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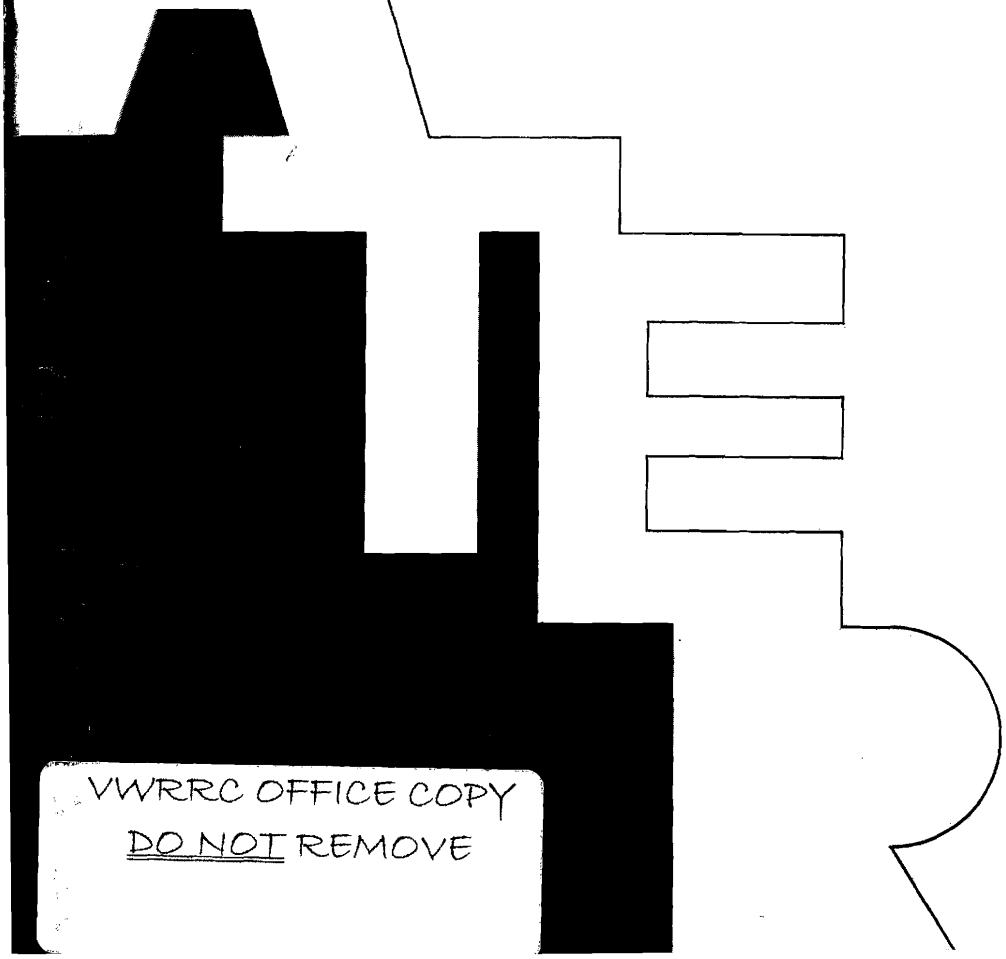

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ANNUAL REPORT
WATER RESOURCES RESEARCH ACTIVITIES
UNDER PUBLIC LAW 88-379
FISCAL YEAR 1969

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 fifth 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

TABLE OF CONTENTS

DIRECTOR'S REPORT

Although Virginia has an average of 43 inches of rain per year, water problems of both quantity and quality are very prevalent in the Commonwealth. Research aimed at providing information related to both short and long range objectives are a necessity if effective utilization of its water resource is to contribute to a strong state economy and at the same time provide a quality environment for its citizens.

In an effort to identify many of the critical water problems facing the state, a series of meetings was held with state agency leaders. Discussions centered around water problems of immediate concern and those that appear to be shaping on the horizon. Faculty members from a variety of disciplines participated in an effort to identify the type of research likely to develop the information for better coping with these water problems. It became increasingly evident to numerous agency personnel and faculty that many of the problems could not be solved independently and that ultimately we could not put the solutions together and solve the problems as a whole. The sum of the solutions from separate disciplines is not likely to be the solution of the whole.

Much of the information which research can provide is viewed by state agency personnel in terms of technical and economic needs. The legal and institutional restraints appear less obvious and awareness of the deficiencies in the field of sociology and psychology as related to water resources is practically nonexistent.

The discussions revealed several areas having informational deficiencies for which there is a need for immediate research.

Temperature Criteria--The water quality standards adopted by the state have been accepted by the Department of the Interior except the one related to temperature. Research is needed to develop background information so that a standard consistent with the state goals and satisfactory to the Federal Government can be approved in the immediate future.

Combined Sewers--Several of the urban areas of the state must find an immediate solution to the problems of pollution from combined sewer discharges. The pollution due to overflows from sewers to water courses

of the state was highlighted in a recent report by the Federal Water Pollution Control Administration. It indicated that storm runoff from a 14 day accumulation after a two hour rain had the pollution effect of one and a half times an equivalent amount of untreated sewage.

Methodology for Fish Kills--Fish kills are a recurring problem with no end in sight. Agencies responsible for determining the cases of such kills have extreme difficulty in evaluating the various factors and their interrelationships. Much work is needed in developing a better understanding of various factors which may contribute to the rapid die off of fish and in perfecting techniques designed to isolate with relative certainty the significant factors in each occurrence.

Compatibility of Oyster Beds And Waste Water Outfalls--The oyster industry is a significant one in the state. Yet, growing beds for oysters are decreasing at an alarming rate. Beds are closed for health consideration whenever there is an insufficient buffer zone between it and a waste water discharge. Better and more reliable operations of waste treatment facilities must be developed before the present health safeguards can be modified. The closing of oyster beds is likely to continue in the face of an expanding population and the accompanying waste facilities.

Waste Stabilization Ponds--At the present time waste stabilization ponds appear to be one of the most feasible alternatives for handling waste water in parts of the Commonwealth. Although an extensive amount of research has been done on the construction and operations of stabilization ponds, satisfactory results have not always been obtainable. The operating experience in Virginia has been contrary to the research results obtained in other areas of the United States. Research is needed to develop techniques to make this method of treatment an acceptable one for the Commonwealth.

Agricultural Pollution--Most of the attention toward pollution control has been directed to point sources (municipalities and industry). Increasing attention is being given to agricultural pollution while the agricultural industry denies that it either exists or is minimal. Quantitative data to support either position is very scarce. Much research is needed to determine the amount of pollution due to pesticides, herbicides, sediments, and nutrients associated with agriculture. Increased attention needs to be given the pollution potential resulting from the operation of feed lots and agricultural processing

plants. Additional work on alternative methods of control is needed if the pollution attributable to agriculture is anything but token.

Seawater Encroachment--Uncontrolled groundwater pumping in the coastal area and the dredging of tidal streams has increased the hazards from seawater encroachment. The extent of this problem is not known and most of the citizenry have little appreciation of the consequences of this phenomena. Research on how to manage groundwater pumping in the coastal areas is badly needed. Alternatives must be formulated and evaluated economically so that rational decisions can be made.

Monitoring and Sampling--Unlimited sampling and continuous monitoring is highly desirable but not economically feasible at this time. Planning and effective regulation of the water resources is dependent in part on the amount of information available. Because of the restraints of both time and money, it is highly desirable to know what parameters are critical, to know the extent they provide some indices by which others can be forecast with reasonable accuracy, and to know where, when and how often samples must be taken to have statistically significant data.

Reservoir Drawdowns--Multiple use of reservoirs is an economic necessity. Many uses are not completely compatible and much information is needed to determine costs and benefits to the other uses when increased emphasis is given to one use in preference to another. It has been demonstrated that these costs and benefits vary widely depending on whether they are considered from a local, regional, or national viewpoint. Virginia needs more quantitative data in terms of local and state costs and benefits, especially in the area of water based recreation.

Water Management Programs--The use of water in some sections of the state has developed symptoms which offer the potential for a water crisis in the not too distant future. The full range of alternatives has not been explored and consideration of the basic opportunities such as conjunctive use of surface and ground waters has not received serious attention. The intensity of the problem is accentuated by the increasing water demand of a growing urban complex, by increased use of water for intensive agriculture, and by the large industrial users in the critical water zone. The solution is complicated because the water problem overlaps the political boundaries of cities, counties and between states. Much research is needed to develop the range of alternatives before irrevocable decisions are made and the situation degenerates into chaos.

Wetlands--Little is known about the resource potential of marshlands. They are viewed by many as a liability. Their use has been largely limited as places to drain, fill, or to house the spoil material from dredging. Their recreational potential and maintenance for the existing ecosystem has not been fully explored. A fuller understanding of this resource should be attained before irreversible decisions are made. A true cost of benefits foregone should be more fully examined before the resource is utilized indiscriminately. A fuller understanding of the long range potential is a must.

Water Resources and Economic Growth--Although water is an indispensable commodity for life and a vital resource for some industries, very little scientific information exists on its relationship to economic growth of the state. More information is needed to determine if better allocation of the resource would have substantial impact on economic growth. Research into such questions as the following is important: If maximum economic growth were the goal of the Commonwealth, would the better management of this resource be a major factor?

Evaluation of Recreation and Wildlife--The ratio of benefits to costs has been the conventional method for determining project feasibility. Factors related to water base recreation, aesthetics, etc., do not lend themselves easily to quantification in dollars. Serious research into the development of alternatives to market pricing for evaluating recreation and wildlife benefits is a necessity as these aspects of the water resources will assume a larger role in the future.

Water Pricing--Water in most parts of the state is one of the cheapest products purchased by industry and individuals. Investigation needs to be made into whether a different pricing structure would encourage more economic use of the resource and influence industrial development. Is pricing a more effective means of allocating water than government regulations?

The list does not include all of the areas which need research, yet it will take a significant financial input on a sustained basis by State Government if the informational gap is to be closed for the enumerated projects. Increased emphasis is being placed on some of the most urgent research needs with funds made available from the Federal Government. A majority of the matching fund projects being initiated next fiscal year are directed toward areas of immediate need. Project B-009-VA deals with the effects of reservoir

operating policy on recreational benefits, B-017-VA is concerned with the effects of heated waste waters upon microbial communities, and B-025-VA is analyzing and evaluating the water resource administrative agencies of the state.

Advanced waste treatment (tertiary) looms on the horizon as a necessity for some facilities in the State. Project A-032-VA has as its primary purpose the development of an electrochemical process that could lead to a more economical method for regenerating carbon now used in tertiary treatment plants. Nuclear power generation is to become a physical reality at several locations in Virginia. Project A-031-VA is a pre-impoundment study to determine the biological and chemical characteristics of the North Anna River prior to receiving the discharge from a thermal reactor. Knowing the original conditions and changes which have been affected by the nuclear installation, more effective regulations and safeguards can be formulated for the future.

Storage is a fundamental to any water management program. Surface storage is very vulnerable to evaporation losses and underground storage is an unknown factor in many situations. Work on project B-021-VA is designed to predict surface temperature variations, and evaporation losses. In addition it hopes to develop a methodology for predicting the effects of particular thermal loading rather than resorting to measuring them experimentally. Project A-023-VA attacks the unknown in underground storage. It is developing a method for measuring ground water reservoir storage by the measurement of tidal fluctuations.

Some of the research completed to date has found immediate application. Project A-008-VA was concerned with the statutory and case law dealing with water resources in the Commonwealth. The response to the first printing of the report (500 copies) was exhausted within six months. The demand is such that a second printing is in press. The city attorney for the City of Harrisonburg offer this comment: "I would like to take the opportunity to compliment you for an excellent and much needed publication." He is currently doing legal research on diversion of riverwater for municipal purposes. A law firm in Alexandria doing research on the question of trust theory related to ownership of stream beds by the state stated, "Your Bulletin No. 9, 'Water Resource Laws in Virginia,' has been helpful to me."

Another example of the short time lag between Water Center sponsored research and application of results was in the field of agricultural engineering. Those actively engaged in agriculture in Virginia annually face the problem of

developing procedures or techniques to increase soil-water storage and plant-use efficiency so the optimum crop yields may be obtained. Although the average annual rainfall would appear to be sufficient for most crops grown, short drought periods of two to three weeks are quite prevalent throughout most of Virginia. These short duration droughts cause considerable loss of revenue due to insufficient water. Project A-009-VA had as its major objective a better understanding of the water conservation potential of no-tillage and conventional tillage systems. Hydrologic and climatic data was collected over a statistically designed experiment so that a complete water budget could be maintained during the growing season. As a direct result of the experimental work on this project, no-tillage is being advocated by the extension personnel as providing multiple benefits for row crop farming. The most efficient use of available moisture provided by the no-tillage method was reflected in added crop yields of 26 bushels per acre and a 43.1 percent increase in dry matter. In addition, surface runoff was found to be only one-seventh as great as that for conventional tillage.

Center Involvement in Public Affairs

Liaison between the Water Resources Research Center and the state and federal agencies concerned primarily with some aspect of water resources in the Commonwealth is maintained primarily by the Director through personal contacts. In addition specialty departments such as Sanitary Engineering maintain close contact with the State Water Control Board and the Health Department on current research and the training of personnel.

In the past the most active citizen groups have been the James River Basin Association and the Roanoke River Basin Association. As the result of the water planning being done by the State, citizen advisory groups are being formed as each basin study is completed. The Director meets with these groups to discuss areas of mutual interest and the part that research might play in developing the information necessary for good policy decisions.

The Director continues as a member of the Subcommittee of the Virginia Advisory Legislative Council on the Disposal of Solid Wastes Affecting Waters and Streams and the Licensing of Water and Sewage Plant Operators. This subcommittee has prepared legislation for the mandatory licensing of water and waste water plant operators (industrial and municipal). It is anticipated that it will receive favorable consideration by the General Assembly when it convenes in January, 1970. The Director is also a member of the subcommittee on natural resources of the Rural Affairs Commission.

Specific legislation on various aspects of water as it relates to the study area of this Commission will be sent to the General Assembly for consideration during the next term.

Various professional organizations in cooperation with the Sanitary Engineering Department have conducted, for a number of years, a voluntary five-day short course for water and wastewater operators. The Director participates as part of the faculty for these courses.

The Center sponsored a one-day meeting on the research needs related to pollution from combined sewers. Representatives from West Virginia, Virginia, North Carolina, and the District of Columbia attended. Participation was limited to representatives from cities having specific problems in this area, faculty members doing active research in this field, state agency personnel involved in the regulations of waste water discharge, consultants with public supported projects, and personnel in charge of the research program at the federal level. The purpose of the meeting was to learn first hand the results of ongoing research in this area, to determine research needs not being met, and to promote a good understanding between researchers interested in the area and cities with problems needing immediate attention. The meeting generated a large interchange of ideas and the next year should produce both new research in these areas and possible demonstration projects.

The Center recognized that many of the persons actively involved in both air and water pollution are primarily technically oriented both from education and experience. Since the broad economic problems associated with both air and water pollution are very similar, a three-day seminar on the "Economics of Air and Water Pollution" was sponsored. It was a seminar devoted to economics for the non-economist. The faculty was principally economists who had been or now are working in this field. Some of those with national reputations included:: Roland McKean, University of Virginia, Gordon Tullock, Virginia Polytechnic Institute, David Allee, Cornell University, Clifford Russell, Resources for the Future, and Robert Haveman, Subcommittee on Economy in Government, Joint Economic Committee. The program was well received by the engineers and administrators who participated.

The League of Women Voters for South Carolina, North Carolina, and Virginia sponsored a workshop, "Land and Water for Tomorrow," for selected state leaders in the three states. The Director participated in

presenting a paper highlighting the water problems of the Piedmont Region, a geographic area common to the three states.

Center Involvement in Academic Affairs

In an effort to mobilize and coordinate the research capabilities of the University a memorandum of understanding was executed between the Agricultural Experiment Station; Research Division, ARS, U.S. Department of Agriculture; and Water Resources Research Center. Although good liaison existed between these three agencies and joint participation in research of common interest had occurred in the past, it is thought that this agreement will encourage and provide the vehicle for much more cooperatively sponsored research in the future.

The Center, in an effort to improve dissemination techniques such as those involved in the selecting, abstracting, and indexing of significant articles from the water resources literature, sponsored a member of the library staff to an Institute on the abstracting and indexing of literature of water resources. It is believed that the quality of work in this area will improve and the researchers will sustain both a short and long range benefit.

The Director has been appointed to the Committee on Patents and Proprietary Rights which is giving a comprehensive review to the University's policy in this area. A liberal but fair patent policy is just another added incentive in the recruiting of quality researchers.

In an effort to identify current research being done at all the institutions of higher learning throughout the State, the Center has compiled a publication, "Water Resources Research in Virginia." In connection with this inquiry another publication, "Water Resources Research Interests in Virginia," developed. This identifies those faculty members who are doing or would like to do research on water problems. The talents and capabilities of staff personnel at all the institutions of higher learning within the Commonwealth are now readily identifiable.

REMOVAL OF TRACE ORGANICS FROM WATER BY ADSORPTION ON COAL

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September 1969

REMOVAL OF TRACE ORGANICS FROM WATER BY ADSORPTION ON COAL

Conventional water and waste treatment practices have little or no effect on an increasing number of the highly complex, synthetic organic wastes which presently contaminate drinking water supplies. In order to protect these water supplies new technologies for water and waste treatment must be developed. The use of activated carbon as an adsorbent has been thoroughly evaluated. More recently a process has been suggested which utilizes the properties of coal as an adsorbent, flocculent, and filter aid for purposes of facilitating the treatment of waste waters. In evaluating this process there is a real need for quantitative data which describe the extent of adsorption of persistent organics on coal. By comparing these data with published work describing adsorption on activated carbon, the possibility of properly evaluating the coal process will be enhanced.

This research was designed to evaluate and extend the work currently being done in coal filtration by determining how effective coal is as an adsorbent for the removal of the persistent organics and the economic feasibility of substituting coal for activated carbon as an adsorbent.

In conducting this study to obtain the quantitative data required, the project objectives were (1) the evaluation of the extent of adsorption on coal of biochemically resistant organic materials in an aqueous solution; (2) the determination of the kinetics of such adsorption processes, (3) the evaluation of the extent to which adsorption on coal may be substituted for adsorption on activated carbon as an advanced waste treatment process, and (4) the evaluation of the uptake kinetics and sorptive capacity of coal for phosphate containing compounds.

General Procedure:

Both batch and continuous flow column studies were utilized as contact processes. In the batch type tests suitable amounts of coal were added to distilled water buffered to maintain a specific pH. The solute was added and system mixed for a specified period of time. The coal was separated from the liquid phase by membrane filtration and the residual concentration of solute was determined analytically.

