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USER GUIDE to HYDROLOGY

Mining and Reclamation in the West

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MINING AND RECLAMATION IN THE WEST

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
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Chapter 4
SNOW MANAGEMENT

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Management of snow in mined areas becomes a topic of concern for the hydrologist in a number of situations. First, of course, is the consideration of whether or not snow distribution is a problem in the mining area. If it is, as determined through observation as well as measurement, then consideration must be given to how snow can affect the mining operation in terms of distribution, spoil/snow interaction, runoff, impacts on and benefits to reclamation, and access to the area. Major snow-related considerations are discussed further in this chapter.

How does the hydrologist determine whether snow distribution is a problem in the mining area?

The hydrologist should rely on the premining survey and inventory, as well as general knowledge of the area, in deciding whether snow is a problem.

Discussion:

Mining plans should include information on the winter climate: seasonal snowfall and precipitation water-equivalent, wind speed and direction, temperature (monthly means, maximums, and minimums), and the distribution of snow by wind. Snow drifting patterns should be documented by both aerial and ground photographs taken at monthly intervals throughout one or more winters. Snow profiles of major accumulation areas at time of maximum accumulation should also be included.

Wind direction prevailing during the drifting season (if any) can be determined from the aerial photographs, and from ground observations of drifting patterns, snow particle abrasion of posts and exposed rocks, and "hedging" of vegetation.

How will snow distribution affect mining operations?

While impacts are site-specific, effects will be elevation-related, leading to different problems on the plains than in mountainous mine sites.

Discussion:

Snow distribution patterns reflect the interaction of seasonal snowfall amounts, topography, vegetation, wind, and air temperatures. Snow distribution should be considered of major importance in areas where blowing and drifting snow are common features of the winter climate. Snowdrifts can block access roads and generally impede mining operations.

Another problem that must be considered is soil erosion generated by melt from drifted snow. Surface runoff from rapid melting of these drifts may result in rill and gully formation. Saturation of dumps, resulting in slumping or mass failure, may also occur. This is particularly true on mines located in mountainous terrain. Both of these occurrences may contribute to sediment loads in streams. Finally, irregular, old dump sites may increase snow retention, resulting in too much water being held within the waste materials.

Two possible solutions exist for these problems. First, in areas where snow drifting is determined to be a problem prior to mining, proper mine design may be effective in reducing snowdrift accumulation. Second, if the mine already exists and has not been designed to mitigate snowdrift problems, methods are available for manipulation of snow movement on-site.

What are the most effective methods of controlling snow deposition?

The most common methods of controlling *snow deposits are snow fences and other artificial barriers (fig. 5). Other techniques include manipulation of the terrain (shaping), and management of the surface roughness.*

Discussion:

Properly designed snow fences can provide effective protection against snowdrifts, or they can be used to store large volumes of water to augment local water supplies for irrigation or other uses. (Figure 6 shows how to determine volume of water stored.) The keys to successful snow fence systems for preventing drifts include: (1) sufficient *capacity* to store the predicted seasonal snow transport; (2) the use of *tall* fences in preference to multiple rows of shorter structures; (3) proper *fence design*; (4) proper *placement* in relation to the protected area; (5) the use of *long* fences (greater than 30 times the fence height); and (6) *orientation* perpendicular to the prevailing wind.

Snow transport water-equivalent, q (in ft^3 of water per foot of fence length) can be estimated from

$$q = 5000\, P_r\, (1 - 0.14^{0.0001 R})$$

where P_r is relocated precipitation (feet, water-equivalent) and R is the "fetch" or contributing distance (feet). This method is described in the reference by Tabler (1975a). For 50-percent porous fences on level terrain, the maximum water-equivalent capacity of a snow fence having height H is approximately $10H^2$. From these relationships, then, it is possible to determine the required fence height. Construction cost per unit volume of snow storage decreases with increasing fence height, so it is less expensive to build a single row of 12-ft-tall fence, for example, than 4 rows of 6-ft fence having equivalent capacity.

