4.0 – DRAINAGE

This is one in a series of Syntheses of Best Practices related to the effective management of road salt in winter maintenance operations. This Synthesis is provided as advice for preparing Salt Management Plans. The Synthesis is not intended to be used prescriptively but is to be used in concert with the legislation, manuals, directives and procedures of relevant jurisdictions and individual organizations. Syntheses of Best Practices have been produced on:

1. Salt Management Plans
2. Training
3. Road, Bridge and Facility Design
4. Drainage
5. Pavements and Salt Management
6. Vegetation Management
7. Design and Operation of Maintenance Yards
8. Snow Storage and Disposal
9. Winter Maintenance Equipment and Technologies
10. Salt Use on Private Roads, Parking Lots and Walkways
11. Successes in Road Salt Management: Case Studies

For more detailed information, please refer to TAC's Salt Management Guide - 2013.

INTRODUCTION

Salt-laden runoff can have adverse effects on the natural environment. The nature and extent of these effects are site specific, and may be temporary or can persist for long periods of time. In some areas, the concentration of chloride in the groundwater and stream baseflow may reach levels sufficient to impair the potability of groundwater or alter aquatic habitat. This Synthesis of Best Practices establishes Guiding Principles to aid in the design of drainage works for existing or new roadways and parking lots, and provides a framework to identify the specific practices that can be implemented to minimize potential effects of salt on the surrounding environment.

This Chapter of the Synthesis of Best Practices does not specifically address the effects of salt-laden runoff and salt spray on vegetation. The Synthesis of Best Practices for Vegetation Management provides information on that aspect of snow and ice control chemicals. It also does not deal with other contaminants in pavement runoff.

RELATIONSHIP TO SALT MANAGEMENT

Most of the salt that is placed on a pavement during snow and ice control operations eventually runs off with the pavement drainage. This drainage enters the

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environment through three primary pathways. The first is through overland drainage or stormsewer systems, ultimately discharging to nearby surface water. The second is infiltration into the ground, potentially entering groundwater. The third is through spray caused by traffic and wind, potentially affecting adjacent vegetation and agricultural crops. If any of these pathways introduce high salt concentrations to salt vulnerable areas, then adverse effects may occur. Proper drainage planning and design can reduce the potential effects on salt vulnerable areas by isolating the drainage from vulnerable areas.

This Synthesis of Best Practices, when used in combination with other policies and guidelines for drainage design, will assist in the responsible selection of drainage management measures. Regardless of the policy framework, the following guiding principles exist for creating an overall management plan that also minimizes salt related effects:

1. Safety is the priority. Drainage design must ensure that pavement runoff is efficiently and safely removed from the travel surface.
2. Drainage design must consider, comprehensively, all drainage related impacts in the formulation of a responsible and effective management strategy.
3. The most significant, potential, long-term impact of salt-laden runoff is impairment of domestic groundwater supply.
4. Drainage design must endeavor to protect the natural environment.
5. Drainage design must be practical and must not impose undue maintenance requirements.

SALT MANAGEMENT PRACTICES

The main purpose of any pavement drainage system is to convey runoff safely downstream to either a natural or man-made drainage system. Management measures should be implemented to ensure that this is done with minimal impact to the infiltration characteristics, water quality, erosion potential, and flood risk of the receiving drainage system. At the onset of any drainage design, sufficient information should be collected to characterize the existing drainage system surrounding and downstream of the paved area.

IMPACT IDENTIFICATION

A detailed surface water assessment should be completed to identify all potential effects to natural features as a result of the paved area. The requirements of the assessment will be defined by the policy framework in the area where the drainage design is being completed. As a minimum, the assessment should include a review of the effects of salt-laden surface water on potable water taken from groundwater sources, sensitive aquatic habitat, agricultural lands, wetlands and wildlife.

Each of these features is described below. Guidelines have been provided to establish the relative importance of each feature as defined by low, medium or high potential for impact. Specific site characteristics may require that other features be considered as well. The impact potential identified for all significant features will assist in the selection of suitable mitigative measures.