In the fluidized column studies a mixture of coal and water was introduced into a small tube. After selection and calibration of an appropriate flow rate a feed solution containing the solute in solution was introduced to a constant head tank. By operating the system in an upflow manner it was possible to maintain a fluidized column which allows the use of small granules without the attendant problem of plugging that frequently occurs in downflow operations. Effluent from the column was analyzed for concentration of the solute under study.

Suitable analytical procedures were employed to determine residual solute concentrations. Pesticide analysis was conducted by direct liquid-liquid extraction of the organic into hexane and subsequent analysis by electron capture gas chromatography. Phosphate concentrations were measured utilizing a Technicon Auto-analyzer and an adaptation of the aminonaphtholsulfonic acid method for orthophosphate determination.

Three representative pesticides and a number of phosphorus containing compounds were used as solutes. The selected pesticides were lindane, a representative chlorinated hydrocarbon, parathion, typical of the organic phosphorus insecticides, and chloroisopropyl carbamate (CIPC) a widely used organic herbicide. Four grades of coal were considered and significant differences in sorption with differing coals were noted. Some studies were also conducted for comparative purposes with activated carbon.

Pesticide Removal (Batch Study):

In the lindane studies approximately eighty to ninety per cent removal of this insecticide was achieved within one hour utilizing a batch type operation and high volatile C bituminous grade coal. An initial lindane concentration of 100 parts per billion was employed and the removal was noted to vary significantly with pH. The per cent removal increased with decreasing lindane concentrations. the lindane adsorption data was reasonably well described by the Freundlich equation.

The results of batch kinetic studies of parathion uptake indicated that all four of the coal types tested exhibited similar rates of adsorption. One gram of each of the coals tested was capable of removing about 90 per cent of the parathion in 100 milliliters of a 1.0 mg/l parathion solution. The kinetics of adsorption was not affected by the pH of the system.

The data from batch equilibrium studies for parathion adsorption on coal was adequately expressed by either a Langmuir or a Freudlich isotherm. It was postulated that parathion forms a monolayer on the coal surface during adsorption since the equilibrium adsorption data could be expressed as a Langmuir isotherm. Activated carbon was found to be 24 times more effective than coal in removing parathion from solution.

Pesticide Removal (Continuous Flow Study):

Column studies were conducted to observe the susceptibility of parathion to removal in a continuous flow process. High Volatile Bituminous C coal removed 0.045 milligrams of parathion per gram of coal at a flow rate of 25 ml/min. and 0.035 milligrams of parathion per gram of coal was removed at a flow rate of 5 ml/min. Normalized breakthrough curves adequately represented these systems.

Batch kinetic studies indicated that all four coal types tested had similar rates of adsorption of CIPC. Two grams of each of the coals were capable of removing 75 to 90 per cent of the CIPC from 100 milliliters of a 20 ppm solution. Activated carbon was estimated to be about 1000 times more efficient than coal in removing CIPC from solution. The lower limiting concentration for removal of CIPC from dilute solution by coal in a batch system appeared to be about two milligrams per liter.

Under continuous flow conditions, High Volatile Bituminous C Coal was from 3.5 to seven times as efficient as the other three coals tested in removing CIPC from dilute solution. The quantity of CIPC adsorbed per unit weight of coal was inversely proportional to the flow rate and independent of the quantity of coal in the column.

Phosphate Removal:

Attention was focused on the possibility of significant removals of various forms of phosphate in a coal contact process of the type utilized. Since phosphate removal is currently a major concern in the treatment of sewage and industrial wastes, and inasmuch as initial studies showed promising results, considerable effort was devoted to this phase of the work.

The phosphate studies included consideration of orthophosphate, metaphosphate, and polyphosphate compounds. The uptake by the finely ground coal was in each case relatively rapid with at least ninety-five per cent of the equilibrium value being achieved in one hour. Equilibrium was reached, on the average, after an uptake of about one milligram of phosphate per gram of coal assuming an initial phosphate concentration of 20 mg/l. Equilibrium data was shown to fit a Freudlich isotherm at low phosphate concentrations and a Langmuir isotherm at higher concentrations. A sixty to eighty per cent increase in pyrophosphate over orthophosphate removal was noted while the removal of metaphosphate was similar to that of orthophosphate.

Consideration was given to the mechanism of phosphate removal. Batch studies have indicated that optimum removal occurs when the system pH is in the range of 4.0 to 5.0. This pH corresponds to the point where ferric phosphate is least soluble and a surface reaction involving the formation of this compound has been postulated as an important mechanism in achieving the observed removals. Further support for this theory is gained from the studies utilizing various coals. Enhanced phosphate uptake was noted with lower grade coals and a definite correlation was observed between phosphate uptake and iron content of the coal. The fact that lower grade coals are more promising as contact media in terms of contaminant removal greatly increases the potential of the process for economically feasible applications in the wastewater treatment field.

Conclusions:

1. The use of coal as an absorbing medium for synthetic organic pesticide removal is technically feasible. Economic considerations will govern the suitability of the process for particular installations.

2. Phosphate uptake by coal is governed by the nature of the coal and the form of phosphate present. Significant levels of removal were observed.

3. The use of a properly selected coal in a moving bed filter will result in significantly higher removals of persistent organics and phosphorus containing compounds than would result from more conventional methods of wastewater treatment.

MICROBIAL RELEASE OF SOLUBLE PHOSPHATE IN AN ACTIVATED SLUDGE ENVIRONMENT

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MICROBIAL RELEASE OF SOLUBLE PHOSPHATE IN AN ACTIVATED SLUDGE ENVIRONMENT

One of the major problems confronting the water problem control industry today is the eutrophication of surface waters receiving raw and treated wastes. It is almost universally agreed that, in the vast majority of cases, the key to controlling eutrophication is the control of the concentration of phosphorus in the receiving water (9). Recognition of this problem has led numerous investigators to study the variables that affect phosphate removal by activated sludge for the purpose of developing a process modification that would produce an effluent low in phosphorus. The preliminary results from these studies indicate considerable potential for success. Several studies have shown that rapid uptake of phosphate can be accomplished with activated sludge under proper environmental conditions. Frequently, however, a considerable portion of the phosphate is lost back to solution if processing is continued such as occurs in conventional activated sludge treatment. To accomplish maximum removal of phosphate, that is to say, a minimum concentration of phosphate in the final effluent, it is necessary to prevent microbial release back to the outflow. Present knowledge of the variables and mechanisms involved is inadequate to accomplish this.

One of the primary points of disagreement that has arisen among investigators of biological phosphate uptake is the existence of "luxury uptake." That is to say, do activated sludge organisms take up more phosphorus than that actually required for satisfactory BOD removal or is phosphate uptake basically a function of carbon metabolism? Greenberg et. al. and Levin and Shapirol, have reported that uptake does occur. Numerous other investigators, however, such as Hall and Engelbrecht, Sekikawa, et. al., Bogan, and Helmers, et. al. have shown a linear relationship between phosphate removal and BOD applied, indicating luxury uptake did not occur. If luxury uptake can not be accomplished, and the preponderance of the evidence seems to indicate that it, at least normally, does not occur, then it is vitally important that phosphorus that has been removed from solution not be leaked back to the plant effluent. Observations indicate that this very thing is, in fact, occurring in most sewage treatment plants. Research teams such as Priesing, et. al. have shown that high percentage removal of phosphate can be obtained during the early stages of aeration, but it is difficult to maintain throughout the entire treatment process. Better methods of phosphate release control are essential if low phosphate effluents are to be attained.

General Procedure:

The analysis of operational parameters is being conducted in two stages. The first involves batch-type studies using model activated sludge units and the second is concerned with continuous flow situations. The activated sludge used for all experiments is maintained in such a manner that its biological and physical characteristics are consistent with that used for domestic sewage processing.

Batch-type studies are being conducted to determine what minimum level of dissolved oxygen (DO) must be maintained during treatment to prevent phosphate release. Further experiments are being conducted to determine if soluble phosphate release occurs during extended aeration, and, if so, to determine the optimum aeration period with regard to uptake and release of phosphorus.

Batch-type studies are being used to evaluate the effect of aeration rate and duration of the aeration period on subsequent release of phosphate under anaerobic conditions. To obtain consistent mixing without increasing the dissolved oxygen level, nitrogen will be bubbled through the sludge during some of the experiments.

A second phase of the batch studies involves investigation of the effect of the food-to-microorganism ratio on phosphate uptake and release. The primary objective of these studies will be to determine if a minimum ratio of food-to-microorganisms must be maintained during aeration to prevent phosphate leakage.

Evaluating stimulation and retardation on microbial phosphate release by chemical addition is another major phase of this study. Using batch units, chemicals are added to activated sludge systems during and after phosphate uptake and the results are compared to control units. Primary attention is being directed towards chemical control of phosphate release under anaerobic conditions.

Results:

Although continuous flow experiments are presently underway, nearly all of the results obtained to date are from batch-type reactors. The batch studies were designed primarily to define the nature and extent of phosphate uptake that could be accomplished, and to study the effect of chemical parameters on subsequent release. In keeping with the ultimate goal of

chemical control of phosphate release, extensive studies were conducted to clearly define the relationships between oxidation-reduction potential (ORP), dissolved oxygen (DO) concentration, pH, and phosphate release. The sludge was permitted to go anoxic or was purged with nitrogen gas to hasten anoxic conditions and maintain stirring, and the change in ORP, DO, pH, and phosphate concentration was monitored. Since operational control must also be considered, experiments determining the time required for phosphate uptake and the extent of aeration before subsequent release were also performed. Following these studies, attempts were made to control release by adding various concentrations of sulfate salts, chemicals known to be effective in reducing phosphate release in pure culture studies.

Phosphate uptake obtained during the investigation was considerably in excess of what would be predicted by the carbon limitation theory. The ratio of initial COD to maximum phosphorus uptake varied from 64:1 to 36:1 with an average of 47:1. This uptake was accomplished in less than eight hours in all experiments. Although the initial soluble phosphate concentration varied, it has no effect on the extent of uptake as long as it was in excess. Uptake was very rapid at first but declined as aeration progressed. After the organic substrate had been stabilized, continued aeration caused a soluble phosphate release varying from 9 to 21 percent of the original uptake. The percent soluble phosphate release during extended aeration varied directly with the magnitude of original uptake.

When aeration was discontinued following phosphate uptake, the DO concentration rapidly dropped to zero. The disappearance of DO from the mixed liquor was always accompanied by a significant release of soluble phosphate. The anoxic release varied from 57 to 87 percent of total uptake during the first 90 minutes after aeration had been terminated. No relationship between total uptake and degree of anoxic release could be established. During the anoxic studies there was also a characteristic decrease in ORP. However, the time and magnitude of this decrease varied considerably. In the vast majority of the experiments, the change in ORP did not coincide with any change in soluble phosphate release, although simultaneous change did occur in two instances. In most cases release preceded any change in ORP and was obviously more closely related to DO change. The pH did not vary during the studies? therefore, it has no effect on the phosphate releases observed.

Both NA_2SO_4 and $MgSO_4$ were added to reactors to prevent the release of phosphate under anoxic conditions. When the sulfate salts were

added in concentrations of less than one percent; there was no appreciable effect on the amount of phosphate released. However, a two percent solution of $MgSO_4$ inhibited phosphate release by 46 percent in comparison to the control. Since it is known that sulfate salts tend to inhibit cell lysis, it appears that a very large percentage of the soluble phosphate released during anoxic conditions is due to cell lysis rather than leakage from a viable cell or change in chemical solubility. In fact, whether leakage from a viable cell actually occurs is open to question.

Studies presently underway have indicated that pH changes may also result in the release of soluble phosphate. It appears that such release is due to a change in solubility of phosphate compounds. If such is the case, pH changes could also account for a certain portion of phosphate uptake. Additional studies are planned to more adequately define the relationship between phosphate uptake and release, and pH, hardness, alkalinity, and other chemical constituents.

Continuous flow experiments are planned to study the effect of various operational parameters on phosphate release. Particular emphasis will be placed on the effect of different DO and agitation levels during uptake on the time and extent of subsequent release under anoxic conditions. Further chemical suppression studies are planned and in many cases will be applied to continuous flow situations. These studies should all be completed during this calendar year.

SOLAR REFLECTANCE OF MONOLAYER-COVERED WATER SURFACES AS RELATED TO EVAPORATION SUPPRESSION

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SOLAR REFLECTANCE OF MONOLAYER-COVERED WATER SURFACES AS RELATED TO EVAPORATION SUPRESSION

Water reservoirs in the United States experience an average evaporation loss of six feet of water depth annually. With increased population and industrialization, the demands for water increase. Consequently, it is very important that new methods of water conservation be investigated.

During the past fifteen years, there has been a considerable effort at evaporation suppression through the use of monolayer chemical films. Materials such as cetyl alcohol and stearyl alcohol have been found to be effective as barriers to the diffusion of water into the atmosphere. Studies have indicated that the evaporation of small lakes may be reduced by as much as 35%.

If one were to think of the evaporation process in terms of an electrical analogy, $I = \frac{\Delta V}{R}$ or $\text{Evaporation} = \frac{\text{Driving Potential}}{\text{Evaporative Resistance}}$ it would be evident that the previous studies have tried to reduce evaporation by increasing the "evaporative resistance."

It is known that applications of cetyl alcohol monolayers tend to increase the temperature of the water surface. This is because the heat loss or cooling effect which accompanies evaporation is reduced with evaporation suppression. Therefore it is seen that an increase in the "evaporative resistance" is known to include a corresponding increase in the "driving potential" (since the water temperature increases).

An alternate approach to the evaporation suppression problem would be to attempt to reduce the "driving potential" by reducing the amount of incident energy absorbed by the water surface. An analysis of the literature shows that the major factors in the "energy budget equation" are the energy absorbed from the sun and sky, the energy emitted by the water surface, and the energy lost as a result of evaporation. If the absorbed energy could be reduced, it would logically follow that the energy loss terms would also be reduced. This would be accompanied by a decrease in the water temperature and the rate of evaporation. Therefore, the investigation of ways to increase the reflection of incident solar energy is important.

An extensive analytical study of the reflectance of film-covered water surfaces has shown that the reflectance change may be significant, if a properly selected film is used. The important film properties, from an optical standpoint, are the index of refraction, n; the coefficient of absorption, k; and the thickness of the film. An adequate film would also require an ability to spread and be maintained on the water surface. In addition, certain health and economic considerations must be made.

Two major objectives of this study are:

(1) to determine what chemical substances would substantially increase the solar reflectance of water systems upon application to the surface as a monolayer of film.

(2) to determine the change in water evaporation which would result from increasing the solar energy reflectance.

As an outgrowth of the above mentioned objectives, it became necessary to make a more basic investigation of the diffusion mechanism. This mechanism strongly influences the effectiveness on monolayers to retard evaporation.

There were two basic categories of substances studied.

Dyes: By their very nature, dyes have a high coefficient of absorption in the visible energy wavelengths where most solar energy is found. It has been shown that a yellow dye pigment in the bulk form may reflect as much as 68.5% of the solar energy when incident normal to the surface.

Polymers: An increase in film thickness tends to increase the reflectance for films having certain optical properties. Because of their physical nature, polymers should produce thicker films. Thus it should be possible to enhance reflectance with certain polymeric materials.

One major emphasis of the work related to both dyes and polymers was the search for products which, when applied to a water surface, will:

(a) form stable monolayers themselves,
(b) form a stable monolayer in solution with other monolayer forming substances, or
(c) form a stable thin film.

General Procedures:

A major search of chemical materials was made in an effort to find a chemical which both formed a monolayer or stable film on water surface and also significantly increased the solar energy reflectance. Both pure chemical substances and mixtures of substances (including dyes) were considered. An experimental apparatus was used for measuring the increase in solar reflectance resulting from application of such monolayers and films on water surfaces.

The analytical study for determining the change of evaporation resulting from an increase in the solar reflectance was made with the aid of a digital computer. The procedure called for solution of the one-dimensional transient heat transfer equation by numerical methods. Transient boundary conditions at the water surface simulated variation of solar radiation, back radiation, convection, and evaporation with the time of day.

Analytical and experimental procedures were used to study the diffusion of water vapor through a monolayer. The analytical model assumed that the energy required for water vapor to penetrate the monolayer was proportional to the surface tension of the monolayer. From this it was shown that the diffusion coefficient should be proportional to the surface pressure. Experimental measurements confirmed this theory for liquid monolayers.

Results:

It was found that Union Carbide Experimental Silicone S-1362-91-2

(a) forms a stable film on a water surface

(b) reflects solar energy about 1.7 times as well as a plain water surface

(c) is difficult to remove from a water surface, and

(d) acts as a diffusion barrier when spread on a water surface (decreasing evaporation 10%) and when spread on top of a linoleic acid monolayer (reducing evaporation 15%).

Increasing the solar energy reflectance was shown to decrease evaporation. However, it was shown that the solar reflectance must be increased to approximately 10 times that of a plain water surface for a 20% reduction of evaporation. Therefore, it is projected that optimum evaporation suppression can only be obtained when films which act as a reflector also act as a diffusion barrier. It was shown that Union Carbide Experimental Silicone, S-1362-91-2, combined both these properties. It is to be noted, however, that this material is not a very significant reflector (reflecting only 1.7 times as much energy as a plain water surface) and that it also does not decrease diffusion of water vapor as well as cetyl alcohol (10% compared with 37% evaporation reduction). The diffusion barrier effectiveness of any material which forms as a liquid monolayer on a water surface can be quickly determined by measuring its surface pressure.

SIMULATION OF THE HYDROLOGIC CYCLE ON SMALL AGRICULTURAL WATERSHEDS BY DIGITAL TECHNIQUES

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SIMULATION OF THE HYDROLOGIC CYCLE ON SMALL AGRICULTURAL WATERSHEDS BY DIGITAL TECHNIQUES

The rapid development of high speed digital computers over the past decade has opened a new era in watershed engineering research. Problems that were heretofore either too complex or time consuming for manual solution may now be programmed and solved quite effectively by digital equipment. A typical example would be simulation of the hydrologic cycle.

Digital equipment has proven to be an invaluable tool in quantitative studies of various segments of the hydrologic cycle. A number of institutions have developed simulation techniques with varying success for specific elements of this cycle. The most famous of these and one of the first models to attempt to simulate the entire hydrologic cycle over a given area is the Stanford Watershed Model. The development and testing of this model has been primarily for large river systems using climatic, hydrologic and meteorologic data collected in the far west.

