May 1966

Water Resources Research at the University of Connecticut

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SECOND ANNUAL WATER RESOURCES CONFERENCE SPONSORED BY THE INSTITUTE OF WATER RESOURCES, THE UNIVERSITY OF CONNECTICUT

Water Resources at the University of Connecticut

PROCEEDINGS OF THE SECOND ANNUAL

WATER RESOURCES CONFERENCE

Held in the Auditorium
College of Agriculture Building
The University of Connecticut
Storrs, Connecticut
May 18, 1966

Under the sponsorship of the Institute of Water Resources
The University of Connecticut

CONTENTS

Foreword

These Proceedings include summaries of papers presented at the Second Annual Water Resources Conference held at The University of Connecticut, May 18, 1966.

These conferences, sponsored by the Institute of Water Resources of the University, are designed to bring together for formal and informal discussions, representatives of the various public and private agencies and groups which are concerned with water resources use and development.

The theme for this conference, "Water Resources Research at The University of Connecticut," was selected so that present research and future plans could be discussed by the individual project leaders and so that interested individuals could be informed of the diverse efforts sponsored by the Institute. The title of each presentation is the same as that of the research project. Also given for each are the personnel, academic departments, planned duration and the objectives.

Research, both applied and fundamental, is needed to solve present water problems and to establish a firm foundation for future action programs. The Institute of Water Resources research is making significant contributions to the fund of knowledge necessary for the orderly and proper development of water resources in Connecticut.

William C. Kennard
Director
Institute of Water Resources

Welcome

to the Second Annual Conference on Water Resources.

A digest of the remarks made by
W. B. Young, Dean, College of Agriculture, The University of Connecticut.

The story of water is in many ways a story of life itself. Truly, water is the fountain and foundation of life. Life's watery beginning continues to be reflected in all living processes, both plant and animal. It is, therefore, no wonder that as the years go by man becomes more concerned in the importance of water for the well-being of civilization.

We now realize that uncontrolled pollution is wasting our water resources. We can no longer afford this waste, for if we do not halt pollution we will not be able to meet the needs of a growing population and an expanding economy. Thus, individually and collectively, we have a responsibility to help conserve our water resources. We are finding interested parties on every hand from individuals to municipal officials, manufacturers, conservationists, farmers, housewives, and others. The nation is not running out of water. The problem is that we are just using so much more of it.

Today we are predominately an urban nation and our domestic, municipal, industrial and agricultural fresh water use has risen six and a half times over what it was in the early 1900's. It has been predicted that by the 1980's our fresh water needs will exceed six hundred billion gallons per day. This will be 150 times the amount we used in 1900; and within 15 to 20 years the daily demand for fresh water may well be equal to the daily supply. When and if the demand exceeds the supply for fresh water we must reuse the water, over and over. To be suitable for reuse, the water must be of the right quality. This requires adequate pollution-control measures.

The three primary users of water are industry, irrigation, and municipal. Here is a projection into the 1980 period: industry will more than double; irrigation will increase approximately 20%; and municipal use will go up approximately 80%. The three will, however, still remain in their respective positions in the use of water—industry leading, irrigation or agriculture second, and municipal third.

It has been proven in our country as well as countries throughout the world that notable increased production per acre can be gained by irrigating the majority of our crops. However, water used for agricultural irrigation is to all practical purposes consumed. It is of course eventually returned to the hydrologic cycle as rain but it is unlikely to fall back on the place from which it was taken.

For many years our government policy in this country has encouraged development of agriculture in the dry Southwest by offering water for irrigation at a very low cost. However, the use of water in the future for the continuation or increase of such projects may have to be determined on a public utility basis. It is estimated that in 1965 the United States put approximately 36% of its water to work irrigating western farm lands.

Industrial and domestic uses of water always put less strain than agriculture on the supply. Water used for these purposes can be returned to the systems quickly and to a predetermined place. However, its chemical composition is altered in the process of use and it must be treated before it is again used.

It is important to the present and future generations that research in water resources be carried on, that we seek new answers.

We must develop an orderly and efficient conservation and development of the country's water resources and the only way this can be done is through scientific research. It has been demonstrated in medicine, in industry, and in agriculture that the needed answers to the problem can be attained only through continued and endless scientific research programs.

To those of you who are doing or are interested in the research of water resources you face a great challenge and a great opportunity for the benefit of all mankind.

Introduction

Water Resources Research at The University of Connecticut – An Overview.

A digest of the remarks made by

W. C. Kennard, Director, Institute of Water Resources, The University of Connecticut.

The Institute of Water Resources came about by the recognition of the fact that water is one of our most valuable natural resources and that there has been a greatly increased research and training effort at this University on the part of scientists representing a number of disciplines. These expanded activities indicated the need for coordination to enhance effectiveness and to promote interdisciplinary studies. The Institute of Water Resources was approved for activation in July of 1964.

The scope of the Institute is as follows: "Research on water in any part of the hydrologic cycle which can be used directly or indirectly by man comes under the purview of the Institute. It includes any study which adds to the knowledge of the quantity, quality, nature or uses of water, including those designed to provide information on the nature, sources, production, behavior, transport, and conservation of water, including socio-economic aspects, for agricultural, domestic, industrial, municipal, and recreational uses by citizens of the State."

The objectives are as follows:

1. To encourage basic and applied research and develop technical competence in the broad field of water resources.

2. To coordinate and sponsor research related to water resources in the several Colleges and Schools of the University.

3. To increase the opportunities for interdisciplinary education and training of advanced students.

4. To sponsor seminars, symposia and other meetings on water resources problems and research.

5. To assist interested and qualified University staff members in obtaining financial support and facilities for water resources research.

6. To sponsor participation of visiting scientists in the water resources research programs.

The scope and the objectives originally adopted continue to serve our purposes well—we now look to the conduct of a variety of research efforts and the training, particularly at the graduate level, which will result from these studies.

PRESENT RESEARCH PROGRAM

For discussion purposes, the research program can be divided into two parts: those studies which are supported directly with funds available to the Institute of Water Resources and water-related projects which are supported with funds from other sources.

