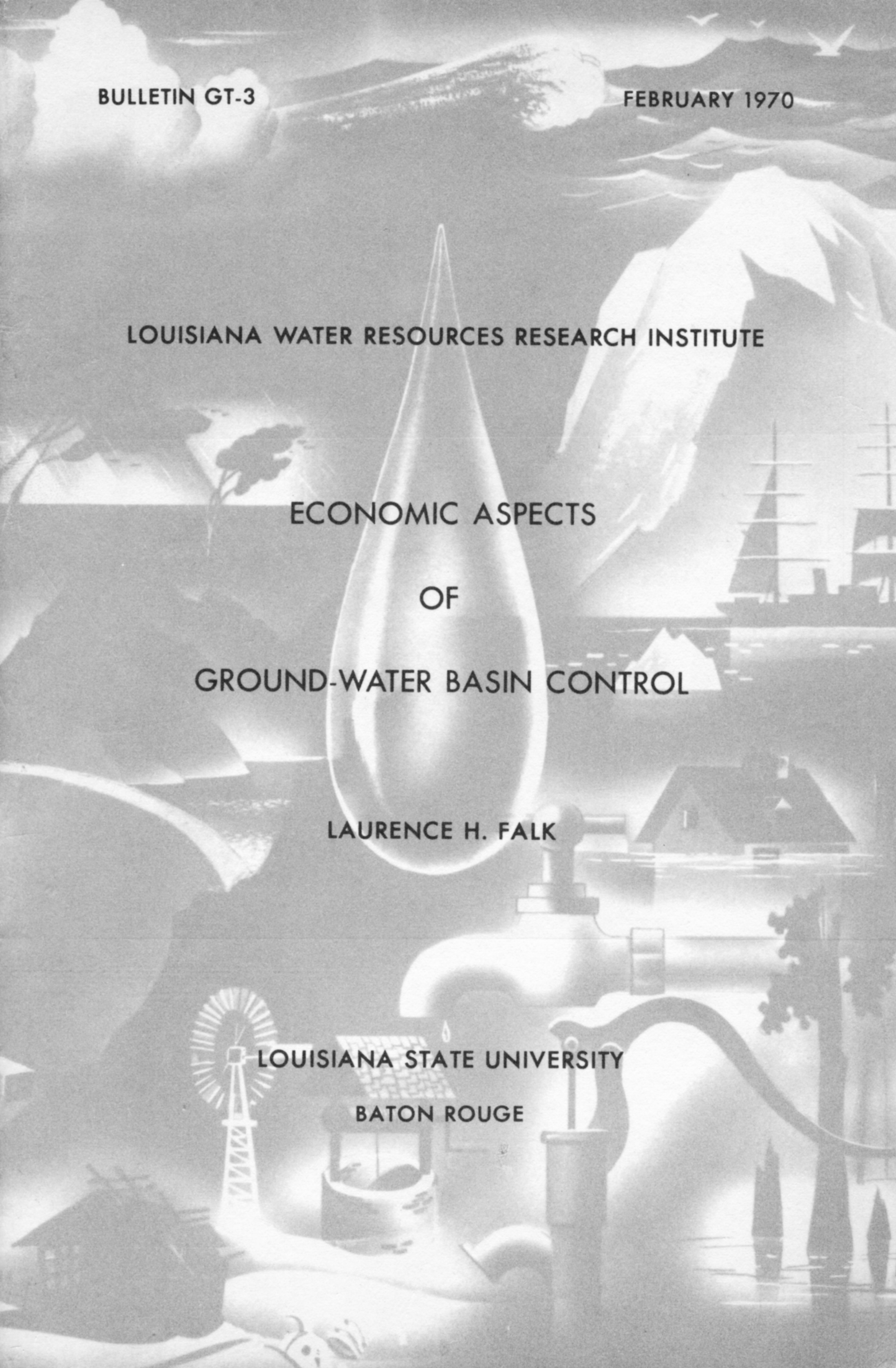

BULLETIN GT-3 FEBRUARY 1970

LOUISIANA WATER RESOURCES RESEARCH INSTITUTE

ECONOMIC ASPECTS OF GROUND-WATER BASIN CONTROL

LAURENCE H. FALK

LOUISIANA STATE UNIVERSITY
BATON ROUGE

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ACKNOWLEDGEMENTS

I am very grateful for the assistance and encouragement given me by many people at different stages of this work. Sincere thanks are due the members of my committee; Professors W. J. Stober, J. P. Payne, R. F. Smith, W. F. Campbell, and P. F. Boyer, for their constructive criticism. In particular, Professor W. J. Stober, who patiently directed the research and gave very generously of his time and ideas during the preparation of the manuscript, deserves an extra measure of gratitude. Any errors or opinions are mine, of course.

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Finally, the assistance, encouragement, and sacrifices of my wife, Sylvia, should be noted with the greatest measure of gratitude and affection.

Laurence H. Falk

EDITORIAL NOTE

This publication is the third of a series that will, it is hoped, increase the readership of selected graduate-level papers concerning water resources. In this broad field, problems involving humanity (its present or future welfare) spring up to confuse--and mistakes, to snare--planners, designers, and constructors. Consequently, the papers chosen to be published will be those that stimulate thinking, warn of danger, criticize accepted theories, and evaluate real problems.

Larry Falk, who now works at Rutgers University, originally submitted this economic study to Louisiana State University as his doctoral dissertation. Financial support for the study came from matching-funds grants (Project Nos. B-001-LA, B-003-LA, and B-005-LA) provided by the Federal Office of Water Resources Research and the East Baton Rouge City-Parish government under Public Law 88-379.

After service in the U. S. Army, Larry studied for his B.S. in Business Administration (Economics Major) at the University of Denver. From 1952 to 1963, he worked in industry, spending eight years of this period as an analyst in the crude oil purchasing department of a major oil firm. He gained further experience with the Public Affairs Research Council in Baton Rouge for two years before starting his doctoral studies at LSU in 1965.

Very minor changes in the text and illustrations have been made. The ideas and style are those of the author; they do not necessarily reflect any official point of view adopted by Louisiana State University.

Charles W. Hill
Research Associate

AUTHOR'S ABSTRACT

In recent years economists have been giving increasing attention to the problems associated with water resource development. Quite logically, most of the studies have been done on projects involving very large expenditures, such as flood control, navigation improvement, irrigation, and hydro-electricity. Usually these projects involved federal funds.

Expenditures for water resources at the local level have been largely neglected. When they have been examined, the viewpoint has not been that of the local community itself. Rather, the studies have taken the national view. Hence the decision rules that have been used for local projects are those developed to evaluate federal projects.

The major objective of the research reported here was the devising of an economic model for use in deciding among alternative local ground-water basin projects <u>from the point of view of the local community itself</u>. A subsidiary goal was the examining of the effect on national welfare of local use of the decision-making model.

The economic model incorporates benefit-cost analysis. The relevant cost of any local water project is the present-value unit cost obtained by discounting the costs incurred over time by the community's cost of capital. Benefits are measured by the costs avoided by undertaking the project; thus, if the alternative to the project is inaction, the benefits are the costs of inaction.

As an alternative to a community project, private water-using companies may undertake projects to secure their own water supplies. Then the benefit used in evaluating the community project should be the present-value unit cost of the corporate project (determined by discounting costs incurred over time by the corporate cost of capital).

The results of a hypothetical comparison between a corporate project and a non-profit community project show that, with constant returns to scale and equal costs of capital, the present-value unit cost of water is less for the corporate project than for the community project. The benefit-cost ratio will favor the community project, however, because the after-tax cost for a corporation purchasing water from the non-profit project is lower than the present value unit cost of the corporate project. Therefore, it is advantageous for the community to undertake the non-profit project. This conclusion very unlikely will be nullified by either differences in costs of capital or diseconomies of scale.

The community decision-making model will be found to be nonoptimal from the national welfare viewpoint, in most cases. This is largely a result of the corporate income tax structure. Changes in the tax laws would be needed in order to correct the resultant misallocations.

A case study of the conjunctive use of ground and imported water in Los Angeles County, California, reveals several economically inefficient practices. Ad valorem taxes are used to finance ground-water variable costs. Thus, for all practical purposes, they are transformed into fixed costs--even in long-run production. Thus, the ground-water supplies are misallocated. Simultaneously, some water users are using imported water, which costs them more than the unit ground-water cost. This is a further violation of the conditions for economic efficiency. The cost differentials persist because the market in ground-water rights is imperfect.

It is concluded that economic efficiency could be improved in the case-study area by the elimination of certain ad valorem taxes and the inclusion of the costs they now cover in user charges, and by the elimination of adjudicated water rights. Instead, anyone would be allowed to pump any desired quantity of water. Pumping charges would be assessed to bring the marginal cost of ground water up to the cost of the imported water substitute.

CONTENTS

FIGURES

TABLES

ECONOMIC ASPECTS OF GROUND-WATER BASIN CONTROL

DESCRIPTORS: *marginal costs, *capital costs, unit costs, cost comparisons, *conjunctive use, alternative costs, water rights, water management (applied), resource allocation, economic efficiency, prices, discriminatory pricing, water transfer, *assessments, tax rate, *discount rate, interest rate, *cost-benefit analysis, *benefit-cost ratio

ABSTRACT: Existing water laws allow the misallocation of water because it is not being put to its most valued uses. Water should be subject to unconditional ownership and purchased or sold at will as long as the price reflects its marginal social cost. The present-value unit cost of replacement water produced by a private project will be less than that produced by a non-profit community project because of the corporate income tax structure, if the cost of capital is the same and the returns to outlay are constant. However, owing mainly to unequal discount rates, a community project will be more favorable, according to the benefit-cost ratio between the cost of purchasing water from the community project and the cost of the community project. Differences between the community and the national social discount rates will generally give ambiguous comparisons of economic efficiency. In Los Angeles County, water resources are misallocated because ad valorem taxes partially finance variable production costs. In addition, the prices of water imported by the Metropolitan Water District have not reflected the marginal social costs. Efficiency could be restored by: use of pumping charges instead of ad valorem taxes; discontinuance of mandatory sales of surplus-water rights; institution of bidding for water rights; and setting of firm prices for imported water.

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CHAPTER I

INTRODUCTION

PURPOSE AND SCOPE

Although economists have devoted much attention to federal water resource projects, they have largely ignored investments at the state and local level. Whenever local projects have been analyzed, the procedure was much the same as that used for federal projects. Hirshleifer, DeHaven, and Milliman [1960] for example, in studying the problems of New York City and Los Angeles, used the approach that they recommend also for examining federal water projects. From the national standpoint, their analysis may shed much light on the welfare effects of local projects. It may also show up "poor" water investments at the local level. However, the model used to decide among alternatives did not reflect how the community itself might look at the problem.

The present study has the primary objective of developing an economic model for choosing among alternative groundwater basin control measures from the viewpoint of the investing community.

The secondary objective is the consideration of the effects on the national welfare when this local decision-making model is used. The factors that may cause local water projects to be selected which are not optimal for the nation are analyzed, but no policies are suggested to close the gap between local and national optimums.

A hypothetical numerical example then illustrates how a local community might use the model. Variations in the parameters that cannot be precisely determined show that ignorance of the exact values is not serious. Under normal conditions, the model will point unambiguously to the optimal decision for the local community.

In a case study, several uneconomical practices are noted in the financing of the Central and West Basin Water Replenishment District of Los Angeles, California in its systematizing of the conjunctive use of ground and surface water. Although corrective procedures are suggested, they are not intended to be recommended changes. Rather, the purpose of the case study is to demonstrate the importance of considering the economic effects of basin management.

SOURCES

The increasing store of water resources literature has neglected certain economic considerations that significantly affect local water supply decisions. A local community considering an increase in water supply must answer the question: Should private firms--including, perhaps, private water utilities--augment their own supplies, or should the community itself undertake the project? In answering this, the local governing authorities would have to consider three cost determinants that have received inadequate attention:

(1) Corporate income taxes
(2) Differences in community and corporate costs of capital
(3) Effects of economies or diseconomies of scale on project costs

The effect of corporate income taxes required searching in the areas of managerial economics, corporate finance, and taxation. Quite useful were the newer texts on capital budgeting and the standard reference works on taxation.

For the case study of the Central and West Basin Water Replenishment District (Los Angeles, Calif.), data was obtained from reports by the District, publications of the California Department of Water Resources, the Los Angeles County Taxpayer's Guide, and the Metropolitan Water District Annual Report for each fiscal year from 1938 through 1966.

Much background information was gathered during a field trip to Los Angeles in June, 1966, when several persons directly involved in the management of the county water supply were interviewed. Follow-up interviews were later made by telephone and again in person during a symposium on salt-water encroachment into aquifers at LSU.

For the discussion on ground-water law and as background material for making the local decision-making model and studying the Los Angeles system, a recently published handbook on water law [Hardy, 1966] and the bibliography developed by Leila O. Cutshaw during its writing were used extensively.

STUDY PLAN

After a brief, elementary treatment of basic hydrology in Chapter I, the allocation of existing water supplies is examined in Chapter II. The basic doctrines underlying water rights, particularly in their application to ground water, are discussed in relation to economic efficiency. Flat-rate water pricing is also briefly treated.

In Chapter III, a model for choosing among local water-supply alternatives is developed and applied with a numerical example. The results are discussed from a welfare standpoint. In this connection, divergent views on the social rate of discount are summarized.

Chapter IV is a case study of ground-water management in the Central and West Basin Water Replenishment District of Los Angeles County, California. Calculations of the average and marginal costs for imported water are made, and the arrangements for financing ground-water production are critically evaluated against these estimated average and marginal costs. This is followed by an analysis of pricing methods for imported water. After the conclusion is reached that existing pricing and financial arrangements have led to inefficient use of both ground and imported water, the criteria for efficient conjunctive use are then established.

Three major conclusions are drawn in the final chapter. First: existing water laws lead to misallocation of the nation's water resources. In most instances, an improvement would result from the establishment of firm, tradeable water rights. However, another approach is suggested for the study area due to uncertain future costs of imported water.

Second: although a community may undertake a locally optimal project, the result for the nation as a whole may be the misallocation of resources.

Third: the inefficient practices in Los Angeles County apparently result, at least in part, from existing water laws that reward premature appropriation of water.

GROUND-WATER HYDROLOGY

General

Ground-water hydrology, a relatively new science, developed slowly after modern geological principles had been formulated near the end of the eighteenth century. Although shallow wells have been in use for many centuries, early concepts of the origin of ground water were curious mixtures of superstition and faulty deduction. In recent years, the science of ground-water hydrology has advanced significantly, not only as the result of extensive hydrological data gathering, but from the explosion of knowledge in botany, chemistry, physics, meteorology, and other sciences [Jones, et al., 1963, pp. 11-19].

The occurrence of ground water can best be understood in the context of the hydrologic cycle--"the endless circulation of water from the primary reservoir, the ocean, to the atmosphere, the land, and back to the ocean over or beneath the land surface" [McGuiness, 1963, pp. 10-11]. Accordingly, a brief discussion of the hydrologic cycle is presented below.

Precipitation

Although the hydrologic cycle is a continuum, the usual description of it begins with the oceans, which constitute 71 percent of the earth's surface area. Water evaporates from the oceans into the atmosphere due to the heat of the sun. Normally the water vapor is invisible as it leaves the surface of the water, but under the proper conditions it forms visible clouds. When certain other conditions are satisfied, the moisture condenses and falls back to earth as precipitation--rain, hail, sleet or snow--collectively called "water of meteoric origin" [Johnson, Inc., 1966, P. 15].

About 30 inches of precipitation per year fall on the 48 conterminous states of the United States--an abundant meteoric water supply compared to that of other nations [McGuiness, 1963, p. 10]. However, because of the characteristics of the hydrologic cycle, the distribution is irregular in space as well as time.

Part of the water that evaporates from the oceans falls on land in response to one or more of three processes involving warm, moisture-laden air [Davis and DeWiest, 1966, pp. 17-18]:

(1) Cyclonic - the warm air mass, either stationary or in horizontal motion, encounters a cold-air mass.
(2) Convectional - an air mass, receiving heat and water vapor at the earth's surface, becomes cooled as it rises vertically.
(3) Orographic - a moving warm air mass is forced to ascend and lose heat when a landform barrier is in the way.

Meteoric water falls irregularly with respect to geographical location, although coastal areas generally receive more. Because in the northern hemisphere the prevailing winds are westerly, it is convenient to begin with the west coast in describing the general pattern of precipitation in the United States.

Evaporated water from the Pacific Ocean is carried by the westerlies to the coast, where high mountain ranges force the warm winds to rise and cool. As a result, part of the moisture contained in the air condenses and falls as some form of precipitation on the windward side. In the cooler northern coastal states, greater precipitation occurs. Some parts of Washington, in the Coast and Cascade Ranges, receive more than 100 inches annually. But, north or south, the precipitation varies directly with the height of the mountain barriers.

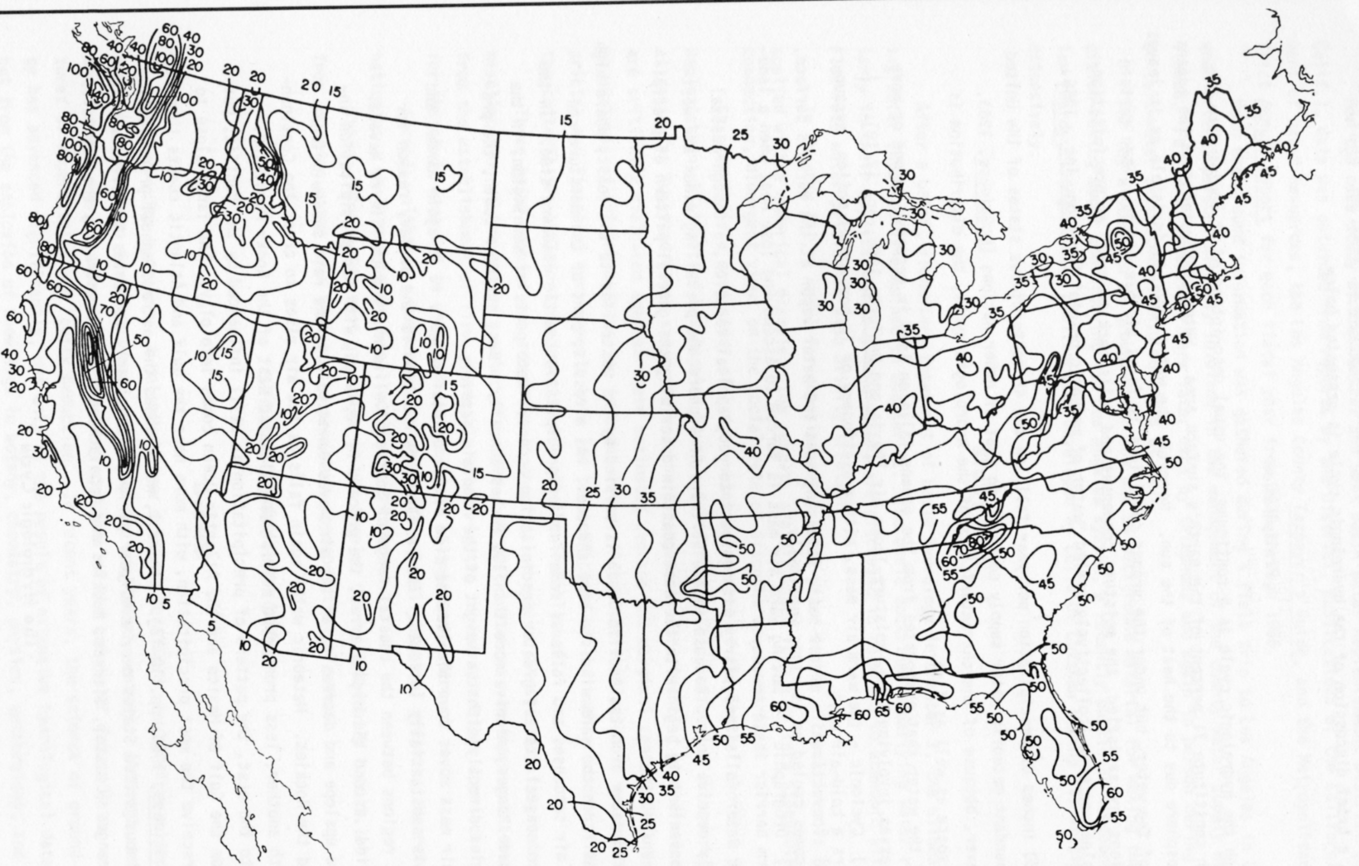
As the air mass moves down the leeward side of the coastal ranges, it is again warmed and precipitation is substantially lessened. The resultant rain shadow is the primary reason for arid or desert regions between the coastal range of Southern California and the Sierra Nevada.

