

SITING, DESIGN AND OPERATIONAL CONTROLS FOR SNOW DISPOSAL SITES

Scott R. Wheaton¹ and William J. Rice, P.E.²

¹Watershed Scientist, Municipality of Anchorage, PO Box 196650, Anchorage, AK, wheatonsr@ci.anchorage.ak.us

²Senior Engineer, MWH Americas, Inc., 4100 Spenard Rd, Anchorage, AK, William.J.Rice@mw.com

ABSTRACT: The Municipality of Anchorage, at 61° north latitude, plows and hauls snow from urban streets throughout the winter, incorporating grit and chloride applied to street surfaces for traffic safety. Hauled snow is stored at snow disposal facilities, where it melts at ambient spring temperatures. Municipal studies performed from 1998 through 2001 show that disposal site melt processes can be manipulated, through site design and operations practices, to control chloride and turbidity in meltwater. An experimental passive 'V-swale' pad configuration tested by Anchorage investigators reduced site meltwater turbidity by an order of magnitude (to about 50 NTU from the 500 NTU typical of more conventional planar pad geometries). The Municipality has developed new siting, design and operational criteria for snow disposal facilities to conform to the tested V-swale pad configuration.

KEYWORDS: Urban Snow Control, Snow Storage, Snow Disposal, Snowmelt, Design Criteria

INTRODUCTION

Economical and effective control of pollutants released from snow disposal sites serving high latitude communities presents problems peculiarly reflecting the impact of a subarctic climate. At high latitudes snow plowed from streets accumulates rather than melts due to low solar insolation and daily temperature ranges that generally remain below 0°C throughout the winter. As plowed snow accumulates and exceeds available storage space along streets, it is hauled to central storage areas and placed as a compact snowfill. High fuel costs usually prohibit forced melting, so instead the hauled snow is stored and allowed to melt under ambient spring weather conditions.



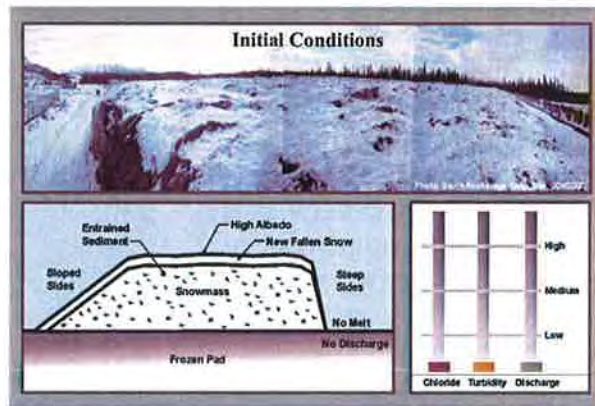
Pollutants contained in stored snow also reflect the effects of an arctic climate on street maintenance practices. At high latitudes, deicing often has limited use in improving road traction, and instead grit is widely applied. Salt (granular sodium chloride) is added to grit in amounts necessary to maintain fluidity during application (in Anchorage about 5% by weight of grit). A fraction of the applied grit and salt, as well as fugitive pollutants from vehicles, becomes incorporated into hauled snow. When seasonal melt occurs, the stored snowfill releases these pollutants in a complex fashion. Studies performed by the Municipality of Anchorage (MOA) over the last several years have shown that the manner in which pollutants are released strongly reflects the initial source of hauled snow, the melt processes of stored snowfill, and the geometry of storage areas and the snowfills themselves. Based on findings from these studies, the Municipality has developed effective new snow storage site design and operation practices that address control of a range of pollutants, particularly sediment.

- Chloride can be controlled passively only through detention and dilution.
- Mobilization of metals and PAHs is related to chloride concentration, but a large fraction can be controlled with particulate capture.
- Particulate loading in meltwater is related to the geometry of the snowfill and the pad on which it is situated, and may be controlled by manipulation of these elements.

The first two principles have been examined in detail by other investigators (Novotny et al., 1999; Oberts et al., 2000) but the potential influence of site and snowfill geometry on pollutant release has not been significantly addressed. Observations at Anchorage suggest the melt processes that occur within and around a snowfill mass, along with the aspect, geometry and physical characteristics of the stored snow, play central roles in how the snowfill melts and the degree to which pollutants are mobilized during melting. MOA site investigators have identified three main stages in the melting of a snowfill: a) ripening, b) main melt and vertical deflation, and c) final melt and disintegration. These melt stages and their relation to pollutant mobilization are summarized below.