Because the interactions between the many phases of the hydrologic cycle are so complex and the exact mathematical formulation combining these integral relationships simply are not well understood, impericisms constitute a large part of present watershed model development. It is doubtful this condition will be circumvented in the foreseeable future. This problem, however, along with the ever pressing need by design engineers for quantitative answers about various hydrologic and hydraulic components of a given watershed area, necessitates continuous and rigorous testing of present concepts in watershed models. These concepts must be tested for different watershed sizes, geographic regions, physical characteristics as well as varying climatic and meteorologic experiences.

Since the Stanford Watershed Model was designed and tested with data collected primarily from large river basins there remains a great need for a comprehensive watershed model to study the flow regimes from small agricultural watersheds. This need is accentuated by the ever increasing demands that society places on the conservation use and distribution of inland waters. These changes make it of utmost importance that we develop procedures and techniques to determine the hydrologic implications of a given area's response when subjected to specific climatic, land use, and meteorologic experiences. In agricultural watersheds the effect of various land

uses or cropping systems becomes increasingly important. Under these conditions the design engineer must be able to determine how much water will be available for rural and urban use. It becomes readily apparent that a complete understanding of the hydrologic regime in quantitative terms on these small watersheds will greatly facilitate the efficient conservation and utilization of this basic natural resource. A realistic balance between potential water uses may hopefully be obtained. Modification of the Stanford Watershed Model to study the flow regimes on small agricultural watersheds appears to be the most logical approach for solving this problem.

This study was initiated as a cooperative endeavor between the VPI Division of Research, Virginia Water Resources Research Center and the Agricultural Research Service with the following general objectives: (a) To evaluate the effectiveness of the Stanford Water Model for synthesizing streamflow records on small agricultural watersheds in Virginia, (b) to modify the model as may be required to fit the flow regimes of these watersheds and (c) to evaluate the effect of tillage practices, namely the no tillage and conventional tillage practice of corn production on water yields.

Since 1957, detailed hydrologic data have been collected and processed on 10 complex watersheds by the Agricultural Research Service in cooperation with the VPI Division of Research. These watersheds are scattered throughout Virginia and range in size from approximately 200 acres to 3000 acres.

A Fortran version of the Stanford Model was obtained from the USWB and adapted to the IBM 360 system at VPI. The Crab Creek and Brush Creek watersheds were selected to test the applicability of this algorithm for studying flow regimes on small agricultural watersheds because of their contrasting hydrologic responses. Primary emphasis was placed on synthesizing water yields.

The first part of this study is concerned with the adaptation and use of the Stanford watershed model for predicting water yields from two small agricultural watersheds. The last portion of the study deals with the development of a modified moisture accounting procedure to be incorporated into the Stanford Model to study the influence of tillage practices on water yields.

Adaptation and use of Stanford Watershed Model:

The watershed parameters described in Table 1 and quantified in Table 2 were used to generate synthetic daily streamflow for water year 1960-61 on the Crab Creek and Brush Creek watersheds. Comparisons of synthetic with actual values are shown in Figures 1 and 2. Monthly water yields and peak discharges, and monthly precipitation and potential evaporation are compared in Tables 3 and 4. Major discrepancies in flow timing in winter months are due in part to snowmelt, which was not modelled in this study. Primary emphasis was placed on fitting monthly yield data for the 6-month growing season, April through September.

Moderate success was achieved in obtaining water yield estimates for both watersheds. The yield data in Table 3 show that the 2 watersheds represent very contrasting hydrologic responses, although they are roughly the same size, have the same land use and geographically are within 11 miles of each other. The low water yields on Crab Creek were extremely difficult to model accurately. For example, a difference of 0.04 inch in the September estimate for Crab Creek represented an error of 18.2 percent whereas a 0.24 inch difference in the August estimate on Brush Creek represented an error of only 16.3 percent. The percentage error for the annual yields is 1.1% and 2.1% for Crab Creek and Brush Creek, respectively. Peak discharge rates are also given in Table 3. As would be expected, more scatter is apparent in these results. The criterion which must be used in fitting individual hydrographs over the year is to select one or more representative well-defined hydrographs and adjust the appropriate watershed parameters, namely CBI and CC by trial until the synthesized hydrographs match the selected recorded hydrographs. The maximum peak discharge for water year 1960-61, which also represents the second highest peak recorded was modelled by adjusting CBI, CC, UZSN and FLZSN until a relatively good fit resulted. However, the annual water yield was increased from 5.5 inches to 6 inches.

Some difficulty was encountered in modelling short-duration, high-intensity summer storms and still retain reasonable estimates of water yields. The major problem appears to be timing and model sensitivity. Two hypothetical dimensionless storage reservoirs - upper zone (UZS) and the lower zone (FLZS) together with groundwater storage, combine to represent soil moisture profiles and groundwater conditions. The initial response of the watershed to a given rainfall event is modelled by the upper zone and consequently becomes very important in small, high-intensity storms. When the moisture supply is less than extractions for periods sufficiently long to allow UZS to become zero, then the model became much less responsive to small high-intensity storms. Examples of these situations are reflected in Figure 1 (Crab Creek) for the rainfall events occurring on June 10 and August

TABLE 1 -- Description of the Stanford Watershed Model Parameters Used in the USWB - VPI Fortran Version

	Symbolic Name of Parameter	Description
		15 Basic Model Parameters
1.	AREA	Watershed area in square miles.
2.	CBI	Infiltration index which controls the rate of infiltration.
3.	CC	An interflow index controlling the time distribution and quantities of moisture entering interflow.
4.	CSSR	Streamflow channel routing parameter. From continuity equation $q = k\ do/dt$ then $CSSR = \frac{1/K - \Delta t/2}{1/K + \Delta t/2}$
5.	EPXM	The maximum interception rate for a dry watershed. Grassland - 0.10 in./hr. Moderate Forest Cover - .15 in./hr. Heavy Forest Cover - .20 in./hr.
6.	FIA	The fraction of the watershed which has impervious area draining directly into a stream.
7.	FK1	Ratio of average rainfall on the watershed to the average rainfall at the recording gage.
8.	FK3	A measure of the rate of loss through evapotranspiration. Open Land - 0.20 in./hr. Grassland - .23 in./hr. Light Forest - .28 in./hr. Heavy Forest - .30 in./hr.
9.	FKGS	Antecedent groundwater index - usually assumed to be 0.97.
10.	FLIRC	Interflow recession constant.
11.	FLKK4	Groundwater recession which is equal to $1\text{-}R^{1/96}$ where R is the minimum observed daily recession constant of groundwater discharge 24 hours earlier.
12.	FKSI	Stream channel storage recession parameter.
13.	FKV	An index used to provide curvelinear base flow recession.
14.	FLZSN	Nominal lower zone storage index and approximately equals the volume of water held in the soil profile between the soil surface and the water table that will drain by gravity.

Table 1. Continued

5.	UZSN	Soil moisture storage capacity index of the upper zone and is an indication of interception and depression storage. Steep slopes, limited vegetation. Low depression storage -- 0.06 (FLZSN) Moderate slopes, moderate depression storage -- 0.08 (FLZSN) Heavy vegetal or forest cover, soils subject to cracking, high depression storage, very mild slopes -- 0.14 (FLZSN)
	9 Initial Moisture Parameters	
.	GWS	Current value of groundwater slope index and gives an indication of antecedent moisture conditions.
.	FLZS	Current soil moisture storage. FLZS is an index of the volume of water stored between the soil surface and the groundwater table.
.	RES	Current overland flow surface detention storage.
.	REM	Current delayed infiltration of percolation from upper zone to lower zone and groundwater storage.
.	RI	Discharge at the end of the previous water year.
.	SCEP	Interception storage.
.	SGW	Groundwater moisture storage.
.	SRGX	Interflow storage.
.	UZS	Current upper zone storage.

TABLE 2 -- Summary of Watershed Parameters and Initial Moisture Parameters for Crab Creek and Brush Creek Watersheds

Model Parameters		Crab Creek	Brush Creek
	Basic Model Parameters		
1.	AREA	1.228	1.395
2.	CBI	1.2	10.0
3.	CC	1.5	1.5
4.	CSSR	0.94	0.902
5.	EPXM	0.107	0.116
6.	FIA	0.	0.
7.	FK1	1.0	1.0
8.	FK3	0.206	0.2299
9.	FKGS	0.97	0.97
10.	FLIRC	0.43	0.839
11.	FLKK4	0.00158	0.0015
12.	FKSI	0.17	0.407
13.	FKV	1.0	1.0
14.	FLZSN	8.0	13.2
15.	UZSN	0.64	1.056
	Initial Moisture Parameters		
1.	GWS	0.30	0.70
2.	FLZS	4.0	30.0
3.	RES	0.	0.
4.	REM	0.	0.
5.	RI	0.0077	0.0303
6.	SCEP	0.	0.
7.	SGW	0.15	0.20
8.	SRGX	0.	0.
9.	UZS	0.	0.

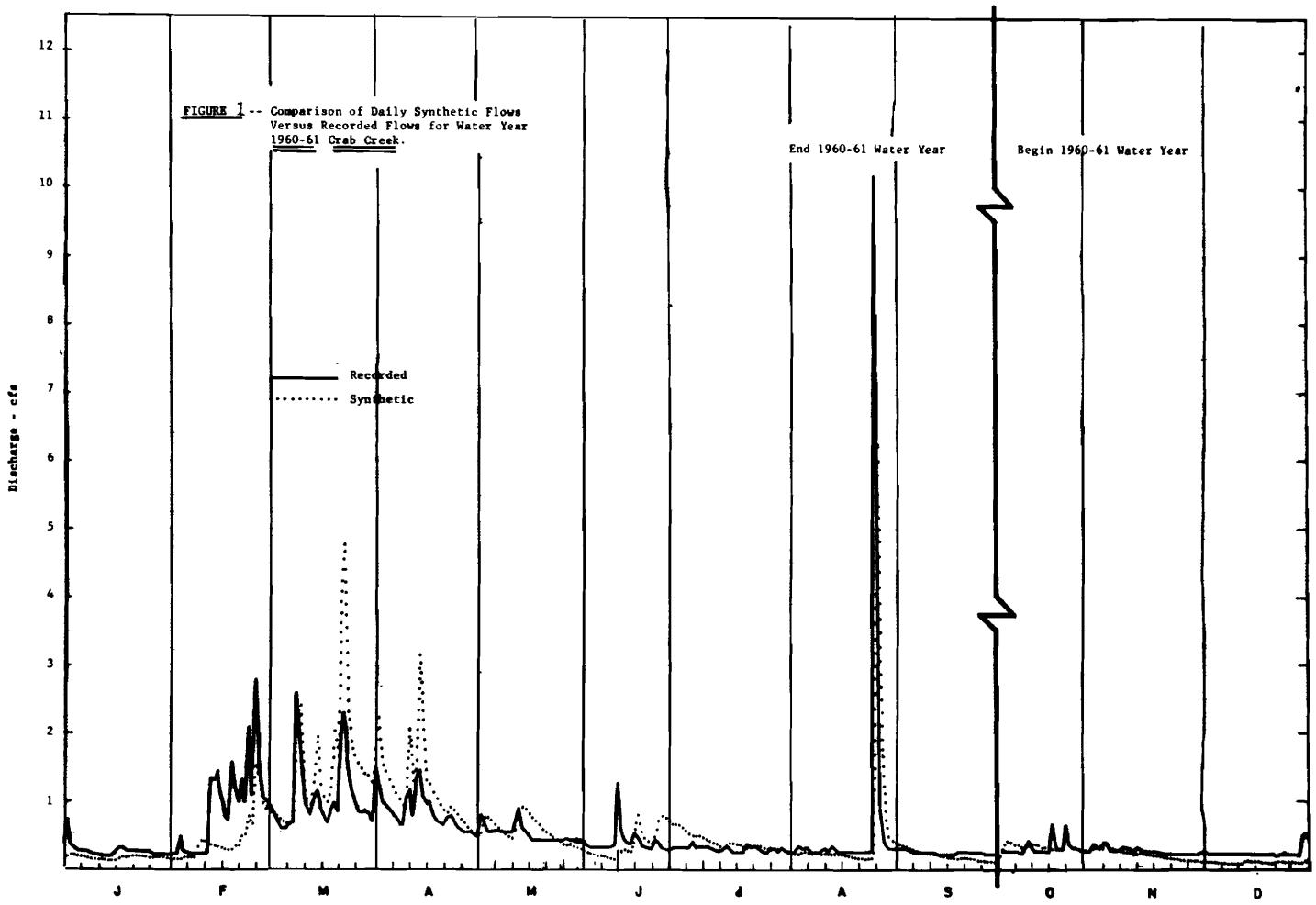

FIGURE 1 -- Comparison of Daily Synthetic Flows Versus Recorded Flows for Water Year 1960-61 Crab Creek.

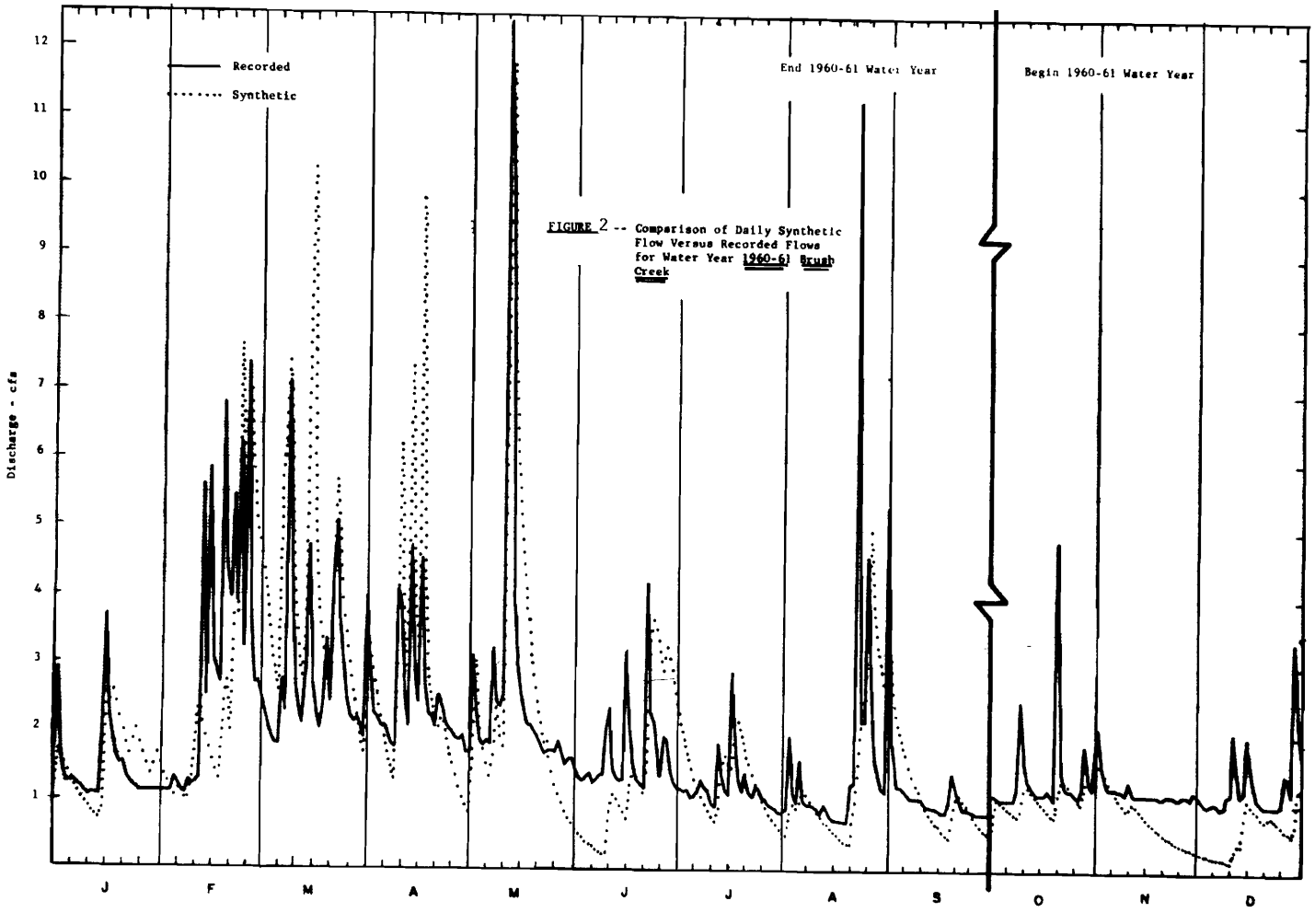

FIGURE 2 -- Comparison of Daily Synthetic Flow Versus Recorded Flows for Water Year 1960-61 Brush Creek

TABLE 3 -- A Comparison of Monthly Water Yields and Peak Discharges for Brush Creek and Crab Creek

Date 1960-61	Brush Creek				Crab Creek			
	Water Yield		Peak Discharge		Water Yield		Peak Discharge	
	SYN (INS)	ACT (INS)	SYN (cfs)	ACT (cfs)	SYN (INS)	ACT (INS)	SYN (cfs)	ACT (cfs)
October	0.90	1.15	1.46	4.86	0.31	0.29	0.55	0.67
November	0.65	.97	1.58	2.12	.17	.23	.35	.38
December	.50	1.08	1.25	3.37	.09	.24	.15	.51
January	1.30	1.21	2.59	3.68	.17	.29	.23	.77
February	2.05	2.31	7.66	7.39	.39	.81	1.53	2.81
March	3.40	2.39	10.25	7.13	1.46	1.00	4.78	2.62
April	2.27	2.07	9.80	5.13	1.08	.77	3.15	1.48
May	2.34	2.27	11.78	12.41	.54	.49	.92	.91
June	1.22	1.37	3.65	4.21	.39	.36	.81	1.28
July	1.09	1.03	2.20	2.90	.34	.29	.53	.42
August	1.23	1.47	4.99	11.26	.50	.59	6.23	10.17
September	0.88	0.84	3.11	1.96	.18	.22	.37	.30
Total	17.8	18.2			5.62	5.58		

TABLE 4 -- Monthly Precipitation and Potential Evaporation on the Crab Creek and Brush Creek Watersheds

Date 1960-61	Crab Creek		Brush Creek	
	Precipitation INS.	Evaporation INS.	Precipitation INS.	Evaporation INS.
October	3.73	1.62	2.21	.32
November	.51	1.07	.31	.21
December	1.47	.53	1.61	.11
January	.93	.65	1.59	.13
February	3.88	.73	3.91	.73
March	4.45	1.49	4.42	1.49
April	2.25	2.34	3.16	1.80
May	2.21	3.15	3.89	2.86
June	3.98	4.31	3.82	3.32
July	2.87	4.46	1.98	3.71
August	5.16	3.47	6.55	3.47
September	.42	2.75	.59	2.75
TOTAL	31.86	26.57	34.04	20.91

25. The June 10 storm consisted of a short duration rainfall of 1.58 inches, which resulted in an actual daily peak discharge of 1.28 cfs contrasted to a synthetic daily peak discharge of 0.29 cfs. The antecedent moisture supply for 28 days prior to this event was only 0.31 inches. As a result UZS became zero, resulting in less sensitivity in the model. On June 15 another rainfall of 1.02 inches resulted in an actual daily discharge of 0.54 cfs compared to a synthetic daily discharge of 0.81 cfs. The August 25 rainfall of 2.47 inches resulted in an actual peak daily discharge of 10.2 cfs compared to a synthetic daily discharge of 6.2 cfs. Antecedent moisture conditions were such that the UZS was also reduced to zero before this event.

