PREDICTING TIME OF PEAK SNOWMELT RUNOFF FROM SNOW PILLOW DATA

by

Phillip E. Farnes [1/]

Introduction

Montana's first snow pillow was installed in the fall of 1963. This pillow was constructed of nylon-reinforced butyl material. An onsite water-level recorder provided a continuous record of snow water equivalent during accumulation and melt.

Since then, 60 snow pillows made of butyl or nylon-reinforced neoprene, generally 10 feet in diameter, have been installed in the headwaters of snow-fed Montana streams and rivers.

Since 1977, SNOTEL (SNOw survey TELemetry) electronics has replaced onsite recorders at most locations and data are transmitted daily. In addition to the original butyl snow pillow, stainless steel pillows were installed at most SNOTEL sites. Data from metal pillows have not been evaluated because most have only 3 to 5 years of record.

Using the snow pillow data and stream gage data now available, it is possible to reasonably predict the date of peak streamflow from snowpack runoff. These data are particularly important to reservoir operators and those involved in flood forecasting and control. They are also helpful to state officials responsible for administration and allocation of streamflows and to irrigators with direct diversions and junior water rights.

Preliminary Analysis

In Montana, our early attempts to correlate timing of peak streamflow on snowfed streams using common climatic variables revealed:

(1) Rainfall during maximum snowmelt runoff increases the size of the snowmelt peak, but does not influence the date of peak flow except in years of very large rainfall.

(2) In any given year, the relationship between the dates when streams in any given area peak are fairly consistent and are related to the influx of large, warm air masses and the elevation of each basin's headwaters.

(3) Streams within a given area that have lower-elevation headwaters or lower mean basin elevations always experience their peak snowmelt runoff before those with a higher basin elevation.

(4) The annual snowmelt peak data on any given stream falls within a period of about 45 days.

(5) Peak flow dates do not coincide with days having the highest onsite snowmelt rate.

Early Forecasting Attempts

The first snow pillow in Montana was installed in 1963 at Lick Creek, a low-elevation site, in the Gallatin River drainage. The Gallatin River is one of the three headwater streams of the Missouri River in southwest Montana. Records of the first 6 to 8 years show that the peak flow of the Missouri River headwaters occurred within 3 weeks after all of the

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1/ Supervisory Hydrologist, Snow Survey Data Collection Office, Soil Conservation Service, Bozeman, Montana.
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snow had melted at the Lick Creek snow pillow. After the snow melted, there was no way to update predictions with snowpack data when weather changes either advanced or delayed the peak. Records from higher-elevation snow pillows in the drainage indicated the flow generally peaked some time after melt began, but before all the snow melted. The peak flow date did not appear to coincide with a specific water equivalent level or rate of snowmelt. However, the date when the snow pillows had melted to one-half of that season's maximum snow water equivalent did appear to be related to the date of the peak flow.

It was concluded that each pillow site has a unique relationship with the snowmelt runoff produced in a given basin. Snowmelt runoff peaks when a moderately daily snowmelt is occurring over a large portion of the drainage. It does not peak at the maximum snowmelt rate because the snow-covered area is by then quite small. The peak snowmelt runoff does not develop when low-elevation snowmelt begins, because the contributing area is relatively small. Usually only low elevations are contributing and the snowpacks at higher elevations are not yet isothermal and may even be increasing.

Relationships Between Snow Pillows Data and Peak Runoff Dates

Two dates are important in determining the relationship between snow pillow data and peak runoff dates. The first is the date that the snowpack at each snow pillow melts to one-half of its seasonal maximum water equivalent. The other date is time of melt-out or when all snow is melted at the site. Dates of one-half melt and melt-out are tabulated and compared with dates when streams reach their annual peaks. Generally, the best relationships are obtained with date of melt-out for lower-elevation sites and date of one-half melt for higher-elevation snow pillows. In years when exceptionally heavy rainfall determines the day of the season's peak flow, these relationships help to identify the date of secondary peak flows caused by snowmelt.

SCS has determined the relationships between streamgage and snow pillow data in Montana from records since 1963. Table I is an example of the tabulated data, and figures 1 and 2 graph this relationship. It should be noted that some of the variation is related to temperature and precipitation patterns in individual years.

Forecasting Date of Peak Flow

Once relationships between snow pillow data and peak flow dates have been determined, projections of probable peak flow dates can be made. Usually these projections are made after snowmelt has begun and maximum snow water equivalent values are determined. Probable dates for one-half melt and melt-out are based on normal daily melt rates during specific periods, such as between May 1 and May 15, May 15 and June 1, and June 1 and June 15. Table II contains these values for some snow pillow sites in Montana. In early spring, dates of one-half melt or melt-out at each snow pillow site are projected using these melt rates. These dates are adjusted as the season progresses and daily data are received from SNOTEL. Estimates of peak flow dates are updated accordingly.

