WATER

ANNUAL REPORT
FISCAL YEAR 1966

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ANNUAL REPORT
FISCAL YEAR 1966

ANNUAL REPORT

WATER RESOURCES RESEARCH ACTIVITIES

UNDER PUBLIC LAW 88-379

FISCAL YEAR 1966

Submitted to the Director
Office of Water Resources Research
U. S. Department of the Interior
Washington, D. C. 20240

Water Resources Research Center

Virginia Polytechnic Institute

Blacksburg, Virginia 24061

PREFACE

The Water Resources Research Act of 1964, Public Law 88-379, July 17, 1964 as amended by Public Law 89-404, April 19, 1966, authorized the establishment of State Water Resources Research Institutes or Centers in each of the 50 states, plus Puerto Rico. The purpose was to stimulate, sponsor, provide for, and supplement present programs for the conduct of research, investigations, experiments, and the training of scientists in the fields of water and of resources which affect water so as to assist in assuring the nation at all times of a supply of water sufficient in quantity and quality to meet the requirements of its expanding population.

The Act authorizes appropriations every year (continuing indefinitely) to assist each participating state in establishing and carrying out the responsibilities of a competent, qualified Water Resources Research Institute or Center at one University in each state. It also provides for annual matching funds for the centers, and authorizes annual grants, contracts, matching or other arrangements with educational institutions including the center universities, foundations, private firms, individuals, and local, state, and federal government agencies to undertake research into any aspect of water problems related to the mission of the Department of the Interior which may be deemed desirable and are not otherwise being studied.

In August 1964, Governor Harrison, by letter to President T. Marshall Hahn, designated the Virginia Polytechnic Institute as the center for Water Resources Research in the Commonwealth of Virginia. The Center was established to plan and conduct competent research, investigations, and experiments of either a basic or practical nature, or both, in relation to water resources and to provide for the training of scientists through such research, investigations, and experiments. It also provides the mechanism for cooperation in water resources research with other institutions of higher learning, private research groups, and action agencies throughout the state.

This is a summary of the second Annual Report submitted to the Office of Water Resources Research, Department of the Interior, in compliance with Section 506.1 of the Rules and Regulations Pursuant to the Water Resources Act of 1964 (Federal Register, December 3, 1964).

William R. Walker, Director

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MULTICOMPONENT MASS TRANSPORT IN AQUEOUS AND MEMBRANE SYSTEMS

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August 1966

OBJECTIVE

The objective of this project is the development and critical evaluation of mathematical models for multicomponent mass transport in aqueous and membrance systems. The research performed in the past year can be classified into four areas:

1. Literature search
2. Theoretical developments
3. Collection of experimental data
4. Critical evaluation of mathematical models developed.

PROGRESS

Results of Literature Search

The system of H_2O-NaCl-HNO_3 (water-sodium chloride-nitric acid) was selected as a convenient system for detailed study. Free diffusion, electrical conductivity, and transference numbers were the transport data chosen for study. A comprehensive search was made of the literature to collect all of the pertinent existing transport data for all possible combinations of the components in the H_2O-NaCl-HNO_3 system. That is, a search was made for free diffusion data, electrical conductivity data, and transference data for the following binary and ternary systems.

NaCl-H_2O	HCl-H_2O	HNO_3-$NaNO_3$-H_2O
HNO_3-H_2O	HCl-HNO_3-H_2O	NaCl-HNO_3-H_2O
$NaNO_3$-H_2O	HCl-NaCl-H_2O	$NaNO_3$-HCl-H_2O
	NaCl-$NaNO_3$-H_2O	

A summary of the results of this literature survey is given in Table 1. Reference numbers are listed for the type of data indicated in the table headings. The references are detailed in the bibliography.

Results of Theoretical Development

Only a summary of theoretical results will be included in this report. The theoretical developments are adequately covered in the papers, "Approximate Matrix Methods of Multicomponent Mass Transport in Membranes"

RESULTS OF LITERATURE SURVEY

Data System	Electrolytic Conductance	Diffusivity	Transport Number
$NaCl-H_2O$	7, 12, 22, 26 27, 28, 32, 36	2, 7, 21, 28 36, 39, 42	1, 6, 12, 13, 18 21, 27, 29, 30 43, 44
$HCl-H_2O$	1, 13, 14, 22 28, 35, 36, 38	2, 7, 28, 36 39	1, 12, 13, 14, 18 19, 21, 25
HNO_3-H_2O	1, 16, 17, 22 28, 32, 37	2, 23	1, 3, 4, 15, 16 22, 24, 25, 28, 32 40
$NaNO_3-H_2O$	11, 12, 22, 28 41	20, 23, 33, 36	4, 32
$HCl-HNO_3-H_2O$	9	-------	-------
$HCl-NaCl-H_2O$	5, 10, 21, 31 34	2, 28	-------
$NaCl-NaNO_3-H_2O$	8	-------	-------
$HNO_3-NaNO_3-H_2O$	-------	28	-------

Table 1

and "Convergence of Approximation Methods Used in Multicomponent Mass Transport." These papers will be published in the Transactions of the Faraday Society and Industrial and Engineering Chemistry--Fundamentals Quarterly respectively.

a. An approximate matrix inversion procedure was shown to be particularly applicable to the handling of multicomponent mass transport in membranes, and the conditions for convergence of the method were given.

b. A series expansion procedure was developed for use in handling multicomponent mass transport in solutions, and the conditions for convergence of the method were given.

c. A method for extracting model parameters from experimental data was developed.

Collection of Experimental Data

Because of the shortage of information available for ternary systems, a complete set of electrical conductivity data for the system $NaCl-HNO_3-H_2O$ was determined for the concentration range of 0-1.0N. The determinations were made at 25°C. These data are given in Figure 1. Correlation of

these data awaits successful completion of correlation of the literature binary data--a goal currently being pursued.

Critical Evaluation of the Mathematical Models Developed

The model for multicomponent mass transport currently being evaluated in an approximate, inverted form of the Stefan-Maxwell equations in which the driving forces have been generalized to include gradients in both chemical and electrical potential. The approximate inversion procedure is covered in the publications emanating from this research. Only a summary of the main results are given here.

A model for multicomponent mass transport consists of a flux expression for each component in the system. The flux equations must be an explicit expression containing: driving forces, F_i, concentrations, and parameters for the system. From irreversible thermodynamics, the general form of these flux expressions is known to be linear in the forces. Thus in a system of n-components, the flux of species i, N_i, must be of the form shown in Eq. (1):

$$\vec{N}_i = \sum_{j}^{n} 1 \quad L_{ij} F_j \tag{1}$$

The L_{ij} are the phenomenological coefficients, and these are complex functions of concentration and system parameters, but are independent of the forces, F_j. A model for multicomponent mass transport gives an explicit, algebraic expression for the L_{ij} in terms of the concentrations, C_j, and the system parameters.

In the model developed for testing here, the system parameters are given the symbol N_{ij} and the predicted expression for the L_{ij} given in (1) are as follows:

$$L_{ii} = C_i U_i \tag{2}$$

$$L_{ij} = N_{ij} C_i U_i C_j U_j \tag{3}$$

$$i \neq j$$

$$\text{where:} \quad U_i = \left(\sum_{j \neq i} C_i N_{ij}\right)^{-1} \tag{4}$$

SPECIFIC CONDUCTIVITY VERSUS CONCENTRATIONS

OF SODIUM CHLORIDE AND NITRIC ACID

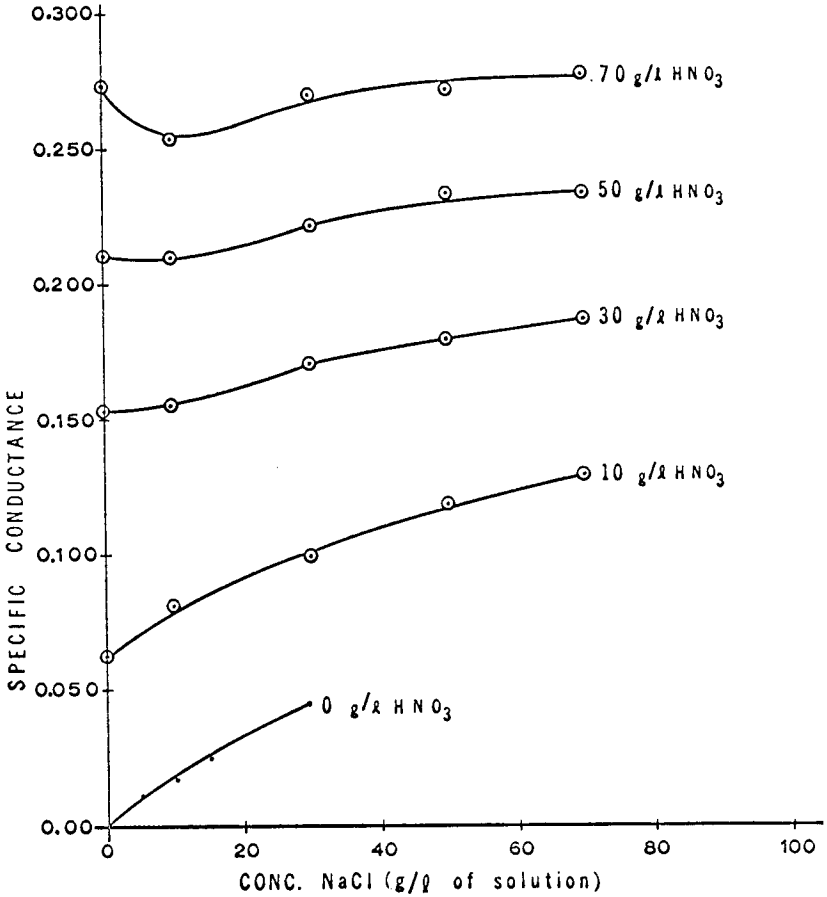

Figure 1

The testing of this model is carried out in several steps. First of all, predictive expressions are derived for the transport data using the flux expressions given in Eq. (1), (2), (3), and (4). Then a computer program is developed to select an optimum set of parameters N_{ij} using a least square error criteria. These optimum parameters are used to predict transport data for which complete experimental data is also available. And finally, experimental and predicted results are compared. Binary data obtained from the literature is being processed currently. Figures 2, 3, and 4 show some preliminary results for the system $NaCl-H_2O$. In Figure 2, the experimental electrical conductivity is shown as a function of salt concentration over the range 0-1.0N (solid curve). The calculated conductivities are shown as small circles at the concentration intervals of 0.1N. Figure 3 shows predicted and experimental data for free diffusion, and Figure 4 shows similar data for transference number.

Another parameter being investigated is the effective hydration number of the salt. For example, Figure 5 shows the behavior of the optimum predicted diffusion coefficient for HCl in H_2O with the effective hydration number of the acid as a parameter.

To date, preliminary correlations have been made of the binary systems $NaCl-H_2O$, $HCl-H_2O$, HNO_3-H_2O. Optimum parameters have been obtained for these three systems with the effective water of hydration as a parameter ranging from 0.5 to 7.5 in increments of 0.5. As yet, the computer programming that will select the optimum water of hydration has not been developed.

Tentative conclusions made on the basis of the results to date are:

a. The model of multicomponent mass transport currently developed with one set of parameters can be used to predict free diffusion, electrical conductivity, and transference numbers. Maximum deviations of predicted vs. experimental data are on the order of 2-5% in the concentration range 0.1 to 1.0N. Somewhat less satisfactory agreement is observed in the concentration range 0-0.1N.

b. For salts, the parameter representing anion-cation interactions (N_{12}) is an order of magnitude greater than the parameters reflecting ion-solvent interactions.