Water Yield Predictions--To gain some insight into the representativeness of predictive ability of the model, the watershed parameters established for water year 1960-61 were used to simulate streamflow records for water years 1961-67 on both Crab Creek and Brush Creek. Theissen-weighted rainfall and potential evaporation were the only additional input (Tables 7 and 8). These results are presented in Tables 5 and 6. On the average, the synthetic water yield estimates were biased upwards. On the Crab Creek watershed maximum and minimum errors of +3.2 and -0.52 inches, respectively, were noted for annual water yield estimates. On Brush Creek a maximum error of +3.3 inches and a minimum error of -0.6 inch occurred.

Peak discharge estimates were more erratic. The maximum recorded daily discharge rate on Crab Creek was 14.84 cfs compared to a synthesized discharge rate of 13.26 cfs for the same date. On Brush Creek a maximum daily discharge rate of 21.88 cfs was recorded in February. The corresponding synthetic peak discharge was only 5.44 cfs. The higher recorded value was due to snowmelt.

Statistical Analysis--A test of "goodness of fit" was run on the data presented in Tables 3, 5, and 6 for both the monthly water yields and the maximum daily peaks. The means of the data were compared both on annual and seasonal basis. The two seasons selected were October through March and April through September. The results of this analysis are summarized in Table 9. These data represent the average difference between the recorded and predicted data. The negative differences refer to high predicted values. Statistical significance is denoted by the symbols NS for no significance at 15% level and the symbol ** for significance at 1% level. Inspection of these data readily show that reasonable estimates of yields and peaks did occur for all data with the exception of the peak flows on Brush Creek during the October through March period.

TABLE 5 -- Summary of Monthly Water Yields and Peak Discharges for Water Years 1961-67 Using the Watershed Parameter Established for Water Year 1960-61, Crab Creek

Date	1961-62		1962-63		1963-64		1964-65		1965-66		1966-67	
	SYN	ACT	SYN	ACT	SYN	ACT	SYN	ACT	SYN	ACT	SYN	ACT
						Water Yields - Inches						
October	0.16	0.26	0.28	0.19	0.02	0.11	0.14	0.13	0.33	0.23	0.68	0.29
November	.41	.31	.94	.33	.02	.12	.09	.12	.18	.12	.36	.16
December	2.23	1.08	1.69	.49	.05	.11	.18	.18	.07	.10	.83	.30
January	1.28	.97	1.13	.62	.22	1.35	.62	.46	.25	.19	1.03	.76
February	1.46	1.12	.45	.41	.67	.39	.83	.59	.99	.85	.89	.54
March	2.40	1.70	1.89	1.28	.65	.57	1.06	.73	.92	.49	2.45	1.56
April	.93	.90	.27	.40	1.14	.61	.72	.43	.27	.21	.43	.41
May	.20	.51	.27	.27	.34	.25	.36	.27	.85	.38	.58	.31
June	.27	.47	.24	.16	.22	.17	.40	.16	.26	.15	.48	.19
July	.59	.45	.07	.18	.11	.18	.20	.16	.06	.12	.17	.17
August	.54	.27	.03	.13	.08	.14	.20	.21	.21	.39	.31	.41
September	.23	.15	.02	.12	.07	.12	.17	.21	.27	.15	.25	.16
Total	10.70	8.18	7.28	4.58	3.59	4.12	4.95	3.65	4.65	3.37	8.45	5.26
						Peak Discharges - cfs						
October	0.59	0.84	0.48	1.40	0.03	0.13	0.19	0.28	0.67	1.36	5.02	2.82
November	2.51	.97	5.04	2.26	.04	.35	0.20	0.45	0.30	0.15	0.66	0.30
December	10.96	7.78	5.48	1.44	.08	.15	0.29	0.74	0.14	0.12	2.73	0.58
January	2.93	2.79	2.38	1.53	.40	11.19	1.58	1.81	0.74	0.50	3.61	3.08
February	5.74	3.45	0.70	2.90	2.93	1.25	2.67	3.35	2.86	6.31	2.07	1.60
March	10.11	7.48	7.87	4.12	1.21	1.95	8.02	5.79	3.07	1.58	13.26	14.84
April	2.19	1.84	.73	.62	6.80	2.36	1.34	0.80	0.62	0.41	0.82	0.62
May	.33	.74	.48	.51	.68	.40	0.74	0.69	4.59	2.36	0.78	0.66
June	.60	2.69	.46	.24	.42	.33	0.61	0.30	0.52	0.36	1.03	0.38
July	5.58	2.35	.11	.78	.18	.50	0.28	0.54	0.12	0.49	0.26	0.28
August	1.98	.50	.06	.21	.13	.34	1.45	2.32	1.18	6.29	1.33	4.24
September	.40	.27	.03	.34	.11	.27	0.71	2.27	0.57	0.31	0.47	0.50

TABLE 6 -- Summary of Monthly Water Yields and Peak Discharges for Water Years 1961-67 Using the Watershed Parameters Established for Water Year 1960-61, Brush Creek

Date	1961-62 SYN	1961-62 ACT	1962-63 SYN	1962-63 ACT	1963-64 SYN	1963-64 ACT	1964-65 SYN	1964-65 ACT	1965-66 SYN	1965-66 ACT	1966-67 SYN	1966-67 ACT
Water Yields - Inches												
tober	1.45	1.06	1.39	0.85	0.53	0.46	1.84	1.08	1.41	0.88	1.01	0.99
vember	2.09	1.42	3.57	1.87	1.08	0.77	0.72	0.98	0.42	0.66	0.84	0.96
cember	4.19	2.27	2.44	1.78	1.09	0.65	1.56	1.24	0.21	0.62	1.29	1.02
nuary	2.78	2.21	1.43	1.69	2.04	2.30	1.60	1.37	0.78	0.65	1.21	1.54
bruary	2.07	2.16	0.98	1.33	1.94	1.45	1.27	1.64	2.17	2.20	0.86	1.10
rch	2.57	2.90	3.01	2.93	1.20	2.06	1.84	2.24	1.30	1.36	1.98	2.26
ril	2.28	2.56	0.28	1.24	1.71	1.70	1.62	1.53	0.58	1.00	0.61	1.07
y	0.37	1.46	1.01	1.11	0.98	1.02	1.03	1.10	1.55	1.35	1.52	1.18
ne	0.85	1.00	1.13	0.77	0.90	0.65	1.43	0.91	0.55	0.55	0.84	0.66
ly	1.38	1.23	0.56	0.52	1.19	0.65	1.67	1.46	0.14	0.44	0.31	0.63
gust	1.80	0.81	0.43	0.38	0.70	0.89	0.58	0.68	0.61	0.55	0.66	0.81
ptember	1.26	0.72	0.76	0.55	1.64	0.62	0.67	0.60	0.46	0.57	0.76	0.56
tal	23.1	19.8	17.0	15.0	15.0	13.2	15.8	14.8	10.2	10.8	11.9	12.8
Peak Discharges - cfs												
tober	4.46	6.07	4.67	3.08	1.49	0.63	3.87	4.52	3.72	5.51	3.05	11.75
vember	10.60	6.40	10.60	16.53	2.96	4.06	3.53	8.10	0.68	1.12	1.86	3.85
cember	13.31	9.29	5.22	6.17	2.08	1.21	2.96	3.65	0.55	0.83	3.12	2.25
nuary	6.79	9.23	3.99	4.49	3.28	14.38	2.71	3.80	2.31	1.54	2.59	5.32
bruary	13.78	10.83	1.87	3.87	4.83	8.51	2.69	7.67	5.44	21.88	1.97	3.62
rch	8.42	15.47	7.53	12.62	2.20	11.45	5.78	16.26	3.64	4.45	4.65	15.30
ril	9.19	8.21	1.06	2.19	4.07	6.94	3.65	3.00	1.41	2.33	1.88	2.73
y	1.33	3.19	2.50	3.76	2.03	2.84	2.29	2.99	4.42	8.60	2.49	2.72
ne	2.21	2.75	2.76	1.94	1.73	2.44	3.23	2.30	1.73	0.98	2.64	1.68
ly	6.95	8.71	1.04	1.07	3.00	3.24	5.52	5.41	0.82	4.87	0.77	2.56
gust	5.77	1.60	0.86	1.24	5.27	13.67	1.76	4.14	1.00	2.02	2.62	6.72
ptember	3.66	2.21	1.78	1.43	1.88	2.01	1.41	2.66	1.07	2.79	1.92	1.91

TABLE 7 -- Monthly Precipitation and Potential Evaporation on the Crab Creek Watershed for Water Years 1961-67

Date	1961-62 P	1961-62 INS. E	1962-63 P	1962-63 INS. E	1963-64 P	1963-64 INS. E	1964-65 P	1964-65 INS. E	1965-66 P	1965-66 INS. E	1966-67 P	1966-67 INS. E
October	3.24	1.91	2.97	1.67	0.08	2.37	1.87	1.52	3.47	1.85	3.30	1.85
November	3.76	.90	4.00	.66	3.48	.85	2.31	1.21	.72	.92	1.91	1.01
December	5.18	.49	4.03	.35	1.67	.36	2.31	.47	.08	.63	3.28	.55
January	2.37	.51	1.08	.50	3.59	.74	3.33	.64	3.24	.37	2.06	.77
February	3.59	.88	1.12	.66	3.43	.74	2.20	.85	3.87	.55	2.05	.81
March	3.44	1.14	3.96	1.60	2.33	1.39	3.43	1.26	.84	1.81	4.24	1.73
April	1.78	2.94	.97	3.84	3.98	2.78	2.28	2.92	2.88	2.03	1.95	3.57
May	1.83	3.65	2.56	3.49	1.89	3.84	3.61	4.41	2.79	3.73	3.78	2.83
June	3.84	4.35	.77	5.00	1.61	5.25	1.96	4.33	1.27	5.32	2.41	5.45
July	5.97	4.26	3.91	4.39	4.64	4.25	3.30	4.53	3.33	5.24	2.19	4.43
August	1.03	3.65	1.49	3.27	3.12	3.18	4.91	3.75	6.07	3.26	6.40	3.24
September	2.63	2.02	3.26	2.58	2.46	2.46	2.67	2.53	4.22	2.26	2.27	2.76
Totals	38.66	26.70	30.12	28.01	32.28	28.21	34.18	28.42	32.78	27.97	35.84	29.00

TABLE 8 -- Monthly Precipitation and Potential Evaporation on the Brush Creek Watershed for Water Years 1961-67

Date	1961-62		1962-63		1963-64		1964-65		1965-66		1966-67	
	P	E	P	E	P	E	P	E	P	E	P	E
	INS.	INS.	INS.	INS.	INS.	INS.	INS.	INS.	INS.	INS.	INS.	INS.
October	3.52	0.38	2.08	0.33	0.13	0.47	3.03	0.30	2.94	0.37	3.84	0.37
November	3.55	0.18	5.63	0.13	4.07	0.17	2.62	0.24	.90	0.18	2.41	0.20
December	4.35	0.10	3.69	0.07	1.83	0.07	2.65	0.09	.15	0.13	3.15	0.11
January	3.30	0.10	1.12	0.10	3.57	0.15	2.42	0.13	2.63	0.07	1.83	0.15
February	3.05	0.88	1.55	0.66	3.80	.74	2.78	0.85	4.26	.55	1.66	0.81
March	3.84	1.14	4.53	1.60	2.23	1.39	4.00	1.26	1.11	1.81	4.43	1.73
April	2.63	2.26	0.96	2.96	4.08	2.14	2.86	2.25	2.20	1.56	1.91	2.74
May	1.76	3.32	2.76	3.17	2.24	3.49	3.52	4.01	3.61	3.39	4.14	2.58
June	1.54	3.35	1.69	3.85	2.36	4.04	2.99	3.33	.58	4.09	0.86	4.19
July	6.92	3.55	2.36	3.66	4.66	3.53	5.45	3.77	3.47	4.37	2.81	3.69
August	1.37	3.65	1.52	3.27	5.91	3.18	2.97	3.75	2.75	3.26	5.66	3.24
September	2.83	2.02	3.65	2.58	2.53	2.46	2.90	2.53	4.08	2.26	1.68	2.76
Total	38.66	20.93	31.54	22.38	37.41	21.83	38.19	22.51	28.68	22.04	34.38	22.57

TABLE 9 -- Summary of Statistical Analysis of Monthly Water Yield and Maximum Daily Peak Discharge Data for Water Years 1960-67

Sample	Difference Between Means		
	Annual	October-March	April-September
Crab Creek:			
Yields	-0.13^{NS}	0.19^{NS}	-0.05^{NS}
Peaks	-0.08^{NS}	-0.23^{NS}	0.07^{NS}
Brush Creek:			
Yields	-0.07^{NS}	-0.11^{NS}	-0.03^{NS}
Peaks	1.68**	2.53**	0.82^{NS}

Moisture Accounting System for Conventional and No-Tillage Corn Practices:

The major objective during this phase of the research program was to develop a mathematical model sufficiently sensitive to detect differences in the available soil water under no tillage and conventional tillage corn practices. The model must be capable of predicting with reasonable accuracy runoff and evapotranspiration from the two contrasting soil cover conditions.

The model is basically an accounting system which can be expressed as:

$$SM_t = SM_{t-1} + P_t - Q_t - PC_t - ET_t + I_t$$

where:

P = Rainfall (inches)
Q = Runoff (inches)
PC = Deep percolation (inches)
ET = Evapotranspiration (inches)
I = Irrigation (inches)
t = time unit

In this model it is normally assumed that P and I will be known and that Q, PC, and ET must be estimated by empirical methods. An empirical infiltration relationship is being used to estimate surface runoff and percolation. This equation can be expressed as:

$$f = as^n + f_c$$

where:

f = infiltration rate (in./hr.)
s = remaining unfilled pore space above some datum (inches)
f_c = final infiltration rate (in./hr.)
a&n = constants that depend on surface conditions, soil type, root development, etc.

The evapotranspiration process is quite complex, and, as a result, it is extremely difficult to predict values under field conditions. During the first 40-50 days after plowing (conventional area) and spraying with a mixture of paroquot and atrizine (no tillage) the loss of soil water is primarily by the evaporation process. As the corn develops its root system and its growth is such that a canopy is developed over the area, transpiration becomes the primary mechanism by which soil water is lost.

Because of these two distinct periods the procedure for estimating ET was developed in two parts. The first part deals entirely with evaporation and the second group of formula deal with transpiration and small evaporation losses.

Evaporation--Evaporation formula for groseclose silt loam soil have been developed from actual field measurements of pan evaporation, soil water, precipitation and runoff which were collected from a statistically designed tillage experiment. A plot of the ratio of actual available water to total available soil water in the 0-12 inch soil profile yielded the following relationships for conventional tillage and no tillage practices.

where:

E_s = Soil water evaporation during time interval $t_1 - t_2$

W_t = Total available water held in o-12" profile between 1/3 and 15 atms. tension.

To allow variations from the climatic conditions implicit in the derivation of equipment 4, 5, and 6 the relationships are modified by the ratio $E_{pa}pb$ where E_{pa} is equal to the daily pan evaporation on the date E_s is being determined and E_{pb} is equal to the average daily pan evaporation for the period used in the derivation of equations 5, 6, and 7.

The resulting working equations become upon substitution into equations 5, 6, and 7:

$$(E_s)_{cl} = 15.32\times10^{-2}\ E_{pa}W_T(\ (0.95)^{t1} + (0.95)^{t2}) \qquad (8)$$

$$(E_s)_{c2} = 4.01\times10^{-2}\ E_{pa}W_T(\ (0.977)^{t1} + (0.977)^{t2}) \qquad (9)$$

$$(E_s)_{nT} = 4.42\times10^{-2}\ E_{pa}W_T(\ (0.09748)^{t1} + (0.9748)^{t2}) \qquad (10)$$

Evapotranspiration--Evapotranspiration relationships are being developed using the concept of potential evaporation, which may be simply defined as the maximum possible soil water loss from an actively growing crop subjected to a given set of atmospheric conditions and an unlimited soil water supply. In this study pan evaporation is assumed to represent potential conditions. To simulate actual field conditions the potential value is modified by a growth or seasonal index and a stress or demand factor.

The working equation is of the form:

$$ET_a - G\ D\ E_{pa} \qquad (11)$$

where:

Et_a = actual evapotranspiration

G = growth index

D = demand index

E_{pa} = pan evaporation

The growth index is determined from Figure 3 which was adapted from data given by Denmead and Shaw.[1] The demand index is determined from the appropriate curve given in Figures 4 and 5. These curves were developed from 3 years of actual soil moisture data that was collected on a statistically designed experiment to study the hydrologic aspects of no tillage versus conventional tillage methods of corn production.

A continuous record of the soil water status may be synthesized on small plot area utilizing equations 1, 8, 9, 10, and 11 in the moisture accounting equation. A study of water yield relationships on a watershed scale can be made by incorporating these relations into the Stanford Watershed Model.

Summary:

A Fortran version of the Stanford Watershed Model was used to synthesize streamflow records on two small watersheds in Virginia. Annual water yields were matched for both areas for water year 1960-61 and then the resulting watershed parameters were used to synthesize streamflow records for water years 1961-1967.

A statistical evaluation of the synthesized and recorded mean monthly water yields showed no statistically significant difference at 15% level for

[1]Denmead, T. and R. H. Shaw. Evapotranspiration in relation to the development of the corn crop. Agron. Jour. 51: 725-726, 1959.

Crab Creek and Brush Creek data. The estimates of the maximum daily peak discharge on Brush Creek for the months October through March were found to be significantly different from the recorded values at the 1% level.

Since snowmelt was not modelled, some discrepancies in streamflow were noted in both magnitudes and the timing of peak discharges. Difficulty was encountered in modelling the groundwater recession from Brush Creek. Simulations tended to underestimate predominate groundwater flow periods. Although somewhat erratic, estimates of peak daily discharge rates were reasonably good. The major difficulty occurred during the summer months when antecedent moisture conditions were such that UZS was reduced to zero, resulting in decreased sensitivity. Estimates of instantaneous peak discharge rates were disappointedly poor.

