DATA ACQUISITION SYSTEMS (DAS) FOR HYDROLOGICAL MEASUREMENTS

V. C. GOYAL

National Institute of Hydrology, Roorkee-247 667

ABSTRACT

With the availability of cheap reliable micro-electronic devices, such as microprocessors, solid state devices, sensors based on new technologies and communication systems, measuring instruments have become much more capable and intelligent for use in many fields, including operational hydrology. The characteristics of these devices, such as low cost, low power consumption, high reliability, and toleration of a wide range of environmental conditions make them particularly suited for applications in operational hydrology. These instruments are capable of working unattended for long periods, usually in remote sites, far from mains electrical supply. In addition to the direct use of microprocessor technology in measuring instrumentation and data transmission systems, on-site data processing and analysis is also being carried out using state-of-art intelligent instruments.

Data Acquistion System (DAS) are increasingly being used for hydrological data collection and processing. These systems provide an accurate, real-time (if required) analyses alongwith data collection and transmission for applications in various hydro-meteorological studies. The chapter compiles the relevant information about various DAS and hydrometeorological sensors.

1. INTRODUCTION

Collection of hydro-meteorological data is a very basic need for water resources planning, development and management. The amount of water in different phases of the hydrologic cycle, and its movement from one phase to another forms the basis of hydrological measurements.

Data on various hydro-meteorological variables, eg precipitation, discharge, soil moisture, etc. are required for hydrological forecasting and efficient water management. Some hydrological variables, eg rainfall, streamflow and ground water have been measured for many years, albeit mostly for specific purposes. With the advent of microprocessors/microcontrollers, sensors based on new technologies and communication systems, hydrometric measurement systems are tending to become multipurpose. Nation wide schemes to measure hydrological variables are now considered essential for the development and management of water resources of a country (Shaw, 1983).

Data Acquisition Systems (DAS) are designed to accept multiple data input signals, to process the data according to user-specified functions, and to store and/or output the data in a meaningful form to devices such as memory-modules, recorders, printers, etc. These systems provide an accurate, real-time (if required) analyses alongwith data collection and transmission for applications in various hydro-meteorological studies.

Automatic DAS are normally used to augment a basic manual observing network. This is done to collect data from sites which are difficult to access or are inhospitable or, at manned stations, collect data outside the normal working hours of the observing staff. Basically, any DAS comprises of three components- sensors, data collection system, and data transmission system. Most of the working hydrologists are aware of the term Automatic Weather Station (AWS). In fact, AWS is a particular type of DAS in which the sensors are mostly meteorological sensors; whereas the DAS covers any type of sensors.

2. COMPONENTS OF A DATA ACQUISITION SYSTEM

During the last two decades, the availability of cheap reliable microelectronic devices, such as microprocessors and solid state memories, has lead to their incorporation in measuring instruments for use in many fields, including operational hydrology. The characteristics of these devices, such as low cost, low power consumption, high reliability, and toleration of a wide range of environmental conditions make them particularly suited to applications in operational hydrology. These instruments have to be capable of working unattended for long periods, usually in remote sites, far from mains electrical supply. In addition to the direct use of microprocessor technology in measuring instrumentation and data transmission systems, on-site data processing and analysis is also being carried out using state-of-art intelligent instruments (WMO, 1986).

Functionally all DAS must have (i) hydro-meteorological sensors, (ii) electronics to convert the sensor signal to a digital value, and (iii) either electronic storage media to collect the data on site or telecommunications hardware to transmit the digital value, or both. The electronics may be designed specific to the sensors and functions offered by the system; or the DAS may use a stand-alone data-logger to perform the measurement, communication, and in some cases, data storage functions. Additional components to the systems include (i) the mast and mounting hardware necessary for the proper deployment of the sensors, (ii) protective housings for the electronics, and (iii) the power supply. The schematic of a DAS is shown in Fig 1.

