WATER RESOURCES PROBLEMS

AND

RESEARCH NEEDS

OF

NORTH CAROLINA

An

Institute Report

March 1, 1967

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C O N T E N T S

FOREWORD

This summary of North Carolina's water resources problems and related research needs is the basis for the development of the Water Resources Research Institute's long-term research program.

Water resources problems, research needs, and current research activity are discussed within the four broad categories of water resources planning, water conservation (more efficient water use), water quantity management, and water quality management.

Attention is given to all currently recognized water resources problems and is not limited to those most heavily dependent upon research for solutions. Research needs are identified where it is believed additional research will contribute to solutions of these problems. In most cases, a multi-faceted attack consisting of the vigorous application of known planning, development, and management techniques by action agencies, local government, and private industry together with an imaginative and responsive research program will be required. The relative emphasis given to action or research activities will depend upon the nature of the particular problems involved. The overall objective should be to effectively utilize existing knowledge to the extent that it is available and to supplement this with additional information through research where necessary. A water resources program undertaken without regard for the limitations of present knowledge would be just as short-sighted as a program structured on the assumption that all action must be postponed until the ultimate answers are provided by research. The State must move ahead strongly on both fronts.

References to current research activity should not be interpreted as fulfilling existing research needs, nor should the identification of such needs carry the implication that these must be met entirely by the State of North Carolina. Many of the more general problem areas require multiple research input from various levels of government, universities, and private industry, and it is the total effort which must be considered.

The Federal Council For Science and Technology research classification has been used as a guide for the organization of this report to assure comparability with the total national research effort and Federal reporting in this area. The Council's report, "A Ten-Year Program of Federal Water Resources Research," is the primary source of information for the summarization of water resources research activity of the various Federal agencies at the national level.

David H. Howells
Director

INTRODUCTION

North Carolina has an adequate supply of surface and ground water to meet its present and future needs if managed with vision and understanding of the increasingly complex problems involved. The steady population expansion and redistribution from rural to urban areas, industrial growth, increasing use for irrigation, growing demand for water-based recreation, and steady encroachment on fish and wildlife growing areas together with other changing land and water use patterns will bring an endless array of conflicts in the use of streams, lakes and estuaries.

Earlier concepts of water use and management which led to limited purpose water projects, piecemeal planning, inefficient water distribution and wasteful use, disregard of the ecological impact of water development, and many other practices of a bygone era can no longer be condoned. Present and future problems require solutions which take full cognizance of all aspects of water needs and use throughout the rapidly changing State of North Carolina.

WATER RESOURCES PLANNING

WATER RESOURCES PLANNING

Water is a renewable resource and can be efficiently managed if the public policy and requisite laws and institutions, planning techniques, and basic understanding of the problems involved are sufficient for this purpose. Water resources management implies a central plan as a guide and source of orientation for an action program. The techniques of plan formulation and implementation are dependent upon laws and institutions which can restrict or facilitate their application and usefulness. They are also dependent upon a sound understanding of future water demands and the costs and benefits of management decisions. The full range of structural and non-structural options should be considered in the management process and their impact on the environment understood.

State Water Plan

North Carolina has no formal water plan at the present time but is working toward the development of such a plan through its stream classification program; the compilation of available data, reports, and administrative and policy statements; the support of studies concerning water resources planning needs; and the current water law study.

A report, "Flood Damage Prevention in North Carolina," prepared in 1963 for the Department of Water Resources by the Institute of Government in collaboration with the Tennessee Valley Authority, identified the following problems associated with flood damage prevention in North Carolina:

1. The need for legislation to regulate encroachment on channels and floodways and to assure the safety of dams and levees.

2. Lack of programs for the public acquisition of land and easements to prevent undesired obstruction or settlement of flood-prone areas and of desirable dam and reservoir sites to preserve them for future needs.

3. Lagging topographical mapping program which is fundamental to the planning process.

A second study, "North Carolina Water Resources Planning," also prepared for the Department of Water Resources by the Institute of Government, reviewed the problems associated with water resources planning as well as related activities, needs, and guide lines. The increasing localization of demand for water and sewer services in urban areas brought about by population movement from farm to cities, the need for additional low-flow augmentation and more effective waste treatment, rising demands for steam-electric cooling water, increasing demand for water-based recreation, the potential expansion of farm irrigation, and the increasing competition for the available water supply were all cited as problems hastening the day when the existing legal structure for water rights law will require thoughtful examination. The report concluded that the overriding needs of the next twenty years or so for water resources development and conservation in North Carolina will include:

1. Absorbing the stresses upon water supply and waste disposal facilities imposed by increasing urbanization and industrialization of the Piedmont.

2. Meeting the needs of water supply and waste disposal for the increasing rural non-farm population and industries in such areas.

3. Developing and properly using the storage reservoirs that will be required to augment stream flows to meet greatly increased waste dilution requirements.

4. Supplying the water recreational facilities needed to serve an expanding demand.

5. Providing water rights laws and other laws and institutions to resolve intensified and more complex disputes among water users.

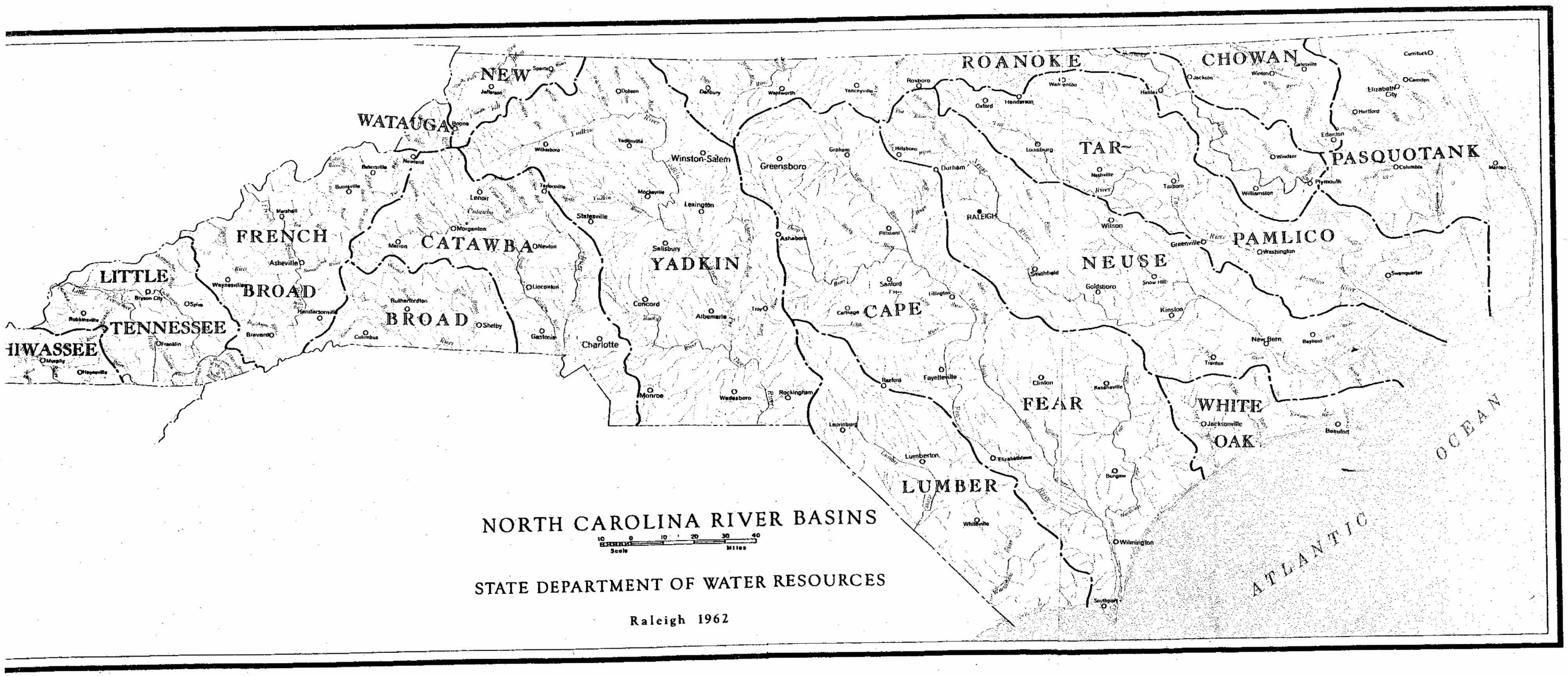
6. Meeting the evolving demand for supplemental farm irrigation.

The State is divided into seventeen river basins for water resources planning. Only four of these watersheds--the Tar-Pamlico, Neuse, Cape Fear and the White Oak--are wholly in North Carolina. Basin-wide planning by the Corps of Engineers, Tennessee Valley Authority or the Southeast Study Commission is underway in nine basins, pending in two, and completed in two (Neuse and Savannah). There is no basin-wide planning in four watersheds--the Chowan, Pasquotank, Watauga and White Oak.

A large potential water resource development program has been proposed by Corps of Engineers, Tennessee Valley Authority, and the Soil Conservation Service. This together with municipal waste treatment needs projected by the State Stream Sanitation Committee, total approximately $850 million over a ten-year period. Almost half of this amount represents the projected needs for municipal water supply and pollution control facilities. The remainder includes $395 million for river basin development, $16 million for waterways and harbors, and $40 million for coastal protection. A total program of this magnitude deserves comprehensive planning of the highest quality.

River basin planning, as presently practiced, has a number of limitations which should receive increased attention. The plans are largely developed by Corps of Engineers, Tennessee Valley Authority, and the Soil Conservation Service and are subsequently reviewed by other Federal and State agencies. The review process offers the primary opportunity for input from the State. This might be satisfactory if the State's economic development objectives and water plan were sufficiently detailed to serve as a basis for Federal projections of water use and needs. The relationship of water resources to the State's economy must be considered in the planning process, even though imperfectly understood at the present time. Water projects may encourage many types of economic development. Some of these may be complementary and others mutually exclusive. The future location of industry, for example, can have profound effect on other water uses. While the stream classification program partially answers the question, it too has the same built-in limitation. There is no overall development plan which includes sufficient detail for this program.

Broader consideration needs to be given to all aspects of land and water resources in river basin planning. The requirements of forest land management and forest utilization, for example, need to be considered in the design and



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operation of impoundment structures so as not to alter the natural regimen to such an extent that it is out of phase with the developmental stage of newly germinated seedlings or emerging sprouts. Successful regeneration or forest renewal is the first requirement of successful forest management. A predictable overflow pattern is also essential for efficient harvesting operations.

There are considerations which clearly transcend river basin configuration as a basis for planning. The best current example of this is the 12-State Appalachian Regional Development Program. The concept of the Piedmont as the industrial center of North Carolina points to similar regional planning needs. In the case of the lower coastal region, river basin delineation is largely artificial, and planning on this basis is relatively meaningless. Here, the regional characteristics are dominant, and total coastal area planning of the nature envisaged under the 3-State Coastal Development Program is required.

If the State is to be an effective participant in future water resources planning, it should be in a position of initiative to influence planning on the basis of its own program for the utilization of its water resources. This needs to include long-term concepts of water use which could serve to guide the location of industry, urban development, recreational development, and agriculture on the one hand, and necessary conservation of the natural environment on the other. Additional personnel and funds would undoubtedly be required by the Department of Water Resources for the implementation of an expanded program of this type.

Water Law and Institutions*

The 1965 General Assembly directed the Board of Water Resources to study the need for State regulation of water usage and to report with recommendations through the Governor to the 1967 General Assembly. A brochure outlining the problem, background information, and potential solutions was released in mid 1966 for study and comment preparatory to public hearings leading up to the preparation of final recommendations.

The brochure assumes that additional regulatory powers are needed whenever withdrawals or use of ground and surface water do not serve the best interests of the people of the State, limit economic development, or create conflicts in water use or conditions not amenable to control under existing law. Ground water problems are particularly emphasized in the report. These include:

1. Unsatisfactory nature of the common law applicable to ground waters under circumstances of impinging water uses.

2. Inadequacy of existing laws relating to minimum standards for well construction, qualification of well drillers, and provisions for obtaining underground information from well drillers.

3. Lack of authority to require the capping of unused artesian wells and abandoned wells, inability to control the withdrawal of ground water, to meter its use, or otherwise manage this valuable resource.

*"Institution" in this report refers to the organizational means for the implementation of water resources planning, development, and management.

In a discussion of the regulatory powers needed for the management of surface waters, the brochure concludes that the population and industrial growth of the State will continue to impose greater and greater stresses on the available water supply in order to satisfy mounting requirements.

