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NETWORKS PLANNING FOR WATER INVESTIGATIONS

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ABSTRACT

Ever mindful of the need to minimize the repercussions of management actions on the aquatic system and to preserve the diversity of individual choices for the generations to come, the manager is confronted with the urgency and the quality of his decisions. Often, the lack of directly useful historical precedents and the absence of decisional criteria based on a profound understanding of environmental processes oblige him to opt, at great cost, for the socially secure aspects of management and for discrete, sectorialized interventions. The systematic acquisition of basic data is indispensable for all levels involved in the preparation of environmental interventions. In effect, data acquisition networks concerning water resources provide the bases on which managers and investors alike depend for determining the viability of industrial, urban, or agricultural development. On the other hand, data acquisition networks permit consideration of the present and future availability of water as a function of technology. Specifically, data must be collected on surface waters, groundwater, wastewaters (municipal and industrial), and precipitation. The data acquisition network must permit not only an evaluation of the quantity and quality of actual water reserves but also the determination of water availability in space and time. This article analyzes the methods for acquiring water quality data employed in Great Britain and in Holland. For these countries, the groups responsible for the data acquisition network are described by analyzing their objectives, techniques, successes and failures, efficiency, financial backing, personnel, and methods of data treatment.

The foundations governing the establishment of a data acquisition network were laid down following the conscious realization of the fundamental need for environmental knowledge in a context of over-utilization [1, 2]. This need to know and to invest considerable effort toward the acquisition of knowledge is a

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normal step in the reversal of a situation where man dominates his environment toward one where man adapts social demand to environmental capacity [3, 4]. Moreover, the acquisition of environmental knowledge is a preliminary step in the management of water resources. This knowledge is provided through the characterization of quantitative and qualitative aspects of the resource.

The acquisition of the knowledge necessary for resource management is generally accompanied by the accumulation of large amounts of information and data. It is useful to make a distinction between information and data [5]. These two terms are used by all sectors of society which desire to communicate their thoughts and discoveries to others; however, different interpretations and uses of these words exist. Generally, data refer to facts collected for treatment and analysis by scientists, economists, engineers, and technicians. Information is the interpretation of data, techniques, thoughts, conclusions, results, decisions, and other facts which can be communicated from one person or organization to another.

DATA CATEGORIES

The objective of information and data is to furnish the planner with the necessary knowledge to make decisions and to elaborate diverse solutions to identified problems. There are several large categories of data which support planning in hydrographic basins.

Hydrometeorological Data

This category includes all data directly related to the elements of the hydrological cycle [6]: precipitation; evaporation; water budgets; lake, river, and water table levels; and other pertinent facts concerning solar radiation, humidity, wind, temperature, and barometric pressure. Certain data are only necessary for the completion of data inventories and there is usually a considerable delay between the time these data are acquired in the field and the time they are made available. Other observations are necessary for operational ends and are often required immediately for diverse needs, notably for the regularization of flows, for prediction of flows, and for flood forecasts.

Water Quality Data

Data on water quality are generally more timely than data concerning water quantity. With respect to hydrometeorological data, water quality sampling programs require a much greater level of flexibility. It is not necessary to perform analyses to determine all of the observable chemical characteristics at each place; however, given that water quality can change rapidly, it is essential to take samples often at different fixed locations [7-9]. The problems of sampling and analysis must equally take into account the placement and nature of possible and known sources of pollution, notably the important sources in regions of intense agricultural or recreational activity.

Socio-economic Data

A resource management plan cannot function appropriately without a vast inventory of economic data concerning not so much the importance and physical state of the resource as the appreciation or prediction of tendencies in use, or the evaluation of use options [10]. It must include statistics on population, water use, and the demand in products and services. Such an inventory is based on economic forecasts of revenues and expenses, information on capital goods and land values, long-term policies and plans of government in general, and ministries implicated in resource management in particular, as well as on data concerning planning questions in general. The update of economic data requires a periodical rather than a continuous effort. Nevertheless, the efficiency of the system can be determined by measuring the difference in the value of water resources before and after the implementation of a plan. Without data on the economic foundations of a region and the regular updating of these data, it is impossible to perform an efficacious analysis.

Related Data

Technical studies of water utilization have identified several sectors for which it is advantageous to have data available. For example, it can be difficult to quantify the relations between fauna and water if data on the population of different species are incomplete. Without such data, the difficult task of deriving reliable judgements on the repercussions of water projects is rendered even more complicated. Similar difficulties are encountered when studying the fisheries of a basin or when the various methods used by different organizations to estimate catches further complicate the situation.