As the winds ascend the high Sierras, the process is repeated, with the precipitation increasing on the upslope and decreasing as the air moves downward into the rain shadow between the Sierras and the Rockies. Meteoric water again falls as the air rises to cross the Continental Divide, with another, less pronounced rain shadow situated east of the Rocky Mountains.

Farther to the east, the pattern of precipitation is still influenced by the Pacific, but water vapor from the Gulf of Mexico and the Atlantic Ocean comes into play. The lands close to the warm Gulf receive the most precipitation, with more near the Gulf and Atlantic coasts than farther inland [McGuiness, 1963, pp. 10-12]. Figure 1, which shows the average annual precipitation in the conterminous United States over a 40-year period, also clearly indicates the affects of the high mountain ranges (Coastal, Sierras, Rockies and Appalachians) in concentrating the rainfall.

The Hydrologic Cycle

Of the 30-inch average depth of water that falls on the United States annually, the major portion--21 or 22 inches--is vaporized. The remainder appears as liquid water on or below the land surface [Kazmann, 1965, p. 4]. Some water not included in the average figure evaporates in



AVERAGE ANNUAL PRECIPITATION (INCHES) IN THE UNITED STATES 1899-1938

Source: Environmental Science Services Administration

FIG. 1

the air between the clouds and the land surface. The remaining evaporation losses are in two forms (evapotranspiration): direct evaporation from wet surfaces, and transpiration through plants from their leaves and stems. The precipitation adhering to trees and other vegetation (intercepted water) accounts for a large portion of the total evaporation [DeWiest, 1965, pp. 15, 37-50].

The 8 or 9 inches of water not returned to the atmosphere as vapor (except evaporation from surface channels) are called runoff. They constitute the nation's potentially available water supply, if converted sea water and water reclaimed through recent technological advances are ignored.

Although some of the runoff eventually collects in surface streams, the remainder percolates underground where permeable soil is present. The force of gravity moves ground water downward through alluvial deposits, porous rock, gravel, or sand. Ultimately, it may either reappear at the surface in artesian springs or seeps, or discharge below sea level into the oceans. The larger part of ground-water discharge reaches surface streams and keeps them flowing even during dry periods [McGuiness, 1963, pp. 10-16]. Streams and rivers, of course, flow downhill into the oceans, which receive over 90% of the total runoff. Figure 2 is a schematic drawing of the complete hydrologic cycle.

Ground Water

Ground water is increasing as an important supply source. Surprisingly, less than 3% of the world's available fresh water occurs in streams and lakes. Owing to large, expensive surface water projects, we tend to think of surface water as the largest potential source, but 97% of our water lies underground [Johnson, Inc., 1966, pp. 5-6].

Underground flow comprises an estimated 33 to 40% of the average total runoff. This average is greatly exceeded in certain areas [Hirshleifer, DeHaven, and Milliman, 1960, p. 19]. Not all the ground water is available currently at economical cost, however; hence 81 percent of present supplies are drawn from surface sources. Nevertheless, five states--Arkansas, Arizona, Mississippi, New Mexico and South Dakota--depend on ground water for over half their total water supplies. Eight others--California, Florida, Iowa, Kansas, Nebraska, Oklahoma, Texas and Vermont--use ground water for 25 to 50 percent of their supply. In another 13 states, ground water supplies 10 to 25 percent of total needs [Todd, 1959, pp. 6-8].

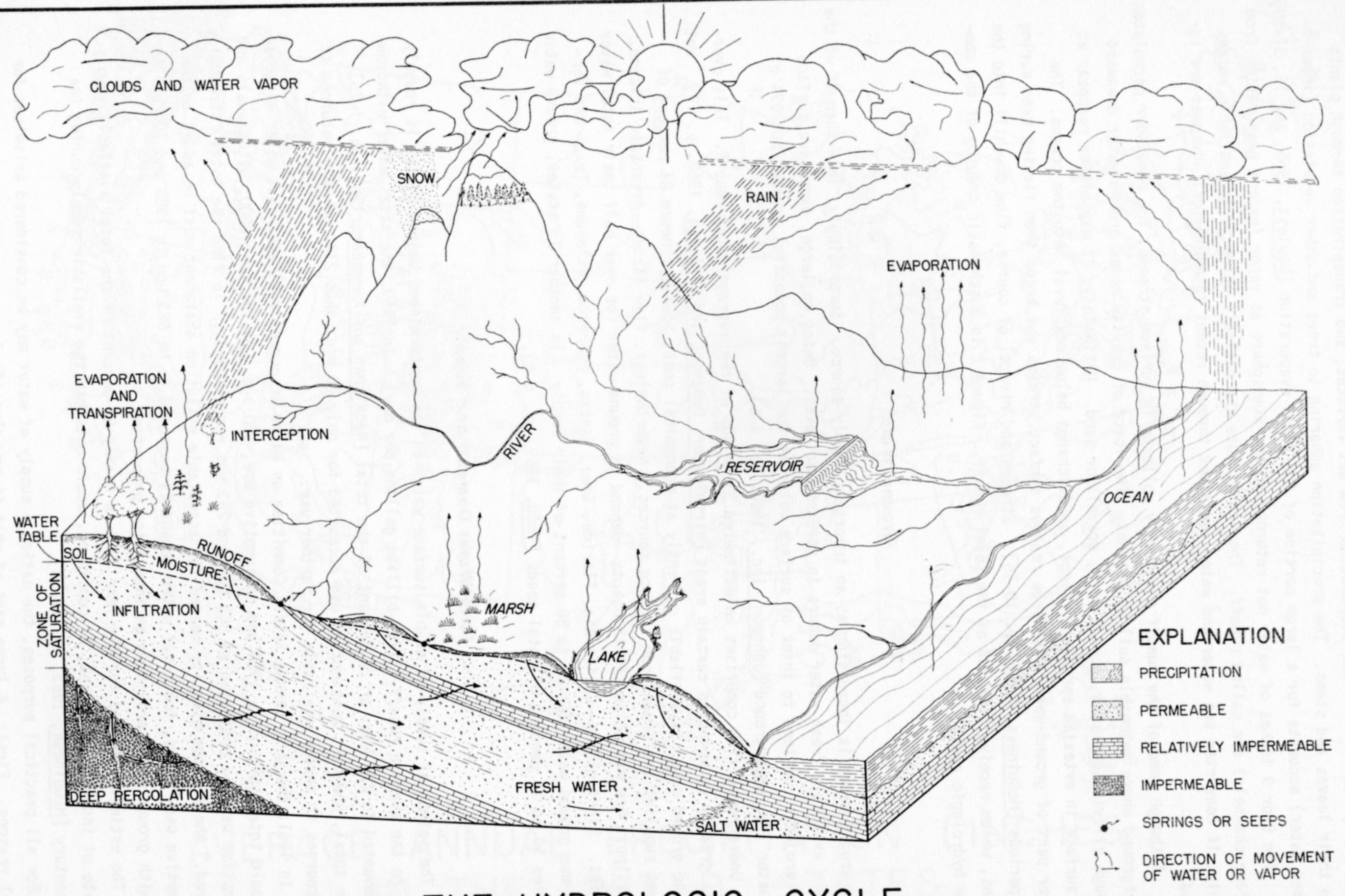
Total Water Demand and Supply

The potential supply of usable surface water in the conterminous United States is roughly equal to the average runoff (1,200 billion gallons per day). In 1960, the total water withdrawals amounted to 270 bdg, or 22 percent of the total [MacKichan and Kammerer, 1962, pp. 1-26]. Of the total, however, consumptive use accounted for only 60 bgd; thus 210 bgd were returned to watercourses to become available for further use.

In 1961, the U.S. Senate Select Committee on Water Resources estimated that water withdrawals would total 559 bgd in 1980 and consumptive use, 190 bgd. By the year 2000, withdrawals and consumptive use are projected at 888 bgd and 253 bgd respectively. To find the total "streamflow required," the minimum quantity needed for acceptable pollution abatement must be added to the consumptive use. Thus, the total water demand is expected to be 523 bgd in 1980 and 700 bgd in 2000 with ground water providing an increasing proportion.

The estimated demand for the year 2000 is nearly 60 percent of the total available supply. The rate of increase in demand, if continued, would outstrip the available supply during the next century [McGuiness, 1963, pp. 79-85].

For all practical purposes, the nation's supply of water may be considered unlimited for several reasons. First: A large part of what is now classified as consumptive use is "consumptive" only because the facilities do not exist for reclaiming the water. Sewage water can be



THE HYDROLOGIC CYCLE

FIG. 2

Used with permission of the Texas Water Commission treated and reused. Second: Evapotranspiration is now responsible for a significant amount of consumptive use. Water-loving plants (phreatophytes) grow along water courses or reservoirs. Control of such plants has already resulted in some reduced water loss. Further reductions can be effected by controlling evapotranspiration in agricultural irrigation with what is already known about the adaptation of crops to moisture constraints. Suppression of evaporation from reservoirs, by several methods of reducing water surface exposure, also holds promise. Third: Improved irrigation ocan reduce seepage and conveyance losses. Fourth: Weather modification may add considerably to usable water supplies at some future date. Finally: Methods have been developed for converting sea water to fresh water, although the present cost is still prohibitive in areas where alternative sources of water are available [Ackerman, 1965, pp. 450-67; McGuiness, 1963, pp. 93-100].

THE MYTH OF WATER SHORTAGE

It is frequently stated that the United States is suffering, or will suffer, from a severe water shortage unless immediate conservation measures are undertaken [Carhart, 1959, pp. 13-29]. In the preceding section, the opposite conclusion was drawn. To say that the supply of water is virtually unlimited leaves part of the story untold.

Additional supplies of water can be obtained only by developing increasingly large amounts of our resources. Conversion of sea water to fresh water, now technically feasible, could take care of man's water requirements forever. However, the unit cost of desalinized water, is at present many times more than that of water obtained from other sources. As of 1962, the desalting of seawater cost nearly $400 per acre-foot (considerably over one dollar per thousand gallons) [Linsley and Franzini, 1964, p. 440]. In contrast, the evaporation of fresh water can be prevented by spreading a one-molecule thick substance such as cetyl alcohol on the water surface at a cost of $40 per acre-foot--one-tenth the cost of desalinization [McGuiness, 1963, pp. 93-94]. Even this procedure costs more than normally produced water. In Chapter IV, for example, it is shown that the average total cost of Colorado River water, delivered through a 242-mile aqueduct and then softened and filtered, has been fully recovered by charging no more than $40 per acre-foot. And this source is probably among the most expensive in the United States today.

In summation, while one can say that there can be no "shortage" of water, water will become more costly as future demands increase. This nation can obtain all the additional water desired as long as we are willing and able to pay the high cost.

GLOSSARY

At this point it will help if some technical terms and measurement conversions are defined in preparation for the chapters that follow [Milne, 1968, pp. 143-44; Jones et al., 1963, pp. 33-35].

Acre-foot. The volume of water required to cover one acre to a depth of one foot.

Alluvium. Soil or earth material that has been deposited by running water or floods.

Aquifer. A body of earth material (strata, formation, or group of formations) that is porous, permeable, and water-bearing, and has hydraulic continuity.

Artesian (or Pressure) Aquifer. A confined aquifer in which the water is under sufficient pressure to cause it to rise above the zone of saturation at that place if the opportunity were afforded.

Fault. A fracture or fracture zone in the earth along which strata are displaced. The displacement may result in an aquifer being cut off from the water source.

Forebay Area. An area containing unconfined ground water (where hydraulic continuity with the ground surface generally exists) with a location that allows subsurface flow to a body of confined ground water.

Ground Water. Subsurface water that occurs in and moves through an aquifer in response to pressure.

Ground-Water Basin. A ground-water storage area; one or more connected aquifers that may be considered as one hydrologic unit.

Hydraulic Gradient. The imaginary line joining the heights to which water would rise in wells that are screened in a confined aquifer; the profile of the water table in an unconfined aquifer.

Hydrology. The applied science concerned with the waters of the earth's hydrologic cycle: precipitation, storage, infiltration, evaporation, runoff, and disposal.

Percolation. The movement of water under hydrostatic pressure through the pores of rock or soil.

Permeability. The ability of a material to transmit a fluid through its pores under given conditions.

Piezometric Surface. An imaginary surface that everywhere coincides with the static level of water in an unconfined aquifer. It is the surface to which the water in a confined or artesian aquifer would rise if afforded the opportunity to do so (sometimes used as a synonym for hydraulic gradient).

Pressure Area. A ground surface area underlain by a confined aquifer.

Transmissibility, Coefficient of. The amount of water in gallons per day which will pass through a one-foot wide vertical strip of the aquifer under a hydraulic gradient of 1.00 (100%).

Selected Water-Measurement Constants

Area:

1 acre = 43,560 sq. ft
1 sq mile = 640 acres.

Volume:

1 million gal = 3.0689 acre-ft.
1 thousand gal = 0.0030689 acre-ft.
1 acre-ft = 325,851 gal = 43,560 cu ft

Discharge:

1 acre-ft per day = 226.29 gal per min.
1 acre-ft per day = 0.32585 million gal per day
1 acre-ft per day = 0.050417 cubic ft per sec

Miscellaneous:

1 ft of water = 0.43344 lbs per sq in
To raise 1000 gal. of water 100 ft per second requires 0.314 kilowatt-hours.

CHAPTER II

ALLOCATION OF EXISTING SUPPLIES

WATER AS AN ECONOMIC GOOD

Water, an economic good or resource, exhibits the essential qualities of all other economic goods or resources. Water exists abundantly in nature. Nevertheless, it can be obtained for human use only through the application of varying amounts of scarce resources.

Like the production of other economic goods, water production must eventually obey the law of diminishing returns. For any given location and state of water-production technology, an increased water output is ultimately associated with increasing marginal and average costs. One locality may experience falling costs for production from one source, but in resorting to new sources, will encounter rising marginal and average costs in the long run [Hirshleifer, DeHaven, and Milliman, 1960, pp. 95-96]. Society can develop additional water supplies, if it desires, but only at higher unit costs. If scarce resources are diverted to produce additional water, society will gain only if it values the additional water more than the economic goods that are foregone as a result of the diversion.

Although the pointing out of the fact that water is like other economic goods may seem trivial, historically this has apparently never been clearly understood. Even economists themselves have not always recognized the close relationship between water and other goods. There is ample evidence that today's professionals who are charged with obtaining or allocating water supplies feel also that, somehow, water is "different."

The misunderstanding probably springs from two truths: (1) that water is abundant; and (2) that man cannot survive without water. These observations evidently prompted Adam Smith's distinguishing between "value in use" and "value in exchange" in his famous "diamond-water paradox" [Smith, 1776, p. 28]. Smith supposed diamonds to have market value, but no value in use; and water, to have a high value in use, but no value in the market place. That man cannot live wthout water has been largely responsible for laws which have placed water above other economic goods. For example: the U. S. Supreme Court's recognition that "water is a valuable resource and essential to life" underlies its acceptance of state regulation of water resources [Boerschinger, 1965, p. 128].

The objective of this chapter is threefold: first, to present a brief exposition of existing water laws, with emphasis on state laws pertaining to ground-water production; second, to discuss the conditions for optimum allocation of water resources and show that some of the present water laws generally violate these conditions and that the selling of water on a flat-rate basis also misallocates resources; third, to generate improvements in existing water laws and practices and draw conclusions that will have a bearing on the chapters to follow.

WATER LAW IN THE UNITED STATES

In general, water law in the United States falls into either of two classifications. The eastern states have traditionally adhered to the riparian doctrine of water law; the western states, the doctrine of appropriation. Because the two doctrines overlap, the discussion of the subject in this chapter is limited to brief generalizations about existing laws. Anomalies, which may be found in the laws of individual states, will be ignored except when they are considered to be of particular significance to this study. In particular, a number of western states have laws incorporating both riparian and appropriative rules [Kazmann, 1965, pp. 201-202].

The Riparian Doctrine

The common law riparian doctrine holds that the owner of land that borders a stream, river, or body of water is entitled to take water for use upon his land [Doyle, 1950, p. 405]. This right is inseparable from the title to the land itself [Davenport and Canales, 1956, p. 283] although, as it is also with an appropriative right, the riparian right is merely usufructuary as opposed to private ownership of the corpus of the water itself [Hirshleifer, DeHaven, and Milliman, 1960, p. 231].

Riparian water users along a stream are said to have coequal rights. The first user gains no priority over subsequent users and, in theory, may utilize the water bordering his land. However, he must return the water to the stream in view of the rights of downstream landowners. In the extreme, then, there would be no consumptive use of water. Water would be returned to its original course by all users until it flowed into the ocean.

The courts, long recognizing the great economic waste that results from such a position, have held that each riparian owner has a right to diminish the stream flow as long as the water consumed is put to "reasonable" use. In the event a use is contested, its "reasonableness" is passed upon by the courts. What is considered "reasonable" during periods of normal precipitation may be adjudged "unreasonble" during times of drought. Rights are not lost by non-use and reasonableness may be revaluated after a change in circumstances [Trelease, 1965, pp. 272-89].

States that hold to the riparian doctrine for surface waters extend it also to ground water. The legal principle of "reasonableness" is usually applied to any definite underground stream known to be a source or continuation of a surface watercourse. Percolating water (ground water that is not a part of a definite underground watercourse) is subject to three variations in the basic riparian doctrine. According to qualified hydrologists, such distinctions between ground and surface water are unscientific. Even less valid is the classification of ground water as underground streams or percolating water. Most usable water is meteoric (precipitated). It moves either on or under the surface in response to gravity or pressure to seek a static level [Foley, 1957, pp. 495-96].

Despite the divergence between the scientific and legal viewpoints, some states apply the English common law rule of absolute ownership. The owner of overlying land may use percolating waters in any manner that he deems best and need not consider the effect of his withdrawals on the water supplies of his neighbors.

A number of courts in the eastern United States have extended the principle of "reasonableness" to all ground-water production. A landowner whose water supply is adversely affected by the pumpage of a neighbor may seek remedy in the courts.

There exists, finally, a third subdoctrine, known as the "correlative rights rule," that developed in California and Utah. It requires not only reasonable use, but also equal or proportional rights in the common pool of ground water for all surface owners. Water rights are adjudicated under this rule. A pumper with records of large "reasonable" use receives a larger quota than one with records of less usage [Kirkwood, 1948, pp. 2-4].

The Doctrine of Appropriation

In contrast to riparian rights, the doctrine of appropriation presupposes that the right to use flowing water is apart from the title to adjacent lands [Davenport and Canales, 1956, p. 283]. It may be stated simply as"first in time, first in right." Water rights may be obtained by a person merely by diverting water to his use. The user need be neither riparian owner nor a landowner [Boerschinger, 1965, p. 110]. Prior appropriators have preference over later (junior) users.

In the humid and "water-logged" East, most economic demands for water can be satisfied by using the riparian rule [Hirshleifer, DeHaven, and Milliman, 1960, pp. 232-33]. In the arid western states, because it was only natural to divert water from its normal watercourses to non-riparian land, the appropriative system developed and still prevails.

The courts in "appropriative" states do not normally pass on the "reasonableness" of water use. Usually, all that is required is the beneficial (non-wasteful) use of appropriated water [Breitenstein, 1950, p. 346]. A usufructuary right of an absolute nature, granted to a senior appropriator, allows the consumption of water even at the expense of subsequently sought domestic uses [Gross, 1965, p. 265]. Except where statutes provide for regulation by an administrative agency, the use of appropriated water need not be "reasonable" in relation to the rights of others.

Water consumed under a senior appropriative right may be diverted to a beneficial use only through a procedure of condemnation and just compensation [Bell, 1965, pp. 382-85]. Senior appropriators are protected against junior appropriators; junior users are protected against increased usage by senior users. During droughts, however, the result is that junior appropriators may have their water supplies cut off completely because seniors continue to take up to their full quotas [Hirshleifer, DeHaven, and Milliman, 1960, p. 36].

