SUMMARY OF WATER RESOURCES RESEARCH UNDER THE GEORGIA WATER RESOURCES RESEARCH PROGRAM

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REFERENCE: Proceedings of the 1989 Georgia Water Resources Conference, held May 16 and 17, 1989, at The University of Georgia. Kathryn J. Hatcher, Editor, Institute of Natural Resources, The University of Georgia, Athens, Georgia, 1989.

OVERVIEW. In this paper the author recounts the history of the Georgia Water Resources Research Program, describes the method of operation and provides some examples of outstanding research programs. These programs have produced substantial additional funding and/or have produced substantial contributions to the literature of water resources. The paper concludes with a brief outline of a design for State funding of water resources research to meet State needs through available expertise and facilities of the University System and to suggest possible programs and funding levels that are needed for an effective water resources research program in Georgia. This conference is an ideal place to seek support from the Georgia water resources community for additional State funding of water resources research. The author wants you to consider the proposed options and suggest other options for improving knowledge about our water resources.

HISTORY. A formal water resources research program was begun in Georgia in July, 1963 (WRC, 1966). This was a University System program prepared for the impending passage of the Federal Water Resources Research Act of 1964 (PL 88-379; 78 Stat. 329). The Federal Water Resources Research Act established 54 water resources research institutes, one in each state and designated territories. In the 50 states the centers were established at the recognized land grant institution with one exception. Subsequently, in December, 1964 the Board of Regents established the Institute of Natural Resources to include a division of water resources to coordinate water resources research.

As a result of intensive work by Dr. Carl Kindswater, the Georgia Legislature, as provided for in the Federal Act, established the Water Resources Research Center for Georgia at Georgia Tech. This program received official sanction when Governor Sanders signed HB 497, GA Act 186 (GA. Stat. 12-5 1-3; Conservation and Natural Resources) into law on March 24, 1965. Final acceptance of the Georgia Program was made by the Secretary of Interior on May 1, 1965. The 1965 research program consisted of eight projects -- 5 from Georgia Tech and 3 from The University of Georgia. The establishment of this program was initially a shared or joint program between Georgia Tech and The University of Georgia, as provided and administered through the Board of Regents of the University System.

In 1975, at the insistence of the Federal Administrators, the program was made a state-wide competitive program, open to all universities located within the State. This method of operation for the State allotment program remains the same today with administrative responsibility resting at Georgia Tech and with cooperating administrative assistance from The Institute of Natural Resources regarding all University of Georgia and related Experiment Station projects.

Over the 24 year history of this program there have been 113 projects funded through the allotment program at Georgia Tech, 95 at the University of Georgia and 16 at other universities (Table 1). This allotment program has totaled 2.5 million dollars over the 24 year period averaging about 105 thousand dollars per year. In addition there have been 14 matching grant projects ($442.3k) funded at Georgia Tech and 17 matching grant projects ($361.8k) funded at The University of Georgia. These 31 projects for $803.8k were funded on a nationally competitive basis from proposals submitted by consulting firms, individuals and universities. No matching grants have been funded at other universities in the State. The total Federally funded water resources research program through 1988 consists of 258 projects for a total funding of $3.341 mil. Admitted administrative costs have been $636.7k or about 19 percent of total funds received.

TEACHING RESULTS. The most important aspect of the Georgia Water Resources Research program is the number of students supported. Over 300 students (76 undergraduate, 150 Master and 75 Ph.D. students have been supported in full or in part through the research funds for this program. These students have been supported in most of the fields offered at the participating universities -- from agricultural engineering to zoology (Table 2).

RESEARCH RESULTS. Unfortunately, we have not been sufficiently diligent in tracking the research results of this program. However, a look back suggests the program has been very effective in producing research of importance and value for the State, the nation and international users. One difficulty is that completion reports are required from the principal investigators at project completion. These list only theses, dissertations and journal articles through project completion. Many journal articles, a few theses and most citations, as well as any applications, develop after the final completion report is submitted. We have no good way to account for these although we can infer they are substantial from the ancedotal references of a few perennial participants. A few selected titles by subject area are presented in Table 3 in order to indicate the breadth of research in the program.

Two anecdotes from The University of Georgia are given to indicate some of the continuity of the program. As Dr. Kahn explains, the program emphasizes the new, first proposal from young professors because of the limited funds and short, one year cycles without any assurance of continuation.

