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DATA ACQUISITION NETWORKS*

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ABSTRACT

Studies concerning water resources are a central preoccupation in the majority of developed countries. Data acquisition is an important part of these studies. A number of private and government organizations undertake sampling to gain physicochemical and biological data for the evaluation of water quality. However, data acquisition networks are very costly, and it is imperative that any investments made will yield the desired results. This article analyses the methods of data acquisition currently in effect in Belgium and France. For these countries, the groups responsible for data acquisition networks are described through an analysis of their objectives, techniques, successes and failures, efficiency, sources of financing, personnel, and their methods of data treatment.

INTRODUCTION

The planner must have available a complete body of information that permits him to elaborate a number of solutions to problems that occur, and to specify the probable repercussions of each [1]. These problems include most notably those concerning the quality, quantity and utility of water, corrective measures to permit dam construction, the expansion of watercourses, flood control and diverse engineering works. As well, there are biological problems which concern algae, plankton, or perhaps benthic biota and which entail the whole host of problems associated with different fish species.

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Due to the acuteness and complexity of problems in water resource management, data acquisition networks have been instituted in several countries. These programs are very costly, but have proved indispensable as the resource manager faces complex problems, that need urgent response, for which it is imperative to possess continuous information from a number of important places [2].

FIRST CASE STUDY: BELGIUM

Belgium has a very big problem with water. Though the country has a fairly humid climate and abundant precipitation, consumer demand for water becomes critical in dry years. This state of affairs is in large measure attributable to the high population density, the high degree of industrial and agricultural development and the constant need for water in the ship canals. These problems fall within the purview of four ministries [3, pp. 50-54]:

1. Public Works, for waterways and large hydraulic works, and for town planning and national development;
2. Agriculture, for non-navigable watercourses, drainage and irrigation;
3. Public Health, for drinking water supplies and wastewater purification;
4. Economic Affairs, for groundwater (Belgian mines and geological services administration) and industrial water requirements (industrial administration).

On February 16, 1965 a water commission [*Commissariat Royal au Problème de l'Eau* (CRPE)] was set up by royal decree. It had the responsibility of coordinating all work in this area, and assumed the following objectives:

- make an inventory of water requirements and resources [4];
- study the most urgent problems and suggest measures to overcome them to the government;
- make up a national balance sheet of requirements and resources with a view to establishing a coherent water policy [5].

A campaign to determine requirements and resources was started in 1965. It is now underway and should continue for about three years so as to scientifically cover a complete hydrological cycle [6]. There have also been special studies of the most urgent problems, almost all of which are related to supplying the nation with drinking water. The third task of the water commission CRPE was to make up regional balance sheets, determine times at which there could be water shortages and suggest possible ways of making up such shortages. Since this approach took into account the differing situations in the various parts of the country, the work to be undertaken was much easier to decide upon.

Table 1

Parameters Measured by the Institute for Hygiene and Epidemiology

Temperature[a]	°C
Color	
pH	
E_H	mV
Conductivity (at 20°C)	μS/cm
Suspended matter, residue at 105°	mg/l
Deposit after 2 hrs of sedimentation	ml/l
Dissolved oxygen (in situ)	mg/l
Oxygen saturation	%
Dissolved oxygen (on arrival)	mg/l
Dissolved oxygen after 24 hrs	mg/l
Dissolved oxygen after 48 hrs	mg/l
BOD_2	mg/l
BOD_5 (dilution method)	mg/l
BOD (calc. from BOD_1 and BOD_2	mg/l
BOD SAPROMAT	mg/l
Chemical oxygen demand:	
with K_2 Mn_2 O_8 cold 3 min	mg/l
with K_2 Mn_2 O_8 warm 10 min	mg/l
with K_2 Cr_2 O_7 warm 2 hrs (COD)	mg/l
Decoloration with methylene blue	
Alcalinity by phenolphthalein (TAP)	mg/l
Alcalinity by methylorange (TAM)	mg/l
Total hardness	mg/l
Temporary hardness	mg/l
Permanent hardness	mg/l
Free chlorine	mg/l
Chlorides	mg/l
Sulfates	mg/l
Hydrogen sulfides (qualitative)	
Ammonia nitrogen	mg/l
Nitrous nitrogen	mg/l
Nitric nitrogen	mg/l
Organic nitrogen	mg/l
Total nitrogen	mg/l
Soluble orthophosphates	mg/l
Total phosphorus	mg/l
Silicates	mg/l
Phenols	mg/l
Anionic detergents	mg/l
Nonionic detergents	mg/l
Cyanides	mg/l

Table 1 (cont.)