Not all western states adhere exclusively to the doctrine of appropriation. Some states, California for example, use both doctrines. Of the 17 western states, only eight have explicitly repudiated the riparian rule. In these eight, the appropriative rule is applied to percolating ground water [Hirshleifer, DeHaven, and Milliman, 1960, p. 233].

RIPARIAN DOCTRINE REPUDIATED BY:	RIPARIAN DOCTRINE NOT REPUDIATED BY:
Arizona	California
Colorado	Kansas
Idaho	Nebraska
Montana	North Dakota
Nevada	Oklahoma
New Mexico	Oregon
Utah	South Dakota
Wyoming	Texas
	Washington

Interstate Regulation of Water

Interstate water rights have been established by either interstate agreements or federal regulations under the commerce clause of the Constitution. Most interstate compacts have been entered into only under the most urgent circumstances, because state legislatures are usually reluctant to surrender rights for a period of years.

In recent years the federal government has increased its control over interstate streams and their tributaries, although it was originally limited to streams that are navigable in fact. Federal control now includes any river even remotely susceptible of being navigable. [Forer, 1961, pp. 337-43].

Trends in Water Law

In 1957, the legislature of Iowa established a new water rights act, which decrees that all uses of water must be beneficial and that prohibits the diverting or taking of water for most uses without a permit from the Water Commissioner [O'Connell, 1962, p. 551]. Permits are given for short periods of time only. Other states in the eastern U.S. are beginning to follow the lead of Iowa by shifting toward administrative control of water resources.

In the West, state ownership and control of water resources--a trend which has arisen only recently in the East--has been accepted for some time. In 17 western states, laws have declared water to be the property of the state or its people [Hirshleifer, DeHaven, and Milliman, 1960, p. 248].

Transferability of Water Rights

In general, water rights cannot be transferred from one person to another. Riparian doctrine holds that a landowner has the right to use water bordering or coursing his land, but he cannot use the water on non-riparian land or sell it to other owners. Appropriative law, more flexible, allows water to be used on non-riparian land. Some states allow for transfer of water rights from one user to another; other states do not allow the sale or exchange of rights and even prohibit transferring of water from the use for which it was originally appropriated [Hirshleifer, DeHaven, and Milliman, 1960, pp. 239-42].

The new trend, control of water rights by federal or state administrative agencies, may result in even less flexibility in the private transfer of water rights. It embraces the idea that private ownership of water is to be avoided, that water should belong to all the people; hence the allocation of water is better accomplished through public agencies. Public agencies can then transfer water from less important to more important uses when a transfer is necessary.

According to Hirshleifer, DeHaven, and Milliman [1960, pp. 35-36], this trend is not likely to improve allocation of water resources.

> "Now there are indeed problems, which we will discuss later, arising out of market-place competition for water supplies--and, of course, there are also problems arising out of political or bureaucratic allocations of water. The point we wish to make here is that the latter procedures cannot eliminate competition for water; the conflict of interest remains whatever the process for making the decision. The only effect is that competition is shifted from the market arena to the political arena, as each contestant attempts to influence the outcome through control of votes and political influence instead of dollars and economic influence."

Later, the same authors, after a discussion on bureaucratic control of water from the practical side (logrolling, pork barrel legislation, and patronage) conclude [p. 86]:

> "The frequent success of demagogues, the constant revelations of corruption, and the low level of public debate all support the inference that perfection is no more achieved in the political than in the market process. We obviously cannot attempt here to assess the performance of one process against the other, either in general or in particular sectors. Rather, our purpose is to establish somewhat convincingly that one cannot readily assume that perfect or even reasonably satisfactory political processes are available to correct market imperfections. Instead, it is necessary to consider the prospects for useful corrective intervention case by case."

Summary

Existing water supplies are allocated, for the most part, under two distinct types of rules--the riparian and appropriative doctrines. The first limits ownership of water to owners of land contiguous to surface or "underground" watercourses. Under the second, water rights are gained by diverting water from a natural watercourse and putting it to beneficial use.

A riparian right may be lost if the use is not reasonable (as interpreted by the courts). Domestic use usually receives top priority.

The use of appropriated water need not be reasonable in the sense that it must be gauged against a hierarchy of priorities, but must either be used beneficially (a matter also subject to court interpretation in contested cases or allowed to continue its original course.

Neither doctrine provides firm water rights that may be sold in the marketplace. The trend is not toward transferrable private rights, but toward public ownership.

OPTIMAL ALLOCATION OF WATER

Value in Use

The term "value in use " has been borrowed from Smith, [1776, p. 28] by Hirschleifer, DeHaven, and Milliman [1960, p. 37], and is used here in the same sense. It denotes the value to society of a given quantity of water. If social costs or revenues are equal to private ones and perfect competition prevails, the marginal value in use may be taken as the demand price for water (as a product) or the value of the marginal product of water (as an input).

Optimal allocations of water require that: (1) the values in use to each user be equated at the margin; and (2) the common marginal value in use be equal to the marginal social cost. These conditions are a specialization of a general welfare theorem that will be taken here without proof. (See Samuelson [1958, pp. 229-46] for a proof of the general theorem; for the derivation from welfare economics of benefit-cost analysis for water resource development, see Eckstein [1958, pp. 70-75].) If there is more than one source of water, the resource is optimally allocated when the marginal social costs of all sources of water are equated--provided, of course, that the first condition is satisfied.

Assuming that: (1) perfect competition exists in both product and factor markets; (2) private demand does not differ from social demand for water; and (3) marginal private costs of water include all social costs; then a system of private ownership of rights and market prices will bring about optimal allocation of a community's water resources.

The demand for water is inversely related to its price. When water is a consumable commodity, the rational consumer utilizes precisely the quantity of water that equates his marginal value in use with the supply price. Additional consumption yields less satisfaction than its cost, thus calling for a reduction in use. Use of a quantity smaller than optimum results in marginal benefits greater than the cost at margin and thus calls for additional consumption.

The factor market operates similarly. To maximize its profit, a firm uses water up to the point where the supply price equals the value of the marginal product of water to the firm. Additional units cost more than the revenue obtained by their application. Use of less than the optimal amount results in marginal revenues exceeding marginal costs. The entrepreneur is then prodded into a greater use.

Any owner of water rights will use water to the point of maximum satisfaction or profit--no more and no less. If his rights exceed his needs, he will sell his surplus rights. An owner with a deficiency or with no rights at all will buy water rights until the marginal cost of his additional rights and his marginal value in use are equal. In a perfect market, the result would be one water price, for any given total usage, that would be equal to the marginal value in use for any user. Users whose marginal values in use exceed the supply price of water, and hence exceed the marginal value to others, would buy additional rights--thus bidding up the price of water rights. Simultaneously, other users would experience a rise in opportunity costs that would exceed their marginal values in use; they would sell rights and reduce their water use to the point where their marginal values in use would once more equal the marginal cost. (A schematic representation of the marginal value in use-marginal cost equating effect of a perfect market in water rights is presented in Figure 10.)

Impediments to Optimal Marketing

Optimum allocation may not result from a system of market prices for several reasons. If firms that purchase or produce water under constant-cost conditions sell their output in imperfect competition, the water resource will be used only to the point where the marginal revenue product is equal to the marginal cost. Here, water is underutilized, because the value of its marginal product or the value of the incremental unit to society is greater than its cost. In view of the findings of the case study of the Los Angeles area (Chapter IV) and the contention that current water-pricing policies lead to underpricing and overbuilding in water supply [Hirshleifer, DeHaven, and Milliman, 1960 pp. 107-13], overpricing and underutilization due to imperfect competition is worth mentioning.

Marginal private costs that are relevant to producer or user decisions may not reflect marginal social costs. This second reason has been well recognized in the literature. Mishan [1964, pp. 98-154] discusses this situation and lists references on external effects. Marginal private costs may understate marginal social costs either because of external diseconomies or because some of the costs associated with increased use are transferred to society.

A classic example of diseconomies is the common ground-water pool. Increased pumpage by one well owner can lower the water levels and hence raise marginal pumping costs for other users, while his own marginal pumping cost may remain constant or even fall as a result of the decreasing power costs frequently associated with increased pumpage. In this instance, true marginal social costs are not reflected in the costs of the individual whose pumpage increases. The marginal social cost of producing the increment may be determined only by summing the added costs that are imposed upon all the well owners who draw from the common pool. Another type of external effect (demonstrated in Chapter IV) can be created by financing additional water supplies or aquifer protection from ad valorem taxes--thus transforming a cost that is variable from the standpoint of society into one that is fixed with respect to changes in water use.

When a large water-supply project incurs substantial fixed costs and operates with excess capacity and if the price is set at a level high enough to cover average total cost, price overstates marginal social cost and the water is underutilized. Another possible cause of underutilization, external economies, may cause private costs to overstate social costs; however, this possibility does not seem important in the area of water resources.

Finally, for a private rights-market price system to accomplish optimal allocation, the market must be strong and active. A perfect market depends on perfect knowledge of prices. In the real world, the market in rights will be weak unless adequate knowledge of alternatives is available to prospective traders. Chapter IV contains a discussion of the situation in which a system of tradeable ground-water rights operates inefficiently because future prices of supplementary water cannot be known with reasonable certainty by prospective sellers or buyers.

Free Market Versus Administrative Control

A system of private ownership of rights and market prices will optimally allocate water, subject to the exceptions noted above. The question naturally arises: Do the exceptions provide sufficient justification for abandoning the idea of private ownership and private market in water rights? Each exception must be considered separately to provide the answer.

Imperfect competition, to the extent that it exists in the economy, poses a problem. Any decision in favor of a free market in water rights may or may not be in the direction of economic efficiency if market imperfections exist elsewhere in the economy [Lipsey and Lancaster, 1956-1957, pp. 11-32; McManus, 1959 pp. 209-22; Lipsey and Lancaster, 1959, pp. 225-26; Mishan, 1962, pp. 205-17]. It seems reasonable, however, to insist that imperfections need not be taken as an argument against providing a free market in water rights; rather they may be considered an argument against themselves. If imperfect competition is a parameter that cannot be altered, then there are few suggestions for economic welfare that may be offered in the absence of a complete knowledge of the social welfare function.

The United States government, however, is committed to the elimination of serious market imperfections. The analysis presented in this report is based on the assumption that the federal government will be reasonably successful in this endeavor.

External diseconomies (where marginal social costs exceed marginal private costs) may be eliminated by the levying of a tax or pumpage charge on each unit of production. External economies or economies of scale may be handled by subsidizing each unit of production.

Inefficiency resulting from imperfect knowledge cannot be eliminated by a free market in water rights per se. A procedure for handling such a case is presented in Chapter IV.

It should be stressed here that nothing in this section militates against a system of firm tradeable private water rights. In fact, a strong presumption exists that the best system of water laws would provide for private ownership of water rights and their unlimited sale and transfer. If administrative control is warranted because of any of the above problems, such control can probably rely on tax, subsidy, or pricing measures applied in conjunction with a private market in rights. Failing this, it can attempt to simulate the resource allocation effects of the free market by applying appropriate regulation.

Evaluation of Existing Water Laws

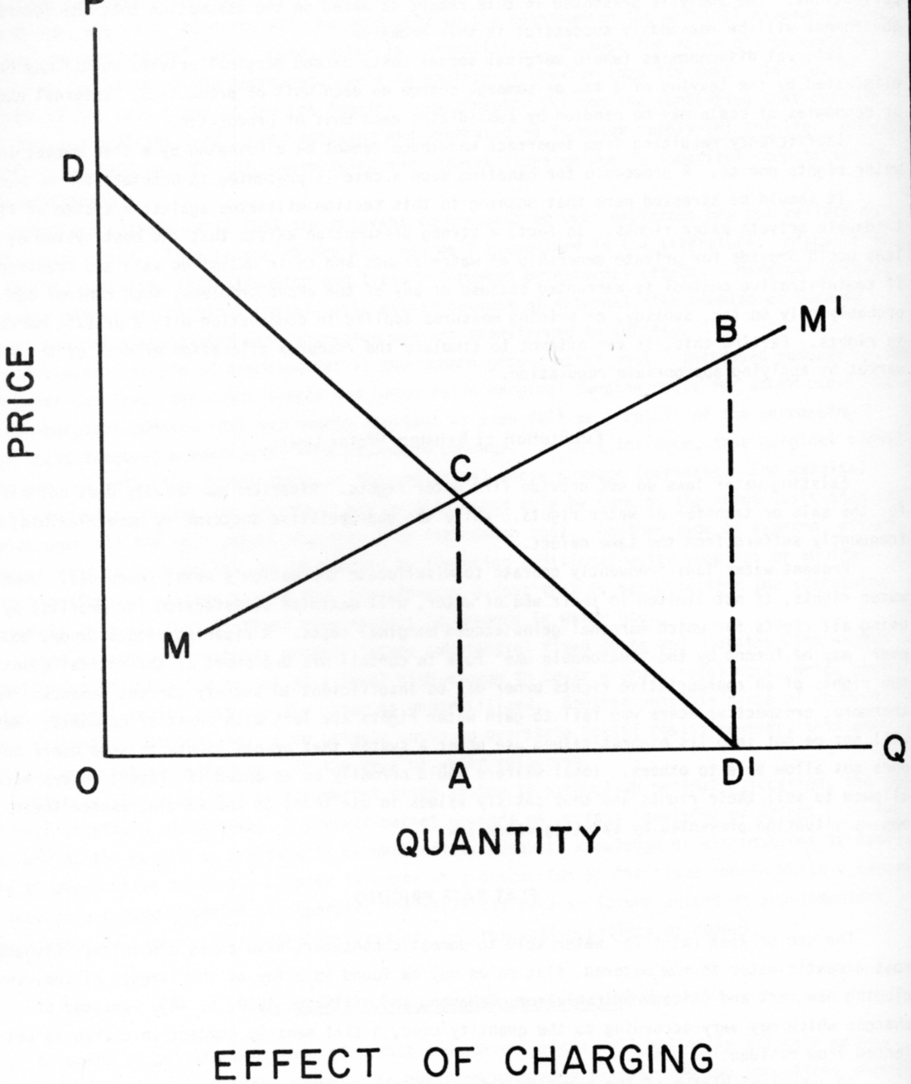
Existing water laws do not provide firm water rights. Riparian law usually does not allow for the sale or transfer of water rights. While the appropriative doctrine is more flexible, it frequently suffers from the same defect.

Present water laws frequently operate to misallocate the nation's water resources. Owners of water rights, if not limited in their use of water, will maximize satisfaction (or profits) by using all rights for which marginal gains exceed marginal costs. A riparian rights owner, however, may be forced by the "reasonable use" rule to curtail his use short of the optimal quantity; the rights of an appropriative rights owner may be insufficient to satisfy current demands. Furthermore, prospective users who fail to gain water rights are left with unsatisfied wants. Water will not be put into its highest-valued use under a system that grants rights to some users but does not allow sale to others. Total welfare would normally be enhanced if present owners were allowed to sell their rights and thus satisfy values in use that, at the margin, exceed their own--a situation prevented by existing water law.

FLAT-RATE PRICING

The use of flat rates for water sold to domestic consumers also poses a problem. Although most domestic water is now metered, flat rates may be found in a few of the largest cities--including New York and Chicago [Hirshleifer, DeHaven, and Milliman, 1960, p. 44]. Instead of charges which may vary according to the quantity used, a flat monthly connection charge is collected from residential users.

An important virtue of the quantity pricing system is its ability to restrict water consumption to the highest valued uses. A properly regulated or administered municipal water company will have a price schedule that equates the marginal cost of water to the total demand. At this point, the total welfare is at a maximum. Greater use would mean that, at the margin, the cost of water to society is greater than the value to society. Flat rates have the effect of causing a greater than optimal use. The "extra" resources required to produce the "surplus" water would be of greater value to society if they were put to other uses. (Flat rates on water, however, have long been justified by social revenue arguments. It has been held that flat-rate pricing will benefit public health, since it will promote personal cleanliness among the masses [Sleeman, 1955, pp. 231-45].)



EFFECT OF CHARGING FLAT RATES FOR WATER

FIG. 3

Figure 3 illustrates the problem. The demand curve for a municipality is the line DD'. The marginal costs are MM'. Proper water rates and metering will result in the use of quantity OA. Since the demand may be taken as a measure of marginal utility or marginal value in use, the net value in use (the total value in use less the total cost) is maximized at C. Flat-rate pricing will let users consume water to point D', beyond which any more use would have zero or negative value. Although flat-rate consumers do pay for their water, they can use the surplus beyond point A as if the price were zero, for the flat rate covers whatever quantity is taken. Therefore, it behooves flat-rate consumers to use any water that has a positive value to them. The result is an economic loss to society that may be measured by the triangle CBD'. For such an argument, however, it has been assumed that each potential customer is willing to pay the flat rate. To put it another way: the area under each individual demand curve must represent a total value in use per unit of time that is greater than the flat price charged for the same period of time.

SUMMARY

Misconceptions about the economics of water are common. It has been the primary intent in this chapter to dispel the notion that water is "something special." Water is like any other economic good or resource. Whether additional supplies of water should be sought depends on their value in relation to that of alternative goods which could be obtained with the same amount of sacrifice.

An analysis of water laws makes it clear that water is given a special place among resources. Two doctrines of water law, appropriative and riparian, prevail in the United States. Under both, the right to water is generally treated as an untradeable commodity, though appropriative doctrine, which allows for some trading, is probably better suited as a basis for improving water laws [Trelease, 1957, pp. 301-22]. The current trend, however, is toward more, not less, judicial and administrative control of water.

Optimal allocation of water resources can usually be accomplished by the ordaining and maintaining of a system of tradeable private water rights. Any of the previously enumerated problems can be corrected by the superposition of certain measures, such as charges or subsidies, upon the basic tradeable rights-market price system.

Existing water laws allow the misallocation of resources because water is not being put to its most valued uses. Further misallocation, the overcommitment of resources to water production, has resulted from the now diminishing practice of charging flat rates for residential water.

The indicated corrective measures would begin with the treating of water like any other economic good--making it subject to unconditional ownership, allowing it to be purchased or sold at will. However, other measures would have to ensure a price for water that reflects its marginal social cost.

In the following chapters the assumption has been that the existing legal barriers to economic efficiency can be eliminated. In particular, it will be assumed in Chapter III that the community as a whole has no legal advantage over individuals in obtaining additional water supplies. That the community has at least one advantage, the right of eminent domain, only strengthens a major conclusion of Chapter III--that a community project is likely to be chosen over a corporate alternative. Any such legal advantage, however, is excluded from the model which considers cost advantages only. The analysis of Chapter IV incorporates the assumption that the elimination of existing water quotas in the West and Central Basins of Los Angeles poses no insoluble problem of legality or constitutionality.

CHAPTER III

DECISIONS TO AUGMENT EXISTING SUPPLIES

INTRODUCTION

Water will be efficiently allocated if a sound legal framework and an efficient pricing system have been established. The efficient allocation of existing supplies is a condition necessarily precedent to rational decisions regarding the development of additional water supplies. Otherwise it will not be clear when demand is increasing at a rate that warrants investment in new water-producing facilities. New sources may be prematurely developed either under water laws that do not allow trading of rights or pricing policies that cause overutilization of water.

A community's increasing water demands may prompt it to consider investment in new supplies. The decisions regarding additions to or replacement of existing ground-water supplies will involve costs that occur over time. On the one hand, a decision to undertake a water-supply project commits the community to an investment of resources not only in the present, but also during the life of the project. A decision to take no action, on the other hand, may postpone large expenditures, but such a decision is not without its costs.

The costs attached to inaction represent increased pumping costs as water levels are lowered by pumpage in excess of natural recharge; costs associated with a reduction in water use; costs occasioned by land subsidence; or costs of privately undertaken supply projects. These costs accrue to industry as increases in the price of water (an input) and to the general public as lost satisfaction or (in the case of land subsidence) as property damage.

Water is both an input to industry and a commodity to residential consumers. The demand for industrial water is a function of its marginal productivity. A profit-maximizing firm will use water to the point where its cost is equated with its marginal revenue product, which, under the assumption of perfect competition, is the value to society of the marginal product. As the demand for a firm's product increases, its use of water increases, and society will place a higher value on a given quantity of industrial water.

The residential demand for water is a function of its price, as well as the population, income, and prices of other commodities. Other things being equal, growing incomes and increasing population raise the residential demand. Again, society has placed a higher value on any amount of water devoted to residential consumption.

