A Simple Snowmelt Lysimeter

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Abstract. A simple gage on the lysimeter principle has been developed to provide continuous readings of the volume of water flowing from the base of a snowpack in the form of surface melt alone or rain percolate and surface melt combined. The data obtained show promise, after two seasons, of being applicable in river flood forecasting, as well as in studies of snow hydrology.

INTRODUCTION

Forecasting the occurrence of spring peaks on snow-fed streams requires considerable knowledge of the timing and rate of water flow from the snowpack. To date, hydrologists have relied upon several techniques for determining snowpack outflow. The formula technique, whereby meteorologic data are substituted into standardized snowmelt equations, is commonly used. So also are such recently developed instruments as the pressure pillow snow gage and isotope snow gages, utilizing stationary or portable emissive sources, which give readings of the net change in a diminishing snowpack [*Martinelli*, 1966]. Users of these instruments assume that a large portion of this change represents snowmelt. These aforementioned techniques represent, at best, only estimates of flow from a snowpack.

A need exists for an instrument that will measure directly snowpack outflow in situ, yet be reasonably accurate, of low cost, and practical for sampling the multitude of hydrologic environments that characterize a mountain watershed. Such an instrument, the snowmelt lysimeter, has been developed at the Priest River Experimental Forest in northern Idaho and shows promise of fulfilling these requirements. This gage, tested for two winters in a zone of medium snow depth, provides continuous readings of the volume of water flowing from the base of a snowpack, either in the form of surface melt alone (which may include radiation melt, condensation melt, convection melt, and rain melt), or rain percolate and surface melt combined.

The concept of a snowmelt lysimeter is not new. Two large lysimeters (600 and 1300 square feet in area) were operated successfully for several years at the Central Sierra Snow Laboratory [*Boyer*, 1954; *Hildebrand and Pagenhart*, 1954, 1955; *U. S. Army, Corps of Engineers*, 1956]. During the same period, a small (2-square-foot) portable lysimeter constructed at the Willamette Basin Snow Laboratory proved unsatisfactory [*U. S. Army, Corps of Engineers*, 1956]. In a very recent investigation, significant results were obtained by using shallow cylindric lysimeters 16 inches in diameter, although they were filled with snow prior to the measurement period [*Megahan et al.*, 1967].

The snowmelt gage described in this report has a surface area of 2.72 square feet and appears more adaptable for research and operational use than earlier lysimeters. It incorporates several features not found in other snowmelt gages.

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DESCRIPTION OF THE LYSIMETER

The apparatus consists of two units: a trough assembly and a catchment tank with water level recorder. A plastic drain hose, buried sufficiently deep to prevent freezing, connects the trough assembly with the catchment tank.

Trough assembly. The galvanized steel

Fig. 1. Trough assembly with barrier support frame.

trough is 23 by 17 by 6 inches with an outlet drain in the base. To prevent clogging of the drain, a wire mesh screen, reinforced by steel bars, lies across the bottom of the trough. Bolted to each corner of the trough is the leg of the barrier support frame (Figure 1). A barrier of white, opaque polyethylene is pulled up the frame at intervals during the snow accumulation period. The height of the frame and thermoplastic barrier is determined by the anticipated depth of snow. The site chosen for the trough should be surrounded by large trees to prevent snow creep, or glide, from bending the barrier support frame. As a further precautionary measure, the frame is guyed.

Three to four inches of the catchment trough are left exposed above ground. Two inches of duff and needle material are placed in the trough to approximate the surface of the surrounding forest floor. To prevent the rather sudden, unnatural change in moisture tension in the trough that would be caused by the duff-air interface at the screen, 2 inches of clean, coarse gravel are sandwiched between the screen and duff layer.

The polyethylene barrier, when extended, prevents the inflow of snowmelt from the surrounding pack. The base of the plastic barrier is made leakproof by cementing it to the rim of the trough and clamping it with a rubber gasket.

Catchment tank and water level recorder. The catchment tank and recorder shelter may be combined in a 50-gallon drum, modified for side entrance. Two angle iron braces are welded on the inside to support an FW-type recorder. A brass faucet drains the tank. If a larger recorder is desired, the side entrance is eliminated, and a top entryway is provided instead. A shelter, resting on top of the barrel, protects the recorder. This latter modification allows for more tank capacity before draining and permits the use of a large roll chart recorder, such as the A-35 type. The outlet of the drain hose, connecting the trough to the catchment tank, should enter the barrel below the level of the initial charge (ethylene glycol mixture with oil layer) to prevent freezing.

Approximately a 1-to-1 ratio exists between the cross-sectional area of trough and catchment tank; hence 1 inch of percolate in the trough virtually equals a 1-inch rise in the tank. For greater precision, the catchment tank is calibrated in situ to adjust for the increase in cross-sectional area associated with the two reinforcing rings on the wall of the tank and for the volume of water backed up in the connecting hose as water rises in the tank.

OPERATION

The trough assembly is made ready early in the fall to allow the shallow duff layer to reach equilibrium or comparable wetness with the surrounding forest floor. If scheduling prevents this, the material is wetted artificially to approximate the adjacent surface floor. The trough is now ready to receive the first snow of the season. Because of the early season bulkiness of the polyethylene barrier, care should be taken to insure even buildup of the snow column during early stages of accumulation. Snow is carefully placed in the voids along the border created by the overlapping thermoplastic. This problem is minimal once the snow depth reaches 6 to 8 inches.