The former aspect is the one which will be covered in detail in the presentations which will be given today by the project leaders.

A recent survey has shown that nearly 40 professorial staff members have conducted or are now conducting many research efforts directly related to some aspect of water. Research is underway in 15 different departments and 6 schools and colleges of the University.

Included in the research are such varied projects as river basin mapping, stream flow analyses, erosion studies, saline water conversion, water chemistry, climatology, sewage disposal studies, determination of radioactivity in water and marine organisms, microclimatic investigations, the study of fish, water problems in urban areas, and the use of water for recreation.

Projects are financed by grants and/or contracts from a wide range of organizations. This shows not only a widespread interest in the problems of water but also a willingness to provide funds for conducting needed research.

PLANS FOR THE COMING YEAR

The research projects supported directly by the Institute are planned to vary in duration from one to five years. Two of the projects which will be reported today will terminate at the end of this semester. The data have been collected and the project lead-

ers are preparing manuscripts for publication later this year. The other nine projects to be reported upon today will be continued at least through June 1967 in order to accomplish their objectives.

In addition, new projects are planned for activation soon. This is a result of our efforts to broaden the scope of the Institute's research while continuing support of studies in the more traditional areas of geology, hydrology and engineering. One project is a study entitled, "Integration of Connecticut Water Rights Laws and Pollution Control Laws."

Another area of major interest which needs expanded effort is that of water chemistry. We now have a project entitled, "Ion-Ion and Ion-Molecule Interactions in Aqueous Salt Solutions" which is being developed as a part of our program for the coming year.

LONG-RANGE GOALS

These additions represent our plans for the immediate future. What about long-range goals? With increasing numbers of people and expanding industrialization and urbanization, demands for water will continue to increase. I am confident that studies in sociology, political science, economics, climatology and many other areas will be needed to complement studies in the physical and biological sciences and engineering. We plan to continue to expand our research as individuals trained in appropriate disciplines can be brought into the Institute and as adequate funds are available.

SUPPORT OF RESEARCH

First I would like to discuss briefly the Federal programs: one important piece of legislation is the Water Resources Research Act of 1964, P. L. 88-379. This Act provides funds for institutes or centers for water resources research at each state university. The law provides that each such center receive $75,000 in the first year of operation, $87,000 in the second and third year, and $100,000 annually thereafter. The Institute of Water Resources has been designated as the recipient of these monies for the State of Connecticut.

Public Law 89-404 approved April 19, 1966 amends P. L. 88-379 in a manner which will be of direct interest to many of you. The approved amendment provides authority for the Secretary of the Interior to "make grants or award contracts or make other arrangements with private and public institutions, agencies, or companies to undertake research into any aspect of water problems related to the mission of the Department which he may deem desirable and which are not otherwise being studied." The Act provides for this purpose $85 million over the 10-year period. These funds will permit a greatly expanded research program and one in which many agencies and groups in Connecticut can be active participants.

Other Federal acts having research implications and funds are:

1. Water Quality Act of 1965.
2. Water Resources Planning Act.
3. Federal Water Project Recreation Act.
4. Housing and Urban Development Act, and others.

In addition, a great amount and variety of Federal legislation is now pending.

Many State and private groups are actively conducting or supporting research. Included are the State Water Resources Commission, the State Department of Health, and the State Board of Fisheries and Game, to name but a few. A new agency within state organizations is the Connecticut Research Commission. Its function is to support research which will foster the economic and general development of the State of Connecticut. This commission recently has taken action to support a proposal entitled, "Hydrology of The University of Connecticut Well Field" under the supervision of Dr. Perry Rahn of our Department of Geology and Geography. Another group which has been active in a special field of water is the Governor's Clean Water Task Force. This group's report will certainly contain recommendations important to water resources research and we can be sure that water legislation will be a matter of major concern to our General Assembly during the session which begins January 1967.

Many private groups also have been and are concerned with the development and proper use of our water resources.

SUMMARY

The program of water-related research at this Institute and at this University is varied and extensive. We believe that greater effort needs to be and will be made in the future.

Our water-related research is only a part, although I believe an increasingly important part, of such activities in the State. The proper development of water resources necessitates a constructive interaction between and partnership among government, university and private organizations. Our research will supplement and complement the activities of other groups in this State that are concerned with water resources use and development.

Research can provide the knowledge needed to understand the problems and enable us to tackle them in the most efficient manner.

PROJECT TITLE: Individual Waste Disposal Systems

PERSONNEL: W. C. Wheeler, G. W. Hawkins, J. J. Kolega, S. E. Wedberg, W. J. Widmer

DEPARTMENTS: Agricultural Engineering, Bacteriology and Civil Engineering

PLANNED DURATION: June 1965 through June 1970

OBJECTIVE: To determine the effect of oxygen and temperature on the over-all operation of individual septic tank type disposal systems.

REPORT OF ACTIVITIES AND PLANS:

The immediate objective was to determine if small septic tanks fed with a laboratory media could be used to represent large septic systems fed with agricultural waste. At the same time observations of temperature differences within and between tanks were being made.

The first test consisted of two stainless steel tanks in a water bath whose temperature was controlled at 25°C. ± 1°. One tank was fed egg white and the other trypticase soy on a four day detention period with the pH and an indicator of the chemical oxygen demand (C.O.D.) (measured with a spectrophotometer) being obtained for the effluent. The plot of the C.O.D.'s (spectrophotometer readings) of the two tanks were made along with a linear correlation between these tanks and its 95% confidence limits.

The second test consisted of six glass tanks each containing 680 ml. of fluid and maintained at 24°C. ± 1°C. These tanks were paired; with one of each pair being fed egg white powder mixed with water at .0075 gram/mil and the other trypticase soy at .01 gram/ml. The pairs of tanks were fed on a ten, twenty and thirty day detention period. A correlation between the data of the egg white and trypticase soy tanks was in the range of 0.80 to 0.90.

Tests of the six tanks are now underway at 16°C. and will be examined at several other temperatures. Tanks of different sizes will also be tested for correlation. An attempt will be made to determine if there is a significant difference in temperature between the tanks and locations within each tank. The dissolved oxygen has been measured on some of the samples. As the necessary equipment on order arrives, an effort will be made to make more representative measurement of the dissolved oxygen in the influent, tank fluid and the effluent.

