HYDROLOGY AS A SCIENCE?

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Mankind has been curious about the earth on which it lives since ancient times. Multitudes of questions have arisen because of this curiosity. Some of these may have been -- What makes the sea salty? What is the source of water coming from springs? What makes rain?

As mankind sought answers for these, other equally perplexing questions arose. How does water occur in the ground? How do you get water out of hard rock formations? How do some streams erode hard rocks and yet fail to move sand?

How did mankind attempt to solve these questions? In the past, scientific knowledge was minimal and methodology nil. Today guidelines, established in the past or present, are used to build up a method of investigation for the compilation of scientific knowledge required for their solutions. Today it is called Hydrology - the science of water.

We now have called Hydrology a science! A question still remains with many as to the truth within the statement. In order to establish the truth or destroy the disbelief present, let's look at what is science.

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WHAT IS SCIENCE?

What is the definition of science? According to the Random House Dictionary of the English Language, science is a branch of knowledge or study dealing with a body of facts or truths systematically arranged and showing the operation of general laws; knowledge gained by systematic study. Systematic study implies experimentation, observation, classification, and practice.

Also of interest is the legal dissertation of science from Corpus Juris Secundum [79 C.J.S. 455, Science (1952)]: Quote "SCIENCE. In a sense 'science' means knowledge obtained individually by study of facts, principles, causes, etc.; knowledge of many methodically digested and arranged so as to be attainable by one; accumulated and accepted knowledge which has been systematized."

Many other definitions of science have been developed and recorded but in all instances the implication of attained knowledge is included. Now we may ask again - Is hydrology a science?

DEVELOPMENT OF SCIENCE OF HYDROLOGY

Two broad types of knowledge may be attained -- experimental and historical. Experimental knowledge is derived from experiments designed and developed to obtain specific data. These provide the bases for practically all our knowledge in the realms of physics, chemistry, and other hard sciences. The experiments could be repeated by any competent observer and the results could be verified if the same data were utilized. From these experiments, universal laws of nature were established.

The second type of knowledge is historical which consists of facts not attained through experimentation. Data cannot be obtained at will. The knowledge is certain and authentic when observed by competent observers and does not negate the laws of causality. Many of the phenomena of hydrology are isolated and natural events which cannot be duplicated by experimentation. Thus these data are historical as mankind has been unable to "back-up" in time.

Within the purview of the previously stated definitions, hydrology can be considered a science. All data must be defined and verified, organized and correlated, and must be universal in application. Systematic study is required; the study of water.

When did the science of hydrology begin? The exact origin is hard to trace and is probably buried in antiquity. Man has forever realized that water is essential for his survival and has worked toward maintaining its supply. The science of hydrology was involved throughout history. The progressive extensive exploitation of waters of the world in recent times has necessitated an intensive study of water in its natural form and occurrence. The body of knowledge developed by the scientific investigations and studies is recognized as hydrology throughout the world.

It is an interdisciplinary science, involving the integration of other earth sciences in order to explain the life history of water and its physical, chemical, and biological character. Other sciences that overlap into the science of hydrology are agricultural sciences, meteorology, climatology, geology, geomorphology, chemistry, physics, hydraulics, mechanics, and mathematics.

DEVELOPMENT OF A HYDROLOGY CURRICULUM

In order to effectively carry out the scientific investigations relating to water, properly trained personnel with the ability to recognize, organize, correlate, etc. the derived data became a prerequisite. To satisfy this prerequisite educational programs with this type of training as its prime objective were developed.

Knowledge required for understanding and solving complex water problems may be considered as a continuum extending from the basic physical sciences through the applied sciences and into the behavioral sciences. The breadth of knowledge encompassed is as great or greater than in any other field of study. The educational program in hydrology strives for a general education across the continuum especially at the undergraduate level with specialization available at the graduate level.

Historically, training in hydrology at the university level has been implemented within several established disciplines with little or no integration among these disciplines. Also training in the behavioral sciences with emphasis on water has been very limited especially in the social, political and economic fields. Recently there has been concerted effort on several campuses to integrate and broaden hydrology education by the development of interdisciplinary programs.

The importance and need of having properly trained scientists in hydrology are receiving greater recognition and emphasis as our society attempts to cope with the complex problems surrounding water. With greater demands being placed on our natural resources, virtually insurmountable problems develop in providing an adequate and suitable water supply at a desired location or for a specific requirement. Many agencies make decisions relating to water; these decisions involve the populace introducing the complex interrelationship between socio-politico-economic problems. These problems require special attention and skills; their solutions are more complex than the empirical solutions generally developed in engineering and science technology. Methodologies rather than specific models are essential as the life of a model may be short; new knowledge is an exponential function implying that knowledge of today will probably be superseded within a students program. A continual update of hydrology training or any other training program, must exist in order to maintain this pace.

