Unmanned Measurement of Snow Water Equivalent Using Natural Soil Radioactivity

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Abstract: The attenuation by snow cover of natural gamma radiation emitted from the soil serves as an excellent index to the water equivalent of the snow cover. A small portable gamma ray detector was installed on a boom about six feet above the ground at the National Weather Service-Agricultural Research Service cooperative snow study site at the ARS Sleepers River Watershed near Danville, Vermont for the 1970-1971 snow season. Comparison of gamma ray count rates with snow measurements taken at the site indicates that the small unshielded gage could be used to measure water equivalent (range 2 inches to 15 inches) with a standard error of 0.6 inch without preliminary editing of gamma ray count rates. A major source of this error was the deposition of radioactive aerosols on the snow surface by precipitation. The deviation of gamma ray count rates due to precipitation events is short-lived and a simple editing procedure on the count rate time trace reduced the snow season standard error to 0.43 inch water. The edited count rate yielded six percent error in the three to five inch water equivalent range, decreasing to four percent in the 10 to 15 inch water equivalent range. This measurement method could be extremely valuable in providing unmanned measurement of snow water equivalents at remote locations.

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I. Introduction

Measurement of snow water resources at remote locations is of vital importance to water resource planners, river forecasters, hydroelectric operators and many others. Commonly used methods of obtaining unmanned measurement of snow water equivalent at remote locations fall into two categories: (1) weighing devices (snow pillows), and (2) nuclear counting devices. The basis of the nuclear counting measurement methods is the attenuation of gamma rays by snow water intervening between radioactive source and detector. A common nuclear method [Corps of Engineers, 1955] involves placing a strong gamma ray source at ground level with a detector being suspended over the source. Use of a sufficiently strong source allows good point measurement accuracy in deep snow cover even in the presence of natural background radiation "noise". A second and more elaborate nuclear counting method is the double probe snow profiling gage [Smith et al., 1970] designed not only to ascertain total snow cover water equivalent, but to determine the density profile within the pack as well. Yet another nuclear counting method is that to which this paper is addressed: the attenuation by snow cover of natural background gamma radiation emitted from the soil provides an excellent index to the water equivalent of the snow cover [Zotimov, 1968; Kogan, 1971; Peck et al., 1971]. Advantages of this method are several:

1) The measurement is representative of a larger area than the three aforementioned "point" measurements. Since radioisotopes in the soil provide the gamma rays, the "source" is spread out over the surface of the earth. The effective "look area" of a detector

suspended ten feet above the ground is on the order of hundreds of square feet. The effective "look area" increases with height above the ground, and decreases with greater snow water equivalents.

2) The safety in avoiding placement of strong radioactive sources is an attractive feature. In addition, the considerable effort required to meet radiation safety regulations is saved.

3) Since the "source" is distributed in the soil, count rates obtained during bare-ground periods may serve as a rough index of soil moisture. This capability is presently under investigation but not further discussed in this paper.

4) The "source" may be strengthened by mixing radioactive material into the top soil mantle, in the vicinity of the detector, as long as dose rates are kept well within allowable limits.

4) Ease of installation is a plus factor. Aside from the data transmission system (necessary for any unmanned measurements) all that is required is placement of a gamma counting device on a pole or boom at sufficient height above the ground.

The measurement method is not without its disadvantages. Two of the most important are listed:

1) The most prominent disadvantage of this measuring procedure is diminished accuracy as water equivalents increase. Gamma radioactivity is always present in small amounts from foliage and atmospheric sources. Since bare-ground count rates are typically slightly less than two orders of magnitude larger than "noise" rates, the signal-to-noise ratio may decrease significantly

as deepening snow cover attenuates more and more of the signal.

2) Natural background radiation may differ considerably in magnitude and spectral composition from site to site. This would indicate snow tube measurements taken at periods of various snow depth would be required in conjunction with gamma count rates in order to formulate count rate versus water equivalent curves at each site. Fortunately this is an initial rather than a continuing effort.

