ECONOMICS OF WATER RESOURCES:
From Regulation to Privatization

Second Edition

NATURAL RESOURCE MANAGEMENT AND POLICY

EDITORIAL STATEMENT

There is a growing awareness to the role that natural resources such as water, land, forests and environmental amenities play in our lives. There are many competing uses for natural resources, and society is challenged to manage them for improving social well being . Furthermore, there may be dire consequences to natural resources mismanagement. Renewable resources such as water, land and the environment are linked, and decisions made with regard to one may affect the others. Policy and management of natural resources now require interdisciplinary approach including natural and social sciences to correctly address our society preferences.

This series provides a collection of works containing most recent findings on economics, management and policy of renewable biological resources such as water, land, crop protection, sustainable agriculture, technology, and environmental health. It incorporates modern thinking and techniques of economics and management. Books in this series will incorporate knowledge and models of natural phenomena with economics and managerial decision frameworks to assess alternative options for managing natural resources and environment.

This book addresses economic and management aspects of water resource, with emphasis on the interaction of quantity and quality. The main theme of the book is that water is a multiproduct commodity with values for both its availability and quality. The book develops an analytical microeconomic framework for water quantity-quality supply and demand, and uses it to address quality-pollution issues, and to demonstrate public policy and institutional approaches to water resource management with emphasis on the interaction of quantity and quality.

The Series Editors

Recently Published Books in the Series

Martin, Wade E. and McDonald, Lisa A.:
Modeling Environmental Policy
Parker, Douglas D. and Tsur, Yacov:
Decentralization and Coordination of Water Resource Management
Just, Richard and Netamjahu, Sinaia:
Conflict and Cooperation on Trans-Boundary Water Resources
Antle, John, Capalbo, Susan and Crissman, Charles:
Economic, Environmental, and Health Tradeoffs in Agriculture: Pesticides and the Sustainability of Andean Potato Production

ECONOMICS OF WATER RESOURCES: From Regulation to Privatization

Second Edition

by

Nicolas Spulber and Asghar Sabbaghi

Springer Science+Business Media, LLC

Library of Congress Cataloging-in-Publication Data
Spulber, Nicolas.
Economics of water resources: from regulation to privatization / by Nicolas Spulber and Asghar Sabbaghi. -- 2nd ed.
p. cm. -- (Natural resource management and policy)
Includes bibliographical references and index.
ISBN 978-94-010-6039-4 ISBN 978-94-011-4866-5 (eBook)
DOI 10.1007/978-94-011-4866-5
1. Water resources development. 2. Water resources development--Econometric models. 3. Water resources development--Government policy. 4. Water quality management. I. Sabbaghi, Asghar, 1949- . II. Title. III. Series.
HD1691.S72 1997
333.91--dc21 97-42782
CIP

Originally published by Kluwer Academic Publishers in 1998
Softcover reprint of the hardcover 2st edition 1998

Printed on acid-free paper.

For Pauline and Manijheh

Table of Contents

List of Figures

List of Tables

There is a time when men most need winds;
There is a time for waters from the sky,
for raindrops, daughters of the cloud...

If water is the best of things...

Pindar
(*Olympian Odes* XI and XIII translated by W. Barnstone)

Preface

The appearance of this Second Edition has been encouraged by the favorable reception of the first. This has offered us the opportunity to update the materials and to expand the exposition of our central theses concerning (1) the integration of water quantity-quality issues and the treatment of water as a multi-product commodity, with the market playing a major role in determining water quality-discriminant pricing; (2) the drawbacks of public controls, regulation and enforcement, and the need to expand privatization of water supply and of water and wastewater treatment facilities to ensure their appropriate development and modernization through increased reliance on private capital; (3) the unification and centralization of water management on the river basin level in order to handle effectively the expanding pressures for water availability, for the elimination of waterborne disease, for extensive and effective pollution abatement as well as coping with the related issues of soil erosion, siltation in streams, channels, and reservoirs, protection against distress from drought and floods, and with the myriad problems relating to the environment, recreation, and navigation.

We have maintained the division of the book into four major parts and 12 chapters. In Part I we present the conceptual framework within which we examine the elements interacting in the management of water resources, indicate why the role of the market is now limited with respect to the quantity-quality price of water, and point to the mechanisms which can pull competitive water price and quality-graded quantity of water in line with their equilibrium levels. In Part II we discuss the questions of water quality control, the nature and impact of pollution, and water recycling and reuse, and analyze existing policy instruments with regard to standards, permits, and the regulation of withdrawals and effluents. In Part III we point to the deficiencies of engineering solutions in the choice of public expenditures needed for the construction, expansion, and upgrading of water and wastewater systems; we consider in detail the role of privatization as well as the centralization of management on the river basin level, and we outline the relationships between the price of water services, social equity, and allocative efficiency. In Part IV we draw attention to the limits of regulation and stress the need for coordinating all water supply programs, projected demand, recycling and reuse, and all measures directed to quality control.