The water pollution control laws of the State recognize waste disposal as a valid use of surface waters by providing for the issuance of permits for the disposal of waste waters and for the establishment of water quality standards and classification of streams according to best usage. Federal law now authorizes the provision of storage capacity in Federal reservoirs for low-flow augmentation and water quality control on a non-reimbursable basis when the benefits are regional or national in scope. There is no authority for the regulation of water withdrawals, however, even when these reduce stream flow to the extent that pollution abatement measures are rendered ineffective. The Pigeon, French Broad Tuckasegee, and the South Fork of the Catawba Rivers; the Catawba Basin Streams in Mecklenburg County; and the Rocky, Haw and Northeast Cape Fear Rivers are cited as streams where <u>one or more</u> of the following are required:

1. High degree of waste treatment.

2. Upstream storage for low-flow augmentation.

3. Regulation of water withdrawals.

4. Regulation of water releases from hydroelectric power developments.

Other questions raised in the brochure include:

1. The need for the control of ground water recharge.

2. The effect of swamp and marsh drainage on ground water, fish, and wildlife.

3. The need for legislation providing for flood plain zoning.

4. The need for additional State participation in coastal erosion projects, recreational development and municipal water supply in Federal reservoirs, and small watershed projects by sharing in the cost of storage for water supply, recreation, and low-flow augmentation.

A four-year study of available sources of water supply, present and potential water usage, and arrangements made by water users to secure sources of water was undertaken by Professor Milton S. Heath, Jr., Institute of Government, early in 1963 under a Public Health Service grant. The principal objectives were to identify potential conflicts among water users, to evaluate the operation of the existing structure of laws and political institutions affecting water use and their impact on water resource development, and to point toward possible changes in laws and political institutions which might help to eliminate conflicts upon economic growth. The first reports, U.N.C. Water Resource Papers 2-12, dealt with surveys of irrigation in eleven counties representative of the Mountain, Piedmont, and Coastal Regions of the State.

Little evidence of disputes arising from irrigation was reported for any of the study counties. The irrigation surveys also suggested that irrigators in the study areas are able to live under the existing legal structure without serious difficulty. A subsequent report, U.N.C. Water Resource Paper No. 14, however, calls attention to the impact of the large ground water withdrawals at the Texas Gulf Sulphur Mine and its effect on neighboring irrigators. This is cited as a leading example of current water use conflict involving irrigators.

A study of "Industrial Water Use in North Carolina," by William R. Walker, was published by the Institute of Government in 1964 as U.N.C. Water Resource Paper No. 13. This reported that very few conflicts have arisen in the past concerning water rights, although some current water practices appear to be at least a technical violation of the law. Most legislation, it related, has been concerned with the effect of waste discharges, and these practices will be scrutinized more closely as the demand for water increases. Among the problems which may eventually require comprehensive rather than piecemeal treatment, the author included the following:

1. Provision for the interbasin transfer of water.

2. Rights of a municipality to use water from a stream if it is not a true riparian owner and the taking of water is in conflict with a riparian owner.

3. Rights of an industry taking its water from a municipal source as opposed to another industry on the same stream which is, in fact, a true riparian owner.

4. Rights of an industry or municipality to discharge wastes into a lake which do not cause a nuisance or health hazard but do impair certain recreational interests.

5. Rights of a municipality or industry to water from a stream where only a pumping station abuts on the stream and water is transported to the point of ultimate use.

6. Rights of a riparian owner to waters which are released from a Federal project when the storage of the water released was purchased by another downstream user.

7. The right to divert water from projects licensed by the Federal Power Commission.

Other reports in this series pertaining to water law and institutions include "Land Use Implications of Surface Water Allocation," by Vernon E. George, published as U.N.C. Water Resource Paper No. 16, and "Contemporary Eastern Water Rights Legislation," by Professor Milton S. Heath, Jr., published as U.N.C. Water Resource Paper No. 17. The first of these deals with legal and institutional arrangements for water use and their implications concerning land use development density, form, composition, and social makeup. The substance of the second report also appears as two chapters of the State Department of Water Resources water law brochure. In summary, this report consists of a relatively brief resume of the subject of water rights law as a whole, combined with a systematic survey of recent legislation enacted on the subject of water use regulation by Eastern states. It also seeks to fill in occasional gaps in the general literature on water rights law, such as the absence of a comprehensive analysis of legislation and case law concerning the use of diffused surface waters.

Subsequent reports anticipated from the Institute of Government study will be concerned with ground water chemistry, effect of supplemental irrigation of the hydrology of a watershed, case studies in North Carolina water resources law and administration, organization for local water and sewer services, future irrigation of flue-cured tobacco, and a final overall report to complete the research program.

A problem not covered in the above reports which is creating considerable difficulty for State agencies responsible for fisheries and wildlife management in the estuaries and sounds of North Carolina is that of ownership of underlying and contiguous lands. These areas represent valuable land and water resources of great commercial and recreational significance. How much of this is in public or private ownership is presently unknown. Until ownership is clarified in law, there is no way to determine how much of the resource is in jeopardy and the extent to which acquisition programs should be developed to preserve these areas in public interest.

Current research involving water law and institutional aspects of water resources planning is conducted at the national level by the Economic Research Service and includes an intensive legal-economic analysis of water law throughout the United States. In the area of institutions the research is directed primarily at special district structure with emphasis on land and water resource management. Resources for the Future and some universities, such as the University of Wisconsin, have also been involved in institutional research.

Water law and institutional research in North Carolina includes investigations of water pollution control laws and contrasting program administration in a number of selected states to determine the relative efficiency of State water pollution control programs in terms of economy, technical proficiency, political viability, and social and land use effects; the organizational arrangements for public water services; and an exploration of the impact of environmental engineering policies on urban growth patterns.

Summary of Water Law and Institutional Research Needs:

1. Continuing analysis of present and potential conflicts in water use.

2. Socio-economic and planning significance of existing water resource laws and institutions and suggested modification for greater effectiveness under current and future conditions.

3. Optimization of State and local roles in water resources planning and management.

4. Clarification of ownership and related laws associated with lands underlying in intertidal areas of coastal North Carolina.

Planning Techniques

One of the most neglected areas in water resources research is the methodology of planning. The procedures for project planning and evaluation have not advanced at a rate consistent with the increasing complexity of water resource development. The multipurpose, multicomponent systems of today coupled with ever-increasing technological and socio-economic alternatives are becoming exceedingly complex. The relative permanence of water resource projects, their high cost, and their profound effect on the environment demand improved planning techniques to assure efficient designs for the present and latitude for modification in the future.

Present research on water resources planning techniques is quite limited, and a large fraction of this effort is directed toward hydrologic simulation and synthesis. Nationally, the Agricultural Research Service is currently studying deterministic and parametric methods for synthesizing the hydrology of watershed systems. The Corps of Engineers is investigating hydrologic simulation techniques, probability and correlation analysis, and other methods useful in the application of hydrology to planning. The Economic Research Service has studies underway on mathematical programming, input-output models, simulation methods, and statistical sampling as applied to water resources planning.

Research in North Carolina concerning the methodology of water resources planning includes studies of the practicality of a systems-oriented research project involving the integrated analysis of political-institutional, economic and physical-technological systems, with special reference to impacts of current and perspective industrial development associated with phosphate exploitation; the modifications required in river system simulation models to allow them to be used to test the results of weather modification measures and of new and improved methods of weather prediction; a mathematical model of water flow in Pamlico Sound and Estuaries; and the development of a realistic method to determine the optimum level of water quality in streams as defined in economic terms.

Summary of Research Needs Related to Planning Techniques:

1. Improved water resources planning criteria and techniques.

2. Alternative bases for comprehensive water resources planning in areas where river basin delineation is vague or other features are of dominant interest.

Water Demand

No definitive studies of future water demand for municipal and industrial water supply, irrigation, and other uses have been made for the State as a whole. Pollution survey reports of the State Stream Sanitation Committee, prepared for all river basins in North Carolina, present information related to stream conditions, water use, sources of pollution, pollution prevention measures in effect during the period of study, and recommended classifications of streams. Quantitative data on existing municipal and industrial water use is included. The Department of Water Resources has created a Division of Water Management, one function of which is to survey current water use and to undertake the projection of future needs.

Corps of Engineers reports include projections of municipal and industrial water supply needs for the years 1980 and 2010. Estimates are based upon national trends with modification to account for local conditions. Projected needs for agricultural irrigation are also included. These assume an average annual rate of increase of irrigable land of 2½ per cent and a use of 2 acre-feet of water for each acre of crop irrigated.

Surveys of irrigation practice made in 1962 by Professor Milton S. Heath, Jr., Institute of Government, U.N.C. Water Resource Papers Nos. 2-12, reported that little or no reliable data could be obtained on water usage. Estimates of average water use on various crops, provided by the Department of Biological and Agricultural Engineering at North Carolina State University, were included in U.N.C. Water Resource Paper No. 2, and were expanded and refined in Paper No. 14. A related Institute of Government study of "Industrial Water Use in North Carolina," by William R. Walker, U.N.C. Water Resource Paper 13, reported existing water use practices for the food processing, pulp and paper, textile, quarry, and hydro-electric and steam generating industries.

Municipal water supply storage has not played a significant role in the small watershed projects of the Soil Conservation Service up to the present time, but it is likely to be provided in an increasing number of projects in the future. Projections of storage requirements for periods as long as fifty years are made by the individual municipalities.

Prospective water needs are generally considered in the light of fixed requirements based upon current practice. Very little consideration has been given to price-demand relationships. Present water use in North Carolina, as elsewhere, is economically inefficient and more representative of long-established habit than actual need. Very few restraints have been imposed on water use, and consumers have grown accustomed to relatively unlimited water at negligible cost. When the cost implications of wasteful use for both water supply and pollution control are considered, it is apparent that not enough attention has been given to the conservation of water through economic or other constraints. Municipal and industrial needs can often be met with appreciably less water than present practice calls for. The long-term projection of future water needs on the basis of current water use in the absence of some consideration of price-demand relationships will impose unnecessary structural costs and related burdens on the economy. Projections of future need should include alternates assuming various levels of efficiency in water use and the extension of existing supplies through the application of economic theory to water pricing and allocation as well as capital investment in new source development.

Research on the production functions of water in various uses applicable to North Carolina, the optimum quantity of water for non-production purposes, and the price-demand relationships is fundamental to reliable estimates of future water needs.

Nationally, five agencies carry on modest research programs in this general area. The Agricultural Research Service is investigating the demands for rural domestic use, irrigation, and leaching of saline soils. The Economic Research Service is developing schedules of value compared with the quantity of water used, with emphasis on irrigation and livestock use. Information on trends in water use and the requirements for specific industries and municipal use is being compiled by the Geological Survey. The Bureau of Mines has been surveying the mineral industry at five-year intervals to determine methods of use and quantities used. Data from Federal irrigation projects are studied by the Bureau of Reclamation to improve methods for estimating irrigation water requirements and to determine the accuracy of water use records.

There is no current research activity in North Carolina directed toward this important problem area.

Summary of Water Demand Research Needs:

1. Price-demand relationships in the allocation of water resources.

Evaluation Process

Comprehensive water resources planning is a relatively new development which was encouraged by Congressional authorization for expanded multiple purpose storage. The application of systems analysis techniques to the planning process can greatly extend the possibilities for rational systems if reliable methods for identifying and quantifying benefits and costs of projects can be developed and the assumptions for population growth and distribution, economic development and water use are sound.

The measurement of benefits and costs for many water uses is highly imperfect at the present time. Special attention to the present and projected commercial value of fisheries and the intangible aspects of esthetics, recreation, fish and wildlife is needed. This is particularly true in North Carolina where recreational, fish and wildlife resources hold great potential for ultimate economic development. It is entirely possible that, in the absence of realistic criteria for measuring the benefits associated with the less "tangible" values, inadequate attention will be given to the ultimate economic value of these water uses in the face of more apparent dollar returns from immediate industrial development. The concept of "Variety Vacationland" must be built into the planning process in balance with the more tangible water uses if, in fact, the very resources upon which it depends are to be preserved. This can only be done if better means are developed for evaluating the less tangible benefits.

On the national scene, the Economic Research Service is analyzing Federal agency practices concerning the evaluation of water resource project benefits, discount rates, planning horizons and other aspects of project evaluation. It is also conducting research on projection methodology and has developed and is testing an irrigation projection technique that simultaneously considers historical trends, limits on water supplies, economic feasibility, and a range of possible policy constraints in estimating future irrigation and associated water use trends. Research in the Corps of Engineers currently includes evaluation of the impact of water resources development on economic change and evaluation techniques for waterway transportation studies. The Bureau of Reclamation has been analyzing operation and maintenance costs with a view to providing a better basis for future cost estimates. The current Federal research on the evaluation process falls substantially short of dealing with all the many topics which need exploration.