The systematic acquisition of basic data is very costly and necessitates an ever more elaborate logistical apparatus [8]. For this reason, it is necessary to clearly define the objectives of the structure and operation of a measuring network; it is equally important to evaluate the efficiency and cost-effectiveness of networks maintained in operation for long periods. In effect, the acquisition of environmental knowledge is indispensable at all levels involved in the preparation of interventions in the environment. Moreover, the acquisition of data on a regular basis allows scientists to realize significant projects of research. This basic research often furnishes valuable information that was not foreseen when the studies were first proposed. However, although the importance of developing basic environmental data in all disciplinary sectors is recognized in principle, a large portion of scientific effort is devoted (due to social pressures) to the acquisition of knowledge useful only in the short term, and to the application of basic knowledge already acquired to the betterment of mankind and the protection of his environment [10].

FIRST CASE STUDY: GREAT BRITAIN

In England, the central government exercises an important control over administrative activities in the basin. The majority of water policies are adopted by the central government and applied by regional administrations. The *Law on Water Resources* (1963) addresses the entire problem of water resource management from a global perspective. The aspect of water quality management is covered by the regulatory powers provided in the *Law on Rivers*, of 1951 [11] and 1961 [12]. These powers are exercised by basin administrations whose activities can cover one or several basins. The basin administrations have also been given a key role in the collection and analysis of basic data and information. These administrations are conferred powers to directly regulate water use and wastewater discharges, to define water use rights, and to construct and operate installations, notably reservoir, to increase the value of water resources.

There are many laboratories in Britain concerned with water quality data acquisition. Even where they are a government responsibility, some of their funds come from the private sector. They are carrying out advanced studies of aquatic phenomena in lakes and rivers. This article analyses four groups of scientists. The first two work for the Freshwater Biological Association at two laboratories: the Windermere Laboratory and the River Laboratory, and the two other groups work for the Department of the Environment at the Water Pollution Laboratory and the Water Resources Board (Figure 1).

The Freshwater Biological Association

The Freshwater Biological Association is an independent non-profit agency. It was founded in 1929 and its first constituent, the Windermere Laboratory built in 1931, made itself an international reputation in lake biology. The River Laboratory, built in 1965, does research on the biology of rivers. The Association has a program of basic research described in the Memorandum of Association [13]. The program is centered on the biology of freshwater and saltwater plants and animals and is of some importance for fisheries, pollution control, and river management.

The Association has more than 1,400 individual members (biologists, naturalists, fisherman, etc.) as well as organizations interested in the water sciences (fishing clubs, universities, etc.). It is subsidized mainly by the Natural Environment Research Council but its individual members and member organizations also contribute to its finances. Members receive an annual report of the Association's activities. The Freshwater Biological Association also supplies on request copies of articles that its research workers have had published in specialized publications.

The River Laboratory – The River Laboratory (Figure 2) is a constituent of the Freshwater Biological Association. It was built in 1963 and began operations in 1965. It has a staff of thirty-two experts in various fields such as water physics, water chemistry, plant, invertebrate and fish biology, and organic wastes. The laboratory is subsidized mainly by the Natural Environment Research Council and receives various services from independent agencies such as the Avon and Dorset River Authority.

The River Laboratory has worked out a research program centered on the study of the unpolluted [14], fertile rivers [13] in the south of England. The program is first and foremost one of basic research; problems of a practical nature come up only as a consequence of this work. The various disciplines (inorganic chemistry, biochemistry, macrophyte studies, algology, invertebrate zoology, fish ecology, and, where the occasion arises, microbiology) work around one main theme: *production ecology*. The object of study here is the specific nature of the habitat of river plants and animals. The program consists of basic rather than applied research since the scientists are of the opinion that detailed knowledge of the organisms that live in rivers will lead to suitable water use and to improved pollution control [15].

In the laboratories, fourteen scientists plan the research programs. In addition, the River Laboratory has set up two important services: the Fluvarium (1968) and the Waterston experimental station (1970). At the Fluvarium, it is possible to grow and study many kinds of aquatic plants and animals in a controlled environment. The Waterston experimental station was originally given the task of studying the chemical changes in river water that result from animal and plant activities; it is also conducting an experimental study of fish and invertebrate populations. The Laboratory has also acquired the right to fish certain channels along the Frome River.

The River Laboratory has no data acquisition network but maintains close contact with many independent agencies such as the River Authorities. However, the scientists are developing a system for making continuous fish counts and for recording the concentration of dissolved oxygen and sunlight intensity. In addition, the laboratory is in the process of setting up a data bank linked to the Atomic Energy Research Establishment computer at Winfrith. An annual report of the laboratory's activities is given to the Freshwater Biological Association and there is a hall open to the public which contains exhibits of the laboratory's work.

