18 | 22 | 27 | 31 | 36 | 40 | 45 |
| 96 | 3 | 7 | 10 | 13 | 17 | 20 | 24 | 27 | 30 | 34 |

**Model Input**

Scenarios provided by SDOT. Scenarios selected to represent heaviest application amounts for each control material. Cl- concentrations in snow and ice control materials calculated from MDS sheets or SDOT-provided information.

**Model Assumptions**

- Flow estimates based on daily average of continuous 5-min flow data from December through February during the period of record for SPU data recorders in the receiving water.
  - o Winter Mean Flow = Average mean daily flow from Dec-Feb for period of record. This is intended to represent typical winter flows.
- Duration of runoff ranges from 6 to 96 hours.
- 80% of Cl- load applied to roadways in the drainage basin is diluted by the total creek flow.
- Cl- uniformly washes off throughout the runoff duration.

See accompanying text for more information.

**Unlikely Scenario Rules**

Rule 1. If the scenario is for 2" or over of accumulation (Scenarios 3a and 3c)...
Rule 1a. runoff in 6 hrs or less is unlikely (because will likely take greater than 6 hrs for over 2" accumulation to melt off)
Rule 2. If 5 or greater applications of any scenario...
Rule 2a. runoff in 12 hrs or less is unlikely (because more applications indicate more accumulation which would likely take more than 12 hrs to meltoff) more accumulation which would contribute to flow)
Rule 3. If the scenarios is for trace to 2" of accumulation (Scenario 2c)...
Rule 3a. runoff in 72 or more is unlikely (becasue accumulation of less than 2" is unlikely to take 3 or more days to runoff) flows)
Rule 4. If 3 or less application of any scenario...
Rule 4a. runoff in 72 hrs or more is unlikely (because fewer applications indicate less accumulation which is unlikely to take 3 days to runoff) accumulation and less likely to have max flow scenarios)

# Conservative[1] Analysis of Various SDOT Deicing Scenarios - Typical Winter Flow

## Piper's Creek

Winter Mean Flow - Average mean daily flow from Dec-Feb for period of record.

| | |
|---|---|
| Lane Miles (LM) Sand and Ice | 21 |
| Lane Miles Friction | 2.2 |
| Percent of salt runoff to reach receiving water | 80% |
| | cfs |
| **Flow:** | 2.5 |

| WDOE WQ Standards: | Legend |
|---|---|
| Chronic: 230 mg/L. A 4-day average concentration not to be exceeded more than once evey three years on the | Over acute standard |
| | Over chronic standard |
| Acute: 860 mg/L. A 1-hour average concentration not to be exceeded more than once evey three years on the average (WAC 173-201A-240). | Over chronic concentration, but for fewer than 4 days |
| | Below chronic and acute standards |
| | Unlikely scenarios |

**Volume Calculations**

| Flow (cfs) | up/down (cfs) | Baseflow (L/hr) | up/down (L/hr) | 1 h volume (L) |
|---|---|---|---|---|
| **2.5** | **0** | **250,386** | **-** | **250,386** |

**Scenario:** **3.a** 2" and over of accumulation
Liquid Anti-Ice

| mg Cl per cycle | Prewet. gal/LM | Gallons per LM |
|---|---|---|
| 255,162,954 | | 25 |

**Table C2-E**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 170 | 340 | 510 | 679 | 849 | 1,019 | 1,189 | 1,359 | 1,529 | 1,698 |
| 12 | 85 | 170 | 255 | 340 | 425 | 510 | 594 | 679 | 764 | 849 |
| 24 | 42 | 85 | 127 | 170 | 212 | 255 | 297 | 340 | 382 | 425 |
| 36 | 28 | 57 | 85 | 113 | 142 | 170 | 198 | 226 | 255 | 283 |
| 48 | 21 | 42 | 64 | 85 | 106 | 127 | 149 | 170 | 191 | 212 |
| 72 | 14 | 28 | 42 | 57 | 71 | 85 | 99 | 113 | 127 | 142 |
| 96 | 11 | 21 | 32 | 42 | 53 | 64 | 74 | 85 | 96 | 106 |

**Scenario:** **2.c** Trace to 2" of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 512,750,447 | 4 | 100 |

**Table C2-F**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 341 | 683 | 1,024 | 1,365 | 1,707 | 2,048 | 2,389 | 2,730 | 3,072 | 3,413 |
| 12 | 171 | 341 | 512 | 683 | 853 | 1,024 | 1,195 | 1,365 | 1,536 | 1,707 |
| 24 | 85 | 171 | 256 | 341 | 427 | 512 | 597 | 683 | 768 | 853 |
| 36 | 57 | 114 | 171 | 228 | 284 | 341 | 398 | 455 | 512 | 569 |
| 48 | 43 | 85 | 128 | 171 | 213 | 256 | 299 | 341 | 384 | 427 |
| 72 | 28 | 57 | 85 | 114 | 142 | 171 | 199 | 228 | 256 | 284 |
| 96 | 21 | 43 | 64 | 85 | 107 | 128 | 149 | 171 | 192 | 213 |

**Scenario:** **3.c** 2" and over of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 984,674,821 | 4 | 200 |

**Table C2-G**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 655 | 1,311 | 1,966 | 2,622 | 3,277 | 3,933 | 4,588 | 5,243 | 5,899 | 6,554 |
| 12 | 328 | 655 | 983 | 1,311 | 1,639 | 1,966 | 2,294 | 2,622 | 2,949 | 3,277 |
| 24 | 164 | 328 | 492 | 655 | 819 | 983 | 1,147 | 1,311 | 1,475 | 1,639 |
| 36 | 109 | 218 | 328 | 437 | 546 | 655 | 765 | 874 | 983 | 1,092 |
| 48 | 82 | 164 | 246 | 328 | 410 | 492 | 574 | 655 | 737 | 819 |
| 72 | 55 | 109 | 164 | 218 | 273 | 328 | 382 | 437 | 492 | 546 |
| 96 | 41 | 82 | 123 | 164 | 205 | 246 | 287 | 328 | 369 | 410 |

**Scenario:** **4.b** 3:1 Sand:Solid NaCl
Prewet with Liquid Anti Ice
Friction Areas Only

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 32,071,768 | 4 | 271 |

**Table C2-H**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 21 | 43 | 64 | 85 | 107 | 128 | 149 | 171 | 192 | 213 |
| 12 | 11 | 21 | 32 | 43 | 53 | 64 | 75 | 85 | 96 | 107 |
| 24 | 5 | 11 | 16 | 21 | 27 | 32 | 37 | 43 | 48 | 53 |
| 36 | 4 | 7 | 11 | 14 | 18 | 21 | 25 | 28 | 32 | 36 |
| 72 | 2 | 4 | 5 | 7 | 9 | 11 | 12 | 14 | 16 | 18 |
| 96 | 1 | 3 | 4 | 5 | 7 | 8 | 9 | 11 | 12 | 13 |

**Model Input**

Scenarios provided by SDOT. Scenarios selected to represent heaviest application amounts for each control material. Cl- concentrations in snow and ice control materials calculated from MDS sheets or SDOT-provided information.

**Model Assumptions**

- Flow estimates based on daily average of continuous 5-min flow data from December through February during the period of record for SPU data recorders in the receiving water.
  - o Winter Mean Flow = Average mean daily flow from Dec-Feb for period of record. This is intended to represent typical winter flows.
- Duration of runoff ranges from 6 to 96 hours.
- 80% of Cl- load applied to roadways in the drainage basin is diluted by the total creek flow.
- Cl- uniformly washes off throughout the runoff duration.

See accompanying text for more information.

**Unlikely Scenario Rules**

Rule 1. If the scenario is for 2" or over of accumulation (Scenarios 3a and 3c)...
Rule 1a. runoff in 6 hrs or less is unlikely (because will likely take greater than 6 hrs for over 2" accumulation to melt off)
Rule 2. If 5 or greater applications of any scenario...
Rule 2a. runoff in 12 hrs or less is unlikely (because more applications indicate more accumulation which would likely take more than 12 hrs to meltoff) more accumulation which would contribute to flow)
Rule 3. If the scenarios is for trace to 2" of accumulation (Scenario 2c)...
Rule 3a. runoff in 72 or more is unlikely (becasue accumulation of less than 2" is unlikely to take 3 or more days to runoff) flows)
Rule 4. If 3 or less application of any scenario...
Rule 4a. runoff in 72 hrs or more is unlikely (because fewer applications indicate less accumulation which is unlikely to take 3 days to runoff) accumulation and less likely to have max flow scenarios)

# Conservative[1] Analysis of Various SDOT Deicing Scenarios - Typical Winter Flow

## Longfellow Creek

Winter Mean Flow - Average mean daily flow from Dec-Feb for period of record.

| | |
|---|---|
| Lane Miles (LM) Sand and Ice | 16 |
| Lane Miles Friction | 10.1 |
| Percent of salt runoff to reach receiving water | 80% |
| **Flow:** (cfs) | 2.1 |

**WDOE WQ Standards:**

Chronic: 230 mg/L. A 4-day average concentration not to be exceeded more than once evey three years on the

Acute: 860 mg/L. A 1-hour average concentration not to be exceeded more than once evey three years on the average (WAC 173-201A-240).