After each storm that produces significant snowfall, the snow column is continued by slicing down to the top of the polyethylene barrier, using a snow shovel (Figure 2). The barrier is then pulled upward, about one-half inch above the level of new snow; the displaced snow is then shoveled against the outside of the thermoplastic wall. This operation is repeated throughout the winter period of snow buildup. Between storms, the snowpack may settle, leaving the wall of polyethylene exposed well above the snow surface. The barrier is then pulled down the frame, again to within one-half inch of the snow surface. It is essential that the barrier be kept extended slightly, particularly following cold periods. If this is not done, rainfall may flow laterally over the ice crusted surface and into the perimeter of the snow column. This extraneous inflow would give false readings.

In the ablation season, the general operational procedure is reversed, except that the polyethylene barrier is cut away with a pocket knife. This step should be performed on alternate days or daily during periods of rapid melt, so as to minimize the effect on the microclimate immediately above the snow surface.

Energy radiated from the polyethylene barrier extending above the snow accelerates melting along the north rim of the snow column; in contrast, the extended barrier shades the south rim and thus decelerates the melt processes on this portion of the snow column.

EXAMPLE OF OUTFLOW DATA

Some typical outflow data, which represent the spring snowmelt season of 1967, are presented herein. These data were collected from two instruments located in small, cleared openings between 3600 and 4000 feet MSL in a mixed conifer stand.

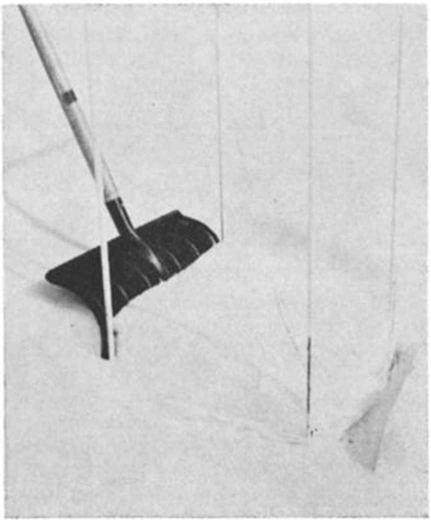

Fig. 2. Formation of snow column following a fresh fall of snow.

Volumetric measurements of water draining from the snowpack for the period May 1–19, 1967, are shown in Table 1. The following outflows occurred during this period: a maximum daily outflow of 2.02 inches on May 16; a maximum hourly outflow of 0.23 inch between 1200 and 1300 hours on May 8; and a maximum 2-hour outflow of 0.41 inch between 1200 and 1400 hours on May 16 (Figure 3). Note in Table 1 for Station 39 that cool, rainy weather decreased the daily melt rate to 0.07 inch on May 11. There followed a second period of warm, clear weather, which accelerated daily outflow rapidly to 2.02 inches in a span of six days. Elevation difference between the two stations is probably exemplified by the lag in outflow of 1.34 inches (8.84–7.50) for the first thirteen days of May.

TABLE 1. Snowpack Outflow for May 1–19, 1967, Priest River Experimental Forest in Northern Idaho

May 1967	Snowpack Outflow (Inches, water equivalent): Station 29 North, 3600 ft	Station 39 North, 4000 ft
1	0.34*	0.09*
2	0.54*	0.30*
3	0.47	0.15
4	0.49*	0.26*
5	0.95	0.65
6	1.37	1.37
7	1.44	1.31
8	1.50	1.11
9	0.68*	0.90*
10	0.40*	0.54*
11	0.36	0.07
12	0.25†	0.19
13	0.05†	0.56
14	Bare of snow	1.14
15		1.34
16		2.02
17		1.93
18		0.56†
19		0.02†
20		Bare of snow
Total	8.84	7.50 (13 days) 14.51 (19 days)

* Includes rain percolate and rain melt.

† Snowmelt gage only partially covered with snow.

Fig. 3. Hourly snowpack outflow, Station 39, May 16–17, 1967.

The season's maximum melt rate of 2.02 inches measured on May 16 appears to be very large. Nonetheless, this magnitude of melt compares closely with theoretic calculations by *Rantz* [1964], who determined for a Sierra Nevada snowfield that the maximum snowmelt computed for any day was 2 inches.

ADVANTAGES AND DISADVANTAGES OF THE MELT GAGE

Outflow data from this new snowmelt lysimeter show promise, after two seasons, of being applicable to predicting the timing of peak flow, as well as to studies of snow hydrology. The experimental network of three gages was expanded during the winter of 1967–1968 to seven gages, at elevations of from 3600 to 5100 feet. Future plans call for extending the network to above 6000 feet elevation in order to test the feasibility of operation in snowpacks exceeding 100 inches in depth. Two winters' experience indicates the following advantages and disadvantages of the melt gage.

Advantages

1. A vertical block of undisturbed snow is isolated from the surrounding snowpack by a thin sheet of plastic material; consequently, the yield of outflow from this finite volume is unconfounded by extraneous inflow.

2. The melt gage is very sensitive to changes in the amount of water draining from a snowpack. Readings down to 0.005 inch of outflow per hour are discernible on an FW-type chart.

3. Costs of constructing and installing an individual snowmelt lysimeter are relatively low. Additional expense of building a permanent access shaft to service the stilling well in deep snowpacks raises the total expenditure. The total cost, including access shaft, is under $700.

Disadvantages

1. The gage has not been tested in deep snowpacks on steep, treeless topography where the forces causing slow, downhill movement of the snowpack are prevalent. We suspect that the polyethylene barrier and support frame would be vulnerable.

2. The polyethylene barrier and support frame cause some abnormal surface melt at the borders of the snow column. It is possible, but not yet proved, that the affected melt processes may be compensating. Border effect was observed on all gages; therefore relative differences between environmental sites may be unchanged.

3. The gages require weekly or biweekly servicing in winter by an experienced technician; more frequent servicing is needed during the spring melt season. With the advent of the small, dependable snowmobile, the cost of servicing a network of gages in a roaded watershed need not be excessive.

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