Preliminary testing of the soil water prediction model for no tillage and conventional tillage systems indicate good agreement between synthesized and actual measurements. Soil water loss is estimated from equations developed for (a) evaporation occurring immediately after plowing and (b) the evapotranspiration process which predominants after sufficient root and plant development has occurred.

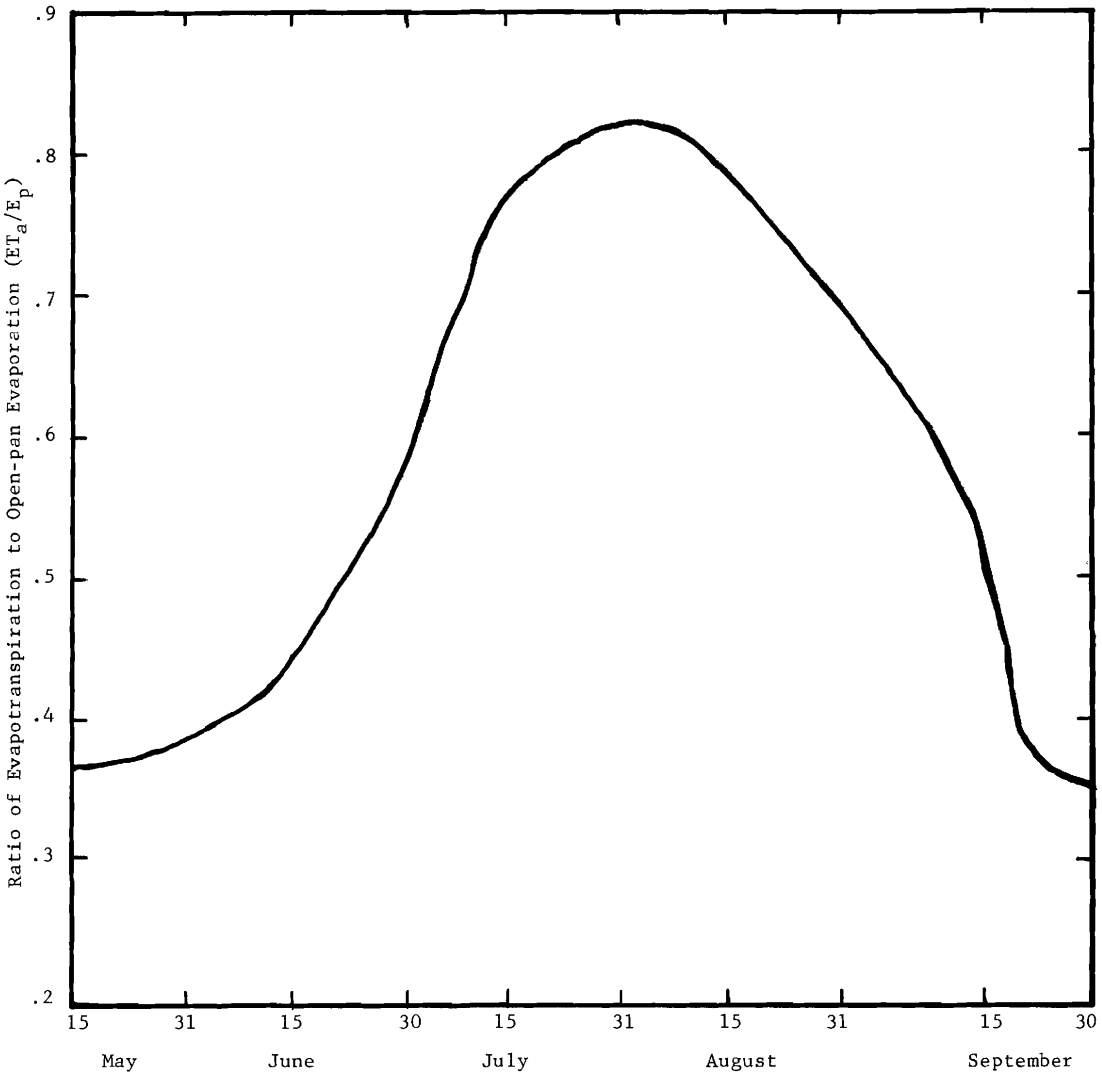

FIGURE 3 -- Ratio of Evapotranspiration of Corn to Open-pan Evaporation Throughout the Growing Season.

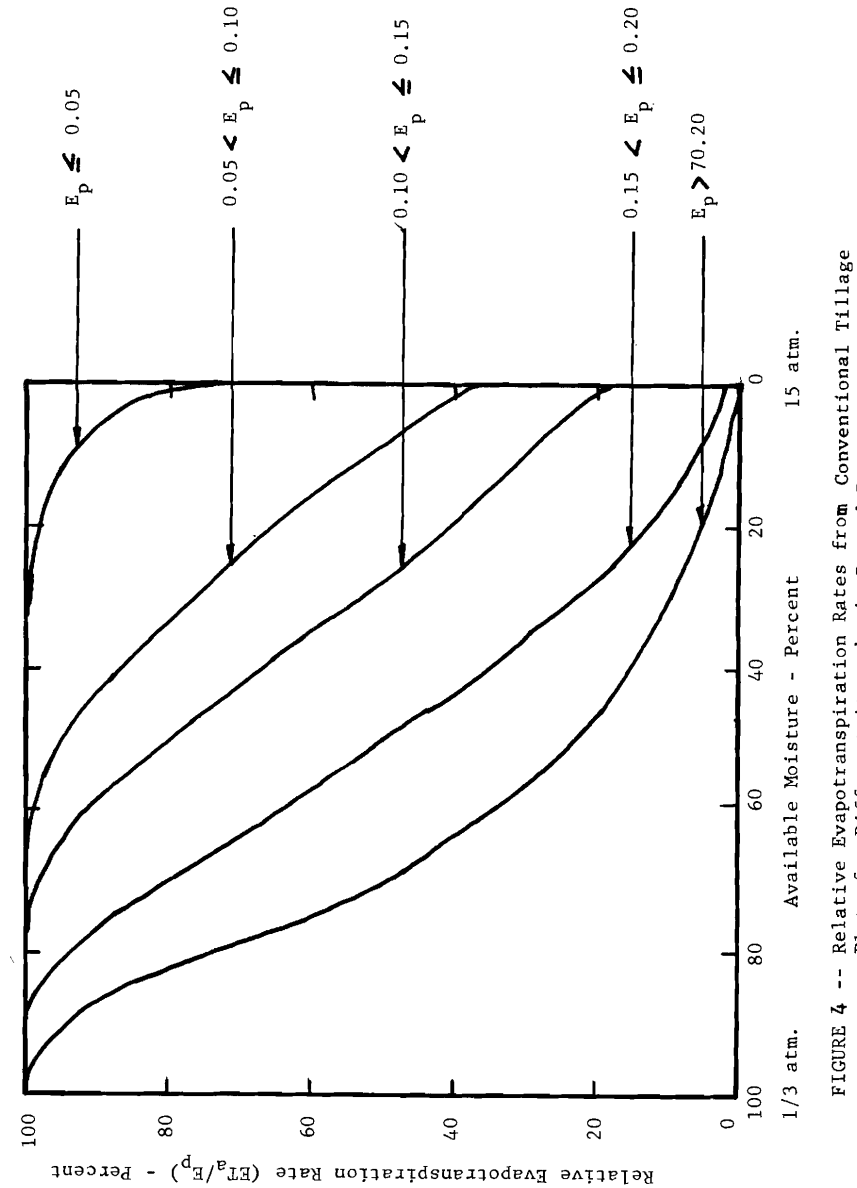

FIGURE 4 -- Relative Evapotranspiration Rates from Conventional Tillage Plots for Different Atmospheric Demand Rates

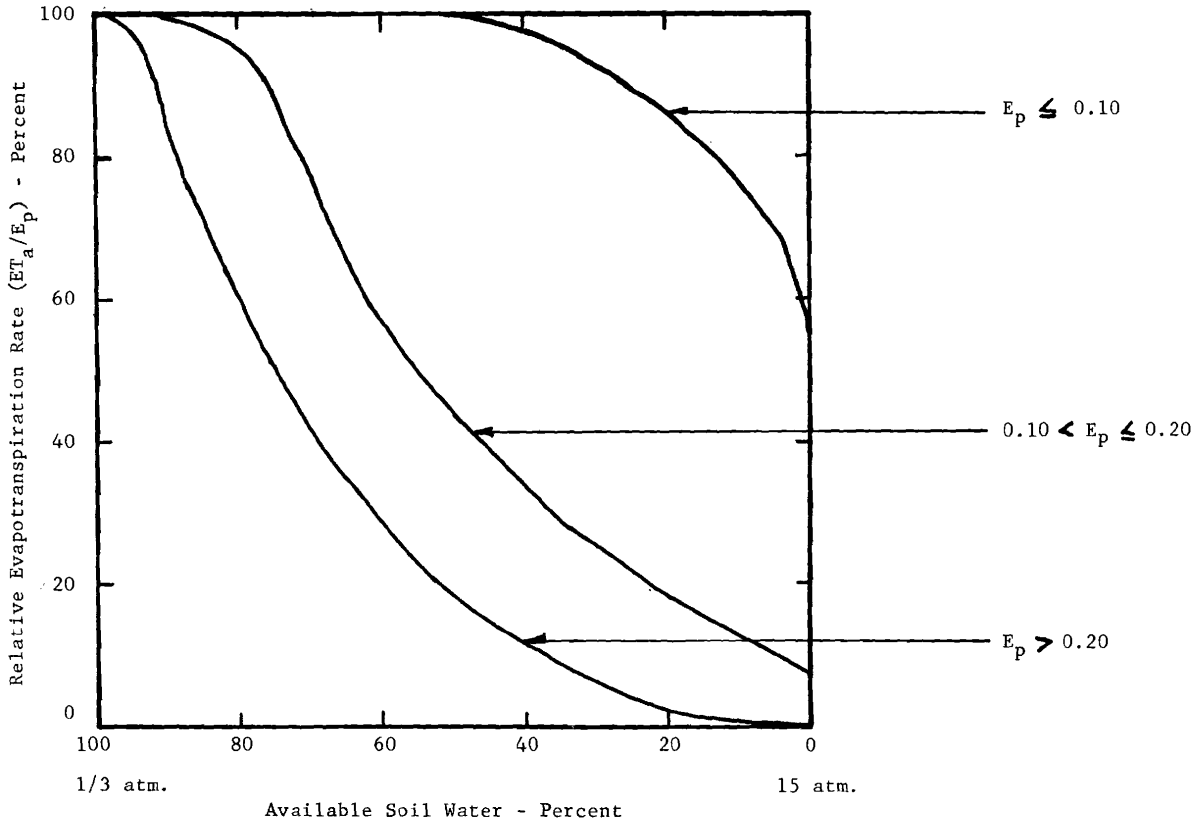

FIGURE 5 -- Relative Evapotranspiration Rates on No-Tillage Plots for Different Atmospheric Demand Rates

PERCEPTION OF WATER RESOURCE PROBLEMS: A PILOT STUDY

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PERCEPTION OF WATER RESOURCE PROBLEMS: A PILOT STUDY

Increasingly, research attention has been directed toward the quantity and quality of water resources as these significantly relate to the well-being of man in society. The majority of these research efforts has been of a technical nature, with research into the social aspects of water resources neglected.

As an initial effort to gain insight into the relationship between the perception of water problems by the public and attempts of the water expert to deal effectively with water problems, this pilot study has dealt with the research question, What are the social factors related to the public's perception of water resource problems?

A sample was drawn from the telephone directories of Montgomery County, Virginia, including the city of Radford and the towns of Blacksburg, Christiansburg, and Shawsville. This sample provided a cross-section of respondents with a wide range of occupational and educational backgrounds. The selection of respondents resulted in a sample size of 453.

The respondents were interviewed over the telephone, by a trained, professional interviewer who used a fixed interview schedule. The interview schedule was constructed to gather data on the social characteristics of the respondents and their perceptions of water problems, the source of these perceptions, and the respondents' feelings about what should be done to solve the perceived problems and who is responsible to undertake such action.

The major findings related to the public's perception of water problems were:

1. Three per cent of the respondents volunteered a perception of water as a major problem facing the world today.

2. Thirty-four per cent of the respondents indicated that they had considered water resources a problem.

3. More males than females perceived water resources to be a problem.

4. Those respondents under forty-four years of age, who have lived at their present address a relatively short time, reside in a multiple dwelling, have continued their education beyond high school, are employed in professional or managerial occupations, and have an income in excess of $10,000 per year, tend to report a water resource problem perception more often than other respondents having other social characteristics.

5. The most common water resource problem verbalized by respondents was pollution, followed by water shortage.

The major findings related to various correlates of a water resource problem perception were:

1. Seventy-five per cent of the respondents reported that they had heard or read a discussion of some aspect of water resource problems.

2. More males than females indicated that they had heard or read a discussion of some aspect of water resource problems.

3. More of the younger respondents, who has continued their education beyond high school, and had a yearly income in excess of $10,000 per year, verbalized having heard or read a discussion of some aspect of water resource problems to a greater extent than respondents having other social characteristics.

4. Television was reported as the source of information on water resource problems more often than any other single communications media.

5. The most common water resource problems reported by the respondents as being discussed were water problems related to pollution.

The major findings related to the public's view of what should be done to solve water problems were:

1. Only three per cent of the respondents felt, for one reason or another, that water resource problems could not be solved.

2. Forty-one per cent of the respondents declined to suggest a solution to water resource problems.

3. The majority of respondents who offered a solution to water resource problems felt that there was a need to enact more effective legislation.

4. The majority of respondents felt that the private citizen and appropriate federal agencies were primarily responsible for initiating action to cope with water resource problems.

The above findings constitute only the major findings of possible general interest, and must be understood as resulting from a somewhat limited pilot study.

GENERALIZED INITIAL CONDITIONS FOR THE STOCHASTIC MODEL FOR POLLUTION AND DISSOLVED OXYGEN IN STREAMS

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GENERALIZED INITIAL CONDITIONS FOR THE STOCHASTIC MODEL FOR POLLUTION AND DISSOLVED OXYGEN IN STREAMS

Today there is a tremendous volume of waste material that is being deposited daily into the streams and rivers throughout the United States. The waste material is a by-product of an industrial and population expansion and is increasing in volume and complexity daily. These wastes cannot all be treated and transformed into inert, non-toxic compounds prior to being let into the streams. In the last decade the problem received considerable attention and state and federal water-pollution laws have been enacted. When a regulatory agency wishes to restrict the quality of organic waste discharged into a body of water, it will need some criteria for judging the pollutants introduced into the stream.

Streams have the capacity to assimilate organic matter in addition to diluting it. This assimilative capacity helps a municipal sewage plant cut waste treatment costs. A major factor that streams depend on to reduce the amount of pollution is dissolved oxygen. If sufficient oxygen is available in a stream, then the complex organic wastes are reduced to simpler compounds by aerobic reactions which can be measured. The complex carbon molecules react with the available oxygen to release carbon dioxide.

The parameter usually used to measure the aerobic reactions is the biochemical oxygen demand (BOD). This measurement is made in a laboratory test of a stream-water sample. The amount of oxygen consumed in 5 days by the aerobic bacteria is stabilizing the organic matter is denoted as the BOD. The temperature, amounts of sample, and other conditions are specified in the test. The BOD parameter is measured in units of parts per million (ppm) or milligrams per liter (mg/l), since both units of measure are equivalent.

Along with the BOD is the other critical parameter, dissolved oxygen (DO), which is also measured in ppm or mg/l. An adequate supply of DO in a stream is necessary for fish and for decomposing organic materials. If sufficient dissolved oxygen is not available to the fish, they will eventually suffocate. If the organic waste material does not have sufficient oxygen, anaerobic reactions will predominate and result in undesirable and lethal end-products. These reactions result in excessive amounts of carbon dioxide, carbon monoxide, ammonia and other substances lethal to fish.

There are other stream characteristics which complicate the issue. One problem is that the maximum solubility of oxygen in a stream is relatively low. This concentration is only about 9 ppm of 70°F. As the temperature increases during the warmer months or in thermally polluted areas, the solubility decreases thus yielding the most dangerous stream conditions.

Another stream characteristic that poses a problem is the characteristically small DO range. Most fish need about 5 ppm of DO to maintain life. If the maximum DO level of a stream is 9 ppm, then the range is quite small - especially since the DO concentration can change quite rapidly. Furthermore, normal stream conditions rarely permit the DO to attain its maximum concentration. There is always some pollution in a stream. This pollution may be the residue of some larger amount of pollution introduced upstream. It might also be pollution added in small amounts all along the stream stretch. In any case the dissolved oxygen never attains its maximum concentration.

It is imperative that sufficient oxygen be available in a stream to promote healthy decomposition of organic wastes and healthy fish. The safe dissolved oxygen range is quite small to maintain fish life. Dissolved oxygen levels must be carefully observed since the concentration can drop below desired levels quite rapidly. It is not sufficient to just observe the DO levels since the BOD indicates how much oxygen organic materials will eventually need to complete its irrevocable reactions. Thus one must study both the BOD and DO levels to predict how much pollution is allowed into the stream before the fish habitat is endangered.

One method of pollution control, as explained by Thayer and Krutchkoff, in Water Resources Research Center Bulletin No. 3, is a probabilistic stream standard whereby the polluter is allowed to deposit organic waste materials that have higher BOD and lower DO values a certain proportion of the time than is normally allowed. This standard, unlike an effluent standard, can be more realistic in protecting fish and usually better matches the stream standards with the actual stream requirement. For example to require that DO concentration never be less than 4 ppm may be difficult to satisfy. However, to require that the concentration not be less than 2 ppm more than 5% of the time and not be less than 4 ppm more than 40% of the time may be easier to satisfy. It could happen that this standard be set higher than the usual and thus would necessitate a higher degree of treatment. However, the important point is that the treatment degree or quality standard can more accurately fit the needs of the stream.

The objective of this study is to use a stochastic approach and predict the biochemical oxygen demand (BOD) and dissolved oxygen (D)) concentrations at several points downstream. In this determination the stream or river stretch will be analyzed as a series of stream segments of homogeneous conditions. Where a major source of pollution is introduced or where major changes in stream parameters occur, another stream segment should be considered for t days of travel. The approach will be to use generalized initial conditions in the form of probability distributions not available in Thayer and Krutchkoff's model.

A study of the correlation between BOD and DO indicated that these variables were not independent except possibly for large values of the time variable. This result generally prevents representing the required joint distribution of BOD and DO as the product of the marginal distributions which are readily available.