II. Experiment and Results

A small portable gamma ray detector was installed on a boom about six feet above the ground at the National Weather Service-Agriculture Research Service cooperative snow study site at ARS Sleepers River Watershed near Danville, Vermont for the 1970-1971 snow season. The detector was mounted in a box insulated with two inches of styrofoam and maintained at nearly constant temperature throughout the snow season. The detector output pulses were input to a scaler which accumulated the counts for a fixed period of time (usually one hour). The accumulated count was then recorded by the station observer and the scaler reset to zero. Generally four or five hourly totals were obtained on the days the station was attended. As of April 1, 1972, an automatic recorder was installed at the site to give an hour-by-hour trace of the count rate, but results are not included in this paper.

First consider Figure 1. In this figure the average daily count rate is plotted against the measured water equivalent value obtained by averaging results from three snow courses in the immediate vicinity of the gamma detector. A best-fit line through the points of Figure 1 yielded 0.6 inch water standard error. Since the snow course measurement should be at least within a few tenths of inches of water and since the standard deviation of a 30,000 per hour count rate is less than one percent, a considerable amount of error remains yet to be explained. Additional sources of error may be

1) significant impinging gamma flux from radioactive isotopes in the air,
2) deposition of radioactive aerosols on the snow surface by precipitation, and
3) difference in true snow course water equivalent and true water equivalent of the effective area "seen" by the gamma ray detector.

It is anticipated that most of the error is due to (1) and (2), and it is noted that the presence of either or both of these would increase the count rate from that value properly reflecting the snow water equivalent. The smoothness of the envelope curve drawn on the lower side of the points in Figure 1 supports the supposition that most of the error not attributable to snow course error is due to atmospheric "noise" radiation and precipitation events.

The lower envelope curve shown in Figure 1 was used to convert each hourly count rate to a corresponding water equivalent. Note that erroneously high count rates would yield correspondingly low inferred water equivalents. The water equivalents thus inferred for January 1971 are shown in Figures 2, 3, and 4. In these figures are also plotted hourly precipitation and measured water equivalent from snow courses and a nearby snow pillow.

The correspondence between occurrence of precipitation and departure of the gamma-inferred water equivalent from measured water equivalents is immediately obvious. Precipitation induced error is seen most notably on the fifth, seventh, fourteenth, twenty-first, and twenty-sixth of January. Several other smaller departures are also seen in correspondence with precipitation events. It is also seen that four to six hours are required after precipitation has ceased for the inferred water equivalent to "decay" back up to the equilibrium value.

The considerable error due to precipitation events need not be a major obstacle to using this snow measurement method operationally. If count rate values were telemetered say every six hours, the resulting trace could be visually edited to remove the high frequency fluctuations as would result from occurrence of precipitation. To get some idea of the accuracy resulting from such an editing procedure, all the events in Figure 1 having no precipitation during the counting period or in the previous four hours were plotted in Figure 5. The resulting season standard error for this subset of points was 0.43 inch water, an improvement of 0.2 inch over the unedited data. The standard errors within the different water equivalent ranges are given in Figure 5. These correspond roughly to six percent error in the two to five inch water equivalent range decreasing to four percent error in the 10 to 15 inch water equivalent range. This error could probably be reduced still further by shielding the gamma detector from atmospheric "noise" with an appropriate thickness of lead placed over the top of the detector (such a shield will be placed over the gamma detector at the Townline snow research station in summer 1972). It is further noted that some of the residual error in Figure 5 must be attributed to error in the snow course water equivalent measurements.

III. Conclusions

The use of natural soil radioactivity to infer snow cover water equivalents is certainly an attractive prospect in terms of accuracy and practicality. The method however may not be useful in measuring deep (twenty inches water equivalent or more) snow covers without enrichment of soil radioactivity and/or shielding the detector from atmospheric "noise" radiation. The results of the 1970-1971 snow season experiment at the NWS-ARS cooperative research site show that at least operational accuracies can be obtained even without shielding or soil radioactivity enrichment if simple editing is made on the count rate time trace to remove precipitation-induced error. Implementation of such a system on properly exposed remote data collection and transmission platforms such as the National Weather Service's Data-Collection-Platform (DCP) System [Flanders and Schiesl, 1972] could be made with a minimum of effort.