HYDROLOGY FOR THE POPULACE

As stated previously, decisions relating to water are made and the decisions involve the populace. Too frequently the populace is ignorant or uninformed as to the ultimate effect of these decisions. Hence, an informed populace would permit or require decisions which were sound and in the best interest of the populace as a whole.

In order to try to inform the populace, an introductory course in hydrology was introduced within the Department of Hydrology and Water Resources at the University of Arizona. This course is in addition to the professional hydrology courses in the department and is intended for the non-scientific oriented students. It was felt that water could be the one topic upon which attention could be focussed and demonstrate the interrelations between water and many other disciplines. The course was thus aptly entitled "Water and the Environment."

This program consists of two parts with each part a four unit course thus requiring two semesters for the completion of the total eight units assigned to the program. It is considered a laboratory science course and includes a 3-hour laboratory period in addition to the 3-hours of lecture per week. Because it is a laboratory science course it has been positioned beside the classical basic science courses such as chemistry, physics, biology, and geology. Students enrolled in some of the university's curricula can satisfy their science requirements by satisfactory completion of the course.

The direction of the course was to introduce the occurrence of water through the use of the hydrologic cycle. After this introduction, each phase could be covered in detail to provide a physical basis for water. The course then would build upon the basic physical concepts presented and would permit discussion of the present and future problems for each area. Figures 1 and 2 represent an organizational chart for each of the two parts of the course. This arrangement or sequence was considered to be most desirable as the physical aspects of the system must be known prior to delving into specific problem areas. For example, the statement "the Colorado River is polluted" may be a true statement but it by itself is not adequate information from which the problem can be solved. The physical system - nature, type, extent of pollutant, etc. - must be known before any solution can be derived. Thus the direction of the course attempted to provide the physical aspects followed by the specifics.

Several problems were encountered during the initial offering of the course; some of which were predicted while others were unexpected. One of the major problems was, and still is, the lack of a suitable text. Because of the broad scope of the course, several books would be required but this requirement is somewhat unrealistic for economic reasons if for no other. There are other reasons; one of which being the student. Since freshmen are the intended student, expecting them to utilize 3-5 books for a course is futile. They are not attuned to this type of activity. To circumvent the problem a select list of references was compiled and these books were made available at the University's library. The list as included in this paper is by no means complete but does cover a very broad spectrum of water and its related areas. This does not solve the problem of an inadequate text but does permit a temporary solution to the problem.

Another major problem was scientifically designed laboratory experiments. These experiments are a prerequisite for the course if it is to satisfy the requirement as a laboratory science. Scientific method must be stressed but yet