In spite of this result the equations were solved assuming independence. Computor programs were then written to accept the product of the marginal distributors of BOD and DO as the input joint distribution. The output of these programs were compared extensively with the output of the program already available. They were found to be virtually identical in prediction of (BOD) and nearly identical in the prediction of (D0). Of course, no comparison could be made in the case where stream parameters were varied along the stretch due to the fact that the Thayer and Krutchkoff program did not allow for this capability. Simulation studies, however, indicate that the results of this program under conditions of varying stream parameters is indeed correct.

Results:

The final result is a computer program which can perform the arithmetic needed to find the BOD and DO probability distributions. The program handles the involved arithmetic and is very versatile in its ability to handle complex stream conditions and provides a joint density function for both pollution and dissolved oxygen with given initial conditions. The initial conditions have been generalized to permit the output for one stream segment to be the initial conditions for the suceding stream segment.

The predicted concentrations are in the form of marginal distributions for both BOD and DO. The conditional distributions are not obtained since their interpretation would be questionable. That is, given a BOD value at

some point downstream, we are not interested in the DO distribution. What is of interest is the marginal distributions of BOD and DO along a stream stretch whose parameters may change at known locations.

The application of this study lies in the analysis of an entire stream stretch to determine if it is healthy for the users within certain preset probabilistic standards. The determination can then be made whether or not the quality of a certain polluter's effluent will be detrimental to the fish population or to the human population prior to disasterous results.

ADSORPTION OF ORGANIC COMPOUNDS ONTO SOLIDS FROM AQUEOUS SOLUTIONS

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ADSORPTION OF ORGANIC COMPOUNDS ONTO SOLIDS FROM AQUEOUS SOLUTIONS

Removal of organic contamination from water is important both for large scale purification and for identification by some chemical analysis to develop reliable standards of water quality. Adsorption of organic contaminants onto solid surfaces has been used for both purposes. Adsorption could presumably play a much greater role, however, if the adsorption process were better understood. The degree of removal of a contaminant by adsorption depends upon a number of factors including competition of contaminant and water molecules at the solid surface and the interaction of the contaminant with water in the bulk solution. Organic contamination in water represents a diversity in molecular structure from formaldehyde to phenols to polynuclear hydrocarbons to insecticides and detergents. The research involves the study of the factors effecting adsorption on several different solids of compounds containing functional groups which are representative of common contaminants. Aqueous solutions of phenol were chosen for study since phenol is a common pollutant. Solids chosen for study range from high energy silica surface to the very low energy Teflon surface.

A comprehensive study of the adsorption of organic compounds onto solids from aqueous solutions involves not only the determination of the adsorption isotherms but also extensive characterization of the solids used. Three techniques have been used to characterize the solids; namely:

1. determination of surface areas by low temperature nitrogen adsorption;

2. determination of critical surface tension by contact angle measurements; and,

3. infrared spectroscopic analysis.

The surface areas of the adsorbents were measured using a conventional BET apparatus employing nitrogen as the absorbate. Surface energies which play a predominant role in adsorption may be estimated from contact angle measurements. The contact angles were measured directly by projecting the image of liquid droplets placed on a polyolefin (Microthene) film. The results of such measurement are shown in figure 1, where the cosine of the measured angle has been plotted on a function of the surface tension of the liquid

droplet. This is in good agreement with the literature value of 31. ergs/cm^2 for the critical surface tension of polyethylene. The agreement suggests that the surfaces of the polyolefin and polyethylene are quite similar. Infrared spectroscopy permits identification of molecular species on the solid which may participate in the adsorption process.

An isotherm representing the adsorption of phenol from aqueous solutions at 25°C onto Microthene-500 is shown in figure 2. The amount of phenol adsorbed per gram of Microthene as a function of equilibrium concentration of phenol is plotted in this figure. The amount of phenol adsorbed increases as the phenol concentration in solution increases. Adsorption from aqueous solutions on polymer surfaces has received scant attention. The low energy of polymers as shown in figure 1 should enhance the adsorption of phenol as is evidenced in figure 2.

A number of other surfaces are being studied to permit a better understanding of adsorption at the liquid/solid interface. These represent a wide range of surface energies.

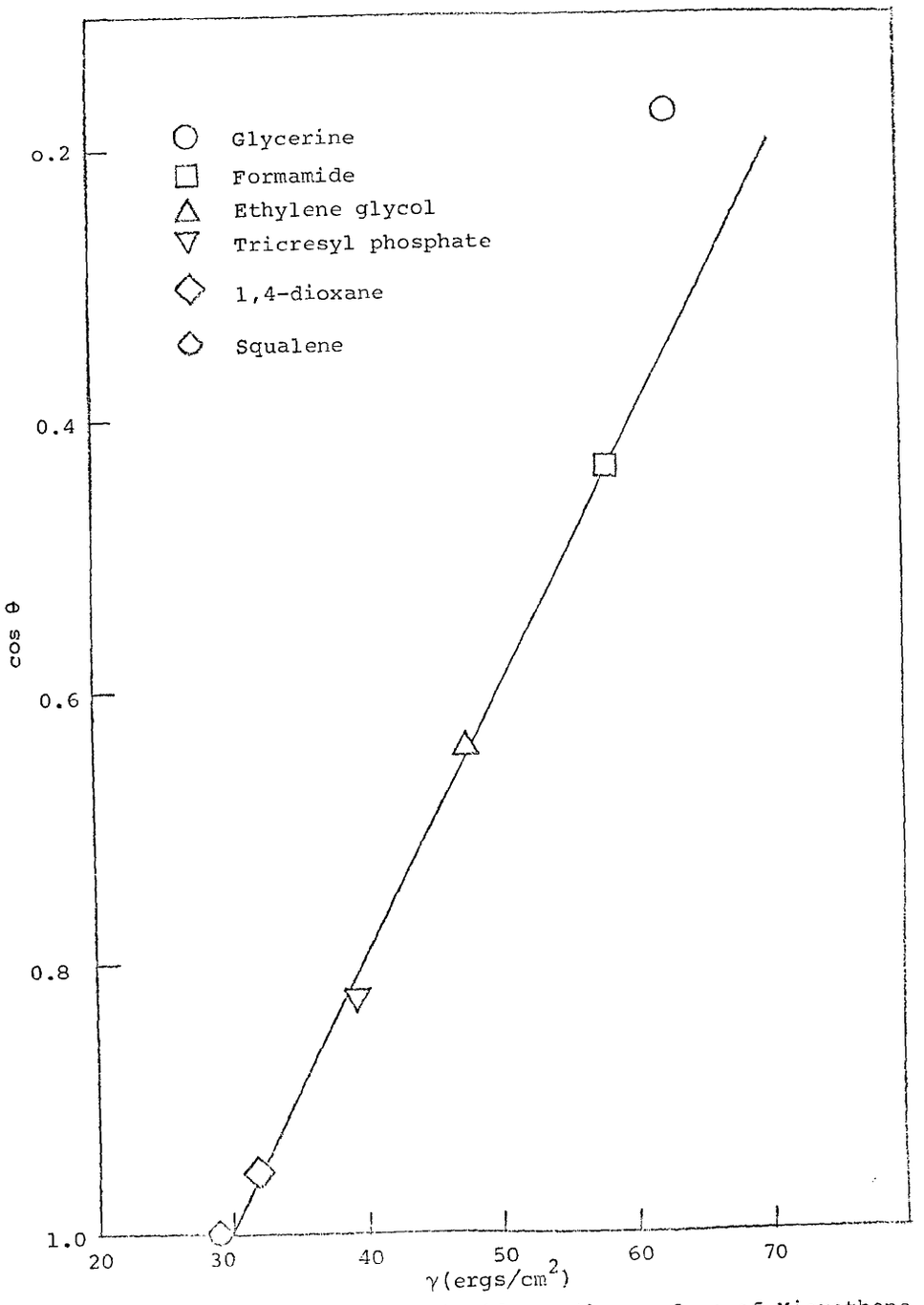

Figure 1. Wettability of various liquids on the surface of Microthene 500.

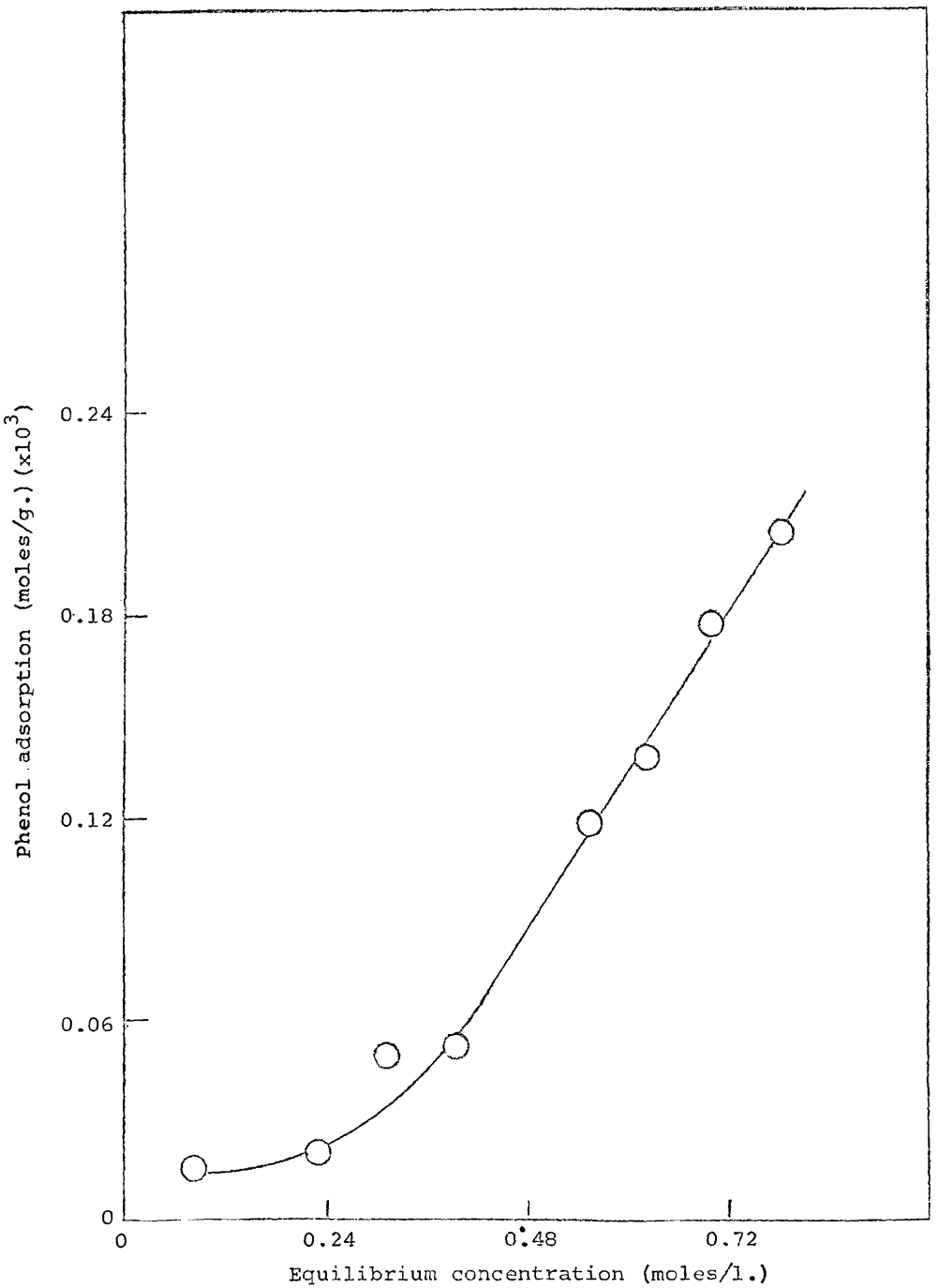

Figure 2. Adsorption of phenol from aqueous solution on Microthene-500 at 25°C.

GROUND WATER RESERVOIR RESPONSE TO EARTH TIDES

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GROUND WATER RESERVOIR RESPONSE TO EARTH TIDES

Specific storage capacity of a ground water reservoir of any kind is important to know because freedom of movement of recharging surface water is a measure of storage capacity. It is anticipated that the value of a ground water reservoir to sustain human needs during, for instance, a period of contaminating nuclear fall out will depend in part upon the intensity of the radiation, of course, but also on the size of the ground-water storage reservoir under consideration. The larger the reservoir the slower the rate of ingress of recharging water and the longer the reservoir will supply water free of significant radioactivity. Since ground water may be the only usable source of domestic water free of radiation following a period of strong nuclear fallout, human survival may, indeed, depend upon how much we may have learned about specific storage capacity of ground-water reservoirs and their rate of water turnover or recharge.

The possibility of exploiting large caverns filled with fresh water is of particular interest in the Appalachian area since the cavities are widely distributed. A specific example is formed in Study Area #2 near Saltville, Virginia. The well was drilled into a cavern of unknown size. The cavity provides the main storage reservoir from which fresh water is pumped. During the summer and autumn noticeable drawdown in the well is observed, and during winter and spring the recharge level is raised to the point where the well overflows. Although a relatively small amount of water is now supplied by the well, the reservoir may have the capacity to supply large quantities of water should the need arise. It is necessary to establish the cavity volume in order to estimate its potential capacity. Measurement of earth tide fluctuation seems to offer the most reasonable way of oftaining such an estimate of volume.

If the pattern of earth tide water level fluctuation in an area can be established then it may be possible to record water level fluctuation in new wells for short periods of time to establish aquifer potential.

The objectives of this research project include development and evaluation of methods for determining ground water reservoir storage and porosity parameters from measured tidal fluctuation of well water level. This research involves continuous recording of water level in wells for periods of two to three months, development of methods for filtering out nontidal water level fluctuations, harmonic analysis of tidal data, and modification

theoretical tidal response equations for idealized ground water systems. At the end of the first year of a two year project tidal records have been obtained from twelve wells distributed in the Appalachian Valley and coastal plain areas of Virginia. Methods for filtering and spectral analysis of data have been developed, and are being applied to the data as they become available.

General Procedure:

Mechanical chart recorders have been placed in water wells near the following communities in Virginia: Blacksburg (1 well), Cripple Creek (2 wells), Independence (2 wells), Narrows (1 well), Williamsburg (3 wells), Kilmarnock (1 well), Suffolk (1 well), and Camp Peary (1 well). At least two months of continuous recording is available from each of these wells.

Field work was initiated in July, 1968 and has continued with only minor delays. Temporary difficulties included failure of flats to move freely in wells, and maintenance problems associated with bad weather during the winter months.

The wells used in this study are maintained by the Virginia Division of Water Resources, Virginia Polytechnic Institute, Appalachian Power Co., Celanese Fibers Co., and the Virginia American Co.

Field operations will continue during the coming year using additional wells maintained by the Virginia Division of Water Resources and the Olin Mathison Chemical Co.

The processing of tide records from wells first requires data to be put in digital form. Records obtained during the first six months of operation were manually digitized using gridded templates, then punched on computer cards. During the past three months a semiautomatic digitizing system has been obtained which provides for much more rapid data preparation. Computer programs have been prepared for modification of the digitizer output to be compatible with analysis programs.

Analysis of digitized data commences with separation of tidal and nontidal water level fluctuations. A method was developed which compares the recorded data with a theoretically generated tidal potential record. Corresponding zero cross-over times are computed and smoothed to give a record of nontidal water level fluctuation. This is then subtracted from the observed record to obtain the tidal response record. This method avoids some

of the drawbacks of harmonic filters, since it does not require convolution of a finite approximation of a theoretically infinite operator with the observed data.

Correction of the tidal response record for barometric effects requires comparison of the observed record with barograms obtained at or near the well-site. Gradients for periods of several days are compared with short term tidal gradients measured from four to six hours of record length to obtain the barometric correction factor. Preliminary analysis indicated that the barometric correction is very small for wells in the Appalachian Valley but that it may be appreciable for coastal plain wells.

Following barometric correction the tidal response records are then analysed for spectral content which will be compared with theoretical tidal potential spectral components. Computer programs have been prepared for spectral analysis and generation of tidal potential records. Well data are being prepared for this analysis, but at this time the barometric corrections have not been completed.

Results:

Examination of data from 12 wells indicates tidal water level fluctuations of from 0 to 12 cm. in wells located in the Appalachian Valley, and from 0 to 25 cm. in wells on the coastal plain. In the Appalachian Valley tidal amplitudes appear to depend in part on the diameter of the well. This suggests that the local ground water reservoirs are porous zones of finite volume. The volume and porosity will be estimated following complete processing of the data. No tidal response was observed in wells near Independence and Narrows, Va. Preliminary examination suggests that porosity was too low in the former area and that the aquifer was unconfined in the latter area. Tidal response would be very small in these situations. The tidal amplitudes observed on the coastal plain appear to be more directly related to the reservoir porosity and barometric effects as would be expected for artesian aquifers of large areal dimensions. Estimates of porosity and specific storage will be attempted after a more thorough processing of the data.

Table 1. Predominant algae and zooplankton in Westhampton Lake during the summer of 1968

Division	Species
ALGAE	
Chlorophyta	*Closterium* sp.
	Cosmarium sp.
	Hydrodictyon reticulatum
	Sphaerocystis schroeteri
Chrysophyta	*Asterionella* sp.
	Stauroneis sp.
Pyrrophyta	*Ceratium hirudinella*
	Peridinium willei
Cyanophyta	*Anabaena spiroides*
	Oscillatoria tenuis
ZOOPLANKTON	
Cladocerans	*Daphnia ambigua*
	Bosmina coregoni
Copepods	*Mesocyclops edax*
Rotifers	*Polyarthra* sp.
	Keratella sp.

Table 2. Rate of gross photosynthesis in Westhampton Lake during summer of 1968. Estimated by light, dark bottle technique in lake. Rate of Photosynthesis (ppm O_2 hr^{-1})

Depth (ft)	July 31	August 6	August 14	Average
0	0.19	0.22	0.68	0.36
1	0.19	0.19	0.54	0.31
2	0.06	0.12	0.15	0.11
3	0.08	0.03	0.18	0.10
4	0.06	0.04	0.35	0.15
5	0.02	0.14	0.11	0.09
6	0.00	0.02	0.00	0.01
7	0.09	0.02	0.00	0.04
8	0.01	0.01	----	0.01

Table 3. Concentration of zooplankton (copepods and cladocerans and rotifers) in Westhampton Lake during summer of 1968. Day samples collected between 1300-1500, night samples between 2200-2300. Concentration of zooplankton (# liter^{-1})

Depth (ft)	July 30 Day	August 15 Day	August 15 Night	September 20 Day
0	0	0	130	215
1	8	5	205	350
2	0	50	60	190
3	12	80	80	835
4	48	150	215	340
5	52	70	65	245
6	20	55	65	260
7	12	60	5	555
8	4	70	15	60

(Date and Time)

INVASION OF THE AQUATIC HABITAT BY AMPHIBIOUS SPECIES OF POLYGONUM

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INVASION OF THE AQUATIC HABITAT BY AMPHIBIOUS SPECIES OF POLYGONUM

Emergent species of Polygonum are aggressive invaders of shallow water situations, while P. amphibium may cover the entire surface of a reservoir in floating mats. The effect upon evapo-transpiration rates alone must be profound. These species are capable of dominating the entire aquatic ecosystem under ideal conditions for their growth. They are good competitors with other plant species due to vigorous vegetative growth and numerous other factors.