Preliminary studies were made on moving water through soil contaminated with *Escherichia coli* by a temperature gradient. It was found that the *E. coli* moved with the water.

PROJECT TITLE: Diffusion through Multiperforate Septa

PERSONNEL: R. Lee

DEPARTMENT: Plant Science

PLANNED DURATION: June 1965 through June 1966

OBJECTIVE: To test theoretical arguments for the dependence of membrane diffusion on pore size and number over the range characteristic of leaf epidermis.

REPORT OF ACTIVITIES AND PLANS:

The use of water by plant species is highly consumptive in nature, and probably accounts for one-third to one-half of the annual precipitation. Moreover, plant water use is widely held to be "luxurious," and exceeds by far the optimum metabolic requirement for agricultural crops or forest trees.

Different rates of water use by plant species and types has been qualitatively established. The thesis is of considerable practical importance. For example, the conversion from one type of vegetative cover to another has often resulted in a significant water saving in the form of usable streamflow.

Plant life requires the ultimate control of water losses at the leaf surfaces, i.e., in the vapor phase. The regulatory mechanism is the system of leaf pores or stomata, but the actual degree and significance of such regulation is not well-defined. This study has been an attempt to clarify the biophysical aspects of the problem, by an investigation of diffusion through membranes simulating leaf epidermis. Much of the historical uncertainty has resulted from:

1. The interpretation of Fick's Law resistances in terms of an intuitive "interference" concept.
2. The adherence to Stefan's (1881) "diameter law" rather than a properly qualified physical relationship.
3. Neglect of the thermodynamic aspects of diffusion phenomena.

Based on current research results it is concluded that:

a. The measurement of evaporation through porous membranes simulating leaf epidermis is useful in the prediction of stomatal regulation–providing the thermal relations are meticulously evaluated.

b. Significant stomatal control of foliar transpiration in nature is to be expected over a wide range of aperture sizes and numbers.

c. Leaf diffusion coefficients derived from studies of leaf micro-structure will provide a first approximation of the differential water use to be expected among various cover types on similar sites.

PROJECT TITLE: Effects of Simultaneous Variation of Temperature and Dissolved Oxygen on the Resistance of Fishes to Controlled Pollutants

PERSONNEL: W. R. Whitworth

DEPARTMENT: Plant Science

PLANNED DURATION: June 1965 through June 1967

OBJECTIVE: To measure the effects of simultaneous variations of temperature and dissolved oxygen on the response of fishes to a synthetic pollutant.

REPORT OF ACTIVITIES AND PLANS:

Contamination of inland and coastal waters through modern silvicultural practices, multiple use of watersheds, modern farming practices, and various domestic and industrial wastes have made it necessary to establish water quality criteria. These criteria have, of necessity, been arbitrary because our knowledge of the effects and interactions of the many factors present is incomplete.

Studies designed to measure the ability of aquatic organisms to tolerate environmental conditions have progressed from the single end point and all but one variable held constant to the entire range of tolerances and simultaneous variation of many variables. Since the environment is a fluctuating multivariable system the latter approach more closely approaches "natural" conditions. Water quality criteria are usually more concerned with extremes of the range which allow the successful completion of the life histories of the aquatic organisms present. To investigate the entire range of an organism's response to a group of factors we must use another end point, e.g. growth, and activity, or else stress the animal with a lethal substance and determine the area within the range of all factors at which the maximum, or optimum, survival time occurs. Unfortunately qualitative responses are extremely difficult to measure with many groups of aquatic organisms, especially fishes, and death is the end point frequently employed.

The primary purpose of the present study is to measure the response of fishes to simultaneous variation of temperature, dissolved oxygen, and lead. The response in this case being survival. The range of response of fish to many factors has been well documented, e.g. temperature, oxygen, salinity, carbon dioxide, and activity, as have the relationships between the response and the variables which may relate to the pre-test conditions. It has also been shown that the response of an organism to one variable may be greatly influenced by another variable, e.g. effect of toxicity of un-ionized ammonia by dissolved oxygen, cyanide and dissolved oxygen, temperature and dissolved oxygen, etc. Temperature and dissolved oxygen levels were selected as two variables because of their demonstrated importance as limiting factors. After contacting many of the industries in this state we selected lead because (1) lead seems to be a common pollutant in some effluents and is potentially important because of increased use of petroleum products, and (2) there is relatively less information available regarding its effects on the aquatic environment.

A continuous flow bioassay is employed so that the test medium is continually renewed. Waters from two reservoirs (one having a known concentration of lead) are mixed to obtain 4 levels of lead (one being a zero level); the oxygen level lowered or raised, and the temperature lowered or raised. These waters continually flow through closed test vessels containing fish. Tests will be run for varying periods of time to measure the acute (short term) and chronic (long term) effects of the factors on fish. Results from this study will reveal the effects of temperature, dissolved oxygen, lead and their interactions on fishes.

The first phase of this project will be completed by fall. The second phase of the experiment will be concerned with the ability of fish to avoid waters of unfavorable levels of temperature, dissolved oxygen and lead.

PROJECT TITLE: Rate and Direction of Ground Water Circulation in Close Spaced Bedrock and Gravel Wells Under the Influence of Non-Synchronous Pumping Time and Rates

PERSONNEL: L. Frankel, H. F. Thomas

DEPARTMENT: Geology and Geography

PLANNED DURATION: June 1965 through June 1967

OBJECTIVE: To determine the spacing required to deter inter-well contamination, and the time required to decontaminate an area once contamination occurs.

REPORT OF ACTIVITIES AND PLANS:

As many communities without a central water and sewage system develop to accommodate large populations, and in doing so subdivide large areas into smaller ones, each containing a well and septic tank, the chances of ground water contamination become greater.

The purpose of this investigation is to study the migration of ground water through surficial deposits of various textural ranges. It is believed that this information will give insight to the contamination problem, particularly in locales where there is a high water table and water is obtained from sediments in relatively close proximity to waste disposal. In these areas, the non-synchronous pumping of shallow wells may interfere with the migration of biological and chemical contaminants in the direction of the slope of the "natural" ground water table, and result in the recirculation of water whose quality continues to deteriorate because of insufficient dilution by uncontaminated water.