Legend
- Over acute standard
- Over chronic standard
- Over chronic concentration, but for fewer than 4 days
- Below chronic and acute standards
- Unlikely scenarios

**Volume Calculations**

| Flow (cfs) | up/down (cfs) | Baseflow (L/hr) | up/down (L/hr) | 1 h volume (L) |
|---|---|---|---|---|
| **2.1** | **0** | **209,012** | **-** | **209,012** |

**Scenario:** **3.a** 2" and over of accumulation
Liquid Anti-Ice

| mg Cl per cycle | Prewet. gal/LM | Gallons per LM |
|---|---|---|
| 193,885,547 | | 25 |

**Table C2-I**

| Duration of washoff (hrs) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Number of application cycles** | | | | | | | | | |
| 6 | 155 | 309 | 464 | 618 | 773 | 928 | 1,082 | 1,237 | 1,391 | 1,546 |
| 12 | 77 | 155 | 232 | 309 | 387 | 464 | 541 | 618 | 696 | 773 |
| 24 | 39 | 77 | 116 | 155 | 193 | 232 | 271 | 309 | 348 | 387 |
| 36 | 26 | 52 | 77 | 103 | 129 | 155 | 180 | 206 | 232 | 258 |
| 48 | 19 | 39 | 58 | 77 | 97 | 116 | 135 | 155 | 174 | 193 |
| 72 | 13 | 26 | 39 | 52 | 64 | 77 | 90 | 103 | 116 | 129 |
| 96 | 10 | 19 | 29 | 39 | 48 | 58 | 68 | 77 | 87 | 97 |

**Scenario:** **2.c** Trace to 2" of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 389,613,379 | 4 | 100 |

**Table C2-J**

| Duration of washoff (hrs) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Number of application cycles** | | | | | | | | | |
| 6 | 311 | 621 | 932 | 1,243 | 1,553 | 1,864 | 2,175 | 2,485 | 2,796 | 3,107 |
| 12 | 26 | 311 | 466 | 621 | 777 | 932 | 1,087 | 1,243 | 1,398 | 1,553 |
| 24 | 1 | 155 | 233 | 311 | 388 | 466 | 544 | 621 | 699 | 777 |
| 36 | 0 | 104 | 155 | 207 | 259 | 311 | 362 | 414 | 466 | 518 |
| 48 | 0 | 78 | 117 | 155 | 194 | 233 | 272 | 311 | 350 | 388 |
| 72 | 0 | 52 | 78 | 104 | 129 | 155 | 181 | 207 | 233 | 259 |
| 96 | 0 | 39 | 58 | 78 | 97 | 117 | 136 | 155 | 175 | 194 |

**Scenario:** **3.c** 2" and over of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 748,205,071 | 4 | 200 |

**Table C2-K**

| Duration of washoff (hrs) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Number of application cycles** | | | | | | | | | |
| 6 | 597 | 1,193 | 1,790 | 2,386 | 2,983 | 3,580 | 4,176 | 4,773 | 5,370 | 5,966 |
| 12 | 298 | 597 | 895 | 1,193 | 1,492 | 1,790 | 2,088 | 2,386 | 2,685 | 2,983 |
| 24 | 149 | 298 | 447 | 597 | 746 | 895 | 1,044 | 1,193 | 1,342 | 1,492 |
| 36 | 99 | 199 | 298 | 398 | 497 | 597 | 696 | 795 | 895 | 994 |
| 48 | 75 | 149 | 224 | 298 | 373 | 447 | 522 | 597 | 671 | 746 |
| 72 | 50 | 99 | 149 | 199 | 249 | 298 | 348 | 398 | 447 | 497 |
| 96 | 37 | 75 | 112 | 149 | 186 | 224 | 261 | 298 | 336 | 373 |

**Scenario:** **4.b** 3:1 Sand:Solid NaCl
Prewet with Liquid Anti Ice
Friction Areas Only

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 146,862,576 | 4 | 271 |

**Table C2-L**

| Duration of washoff (hrs) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Number of application cycles** | | | | | | | | | |
| 6 | 117 | 234 | 351 | 468 | 586 | 703 | 820 | 937 | 1,054 | 1,171 |
| 12 | 10 | 117 | 176 | 234 | 293 | 351 | 410 | 468 | 527 | 586 |
| 24 | 0 | 59 | 88 | 117 | 146 | 176 | 205 | 234 | 263 | 293 |
| 36 | 0 | 39 | 59 | 78 | 98 | 117 | 137 | 156 | 176 | 195 |
| 72 | 0 | 20 | 29 | 39 | 49 | 59 | 68 | 78 | 88 | 98 |
| 96 | 0 | 15 | 22 | 29 | 37 | 44 | 51 | 59 | 66 | 73 |

**Model Input**

Scenarios provided by SDOT. Scenarios selected to represent heaviest application amounts for each control material. Cl- concentrations in snow and ice control materials calculated from MDS sheets or SDOT-provided information.

**Model Assumptions**

- Flow estimates based on daily average of continuous 5-min flow data from December through February during the period of record for SPU data recorders in the receiving water.
  - o Winter Mean Flow = Average mean daily flow from Dec-Feb for period of record. This is intended to represent typical winter flows.
- Duration of runoff ranges from 6 to 96 hours.
- 80% of Cl- load applied to roadways in the drainage basin is diluted by the total creek flow.
- Cl- uniformly washes off throughout the runoff duration.

See accompanying text for more information.

**Unlikely Scenario Rules**

Rule 1. If the scenario is for 2" or over of accumulation (Scenarios 3a and 3c)...
Rule 1a. runoff in 6 hrs or less is unlikely (because will likely take greater than 6 hrs for over 2" accumulation to melt off)
Rule 2. If 5 or greater applications of any scenario...
Rule 2a. runoff in 12 hrs or less is unlikely (because more applications indicate more accumulation which would likely take more than 12 hrs to meltoff) more accumulation which would contribute to flow)
Rule 3. If the scenarios is for trace to 2" of accumulation (Scenario 2c)...
Rule 3a. runoff in 72 or more is unlikely (becasue accumulation of less than 2" is unlikely to take 3 or more days to runoff) flows)
Rule 4. If 3 or less application of any scenario...
Rule 4a. runoff in 72 hrs or more is unlikely (because fewer applications indicate less accumulation which is unlikely to take 3 days to runoff) accumulation and less likely to have max flow scenarios)

# Conservative[1] Analysis of Various SDOT Deicing Scenarios - Typical Winter Flow

## Fauntleroy Creek

Winter Mean Flow - Average mean daily flow from Dec-Feb for period of record.

| | |
|---|---|
| Lane Miles (LM) Sand and Ice | 1 |
| Lane Miles Friction | 0.8 |
| Percent of salt runoff to reach receiving water | 80% |
| **Flow:** (cfs) | 0.4 |

| WDOE WQ Standards: | Legend |
|---|---|
| Chronic: 230 mg/L. A 4-day average concentration not to be exceeded more than once evey three years on the | Over acute standard |
| | Over chronic standard |
| Acute: 860 mg/L. A 1-hour average concentration not to be exceeded more than once evey three years on the average (WAC 173-201A-240). | Over chronic concentration, but for fewer than 4 days |
| | Below chronic and acute standards |
| | Unlikely scenarios |

| Flow (cfs) | up/down (cfs) | Baseflow (L/hr) | up/down (L/hr) | 1 h volume (L) |
|---|---|---|---|---|
| **0.4** | **0** | **44,752** | **-** | **44,752** |

**Scenario:** **3.a** 2" and over of accumulation
Liquid Anti-Ice

| mg Cl per cycle | Prewet. gal/LM | Gallons per LM |
|---|---|---|
| 10,651,737 | 0 | 25 |

**Table C2-M**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 40 | 79 | 119 | 159 | 198 | 238 | 278 | 317 | 357 | 397 |
| 12 | 20 | 40 | 60 | 79 | 99 | 119 | 139 | 159 | 179 | 198 |
| 24 | 10 | 20 | 30 | 40 | 50 | 60 | 69 | 79 | 89 | 99 |
| 36 | 7 | 13 | 20 | 26 | 33 | 40 | 46 | 53 | 60 | 66 |
| 48 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| 72 | 3 | 7 | 10 | 13 | 17 | 20 | 23 | 26 | 30 | 33 |

**Scenario:** **2.c** Trace to 2" of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 21,404,686 | 4 | 100 |

**Table C2-N**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 80 | 159 | 239 | 319 | 399 | 478 | 558 | 638 | 717 | 797 |
| 12 | 40 | 80 | 120 | 159 | 199 | 239 | 279 | 319 | 359 | 399 |
| 24 | 20 | 40 | 60 | 80 | 100 | 120 | 140 | 159 | 179 | 199 |
| 36 | 13 | 27 | 40 | 53 | 66 | 80 | 93 | 106 | 120 | 133 |
| 48 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| 72 | 7 | 13 | 20 | 27 | 33 | 40 | 47 | 53 | 60 | 66 |
| 96 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |

**Scenario:** **3.c** 2" and over of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 41,105,093 | 4 | 200 |

**Table C2-O**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 153 | 306 | 459 | 612 | 765 | 919 | 1,072 | 1,225 | 1,378 | 1,531 |
| 12 | 77 | 153 | 230 | 306 | 383 | 459 | 536 | 612 | 689 | 765 |
| 24 | 38 | 77 | 115 | 153 | 191 | 230 | 268 | 306 | 344 | 383 |
| 36 | 26 | 51 | 77 | 102 | 128 | 153 | 179 | 204 | 230 | 255 |
| 48 | 19 | 38 | 57 | 77 | 96 | 115 | 134 | 153 | 172 | 191 |
| 72 | 13 | 26 | 38 | 51 | 64 | 77 | 89 | 102 | 115 | 128 |
| 96 | 10 | 19 | 29 | 38 | 48 | 57 | 67 | 77 | 86 | 96 |

**Scenario:** **4.b** 3:1 Sand:Solid NaCl
Prewet with Liquid Anti Ice
Friction Areas Only

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 12,190,174 | 4 | 271 |

**Table C2-P**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 45 | 91 | 136 | 182 | 227 | 272 | 318 | 363 | 409 | 454 |
| 12 | 23 | 45 | 68 | 91 | 113 | 136 | 159 | 182 | 204 | 227 |
| 24 | 11 | 23 | 34 | 45 | 57 | 68 | 79 | 91 | 102 | 113 |
| 36 | 8 | 15 | 23 | 30 | 38 | 45 | 53 | 61 | 68 | 76 |
| 72 | 4 | 8 | 11 | 15 | 19 | 23 | 26 | 30 | 34 | 38 |
| 96 | 3 | 6 | 9 | 11 | 14 | 17 | 20 | 23 | 26 | 28 |

**Model Input**
Scenarios provided by SDOT. Scenarios selected to represent heaviest application amounts for each control material. Cl- concentrations in snow and ice control materials calculated from MDS sheets or SDOT-provided information.

**Model Assumptions**
- Flow estimates based on daily average of continuous 5-min flow data from December through February during the period of record for SPU data recorders in the receiving water.
  - o Winter Mean Flow = Average mean daily flow from Dec-Feb for period of record. This is intended to represent typical winter flows.
- Duration of runoff ranges from 6 to 96 hours.
- 80% of Cl- load applied to roadways in the drainage basin is diluted by the total creek flow.
- Cl- uniformly washes off throughout the runoff duration.

See accompanying text for more information.

