

INTRODUCTION

Water is a substance which plays a crucial part in the existence of life on Earth. It forms the living mass and, together with the soil and the air, represents the living environment. The energy which is accepted by this system from the universe helps to sustain essential life processes. The hydrological cycle, or the process of permanent movement and transformation of water, connects the human being with all the elements of this environment in such a manner that any change results in a chain of consequences which spread throughout the ecological system.

For billions of years the development of the ecosystem was determined by the interplay of uncertain causes. A fundamental change occurred with the emergence of civilization. Man started to influence this system intentionally and systematically: gradually mankind's everyday existence came to have a more serious and detrimental effect on the environment. Up until now the energy which mankind used during his development has been negligible in comparison with the amount of energy used through natural processes. Nevertheless, even the water management and agricultural activities of ancient civilizations already had a drastic and irreparable impact on waste areas as a result of systematic efforts over long periods of time.

Today the march of technology appears irrepressible and irreversible throughout the world. The process of deforestation, land cultivation, urbanization and industrialization are rapidly changing the character of the earth's surface and the quality of the water, soil and air, as well as affecting the acceptance of solar energy. The scale of these human activities has now reached such a proportion that the impact of one single generation is comparable with the impact of all preceding generations. The amount of energy currently manipulated by man is no longer negligible in comparison with the total amount of energy used during natural processes. Civilization confines the world and mankind to monotonous, unambiguous structures which are very difficult to control effectively. Man alters the natural equilibrium without considering the global consequences of his actions. In the course of a few decades he is able to exhaust some natu-

ral resources and irreversibly pollute his environment. An unfavourable accumulation of the negative consequences of his activities, transferred in the framework of the hydrological cycle, threatens his own existence. Man has started to live at the cost of future generations.

The roots of this incomprehensible situation lie not only in mankind's misguided endeavour to achieve maximum economic benefits through minimum efforts and without considering secondary effects, but also in his traditional thinking processes. These were formed in the period when man still observed natural phenomena separately, without taking account of their interrelationship. In the past the observer of natural phenomena in one scientific discipline had no reason to follow up their inter-disciplinary relationships. The interrelationship of natural phenomena and the likely consequences of such a relationship were not taken into consideration.

This situation is also reflected in the field of water resources. The theoretical background to this field is traditionally formed by:

- hydraulics (the study of the physical regularities of water motion and function);
- hydrochemistry (the study of the physical, chemical, biological and bacteriological properties of water);
- hydrology (the study of the time and space distribution of various aspects of the hydrological cycle) and
- hydrogeology (the study of the occurrence and movement of subterranean waters and their geological environment).

The descriptive scientific disciplines are concerned with the study of two different categories of phenomena.

The first category comprises phenomena which are based on simple relationships among several variables. Here it is necessary to neglect those variables whose influence is unimportant and to derive the mathematical relationships among these variables whose influence is decisive.

The second category includes phenomena with a high degree of occurrence. Here it is not necessary to trace their mutual relationships, but rather to study the result of their interplay, when the relations between causes and consequences are to be determined and classified on the basis of statistical methods and the theory of probability.

However the size and number of water projects and other development activities which influence the hydrological cycle have reached such proportions that the majority of problems involved extend beyond the boundaries of the above traditional disciplines. These problems cannot be solved with the tools of the above methods. Present-day water management problems are inter-disciplinary in nature and as such include complex phenomena with complicated mutual interrelationships. These interrelationships are more important than the number of

variables involved.

It is not enough to investigate these problems by researching selected important variables and relationships. Using statistical methods and the theory of probability for this purpose represents a complicated mathematical exercise with only little relevance to reality. Such an approach is unlikely to lead to the desired goal.

The solution of inter-disciplinary problems in water development and management practice on the basis of the traditional approach tends to ignore the key development and environmental factors. This leads among other things to:

- the separate development of either surface or groundwater resources,
- the use of high quality water for low quality requirements and vice versa,
- the over-excessive use of water for certain purposes, thus inhibiting or excluding more valuable uses,
- the neglecting of water re-use, water re-cycling, and waste material recovery possibilities and other water saving practices,
- the loss of nutrients or raw materials from the place of immediate or potentially easy utilization, and
- the neglecting of important secondary aspects, constraints and hazards of many water and other development projects.

The traditional approach is also one of the reasons of:

- over-excessive use of natural resources,
- the increasing deterioration of the natural environment, and
- the economic failure of many water development projects.

When investigating contemporary water development and management problems including their ecological, economic and social aspects, it is necessary to analyze a large number of elements whose interrelationships depend on the prevailing conditions. Such problems can be solved by limiting the problem area, simplifying it to the point of analytic tractability, and defining systems which preserve all vital aspects affected by various possible amendments. All important elements and dynamic interrelationships should be analyzed and not just generally, but also on the basis of their specific behaviour. It is necessary to employ a combination of different probabilistic and analytic methods, including modelling and investigating the sensitivity of the outputs to the assumptions made and to facets of the problem excluded from the formal analysis.

New scientific methods for the solution of the contemporary problems in water management include analogy, operation research, system analysis and cybernetics. The distinctive features of these methods are their emphasis on measurement and on the use of conceptual models described in quantitative terms, the verification of their theoretical predictions, and their awareness that concepts are conditional and subject to growth and continuous change.

This new approach should be defined within the framework of water resources management, i.e. within a complex of activities whose objective is the optimum utilization of water resources with regard to their quality and availability and the requirements of society. These water management activities should at the same time also ensure an optimum living environment, above all through protection of water resources against deterioration and exhaustion as well as through the protection of society against the harmful effects of water. In the course of these activities water resources management should avail itself of the entire spectrum of explicit sciences, gradually coming to form the sphere of its own theory.

The present monograph deals with the fundamental interdisciplinary problems of this complex sphere, an understanding of which is indispensable for successful water resources management in the widest sense of its social functions and environmental consequences.