ELECTRICAL CONDUCTIVITY OF

SODIUM CHLORIDE SOLUTION

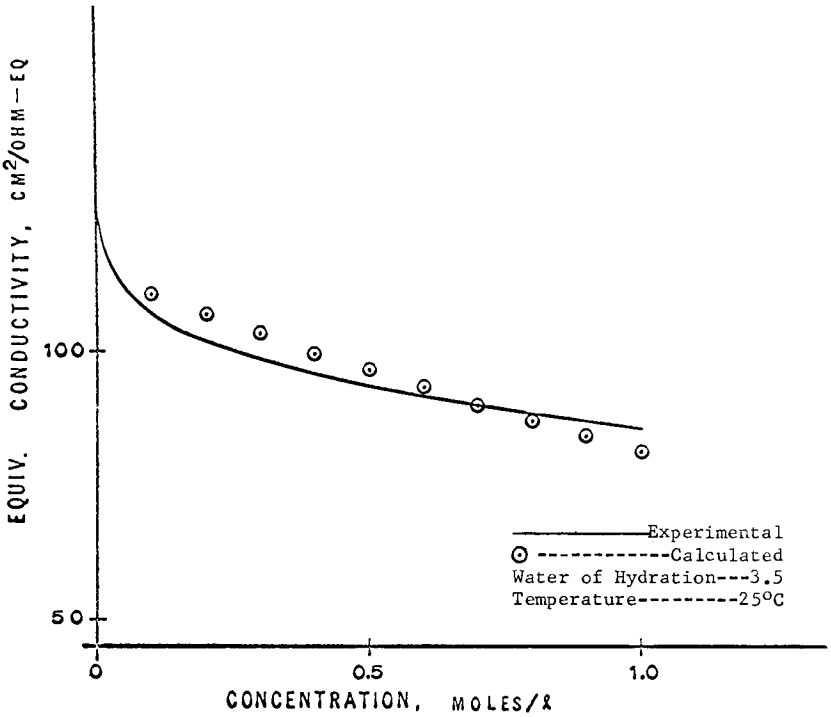

Figure 2

DIFFUSION COEFFICIENT OF SODIUM CHLORIDE

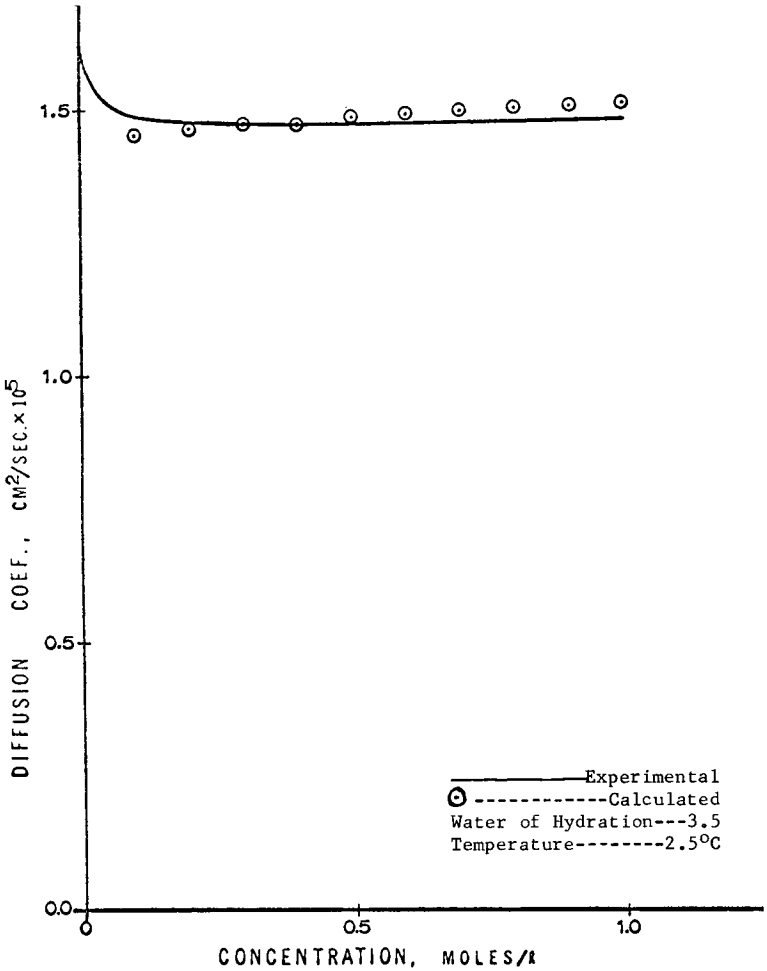

Figure 3

TRANSFERENCE NUMBER OF

SODIUM CHLORIDE SOLUTIONS

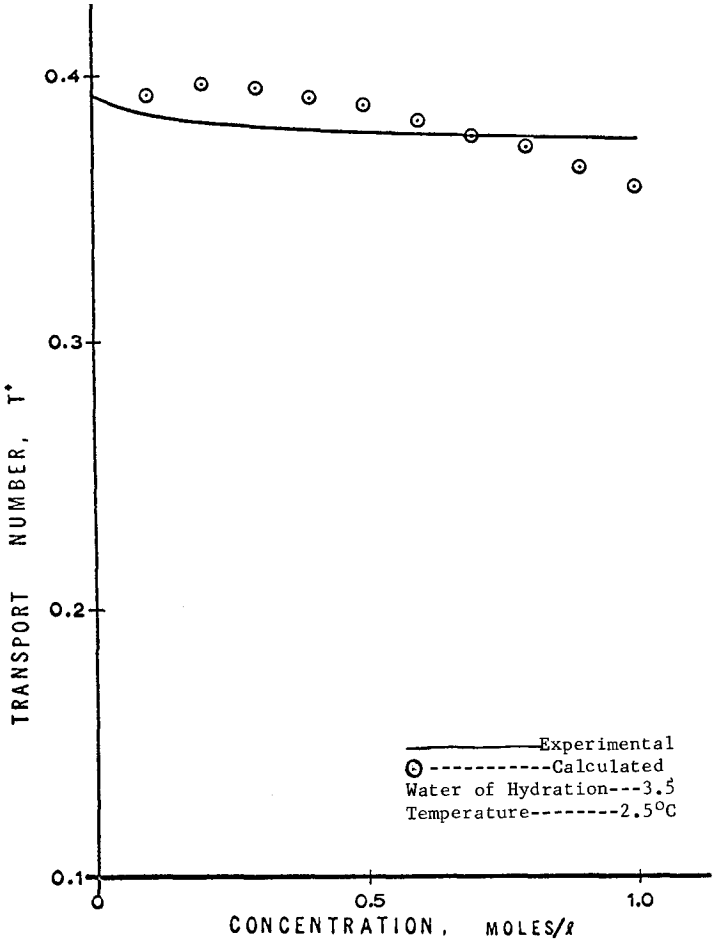

Figure 4

PREDICTED DIFFUSION COEFFICIENT FOR SEVERAL

EFFECTIVE WATERS OF HYDRATION FOR $HCl-H_2O$

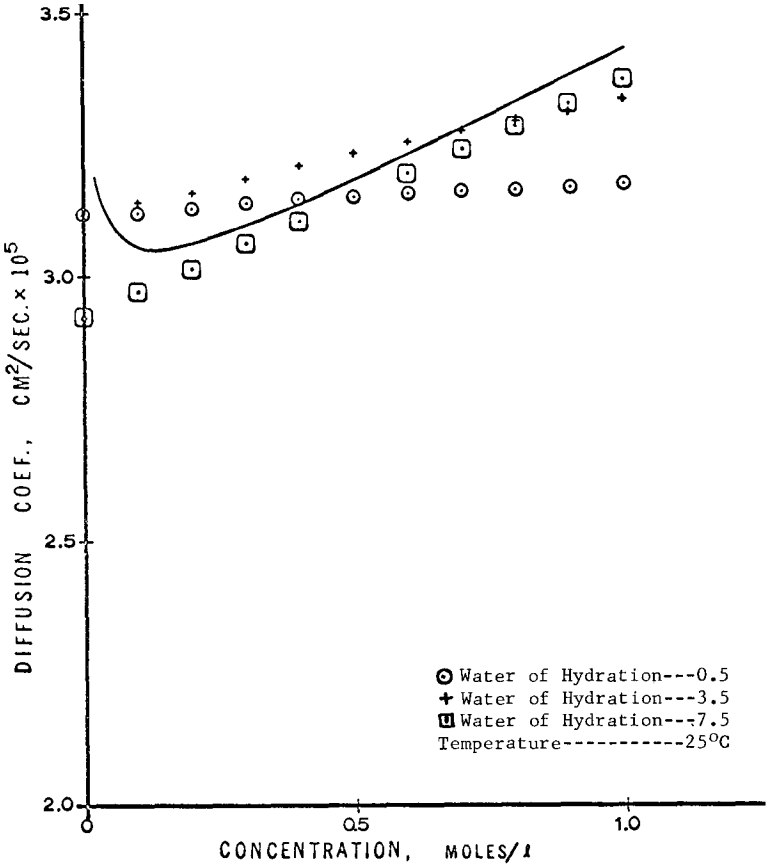

Figure 5

For acids, however, the anion-cation interaction parameter is of the same order of magnitude as the ion-solvent interactions. This result is rather surprising and is as yet unexplained.

c. The multicomponent mass transport model, as presently developed, is sufficiently accurate to be useful in correlating data. However, an improved model is needed for the more exacting role of data extrapolation.

Project work includes completion of the mass transport correlations for binary systems and ternary systems. A computer program to establish optimized water of hydration numbers also needs to be developed. Some additional experimental data may be needed for ternary systems but this is uncertain at present.

Finally, it is hoped that theoretical improvements can be made in the mass transport model, but work on this is being delayed until further correlations are completed.

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C O N C E N T R A T I O N

O F

P H O S P H A T E S L U D G E S

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August 1966

OBJECTIVE

The treatment of domestic sewage presently has the goal of removal of suspended solids and the mineralization of organic pollutional constituents so as to avoid excessive depletion of dissolved oxygen in receiving waters. Problems have arisen in natural watercourses receiving mineralized effluents from sewage treatment plants from overgrowths of algae and other aquatic plants. The problem has been termed "secondary pollution." The control of secondary pollution by limiting the discharge of an essential fertilizer element such as nitrogen or phosphorous has been advocated. Other objections to the presence of excessive phosphates are the increased turbidity resulting from stabilization of dispersions and the increased coagulant demand at downstream water treatment plants. The present investigation is concerned with the application of a chemical treatment process using lime to effect a partial removal of phosphate from effluents of sewage treatment plants. The object is the investigation of crystal seeding techniques to minimize sludge volume and maximize the efficiency of the process in terms of reagent requirement.

PROGRESS

The removal of phosphate from sewage treatment plant effluents is not a new process; it has been studied previously. The limitations associated with the previous processes were the cost of the lime, the additional volume of sludge, and the high pH of the effluent. A review of the limitations suggested an investigation of phosphate removal from supernatant liquor of sludge digestion. Supernatant liquor of sludge digestion normally amounts to less than 0.5 per cent of the sewage flow, yet it is reported to contribute about 70 per cent of the total phosphate to the effluent. The indicated procedure would eliminate the effluent pH problem, would minimize reactor tank sizes, and would not adversely affect lime dosage per unit of phosphate removed. It is felt that such a process

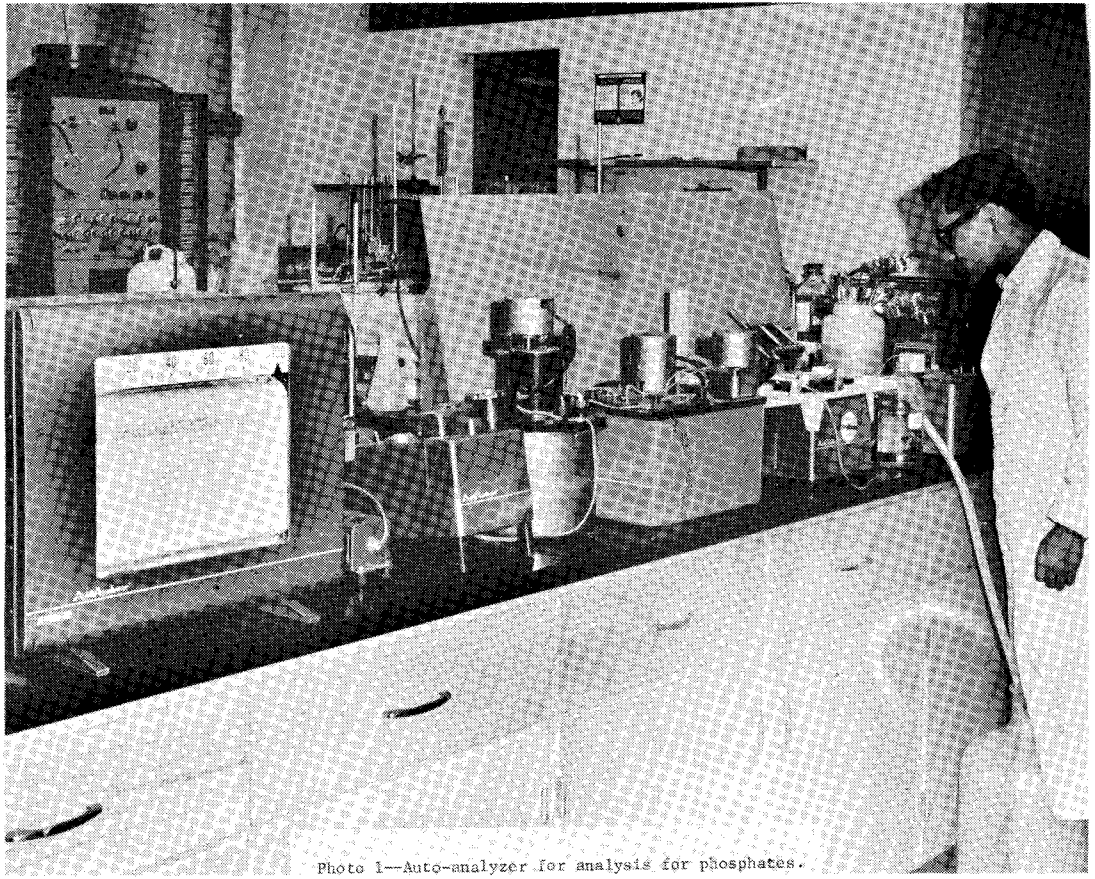


Photo 1--Auto-analyzer for analysis for phosphates.

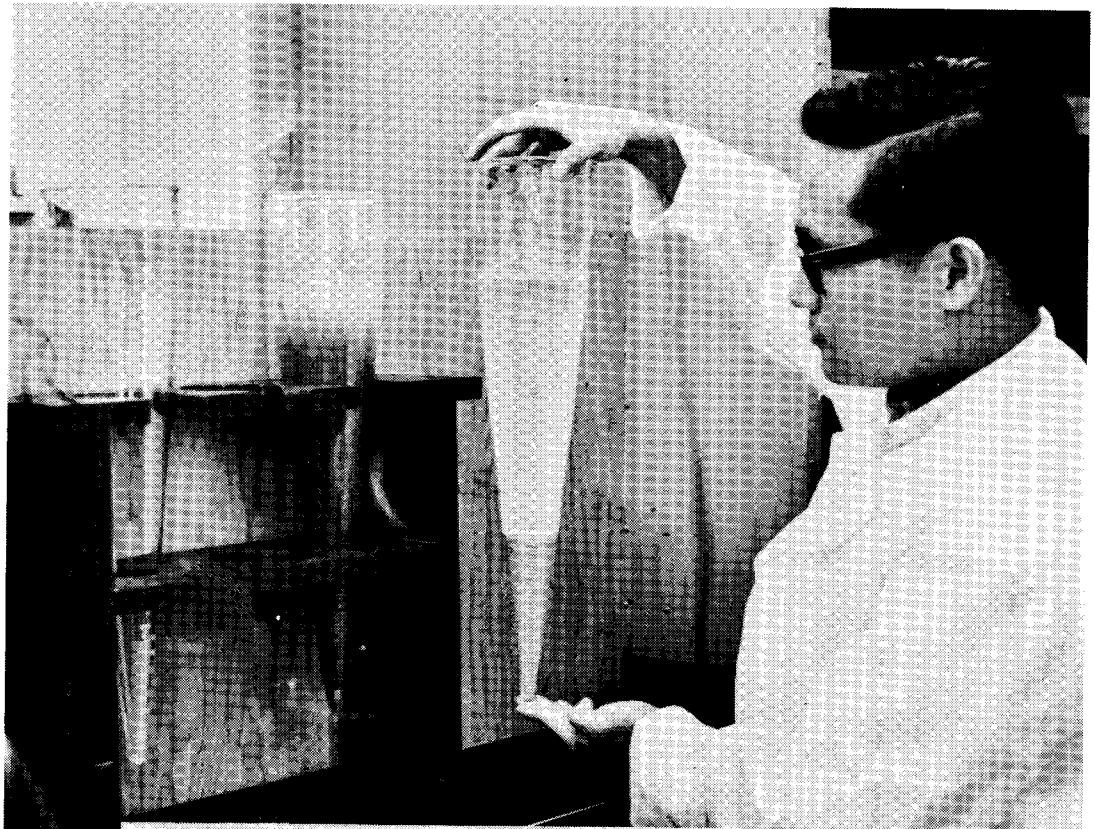


Photo 2--The effect of lime treatment on the clarity of digester supernatant liquor.

would be practical for an immediate partial removal of phosphate from sewage effluents pending an overall program of control of phosphate contributors to a watershed. The expected reduction in phosphate would amount to 55 to 65 per cent.

The first phase of the research consisted of the development of methods of analysis of total phosphate (organic, polymerized and ortho) in the complex highly colored supernatant liquor. An automated analysis was a practical necessity in view of the large number of determinations involved. A digestion procedure was developed to destroy color interference and to convert all phosphate to the ortho form prior to analysis colorimetrically. Automated analysis of the digester supernatant, high in color and suspended and dissolved materials, proved feasible inasmuch as satisfactory correlation with the digestion procedure was obtained.

Digestor supernatant liquor was obtained from the Stroubles Creek Sewage Plant of the Blacksburg-VPI Sanitation Authority and characterized by analysis of pH, alkalinity, acidity, suspended solids, total solids and fixed solids. Samples of supernatant were treated for removal of phosphate by addition of slurried high calcium hydrated lime. The pH, sludge volume, and suspended solids concentration, were observed as functions of the settling time. Analysis of the residual phosphate results and the sedimentation-compaction curves suggested that a settling period of about 12 hours was desirable. Under these conditions, 80 to 90 per cent removal of phosphate could be effected by lime dosages of from 6500 to 8000 ppm. The sludge volume was increased about ten percent above volumes for normal treatment.

The second phase of the studies consisted of treatment of the digestor supernatant with slurried high calcium hydrated lime in the presence of previously precipitated sludge (reaction product). This "return sludge" process indicated that an increase in sludge density and a reduction in lime dosage for comparable process performance was effected by the modified procedure. The implication to date is that lime dosages can

be decreased by about 15 per cent through employment of the return sludge process and the volume of sludge to be handled will be decreased by about 25 per cent. Ancillary benefits were realized in terms of reduced concentrations of hardness, pollutional material, and alkalinity. The experimental results are summarized in the accompanying Tables and Figures.

Work remaining to be done on this project includes the investigation and evaluation of the following variables:

1. The effect of dosage of seed nuclei
2. The effect of rate of reagent addition
3. The effect of agitation rate
4. The effect of temperature
5. The effect of conversion to continuous flow
6. The effect of biological pretreatment.

During the calendar year, 1966, it is anticipated that an evaluation will be completed of the effect of dosage of seed nuclei, the effect of rate of reagent addition and the effect of biological pretreatment.