Volatile oils	mg/l
Floating oils	ml/l
Hexavalent chromium	mg/l
Sodium	mg/l
Potassium	mg/l
Iron	mg/l
Toxicity to *Lebistes leticulatus*	
survivors from 0 to 6 hrs at a concentration of %	
survivors from 6 to 24 hrs at a concentration of %	
Metals	
Hydrobiological research	
Influence on self-purification and biodegradability	

[a] Determination made at time of sampling

When its mandate expired in 1969, the Commissariat Royal au Problème de l'Eau (CRPE) gave place to an interdepartmental water commission. The overall results of all these activities were:

A– the classification of surface water into four categories:

1. water fit for human consumption;
2. water for fishing or consumption by animals;
3. water for industrial purposes;
4. other watercourses, trenches, ditches, culverts along highways.

B– the establishment of standards for industrial wastewater discharged into public sewers;

C– the promulgation of laws to protect surface and groundwater.

As regards these studies, three interesting projects may be pointed out:

1. a laboratory for analyses (Institute for Hygiene and Epidemiology) was set up (Table 1);
2. a mathematical model for the North Sea was worked out [7-9];
3. a mathematical model of pollution in the Sambre river was worked out (Table 2) [10].

These last two projects were undertaken because of the priority assigned to pollution studies by the Interdepartmental Commission on Science Policy.

SECOND CASE STUDY: FRANCE

Responsibility in the area of water resources is divided among the Ministries of Agriculture, Industrial and Scientific Development, Economic Affairs, Public Works, Public Health, the Ministry of the Interior and Electricité de France (French hydro) [11].

The permanent water secretariat: SPPE (Secrétariat Permanent des Problèmes de l'Eau), has the task of setting up an inventory of data gathered by all those responsible for data acquisition and of routing the data to users. The Ministry of Agriculture is the organization most closely connected with water and quality data acquisition. The centre for engineering design and technological research in agriculture, forestry and rural works: CERAFER (Centre d'Études techniques et de Recherches technologiques pour l'Agriculture, les Forêts et l'Équipement Rural), organizes studies of rivers and wastes through the regional water management service: SRAE (Service Régional d'Aménagement des Eaux). It gets help with scientific methodology from a group of researchers at the University of Besançon. The Ministry of Agriculture has also set up a centre for the study of lakes (Thonon Lake Hydrobiology Station) which has reached very high standards and has an international reputation.

Parallel to this purely governmental organization, there are agencies [12-14] in the drainage basins with representatives of the various levels of government and of the private sector (fishing associations, industry, naturalist groups, etc). These agencies have the task of coordinating the resource development efforts of the various levels of government and the private sector [15]. They are financed by user fees and government grants. Obviously, they need water quality data on discharged and natural water. These they obtain through the cooperation of private laboratories and the Ministry of Agriculture.

SPPE

The permanent water secretariat is a governmental agency attached to the minister responsible for the environment. Its aim is to establish an inventory of quantitative and qualitative data on the territorial waters of France, and it is a fairly important management tool. It supplies drainage basin agencies (departmental and financial) with quantitative and qualitative data on the waters for which they are responsible, and influences government policy by identifying environmental quality control priorities. The secretariat has set up an operational national file of qualitative and quantitative data on water. This was justified by the confusion that prevailed in the area of data acquisition. As the file becomes operational, it will also contribute to standardization of sampling and analysis methods throughout France.