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NOAA-ARS COOPERATIVE SNOW RESEARCH PROJECT, TOWNLINE STATION
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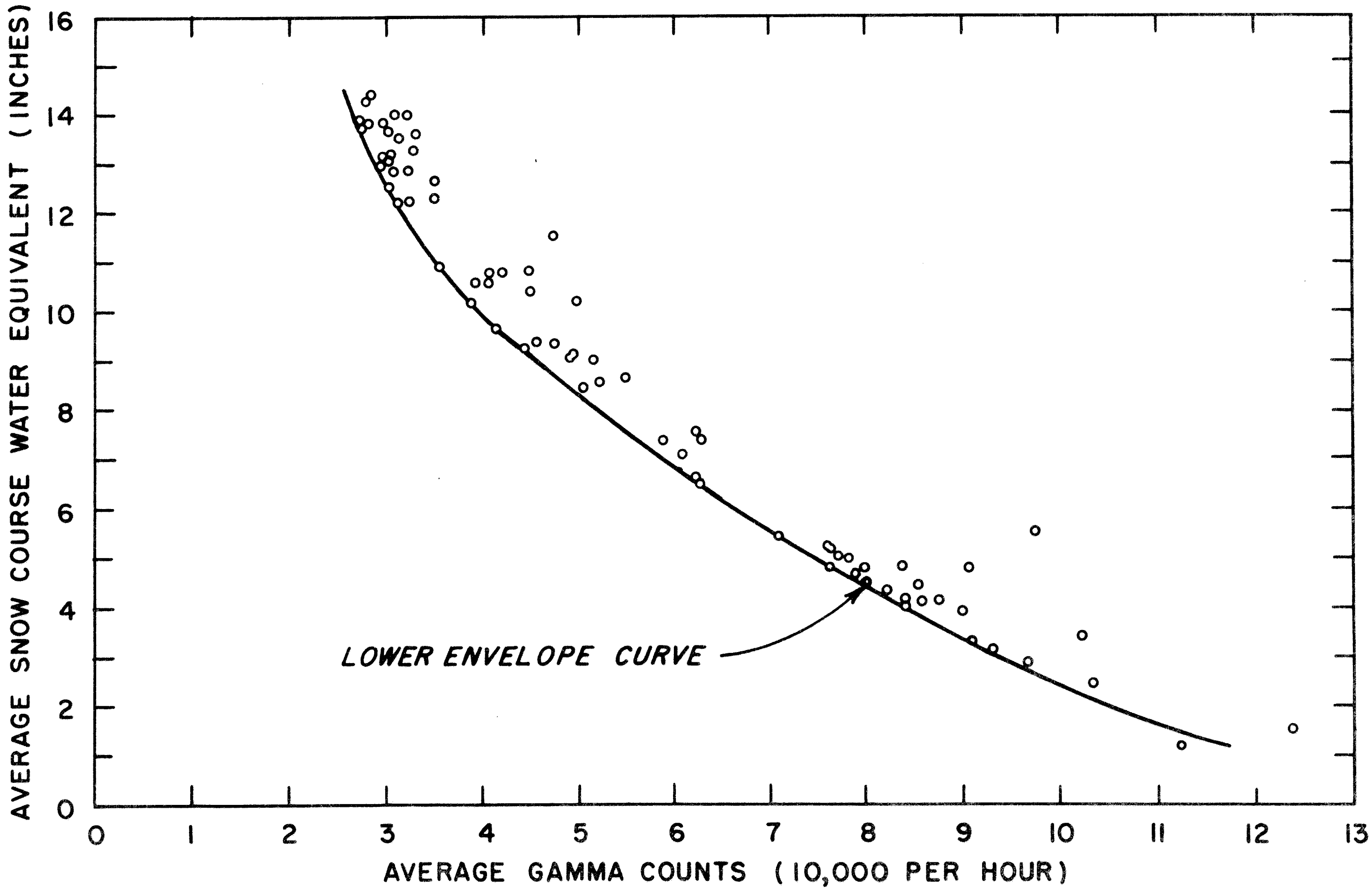