**Unlikely Scenario Rules**
Rule 1. If the scenario is for 2" or over of accumulation (Scenarios 3a and 3c)...
Rule 1a. runoff in 6 hrs or less is unlikely (because will likely take greater than 6 hrs for over 2" accumulation to melt off)
Rule 2. If 5 or greater applications of any scenario...
Rule 2a. runoff in 12 hrs or less is unlikely (because more applications indicate more accumulation which would likely take more than 12 hrs to meltoff) more accumulation which would contribute to flow)
Rule 3. If the scenarios is for trace to 2" of accumulation (Scenario 2c)...
Rule 3a. runoff in 72 or more is unlikely (becasue accumulation of less than 2" is unlikely to take 3 or more days to runoff) flows)
Rule 4. If 3 or less application of any scenario...
Rule 4a. runoff in 72 hrs or more is unlikely (because fewer applications indicate less accumulation which is unlikely to take 3 days to runoff) accumulation and less likely to have max flow scenarios)

**Attachment C3. Conservative Chloride Analysis – Various Scenarios – Sensitivity Analysis**

**Method**

To evaluate how risk associated with various SDOT treatment scenarios changed with changes in creek flow, a sensitivity analysis was performed. The same simple, spreadsheet model was used to evaluate various SDOT snow and ice control scenarios during various stream flow conditions. Refer to method description in Attachment C1. The model was expanded to look at extremely low creek flow rates and creek flow rates during typical large winter storm events. These scenarios were applied to the four Major Creeks that have snow and ice routes within their basins.

**Inputs**

**Snow and Ice Control – Various Scenarios**

The same materials and application rates were used as for Various Scenarios. These are outlined in Attachment C2, Various Scenarios – Typical Conditions.

**Assumptions**

As part of the simple model, the following creek flow rates were evaluated:

**Winter Minimum Flow** = Minimum mean daily flow from December through February for the period of record. This extremely low flow is intended to represent the unlikely worst case scenario.

**One-half Winter Maximum Flow** = One-half of the maximum mean daily flow from December through February for the period of record. This is intended to represent flow during typical large winter storm events.

Creek flow estimates are based on the daily average of continuous 5-min flow data from December through February during the period of record for SPU data recorders that represent flow near the mouth of the creek.

**Washoff Extent and Duration**

Washoff extent and duration assumptions were the same as used for Typical Scenarios. These are outlined in Attachment C1, Conservative Chloride Analysis – Typical Scenarios.

**Unlikely Scenarios**

Some scenarios included in the analysis seemed unlikely due to either conditions under which a deicing practice is used or likelihood that a flow condition occurred. For example, it is unlikely that SDOT would do 10 applications of any deicing practice, runoff would occur over a six hour period, and it would be extremely low flow conditions. The following rules were used for deemphasizing unlikely scenarios:

**Rule 1.** If the scenario is for 2" or over of accumulation (Scenarios 3a and 3c)...
**Rule 1a.** runoff in 6 hrs or less is unlikely (because will likely take greater than 6 hrs for over 2" accumulation to melt off)
**Rule 1b.** baseflow scenarios are unlikely (because runoff of over 2" accumulation will contribute to flow)

**Rule 2.** If 5 or greater applications of any scenario...
**Rule 2a.** runoff in 12 hrs or less is unlikely (because more applications indicate more accumulation which would likely take more than 12 hrs to meltoff)
**Rule 2b.** baseflow scenarios are unlikely (because more applications indicate more accumulation which would contribute to flow)

**Rule 3.** If the scenario is for trace to 2" of accumulation (Scenario 2c)...
**Rule 3a.** runoff in 72 or more is unlikely (because accumulation of less than 2" is unlikely to take 3 or more days to runoff)
**Rule 3b.** 1/2 max flow scenarios are unlikely (because accumulation of less than 2" is unlikely to cause highest flows)

**Rule 4.** If 3 or less applications of any scenario...
**Rule 4a.** runoff in 72 hrs or more is unlikely (because fewer applications indicate less accumulation which is unlikely to take 3 days to runoff)
**Rule 4b.** 1/2 max flow scenarios are unlikely (because fewer applications indicate less accumulation and less likely to have max flow scenarios)

Note that Rules 1 and 2 refer to unlikely high concentration scenarios and Rules 3 and 4 refer to unlikely low concentration scenarios. Situations resulting in these conditions are shaded out in the C2 tables.

**<u>Results</u>**
Model results are shown in four tables for each Major Creek for each of the two flow rates in the attached tables.

**<u>Discussion</u>**
Model results from this conservative analysis indicate:

- During extremely low flow conditions, chloride concentration may be a concern for friction sand:solid NaCl application in Thornton Creek (Table C3-D).
- During extremely low flow conditions, chloride concentrations may be a concern for:
    - Solid NaCl applications in Thornton Creek (Table C3-B).
    - Solid NaCl application associated with a relatively short washoff period or repeated NaCl applications in Longfellow Creek (Table C3-R).
    - Solid NaCl application associated with a relatively short washoff period (Tables C3-B, C3-J and C3-R).
- During high creek flows, chloride concentrations were not a concern in any creek basin (Tables C3-E, C3-F, C3-G, C3-H, C3-M, C3-N, C3-O, C3-P, C3-U, C3-V, C3-W, C3-X, C3-CC, C3-DD, C3-EE and C3-FF).

Note that concern ("risk") associated with chloride concentrations was assessed by comparing conservative estimates of chloride concentrations in the creek to acute and chronic water quality standards. These standards are not to be exceeded more than once every three years on the average. The average three year frequency is not considered in the model but may be a factor for SDOT when evaluating approaches to infrequent storm events.

# Conservative[1] Analysis of Various SDOT Deicing Scenarios - Minimum Winter Flow

## Thornton Creek

Winter Minimum Flow - Minimum mean daily flow from Dec-Feb for period of record.

| | |
|---|---|
| Lane Miles (LM) Sand and Ice | 62 |
| Lane Miles Friction | 18.2 |
| Percent of salt runoff to reach receiving water | 80% |
| Flow: (cfs) | 0.6 |

| WDOE WQ Standards: | Legend |
|---|---|
| Chronic: 230 mg/L. A 4-day average concentration not to be exceeded more than once evey three | Over acute standard |
| | Over chronic standard |
| Acute: 860 mg/L. A 1-hour average concentration not to be exceeded more than once evey three years on the average (WAC 173-201A-240). | Over chronic concentration, but for fewer than 4 days |
| | Below chronic and acute standards |
| | Unlikely scenarios |

**Volume Calculations**

| Flow (cfs) | up/down (cfs) | Baseflow (L/hr) | up/down (L/hr) | 1 h volume (L) |
|---|---|---|---|---|
| **0.6** | **0** | **57,495** | **-** | **57,495** |

[1] Tending towards worst-case.

**Scenario:** **3.a** 2" and over of accumulation
Liquid Anti-Ice

| mg Cl per cycle | Prewet. gal/LM | Gallons per LM |
|---|---|---|
| 746,339,673 | | 25 |

**Table C3-A**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 2,164 | 4,327 | 6,491 | 8,654 | 10,818 | 12,981 | 15,145 | 17,308 | 19,472 | 21,635 |
| 12 | 1,082 | 2,164 | 3,245 | 4,327 | 5,409 | 6,491 | 7,572 | 8,654 | 9,736 | 10,818 |
| 24 | 541 | 1,082 | 1,623 | 2,164 | 2,704 | 3,245 | 3,786 | 4,327 | 4,868 | 5,409 |
| 36 | 361 | 721 | 1,082 | 1,442 | 1,803 | 2,164 | 2,524 | 2,885 | 3,245 | 3,606 |
| 48 | 270 | 541 | 811 | 1,082 | 1,352 | 1,623 | 1,893 | 2,164 | 2,434 | 2,704 |
| 72 | 180 | 361 | 541 | 721 | 901 | 1,082 | 1,262 | 1,442 | 1,623 | 1,803 |
| 96 | 135 | 270 | 406 | 541 | 676 | 811 | 947 | 1,082 | 1,217 | 1,352 |

**Scenario:** **2.c** Trace to 2" of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 1,499,771,007 | 4 | 100 |

**Table C3-B**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 4,348 | 8,695 | 13,043 | 17,390 | 21,738 | 26,085 | 30,433 | 34,781 | 39,128 | 43,476 |
| 12 | 2,174 | 4,348 | 6,521 | 8,695 | 10,869 | 13,043 | 15,217 | 17,390 | 19,564 | 21,738 |
| 24 | 1,087 | 2,174 | 3,261 | 4,348 | 5,434 | 6,521 | 7,608 | 8,695 | 9,782 | 10,869 |
| 36 | 725 | 1,449 | 2,174 | 2,898 | 3,623 | 4,348 | 5,072 | 5,797 | 6,521 | 7,246 |
| 48 | 543 | 1,087 | 1,630 | 2,174 | 2,717 | 3,261 | 3,804 | 4,348 | 4,891 | 5,434 |
| 72 | 362 | 725 | 1,087 | 1,449 | 1,811 | 2,174 | 2,536 | 2,898 | 3,261 | 3,623 |
| 96 | 272 | 543 | 815 | 1,087 | 1,359 | 1,630 | 1,902 | 2,174 | 2,446 | 2,717 |

**Scenario:** **3.c** 2" and over of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 2,880,127,667 | 4 | 200 |

**Table C3-C**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 8,349 | 16,698 | 25,047 | 33,396 | 41,745 | 50,094 | 58,443 | 66,792 | 75,141 | 83,490 |
| 12 | 4,174 | 8,349 | 12,523 | 16,698 | 20,872 | 25,047 | 29,221 | 33,396 | 37,570 | 41,745 |
| 24 | 2,087 | 4,174 | 6,262 | 8,349 | 10,436 | 12,523 | 14,611 | 16,698 | 18,785 | 20,872 |
| 36 | 1,391 | 2,783 | 4,174 | 5,566 | 6,957 | 8,349 | 9,740 | 11,132 | 12,523 | 13,915 |
| 48 | 1,044 | 2,087 | 3,131 | 4,174 | 5,218 | 6,262 | 7,305 | 8,349 | 9,393 | 10,436 |
| 72 | 696 | 1,391 | 2,087 | 2,783 | 3,479 | 4,174 | 4,870 | 5,566 | 6,262 | 6,957 |
| 96 | 522 | 1,044 | 1,565 | 2,087 | 2,609 | 3,131 | 3,653 | 4,174 | 4,696 | 5,218 |

**Scenario:** **4.b** 3:1 Sand:Solid NaCl
Prewet with Liquid Anti Ice
Friction Areas Only

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 264,410,686 | 4 | 271 |

**Table C3-D**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 766 | 1,533 | 2,299 | 3,066 | 3,832 | 4,599 | 5,365 | 6,132 | 6,898 | 7,665 |
| 12 | 383 | 766 | 1,150 | 1,533 | 1,916 | 2,299 | 2,683 | 3,066 | 3,449 | 3,832 |
| 24 | 192 | 383 | 575 | 766 | 958 | 1,150 | 1,341 | 1,533 | 1,725 | 1,916 |
| 36 | 128 | 255 | 383 | 511 | 639 | 766 | 894 | 1,022 | 1,150 | 1,277 |
| 72 | 64 | 128 | 192 | 255 | 319 | 383 | 447 | 511 | 575 | 639 |
| 96 | 48 | 96 | 144 | 192 | 240 | 287 | 335 | 383 | 431 | 479 |

**Model Input**

Scenarios provided by SDOT. Scenarios selected to represent heaviest application amounts for each control material. Cl- concentrations in snow and ice control materials calculated from MDS sheets or SDOT-provided information.