EFFECT OF LIME DOSAGE AND SETTLING TIME ON PHOSPHATE REMOVAL FROM DIGESTER SUPERNATANT LIQUOR

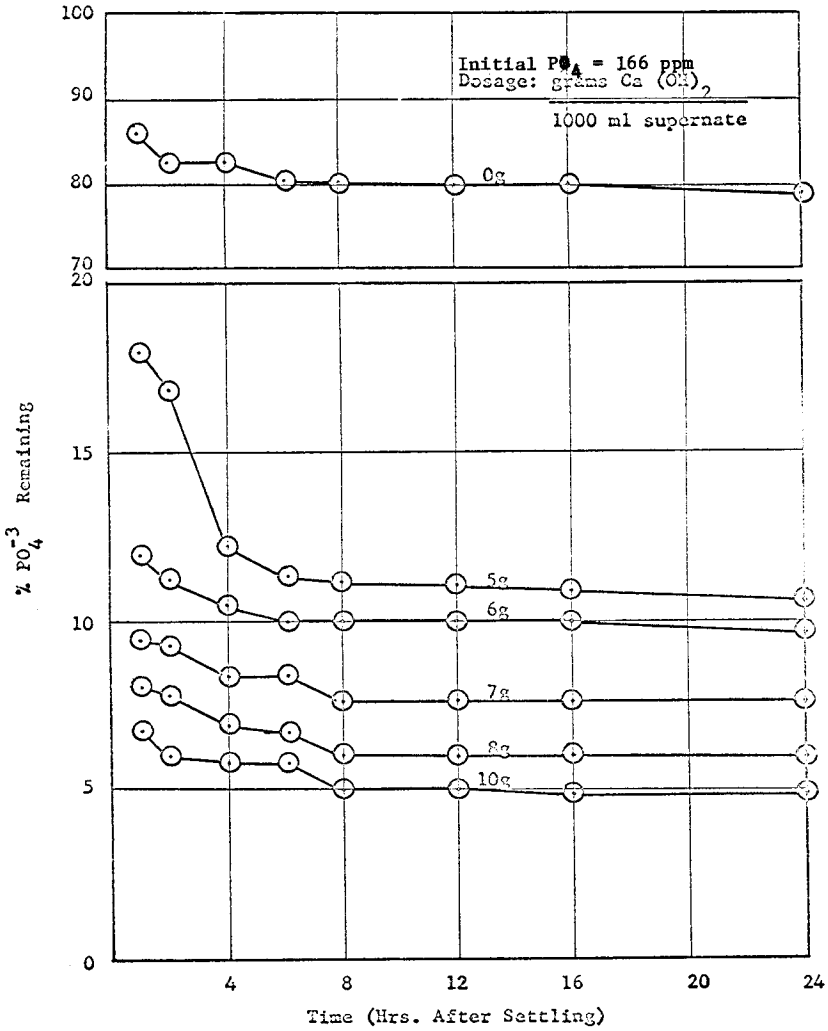


Figure 6

SETTLING CHARACTERISTICS OF SLUDGES PRODUCED

BY LIME TREATMENT OF SUPERNATANT LIQUOR

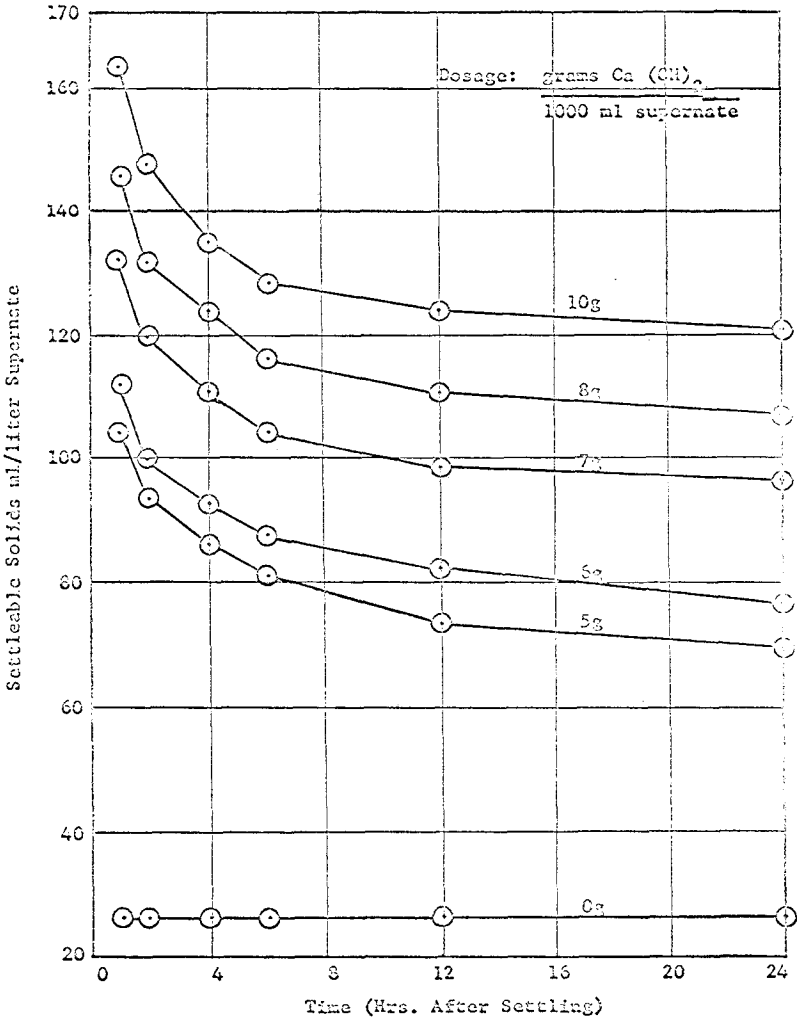


Figure 7

THE EFFECT OF SLUDGE RETURN ON PHOSPHATE RESIDUAL FROM

TREATMENT OF DIGESTER SUPERNATANT WITH LIME

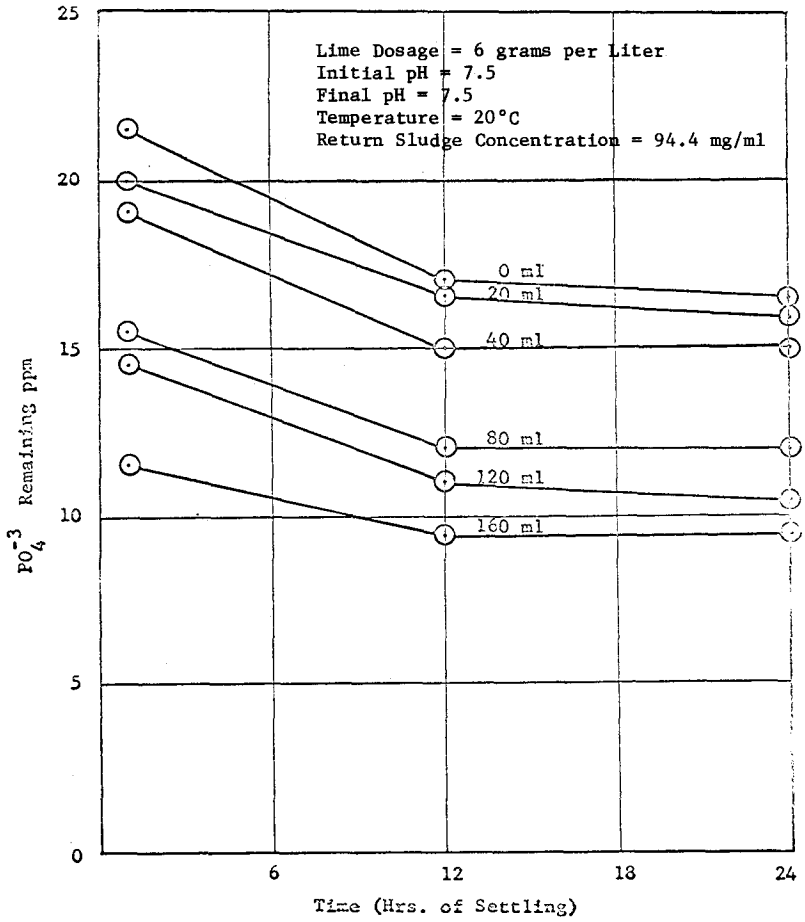


Figure 8

EFFECT OF RETURN SLUDGE ON SLUDGE VOLUME FROM

TREATMENT OF DIGESTER SUPERNATANT WITH LIME

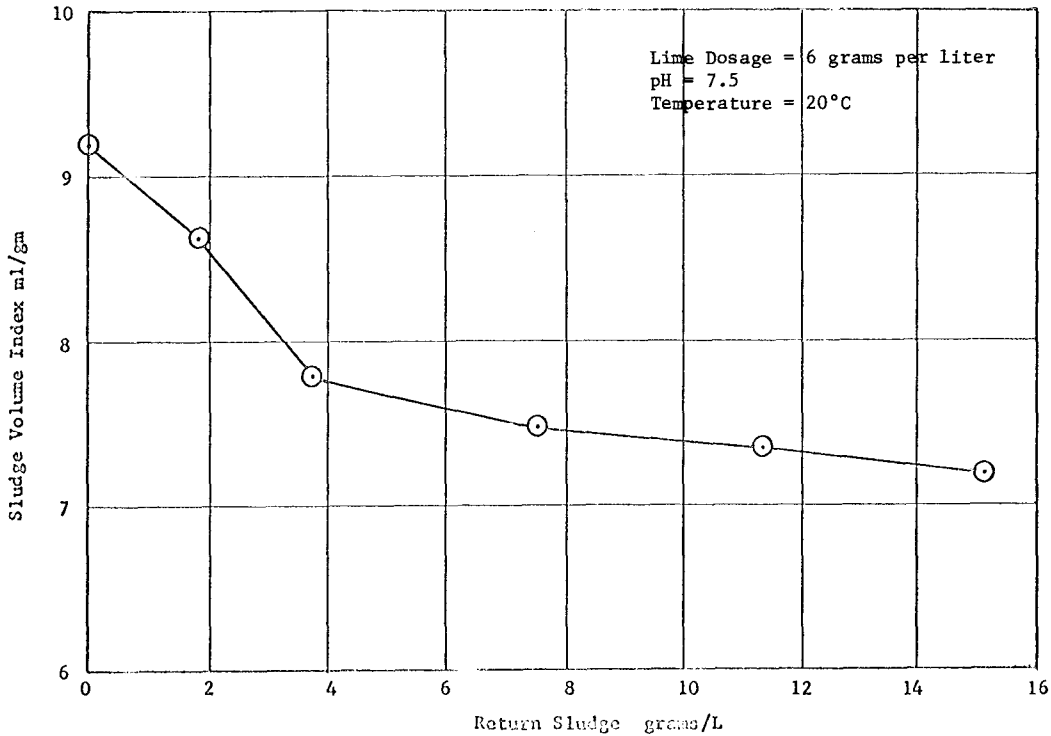


Figure 9

RESULTS OF CHEMICAL CHARACTERIZATION OF

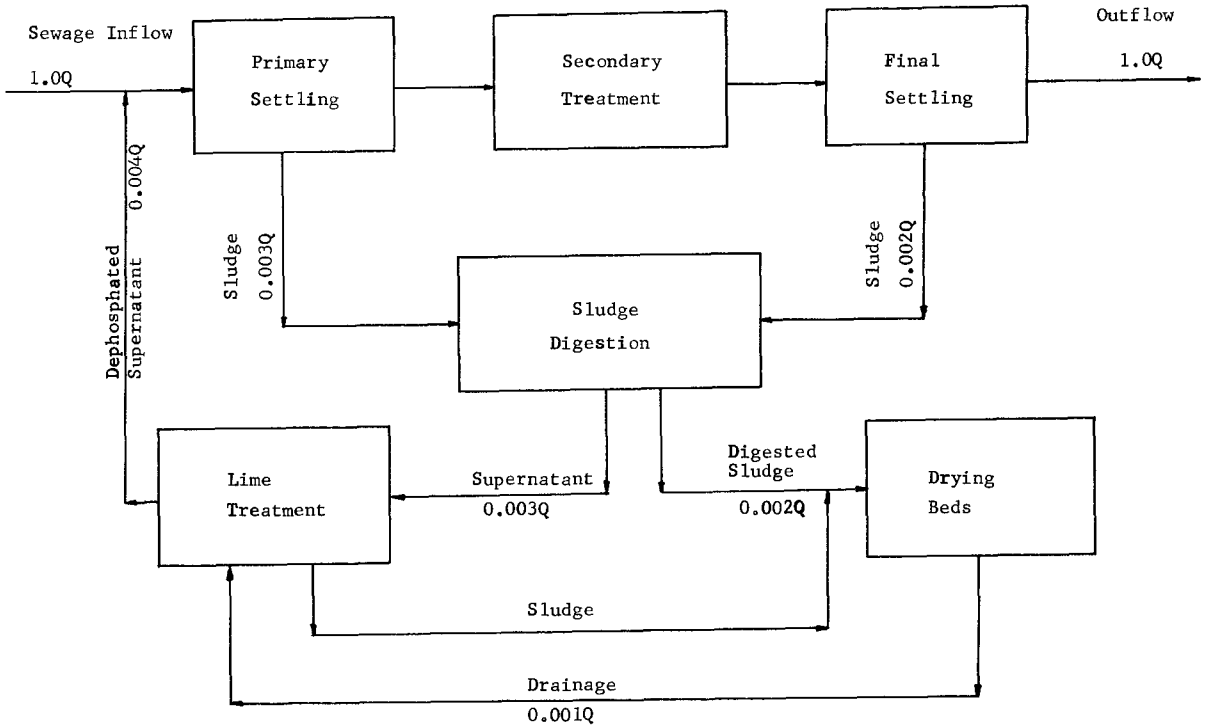
INFLUENT AND EFFLUENT FROM

LIME TREATMENT OF DIGESTER SUPERNATANT LIQUOR

Items	Influent	Effluent	Percentage Decrease
pH	7.84	12.10	------
Acidity, ppm as $CaCO_3$	327	0	100.0
Alkalinity, total, ppm as $CaCO_3$	3047	2265	25.6
Volatile Acid, ppm	147	59	60.0
Total Solids, ppm	3965	2127	46.4
Volatile Solids, ppm	2181	849	61.0
Fixed Solids, ppm	1784	1378	22.8
BOD, ppm	562	300	46.5
Hardness, Total, ppm as $CaCO_3$	23085	15675	32.2
Phosphate, ppm as PO_4	172	11.5	93.4

Table 2

PHOSPHATE REMOVAL FLOW SHEET



WATER QUALITY IN RELATION TO AQUATIC PLANTS AND THEIR CONTROL

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August 1966

OBJECTIVE

Chara vulgaris and *Myriophyllum spicatum* (Eurasian milfoil) are two aquatic plants which present problems to some areas of Virginia. Chara is probably most severe of the weed problems in small water impoundments in hard water regions. Milfoil has invaded the oyster fishing areas of Virginia and has been found in some fresh water ponds. Current methods for control of these aquatic plants are not applicable to small impoundments or create potential health hazards to oyster growing areas.

PROGRESS

Field trials were initiated to test the effectiveness of certain herbicides on these aquatic plants. 2,4-D and the disodium salt of endothall at 20 lb/acre and 3 ppm respectively appear to control Eurasian milfoil. The disodium salt of endothall was applied on May 1, 1966 to a one-acre pond (90% covered with milfoil) and periodic checks show very little regrowth to date.

Dichlobenil was supplied post emergent on chara in two ponds. In one of these ponds, varying granular rates were used. Dichlobenil has label registration for pre-emergent chara applications; however, in most Virginia waters, chara grows throughout the year. Results to date are not conclusive.

Radioactive nutrients and herbicides are being applied to segments of these plants in an attempt to trace their translocation patterns and sites of accumulation. The results from these applications should become apparent in the near future.

Photo 3 shows four temperature controlled water baths installed during July and August of 1965. The baths are equipped with refrigeration, heating elements, circulating pumps and thermostats. Above each tank a bank of 10, one-hundred watt Gro--Lux flourescent lights permits light intensity and duration to be altered. These water baths enable plant

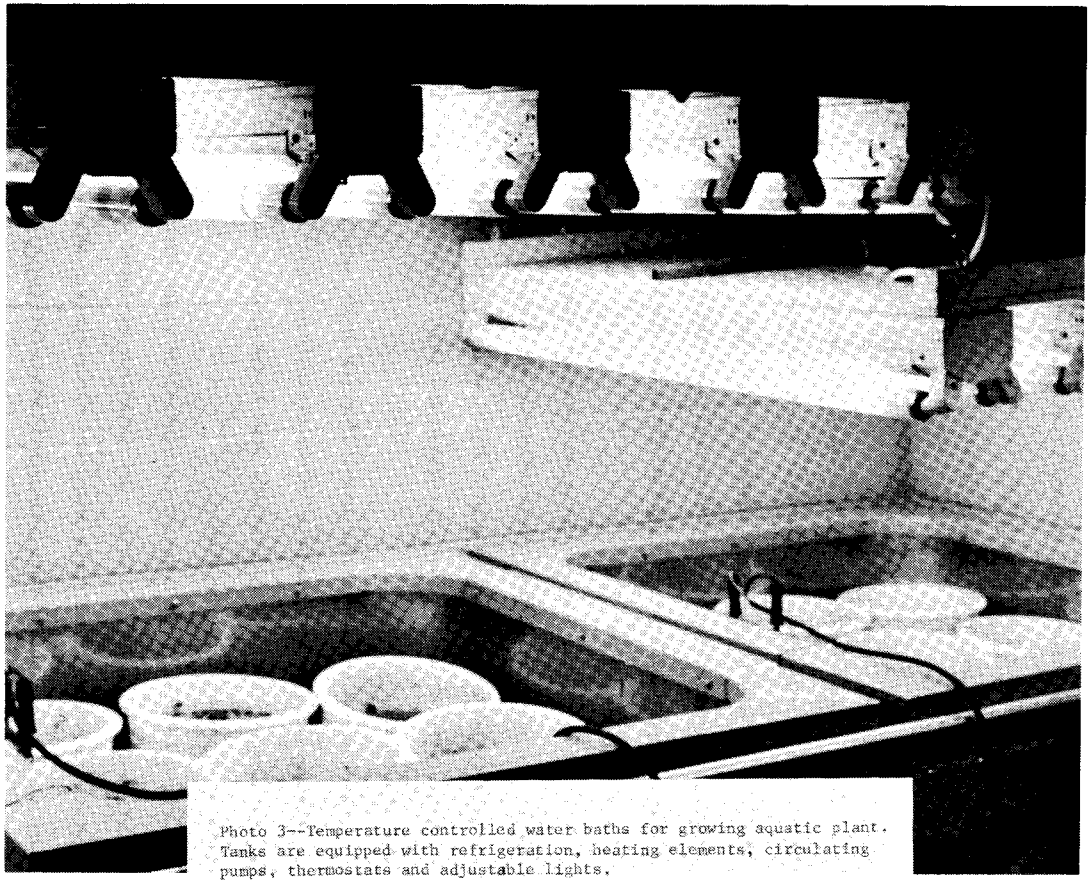

Photo 3--Temperature controlled water baths for growing aquatic plant. Tanks are equipped with refrigeration, heating elements, circulating pumps, thermostats and adjustable lights.

Photo 4--Interior of environmental controlled growth chamber in which plants are placed when more detailed studies are to be carried out.

specimens to be maintained in the laboratory under controlled conditions. An environmental controlled growth chamber was also installed in which plants are placed when more detailed radioactive studies are made.

Photo 5, 5A, and 6 show the aquatic plants Chara vulgaris and Potamogeton crispus prepared for treatment with radioactive chemicals. In preparing for these studies, the plants are strung through funnels leaving part of the plants exposed above and below the funnel stem. The stem is then filled with melted eicosane (m.p. approximately 95°F) which hardens to form a barrier between upper and lower portions of the plant. The water above and below the eicosane barrier may be treated differently. Chara plants treated in this manner show cytoplasmic movement when viewed under a microscope, indicating the cells are still functioning.

Autoradiographs made from chara plants treated with C^{14} labeled 2,4-D at 1, 2 and 3 ppm indicate that radioactive substances move from site of application to untreated areas. Radioautographs made from chara treated at 1, 2 and 4 ppm C^{14} labeled simazine indicate very little movement of radioactive substances.

Partitioned chara and milfoil plants were also treated with $C^{14}O_2$ added to the water media as sodium biocarbonate. Autoradiographs were made and initial results show that C^{14} moved throughout the plants in twenty-four hours.