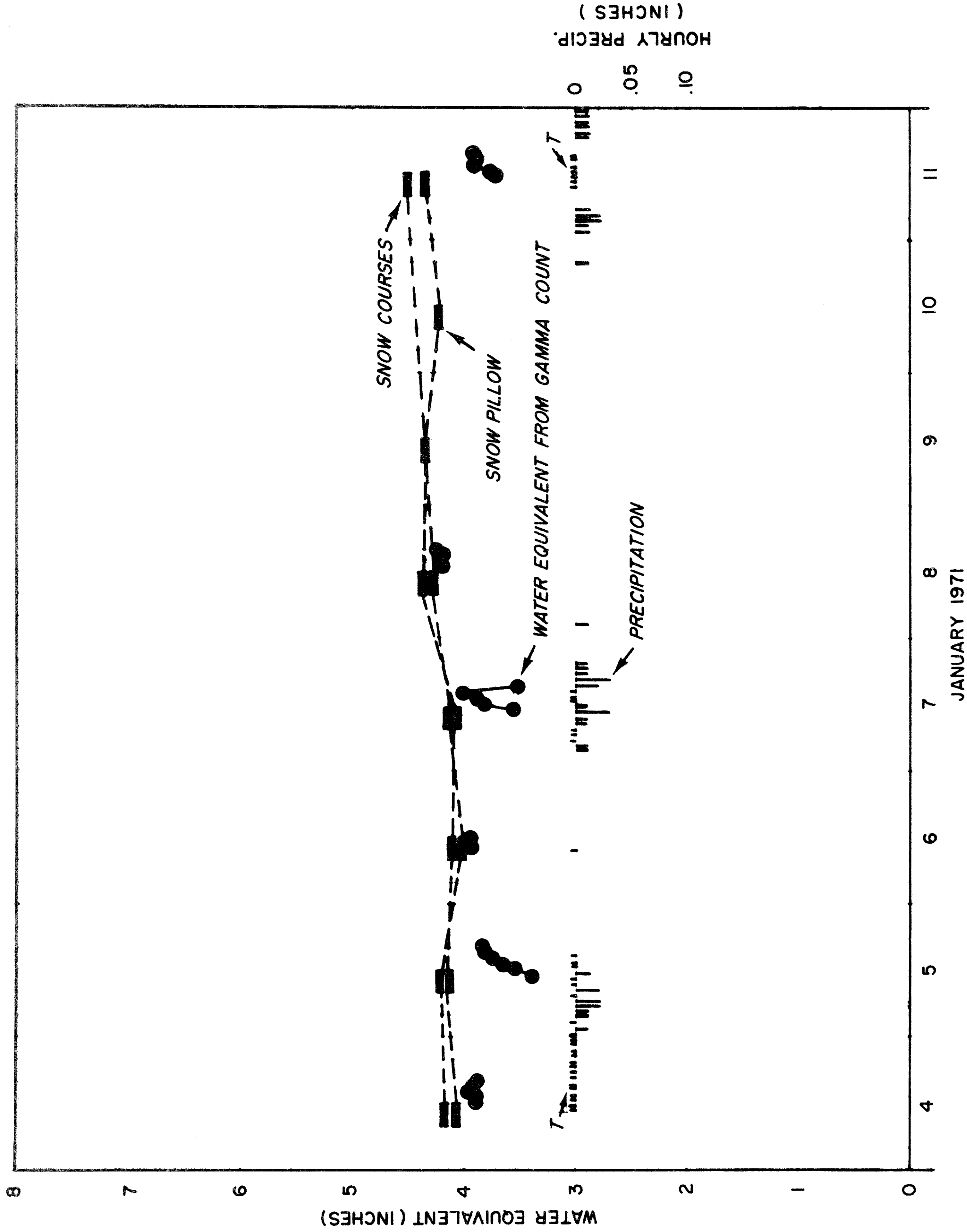
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