**Model Assumptions**

- Flow estimates based on daily average of continuous 5-min flow data from December through February during the period of record for SPU data recorders in the receiving water.
- o Winter Minimum Flow = Minimum mean daily flow from Dec-Feb for period of record. This extremely low flow is intended to represent the unlikely worst case scenario.
- Duration of runoff ranges from 6 to 96 hours.
- 80% of Cl- load applied to roadways in the drainage basin is diluted by the total creek flow.
- Cl- uniformly washes off throughout the runoff duration.

See accompanying text for more information.

**Unlikely Scenario Rules**

Rule 1. If the scenario is for 2" or over of accumulation (Scenarios 3a and 3c)...
Rule 1a. runoff in 6 hrs or less is unlikely (because will likely take greater than 6 hrs for over 2" accumulation to melt off)
Rule 1b. baseflow scenarios are unlikely (because runoff of over 2" accumulation will contribute to flow)
Rule 2. If 5 or greater applications of any scenario...
Rule 2a. runoff in 12 hrs or less is unlikely (because more applications indicate more accumulation which would likely take more than 12 hrs to meltoff) more accumulation which would contribute to flow)
Rule 2b. baseflow scenarios are unlikely (because more applications indicate
Rule 3. If the scenarios is for trace to 2" of accumulation (Scenario 2c)...
Rule 3a. runoff in 72 or more is unlikely (becasue accumulation of less than 2" is unlikely to take 3 or more days to runoff) flows)
Rule 3b. 1/2 max flow scenarios are unlikely (because accumulation of less than 2" is unlikely to cause highest
Rule 4. If 3 or less application of any scenario...
Rule 4a. runoff in 72 hrs or more is unlikely (because fewer applications indicate less accumulation which is unlikely to take 3 days to runoff) accumulation and less likely to have max flow scenarios)
Rule 4b. 1/2 max flow scenarios are unlikely (because fewer applications indicate less

# Conservative[1] Analysis of Various SDOT Deicing Scenarios - Maximum Winter Flow

## Thornton Creek

1/2 Winter Max Flow - One-half of the maximum mean daily flow from Dec-Feb for period of record.

| | |
|---|---|
| Lane Miles (LM) Sand and Ice | 62 |
| Lane Miles Friction | 18.2 |
| Percent of salt runoff to reach receiving water | 80% |

| | cfs |
|---|---|
| **Flow:** | 47.8 |

| WDOE WQ Standards: | Legend |
|---|---|
| Chronic: 230 mg/L. A 4-day average concentration not to be exceeded more than | Over acute standard |
| | Over chronic standard |
| Acute: 860 mg/L. A 1-hour average concentration not to be exceeded more than once evey three years on the average (WAC 173-201A-240). | Over chronic concentration, but for fewer than 4 days |
| | Below chronic and acute standards |
| | Unlikely scenarios |

**Volume Calculations**

| Flow (cfs) | up/down (cfs) | Baseflow (L/hr) | up/down (L/hr) | 1 h volume (L) |
|---|---|---|---|---|
| **47.8** | **0** | **4,876,586** | **-** | **4,876,586** |

[1] Tending towards worst-case.

**Scenario:** **3.a** 2" and over of accumulation
Liquid Anti-Ice

| mg Cl per cycle | Prewet. gal/LM | Gallons per LM |
|---|---|---|
| 746,339,673 | | 25 |

**Table C3-E**

| Duration of washoff (hrs) | Number of application cycles 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 26 | 51 | 77 | 102 | 128 | 153 | 179 | 204 | 230 | 255 |
| 12 | 13 | 26 | 38 | 51 | 64 | 77 | 89 | 102 | 115 | 128 |
| 24 | 6 | 13 | 19 | 26 | 32 | 38 | 45 | 51 | 57 | 64 |
| 36 | 4 | 9 | 13 | 17 | 21 | 26 | 30 | 34 | 38 | 43 |
| 48 | 3 | 6 | 10 | 13 | 16 | 19 | 22 | 26 | 29 | 32 |
| 72 | 2 | 4 | 6 | 9 | 11 | 13 | 15 | 17 | 19 | 21 |
| 96 | 2 | 3 | 5 | 6 | 8 | 10 | 11 | 13 | 14 | 16 |

**Scenario:** **2.c** Trace to 2" of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 1,499,771,007 | 4 | 100 |

**Table C3-F**

| Duration of washoff (hrs) | Number of application cycles 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 51 | 103 | 154 | 205 | 256 | 308 | 359 | 410 | 461 | 513 |
| 12 | 26 | 51 | 77 | 103 | 128 | 154 | 179 | 205 | 231 | 256 |
| 24 | 13 | 26 | 38 | 51 | 64 | 77 | 90 | 103 | 115 | 128 |
| 36 | 9 | 17 | 26 | 34 | 43 | 51 | 60 | 68 | 77 | 85 |
| 48 | 6 | 13 | 19 | 26 | 32 | 38 | 45 | 51 | 58 | 64 |
| 72 | 4 | 9 | 13 | 17 | 21 | 26 | 30 | 34 | 38 | 43 |
| 96 | 3 | 6 | 10 | 13 | 16 | 19 | 22 | 26 | 29 | 32 |

**Scenario:** **3.c** 2" and over of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 2,880,127,667 | 4 | 200 |

**Table C3-G**

| Duration of washoff (hrs) | Number of application cycles 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 98 | 197 | 295 | 394 | 492 | 591 | 689 | 787 | 886 | 984 |
| 12 | 49 | 98 | 148 | 197 | 246 | 295 | 345 | 394 | 443 | 492 |
| 24 | 25 | 49 | 74 | 98 | 123 | 148 | 172 | 197 | 221 | 246 |
| 36 | 16 | 33 | 49 | 66 | 82 | 98 | 115 | 131 | 148 | 164 |
| 48 | 12 | 25 | 37 | 49 | 62 | 74 | 86 | 98 | 111 | 123 |
| 72 | 8 | 16 | 25 | 33 | 41 | 49 | 57 | 66 | 74 | 82 |
| 96 | 6 | 12 | 18 | 25 | 31 | 37 | 43 | 49 | 55 | 62 |

**Scenario:** **4.b** 3:1 Sand:Solid NaCl
Prewet with Liquid Anti Ice
Friction Areas Only

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 264,410,686 | 4 | 271 |

**Table C3-H**

| Duration of washoff (hrs) | Number of application cycles 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 9 | 18 | 27 | 36 | 45 | 54 | 63 | 72 | 81 | 90 |
| 12 | 5 | 9 | 14 | 18 | 23 | 27 | 32 | 36 | 41 | 45 |
| 24 | 2 | 5 | 7 | 9 | 11 | 14 | 16 | 18 | 20 | 23 |
| 36 | 2 | 3 | 5 | 6 | 8 | 9 | 11 | 12 | 14 | 15 |
| 72 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 | 8 |
| 96 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |

**Model Input**

Scenarios provided by SDOT. Scenarios selected to represent heaviest application amounts for each control material. Cl- concentrations in snow and ice control materials calculated from MDS sheets or SDOT-provided information.

**Model Assumptions**

- Flow estimates based on daily average of continuous 5-min flow data from December through February during the period of record for SPU data recorders in the receiving water.
- o One-half Winter Maximum Flow = One-half of the maximum mean daily flow from Dec-Feb for period of record. This is intended to represent flow during larger winter storm events.
- Duration of runoff ranges from 6 to 96 hours.
- 80% of Cl- load applied to roadways in the drainage basin is diluted by the total creek flow.
- Cl- uniformly washes off throughout the runoff duration.

See accompanying text for more information.

**Unlikely Scenario Rules**

Rule 1. If the scenario is for 2" or over of accumulation (Scenarios 3a and 3c)...
Rule 1a. runoff in 6 hrs or less is unlikely (because will likely take greater than 6 hrs for over 2" accumulation to melt off)
Rule 2. If 5 or greater applications of any scenario...
Rule 2a. runoff in 12 hrs or less is unlikely (because more applications indicate more accumulation which would likely take more than 12 hrs to meltoff) more accumulation which would contribute to flow)
Rule 3. If the scenarios is for trace to 2" of accumulation (Scenario 2c)...
Rule 3a. runoff in 72 or more is unlikely (becasue accumulation of less than 2" is unlikely to take 3 or more days to runoff) flows)
Rule 4. If 3 or less application of any scenario...
Rule 4a. runoff in 72 hrs or more is unlikely (because fewer applications indicate less accumulation which is unlikely to take 3 days to runoff) accumulation and less likely to have max flow scenarios)

# Conservative[1] Analysis of Various SDOT Deicing Scenarios - Minimum Winter Flow

## Piper's Creek

Winter Minimum Flow - Minimum mean daily flow from Dec-Feb for period of record.

| | |
|---|---|
| Lane Miles (LM) Sand and Ice | 21 |
| Lane Miles Friction | 2.2 |
| Percent of salt runoff to reach receiving water | 80% |

| | cfs |
|---|---|
| **Flow:** | 1.3 |

| WDOE WQ Standards: | Legend |
|---|---|
| Chronic: 230 mg/L. A 4-day average concentration not to be exceeded more than | Over acute standard |
| | Over chronic standard |
| Acute: 860 mg/L. A 1-hour average concentration not to be exceeded more than once evey three years on the average (WAC | Over chronic concentration, but for fewer than 4 days |
| | Below chronic and acute standards |
| | Unlikely scenarios |

**Volume Calculations**

| Flow (cfs) | up/down (cfs) | Baseflow (L/hr) | up/down (L/hr) | 1 h volume (L) |
|---|---|---|---|---|
| **1.3** | **0** | **134,562** | **-** | **134,562** |

**Scenario:** **3.a** 2" and over of accumulation
Liquid Anti-Ice

| mg Cl per cycle | Prewet. gal/LM | Gallons per LM |
|---|---|---|
| 255,162,954 | | 25 |