Windermere – The Windermere Laboratory (Figure 2) is carrying out studies on sixteen lakes. Among its significant experiments, mention may be made of the one at Lake Blelham Far where sections of the lake have been isolated in gigantic tubes and it has been shown that the mud in the lake plays little role in eutrophication. The experiment has also revealed the presence of mineral compounds during overturning. These studies are of great importance for water use in the area. By the isolation of a large volume of water, changes of lake productivity can already be shown. Also, some mathematical models of the behavior of the tubes are now in use.

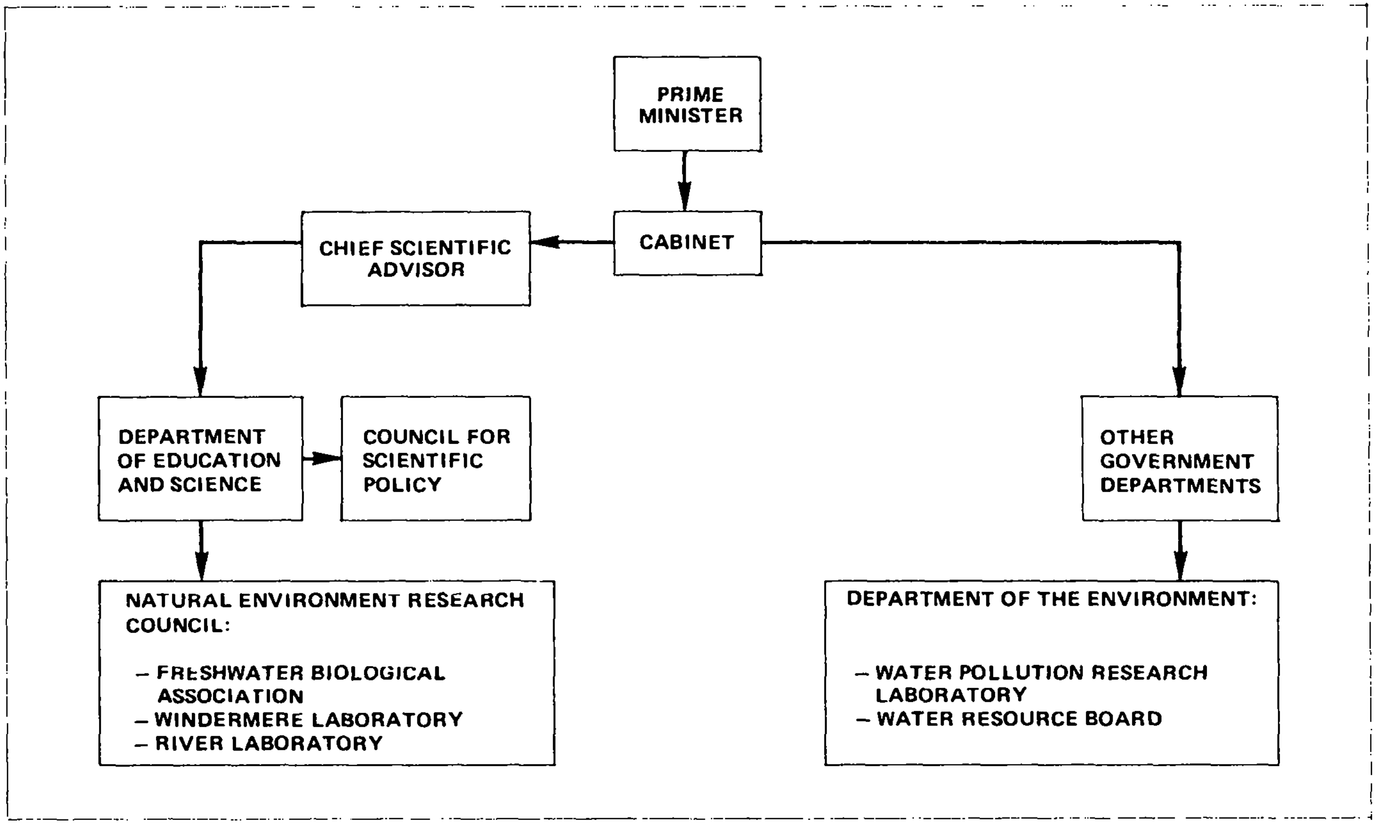

Figure 1. Government organization chart showing British scientific agencies analyzed.