A number of different aspects of the evaluation process used in water resources planning are being studied in North Carolina. These include the effects of water development on industry location decisions, analytical tools for the evaluation of benefits of outdoor recreation at Corps of Engineers' reservoirs, procedures for estimating the effects of water development projects on local government social overhead expenditures, the national employment effects of water resource projects, and techniques for making improved estimates of the magnitude and area distribution of secondary or indirect benefits which can be used in project planning evaluation. An exploratory study of the simulation of regional economic impacts of water resources development will be undertaken early next fiscal year.

Other investigations include the development of criteria for evaluating the quality of water-based recreation facilities and a study of the physical and economic effects of flooding on agriculture with the objective of improving the information used in evaluating flood control projects benefiting agriculture.

Summary of Research Needs Related to the Evaluation Process

1. Techniques for projections of population growth and distribution, economic development, and water requirements.

2. Methods for evaluating benefits and costs of water projects and other economic development measures affecting water resources with particular emphasis on recreation, fish and wildlife and esthetics.

Non-Structural Alternatives

Efforts to deal with water problems in North Carolina, as elsewhere, are usually directed toward the construction of engineering works and not toward non-structural alternatives which may offer more efficient choices. The limitations of existing legislation and policy concerning the curtailment of flood damages might be more widely recognized. Non-structural alternatives involving flood plain regulation and more efficient use of the bottom lands for the common good needs greater attention. As an example, the Task Force on Federal Flood Control Policy in its report, "A Unified National Program for Managing Flood Losses," of August 10, 1966, suggested that the full cost of flood plain occupancy be shifted to the prospective occupants through the imposition of mandatory, risk-related, annual occupancy charges. The charge would be equivalent to the occupant's estimated annual damages plus any costs his occupancy causes others. Payments would be made to an indemnification fund which would be used to compensate those suffering flood damages. There is reason to believe that the same principles might apply to the occupants of coastal areas which experience frequent hurricane damage.

Water supply and waste disposal present a complex of problems, some of which lend themselves to non-structural solutions. More efficient water use can be as effective as construction in the implementation of water supplies. Insofar as water pollution control is concerned, primary dependence has been given to waste treatment and direct regulatory practices. In situations where the absence of clearly defined economic advantages has resulted in little incentive for industry to rigorously examine process changes and waste recovery as alternatives to treatment, this type of activity is now being encouraged by the Clean Waters Restoration Act of 1966 which authorizes Federal matching grants to industry and others for research on improved methods of waste control and treatment.

The applicability, including advantages and disadvantages, of effluent charges to encourage optimal reductions in waste discharges, proper levels of treatment, and appropriate industrial location decisions has not been thoroughly examined and deserves further study. It is apparent from the nature of the response by public officials to suggestions concerning the adoption of the effluent charge approach, that further study of the legal and administrative aspects are very much needed. Likewise, continuing study might be given to financial incentives for water conservation, waste control, and water quality management programs by industry. Among possible alternatives which might be considered are grants for part of the operation and maintenance cost of pollution control facilities, tax exemption on the appropriate portion of production facilities having specific pollution reduction features, and current-year tax relief for treatment plant construction costs.

Questions pertaining to the areas of North Carolina to be conserved in their natural state, areas to be developed for recreational purposes, industry, agriculture, and so on require at least partial answers. The encouragement of wet industries to locate in specific areas designated for this purpose, as an example, offers the possibility of establishing a pattern to economic development and easing the pressures on other uses of water resources elsewhere. The classification of streams by the State Stream Sanitation Committee would seem to encourage this and provides a means for upgrading water quality as required in the public interest. This is limited to water quality, however, and does not protect the wetlands from drainage or the estuaries from filling and dredging. The advantages and disadvantages of zoning with respect to water use should be thoroughly investigated to determine the extent to which this technique might be useful to guide the development and management of North Carolina's water resources.

The Tennessee Valley Authority, Corps of Engineers and the Geological Survey provide assistance in flood plan zoning. These programs are discussed under the "Water Quantity Management" section of this report.

The Economic Research Service is currently studying the applications of zoning to water management. They are considering land-use zoning, stream zoning, taxing policy, public policy, and other measures as means of water quality control and flood damage reduction. The Weather Bureau is applying systems-analysis methods to flood forecasting as a means of increasing the usefulness of this service in flood damage reduction and improved water utilization. The Corps of Engineers plans to undertake research related to flood plain use. The current national program in this important area of research need is very limited at the present time.

The only research on non-structural alternatives currently underway in in North Carolina is a project on rural zoning. While devoted primarily to general rural zoning, this also includes flood plain and recreational zoning.

Summary of Research Needs Related to Non-Structural Alternatives:

1. Non-structural alternatives for the control of flood damages.

2. Non-structural alternatives to water supply development.

3. Effluent charges and other inducements for waste reduction as effective pollution control measure and an alternative to waste treatment.

4. Financial incentives for control of pollution by industry.

5. Land-water use zoning as a means for optimizing water resources development and conserving wildlife areas.

Ecological Impact of Water Development

The construction of water control structures, stream channelization, wetland drainage, filling, dredging for shipping and pleasure boating, and pollution all have a major impact on the ecology of North Carolina's waters.

The alteration of stream flow regimes from free-flowing streams to impounded waters completely alters the aquatic environment and sometimes creates serious problems in the management of downstream waters and in the use of the reservoirs for water supply, recreation, and other purposes. This is a matter deserving serious study and will be discussed further under "Water Quality Management."

Earlier reference was made to the effect of changes in stream flow regimens on forest management. It may well be that impounded water will improve the soil moisture regimen around the periphery sufficiently to largely offset the loss in production resulting from the reduced growing stock represented by the flooded area. Or, it is possible that manipulation of the overflow duration and season may improve germination, early growth of seedlings and sprouts, or both. Traditional cost-benefit assessment does not give adequate consideration to the needs of forest land management. For example, the loss in productivity from growing stock in reservoirs is recognized, but downstream loss in growth by water tupelo and certain other bottom-land species because of changes in frequency and duration of flooding is not considered.

Stream channelization for drainage and flood control can destroy both fish and wildlife habitat and the wetland necessary for the growth of swamp hardwoods. It can also adversely influence receiving waters. Criticism has been levied against the small watershed projects by forestry, wildlife, and recreation interests. While there is no thoroughly established scientific evidence in support of the allegations, there is sufficient knowledge of cause and effect relationships to justify concern and further investigation. The Soil Conservation Service reports that the ecological impact of small watershed projects is being considered and that design modifications have lessened adverse effects. Mitigation measures are planned to further offset damages. The effects of drainage on natural habitat and other resources should be better understood in the interest of a sound assessment of the long-term benefits and costs of the small watershed projects.

Dredging in the sounds for the maintenance of navigational channels, dredging and filling of marsh areas for small boat access and commercial development, and the drainage of marsh areas for mosquito control all have ecological impact on the estuarine environment which can reduce or eliminate important fish, shellfish, and wildlife species. The effects of these changes need to be well understood if water development is to proceed in balance with fish and wildlife preservation.

North Carolina is confronted with major wetland problems in the Dismal Swamp and other parts of the Coastal Region where strong pressures have developed for the conversion of such areas to productive agriculture. These are, perhaps, most strongly felt in the Dismal Swamp region where the proposed conversion will require wholesale drainage and physical chemical alterations of the soil. Many areas in Virginia have already been drained or filled for housing. Conservation interests in both Virginia and North Carolina have urged that portions of the Swamp be preserved as a park or wildlife area. With much of the Swamp in private ownership, modifications are proceeding rapidly. A study of the ecology of the Swamp and of the effects and relative values of various land use practices is needed.

In view of the complexity and cost of studying the ecological impact of water resource development every effort should be made to identify "indicator species" sufficiently representative of the environment so that these could be used to form baselines and to predict and monitor ecological changes in advance of and subsequent to water resource development. Where pressures for development are particularly intense, it may be necessary to design limited, short-term studies to provide "best judgment" decisions in the public interest.

At the national level, the Bureau of Commercial Fisheries is conducting extensive research on the effects of water projects on anadromous fish. The Corps of Engineers plans research to determine whether multilevel outlets on dams to control the temperature and oxygen content of released water are justified and the method of operation required. Other related research is discussed under "Water Quality Management."

Research on the ecological impact of water development in North Carolina includes investigations of the influence of the changed water regimens imposed on the Roanoke River bottom-lands by the Kerr Dam on hardwood regeneration; the ecology, present and alternative future land use patterns of the Dismal Swamp (to be undertaken next year); the effects of salt marsh mosquito control procedures on biotic communities; habitat alterations from changing salinities and other physical and chemical characteristics of sound waters; the distribution of aquatic life in relation to water quality; the character of food chains and measurement of the flow of energy and materials in the food chains in estuarine waters; and the cycling of elements through biota, sediment, and water of the estuarine environment.

<u>Summary of Research Needs Related to Ecological Impact of Water Resources Development</u>

1. Effects of changes in water regimens on fish, wildlife, and forest growth.

2. Effects of marsh drainage for mosquito control on estuarine ecology.

3. Effects of actual and potential dredging for navigation and pleasure boating on estuarine ecology.

4. Evaluation of alternative land use proposals for the development of wetland areas and their relative ecological impacts.

5. Identification of "indicator species" for use in measuring the ecological impact of water resource development.

WATER CONSERVATION

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Efficient water use is important to the management of North Carolina's water resources as a means of avoiding or ameliorating conflicts in water use and encouraging better utilization of existing sources of supply. The reduction of water use without adverse effect on the users offers a means for the extension of existing municipal and industrial water supplies. More efficient water use can mean less capital investment in water supply development and water pollution control. A search for new sources to serve the State's expanding water needs without earnestly seeking ways to reduce consumption would be shortsighted and not in the public interest.

Saline Water Conversion

The State's broad expanse of coastal and estuarine areas dictates that consideration be given to the supplementation of limited supplies of fresh water through desalination. As coastal development accelerates and water demand increases, there will be need for additional sources of supply. This may occur first in the Outer Banks as the potential tourist impact from the expanded National Seashore begins to materialize. Unless ground water withdrawals on the mainland side of the sounds are managed so as to prevent salt water intrusion of the fresh water aquifers, intruding salt water may have to be treated by saline water conversion techniques.

The techniques and systems used in desalination are also applicable to advanced waste treatment. The effluent from modern secondary waste treatment plants may contain only one per cent as much dissolved solids as ocean water and can become economically attractive as sources of supply for direct reuse after advanced treatment.

Desalination research at the Federal level is conducted primarily by the Office of Saline Water. Some work on the application of desalination procedures to waste water treatment has been done by the Federal Water Pollution Control Administration. The Office of Saline Water research laboratory at Wrightsville Beach is the center for O.S.W. activity in North Carolina. Other desalination research underway includes a measurement and control study of a direct contact freezing process, the ion exclusion properties of inorganic membranes prepared from inorganic hydrous oxide cells, and the distribution coefficients of ionic species between aqueous solutions and solid phase membrane materials at elevated pressures.

Summary of Desalination Research Needs:

There are no apparent research needs in this field which cannot be met by the present research program of the Office of Saline Water.

Water Yield Improvement

Watershed management is another means by which North Carolina might increase the productivity of existing sources of water supply. A good deal of research has been conducted by the Forest Service, T.V.A. and others on forest watersheds toward the role of watershed management practices on water yields. Yet, little

of the information has actually been translated into practice in the management of Federal, State and private forest lands and municipal watersheds. This important alternative to new source development should be investigated.

North Carolina has about 64 per cent of its land area in some form of forest cover; hence, nearly two-thirds of the watershed lands are affected in some way by the composition, condition, and manipulation of the forest cover. In a general way it is known that composition, condition, and manner of manipulation have a bearing on water yield and quality from forested or partly forested watersheds, but not nearly enough about the specifics are known. The Forest Service estimates that only a low level of management of forest land in North Carolina for improved water yield could produce one-third billion gallons of extra water per day. The kind of work started by the Forest Service in the mountains of North Carolina needs to be extended into other physiographic provinces of the State from the standpoint of desirable species utilization, road location and construction practices, and optimum cover composition considered critical to improved water yield and quality.

Other means for water yield improvement under investigation at the national level include water harvesting from impervious surfaces, phreatophyte control, snow management, and evaporation suppression. The Agricultural Research Service, Forest Service, Geological Survey, and Bureau of Reclamation are all involved.

Current research by the Forest Service and other groups in North Carolina on water yield improvement includes basic investigations of the mechanics of water behavior as influenced by forest vegetation, soil properties, atmospheric factors, and stream hydraulics with the ultimate objective being to develop effective techniques for managing watersheds for improved water yield and other purposes. Another program is charged with development of effective water control and soil management techniques for wetland forests of the coastal plains. Other investigations involve four small agricultural watersheds and measurement of the effect of various types of cover on soil moisture, evapotranspiration, runoff, and ground water levels; basic research in the moisture and energy flux within the forest.