<u>The benefits or net returns of a project to provide an additional water supply are thus the costs associated with the alternative, the failure to take action.</u> Or--to put it another way--the costs of failing to act are the benefits foregone as a result of inaction. The increased demands of society call for additional water when the marginal cost of a new supply is less than the marginal value placed on it by the community.

An increase in the community's demand for water may prompt an investigation of available alternatives, with two questions to be answered: Is inaction the least-cost alternative? and What is the least-cost alternative of developing additional supplies if additional supplies are clearly warranted? The primary objective of this chapter is to answer these questions by specifying an economic model for the determination of benefit-cost ratios for a local community. A secondary purpose is to discuss the welfare implications of this model (because it produces different results from one that measures benefit-cost ratios for the nation as a whole).

CRITERIA FOR CHOICE

Benefit-Cost Ratios

Traditionally, water projects are evaluated on the basis of benefit-cost ratios. Both the future benefits and costs are discounted by an "appropriate" interest rate. A project is justified only if the ratio of benefits to costs exceeds unity, and among competing projects, the one with the highest such ratio is considered "best" [Eckstein, 1958, pp. 47-70].

That the ratio of a project should be greater than one is clear. A project that costs more than it is worth should not be undertaken. It does not necessarily follow that projects competing for public funds should be ranked by their ratios and that such ranking should determine budgetary priorities. Errors may result from such an approach.

First: in the selection between mutually exclusive projects, the net benefits (benefits minus costs) are important. For example: a project with expected benefits of $2,000 and total costs of $1,000 has a benefit-cost ratio of 2, but it would not be preferable to one yielding $1,500,000 in estimated benefits at a cost of $1,000,000, although the benefit-cost ratio of the second project is only 1.5. To forego an estimated net gain of $500,000 in preference to one of only $1,000 would be unreasonable.

Second: benefit-cost ratios can be ambiguous; the benefits with a portion of costs deducted may produce ratios that differ from ratios which include all benefits and costs. To illustrate: it may be convenient to express project benefits net of part of the costs; e.g., $1,000 less $600 in one type of costs yields $400 in net benefits. If the basic expenditure is $200, the benefit-cost ratio calculated on this basis is 2. However, if total costs and benefits are included, the ratio would be $1,000/$800 = 1.25.

The better criterion for rating projects would be benefits minus costs, which in the last example is $200, whichever way the calculation is made [McKean, 1958, pp. 107-16; Hirshleifer, DeHaven, and Milliman, 1960, pp. 137-38]. Moreover, subtraction of costs from benefits shows the net gain in present value and, if the proper costs, benefits, and discount rates are used, any project with positive net benefit should be undertaken. If this is not possible, i.e., if "capital rationing" is necessary, the problem becomes more complex [Hirshleifer, DeHaven, and Milliman, 1960, pp. 169-74]. Discussion of this aberration, however, will not be covered since it is not pertinent to the problem at hand.

Despite these shortcomings, the benefit-cost ratio will be used as the criterion throughout this study. In the context used, the benefit-cost ratio will give the same results as the net-benefits criterion--a consequence of how the benefits are measured--as the cost of the best alternative course of action. With this approach, only one course of action will yield a benefit-cost ratio in excess of unity, and only it will yield positive net benefits.

Application of Benefit-Cost Ratios

The measurement of benefits and costs is an extremely difficult problem in appraising the feasibility of a large multi-purpose water project. Total benefits are appropriately measured by the entire areas under the pertinent demand curves for all outputs of the project, including consumers' surplus; total costs should consider the entire value of the product lost in the private sector due to the diversion of resources to the water project.

A simple price-times-quantity calculation does not correctly measure benefits, and in the case of cost measurement, such a calculation will be inadequate if, as a consequence of the project, resource prices are changed or the inputs are bid away from firms operating in imperfectly competitive product markets [Dunn, 1967, pp. 337-42; Stober, Falk, and Ekelund, 1968, pp. 563-68]. Moreover, estimation is particularly difficult for benefits that are not marketed, e.g., recreation provided by a reservoir project [Knetsch and Davis, 1966, pp. 125-42]. The allocation of the costs of multi-purpose projects to individual purposes is another difficult problem [Hirshleifer, DeHaven, and Milliman, 1960, pp. 93-94]. Fortunately, the problems that must be faced in measuring benefits and costs for single-prupose projects are much fewer.

This report is limited to a single-purpose project. The approach considers only direct benefits and costs to the locality. The diversion of resources to the project is assumed to be minimal.

Nevertheless, one difficulty, the problem of uncertainty in benefit and cost streams, is ignored. As yet, there is no completely satisfactory way of handling uncertainies in water resource systems design. Although advances are being made in this area, and some tools now exist which would be of value in local water project studies [Dorfman, 1966, pp. 129-58], these developments have not been used because they would complicate the analysis to the extent of obscuring several important points.

As noted above, the benefits derived from any community water project may be measured by the costs of the best alternative to the action contemplated, since they are the costs avoided by undertaking that project. Possibly, the best alternative is simply failure to act. The benefits of the action are thus the costs of inaction, or, more precisely, the discounted stream of future costs and benefits foregone as a result of failing to replace or augment the ground-water supply. If the benefit-cost ratio for the best possible action proves to be less than unity, a decision in favor of inaction is optimal.

The choice between any two possible community projects A and B may be made in the same manner. If the benefit-cost ratio for project A is greater than unity (based on the costs of its best alternative, B), then A should be undertaken. If the ratio for project A is less than unity, its reciprocal, the benefit-cost ratio for B, is greater than unity; project B should then be chosen.

After selecting the best possible community project, the community still has the option of letting private firms undertake their own projects as an alternative to the community project. The benefits (numerator) for the benefit-cost ratio used in making this decision are the costs associated with the private projects. The costs (denominator) are, of course, the costs that would be incurred by the community project. A procedure for measuring and comparing these benefits and costs is presented in the following section.

MEASURING THE COSTS AND BENEFITS OF COMMUNITY ACTION

The Present Value of Future Costs

Costs incurred at future points in time have different values when they are viewed from the present. To illustrate: let C_o be a cost arising at the present time and C_t, a cost arising t years from now. If C_o could be postponed for t years and the consequent saving invested at the rate of r (compounded annually), the original sum C_o will have a value of $C_o(1 + r)^t$ after t years. To put C_o and C_t on an equal footing, C_t must be equal to $C_o(1 + r)^t$. The present value of a cost incurred in year t (PVC_t) is defined alternatively as:

$$C_o = PVC_t = \frac{C_t}{(1 + r)^t} \quad (3\text{-}1)$$

The PVC_t (present value of a future cost) is the amount that, if set aside now and invested at r%, would have returns equal to the cost when it is incurred in t years.

In general, the present value of a stream of yearly costs, C_t, is

$$PVC = \sum_{t=1}^{n} PVC_t = \sum_{t=1}^{n} \frac{C_t}{(1 + r)^t} \qquad (3\text{-}2)$$

Because the cost in year t is discounted for the entire year t, as well as for the preceding t-1 years, the equation treats costs as being incurred on the last day of the year. Thus annual discounting will understate the present value of future costs.

In lieu of discrete annual discounting, continuous discounting might be used. In this case, e^{-rt} would replace $(1 + r)^{-t}$ as the appropriate discount factor and the definite integral would replace the summation sign. Although continuous discounting is more consistent with the view that output is a continuous flow over the course of the year and that costs are incurred at monthly and weekly intervals, for expository purposes the more familiar discrete discounting method is employed. The difference in the present values of costs is not great and in no way affects the comparisons to be made.

Immediate cash outlays, such as initial costs of construction, should not be discounted. Thus to include these in the general equation, we must sum from zero to n, where costs at time zero, C_o, represent immediate cash outlays. Equation 3-2 then becomes

$$PVC = \sum_{t=o}^{n} \frac{C_t}{(1 + r)^t} = \sum_{t=o}^{n} C_t(1 + r)^{-t} \qquad (3\text{-}3)$$

The present value <u>unit</u> costs for both a non-profit community project and the private alternatives can be calculated by an adaptation of the above formula. For the community project, let x_p represent the unknown present-value unit cost of water, which is assumed to remain constant over the life of the project, and let q_t represent the quantity of water produced in year t. Then the total cost for the project in year t will be $x_p q_t$. Similarly, if x_c (also assumed to be constant) represents the unknown present-value unit water cost of q'_t units of water in year t for the private alternatives, the alternative cost in the year t will be $x_c q'_t$. It follows that for a community project with a life of n years, the sum of the present-value costs will equal the sum of quantities produced in each year multiplied by the present-value unit cost and discounted by the appropriate factor. Symbolically,

$$\sum_{t=o}^{n} PVC_t = \sum_{t=o}^{n} (x_p q_t)(1 + i)^{-t} \qquad (3\text{-}4)$$

where i is the discount rate for the community project. Because x_p is a constant, it may be factored out of the summation. Upon dividing both sides by the sum of the discounted quantities, we have

$$x_p = \frac{\sum_{t=o}^{n} PVC_t}{\sum_{t=o}^{n} q_t(1 + i)^{-t}} \qquad (3\text{-}5)$$

With k as the discount rate for the private alternatives, the present-value unit cost associated with the failure of the community to take action is

$$x_c = \frac{\sum_{t=o}^{n} PVC_t}{\sum_{t=o}^{n} q'_t(1 + k)^{-t}} \qquad (3\text{-}6)$$

It may be helpful to take a somewhat different approach and view the present-value unit cost as an internal price that must be charged for water. This internal price, multiplied by quantities produced in each year, generates a revenue stream that, when discounted, equals the present value of all costs. Thus the internal price (present-value unit cost) is a price just sufficient to cover all costs associated with the project.

The discount rate can be interpreted as the rate of return over cost--or simply--the net rate of return on the investment outlay. This may seem to be a rather strained interpretation, since the discount rate, which must be selected first, determines (together with the cost and quantity streams) the present-value unit cost of water. However, it serves to elucidate that the discount rate must bear some relationship to the net rate of return which a firm expects to realize on alternative investment projects. But to say simply that the discount rate used to calculate present-value unit cost must reflect the net rate of return on alternative investment projects is far too vague.

Appropriate Discount Rates

The discount rate for the community project is the cost of capital to the sponsoring body. The cost of capital is the interest rate.

The discount rate to be applied to the private alternative, however, presents greater difficulties. If, as it will be assumed, the private alternative is an increased cost of water to industrial firms and municipal waterworks, the relevant rate of discount is the corporate cost of capital.

"Cost of capital," as applied to a profit-making corporation, raises several theoretical issues not yet satisfactorily resolved [Modigliani and Miller, 1958, pp. 261-97; Durand, 1959, pp. 639-55]. While an attempted resolution or even a complete treatment of these issues is beyond the scope of this study, a brief discussion is necessary.

As a start, it should be noted that a corporation has alternative sources of funds--for example: retained earnings, depreciation allowances, loans from financial institutions, and the issuance of bonds or stock. Each source has a different objective cost. Because a water-replacement project will be long-lived, only the following need be considered; new shares, long-term loans, bonded debt, preferred stock, retained earnings, and depreciation allowances.

Normally, the cost of equity capital is calculated as either a ratio of expected-earnings-per-share to price-per-share [Dean, 1951, p.43] or some variation of a current dividend/price ratio, with allowance made for expected dividend growth [Bierman and Smidt, 1960, pp. 141-48]. The cost of borrowed capital is uniquely dependent on two factors: (1) the effective interest rate at which the corporation can borrow; and (2) the corporate income tax rate. Inasmuch as interest payments are expenses deducted from revenue in arriving at taxable income, the cost of borrowed capital is not the full amount of the effective interest rate, but rather the interest rate less the marginal tax rate multiplied by the interest rate. In short: the actual cost of borrowed capital is obtained by multiplying the effective interest rate by one minus the marginal tax rate.

The effective interest rate is readily calculated as the current yield to maturity on the corporation's long-term debt, adjusted, when necessary, for underwriting costs associated with a new debt issue. The cost of obtaining capital by the issuance of new preferred stock is similarly determined by the current yield on preferred stock.

The cost of capital from internal sources requires more detailed treatment. At first glance, internally-generated funds seem costless because they require no explicit cash outlay. This is not the case, however. The retaining of earnings to finance an investment project has an alternative--the payment of dividends. If we assume the financial well-being of the shareholders to be the overriding concern of corporate directorships, then the decision, either to retain earnings or to pay dividends, should hinge on the effect that each alternative has on the net worth of the shareholders. Specifically, an investment project financed by internal funds should be undertaken only if the market value of corporate shares increases by an amount at least as great as the foregone dividends.

Because the market evaluates shares on the basis of expected earnings, the increase in the market value of shares will be greater than the investment outlay only if the expected net rate of return on the investment outlay is greater than the ratio of expected earnings to the price of shares, i.e., the cost of equity capital. Thus the cost of equity capital is also the appropriate cost of capital to be applied to internal sources.

The same argument applies to depreciation allowances. If such funds do not provide a rate of return at least as great as the cost of capital, then they should not be retained [Cohen and Robbins, 1966, pp. 749-51].

To restate the argument symbolically: if E represents expected annual earnings and M, the total market value of the corporation's shares, then r, the cost of capital, will be E/M. In a perfectly-functioning capital market, the cost of equity capital may be assumed constant with respect to changes in expected earnings because such an increase will lead to an increase in the price of shares as the market discounts the expected increase in earnings. Thus we may write

$$\Delta M = \frac{\Delta E}{r} \tag{3-7}$$

Let ΔI represent the increase in investment outlay (foregone dividend) and $\Delta E'$, the resulting increase in expected annual earnings on the investment outlay, which, for purposes of exposition, is assumed to be a perpetual flow. Then

$$\Delta I = \frac{\Delta E'}{i} \tag{3-8}$$

where i is the expected rate of return on the investment outlay. Now, if knowledge of the investment project is communicated to the market and the market evaluates expected earnings in the same way as corporate management ($\Delta E = \Delta E'$)

$$\Delta M > \Delta I \text{ only if } i > r$$

In other words, the change in the market value of the corporation's outstanding shares is greater than the investment outlay, or foregone dividend, only if the rate of return on investment is greater than the cost of capital.

One tempting, but unwarranted conclusion is that the cost of capital will depend upon the method of financing. If an investment outlay is financed by equity capital or internal sources, one rate would seem applicable; by long-term debt or preferred stock, still other rates would seem applicable. The method of financing an investment will have an effect, even if only minor, on the capital structure. Internal or equity financing will lower the debt/equity ratio; debt financing will raise it.

If we assume that each corporation has an optimal capital structure to build and maintain, then the financing of the investment outlays must leave the structure unaffected. In other words, the decision to alter the capital structure is a separate decision.

This point leads to the conclusion that there is but one cost of capital, which must be a weighted average of the cost of equity and senior capital [Donaldson and Pfahl, 1963, pp. 438-40]. Moreover, if we assume that a corporation has an optimum capital structure, or what it conceives to be the optimum, the appropriate weights are the current percentages of the capital provided from debt and equity sources. Thus, although one project may be financed by the issue of debt, for example, maintenance of the desired capital structure may require that other projects be financed by equity capital.

It should be recognized that this conclusion concerning the cost of capital rests on several arbitrary assumptions. First: the overriding objective of the corporation is the maximization

$$x_c = \frac{\sum_{t=o}^{n} [K'_t + (1 - T_t)(A'_t + M'_t) - S'_t - (T_t)(D_t)] [(1 + k)^{-t}]}{\sum_{t=o}^{n} q'_t (1 + k)^{-t}} \qquad (3\text{-}12)$$

The current (1969) 7% federal investment tax credit is omitted from the analysis in this chapter. Since its introduction by the Revenue Act of 1964 [Cook, 1967, pp. 227-33], the credit has been used by the government both as an incentive to investment and as a counter-cyclical tool. In 1966, it was suspended as an inflation combatting measure. Originally, the suspension period was to run from October 10, 1966 through December 31, 1967 (P.L. 89-800), but it was reinstated earlier than planned, on March 9, 1967 (P.L. 90-26). Since the credit is a direct offset to taxes, it can be taken as a deduction in costs during the year of construction. This can be accomplished easily by replacing K_t by 0.93 K_t in Equation 3-12. No other changes need be made; the credit does not affect the depreciation basis.

For purposes of comparison, the initial assumption is made that private water users will be forced to take action and that this action will involve a cost stream identical in timing to that of the community alternative. In the derivation of a benefit-cost ratio for a community project, two more assumptions will be made: that the management of the community project is neither more nor less efficient than the managements of the best corporate alternatives; and that there are constant returns to outlay in the production of water.

The first assumption concerning community projects requires no comment. The second is necessary because the community project, by supplying water to a group of water users, will have to be larger than any single corporate project.

With the assumption of constant returns to outlay, a corporate project may be looked at in two ways. It may be thought of as one large corporate project composed of several individual projects that together provide the same quantity of water as the community project. Hence it will have the same costs. Alternatively, it may be viewed as a single project that is identical to the community project (reduced by an appropriate scale factor).

If the second view is adopted, then, although each cost for the corporate project will be smaller, the output will be reduced proportionately. Thus in either case, the primes in Equation 3-12 can be eliminated. With the further assumption that the cost of capital is the same for the community and corporate projects (i = k), then Equation 3-12 can be written

$$x_c = \frac{\sum_{t=o}^{n} [K_t + (1 - T_t) (A_t + M_t) - S_t - (T_t)(D_t)][(1 + i)^{-t}]}{\sum_{t=o}^{n} q_t (1 + i)^{-t}} \qquad (3\text{-}13)$$

This equation would be the numerator of the benefit-cost ratio for a community project expressed in unit costs and benefits, given identical corporate and community costs--including capital. Equation 3-10 for x_p, the project unit cost, is the denominator of the benefit-cost ratio. However, for this use, it is incomplete. We must use the "net community cost per unit." If companies purchased water from the community in lieu of providing their own supplies, they would have to pay the community x_p to cover all project costs, including interest. But if the marginal tax rate is constant over time, the net community cost per unit would be only $(1 - T)x_p$, since the purchases are deductible from gross income for tax purposes. Hence both sides of Equation 3-10 are multiplied by (1 - T) to form the denominator. The discounted quantity streams cancel out, and the benefit-cost ratio becomes

$$\frac{x_c}{(1-T)x_p} = \frac{\sum_{t=o}^{n}(K_t+A_t+M_t-S_t)(1+i)^{-t} - T\sum_{t=o}^{n}(A_t+M_t+D_t)(1+i)^{-t}}{(1-T)\sum_{t=o}^{n}(K_t+A_t+M_t-S_t)(1+i)^{-t}} \quad (3\text{-}14)$$

Assuming construction costs to be incurred at time zero, we arrive at

$$\frac{x_c}{(1-T)x_p} = \frac{1}{(1-T)}\left\{1 - T\left[\frac{\sum_{t=o}^{n}(A_t+M_t)(1+i)^{-t} + \sum_{t=o}^{n}D_t(1+i)^{-t}}{\sum_{t=o}^{n}(A_t+M_t)(1+i)^{-t} + K_o - S_t(1+i)^{-t}}\right]\right\} \quad (3\text{-}15)$$

Now, it is clear that $\sum_{t=0}^{n} D_t = K_o - S_n = K_o - S_t$

That is, the total depreciation allowed over time is equal to the initial capital outlay in year zero less the salvage value in the final year n. With a positive rate of discount, however,

$$K_o - S_t(1+i)^{-t} > \sum_{t=o}^{n} D_t\ (1+i)^{-t} \quad (3\text{-}16)$$

since D_t is discounted and netted of S_t. It follows, then, that the bracketed terms in Equation 3-15 are less than unity. Thus the benefit-cost ratio would be greater than unity, even in the unlikely event that the corporate cost of capital is as low as the community borrowing rate.

Tax Advantage for Community Projects

To repeat, the benefit-cost ratio must always be greater than unity whenever the returns to scale are constant and the costs of the two projects are discounted with the same interest rate. The absolute value of the ratio will depend on the: tax rate, life of the project, timing of capital outlays, method of depreciation, and discount rate. As the marginal tax rate is increased, the denominator of Equation 3-14, and hence that of Equation 3-15, is reduced by the full amount of the tax; the numerator, by only a fraction of the tax. Thus the benefit-cost ratio is raised.