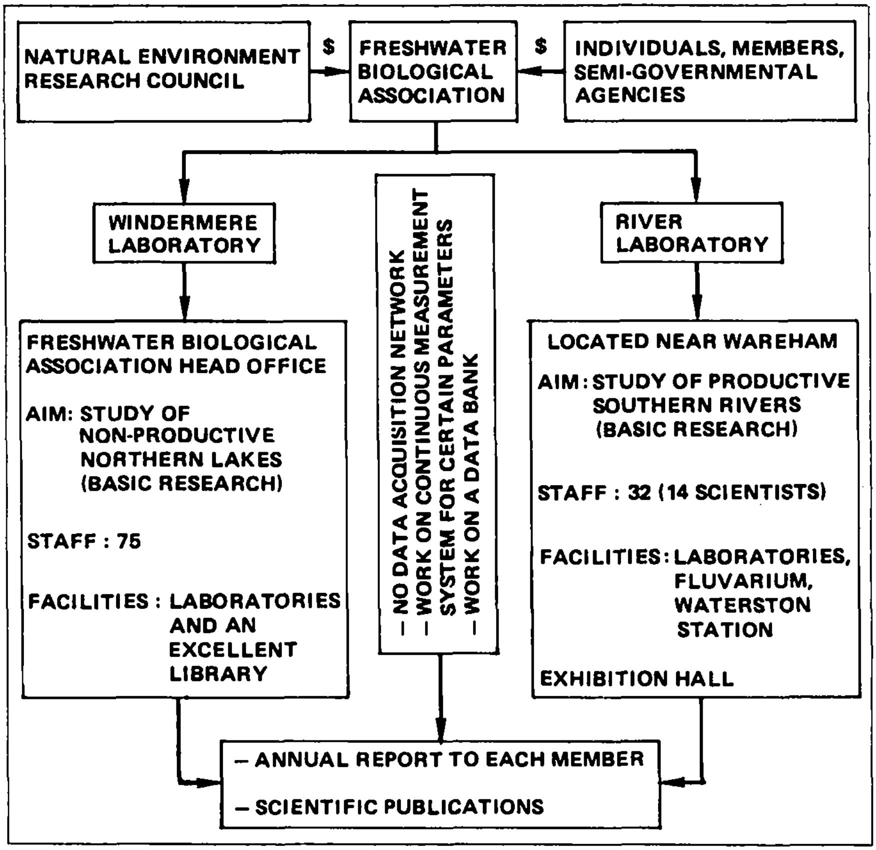

Figure 2. Organization of the Windermere and River Laboratories.

Other experiments are of great interest: there are studies of biological controls on water blooms, fish population control, and lake sediments. The other aspects of water biology also being investigated include: algae, macrophytes, benthos, invertebrates, physiology, chemistry, wastes, bacteria and plants, and animals of the Quaternary. None of the particular studies are continued indefinitely but Freshwater Biological Association policy is to keep researchers at work in almost all areas of water biology.

THE DEPARTMENT OF THE ENVIRONMENT

In October 1970, the government of the United Kingdom announced the creation of a Department of the Environment under a secretary of state responsible for various environment-related activities. It assumed the responsibilities of three former departments: Housing and Local Government, Transport, and Public Building and Works. In addition, the Department of the Environment was responsible for four research establishments, one of which was the Water Pollution Research Laboratory, formerly under the Department of Trade and Industry.

The diversity of measuring techniques for pollution indices and the lack of centralization in the work of the agencies concerned (the River Authorities) led the Department of the Environment to work out a program of definite action on the basis of many recommendations such as standardization of methods and data [16]. The government agencies involved (the Water Pollution Research Laboratory, the Water Research Association, etc.) at that point became essential adjuncts to already existing agencies such as the River Pollution Survey and the Water Resources Board.

The creation of a network using continuous measurement methods and lending itself to standardization would seem to be essential for quality analysis of the main watercourses. Through standardization of data and use of optimal sampling methods, a better assessment could be made of the impact of waste discharge on the water environment [17]. The stations in the network would be located above areas affected by tides, for the purpose of facilitating the collection of information on the entire drainage basin and on the quantity of fresh water flowing from the basin into the sea.

The sampling points would be determined on the basis of standards established by representatives of the River Authorities. Sampling would have to be done at a total of 150 to 200 points to cover England and Wales [18]. The sampling methods would have to be standardized so that sampling could be done in the same way at each station. Sampling frequency would be determined on the basis of the confidence intervals for the various parameters. Many government laboratories suggest setting sampling intervals in such a way as to simplify compilation of the results. The results of the analyses (Table 1) will be grouped; three sampling frequencies are recommended. The analyses made would not necessarily be the same at all stations and could be modified in the light of the results obtained. Finally, the possibility of making analyses by emission spectrophotometry is being studied. A file would be started on each parameter analyzed and it could be consulted when new aspects of pollution are taken up.