Summary of Research Needs Related to Water Yield Improvement

1. Investigation of benefits to be realized from the application of water yield management techniques to forest lands.

Use of Brackish Water and Water of Impaired Quality

The continued development of the coastal areas will impose increasing demands for water supply by industry, agriculture, and municipal use. The great abundance of water of varying salinity in the estuaries gives rise to questions as to its use for the irrigation of salt-tolerant crops and for industrial purposes. The potential threat of salt water intrusion into the ground water supply of the coastal region and the increasing quantities of treated wastes emphasize the need for the investigation of the possible direct use of brackish water and waters of impaired quality.

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The primary national research effort into the use of such waters is being carried on by the Agricultural Research Service which is investigating the

effects of various dissolved salts on soil and plant growth, and methods of leaching saline soils.

A preliminary investigation of the use of brackish water for turf irrigation was recently undertaken in North Carolina.

Summary of Research Needs Related to Use of Water of Impaired Quality

1. Use of brackish water for the irrigation of agricultural crops.

2. Potential use of brackish and treated waste waters as raw water sources for municipal and industrial water supply.

Conservation in Domestic Use and in Industry

The cost of waste treatment in the control of water pollution is a function of the volume treated as well as the waste composition. Conservation of water through more efficient water use will also bring economies in waste treatment. Thus, a more prudent use of water could avoid or postpone capital investment in both water supply and pollution control facilities. The design of optimal systems for the control of pollution should also consider the optimization of water use if they are to be truly efficient systems.

With regard to municipal water supplies, water use can be reduced through the control of leakage from distribution systems, water accountability through the metering of all water users, increased efficiency in use through pricing techniques, and redesign of sanitary and other water use fixtures. Distribution system losses can be curbed through existing survey and maintenance techniques. The majority of North Carolina's water systems are metered and accountability for water use can be imposed through political and management decisions.

The bulk of water utilities in North Carolina, as elsewhere, use the declining or "promotional" block rate pricing system. This system favors the heavy water consumer and encourages use for purposes of less value than would be the case if the same unit price were universally applicable. Promotional pricing also contributes to a poor load factor and the associated capital investment in plant and system required per unit of water consumed. Greater application of economic reasoning to water pricing could bring a more efficient allocation of municipal water and considerably extend the use of present supplies.

Water use has not been an important consideration in the design of sanitation fixtures and household appliances. Savings of twenty to thirty per cent of present average per capita daily use might be realized as the result of redesign of these fixtures and appliances for more efficient water use. This could be attained without any changes in pricing structure or conscious effort on the part of the water user.

While the redesign of sanitary fixtures and appliances for water conservation would bring no immediate economies in water use, it is important as a long-term objective. The responsibility for redesign probably rests with the individual manufacturers, who are not likely to move in this direction in the absence of expressions of concern from water consumers, management, regulatory agencies, and research interests.

Industrial water use also deserves careful examination toward the end of minimizing water use and the volumes of waste streams through modifications in operational practices or redesign of industrial processes.

There is no current research effort at the Federal or State level dealing with the conservation of water in domestic and industrial use, though the need for a research effort in this area has been recognized.

Summary of Municipal and Industrial Water Conservation Research Needs

1. Pricing as a means of increasing the efficiency of water use and conservation of the municipal water supply.

2. Optimization of water use in the design of sanitary fixtures and home appliances.

3. Water conservation in industry through process changes and recycling.

Conservation in Agriculture

Agricultural use of water in North Carolina has not yet developed to a point where conservation has become a recognized need. The rapidly growing practice of sprinkler irrigation in which farmers are frequently dependent upon ponds and other limited sources of supply could contribute to future problems, however. The most noteworthy recent conflict with other water uses, as discussed under Water Resources Planning, has been with the phosphate mining industry in Beaufort County where industrial rather than agricultural use was the causative factor.

Conservation in agriculture will become increasingly important in water-short areas as benefits from supplemental irrigation become more widely recognized and the practice more prevalent.

The possibility of increasing the efficiency of water use by crops and forests holds great promise, but the research in this area is scant. It is estimated that an acre of corn uses some 1,300 tons of water during a growing season. If the efficiency of water use could be increased by only 10 per cent, this would be equivalent to one acre-inch of rain during the growing season. A 10 per cent reduction in water use by a forest would produce even larger savings.

The Agricultural Research Service is conducting limited research on improved techniques of applying irrigation water to minimize loss and waste and optimize the net return in production.

Research in North Carolina dealing with water conservation in agricultural use includes studies of the nature and magnitude of the forces holding water on clays and its availability to plants, soil physical properties affecting water movement, moisture supplying power of various soils, moisture movement through porous media to seeds and plant roots, development of drainage criteria, moisture requirements for crops for maximum net returns, critical periods of moisture stress, supplemental water needed in the Coastal Plain, effect of excess soil water on crop growth and water use, and the effect of water table depth on crop performance.

Summary of Research Needs Related to Water Conservation in Agriculture:

1. The physiological and morphological factors influencing efficient water use by crops and forests.

2. The influence of physical and chemical management practices on water use efficiency and related crop and forest growth.

3. Application of irrigation water for minimal use and maximal crop response.

4. The influence of drainage on crop performance.

5. The physiological and morphological bases for drought resistance and the basis for tolerance to high water levels by certain crop plants.

WATER QUANTITY MANAGEMENT

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Problems associated with water quantity management in North Carolina include the damaging effects of recurring floods and hurricanes; the effects of man's activities on the quantities and characteristics of surface and ground water flow; and its storage and availability to meet increasing water needs.

Surface Water Management

The report, "Flood Damage Prevention in North Carolina," states that flood damages in North Carolina are on the increase, largely because of continuing development in the flood plains. The encroachment problem in North Carolina was illustrated by reference to the Cape Fear River Basin. Damages suffered along the Cape Fear River due to the flood of 1945 were estimated at $4.7 million. A similar flood occurring with the state of development in 1960 and in the absence of land use control measures would have caused estimated damages in excess of $10.9 million. The Wilmington District of the Corps of Engineers estimated that approximately one-third of this increased damage potential is due to encroachment.

Damaging floods can occur almost anywhere in North Carolina according to the Institute of Government Report. One or more communities in most of North Carolina's counties have experienced sufficient flood damage to be reflected in some official report by SCS, TVA, USGS, Corps of Engineers, Weather Bureau or other governmental agency. In addition, at least eleven counties have suffered general flood damage of county-wide proportions.

In the flood damage report, Heath points out that periodic flooding is an inevitable natural phenomenon and that flood damage is not the natural result of the floods, but of development in the flood plains. Historically, control of flood damage has been sought by such structural means as dam building and channel improvement. Because of the relentless encroachment upon the flood plains, flood damage continues to rise in spite of the tremendous investment in public works for this purpose. Greater attention needs to be given to methods for preventing damage rather than the control of floods. Further discussion of non-structural alternatives is included in the section of this report dealing with that subject. The State Department of Water Resources orientation brochure contains the observation that "no substantial response to this report (Heath Report) and its recommendations is yet in evidence."

Several Federal agencies have developed studies and programs related to localized flood problems in North Carolina. The studies are directed primarily toward the supplying of information needed as a foundation for land use planning and regulation in flood plain areas. These include the preparation of factual reports by TVA on flood situations in local areas as a basis for local action. The Corps of Engineers was authorized to undertake a comparable program of local flood plain studies in 1960. Flood planning maps showing inundated areas and elevations for selected historical floods can be provided to communities on a fifty-fifty cost-sharing basis by the Geological Survey. The Weather Bureau, Geological Survey, Forest Service, and Soil Conservation Service collect data, conduct studies, and perform other services concerning floods.

Channel improvements are frequently used as structural means for flood control and drainage improvement. Quite often the adverse effects downstream from channel improvements do not receive the same attention as the evaluated benefits above the project areas. Because of the effects of channel improvements on flow regimens more research should be devoted to changes in flood characteristics and consequent impact on downstream areas and receiving waters. This is particularly significant where increased velocities greatly increase sediment transport which would be harmful and costly where deposition can affect channel capacities and cause shoaling in navigation waters.

The geomorphology of a stream system is dependent to a large extent on the average and extremes of flow over a long period of time. The construction of artificial facilities within the system which can change these long-time characteristics will ultimately change the character of the stream channels in the system. These changes can, in time, cause damaging and harmful results despite present apparent benefits. An example of this effect would be the gradual deterioration of a river channel below a constructed reservoir which had materially reduced flood flows that formerly maintained adequate channel capacity. As the capacity of the channel decreases from non-use as a conveyance for floods, the ultimate result might be that even with reduced flood volumes, damage from relatively smaller floods could equal or exceed those prior to the construction of flood control structures in the system.

The construction of facilities within a stream system which can change the flow regimen of a stream may also change the tidal flow characteristics at its mouth. This in turn could materially affect the extent to which sea water might migrate up the estuaries. Similarly, the development of navigation channels, particularly deep channels for ocean-going vessels, will very likely have a significant effect on salt water encroachment and quality of water along long reaches of a stream channel.

The steady trend toward increasing urbanization and its attendant transformation of farm lands and forested areas to highways, shopping centers, paved streets, and residential developments sharply alters surface runoff characteristics and reduces retention and recharge of underlying ground waters. This has the effect of increasing the volume and frequency of flood peaks, reducing the low flows, and increasing the flow of polluting materials from runoff surfaces.

Drainage is of primary importance in the flat coastal plain where the preservation of wet lands is an important conservation objective. There are continuing conflicts between agricultural interests on the one hand and fish, wildlife and forestry interests on the other. Until recently, the development of drainage districts has proceeded largely on the basis of agricultural needs, with less attention being given to other needs, particularly forest production. The Soil Conservation Service states that during the past three years local sponsors of small watershed projects have been considering and planning for other sources such as fish, wildlife and forestry. Mitigation measures are reported to be planned when damages are anticipated.

The orientation brochure on the "Wise Management of North Carolina Water Resources through Law" states that North Carolina stands sixteenth among the states in acreage of drainage projects. Twenty-seven counties in North

Carolina were reported to have important drainage problems. Further discussion of water use conflicts and the ecological impact of drainage projects is given under the section on Water Resources Planning in this report. The Soil Conservation Service and the Corps of Engineers support local drainage projects under their respective programs.

The Institute of Government Report on "Flood Damage Prevention in North Carolina" also reviewed the flood problems created by hurricanes and other coastal storms. Damages have tended to increase in recent years, it concluded, because of increased development of coastal areas. One of the most damaging hurricane seasons to affect the State occurred in a thirteen-month period during 1954-55 when four hurricanes struck the coast. Total damages were estimated at nearly $320 million.

The Corps of Engineers is authorized to conduct hurricane studies to determine the best means of preventing loss of life and damage to property and to participate in the cost of building shore protection projects with State and local government. North Carolina has appropriated funds for cost sharing in local projects and for the conduct of studies on beach protection and sand erosion control. Funds were recently made available by the Seashore Commission for additional research at North Carolina State University. The National Park Service has made substantial expenditures for hurricane protection works within the Cape Hatteras National Seashore Recreational Area. This program includes extensive land acquisition and stabilization by grass planting.

The national research effort on surface water management includes land-forming practices, historical-economic studies of flood control and drainage programs, and economic interpretations of data from experimental watersheds by the Agricultural Research Service. The Forest Service is studying methods for rehabilitating damaged watersheds and protecting water quality by devising improved road location, construction criteria, and logging techniques. The effect of flood retarding structures and land management practices on runoff and stream flow is being investigated by the Geological Survey. The Bureau of Sports Fisheries and Wildlife is concerned with the relation of land drainage to wildlife habitats.

Studies related to the management of surface water resources in North Carolina include research on streamflow and flood routing procedures, the hydraulics and hydrology of coastal estuaries and sounds, saturated moisture movement through porous media, rainfall disposition over a sloping land mass, and water table behavior in relation to land surface treatment. Coastal erosion studies include the vegetative stabilization of the Outer Banks; the delineation of probable areas of severe erosion using long-term lapse aerial photography and wave refraction techniques; and sand origin, erosion and movement in the coastal areas. There is a cooperative investigation of the Ahoskie Creek Watershed involving the collection, analysis, and interpretation of basic data on rainfall-runoff relationships, hydrograph characteristics, crop distribution and yields, and channel behavior with respect to the rate of aggradation or degradation to guide the planning and evaluation of small watershed projects. Other work involves the collection and reporting of peak-flow data on small streams, flood magnitude and frequency, the effects of urbanization and flood plain development on runoff characteristics, the effects of small dams on flood reduction, and the combined effects of improvements in watershed management and dams on water yield, erosion, and sedimentation.