There is indication that a single fruit brought in by a waterfowl can result in the complete take-over of a small reservoir by P. amphibium. The Pudding Creek Reservoir in northern California (Mitchell, 1967) is covered by mats of the plant, all of which are female (male sterile). With no obvious pollen source these plants have done remarkably well. Local residents had never seen the plant before the building of the dam, but claimed that it had formed great masses by the second season after the water rose.

The conscious planting of both native and Eurasian Polygonum species by man in our lakes and waterways presents some interesting problems. Since Polygonum fruit are a major food source for waterfowl, they are made available by federal, state, and private organizations for seeding purposes. This breaks down the natural geographic barriers between species, allowing combinations which would be highly unlikely under natural conditions. If amphibious Smartweed did, indeed, arise as a hybrid derivative of semi-aquatic species, it appears that man is increasing the likelihood that such an event will occur again.

The non-amphibious variety of P. amphibium formerly known as P. coccineum has the common name "Devil's-shoestring," and is an invader of drainage systems, irrigation ditches, flumes and rice fields all over the United States. It is particularly drought-resistant, and develops woody rhizomes up to an inch thick and 15 feet long. Discing and mowing practices are aiding the spread of this native weed along our highway ditches and into wet fields and reservoirs. There remains the question of how many amphibious capabilities these populations retain. It is possible that they could reproduce the aquatic variety under certain conditions and after several generations, but this has yet to be studied.

In the summer of 1968 a six week collecting trip was undertaken to collect both living and dried specimens of the plant genus, Polygonum. The success of this venture was extraordinary; survival of shipped plants was over 90%. At present, we have the largest collection of Polygonum in the country. There are 219 sets of living plants representing over 100 populations from 23 states. All but one American species of Smartweeds are represented, including an extremely rare one from Arizona.

In addition to the living materials, dried voucher specimens were obtained from each population in the field. These now number over a hundred sets, and they have been identified in the herbarium since the trip. They are now in the V.P.I. herbarium, set aside for further study, and will be deposited in the regular collection when this study is completed. Data on location, habitat, associated species etc. was compiled in the field to be transcribed onto the labels of completed and mounted specimens.

A pilot experiment has been initiated concerning plagiotropy (horizontal growth response) in different genotypes of amphibious Polygonum. In borrowed space in an environmental control chamber plants of three populations (representing two extremes and an intermediate) are being tested for their response to reflective and non-reflective substrates. This reaction is extremely important in assessing "amphibiousness" since the hormonal control of prostrateness is directly linked to the plants' capability to break the water surface and become emergent. Results to date indicate that vertically oriented plants of the same clone show little difference in response to black and white backgrounds (16 hr. day, saturated substrate, 80°F-60°F). This is to be expected since negative geotropism and growth directly toward the light should overcome any tendency for horizontal growth. The next step will be to orient the plants horizontally and to measure differences in growth responses: length of internodes and angles of upward bending should be good indicators of each ramet's capability for restoring its original orientation over different substrates.

The experimental work involving submergence of clones and subsequent study of the morphological and anatomical responses remains to be done. Controlled environmental conditions will be possible upon the arrival of growth chambers; however, much experimental work will be possible in the laboratory since much of the equipment for monitoring lab conditions is now arriving. Cytological studies involving use of the "squash technique" for determining meiotic chromosome numbers have not been successful. Use of another technique for somatic chromosome number determination from root tips will be employed starting in mid-June.

TREATMENT OF DYEING BATH WASTE STREAMS BY FOAMING AND FLOTATION TECHNIQUES

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TREATMENT OF DYEING BATH WASTE STREAMS BY FOAMING AND FLOTATION TECHNIQUES

With a growing interest on the part of the public in clean streams and ever increasing pressure on the part of both state and Federal Government to keep deleterious substances out of the public waters, an urgent need has arisen for the textile industry in Virginia and the southeastern United States to find an economical, effective means of treating dye bath wastes. The increased demand for synthetic fibers (dacron, nylon and orlon) has accentuated the problem since dispersed dyeing techniques are used in their manufacture. Synthetic fibers are relatively unreactive and not easily dyed by conventional techniques. These fibers have a hydrophobic characteristic, necessitating the adding of a swelling agent "carrier" such as o-phenylphenol to improve the dyeability of polyesters and retarders or dispersants to regulate the dyeing rate. The results of these sophisticated dyeing techniques is improved color characteristics and waste streams that are difficult to treat. Conventional techniques such as aeration, settling, and flocculation are not entirely satisfactory in treating black and blue-black waste streams.

This study was designed to investigate waste treatment and color removal of dispersed dye bath waste using foaming techniques. The work includes a study of dispersant surfactant using foam fractionation, adsorptive bubble fractionation, and homogeneous ion flotation (complexing). The project objectives include:

(1) A better understanding of the mechanisms involved

(2) An estimate of the costs using developed techniques in conjunction with traditional means of separation (flocculation).

(3) Foaming techniques that will be helpful in the removal of phenol and phenol derivatives.

General Procedure:

Studies were made on the removal of color bodies and COD from a simulated dye waste consisting of 400 ppm of Foron "K" Powder and 200

ppm of Dispersing Agent #8. This solution approximated the concentration of waste and dispersion agent leaving a commercial dye bath assuming 90% utilization of the dye and surfactant.

Initial efforts were directed toward the development of analytical techniques to provide a quantitative measure of what is occurring in the system. Standard analytical measurements have been set up to measure COD, pH, absorbence and turbidity. An analytical test for surfactant has been difficult to come up with because of inherent problems of working with a suspended particule dye system. Spectrophotometric techniques have been unsuccessful because of masking of the dye peaks.

The first tests were made to remove the dispersed dye from a simulated waste stream using an Ultracentrifuge (up to 100,000q for one hour) and Millipore filters (.45 to .05ru). Satisfactory concentration of the dye was not attained in the Ultracentrifuge and plugging problems occurred with filters. These experiments were abandoned.

Foam fractionation studies were then started and the results were encouraging. A 200 to 300 per cent increase of COD in the overhead with a 5 to 10 per cent decrease of COD in the bath was found from initial tests. Absorbence measurements were also higher in the overhead than in the remaining bath material indicating a concentration of color. Increasing the pH from about 7 to 11 had little effect on the results.

During the initial foaming tests, a red dye was observed in the overhead product while a greenish dye constituent settled out in the bath. After discovering that the dye being used was a mixture of several dyes, it was felt that what was occurring in the system could be better defined with a pure dispersed dye material and a single surfactant.

Three pure dispersed dyes (Dispersed Blue BG, Dispersed Brown 3BL and Dispersed Yellow W) with sodium lignosulfonate as a dispersing agent were obtained for further testing. The simulated waste of these materials contained 300 ppm dye and 100 ppm dispersing agent. Foaming tests were made on this material and concentration reductions of COD, color and turbidity were less than 10 per cent in the bath material. It was concluded that efficient use of a foam fractionation technique could not be accomplished with the pure dye system.

A program of testing was initiated to study various classes of coagulant and foaming aids. Coagulant aids included cationic, nonionic and anionic

surfactants. Initial tests of all of these materials added to the simulated dye bath waste indicated that cationic polyelectrolytes and cationic surfactants might be helpful in improving foam fractionation results. Additional studies on various materials from each of these classes showed that the additional cationic surfactants gave the greatest improvement in the results.

An extensive study using a cationic surfactant as a foaming aid in the simulated dye bath waste was conducted. Surfactant concentrations of 25, 50 and 100 ppm were used. For a 50 ppm surfactant concentration, COD concentration reductions in the bath ranged from 35 to 55 percent. These results assumed that all surfactant is foamed out of the bath and the concentration reductions are based on a surfactant free bath. Color and turbidity concentration reductions ranged from 70 to 90 per cent and 60 to 75 per cent respectively.

Results:

The results indicated that COD, color and turbidity concentration reductions were strongly influenced by surfactant concentration and slightly influenced by volume of air per unit weight of feed in the column. Foam and liquid heights in the column had little effect on the results.

Combinations of various polyelectrolytes with cationic surfactants have not improved the results. Several tests have been made with the total composite waste from an actual textile dyehouse. These results have been better in terms of color and turbidity concentration reductions than the results using the simulated waste. Additional tests are being made with the actual waste.

The results of this work indicate that foam fractionation can be an efficient technique for COD, color and turbidity removal in textile dye house wastes. An optimization study is being planned to determine what type of cationic surfactant would be more efficient in minimizing surfactant concentration and air rate while achieving high concentration reductions of COD, color and turbidity.

EFFECTS OF ZOOPLANKTON ON PHOTOSYNTHESIS BY ALGAE IN LAKES

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EFFECTS OF ZOOPLANKTON ON PHOTOSYNTHESIS BY ALGAE IN LAKES

Large populations of algae commonly occur in eutrophic waters. During blooms of algae, especially blue-greens, the quality of water will decline due to foul odors and unpalatable tastes. After these blooms, important commercial and sports fish may be reduced or displaced because of oxygen deficits brought about by decomposing algae.

Zooplankton, the microscopic animals in water, are potential regulators of algae. They feed on algae and excrete materials that are required for algal growth. The present study is designed to ascertain the extent to which zooplankton regulate natural assemblages of algae. The results of the study could lead to biological controls of the large quantities of algae that appear in nutrient enriched waters.

These results might well be applied in designing methods of drawing water from impoundments and in stocking waters with zooplankton. The times and depths of drawing water from impoundments could be adjusted to retain zooplankton or to eliminate them from impoundments depending upon whether the zooplankton are beneficial or detrimental to water quality. Stocking reservoirs with zooplankton that would diminish undesireable algae also could be done.

General Procedure:

The experiments were conducted in Westhampton Lake, Richmond, Virginia. Natural assemblages of algae were confined (one in paired aquaria in the lake with and one without migratory zooplankton). The quantities and rates of photosynthesis of the algae were measured over several days. Differences between the aquaria then were used as estimates of the effects of the zooplankton on algae.

Pilot studies were conducted in order to design routine experiments. Various techniques and sources of error that were examined are reported below.

Three prototype aquaria were designed and tested. The original aquaria were to consist mostly of plexiglass, but polyethylene was found to be

adequate and much less expensive. The aquaria were polyethylene cylinders, three feet in diameter. The major difference between the prototypes was the way in which they were closed at the base. The first type was closed by twisting polyethylene at the base of the aquarium after it was suspended in the lake. This type was very cumbersome and it was diffifult to ascertain the amount of leakage. The second type has a conical base with an opening that could be closed by using a rubber ball as a stopper. The third type had a plexiglass base with an opening that could be closed with a piece of plexiglass and was chosen for the routine experiments because it was the easiest to manipulate.

The length of the aquarium depended on the vertical distribution of algae and zooplankton in Westhampton Lake. The aquarium had to be deep enough to include most photosynthetically active algae, but shallow enough to exclude migratory zooplankton in one of the paired aquaria. The pilot studies showed that 75 percent of the photosynthesis in the lake was carried on by algae in the upper three feet of water (Table 2). They showed also that the majority of migrating zooplankton remain below two to three feet during the day and rise toward the surface at night (Table 3). Therefore an aquarium three feet in depth was chosen for the routine experiments.

Two techniques were examined for confining the algae with different concentrations of zooplankton. The first method employed paired aquaria-one with and one without a closed base. The aquaria were suspended in the lake during the day when the migrating zooplankton were below 3 feet. It was thought that zooplankton would be excluded from the closed aquarium and would migrate into the open aquarium at night. The concentrations of the zooplankton in the paired aquaria, however, were not very different.

The second method again employed paired aquaria, but one was suspended at night and the other during the day. Both aquaria were closed at the base. This method was effective in confining different concentrations of zooplankton and was chosen for the routine experiments.

The effects of the aquaria on three physical factors of lake water were examined. Light intensity, temperature and turbulence were compared within and outside the aquaria because of their influence on distribution and photosynthesis of algae. Prior studies indicated that aquaria may affect these factors (Strickland et al., 1961). No chemical comparisons of water within

and outside the aquaria were made. Light intensity and temperature were measured from the lake surface to a depth of nine feet with a submarine photometer and thermistor thermometer.

Two studies were designed to estimate turbulence. The measure of turbulence was the rate of settling by algae. Pails of filtered lake water were suspended at depths of three to four feet. After one to two days, the water in the pails was analyzed for chlorophyll.

Chlorophyll was the routine measure of concentration of algae. Samples were concentrated on millipore filters and analyzed according to the method of Lorenzen (1967). A major problem in the analysis was the high turbidity blank in the spectrophotometric readings. Occasionally these blanks would be as high as 80% of the uncorrected readings. Lorenzen (pers. comm.) suggested that these turbidity blanks resulted from "salting out" of the millipore filters with the addition of acid and that the use of glass filters would reduce these blanks. The method of chlorophyll analysis was found to be very well suited for our work. It, unlike most others, corrected for the presence of pheo-pigments, the degradation product of chlorophyll. The studies showed that pheo-pigments were highly concentrated in Westhampton Lake and without corrections for their presence errors in estimates of chlorophyll concentrations and distributions would have resulted.

Originally the rate of uptake of radioactive carbon was to be the routine measure of photosynthesis and radioactivity was to be measured with a Geiger counter. A liquid scintillation counter, was made available for our research so we decided to use it rather than the Geiger counter. By using the scintillation counter, several sources of error inherent in the Geiger technique were overcome (Strickland, 1960) and large numbers of samples could be handled at a time. The efficiency of counting was estimated at 100% for samples of algae that were incubated for three hours and 50% for algae incubated for five hours. Several scintillation liquids "cocktails" were tried and the most suitable for our work was Triton (Packard Inst. Co.) and a toluene, organic fluor base abbreviated PPO:POPOP (New England Nuclear). A curve of light attenuation "quenching curve" for the scintillation fluid has been estimated.

The oxygen evolution technique for measuring photosynthesis was also examined. Lake water was siphoned into initial, dark and two light BOD bottles. The concentration of oxygen in the initial bottle was measured and the dark and light bottles were suspended in the lake or an incubator. After

several hours, the concentrations of oxygen in the latter bottles were measured. Oxygen concentrations were measured with an oxygen meter and occasionally by the Winkler technique.

Results:

There was no appreciable difference in temperature within and outside the aquaria. The average temperature in aquaria suspended to a depth of five feet was the same as the lake down to the depth (29°C). The lake temperatures ranged from 29°C at the surface to 20°C at nine feet. The greatest gradient in temperature occurred below five feet.

Light intensity was lower by 1 to 8% within than outside the aquaria. This decrease in light intensity was due largely to scattering and absorption of light by the polyethylene, which decreased light by approximately 3%, and material such as algae that adhered to the sides of the aquaria. Both within and outside aquaria, light intensity was attenuated to 0% surface illumination at a depth of six feet.

The results of the studies on turbulence were inconclusive. In the first study, 40% more settling occurred within than outside a closed aquarium. A comparison between aquaria that were closed and open showed, however, a twofold increase in settling in the open aquarium, the one which most closely approximated the lake per se.

The predominant forms of algae and zooplankton were identified and summarized in Table 1. Among the algae, Asterionella sp. predominated during the early summer and A. spiroides, O. tenuis, G. Shroeteri and C. hirudinella predominated during the mid-late summer. Among the zooplankton, the copepod M. edax predominated throughout most of the summer. Rotifers made up a significant proportion of the zooplankton population (approx. 60%) during the mid-summer. Cladocerans never made up more than 7% of the total number of zooplankton in the lake.

Chlorophyll was homogeneously distributed within the upper three feet. A peak in chlorophyll consistently occurred between four and seven feet. The average peak at five feet was nearly twice the concentration at other depths. Pheo-pigments made up nearly 52% of the algal pigments analyzed and increased from the surface toward the bottom of the lake. The concentration of oxygen in duplicate light bottles differed by about 1% and between light

and dark bottles by about 25%. The oxygen evolution method was chosen for routine experiments because it is accurate enough for our study and is easier than the radioactive carbon uptake method.

During the next year a series of routine experiments to estimate the effects of zooplankton on algae will be conducted. Natural assemblages of algae will be confined in paired aquaria - one closed during the day to exclude zooplankton and one closed at night to include zooplankton - suspended in Westhampton Lake. Samples will be taken daily over 3-4 days from the aquaria and the lake. The samples will be analyzed for photosynthesis and concentrations of chlorophyll, algae (#/liter) and zooplankton (#/liter). Gut contents of zooplankton also will be examined. These data will be used to ascertain the effects of aquaria (e.g. increased settling, decreased flushing after storms) and zooplankton on photosynthesis.

BIOLOGICAL AND CHEMICAL STUDY OF VIRGINIA'S ESTUARIES

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BIOLOGICAL AND CHEMICAL STUDY OF VIRGINIA'S ESTUARIES

Our nation's estuarine systems truly serve as multi-use natural resources. Therefore, like any natural resource, they must be developed so that the maximum benefits can be realized, they must be managed so that a sustained yield can be obtained, and they must not be abused in such a way that only a few can benefit.

The three estuaries being studied in this investigation are at the present time heavily utilized. All are major seafood-producing areas. They are heavily used by sport fishermen and for water contact sports. Their aesthetic value is of immeasurable importance to the millions of tourists who visit the historical Tidewater Virginia area.

In addition, several industries utilize the saline water for cooling purposes. Commerce and military activities make use of the estuaries. The systems also serve to assimilate the domestic and industrial wastes from the human activities along the shores.

Our estuarine systems are the final recipients of the waste products of man's activities. Most materials introduced into the inland drainage systems undergo oxidation and stabilization before entering the tidal basins. The inorganic ions eventually enter the estuaries as dissolved solids in the freshwater inflow. The ionic composition includes nitrates and phosphates from land run-off and from waste treatment plants.

The tidal portions of our nation's streams have the natural characteristics which tend to concentrate human populations and industrial activities. The waste products of these activities may be piped through sub-aqueous outfall lines directly into continental shelf waters but more often they are discharged into the adjacent estuary.