The first is the research by Dr. Bernard C. Patten in

Table 1. GEORGIA WATER RESOURCES RESEARCH PROGRAM FEDERAL FUNDING: FEDERAL WATER RESOURCES RESEARCH ACT, 1964 AND AMENDMENTS

Award Date Fiscal Year	Ga. Tech Allotment Projects	UGA Allotment Projects	Other Allotment Projects	Administrative GA Tech	Administrative UGA	Total Allotment Program	Ga. Tech Matching Grants	UGA Matching Grants	Total Matching Focused Grants	Total Water Program
					($1,000)					
1965	(6) 40.1	(2) 13.7	0	20.2	1.0	75.0	0	0	0	75.0
1965	(7) 32.5	(3) 32.5	0	21.5	1.0	87.5	61.0	(2) 37.9	98.8	186.3
1967	(6) 32.5	(3) 32.5	0	21.5	1.0	87.5	0	(2) 23.9	23.9	111.4
1968	(6) 37.5	(6) 37.5	0	24.0	1.0	100.0	0	(1) 11.4	11.4	111.4
1969	(6) 37.5	(6) 37.5	0	24.0	1.0	100.0	24.6	(1) 31.9	56.6	156.6
1970	(6) 35.5	(5) 37.5	0	26.0	1.0	100.0	0	(1) 16.6	16.6	116.6
1971	(6) 37.5	(6) 37.5	0	24.0	1.0	100.0	(2) 68.4	(0) ?	(2) 68.4	168.4
1972	(5) 39.5	(6) 39.5	0	20.0	1.0	100.0	(2) 28.0	(2) 57.5	(4) 85.5	185.5
1973	(5) 37.5	(7) 37.5	0	24.0	1.0	100.0	(1) 27.8	(1) 38.4	(2) 66.2	166.2
1974	(6) 47.5	(6) 37.5	0	24.0	1.0	110.0	(4) 71.2	(2) 11.9	(6) 83.1	193.1
1975	(5) 38.9	(3) 29.1	(1) 2.7[1] (1) 10.8[2]	27.5	1.0	110.0	(1) 20.0	(1) 17.0	(2) 37.0	147.0
1976	(5) 47.6	(5) 48.0	(1) 2.6[1] (1) 10.8[2]	27.5	1.0	137.5	(2) 60.0	(0)	(2) 60.0	197.5
1977	(6) 49.4	(2) 14.3	(1) 10.2[2]	27.5 (1)	1.0 7.6[3]	110.0	(1) 19.1	(1) 24.2	(2) 43.3	153.3
1978	(6) 49.4	(2) 14.3	(1) 10.2[2] (1) 7.6[3]	27.5	1.0	110.0	(0) 0	(2) 55.8	(2) 55.8	165.8
1979	(5) 41.8	(3) 28.0	(2) 9.2[4] (1) 2.5[3]	27.5	1.0	110.0	(1) 62.2	(1) 35.0	(2) 97.2	207.2
1980	(3) 28.0	(4) 35.5	(2) 8.6[4]	27.5	1.0	100.6	(1) 79.4 24.6*	0	104.0	204.6
1981	(4) 31.7	(4) 37.6	(1) 2.4[4]	27.5	1.0	116.0	38.0	(2) 109.0	147.0	263.0
1982	(3) 24.4	(2) 16.0	0	27.1	1.4	115.0	(1) 41.6 145.5	0	187.1	302.1
1983	(4) 60.0	(3) 35.0	0	19.0	1.0	115.0	0	0	0	115.0
1984	(3) 48.0	(3) 35.0	12.0[5]	19.0	1.0	115.0	0	0	0	115.0
1985	(3) 39.5	(3) 40.5	0	28.0	1.0	109.0	0	0	0	109.0
1986	(3) 42.3	(4) 43.4	0	32.3	1.0	119.0	0	0	0	119.0
1987	(2) 26.0	(3) 39.0	(1) 7.0[2]	32.1	1.0	105.0	0	0	0	105.0
1988	(2) 26.0	(3) 32.0	(1) 13.0[5]	33.1	1.0	105.0	0	0	0	105.0
	(113) 930.6	(94) 790.9	(16) 117.2	612.3	24.4	2537.1	(14) 771.4	(17) 470.5	1241.9	3779.0

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Wetlands Ecology in the Okefenokee Swamp. The Georgia Water Resources Research program first funded a wetlands ecology project in 1974, focused on the Okefenokee Swamp -- a 396,000 acre wildlife refuge and wilderness area. This project was funded for $17,200 for Dr. Patten for work on "Simulation and Systems Analysis of Nutrient Cycling in the Okefenokee Swamp." This produced a dissertation by Edward L. Rykiel on The Okefenokee Swamp Watershed: Water Balance and Nutrient Budgets, three journal articles and a technical report.

