AUTOMATIC DATA ACQUISITION IN THE WESTERN UNITED STATES

by
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Introduction

For the past several years the Soil Conservation Service has been active in the design and development of a remote telemetry data acquisition system in the western United States. The purpose of the system is to obtain snow and other hydrometeorological data from the remote and rugged western mountains on a daily or more frequent basis. The need for these data becomes more pressing each day with the increased demand for water in the rapidly expanding economy of the West.

The invention and development of snow pillows by the Soil Conservation Service and the advent of solid state, low power drain radio transceivers and low cost computers has made this type of system possible.

At this time the Soil Conservation Service has operational networks in eight western states acquiring data from 34 remote sites. Long-range plans call for the installation of over 500 remote data sites in the 11 western states served by our program. Each state will have one or more base stations which, in turn, will be linked by teletype circuits to base stations of other adjacent states and to our Western Regional Computer Center in Portland.

The type of equipment used at remote sites, repeaters, and base stations is described and discussed. Local, state, regional, and westwide system plans are outlined.

EQUIPMENT USED

The development of telemetered automatic data systems, suitable for wintertime use in the rugged and remote snow-covered mountains of the Western United States, is the outgrowth of a series of technological "breakthroughs" in several scientific fields. The principal development was the invention of the snow pressure pillow by the Soil Conservation Service in the early 1960's. 2/

Typically, a snow pressure pillow is fabricated from either neoprene rubber, sheet metal, or stainless steel (Fig. 1). The material is welded or soldered into thin containers. These containers are either circular, ranging from 6' to 12' in diameter, or 4' by 5' rectangles. They are fitted with two outlets: one for filling and readout, and one for releasing entrapped air. The pillows are filled with a methanol (methyl-alcohol) and water solution. Dependent on temperature considerations and pillow capacity, which ranges from 5 to 200 gallons, the solution varies from pure methanol to a 50/50 mixture of methanol and water.

A pillow, or a group of interconnected pillows, is usually installed flush with the ground surface. The weight of the snow on the pillow configuration causes an increase in the internal pressure of the pillow fluid. This pressure is measured by means of a pressure transducer.

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Presented at Eastern Snow Conference, Oswego, N.Y., February 1972

2/ R. T. Beaumont, "Mt. Hood Pressure Pillow Snow Gage," Journal of Applied Meteorology, October 1965

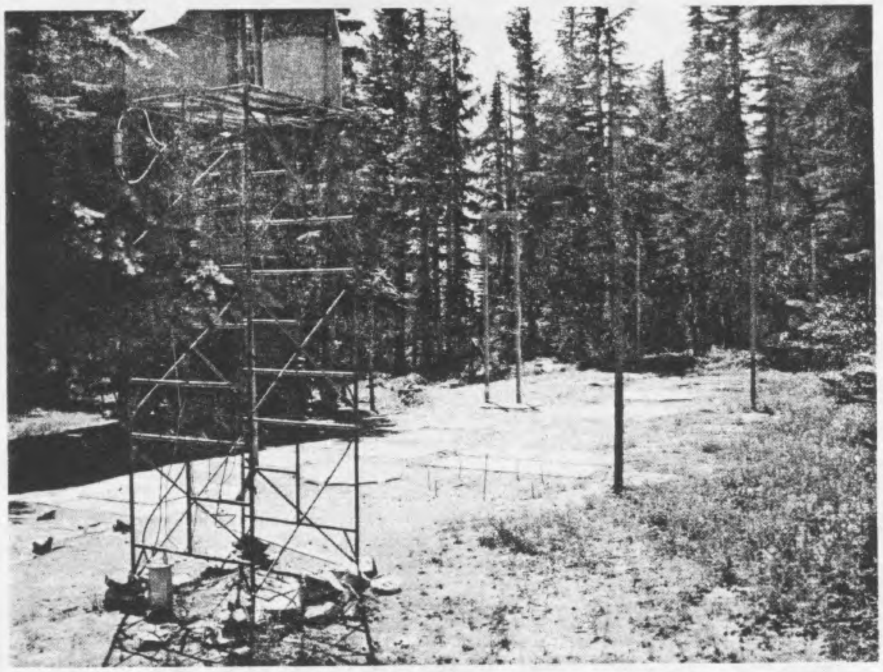

Figure 1. A view of a variety of rubber and metal snow pillows at the Mt. Hood Test Site near Portland, Oregon