Procedures Currently Being Used in Montana

Relationships have been developed for various Montana watersheds not affected by reservoir regulation and are used to forecast timing of snowmelt peaks in Water Supply Outlook reports. These include Big Hole River near Melrose; Madison River Inflow to Hebgen Lake; Gallatin River near Gallatin Gateway; Missouri River at Toston; Yellowstone River at Corwin Springs, Livingston and Billings; Boulder River near Big Timber; Stillwater River near Absarokee; Clarks Fork River near Belfry; Blackfoot River near Bonner; Clark Fork River above and below Missoula; Bitterroot River near Darby; North Fork Flathead River near Columbia Falls; Middle Fork Flathead River near West Glacier; and Inflow to Hungry Horse Reservoir.

These estimates are available to agricultural water users and others involved with water management or distribution. Examples of the relationships that are currently in use are as follows:

TABLE I. PEAK FLOW AND MELT DATES

Water Year	Big Hole River near Melrose		Saddle Mountain Snow Pillow	Gallatin River near Gallatin Gateway		Lick Creek Snow Pillow
	Peak Daily Flow, cfs	Date of Peak	Date of 1/2 Melt	Peak Daily Flow, cfs	Date of Peak	Date of Melt-out
1964	11,200	6/10		5,840	6/07	5/25
1965	10,700	6/13		6,350	6/13	5/31
1966	3,100	5/11		4,010	5/30	5/06
1967	10,200	6/08		5,670	6/22	5/22
1968	6,890	6/13	6/09	6,280	6/20	5/31
1969	8,780	5/21	5/26	4,950	5/27	5/08
1970	8,650	6/08	6/08	7,750	6/09	6/04
1971	9,300	6/01	6/03	7,480	6/27	5/29
1972	13,400	6/10	6/13	5,000	6/08	5/16
1973	2,440	5/21	5/27	5,370	6/10	5/26
1974	9,870	6/17	6/18	8,970	6/17	5/28
1975	12,100	6/21	6/23	7,180	7/04	6/11
1976	10,500	5/20	6/04	5,300	6/22	5/18
1977	4,630	6/10	6/01	3,190	6/10	5/10
1978	7,240	6/10	6/19	4,920	6/10	5/21
1979	7,230	5/27	5/31	4,250	5/28	5/16
1980	6,410	5/11	5/19	3,930	5/23	5/10
1981	8,810	6/09	6/01	4,960	6/08	5/28
1982	9,200	5/28*	6/20	5,682	6/28	6/08
1983	7,650	5/31	6/07	5,830	6/11	5/30

*Secondary peak of 8,740 cfs on 6/17/82.