Summary of Research Needs Related to the Control of Water on Land

A number of research needs associated with control of runoff from forest and agricultural watersheds, drainage problems, and non-structural controls for flood damage have been included under other sections of this report. While application of existing knowledge is obviously lagging in this area, there are additional research needs, including:

1. Optimization of structural and non-structural aspects of flood damage protection.

2. Land-forming practices for optimal water and agricultural management.

3. Beach erosion control and sand dune preservation, including the selection and development of salt tolerant species of vegetation.

4. Effects of channel improvement on sediment transport and downstream flow regimens.

5. Effects of water resource developments on tidal flow characteristics and salt water encroachment.

Ground Water Management

According to the Department of Water Resources orientation brochure on the "Wise Management of North Carolina Water Resources through Law," the State's underground reservoir contains more than 90 per cent of the total supply of available fresh water at any one time. It continues to be the principal source of domestic water supply and is being rapidly developed for agricultural and industrial use as well.

Some important conflicts involving the ground water supply have arisen, though these are still limited in number. The brochure concludes that ground water problems will increase in magnitude and complexity as development continues and that planning for proper development is a necessity. A comprehensive State-wide plan for management of the ground water resource has not yet been attempted. However, the study program of the State's Ground Water Division is pointed in this direction.

Ground water problems in the Mountain and Piedmont regions continue to be localized and isolated. In the Coastal Region, problems are more extensive and generalized. At many locations near the coastal estuaries salt water occurs at rather shallow depth in the aquifers. There is often no impermeable layer between the shallow aquifers and surface waters, thus permitting a direct hydraulic connection. With excessive pumping and lowering of the fresh water level, saline waters enter the aquifers from underlying formations or the estuaries. Where the deeper artesian aquifers contain underlying saline waters, vertical contamination of the fresh water occurs when a well penetrates into the brackish area. The Department of Water Resources reports in its orientation brochure that with expected increases in water use, the effects of pumping at municipal and industrial sites throughout the Coastal Plain will continue to expand and will eventually coalesce at many places. The location and water needs of new industries, therefore, need to be carefully considered against the projected requirements of existing users. Excessive pumping at Franklin, Virginia, has brought declines in the water level in Murfreesboro, North Carolina, and planned increases in withdrawals will bring further adverse effect on the North Carolina supply with attendant need for interstate negotiation and agreement.

Drainage projects for the improvement and reclamation of wet-land areas for agricultural use are under rather continuous development. These regions are important recharge areas for the extensive aquifers of the Coastal Plain. While these presently contain waters in excess of that required to recharge the aquifers, continued economic development will increase the demand and recharge requirements and may eventually exceed the capacity of the surface and near surface storage, deplete the potential ground water supply, and contribute to the likelihood of salt water intrusion from the estuaries.

Problems resulting from the improper installation, development and use of wells are said to be common throughout the State. These include locations near sources of pollution, improper horizontal spacing and vertical location, misalignment, and other problems.

The effect of the massive withdrawals of ground water from the Castle Hayne aquifer in Beaufort County by the Texas Gulf Sulphur Company in its phosphate mining operation highlights the rapidly emerging ground water management problems associated with the economic development of the Coastal Region. The conflicts with agricultural and other uses and the potential threat of salt water encroachment which might result from such intense local pumping and drawdown is the principal problem affecting additional ground water development in the County. Although all existing information concerning this problem has not yet been made public, it is reasonably certain that further studies will be required and strengthened water management procedures be considered in the interest of the long-term overall development of that area.

Nationally, the Agricultural Research Service is studying the problems and techniques of artificial ground water recharge and is investigating methods of exploring subsurface aquifers to evaluate their suitability for recharge, methods of accomplishing recharge, and the effect of suspended and dissolved material in the recharge water on the process of recharge and the quality of ground water. The Geological Survey is undertaking studies of the feasibility and benefits of artificial recharge, appraisal of brackish ground water resources, and the effect of withdrawals on ground water regimen.

Ground water research and investigations in North Carolina include a geophysical survey of the bottom of the Pamlico River and interpretation of geophysical and subsurface geologic data in terms of hydrologic conditions in ground water aquifers; a study of the factors controlling ground water in crystalline rocks and methods of improving predictability of yields; an investigation of the extent and mechanics of salt water intrusion; research on the origin, history, occurrence, structure and chemical composition of the Castle Hayne aquifer limestone to increase the understanding of its porosity and permeability for a better control and development of this important resource. Other studies include the systematic and periodic measurement of water levels in observation wells to obtain records of changes in water levels caused by natural or man-made forces; the investigation of the physical characteristics and productivity of important aquifers; and a study of water resources in the Outer Banks.

Summary of Ground Water Management Research Needs:

1. Increased use of underground storage for the water supply.

2. Prevention and control of salt water intrusion.

3. Ground water management techniques.

WATER QUALITY MANAGEMENT

WATER QUALITY MANAGEMENT

Water quality management in North Carolina needs to be viewed in the context of the State and Federal water pollution control programs authorized by the Stream Sanitation Law of 1951 and the Federal Water Pollution Control Act as amended in 1966. The State program was established by the Stream Sanitation Committee to maintain water quality for health, recreation, fishing, agriculture, industry, and wildlife. Water quality standards have been developed, all surface waters have been surveyed and classified in accordance with their present or contemplated best usage, public hearings have been held, and comprehensive pollution abatement plans have been prepared for each river basin. The amended Federal Act requires the adoption by North Carolina before June 30, 1967, of water quality criteria applicable to interstate waters and a plan for the implementation and enforcement of these criteria. The State's water quality standards and classification of all its streams under the Stream Sanitation Law of 1951 are expected to fulfill the Federal requirements for interstate waters.

Current activity is directed toward compliance with established quality standards through waste control and treatment systems. This latter stage may prove to be the most difficult of all. The need to preserve and upgrade water quality in the face of mounting demands from a growing and urbanizing population, expanding industry, increasing irrigation, continuing needs for fish and wildlife conservation, and almost unlimited potential as a major recreation center will pose increasingly difficult problems in the years ahead. Clean water must be provided for this multiplicity of uses in the face of more and more wastes and greater demands upon the water resource. Water quality will be the limiting factor in the management of the State's water resources.

Identification, Sources and Fate of Pollutants

An important fundamental to water quality management is continuing intelligence on the nature and extent of all significant pollutants. Analytical techniques have been fairly well developed for the more common substances, but modern technology is producing a steady stream of new waste materials which may enter the water resource in only trace amounts. A formidable problem in North Carolina is the array of agricultural chemicals widely used throughout the State. There is no monitoring program for the detection of pesticides in surface or ground waters at the present time. The monthly monitoring of chlorinated hydrocarbons in oysters, clams, fish and plankton samples at eighteen stations has been undertaken by the University of North Carolina's Institute of Fisheries Research at Morehead City, N. C. Analyses are done at the Department of the Interior Laboratory at Gulf Breeze, Florida. In view of the potential threat of pesticides to human health and to fish and wildlife and related aquatic food chains, it is important that steps be taken to develop a more comprehensive monitoring system.

In the past, primary attention has been given to discrete sources of pollution which could be characterized and quantified as to their anticipated effect on water quality. It is becoming increasingly apparent that grave errors of omission have been made by not adequately considering the more diffuse sources of pollution. One of the most important of these from the National standpoint is the overflow from combined sewer systems. Fortunately, North Carolina has largely separate systems and this is not a general problem. A closely related source of pollution which is of State concern is the by-passing of wastes from sanitary sewer systems to water courses without treatment due to excessive infiltration of ground water into the system. Sanitary sewer systems are normally designed to handle limited amounts of infiltration, but where the jointing is particularly poor and the water table high, large amounts of ground water can enter the systems, increasing the total flow beyond the design capacity of the treatment plants and necessitating by-pass directly to the stream.

Until recently, little attention has been given to the effects of urban land runoff on the quality of receiving streams. It is now known that the flushings from roofs, yards, city streets, and other urban areas carried by storm sewers to water courses can contribute appreciable amounts of pollution which should be considered in overall management of water quality. The effect of urban runoff on North Carolina streams is not well understood and insufficient information is available to account for this source of pollution in water resources planning.

The runoff from agricultural land also exerts an important influence on water quality. Pesticide, herbicide, and fertilizer residues, sediment, and animal wastes entering a stream impose a diffuse influence that must be better understood and considered in the overall water quality management scheme. North Carolina is experiencing the rapid development of concentrated poultry, hog, and livestock growing which is contributing substantially to the total waste input into water courses. Agricultural complexes of this type can have the same pollutional impact as a small city and must receive the same attention insofar as the polluting effects of their wastes are concerned.

Increasing interest and wider use of fertilizers, herbicides, and pesticides in forestry also represent possible sources of water pollution. Contamination is related to techniques of applying chemicals and guides are needed to prevent unnecessary pollution of open water surfaces. The likelihood of contaminating ground water has not been well defined. There is need to determine the extent to which baseflow water quality and stand growth and structure characteristics are affected by differing rates of application of pollutants and how these vary between soils.

The changing nature and quantities of wastes discharged by North Carolina industries is a matter of continuing concern to the State Stream Sanitation Committee. The characterization of complex new wastes is an essential prerequisite to understanding of their effects on receiving waters and amenability to treatment.

The careless handling of raw earth in the construction of highways, housing developments, shopping centers, and other urban construction contributes large amounts of sediment to the streams draining these areas with attendant deterioration of water quality, damage to fish and wildlife, and filling of streambeds. There is a need to see what can be done in road maintenance to reduce sedimentation from road ditches periodically scraped to raw form, particularly along unpaved county and other secondary roads. Under present practices the amount appears large enough to deserve critical assessment.

The Agricultural Research Service is studying the movement of agricultural chemicals from the land to streams by overland and subsurface routes and the behavior of these chemicals in reservoirs. The Forest Service is investigating the fate of pesticides applied to forest land and the Geological Survey is studying the movement of pesticides in streams and ground water. Work on the movement of pollution from septic tanks, waste dumps, farms, and other sources to the ground water, streams and coastal waters together with the persistence and degradation of pollutants is being undertaken by the Federal Water Pollution Control Administration.

Research on the identification, sources and fate of pollutants in North Carolina includes studies of pesticide residues; the relationship between soil properties and the leaching of nutrients and pesticides to ground and surface waters; residues of chlorinated hydrocarbons in oysters, clams, fish, and plankton; microbial detoxication of herbicides in aquatic environments; analytical and statistical techniques dealing with free chlorine residuals, bacterial quality of treated effluents, biochemical oxygen demand determinations, and the biochemical utilization of combined sources of oxygen. Other investigations are being conducted to determine the contributions of calcium, magnesium, nitrogen, phosphorus, potassium, and herbicides from controlled watersheds; measurements of the radioactivity and identification of radionuclides present in marine organisms, water, and sediment in the coastal estuaries; the development of means for the prediction of water temperatures downstream from waste heat discharges and the distribution of cooling waters in reservoirs under various plant loading and meteorological conditions; the distribution of fecal and non-fecal coliform organisms from unpolluted land areas and the survival and multiplication rates of fecal coliforms in waste-disposal lagoons, streams, and reservoirs. A study leading up to the design and testing of a water monitoring system for pesticides in North Carolina will be undertaken next fiscal year.

Summary of Research Needs Related to the Identification, Sources and Fate of Pollutants:

1. Design of a State monitoring program for pesticides in water, sediments and aquatic life.

2. Extent and nature of pollution from municipal wastes bypassed directly to North Carolina streams.

3. Quality of urban runoff and effect on receiving waters.

4. Quality of agricultural land runoff and effect on receiving waters.

5. Assessment of stream sedimentation from urban and highway construction and effect on streams and water uses.

Effects of Pollution

The control of pollution and management of water quality require insight into the effect of pollutants on all of man's uses of the water resource and the aquatic environment.

In general, the effects of municipal wastes on receiving waters are reasonably well understood insofar as the oxygen-depleting nature of decomposable organic materials is concerned. The same can be said for degradable industrial wastes. This is not to infer any lack of problems associated with the disposal of such wastes, which are increasing at rates higher than the aggregate efficiency of waste treatment. The primary sources of industrial wastes in North Carolina are the pulp and paper, textile, synthetic fibers, food processing, and phosphate industries.