Heretofore, the issues of water quantity, water supply, and water pricing, together with the question of the most appropriate public policy for the allocation of this supply to users, have not usually been tackled in a truly *market determined framework*. Even in the United States, where government organizations supply the enormous water needs of approximately half of all agricultural acreage in the West, the prices charged by public agencies, have historically been nominal and unrelated to either the cost of supply or the values derived. Milliman (1963), Warford (1966), and Hanke and Davis (1973), have correctly pointed out that the prices charged for domestic water supply or sewage disposal are seldom arrived at through a market-type interaction between supplies and users of such services. The reasons for this situation are, as indicated by Bower et al. (1984), (1) that the services of natural watercourses, such as the removal and dilution of wastewater, are not privately owned; (2) that the services with which these waste removal operations compete (such as the provision of recreational opportunities) are usually considered common property; (3) that the users have not treated water as an economic commodity, the market has not been used as a means of solving the scarcity problem, and thus the level of water supply and water prices have often been made by administrative decision.

In the specialized literature of the field, the term *water markets* refers mainly if not exclusively to permanent or temporary water *transfers*—interstate, interregional, interbasin and sub-basins, and intersectoral—or to agricultural-to-urban transfers (Anderson & Hill et al. 1997). Thompson (1997) has examined traditional water management approaches such as the public resource paradigm, implying active governmental involvement in the development, operation, and subsidization of water supply projects; and a local resource paradigm focusing on local preferences in water use and discouraging water transfers between watersheds. He highlights some of the implications of traditional approaches acting in direct opposition to water markets. Since market prices for water are seldom available or observable, other authors (Young 1996) suggest that what is needed as an alternative to water related investments and allocation decisions are shadow or accounting prices reflecting economic benefits and value. As Grigg (1996) notes, while much attention has been given to water supply utilities with well-developed models for setting rates and user charges, procedures for wastewater are not as well established, and they have been driven by the EPA's requirements relating to federal grants. According to Boland (1993), objectives such as economic efficiency, fairness, equity, revenue, sufficiency, net revenue stability, and simplicity and understandability, have to drive the water pricing efforts. He argues that the tariff should avoid rate shock, provide for smooth transition for easy implementation, and support good bond ratings. The present work takes a broader, integrated approach to the problems of water resources, tying (1) quantities of water supply of different qualities to (2) quantities of water demand with the use of free market mechanisms in allocating water and controlling water pollution. We assume that water is processed and supplied as a multiproduct commodity similar to petroleum, and that it is traded in the market where potential buyers and sellers are attracted by economic gains or utility in any transaction and transfer of it. As with various types of car fuel, various types of water, each graded according to quality level and cost, are produced and transferred by various profit-maximizing firms. Any firm is assumed to seek out various natural sources of water, such as streams, lakes, estuaries, and groundwater, as well as reusable water; each source can be categorized by its quality level, by the treatment and distribution processes appropriate to it, by its capacity limitations, and by the cost of producing and distributing its contents. We consider various customers as demanding various types of water, each characterized according to quality level, price, and suitability for specific purposes such as drinking, bathing, recreation, industry, agriculture, and others; each water type thus requires an appropriate quality level and specific treatment. Supplying firms and customers are assumed to search for complete information about market forces and to make economic decisions in pursuit of their own self-interest and well-being in a competitive market. Therefore, when a change in demand for water of any given quality level stimulates a change in marginal values of that water, mutually beneficial reallocations will occur. We also use market efficiency assumptions in analyzing demand behavior of various customers, in the sense that quality-graded water will transfer from lower-valued to higher-valued uses when differences in water values at the margin are large enough to economically justify a market transaction. We assume, particularly, that transactions and transfers of quality-graded water, motivated by economic gains and well-being and as the result of competition, occur not only between agents from different sectors (e.g., from agriculture to industry, municipalities, etc.) *but also between customers within all these sectors.*

