A hydrometeorological telemetric network for the water resources monitoring of the Athens water resource system.

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Abstract: In the development of a decision support system (DSS) for the management of the Athens water resource system, special emphasis has been given to the real time feeding of the DSS with reliable hydrological data, using a telemetric system. This paper is concentrated on the description of this telemetric system that measures hydrometeorological variables of the river basins, and on the management of the telemetric data. The stations of the telemetric system can provide data of high reliability, without delay, and less costly than conventionally measured data. The information collected includes stage and discharge data from the main stream of each river basin, water level data of the reservoirs, rainfall and meteorological data. The data collection procedure is done periodically by the central telemetric system and all data is stored in the database for immediate use by other systems. Apart from feeding the DSS, the telemetric system will serve other purposes such as the monitoring and establishment of reliable time series of the atmospheric and water resources conditions of the area, and the supply of hydrometerological information in real time on the Internet.

Key words: telemetric network, decision support system, hydrometeorological stations, Athens water recourse system, Greece

1. INTRODUCTION

The last decade special emphasis has been given to the installation of telemetric hydrometeorological stations in order to provide real time and high reliability data, with less cost than conventionally measured data. Several researchers have presented their experiences about the function of such telemetric networks (e.g. *Slaughter et. al.,* 2001).

In most countries, however, the new technologies in data acquisition have not been implemented widely so far. For example, in Greece the hydrometeorological variables are measured from various agencies, using mostly conventional instruments (gauges and recorders). The operational utilisation of these measurements has the following serious disadvantages:

- in many cases the measurements are not as reliable and accurate as needed;
- the temporal scale of measurement is inappropriate (too coarse) for several applications;
- there is significant delay in the availability of the measurements;
- the malfunctions of the instruments may not be detected in time;
- each agency uses different methods for data measurement, manipulation and processing;
- conventional networks have high installation and operation costs.

Thus, the existing conventional measuring systems cannot support efficiently the development of modern water resource management systems. In most cases water agencies that develop such management systems have to build their own modern measuring networks. This was the case for the Athens Water Supply and Sewage Company (EYDAP), who run an expanded multireservoir system to supply water to Athens and proceeded to the development of a modern decision support system (DSS) to control that system. The DSS, now in its final stage of development, uses simulation and optimisation techniques combined with data base and geographical information systems (GIS). The DSS explores alternative management practices and locates optimal solutions for the operation of the water resource system (*Koutsoyiannis et. al.,* 2002).

In the development of the DSS the efficient data gathering, storage and manipulation has been given great importance. An automated telemetric system has been included in the DSS, in order to provide data of high reliability, without delay, and less costly than conventionally measured data. The peripheral telemetric stations are located near the main reservoirs and transfer automatically or semi-automatically hydrological data to the DSS. The specific telemetric network includes three types of stations: meteorological, reservoir stage and river stage (for the main stream that discharges to the reservoir). The meteorological variables that are measured include: precipitation, temperature, relative humidity, wind speed, direction and gust, solar radiation, and sunshine duration. Also some derivative variables are calculated such as evaporation. From the measured reservoir stage the storage and the area of the reservoir are calculated. Finally, from the river stage and sporadic stage-discharge measurements the river discharge is calculated. The data collection procedure is initiated periodically by the central telemetric system and the data is stored in the data base for immediate use by others systems.

2. SYSTEM OVERVIEW

As shown in Figure 1 the water resource system of Athens comprises four reservoirs located in different rivers. In each of the four basins three telemetric stations are installed, in order to collect meteorological data, water level data of the reservoirs and stage data from the main stream of each river basin. Also the river discharge will be measured with conventional methods, in order to convert the river stage time series to discharge.

