THE COOPERATIVE SNOW HYDROLOGY PROJECT - ESSA WEATHER BUREAU AND ARS SLEEPERS RIVER WATERSHED

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INTRODUCTION

In 1964 the Office of Hydrology of the U.S. Weather Bureau, ESSA, and the Sleepers River Research Watershed of the Agricultural Research Service, U.S.D.A., began planning a cooperative research project in the physics of snowmelt as it relates to snow hydrology. Both agencies have many responsibilities in snow hydrology, particularly as it relates to the prediction of snowmelt hydrographs.

The Weather Bureau, for example, maintains a series of River Forecast Centers which have the responsibility of predicting river stages during potential flood periods. Current snowmelt calculation procedures are, in general, based on degree-day melt factors. For the past several years the Office of Hydrology has been conducting research on improving these melt-factor methods. In addition, considerable time has been spent developing more accurate energy balance procedures. Data collected in the past have been exhausted or proved inadequate during these studies. Thus the Office of Hydrology feels new data are necessary to continue this research and hopefully to answer some of the remaining questions.

The Agricultural Research Service, on the other hand, maintains a watershed engineering research program throughout the United States which is charged with studying all phases of the hydrologic cycle. Research results from ARS watersheds are used by numerous action agencies in the planning and design of water supplies, flood protection, and other water resources projects. Runoff from melting snows is a very important part of the hydrologic cycle in the Northeast and has been one of the research investigations at the Sleepers River Research Project in Danville, Vermont for a number of years.

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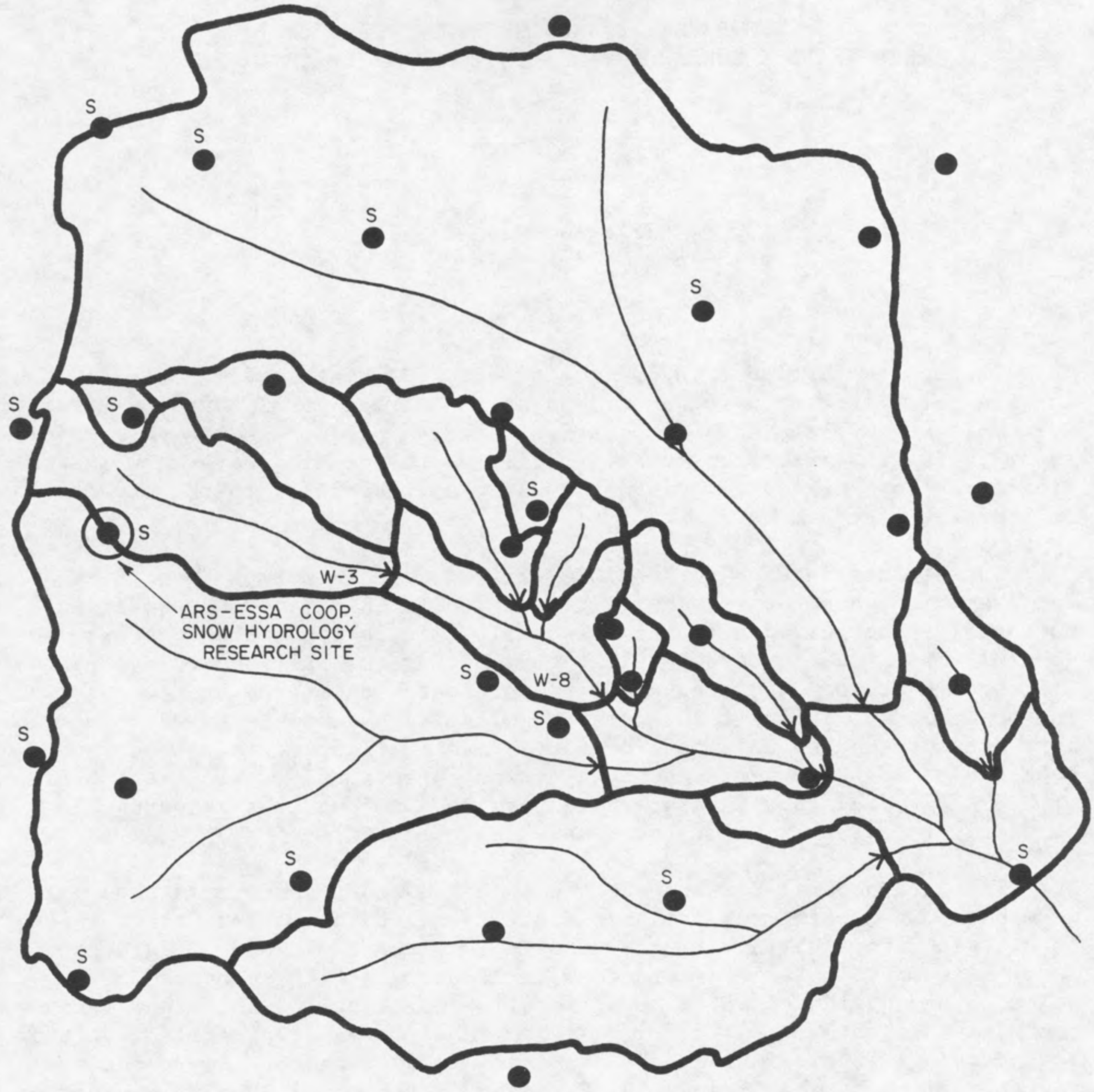