If the present value of the depreciation allowance increases relative to the present value of construction costs, the benefit-cost ratio will be lowered. This effect may be brought about by: an allowance, for tax purposes, of a more rapid writeoff; a reduction in the life of the project; or, a postponement of capital outlays.

In the extreme case of rapid write-off allowance, consider the entire investment written off at the time it occurred. If $S_t = 0$ for all t

$$\sum_{t=o}^{n} D_t\ (1+i)^{-t} = K_o$$

and the bracketed terms in Equation 3-15 would equal unity, as would the benefit-cost ratio.

Finally, an increase in the discount rate, by the placing of a heavier premium on present costs, reduces the present value of depreciation relative to that of capital outlays and, hence, increases the benefit-cost ratio.

The conclusions expressed in Equation 3-15 can be rephrased as relative unit costs. With both sides of Equation 3-15 multiplied by $(1 - T)x_p$, the unit cost of the corporate project is seen to be less than the price that the community must charge to cover its costs. The important point is that the unit cost of the corporate project is greater than the net cash outlay resulting from the purchase of a unit of water from the community project at price x_p. Corporate water users, therefore, realize a cost saving by purchasing from the community project.

Let us recall that the i's in the numerator of Equation 3-15 represent the corporate cost of capital and those in the denominator, the community cost of capital. Therefore, an increase in the corporate cost of capital relative to that of the community reduces the numerator (bracketed terms) relative to the denominator and thus raises the benefit-cost ratio.

Finally, we observe that the currently authorized investment tax credit, which allows a company a 7 percent tax offset on certain depreciable investments, tends to lower the benefit-cost ratio. Calculations show, however, that a much larger credit would be required to invalidate the previous general conclusion that the benefit-cost ratio of Equation 3-15 will be greater than unity. An example in the following section shows the effect of the present tax credit on a benefit-cost ratio for a hypothetical case that incorporates the assumption of constant returns to outlay.

Economies of scale in the production of water strengthen this conclusion. If, on the other hand, diseconomies of scale are important, then the preceding analysis has overstated the advantage of the community project. However, in a later discussion it is shown that diseconomies of scale must be substantial.

The cost of capital for the community project will almost inevitably be less than that for the corporate project. If the project is an arm of a state or municipal government, the community will be able to issue tax-exempt bonds, and hence, in most circumstances, to borrow at a lower rate than the corporation. In short, the federal and state corporate income taxes, combined with a lower cost of capital for a community project, provide a cost advantage that can be offset only by strong diseconomies of scale in the production of water.

COMMUNITY PROJECT BENEFIT-COST RATIOS: AN EXAMPLE

A general method has now been developed for calculating benefit-cost ratios for alternative water-replacement projects. An application will illustrate the significance of the conclusions.

Again we assume constant returns to outlay. The corporate project may then be viewed as an agglomeration of company projects having a total cost and a water output identical to those of the community project. Further, we assume that either project must replace a portion of the ground-water supply (100,000 acre-feet per year) at a given point in time (time zero), and that the demand for water will remain constant at this level over the life of the project.

Construction costs for the project (or group of projects), totaling \$10,000,000, are treated as being incurred at time zero. The facilities will be sold for a net salvage return of \$100,000 at the end of year 30. Operating costs, assumed to be directly related to output (\$5.50 per acre-foot), are \$550,000 per year. Maintenance costs are treated as a constant annual percentage (2%) of construction costs and thus total \$200,000 a year.

Unit Costs for a Non-Profit Community Project

The calculation of the present-value unit water cost of the community project is straightforward. With the data from the preceding paragraph in Equation 3-10, the cost per acre-foot becomes

$$x_p = \frac{10{,}000{,}000 + \sum_{t=1}^{30} (550{,}000 + 200{,}000)(1+i)^{-t} - 100{,}000\ (1+i)^{-30}}{\sum_{t=1}^{30} 100{,}000\ (1+i)^{-t}} \qquad (3\text{-}17)$$

This reduces to

$$x_p = \frac{10{,}000{,}000 + 750{,}000\ \frac{(1+i)^{30} - 1}{i(1+i)^{30}} - 100{,}000\ (1+i)^{-30}}{100{,}000\ \frac{(1+i)^{30} - 1}{i\ (1+i)^{30}}} \qquad (3\text{-}18)$$

Table 1 provides unit costs for discount rates (cost of capital) of 4, 6, 8, and 10%. An increase in discount rate from 4% to 6% raises the unit cost by \$1.48 per acre-foot; an increase in the discount rate from 4% to 10% increases the cost by \$4.83. The average annual cost rises by \$483,000 as the cost of capital is increased from 4 to 10%.

TABLE 1

WATER COSTS AT SELECTED DISCOUNT RATES
(Community Project)

Discount Rate	Present-Value Unit Cost (\$ Per Acre-Foot)	Average Annual Cost (\$)
0.04	13.27	1,327,000
0.06	14.75	1,475,000
0.08	16.37	1,637,000
0.10	18.10	1,810,000

Unit Costs for a Corporate Project

Computation of unit costs for the corporate project is complicated by the corporate tax structure. In Louisiana, for example, a corporation with an annual income in excess of \$25,000 pays marginal federal income tax at a rate of 48% (we are ignoring the temporary 10% surcharge of 1968) and the Louisiana state corporation income tax of 4%. Because each level of government allows the deduction of the tax actually paid to the other in arriving at taxable income, the net tax calculation is also involved. To calculate T, the net tax rate applicable to a one-dollar increment in income, we let F represent the nominal federal rate; S, the nominal state income tax rate; and T_f and T_s, the applicable net rates for the federal and state governments respectively. Now

$$T_s = S(1 - T_f) \qquad (3\text{-}19)$$

and

$$T_f = F(1 - T_s) \qquad (3\text{-}20)$$

Substitution of Equation 3-20 in Equation 3-19 (and vice versa) gives us

$$T_s = \frac{S - FS}{1 - FS} \qquad (3\text{-}21)$$

and

$$T_f = \frac{F - FS}{1 - FS} \qquad (3\text{-}22)$$

which, added together, yield

$$T = T_s + T_f = \frac{F + S - 2FS}{1 - FS} \qquad (3\text{-}23)$$

With Equation 3-23, the net marginal corporate income tax rate T in Louisiana is 49.1% for our example. This rate is assumed to remain constant over the life of the project, and no allowance is made for an investment tax credit.

The calculation of depreciation is complicated by the existence of more than one allowable method. If each participating company employed the "straight line" method, the annual depreciation would be simply 1/30th of construction costs less salvage value. A more realistic assumption is that each company uses sum-of-the-years digits depreciation. This method yields the greatest present value of the depreciation allowance for projects having the characteristics assumed above--given any reasonable range for corporate cost of capital [Davidson and Drake, 1961, pp. 442-52; Hall and Jorgenson, 1967, pp. 399-400]. Sum of the years-digits depreciation, therefore, minimizes the present-value unit cost for the corporate project.

Table 2 gives unit costs for the corporate project. These figures were obtained by substituting the data of this section into Equation 3-12. As in the case of the community project, it is seen that unit costs are highly sensitive to variations in the discount rate. The average annual cost of water ranges from $766,000 when costs and outputs are discounted at 4% to $1,214,000 when discounted at 10%.

TABLE 2

WATER COSTS AT SELECTED DISCOUNT RATES FOR CORPORATE PROJECTS

Discount Rate	Present-Value Unit Cost ($ Per Acre-Foot)	Average Annual Cost ($)
0.04	7.66	766,000
0.06	9.02	902,000
0.08	10.51	1,051,000
0.10	12.14	1,214,000

Comparison of Community and Corporate Costs

Tables 1 and 2 show that the corporate project can apparently produce water at a lower unit cost. Even if the cost of capital were 10% for the corporate project and only 4% for the community project, the unit cost would appear to be less. As demonstrated earlier, this paradox results from the tax structure.

The relevant comparison should not be between the apparent unit costs of the corporate and community projects. We must compare the costs to the company--the cost of purchasing water from the community project against the cost of a company project. It will be recalled that the purchasing cost is equal to the product of unity minus the corporate tax rate and the price charged by the community. Thus in Table 3 we have a comparison between the purchase cost and the company project cost. The purchase cost is 50.9% (100-49.1) of the community costs given in Table 1. Note that the purchasing cost is lower than the producing cost at every discount rate. Moreover, the difference between the two increases as the discount rate increases--from a low of $0.87 per acre-foot at 4% to a high of $2.84 at 10%. This, in turn, means that if both projects had a 4% cost of capital, the corporation would save 11.9% of the total cost by purchasing water from the community. If the cost of capital were 10% for both, the cost saving would be 24.1%.

TABLE 3

UNIT COST OF WATER TO CORPORATION PRODUCING ITS OWN SUPPLY AND PURCHASING FROM THE COMMUNITY PROJECT

Discount Rate	Cost of One Acre-Foot of Water to the Corporation: Producing Own Supply ($)	Purchasing from Community Project ($)	Difference ($)	Difference (%)
0.04	7.66	6.75	0.91	11.9
0.06	9.02	7.51	1.51	16.7
0.08	10.51	8.33	2.18	20.7
0.10	12.14	9.21	2.93	24.1

The effect of a different discount rate for each project is examined in Table 4, which shows the savings to the corporation that purchases, rather than produces its water. If the community project is an arm of a state or municipality, tax-exempt revenue bonds can be issued. The community cost of capital will be lower than the corporation cost. The more important savings in the table are those below the principal diagonal. At this time, municipal bond yields are about 5.25% and appear to be rising (Wall Street Journal, March 17, 1969). If we then assume an effective interest rate of less than 6% as normal for a state or municipally sponsored project, then columns 1 and 2 of Table 4 are relevant for savings comparisons.

If the cost of capital to the corporation is 8%, for example, and the community interest rate is 4%, the corporation would realize a saving of $3.76 per acre-foot by purchasing water from the community project rather than by producing its own replacement supply. If the community were forced to pay a 6% interest rate, and the corporate cost of capital remained at 8% the advantage would be reduced to $3.00 per acre-foot.

TABLE 4

SAVINGS TO CORPORATION BY PURCHASING OF WATER FROM THE COMMUNITY PROJECT

(Dollars per Acre-Foot)

Corporate Cost of Capital	Community Cost of Capital: 0.04	0.06	0.08	0.10
0.04	0.91	0.15	-0.67	-1.55
0.06	2.27	1.51	0.69	-0.18
0.08	3.76	3.00	2.18	1.30
0.10	5.39	4.63	3.81	2.93

Our basic conclusion, that it is less expensive for the corporation to purchase water from the community project rather than to supply its own needs, is incorrect only if the corporation cost of capital is substantially lower than that for the community project. In Table 4, we see that only if the community rate is more than 6% and the corporation rate is 4% or less will the corporation's cost of producing water be lower than the effective cost of purchasing water from the community project. Alternatively, with a 6% corporation rate, the community rate must be over 8% to make the corporate project feasible. Such cases are unlikely. We may conclude that realistic differences in the costs of capital will always give the advantage to the community project.

Benefit-Cost Ratios

Figure 4 shows benefit-cost ratios for community and corporation costs of capital from 0% to 10%. The assumption of constant returns to outlay has been retained. The shaded area, encompassing all reasonable discount rates--2% to 7% for the community project and 6% to 9% for the corporate project. Every combination of rates within this area yields a benefit-cost ratio greater than unity. Again, we see the strong bias in favor of the community project. For example: if the community rate were 5%, and the corporate rate 7%, the resulting benefit-cost ratio is 1.36. Under these conditions, $1.36 in present-value benefits would be returned to the community for each $1 in present-value costs; the community project would be most desirable.

If the federal investment tax credit be included, the benefit-cost ratios would be lowered slightly. With a 7% corporate cost of capital, the corporation unit cost would fall from $9.64 to $9.08; with the community cost of capital at 5%, the benefit-cost ratio would be reduced from 1.36 to 1.28.

It has been noted that economies of scale, or increasing returns to outlay, strengthen the comparative advantage of the community project. The possibility of diseconomies of scale bears examination. How strong must diseconomies of scale be to overturn our basic conclusion?

For some idea of the necessary magnitude, let us suppose that the corporate project again has the $10,000,000 initial construction cost, $750,000 annual operation and maintenance costs, and $100,00 salvage value. But let us now assume: that the community project costs $13 million; that operating costs remain at $5.50 per acre-foot, or $550,000; and that maintenance costs remain at 2% of construction costs, or $260,000 per year. Again, the project life in either case is 30 years and the salvage value at the end of year 30 is $100,000.

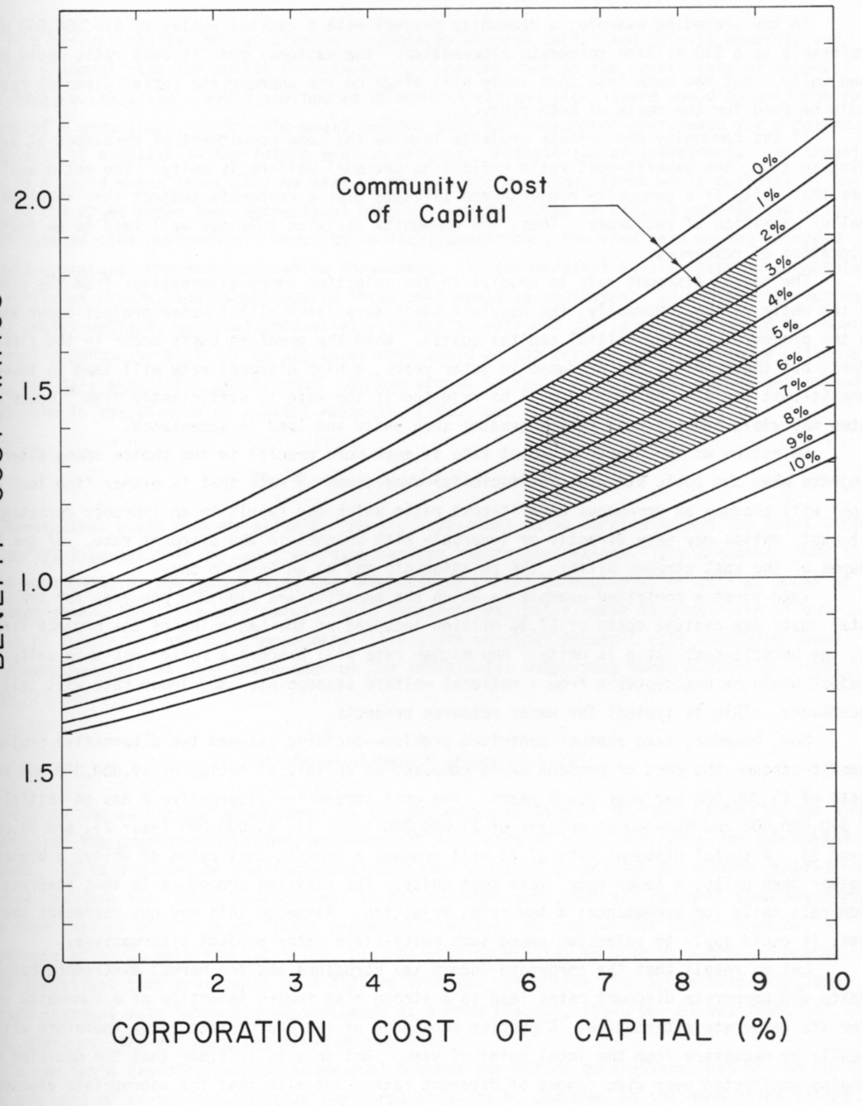
A benefit-cost ratio of unity will result if both the community and corporate rates are 5.8%. Thus a corporate project involving a capital outlay of $10,000,000 costs precisely the same, from the community standpoint, as a community project having a $13,000,000 capital outlay. The use of more realistic rates of 7% and 5% (corporate and community projects respectively) would call for selecting the community project--even if its capital outlay totalled $15,000,000 and maintenance costs were increased proportionately--because the benefit-cost ratio would then be 1.08. Clearly, diseconomies of scale must be substantial if they are to overturn the basic conclusion. Federal and state corporate income taxes, combined with a lower community cost of capital, provide a distinct cost advantage to the community project.

PUBLIC INVESTMENT CRITERIA AND NATIONAL ECONOMIC WELFARE

The literature on public-investment optimization has been concerned only with the effect of capital expenditures on national welfare--principally with federal expenditures. Investments by state and local governments have received scant consideration. The tools developed to analyze federal expenditures remain generally applicable, but the local problem, as it has been shown in the preceding sections, is sufficiently different and requires modification of the analysis.

This situation should be disquieting to welfare economists but we have answered the question: how should a local community choose between alternative water projects?

Existing institutions have formed the framework within which the answer was formulated. Only the viewpoint of the locality has been given consideration. However, it is evident that if the community project requires a commitment of resources considerably in excess of the corporate alternative, it is not optimal for the national welfare.



COMMUNITY PROJECT

BENEFIT - COST RATIOS
(ASSUMING CONSTANT RETURNS TO OUTLAY)

FIG. 4

The Appropriate Social Discount Rate

In the preceding example, a community project with a capital outlay of $15,000,000 was found preferable to a $10 million corporate alternative. The national benefit-cost ratio would be less than unity. But how much less than unity will hinge on the appropriate social discount rate that would be used for the costs of both projects.

If the community and private projects involve the same commitment of resources at every point in time, the benefit-cost ratio reflecting national welfare is unity. The ratio would be less than unity if a community project were selected over a corporate project that required a smaller sacrifice of resources. Thus, the community decision rule may well lead to an inefficient allocation of resources.

The social discount rate is crucial in the selection among alternatives from the viewpoint of the whole nation. Normally, the heaviest costs associated with a water project occur early in the project life (the initial capital costs). When the greatest costs occur in the first few years, but the benefits are produced in later years, a high discount rate will tend to lower the benefit-cost ratio. The project will be rejected if the rate is sufficiently high. Lower discount rates may yield benefit-cost ratios greater than unity and lead to acceptance.

Selection of the proper discount rate is much more crucial in the choice among alternative projects when the costs streams are dissimilar over time. A rate that is either "too low" or "too high" will produce an erroneous benefit-cost ratio which may result in an improper decision. Benefit-cost ratios may vary directly or inversely with changes in the discount rate. If the time shapes of the cost streams differ, the relationship may be an inverse one.

Take first a contrived example in which the benefits are $100,000 per year for ten years and total costs are capital costs of $7.36 million incurred at the beginning of the project life. At 6%, the benefit-cost ratio is unity. Any higher rate will produce a ratio less than unity. The project would be unacceptable from a national welfare standpoint. Any lower rate will call for acceptance. This is typical for water resource projects.

Now, however, take another contrived problem--deciding between two alternative projects. The benefit-stream--the cost of project A--is composed of an initial outlay of $9,000,000 and subsequent costs of $3,300,000 per year for 3 years. The cost stream for alternative B has an initial outlay of $10,000,000 and subsequent outlays of $1,000,000 (year 1), $3,000,000 (year 2), and $5,000,000 (year 3). A social discount rate of 7% will produce a benefit-cost ratio of unity; a higher rate, greater than unity; a lower rate, less than unity. The decision procedure is thus reversed. A high rate calls for acceptance; a low rate, rejection. Although this may not represent the usual case, it could apply to selection among some multi-stage water project alternatives.

Let us recall that the corporate income tax structure and the normal divergence between community and corporate discount rates lead to a strong bias toward selection of a community project over its corporate alternative. A precise knowledge of the appropriate rates therefore will not usually be necessary from the local point of view. Not only is it clear that the decision normally remains unaffected over wide ranges of discount rates, but also that the appropriate discount rates are the community borrowing rate and corporate cost of capital.

Benefit-cost studies of federal investment alternatives are more likely to be in error because there is no unanimity of opinion concerning the social discount rate. Furthermore, the analysis of local water projects from the national welfare viewpoint may lead to mistaken results. A social rate that is "too low" may overstate or understate the benefit-cost ratio, as may a rate that is "too high". Unfortunately, experts not only disagree on the precise social rate, but they even disagree on its theoretical underpinnings. As a result, federal agencies use rates that range from 3% to 12% [Whipple, 1968, pp. 37-45].

The following paragraphs contain a cursory examination of the existing controversy over the social rate of discount. Although only a few of the many conflicting views are presented, they should be sufficient to indicate the scope of the problem.