Table 2
Standards for Discharges to Rivers in Belgium

Criteria	Control Area	Unit	1. Waters Destined for Human Consumption	2. Waters Suitable for Raising Livestock and Supporting Fish			3. Water For Industrial Purposes	4. Public Conduits, Ditches, and and Gutters		
				salmonids	mixed	cyprinids		Gutters	Ditches and Conduits: Sewage	Ditches and Conduits: Industrial and Agricultural Waters
Temperature	R[a]	°C	<25 (at the intake)	<20	<23	<25	<30	ALL WASTES PROHIBITED (SEWAGE, INDUSTRIAL AND AGRICULTURAL WATERS)	–	<35
pH norm	R	–	6.5 < pH < 8.7	6.5 < pH < 8.7			6.5 < pH < 8.7		–	6 < pH < 10
pH exceptional and passing			5.0 < pH < 9.2	5.0 < pH < 9.2			5.0 < pH < 9.2			
O_2 norm	R	% sat.	>70 (at the intake)	>90	>90	>70	>3		–	–
O_2 exceptional and passing[b]		mg/l	60	>5	>4	>3	>1			
Sedimentation 2 hrs	E[c]	ml/l								
norm			<1.5	<1.5			<1.5		<1.5	<1.5
locally[d]			<1.0 or <0.5	<1.0 or <0.5			<1.0 or <0.5			

Suspended solids (increase over entire stream)	R	mg/l	<60	<60	<100	–	cannot cause damage
Toxic substances norm locally	R	mg/l mg/l	< toxicity threshold < toxicity threshold	<dilution limit <minimum lethal dose	–	–	–
Diverse chemicals	R	mg/l	admissible for proper functioning of treatment facilities	< levels adequate for industry and agriculture	–	no odor	no oil, grease or gasoline; no odor
Pathogens (tuberculosis,typhus)	E	–	0	0	–	–	0
Biochemical consumption		mg O_2/l	BOD_2 - 20°C <4 (at the intake)	–		stability 3 days by methylene blue (E)	–

Royal Decrees of December 29, 1953 and December 3, 1963

[a] River = river

[b] maximum 1 month per year

[c] E = effluent

[d] may in every case exceed the value of receiving waters by 0.5 ml/l

Changes in water quality in France are being studied through the use of quality monitoring methods over the period 1971 (first sampling) to 1976 (second sampling). The samples are being taken at 1200 stations throughout France. It was possible to set up a network of this kind through close cooperation between departmental authorities and financial agencies. However, the lack of coordination and standardization in the selection of sampling stations continues to detract from the network's effectiveness. Also, the network does not make it possible to obtain rapid monitoring or detection of sporadic or unforeseen phenomena. For example, three months to a year may go by before the network detects the accidental spilling of a dangerous pollutant. Still, continuing participation by several departmental, regional and drainage basin agencies in the network's operations guarantees a certain adaptability of goals to the regional economies.

Physical, physicochemical and biological parameters are measured at the stations. No strict sampling frequency has been established. The secretariat, through its twenty-five laboratories across the country, can do all the standard analyses. The equipment in these laboratories is of the conventional type except at the two continuous measurement stations now being tried out.

The permanent water secretariat's data acquisition system operates with ordinary computer methods. At present, the data bank contains only surface water quality data. However, thought is being given to adding similar data on atmospheric water and groundwater. The secretariat does not use a quality model: those responsible for the national file say mathematical models of quality do not provide much meaningful information. Rather the secretariat aims to develop a numerical classification system for the main watercourses. This classification would be based on certain physicochemical and biological parameters. The secretariat publishes 4000 copies of the national file annually. Of these, 2000 are for distribution and 2000 for sale. The secretariat also sees to supplying each of the ministries concerned (Public Works (Water), Agriculture, Public Health) with pertinent data from the file.

CERAFER

The center for engineering design and technological research in agriculture, forestry and rural works comes under the Ministry of Agriculture. One of its objectives is to gain knowledge about water quality in France. To this end, it operates a national water quality data acquisition system, through SRAE (regional water management service). A kind of water quality control can be carried out through the issuing of court orders based for the most part on quality data supplied by water laboratories. Close cooperation between CERAFER and the University of Besançon permits development of biological analysis methods, training of technical staff and provision of the necessary technical support to regional (SRAE) laboratories. All results are published

regularly and CERAFER is required to send them to water and fishing regulatory bodies, to various government services and to the national file authorities.