The question of the *supply of water* in usable quantities and quality is part and parcel of the broad problem of management of all natural water resources, from the food chain to wildlife propagation and outdoor recreation. We pay close attention to notable contributions made in the literature concerning water sources such as rivers, lakes, groundwater, etc.; to the factors affecting supply, such as planning (including water production costs), water availability and pricing systems; and to other factors as well, focused on locations of sources, distribution systems, and administrative organization. Nakashima et al. (1986), for instance, have developed a two-stage optimization model for a regional water system consisting of water production and water transmission facilities. In this model, water allocation and transmission are defined as planning decisions regarding (1) the amounts of water to be allocated from each potential source to each demand center (community), and (2) how the water should be transmitted. Other studies have focused on ways of augmenting the volume of streamflow during a drought (Goodman et al. 1978). Gupta and Goodman (1985) examined a hydrodynamic groundwater model integrated into a multilevel management model and used it to formulate a composite model for investigating groundwater reservoir operation for drought management. Other studies (Aguado et al. 1977, Alley et al. 1976, Willis & Newman 1977, Molz & Bell 1977, Aguado & Remson 1980, and Remson & Gorelick 1980) have combined simulation models of a particular groundwater system with an optimization model employing the so-called "embedding technique." They have tried to analyze management plans for various types of groundwater problems, such as draining an excavation site, disposing of wastewaters, exploring an aquifer, and controlling hydraulic gradients. Willis and Liu (1984) and Dauer et al. (1985) have used multi-objective programming techniques to develop tradeoff curves for optimal groundwater management in single aquifer systems. The embedding technique has been extended by Yazicigil and Rasheeduddin (1987) to determine optimal groundwater management schemes in a multi-aquifer system under both transient and steady-state conditions.

Valuable papers have focused on the challenges posed by a new water supply and the need to evaluate various sites for proposed reservoirs, treatment plants, pipelines and distribution systems, considered from the standpoint of the overall system. Models have been constructed for optimal scheduling and sequencing water supply projects: dynamic programming for solving multiobjective functions in water resource development, planning models for coordinating regional water resource supply and demand, and so on. Optimizing water distribution systems has also been studied, notably by Walski et al. (1987), Orr et al. (1990), and Gulter (1992). Yet such optimization models, reported in civil engineering literature, have not been used by practitioners (Karamouz et al. 1992).

A number of papers have examined the question of optimum capacity expansion interval for water supply or sewage treatment plants (Manne 1961 and 1967, Scarato 1969, Berthouex & Polkowski 1970, Lauria et al. 1977). Several studies have addressed the potential for most water supply authorities to exercise joint supply-demand management through integrated pricing and capacity expansion programs (Hirschleifer et al. 1960, Gysi & Loucks 1971, Riordan 1971a and 1971b). A general programming model was developed by Dandy et al. (1984) aimed at identifying optimum water pricing and capacity expansion policies for water supply subject to the presence of administrative constraints on price. The model includes constraints on the maximum acceptable change in price from one year to the next, as well as financial constraints on acceptable levels of cost recovery.

Other studies have advocated *regionalization* to ameliorate problems in industrial water supply (McPherson 1970, Metropolitan Water 1971, National Water Commission 1973, Koelzer & Bigler 1975, American Water Works 1980, Gilbert 1983, McGarry 1983, and Miller 1987). Examples of appropriate new management or contractual administrative arrangements include (a) a complex urban water system that might be operated more effectively under a single management structure, or (b) an urban complex of independently owned or operated water systems that could have a master coordination plan, as well as remotely located rural or suburban water systems that could obtain economies of scale under a single management structure. As Clark (1979, 1983) points out, regionalization offers economies of scale both in the construction of capital facilities and in operational costs. Grigg (1989), however, considers the complex cost structure of water supply systems as a barrier to regionalization. As Grigg and others have noted, upward pressures on water supply rates are caused by safe drinking water rules, difficulty in finding new supplies, and the need for repair, replacement, and rehabilitation of facilities (Mellendorf 1983, Humphrey, 1985, Grigg 1985, Phillips 1985). Furthermore, according to Grigg, the unique local investment and operating history of each water system causes a wide variation in rates. As a result, and in the absence of much rate regulation, water cost factors are not widely publicized. Disparate cost accounting methods are another barrier to successful regional cooperation. In presenting methods to classify water utility costs, Clark (1983) identifies utility functions as acquisition, treatment, delivery, and support services, and suggests cost categories of labor, power, chemicals, materials, and miscellaneous. Due to the cost and rigidity of accounting systems, such analytical cost assignment methods are not in widespread use by management. However, Clark states that standardized accounting procedures based on product and responsibility accounting are needed. Because of problems in finding new supplies and meeting quality standards, compounded by excessive reliance on traditional technology, water supply will be subject to cost increases without any concomitant improvement in services. Citing examples of successful integration, cooperation, and development toward regionalization, Grigg (1989) notes that regionalization should be considered on a case-by-case basis as a potential solution to some of these problems.