The Market Rate of Interest

In a perfect capital market with no divergences between social and private benefits and costs, the discount rate for public investment would be the same as the market rate of interest [Arrow, 1966, p. 14]. In a world unaffected by uncertainty and risk, there would be only one rate for loans of a given term. This rate would reflect both the consumers' preference for a dollar today instead of a dollar in the future and the marginal productivity of investments. Abstracting further to a world where taxes play no part in the private decision, firms would optimize by investing to the point where the (decreasing) marginal productivity of capital equaled the (rising) marginal rate of time preference. Under these ideal conditions, the resultant market interest rate would operate as the norm for public investment. If the marginal public investment exhibited a higher rate of return, additional public investment would be indicated. To achieve the optimal state of social welfare, marginal productivity in the private and public spheres should be equated. The "social opportunity cost" of public investment would be the private return foregone [Hirshleifer, DeHaven, and Milliman, 1960, pp. 116-48]. McKean argues in favor of using the market-determined interest rate in the absence of capital rationing [1958, pp. 76-81].

The Conservationist Viewpoint

Other views would perhaps allow for public investment to be carried beyond the point dictated by the market interest rate to conserve resources for future generations. The argument given is that the government is the guardian of the interests of unborn generations, as well as those of the present generation. The government should therefore exhibit a lower marginal rate of substitution of future for present consumption: i.e., its marginal discount rate should be lower than the marginal rate of time preference of the individuals comprising today's society [Pigou, 1962, pp. 23-30].

Dual Individual Time Preference Rates

Akin to the authoritarian argument of the preceding section is one that, based on the time preferences of the present-generation, hypothesizes two rates of time preference for the normal individual. It is grounded on the individual consumer's desire to provide for future generations. One person may care for future generations, so the argument goes, but his personal time preference rate is such that he will give up little present consumption to provide for them. However, if other persons offer to make the sacrifice, too, he will be willing to give up a greater amount. Thus the individual time preference rate differs from the collective time preference rate, and the market interest rate loses its significance as a norm [Baumol, 1952, pp. 91-92; 1965, pp. 131-32; Sen, 1961, pp. 479-96; Marglin, 1963, pp. 95-111].

To use Sen's example, suppose individual A cares for future generations, but not enough to give up one unit of present consumption for three units to be consumed by the generation living twenty years hence. If, however, B, another individual, also offers reduce his consumption by one unit for three in the future, A may be willing to sacrifice his unit because the future generation will then receive six units. Let us not assume, however, that A is concerned only with the welfare of unborn individuals and completely unconcerned with the sacrifices of neighbor B. Individual A may consider one future unit to be worth 0.3 of his own present unit and may feel B's sacrifice of one unit to be 0.7 as unpleasant as sacrificing one unit himself. Saving together, the two men produce six future units having a present value to A of 0.3 x 6.0 = 1.8 units. A's calculation of the present-value cost of this measure, however, is only 1.7 units--1.0 representing his own sacrifice and 0.7 the loss he experiences because of B's unit sacrifice. He therefore feels that the total present-value gain exceeds the total present-valve cost, and is thus willing to give up the one unit of consumption--something he would not have done by himself.

This paradox has been criticized by Tullock [1964, pp. 331-36] because it requires strange individual utility functions. For today's society to desire to provide for tomorrow's undoubtedly richer society is the analog of desiring to tax the poor to support the rich. It is much more likely, says Tullock, that individual preferences will gravitate toward supporting today's poor, or, perhaps through foundations, tomorrow's poor. It is unlikely, he feels, that the individual wishes to support all people of the future generation.

Other Views on the Discount Rate

Krutilla and Eckstein [1958, pp. 78-130] calculate a social opportunity cost of federal capital by considering the impact of alternatives to federal water projects. For instance: tax reductions are hypothesized as alternatives; the investment rates of return available to groups receiving the reductions are weighed into the social opportunity cost. The rate calculated with 1955 data was 5-6%.

Eckstein [1958, pp. 81-90] expresses a different view. Beginning with the riskless market interest rate, he allows for risk in three ways: (1) primarily by adding a risk premium of 0.5 to 1% to the pure interest rate; (2) by shortening the period of analysis; and (3) by incorporating safety allowances in the cost and benefit streams.

Hirshleifer, DeHaven, and Milliman [1960, pp. 116-21, 139-48] begin with the pure market interest rate (estimated at 4% in April, 1960, but undoubtedly higher at present), and modify it by considering risk, equity financing, and the corporate income tax to obtain a rate slightly over 10%. Their argument is that, for optimal resource allocation, the public discount rate should be equal to the return demanded by the private market on utility investments. If the rate used by the government is lower, better investment opportunities exist in the private sphere. Total productivity, hence benefits to society, would be enhanced by reducing public investment and increasing private investment. They believe that the rate resulting from time preferences (and productivity) exhibited by the present generation need not be modified for the claims of posterity. If a disparity does exist between the market interest rate and the rate that would properly satisfy the claims of the future, it would be better for the government to take appropriate monetary and fiscal action to drive them to equality than to use different discount rates in the private and public spheres. Equating the rates would prevent the inefficiencies that would be caused by divergent public and private marginal productivities of investment [1960, p.120].

Arrow [1966, pp. 13-32] approaches the problem by noting that there is a "natural rate of interest" associated with the "natural rate of growth." Utilizing a Harrod-type growth model, he derives the natural rate of interest as the sum of two terms: (1) the equivalent of Bohm-Bowerk's first reason for interest, the lower marginal utility of future consumption due to expected growth in wealth; and (2), equal to his second reason, systematic undervaluation of future utilities. Although this natural rate of interest is the proper rate for public discounting, there is another rate for discounting returns to private investment. The rates should be different to obtain maximum welfare under the condition of steady growth--a type of "constrained" optimum limited by conditions. A true optimum can only be achieved if the government always uses the proper monetary and fiscal policy (including repayment of the national debt, if required) to overcome divergence between the true time preference and the preference observed in the market. Should this unlikely condition obtain, the riskless private and public rates would be identical.

Application to Local Project Analysis

Although the preceding discussion falls far short of exhausting the subject, it should make clear that the matter of the national discount rate is not yet settled. Should one desire to compute a national benefit-cost ratio for a local project, he would have to recognize that his answer may or may not indicate true efficiency. Using a "reasonable" range of discount rates, one may find that the ratio always falls above or below unity or else discover a ratio less than unity for some rates and greater than unity for others. Which answer is correct?

Fortunately, economic analysis from the local viewpoint is not likely to encounter such ambiguity. The corporate income tax, which helps obscure the national discount rate, can be given some credit for simplifying the local problem.

CONCLUSIONS

The basic proposition of this chapter has been that benefit-cost analysis is an appropriate procedure for evaluating community investments in water projects. Because such projects are long-lived, with cost and benefit streams extending many years into the future, the costs and benefits must be discounted for purposes of comparsion. The relevant cost for the comparison is the present-value unit cost of water, an internal price just sufficient to cover all costs associated with the project.

The rate at which costs and outputs should be discounted is the cost of capital to the organization undertaking the project. Although the corporate cost of capital has a definite meaning, the difficulties involved in its measurement require the use of a range of discount rates to approximate a "true" cost of capital.

Because water replacement projects may be undertaken by either corporate users on a private, individual basis or collective community action, the comparison in this chapter was between a corporate project and a non-profit community project. With the assumptions of constant returns to outlay and equal costs of capital, the present-value unit cost of water is lower for the corporate than for the community project. This disparity results from the corporate income tax structure. However, since the cost of water produced by the corporate project was found to be greater than the cost of purchasing water from the community project, the basic conclusion is that the benefit-cost ratio for the community will exceed unity; hence it is in the best interest of the community to decide in favor of the non-profit community project. In other words--the benefits to the community (measured by the cost of the best corporate alternative) exceeds the after-tax costs associated with purchasing from the community project. Inasmuch as the community project will be larger than individual corporate projects, increasing returns to scale in the production of water strengthen the advantage of the community project. Decreasing returns to scale, on the other hand, work to the advantage of the smaller corporate project and decrease the community benefit-cost ratio. In most instances, the differences in the cost of capital will operate in favor of the community project.

In the numerical examples, the community project costs of capital that are lower than those for the corporate project will give community benefit-cost ratios that exceed unity by a substantial margin. Construction and maintenance costs for the community project must be a great deal higher than those for the corporate project to eliminate the community advantage. Thus, although diseconomies of scale weaken this advantage that makes it that more economical for the corporation to purchase water from the community project, they must be very strong before the advantage is reversed. In short, the community project is found to have an inherent cost advantage resulting from the corporation income tax structure. Moreover, this advantage is likely to be strengthened by a cost of capital that is lower for the community than for the corporate project.

The community benefit-cost ratio differs from one computed to reflect the national welfare. A project that is justified from the community standpoint may not be efficient for the whole country. However, because there is no consensus on the social discount rate to be used for computing the national benefit-cost ratio, the results of any comparison will most likely be ambiguous.

reliance has been placed upon imported river water. For example: the direct use of imported water amounted to only 74,000 acre-feet in 1950, but by 1965, 287,000 acre-feet, or slightly more than 50 percent of the total use, were delivered directly. Moreover, imported water has been an important source of recharge for the ground-water basins.

Currently, the West and Central ground-water basins yield 280,000 acre-feet of ground water per year. As natural recharge is not sufficient to sustain this production, large amounts of imported water, local runoff, and small amounts of reclaimed sewage water are spread in the forebay (non-pressure) area and join the main body of ground water in the aquifers of the seaward pressure area. However, because the principal well fields in the pressure area are at some distance from the forebay, spreading alone has not been sufficient to prevent intrusion of ocean water. Consequently, two fresh-water injection barriers have been constructed. They also serve as an additional source of recharge.

Direct delivery from the Colorado River through the Colorado River Aqueduct is the principal source of imported water. In addition, about 25,000 acre-feet of water are obtained through the Whittier Narrows from the upper San Gabriel Valley. Finally, that part of the District that lies within Los Angeles proper also receives Owens River-Mono Basin water (from the Sierra Nevada mountains) that is commingled with ground water from the San Fernando Valley and delivered through the Los Angeles Aqueduct [Central and West Basin Water Replenishment District, 1966, pp. 25-29].

The hydrographical characteristics of the Replenishment District, combined with its high population density and industrial base, have led to a high cost of water. Bookman and Edmonston [Central and West Basin Water Replenishment District, 1967, pp. 12-14], consulting Civil Engineers, estimate that the district capital investment in local water facilities totals $423 million (reproduction cost-new). The annual total cost of ground-water production, including operation, maintenance and amortization for the wells as well as for the spreading and barrier facilities, is $51 million. To this must be added: (1) $14 million yearly for purchasing imported water; (2) a basic M. W. D. tax of $9 million, which does not include special "back taxes" paid by areas of the District annexed to the M.W.D. subsequent to its inception; and (3), about $3 million in yearly earnings of private water companies. The resulting total, $77 million, divided by the current annual use of 600,000 acre-feet, yields an average cost of $130 per acre-foot.

Averages, however, may be highly misleading; the average cost of water in the Replenishment District is no exception. The main purpose of this case study is to examine in detail the average and marginal costs of water, both to individual users and to the District as a whole. Efficient use of water requires that allocation of the limited supply be such that an increment have the same value in each use and that this value be equal to the cost to society.

A second purpose is to determine to what extent existing arrangements either aid or hinder efficient allocation. An analysis is first made of the average and marginal costs of ground water to ground-water producers. Then private and social costs of ground-water production are compared and implications drawn for economic efficiency.

Next, the cost of imported water is examined and the pricing practices of the Metropolitan Water District of Southern California are analyzed. Finally, the question of the conjunctive use of water is explored, and the rationing of ground water through quotas is compared with a pumping assessment alternative.

GROUND WATER

The Central and West Coast ground-water basins are fed naturally by percolation into the forebay areas in the northeastern part of the Central Basin. Originally, water moved seaward through the aquifers to the south and west. About 10,000 acre-feet per year flowed into the West Coast Basin across the Newport-Inglewood fault, which separates the two basins. Some water also flowed south from the Central Basin into the ground-water basins of Orange County. Fresh water from the basins finally moved into the Pacific Ocean at points of aquifer outcrop.

From modest beginnings, late in the last century, ground-water production increased until withdrawals began to exceed total recharge during the 1930's. As water levels in the West Coast Basin declined, the movement across the fault from the Central Basin increased to its present level of 20,000 to 25,000 acre-feet each year. Increased production in the Central Basin has reversed the flow across the Orange County line; now 29,000 acre-feet move annually from Orange County into the Central Basin.

Of more significance: After pumpage in excess of natural recharge had reversed the natural seaward gradient, sea water moving into the aquifers along the coast line causes the abandonment of some wells in coastal communities and threatened much of the remainder of the ground-water basins [Ostrom, 1965, pp. 110-112].

Quite early, private water companies, county waterworks districts, cities, industrial plants, and concerned private citizens became involved in efforts to preserve and supplement the existing water supply [Ostrom, 1953, pp. 116-122]. The execution of each scheme occasioned the formation of a new agency or the assignment of new responsibilities to an existing agency. No existing agency was given overall authority, nor was any new agency created with such powers. Despite this proliferation of agencies and the division of responsibilities, the handling of the basin water problems has been well coordinated through voluntary agreement. [Bookman, 1968, pp. 176-181].

Four principal measures have been taken to protect the ground-water supply. First: facilities were constructed for the capture and spreading of local runoff for percolation into the principal aquifers. From 1938 through 1966, an average of 27,000 acre-feet of runoff were conserved and spread annually. Currently, runoff conservation averages 38,000 acre-feet per year [Milne, 1968, p. 139].

The wide variation in precipitation, and hence in the local runoff, prompted the District to purchase water for spreading in the forebay areas. In recent years, an average of 130,000 acre-feet has been purchased annually, most of which has been Colorado River water purchased at special off-peak rates from the Metropolitan Water District. About 15,000 acre-feet of reclaimed sewage also is spread each year [Central and West Basin Water Replenishment District, 1966, p. 54].

The adjudication of ground-water rights, first in the West Basin and then in the Central Basin, was an attempt to fix maximum production levels and ration the existing supply. An interim agreement (March 1, 1955) voluntarily restricted pumping in the West Coast Basin. On October 1, 1961, with litigation completed, the adjudicated water rights totaled 64,137.55 acre-feet per year.

An agreement to restrict production in the Central Basin became effective on October 1, 1963. The final judgement, rendered effective October 1, 1966, limited the total pumpage to 217,400 acre-feet per year. Current annual extractions are very close to the total adjudicated rights for the two basins [Milne, 1968, pp. 133, 139].

The fourth (and most recent) measure has been the construction of two fresh-water injection barriers to halt salt-water intrusion. The first project, ultimately to be an 11-mile line of injection wells to protect the West Coast Basin, is now (1969) about 70 percent complete. It uses 45,000 acre-feet of Colorado River water. In the one-mile long Alamitos Barrier Project, 5,000 acre-feet are injected to protect a portion of the Central Basin [Bruington, 1968, p. 162]. A third barrier project has been proposed for the West Coast Basin at Dominguez Gap [Central and West Basin Water Replenishment District, 1966, p. 20]. Despite the measures taken to protect existing ground-water supplies, the growing demand for water still requires importation of increasing amounts of Colorado River water.

Each project involves costs that, with the exception of adjudication, are covered by annual payments in the form of ad valorem taxes, pumping assessments, or direct payments for purchased water.

COSTS TO WATER USERS

Direct Costs

The direct cost of ground water to an individual producer includes: (1) capital costs associated with drilling and well completion; (2) pumping costs; and (3) the pumping assessment levied by the Replenishment District. Because capital costs per acre-foot are affected by a number of variables, such as the depth and diameter of the well, the type of pipe and appurtenances and--most important--the extent of use, any estimate of average capital recovery is arbitrary. It is about $2.80 per acre-foot for a company that produces 1,000 to 1,400 acre-feet per year. This estimate is based on figures obtained in 1966 from the Los Angeles Flood Control District. For a different and higher estimate, see Bookman and Edmonston (Central and West Basin Water Replenishment District, 1967, p. 10). Pumping costs are about $7.00 per acre-foot, on the basis of data obtained from the same agency. The Replenishment-District pumping assessment is based on the annual replenishment needs of the basins. For the water year 1966-67, the assessment was $6.20 per acre-foot [Central and West Basin Replenishment District, 1966, p. 63]. Thus, the average producer of ground water, with all wells completed, bears a direct cost of $16.00 per acre-foot, of which $13.20 is short-run variable cost.

Indirect Costs

Several special ad valorem taxes provide revenue to finance the District water program. Because these are levied on property values, their amount is independent of the quantity of water used by the individual consumer. It may then be treated as a fixed cost that varies only with tax rates or assessed property valuation. This means that a substantial portion of the cost of water is made independent of water use and is borne by the property owner.

An ad valorem tax is levied to support benefit zones I and II in the Los Angeles Flood Control District (that together include most of the Replenishment District). The tax receipts are used to purchase replenishment water and finance the construction of barrier projects. In the fiscal year 1967, the rate was $0.05 per $100 of assessed valuation of land and improvements. The District general fund comes from another ad valorem levy, part of which is used to finance water spreading. The portion of the levy used for spreading was estimated at $0.00369 per $100 of assessed valuation for the same year. (This rate was calculated from: the cost of spreading 130,000 acre-feet of purchased water, including sewage, estimated at $1 per acre-foot; estimated cost of spreading the current average of about 38,000 acre-feet of runoff, $10 per acre-foot. Thus the total cost of spreading operations including amortization of facilities, is approximately $510,000, representing 2.46 percent of the $20,736,944 collected from the full general-fund levy).

The Metropolitan Water District also levies property taxes to meet a portion of the current and expected future costs of importing water into the area. The balance is paid directly by the West Basin and Central Basin Municipal Water Districts, which function as wholesalers. They in turn receive payments from users. In 1967, the rate was $0.14 per $100 of assessed valuation on all taxable property (personal property as well as land and improvements). In addition, a special "back tax" is collected from those areas in the basins that were annexed to the M.W.D. after it began delivering Colorado River water to the Los Angeles metropolitan area. The "back tax", varying widely within the District, now ranges from zero to $0.13 per $100 of assessed valuation on all taxable property, and will continue in the originally-annexed portion of the West Coast Basin until 1978; in the Central Basin original area, until 1984.

Finally, the Central and West Basin Water Replenishment District levies a property tax to cover the administrative costs connected with its replenishment activities. The rate for 1967 was $0.002 per $100 of assessed valuation [Los Angeles County, 1967, pp. 49-76]. The average ratio of assessed value to actual value or selling price for residential property is about 20 percent in Los Angeles County. For industrial property, the rate is considerably higher--about 45 percent. The assessment ratio for public utilities is thought to be close to 50 percent. However, the state plans to have all assessments equalized at 25 percent of market value by 1971 [Mr. Frank Thill, California Taxpayers' Association, personal conversation].

Average Total Cost of Ground Water

Table 5 shows the estimated average total costs for ground-water production for companies with market values of 10, 50, and 100 million dollars and for selected annual pumping rates from 50 to 10,000 acre-feet. (The calculations are explained in the Appendix, Example 1.) For simplicity, the effects of corporate income tax on after-tax costs are ignored; however, no qualitative changes would result from their inclusion in this analysis.

TABLE 5

AVERAGE TOTAL WATER COSTS TO GROUND WATER-PRODUCERS
(M.W.D. Tax $0.14 and $0.27 per $100)
(Dollars per Acre-Foot)

Annual Ground-Water Production (Acre-Feet)	Plant Valuation (Market Value)					
	$10,000,000		$50,000,000		$100,000,000	
	(0.14)	(0.27)	(0.14)	(0.27)	(0.14)	(0.27)
50	193.16	310.16	837.48	1,422.48	1,642.88	2,812.88
100	103.18	161.68	425.34	717.84	828.04	1,413.04
500	33.09	44.79	97.52	156.02	178.06	295.06
1,000	24.18	30.03	56.40	85.65	96.67	155.17
5,000	16.58	17.75	23.02	28.87	31.08	42.78
10,000	15.68	16.27	18.91	21.83	22.93	28.78

The calculations in Table 5 use both the minumum, or normal, M.W.D. levy of $0.14 per $100 of assessed valuation and the maximum rate of $0.27. We see immediately that the user's location within the District makes a substantial difference in his unit cost of water. For example: for a $50,000,000 plant that produces 1,000 acre-feet per year in an area which pays no "back tax" to the M.W.D., water costs $56.40 per acre-foot; for a comparable plant in an area subject to the highest M.W.D. levy, the cost is $85.65.