This hydrologic work was continued through a competitive matching grant in 1977 for $42,394 from the USGS water program that produced a second dissertation by Elizabeth R. Blood on Environmental Impact of Upland Streams on the Okefenokee Swamp (a winner of the UCOWR Best Dissertation Award in 1982) and several journal articles. This start of $59,594 later produced funding for wetlands hydrologic studies from National Science Foundation of $3,808,596 through 1985. These funds led to the creation of a long term ecological research (LTER) program that lasted through 1987 in the Okefenokee Swamp. Scholarly productivity includes the editing of 8 books by the principal scientist in ecological modeling and some 102 publications, mostly stemming from Okefenokee Swamp research efforts. An additional 8 dissertations were produced by graduate students, most of whom continue tow ork in wetlands hydrology/ecology or closely related areas.

Table 2
Number of Students Trained by Discipline and Level
FY65 - FY84, Georgia Water Research Institute

Discipline	Level of Training			
	Under-graduate	Master's Degree	Ph.D. Degree	Totals
Engineering				
Agricultural	2	2	-	4
Chemical	3	6	1	10
Civil	9	19	4	32
Electrical	2	2	-	4
Environmental	-	20	2	22
Industrial and Systems	1	8	6	15
Materials	2	-	-	2
Mechanical	1	1	-	2
Textile	-	4	1	5
Physical and Natural Science				
Agronomy	1	2	1	4
Biology	22	22	3	47
Chemistry	6	2	14	22
Earth Sciences	1	10	7	18
Food Sciences	-	4	1	5
Forest Resources	9	3	4	16
Geography	2	1	3	6
Mathematics & Computer	-	1	-	1
Physics	3	1	-	4
Law and Social Sciences				
Business Administration	-	2	2	4
City Planning	1	7	-	8
Economics	3	4	3	10
Landscape Architecture	-	1	-	1
Law	-	-	7	7
Management	1	3	-	4
Psychology	7	2	-	9
Other, Unclassified				31
TOTALS	76	127	59	293

This research produced one of the foremost centers of ecological systems analysis in the world with invitations to participating scientsits to share their findings in many countries of Asia and Europe and in the Soviet Union. This live wetlands model of the Okefnokee Swamp, with the accompanying refine-ment of knowledge about its hydrology, ecology, climate, flora, fauna, nutrients and the behavior of these subsystems in a near natural state is of enormous value to wetlands managers. The best testimonial to the knowlege generated through this wetlands research is a book published by A. D. Cohen et. al., in 1984 by Wetlands Surveys on The Okefenokee Swamp: Its Natural History, Geology and Geochemistry. This compendium of some 700 pages (40 articles) was based heavily on the result of 11 years of research begun by the Georgia water program in 1974, representing a vast range and depth of scientific findings.

The second anecdote is more personal. It may overstate the value of the Program whereas other cases are understatements. The first study of water resources economics in Georgia was funded by the Office of Water Resources Research (now USGS Water Program) in 1966. It was also the senior author's first outside funded project. It was a matching grant project at The University of Georgia on "The Price and Demand Structures for Water in a Humid Area." It was a matching grant possibly because of the low esteem of social sciences as a legitimate research area in water resources at that time. The results were classic demand models for water -- estimates of price and income elasticities, i.e., measures of consumer response to prices of water services. These original studies are still valid in practice and they have been proven accurate through hundreds of subsequent replications by other economists. The demand studies serve as a basis for ratemaking in water supply organizations and for the conservation efforts through economically correct pricing that have been more popular for the last decade than they were in 1968.

Research support from the water research program for economic work since 1966 has totaled $178,804 at The University of Georgia. This Federal funding for research has generated an additional $186,800 of direct state funds for water economics and management research, $112,000 of other Federal agency funds for related economics research and about $25,000 from international sources.

This water prorgram research has produced:

(1) teaching materials for courses and seminars on water resources economics, including one textbook;
(2) seven Masters theses and eight Doctoral dissertations in water resource economics;
(3) 61 technical publications and articles;
(4) 36 technical presentations in water resources economics.

Perhaps more important than numbers of research activities and dollars is the contributions these efforts have made to advancing the state of the art in both methodologies and applications of economic analyses to water resources. Work in this area defined a universal cost sharing model for determining the true yield (cost recovery, subisdies and sharing of costs) on a present value basis for all Federal agencies for each or any

combination of 32 project purposes. This model, perfected in 1975, has been used continuously by the executive branch, all construction agencies, the Congress and some states to define their costs of water project services as a basis for formulating investment policy. All water resource development acts since 1976, including the 1986 Water Resources Development Act used these data to redefine cost sharing after 150 years of bad habits. This model now serves as a basis for renegotiating some contracts for major water pricing and repayment contracts between Federal and non-federal parties.