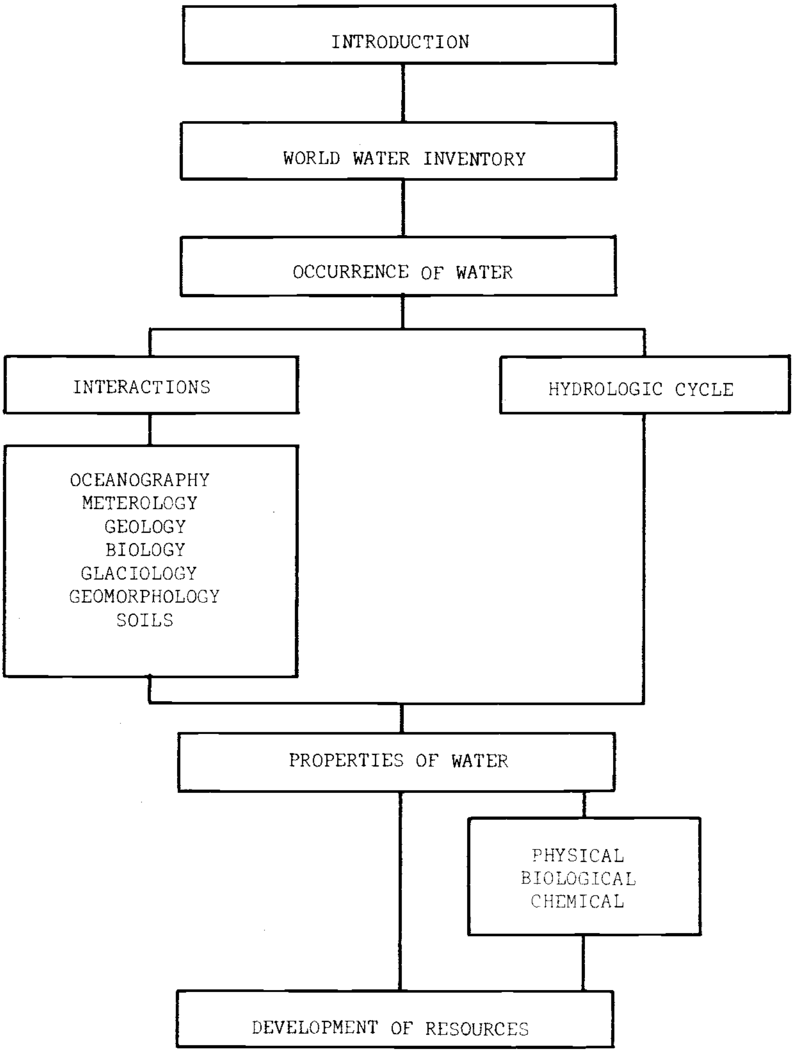

FIGURE 1. Subject matter organizational chart for the first semester of the course - "Water and the Environment"

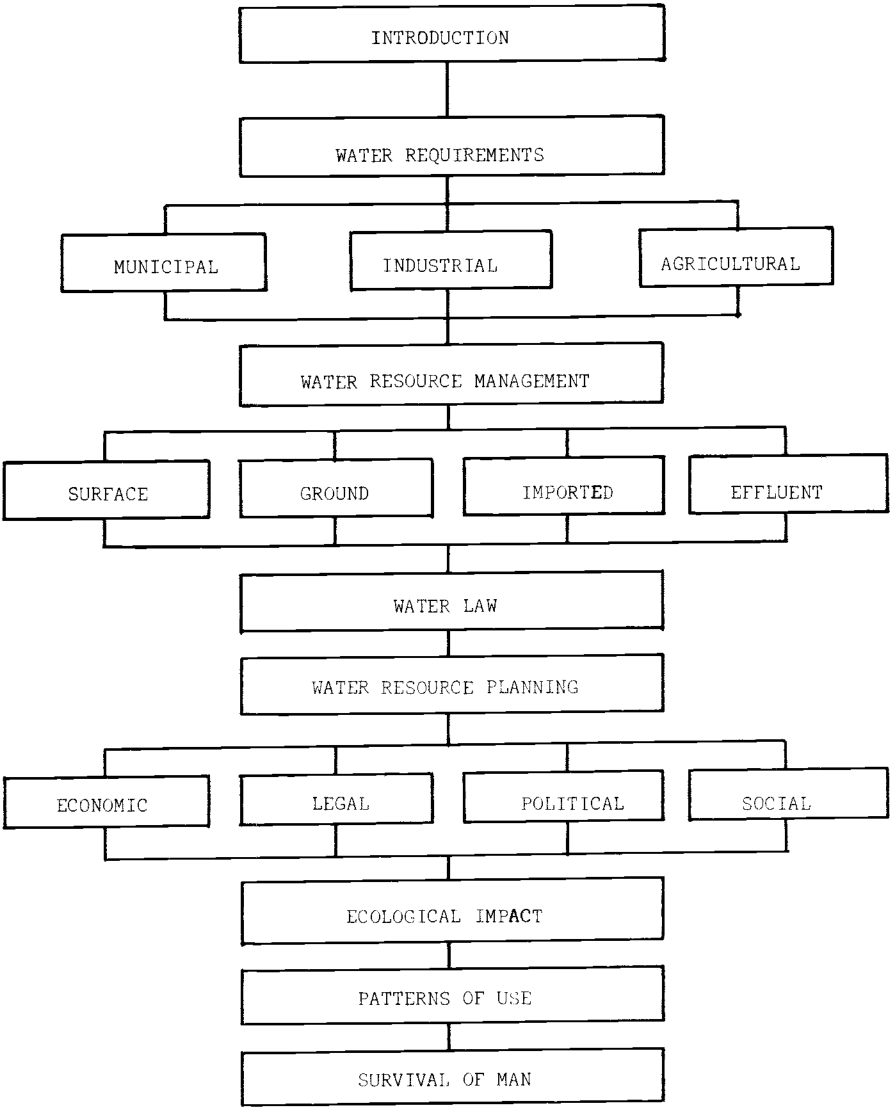

FIGURE 2. Subject matter organizational chart for the second semester of the course - "Water and the Environment"