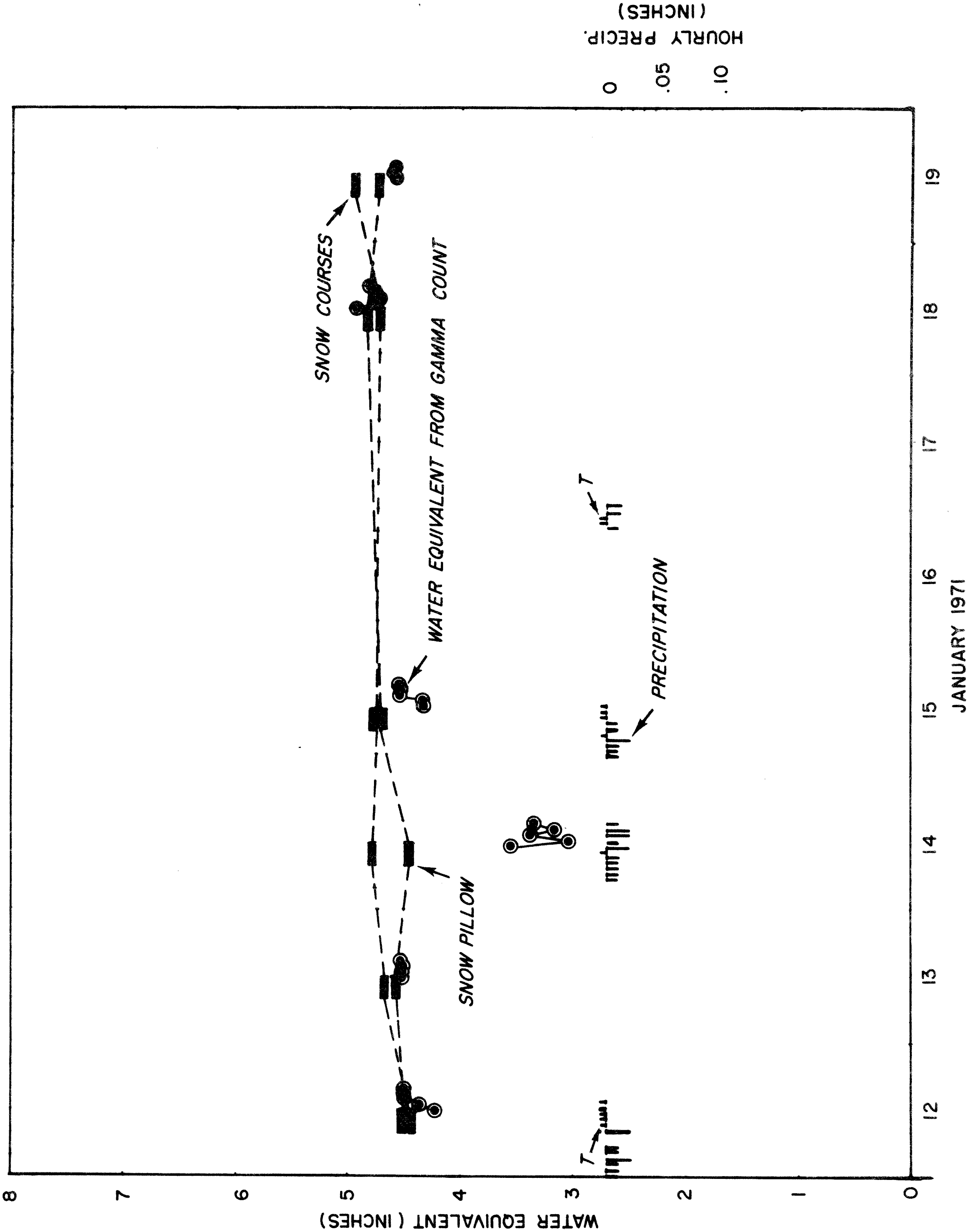
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