Chara cells in the middle of the thallus were destroyed by dipping in 50°C water for one minute and then being placed in eicosane funnels. $C^{14}O_2$ was applied above and below the barrier and the autoradiographs indicate that C^{14} moved across the inactive cell, with some resistance, to the living areas. The C^{14} does not appear to accumulate appreciably in the dead cells.

Plant extractions were made from chara plants treated with $C^{14}O_2$. In an attempt to identify C^{14} labeled products in the extractions, paper chromatographs were made using two solvent systems and co-chromatographed with known sugars. Chemical extractions and paper chromatographs were

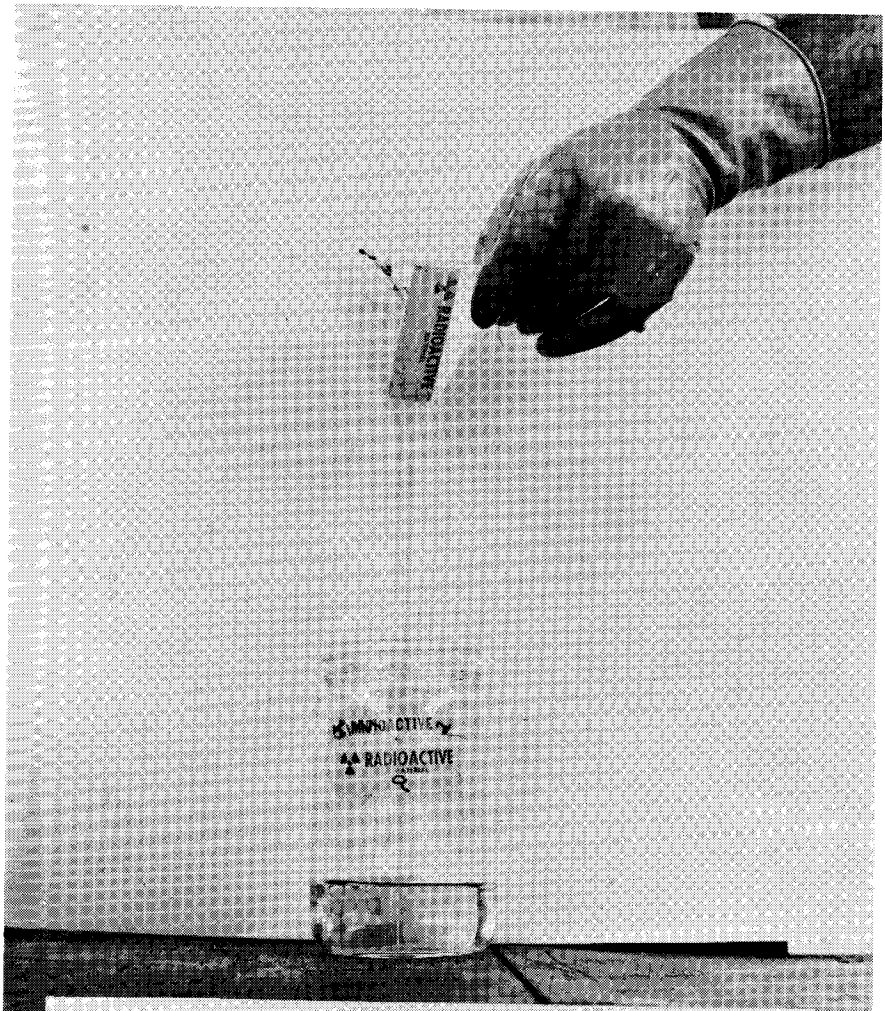

Photo 5--*Chara vulgaris* prepared for treatment with radioactive chemicals. The funnel stem contains an eicosane barrier which separates the plant parts.

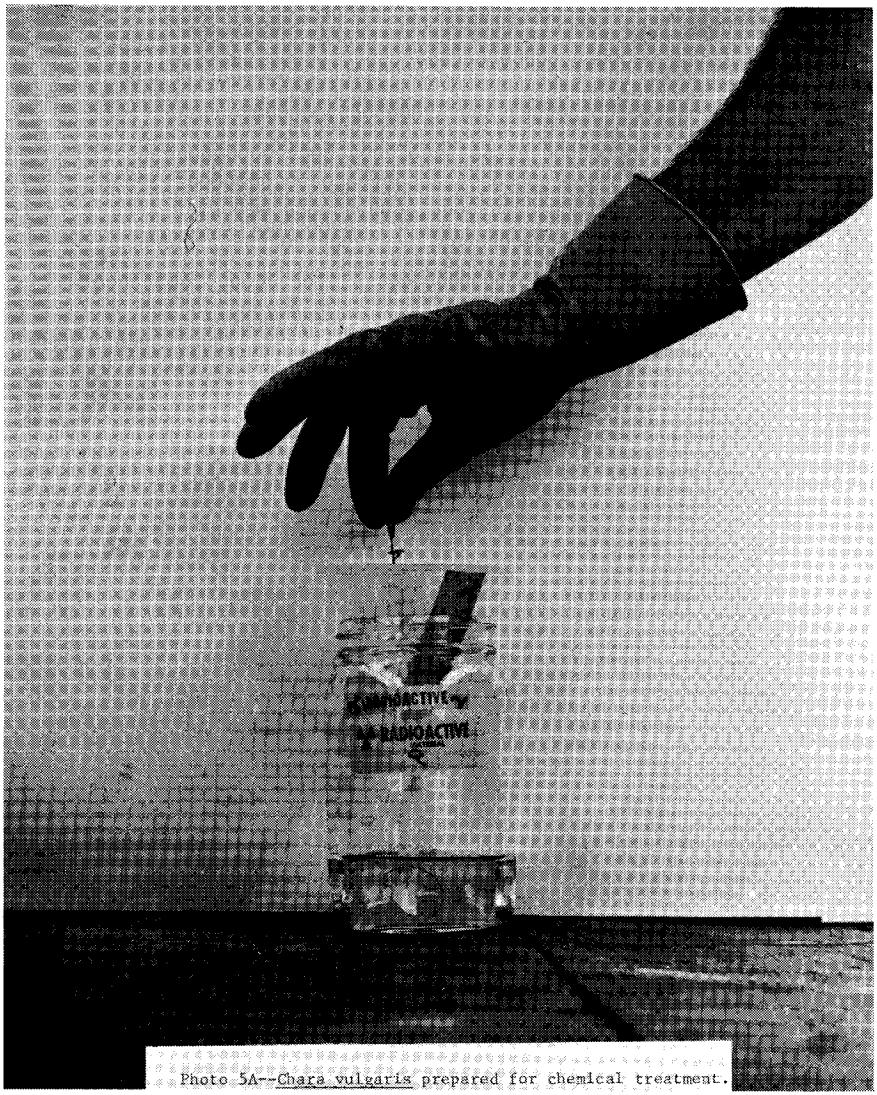

Photo 5A--Chara vulgaris prepared for chemical treatment.

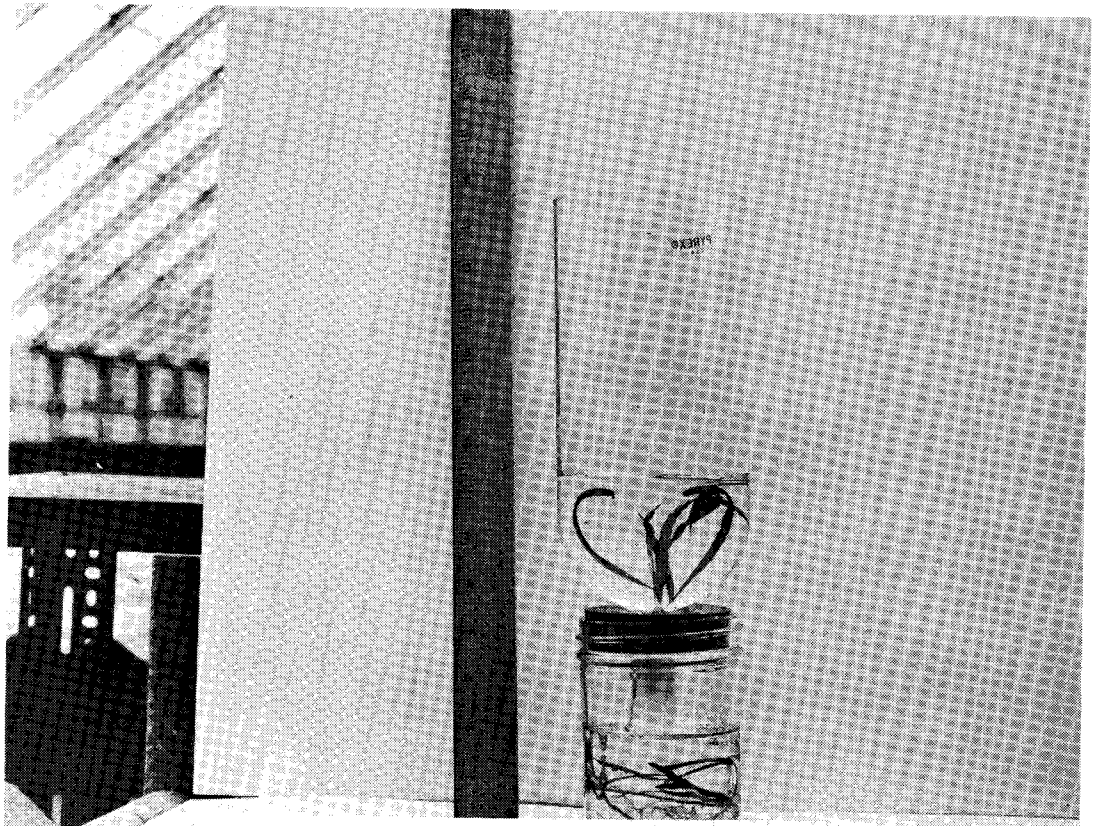

Photo 6--*Potamogeton crispus* prepared for treatment with radioactive chemicals.

also made using chara plants treated with C^{14} labeled 2,4-D in an attempt to identify herbicide degradation products.

Different methods of culturing Myriophyllum spicatum in the laboratory were investigated. Individual plants propagated in small cups containing sand medium for support and attachment (Photo 7) showed best overall growth, whereas those propagated in small cups containing soil gave larger root systems as determined by dry weights. Each cup was placed in a plastic bucket which contained water to simulate the natural aquatic environment.

Uptake, translocation, and site of accumulation of radioactive sulfur, phosphorous, and calcium are to be studied in Chara vulgaris and Myriophyllum spicatum. Attempts will be made to determine whether these specimens absorb and translocate nutrients from the soil-attached plant parts or directly from the water media. If nutrients are found to enter these plants via the water media rather than through the root system, it offers interesting possibilities for minimizing growth by controlling nutrient uptake. Similar treatments will be made using two common herbicides 2,4-D and simazine. Plant extractions and chromatography will be used to identify degradations products of the herbicides when applied to water surrounding the plants. The results may prove herbicides are absorbed directly into the plant tissue without entrance through the roots. If this method proves satisfactory, a more efficient and economic way will have been developed to treat these two aquatic plants.

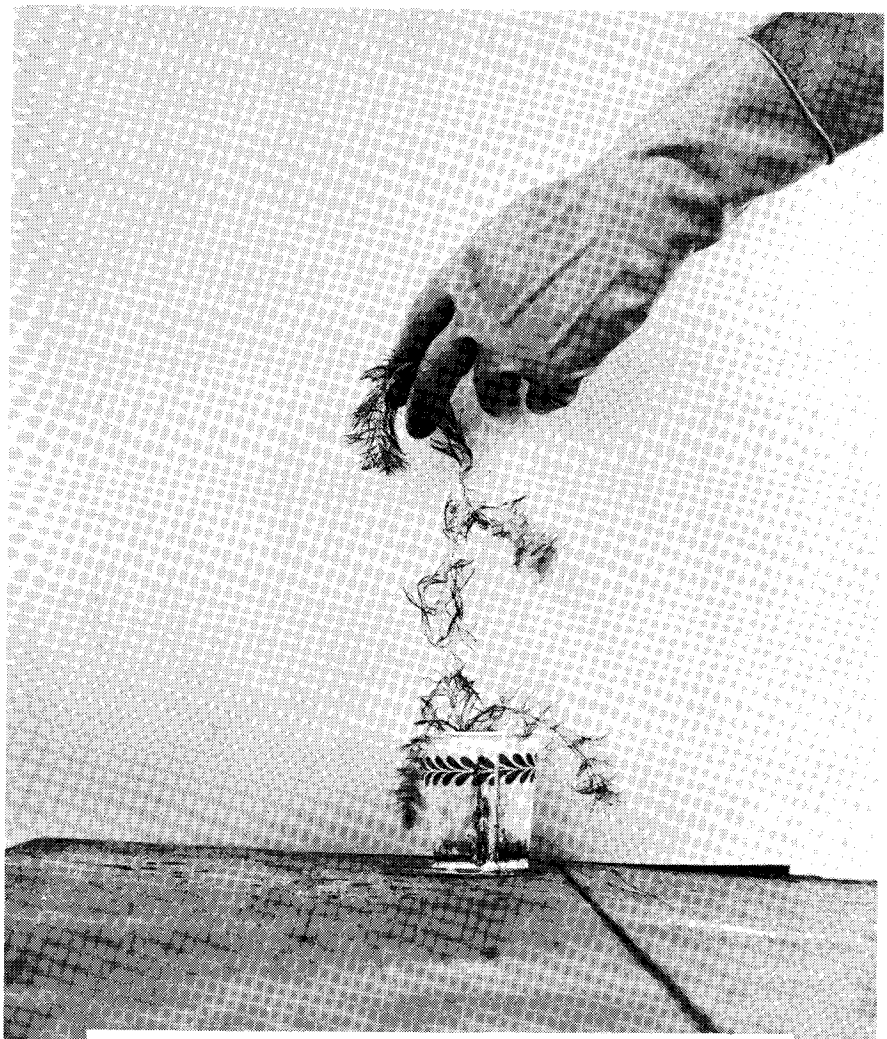

Photo 7--Individual plant of *myriophyllum spicatum* growing in small cup containing sand for attachment.

EVALUATION OF GEOHYDROLOGIC FACTORS IN ESTIMATION OF RUNOFF COEFFICIENTS IN WATERSHED EMBRACING MULTIPLE GEOLOGIC TERRANE

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August 1966

OBJECTIVE

The objectives of this research are to develop quantitative data on rainfall and runoff in a select watershed whose entire bedrock geology has been mapped in detail and whose area embraces a number of geologic terranes typical of watersheds in the Central Appalachian Mountains. The area selected for study is the Peak Creek Watershed of Wythe and Pulaski counties, Virginia, the lower portion of which constitutes Gatewood Reservoir, the public water supply impoundment area for the Town of Pulaski.

PROGRESS

Long-period water discharge recorders have been established at eight strategic locations designed to cover the readily distinguishable geologic terranes, each of which has different characteristics of runoff. From these data, it will be possible to determine rather accurately the rainfall-runoff on sample areas in the Peak Creek Watershed, whose individual areas are precisely known. The total area underlain by a given set of similar rock formation (constituting a sampled terrane) can be determined from available geologic maps and the expectable consummate runoff for each geologic terrane in the watershed can be calculated on the basis of that observed in sample plots. The total discharge of water from the fifteen square-mile drainage area can be determined accurately from water released from the reservoir plus calculated loss by direct evaporation of impounded water in Gatewood Reservoir. The calculated total theoretical runoff values for the total areas of all geologic terranes will be adjusted by established procedures, and an accurate approximation of the rainfall-runoff coefficient for each terrane underlain by different type of rock can be derived. Since these terranes are duplicated in many other watersheds, the runoff values will be useful in estimation of the potential value of other impoundment areas composed of one or more of the representative terranes studied in the Peak Creek Watershed.

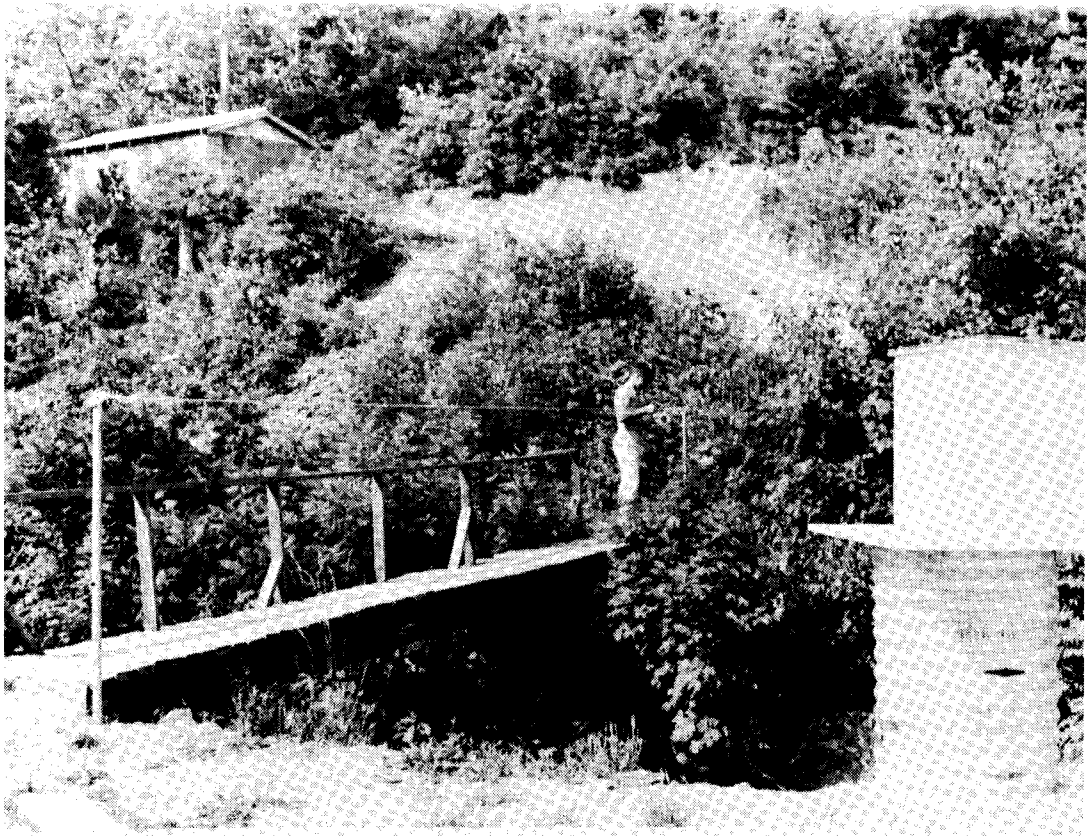

Photo 8--Gaging station just downstream from Gatewood Dam; channel cross section being defined by team of students.