RIPENING: THE COLD SNOWFILL UNDERGOES INTERNAL CHANGES

Snowfills hauled from Anchorage streets consist of lightly compacted snow and ice. These masses generally contain a homogenous, dilute distribution of fine mineral particles, and applied and fugitive chemicals. At conventional Anchorage snow disposal sites, heavy equipment operators place hauled snow onto earthen pads in a series of one or more lifts, each 2 to 4 meters thick. By the end of winter, the total mass of snow stored at any one of Anchorage’s facilities is on the order of $7 \cdot (10^4)$ cubic meters. Snowfills are steep-faced on several sides but often have one or more low-sloping faces where snow has been pushed into place. The albedo of a snowfill at the beginning of the melt period is typically high as a result of a covering of fallen snow and the snowfill’s initial homogenous nature. Though no data has been collected at Anchorage snow disposal sites to confirm this, at the end of winter snowfills likely have low core temperatures relative to ambient spring conditions. Similar spring temperature gradients have been reported for much thinner natural snowpacks (Luce and Tarboton, 2001).



Initial Snow Conditions		
Constituent	Range	Median
Water Equivalent	60%-72%	60%
Chloride	53-140 mg/L	115 mg/L
Total Sediment	0.6-14.6 kg/cu.m	3.25 kg/cu.m

RADIANT ENERGY BEGINS TO MELT THE SNOWFILL SURFACE

With the rapid rise in solar radiant heat, the top of snowfills begin to melt early in spring (March in Anchorage). However, water formed from this melt infiltrates and does not flow across the surface of the snowfills. ‘Moulin’-like features, on the order of 3 to 5 cm across, are common and are thought to result from formation and rapid break-through of small puddles of meltwater at the surface. Also coring showed no continuous horizontal ice layers within snowfills (despite an Anchorage maintenance practice of watering tops of lifts to allow passage of winter truck traffic).

For the experimental V-swale pad configuration, seepage at the pad perimeter was almost absent. Almost all meltwater discharge from the snowfill was confined to a single point at the downgradient end of the V-swale. Meltwater also exited the V-swale snowfill as an integrated flow—not as seepage—with this flow beginning at approximately the same time as more distributed seepages were first observed at adjacent, conventionally configured snowfills.

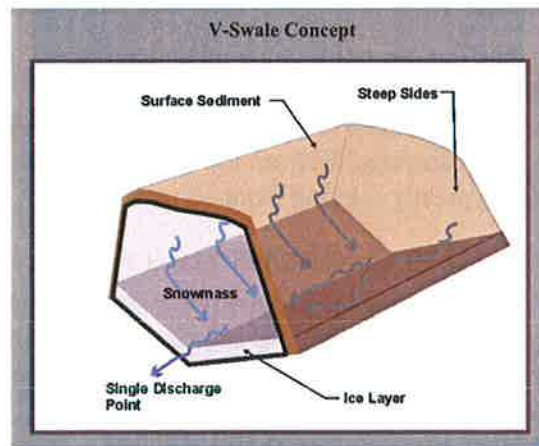
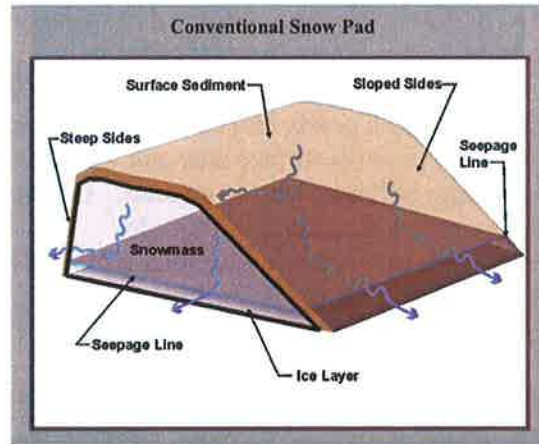
THE BASAL ICE CONTROLS SEEPAGE

During the middle meltwater stage, discharge observed at relatively flat, conventionally-configured Anchorage sites tends to occur as a continuous seepage along the top surface of the basal ice layer and around the entire perimeter of snowfills. Little or no early flow occurs under the basal ice, though pad geometry can work to encourage development of sub-basal ice meltwater conduits as the melt season progresses. At this stage, flows across the pad surface are directed along the perimeter of the basal ice (not under or through it). Though the seepages themselves have very low kinetic energy as they exit from the snowfill, erosive power as these flows integrate can become greatly enhanced by the configuration of both the snowfill and the pad on which it is placed.

For meltwater discharge from the experimental V-swale, the flow exit point remained confined to the downslope end of the pad throughout this stage of the melt season. Concentrated internal flows along the axis of the V-swale tended to slowly erode the basal ice headward along the trough of the swale. As removal of the basal ice progressed up the trough, snow pad soils became exposed to erosion and are believed to have contributed to turbidity measured in meltwater at this site. However, exposed trough soils rapidly self-armored, limiting these effects.