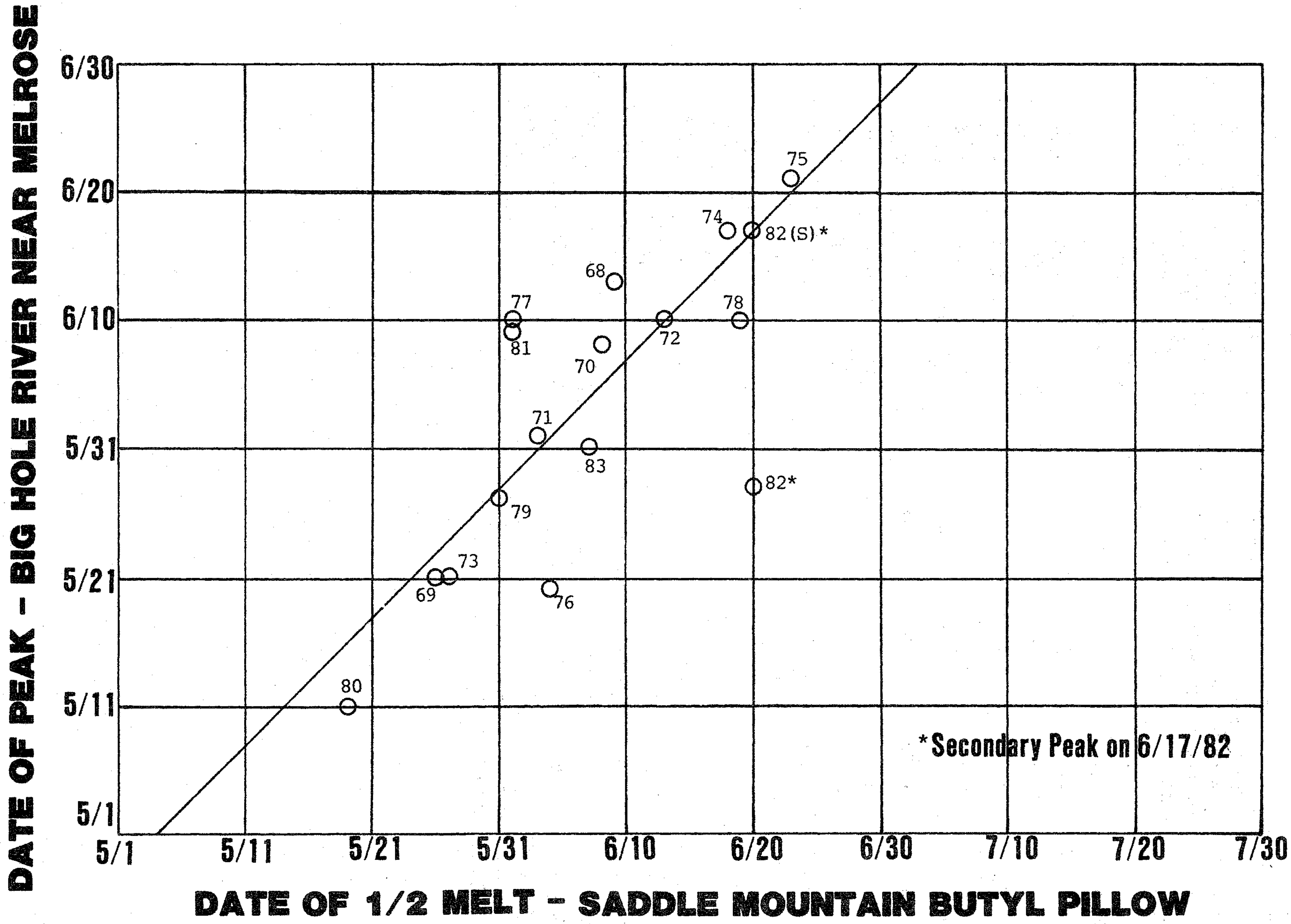

FIGURE 1. COMPARISON BETWEEN PEAK FLOW AND 1/2-MELT DATES FOR BIG HOLE RIVER, MT

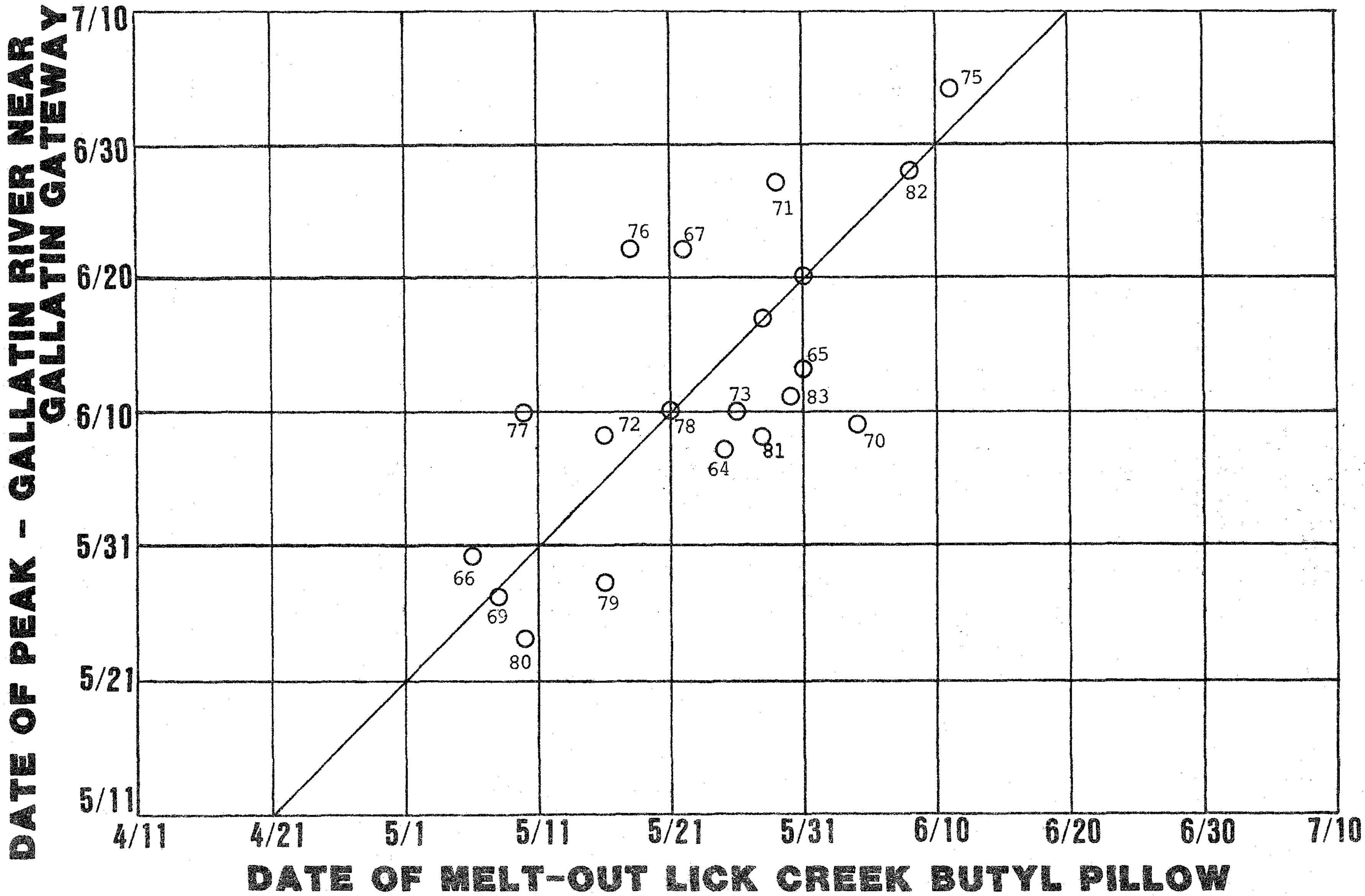

FIGURE 2. COMPARISON BETWEEN PEAK FLOW AND MELT-OUT DATE FOR GALLATIN RIVER, MT

TABLE II. AVERAGE DAILY MELT RATE, IN MILLIMETERS, FOR SELECTED BUTYL SNOW PILLOW SITES IN MONTANA

ADJUSTED TO THE 1961-1980 BASE PERIOD.

SNOW PILLOW LOCATION	TIME PERIOD			
	May 1-15	May 16-31	June 1-15	June 16-30
Banfield Mountain	9	14	25	--
Black Bear	6	15	21	30
Black Pine	7	12	20	--
Carrot Basin	0	8	13	26
Cole Creek	0	8	13	--
Copper Bottom	16	--	--	--
Copper Camp	10	20	31	--
Deadman Creek	9	--	--	--
Fisher Creek	2	8	18	28
Flattop Mountain	5	13	20	23
Grave Creek	10	--	--	--
Hawkins Lake	4	13	22	--
Hoodoo Basin	10	20	25	38
Lick Creek	6	21	--	--
Maynard Creek	4	11	--	--
Mount Lockhart	5	14	15	
Noisy Basin	7	17	20	22
Northeast Entrance	6	17	--	--
Poorman Creek	13	20	32	--
Rocker Peak	0	6	12	21
Saddle Mountain	3	11	17	33
Shower Falls	0	8	13	22
Spur Park	2	8	17	27
Stahl Peak	1	16	17	22
Tepee Creek	4	9	17	--
Twelvemile Creek	14	24	--	--
Twin Lakes	7	15	23	42
Waldron	7	14	--	--
Whiskey Creek	10	19	--	--
White Mill	3	8	12	21

Big Hole River near Melrose

1 to 3 days before Saddle Mountain reaches one-half melt. Usually same day as Gallatin River peaks and 1 to 3 days after Bitterroot River peaks.

Gallatin River near Gallatin Gateway

4 days before Bridger Bowl goes bare, 10 days after Bridger Bowl reaches one-half melt, 20 days after Lick Creek goes bare, 4 days after Maynard Creek goes bare, or same day Shower Falls reaches one-half melt. Usually same day Yellowstone River peaks.

Summary

Simple time-sequence relationships between snowmelt and day of peak streamflow add another dimension to the hydrologist's ability to predict significant hydrologic events.

To determine a relationship requires a few years of snow pillow records and streamgage data. To project dates of peak streamflow requires frequent measurements of snowmelt progress, usually from a real-time data collection system such as SNOTEL. This method provides a simple, realistic estimate of peak flow dates on streams where daily runoff forecast models have not yet been developed, where existing models cannot accurately predict date of peak flow, or as a check for peak flow dates projected with existing models.