The results could be brought together in a data bank. For example, the information gathered at the stations would be sent to the Department of the Environment, standardized and then returned to the River Authorities. This information would be compiled monthly and an annual report published. The plan is to link the network eventually to the agencies studying drainage basins in France and certain other agencies working on the North Sea costs. Such cooperation would make it possible one day to compare results on an international scale. It would also make it possible to perfect the various methods used and to increase our knowledge of the elements of water physiology.

Table 1. Sampling Frequency for Various Parameters, Water Pollution Laboratory

Monthly Sampling	*Seasonal Sampling or Frequency to be Determined by Preliminary Experiments*
Temperature	Fluorine, Sulfate
pH	Total Phosphate
Conductivity	Silica, Carbonate
Dissolved Oxygen	Ca, Mg, Mn
Ammoniacal Nitrogen	Fe, B, Cr, Cd
Total Nitrogen	Ni, Pb, As, Zn
Suspended Solids and Ashes	Cu, Hg, Se, V
Chloride	Phenols
Orthophosphate	PCB
Alkalinity	Pesticides
Total Organic Nitrogen	Chlorophyll
TOC, BOD, and Inhibited BOD	Organosilicons
Anionic or Nonionic Detergent	

The Water Pollution Laboratory – The Water Pollution Research Laboratory (Figure 3) is a government laboratory that was set up in 1927 as one part of the Laboratories of the Department of Scientific and Industrial Research. It was later transferred to the Ministry of Technology and finally in 1971 became part of the Department of the Environment. The laboratory does research on the environment and on urban effluent quality. It also studies the effects of many kinds of pollutants discharged into watercourses and supplies information on a number of pollution control techniques.

It does both basic and contract research, and therefore looks at numerous aspects of water pollution, such as the effects of pollutants on surface water, and the treatment of wastewater and industrial effluents. The laboratory's research program is designed to meet the requirements of its users such as the Water Pollution Control Agency, the Confederation of British Industry, the Association of River Authorities, and various government agencies. The program is planned on the basis of information gathered from the scientific literature. The laboratory thus works closely with industry and government.

The laboratory includes offices, a library, pilot laboratories, advanced research laboratories, isothermic chambers, workshops, and the most modern scientific equipment. The staff consists of a multi-disciplinary team of 120 scientists and a support group of about 100. These work in three sections, as described in the guide published for the annual exhibition. The laboratory has no data acquisition network; it uses a statistical sampling method.