Proper fence design includes 50-percent porosity, a bottom-gap of 0.1H, and the use of horizontal slats having widths less than (approximately) 8 inches. A 15° inclination from verti-

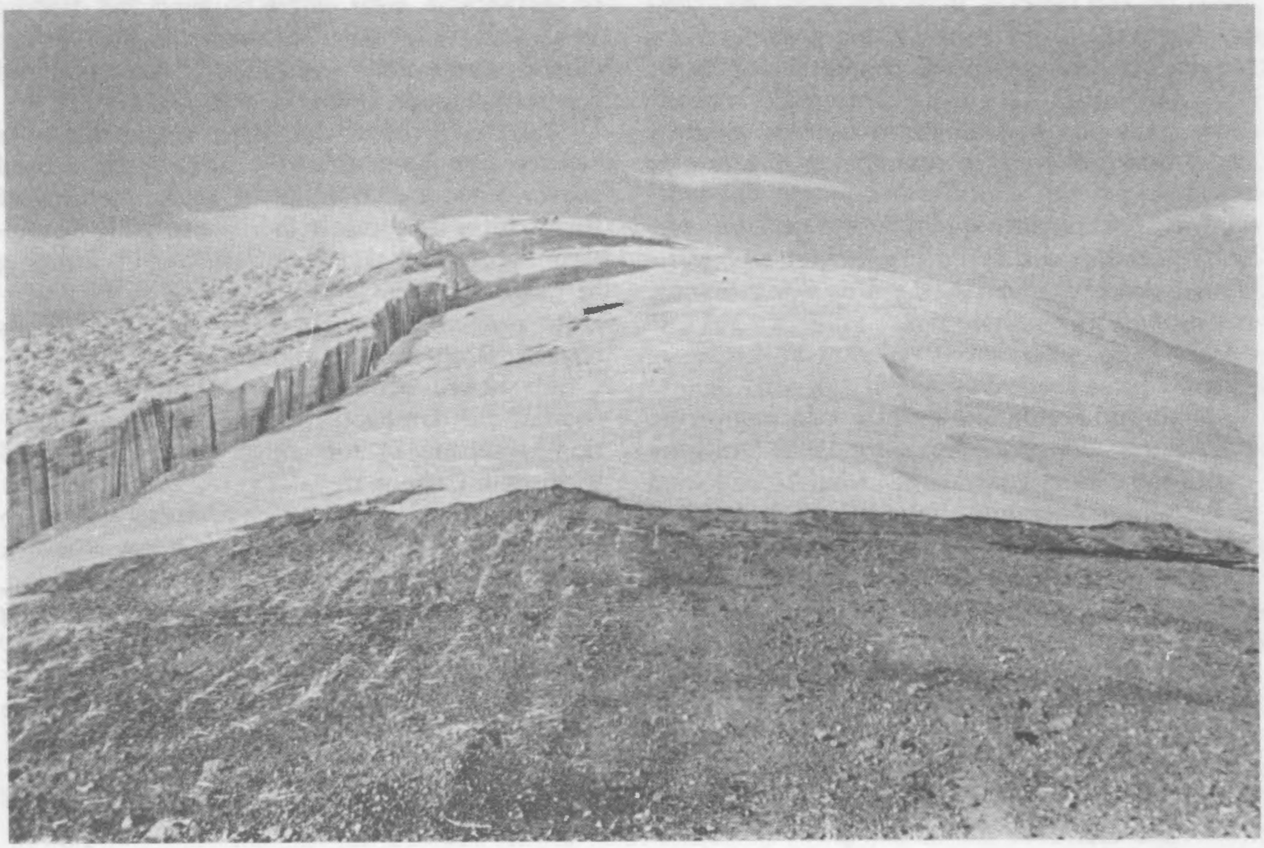

Figure 5. Snow fence.

cal, downwind, also increases capacity by about 25 percent. Engineering drawings for effective snow fences are given in Tabler (1974).

The maximum length of the lee drift behind a full fence is 30H, so fences should be placed at least 30H upwind from the area to be protected.

Snow fences for protecting transplanted shrubs and augmenting soil water should be shorter, or more porous, than those used for drift prevention. Fences that are 2 ft tall, spaced 60 ft apart, will provide a relatively uniform snow cover on level terrain. On windward-facing slopes (greater than about 10 percent) or on ridge crests, however, spacing should be reduced by about half in order to achieve a uniform snow distribution. Fencing that is 4 ft high, having about 75-percent open area (porosity) will also result in a sufficiently shallow, uniform deposit, at least on level terrain. Again, spacing should be about 30H, or 120 ft for a 4-ft fence.