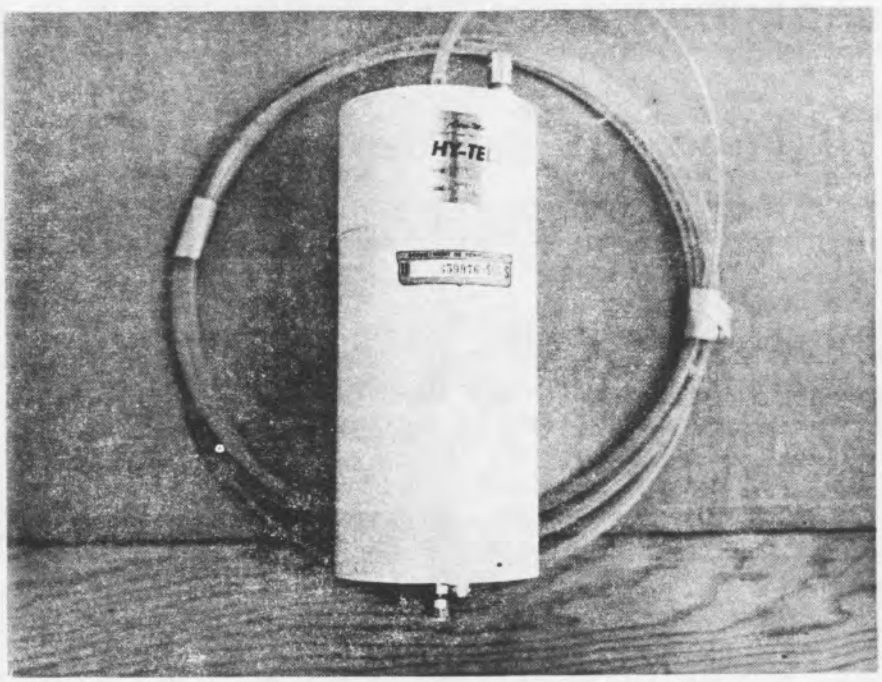

Figure 2. A '0 to 5' psi transducer of the inductive type

A pressure transducer is a device that converts pressure in pounds per square inch (psi) in our application to an electrical output (Fig. 2). Pressure transducers are not new but improvements in them have resulted in a wide variety of reasonably priced, accurate, reliable, and small-sized pressure transducers in the required low pressure (0-5 psi) range.

Fluid pressure is fed from the snow pillow outlet by means of rubber, plastic, or metal tubing to the pressure inlet of the transducer. The fluid pressure actuates a bellows or impinges upon a diaphragm. The movement of the bellows or diaphragm causes a change in the resistance or inductance of the electrical circuit on the output leg of the transducer. The transducer's electrical output, which is usually converted to voltage, is then injected after appropriate interface modification into a radio for transmission from the remote data site to the base station.

In the past several years integrated circuits, transistors, solar cells, thermoelectric generators, and rechargeable Ni-Cad* or Gel/Cell batteries have revolutionized the use and application of radio transceivers at remote data sites. It is now possible to purchase "off the shelf" self-contained transceivers that weigh less than 20 pounds, cost less than $1,000, and operate for up to 9 months, unattended (Fig. 3).

Data is transmitted by such radios via repeater links, as required, to a central base station radio unit (Fig. 4). There the data is converted to a digital form either by use of a small process-control digital computer and/or predesigned solid state logic boards. The data can then be displayed and/or retransmitted by use of microwave or leased-line teletype circuits.

In a similar fashion--by using appropriate sensors--precipitation, temperature, wind speed and direction, relative humidity and a host of other hydrometeorologic parameters can be remotely sensed and telemetered.

EQUIPMENT REQUIREMENTS

Obviously, in the design, installation, and operation of an automatic data network system, the quality and quantity of the hydrometeorological data are of primary importance.

Probably there are no more severe natural environmental conditions than those encountered in the snow-covered regions of the world. Except for surface use, similar sensing and telemetry equipment in an ocean environment would encounter only four principal problems: pressure/temperature changes, moisture, corrosion, and signal transmission attenuation. If the station were at a fixed location, pressure/temperature would become a static design constant.

Likewise, space applications are primarily affected by temperature and 'g' forces at launch. The vacuum conditions in space are actually almost ideal for equipment operation.

*Trade names are used solely to provide specific information. Mention of a trade name does not constitute a guarantee of the product by the U.S. Department of Agriculture nor does it imply an endorsement by the Department over comparable products that are not named.