FIGURE 1. MAP OF SLEEPERS RIVER RESEARCH WATERSHED SHOWING LOCATION OF COOPERATIVE ARS-ESSA SNOW HYDROLOGY RESEARCH STATION.

LEGEND:

- ● WEATHER STATIONS
- S SNOW COURSES
- V STREAM GAGING STATIONS
- ━━ WATERSHED BOUNDARIES

N

SCALE:

1 INCH = 1.2 MILES

As a result of the negotiations between the two agencies, it was agreed that a full-scale cooperative study would be launched within the Sleepers River Research Watershed where considerable data on the hydrologic cycle were already available. Both agencies agreed that the research emphasis should initially be concentrated on understanding the physical processes involved in the metamorphosis and melting of the snowpack. Consequently, a complete data collection station has been installed in the Sleepers River Watershed by the two agencies, at the location shown in Figure 1.

The purpose of this paper is to describe the instrumentation and data reduction system for this station.

DESCRIPTION OF THE STATION:

The cooperative station is located on gently rolling terrain 500 feet below and 3000 feet distant from the western divide of the research watershed, at an elevation of 1800 feet. The site itself consists of a 2-acre fenced-in area in an abandoned field. A 2-mile power line was constructed along the road that leads to the site, and two instrument shelters and a standby generator house have been constructed. The station is operated by a Meteorological Technician assigned by ESSA for this specific job, who receives backup support and considerable assistance in construction from ARS personnel at the Sleepers River Research Watershed.

INSTRUMENTATION AND MEASUREMENTS:

To determine the needed instrumentation, all significant forms of mass and energy exchange were first listed as shown in Table 1.

Table 1. FORMS OF MASS AND ENERGY EXCHANGE IN SNOW HYDROLOGY.

Mass	Energy
(1) Precipitation	(1) Radiation
(2) Condensation, evaporation sublimation	(2) Convective heat transfer between snow surface and atmosphere
(3) Soil moisture	(3) Latent heat transfer
(4) Snowpack runoff	(4) Conductive transfer of heat within the snowpack and between the snow and the soil

It was determined from this tabulation that the following instrumentation would be required in the initial phase of the project:

I. Measurement of mass flux:

(1) Precipitation:

(a) Universal-type weighing precipitation recorder with alter windshield.

(b) Standard 8-inch nonrecording precipitation gage with alter windshield.

(2) Condensation, evaporation, sublimation:

(a) Measured by repetitive weighings of small plastic refrigerator pans filled with snow and placed flush with the surface of the pack.

(3) Soil moisture:

(a) Periodic neutron meter measurements will be made to measure soil moisture below 6 inches.

(b) Soil density will be measured by a two-probe gamma density gage extending 30 feet into the soil.

(4) Snowpack runoff:

(a) Snow depth will be measured by snow stakes and snow-tube measurements.

(b) Snow density will be measured by the weighing Adirondack- and Mt. Rose-type samplers.