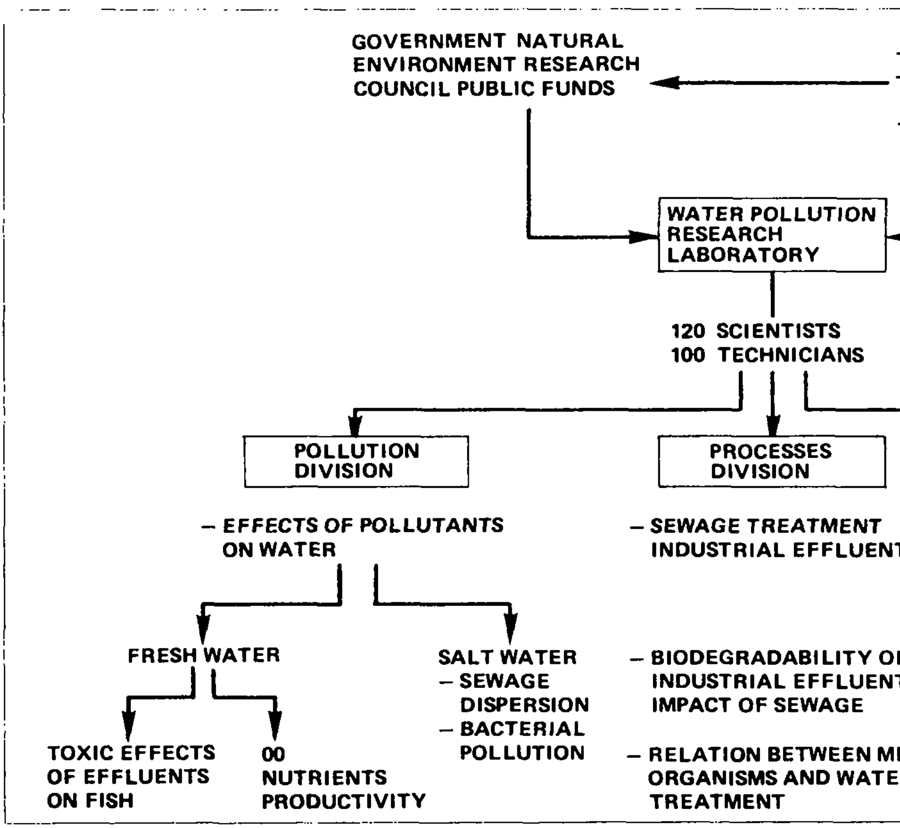

Figure 3. Organization of the Water Pollution Resear

The laboratory also has an Information Service on Toxicity and Biodegradability (INSTAB). In addition, it runs a data bank that codifies the use of more than 1,500 substances with respect to sewage treatment. Requests from overseas for information are filled on payment of certain charges. An idea of the importance of the Water Pollution Research Laboratory in the field of pollution can be gained from looking at its scientific and technical publications.

The Water Resources Board – The Water Resources Board is an advisory body financed by the government and by private interests. The Board has worked out a policy that embraces the most modern water research methods (automatic continuous measurement system, data acquisition system, network). One section of the Water Resources Board has the task of conducting water use study programs. One of these, dealing with optimal water use, is underway in the Trent River basin (Trent Research Program). The Trent is the third largest river in the United Kingdom; it is 187 miles long and its drainage basin covers 4,029 square miles. Research projects in the basin are directed by seven members of the Board. There is also a scientific staff of thirty (engineers, biologists, economists, statisticians, hydrologists) and a support staff of twenty-seven assigned to the various projects.

The main aims of the water study in the Trent River basin are assessment of the costs and benefits resulting from water use and launching of a program to optimize use of the river's waters [19]. Work toward these aims is undertaken through a number of research projects: evaluation of additional water demand, possibility of increasing the river's flow, study of the quantity of water in the basin with a view to increasing its capacity, suitability of using a detention basin for purification [20, 21], possibility of producing drinking water from the water in the river [22], planning of the effluent quality standard so as to obtain a specific quality of water in the river, and estimation of the demand for water for recreational purposes and determination of the benefits of this use [23].

The laboratory is equipped with two automatic monitoring systems and possesses an IBM data acquisition system. Sampling is either manual or automatic; some physical, physicochemical, and biological parameters are given in Figure 4. Information is recorded on magnetic tape and can also be recorded directly. However, no data bank has been set up: interpretation would be too difficult.

A complex, flexible mathematical model has also been worked out. It functions at three levels: the river, water use, and optimal use of invested capital. The model of the Trent River is valid for periods of ten years and will cover the period up to the year 2001. This program will make a quantitative and qualitative assessment of the river and determine costs and benefits associated with the proposed operations [24].

The theoretical model that has been worked out divides the river into thirty-three sections. Each section is further divided into parts (stages) where various operations are carried out. The model's effectiveness can be determined by