INITIAL POLLUTANT RELEASE BEGINS

Initial pollutant release begins with the first meltwater discharge from a snowfill. At Anchorage sites, because of early leaching and low meltwater volumes (3 to 5 liters/second [L/sec]), chloride concentrations from the initial discharge can be extremely high (10^3 to 10^4 milligrams per liter [mg/L]), dependent apparently upon deicing and snow hauling practices as they reflect year-to-year climate variability. At Anchorage, peak chloride releases wane within several weeks of first snowmelt discharge and fall rapidly as melting progresses. By the end of the middle stage of melt, flow is at a peak (10 to 30 L/sec) but chloride concentrations have typically fallen to concentrations of 10^2 mg/L or less.

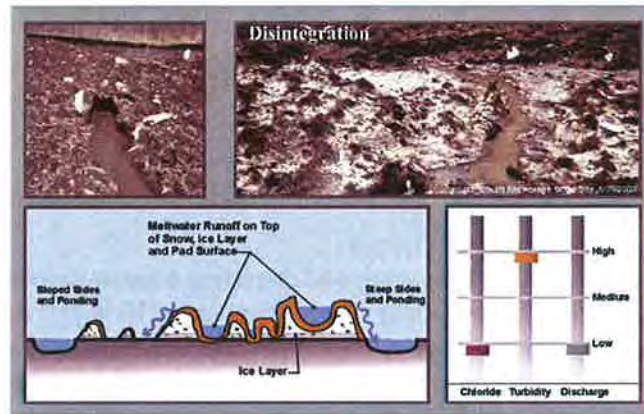


FINAL MELT: THE SNOWFILL DISINTEGRATES

In the beginning of the last stage of melt, a basal ice layer underlying a snowfill becomes exposed locally. At this point, the direction of meltwater flow from a snowfill becomes less influenced by the transmissive characteristics of the snow mass and subsurface conduits, and more influenced by the underlying ground topography as reflected in the surface of the basal ice layer. Sediment collapses onto the basal ice layer and becomes subject to erosion and mobilization by relatively high meltwater flows. The underlying ground surface may also become exposed to erosion as the basal ice is melted or eroded.

Though chloride concentrations are relatively low at this final stage of melt, the erosive power of the meltwater flows and the collapse of the accumulating surface sediment onto flow surfaces greatly increases potential for the mobilization of particulates. The increasing isolation of snowfill remnants raises the potential for erosion as flows from

upgradient snowmelt sources are directed across increasingly bare pad surfaces and against sediment collapsing from downgradient snowfills. Thawing of the pad surface may also reduce the mechanical resistance of surface soils to erosion. This may be particularly true where the pad soils have been weakened by ice segregation during winter freezing and are not protected by vegetation. All in all, as the snowfill at a site disintegrates into isolated snow masses, the basal ice layer erodes, and the pad soils become exposed to flows, the potential for mobilization of particulate pollutants rises dramatically. At this point, concentrations of particulates in meltwater can remain markedly high until most of the remaining snowfill is gone and flows subside.



CONCLUSIONS

Observation of the melting process at Anchorage snow disposal sites suggests a number of control opportunities. Control opportunities can be generally grouped as they address chloride (and soluble pollutants), or particulates (and adsorbed pollutants).

CHLORIDE CONTROL

Chloride and other soluble pollutants are not readily treated by simple technologies. Passive (non-chemical) treatment of chloride is best addressed through: control of street treatment processes, dilution of early meltwater discharges, and application of snow disposal site location criteria. Analysis of Anchorage salt application practices suggests total chloride loading could be reduced by as much as 60% through use of heated sand sheds. Because of leaching, however, detention and dilution of early snowmelt remains a critical element in snow disposal site design and operations criteria. Dilution with shallow ground water has been shown to be a viable option in Anchorage, but implementation requires knowledge of area hydrogeology (Wheaton, et al., 1998a) and acceptance of some changes in the structure of local vegetation communities (Hansen, 2001). On the other hand

also limits late-stage sediment mobilization by helping to short-circuit flows to armored channels. Note that because of variability in the thickness of the basal ice layer, controlled side slopes and swale widths are important to ensure that internal flows are directed to the swale trough. Based on observations of variability in basal ice thickness, MOA has established design parameters that are expected to successfully contain meltwater within the V-swale.