During June and July, 1966, it was the intention of the investigators to obtain precise stream current measurements during various levels of stream discharge. However, the measurement data are limited because most of the streams that were to be studied dried up during a severe drought which began in early July.

Some curious anomalies have come to light. Station 6, located on Silurian orthoquartzite, gages discharge for the West Fork of Cove Creek, particularly the portion underlain by limestone and calcareous shale. Surface discharge is still noticeable, but farther downstream at Station 3 the stream is dry. Since the shale bedrock at Station 3, exposed on hills near the stream bed, is impervious, and since there is no noticeable alluvial deposit on the valley bottom at Station 3 which could absorb the upstream discharge, there is a problem as to what happens to the upstream surface water when it descends onto shale terranes.

Investigation shows that some continual drainage of tight shale-sandstone terranes is effected through a thin but significant alluvial shingle of shale and sandstone pebbles which has backfilled bottom portions of minor and major stream valleys to depths of 5 to 15 feet. The dry stream beds on sandstone-shale terranes are not discharging any surface runoff, but the alluvial deposits flooring these valleys are piping some underflow downstream. We are devising means for measuring this discharge by correlating it with the static ground-water level as measurable in the inside of the corrugated iron pipe at each gaging station.

The summer drought of 1966 will furnish record-making low rainfall-runoff data which will in due course yield to rising discharges of profoundly wetter seasons to come. One basic fact seems already clearly apparent. During the summer months more people observe the dryness of stream beds in sandstone-shale terranes than observe the same streams in winter weather. Hence erroneous impressions about low runoff from sandstone-shale terranes may be derived. Also significant underflow beneath summertime dry stream channels escapes direct notice. It is, therefore,

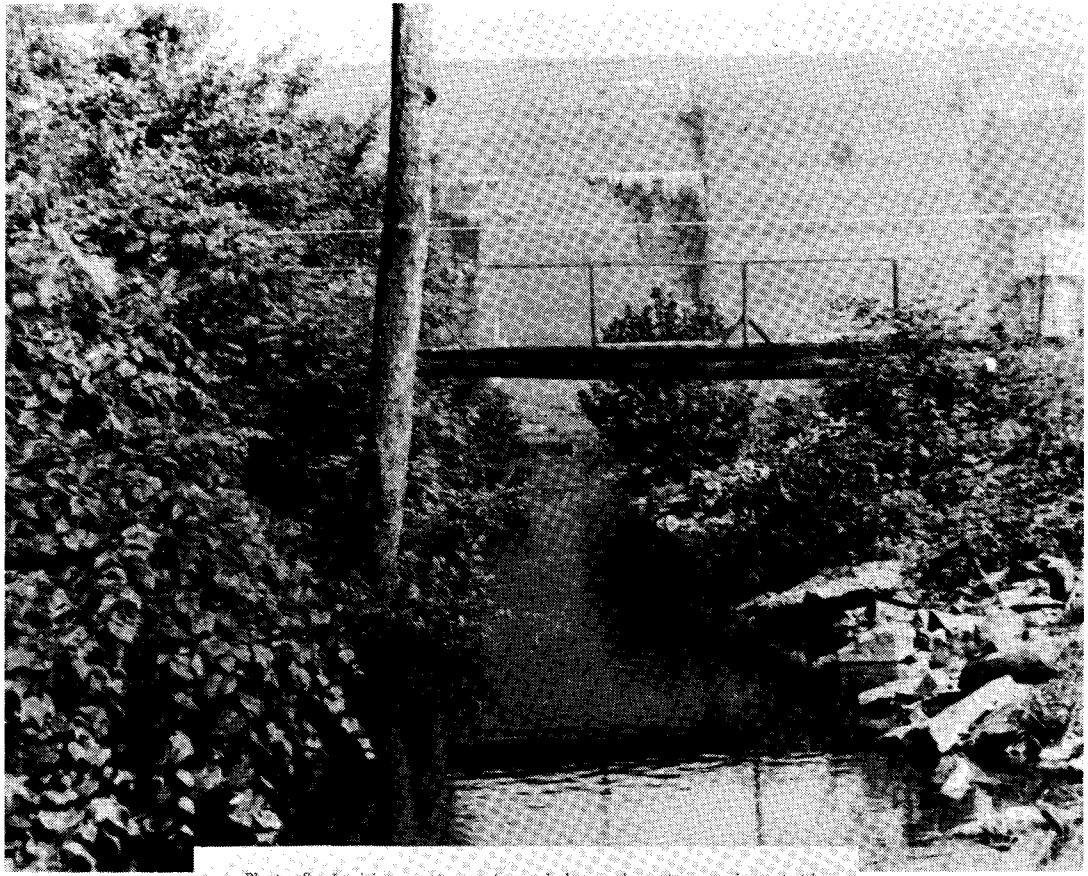

Photo 9--Looking upstream toward dam and master gaging station.

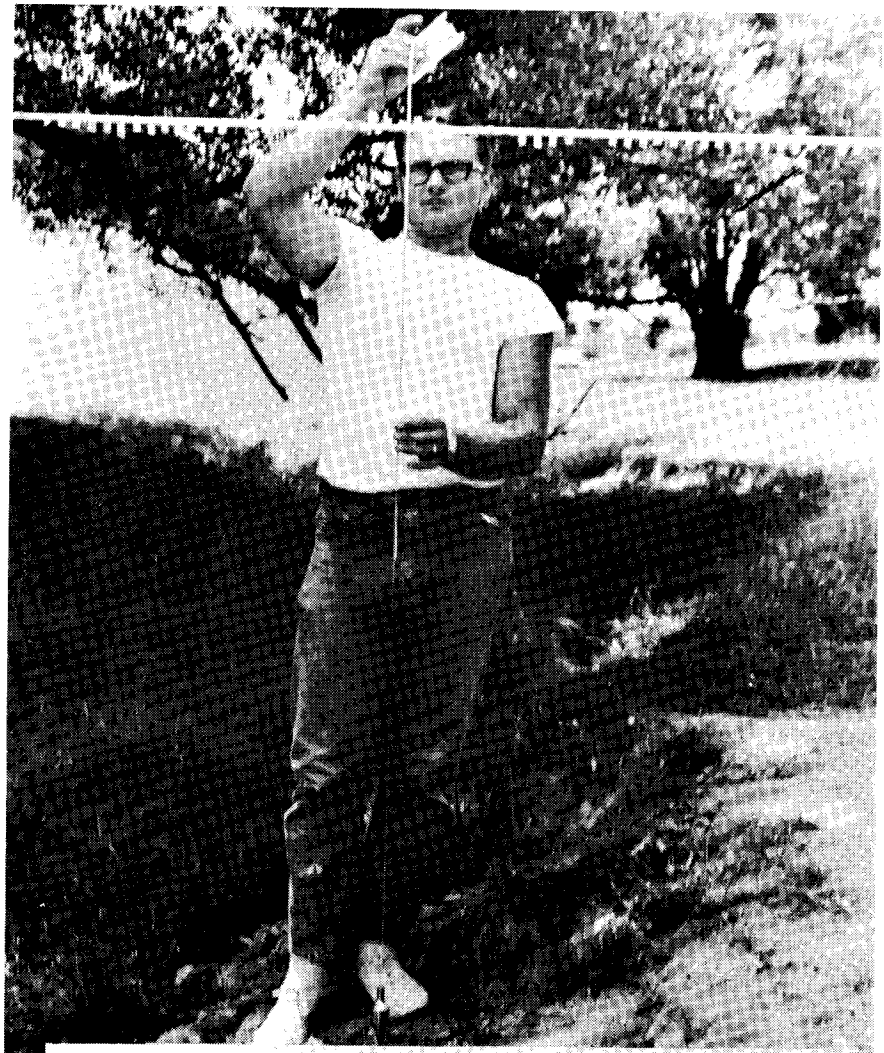

Photo 10--Measuring profile of stream channel at gaging station in Crockett Cove near headwaters of Peak Creek.

Photo 11--Stream discharged along upper reaches of west fork of Peak Creek at Station 6.

easy to sell shale terranes short as areas favorable for water supply impoundment. This rather intuitive observation, we believe, will be fully corroborated when the shale terranes shed their rainfall that runs off directly for a given geologic terrane, the smaller the area needed for impounding a unit quantity of storage water. Because runoff water on shale terranes is soft and of low turbidity, it is of excellent quality for domestic and industrial purposes. We believe the high runoff factor on shale terrances will enhance usefulness of many small watersheds in the Appalachians. One might reflect on the lament of the "local authorities" in Pulaski who claimed Gatewood Reservoir would never fill up and was, therefore, of no use to Pulaski. When the gates of the dam were first closed for initial impoundment, the reservoir, much to the astonishment of everyone including the engineers, was filled to the top of the spillway in just 12 days.

The Peak Creek Watershed, therefore, is expected to yield a wealth of valuable data, the sum of which will doubtless show the abnormally high runoff that is characteristic of shale-sandstone terranes in the Appalachians.

The dry summer has provided ample time to make very accurate cross-section profiles at the points of flow gaging so that quantities of discharge can be calculated very accurately on the basis of gaging data.

The eventual break in the drought will produce dramatic flow changes in the Peak Creek reservoir which will require accumulation of current flow measurements under conditions of higher discharge. With a cumulative rainfall deficiency of over 6 inches by July 1, 1966, it will be interesting to see the rapidity with which stream discharge increases.

The somewhat anamolous situation of continuing surface discharge of Peak Creek near its headwaters, in limestone country, even during the 1966 prolonged drought contrasts sharply with complete absence of visible runoff downstream on shale terranes. The only explanation that appears reasonable is that the shale valleys being gaged are rock-cut valleys

Photo 12--Dry stream bed on shale terrane near water line of Gatewood Reservoir.

developed during a more vigorous erosional regimen, valleys that were or have been backfilled to significant extent with alluvium composed of shale chips. This loose, coarse material must be piping the significant upstream runoff as underflow discharge below the dry stream channels at the lower gaging stations on Peak Creek.

Preliminary observations point up what probably will turn out to be a valuable generalization for evaluation of impoundment potential for small watersheds in the Central Appalachians. Shale terranes doubtless provide inordinately high runoff which is capturable by impoundment dams and reservoirs. The recharge during summer dry spells is primarily by intermittent flash runoff from summer rains.

Collection of rainfall and stream flow data will continue for another year and a half. Data will be analyzed and a mathematical relationship developed with a different coefficient for each bedrock type. This empirical relationship will enable the runoff from a region in Appalachia to be closely approximated when bedrock conditions and rainfall records are available.

Photo 13--Dry stream bed with stationary isolated pond depicting ground-water level just below the stream bed at Gaging Station No. 1.

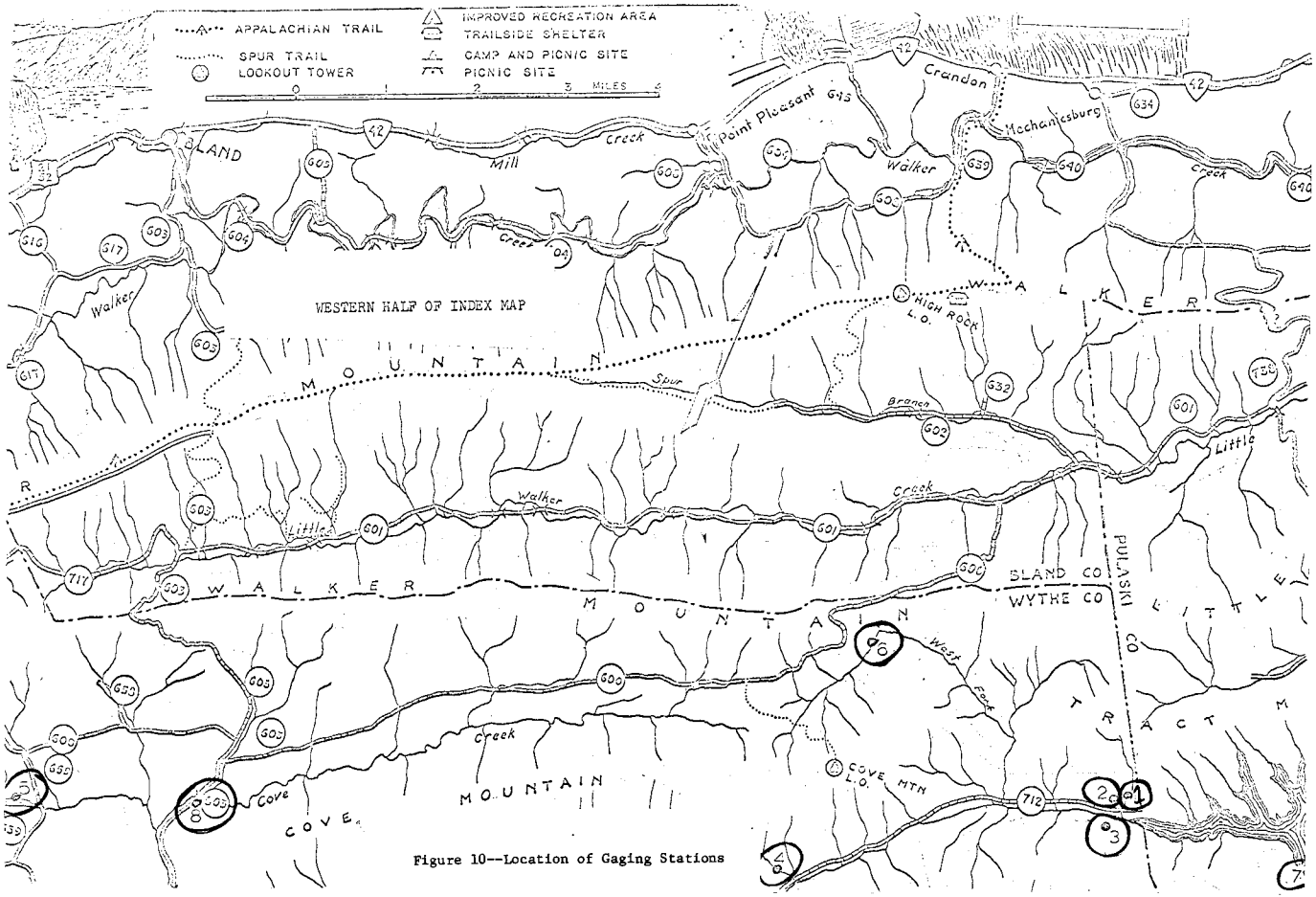

Figure 10--Location of Gaging Stations

EVALUATION OF THE EFFECT OF TRACE ELEMENTS ON THE ACTIVITY OF MICROORGANISMS

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August 1966

OBJECTIVE

In Virginia, North Carolina, and Maryland, abnormal ecological conditions have been reported which cause the activities of various microorganisms to be greatly reduced. This condition has been attributed to differences in the water quality of these regions. It has considerable economic significance because the microorganisms important in the food and dairy industry are affected to a considerable degree.

The objectives of this research are to isolate and identify the "tardus factor" from the water supplies in the area, to determine the extent of the geographic area in which the factor is predominate, and to attempt to predict the impact of this trace element on other aspects of the environment which are more subtle and difficult to observe.

PROGRESS

During the past year, this investigation has been concerned with (1) the isolation of lactic streptococci from the Blue Ridge area of Virginia, (2) the examination of the physiology of the lactic streptococci, and (3) the effect of various trace elements on these microorganisms. Previous work demonstrated that in the Blue Ridge Region of Virginia, the lactic streptococci display unusual fermentation characteristics. The investigation has demonstrated that when water, which has not passed through a mixed-bed ion exchange resin followed by distillation, is used to prepare the media in which several American Type Culture strains of Streptococci lactis are grown or transferred, it loses its ability to rapidly ferment lactose and produces unusual end products. The change occurs in these bacteria after 6 to 14 transfers in such media, and the bacterial will not revert to the characteristics of the original culture. In order to determine the extent of this phenomenon, cultures were isolated from an area 100 miles in radius in Southwestern Virginia. Approximately 50% of all cultures isolated were very similar to the altered bacteria isolated in the laboratory. Typical cultures of S. lactis

produce large quantities of lactic acid, but 50% of the isolates produce large quantities of acetic acid, formic acid, and enthanol, in addition to lactic acid. Morphologically and physiologically, these cultures were otherwise indistinguishable from a typical S. lactis. Under anaerobic conditions, these altered streptococci produced large quantities of enthanol, formic acid, acetic acid, and lactic acid, whereas under aerobic conditions, acetic acid is produced in large quantities and the amounts of formic acid and lactic acid are reduced.