The most economical method of snow management for augmenting soil water, however, is through manipulation of surface roughness rather than the use of artificial barriers. In general, mined areas should be left with as rough a surface as possible, to provide numerous depressions for snow retention. Contoured furrows, ripped strips, terraces, and pits or gouges are all preferable to smoothly graded and harrowed surfaces; however, careful contouring of two-dimensional roughness features is essential to avoid gradients that might induce gully formation.

Benefits of rough surfaces include retention of rainfall as well as snow, reduced evaporation, protection against abrasion by wind-blown soil and snow particles, shading, and reduced wind and water erosion. Rough surfaces are gradually smoothed out by weathering processes over the course of the few years needed for successful establishment of vegetation.

Another possible method for controlling deposition of wind-transported snow is through appropriate shaping of the terrain. The method

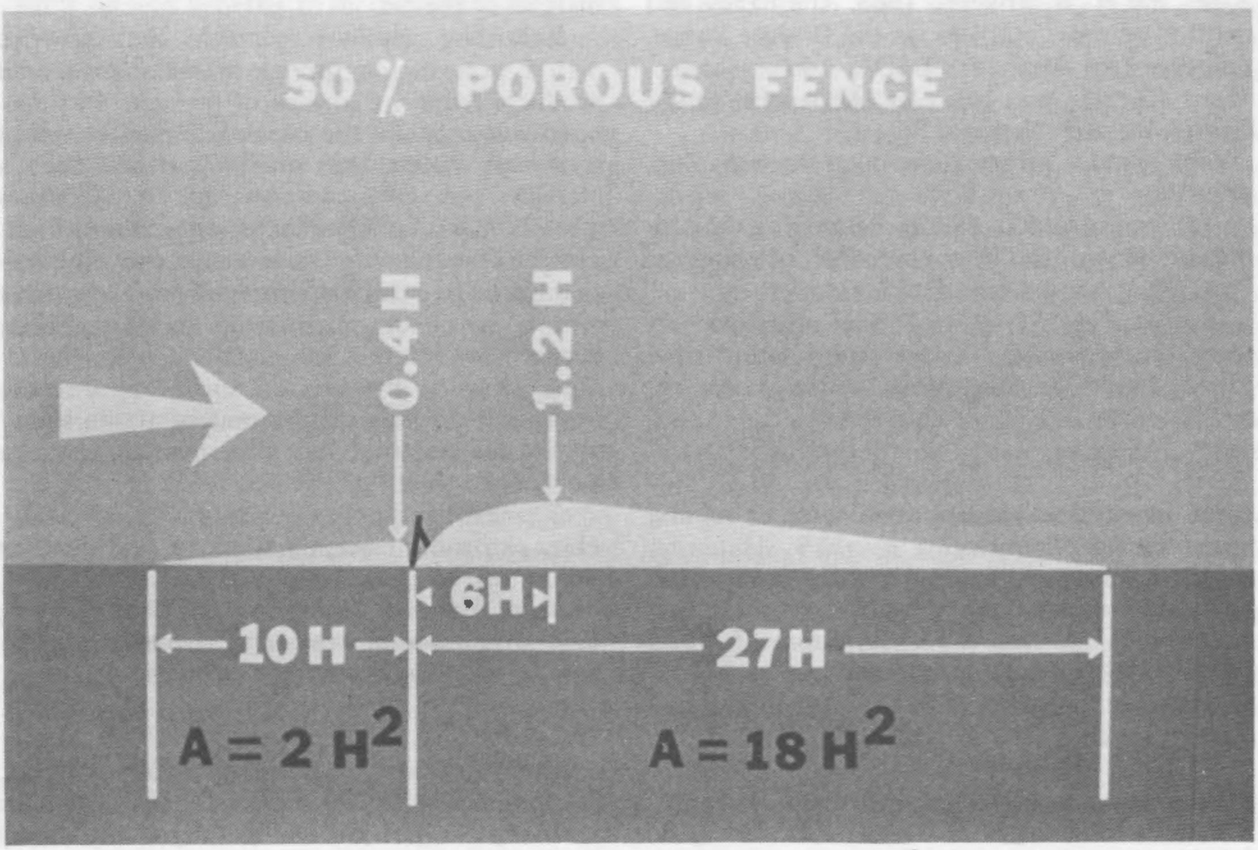

Figure 6. Ideally, a snow fence is 50-percent porous; a simple equation—10 x H^2 (height of the fence)/lineal ft of fence—can be used to determine approximately the volume of water stored behind a snowfence.