Two well fields, which have been established along the Skungamaug River are near completion. One field is situated in fine-textured glacio-lacustrine sediments; it contains four six inch screened wells and sixteen well points. The other field is in coarser-textured kame terrace materials; it contains six six inch screened wells.

The surficial samples collected during the drilling phase have been mechanically analyzed and the raw data statistically calculated by means of a computer program to determine in detail the sediment character of the fields. The bedrock topography under and adjacent to the fields is to be determined utilizing a portable hammer seismograph.

After more data are gathered on the natural physical and chemical characteristics of the ground water and the configuration of the water table, the preparation phase of this study will be completed.

The testing phase which will consist of introducing tracers and noting their migration patterns under different pumping conditions is expected to begin during the summer of 1966.

PROJECT TITLE: The Role of Regional Planning in the Public Management of Water Resources: The Case of the Farmington River Basin

PERSONNEL: Roger E. Kasperson

DEPARTMENT: Geology and Geography

PLANNED DURATION: June 1965 through June 1966

OBJECTIVE: To examine critically the role of water resources planning in the use of the Farmington River and to suggest methods of improving the planning process.

REPORT OF ACTIVITIES AND PLANS:

The fundamental problem of the present study may be stated as follows: How well do the existing organizational structure and planning processes serve the public interest in the development of water resources in the Farmington River Basin. Such an investigation has much relevance for current research in water resources, since in the final analysis much of the use of these resources will be determined by public decisions. This study should properly be regarded as a prototype since it will delimit profitable areas for future research. Finally, it is, in a sense, a study of a study because it is concerned with the ultimate success of the Farmington River Plan prepared by Traveler's Research.

The methodology employed for the study began with a series of models and theory of water resource planning. It was decided then to utilize the normative theory of Arthur Maass and to compare it with the empirical situation. To accomplish this, the researchers reviewed past plans and efforts by various governmental agencies in the Farmington Basin. Then, a large-scale interviewing program gathered information concerning attitudes and behavior by different agencies in groups in the planning process. Four major levels were delimited for interim purposes. At the grass-root levels, 375 interviews were taken with citizens in their homes in an effort to determine awareness and perception of water resource problems and personal activities taken to deal with these problems. At the interest group level, nearly 300 questionnaires were collected from members of the Farmington River Watershed Association. Preliminary results indicate a surprisingly low degree of awareness and concern among both these groups with water resource problems.

"Open-end" interviews were also conducted among the local officials of the towns represented in the watershed. Individual town programs were assessed and the degree of interaction between local officials and governmental agencies evaluated. As expected, it was found that there was relatively little coordination among local efforts and a lack of knowledge of the Traveler's Plan. In fact, most towns had not been consulted in the formulation of the plan. The breakdown in communication was especially evident at the Massachusetts-Connecticut boundary. Finally, nearly 25 interviews were conducted among the major governmental agencies involved in water resource planning in the Farmington. Past efforts and future plans were noted and policy conflicts delimited. Opinions of the Traveler's Plan were solicited. Preliminary results indicate a surprisingly high degree of interaction and communication among the agencies.

The current stage of progress of the research is the processing of the data collected in the field. This work is nearing completion and writing will soon be initiated. The output from the project will consist of an evaluation of the empirical situation in the light of existing theory and the formulation of a deductive-empirical model of water resource planning. A series of policy recommendations for improving the public management of water resources will also be forthcoming.

PROJECT TITLE: Correlation of Trace Elements in Ground Waters and Aquifers within the Connecticut River Basin

PERSONNEL: H. C. Liese

DEPARTMENT: Geology and Geography

PLANNED DURATION: June 1965 through June 1967

OBJECTIVES: To determine trace element concentrations in the aquifers and in the ground water (and solid residue)—via spectrographic and spectrophotometric analysis.
To correlate ground water and aquifers on the basis of trace element content.
To compare these correlations with those of previous studies (based solely on major elements and overall mineralogy).

REPORT OF ACTIVITIES AND PLANS:

Recent investigations have revealed that one of the most significant factors that influences the chemical quality of ground water in Connecticut is the mineralogy of the bedrock units and unconsolidated deposits. These recent correlative studies have been based primarily (solely?) on major element analyses of the water and mineral identification of the aquifers. The purpose of this study would be to further and establish more precisely this correlation between ground water and aquifer, on the basis of minor and trace element concentrations. The results of this study could contribute significantly to a better understanding of such ground water problems as pollution and direction of movement. In addition, "unusual" variations in element content would be correlated with communities in which health records are "unusually" poor or good.

The anticipated procedure for attaining this goal is outlined below:

Phase 1: Employing the available equipment, the determination of minor and trace element concentrations from certain minerals separated from selected bedrock units of Eastern Connecticut; the evaluation of the resultant data and equipment relative to feasibility, precision, and accuracy.

Phase 2: Same as phase 1, but determining elements in selected water samples and solid residues. Cooperation will be sought with the Connecticut Water Resources Commission and the U.S.G.S. relative to details of specific analytical techniques and problems involved in such determinations.

Phase 3: Systematic collection of samples from a particular drainage basin in Connecticut – and their element determination. Again, cooperation will be sought with the above-mentioned organizations.

Phase 4: Interpretation, correlation, and evaluation of data, and comparison with results and conclusions of previous studies. Preparation of final report.

Total anticipated time is estimated at 5 consecutive years from date of origin (July 1965).