(c) Snow density for given layers and new snow will be measured by a CRREL sampler.

(d) Snow depth and density will be measured by two remotely operated twin-probe gamma density gages.

(e) Total snow water equivalent will be measured by four 12-foot-diameter snow pillows with recorders, and nine 2-foot-diameter snow pressure pans with manometers.

II. Measurement of energy fluxes:

(1) Radiation:

(a) Incoming solar radiation from an upright, temperature compensated, 50-junction Eppley pyranometer.

(b) Reflected solar radiation from an inverted, temperature compensated 50-junction Eppley pyranometer.

(c) Net radiation from a miniature shielded Fritschen net radiometer and a Beckman and Whitley ventilated net radiometer.

(d) Total all wave radiation will be measured with a Beckman and Whitley total hemispherical ventilated radiometer. Backup radiation instruments, in case of failure of the above, are fully installed and instantly available.

(2) Convective heat transfer between the snow surface and atmosphere: (Convective heat transfer cannot be measured directly, but can be related to the following measured variables.)

(a) Wind from two precision anemometers maintained at 1.5 and 6.5 foot above the snow surface.

(b) Air temperature from aspirated precision thermistors maintained at 1.5 and 6.5 foot above the snow surface.

(c) Dewpoint temperatures from lithium-chloride dew cells and precision platinum resistors maintained at 1.5 and 6.5 foot above the snow surface. (Both (b) and (c) sample the same air stream. Backup instrumentation, in case of failure of (a), (b), and (c), is installed and instantly available.

(d) Snow surface temperature measured by a Barnes infrared thermometer.

(3) Latent heat:

(a) Determined from measurement of condensation, evaporation or sublimation mass flux. This measurement will also be related to the variables listed under convective heat transfer so that latent heat transfer can be computed when measurements of vapor flux are not made.

(4) Conductive transfer of sensible heat:

(a) Snowpack and soil profile temperatures measured by copper constantan thermocouples placed at 3, 2, 1, 1/2, and 1/4 foot below the ground surface; at the ground-snow interface; and at 1, 2, and 3 foot above the ground surface. Two additional thermocouples were maintained close to the snow-air interface.

(b) Soil heat flux will be measured by two Beckman and Whitley heat flux transducers and two Thornthwaite heat flow discs. These instruments are not yet operational.

III. Miscellaneous instrumentation:

(1) Temperature:

(a) Standard U.S. Weather Bureau maximum-minimum registering thermometers.

(b) Thermograph in standard shelter.

(2) Dew point and humidity:

(a) Hair hygrograph in standard shelter.

(b) Aspirated psychrometer in standard shelter.

(3) Ground-water levels:

(a) Ground-water well and recorder.

(b) Two-probe gamma density gage extending to a depth of 30 feet.

(4) Free surface evaporation:

(a) Class A evaporation station operated between May 1 and October 1.

(b) Experimental X-3 insulated evaporation pan which is being tested at the station. (These are for additional studies not connected with snow.)

(5) Albedo:

(a) A portable battery-powered instrument, using an Eppley pyranometer as a sensor, has been developed for measuring the albedo of the snow surface. The instrument is constructed so that the Eppley bulb may be consecutively exposed to the sky and the snow surface and the energies received from each read directly on a dial.

All of the instrumentation is located and laid out with respect to the direction of incoming solar radiation, so that no shadows are cast upon the sensors, and the sensor masts are constructed to swing around for checking so that the technician need not walk in the study area. The physical plan of the instrumentation at the station is shown in Figure 2.