The senior author, and graduate students, developed the first goal programming model for balancing economic and environmental values for project planning as required under the National Environmental Policy Act (NEPA) and the current project planning "Principles and Guidelines." This model quanti-fied all of the relevant environment/economic data on the Cross Florida Barge Canal as a model of multiple objective evaluation of project costs and benefits. This model has been used occasionally by world bank consultants in developing countries and is now being applied in the People's Republic of China.

At the state level this economic work led to active participation in the development by DNR/EPD of a Georgia water management strategy that serves in part as the current state water plan. The authors and helpers produced 13 river basin water budgets and a two prototype river basin appraisal reports for purposes of documenting water resource supplies, uses and permitting conditions.

FUTURE RESEARCH. It seems unlikely that the Federal funds for this program will increase. The history of funding (Table 1) indicates no increase in nominal funds while real funds available have declined by half or more. Georgia has never put any cash directly into the program as most of our neighboring states have done. However, the efforts have been made to do this in the early years and again in recent years. Georgia Tech, with UGA and DNR support has included requests for State funding for 250 - 400 thousand annually, to be earmarked for water research. So far the requests have fallen on deaf ears in the University System administration. The Legislature could solve this need directly but we have chosen, so far, to work through the Chancellor's office, to improve research funding for water resources. Perhaps the Georgia AWRA could be of some help in strengthening our lobbying effort to provide a research base and improve student training so badly needed in Georgia.

LITERATURE CITED.

Water Resources Research Center. 1966. "1966 Annual Report." Georgia Institute of Technology. Atlanta. pp. 1-5.

Environmental Resources Center various Annual Reports, 1966-89. Georgia Institute of Technology. Atlanta.

Table 3. Georgia Water Resource Program Selected Publications by Subject Area

Agriculture
0673 Cost of Waste Water Pollution Abatement in Poultry Processing and Rendering Plants in Georgia, W.R. Kerns
1082 Irrigation System Efficiency Survey for Georgia, J.R. Stansell

Chemical Analysis
0680 Chemical and Spectroscopic Characterization of Humic Substances of Southeastern U.S. Coastal Streams, J.H. Reuter
0382 Application of Electrochemical Detectors for Ultratrace Pesticide and Coal Phenolic Residues in Water, J.L. Anderson

Conservation
0777 Conservation of Water, Chemical and Energy in Dyeing Nylon Carpet, W.C. Tincher
0479 Water Conservation and Alternative Water Supplies, J.R. Wallace

Cost Financing
0677 Financing and Cost Sharing Municipal Water Supply Systems, R.M. North
0782 Analysis of Alternatives for Cost Sharing Water Resources Projects and Programs, R.M. North

Fish
1274 The Effect of Hypolimnion Discharge Upon Age and Growth of the Blue Gill, R. Dudley
0176 The Cause of Trout Fish Kills Occurring in the Water from the Aerated Hypolimnion of Deep Lakes, R.S. Ingols

Floods and Droughts
0379 An Improved Sediment Delivery Model for Piedmont Forests, R.G. Burns
0883 The Effect of Hydroperiod on Floodplain Forest Production, J.B. Birch

Ground Water
0676 Multivariate Analysis of Georgia Coastal Plain Groundwaters, C.O. Pollard
0283 Aquifer Parameter Prediction by Numerical Modeling, M.M. Aral

Hydrological Cycle
0374 Sensitivity Analysis of a Thunderstorm Rainfall Model, J.R. Wallace
0183 Basin-scale Evapotranspiration Determination through Watershed and Climate Analysis, L.A. Harper

Industry
0868 Determination, Evaluation and Abatement of Color in Textile Plant Effluents, R.K. Flege
0481 An Evaluation of the Potential for Water Conservation and Reuse in the Georgia Pulp Paper Industry, G.M. Battaglia

Land Disposal
1074 Land Disposal of Wastewater: Processes, Design Criteria, and Planning Considerations, J.P. Hartigan
0783 Identification and Assessment of Effluent Residuals in Treated Leachate from Landfill Disposal Sites, J.G. Pohland

Law
0475 Survey and Analysis of Urban Drainage Ordinances and a Recommended Model Ordinance, T.N. Debo
0583 Legal Aspects of Water Resources: A Survey of the Law in Georgia, J.O. Smith

Management
0772 A Program for Metropolitan Water Management, G.E. Willeke
0185 Analysis of Wetland Trends and Management Alternatives for Georgia, S.W. Woolf

Municipal Water and Wastewater
0677 A Variable-Discharge Model for Facultative Oxidation Ponds, F.M. Saunders
0585 Heavy Metal Composition of Treated Municipal

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ISBN 0-935835-01-6

UPD 3705/5-89