Careful attention also must be devoted to the complex issues concerning water uses, to the models proposed in this connection and to the definitions of the determinants of *water demand*. Serious attempts have been made to include considerations of residual generation in these studies. To start with, municipal water demands in different categories, including the residential, industrial, commercial, transportation, and public services sectors, have been examined extensively. Residential water demands have been the subject of considerable statistical modeling, displaying the expected inverse relationship between the amount of water produced and the price charged per unit of water (Hanke 1978). Due to the rapid growth of the urban population in many developed as well as less developed countries, which strongly impacts water requirements, a vast number of models have been proposed for tackling the question of water demand planning. Notable among these are the model proposed by Samuels and Kerr (1980), using three predictors (income, population, and water use) and three sectors (domestic, industrial, and public). Other modelers, such as Lauria and Chiang (1975), have formulated a predictive model solely for municipal use, based on the following variables: population, average annual per capita income, and annual rainfall. Still other studies have devised water quality management models, including multiperiod design of regional or municipal wastewater systems; cost allocation methods to induce effluent dischargers to participate in regional water systems; models to predict the quality of effluent (in particular, whether it meets certain established standards); models for finding optimal waste removal policies at each polluting source, and so on.

Both industry-level and plant-level water demand models have been developed, notably for electricity generation, petroleum refining, and the manufacturing of important chemical products (Thompson et al. 1976, 1977, 1978). Plant-level models of paper mills have been proposed by Sawyer et al. (1976) and Noukka (1978). Stone and Whittington (1984) have used a mixed-integer programming approach to model industrial water demands for a hypothetical coal-fired power plant. The water demands generated by new projects in energy resources such as oil, shale, and synthetic fuels (all highly intensive water users) have been considered notably by Hampton and Ryan (1980) in a comprehensive nationwide assessment of water needs for energy development for 1985-2000. They have calculated energy-balance for several different types of water resource projects. Buras (1979) has attempted to show the feasibility of integrating data on water resource availability and water consumption into energy-economy models. Brill et al. (1977) have studied the potential interaction of water system use and coal reserves exploitation in the Ohio River Basin, demonstrating the impact that the development of a sizeable energy industry could have on the allocation of water resources in this large basin.

The modeling of *agricultural demand* for water has also attracted the attention of many researchers. Methods of estimating water use in agricultural unit processes range from assuming simple water use coefficients (amount of water per hectare or per animal) to more sophisticated analyses based on climatological, soil, and crop growth data. Considerable efforts have been made to develop linear programming (LP) models for agricultural activities at the national, regional, and farm levels. These models simultaneously consider (1) exogenous variables affecting food requirements; (2) government programs to control supply and increase food exports; (3) technological advances; and (4) the pricing of water through public investment in irrigation development. Heady et al. (1972), for instance, developed an interregional LP model of U.S. agriculture (applying the engineering/programming approach) that yielded the least-cost distribution of agricultural production by crop type and geographic region, under assumptions regarding resource availability and their costs (including the price of water), farm support programs, and consumer and export demand for agricultural products. A number of other mathematical programming models include some of nonlinear, dynamic, and stochastic aspects of irrigation systems (Windsor & Chow 1971, Asopa et al. 1973, Dudley et al. 1972, Ahmed & Van Bevel 1976 and Palmer-Jones 1977), and these models have been concerned primarily with how the depth and timing of irrigation is scheduled in response to changing weather conditions. Gouevsky and Maidment (1980), have employed an LP model providing detailed information about water demand and its impact on agricultural production in a region.

