CRITERIA FOR DETERMINING MOUNTAIN SNOW PILLOW SITES 1/

By

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Rapid technological advances are being made in snow surveying. Keeping pace with these advances requires continual updating of ideas and procedures. Use of snow pillows and telemetry is relatively new to snow surveying and streamflow forecasting. As with all new innovations, there are many problems. One that deserves serious consideration is good site location.

All mountain locations are not good data collection sites. Since data is used as an index to very large areas, a site situated in a micro-climate could provide misleading information even though all data were collected according to prescribed methods. Some criteria for snow course location are outlined by Codd and Work 3/. These criteria are generally acceptable for snow pillow sites except for accessibility. When measurement is by ground crew with oversnow vehicle, skis or snowshoes, accessibility is important. However, in establishing a telemetry system, accessibility should not be considered as a major criterion. It is advantageous if a good data site is accessible by road; however, if the best location is not readily accessible, provision should be made for getting the shelter and equipment to the best site. It may be necessary to use a helicopter to transport materials to the site, or pack animals may be the best means of transportation. A good site should not be sacrificed for a less desirable site just because it is not readily accessible by road.

To locate the Shower Falls pillow site where we believed it should be, 18 pack animal loads of material over five miles of trail was necessary.

A helicopter was required to install the Taylor Peaks pillow site. Five loads of material were transported about six miles from the end of the road to a good site accessible only by a poor trail.

In addition to other criteria, the radio signal path must be considered if data are to be transmitted by radio from the data site. Even though it is not presently planned, all pillow sites should be located with telemetry in mind.

During the past few years, we have analyzed Montana snow courses to determine why one high elevation snow course correlates better with streamflow than another, even though both may be at similar elevations and have comparable snow accumulation. We compared individual snow course data, along with antecedent conditions and spring precipitation, with runoff using multiple regression analysis. We processed data for five drainages having snow courses located "back in the mountains" and in pass areas, or on outlying ridges. In all cases, April through July runoff was the dependent variable. The three independent variables used were November + December + January streamflow (as an index to antecedent soil moisture conditions), April 1 or maximum March 1 or April 1 snow water equivalent, and April + May + June precipitation. Results are summarized in Table 1. R^2 is the square of the correlation coefficient of the multiple regression with the three independent variables. From analyses it was apparent that courses "back in the mountains" are better indexes than those on a ridge that extend out from the main mountain range, or those in the vicinity of a saddle or mountain pass.

In an attempt to evaluate the results in Table 1, it appears possible that a storm front traveling through a pass in a mountain range may converge and result in increased precipitation, similar to that caused by orographic uplift. The greater the wind or speed of the front, possibly the larger the snow deposition in the pass area as compared with other areas in the mountain range. When storms move slowly, deposition in the pass area is comparable to other locations in the mountain range. Snow courses located in this kind of site would possibly provide overindexing in years of above average wind. To obtain

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TABLE 1
MULTIPLE REGRESSION ANALYSIS FOR MOUNTAIN, PASS AND RIDGE SNOW COURSES

Station	Snow Course	R^2	Elev.	1948-62 Ave. Apr. 1 W. E.
Swan River near Big Fork 1941-66 - 26 years	North Fork Jocko	.860	6330	46.7
	Big Creek	.824	6750	46.4
Gallatin River near Gateway 1939-66 - 28 years	Devil's Slide	.773	8100	22.3
	Crevice Mountain	.646	8400	9.5
	Twenty-One Mile	.605	7150	18.2
	Hood Meadow	.591	6600	10.0
	New World	.373	6700	10.8
Bitterroot River near Darby 1939-66 - 28 years	Moose Creek	.805	6200	17.1
	Nez Perce Camp	.805	5680	15.8
	Nez Perce Pass	.754	6570	18.3
	Gibbons Pass	.716	7100	25.0
Prickly Pear Creek near Clancy 1941-66 - 26 years	Ten Mile Upper	.718	8000	14.3
	Ten Mile Middle	.720	6800	11.2
	Ten Mile Lower	.664	6600	7.2
	Stemple Pass	.566	6600	11.0
N. Fk. Sun River near Augusta 1949-66 - 18 years	Wrong Ridge	.836	6800	22.2
	Freight Creek	.789	6000	17.0
	Wrong Creek	.708	5700	15.8
	Cabin Creek	.656	5200	7.0
	Goat Mountain	.654	7000	12.3
	Marias Pass	.621	5250	20.1