Phase 1 should be completed by July 1967. Up to date, five minerals (quartz, plagioclase, potassic feldspar, biotite, and magnetite) from each of approximately 50 rock samples (representing 9 metamorphic units) have been separated and prepared for spectrographic analysis. The magnetite samples have been analyzed, and the elements detected include Mn, Mg, Cu, Ca, Ag(?), V, Mo(?), Ti, and Zr. In part, concentrations are related to specific rock units. The samples were arced in a modified Wadsworth mount spectrograph (Applied Research Laboratories), having a 1.5 meter, 960 lines per mm. grating. Spectral lines were determined and measured with a viewer-comparator. Precision was evaluated by determining the standard deviation of 40 runs of one magnetite sample and the results for 5 elements ranged from 5% to 12%. Accuracy is still not known precisely. Owing to the method of measuring intensities, it is believed that, at best, all the results will be semiquantitative. Chemically analyzed standards are being run in order to evaluate the accuracy. It is believed that semiquantitative analysis will be sufficient for ultimate interpretations regarding correlation, in view of the existence of several variable influential environmental factors that could not be quantitatively assessed.

PROJECT TITLE: Relation of Bedrock Fracture Systems to Underground Water Supplies in the Stafford Springs, South Coventry, Spring Hill and Westford Quadrangles

PERSONNEL: Janet M. Aitken

DEPARTMENT: Geology and Geography

PLANNED DURATION: June 1965 through June 1967

OBJECTIVE: To provide information pertinent to problems of potential supply, questions of atypical or excessive flow—and potential contamination.

REPORT OF ACTIVITIES AND PLANS:

The existence of rather well defined fracture systems in northeastern Connecticut suggests that these fractures not only provide avenues of infiltration of groundwater but also provide easy access for contaminants. By investigating systematically the orientation, spacing, and relationships of fracture systems to specific formations or rock types, it is felt that valuable data can be provided for future development and preventive measures.

The data collected may be summarized as follows:

1. *Regional.* Over the area as a whole there is a three-component joint system with the following orientations:

a. roughly North and South
b. roughly East-West
c. diagonal fractures 30 - 50° East or West of North

These show local deviations which will be mentioned briefly elsewhere, but in general seen closely related to the regional fold structure of the area. They may be classified generally as AC or tensional joints and diagonal joints, longitudinal joints are not conspicuous. Tension joints are responsible for most of the abrupt ledges facing S-SE-SW and are reasonably open-space, 6" - 12" apart. Diagonal joints depend on lithology – best developed in fine-textured gneissic zones, obviously important on intersections. No significant correlation was found between spacing and rock types. There does seem to be some significance to local distribution perhaps reflecting major movement zones.

2. *Local.* Outstanding local variants in orientation and/or frequency of occurrence were found at:

a. between Merrow and South Willington
b. South Coventry area
c. South of Stafford Springs on Route 32 – SW to Tolland
d. Bolton Notch

The first two cases apparently reflect slight changes in trend of regional structure. However, the last two cases are thought to represent late overprint structures associated with movement zones possible relating to the en echelon *faults* penetrating the crystalline border from the Triassic.

It is significant that diabase dikes found in the area follow the same trend. They also provide important zones of intersection.

3. *Statistical Interpretation.* The common trends and plunges of possible lines of intersection are as follows:

Cross joints - N 60 - 85 NE - plunging 30° E

Cross joints and AC joints - N 80 - 109 E - plunging 30 - 45 E

Longitudinal joints and x-joints give a variety of trends - e.g., S 65 W - plunge 54° SW; S 36 E - plunge 70 SE; E 25 - plunge 42 SE

4. *Spacing.* Commonly fractures are spaced a foot or two apart. Closer intervals are observed in areas of pronounced folding (e.g., Merrow-W. Willington) or in areas of possible faulting (e.g., Bolton Notch, South of Stafford Springs - to Tolland). In some areas spacing is reduced to intervals of 4 - 6" and outcrops are badly shattered.

Some variability in fracture spacing appears to be related to rock type. Commonly coarse pegmatitic lenses have only a few fractures widely spaced. Closest spacing is found in dense, medium-grained gneissic rocks rich in biotite.

During the course of the study a collection of granitic materials was made to be used also by Dr. Liese.

Investigation of position of bedrock-surficial interface and experimental work on highly fractured bedrock zones is being carried on by means of a Huntec - FS-3 Portable Seismograph.

At present survey lines are run by a simple refraction method utilizing a hammer power source and a single pick-up. The first layer interface has been picked up at depths of 6 - 20 .

No lines have been run as yet over intensely fractured zones in bedrock.

PROJECT TITLE: Analysis of Quasi-Periodic Weather Data

PERSONNEL: C. J. Posey

DEPARTMENT: Civil Engineering

PLANNED DURATION: June 1965 through June 1967

OBJECTIVE: To test a method of analysis of temperature data which is subject to both purely periodic (yearly) and non-periodic ("random" or "stochastic") influences, to see how useful the method might be in application to this type of data.

REPORT OF ACTIVITIES AND PLANS:

The type of analysis being used in this study is apparently new to this field, though it has been applied in several others. Independently developed by at least three investigators, the first published description known to the writer appeared in 1936. It had to do with the identification of roughness profiles, the field in which it has been most widely used. The method is based on the assumption that an equally-spaced sequence of values of an independent variable which has a non-periodic component of fluctuation can be identified and distinguished from another such series which is the result of a different set of physical causes by means of frequency distribution of values of the variable and of its first and second derivatives. Thus, if the variable is land-surface elevation along a north-south line, the distribution of elevations encompasses the total relief along the line, the first derivative tells the range of slopes in that direction, and the second derivative reveals the sharpness of curvatures. These measures have been found to be sensitive enough to identify different glacial drift areas in Iowa.

There is, however, no possibility of a mathematical proof that these three frequency distributions provide a unique means of identification, since it is easy to invent patterns of variation that differ in a manner which would not be revealed by this analysis. Hence, proof of the usefulness of the method has to be entirely pragmatic. Fortunately the mathematically possible exceptions seem to be of a type impossible to arise from natural causes.

In the present study the independent variable is the daily maximum temperature. The existence of punched cards with plenty of data and the availability of a digital computer made it possible to investigate this variable which, as we all know, has capricious fluctuations of varying length superimposed upon one of strict 365-¼ day period. Data are being analyzed from Storrs, Connecticut and from Taipei, Taiwan, and it is expected that data from a station in eastern Colorado will be added. The conclusions indicated by the work completed seem to be of such significance that it is unsafe to state them, even tentatively, until more data have been analyzed.