The data indicate that there is a "factor" present in the water of certain areas of western Virginia which decreases the ability of S. lactis to rapidly ferment lactose and a new pathway is induced allowing the further conversion of lactic acid to other products. The products produced by this new metabolic pathway are greatly affected by the presence of oxygen. The conversion of carbohydrates to lactic acid in typical S. lactis cultures is not affected by the oxygen concentration to any significant extent. A defined medium has been developed which permits the growth of all cultures of S. lactis tested to date. The previously reported inability of the altered S. lactis cultures to grow on a defined medium with lactose as a carbon source was corrected by the addition of Tween 80 to the medium. This medium should be extremely valuable in future work.

It has been shown that the geographic region under investigation contains elements which are yet unidentified, and these elements drastically affect the metabolism of the lactic streptococci. These organisms are of great importance in the manufacture of fermented dairy products such as cheese.

It has been shown that a mixture of strong acid cation exchanger in the hydrogen form and a strong base anion exchanger in the hydroxyl form will remove the inhibitory elements. It has also been observed that the analytical grade chelex resin and chelex 100 (Bio-Rad laboratories) can remove the same elements. The latter resin is currently being used for

chemical determinations because of the greater ease in releasing the elements from the resin once it has been absorbed. These resins are too costly so as to preclude their commercial use by industry, but research continues for other substances to remove the inhibitory materials which are less expensive.

THE CHROMATOGRAPHIC ANALYSIS OF END PRODUCTS OF S. LACTIS AND THE CHANGED CULTURE OF S. LACTIS (VAR. TARDUS) AFTER 48 HOURS GROWTH ON A YEAST EXTRACT-GLUCOSE-PHOSPHATE MEDIUM

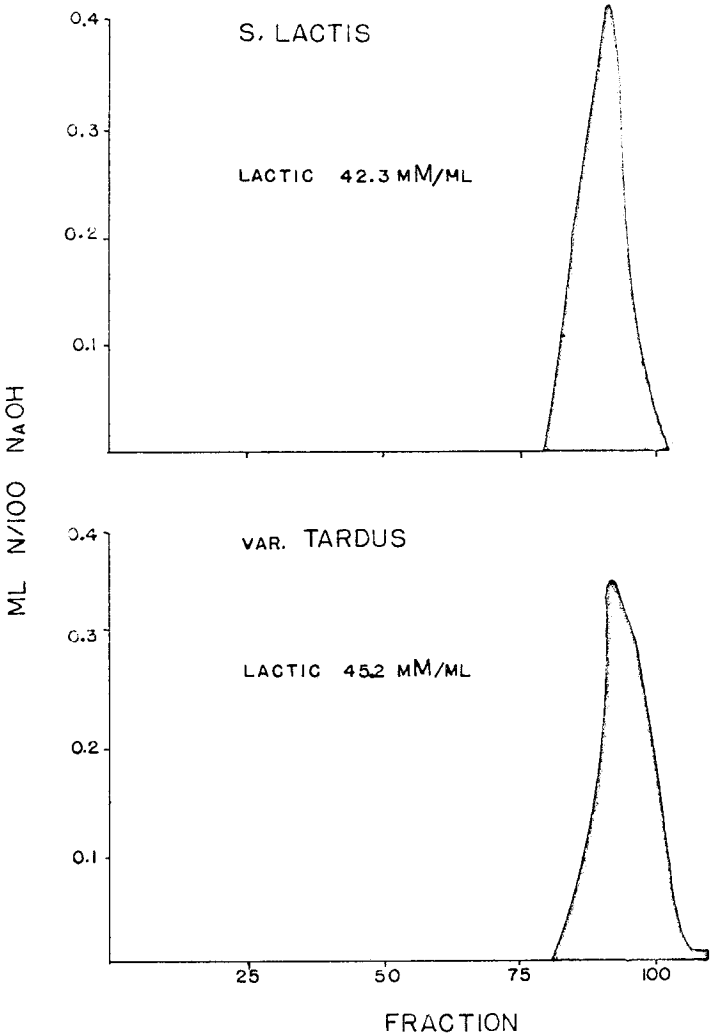

Figure 11

THE CHROMATOGRAPHIC ANALYSIS OF END PRODUCTS OF S. LACTIS AND THE CHANGED CULTURE OF S. LACTIS (VAR. TARDUS) AFTER 48 HOURS GROWTH ON A YEAST EXTRACT-LACTOSE-PHOSPHATE MEDIUM

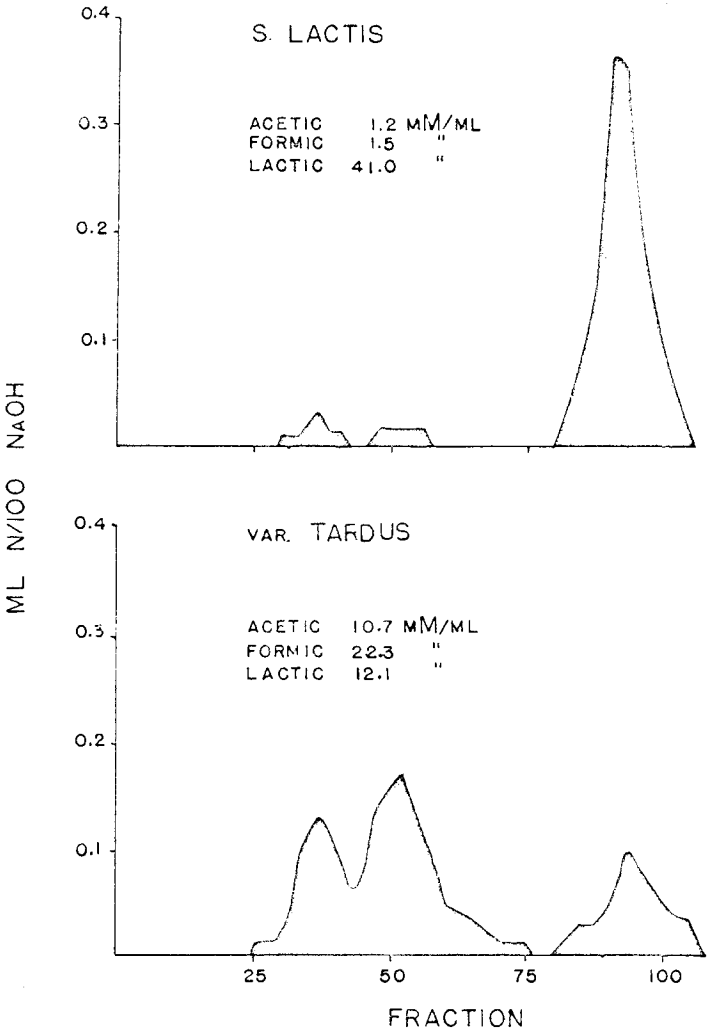

Figure 12

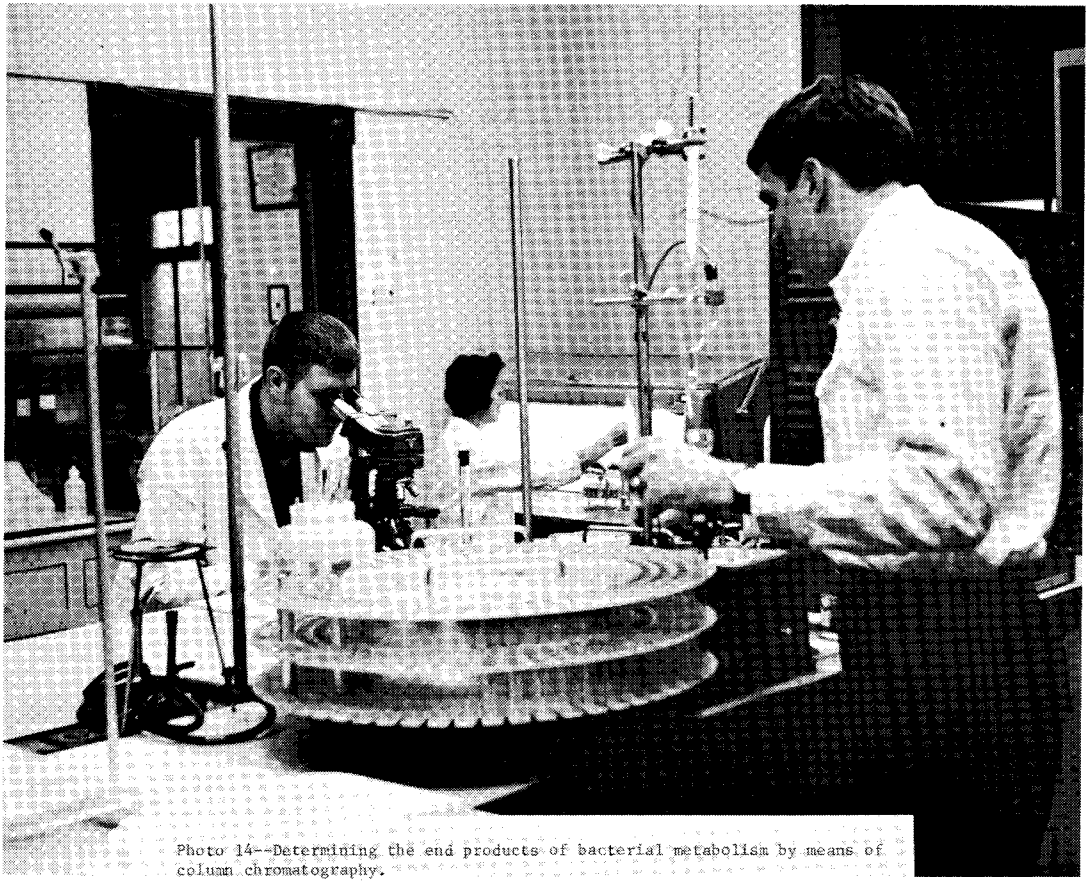

Photo 14--Determining the end products of bacterial metabolism by means of column chromatography.

F L O O D D A M A G E A B A T E M E N T S T U D Y

F O R V I R G I N I A

Professor William R. Walker
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Water Resources Research Center

Virginia Polytechnic Institute

Blacksburg, Virginia

August 1966

OBJECTIVE

From time to time, portions of the state have been subjected to destructive floods. Some have been characterized as flash floods doing extensive damage in a small area. Others have involved substantial portions of total river basins. In addition, hurricanes have been responsible for significant damage along Virginia's coast. Although the loss of life has not been large, the property damage has been very extensive. The economic loss is not limited to actual physical damage in the areas involved, but extends to the general economy of the state by interfering with business, disrupting transportation, and causing a drain on other resources which provide relief to distressed localities.

This is a study designed to provide background information by assessing the flood problem for the state as a whole, by exploring the various methods for flood damage abatement, and by examining the existing preventive and corrective programs of the federal, state, and local governments. In addition, the study will suggest several possibilities for reducing the flood damage in the future.

PROGRESS

Data on the loss of life and the extent of property damage due to floods has been compiled from reports and records of state agencies, Corps of Engineers, T.V.A., U.S. Geological Survey, U.S. Weather Bureau, and the American Red Cross. A rather complete picture exists as to the magnitude of the flood problem, but site visits remain to be made to representative localities to assess the problem at the local level and to determine the feasibility of the various remedial measures available. A map has been prepared showing the towns and cities with severe flooding problems, localities which have made flood studies, governmental units scheduled for the future flood studies, and those progressive areas where planning and implementation to protect against floods has been done at the local level.

An extensive review has been made of the various methods available to lessen damage. Corrective measures include construction of dams and reservoirs, levees and walls, channel improvements, watershed treatments, as well as evacuation, flood forecasting, flood proofing, and urban redevelopment have been explored in depth. The preventive measures under consideration include flood plain regulations (zoning ordinances, subdivision regulation, building codes, health regulations), development of open spaces, tax adjustments, flood signs, and flood insurance. Many of these corrective and preventive measures have long been recognized but some have not been used and others not very effectively. An evaluation of the use of these measures in other states was made to determine the modification necessary to make them more effective and to appraise those with the greatest potential for Virginia.

Various phases of flood abatement have been undertaken by the following federal agencies: Soil Conservation Service, U.S. Weather Bureau, Corps of Engineers, Federal Power Commission, U.S. Geological Survey, and Tennessee Valley Authority. Federal legislation indicated a concern for the flood problems of the state as far back as 1911 but it was not until 1936 that Federal expenditures for flood protection took on significant proportions. The history of the activities of these agencies has been compiled with special emphasis on their programs in Virginia. A detailed study has been made of flood information reports by Corps of Engineers and Tennessee Valley Authority in a few localities which have requested them.

Our research indicates that the state government is not assuming a very active role in flood damage abatement. Its principal activity has been in providing some relief to disaster victims. Virginia has relied very largely on the Federal Government for the building of corrective structures. Although enabling legislation exists authorizing local governments to act, very little responsibility has been assumed and only in recent years has there been any interest in preventive measures such as

flood plain zoning and land use programs.

The latter part of the calendar year, 1966, will be devoted to site visits for determining the extent of local flood damage and consideration of the appropriate combination of the corrective and preventive measures likely to yield the greatest benefit in the future.

Consideration will be given to the type of action the state government must take to implement these programs, especially in the area of land use and flood plain zoning. Finally, suggestions will be made as to possible legal and institutional structures necessary to effectuate a comprehensive flood abatement program.

LINEAR REGRESSION MODEL
FOR
POLLUTION TRANSPORT IN STREAMS

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August 1966

OBJECTIVE

The quantity of available fresh water which Virginia and the nation can expect over the long term, is relatively fixed. However, the quantity of water-borne wastes, a concomitant penalty of increased industrial and pollution growth, is not stable but continually increasing, resulting in ever-increasing tension in maintaining water quality. This tension is further heightened by the demands of economic efficiency and public policy for multiple-purpose development and use of regional water resources.

Thus the need for a reliable and feasible predictor of water quality, acute now, will increase in intensity as time progresses. The most commonly accepted technique in current use is the differential equation developed some 40 years ago on the Ohio River by Streeter and Phelps. The limitations of the Streeter-Phelps methodology are widely recognized by the profession. Numerous modifications have been proposed. One major limitation of the technique and its modifications is that they are deterministic in nature while stream hydrology and pollution loading are not. Professor F. E. McJunkin originally proposed the application queuing theory to treat the stochastic nature of the problem. Some preliminary work was done by Professor McJunkin before his resignation in June, 1966. Dr. W. A. Parsons assumed direction of the project but elected to abandon the queuing theory approach in favor of a modification of the linear regression method. Very little of the preliminary work was forfeited by the shift of methodology. The regression model treats the variation inherent in the system and should result in a model applicable over the range of the variables sampled.

PROGRESS

In order to test the mathematical model developed, it was necessary to have a stream with a large pollution load from a single source. Most of the Appalachian Plateau Region contains streams with steep natural slopes resulting in turbulent flow and large reaeration coefficients.

Streams having a pronounced oxygen sag are not numerous in the area surrounding Virginia Polytechnic Institute. Reed Creek in Wythe County was tentatively selected. The dissolved oxygen profile exhibited pronounced sag. Dye studies, however, disclosed that the transverse dispersion at the sag point was inadequate. The waste material was present in only fifty per cent of the stream. Two diversionary dams were constructed to provide additional mixing. The distribution of waste material through the cross section of the stream was still inadequate making the selection of another stream necessary.

Stroubles Creek was selected as an alternate site. It receives effluent from the waste treatment facilities for the town of Blacksburg and Virginia Polytechnic Institute. The stream flow is considerably smaller than desired, but it does have a pronounced dissolved oxygen sag below the sewage treatment plant. Dye studies and sampling are in process to obtain the necessary data for the statistical analysis.

The variables to be measured include (1) dissolved oxygen concentration above the sewage treatment plant and at the sag point, (2) Biological Oxygen demand in pounds per day above the sewage treatment plant and at the sag point, (3) stream flow, (4) stream temperature, and (5) benthol demand. The effects of slime and algae growths are also to be evaluated. The dissolved oxygen concentration will be the dependent variable and all others as "independent" variables.

Data is now being collected on all the variables under investigation and in sufficient quantity to be statistically significant. No reportable results are available at this time.

Data on the various variables will be collected until the winter season. Coefficients for the variable will be synthesized by using the computer. In the spring and summer months, additional information will be gathered in the field to check the mathematical model.

W A T E R R E S O U R C E L A W S

F O R

V I R G I N I A

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August 1966

OBJECTIVE

Effective planning and development of Virginia's water resources are severely handicapped without a comprehensive appraisal of the existing legal structure with respect to water. Policy decisions and administrative organizations can be placed in better prospective if the legal framework which circumscribes the whole area is better defined.

PROGRESS

Water Rights of Virginia has had its origin in royal charters and patents, legislative enactments, constitutions, and court decisions. These have developed during three major historical periods: the Colonial Period to the Revolution; the Commonwealth from Revolution to the Federal Union; and the Commonwealth from the Federal Union to date.