Ground Water

The suitability of groundwater for potable use and irrigation can be significantly impaired by the infiltration of salt from pavement runoff. To determine the potential for impact from salt-laden runoff on groundwater, the following questions must be addressed:

- Are there domestic wells near the roadway or parking lot?
- If there are wells, do they draw from a sensitive aquifer (e.g., small, shallow aquifer)?
- Are the surficial unconsolidated materials permeable (e.g., sandy soil)?
- Are there any snow management facilities upstream (i.e. snow disposal sites, snowmelt ponds)?
- The degree of potential impact on groundwater can be determined based on the responses to these questions:
- High: The answer is 'yes' to all or first three questions.

- Medium: The answer is 'yes' to the first question and 'yes' to either the second, third or fourth question.
- Low: All other cases.

Aquatic Habitat

Salt-laden runoff may impact aquatic habitat in two ways: sudden pulses of chlorides during spring runoff, and continuous levels of chloride present in the groundwater discharging to the receiving stream. Although both types of effects are a concern, sudden pulses are the greater concern in considering "how much is too much". The following guideline can be used to assess the potential impact:

- High: The receiving watercourse has a permanent baseflow, and the catchment area of the road or parking lot represents more than 10 percent of the catchment area of the stream.
- Medium: The receiving watercourse has a permanent baseflow, and the catchment area of the road represents less than 10 percent of the catchment area of the stream.
- Low: All other cases (i.e. receiving watercourses with no permanent baseflow).

Agricultural Land

Salt-laden runoff can impact crops in cases where there is the potential for water to pond on agricultural lands. This situation can arise where there is poor positive drainage or an outlet has been blocked by ice or debris. Guidelines for assessing potential effects are as follows:

- High: Agricultural land is adjacent to the road or parking lot, and drainage has a high likelihood of ponding or blockage.
- Medium: Agricultural land is adjacent to the road or parking lot, and drainage has a low to moderate potential for ponding or blockage.
- Low: Agricultural land is either outside the road or parking lot runoff influence zone, or there is no agricultural land adjacent.

Wetlands

Swamps, peat bogs, marshes and other types of wetlands can be impacted where runoff is directed to adjacent natural vegetation features. In these cases the runoff may enter the wetland as sheet flow or via a roadside ditch. With very high and prolonged chloride loading, there is the possibility that changes in local plant composition may occur, with the possibility of a reduction in the overall value and diversity of the wetland. Small, perched wetlands that intercept the shallow water table or that are primarily surface water dependant may be most susceptible to chloride loading effects due to their small size and a reduced dilution potential. Large wetlands with extensive catchment areas and high dilution potential are likely more tolerant of chloride loading. Potential effects may be classified as follows for wetlands located adjacent to the roadway:

- High: No clear flow path evident through the wetland and/or small perched roadside wetlands present (<5 ha in size).
- Medium: Poorly defined channel evident through the wetland and/or moderate sized wetland with better dilution potential (5 -20 ha in size).
- Low: Clearly defined channel evident through the wetland and/or large wetland with good dilution potential (>20 ha in size).

Wildlife

Ponded runoff can serve as a salt source for wildlife. The attraction of the wildlife to the saltwater can be a safety hazard. Potential effects may be classified as follows:

- High: located in an area where large mammals (such as elk, big horned sheep, white-tailed deer and moose) are present and where ponding adjacent to the pavement is a current problem or has a high potential based on design limitations and topography.
- Medium: located as above, but ponding is not a current problem or has only a moderate potential based on design limitations and topography.
- Low: located as above, but there is no existing or future ponding problem or large mammals are limited or absent in the area.