Snow Course Description

North Fork Jocko	- Back in mountains near main divide
Big Creek	- Back in mountains but in shallow pass on main divide
Devil's Slide	- Back in mountains near main divide
Crevice Mountain	- On ridge away from main divide
Twenty-One Mile	- In mountain pass on main divide
Hood Meadow	- Back in mountains on valley floor
New World	- On ridge away from main divide and in pass
Moose Creek	- Below mountain pass in general area of Gibbons Pass
Nez Perce Camp	- Below mountain pass in general area of Nez Perce Pass
Nez Perce Pass	- In mountain pass on main divide
Gibbons Pass	- In mountain pass on main divide
Ten Mile Upper	- Back in mountains near main divide
Ten Mile Middle	- Near Ten Mile Upper at lower elevation
Ten Mile Lower	- Near Ten Mile Middle at lower elevation
Stemple Pass	- On main divide but in mountain pass
Wrong Ridge	- Back in mountains near main divide
Freight Creek	- Back in mountains near main divide
Wrong Creek	- Same area as Wrong Ridge at lower elevation
Cabin Creek	- Same area as Goat Mountain at lower elevation on valley floor
Goat Mountain	- On isolated knob away from main divide
Marias Pass	- On main divide but in mountain pass

consistently good forecasts of runoff, a reduction in the snow course index in proportion to winter wind is necessary. From results in Table 1 and from other studies, the lower elevation sites do not appear to be seriously affected by these conditions.

Possibly this could account for some of the correlations found by George Peak 4/ using winter wind, snow accumulation and runoff. Presumably accessibility is a major factor in the area where wind is used to modify forecasts, and snow courses cannot be located "back in the mountains" and still be measured by conventional means.

In the past few years, new snow course and pillow sites in Montana have been located with these analyses in mind. We reviewed forecast points and where we could not explain the forecast error after all data was available it was determined in almost every case the problem was lack of good snow course indexes. New courses were located "back in the mountains" and their data appear to be much more realistic and consistent with runoff than that from the older courses. However, to reach almost all new sites located "back in the mountains" considerably more effort, longer ski or snowshoe trips, or possible use of helicopter is necessary.

To evaluate where the best data collection site may be, we need to take a good look at the terrain. The vertical exaggeration relief maps prepared by the Army Map Service are very helpful. The topography, orientation and location of the mountain range can be viewed in the office and possible locations for index stations determined. Final selection can be made after the prospective sites have been visited in summer and winter. It is my firm belief that it is better to expend as much money and effort as needed to obtain data from one or two good mountain sites than spend the same amount getting considerably more data from many poor sites.

In Montana we have different types of mountain ranges. Some consist largely of rough precipitous terrain, high peaks and large picturesque cirques. Others resemble large rolling hills, but are at high elevations. Still others are a combination of the two. To index the mountain peak area, sites need to be located near the major divide and away from the edge of the range where storms may either slip around or precipitate. For rolling terrain almost any location except one in a non-typical pass will provide a good index. Mountain ranges having both types of terrain can best be indexed by collecting data representative of each different topography. It is better to have data from high elevation sites, which are usually just below timberline; median elevation sites which are normally representative of the largest water contributing area; and low elevation sites near the foothills, than from many sites at nearly the same elevation.

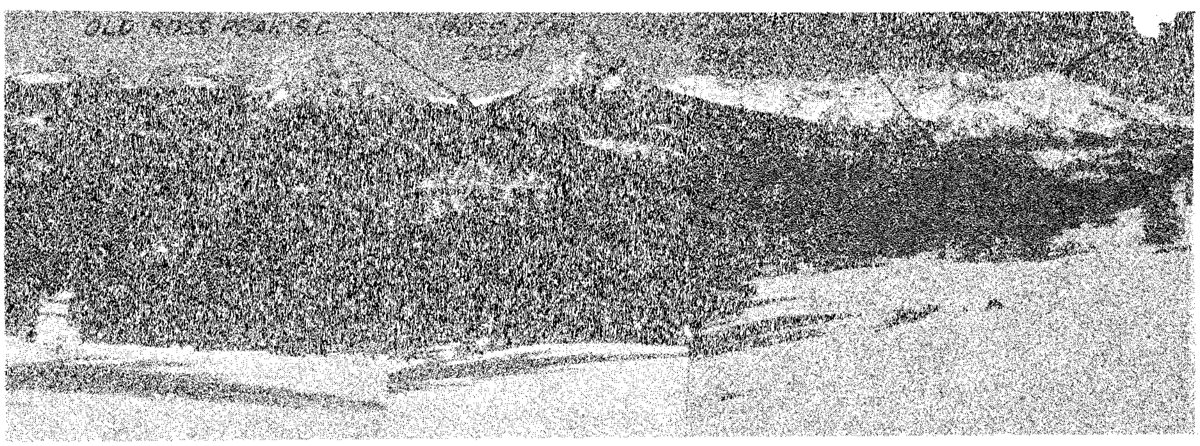

Figure 1. Center portion of Bridger Range.