One aspect of oxygen depletion from degradable organic wastes that appears to require further attention is the degree of dissolved oxygen fluctuation in surface waters throughout the diurnal cycle. During daylight hours algae and other aquatic plants give off oxygen as a result of photosynthesis. The respiratory processes of aquatic life continue throughout the twenty-four-hour period irrespective of illumination. During hours of darkness the demand for oxygen can be met only from physical reaeration after the accumulated dissolved oxygen has been exhausted. Many of North Carolina's streams in the Piedmont and Coastal Regions are slow moving and physical reaeration may not play a very important role in comparison to photosynthesis as a source of oxygen. Water quality standards cite minimum dissolved oxygen levels without reference to time of day. Additional information concerning the nature and timing of dissolved oxygen fluctuations should be helpful in the development of sampling schedules and the interpretation of data. It is understood that previous studies of diurnal variations in dissolved oxygen have been largely devoted to lakes and reservoirs and that investigation of conditions in North Carolina streams has been limited to the Roanoke River immediately downstream from the Kerr Dam. There is need for greater understanding of this phenomenon in flowing streams together with related variations in the respiratory demands of fish life during the hours of darkness when minimum dissolved oxygen levels occur.

Many industrial wastes defy any single categorization as to effect on receiving waters. Where organic wastes are concerned, they are highly variable as to degradability with many being quite stable over long periods of time and exerting their influence on water quality through a prolonged demand on oxygen, toxicity, color, turbidity, taste, odor, and other effects. The chemical nature of a steady flow of new wastes--particularly in the petrochemical, synthetic fibers and similar industries--is largely unknown and their effect on water quality is a matter of conjecture. A great deal of work needs to be done in the investigation of the effects of industrial wastes on water quality. Without such information it is difficult to see how there can be any basis for the projection of industrial development as a part of any overall water quality management scheme.

Much has been said about synthetic detergents as a pollution problem, but this has emphasized the foaming and other qualities of the surface active agents and has largely ignored the more formidable problems being created by the phosphate building compounds used to enhance the cleansing properties. These phosphate compounds, representing a large proportion of the total detergent bulk, are an important source of essential nutrients which stimulate the growth of algae and other aquatic plants. This accelerates the aging process--eutrophication--of lakes and reservoirs. Other sources of phosphorus and of nitrogen--another important nutrient--are the fertilizers used in agriculture and urban living. North Carolina now has a major new source of phosphorus being discharged into its shallow estuaries. This is coming from the phosphate industrial complex in Beaufort County and is contributing to the nutrient enrichment and eutrophication rate of the estuaries. The recurrent growth and decay of algal blooms and the premature choking of lakes and estuaries with aquatic plants can seriously affect the utilization of these waters and create such problems as taste and odors in fresh water supplies which increase the cost of water utilization at locations far removed from the water source.

High nutrient levels from waste discharges and land runoff may be relatively inoffensive in flowing streams, but may have serious effects on quiescent reservoirs created by the construction of dams. The phosphate and nitrate levels in the New Hope and Haw Rivers reported by the Geological Survey in 1964 and 1965 in "Water Resources Data for North Carolina," for example, are sufficiently high to justify serious questions as to the adverse effect on water quality and water use unless ways can be found through waste treatment and agriculture practice to reduce the nutrient load in these streams or means developed to otherwise maintain a balanced ecological environment in the proposed New Hope Reservoir. This same problem will be increasingly encountered elsewhere with existing as well as new structures unless remedial measures are developed. There is little general agreement on the threshhold levels of phosphorus and nitrogen or the various other factors which influence eutrophication of lakes, reservoirs, and estuaries, and much additional research needs to be done.

The many small lakes associated with new housing developments give rise to questions concerning their role in urban development, the effect of urban runoff on their ultimate value as scenic attractions, and their possible adverse effects on downstream water quality. A better understanding of this phenomenon is required if adequate precautions are to be taken to provide for the proper management of these small but heavily used bodies of water.

The increasing use of steam electric generating plants in North Carolina for base power loads together with the inevitable transition to nuclear power underscores the importance of heat as a pollutant and the need to better understand its total effect on the water environment. Increased water temperatures coupled with high nutrient levels in reservoirs and estuaries could accelerate eutrophication even faster than presently anticipated. The possible location of large generating plants on the estuaries together with the wastes discharged by the phosphate industry has the potential for completely upsetting the normal estuarine environment and creating problems far more severe than presently contemplated.

The effects of the large variety of pesticides being used in North Carolina on aquatic life have not been defined. The persistence of these substances, their retention or release from the soil, their effects on consumption by man and animals and the more important forms of aquatic life and related food chains are not understood. The problem is further compounded by the lack of information on the spatial distribution of these substances and their metabolites through the State's water resources.

Five Federal agencies are engaged in research on the effects of pollution on water quality. The Atomic Energy Commission is studying the effects of effluents from reactors on water quality. The Bureau of Commercial Fisheries and Sports Fisheries and Wildlife are investigating the effects of pesticides and other forms of pollution on the aquatic environment. The Geological Survey is studying the effect of pesticides, detergents, and other pollutants on marine life and aquatic growth, the effects of contaminants on ground water movements, and maintenance of well-water equipment. The Federal Water Pollution Control Administration is devoting special attention to the development of effective methods for evaluating the effect of various pollutants on water uses including specific water quality criteria for this purpose.

Studies of the effects of pollution on water quality in North Carolina include research on the adaptation of vertebrates to pesticides; a cooperative investigation of currents in the Pamlico Estuary as related to pollution transport; investigation of the hydraulics and hydrology of Pamlico Sound as related to the dispersion and flushing of wastes; experimental studies of the effluent from phosphate mining operations and its effect on selected component species of biota using artificial pools and estuaries; the measurement of the effects of pollutants and ensuing eutrophication on communities of plankton, rooted aquatic plants, and macrobenthos in the Pamlico Estuary; the development of means for the prediction of the effects of pollution on estuarine waters; the identification, concentration, and turnover rate of some organic compounds important to heterotrophic bacteria in natural waters; the importance of organic compounds excreted during algal photosynthesis to heterotrophic bacteria; and a study of heterotrophic activity of planktonic bacteria with radioisotopes as a method of indicating the degree of pollution and eutrophication. Other research activities in this category concern fluoride and phosphate absorption by crabs and bivalve mollusks in the Pamlico estuary and effects of radiation on the physiology and morphological development of marine organisms.

<u>Summary of Research Needs Related to the Effects of Pollution on Water Quality</u>:

1. Diurnal fluctuation of dissolved oxygen in North Carolina streams.

2. Diurnal variations in respiratory demand for dissolved oxygen of aquatic life in North Carolina waters.

3. The availability of phosphorus, nitrogen, and other nutrients and effect on quality and eutrophication of North Carolina waters.

4. Potential waste heat problem in North Carolina and effect on water quality and eutrophication.

5. Combined effect of nutrient enrichment and elevated temperatures from waste heat discharges on reservoirs and estuaries.

6. Effect of phosphate mining and ore processing wastes on water quality, water uses, and eutrophication of the Pamlico Estuary and Sound.

7. Effect of pesticides in ground and surface waters on aquatic and terrestrial plant and animal life.

8. Role of lakes in urban development and effect of pollution from diffused wastes on their ultimate value.

Waste Treatment Processes

Conventional municipal waste treatment ranges in effectiveness from primary treatment with the removal of the readily settleable and floating materials to relatively high degrees of biological stabilization using trickling filters, activated sludge or related processes. When circumstances demand, secondary treatment plant effluents can be further stabilized and clarified through use of sand filters or oxidation ponds. Nearly all waste treatment research has centered on further refinements of these techniques. Until very recently no significant research effort had been directed toward major advances in waste treatment technology. Advanced waste treatment research is a comparatively new development which is primarily involved at the present time in exploring physical and chemical methods used in industrial and desalination processes to determine their applicability to the complete renovation of secondary treatment plant effluents for reuse. Ideally, waste treatment technology should provide a range of choices across the entire spectrum of treatment effectiveness in building block sequence to meet new requirements with full utilization of previous treatment facilities.

The Sixth Annual Survey of Municipal Waste Treatment Needs of the Conference of State Sanitary Engineers reported that thirty-two communities in North Carolina with a population of 214,528 still discharge raw sewage and sixty-two communities with a population of 431,207 discharge inadequately treated sewage. An additional eight unsewered communities were listed as requiring both collection systems and treatment facilities. The estimated cost of the 102 needed treatment plants is $29.5 million and ancillary works of $23.6 million for a total bill of $53.1 million. These are the current needs in a State which has an effective and forward-looking pollution control program. With continued population and industrial expansion, waste treatment needs will continue to change from the simple to the complex, and an increasing number of facilities with successively higher degrees of treatment will be required.

Municipal waste treatment construction costs have increased about 3 per cent per year. This past trend will probably accelerate with the inflationary pressures coming to bear on the economy. Under these circumstances it is important that increased attention be given to economy of construction and not just to new processes. In the past, economic optimization in treatment plant design has concentrated on the optimal combination of unit processes. Almost no attention has been given to the structural design and construction practices. The concept of economization needs to consider the physical structures and current design practice should be questioned to seek out the minimal physical facility necessary to provide the required degree of treatment.

Industrial waste treatment utilizes many of the processes applicable to municipal wastes in addition to specialized industrial waste treatment processes. The demands upon industry in North Carolina for higher degrees of treatment will parallel those for municipalities. Economy of design and construction is equally important to industry, but should be preceded by rigorous efforts toward waste reduction through in-plant process changes, improved operational practices, chemical substitutions, and so on. Waste treatment should be a last resort and even where required should be accompanied by a continuing effort for waste recovery through by-product development and other alternatives.

The advantages and disadvantages of effluent charges as incentives to waste reduction by industry need to be better understood. Textile, pulp and paper, food processing, and phosphate mining and processing waste are of foremost importance in any consideration of industrial wastes problems in North Carolina.

The construction of waste treatment facilities represents but the first step in the control of pollution from municipal and industrial sources. The quality of operation and maintenance will ultimately determine their success or failure. Such facilities are costly and must be competently operated and maintained if the capital investment is to be protected and the regulatory agency and design objectives are to be met. While North Carolina is ahead of many states in this regard, further improvements are possible. The State's monitoring, educational, and technical society programs are means toward this end.

The Federal Water Pollution Control Administration is conducting the major share of waste treatment research at the national level. Investigations by the Office of Saline Water and Atomic Energy Commission will contribute to the removal of dissolved minerals and radioactive materials.

Research in North Carolina related to waste treatment includes studies to determine the enzymatic cleavage of the ether linkages in lignin and the selective degradation of lignin by enzymatic action for pulp waste by-product development and water pollution control; the development of recoverable and reusable warp sizes to replace starch - an important pollutant from the textile industry; studies of finishing and dyeing and lint-bearing textile wastes, disposal of pulp and paper mill wastes, and the selective removal of metal ions in solution by ion flotation. Municipal waste treatment research activities encompass optimization analysis and comparison of various trickling filter models; the measurement of biological growth on trickling filter media by neutron thermalization; design criteria for final settling tanks and sludge thickeners; the variables affecting the removal of ammonia from water by bubble aeration and of algae by low-flow bubble flotation; the ability of algae to metabolize various organic compounds found in municipal and industrial wastes; and the effects of various types of suspended materials on the rate of oxygen transfer in bubble aeration. Other investigations include an evaluation of the overall anaerobic sludge fermentation process and a continuing study of the use of oxidation ponds in serial sequence to establish levels of tertiary treatment and nutrient removal.

<u>Summary of Waste Treatment Research Needs</u>:

1. Economic optimization in waste treatment plant design, including materials, equipment, structural features, and unit processes.

2. New and more economical unit processes to meet conventional waste treatment needs.

3. Economical unit processes for advanced waste treatment and waste water reuse.

4. Nonstructural alternatives to industrial waste treatment such as process change, chemical substitution, waste recovery for reuse and by-product development.

5. Solutions to the waste treatment problems of the textile, pulp and paper, food processing, and phosphate industries of North Carolina.

Water Treatment

Present water treatment techniques are generally adequate for municipal and industrial water supply needs in North Carolina.

Municipal treatment processes can produce biologically and chemically safe water supplies where raw waters are of acceptable quality. The traditional rapid sand filter plants including chemical coagulation and chlorination cannot remove any appreciable amounts of dissolved organic compounds and inorganic salts. Some question also exists as to their effectiveness in the removal or inactivation of virus. Yet, there is little epidemiological evidence of water-borne disease transmission or toxic effects from chemical wastes, pesticides, and other dissolved substances. Water-borne disease outbreaks still occur, but these can generally be associated with plant malfunctioning or failure to operate all units as planned. The lack of epidemiological evidence in the case of chemical ingestion from water supplies is not sufficient evidence of safety, however, unless related methodology is geared to the sub-clinical effects anticipated from the low-levels of toxic materials. Current epidemiological techniques do not adequately provide for problems of this sort, though a good deal of research effort is now being applied to remedy this deficiency. Requests are now being made to regulatory agencies for authorization to increase filtration rates and decrease sedimentation periods in the treatment at municipal water supplies. Additional information on maximum filtration rates and related minimum sedimentation periods would be useful to guide regulatory actions.