**Table C3-I**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 316 | 632 | 948 | 1,264 | 1,580 | 1,896 | 2,212 | 2,528 | 2,844 | 3,160 |
| 12 | 158 | 316 | 474 | 632 | 790 | 948 | 1,106 | 1,264 | 1,422 | 1,580 |
| 24 | 79 | 158 | 237 | 316 | 395 | 474 | 553 | 632 | 711 | 790 |
| 36 | 53 | 105 | 158 | 211 | 263 | 316 | 369 | 421 | 474 | 527 |
| 48 | 40 | 79 | 119 | 158 | 198 | 237 | 277 | 316 | 356 | 395 |
| 72 | 26 | 53 | 79 | 105 | 132 | 158 | 184 | 211 | 237 | 263 |
| 96 | 20 | 40 | 59 | 79 | 99 | 119 | 138 | 158 | 178 | 198 |

**Scenario:** **2.c** Trace to 2" of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 512,750,447 | 4 | 100 |

**Table C3-J**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 635 | 1,270 | 1,905 | 2,540 | 3,175 | 3,811 | 4,446 | 5,081 | 5,716 | 6,351 |
| 12 | 318 | 635 | 953 | 1,270 | 1,588 | 1,905 | 2,223 | 2,540 | 2,858 | 3,175 |
| 24 | 159 | 318 | 476 | 635 | 794 | 953 | 1,111 | 1,270 | 1,429 | 1,588 |
| 36 | 106 | 212 | 318 | 423 | 529 | 635 | 741 | 847 | 953 | 1,058 |
| 48 | 79 | 159 | 238 | 318 | 397 | 476 | 556 | 635 | 714 | 794 |
| 72 | 53 | 106 | 159 | 212 | 265 | 318 | 370 | 423 | 476 | 529 |
| 96 | 40 | 79 | 119 | 159 | 198 | 238 | 278 | 318 | 357 | 397 |

**Scenario:** **3.c** 2" and over of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 984,674,821 | 4 | 200 |

**Table C3-K**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 1,220 | 2,439 | 3,659 | 4,878 | 6,098 | 7,318 | 8,537 | 9,757 | 10,976 | 12,196 |
| 12 | 610 | 1,220 | 1,829 | 2,439 | 3,049 | 3,659 | 4,269 | 4,878 | 5,488 | 6,098 |
| 24 | 305 | 610 | 915 | 1,220 | 1,525 | 1,829 | 2,134 | 2,439 | 2,744 | 3,049 |
| 36 | 203 | 407 | 610 | 813 | 1,016 | 1,220 | 1,423 | 1,626 | 1,829 | 2,033 |
| 48 | 152 | 305 | 457 | 610 | 762 | 915 | 1,067 | 1,220 | 1,372 | 1,525 |
| 72 | 102 | 203 | 305 | 407 | 508 | 610 | 711 | 813 | 915 | 1,016 |
| 96 | 76 | 152 | 229 | 305 | 381 | 457 | 534 | 610 | 686 | 762 |

**Scenario:** **4.b** 3:1 Sand:Solid NaCl
Prewet with Liquid Anti Ice
Friction Areas Only

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 32,071,768 | 4 | 271 |

**Table C3-L**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 40 | 79 | 119 | 159 | 199 | 238 | 278 | 318 | 358 | 397 |
| 12 | 20 | 40 | 60 | 79 | 99 | 119 | 139 | 159 | 179 | 199 |
| 24 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 79 | 89 | 99 |
| 36 | 7 | 13 | 20 | 26 | 33 | 40 | 46 | 53 | 60 | 66 |
| 72 | 3 | 7 | 10 | 13 | 17 | 20 | 23 | 26 | 30 | 33 |
| 96 | 2 | 5 | 7 | 10 | 12 | 15 | 17 | 20 | 22 | 25 |

**Model Input**

Scenarios provided by SDOT. Scenarios selected to represent heaviest application amounts for each control material. Cl- concentrations in snow and ice control materials calculated from MDS sheets or SDOT-provided information.

**Model Assumptions**

- Flow estimates based on daily average of continuous 5-min flow data from December through February during the period of record for SPU data recorders in the receiving water.
- o Winter Minimum Flow = Minimum mean daily flow from Dec-Feb for period of record. This extremely low flow is intended to represent the unlikely worst case scenario.
- Duration of runoff ranges from 6 to 96 hours.
- 80% of Cl- load applied to roadways in the drainage basin is diluted by the total creek flow.
- Cl- uniformly washes off throughout the runoff duration.

See accompanying text for more information.

**Unlikely Scenario Rules**

Rule 1. If the scenario is for 2" or over of accumulation (Scenarios 3a and 3c)...
Rule 1a. runoff in 6 hrs or less is unlikely (because will likely take greater than 6 hrs for over 2" accumulation to melt off)
Rule 1b. baseflow scenarios are unlikely (because runoff of over 2" accumulation will contribute to flow)
Rule 2. If 5 or greater applications of any scenario...
Rule 2a. runoff in 12 hrs or less is unlikely (because more applications indicate more accumulation which would likely take more than 12 hrs to meltoff) more accumulation which would contribute to flow)
Rule 2b. baseflow scenarios are unlikely (because more applications indicate
Rule 3. If the scenarios is for trace to 2" of accumulation (Scenario 2c)...
Rule 3a. runoff in 72 or more is unlikely (becasue accumulation of less than 2" is unlikely to take 3 or more days to runoff) flows)
Rule 3b. 1/2 max flow scenarios are unlikely (because accumulation of less than 2" is unlikely to cause highest
Rule 4. If 3 or less application of any scenario...
Rule 4a. runoff in 72 hrs or more is unlikely (because fewer applications indicate less accumulation which is unlikely to take 3 days to runoff) accumulation and less likely to have max flow scenarios)
Rule 4b. 1/2 max flow scenarios are unlikely (because fewer applications indicate less

# Conservative[1] Analysis of Various SDOT Deicing Scenarios - Maximum Winter Flow

## Piper's Creek

1/2 Winter Max Flow - One-half of the maximum mean daily flow from Dec-Feb for period of record.

| | |
|---|---|
| Lane Miles (LM) Sand and Ice | 21 |
| Lane Miles Friction | 2.2 |
| Percent of salt runoff to reach receiving water | 80% |
| **Flow:** (cfs) | 5.6 |

**WDOE WQ Standards:**

Chronic: 230 mg/L. A 4-day average concentration not to be exceeded more than

Acute: 860 mg/L. A 1-hour average concentration not to be exceeded more than once evey three years on the average (WAC 173-201A-240).

| Legend |
|---|
| Over acute standard |
| Over chronic standard |
| Over chronic concentration, but for fewer than 4 days |
| Below chronic and acute standards |
| Unlikely scenarios |

**Volume Calculations**

| Flow (cfs) | up/down (cfs) | Baseflow (L/hr) | up/down (L/hr) | 1 h volume (L) |
|---|---|---|---|---|
| **5.6** | **0** | **575,557** | **-** | **575,557** |

**Scenario:** **3.a** 2" and over of accumulation
Liquid Anti-Ice

| mg Cl per cycle | Prewet. gal/LM | Gallons per LM |
|---|---|---|
| 255,162,954 | | 25 |

**Table C3-M**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 74 | 148 | 222 | 296 | 369 | 443 | 517 | 591 | 665 | 739 |
| 12 | 37 | 74 | 111 | 148 | 185 | 222 | 259 | 296 | 332 | 369 |
| 24 | 18 | 37 | 55 | 74 | 92 | 111 | 129 | 148 | 166 | 185 |
| 36 | 12 | 25 | 37 | 49 | 62 | 74 | 86 | 99 | 111 | 123 |
| 48 | 9 | 18 | 28 | 37 | 46 | 55 | 65 | 74 | 83 | 92 |
| 72 | 6 | 12 | 18 | 25 | 31 | 37 | 43 | 49 | 55 | 62 |
| 96 | 5 | 9 | 14 | 18 | 23 | 28 | 32 | 37 | 42 | 46 |

**Scenario:** **2.c** Trace to 2" of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 512,750,447 | 4 | 100 |

**Table C3-N**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 148 | 297 | 445 | 594 | 742 | 891 | 1,039 | 1,188 | 1,336 | 1,485 |
| 12 | 74 | 148 | 223 | 297 | 371 | 445 | 520 | 594 | 668 | 742 |
| 24 | 37 | 74 | 111 | 148 | 186 | 223 | 260 | 297 | 334 | 371 |
| 36 | 25 | 49 | 74 | 99 | 124 | 148 | 173 | 198 | 223 | 247 |
| 48 | 19 | 37 | 56 | 74 | 93 | 111 | 130 | 148 | 167 | 186 |
| 72 | 12 | 25 | 37 | 49 | 62 | 74 | 87 | 99 | 111 | 124 |
| 96 | 9 | 19 | 28 | 37 | 46 | 56 | 65 | 74 | 84 | 93 |

**Scenario:** **3.c** 2" and over of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 984,674,821 | 4 | 200 |

**Table C3-O**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 285 | 570 | 855 | 1,141 | 1,426 | 1,711 | 1,996 | 2,281 | 2,566 | 2,851 |
| 12 | 143 | 285 | 428 | 570 | 713 | 855 | 998 | 1,141 | 1,283 | 1,426 |
| 24 | 71 | 143 | 214 | 285 | 356 | 428 | 499 | 570 | 642 | 713 |
| 36 | 48 | 95 | 143 | 190 | 238 | 285 | 333 | 380 | 428 | 475 |
| 48 | 36 | 71 | 107 | 143 | 178 | 214 | 249 | 285 | 321 | 356 |
| 72 | 24 | 48 | 71 | 95 | 119 | 143 | 166 | 190 | 214 | 238 |
| 96 | 18 | 36 | 53 | 71 | 89 | 107 | 125 | 143 | 160 | 178 |

**Scenario:** **4.b** 3:1 Sand:Solid NaCl
Prewet with Liquid Anti Ice
Friction Areas Only

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 32,071,768 | 4 | 271 |

**Table C3-P**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 9 | 19 | 28 | 37 | 199 | 56 | 65 | 74 | 84 | 93 |
| 12 | 5 | 9 | 14 | 19 | 99 | 28 | 33 | 37 | 42 | 46 |
| 24 | 2 | 5 | 7 | 9 | 50 | 14 | 16 | 19 | 21 | 23 |
| 36 | 2 | 3 | 5 | 6 | 33 | 9 | 11 | 12 | 14 | 15 |
| 72 | 1 | 2 | 2 | 3 | 17 | 5 | 5 | 6 | 7 | 8 |
| 96 | 1 | 1 | 2 | 2 | 12 | 3 | 4 | 5 | 5 | 6 |

**Model Input**

Scenarios provided by SDOT. Scenarios selected to represent heaviest application amounts for each control material. Cl- concentrations in snow and ice control materials calculated from MDS sheets or SDOT-provided information.