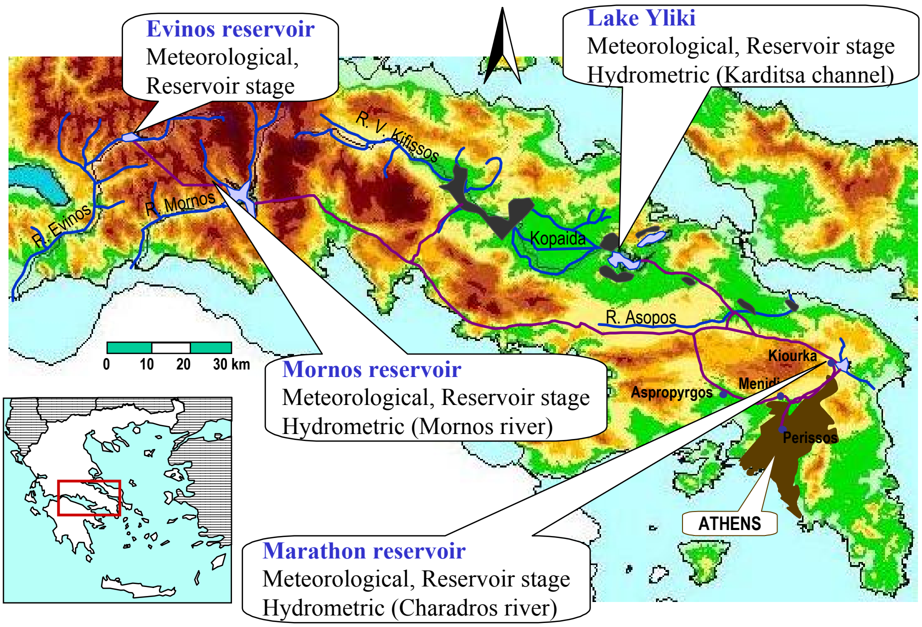

Figure 1: Athens water supply system and sites of hydrometeorological stations.

The main purposes of the telemetric system include:

- the quantitative inspection of the water resources of these water basins that contribute to the water supply of Athens and the improvement of the estimation of the parameters involved to reservoirs' water budget;
- the exploration of the hydrological and climatic characteristics of the study area after compilation of reliable time series of hydrometeorological variables;
- the supply of hydrometerological and water availability information in real time on the Internet for public awareness;
- the feeding of the DSS with reliable data.

The design of the telemetric system includes two main issues, the selection of the appropriate technologies for data measurement, transmission and storage, and the positioning on the appropriate sites. For the first issue there is recent international experience (e.g. *Herschy,* 1999*,* pp. 245-264). However, the local experience is very important for the effective system design. A pilot meteorological station located at the National Technical University of Athens campus operating for almost a decade was served as the main source of experience to the system design. Several types of sensors and devices for energy supply, as well as techniques for data acquisition, logging and transmission were tested (*Koutsoyiannis et. al.,* 2000).

The positioning of the sites of telemetric stations was based initially on specification by World Meteorological Organisation (*WMO*, 1983). Experience for the specific area reported in older studies (*Stavridis et al.,* 1990) was also used. Several visits were made to candidate sites and the characteristics of each site were scored (hydrological suitability, security, availability of electricity and telephony, ease of installation). These candidate site characteristics were recorded and compared in order to select the final location of each station.

Several criteria were examined for the positioning of stations:

- the sites should be hydrologically appropriate and fulfilling the WMO specifications (*WMO*, 1983);
- the sites must be near to EYDAP facilities (dams or water pumping stations) in order to ensure the safety of the station and the availability of electricity and telephony;
- the sites of meteorological stations must be close to the maximum reservoir elevation in order to be as representative as possible for the variables that take part to the reservoir water budget (evaporation, precipitation);
- the reservoir stage stations must be installed to the deepest point of reservoir (but above the dead storage);
- the flow measuring stations must be as close to the dams as possible (above maximum reservoir elevation) in order to measure the maximum portion of inflow to the reservoir.

In Figure 2 the general scheme for data transmission is presented. The main components of the system are the telemetric stations, the Regional Data Control Point (RDCP) near each reservoir and the Data Administration Centre (DAC) in Athens. The telemetric station is composed of the sensors, sensor reading unit, power supply unit (main and backup), data logger and modem. The RDCP, composed of two computers (a desktop and a laptop) and a modem, is responsible for the supervision of the three telemetric stations of one basin. The DAC, composed of a desktop computer and a modem, manages the whole network and all data. There are three different ways for data transmission: normal, optional and emergency. During the normal transmission the data is transported from the data loggers to DAC via telephonic network. The transmission is made at predefined time periods (for example every 24 hours). The optional transmission is done through telephonic network but at unscheduled moments from the stations to DAC, RDCP or other external licensed users. The emergency transmission is made when there is a communication problem between modems. In this mode there is an on site access and the data are entered from the data logger to a laptop computer (part of the local RDCP). The data is stored to RDCP and transmitted to DAC using several alternative ways (e.g. email, fax).