Impact Identification Summary

The potential effects of salt on each of the categories can be summarized in a table similar to the following example. This table represents a starting point for identifying appropriate drainage management practices that can be used to minimize the effects of salt on the adjacent environment:

Impact Potential	Feature That May Be Impacted				
	Ground-water	Aquatic Habitat	Agriculatural Lands	Wetlands	Ground-water
Not applicable			✓		
Low					✓
Medium				✓	
High	✓	✓			

IDENTIFICATION OF ALTERNATIVE MANAGEMENT PRACTICES

The minimization of salt related effects should be one objective of any management strategy formulated for pavement drainage systems. Unfortunately, the range of potential effects from salt-laden runoff offers considerable challenge to the designer. There are a number of practices that can aid in the management of runoff, however, each practice may mitigate some types of effects while accentuating others. For example, promoting rapid conveyance of runoff to a receiving watercourse will reduce the potential for impairment of potable groundwater while increasing potential effects on aquatic environment.

Although not a comprehensive list of measures available to the designer, nine common alternative management practices are identified below. In most cases, these practices will be required to achieve other drainage objectives. For some sites, combinations of these and/or other measures may be required to effectively minimize effects related to salt rich surface drainage.

	Management Practice	Purpose
1	Sheet Flow	Runoff conveyed across grass buffer strips or embankments.
2	V-ditch	Runoff conveyed by ditch to receiving watercourse.
3	Storm Sewer	Runoff conveyed away from sensitive areas using storm sewer system (negligible infiltration potential).
4	Flat Bottom(Trapezoidal)Ditch	Runoff conveyed by ditch with flat bottom ditch.
5	Flat Bottom (Trapezoidal) Ditch with Storage	Runoff conveyed by flat bottom ditch which includes on-line storage to trap sediment and reduce velocities and runoff rates.
6	Dry Basin (Pond)	Runoff directed to stormwater management basin designed to reduce runoff rates and promote sedimentation.
7	Wet Basin (Pond)	Runoff directed to stormwater management basin designed to reduce runoff rates, promote sedimentation and enlarge biological uptake.
8	Buffer Strip and Containment Berm	Berm designed to contain runoff within buffer strip, with positive outlet provided to prevent flooding and sustained water levels.
9	SWM Infiltration Measures	Runoff directed to subsurface with the goal of full infiltration of runoff and promotion of groundwater recharge.

Local drainage policies in different parts of the country may identify additional measures that could be implemented effectively to mitigate drainage effects.

The following table illustrates the merits of each management practice in addressing the potential effects that can result from salt-laden runoff. As the table illustrates, the practices which benefit groundwater effects are typically consistent with those that benefit agriculture, wetlands and wildlife. However, most of these practices have the potential to negatively impact aquatic resources. This table, in conjunction with the ranking summary table prepared at the end of the impact identification process, will help to determine which effects can be successfully mitigated through the use of specific drainage measures.

In most cases conflicts will not arise, and the selection of suitable management practices for minimization of salt effects will be relatively simple. The measures will typically be selected as part of the overall management strategy formulated to achieve other drainage and stormwater management objectives. In cases where objectives are conflicting, the practitioner must review each site on its own merits and set priorities such that the overall effects are minimized.

Management Practice	Characteristics	Feature That May Be Impacted				
		Ground Water	Habitat	Aquatic Lands	Wetlands	Agricultural Wildlife
Sheet Flow	Disperses runoff	×	✓	≈	≈	≈
V-Ditch	Channels runoff downstream.	✓	×	✓	✓	✓
Storm Sewer	Channels runoff with little opportunity for infiltration	✓	×	✓	✓	✓
Flat Bottom Ditch	Channels runoff. Some attenuation of flow rate. Some sediment trapping. Some potential for infiltration.	≈	×	×	✓	≈
Flat Bottom Ditch with Storage	Channels runoff Attenuates flow rate Some sediment trapping Some potential for infiltration	×	×	✓	✓	×
Dry Basin (Pond)	Attenuates flow rate Sediment trapping Potential for infiltration	×	✓	≈	≈	≈
Wet Basin (Pond)	Attenuates flow rate Sediment trapping Potential for infiltration	×	✓	≈	≈	×
Buffer Strip and Containment Berm	Contains and disperses runoff.	×	✓	≈	✓	×
SWM Infiltration Measures	All runoff directed to subsurface for full infiltration	×	≈	✓	≈	✓

Legend:

✓ The identified management measure may reduce the level of impact from salt-laden runoff (i.e. the level of impact potential for a feature may be decreased from high to medium, medium to low, etc.).