There are no known industrial water quality problems which are not amenable to current water treatment processes. The primary effect of low water quality would be to increase treatment costs in proportion to the finished water quality requirements of the individual industries.

Three Federal agencies are conducting water treatment research. The Agricultural Research Service is investigating the removal of pesticides from rural domestic water supplies. Work on more efficient methods for municipal water treatment is being continued by the Federal Water Pollution Control Administration. The Public Health Service is planning additional research pertaining to the health aspects of water supply, treatment, and distribution. Research on methods for the removal of specific elements such as acid, alkali, silica, etc., is being supported by the Office of Saline Water.

Water treatment research in North Carolina includes studies of the mechanism of water filtration and related design rationale, the oxygenation of iron in continuous reactors, and work on boiler scale formation and tube failure.

Summary of Water Treatment Research Needs

With the possible exception of additional work on filtration rates, existing research efforts in water treatment technology, per se, would appear to be adequate. There are many closely related needs, however, dealing with water resources planning, water conservation, and waste water treatment and reclamation which do require additional research. These research needs are included in other sections of this report.

Water Quality Control

Water quality control can be attained through waste reduction, treatment, retention or disposal to the non-water environment; waste dilution through low-flow augmentation; the treatment of streams; the regulation of water use; and other means. The effects of pollution on water quality are closely associated with water quantities and the concept of water quality control implies overall water and waste management to attain desired water quality objectives.

Present water quality standards in North Carolina provide specific criteria for various classes of water. While the seven-day, ten-year minimum flow is used for planning purposes, it does not release the polluter from his obligations to maintain water quality standards should stream flows fall below designated levels. There is no provision for low-flow augmentation storage in existing reservoirs, though the Federal Water Pollution Control Act now authorizes the Federal agencies to include storage capacity for the regulation of stream flow for the purpose of water quality control. Such storage is not in lieu of waste treatment but is supplemental to adequate treatment. Costs for low-flow augmentation are borne by the Federal government if the benefits are widespread or national in scope. Since the benefits from low-flow augmentation storage in Small Watershed Improvement Projects would be primarily local in nature, the sponsors, State, or other non-Federal interests would have to underwrite the added cost of storage for this purpose. The need for low-flow augmentation storage capacity in Small Watershed Improvement Projects as a supplement to adequate waste treatment to protect downstream water uses should be thoroughly explored and recommendations developed as to means for providing this important mechanism for water quality control if required.

It is common in North Carolina, where hydroelectric power is used primarily for peak power demands, to operate the turbines intermittently and to release no water during periods when the generators are out of operation. This can be a daily occurrence of a number of hours' duration with flows reduced to leakage volumes. The effect of intermittent flows on water quality, fish and aquatic life, and other uses has not been adequately defined.

One little publicized avenue available for ensuring that private water power projects will be installed and operated in the interest of water quality management is the Federal Power Commission water power licensing program. F. P. C. provides a forum in which water users can seek to ensure that such projects do not unnecessarily worsen stream quality conditions. A variety of license conditions have been imposed by F. P. C., including provisions concerning minimum stream flows, regulation of reservoirs, location of turbine intakes, and construction of submerged weirs.

The New Hope and Falls of the Neuse impoundments will provide storage capacity for water quality control through low-flow augmentation. The previous reference to the water quality problems which might arise in these impoundments through upstream pollution illustrates the types of problems which can be anticipated in using stored waters for the enhancement of downstream water quality. Even where the waters flowing into reservoirs are of high quality, the quality of reservoir discharges can vary substantially with depth, biological activity, and reservoir dynamics. Where the incoming waters are of relatively low quality, they could have little beneficial value for water quality control and could even have a detrimental effect on downstream water quality. More information about the effect of upstream pollution on reservoir water quality; biological, physical, and chemical changes during storage; and outlet structure design for optimal use of waters of varying quality for water quality management is badly needed.

There have been indications of some interest by North Carolina industrial water users in relying upon flow augmentation as a water quality management device. Clarification of the legal aspects may be necessary as a preliminary step, however. Whatever use may be made of low-flow augmentation in the future, it is obvious that considerable dependence will continue to be placed on waste treatment, prevention, and disposal alternatives which have been discussed earlier in this report. Where agricultural wastes are concerned, increased attention can be given to the control of animal waste storage and disposal and development of agricultural chemicals which readily degrade or remain bound to the soil. A better understanding of the pollution load from urban and agricultural land runoff will provide improved estimates of the effect of these diffuse sources of pollution on water quality and thereby strengthen overall management through a more exact control of discrete sources which are subject to regulation.

Stream aeration offers an opportunity to upgrade water quality, particularly on an intermittent basis involving unusually low flows and critical dissolved oxygen standards. North Carolina streams are relatively small and treatment of an entire stream to upgrade the water quality is a possibility for consideration where circumstances warrant.

Accelerating urban development in some parts of North Carolina has created the need for area-wide water distribution and sewage collection systems. While economics of scale offer many advantages for large water and waste treatment facilities, it should be borne in mind that strategically located, multiple water supply intakes and treated waste outlets might be preferable to single points of supply and discharge from the standpoint of water quality control. This should be considered in any optimization studies dealing with the management of water resources on a regional or basin-wide basis.

Increased demands are being made upon municipal water supply reservoirs for recreational use and regulatory agencies are being asked to relax restrictions on the use of such waters for this purpose. Additional information on permissible types and levels of recreational use that can be permitted before hazards develop would be helpful in the promulgation of appropriate controls.

There is a fairly wide range of water quality control research being carried on by the Federal agencies at the national level. The Agricultural Research Service is interested in techniques for the application of agricultural chemicals which will minimize runoff from agricultural lands to streams or ground water. The Corps of Engineers, Bureau of Reclamation, the Geological Survey, and the Federal Water Pollution Control Administration are investigating reservoirs to determine quality changes and devise procedures to offset quality degradation. The Geological Survey is also studying the manipulation of ground water systems to prevent salt-water encroachment. The Federal Water Pollution Control Administration is investigating the effectiveness of flow augmentation to control pollution.

Research on water quality control in North Carolina includes a sensitivity analysis of damage-duration-return period relationships in low stream flows to arrive at optimum water quality management based on the total performance of a stream; quantitative methodology for determination of the optimal degree of treatment required at each point of waste discharge on a stream to minimize the total combined cost for all plants for a requisite water quality; limnological studies of hydroelectric impoundments; development of sensing devices for the rapid and sequential transmission of limnological information; an investigation of the short-term cycling of various phosphate species in several fresh water environments to establish their desirability for algal growth; identification of the major components of the dissolved phosphorus pool in fresh, estuarine, and sea waters including the nature of soluble organic phosphorus compounds produced by cultures of algae; identification and quantitative evaluation of changes in water quality brought about by impoundment in reservoirs; and the prediction of the pollution assimilative capacity of streams.

Summary of Water Quality Control Research Needs:

1. Need for low-flow augmentation storage in small watershed improvement projects.

2. Effect of upstream pollution on reservoir water quality.

3. Biological, physical, and chemical changes in water quality during storage in reservoirs.

4. Reservoir outlet structure design for optimal use of waters of varying quality for low-flow augmentation.

5. Feasibility for the treatment of polluted small streams as an alternative to low-flow augmentation.

6. Recreational use of municipal water supply reservoirs.

RESEARCH PRIORITIES

RESEARCH PRIORITIES

This report is intended to serve as a framework for the orientation of the Institute's program by sharpening the focus of scientific and public interest on the State's more formidable water resources problems and research needs. Until the problems are identified and critically appraised and the research needs assessed as to relative priority, there is no common ground for the development of a program or rational for seeking the necessary financial support.

The assignment of priorities to any type of "need" is a highly subjective undertaking, and there are bound to be strong correlations between individual responses and backgrounds and interests. This study is no exception. Nevertheless, an attempt had to be made to arrive at some general agreement as to the relative importance of research needs. This was accomplished by asking the members of the Technical and Advisory Committees to evaluate the research needs by assigning numerical priorities of one to five with the highest priority starting at one and decreasing to five. The evaluators were asked to avoid marking those needs with which they were unfamiliar and to indicate deletion where they did not believe a need actually existed. All numerical marks should, therefore, represent a positive and reasonably well-informed response.

As can be noted from the membership rosters in the front of this report, the members of the Technical and Advisory Committees are representative of the academic disciplines most heavily engaged in water resources research, the State and Federal water resources agencies, private industry, and local government. Their collective evaluation of the relative priorities of water resources research needs should be reasonably balanced and indicative of the multiplicity of interests involved in water resources planning, development, and management.

The sixty-three research needs identified in this report are summarized in the Appendix by research category and order of priority on the basis of the twenty-two evaluation forms returned to the Institute by the Committee members. The overwhelming choice of first place was the need to find solutions to the waste treatment problems of the textile, pulp and paper, food processing, and phosphate industries in North Carolina. All in all, research on water quality problems is considered to have the highest priority with a close second from water resources planning. While research needs in the water conservation and water quantity management categories generally ranked lower, there were some notable exceptions with high priorities assigned to water conservation in industry, prevention and control of salt water intrusion, and ground water management.

The indicated priorities are intended only as very general indications of the relative importance of the various needs and not as inflexible criteria for the approval or disapproval of research proposals. They will be useful for the encouragement of new research activity and as points of emphasis for program development. As more experience is gained and the various water resources problems have undergone more detailed analysis, it should be possible to inject increasing accuracy into the establishment of priorities to guide the Institute's research program.

SUMMARY

SUMMARY

North Carolina is confronted with important water resources problems which will become more serious in the years ahead. A comprehensive State water management program which considers all aspects of water use and interrelationships with economic development is required. An active and productive university research program is an essential part of such a plan. This should be oriented toward the more important water resources problems in close coordination with State and Federal agencies to maximize the effectiveness of all research activities.

Water is a renewable resource and can be efficiently managed if the public policy and requisite laws and institutions, planning techniques, and basic understanding of the problems involved are sufficient for this purpose. Existing knowledge concerning water law and institutions, planning techniques, water demand, the evaluation process, non-structural alternatives, and the ecological impact of water development is incomplete and additional research is required. Nineteen research needs dealing with these aspects of water resources planning have been identified.

Water conservation through increased efficiency in water use is important to the management of North Carolina's water resources as a means of avoiding or ameliorating conflicts in water use, encouraging better utilization of existing sources of supply and avoiding unnecessary capital investment in water resource development. Methods for the improvement of water yield, the use of water of impaired quality, and more efficient use for agricultural, domestic, and industrial purposes can be developed through the eleven areas of needed research cited in this report.

Problems associated with water quantity management in North Carolina include the damaging effects of recurring floods and hurricanes, the effects of man's activities on the quantities and characteristics of surface and ground water flow, and its storage and availability to meet increasing water needs. Eight areas of needed research concerning surface and ground water management have been identified.

Water quality problems in North Carolina need to be viewed in the context of the State and Federal water pollution control programs authorized by the Stream Sanitation Law of 1951 and the Federal Water Pollution Control Act as amended in 1966. Water quality standards have been developed by the State, all surface waters have been surveyed and classified in accordance with their present or contemplated best usage, public hearings have been held, and comprehensive pollution abatement plans have been prepared for each river basin. Current State activity is directed toward compliance with established standards through waste control and treatment systems. The Federal Act requires the adoption by North Carolina before June 30, 1967, of water quality criteria applicable to interstate waters and a plan for implementing and enforcing these criteria. The State's water quality standards and stream classification program are expected to fulfill the Federal requirements.

The need to preserve and upgrade water quality in the face of mounting demands from a growing and urbanizing population, expanding industry, increasing irrigation, continuing needs for fish and wildlife conservation, and almost

unlimited potential as a major recreation center will pose increasingly difficult problems in the years ahead. Clean water must be provided for this multiplicity of uses in the face of more and more wastes and greater demands upon the water resources. Water quality will be the limiting factor in the management of the State's water resources. Additional research pertaining to the identification, sources and fate of pollutants; effects of pollution; waste control and treatment processes; and water quality control is required. A total of twenty-five research needs have been noted in this category.

The sixty-three water resources research needs identified in this report are summarized in the appendix by research category and order of priority assigned by the Technical and Advisory Committees. Priorities were derived on a subjective basis and were necessarily influenced by the backgrounds and interests of the persons involved. They are intended only as very general indications of the relative importance of the various research needs and not as an inflexible criteria. Research on water quality problems is considered to have the highest priority with a close second from water resources planning. While research needs in the water conservation and water quantity management categories generally ranked lower, there were some notable exceptions with high priorities assigned to water conservation in industry, prevention and control of salt water intrusion, and ground water management techniques.