**Model Assumptions**

- Flow estimates based on daily average of continuous 5-min flow data from December through February during the period of record for SPU data recorders in the receiving water.
- o One-half Winter Maximum Flow = One-half of the maximum mean daily flow from Dec-Feb for period of record. This is intended to represent flow during larger winter storm events.
- Duration of runoff ranges from 6 to 96 hours.
- 80% of Cl- load applied to roadways in the drainage basin is diluted by the total creek flow.
- Cl- uniformly washes off throughout the runoff duration.

See accompanying text for more information.

**Unlikely Scenario Rules**

Rule 1. If the scenario is for 2" or over of accumulation (Scenarios 3a and 3c)...
Rule 1a. runoff in 6 hrs or less is unlikely (because will likely take greater than 6 hrs for over 2" accumulation to melt off)
Rule 2. If 5 or greater applications of any scenario...
Rule 2a. runoff in 12 hrs or less is unlikely (because more applications indicate more accumulation which would likely take more than 12 hrs to meltoff) more accumulation which would contribute to flow)
Rule 3. If the scenarios is for trace to 2" of accumulation (Scenario 2c)...
Rule 3a. runoff in 72 or more is unlikely (becasue accumulation of less than 2" is unlikely to take 3 or more days to runoff) flows)
Rule 4. If 3 or less application of any scenario...
Rule 4a. runoff in 72 hrs or more is unlikely (because fewer applications indicate less accumulation which is unlikely to take 3 days to runoff) accumulation and less likely to have max flow scenarios)

# Conservative[1] Analysis of Various SDOT Deicing Scenarios - Minimum Winter Flow

## Longfellow Creek

Winter Minimum Flow - Minimum mean daily flow from Dec-Feb for period of record.

| | |
|---|---|
| Lane Miles (LM) Sand and Ice | 16 |
| Lane Miles Friction | 10.1 |
| Percent of salt runoff to reach receiving water | 80% |
| **Flow:** cfs | 0.7 |

| **WDOE WQ Standards:** |
|---|
| Chronic: 230 mg/L. A 4-day average concentration not to be exceeded more than once evey three |
| Acute: 860 mg/L. A 1-hour average concentration not to be exceeded more than once evey three years on the average (WAC 173-201A-240). |

| Legend |
|---|
| Over acute standard |
| Over chronic standard |
| Over chronic concentration, but for fewer than 4 days |
| Below chronic and acute standards |
| Unlikely scenarios |

**Volume Calculations**

| Flow (cfs) | up/down (cfs) | Baseflow (L/hr) | up/down (L/hr) | 1 h volume (L) |
|---|---|---|---|---|
| **0.7** | **0** | **66,669** | **-** | **66,669** |

**Scenario:** **3.a** 2" and over of accumulation
Liquid Anti-Ice

| mg Cl per cycle | Prewet. gal/LM | Gallons per LM |
|---|---|---|
| 193,885,547 | | 25 |

**Table C3-Q**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 485 | 969 | 1,454 | 1,939 | 2,423 | 2,908 | 3,393 | 3,878 | 4,362 | 4,847 |
| 12 | 242 | 485 | 727 | 969 | 1,212 | 1,454 | 1,696 | 1,939 | 2,181 | 2,423 |
| 24 | 121 | 242 | 364 | 485 | 606 | 727 | 848 | 969 | 1,091 | 1,212 |
| 36 | 81 | 162 | 242 | 323 | 404 | 485 | 565 | 646 | 727 | 808 |
| 48 | 61 | 121 | 182 | 242 | 303 | 364 | 424 | 485 | 545 | 606 |
| 72 | 40 | 81 | 121 | 162 | 202 | 242 | 283 | 323 | 364 | 404 |
| 96 | 30 | 61 | 91 | 121 | 151 | 182 | 212 | 242 | 273 | 303 |

**Scenario:** **2.c** Trace to 2" of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 389,613,379 | 4 | 100 |

**Table C3-R**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 974 | 1,948 | 2,922 | 3,896 | 4,870 | 5,844 | 6,818 | 7,792 | 8,766 | 9,740 |
| 12 | 487 | 974 | 1,461 | 1,948 | 2,435 | 2,922 | 3,409 | 3,896 | 4,383 | 4,870 |
| 24 | 243 | 487 | 730 | 974 | 1,217 | 1,461 | 1,704 | 1,948 | 2,191 | 2,435 |
| 36 | 162 | 325 | 487 | 649 | 812 | 974 | 1,136 | 1,299 | 1,461 | 1,623 |
| 48 | 122 | 243 | 365 | 487 | 609 | 730 | 852 | 974 | 1,096 | 1,217 |
| 72 | 81 | 162 | 243 | 325 | 406 | 487 | 568 | 649 | 730 | 812 |
| 96 | 61 | 122 | 183 | 243 | 304 | 365 | 426 | 487 | 548 | 609 |

**Scenario:** **3.c** 2" and over of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 748,205,071 | 4 | 200 |

**Table C3-S**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 1,870 | 3,741 | 5,611 | 7,482 | 9,352 | 11,223 | 13,093 | 14,964 | 16,834 | 18,704 |
| 12 | 935 | 1,870 | 2,806 | 3,741 | 4,676 | 5,611 | 6,547 | 7,482 | 8,417 | 9,352 |
| 24 | 468 | 935 | 1,403 | 1,870 | 2,338 | 2,806 | 3,273 | 3,741 | 4,208 | 4,676 |
| 36 | 312 | 623 | 935 | 1,247 | 1,559 | 1,870 | 2,182 | 2,494 | 2,806 | 3,117 |
| 48 | 234 | 468 | 701 | 935 | 1,169 | 1,403 | 1,637 | 1,870 | 2,104 | 2,338 |
| 72 | 156 | 312 | 468 | 623 | 779 | 935 | 1,091 | 1,247 | 1,403 | 1,559 |
| 96 | 117 | 234 | 351 | 468 | 585 | 701 | 818 | 935 | 1,052 | 1,169 |

**Scenario:** **4.b** 3:1 Sand:Solid NaCl
Prewet with Liquid Anti Ice
Friction Areas Only

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 146,862,576 | 4 | 271 |

**Table C3-T**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 367 | 734 | 1,101 | 1,469 | 1,836 | 2,203 | 2,570 | 2,937 | 3,304 | 3,671 |
| 12 | 184 | 367 | 551 | 734 | 918 | 1,101 | 1,285 | 1,469 | 1,652 | 1,836 |
| 24 | 92 | 184 | 275 | 367 | 459 | 551 | 642 | 734 | 826 | 918 |
| 36 | 61 | 122 | 184 | 245 | 306 | 367 | 428 | 490 | 551 | 612 |
| 72 | 31 | 61 | 92 | 122 | 153 | 184 | 214 | 245 | 275 | 306 |
| 96 | 23 | 46 | 69 | 92 | 115 | 138 | 161 | 184 | 207 | 229 |

**Model Input**

Scenarios provided by SDOT. Scenarios selected to represent heaviest application amounts for each control material. Cl- concentrations in snow and ice control materials calculated from MDS sheets or SDOT-provided information.

**Model Assumptions**

- Flow estimates based on daily average of continuous 5-min flow data from December through February during the period of record for SPU data recorders in the receiving water.
  - o Winter Minimum Flow = Minimum mean daily flow from Dec-Feb for period of record. This extremely low flow is intended to represent the unlikely worst case scenario.
- Duration of runoff ranges from 6 to 96 hours.
- 80% of Cl- load applied to roadways in the drainage basin is diluted by the total creek flow.
- Cl- uniformly washes off throughout the runoff duration.

See accompanying text for more information.

**Unlikely Scenario Rules**

Rule 1. If the scenario is for 2" or over of accumulation (Scenarios 3a and 3c)...
Rule 1a. runoff in 6 hrs or less is unlikely (because will likely take greater than 6 hrs for over 2" accumulation to melt off)
Rule 1b. baseflow scenarios are unlikely (because runoff of over 2" accumulation will contribute to flow)
Rule 2. If 5 or greater applications of any scenario...
Rule 2a. runoff in 12 hrs or less is unlikely (because more applications indicate more accumulation which would likely take more than 12 hrs to meltoff) more accumulation which would contribute to flow)
Rule 2b. baseflow scenarios are unlikely (because more applications indicate
Rule 3. If the scenarios is for trace to 2" of accumulation (Scenario 2c)...
Rule 3a. runoff in 72 or more is unlikely (becasue accumulation of less than 2" is unlikely to take 3 or more days to runoff) flows)
Rule 3b. 1/2 max flow scenarios are unlikely (because accumulation of less than 2" is unlikely to cause highest
Rule 4. If 3 or less application of any scenario...
Rule 4a. runoff in 72 hrs or more is unlikely (because fewer applications indicate less accumulation which is unlikely to take 3 days to runoff) accumulation and less likely to have max flow scenarios)
Rule 4b. 1/2 max flow scenarios are unlikely (because fewer applications indicate less

# Conservative[1] Analysis of Various SDOT Deicing Scenarios - Maximum Winter Flow

## Longfellow Creek

1/2 Winter Max Flow - One-half of the maximum mean daily flow from Dec-Feb for period of record.

| | |
|---|---|
| Lane Miles (LM) Sand and Ice | 16 |
| Lane Miles Friction | 10.1 |
| Percent of salt runoff to reach receiving water | 80% |
| **Flow:** cfs | 37.5 |

| **WDOE WQ Standards:** |
|---|
| Chronic: 230 mg/L. A 4-day average concentration not to be exceeded more than once evey three years |
| Acute: 860 mg/L. A 1-hour average concentration not to be exceeded more than once evey three years on the average (WAC 173-201A-240). |

| Legend |
|---|
| Over acute standard |
| Over chronic standard |
| Over chronic concentration, but for fewer than 4 days |
| Below chronic and acute standards |
| Unlikely scenarios |

**Volume Calculations**

| Flow (cfs) | up/down (cfs) | Baseflow (L/hr) | up/down (L/hr) | 1 h volume (L) |
|---|---|---|---|---|
| **37.5** | **0** | **3,822,061** | **-** | **3,822,061** |

**Scenario:** **3.a** 2" and over of accumulation
Liquid Anti-Ice

| **mg Cl per cycle** | **Prewet. gal/LM** | **Gallons per LM** |
|---|---|---|
| 193,885,547 | | 25 |