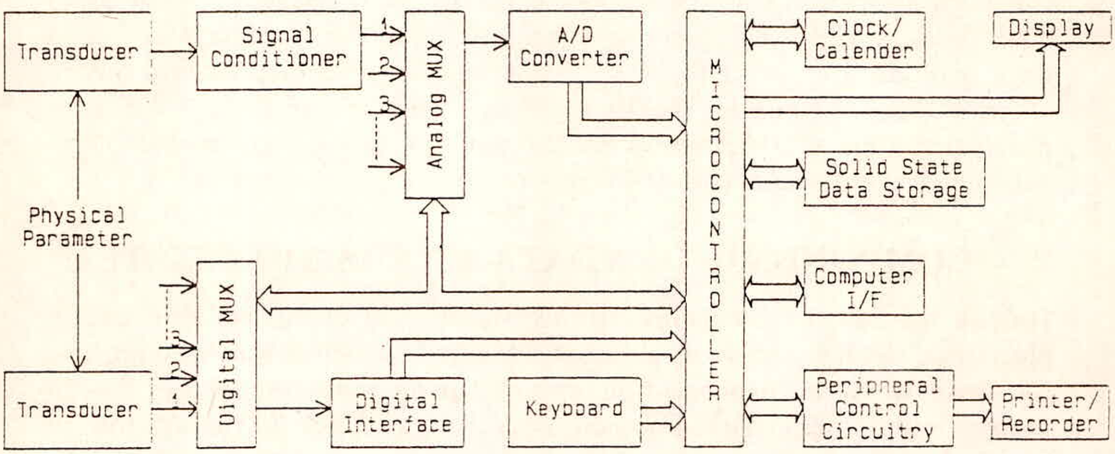

Fig. 1 Functional Block Diagram of a Field DAS

The convenience and reliability with which measurements are retrieved from the field and entered into the computer are important considerations for any measurement system. Data may be stored on site and retrieved manually or retrieved remotely using various communication options. On site storage uses either external devices which are exchanged when the site is visited or memory internal to the system. Internally stored values are transferred to storage devices brought to the field.

The most common electronic media used for external storage are Random Access Memory (RAM), Erasable Programmable Read Only Memory (EPROM) and magnetic tape. Electrically erasable PROMs (EEPROM) are also available, but are costlier. Cassette tape recorders are still used with inexpensive systems. Increasingly portable laptop personal computers are being used as field communication terminals and to retrieve internally stored data.

All automated DAS invariably involve data transmission systems. Two basic situations are found-in one, various sensors are transmitting their data to a single data collection system. In the other situation, different sensors are connected to local computers (microcomputers) and the network transmits the data to a central data collection system for processing.

The most common methods used to remotely access field data are Tanner (1990): (i) short haul or multidrop cables, (ii) standard telephone lines (on rental basis), (iii) UHF or VHF radios, and through communication satellites. Initial hardware and installation costs, reliability, operating distances and data throughput rates, are important in determining the usefulness for a particular application. Remote data retrieval provides timely reporting, early detection of equipment malfunctioning and, for isolated sites, may be the only practical means of regular data recovery.

The data required for various facets of hydrological studies may be broadly classified as follows:

1. Hydro-meteorological data
2. Stream-flow data
3. Ground water data
4. Sedimentation data
5. Water quality data

In order to collect the above mentioned data, the following parameters must be measured:

2.1 Hydro-meteorological Data

a. Precipitation-rainfall and snowfall
b. Evapo-transpiration
c. Relative humidity
d. Air temperature
e. Solar radiation and direction
f. Wind speed and direction
g. Sunshine duration
h. Atmospheric pressure

2.2 Stream-flow Data

a. Discharge-velocity
   - depth (to give cross-sectional area)
   - width
b. Stage

2.3 Ground Water Data

a. Ground Water levels
b. Parameters related to aquifers and leaky-aquifers
c. Well discharge
d. Soil moisture

2.4 Sedimentation Data

a. Bed load
b. Suspended sediments

2.5 Water Quality Data

a. Conductivity
b. Ph
c. Dissolved oxygen
d. Temperature
e. Turbidity
f. Dissolved solids
g. Biological and microbiological content
h. Chemical contents

A combination of some of these parameters may be needed for a particular hydrological study. For example, for studies related surface water, eg flow measurements, generally parameters under categories of ground water and water quality may not be required.

3. MEASUREMENT ASPECTS OF THE DATA ACQUISITION SYSTEM

The most important requirements of hydro-meteorological instruments are:

(a) Reliability
(b) Accuracy
(c) Simplicity of design
(d) Convenience of operation and maintenance
(e) Strength of construction

Being meant for field use, it is important that an instrument should be able to maintain a known accruacy over a long period. This is much better than having a high initial precision which cannot be retained for long under operating conditions. Simplicity and convenience of operation and maintenance are important since most hydro-meteorological instruments are in continuous use and may be located far away from good repair facilities. Robust construction is especially desirable for those instruments which are wholly or partially exposed to the weather.

4. DATA COLLECTION STATIONS

Various systems of hydro-meteorological data acquisition can be classified into three basic groups, i.e. manually operating stations, semi-automated (man/machine mix) and automated (computer-controlled) observing stations. Initially, hydrological observations were made from individual manual stations only. Later on, when it was felt that the data collection, especially from remote observation sites became difficult with manual stations, the concept of hydrological network of stations came up. The network may include some automated and/or semi-automated type of observing stations in addition to the usual manual stations, depending on the need of the system.