As much as possible, all data are continuously recorded on strip charts or digital printers. The necessary visual observations are recorded as needed. All radiation data are integrated on an hourly basis. The twin-

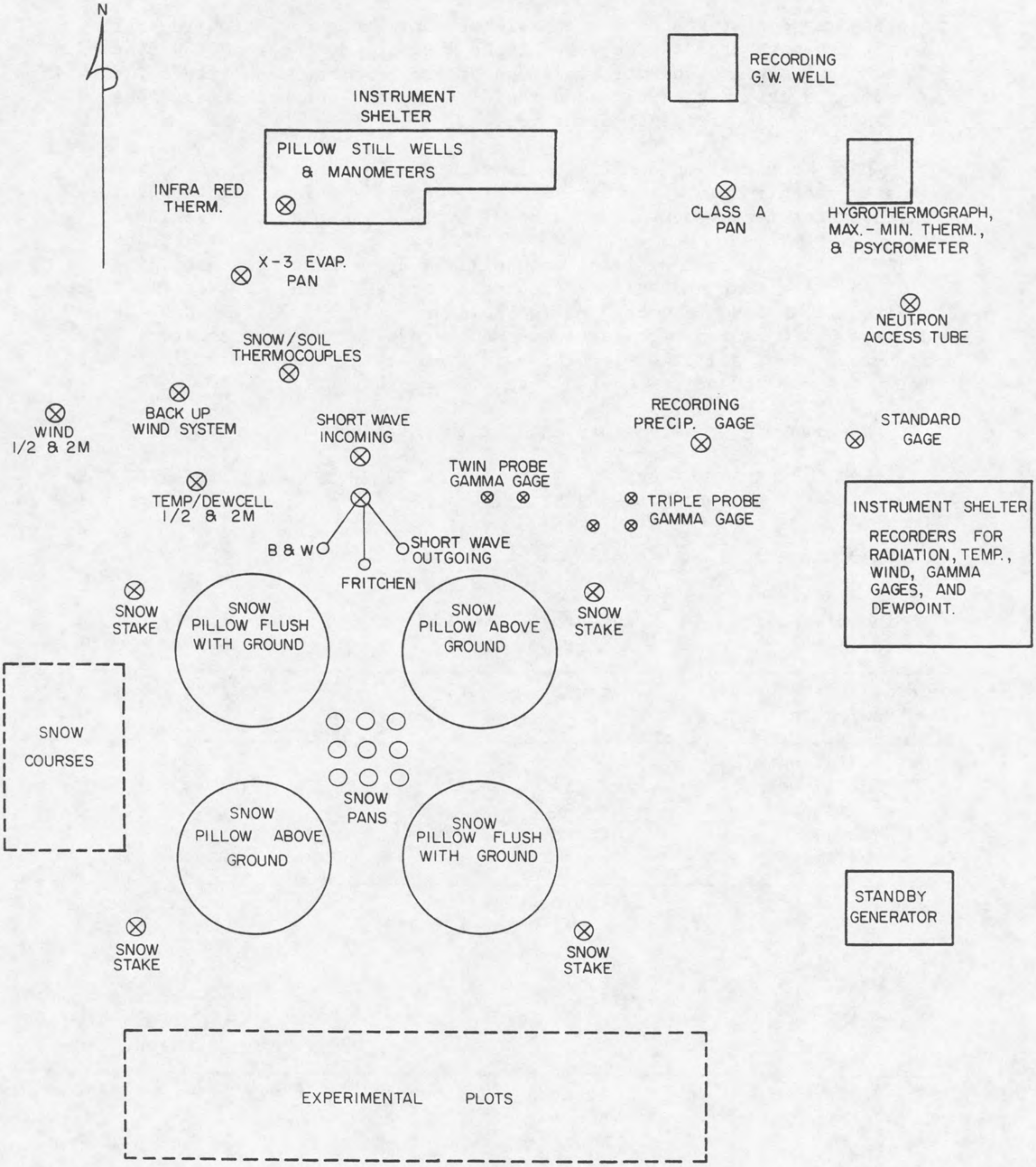

FIGURE 2. PLAN VIEW OF INSTRUMENTATION AT THE ESSA-ARS COOPERATIVE SNOW HYDROLOGY RESEARCH STATION.

probe gamma density gages are capable of continuous operation to profile density changes from the surface of the snowpack down through 30 feet of soil. In practice, however, only one or two complete density profiles will be measured each day except when rapidly changing snowpack conditions necessitate more frequent measurement.

Data tabulated on a daily basis will include snow course and snow density measurements with the CRREL kit, maximum-minimum air temperatures, psychrometer measurements, and general synoptic weather observations.