The network as such comprises 1200 sampling stations across the country. Sampling frequency at each station depends on several factors and ranges between once a year and once a month. The following physical, chemical and biological parameters are analysed: air temperature, water temperature, pH, conductivity, matter settleable in two hours, dissolved oxygen, oxygen consumed in 48 hours, putrescibility (test), BOD_5, COD, Ca^{2+}, and alkalinity with respect to HCO_3^-, NH_4^+, and Cl^-. The biological quality of the water is assessed by a method developed by Tuffery and Verneaux [16]. These analyses are made by SRAE in twenty two mobile laboratories which are equipped for their tasks: the instruments (sondes, electrodes, burettes, etc.) and services (refrigeration unit, distilled water tank, incubator, etc.) necessary to do the work are available and the conditions very good. Analyses that cannot be carried out in the mobile laboratories are done at the regional centre, which has plenty of complex equipment at hand. Samples are of course kept refrigerated during transport.

Four special studies were underway: analysis of pesticide impact, analysis of the impact of heavy metals on the Seine below Paris, development of biological indicators (diatoms, zooplankton) for rivers and development of a "trout-o-meter" (Figure 1). For the future, CERAFER wants to get five to eight regional laboratories set up that would be better staffed (with engineers, chemists and biologists) and better equipped (for atomic absorption, chromatography, gas chromatography, mass spectrography, etc.). These laboratories will form the basis for operations on a scale quite different from existing ones.

Thonon Lake hydrobiology station–The station is supported by the National Institute for Agronomic Research: INRA (Institut national de recherches agronomiques), which is part of the Ministry of Agriculture. It studies the water quality of four of the biggest lakes in France: Geneva, Annecy, Nantua and Le Bourget [17]. Its inventory and research programs are planned and carried out by an internationally renowned team of researchers and assistants. Their aim is to supply the data and develop the knowledge needed for maintaining and increasing the area's tourist potential. For that reason, they have obtained financial support for some of their work from municipalities in the area and from government agencies. International studies of Lake Geneva are a particular activity that take part in [18].

An inventory program to gain knowledge of general water quality, its seasonal fluctuations and its changes over time has been underway for many years. Lake samples are taken at several locations and depths. Lake Geneva, for example, is sampled at 5, 10, 20, 30, 40, 50, 100, 150, 200, 250 and 300 m. There are three kinds of sampling station: regular stations in the lake, outfall stations and