MOA SNOW DISPOSAL SITE DESIGN CRITERIA

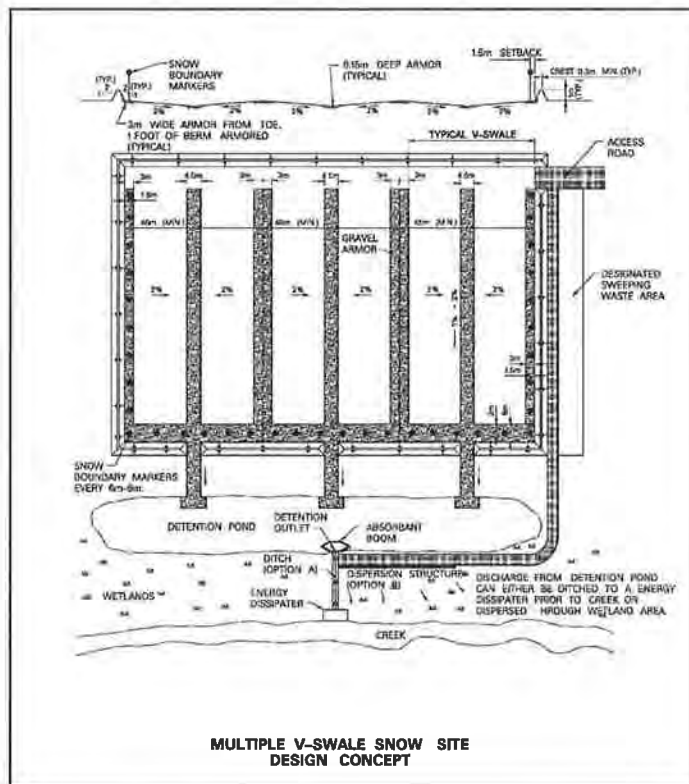
Based on the results of its studies, MOA has developed a set of snow disposal site criteria for Anchorage. MOA criteria particularly emphasize an essential synergy between siting, design and operations. Though the criteria are specific to the typical scale of Anchorage snow storage facilities, they should be adaptable to other northern latitude communities as well. The criteria are generalized here—full text of the recommended criteria can be obtained from MOA upon request.

SITING CRITERIA

- Avoid meltwater discharge to potable water aquifers.
- Avoid meltwater discharge to ‘closed’ lakes and wetlands.
- Avoid reduction of functionality of receiving wetlands.
- Avoid meltwater discharge to streams having winter base flows less than 85 L/sec.
- Optimize opportunities for infiltration to shallow non-potable ground water systems.
- Optimize opportunities for a site orientation sloping down from south to north.

DESIGN CRITERIA

- Map local and site hydrogeology within 300-meter (m) of site.
- Construct pad with a single or multiple V-swale configuration (minimum 45m crest-to-crest swale width, 2% side slope to central trough, and 1-2% longitudinal slope).
- Orient V-swale longitudinal axes downhill from south to north.
- Establish and flag setbacks from swale crests and facility perimeter.
- Armor swale troughs and crests and all facility drainage channels and containment berms.
- ‘Trackwalk’ (imprint with crawler tractor treads trafficking directly upslope and downslope) and vegetate all non-armored pad surfaces with a mix resistant to an annual 2-5cm sediment burial.



Siting, Design and Operational Controls for Snow Disposal Sites

University of Anchorage, Fairbanks (UAF), 1996. Water Quality Effects on Snow Storage Areas. Report No. INE/TRC95.06 SPR-UAF-94-14. April. 64 pp.

Wheaton, S. 1998a, Magnesium Chloride Deicer in Snow Disposal Sites at Anchorage, Alaska: Assessment Design, Document No. WMP APd98001, Municipality of Anchorage WMS, p. 19 and Appendices, March.

Wheaton, S. and Brett Jokela, 1998b, Anchorage Street Deicer and Snow Disposal 1998 Best Management Practices Guidance, Document No. WMP APg98001. MOA WMS, p. 41 and Attachments.

Watershed Management Services (WMS), 1999a. Anchorage Street Deicer and Snow Disposal 1999 Best Management Practices Guidance, Document No. WMP CPg99002. MOA WMS, p. 34 and Attachments, December.

WMS, 1999b, Meltwater Runoff from Anchorage Streets and Snow Disposal: 1999 Data Report, Document No. WMP APr99003 MOA WMS, p. 31 and Attachments, December.

WMS, 2000a, Anchorage Street Deicer and Snow Disposal Investigation: 2000 Data Report, Document No. WMP Apr00004. MOA WMS, p. 34 and Attachments, November

WMS, 2000b, Anchorage Street Deicer and Snow Disposal Investigation: 2000 Best Management Practices Guidance, Document No. WMP CPg00003. MOA WMS, p. 34 and Attachments, November.