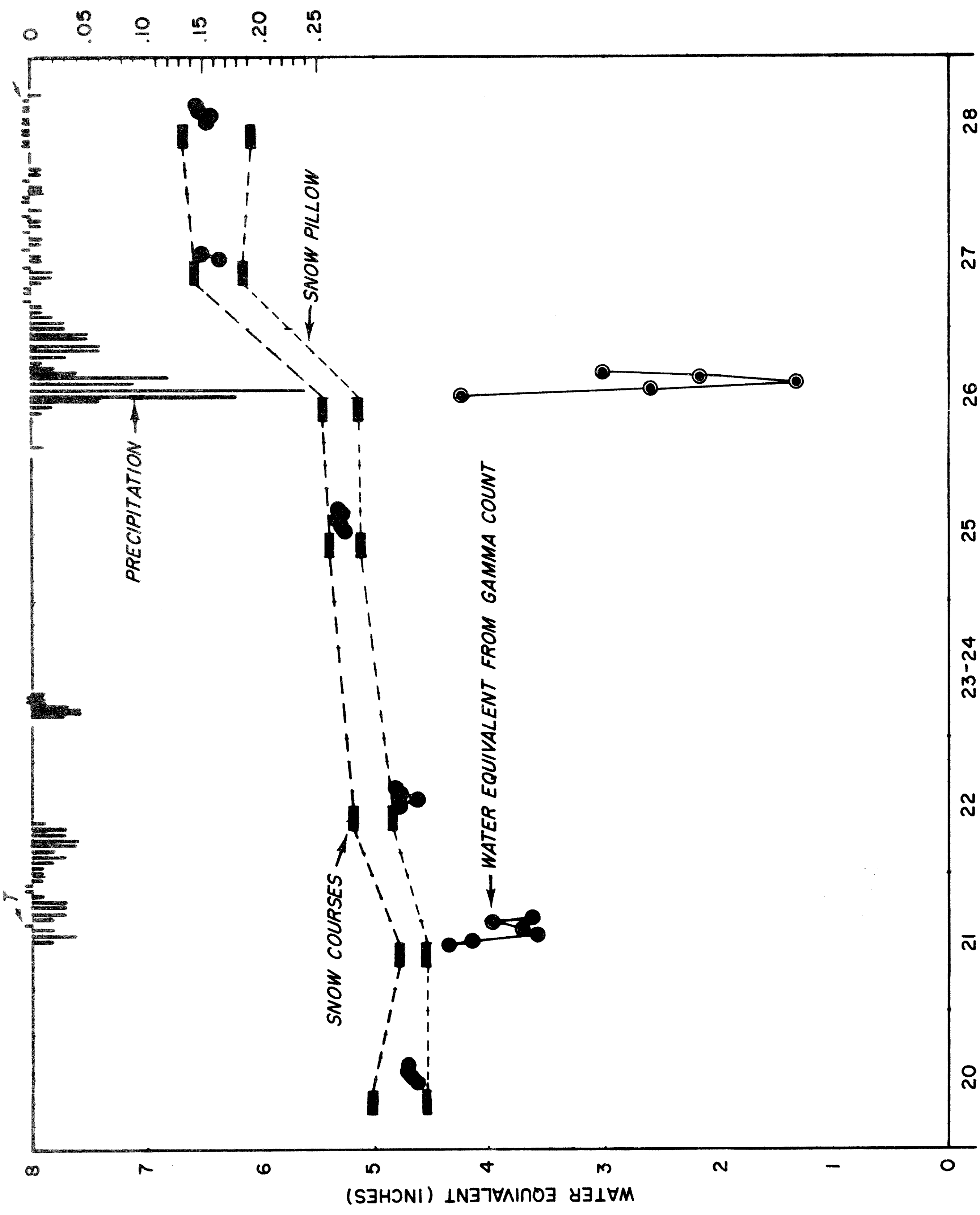
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