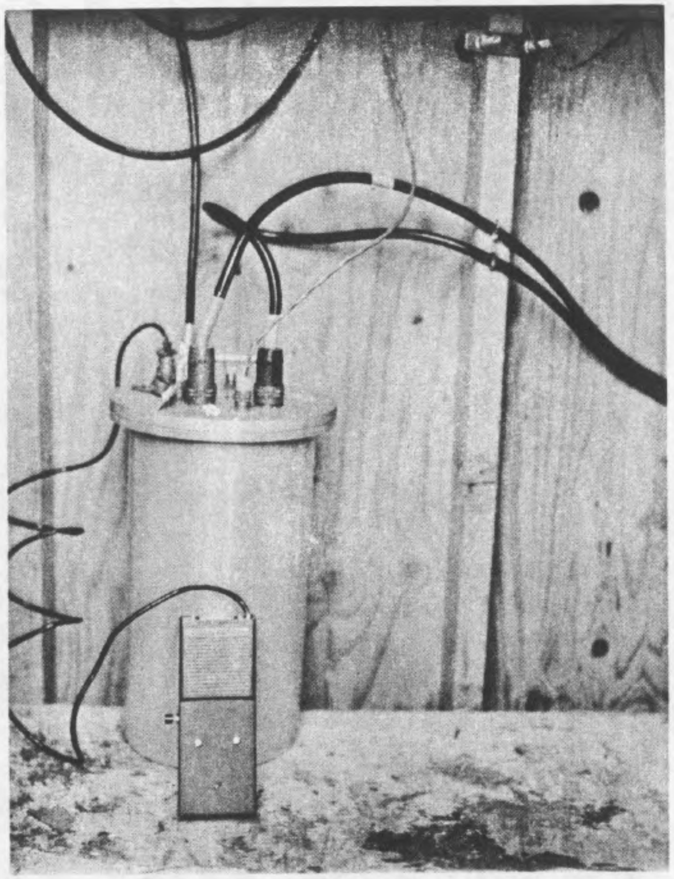

Figure 3. A remote station transceiver and associated interface equipment unit

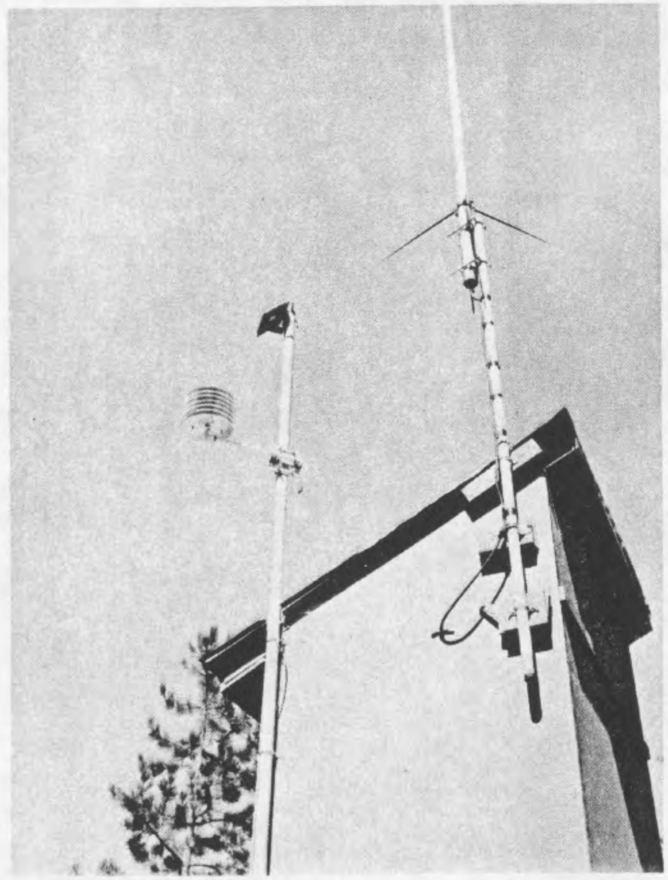

Figure 4. Data station gage house, antenna, solar cell and temperature sensor

Compare this to the principal environmental conditions encountered at a typical data site in the mountainous West:

1.	Temperature range	-30° F. to 100° F.
2.	Snowfall depth	0' - 25'
3.	Wind speed	0 to over 100 mph (gust)
4.	Relative humidity	0% - 100%
5.	Precipitation forms	rime ice, hail, sleet, rain, snow
6.	Physiographic factors	1000' - 12,000' + elev. mountain barriers
7.	Other	vegetal cover, soils, seasonal climatic changes

To meet these environmental conditions the equipment must be compact, reasonably lightweight, transportation shock resistant, modular, and easy to install, service, and maintain. In addition, sensors must be accurate, not affect the value of the parameter being sensed, and under static conditions provide a constant reading (i.e. repeatability).