Waste treatment technology has developed methods for rendering most industrial wastes and domestic wastes quite innocuous; however, the final inorganic products may degrade the receiving waters by producing atypical algal blooms and aquatic nuisance conditions. This has occurred in the bays of Long Island, the upper tidal Potomac River, and in the upper tidal James River.

This study is designed to determine the environmental factors which result in the major ecological differences which exist between the James, York, and Rappahannock estuaries in Virginia. Existing data suggest that these differences may be due to nutrient levels as influenced by enrichment from the freshwater zone and by the turnover rates within the systems. This study is evaluating the four forms of phosphorus and the five forms of nitrogen in the water column and the phytoplankton response to the various levels found. Hydrographic data is being collected on each cruise to describe the physical characteristics of the estuaries. Isohaline zones within and between the three estuaries are being compared.

The study is designed around monthly cruises conducted on each of the three systems, the James and York river stations being occupied at low slack water on one day and the two vessels occupying the stations on the Rappahannock on the following day. This schedule is necessitated by the differences in low slack water periods up the rivers. On the James, for example, the difference in slack water from the mouth to the transition zone is approximately 3 hours, whereas it is 6 hours on the Rappahannock River.

Thirty-six full cruises have been completed in addition to special cruises scheduled to cover atypical conditions and sediment sampling. All data collected are now stored in the VIMS computer facility and additional programs are being developed to permit a more comprehensive analysis of the parameters. In addition, the comparisons within systems and between systems can be correlated with other data collected on non-contract projects.

All cruises are scheduled so that stations are occupied at slack before flood tide. The 20‰, 15‰, 10‰, 5‰ and less than 0.5‰, isohalines are located with a portable induction salinometer. The field sampling program is designed to permit determinations of the total nutrient flux into the estuarine systems and the fate of the nutrient elements in solution and suspension through the systems. Unfortunately, the time required for sample analyses has not permitted extension of the ampling into tidal creeks or salt marshes. A special cruise was made, however, up the channel of the James River to just downstream from a source of heavy nutrient enrichment to determine the level of nutrient loading in the freshwater tidal portion.

The drought conditions experienced during the fall of 1968 provided an excellent opportunity to study quasi-steady state low-flow conditions in the three estuarine systems. The James and the Rappahannock receive enrichment in the freshwater tidal reaches from domestic waste effluent

discharges, whereas the York and Pamunkey system receives nutrients only from agricultural drainage. The latter is minimal during low-flow periods.

The high level of nitrogen enrichment in the freshwater tidal James was reflected in the high values found in the upper estuarine reach. Still unanswered, however, are the pathways resulting in the gross reduction of the oxidized forms as the water mass moves downstream. Freshwater systems usually respond to high nitrogen levels with an increase in phytoplankton productivity and standing crop. The data indicate that this does not occur in the James estuary.

The James estuary is characterized by large bays and shoal areas. Temporary turbidity levels are extremely high during periods of high winds when the waves "touch bottom" in shallow waters. The theory that phytoplankton might be removed from suspension by mechanical action after turbid periods was evaluated by collecting and analyzing top 1 cm sediment samples. The data indicated that the sediments were not serving as a nutrient trap.

The Rappahannock River data indicate this system and the James are similar except that the level of upstream enrichment is much less than that of the James. The expected biological response in the downstream reaches was again absent.

The York River system, which has a very high associated marsh area to water area ration in the upper estuarine and tidal freshwater reaches, displayed a very high degree of stability throughout the salt water area during the summer and fall period. Total phosphorus and total nitrogen levels did not show the characteristic decrease from the transition zone to the mouth that was found for the other two estuaries. The phytoplankton standing crop as indicated by chlorophyll "a" levels decreased toward the mouth but again a higher degree of stability was indicated.

Commercial oyster production in the upper estuaries was very low during the late fall and early winter of 1968. No major mortalities were observed but the planted oysters on the grounds did not "fatten" after the summer spawning season. Commercial growers reported that the low yield of meats per bushel of shellstock (less than 5 pints) made it economically unfeasible to work the grounds. Oyster conditions have generally been poor each year since the extreme drought of 1964, but 1968 appeared to be extremely serious. We are hopeful that the 1969 data will yield information that will provide contrasting conditions and aid in explaining the occurrence which has resulted in a multi-million dollar to the industry.

The remaining objectives include continuance of the present evaluation of the three systems in an attempt to establish a better knowledge of the nutrient pathways through estuarine systems. Studies currently underway by Maryland and Federal agencies in conjunction with this work are providing information which will aid the regulatory and management agencies in making decisions which will maintain the Chesapeake Bay and its tributaries for their natural intended uses.

TRAINING AND EDUCATION ASPECTS OF THE WATER RESOURCES RESEARCH PROGRAM

TRAINING AND EDUCATIONAL ASPECTS OF THE WATER PROGRAM UNDER P. L. 88-379

A. New Courses Developed

ADVANCED SEPARATIONS PROCESS (Not Interdisciplinary)
In this course there is treated: reserve osmosis, foam separation, and fixed bed adsorptions.

BUILDING SYSTEMS TECHNOLOGY I (Interdisciplinary)
A systematic examination of the characteristics and principles of the structural, material, services and production subsystems of building.

BUILDING SYSTEMS TECHNOLOGY II (Interdisciplinary)
Advanced treatment of an approved selection of the subject matter in the course, Building Systems Technology I, and extension of emphasis to the urban scale.

DECISION THEORY (Interdisciplinary)
Decision making under uncertainty.

DESIGN METHODOLOGY I (Interdisciplinary)
A systematic examination of the characteristics and principles of the design process with particular emphasis on the potentialities and applications of systems analysis, simulations and computer-aids.

DESIGN METHODOLOGY II (Interdisciplinary)
Advanced treatment of an approved selection of the subject matter in the course, Design Methodology I.

ENVIRONMENTAL SCIENCE - WATER (Interdisciplinary)
Pollution assessment, waste treatment, aquatic communities, bioassays of toxicants, application factors for disposal of toxicants, problems of pollution control legislation.

ENVIRONMENTAL SYSTEMS DESIGN I (Interdisciplinary)
Design applications of environmental systems analyses with emphasis on a systems approach to optimization. Individual design projects, collaborative work, and field environmental studies.

ENVIRONMENTAL SYSTEMS DESIGN II (Interdisciplinary)
Advanced design applications of subsystem analysis and system optimization techniques to a problem or problems significant in environmental design.

EXPLORATION GEOPHYSICS-INTERPRETATION OF GRAVITY FIELDS (Not Interdisciplinary)
Interpretation of geological structure from gravity data; methods and instruments for gravity surveying.

EXPLORATION GEOPHYSICS-MAGNETIC AND ELECTRICAL FIELDS (Not Interdisciplinary)
Interpretation of geological structure from magnetic and electrical fields; methods and analysis of magnetic and electrical surveying.

HUMAN ENVIRONMENTAL FACTORS I (Interdisciplinary)
A systematic examination of the characteristics and principles of those aspects of the behavioral sciences significant as environmental determinants of design.

HUMAN ENVIRONMENTAL FACTORS II (Interdisciplinary)
Advanced treatment of an approved selection of the subject matter in the course, Human Environmental Factors I.

INDUSTRIAL WASTE TREATMENT (Not Interdisciplinary)
Surveys, treatment characteristics and control.

INTRODUCTION OF ENVIRONMENTAL ECONOMICS (Interdisciplinary)
A study of economic analysis applied to environmental problems such as air and water pollution.

LIMNOLOGY AND STREAM POLLUTION (Interdisciplinary)
Structural, physical, and chemical characteristics of water systems.

MONTE CARLO METHODS (Interdisciplinary)
Computer simulation of random phenomena.

PALYNOLOGY (Not Interdisciplinary)
Palynological principles, preparation techniques, classification and study of plant palynomorphs from algae through angiosperms emphasizing biological relationships between fossil and living groups, life cycles, distribution through time, environmental parameters, and stratigraphic applications of palynology.

PHYSICAL ENVIRONMENTAL FACTORS I (Interdisciplinary)
A systematic examination of the characteristics and principles of those aspects of the physical sciences significant as environmental determinants of design.

PHYSICAL ENVIRONMENTAL FACTORS II (Interdisciplinary)
Advanced treatment of an approved selection of the subject matter in the course, Physical Environmental Factors I.

SOIL PHYSICAL PROPERTIES AND CHARACTERIZATION (Not Interdisciplinary)
A study of the theory and determination of physical soil and soil-water properties important to rural and urban development. Emphasis will be toward relating the results of laboratory determinations to natural soil individuals.

THE STATE COMPREHENSIVE PLANNING PROCESS (Interdisciplinary)
A comparative analysis of the history, philosophical basis, component elements, and trends and issues in the field of state comprehensive planning and programing.

STRATOGRAPHIC PALYNOLOGY (Not Interdisciplinary)
Systematic and biostratigraphic analysis of selected, highly significant plant microfossil groups emphasizing palynological methods for dating and correlating strata, and analyzing ancient environments.

UNIT OPERATIONS IN WATER QUALITY CONTROL (Not Interdisciplinary)
Theory of treatment processes.

UNIT PROCESSES IN WATER QUALITY CONTROL (Not Interdisciplinary)
Chemical and biological treatment.

New Staff Members Added

Burroughs, Roy - Ph.D. - Urban and Regional Planning

Chen, Charles S. - Ph.D. - Mechanical Engineering

Chiang, Robert N. S. - M.Arch. - Environmental Systems

Dollar, C. R. - Ph.D. - Chemical Engineering

Gilbert, M. Charles - Ph.D. - Petrology

Golany, Gideon - Ph.D. - Urban and Regional Planning

Harrison, Wyman - Ph.D. - Physical and Geological Oceanography

Hurst, Homer - M.S. - Environmental Systems

Jenelle, E. M. - Ph.D. - Sanitary Engineering

Keating, Edward L. - M.Arch. - Urban Design

Lambert, John - Ph.D. - Statistics

Mclean, Dewey M. - Ph.D. - Palynology

Michael, C. S. - Curator of Geology Museum

Naworski, J. S., Jr. - Ph.D. - Chemical Engineering

Regetz, Federick D. - M.C.P. - Urban and Regional Planning

Stuart, Robert C. - M.U.R.P. - Urban and Regional Planning

Sullivan, Alfred D. - Ph.D. - Forestry

Staff Members Employed to Replace Those Who Retired, Died, or Moved

Contractor, D. N. - Ph.D. - Hydraulics and Hydrology

Parker, Bruce - Ph.D. - Botany

Pettry, D. E. - Ph.D. - Soil Science

New Research and Training Facilities Other Than Research Equipment Items

A new greenhouse is nearing completion for studies on aquatic flowering plants.

A 3-acre pond was acquired for use by the Fishery Unit.

Byrd Hall, Virginia Institute of Marine Science - 20,000 square feet, water pollution and animal physiology building.

Interdepartmental, Interuniversity, or Regional Agreements Consummated with Respect to Improved Research and Training Capabilities

A Memorandum of Understanding for cooperative research on the hydrology of agricultural watersheds was entered into with the Agricultural Experiment Station of VPI and the United States Department of Agriculture, Agricultural Research Service Soil and Water Conservation Research Division.

It is the intention of the parties to this agreement that a cooperative research program may be developed and carried out in areas of mutual interest as available funds permit. These cooperative investigations shall include, but not necessarily be limited to, the development of a better understanding of the physical processes influencing the nature of runoff from agricultural watersheds. From such an understanding it should be possible to develop methods of predicting the behavior of watersheds under specified conditions.

Examples of specific problems of mutual interest include, application of existing mathematical watershed models to the small agricultural watersheds in the northeast, develop mathematical watershed models for use in simulating watershed and climatic conditions in the northeast, etc.

B. Student Enrollment

	No. Enrolled	No. Graduating
Juniors	113	0
Seniors (Bachelor's degree candidates)	140	95
Master's degree students	69	60
Doctoral degree students	61	27
Postdoctoral degree students	0	0

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

Category of Students	No. Using Equipment, Supplies, etc.
Undergraduates	10
Master's students	21
Doctoral students	22
Postdoctorate students	0

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

Category of Students	Scientific Discipline	Number
Undergraduates	Biology	1
Master	Biology	1
	Chemical Engineering	3
	Civil Engineering	1
	Geophysics	2
	Mechanical Engineering	1
	Sanitary Engineering	1
Doctoral	Agricultural Engineering	1
	Chemical Engineering	1
	Sanitary Engineering	3
Postdoctoral	---	

E. Employment Status of 1968-69 Graduates in Water-Related Fields

Category of grad by degree obtained	No. of Graduates engaged in water-related work in:						
	University or College			Agency or pvt water resources research	Operating and mgmt	Planning	Other wtr resources work
	teach prim	resrch prim	resrch and teach				
Bachelor	0	0	0	1	2	0	1
Master	2	0	0	5	0	0	4
Doctoral	1	1	1	2	0	0	0
TOTAL	3	1	1	8	2	0	5

F. Type of Employment of 1968-69 Graduates in Water-Related Fields

Category of 1968-69 graduate by degree obtained	No. Employed in Water-Related Positions in:				No. ret. for adv. degree	No. enter Military service	No. unemploy or unknown
	Federal Agencies	State Agencies	Col. and Univ.	Other such as private			
Bachelor	3	0	0	1	43	8	40
Master	1	5	2	3	12	8	29
Doctoral	1	0	2	2	4	0	18
TOTAL	5	5	4	6	59	16	87

PUBLICATIONS AND THESES

PUBLICATIONS AND THESES

Publications

Beard, J. T., J. L. Gainer, and D. K. Hollen
1969. The influence of solar radiation reflectance on water evaporation. Bulletin 30. Water Resources Research Center. In press. (A-019-VA)

Cooper, Byron
1969. Geologic control of rainfall-runoff relations in the Peak Creek watershed, Pulaski and Wythe counties, Virginia. Bulletin 25. Water Resources Research Center. 24 pages. (A-004-VA)

Gainer, J. L., J. T. Beard, and R. R. Thomas
1969. Water evaporation suppression. Bulletin 27. Water Resources Research Center. In press. (A-019-VA)

King, Paul H., H. H. Yeh, Pierre S. Warren, and Clifford W. Randall
1969. Distribution of pesticides in surface waters. Journal of the American Water Works Association. Vol. 61. In press. (A-015-VA)

Knapp, John W. and W. J. Rawls
1969. Prediction models for investment in urban drainage systems. Bulletin 24. Water Resources Research Center. 47 pages. (A-011-VA)

Krutchkoff, Richard G. and Richard H. Moushegian
1969. Generalized initial conditions for the stochastic model for pollution and dissolved oxygen in streams. Bulletin 28. Water Resources Research Center. vi + 87 pages. (A-027-VA)

McNeice, F. R., I. W. Stanton, and Paul H. King
1968. Removal of phosphate from solution utilizing a coal contact process. (Abstract). Journal of the Virginia Academy of Science. Vol. 19. Page 192. (A-015-VA)

Neff, Stuart E. and George Simmons
1969. The effects of pumped storage reservoir operation on biological productivity and water quality. Bulletin 21. Water Resources Research Center. vii + 47 pages. (A-012-VA)

Michelsen, D. L.
1969. Research on treatment of dye wastes. Journal of American Association of Textile Chemists and Colorists. Vol. 1. Pages 179-181. (A-017-VA)

Mitchell, Richard S.
1968. Variation in the Polygonum amphibium complex and its taxonomic significance. University of California Publication in Botany. Vol. 45. 65 pages. (A-028-VA)

Philpot, John W. and Richard G. Krutchkoff
1969. Probability forecasts of 30-day precipitation. Bulletin 20. Water Resources Research Center. vi + 245 pages.

Randall, C. W., B. S. Hulcher, and P. H. King
1969. Factors that affect activated sludge phosphate release. Proceedings, Fifth Annual American Water Resources Association Conference. In press. (A-024-VA)

Randall, C. W., D. W. Marshall, and P. H. King
1969. Phosphate release in the activated sludge process. (Abstract). Proceedings of the Second National Symposium on Sanitary Engineering Research, Development and Design. ASCE, Cornell University. July, 1969. (A-024-VA)

Shanholtz, V. O. and J. B. Burford
1969. Numerical experiments with the Stanford watershed model on small agricultural watersheds in Virginia. Proceedings 66th annual convention, Association of Southern Agricultural Workers. In press. (A-018-VA)

Shanholtz, V. O. and J. H. Lillard
1969. Tillage system effects on water use efficiency. Proceedings 66th annual convention, Association of Southern Agricultural Workers. In press. (A-018-VA)

Shanholtz, V. O. and J. H. Lillard
1969. Tillage system effects on water use efficiency. Journal of Soil and Water Conservation. In press. (A-018-VA)

Walker William R.
1969. Amortization of nonconforming uses in flood plain management. ASCE, Journal of Urban Planning and Development. In press. (A-006-VA)

Walker, William R.
1968. Water resources research interests in the colleges and universities of Virginia. Bulletin 17. Water Resources Research Center. 49 pages.

Walker, William R.
1968. Water resources research in Virginia. Bulletin 18. Water Resources Research Center. 50 pages.

Walker, William R. and William E. Cox
1968. Water resources laws in Virginia. Bulletin 9. Water Resources Research Center. v + 182 pages. (A-008-VA)

Theses

Hollen, D. K.
1968. The influence of solar radiation reflectance on water evaporation. M.S. Thesis. University of Virginia. 97 pages. (A-019-VA)

Lash, T. N.
1969. Sorption of a selected herbicide on various coals. M.S. Thesis. Virginia Polytechnic Institute. 60 pages. (A-015-VA)

Marshall, D. W.
1968. The relation of ORP or orthophosphate release by activated sludge. M.S. Thesis. Virginia Polytechnic Institute. 91 pages. (A-024-VA)

McCutchen, Byron
1969. The determination of diffusion coefficients for carbon dioxide and oxygen in water using a quiescent liquid absorption apparatus. M.S. Thesis. 150 pages. (A-025-VA)

McNeice, F. R.
1968. The role of iron in phosphate adsorption on coal. M.S. Thesis. Virginia Polytechnic Institute. 77 pages. (A-015-VA)

Moushegian, Richard H.
1968. The use of generalized initial conditions for a statistical analysis of stream pollution. M.S. Thesis. Virginia Polytechnic Institute. 107

Thomas, R. R.
1969. Prediction of mass transfer through monolayers. M.S. Thesis. University of Virginia. 66 pages. (A-019-VA)

Warren, P. S.
1968. Parathion uptake in coal contact process. M.S. Thesis. Virginia Polytechnic Institute. 77 pages. (A-015-VA)

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