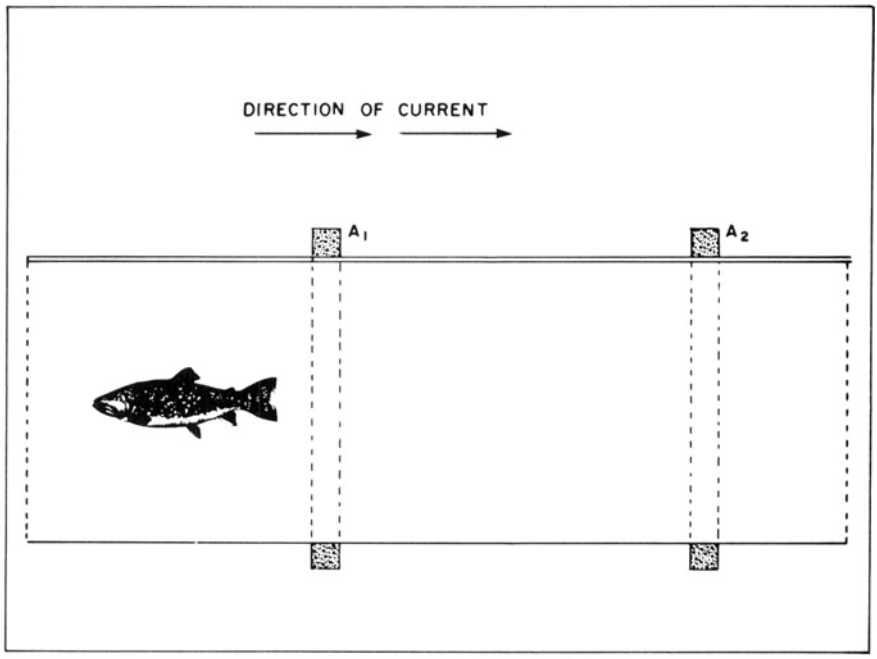

Figure 1. Trout-O-Meter

reference stations. The latter are now taking samples once a month. The list of biological and physicochemical parameters analysed is given in the report of the international commission for the protection of the waters of Lake Geneva against pollution (1971). The laboratory is fully equipped for field work. There is a workshop to develop and build the special equipment for taking water or sediment samples under the conditions laid down by the researchers.

This inventory program, though indispensable, has not been considered sufficient in itself to guide basin development. Deeper-reaching research projects have been carried out to remedy the lack of knowledge. In a research project on water fertility, on-site carbon-14 tracings are made in addition to the measurements already described. Similar measurements are also being made *in vitro* on field samples. All these experiments are aimed at identifying the limiting factor for various types of algae in the water environment.

The laboratory also takes an interest in the ecophysiology of various algae, mainly those which pose problems in eutrophic lakes (*Oscillatoria rubescens*)

with respect to nutrient transport over the thermocline, the role of vitamins in the growth of algae, the measurement of secondary productivity, and sediment accumulation by chemical methods. Taken as a whole, this work is highly impressive. Its prime goal can be clearly distinguished: to study the eutrophication of lakes.

University of Besançon, faculty of natural sciences—In cooperation with CERAFER, the University of Besançon is trying to develop methods for analysing the biological quality of rivers [19]. This research work is carried out alongside instructional activities whose main purpose is to train the technicians needed by the CERAFER program.

In connection with this program, a method for determining the biological quality of running water has been published by Verneaux and Tuffery [16, 20]. The method is an adaptation of the one used by the Trent River Board [21, 22]. Its advantage is that it represents a compromise between scientific requirements and what can be done in a mobile laboratory. The assessment of water quality rests on a sampling of benthic and periphytic fauna. An overall rating or "biotic index" is assigned from a standard table on the basis of the nature and number of species found.

The Rhone-Mediterranean-Corsica water authority—The Rhone-Mediterranean-Corsica water authority: ABRMC (Agence de Bassin Rhône-Méditerranée-Corse) is one of six basin authorities created by the Act of December 16, 1974 [23]. It takes in that part of France which empties its waters into the Mediterranean. The basin covers an area of 130,000 sq km and has a population of eleven million. It accounts for twenty percent of the nation's industrial and agricultural activities and for forty percent of tourist activities. In short, it is a bustling area, with the highest demographic growth rate of any region in France. It has structures that are strong and of long standing and over the last few decades the area has benefited from a national public works policy of broad scope.

The ABRMC authority is working on three kinds of problems: resource distribution, the fight against pollution and flood control. Subsidies for the various research programs are received in the form of fees scaled according to the degree of water degradation, the collection of water from alluvial layers and, in certain areas, net consumption. Analyses are made on the basis of measurements for suspended solids, COD, BOD_5 and conductivity. Fees are assessed according to a table of specific coefficients of pollution [24]. Also, those who have installed treatment equipment and maintain it in good working order get a bonus for this which is deducted from the gross fee.

At regular intervals, the ABRMC authority publishes an information bulletin which sets out its goals and programs for the information of concerned agencies. It has also published a draft white paper setting out a water policy which fits in with a general national development policy. It gives basic data on the Rhone-

Mediterranean-Corsica basin and a description of the current situation with regard to supply (surface water and groundwater) and demand (domestic, industrial, agricultural and hydroelectric). The white paper also deals with various development perspectives for industry, agriculture, recreation and tourism and sets out thoughts on the problems peculiar to certain parts of the basin and on the fight against pollution (protection of drinking water sources, control of industrial and agricultural uses, etc.). The authority has also worked out a flood control program. Side by side with the five other similar bodies in the country, the ABRMC authority plays an important role in the operations and financing of the Association Française pour l'Étude des Eaux (French Association for Water Studies).