**Table C3-U**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 8 | 17 | 25 | 34 | 42 | 51 | 59 | 68 | 76 | 85 |
| 12 | 4 | 8 | 13 | 17 | 21 | 25 | 30 | 34 | 38 | 42 |
| 24 | 2 | 4 | 6 | 8 | 11 | 13 | 15 | 17 | 19 | 21 |
| 36 | 1 | 3 | 4 | 6 | 7 | 8 | 10 | 11 | 13 | 14 |
| 48 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 11 |
| 72 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 | 7 |
| 96 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5 |

**Scenario:** **2.c** Trace to 2" of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| **mg Cl per cycle** | **Prewet. gal/LM** | **Lbs per LM** |
|---|---|---|
| 389,613,379 | 4 | 100 |

**Table C3-V**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 17 | 34 | 51 | 68 | 85 | 102 | 119 | 136 | 153 | 170 |
| 12 | 1 | 17 | 25 | 34 | 42 | 51 | 59 | 68 | 76 | 85 |
| 24 | 0 | 8 | 13 | 17 | 21 | 25 | 30 | 34 | 38 | 42 |
| 36 | 0 | 6 | 8 | 11 | 14 | 17 | 20 | 23 | 25 | 28 |
| 48 | 0 | 4 | 6 | 8 | 11 | 13 | 15 | 17 | 19 | 21 |
| 72 | 0 | 3 | 4 | 6 | 7 | 8 | 10 | 11 | 13 | 14 |
| 96 | 0 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 11 |

**Scenario:** **3.c** 2" and over of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| **mg Cl per cycle** | **Prewet. gal/LM** | **Lbs per LM** |
|---|---|---|
| 748,205,071 | 4 | 200 |

**Table C3-W**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 33 | 65 | 98 | 131 | 163 | 196 | 228 | 261 | 294 | 326 |
| 12 | 16 | 33 | 49 | 65 | 82 | 98 | 114 | 131 | 147 | 163 |
| 24 | 8 | 16 | 24 | 33 | 41 | 49 | 57 | 65 | 73 | 82 |
| 36 | 5 | 11 | 16 | 22 | 27 | 33 | 38 | 44 | 49 | 54 |
| 48 | 4 | 8 | 12 | 16 | 20 | 24 | 29 | 33 | 37 | 41 |
| 72 | 3 | 5 | 8 | 11 | 14 | 16 | 19 | 22 | 24 | 27 |
| 96 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 |

**Scenario:** **4.b** 3:1 Sand:Solid NaCl
Prewet with Liquid Anti Ice
Friction Areas Only

| **mg Cl per cycle** | **Prewet. gal/LM** | **Lbs per LM** |
|---|---|---|
| 127,483,596 | 4 | 271 |

**Table C3-X**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 6 | 11 | 17 | 22 | 28 | 33 | 39 | 44 | 50 | 56 |
| 12 | 0 | 6 | 8 | 11 | 14 | 17 | 19 | 22 | 25 | 28 |
| 24 | 0 | 3 | 4 | 6 | 7 | 8 | 10 | 11 | 13 | 14 |
| 36 | 0 | 2 | 3 | 4 | 5 | 6 | 6 | 7 | 8 | 9 |
| 72 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 96 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 |

**Model Input**
Scenarios provided by SDOT. Scenarios selected to represent heaviest application amounts for each control material. Cl- concentrations in snow and ice control materials calculated from MDS sheets or SDOT-provided information.
**Model Assumptions**
- Flow estimates based on daily average of continuous 5-min flow data from December through February during the period of record for SPU data recorders in the receiving water.
  - o o One-half Winter Maximum Flow = One-half of the maximum mean daily flow from Dec-Feb for period of record. This is intended to represent flow during larger winter storm events.
- Duration of runoff ranges from 6 to 96 hours.
- 80% of Cl- load applied to roadways in the drainage basin is diluted by the total creek flow.
- Cl- uniformly washes off throughout the runoff duration.

See accompanying text for more information.

**Unlikely Scenario Rules**
Rule 1. If the scenario is for 2" or over of accumulation (Scenarios 3a and 3c)...
Rule 1a. runoff in 6 hrs or less is unlikely (because will likely take greater than 6 hrs for over 2" accumulation to melt off)
Rule 2. If 5 or greater applications of any scenario...
Rule 2a. runoff in 12 hrs or less is unlikely (because more applications indicate more accumulation which would likely take more than 12 hrs to meltoff) more accumulation which would contribute to flow)
Rule 3. If the scenarios is for trace to 2" of accumulation (Scenario 2c)...
Rule 3a. runoff in 72 or more is unlikely (becasue accumulation of less than 2" is unlikely to take 3 or more days to runoff) flows)
Rule 4. If 3 or less application of any scenario...
Rule 4a. runoff in 72 hrs or more is unlikely (because fewer applications indicate less accumulation which is unlikely to take 3 days to runoff) accumulation and less likely to have max flow scenarios)

# Conservative[1] Analysis of Various SDOT Deicing Scenarios - Minimum Winter Flow

## Fauntleroy Creek

Winter Minimum Flow - Minimum mean daily flow from Dec-Feb for period of record.

| | |
|---|---|
| Lane Miles (LM) Sand and Ice | 1 |
| Lane Miles Friction | 0.8 |
| Percent of salt runoff to reach receiving water | 80% |
| **Flow:** cfs | 0.5 |

| **WDOE WQ Standards:** | Legend |
|---|---|
| Chronic: 230 mg/L. A 4-day average concentration not to be exceeded more than | Over acute standard |
| | Over chronic standard |
| Acute: 860 mg/L. A 1-hour average concentration not to be exceeded more than once evey three years on the average (WAC 173- | Over chronic concentration, but for fewer than 4 days |
| | Below chronic and acute standards |
| | Unlikely scenarios |

| Flow (cfs) | up/down (cfs) | Baseflow (L/hr) | up/down (L/hr) | 1 h volume (L) |
|---|---|---|---|---|
| **0.5** | **0** | **48,432** | **-** | **48,432** |

**Scenario:** **3.a** 2" and over of accumulation
Liquid Anti-Ice

| **mg Cl per cycle** | **Prewet. gal/LM** | **Gallons per LM** |
|---|---|---|
| 10,651,737 | 0 | 25 |

**Table C3-Y**

| Duration of washoff (hrs) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Number of application cycles** | | | | | | | | | |
| 6 | 37 | 73 | 110 | 147 | 183 | 220 | 257 | 293 | 330 | 367 |
| 12 | 18 | 37 | 55 | 73 | 92 | 110 | 128 | 147 | 165 | 183 |
| 24 | 9 | 18 | 27 | 37 | 46 | 55 | 64 | 73 | 82 | 92 |
| 36 | 6 | 12 | 18 | 24 | 31 | 37 | 43 | 49 | 55 | 61 |
| 48 | 5 | 9 | 14 | 18 | 23 | 27 | 32 | 37 | 41 | 46 |
| 72 | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 | 31 |

**Scenario:** **2.c** Trace to 2" of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| **mg Cl per cycle** | **Prewet. gal/LM** | **Lbs per LM** |
|---|---|---|
| 21,404,686 | 4 | 100 |

**Table C3-Z**

| Duration of washoff (hrs) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Number of application cycles** | | | | | | | | | |
| 6 | 74 | 147 | 221 | 295 | 368 | 442 | 516 | 589 | 663 | 737 |
| 12 | 6 | 74 | 110 | 147 | 184 | 221 | 258 | 295 | 331 | 368 |
| 24 | 0 | 37 | 55 | 74 | 92 | 110 | 129 | 147 | 166 | 184 |
| 36 | 0 | 25 | 37 | 49 | 61 | 74 | 86 | 98 | 110 | 123 |
| 48 | 0 | 18 | 28 | 37 | 46 | 55 | 64 | 74 | 83 | 92 |
| 72 | 0 | 12 | 18 | 25 | 31 | 37 | 43 | 49 | 55 | 61 |
| 96 | 0 | 9 | 14 | 18 | 23 | 28 | 32 | 37 | 41 | 46 |

**Scenario:** **3.c** 2" and over of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| **mg Cl per cycle** | **Prewet. gal/LM** | **Lbs per LM** |
|---|---|---|
| 41,105,093 | 4 | 200 |

**Table C3-AA**

| Duration of washoff (hrs) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Number of application cycles** | | | | | | | | | |
| 6 | 141 | 283 | 424 | 566 | 707 | 849 | 990 | 1,132 | 1,273 | 1,415 |
| 12 | 71 | 141 | 212 | 283 | 354 | 424 | 495 | 566 | 637 | 707 |
| 24 | 35 | 71 | 106 | 141 | 177 | 212 | 248 | 283 | 318 | 354 |
| 36 | 24 | 47 | 71 | 94 | 118 | 141 | 165 | 189 | 212 | 236 |
| 48 | 18 | 35 | 53 | 71 | 88 | 106 | 124 | 141 | 159 | 177 |
| 72 | 12 | 24 | 35 | 47 | 59 | 71 | 83 | 94 | 106 | 118 |
| 96 | 9 | 18 | 27 | 35 | 44 | 53 | 62 | 71 | 80 | 88 |

**Scenario:** **4.b** 3:1 Sand:Solid NaCl
Prewet with Liquid Anti Ice
Friction Areas Only

| **mg Cl per cycle** | **Prewet. gal/LM** | **Lbs per LM** |
|---|---|---|
| 12,190,174 | 4 | 271 |

**Table C3-BB**

| Duration of washoff (hrs) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Number of application cycles** | | | | | | | | | |
| 6 | 42 | 84 | 126 | 168 | 210 | 252 | 294 | 336 | 378 | 419 |
| 12 | 21 | 42 | 63 | 84 | 105 | 126 | 147 | 168 | 189 | 210 |
| 24 | 10 | 21 | 31 | 42 | 52 | 63 | 73 | 84 | 94 | 105 |
| 36 | 7 | 14 | 21 | 28 | 35 | 42 | 49 | 56 | 63 | 70 |
| 72 | 3 | 7 | 10 | 14 | 17 | 21 | 24 | 28 | 31 | 35 |
| 96 | 3 | 5 | 8 | 10 | 13 | 16 | 18 | 21 | 24 | 26 |

**Model Input**

Scenarios provided by SDOT. Scenarios selected to represent heaviest application amounts for each control material. Cl- concentrations in snow and ice control materials calculated from MDS sheets or SDOT-provided

**Model Assumptions**

- Flow estimates based on daily average of continuous 5-min flow data from December through February during the period of record for SPU data recorders in the receiving water.
  - Winter Minimum Flow = Minimum mean daily flow from Dec-Feb for period of record. This extremely low flow is intended to represent the unlikely worst case scenario.
  - o
- Duration of runoff ranges from 6 to 96 hours.
- 80% of Cl- load applied to roadways in the drainage basin is diluted by the total creek flow.
- Cl- uniformly washes off throughout the runoff duration.