Obviously, cost, equipment availability, and a long usable equipment life are equally important factors in such systems.

PROBLEMS ENCOUNTERED

In the development of the present SCS systems, equipment and operational problems have occurred. This was not unexpected since such systems require extensive interfacing of a wide variety of equipment to operate under severe environmental conditions. At the time the snow pillow sensor was being proven feasible by onsite testing, most of us actively engaged in planning felt that telemetering of the data would be relatively easy. We felt that telemetry equipment capable of enabling man to communicate from outer space to earth should be able to send data from Point (A) in the mountains to Point (B) 50 to 100 miles away in the valley.

This theory did not work out in practice. We soon discovered that telemetry problems equaled, if not exceeded, sensor problems. For example, a high-gain omni-directional whip repeater antenna situated on a windswept ridge will, under certain ice riming conditions, come to resemble a supersized, inverted snow cone. The result is signal attenuation, temporary loss of signal and, if extreme, total failure and collapse of the antenna and supporting mast. The ultimate solution now appears to be to enclose the antenna in conical fiberglass radome such as being used most successfully by British Columbia Hydrology and Power Co. in Canada. 3/

Intermittent or complete radio failure, due to such factors as cold-soldered joints, moisture, corrosion, and excessive standby power drain on the batteries, was common in the prototype systems. This type of problem has largely been overcome by improved design, extensive bench testing prior to installation, and scheduling installations for the milder summer months rather than during howling winter snowstorms.

The effects of rapid and extensive diurnal ambient air temperature changes on radios, batteries, and interface equipment have been mitigated by insulation in protective housing and/or burial in the ground.

3/ J. C. Gornall, "Advanced Techniques Overcome Severe Environment Encountered by Mobile Communications System," Proceedings of the Western Snow Conference 39th Annual Meeting, April 1971.

In the early stages of our program, the field interface equipment, which modifies the data from the sensor/transducer for injection into the radio, was a source of telemetry problems and failure. Generally, the interface converts the data into a digital format. This often required a specially designed logic unit. The units were failure prone. The more recent interface logic units are better designed, more universal in application, and much more reliable.

These are but a few examples of the telemetry equipment problems we have encountered and, to a large extent, overcome. Another type of problem in telemetering data is the limited number of radio frequencies available for hydro-met data transmission. This, coupled with the limited number of suitable repeater sites, has resulted in a multitude of difficulties. Close coordination between agencies, tone guarding, time and facility sharing, use of microwave facilities, and conversion to the less crowded UHF hydromet frequency band has been utilized to minimize this type of problem. Use of synchronous satellite repeaters may be the ultimate solution.

It would not be correct to leave the impression that the sensoring equipment used has been without fault. Shortly after we had determined butyl rubber snow pillows were good sensors for the measurement of snow water equivalent, we discovered that the fabric lost methanol due to capillary wicking and, under moderate to heavy snow load, the welded seams often failed. Neoprene rubber properly laminated and welded has virtually eliminated this problem. Another solution has been the use of carefully fabricated galvanized sheet metal pillows.

Snow pillow size has been determined to be an important consideration. The following minimums are recommended: 40 square feet of pillow surface area for up to 30 inches of snow water equivalent; 60 square feet, for 30 to 50 inches; 80 square feet, for 50 to 75 inches; and 120 square feet, for more than 75 inches.

Pillows should be carefully installed with close attention given to seating them firmly to the soil surface and providing adequate drainage. They should be located at least 15 to 20 feet away from any abrupt change in slope. If the snow is likely to be more than 10 feet deep, the distance should be increased to 1.5 to 2 times the maximum expected snow depth.

Snow bridged in the orifice of precipitation gages is a well-known phenomenon. The use of tall, cylindrical, 12"-orifice gages charged with a special self-mixing glyco-meth (ethylene glycol and methanol) solution has produced highly reliable results. 4/

Temperature sensors have not been a serious problem. A reliable, yet reasonably priced, relative humidity sensor is not available at this time. We are currently testing an SCS-designed unit in Wyoming that should meet cost and data requirements.

CURRENT AND PROPOSED SCS NETWORKS

The Soil Conservation Service currently operates a network of 1,450 manually read snow courses in 11 western states exclusive of California, which has a network of over 200 snow courses operated by their Department of Water Resources. In addition, we have a network of 200 aerial markers, 196 soil moisture stations, and 278 precipitation gages.

4/ L. R. Mayo, "Self-Mixing Antifreeze Solution for Precipitation Gages." Pending publication as a U.S. Geological Survey Technical Paper.