× The identified management measure may increase the level of impact from salt-laden runoff (i.e. the level of impact potential for a feature may be increased from low to medium, medium to high, etc.).

≈ The identified management measure will have minimal effect on the level of impact potential.

DESIGN REQUIREMENTS OF PREFERRED MANAGEMENT PRACTICES

The policy framework in the area where the design is being completed will define specific design characteristics of the recommended stormwater management measures. In most cases, stormwater management objectives other than salt management will dictate the design requirements.

In addition to local policy frameworks, design information for these measures can be found in numerous technical documents relating to stormwater management.

SALT VULNERABLE AREAS

Drainage designers need to consider the environmental setting into which their drainage system will be placed. Salt vulnerable areas need to be identified and the potential for salt impacted drainage to affect these vulnerable areas must be assessed. Special design modifications to traditional stormwater management measures may be warranted to protect these salt vulnerable areas. Measures may include clay or geosynthetic liners in conveyance ditches and ponds, infiltration ponds where appropriate or use of storm sewers to transport drainage past vulnerable areas.

TRAINING

Since pavement drainage depends primarily on design and not on operations, typical salt management training programs would pay little attention to drainage issues except to teach the concept and importance of proper design.

Training for drainage designers should include design options for managing the adverse effects of snow and ice control chemicals.

MONITORING AND RECORD KEEPING

It is not practical to monitor all runoff from paved areas for chloride levels. However, responsible authorities should consider monitoring salt vulnerable areas. An actual example includes a cooperation of a local municipality and an environmental authority to add chloride monitors to their stream monitoring network. They measured the chloride concentration in the watercourses as they entered the municipality and again as they left the municipality to track fluctuations. There are many complications with such a monitoring program. These include:

- At what frequency will samples be collected?
- Will the sampling be continuous?
- Will the data be communicated back to a central location automatically?
- The sampling stations will likely need power and telephone capability for communicating the data.
- Sampling locations must be protected from vandalism, flooding and ice effects.
- If conductivity is being used as the measure, then it will need to be correlated to chloride levels.
- Data analysis will have to take into account any confounding data such as chlorides entering the environment from other sources (e.g. private uses, water softeners, landfills etc.).

Records should be kept on the chloride or conductivity levels and snow and ice control events to determine how the levels fluctuate around an event. The analyst will want to be able to draw conclusions on whether or not the applications of best salt management practices are having an effect on the chloride levels in the aquatic environment. It will be important to determine whether or not drops in chloride levels can be attributed to improved practices and not just different weather conditions.

ACKNOWLEDGEMENTS

The development of this *Salt Management Synthesis of Best Practices* was undertaken with funding provided by several agencies. TAC gratefully acknowledges the following funding partners for their contribution to the project.

- Alberta Transportation
- British Columbia Ministry of Transportation
- City of Burlington
- City of Edmonton
- City of Moncton
- City of Ottawa
- City of Toronto
- City of Winnipeg
- Manitoba Infrastructure and Transportation
- Ministère des transports du Québec
- Ministry of Transportation Ontario
- Newfoundland Transportation
- Nova Scotia Transportation and Infrastructure Renewal
- New Brunswick Transportation and Infrastructure
- Regional Municipality of Halifax
- Regional Municipality of Waterloo
- Salt Institute
- Saskatchewan Highways
- Transport Canada

Principle Consultant for update was Ecoplans, a member of the MMM Group Limited and Bob Hodgins (previously with Ecoplans, now an independent consultant).

This document is the product of a project conducted on behalf of the Chief Engineers Council under the supervision of a project steering committee. TAC thanks all the committee members who contributed their time and effort to this project.

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