The four 12-foot-diameter snow pillows are connected to stilling wells equipped with continuous stage recorders located in the concrete instrument shelter located to the north of the pillows. (Fig. 2.). The nine 2-foot-diameter snow pans are connected to manometers in the same shelter. With a few exceptions, all other recording instruments telemeter signals to the large instrument shelter on the east side of the station site.

A summary of observations made at the station is shown in Table 2.

Table 2. A SUMMARY OF OBSERVATIONS MADE AT THE COOPERATIVE ESSA-ARS SNOW HYDROLOGY RESEARCH STATION.

Observation	Values to be Recorded	Frequency
Solar Radiation		
incoming	integrated hourly	continuous - year around
reflected	integrated hourly	continuous - snow season
Total Hemispherical Radiation	integrated hourly	continuous - year around
Net Radiation		
Ventilated radiometer	integrated hourly	continuous - snow season
Shielded radiometer	integrated hourly	continuous - snow season (over X-3 pan during remainder)
Wind	miles traveled/hour at 1/2 m and 2 m above ground or snow	continuous - year around
	miles traveled/day at 2 m above ground	daily - snow season (at 1 m above ground with X-3 pan during remainder)
Air Temperature	instantaneous at end of each hour at 1/2 m and 2 m above ground or snow	continuous - year around
	max-min	daily - year around

Observation	Values to be Recorded	Frequency
Dew-Point Temperature	instantaneous at end of each hour at 1/2 m and 2 m above ground or snow	continuous - year around
	instantaneous	daily - year around
Snow Surface Temperature	instantaneous at end of each hour from thermocouple 1 cm below surface	continuous - snow season
	instantaneous at end of each hour from infrared thermometer	intermittent - snow season
Snowpack Temperature	max-min at 1, 2, 3 and 4 feet above ground as long as sensor is covered by 2 inches of snow	daily - snow season
Precipitation	amount/hour	continuous - year around
	amount/day	daily - year around
Snowpack Water Equivalent	instantaneous at end of hour from 12-foot-diameter snow pillows	intermittent - snow season (at least once per day)
	instantaneous from 2-foot-diameter pressure pans	daily - snow season
	instantaneous from gamma density gages	intermittent - snow season (at least once per day)
Soil temperature	max-min at interface and several levels below ground	daily - snow season
Snow Surface Properties	density - CRREL tube; crystal size and classification	daily - snow season
Snowpack Properties	density, etc. by CRREL kit from pit	weekly - snow season
Snow Evaporation and Condensation	amount from freezer pans set in snow	intermittent - snow season
Areal Snow Cover	visual observations on segments of watersheds W-3 and W-8	weekly - snow season

Observation	Values to be Recorded	Frequency
Areal Albedo	point measurements from albedometer on segments of watersheds W-3 and W-8	weekly - snow season

TREATMENT OF THE DATA:

Data from all of the above instrumentation will be sent to the U.S. Weather Bureau, Office of Hydrology in Silver Spring, Maryland at the end of each month. These will be supplemented by runoff data from watersheds W-3 and W-8, (see Figure 1), and other selected hydrologic data from the Sleepers River Research Watershed instrumentation network. Most of these data will be placed on punch cards (some will require further computer reduction), the remainder tabulated, and it is hoped that complete listings will be available for analysis two weeks after the data are received by the office of Hydrology. Of course, some data does not lend itself to interpretation by machines. These include comments about weather and snow conditions, special observations, information on instrument calibration and failures, photographs, and other such records. A summary flow chart of the data handling is shown in Figure 3.

The entire record, including the machine listings, photocopies of visual observations, and other information and remarks will be compiled as a hydro-meteorological log, similar to those prepared for the Central Sierra Snow Laboratory during the Snow Investigation Studies.

FUTURE STUDIES:

Initial steps have been taken to begin step two of the cooperative study, which is to extend the complete energy balance data obtained at the station to two adjacent gaged watersheds of 3 and 6 square miles area. (See Figure 1, watersheds W-3 and W-8). A 12-foot-diameter snow pillow and pyranometer have been installed at gaging station W-3, and a network of precipitation gages and snow courses has been in existence for a number of years. It is hoped that the comprehensive information obtained from the cooperative ESSA-ARS station plus the additional climatic and hydrologic data obtained in the watershed will permit more accurate analyses of the snowmelt hydrographs. This will provide the agencies involved in this study the necessary data to develop more accurate methods of predicting downstream snowmelt hydrographs.