PROJECT TITLE: Reverse Filter Erosion Protection

PERSONNEL: C. J. Posey

DEPARTMENT: Civil Engineering

PLANNED DURATION: June 1965 through June 1967

OBJECTIVE: To determine the information needed to design reverse-filter erosion protection for soils and other fine-grained materials, and to compare this method with alternative methods.

REPORT OF ACTIVITIES AND PLANS:

As the area taken over by impervious construction such as building roofs, parking lots, and highway and airport pavements increases, there is greater need to take care of the concentrated run-off from rain and snow melt. Drainage ditches lined with grass or rock rip-rap permit some ground-water recharge, but withstand only limited flow before serious erosion begins. Concrete-lined channels are very expensive. They function well, but only up to the design capacity. If that is exceeded, complete failure is apt to result. Asphalt linings are less costly, but are also likely to be destroyed by high flows. Both asphalt and concrete linings hasten runoff and allow little opportunity for ground-water recharge.

A method invented by the Chinese in ancient times spread to India and Europe and is beginning to be used in North America. In its modern adaption, rocks are stuffed into long wire tubes or into wire boxes called gabions. The "rock sausages" or "snakes" are especially resistant to being moved by stream flow, but both they and the gabions may settle due to soil being leached out from underneath. Theoretically, this settling can be eliminated by using an "inverted filter" base, as proposed by Karl Terzaghi to solve the problem of dams being destroyed by underseepage. Terzaghi's suggestion has been thoroughly tested in the laboratories of the U. S. Waterways Experiment Station at Vicksburg, Mississippi, and has been universally adopted for the design of dams and other structures subject to damage if fine material is carried away by underseepage.

The present investigation tests whether Terzaghi's inverted filter will prevent fine material from being eroded out from under rock sausages. Special apparatus is used to subject installations to direct erosion from impingement of a high-velocity jet, and soils of finer particle size are being used than those tested at Vicksburg. Results so far indicate that the finer soils are completely protected by the inverted filter, even though the erosive exposure is much more severe than any previously used in testing, or to be expected in any but the largest drainage ditches.

PROJECT TITLE: The Determination of the Engineering Thermo-physical Properties of Solutions Containing Dissolved Solids

PERSONNEL: D. A. Fisher and L. Greenwald

DEPARTMENT: Mechanical Engineering

PLANNED DURATION: June 1965 through June 1967

OBJECTIVE: To determine the specific heat capacity and enthalpy of normal sea water and its concentrates.

REPORT OF ACTIVITIES AND PLANS:

The current interest in producing pure drinking water from saline, brackish or other contaminated waters has posed many complex engineering problems. Among them, in the field of evaporator design especially, is the need for a catalogue of data on the thermo-physical properties of these solutions. There is at present an acute lack of such engineering data. The purpose of the present research is to provide such data for some selected thermo-physical properties of saline solutions and their concentrates over a suitable range of temperatures.

A thermo-physical property of a solution is a property which specifies the chemical or physical nature of the solution. Examples of such properties are density, specific heat, enthalpy and thermal conductivity. A knowledge of such properties enables one to predict the behavior of a solution as it undergoes some physical change, such as evaporation or a temperature rise.

Evaporator design requires a knowledge of the enthalpy and specific heat of the working solution as a function of temperature and over a range of concentrations. The present research seeks to determine this data for seawater with the aid of a "Drop-Type" or Bunsen ice calorimeter. This type of instrument is currently being used by the National Bureau of Standards and is capable of accuracies in the order of 0.1%. The calorimeter directly measures the heat content, or enthalpy, of the sample at a given temperature. By taking a series of these measurements over a suitable range of temperatures, and fitting the data to a polynomial expression with the aid of a computer, one obtains the enthalpy of the sample as a function of temperature. Taking the derivative of this polynomial directly yields an expression for the specific heat as a function of temperature.

The principle of the calorimeter is quite simple. It is essentially a constant volume chamber filled with a small quantity of pure mercury, and a mixture of distilled, gas free water and ice. All three substances are in thermal equilibrium at atmospheric pressure. A small tube connects the mercury in the calorimeter to an external mercury reservoir, which is a simple capillary tube and beaker arrangement. The sample, in a sealed container, is heated to the desired temperature by means of a nearby furnace. The sample temperature is accurately measured at this time by using a platinum resistance thermometer. The sample and container are then introduced into the calorimeter, and, in coming to thermal equilibrium with their surroundings give off heat which melts a quantity of ice. This causes a quantity of mercury to flow into the calorimeter from the external reservoir in order to maintain a constant volume. This quantity of mercury is then measured by using an analytical balance. A constant factor, independent of the geometry of the calorimeter, relates this mercury volume to the amount of heat added, and thus the enthalpy of the sample and container are known. This enthalpy value will be at the temperature measured in the furnace and have a 0°C. datum. An identical test using the empty container yields the enthalpy of the container alone at that temperature. When the two enthalpies are subtracted, the result yields the enthalpy of the sample alone. Performing these experiments with a seawater sample over the required range of temperatures and concentrations will yield the desired data.

At the present time, the major components of the calorimeter have been assembled. The instrumentation, calibration and experimentation are expected to begin shortly. The calibration will be facilitated by a sample of Al_2O_3 which was supplied by the National Bureau of Standards.

It is expected that when these data are compiled, they will represent the most complete and accurate collection of its kind.

PROJECT TITLE: Reduction of River Heat Pollution by Turbulence Stimulation

PERSONNEL: V. E. Scottron

DEPARTMENT: Civil Engineering

PLANNED DURATION: June 1965 through June 1967

OBJECTIVES: (1) To break up river heat stratification by turbulence stimulation.
(2) To investigate means of raising turbulence levels in order to accomplish item (1).

REPORT OF ACTIVITIES AND PLANS:

About 1961 it became apparent to a number of people who were concerned with river pollution that one of the basic problems that must be faced in the future was the effect of heat introduced by thermal power stations as a consequence of condenser cooling and the like. A limited amount of on site evidence had been collected to show that this heated water tended to stratify in a thin layer near the surface and that this layer persisted for sizeable distances down stream. In certain other cases, it became apparent that part of the heated flow was recirculating back through the condensers to experience a temperature rise closer to 40°F than the designed 20°F.