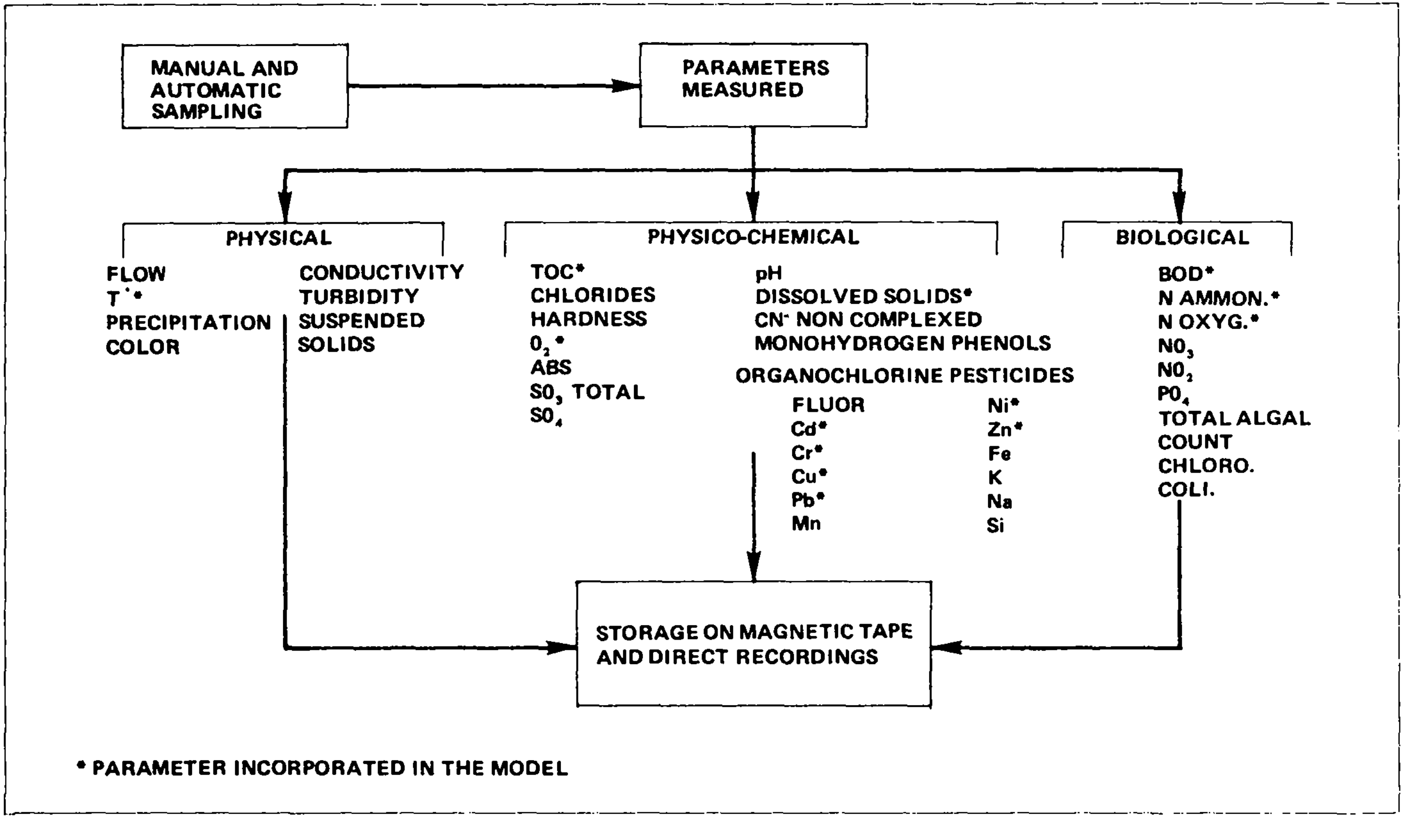

Figure 4. Parameters measured by the Water Pollution Laboratory.

comparison of the data obtained with the parameters measured by the River Authority model. The model is limited to determining the best methods for increasing water treatment effectiveness and to rejecting uneconomic methods. But it can still suggest a number of good possibilities and assess their effectiveness and economic feasibility [25-29]. The quantity and quality of the researchers' scientific publications, their participation in numerous symposiums, and their cooperation in the work of many agencies give the Board great importance. The government has made it a top advisory body. The Board supplies on request copies of articles that its research workers have published in specialized publications.

SECOND CASE STUDY: HOLLAND

The Dutch created their country themselves, by constructing dikes to protect it from the sea and the rivers and by drying out the marshes and lakes and filling in the estuaries. Without the protection of the dunes and dikes, almost half the country would be covered every day by tide water. It is therefore not surprising to find that the Dutch were among the first to set up government services to protect the environment [30]:

- the RID (State Institute for Drinking Water Supply), founded in 1913 to provide the countryside with drinking water;
- the RIZA (State Institute for Wastewater Treatment), founded in 1920; and
- the RIV (State Institute for Public Health), in charge of monitoring water supplies (ground, surface, and atmospheric water).

Alongside these agencies, the universities carry out basic research. For example, in the field of limnology there is the Limnologisch Institut Nieuverschius.

The RID

From the start, the RID (State Institute for Drinking Water Supply) has acted as an advisory body with regard to both the creation of new equipment and the expansion and improvement of private, municipal, and regional enterprises for the supply of water to military and industrial facilities. Toward this end, the Institute has units dealing with administrative, legislative, and economic matters and with preparing projects and carrying out technical work in hydrogeology, chemistry, bacteriology and biology, and research and planning, with a staff of over 100. General water supply policy is handled by the Central Commission for Drinking Water Supplies, an advisory body that comes under the Ministry of Public Health and Environmental Hygiene. The Commission is made up of political, organizational, and technical experts. The RID's director is a member of the Commission and the Institute provides its secretariat. Since 1968, the

Table 2. List of Desired Parameters (State Institute for Wastewater Treatment)