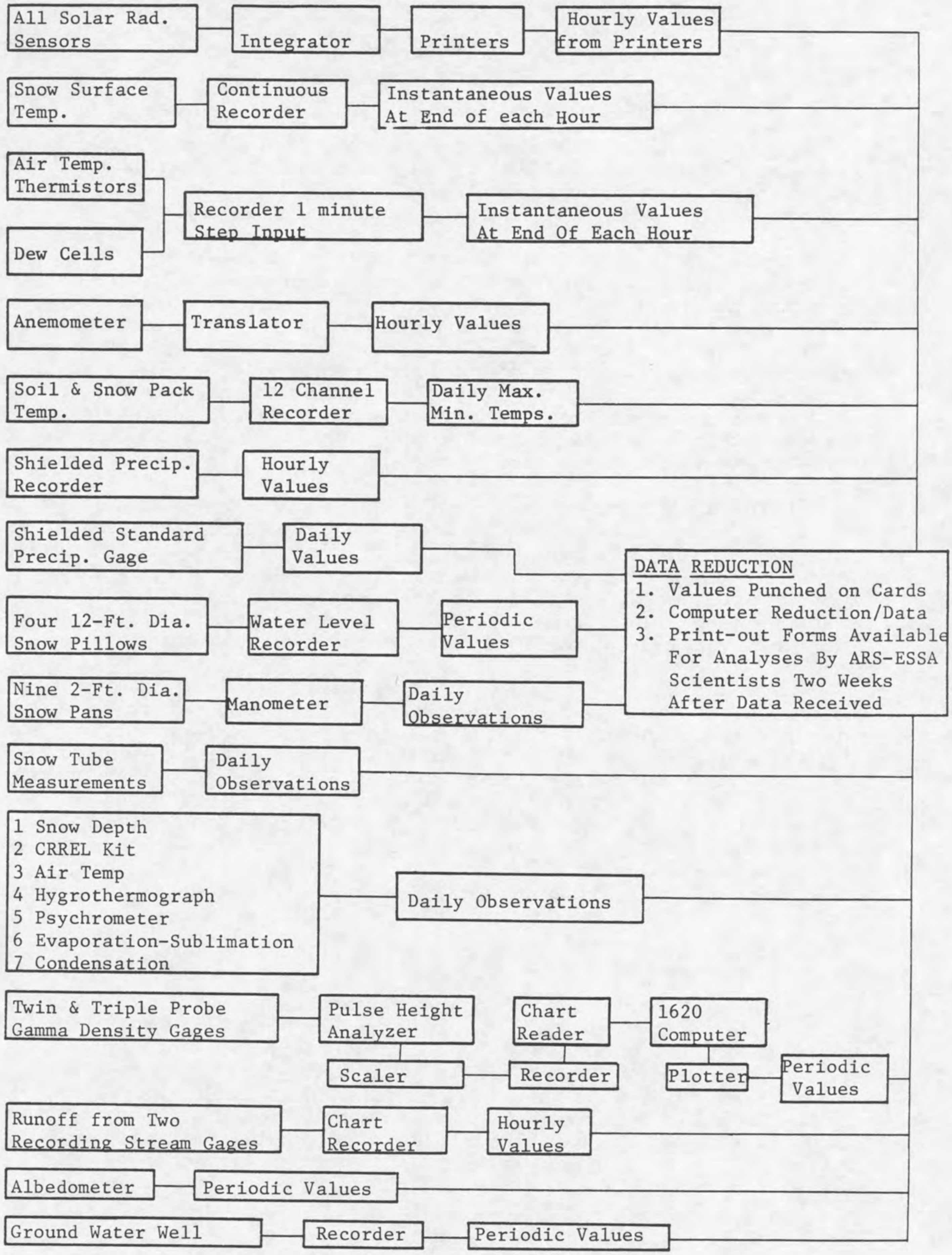

FIG. 3 DATA FLOW ESSA-ARS COOP. STUDY