What effect, if any, does this high temperature zone produce in connection with the river biology? What schemes are available to modify this heat stratification? The first question is under study by several groups and will presumably be understood in the near future. The modification of heat stratification is somewhat less amenable to direct experimental tests. We know, for example, that wind-generated turbulence on the surface of the water will produce high levels of turbulent diffusion in the heated zone. Field tests have indicated that the stratification is broken up quite rapidly by such diffusion. It would appear that other means of generating turbulence might also be effective in mixing these heated river flows.

The objectives of this current research are to study the possibility of generating high turbulence by means of simple boundary shapes. Ordinary boundary roughness at the bottom of a river produces high level turbulence very close to the bottom, but this decreases very rapidly to extremely small levels near the surface. In recent times, the author has been working with both rough boundaries and varying pressures or mean velocities. These tests have indicated that it is possible to generate heavy turbulence away from the boundary. Very simple devices, such as vortex generators of the sort used on airplane wings, are capable of producing high levels of turbulence near a boundary, but we do not know what effect they have on the flow away from the boundary.

Our progress to date has been along two fronts. First, we have studied the existing literature in order to see how much is known of various facets of this problem. Second, we have started to construct necessary experimental equipment.

The literature, in spite of some excellent pieces of work, reveals a real scarcity of information about turbulence. Much of the turbulence data has been assumed without benefit of experimental evidence. Other studies have dealt only with bulk properties and ignored such effects as diffusion.

The laboratory work which we have started does require a bit of explanation. Since we are concerned with the stratification of water, one may well ask why we are proposing to use air flows in our experiments. It turns out that there are no reasonably reliable schemes for measuring turbulence levels in liquids. If we want to measure these levels, we must use air. Another factor of importance is the level of turbulence contemplated. If this is quite low, it is easy to get accurate readings. If the turbulence levels are quite high, it becomes essential to have a standard means for calibrating both electrical and mechanical instrumentation, such as the hot-wire anemometer and the ordinary pitot tube.

A good deal of time has thus gone into the construction of our calibration unit. During the summer we plan to move ahead on the construction of models and the test program.

Attendance List

Baker, John A.
Geologist-in-Charge
U.S. Geological Survey
204 P. O. Building
Middletown, Conn. 06457

Barberet, Gene J. (Mrs.)
Mansfield Conservation
Commission
Farrell Road R. R. #2
Storrs, Conn. 06268

Bartfield, Ira
Hydrologist
River Forecast Center
Bradley Field
Windsor Locks, Conn.

Bertolaccini, Joseph C.
Civil Engineer
Soil Conservation Service
Storrs, Conn. 06268

Bobb, Arthur C.
Professor
Plant Science Dept.
Univ. of Conn.
Storrs, Conn. 06268

Brennan, Michael J., Jr.
Graduate Student
Bacteriology Dept.
Univ. of Conn.
Storrs, Conn. 06268

Brindamour, T. A.
Civil Engineer
Greater Hartford
Flood Commission
11 Asylum Street
Hartford, Conn. 06103

Buck, John D.
Asst. Prof.
Bacteriology Dept.
Univ. of Conn.
Storrs, Conn. 06268

Cervione, M. A.
Hydr. Engineer
U.S. Geological Survey
Federal Building
P. O. Box 715
Hartford, Conn. 06101

Cook, Wendell B.
Assoc. Prof.
3 Hillside Circle
Storrs, Conn. 06268

Cornish, W. B.
Research Asst.
Agricultural Engineering Dept.
Univ. of Conn.
Storrs, Conn. 06268

Curry, John J.
Chief Engineer
223 State Office Building
Hartford, Conn.

Dembrow, Leon W. (Mrs.)
League of Women Voters
Loomis Road
Suffield, Conn.

Despins, William F.
Engineer
c/o The Connecticut
Light & Power Company
P. O. Box 2010
Hartford, Conn.

Dewey, A. W.
Professor
Agricultural Economics Dept.
Univ. of Conn.
Storrs, Conn. 06268

Drobney, Martin
Hydr. Engineer
Soil Conservation Service
Storrs, Conn. 06268

Earl, Thomas
Grad. Asst.
Geology & Geography Dept.
Univ. of Conn.
Storrs, Conn. 06268

Ewing, G. B. (Mrs.)
Editor
Conn. Conservation News
R.F.D. #2
W. Redding, Conn.

Fisher, David A.
Professor
Mechanical Engineering Dept.
Univ. of Conn.
Storrs, Conn. 06268

Foster, E. R.
Executive Director
Conn. River Watershed Council
497 Main Street
Greenfield, Mass.

Giddings, Todd
Graduate Student
Geology & Geography Dept.
Univ. of Conn.
Storrs, Conn. 06268

Grossman, I. G.
Geologist
U.S. Geological Survey
Rm. 204 P. O. Building
Middletown, Conn. 06457

Guttay, A. J. R.
Head
Plant Science Dept.
Univ. of Conn.
Storrs, Conn. 06268

Hale, W. Stanley
County Agricultural Agent
562 New London Turnpike
Norwich, Conn.

Harakaly, Charles H.
Mansfield Center, Conn.

Hawkins, George W.
Asst. Prof.
Agricultural Engineering Dept.
Univ. of Conn.
Storrs, Conn. 06268

Hedden, Daniel T.
Staff Engineer –
Millstone Point Co.
P. O. Box 2010
Hartford, Conn.

Hellstrom, David I.
Civil Engineer
Corps of Engineers
424 Trapelo Road
Waltham, Mass. 02154

Hibbard, John E.
Secretary-Forester

Conn. Forest and Park Assoc.
15 Lewis Street
Hartford, Conn.

Hodovan, Stephen F.
Selectman
Town of Mansfield
Mansfield Center, Conn.