	Application	Priority[a]	Frequency	Change of Automation[b]	Range
1. General Parameters					
1.1 TOC, COD	Total Concentration of Materials	XXX	Continuous	XXX	1-10 ppm
1.2 BOD	Trend, Reclamation	X	Weekly	–	–
1.3 O_2	Disaster, Fisheries	XXX	Continuous	XXX	0-100%
1.4 Temperature	Cooling, Index	XXX	Continuous	XXX	0-30°C
1.5 Conductivity	Inorganic Salts, Agriculture Trend, Influence of Sea	XXX	Continuous	XXX	0-2000 SU
1.6 pH	Acid Wastes, Index	XX	Continuous	XXX	5-10
1.7 Flow	Dilution Capacity, Index	XX	Daily	XXX	–
1.8 Suspended Materials	Toxicity, Index	X	Daily	–	0-200 ppm
1.9 Turbidity	Toxicity, Index	XX	Daily	XXX	0-100 JTU
2. Toxic Elements	Control				
2.1 Total Toxic Materials	Disasters, Drinking, Fisheries, Recreation	XXX	Continuous	–	–
2.2 Metals and Metalloids: As, Be, Cr, Hg, Se, Cd, Pb, Cu, Zn, Sb	Recreation, pH and Hg Accumulation, Index	XX	Daily	X	–
2.3 Organo-Metallic Compounds: Hg, Sn, Pb, Ni	Fisheries, Recreation, Drinking, Index	XXX	Continuous	–	> 0.1 ppb
2.4 Cyanide	Fisheries, Recreation, Drinking, Index	X	Daily		> 10 ppb

2.5 Fluoride	Fisheries, Recreation, Drinking, Index	XX	Daily	–	0.1-3 ppm
2.6 Herbicide	Groundwater, Discharge	XX	Daily	–	> 1 ppb
2.7 Carcinogens	Drinking, Index	–	–	–	1-100 pc
2.8 Radioactivity	Disaster	XX	Daily	XX	0-5000
3. Inorganic Pollutants					
3.1 Phosphate	Trend, Eutrophication	X	Weekly	X	10-1000 ppb
3.2 Nitrate	Trend, Eutrophication	X	Weekly	XX	5-50 ppm
3.3 Chloride	Trend, Aquiculture	X	Weekly	XXX	10-500 ppm
3.4 Sulfate	Trend, Aquiculture	X	Weekly	X	10-200 ppm
3.5 (Bi) Carbonate	Drinking	–	Weekly	XX	–
3.6 Ca, Mg	Drinking, Index	–	Weekly	XX	–
3.7 Na, K		–	Weekly	XX	–
3.8 Ammonium	Drinking, Index	X	Weekly	XX	0.1-10 ppm
3.9 Organic Nitrogen	Eutrophication	X	Weekly	–	0.1-10 ppm
4. Specific Organic Pollutants					
4.1 Oil	Industry, Disaster	XXX	Continuous	X	> 0.5 ppm
4.2 Phenols	Drinking, Control, Taste	X	Weekly	X	2-200 ppm
4.3 Detergents	Domestic Activities	X	Weekly	–	5-200 ppb
4.4 Color	Drinking	–	–	XX	–
4.5 Odor, Aromatics	Drinking	–	–	–	–
5. Hygiene					
5.1 Coliform Bacteria	Recreation, Drinking	X	Weekly	–	–
5.2 Viruses	Recreation, Drinking	X	Weekly	–	–

[a] Priority: X (low), XX (medium), XXX (high).
[b] Chances of Automation: X (good), XX (fair), XXX (poor).

Institute has been operating under the name International Reference Centre for Public Water Supply as part of the World Health Organization.

The RIZA

The RIZA (State Institute for Wastewater Treatment), which combats water pollution, was founded in 1920. It has the task of carrying out scientific research on surface water quality and on means of protecting water from pollution. It also has the job of giving advice on the best methods of getting rid of pollution. To do this, the Institute has:

- laboratories for physiochemical, bacteriological, and radiochemical analysis of surface water and wastewater, and aquariums for hydrobiological studies of the toxicity of certain kinds of wastewater;
- a boat laboratory to study surface water;
- the necessary light and heavy installations (treatment plants); and
- professional staff for the laboratories, and cooperation agreements with universities.

As for water quality surveys, the Institute is still at the stage of program development. From a special concern with monitoring drinking water quality, it is now moving on to design a network for the study of trends in the chemical quality and eutrophication of surface water. Table 2 gives a list of the parameters State Institute for Wastewater Treatment wishes to measure; these reveal the nature of its concerns.

The RIV

The RIV (State Institute for Public Health) authorities are responsible for supplying the population with water. For this purpose, special measures were provided for in the 1957 Act on water supply. This law handed over responsibility for water quality monitoring to regional environmental health inspectors. All water supply enterprises have to provide, on a regular basis, samples of water taken at various stages of treatment and from various points in their distribution networks. In addition, the State Institute for Public Health monitors untreated water and water supplied by all water supply enterprises at least once a year, in the interest of public health.

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