APPENDIX I

WATER RESOURCES RESEARCH NEEDS

BY

RESEARCH CATEGORY

APPENDIX I

WATER RESOURCES RESEARCH NEEDS
by
Research Category

WATER RESOURCES PLANNING

1. Continuing analysis of present and potential conflicts in water use.

2. Socio-economic and planning significance of existing water resource laws and institutions and suggested modification for greater effectiveness under current and future conditions.

3. Optimization of State and local role in water resources planning and management.

4. Clarification of ownership and related laws associated with lands underlying intertidal areas of coastal North Carolina.

5. Improved water resources planning criteria and techniques.

6. Alternative bases for comprehensive water resources planning in areas where river basin delineation is vague or other features are of dominant interest.

7. Price-demand relationships in the allocation of water resources.

8. Techniques for projections of population growth and distribution, economic development and water requirements.

9. Methods for evaluating benefits and costs of water projects and other economic development measures affecting water resources with particular emphasis on recreation, fish and wildlife and esthetics.

10. Non-structural alternatives for the control of flood damages.

11. Non-structural alternatives to water supply development.

12. Effluent charges and other inducements for waste reduction as effective pollution control measure and an alternative to waste treatment.

13. Financial incentives for the control of pollution by industry.

14. Land-water use zoning as a means for optimizing water resources development and conserving wildlife areas.

15. Effects of changes in water regimens on fish, wildlife, and forest growth.

16. Effects of marsh drainage for mosquito control on estuarine ecology.

17. Effects of actual and potential dredging for navigation and pleasure boating on estuarine ecology.

Appendix I (cont.)

18. Evaluation of alternative land-use proposals for the development of wetland areas and their relative ecological impacts.

19. Identification of "indicator species" for use in measuring the ecological impact of water resource development.

WATER CONSERVATION

1. Investigation of benefits to be realized from the application of water yield management techniques to forest lands.

2. Use of brackish water for the irrigation of agricultural crops.

3. Potential use of brackish and treated waste waters as raw water sources for municipal and industrial water supply.

4. Pricing as a means of increasing the efficiency of water use and conservation of the municipal water supply.

5. Optimization of water use in the design of sanitary fixtures and home appliances.

6. Water conservation in industry through process changes and recycling.

7. The physiological and morphological factors influencing efficient water use by crops and forests.

8. The influence of physical and chemical management practices on water use efficiency and related crop and forest growth.

9. Application of irrigation water for minimal use and maximal crop response.

10. The influence of drainage on drop performance.

11. The physiological and morphological bases for drought resistance and the basis for tolerance to high water levels by certain crop plants.

WATER QUANTITY MANAGEMENT

1. Optimization of structural and nonstructural aspects of flood damage protection.

2. Land forming practices for optimal water and agricultural management.

3. Beach erosion control and sand dune preservation, including the selection and development of salt tolerant species of vegetation.

4. Effects of channel improvement on sediment transport and downstream flow regimens.

5. Effects of water resource developments on tidal flow characteristics and salt water encroachment.

Appendix I (cont.)

6. Increased use of underground storage for the water supply.

7. Prevention and control of salt water intrusion.

8. Ground water management techniques.

WATER QUALITY MANAGEMENT

1. Design of a State monitoring program for pesticides in water, sediments and aquatic life.

2. Extent and nature of pollution from municipal wastes by-passed directly to North Carolina streams.

3. Quality of urban runoff and effect on receiving waters.

4. Quality of agricultural land runoff and effect on receiving waters.

5. Assessment of stream sedimentation from urban and highway construction and effect on streams and water uses.

6. Role of artificial lakes in urban development and effect of pollution from diffused wastes on their ultimate value.

7. Diurnal fluctuation of dissolved oxygen in North Carolina streams.

8. Diurnal variations in respiratory demands for dissolved oxygen of aquatic life in North Carolina.

9. The availability of phosphorus, nitrogen and other nutrients and effect on quality and eutrophication of North Carolina waters.

10. Potential waste heat problem in North Carolina and effect on water quality and eutrophication.

11. Combined effect of nutrient enrichment and elevated temperatures from waste heat discharges on reservoirs and estuaries.

12. Effect of phosphate mining and ore processing wastes on water quality, water uses, and eutrophication of the Pamlico Estuary and Sound.

13. Effect of pesticides in ground and surface waters on aquatic and terrestrial plant and animal life.

14. Economic optimization in waste treatment plant design, including materials, equipment, structural features, and unit processes.

15. New and more economical unit processes to meet conventional waste treatment needs.

16. Economical unit processes for advanced waste treatment and waste water reuse.

17. Nonstructural alternatives to industrial waste treatment such as process change, chemical substitution, waste recovery for reuse and by-product development.

Appendix I (cont.)

18. Solutions to the waste treatment problems of the textile, pulp and paper, food processing, and phosphate industries in North Carolina.

19. Guide lines for the evaluation of high-rate filtration in municipal water treatment.

20. Need for low-flow augmentation capacity in small watershed improvement projects.

21. Effect of upstream pollution on reservoir water quality.

22. Biological, physical and chemical changes in water quality during storage in reservoirs.

23. Reservoir outlet structure design for optimal use of waters of varying quality for low-flow augmentation.

24. Feasibility for the treatment of polluted small streams as an alternative to low-flow augmentation.

25. Recreational use of municipal water supply reservoirs.

APPENDIX II

WATER RESOURCES RESEARCH NEEDS

BY

ASSIGNED PRIORITIES

APPENDIX II

WATER RESOURCES RESEARCH NEEDS
by
Assigned Priorities

Research Needs	Number Reporting Each Priority*					
	1	2	3	4	5	Delete
1. Solutions to the waste treatment problems of the textile, pulp and paper, food processing, and phosphate industries in North Carolina	16	3	1	1	1	0
2. Effect of phosphate mining and ore processing wastes on water quality, water uses, and eutrophication of the Pamlico Estuary and Sound	14	2	4	0	0	1
3. Water conservation in industry through process changes and recycling	11	5	3	1	1	1
4. Methods for evaluating benefits and costs of water projects and other economic development measures affecting water resources with particular emphasis on recreation, fish and wildlife and esthetics	11	4	3	2	2	0
5. Effects of upstream pollution on reservoir quality	10	7	3	1	0	1
6. Nonstructural alternatives to industrial waste treatment, such as process changes, chemical substitution, waste recovery for reuse, and by-product development	10	7	2	2	0	1
7. Economic optimization in waste treatment plant design, including materials, equipment, structural features and unit processes	10	3	4	2	2	1
8. Continuing analysis of present and potential conflicts in water use	10	3	3	2	2	2
9. Effluent charges and other inducements for waste reduction as effective pollution control measures and alternatives to waste treatment	10	2	3	4	1	2

Appendix II (cont.)

Research Needs	Number Reporting Each Priority*					
	1	2	3	4	5	Delete
10. Biological, physical, and chemical changes in water quality during storage in reservoirs	9	2	3	3	1	3
11. Improved water resources planning criteria and techniques	9	4	5	3	0	1
12. Design of a State monitoring program for pesticides in surface waters	9	4	4	2	0	3
13. Prevention and control of salt water intrusion	9	3	8	1	0	0
14. Economical unit processes for advanced waste treatment and waste water reuse	8	6	7	0	1	0
15. New and more economical unit processes to meet conventional waste treatment needs	8	5	6	1	0	2
16. Optimization of State and local role in water resources planning and management	8	4	3	2	4	1
17. Land-water use zoning as a means for optimizing water resources development and conserving wildlife areas	7	6	1	2	4	1
18. Effects of changes in water regimens on fish and wildlife and forest growth	7	5	6	2	1	1
19. Need for low-flow augmentation storage in small watershed improvement projects	7	5	3	3	1	3
20. Effect of pesticides in ground and surface waters on aquatic and terrestrial plant and animal life	7	4	6	1	2	0
21. Ground water management techniques	7	4	5	2	1	2
22. Effects of actual and potential dredging for navigation and pleasure boating on estuarine ecology	7	4	4	4	1	1
23. Non-structural alternatives to water supply development	7	3	6	3	0	0

Appendix II (cont.)

Research Needs	Number Reporting Each Priority*					
	1	2	3	4	5	Delete
24. Investigation of benefits to be realized from the application of water yield management techniques to forest lands	7	3	6	2	1	4
25. Pricing as a means of increasing the efficiency of water use and conservation of the municipal water supply	7	1	6	4	1	3
26. Optimization of structural and non-structural aspects of flood damage protection	6	6	5	3	0	0
27. Non-structural alternatives for the control of flood damages	6	5	5	2	2	1
28. Effects of marsh drainage for mosquito control on estuarine ecology	6	5	4	4	1	1
29. The availability of phosphorus, nitrogen, and other nutrients and effect on quality and eutrophication of North Carolina waters	6	5	4	4	1	1
30. Techniques for the projection of population growth and distribution, economic development, and water requirements	6	5	2	3	3	3
31. Beach erosion control and sand dune preservation, including the selection and development of salt tolerant species of vegetation	6	4	4	2	2	2
32. Socio-economic and planning significance of existing water resource laws and institutions and suggested modification for greater effectiveness under current and future conditions	6	4	4	2	3	2
33. Combined effect of nutrient enrichment and elevated temperatures from waste heat discharges on reservoirs and estuaries	5	8	4	1	3	0
34. Application of irrigation water for minimal use and maximal crop response	5	4	4	4	2	1
35. Quality of agricultural land runoff and effect on receiving waters	4	6	6	1	0	2

Appendix II (cont.)

Research Needs	Number Reporting Each Priority*					
	1	2	3	4	5	Delete
36. Reservoir outlet structure design for optimal use of waters of varying quality for low-flow augmentation	4	5	5	1	0	5
37. Assessment of stream sedimentation from urban and highway construction and effect on streams and water use	4	5	3	4	2	3
38. Increased use of underground storage for water supply	4	4	4	5	1	2
39. Extent and nature of pollution from municipal wastes bypassed directly to North Carolina streams because of excess flows in sewer systems	4	3	4	2	5	3
40. Quality of urban runoff and effect on receiving waters	3	7	5	3	0	2
41. Potential waste heat problem in North Carolina and effect on water quality and eutrophication	3	7	2	6	2	1
42. Potential use of brackish and treated waste waters as raw water sources for municipal and industrial water supply	3	6	5	5	2	1
43. Feasibility of the treatment of polluted small streams as an alternative to low-flow augmentation	3	6	5	3	2	2
44. Optimization of water use in the design of sanitary fixtures and home appliances	3	6	2	5	4	3
45. The influence of drainage on crop performance	3	4	4	2	4	2
46. Land forming practices for optimal water and agricultural management	3	3	5	1	3	1
47. Price-demand relationships in the allocation of water resources	3	2	7	5	1	3
48. Diurnal fluctuation of dissolved oxygen in North Carolina streams	2	2	10	1	3	3

Appendix II (cont.)

Research Needs	Number Reporting Each Priority*					
	1	2	3	4	5	Delete
49. Alternative bases for comprehensive water resources planning in areas where river basin delineation is vague or other features are of dominant interest	2	2	4	4	4	4
50. The physiological and morphological factors influencing efficient water use by crop plants	2	2	4	2	4	3
51. Diurnal variations in respiratory demands for dissolved oxygen of aquatic life in North Carolina	1	5	5	1	6	1
52. The physiological and morphological bases for drought resistance and the basis for tolerance to high water levels by certain crop plants	1	1	5	0	7	2
53. Role of artificial lakes in urban development and effect of pollution from diffused wastes on their ultimate value	1	4	6	3	3	4
54. Use of brackish water for the irrigation of agricultural crops	1	2	4	7	5	1
55. The influence of physical and chemical management practices on water use efficiency	0	3	4	2	5	3
56. Clarification of ownership and related laws associated with lands underlying intertidal areas of coastal North Carolina	Research need added as a result of Advisory Committee review. No priorities assigned.					
57. Evaluation of alternative land use proposals for the development of wetland areas and their relative ecological impacts	"	"	"	"	"	"
58. Identification of "indicator species" for use in measuring the ecological impact of water resource development	"	"	"	"	"	"
59. Effects of channel improvement on sediment transport and downstream flow regimens	"	"	"	"	"	"

Appendix II (cont.)

Research Needs	Number Reporting Each Priority*					
	1	2	3	4	5	Delete
60. Effects of water resource developments on tidal flow characteristics and salt water encroachment	Research need added as a result of Advisory Committee review. No priorities assigned.					
61. Recreational use of municipal water supply reservoirs	"	"	"	"	"	"
62. Guide lines for the evaluation of high-rate filtration in municipal water treatment	"	"	"	"	"	"
63. Financial incentives for the control of pollution by industry	"	"	"	"	"	"

* Priorities assigned by Technical and Advisory Committees and range downward from highest at one to lowest at five. "Delete" indicates that reviewer did not consider the item to be a bonafide research need.