The Seine-Normandy water authority—The financing agency for the Seine-Normandy basin: ABSN (Agence de bassin Seine-Normandie) is semi-public [25]. It brings the central government, local authorities, industry and local groups together into a "mini-government" and is financed through various arrangements on a multipartite basis. Its general aim is to make the best possible use of the monies which are granted to safeguard the ecology of the basin as a whole. In theory, that means this "government" is responsible for a certain amount of planning with respect to the maintenance and improvement of environmental quality, and for working out and implementing short, medium and long-range development plans. Success therefore depends on full participation by each group and, above all, on the implementation of planning policies.

Since planning can be based only on knowledge of the area, the authority has itself undertaken, taken the responsibility for, or taken an interest in, environmental quality studies. A white paper describes land use in the basin with zoning according to the principal activities. Water quality objectives are also set forth for each zone on the basis of available data. Long-range planning is based on knowledge of current trends in technology on the one hand, and in socio-economic development on the other.

The Seine-Normandy authority does not at present have a data acquisition network for surface water quality though it recognizes the necessity for such a network for the future. For medium-term planning it has chosen to study water use in the basin. These studies cover all the ecological, social and economic aspects of the situation (urbanization, industrialization, forestry, recreation, etc.) and also include qualitative and quantitative analysis of water from various outfall points, and development of an index for quantifying water quality. The authority maintains a full network for the evaluation of all water inputs. This means, in practice, that wastewater samples are analysed periodically for the various parameters that go into the quality index. The analysis work itself is entrusted to approved laboratories. The authority's own laboratory handles only the adaptation of standard analysis methods to extremely polluted water, and

quality control of analyses. In essence, the index is based on the concentration of dissolved oxidizable materials [26]:

$$OM = SM - \frac{2BOD - COD}{3}$$

where

OM = concentration of oxidizable materials
SM = suspended materials
BOD = biological oxygen demand
COD = chemical oxygen demand

This water quality index is now being used to set the fees each user must pay the authority. It has a number of shortcomings, the most obvious of which is its complete inability to take account of wastewater toxicity in all its aspects. This over-simplification encourages industry to increase the amount of toxic materials in its wastewater in order to reduce the BOD. Similarly, there is an advantage in dumping non-biodegradable substances. Those in charge at the authority are aware of this problem and their laboratory is now working on the establishment of a biological indicator that could be incorporated in the index. Current research is centered on daphnids; researchers are looking at the minimum dilution factor that will allow fifty percent of the individuals in a colony of daphnids to survive for a certain period of time after inoculation. This work is being done systematically for various kinds of effluents. A report will have to be submitted to the authority before implementation can begin.

The need to tackle the problem of individual aspects of water is well understood. So far, this has resulted in the development of an automatic probe that can monitor water quality continuously. Five permanent stations are now in operation and the following parameters are measured continuously: pH, O_2, conductivity, turbidity and redox potential. There is also a biological indicator, the "trout-o-meter" (Figure 1), which is continuously subject to the action of the environment. The "trout-o-meter" is a submerged "endurance chamber" in which any abnormal behaviour on the part of the fish can be detected. The device is connected to an alarm bell which makes it possible to detect water quality anomalies almost immediately.

A trout is placed in a cage submerged in the river parallel to the current (Figure 1). The electrodes A_1 and A_2 are situated perpendicular to the current. When the trout enters area A_1 it gets a shock and, if the fish has sufficient strength, this shock will make it move to a point upstream from A_1. Electrode A_2 is equipped with a device which can detect the presence of the trout in that area and set off the alarm: if the trout is in A_2, there is something wrong with it. The problems encountered at these stations have resulted primarily from poor electrode functioning caused principally by clogging. This situation has prompted the organization of regular visits to the stations. Lack of electrode sensitivity is also a limiting factor.

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