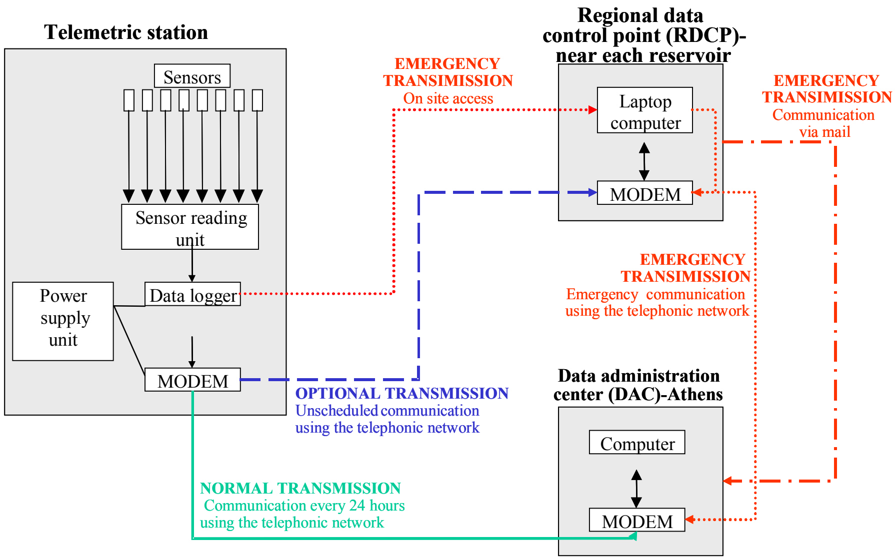

Figure 2: Data transportation.

3. DATA STORAGE AND PROCESSING

For the data manipulation and processing a software application is developed. The application embodies experience from previous similar projects, but makes use of the latest technology in relational databases and software development tools. The data base is developed for the Oracle relational data base system. The application runs on client machines, which connect to the data base via a network.

The data stored for a measuring station includes name, location, co-ordinates, type (meteorological, flow measuring, etc.), functioning period, whether it is still active, and whether it is telemetric. Any information that does not fit into the rest of the fields, from short notes to reports of unlimited length, can be entered in the “Remarks”. In addition, photographs and videos of the station can be stored. Also the “Events” a kind of electronic logbook is used. Any event, such as malfunction, servicing, or extreme weather event, can be entered there. Each station includes several instruments and each instrument has its own remarks and events and also several time series. So each station includes the time series for all its instruments and time series that are not tied to specific instruments (for example, evapotranspiration derived by a method such as Penman). For each time series, general information is stored, such as variable name, time series name, step (10-minute, hourly, daily, monthly, yearly and others), remarks and events. It is also possible to store time series that are not tied to stations, but to other geographical entities, such as water basins; this is particularly useful for areal rainfall. Time series records have flags in order to signal error conditions or other noteworthy circumstances. Numerous flags are available in order to signal out of range values, suspect values, snow, values that were originally missing but were calculated, and so on. The system offers the possibility to copy and paste time series data to and from other applications. Time series importing and exporting is done through ASCII files in a simple format.

Generally, the development of applications which adding functionality that is already provided by existing software (e.g. EXCEL), was avoided. The data processing module includes applications that provide a range check facility, time stamp correction (determination and elimination of irregularities), filling of missing values, time series aggregation, construction of stage-discharge curves and calculating discharge time series. Several forms have been designed for the easy and effective viewing and management of time series data.

4. DISCUSSION

Efficient hydrometeorological data acquisition is essential for a large number of scientific, educational and technical applications. This task is achieved by utilising the advantages of the (extremely raising during the last decade) telemetric technology. The telemetric data in this project is used for operational, research and public awareness purposes.

The operational needs include the real time quantitative inspection of the evolution of water resources of Athens, the improvement of the estimation of the parameters involved to reservoirs' water budget and the feeding of the DSS with reliable hydrometeorological data. The experience of the DSS operation at frequent time spans reveals that to date, the data collection is a harder task than the simulation and optimisation processes or the final results elaboration. It is that anticipated that the whole decision making procedure will be accelerated significantly, as soon as the telemetric network functions operationally.

The research needs include the exploration of the hydrological and climatic characteristics of the different areas of the water resource system. Until now hydrometeorological data of this temporal scale, reliability and accuracy was very difficult to find but also is essential for several scientific and technological applications.

The measuring system also contributes to the public awareness by supplying hydrometerological and water availability information on the Internet. This information includes real time data, daily report of water availability and consumption and other information (e.g. technical reports about telemetric station components). The experience of the last severe drought (at the first years of the nineties) has indicated the strong influence of the information campaign, to the water demand management. In this specific case a 25% reduction of the Athens' water consumption was achieved after a prolonged campaign. A significant element of the campaign was the every day updating (e.g. via newspapers) of the public on the available water quantity. The telemetric network will enhance this procedure by using interactive means provided by the Internet.

To serve the different uses, data must be processed accordingly. For this purpose an advanced data base system has been implemented. This includes a number of data processing functions that can extract and organise information in appropriate form for the use by the DSS, and public information

At this time the various components of the DSS are in different level of development although the whole system already supports EYDAP to the management of the water resource system. Specifically the telemetric network component is in the testing phase and is expected to function operationally by the end of 2002.

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