The water quality issue and the effects of *environmental pollution* also have been extensively studied in a number of significant works. The presence of externality problems lead to a misallocation of productive resources and introduces non-convexities into the consumer indifference surface and production functions (Starrett 1972, Baumol 1972), which can cause economic inefficiencies. To correct these inefficiencies, a role for legal institutions or for public regulation, maintaining market efficiency in defining property rights or mitigating transaction costs, may be suggested. In this context, various modifications of competitive systems have been proposed. One scheme pioneered by Meade (1952) would set up a system of artificial markets for externalities, while the other, first suggested by Pigou (1932), would impose a system of taxes on polluters or subsidies on pollutees. However, as Starrett (1972) mentions, the first system suffers from a thinness of markets (typically there will be only one buyer and one seller of an externality), while the second requires information which the market alone does not provide. Neither would work without some administrative planning. Hardin (1968) argues that one solution to the problem is to increase *private ownership of resources*, since "private property is superior to common in a crowded world." He concludes that the commons may only be effectively protected by an exercise of the authority to reduce the numbers exploiting the commons to a few, effectively internalizing the externalities. Demsetz (1967) suggests that property rights arise when it becomes economic for those affected by externalities to internalize benefits and costs. In order to internalize these externalities in mixed-market economies, he advocates the creation of regional water authorities, covering whole river basin systems, which would be responsible for all sewage works and water users within a region.

According to Aranson (1982), the best public policy toward environmental quality is one that creates clear, unambiguous and alienable property rights which are susceptible to judicial protection. However, it would be quite misleading to assume that an assignment of rights is a simple procedure that can be costlessly achieved and, once completed, also solves the question of externalities. As D. Spulber (1985) notes, the contention that an assignment of property rights makes government intervention unnecessary is ill-founded. The assignment of rights is in itself a formidable and costly enterprise, which might require administrative allocation. It can, however, produce very positive results, often in combination with other administrative instruments such as fees. Assuming a competitive case with small polluters, Spulber shows that effluent charges and tradeable effluent permits lead to long-run optimality with the entry of small firms. On the other hand, he argues, direct intervention through output taxes or output controls, entry tariffs, restrictions, or effluent constraints creates further distortions in the allocation of resources.

In another study, D. Spulber (1989) has examined the potential role of *government regulation in an economic context* and in correcting market failure. He argues that regulation can enhance economic efficiency by further increasing the use of market incentives. In general, incentive-based policy instruments, in his view, improve allocative efficiency when compared with emissions quotas, output or input controls, or technological standards. Air and water pollution thus can be controlled through marketable emission licenses that allocate permission to discharge pollutants to the highest-value users. In some areas such as toxic wastes, which entail a higher probability of health risks and administrative costs, a combination of taxes and standards may be desirable.

The critical issues of water *recycling and reuse* and water reuse costs and benefits have been examined extensively in the abundant water pollution literature. Here, we emphasize the need to analyze water reuse within the context of an integrated system of treatment, management and distribution of water, so that either treated effluent or potable water can be furnished to nonpotable users. Studying the issue within the framework of cost-benefit analysis, Sabbaghi (1984) has shown that the reuse of water, combined with a multi-distribution system, can enable, in particular, a river basin authority to satisfy demands for water in a variety of economic sectors, using appropriate treatment processes to provide water qualities which satisfy the requirements of public health and public acceptance. With regard to water quality management, pioneering work on quantifying the capacity of rivers to assimilate waste began on the Ohio River early in the 1920s. But the first national legislative effort dealing with the problem of water quality management dates from 1948, with the adoption of the Federal Water Pollution Control Act (FWPCA). According to FWPCA, the *states* were to be primarily responsible for controlling water pollution. The Federal Water Pollution Control Act amendments passed in 1972 (PL-500), which became the basis of the 1977 Clean Water Act (CWA, PL-500), made a commitment to a *federally* focused and funded water program and shifted the primary responsibility away from state and local entities. The CWA-mandated water pollution control for both municipal and industrial point-source dischargers, initiated a federal program for nonpoint source water pollution control, and required control of toxic pollutants. The 1987 Water Quality Act amendments to the CWA reversed the 1977 orientation, and again returned control of water pollution to the states. Conceptually, the current regulatory framework rests on a two-fold foundation. The original foundation was established in the form of water quality standards set by the states for each segment of public water. The emphasis of the 1948 act was to identify water bodies degraded by pollution, determine sources of pollution, and to impose sufficient controls on those sources to reduce contaminant loading and meet water quality standards. With the enactment of the 1972 federal statute, the emphasis shifted from water quality standards to a direct imposition of uniform technology standards on all industrial and municipal dischargers. The statute required compliance with the best practicable technology by all industrial dischargers by 1977 and compliance with more stringent standards by 1983 (later changed to 1984). This effort was reinforced through a major federal grant program providing 75 percent of project costs for approved publicly owned treatment works. These requirements were implemented via a permit program, which sets limitations on discharges and other requirements for each significant discharger.