Figure 1 shows the Bridger Range, north of Bozeman, Montana. If a road were to traverse the mountain, it would undoubtedly cross the lowest pass to the left of Ross Peak. One can see that a snow course located near the road would be quite accessible, yet subject to a different weather pattern than the major portion of the range. Yet, how many snow courses do we have in similar areas?

A snow course, Ross Peak, elevation 7000 feet, was located in the general vicinity of this pass in 1939, but was discontinued in 1948 because of erratic and poor correlation. Active snow courses in this area are Sacajawea, elevation 6550 feet, Figure 1; Bridger Bowl, elevation 7250 feet and Maynard Creek, elevation 6210 feet, shown in Figure 2. Snow pillows are installed at Bridger Bowl and Maynard Creek. We believe these locations will provide a good index to the snow pack in the Bridger Range and subsequently good forecasts of Bridger Creek runoff.

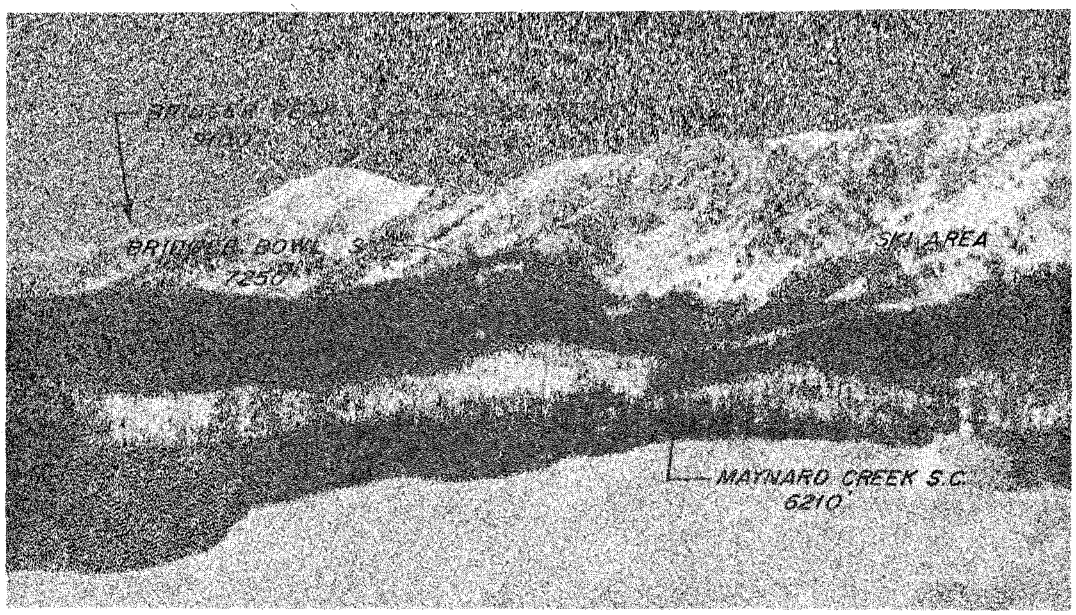

Figure 2. Bridger Bowl area in Bridger Range.

Conclusion

When locating data collection sites in the mountains one needs to be familiar with the area and have a knowledge of sites most likely to provide reliable indexes. It is likely that accessibility will be more difficult and costs greater for snow courses that provide the best indexes. When selecting sites, review the vertical exaggeration maps and choose locations that meet the criteria for good sites. Weigh all criteria carefully. Don't let a road be a guiding criterion. Snow pillows and other automatic sensors are costly installations, but once established, good sites provide data as economically as poor sites and will provide a sound basis for good streamflow forecasts.

REFERENCES

3/ Codd, A. R. and R. A. Work, Establishing Snow Survey Networks and Snow Courses For Water Supply Forecasting, Proceedings Western Snow Conference, April 1955, pp. 6-13.

4/ Peak, George W., Snow Pack Evaporation, Proceedings Western Snow Conference, April 1962, pp. 32-39.