The most important point demonstrated in Table 5 is that the effective cost of ground water varies inversely with production. The reason again is that a significant part of the cost is borne in the form of ad valorem, or property, taxes and is thus independent of water use.

Property owners who do not use ground water subsidize ground-water users. Such an arrangement raises questions of both equity and economic efficiency. On grounds of equity, the heavy reliance on ad valorem taxes has been justified "by those who made the decision on the assumption that the land value had increased as a result of the assurance of a firm water supply." In effect, it was "assumed that a positive externality had been created of benefit to the taxpayer which was as large or larger than the tax burden." [Ostrom, 1965, pp. 570-71] No attempt is made here to appraise this equity argument. At best, it appears questionable.

Extensive use of ad valorem taxes leads to inefficient allocation of resources. Consider first the direct cost to the user of producing an additional acre-foot of ground water. If the wells are being operated below capacity, the user's cost is the sum of the pumping cost and the District pumping assessment, or $13.20 per acre-foot. This value is representative of what economists refer to as a short-run marginal cost--the cost of increasing production by a small increment. We assume this cost to be constant up to the well capacity. Thus we ignore the effect of increased pumping on the water levels and, hence, pumping costs. Our justification is that, with a high coefficient of aquifer transmissibility, small increases in pumping by one producer will have negligible effects on the water levels. The assumption has to be made that marginal pumping cost is the same for every pumper. This assumption is incorrect to the extent that there are differences in well depth (measured from the land surface to the well water levels).

A contrasting possibility that will not be discussed here has been presented by Hirshleifer, DeHaven, and Milliman [1960, p. 65]. Consider the case of an individual producer whose pumping draws down his own water levels, thus generating a rising marginal-cost curve. Here the falling water levels also affect his neighbor by pushing marginal social costs above marginal private costs.

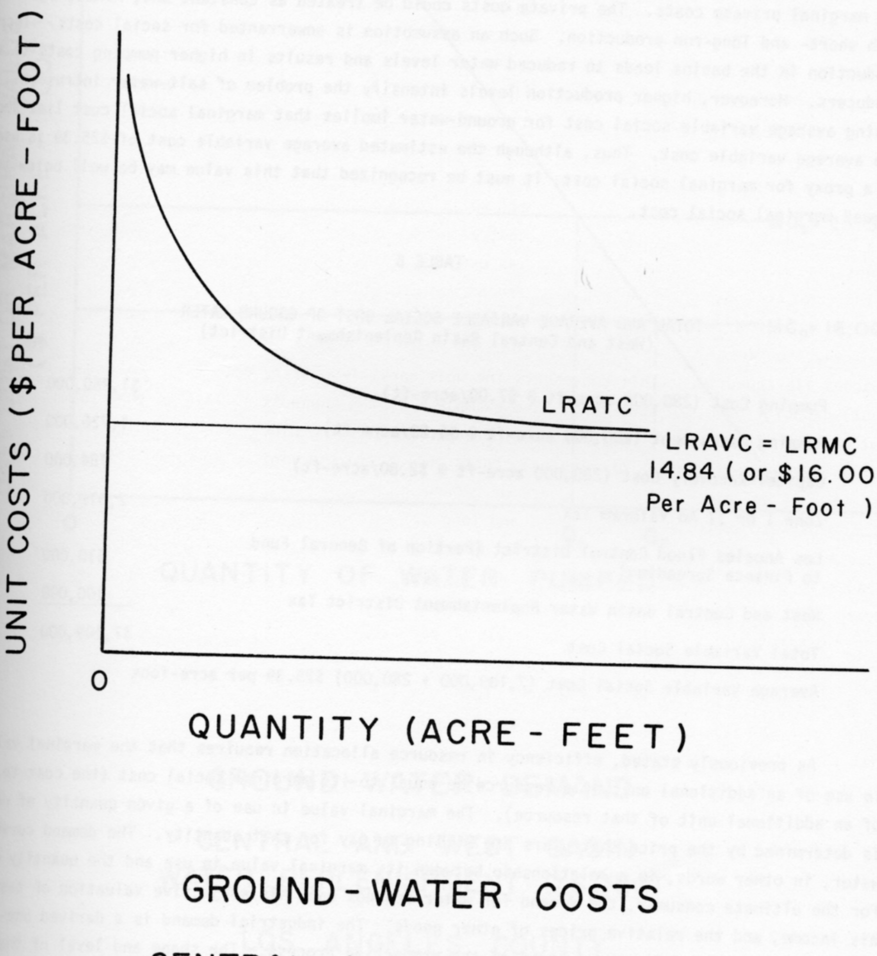
After the maximum capacities of all wells are reached, the producer can increase his output only by expanding his well field. The cost of producing a small increment of water thus rises abruptly at maximum capacity level, or, as economists would say, the marginal cost is discontinuous at the capacity output. A decision to expand the capacity, or, for that matter, to maintain a constant capacity, involves additional capital. The capital cost per unit varies greatly with the production level. It reaches a minimum of $1.64 per acre-foot as the existing well field approaches its capacity. (This represents the unit capital-recovery cost for a well used to its annual capacity of 2,420 acre-feet. See example 1 in the Appendix.) This is the minimum amount that must be considered in decisions to increase the existing capacity. By adding this value to short-run average variable, or marginal, costs, we obtain the minimum long-run average variable cost--$14.84 per acre-foot to producers of ground water. (In the usual case, no distinction would be made between long-run average total and long-run average variable cost. It must be made here because the ad valorem taxes in the costs do not vary with output either in the long or short run.) Because in practice the well field will not be operated at full capacity, the unit capital recovery cost will exceed $1.64. Use of our estimated capital-recovery cost of $2.80 will give the long-run marginal private cost of about $16.00 per acre-foot.

To summarize our findings with respect to private costs: a large fraction of the total cost of ground water is fixed or independent of the amount produced by an individual producer in both short- and long-run production. Consequently, the average total cost of production varies inversely with the output level. The average variable cost, and hence the marginal cost, is constant for short-run production. For output below capacity, this cost can be taken as the sum of pumping costs and the pumping assessment ($13.20 per acre-foot). Finally, the capacity is a variable that can be either expanded by the addition of wells or diminished by failure to replace depreciating equipment. Thus, in the long run, capital-recovery costs must be included. The figure of $16.00 has been taken, somewhat arbitrarily, as an approximation of the long-run average variable and marginal cost. The relationship between the two costs is shown in Figure 6.

THE SOCIAL COST OF GROUND WATER

The financing of part of the costs of protecting and supplementing the water supply by ad valorem taxes transfers costs from water users to property owners. A second, more important effect of such taxes is the divergence between private and social costs, and, what is really significant from the standpoint of economic efficiency, the resulting discrepancy between marginal social and marginal private costs. To draw any conclusions concerning efficiency, we must calculate the marginal social cost of ground water and compare it with the marginal private cost.

Receipts from three ad valorem taxes are used to defray costs that, from the District stand-



GROUND-WATER COSTS

CENTRAL AND WEST BASIN
WATER REPLENISHMENT DISTRICT

LOS ANGELES COUNTY

FIG. 6

point, are variable. The costs of ground-water replenishment and barrier construction are variable in the sense that they depend on the level of ground-water production. Financing these costs by ad valorem taxes converts them into costs that are fixed, from the standpoint of water producers. The estimated social cost of ground-water, presented in Table 6, is substantially higher than the $16.00 found for long-run average variable private costs.

Average variable and marginal social costs have a more tenuous relationship than average and marginal private costs. The private costs could be treated as constant and, hence, equal in both short- and long-run production. Such an assumption is unwarranted for social costs. Increased production in the basins leads to reduced water levels and results in higher pumping costs to all producers. Moreover, higher production levels intensify the problem of salt-water intrusion. A rising average variable social cost for ground-water implies that marginal social cost lies above the average variable cost. Thus, although the estimated average variable cost of $25.39 is used as a proxy for marginal social cost, it must be recognized that this value may be well below the "true" marginal social cost.

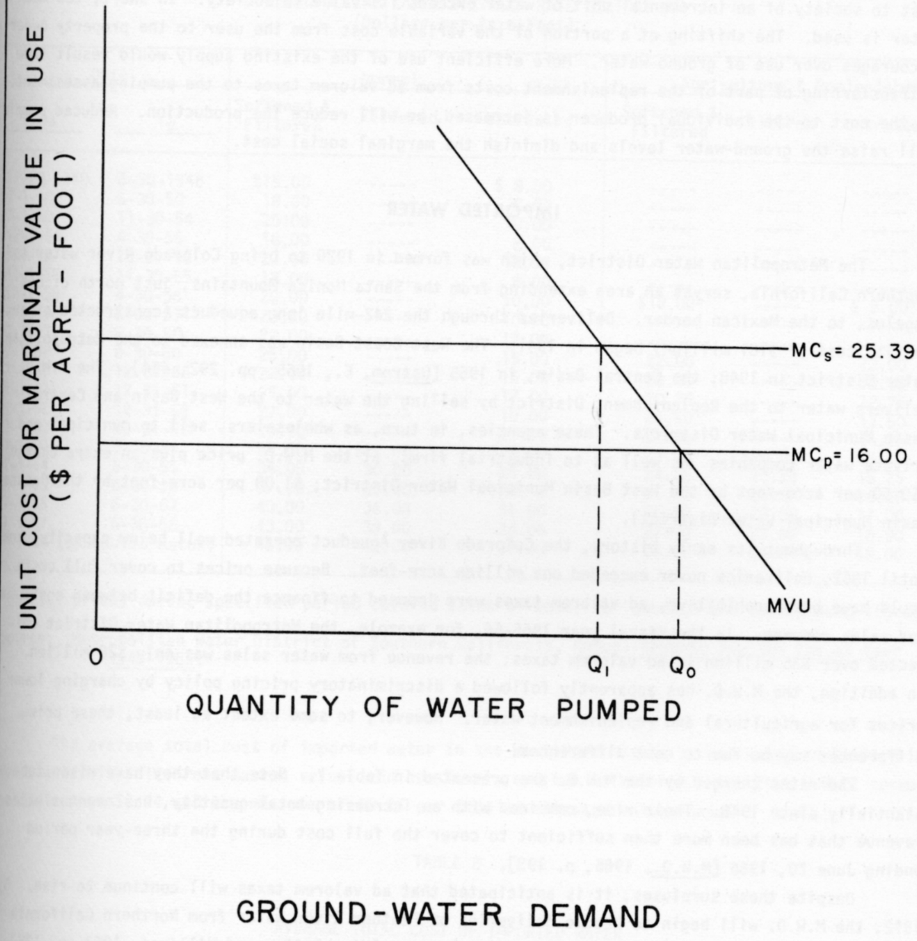
TABLE 6

TOTAL AND AVERAGE VARIABLE SOCIAL COST OF GROUND WATER
(West and Central Basin Replenishment District)

Pumping Cost (280,000 acre-ft @ $7.00/acre-ft)	$1,960,000
Pumping Assessment (280,000 acre-ft @ $6.20/acre-ft)	1,736.000
Capital Recovery Cost (280,000 acre-ft @ $2.80/acre-ft)	784,000
Zone I or II Ad Valorem Tax	2,019,000
Los Angeles Flood Control District (Portion of General Fund to Finance Spreading)	510,000
West and Central Basin Water Replenishment District Tax	100,000
Total Variable Social Cost	$7,109,000
Average Variable Social Cost (7,109,000 ÷ 280,000) $25.39 per acre-foot	

As previously stated, efficiency in resource allocation requires that the marginal value in use of an additional unit of a resource be equal to its marginal social cost (the cost to society of an additional unit of that resource). The marginal value in use of a given quantity of water is determined by the price that users are willing to pay for that quantity. The demand curve for water, in other words, is a relationship between its marginal value in use and the quantity consumed. For the ultimate consumer, the demand for water depends upon his subjective valuation or tastes, his income, and the relative prices of other goods. The industrial demand is a derived one--it depends on the demand for the outputs of the productive process. The shape and level of the industrial demand schedule is also influenced by the state of technology and the prices of other resources or inputs. Essentially, the quantity of water demanded is a decreasing function of the price that must be paid, either by consumers or by business firms. In other words--the marginal value in use declines as quantity is increased.

This argument is graphically represented in Figure 7. The curve MVU is the demand curve of any individual user of ground water; MC_p, the marginal private cost (estimated to be $16.00); and MC_s, the marginal social cost, which is at least $25.39. The individual user has an incentive to increase his use to the point where his marginal cost is equal to his marginal value in use. For smaller quantities, the value of an additional unit of water is more than its cost. For greater quantities, however, the cost of additional units exceeds their value and the user would gain by diminishing his use. Thus Q_o represents the optimal quantity for the individual producer.



GROUND-WATER DEMAND

CENTRAL AND WEST BASIN

WATER REPLENISHMENT DISTRICT

LOS ANGELES COUNTY

FIG. 7

At this level, however, the marginal social cost is greater than the marginal value in use to the individual producer. If the latter reflects the marginal value in use to society, then the cost to society of an incremental unit of water exceeds its value to society. In short, too much water is used. The shifting of a portion of the variable cost from the user to the property owner encourages over use of ground-water. More efficient use of the existing supply would result from a transferring of part of the replenishment costs from ad valorem taxes to the pumping assessment. As the cost to the individual producer is increased, he will reduce the production. Reduced pumping will raise the ground-water levels and diminish the marginal social cost.

IMPORTED WATER

The Metropolitan Water District, which was formed in 1928 to bring Colorado River water to Southern California, serves an area extending from the Santa Monica Mountains, just north of Los Angeles, to the Mexican border. Deliveries through the 242-mile long aqueduct (constructed at an initial cost of $181 million) began in 1941. The West Coast Basin was annexed to the Metropolitan Water District in 1948; the Central Basin, in 1955 [Ostrom, E., 1965, pp. 292, 494]. The M.W.D. delivers water to the Replenishment District by selling the water to the West Basin and Central Basin Municipal Water Districts. These agencies, in turn, as wholesalers, sell to municipal and private water companies as well as to industrial firms, at the M.W.D. price plus an extra charge ($0.50 per acre-foot by the West Basin Municipal Water District; $1.00 per acre-foot by the Central Basin Municipal Water District).

Throughout its early history, the Colorado River Aqueduct operated well below capacity, and until 1962, deliveries never exceeded one million acre-feet. Because prices to cover full costs would have been prohibitive, ad valorem taxes were imposed to finance the deficit between costs and sales revenue. In the fiscal year 1965-66, for example, the Metropolitan Water District collected over $35 million in ad valorem taxes; the revenue from water sales was only $28 million. In addition, the M.W.D. has apparently followed a discriminatory pricing policy by charging lower prices for agricultural and replenishment water. However, to some extent at least, these price differences may be due to cost differences.

The rates charged by the M.W.D. are presented in Table 7. Note that they have risen substantially since 1948. Their rise, combined with an increasing total quantity, has meant a sales revenue that has been more than sufficient to cover the full cost during the three-year period ending June 20, 1966 [M.W.D., 1966, p. 193].

Despite these surpluses, it is anticipated that ad valorem taxes will continue to rise. By 1972, the M.W.D. will begin to handle deliveries of Feather River water from Northern California at an estimated cost of $65 per acre-foot for new water [Hirshleifer and Milliman, 1967, p. 175]. The past history suggests that the rising cost of imported water will be met by some combination of increased price and ad valorem taxes.

Cost of Imported Water

The direct cost to the user of imported water includes the price that he must pay to the municipal water district. For softened and filtered water in fiscal 1967, this price was $40.50 per acre-foot in the West Basin and $41.00 per acre-foot in the Central Basin. In addition, the user of M.W.D. water must initially pay for a connection to a M.W.D. feeder. A typical industrial plant located in a feeder area would pay between $30,000 and $50,000 for the connection [Milne, Clinton, Los Angeles Flood Control District, personal conversation]. If the plant is not located in a feeder area, it must also bear the cost of a line from the feeder to the plant. Furthermore, the user of imported water may need to provide temporary storage to fill minimum needs during a line breakdown. Thus the industrial water user has capital recovery costs. Moreover, he must pay the same ad valorem taxes that ground-water users must pay.

TABLE 7

METROPOLITAN WATER DISTRICT RATE HISTORY
(Dollars per Acre-Foot)

Date		Normal			Agriculture & Replenishment		
From	To	Softened & Filtered	Filtered	Untreated	Softened & Filtered	Filtered	Untreated
12-20-1940	6-30-1948	$15.00	-----	$ 8.00	-----	-----	-----
7-1-48	6-30-50	18.00	-----	8.00	-----	-----	-----
7-1-50	11-30-54	20.00	-----	10.00	-----	-----	-----
12-1-54	4-30-55	18.00	-----	8.00	-----	-----	-----
5-1-55	10-31-55	22.00	-----	10.00	-----	-----	-----
11-1-55	11-30-55	18.00	-----	8.00	-----	-----	-----
12-1-55	4-30-56	20.00	-----	10.00	$18.00*	-----	$ 8.00*
4-30-56	6-30-57	20.00	-----	10.00	-----	-----	-----
7-1-57	6-30-58	22.00	-----	12.00	-----	-----	-----
7-1-58	6-30-60	25.00	-----	15.00	22.00	-----	12.00
7-1-60	12-31-60	23.00	-----	15.00	20.00	-----	12.00
1-1-61	12-31-61	25.00	-----	17.00	20.75	-----	12.75
1-1-62	12-31-62	27.00	-----	19.00	21.50	-----	13.50
1-1-63	12-31-63	29.00	-----	21.00	22.25	-----	14.25
1-1-64	6-30-64	32.00	$29.00	24.00	23.00	$20.00	15.00
7-1-64	6-30-65	34.00	30.00	25.00	24.25	20.25	15.25
7-1-65	6-30-66	37.00	33.00	28.00	25.00	21.00	16.00
7-1-66	6-30-67	40.00	36.00	31.00	26.00	22.00	17.00
7-1-67	6-30-68	43.00	39.00	34.00	27.00	23.00	18.00
7-1-68	(Scheduled Rates)	46.00	42.00	37.00	28.00	24.00	19.00

*Special prices during specified period covered sales of water for surface and underground storage.

Source: Metropolitan Water District of Southern California, Annual Reports for the Fiscal Year 1940-1965.

The average total cost of imported water in the West Coast Basin is estimated in Table 8 for plants with different market values and use levels and two ad valorem rates (the M.W.D. normal or minimum of $0.14 and the maximum of $0.27 per $100 of assessed valuation).

TABLE 8

AVERAGE TOTAL COST OF IMPORTED WATER
WEST COAST BASIN*
(M.W.D. Tax--$0.14 and $0.27 per $100)

(Dollars per Acre-Foot)

Annual Water Use--Acre-Feet	Plant Valuation--Market Value					
	$10,000,000		$50,000,000		$100,000,000	
	(0.14)	(0.27)	(0.14)	(0.27)	(0.14)	(0.27)
50	257.58	374.58	901.90	11,486.90	1,707.30	2,877.30
100	149.04	207.54	471.20	763.70	873.90	1,458.90
500	62.21	73.91	126.64	185.14	207.18	324.18
1,000	51.35	57.20	83.57	112.82	123.84	182.34
5,000	42.67	43.84	49.11	54.96	57.17	68.87
110,000	41.58	42.17	44.81	47.73	48.83	54.68

*For the Central Basin, add $0.50 per acre-foot

A sample calculation is provided in the Appendix (Example 2). The differences within a given column indicate the inverse relationship between use and average cost attributable to ad valorem taxes. Comparison of the costs at the minimum and maximum ad valorem rates show the effect of location within the basin. A comparison of Table 8 with Table 5 reveals the large differential between the costs of ground water and imported water.

Social Cost of Imported Water

The short-run marginal social cost of M.W.D. water in the Central and West Coast Replenishment District is fixed by the pricing policy of the M.W.D. For normal use, this cost was equal in fiscal 1967 to the short-run marginal private cost of $41.00 in the Central Basin and $40.50 in the West Basin. A calculation of the long-run marginal social cost must take into account the construction of additional feeders and user connections. To the extent that these costs are borne by water users, either in the form of increased prices or initial capital outlays, long-run marginal private costs accurately reflect social costs. However, to the extent that construction of new feeders by the M.W.D. are financed by ad valorem taxes, long-run marginal private costs are less than social costs. The discrepancies, if any, between social and private marginal costs of imported water are small compared to the discrepancies for ground water and may be ignored for all practical purposes.