Three type of data collection stations are in use (Quaas et al., 1980). The same are discussed as follows:

4.1 Manned Station

These stations are equipped with manual instruments; observer records the data periodically and transmits to forecast centre via post/telephone/radio communication, as per requirement.

4.2 Semi-Automatic Stations

The stations are equipped with self recording instruments. Data are recorded continuously on a strip chart recorder or periodically logged on electronic data logger or PC/printer. These stations are visited periodically for retrieving data, changing charts, batteries, etc. and for checking serviceability of the instruments.

4.3 Automatic Stations

These stations are meant for remote sites from where manual measurements are difficult, but still the data are required in real time. These stations are equipped with sensors having electrical output, a microprocessor and communication equipment. The programmed microprocessor controls the station functions, viz. at preset intervals, it scans the sensors, compiles the data and transmits to the forecast centre.

5.0 SUITABLE SETUPS FOR DIFFERENT APPLICATIONS

Rather than offering DAS for general applications, it is hoped that, from a user's point of view, systems suitable for different applications, site-specific conditions, and different hydro-meteorological conditions should be configured. The following three classifications could provide a guideline for offering suitable configurations of DAS (Goyal, 1993–94):

5.1 Hydro-Meteorological Conditions

Mountainous
Coastal
Alluvial plains

Deserts
Saline areas
Hard rocks
Ravines

5.2 Applications

Surface water
Ground water
Hydro-meteorological
Agro-hydrological
Snow and glacier
Climatological
Experimental watershed/catchment

5.3 Sites

River basins
Watersheds
Micro watersheds
Point site
Lakes
Reservoirs
Dams

6. CONCLUSIONS

There is an increasing need to expand the number of hydrologic parameters to be sensed, improve the reliability of existing sensors, and improve the efficiency of the stations that provide data to the agencies involved in operational hydrology (Dozier, 1992). The recent growth in automated hydrologic measurement systems can be attributed to many factors including the following :

1. The increasing demand by primray users for real time data for flood warning, reservoir management, irrigation control, hydro-power generation, and water pollution monitoring,
2. The improvements in instrumentation, made possible by the advent of the microprocessor systems and solid state devices,

3. The development of new procedures for collecting and transmitting data permitting automated recognition and reporting of significant events, and
4. The use of improved and reliable data transmission systems.

The hydro-meteorological demands from sensors for use with automatic stations are not very different from those meant for conventional manual use. They must be robust and should have no intrinsic bias or uncertainity in the way in which they sample the variables to be measured. There are some parameters, eg rainfall, water level, temperature, humidity, wind velocity, for which electronic sensors are readily available. The sensors for water quality parameters are now becoming available (WMO, 1988).

The areas where development of electronic sensors for *in-situ* measurements are needed are (1) soil properties and processes, eg water flow, hydraulic properties, solute content and its movement, heat flow, (2) infiltration, (3) sediment deposition and its transport, (4) discharge measurement in streams under turbulent flow, (5) evapotranspiration, and (6) certain water quality parameters.

Automatic DAS are often required to operate unattended for long periods at difficult sites. These may have to operate from highly unreliable power supplies or from sites at which no permanent power supply is available; these systems must, of course, be able to withstand the most severe environmental conditions. However, the cost of providing systems capable of operating under all circumstances, known or unforeseen, for an automatic station is prohibitive and it is essential that before specifying or designing a system, a thorough understanding of the working environment anticipated for the system be obtained.

References

Dozier, J, 1992. Opportunities to improve hydrologic data, Reviews of Geophysics, 30,4,315-331.

Goyal, VC, 1993-94. Data acquisition systems (DAS) for hydrological measurements, Report TN-11, NIH, Roorkee.

Quaas, R, Legaria, G and Dominguez, R, 1980. Experiences in the design and installation of telemetric networks for flood forecasting, Water International, September, 3-6.

Shaw, 1983. Hydrology in Practice, Van Nostrand Reinhold (UK) Co. Ltd.

Tanner, BD, 1990. Automated Weather Stations, Ch. 6 in : Goel, NG and Norman, JM (Eds), Remote Sensing Reviews, Vol 5(1), Harwood Academic Publishers.

WMO, 1983. Guide to meteorological instruments and methods of observation, World Meterological Organisation, No. 8 5th Edition, Geneva, Switzerland.

WMO, 1986. Microprocessors in operational hydrology, Technical Conference on the Use of Microprocessors and Microcomputers in Operational Hydrology (1984: Geneva, Switzerland), D Reidel Publishing Company, Holland.

WMO, 1988. Manual on water-quality monitoring, Operational Hydrology Report No 27, Geneva, Switzerland.