The first portion of this research was historical in nature. It was necessary to have this historical perspective in order to better understand the law and how it reached its present stage of development. Investigation was made into the work of some of the Western scholars (Wiel and Hutchins) mainly to develop background material to help explain the shift from the principles of early Colonial or Commonwealth common law to the principles of the most recent common law of surface water as affected by French civil law and the American authorities (Kent and Story). The works of Hutchins have been drawn on to help clarify the comparative status of the law by reference to developments in the West.

Approximately 275 cases have been analyzed, and it is believed that these include the whole body of case law for Virginia. The Code of Virginia has been reviewed and the cases interpreting the statutes investigated in depth.

In addition, a detailed investigation has been made of lower court decisions, some of which have not been appealed to the highest court of Virginin for decision and others which are still in litigation.

Analysis of the statutory and case law remains to be completed. A summary of the current status of the water law of the state is under preparation. Recommendations regarding possible changes in the legal framework will probably be included in the final draft.

RELATION OF SELECTED ENGINEERING LAND TREATMENTS TO SOIL WATER STORAGE AND RAINFALL USE EFFICIENCY OF CROPS

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August 1966

OBJECTIVE

The primary objective of this research is to develop basic theories and principles which express the effects of specific engineering land treatments on water storage within the soil root zone, and on the accompanying rainfall use efficiency by the growing crop.

During the growing season considerable crop damage can result from short duration droughts, i.e. 5 to 6 days or less. Inspection of past climatological records for the state of Virginia indicates a 70 per cent probability that the drought will not exceed 5 to 6 days. There is also much evidence that improved engineering and management practices can practically eliminate short duration droughts and subsequently minimize the longer ones. There is an urgent need for detailed investigation of possibilities for better storage and plant utilization of water during these short duration droughts.

PROGRESS

The reporting period is essentially limited to the interval from mid-February to June 30 at which time Vernon Shanholtz was employed by the Agricultural Experiment Station to devote full time to this project.

An experimental plan has been formulated and subsequently implemented to carry out the above objective and needs. This initial plan is subdivided into three separate but very closely related approaches: (1) experimental plot studies, (2) laboratory studies, and (3) mathematical model development.

Due to initial problems to obtaining budgetary clearance for capital outlay equipment and subsequent delays in the delivery of several important pieces of equipment, some phases of the data collection program have been severely delayed. It is hoped that all equipment will be received and in working order for the coming fiscal year.

The following sections of this report will be devoted to a discussion of the experimental plot studies, instrumentation, laboratory analyses and

general comments relative to the data that have been collected to date.

Experimental Plots

In the experimental plot studies, two radically different row crop tillage systems, conventional (clean) tillage and no-tillage, are being studied. In the conventional tillage system, the residue of the preceding crop was turn-plowed to a depth of 7 inches with a standard moldboard plow. The seedbed was prepared by two discings with a standard tractor mounted disc. Chemical weed control was used in lieu of crop cultivation. In the no-tillage system, the residue (grass sod) from the preceding crop was killed and regrowth controlled with chemicals. The crop (corn) was planted with a tractor mounted two-row planter that was especially designed to create a desirable seed zone environment without any other soil disturbance during the planting operation.

The experimental plots were laid out according to a randomized complete block design that consisted of four blocks with six treatments per block. Two treatments were for monitoring soil moisture; two were for monitoring soil temperature and plant growth, and also for yield determination. The remaining two were used for obtaining laboratory samples. Sufficient instrumentation is being provided to measure soil moisture, soil temperature, precipitation, pan evaporation, air temperature, wind movement, relative humidity, and net radiation. From these data, a water budget may be determined for the experimental area.

A continuous pictoral coverage of the plot studies has been maintained throughout the spring and summer. The photographs in this section depict the two tillage treatments at various stages of crop growth and some of the instrumentation that is being used to collect basic data. A weather station located at the northeast corner of the plots, includes instrumentation for measuring pan evaporation, maximum-minimum temperature, relative humidity, and precipitation is not shown.

Photo 15--A specially designed tractor with mounted implement for planting corn in no-tillage or conventional tillage seedbeds.

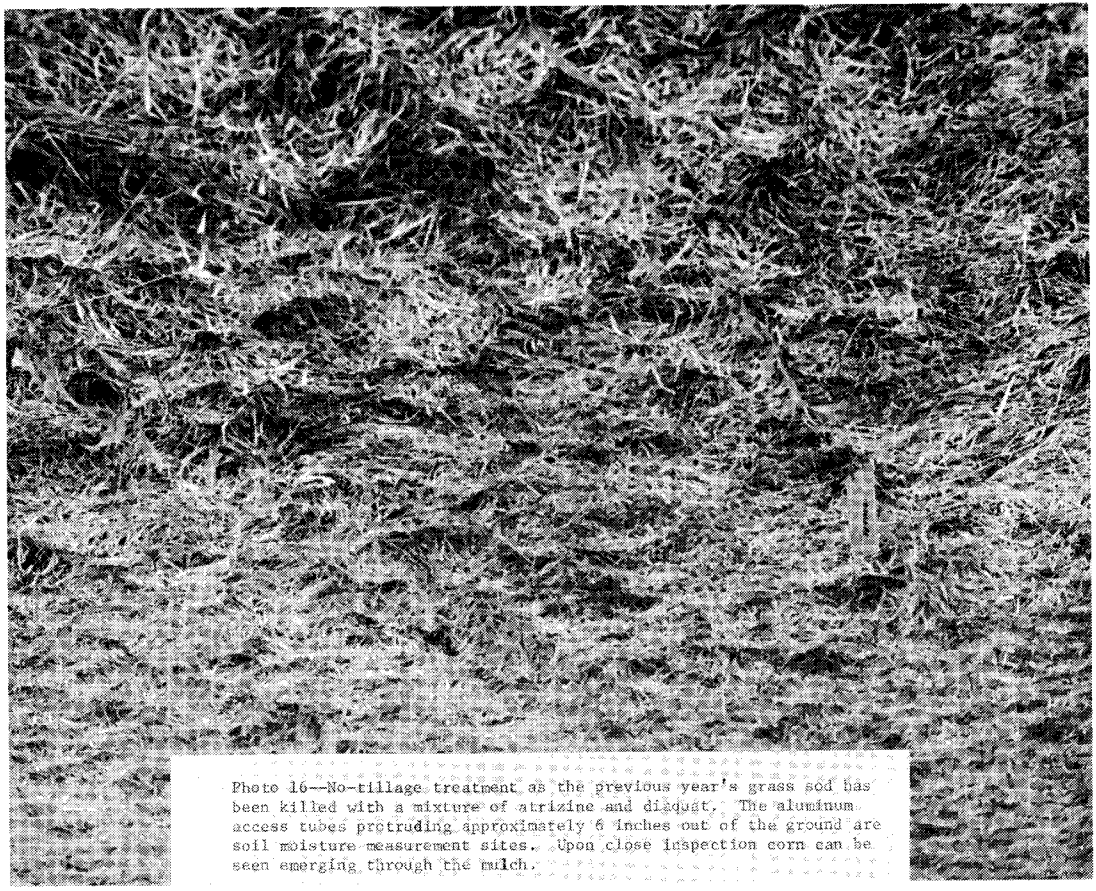

Photo 16--No-tillage treatment as the previous year's grass sod has been killed with a mixture of atrizine and diquat. The aluminum access tubes protruding approximately 6 inches out of the ground are soil moisture measurement sites. Upon close inspection corn can be seen emerging through the mulch.

Photo 17--Corn row in Photo 16 shown at close range. Note the good mulch cover resulting from chemical killing of the previous year's grass sod.

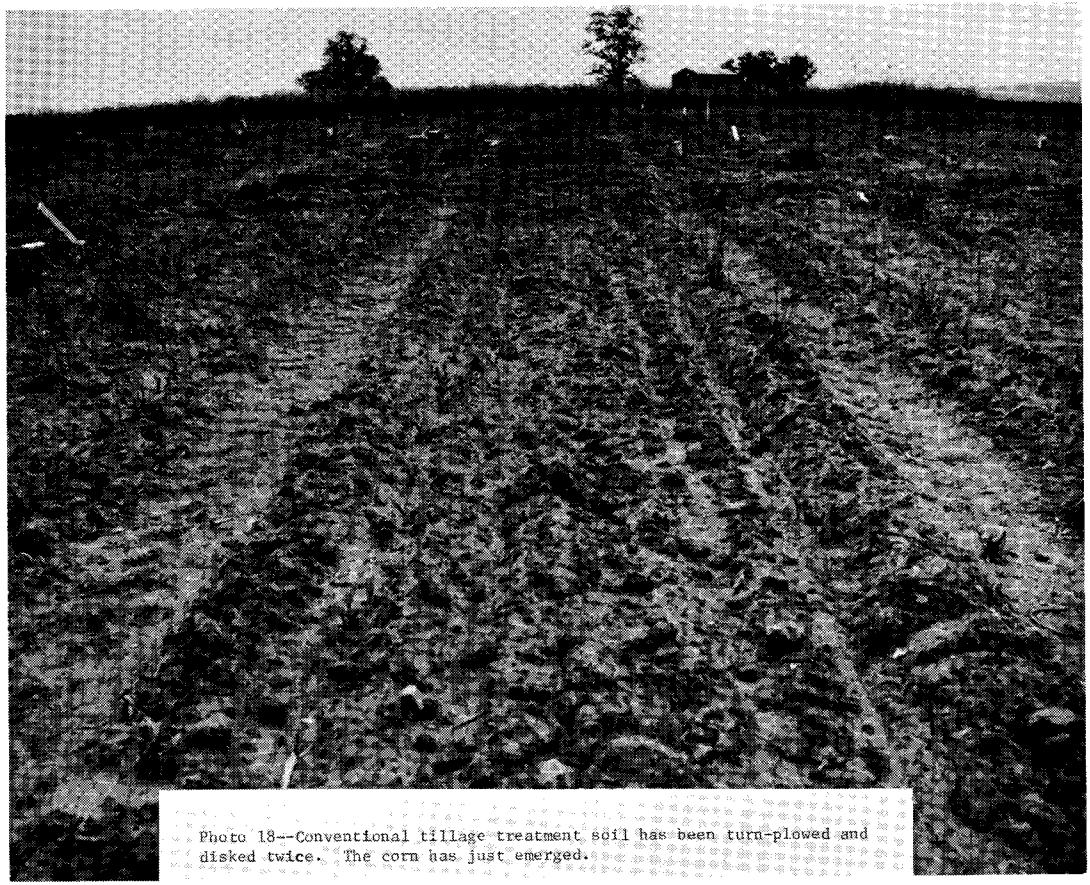

Photo 18--Conventional tillage treatment soil has been turn-plowed and disked twice. The corn has just emerged.

Photo 19--Picture taken approximately two weeks after Photo 18. It shows the equipment used to determine soil moisture at various depths. The depth probe (left) is resting on the access tube shown in Photo 16. Sheets of plywood are used to distribute weight to lessen compaction within plot areas.

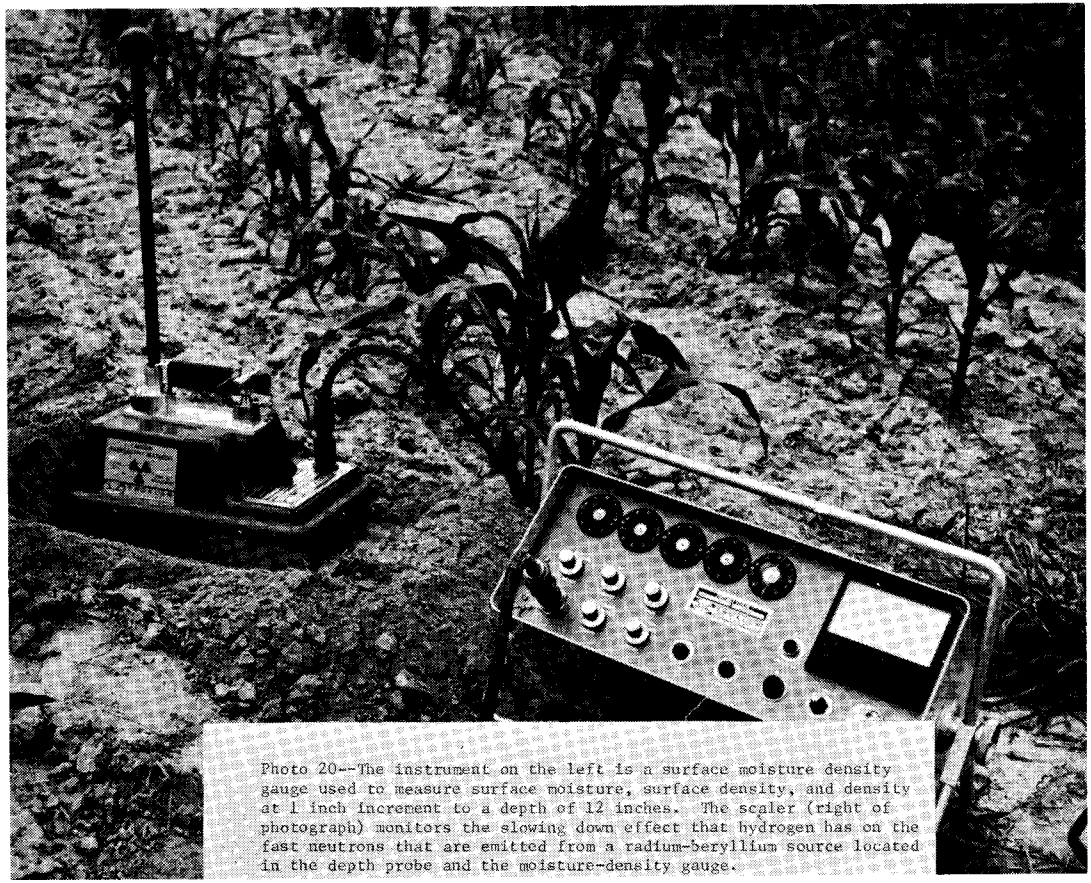

Photo 20--The instrument on the left is a surface moisture density gauge used to measure surface moisture, surface density, and density at 1 inch increment to a depth of 12 inches. The scaler (right of photograph) monitors the slowing down effect that hydrogen has on the fast neutrons that are emitted from a radium-beryllium source located in the depth probe and the moisture-density gauge.

Photo 21--Soil temperature measurements are being obtained at depths of 0, 2, 4, 8, and 90 inches respectively with Copper-Constantan thermocouple wire.

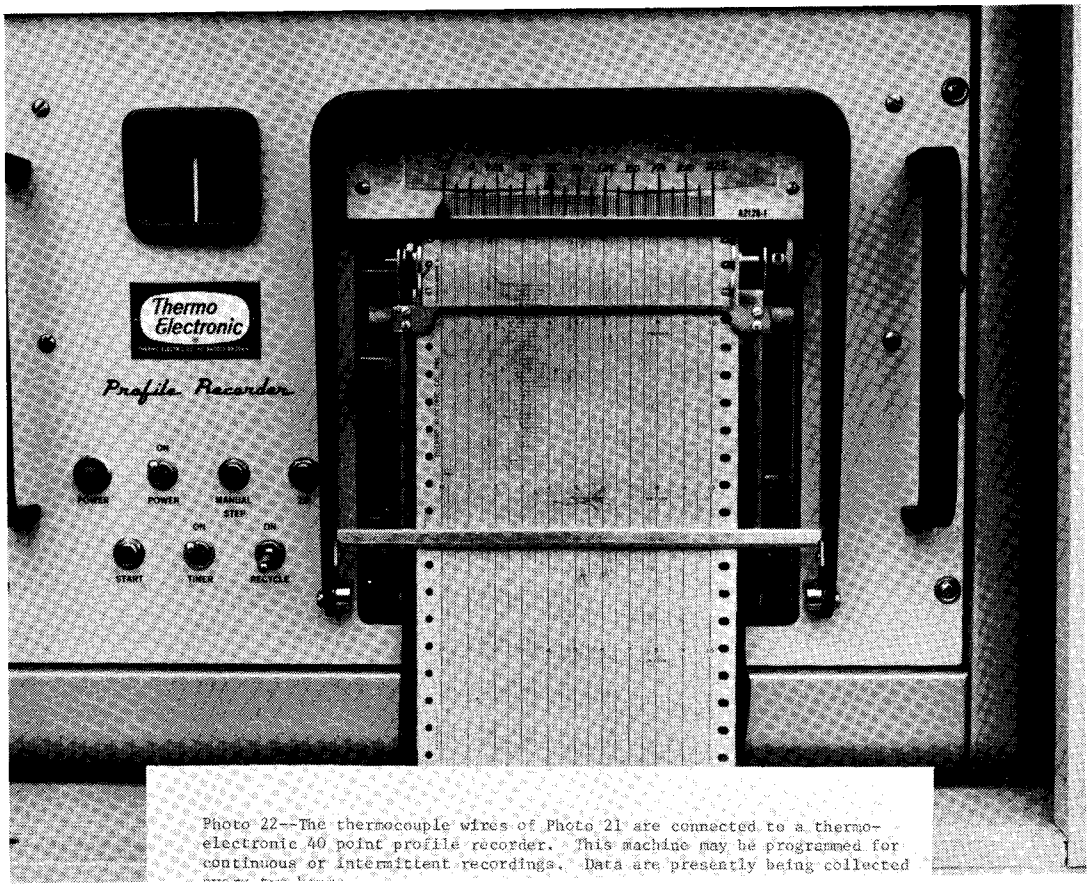

Photo 22--The thermocouple wires of Photo 21 are connected to a thermo-electronic 40 point profile recorder. This machine may be programmed for continuous or intermittent recordings. Data are presently being collected

Photo 23--The air temperature is taken at varying heights within the plot area. The wet and dry bulb temperature is obtained at the surface. Air temperatures are also taken at 18 inches and 54 inches. A centrifugal fan, located 78 inches above the ground is used to pull air across thermocouples located within the insulated arms.