Horton, John
Engineer
U.S. Geological Survey
P. O. Box 715
Hartford, Conn. 06101

Janes, Byron E.
Professor
Plant Science Dept.
Univ. of Conn.
Storrs, Conn. 06268

Kaehrle, William R.
Student
Civil Engineering Dept.
Univ. of Conn.
Storrs, Conn. 06268

Kennard, W. C.
Director
Institute of Water Resources
Univ. of Conn.
Storrs, Conn. 06268

Kersting, E. J.
Director
Ratcliffe Hicks School
Univ. of Conn.
Storrs, Conn. 06268

Kolega, John J.
Assoc. Prof.
Agricultural Engineering Dept.
Univ. of Conn.
Storrs, Conn. 06268

Laramy, Robert E., Jr.
Asst. State Conservationist
Soil Conservation Service
Storrs, Conn. 06268

Lebetkin, George
Chief Chemist
The Metropolitan District
115 Broad Street
Hartford, Conn. 06105

Lee, Richard
Asst. Professor
Plant Science Dept.
Univ. of Conn.
Storrs, Conn. 06268

Leonard, Robert L.
Asst. Prof.
Agricultural Economics Dept.
Univ. of Conn.
Storrs, Conn. 06268

Masterton, William L.
Assoc. Prof.
Chemistry Dept.
Univ. of Conn.
Storrs, Conn. 06268

Mazzaferro, David L.
Graduate Student
Geology & Geography Dept.
Univ. of Conn.
Storrs, Conn. 06268

Melvin, Robert L.
Hydrologist
U.S. Geological Survey
P. O. Building
Middletown, Conn. 06457

Minkus, Alexander J.
Deputy Manager for
Supply and Purification
Metropolitan District
115 Broad Street
Hartford, Conn. 06105

Moeller, William B.
Grad. Student
Civil Engineering Dept.
Univ. of Conn.
Storrs, Conn. 06268

Munsell, R. I.
Retired Agronomist
Storrs, Conn. 06268

Noska, Charles
Grad. Student
Geology & Geography Dept.
Univ. of Conn.
Storrs, Conn. 06268

Papanos, Stanley
County Agent
6 Grand Street
Hartford, Conn. 06106

Partelow, Glenn W.
Student
Middlesex Hall, Rm. 422
Univ. of Conn.
Storrs, Conn. 06268

Pelletier, C. J.
Civil Engineer
R.F.D. #1
Box 35
Storrs, Conn. 06268

Peters, Harold S.
Executive Director
Farmington River
Watershed Association
24 E. Main Street
Avon, Conn. 06001

Peters, R. A.
Agronomist
Plant Science Dept.
Univ. of Conn.
Storrs, Conn. 06268

Prince, Ralph P.
Assoc. Prof.
Agricultural Engineering Dept.
Univ. of Conn.
Storrs, Conn. 06268

Posey, C. J.
Civil Engineer
Civil Engineering Dept.
Univ. of Conn.
Storrs, Conn. 06268

Rahn, Perry H.
Asst. Prof.
Geology & Geography Dept.
Univ. of Conn.
Storrs, Conn. 06268

Rankin, John S.
Director
Marine Research Laboratory
Univ. of Conn.
Noank, Conn.

Rankin, Julia S.
Research Asst.
Bacteriology Dept.
Univ. of Conn.
Storrs, Conn. 06268

Riddell, C.
Veterinarian
Animal Diseases Dept.
Univ. of Conn.
Storrs, Conn. 06268

Ruggles, Fred H., Jr.
Hydrologist
U.S. Geological Survey
P. O. Box 715
Hartford, Conn. 06101

Ryder, Robert B.
Geologist
U.S. Geological Survey
Rm. 204 P. O. Building
Middletown, Conn. 06457

Skauen, Donald M.
Professor
Pharmacy Dept.
Univ. of Conn.
Storrs, Conn. 06268

Smith, Charles A.
Hydrologist
River Forecast Center
Bradley Field
Windsor Locks, Conn.

Smith, P. C.
Civil Engineer
Greater Hartford
Flood Commission
11 Asylum Street
Hartford, Conn. 06103

Southwick, Dwight
Civil Engineer
Soil Conservation Service
Willington, Conn.

Stackpole, Miner B.
Hydraulic Engineer
U.S. Geological Survey
Rm. 224 P. O. Building
Hartford, Conn. 06101

Tedrow, N. Paul
State Conservationist
Soil Conservation Service
Univ. of Conn.
Storrs, Conn. 06268

Thomas, Chester E., Jr.
Geologist
U.S. Geological Survey
Rm. 224 P. O. Building
Box 715 Hartford, Conn. 06101

Thomas, Hugo F.
Asst. Prof.
Geology & Geography Dept.
Univ. of Conn.
Storrs, Conn. 06268

Thomas, Mendall P.
Hydraulic Engineer
U.S. Geological Survey
Federal Building P.O. Box 715
Hartford, Conn. 06101

Trainor, F.
Assoc. Prof.
Botany Dept.
Univ. of Conn.
Storrs, Conn. 06268

Violette, David A.
Student
Civil Engineering Dept.
Univ. of Conn.
Storrs, Conn. 06268

Vitali, Rino
Geologist
Box 99
Main Street
Coventry, Conn.

Ward, Joseph A., Jr.
Chief
Soil Conservation Division
Department of Agriculture
and Natural Resources
State Office Building Rm. 129B
Hartford, Conn.

Wedberg, Stanley E.
Professor and Head
Bacteriology Dept.
Univ. of Conn.
Storrs, Conn. 06268

Wheeler, William C.
Professor and Head
Agricultural Engineering Dept.
Univ. of Conn.
Storrs, Conn. 06268

Whitham, George E.
County Agent Leader
Extension Service
Univ. of Conn.
Storrs, Conn. 06268

Whitworth, Walter R.
Asst. Prof. of Fisheries
Plant Science Dept.
Univ. of Conn.
Storrs, Conn. 06268

Wiggin, David C.
Director
Sanitary Engineering Division
State Dept. of Health
79 Elm Street
Hartford, Conn.

Wilson, William E.
Geologist
U.S. Geological Survey
204 P. O. Building
Middletown, Conn. 06457

Wyman, Edgar P.
Plant Science Dept.
Univ. of Conn.
Storrs, Conn. 06268

Young, W. B.
Dean
College of Agriculture
Univ. of Conn.
Storrs, Conn. 06268