Currently we have in operation telemetered data system networks in eight western states as follows:

State	Base stations	Radio repeaters	Data sites: SCS-owned	Data sites: Cooperator-owned
Alaska	0	0	0	0
Arizona	0	0	0	0
Colorado	1	1	5	0
Idaho	2	3	4	0
Montana	1	2	3	1
Nevada	1	2	7	0
New Mexico	0	0	0	0
Oregon	2	3	6	0
Utah	1	2	7	45
Washington	1	1	1	0
Wyoming	1	1	1	0
Total	10	15	34	46

Our long-range proposed network envisions 507 telemetered data sites, 76 repeaters, and 13 base stations in the western states. Our cost estimate is $8,180,000 for installation over a 5-year period and annual O&M thereafter ranging from $821,000 to $950,000 for the 20-year lifespan of the equipment. Currently we do not have appropriations to accomplish this goal. Efforts are underway to fund this program.

In many instances telemetry installations will be made at existing snow courses having a long historical record. Others will be new installations at more remote sites that are often inaccessible except in summer, using horses or helicopter. Telemetry will eliminate or greatly reduce the need for manual readings at those sites to be located at existing snow courses.

The manual network will be reduced from 1,450 snow courses down to 1,000 to 1,100. Thus, fewer field employees will be needed to measure the manual network. It will also be possible to measure the manual network on a less frequent time basis.

Data from the telemetered sites will be read on a flexible schedule with design capability for hourly, semi-daily, daily, or less frequent readings. Base stations will be located in each of our 11 western state office headquarters. These state office base stations, operating under programable digital process computer control, will interrogate a regional network. Typically, this network will consist of the basins in their state and adjoining states that have the best radio telemetry paths via repeater links.

The process control computer will quantify data, check data for validity, and store data for later retrieval. Data will be exchanged or provided to other users by means of data phone or teletype circuits.

We propose to use our ADP facilities in our Portland, Oregon, Regional Technical Service Center to provide a "central exchange" as well as for processing data, validity checking, and storage facilities beyond the capacity of the smaller state base station computers.

The principal peripheral unit at the base stations that will be used for "hard copy" data display and data exchange is the teletype.

Hydro-met data banks currently being develcped by other federal and state agencies will be provided with the data collected by our system through interconnections either to our state base stations or to our Portland Center.

TABLE 1

PARTIAL LISTING OF PRESENT AND PROPOSED WESTERN TELEMETRY SYSTEMS*

Name	Location	Sponsors	Purpose
Soil Conservation Service	11 Western States	Soil Conservation Service and numerous cooperators	Hydro-met (see text)
Hydro-met Data Management System	Columbia Basin	Corps of Engineers Bonneville Power Administration Bureau of Reclamation U.S. Geological Survey National Weather Service U.S. Forest Service Environmental Protection Agency and numerous other cooperators including SCS	Hydro-met To include a large data bank and operational control facility
Western Washington	Western Washington	U. S. Geological Survey and numerous other federal, state, and private cooperators	Hydro-met To intertie with Columbia Basin Hydro-met System
California	California	California Department of Water Resources and numerous other federal, state and private cooperators	Hydro-met and flood control
Alaska	Fairbanks	Corps of Engineers National Weather Service	Flood warning and Hydro-met
Atmospheric Project	Northern Utah	Utah State University Bureau of Reclamation and cooperators	Weather modification
Colorado River Pilot Project	Durango, Colorado area	Bureau of Reclamation and cooperators	Weather modification
Salt River Project	Phoenix, Arizona	Salt River Valley Water Users Association	Hydro-met and supervisory control

*NOTE: This listing is not intended to be all inclusive.

Since many critical decisions are made based on data such as we collect and propose to collect, it is essential that the data be geographically and hydrologically suitable, accurate, and timely. The system is being designed to meet these objectives.

OTHER NETWORKS

Many other federal, state, and private agencies are individually and collectively designing and installing telemetered hydro-met data system networks in the western United States. A partial listing is given in Table 1.

We are working closely with these other groups in coordinated planning, data exchange, equipment requirements, frequency coordination, and site sharing.

We are also cooperating in the planning and use of satellites both for remote sensing and as repeaters.

CONCLUSION

We hope the concepts and findings presented in this paper will give you an updated insight on the automatic data acquisition activities in the western United States.

It should be emphasized that the purpose of these networks is to provide some of the kinds of data that are needed by western water users to make effective management decisions. An important side benefit is that these same networks can be used by those concerned with monitoring the environment for air pollution and radioactive fallout, those concerned with forest fire prediction and prevention, those concerned with recreation and avalanche prediction, and those concerned with climatology and meteorology.