In practice, while the regulatory framework has functioned forcefully in imposing tight controls on major industrial sources of pollution by requiring the installation of treatment systems for those waste streams, there has been less success in the construction and operation of municipal sewage treatment plants, mainly due to extensive delays in federal funding to support the costs. In order to examine the externality problem caused by water pollution from an economic perspective, various optimization models have been designed, aimed at finding efficient (least-cost) ways of meeting an exogenously given water quality standard. Ever since Streeter and Phelps first presented their well-known formulation in 1925 for predicting dissolved oxygen levels of rivers, *water quality models* in one form or another have often been used in the management of water resources.

Numerous studies have been devoted to analyzing the difficult problems posed by overall management centralization on the river basin level, not only for the situation in the United States but also for those in England, Wales, and France, all of which present interesting variations of the issues involved. To improve predictive capabilities concerning the management of river basins, Graves et al. (1969), Haimes (1971), Hass (1972), Hwang et al. (1973), and Herzog (1976) have used both linear and nonlinear programming techniques. These approaches have proven useful in various ways: they helped researchers to better understand the interactions between the various parts of a system, and they have also allowed estimates of alternative costs of various levels of water quality and of tradeoffs between the variables of the system. However, most of these studies are deterministic and disregard the stochastic nature of a river system. River flows and related parameters also have been assumed constant. In an attempt to overcome these limitations, some studies, such as those of Dysart and Hines (1970) and Hwang et al. (1973), have used a dynamic programming approach, while others, such as that of Davis (1968), have used heuristic approaches (e.g., simulations). The amorphous structure of these models, however, tends to obscure some basic economic interrelationships, and they do not yield insights comparable to those gained from the application of mathematical programming which explicitly incorporates such elements as shadow prices and coefficients of substitution.

Further, it should be noted that water pollution presents additional analytic problems, since discharged effluent affects other agents indirectly through their intake of water. Thus, while most externality models assume that each individual's intake of a pollutant is specified exogenously and remains beyond the individual's control, we recognize that the amount of pollutants within the water supply which are absorbed by an individual consumer or firm will depend upon that individual's intake of water. In addition, changes in the total *in situ* water supply will affect effluent concentration levels, which will indirectly cause external effects upon water users. Thus, individual water withdrawals and enhancement of the water supply by the decision maker will affect the impact of effluent levels upon consumers and firms using the water.

Several policy instruments are analyzed herein within a model of effluent regulation which allows for input substitution by individual firms. We show that effluent charges result in socially optimal entry and firm-scale levels, as well as in the provision of incentives for firms to select the correct input mix. The effluent tax takes average as well as marginal damages into careful consideration. We show further that at free entry market equilibrium, whether the firm subject to an effluent tax will operate above or below the private minimum-efficient scale depends upon whether average external costs exceed or are less than marginal external costs.

After identifying several programs directed at improving water supply and water quality, we examine the interrelationships between water program goals and their administration, along with legislative mechanisms of implementation. Federal as well as state policy instruments, choices and methods of financing water and land resources related to these programs, and, in particular, means of sharing costs and of centralizing recovery of federal disbursements are studied in detail, and the interrelation between programs, priorities, monitoring, and coordination efforts are analyzed with care.

This book is designed for all students of environmental problems, as well as for professionals involved in water resources allocation and in pollution abatement programs at both planning and management levels. It can be used in graduate courses in water resource management, environment management, economics of natural resources and planning, as well as a basic reference work on water resources and on the management of natural resources in general.

The research on which this work is based has been funded by a number of generous grants from Indiana University's Bloomington and South Bend campuses (IUB and IUSB). We are deeply indebted to Professor George Walker, Vice President for Research and Dean of the University Graduate School (IUB) who responded generously to our research requests. We acknowledge gratefully the continuous support received at IUSB particulary from Professor John Swanda, Dean of the Division of Business and Economics.

We also appreciate the help of a number of our colleagues and their kind advice and valuable suggestions for improving the manuscript. We are particularly grateful to Professor Robert A. Becker of the IUB Economics Department, for his valuable remarks concerning a number of significant developments in the text.

Our thanks go also to Vicki Mikulak at IUSB who typed the many versions of the manuscript with patience, diligence and professionalism; to Peg Hausman for competent and precise editorial work on the final version, and to Suzanne Hull and Eric Hartke of the Graphics Department, Instructional Systems Support [Audio Visual Center] (IUB), who produced the graphs included in the text with great ability and understanding. We wish also to thank for their help the Graduate Research Library and the Business/SPEA Library at Bloomington, and the Interlibrary Loan Department at IUSB for their timely processing of our requests for references and periodicals.

Any remaining errors are only ours.

The Authors