See accompanying text for more information.

**Unlikely Scenario Rules**

Rule 1. If the scenario is for 2" or over of accumulation (Scenarios 3a and 3c)...
Rule 1a. runoff in 6 hrs or less is unlikely (because will likely take greater than 6 hrs for over 2" accumulation to melt off)
Rule 1b. baseflow scenarios are unlikely (because runoff of over 2" accumulation will contribute to flow)
Rule 2. If 5 or greater applications of any scenario...
Rule 2a. runoff in 12 hrs or less is unlikely (because more applications indicate more accumulation which would likely take more than 12 hrs to meltoff) more accumulation which would contribute to flow)
Rule 2b. baseflow scenarios are unlikely (because more applications indicate
Rule 3. If the scenarios is for trace to 2" of accumulation (Scenario 2c)...
Rule 3a. runoff in 72 or more is unlikely (becasue accumulation of less than 2" is unlikely to take 3 or more days to runoff) flows)
Rule 3b. 1/2 max flow scenarios are unlikely (because accumulation of less than 2" is unlikely to cause highest
Rule 4. If 3 or less application of any scenario...
Rule 4a. runoff in 72 hrs or more is unlikely (because fewer applications indicate less accumulation which is unlikely to take 3 days to runoff) accumulation and less likely to have max flow scenarios)
Rule 4b. 1/2 max flow scenarios are unlikely (because fewer applications indicate less

# Conservative[1] Analysis of Various SDOT Deicing Scenarios - Maximum Winter Flow

## Fauntleroy Creek

1/2 Winter Max Flow - One-half of the maximum mean daily flow from Dec-Feb for period of record.

| | |
|---|---|
| Lane Miles (LM) Sand and Ice | 1 |
| Lane Miles Friction | 0.8 |
| Percent of salt runoff to reach receiving water | 80% |

| | cfs |
|---|---|
| **Flow:** | 5.6 |

| WDOE WQ Standards: | Legend |
|---|---|
| Chronic: 230 mg/L. A 4-day average concentration not to be exceeded more than | Over acute standard |
| | Over chronic standard |
| Acute: 860 mg/L. A 1-hour average concentration not to be exceeded more than once evey three years on the average (WAC 173- | Over chronic concentration, but for fewer than 4 days |
| | Below chronic and acute standards |
| | Unlikely scenarios |

| Flow (cfs) | up/down (cfs) | Baseflow (L/hr) | up/down (L/hr) | 1 h volume (L) |
|---|---|---|---|---|
| **5.6** | **0** | **575,557** | **-** | **575,557** |

**Scenario:** **3.a** 2" and over of accumulation
Liquid Anti-Ice

| mg Cl per cycle | Prewet. gal/LM | Gallons per LM |
|---|---|---|
| 10,651,737 | 0 | 25 |

**Table C3-CC**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 3 | 6 | 9 | 12 | 15 | 19 | 22 | 25 | 28 | 31 |
| 12 | 2 | 3 | 5 | 6 | 8 | 9 | 11 | 12 | 14 | 15 |
| 24 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 | 8 |
| 36 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5 |
| 48 | 0 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 4 |
| 72 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 |

**Scenario:** **2.c** Trace to 2" of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 21,404,686 | 4 | 100 |

**Table C3-DD**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 6 | 12 | 19 | 25 | 31 | 37 | 43 | 50 | 56 | 62 |
| 12 | 3 | 6 | 9 | 12 | 15 | 19 | 22 | 25 | 28 | 31 |
| 24 | 2 | 3 | 5 | 6 | 8 | 9 | 11 | 12 | 14 | 15 |
| 36 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 48 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 | 8 |
| 72 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5 |
| 96 | 0 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 4 |

**Scenario:** **3.c** 2" and over of accumulation
Solid NaCl
Prewet with Liquid Anti Ice

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 41,105,093 | 4 | 200 |

**Table C3-EE**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 12 | 24 | 36 | 48 | 60 | 71 | 83 | 95 | 107 | 119 |
| 12 | 6 | 12 | 18 | 24 | 30 | 36 | 42 | 48 | 54 | 60 |
| 24 | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 | 30 |
| 36 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 |
| 48 | 1 | 3 | 4 | 6 | 7 | 9 | 10 | 12 | 13 | 15 |
| 72 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 96 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 7 |

**Scenario:** **4.b** 3:1 Sand:Solid NaCl
Prewet with Liquid Anti Ice
Friction Areas Only

| mg Cl per cycle | Prewet. gal/LM | Lbs per LM |
|---|---|---|
| 12,190,174 | 4 | 271 |

**Table C3-FF**

| Duration of washoff (hrs) | Number of application cycles: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 4 | 7 | 11 | 14 | 18 | 21 | 25 | 28 | 32 | 35 |
| 12 | 2 | 4 | 5 | 7 | 9 | 11 | 12 | 14 | 16 | 18 |
| 24 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 8 | 9 |
| 36 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 | 6 |
| 72 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 |
| 96 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 |

**Model Input**

Scenarios provided by SDOT. Scenarios selected to represent heaviest application amounts for each control material. Cl- concentrations in snow and ice control materials calculated from MDS sheets or SDOT-provided information.

**Model Assumptions**

- Flow estimates based on daily average of continuous 5-min flow data from December through February during the period of record for SPU data recorders in the receiving water.
  - One-half Winter Maximum Flow = One-half of the maximum mean daily flow from Dec-Feb for period of record. This is intended to represent flow during typical large winter storm events. This is intended to represent flow during larger winter storm events. Due to the short period of record for Fauntleroy Creek, this value was estimated by using flow data from Piper's Creek.
- Duration of runoff ranges from 6 to 96 hours.
- 80% of Cl- load applied to roadways in the drainage basin is diluted by the total creek flow.
- Cl- uniformly washes off throughout the runoff duration.

See accompanying text for more information.

**Unlikely Scenario Rules**

Rule 1. If the scenario is for 2" or over of accumulation (Scenarios 3a and 3c)...
Rule 1a. runoff in 6 hrs or less is unlikely (because will likely take greater than 6 hrs for over 2" accumulation to melt off)
Rule 2. If 5 or greater applications of any scenario...
Rule 2a. runoff in 12 hrs or less is unlikely (because more applications indicate more accumulation which would likely take more than 12 hrs to meltoff) more accumulation which would contribute to flow)
Rule 3. If the scenarios is for trace to 2" of accumulation (Scenario 2c)...
Rule 3a. runoff in 72 or more is unlikely (becasue accumulation of less than 2" is unlikely to take 3 or more days to runoff) flows)
Rule 4. If 3 or less application of any scenario...
Rule 4a. runoff in 72 hrs or more is unlikely (because fewer applications indicate less accumulation which is unlikely to take 3 days to runoff) accumulation and less likely to have max flow scenarios)

**Attachment D.  Sand and Potential Aquatic Impacts**

Fine sediment associated with road sanding, specifically, and road grit in general can have negative impacts on aquatic ecosystems. Fine sediment deposition in streams, wetlands, and estuarine areas at the mouths of streams degrades habitat and may directly harm aquatic organisms, especially benthic biota. Fine sediment has been shown to harm salmonid eggs and developing embryos (alevins), as well as benthic macroinvertebrates. In the urban environment, sediment frequently carries pollutants such as metals, petroleum hydrocarbons, and organic chemicals. These pollutants can be toxic to native aquatic biota. Therefore, the use of sand should be judicious on roads that drain to sensitive aquatic ecosystems.  Additionally, sand should be removed from road surface via street sweeping or other methods as soon as feasible after snow and ice conditions end.

SPU will support the mitigation of sediment impacts from roadway sanding by cleaning all catch basins located along road sanding routes annually of all accumulated material in the catch basin sump (regulatory requirements call for annual inspection and removal of material only when the catch basin sump is great than 50% full).  SPU will also inspect catch basins after notification by SDOT of sand application and will remove accumulated sediment as required (as soon as feasible after snow and ice conditions end).  Priority will be given to catch basins which drain directly to sensitive aquatic ecosystems (versus the combined sewer system).

**Attachment E.  Glucose and Potential Aquatic Impacts**

Glucose, a type of simple sugar, binds deicing compounds to road surfaces. The increased binding of the deicing compound will lengthen the time for the material to wash into receiving waters. This decreases their concentrations in the aquatic environment. Sugars added to a water body are primarily metabolized by naturally occurring bacteria. These bacteria use some dissolved oxygen in the process. During winter the receiving waters are cold, which reduces bacteria metabolic rates. Also, winter stream flows are high and turbulent, which increases dissolved oxygen concentrations. Slow wash-off of glucose-containing deicers, low cold-weather metabolic demand for oxygen and high concentrations of dissolved oxygen in receiving waters would tend to keep dissolved oxygen concentrations high. The small amount of sugars added to roadway in deicing applications and washing into any of the streams would have negligible impact on concentrations of dissolved oxygen. In wetlands and lakes the small metabolic demand of this material would be diluted and unlikely to contribute significantly to eutrophication.

**Attachment F. Product Specification – Environmental Attributes**

Snow and ice control materials often include additives or impurities which can be a concern to the aquatic environment. For NaCl, $MgCl_2$, $CaCl_2$, and organic materials, these contaminants may include heavy metals (e.g., zinc, copper, lead, and cadmium), phosphorus, and cyanide (NaCl only) (NCHRP 2007).

Specifications and test procedures have been developed to emphasize environmental protection. In this region, Pacific Northwest Snowfighters (PNS) has developed environmental (as well as physical and corrosion related) specifications for snow and ice control materials. PNS also has a Qualified Product List which identifies regional products which have been tested and meet their specifications.

It is recommended that SDOT use PNS qualified products. Alternatively, SDOT should have an established quality testing process that utilizes PNS (or similar) specifications for environmental contaminants of concern.

References

National Cooperative Highway Research Program (NCHRP). 2007. Guidelines for the Selection of Snow and Ice Control Materials to Mitigate Environmental Impacts. NCHRP Report 577. Washington DC. 211 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_577.pdf

Related Web Sites

Pacific Northwest Snowfighters (PNS) Home Page: http://www.wsdot.wa.gov/partners/pns/default.htm
PNS Qualified Product List: http://www.wsdot.wa.gov/partners/pns/pdf/PNSQPL.pdf