many of the subject areas do not lend themselves to this type of effort. The physical, chemical, and biological aspects of water were easily demonstrated through laboratory endeavors but other topics such as ecological impacts, water planning, legal considerations, etc. were extremely difficult, sometimes impossible, to demonstrate within a prescribed or recognized "scientific method" framework. Allied to this problem are the logistics required to implement a truly desirable laboratory program. During the initial stages of any new program, space and equipment are not always at the immediate disposal of the program directors. This thus requires a rather complex and diplomatic management scheme for utilization of existing facilities. Only time and/or money will permit the optimal development of this segment of the program.

Another problem, probably the most partentuous, lies within the students. It is extremely hard to evaluate much less rectify because of the nature of the source of the problem. One aspect of this problem is the extreme ecological orientation of the student. He/she is not interested in the why or how of the problem but rather want an immediate solution. As stated previously they are unaware of why the Colorado River is polluted and it really did not matter so long as they could say "this" is the solution. It became extremely difficult to convey to them the importance of knowledge of the system before an effective solution could be rendered.

A second aspect of the student problem was the student's preparatory training toward handling a laboratory science course. Most had never encountered a lab science course and were not attuned toward the quantitative thinking necessary in this segment. Part of this stems from a lack of training and/or desire for mathematics. Although mathematics was not a stated prerequisite, an implied

SELECTED REFERENCES FOR THE COURSE

WATER & THE ENVIRONMENT

1. WATER, EARTH, AND MAN, R. G. Chorley
2. THE STRUCTURE AND PROPERTIES OF WATER, D. Eisenberg and W. Kauzman
3. A PRIMER ON WATER, L. B. Leopold and W. B. Langbein
4. THERMODYNAMIC PROPERTIES OF WATER TO 1000°C AND 10000 BARS, Geological Society of America
5. A PRIMER ON WATER QUALITY, H. A. Swenson and H. L. Baldwin
6. MODERN HYDROLOGY, R. G. Kazmann
7. WATER AND THE WORLD, A. D. Tweedie
8. THE NATIONS WATER RESOURCES, U. S. Water Resources Council
9. PROBLEM OF WATER: A WORLD STUDY, R. Furon
10. THE FUTURE OF THE OCEANS, W. Friedman
11. WATER WE LIVE BY AND HOW TO MANAGE IT, L. A. Heidle
12. ENVIRONMENT AND MAN, R. Wagner
13. THE SURFACE OF THE EARTH, A. L. Bloom
14. THE LAST RESOURCE: MAN'S EXPLOITATION OF THE OCEANS, T. Loftas
15. WATER: SOLUTIONS TO A PROBLEM OF SUPPLY AND DEMAND, M. Overman
16. WATER, THE WONDER OF LIFE, R. Platt
17. WORLD OF WATER, J. G. Cook
18. WATER BOOK: WHERE IT COMES FROM AND WHERE IT GOES, S. Morrison and J. F. Freeman
19. WATER, THE MIRROR OF SCIENCE, K. S. Davis and J. A. Day
20. PRINCIPLES OF HYDROLOGY, R. C. Ward
21. WATER, 1955 YEARBOOK OF AGRICULTURE
22. ENGINEERING MANAGEMENT OF WATER QUALITY, P. H. McGauhey
23. WATER, Life Science Library
24. THE WORLD OF WATER, W. C. Walton
25. WATER PURITY, E. F. Murphy
26. WATER AND ITS IMPURITIES, T. R. Camp

knowledge was expected. This implication was ill-founded as most of the students were unable to handle even the simplest mathematical manipulations necessary to attain the quantitative solutions. This thus forced some modification upon the objective function of the course.

CONCLUSION

The concept of hydrology as a science course is sound but some problems make it rather difficult to administer within its stated objective function -- to inform the populace about water. Experiences accrued during the first offering of such a course indicate that some of the problems are very real and difficult to evaluate. These same experiences, however, did permit satisfaction, in part, of the stated objective function. The manner of satisfaction may not have been as initially designed but this is rather academic if the function was in fact satisfied. Time will tell as to the true impact that a course of this type may have upon water decisions.

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Jones, P. B., G. D. Walker, R. W. Harden, and L. L. McDaniels, "The Development of the Science of Hydrology," Texas Water Commission Circ. #63-03, April, 1963, 35 pp.