Photo 24--Wet-bulb temperature measurements are obtained by imbedding a thermocouple wire in the tip of a flannel wick that is immersed in distilled water. Air is drawn across the exposed wick tip at a prescribed rate to provide the cooling cue to evaporation.

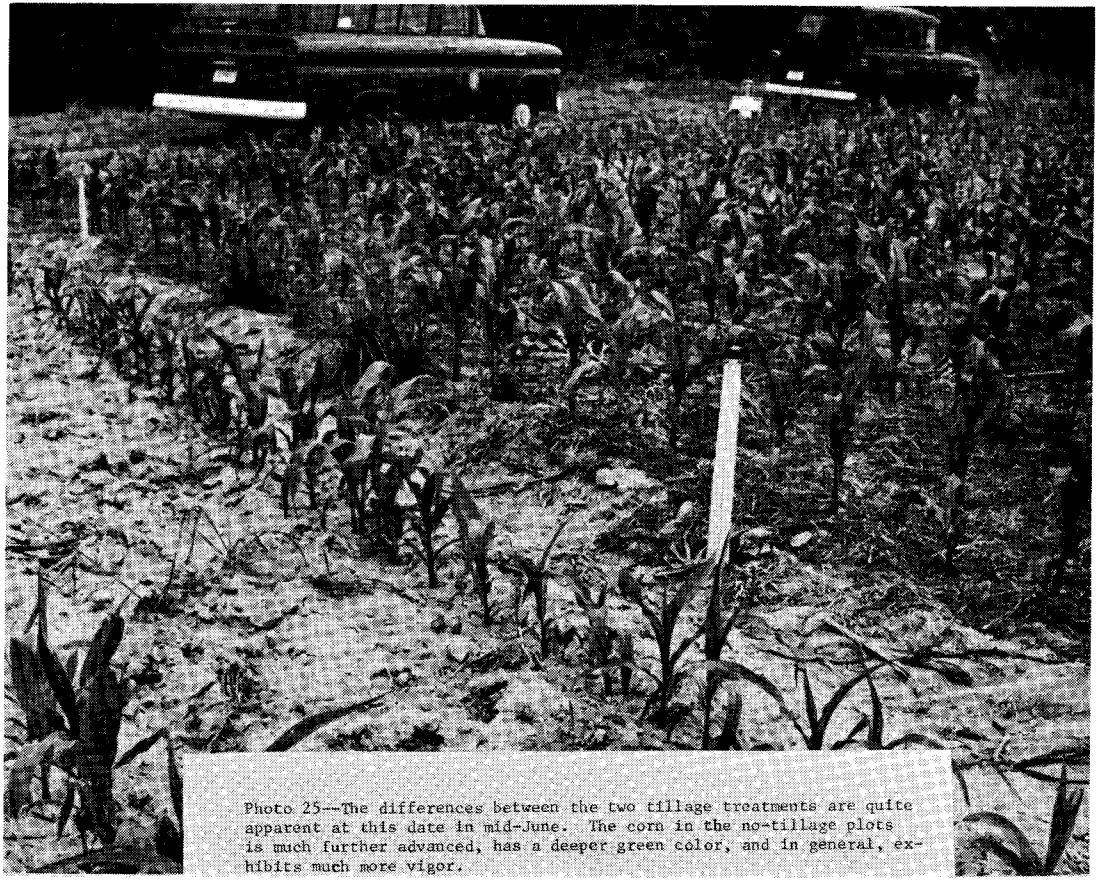

Photo 25--The differences between the two tillage treatments are quite apparent at this date in mid-June. The corn in the no-tillage plots is much further advanced, has a deeper green color, and in general, exhibits much more vigor.

Photo 26--Standard permeameter cylinders equipped with a 6-inch cutting edge and a thin removable aluminum inner liner were used to obtain 6-inch diameter undisturbed soil core samples to be used for laboratory studies. An 8-ton jack, a wide flanged 4-inch steel I-beam and two 12-inch soil augers that were used to anchor the I-beam were used as shown in the above photograph to obtain the samples.

Laboratory Analysis

In general laboratory analysis for this research study may be grouped into (1) soil analyses and (2) environmental studies with undisturbed soil samples.

Soil analyses: Prior to seeding, the soil fertility was determined for all plots. The results showed the area remarkably uniform with respect to pH and fertility. An application of 100 pounds of 10-10-10 fertilizer per acre was applied to maintain a constant level of fertility through the growing season.

Aside from the fertility analyses only limited soil analyses have been performed to date. Moisture determinations to aid in checking the validity of moisture data obtained by the neutron moisture meter and a study of the saturation and drying characteristics of 6-inch diameter undisturbed core samples constitute the lab work. Soil samples are currently being taken for determining bulk densities and the development of moisture tension curves for the various soil horizons in each plot.

Environmental Studies: An important phase of this research program will be environmental studies. Ten year average daily temperature and relative humidity data have been summarized from available weather records being collected at the Agricultural Engineering Farm for selected two week intervals during the growing season. Six-inch diameter undisturbed core samples will be subjected to the above conditions in an environmental chamber. Evaporation rates and germination will be observed under the programmed conditions. Also, some effort will be directed towards compaction and how it may effect germination and evaporation.

Considerable effort has been expended in the development of a suitable apparatus whereby external monitoring of weight changes could be achieved. A steel frame on which eight cantilever beams can be attached has been constructed. This apparatus will fit snugly within the environmental chamber. The undisturbed core samples will be placed on a sling platform which is attached to the cantilever beam. Strain gauges

scheduled for collection during this growing season.

Considerable difference in physical appearance of the no-tillage and conventional tillage crops has been noted. The corn in the no-tillage plots is much further advanced, has a deeper green color, and in general, exhibits much more vigor.

An apparatus to monitor weight changes in 6-inch diameter undisturbed soil cores has been fabricated. Samples have been collected for the initial environmental study run.

The no-tillage treatments had higher surface moisture contents during May; however, with the persistence of severe drought conditions, these differences had decreased to non-significant amounts by June 30.

One more season of field data is needed. After data collection has been completed, it will be modified to correctly reflect moisture conditions under different tillage conditions. In this final form, the model should permit moisture predictions empirically.

TRAINING AND EDUCATION ASPECTS OF THE WATER RESOURCES RESEARCH PROGRAM

Hanes, R. E., M. S., N. C. State University, Agriculture.

Zelazny, L. W., M. S., University of Vermont, Agronomy.

Sorenson, Robert M., Ph. D., University of California, Hydraulic Engineering.

Carson, E. W., Ph. D., N. C. State University, Soil Sciences.

(3) Staff Members Employed to Replace Those Who Retired, Died, or Moved.

Michelson, D. L., Ph. D., Cornell University, Chemical Engineering.

Kirk, Paul, Ph. D., Duke University, Mycology.

King, Paul H., Ph. D., Stanford University, Sanitary and Water Resources Engineering.

(4) New Research and Training Facilities Other Than Research Equipment Items.

One fishery research building in the process of being renovated (about 500 square feet).

One specially designed and instrumented plot system for the investigation of a wide variety of soil-water-plant relationships under selected tillage systems.

Water Analysis Laboratory established and furnished.

(5) Interdepartmental, Interuniversity or Regional Agreements Consummated with Respect to Improved Research and Training Capabilities.

Chemical Engineering Department has an exchange of seminars with near-by schools arranged on a continuing basis.

B. Student Enrollment

	No. Enrolled	No. Graduating
Juniors	51	0
Seniors (Bachelor's degree candidates)	61	53
Master's degree students	52	19
Doctoral degree students	48	6
Postdoctoral degree students	1	0

C. Number of Students Using Equpment and Supplies Purchased Wholly or in Part with P. L. 88-379 Funds.

Undergraduates	5
Master's students	4
Doctoral students	5
Postdoctoral students	0

D. Number of Students Receiving Employment or Other Financial Support Through the P. L. 88-379 Program.

	Scientific Discipline	Number
Undergraduates	Engineering (part time)	1
Master's students	Plant Pathology	1
	Business	6
	Engineering	3
	Geological Science	1
Doctoral students	Chemical Engineering	1
	Ag. Engineering	1
Postdoctoral students		0

E. Employment Status of 1965-1966 Graduates in Water-Related Fields.

Category of 1965-66 school year graduate by degree obtained	No. Employed in Water-Related Positions in				No. ret for adv degree	No. entr mil serv	No. unempl or unkwn
	Federal Agencies	State Agencies	Colleges and Univ.	Other such as Pvt.			
Bachelor	2	7	2	7	3	4	28
Master	2	0	0	1	12	0	4
Doctoral	1	0	1	3	1	0	0
Total	5	7	3	11	16	4	32

F. Type of Employment of 1965-1966 Graduates in Water-Related Fields.

Cat. of 1965-66 sch yr grad by degree obtained	No. of Graduates Engaged in Water-Related Work in						
	University or College			Agcy or pvt wtr resources research	Oper and mgmt	Planing	Other Water Resorcs Work
	teach prim	resrch prim	resrch and teach				
Bachelor	1	1			16		
Master					3		
Doctoral		1			4		
Total	1	2			23		

DIRECTOR'S REPORT

DIRECTOR'S REPORT

During this past fiscal year, the functional organization of the Water Resources Research Center changed slightly, but not the personnel. Professor William R. Walker, formerly executive secretary for both the administrative and technical advisory committees, was named Director of the Center. In this new capacity, Professor Walker assumed the Chairmanship of the Technical Advisory Committee which was formerly chaired by Dr. Byron Cooper during the initial developmental phases of the Center. Administrative responsibility for the operation of the Center remained the same with only a title change.

Interest in the activities of the Center from the University Community have grown throughout the year. This added interest was assisted by the willingness of members of the Technical Advisory Committee to invite the Director to speak to members of their individual disciplines regarding the establishment of the Center, its potential, and the opportunities it offers in terms of education and research. Taped interviews with the Director were broadcast over a network of fourteen stations, giving statewide coverage to the Center's activities. The number and varied proposals submitted for funding during the next fiscal year are further evidence of this increased interest. Most of the projects funded for fiscal year 1966 were continued into fiscal year 1967, leaving only $25,000 available for new projects. Eleven projects were submitted having a combined budget of $160,000. Of these projects, three were from Civil Engineering, one from Biology, one from Chemistry, three from Statistics, and one from Agricultural Economics. The remaining two proposals were from other Universities in the State - one from the Civil Engineering Department of Virginia Military Institute, and one was a combination project from the Mechanical and Chemical Engineering Departments of the University of Virginia. The Center is currently working with faculty members in Economics, Psychology, and Sociology in developing proposals for funding under Title II.

Prior to the creation of the Center, these disciplines had not considered the water field as one where they could make a significant contribution.

In an effort to stimulate multidisciplinary research in water resources by illustrating the spectra of research opportunities and needs in the field, particularly to those members of the University Community who had not heretofore been active in water resources research, a seminar was sponsored by the Center. This seminar on "Multidisciplinary Research As An Aid to Public Policy Formation" was held on campus December 8, 1965. The papers were arranged so that faculty and graduate students could attend those in which they had a special interest without interrupting their teaching or class schedules. Attendance for the various papers ranged from 60 to 100. The speakers and their topics included:

(1) Dr. Jabbar K. Sherwani, Assistant Professor of Hydrology and Water Resources, University of North Carolina, "Marriage of Water Resources Engineering and Economics - Some Promising Progency." Dr. Sherwani is a native of Pakistan and earned his initial degree of B. S. in Civil Engineering at the University of Punjab. Since coming to the United States, he has acquired a M.C.E. from the Polytechnic Institute of Brooklyn, a Ph. D. in Groundwater Hydrology at the University of Utah, and a M.P.H. in Water Resources Economics at Harvard University. His past professional positions include: Deputy Chief, Water and Power Section, Planning Commission, Pakistan; and Consultant, White House Panel on Waterlogging and Salinity in West Pakistan.

(2) Dr. Emil J. Gumbel, Professor of Industrial Management Engineering, Columbia University, "Applications of Extreme Value Distribution to Water Resources Development." Dr. Gumbel did his undergraduate and graduate work at the University of Munich. He has had teaching assignments at the University of Heidelberg, the University of Paris, the University of Lyon in Europe, as well as Newark College, Brooklyn College and Columbia University in the United States. At various times, he has been a consultant to the National Bureau of Standards and Stanford University. In 1952 he

was a Guggenheim fellow. Dr. Gumbel has written more than 300 articles and enjoys an international reputation for his work on the statistics of extreme values.

(3) Dr. Robert V. Thomann, Technical Director, Delaware Estuary Comprehensive Study, "Use of Systems Analysis in Estuarine Water Pollution Control." Dr. Thomann obtained a B.S. in Civil Engineering from Manhattan College in 1956 and his Ph.D. in Oceanography and Meteorology from New York University in 1963. His professional life has been with the U.S. Public Health Service where he worked on the water quality studies of the Connecticut and Delaware Rivers. He also worked as engineer in charge of the Narragansett Bay Hurricane Barrier Study, and is presently Technical Director of the Comprehensive Study being done on the Delaware Estuary. Dr. Thomann is the author of several technical papers on simulation studies using mathematical models.

(4) Dr. William G. Hargis, Director, Virginia Institute of Marine Sciences, "Biological Examination Using Simulation Studies on an Engineering Model to Determine the Effects on Shellfish Productivity of Dredging the James River." Dr. Hargis, in addition to being Director of the Virginia Institute of Marine Science, serves as Chairman of the Department of Marine Science at the University of Virginia and Dean of Marine Science at William and Mary. His academic achievements include a B. A. and M. A. from the University of Richmond and a Ph. D. from Florida State University. His research endeavors include 39 technical papers mainly in areas of biological oceanography, biology of monogenea, systematics, and phylogeny.

All of the results of this seminar are not now evident. It is thought that its impact will be seen during the coming years as the tempo of the Center's program increases. The Statistics Department has become especially interested in the potential of its discipline in the field of Sanitary Engineering and Water Resources. Since this seminar, it has received funding for a project from the U. S. Weather Bureau. Several members of the

faculty have attended national meetings on water quality and pollution control and have returned with enthusiasm regarding the potential contribution of statistics to these technical fields.

It was recognized from the beginning that the Center could not reach its potential and be of greatest service to the state of Virginia unless a forum were provided enabling state and federal agencies concerned with water resources development, local governments, concerned citizens, and the industrial community to have direct communication with the Center. To meet this need, a statewide committee composed of various representatives from these groups was formed. This committee met in May, 1964 in Blacksburg and again on March 11, 1965 in Richmond. At this latter meeting, reports were presented by the various principal investigators on the progress of their work. Prior to this meeting, each member of the committee submitted a list of problem areas in which he deemed that immediate research was necessary. Faculty members then commented on these proposals in terms of whether the suggestions were descriptive of the real difficulty or merely symptomatic of a deeper problem, the direction which the research might take, a literature search of prior work, the research costs, and available sources if any, for funding. Comments and discussion then followed from the floor. During the several months following, interested faculty members met with individual members of the Statewide Advisory Committee to discuss details of a research propsoal. Several proposals are now pending review of various funding agencies.

In recent months, several industries have approached the Center concerning research in certain areas; but these discussions are in the very early stages. It is encouraging that these companies are now looking to the Center to coordinate research not only with faculty members of Virginia Polytechnic Institute but other Universities of the State.

At the first meeting of the Statewide Advisory Committee in May of 1965, many members expressed a basic and urgent need for an inventory of published information and data on the general subject of water resources in Virginia. In an effort to partially fill this gap in the literature, Professors F. E. McJunkin and William R. Walker prepared the material which became Bulletin No. 1 of the Water Resources Research Center, Water Resources of Virginia: An Inventory of Printed Information and Data.

PUBLICATIONS

AND

THESES

PUBLICATIONS AND THESES BASED ON P.L. 88-379-SUPPORTED PROJECTS

Publications

McJunkin, Frederick E., and William R. Walker
1966. Water resources of Virginia - an inventory of printed information and data. Bulletin 1. Water Resources Center. Pages vii + 108.

Sutton, David L., T. O. Evrard, and S. W. Bingham
1966. The effects of repeated treatments of simazine on certain aquatic plants and residues in water. Northeastern Weed Control Conference, Volume 20. Pages 464-468.
Based on project A-010-VA.

Water Resources Research Center, Virginia Polytechnic Institute
1966. Multidisciplinary research as an aid to public policy formation. Bulletin 2. Proceedings of a seminar. Contains four papers and remarks by discussants.
Pages vi + 68.

Wills, George B.
1966. Convergence of approximation methods used in multicomponent mass transport. Industrial and Engineering Chemistry - Fundamentals Quarterly. In press.
Based on project A-002-VA.

Wills, George B., and E. N. Lightfoot.
1966. Transport phenomena in ion exchange membranes. Industrial and Engineering Chemistry (5). Pages 114-120.
Based on project A-002-VA.

Theses

Blanton, S. J.
1966. The comparative physiology of *S. lactis* and *S. lactis* var. *tardus*. M. S. thesis. Virginia Polytechnic Institute. 63 pages.
Based on project A-005-VA.