described by Tabler (1975b) can be used to predict snow accumulation in various terrain configurations, allowing design of drift-free roads and shaping of terrain to optimize snow distribution to facilitate revegetation.

Additional Information:

For further information on snow fences, refer to:

Tabler, Ronald D. 1973. New snow fence design controls drifts, improves visibility, reduces road ice. Annu. Transp. Eng. Conf. (Colo. Univ., Denver, February 1973) Proc. 46:16-27.

Tabler, Ronald D. 1974. New engineering criteria for snow fence systems. Transportation Research Board (National Research Council) Trans. Res. Record 506:65-78.

Tabler, Ronald D. 1975a. Estimating the transport and evaporation of blowing snow. p. 85-104. *In*: Snow Manage. on Great Plains Symp. (Bismarck, N. Dak., July 1975) Proc. Great Plains Agric. Counc. Publ. 73, 186 p.

Montagne, John, J. T. McPartland, A. B. Saper and H. W. Townes. 1968. The nature and control of snow cornices on the Bridger Range, Southwestern Montana. USDA Forest Service, Misc. Report No. 14. Alta Avalanche Study Center, Wasatch National Forest.

For further information on terrain shaping, refer to:

Tabler, Ronald D. 1975b. Estimating the profile of snowdrifts in topographic catchments. Proc. West. Snow Conf. 43:87-97.

Packer, Paul E. 1971. Terrain and cover effects on snowmelt in a western white pine forest. Forest Science, Vol. 17, No. 1, March, pp. 125-134.

What impact does snow contaminated by mining have on water chemistry?

Snow contamination may occur hand-in-hand with acid mine drainage, when oxidation of sulfide minerals occurs. The symptom of this is that metallic concentrations and the mass flow of metals in streams increase during peak snowmelt periods.

Discussion:

Snow contamination occurs via two sources: (1) the incorporation of reactive dust within the snowpack itself; and (2) the capillary suction in the snow/ice matrix at the snow/ground interface.

In snowpacks 5-6 ft deep near high-altitude heavy-metal mines, as many as half a dozen layers of dust materials can be seen. When analyses are run on the contaminated material, it is found to consist primarily of sulfide minerals with a pH of between 2 and 3. This material does not contribute any acid load itself, because oxidation of sulfide minerals is a chemical reaction and is affected by the temperature surrounding the reaction. In a snowpack 32°F or colder, this reaction proceeds very slowly, and is not a source of acid production until the snowpack melts and the material is deposited on the surface. Then, during the summer warm period, the reaction occurs and sulfuric acid is produced. The amount of dust incorporated in the snowpack is variable and depends on what the source of the dust is and how it is measured. For example, in two mines, where the walls are very steep, deposition of as much as a ton of dust per acre over a winter is possible near the margins of the pit.

Regarding capillary suction, the snow/ice matrix acts like a sponge in picking up acid products from the surface of the soil. As snowmelt proceeds and the snowpack starts to bleed snowmelt water, the initial flush will have a metallic ion concentration up to 30 times greater than succeeding increments of snowmelt. The first increment acts as a concentrating mechanism. Thus, during periods of peak snowmelt runoff, a direct relationship exists between stream flow volumes and metallic ion concentrations. How far the ions are sucked up into the snowpack depends on the matrix at the snow/soil interface, but at one mine the height was as much as 15 cm.

How can snow contamination be prevented on mine sites?

Two measures are helpful: (1) minimizing dust production at the site as much as possible; and (2) reducing the acidity on the surface.

Discussion:

Opportunities for reducing dust production are limited at an open-pit site. One possible method, however, is to eliminate any dump faces that might be blown free of snow or become wind-scarred during the wintertime.