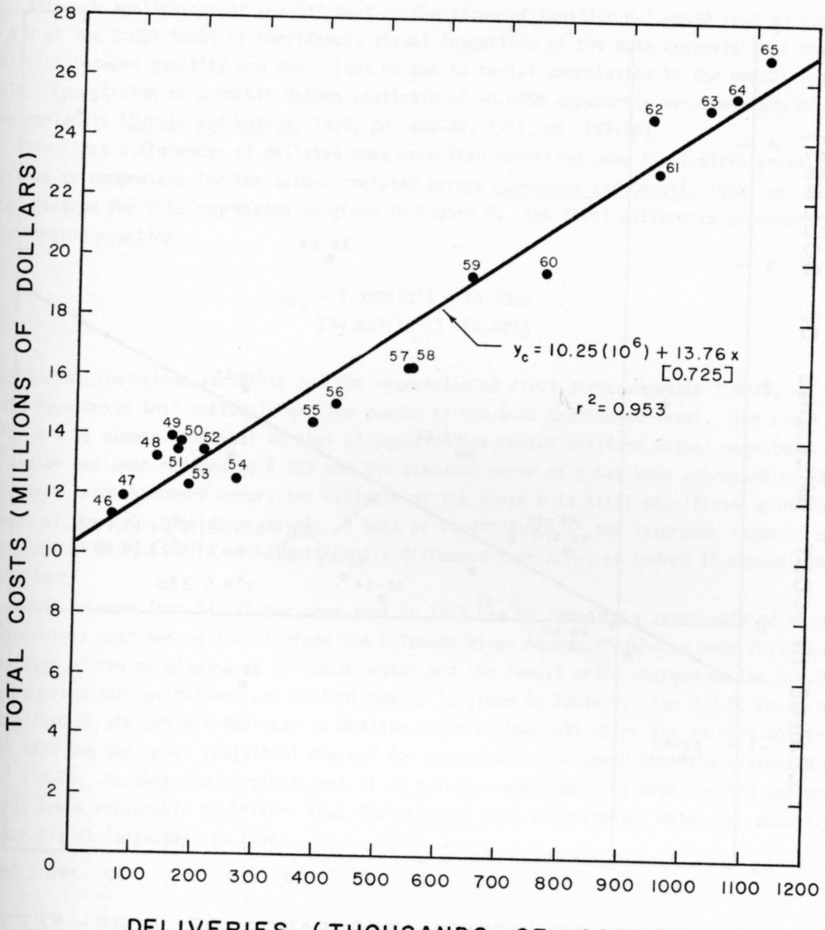
A more fundamental question concerns the pricing policy. Do the prices charged by the M.W.D. correspond to the marginal social cost of imported water? This question is not easily answered. One may first consider the timing of the construction of the Colorado River Aqueduct. Economic justification would have required that the total after-tax, present-value unit cost of aqueduct water delivered to the South Coastal Area be no higher than the after-tax unit cost of the existing supply at the time deliveries first began. The aqueduct operated well below capacity for many years after deliveries began, despite the financing of the major portion of its cost by ad valorem taxes. This condition, coupled with the fact that M.W.D. prices alone have exceeded ground-water costs for many years, is evidence that the aqueduct was prematurely constructed and overdesigned with regard to capacity. In short, the marginal social cost of Colorado River water greatly exceeded its marginal value in use.

Once the aqueduct was in operation, however, the costs of its construction became irrelevant for pricing policy. If the aqueduct is operated at less than capacity, the marginal social cost of delivering an additional acre-foot of water to southern California is simply the addition to operating cost plus the costs of any required new feeders and other facilities.

An attempt was made to estimate this marginal social cost from data in the annual reports of the M.W.D. for the period from 1946 to 1965. Because two types of water (softened and filtered or untreated) were sold, an output index was constructed by weighting each type by its average rage price. The underlying assumption, that price differentials reflected cost differentials, is not entirely true. Part of the average price differential probably resulted from price discrimination based on demand differentials. The remaining differences between M.W.D.'s prices for "normal" and "agriculture and replenishment use," however, are clearly <u>not</u> due to discrimination. Deliveries through laterals that extend into the highly-populated areas are undoubtedly more costly than agricultural and replenishment deliveries. As compensation for changes in the price level, all costs (except depreciation and interest) were deflated by an index of earnings for contract construction in California. A scatter diagram relating deflated cost figures to output was then plotted (Figure 8).

Because the scatter of points appeared linear, a linear estimating equation was used to find parameters by "least-squares" fitting. The resulting equation is

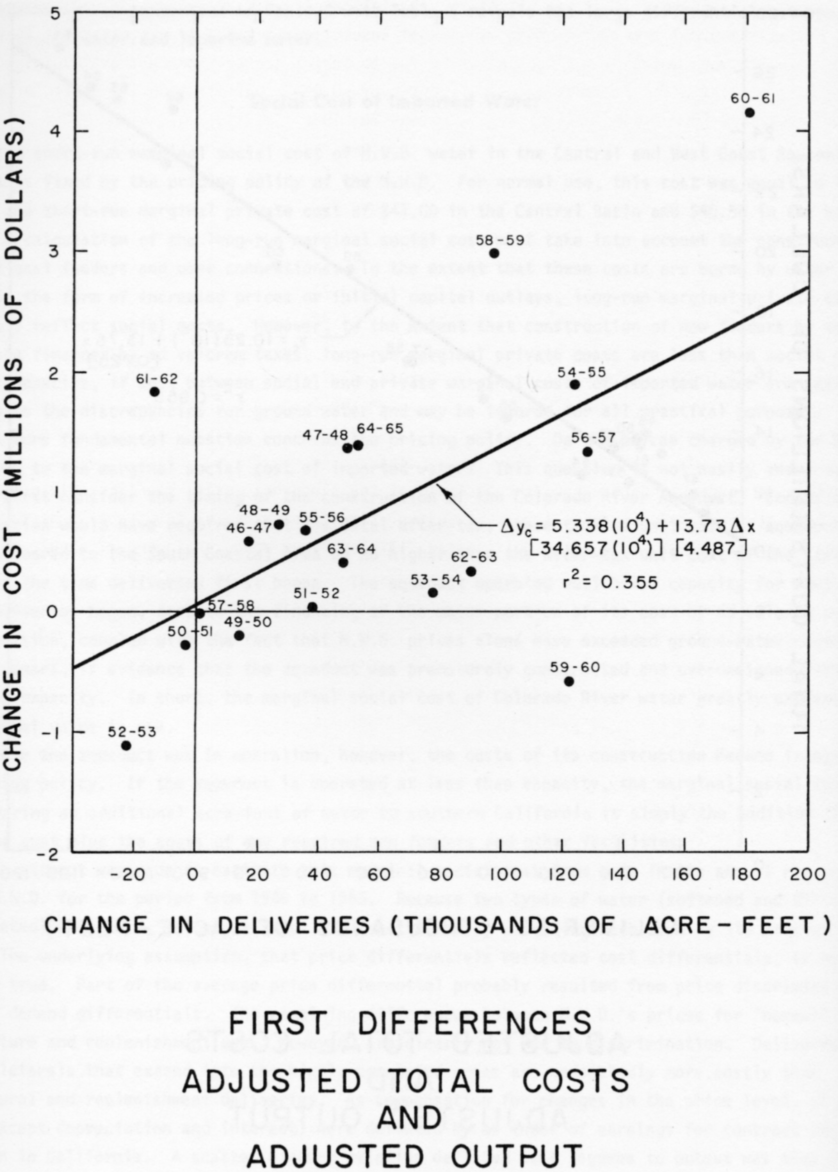
$$y_c = 10.25(10^6) + \underset{[0.725]}{13.76x} \qquad (4\text{-}1)$$



ADJUSTED TOTAL COSTS
AND
ADJUSTED OUTPUT

METROPOLITAN WATER DISTRICT
SOUTHERN CALIFORNIA

FIG. 8



FIRST DIFFERENCES
ADJUSTED TOTAL COSTS
AND
ADJUSTED OUTPUT
METROPOLITAN WATER DISTRICT
SOUTHERN CALIFORNIA

FIG. 9

The coefficient of determination r^2 is 0.953, the standard error of the regression is 1.16 (10^6), and the standard error of b, the marginal cost estimate of $13.76, is $0.725.

Although application of the "t" test to the slope of Equation 4-1 would lead to acceptance of $b \neq 0$ at the 0.001 level of confidence, visual inspection of the data suggests that the high correlation between quantity and cost might be due to serial correlation in the unexplained residuals. Computation of a Durbin-Watson statistic of -0.0458 apparently verifies lack of randomness in the residuals [Durbin and Watson, 1950, pp. 409-28; 1951, pp. 159-78].

The first differences of deflated cost were then regressed upon first differences of adjusted quantities to compensate for the auto-correlated errors [Cochrane and Orcutt, 1949, pp. 32-61]. A scatter diagram for this regression is given in Figure 9. The first-difference procedure yields the estimating equation

$$\Delta y_c = \underset{[34.657(10^4)]}{5.338(10^4)} + \underset{[4.487]}{13.73}\Delta x \qquad (4\text{-}2)$$

Because the Durbin-Watson statistic for the regression of first differences is 1.4031, we can accept the hypothesis that residuals are now random at the 0.02 confidence level. The slope of Equation 4-2 is almost identical to that of Equation 4-1, which utilized actual magnitudes, although the r^2 value has been reduced to 0.355 and the standard error of b has been increased to $4.487. Despite this large standard error, the estimate of the slope b is still significantly different from zero at the 0.01 confidence level. A test of significance of the intercept leads to acceptance of the hypothesis that it is not significantly different from zero, as indeed it should not be, at the 0.01 level.

So it appears that $13.73 per acre-foot in 1965 can be taken as a reasonable point estimate of the marginal cost before 1962 (before the Colorado River Aqueduct operated near full capacity). A comparison of the marginal cost of M.W.D.-water and the lowest price charged by the M.W.D. (for untreated water for agriculture and replenishment) is given in Table 9. The M.W.D. rates have been deflated by the price index used to deflate costs so that all rates are in 1965 dollars. Only in 1956 was the price (adjusted) charged for untreated water lower than the estimated marginal cost of $13.73. Because the marginal cost is an average--applicable to both treated and untreated water--it seems reasonable to believe that the marginal cost of untreated water was actually less than $13.05 (adjusted) in 1956.

TABLE 9

PRICE OF UNTREATED WATER
FOR
AGRICULTURE AND REPLENISHMENT

Metropolitan Water District
1946-1965
(Dollars Per Acre-Foot)

Year	Price	Price Index (1965 = 100)	Price (1965 Dollars)
1946	$ 8.00	38.1	$21.00
1947	8.00	39.7	20.15
1948	8.00	41.3	19.37
1949	8.00	42.9	18.65
1950	8.00	44.7	17.90
1951	10.00	47.8	20.92
1952	10.00	50.6	19.76
1953	10.00	54.3	18.42
1954	8.00	56.3	14.21
1955	8.00	58.1	13.77
1956	8.00	61.3	13.05*
1957	10.00	65.2	15.34
1958	12.00	70.0	17.14
1959	12.00	73.7	16.28
1960	12.00	78.3	15.33
1961	12.75	82.6	15.44
1962	13.50	86.6	15.59
1963	14.25	90.9	15.68
1964	15.00	95.3	15.74
1965	15.25	100.0	15.25

*The marginal cost was $13.73 (in 1965 dollars).

Source: Metropolitan Water District of Southern California, Annual Report for the Fiscal Year, 1946-1965; U.S. Department of Labor, Bureau of Labor Statistics, 1967, Employment and Earnings Statistics for States and Areas, 1939-1966, p. 41. (First three years of price index estimated).

Summary

At the time the decision was made to construct the Colorado River Aqueduct, the value of water was substantially below the marginal cost of the new supply. After the aqueduct was built and while it operated below capacity, the price charged was more than the marginal social cost. Hirshleifer, DeHaven, and Milliman [1960, p. 306] express a different view; they use incremental operating costs of $15 per acre-foot in 1960 that would amount to over $19 at 1965 prices. In the early years of operation, a more efficient allocation of resources could have been accomplished by charging lower prices for Colorado River water, but the early reliance on ad valorem taxes and the practice of price discrimination appear justified on the grounds of economic efficiency--even if such practices do raise questions of equity.

Since 1962 the aqueduct has transported close to its rated capacity of 1,200,000 acre-feet per year. However, beginning in 1974, the available amount is scheduled to decline gradually to 550,000 acre-feet in 1990. The Metropolitan Water District lost entitlement to 650,000 acre-feet as a result of a Supreme Court decision favoring Arizona claims (Arizona v. California, 373 US 546 [1963]). Arizona is expected to gradually exploit the new rights, with the entire amount to be used by 1990.

The estimated marginal cost figure of $13.73 that was applicable before 1962 is no longer relevant. What is relevant is the social cost of adding to existing sources of supply. The California Water Plan, undertaken to augment the water supply of Southern California, among other purposes, involves the construction of the California Aqueduct to bring 2.5 million acre-feet from the Feather River to southern California by the year 2020. The project, which will run to $2.6 billion in capital costs alone, is supposed to begin deliveries to the Los Angeles area in 1971 [California Department of Water Resources, 1965, pp. 158-59; 192-93]. The estimated cost of this water, delivered to the replenishment district, is $65.00 an acre-foot. Because the Metropolitan Water District is committed to purchasing the water, its marginal social cost is thus $65.00 an acre-foot, and the current price charged falls far short.

From this, we can conclude, along with Hirshleifer, DeHaven, and Milliman [1960, pp. 295-351] that the California Aqueduct was prematurely constructed. If the price charged by the M.W.D. had reflected the social cost of additional water, it would have served as an effective rationing device for the existing supplies and might have forestalled construction for many years. As pointed out earlier, the use of water is sensitive to changes in its price. An increase in the price of water and the halting of what is probably discriminatory pricing would have eliminated the use of water for purposes with low marginal values in use. (The extensive use of low-priced Colorado River water for irrigation is the best example. Many business firms in the Los Angeles area also use imported water for cooling on a once-through basis, a practice economically justified from the standpoint of the producer at existing low prices.) Finally, if a higher value were placed on water, reclaimed sewage water and water now being used for irrigation in the Imperial Valley would become feasible alternatives [Hirshleifer and Milliman, 1967, p. 176].

The real problem--overdesign for capacity and the resulting misallocation of resources--arises from failure to consider price as a rationing device. Such terms as water "requirements" and water "shortage" are used without explicit reference to marginal costs; current prices are implied--prices well below marginal social costs. In fairness to the California Water Plan, it should be pointed out that the doctrine of appropriation provides an incentive to over expanding of capacity [Gaffney, 1967, p. 194]. Under this doctrine, municipalities and other entities acquire water rights by use [Hardy,1966, p. B-15]. The earliest user of a water source gains preference over other potential users. Southern California has undoubtedly been enticed by this doctrine to provide for its furture "needs" by laying early claim to Northern California water.

At present, the underpricing of M.W.D. water results in the use of more water than that economically justified and leads to premature expansion of supplies. A corollary to this proposition is that the existing differential pricing policy can be justified only to the extent that it represents differences in true costs.

CONJUNCTIVE USE AND THE TRANSFER OF WATER RIGHTS

The two preceding sections have covered the private and social costs of the two most important sources of water for the Central and West Basin Replenishment District--ground water and imported Colorado River water. The principal conclusion was that the marginal private cost of ground water (estimated to be $16.00 per acre-foot) is substantially below the $40.50 (or $41.00) paid for an acre-foot of M.W.D. water. Such a cost differential can persist because adjudication, besides setting maximum production levels in each basin, has established property rights to ground water.

The establishment of adjudicated rights would provide extremely inefficient allocation if some mechanism did not exist for the transfer of water rights. A holder of ground-water rights, like any other user, has an incentive to produce up to the point where his marginal cost is equal to his marginal value in use. Even if his rights allowed more than this production level, it would still be to his advantage to leave the excess rights unutilized. On the other hand, if his rights were not sufficient to allow production at a marginal level, his production would be at a point where his marginal value in use exceeded his marginal private cost.

Furthermore, new firms starting in the district or users without water rights would be forced to purchase M.W.D. water at higher cost; hence marginal value in use to them would exceed the marginal value in use for those with sufficient access to the cheaper water. As economic efficiency requires that marginal values in use be equal at the margin for all users, adjudication of rights unaccompanied by the right to transfer them leads to inefficient allocations of water.

Because demands change over time, the rigid allocation caused by adjudication leads to increasing inefficiency. Moreover, there is a tendency toward underutilization of ground water. Producers cannot meet expanding demands by increasing production; those with decreasing demands simply fail to utilize their full rights.

Fortunately, an exchange pool exists for the temporary transfer of rights in each basin. Long-term leasing of water rights or the purchase and sale of rights on a permanent basis are also possible. Accordingly, the operation of the two exchange pools are discussed separately below. A few comments are then added on the permanent sale of rights.

West Coast Basin Exchange Pool

Each owner of adjudicated rights in the West Basin who has access to imported water is required to offer to the pool each year an amount equal to the excess of those rights over one half of his estimated total requirement for the ensuing year [Ostrom, 1965, p. 340]. The price at which each owner offers such rights must not exceed the price that he would have to pay for M.W.D. water delivered through the West Basin Municipal Water District. In addition, an owner with excess rights in any year may voluntarily offer them for sale. However, the pool first purchases all rights offered under the mandatory provision before accepting voluntary offers. Offers are accepted on the basis of the lowest prices; rights are sold at the average price of all accepted offers.

Historically, more rights have been offered than demanded. In the water year 1967, for example, ten parties offered rights to 19,777 acre-feet under the mandatory provision; two parties voluntarily offered rights to 858 acre-feet. Requests for rights, however, were only 335 acre-feet. The oversupply of rights has meant that the prices paid by the pool have been much less than the cost of M.W.D. water. For example: the average price for the 335 acre-feet purchased in the 1967 water year was $13.97. Thus the purchaser of rights from the pool who paid the pumping assessment of $6.20 and had an average pumping cost of $9.80 (including capital recovery) could produce ground water at a cost of $29.97 per acre-foot instead of paying $40.50 for M.W.D. water.

Central Basin Exchange Pool

Arrangements for the transfer of water rights in the Central Basin are unlike those in the West Coast Basin. Owners of adjudicated rights who have M.W.D. feeder connections are required to offer a portion of their rights to the pool at a price of $2.00 more per acre-foot than the difference between their cost of M.W.D. water and their cost of ground water [Ostrom, 1965, p. 502]. In the fiscal year 1967, this price for rights was $26.80 per acre-foot. (This price comes from: the charge for filtered and softened water by the Minicipal Water District, $41.00, plus the allowed increase, $2.00, less the sum of the agreed average pumping cost and the pumping assessment, $10.00 and $6.20.) With $16.00 added on (our estimated cost of ground-water production), the cost of ground water produced from transferred rights was $42.80. Note that this was more than the $41.00 price for M.W.D. water purchased from the Municipal Water District.

For the 1967 water year, the rights offered under the mandatory provision amounted to 25,731 acre-feet; the voluntary rights, 372 acre-feet at the same price. Eighty-eight parties bought

44.6% of these rights (11,624 acre-feet) [Max Bookman, consulting engineer, Los Angeles, personal interview].

Economic Efficiency from the Transfer of Rights

To appraise the operation of the two exchange pools, let us hypothesize two water producers (A and B) who are confronted by identical demand curves and marginal costs that are equal and constant. Further, A has rights to Q_A acre-feet; B has rights to Q_B. On their common demand curve (Figure 10), we see that A must limit his production of ground water to OQ_A, where the value to him (P_A) exceeds the cost of an additional unit; B will produce only to point OQ_B' because more water than Q_B' has less value to B than its cost.

Producer B could benefit by selling his rights to (Q_B - Q_B') at any price higher than zero. In addition, A should induce B to sell more than this. The production by A of additional water (Q'_A - Q_A), which equals (Q_B - Q'_B), by purchasing the rights would still leave A at a point on the curve where the value P'_A of an additional unit is greater than its cost. Such a purchase would raise the marginal cost for both A and B; to A, because his actual unit cost is increased, and to B, because his opportunity cost is increased. Their new common marginal cost would be the original marginal cost MC_P increased by the unit price of the purchase.

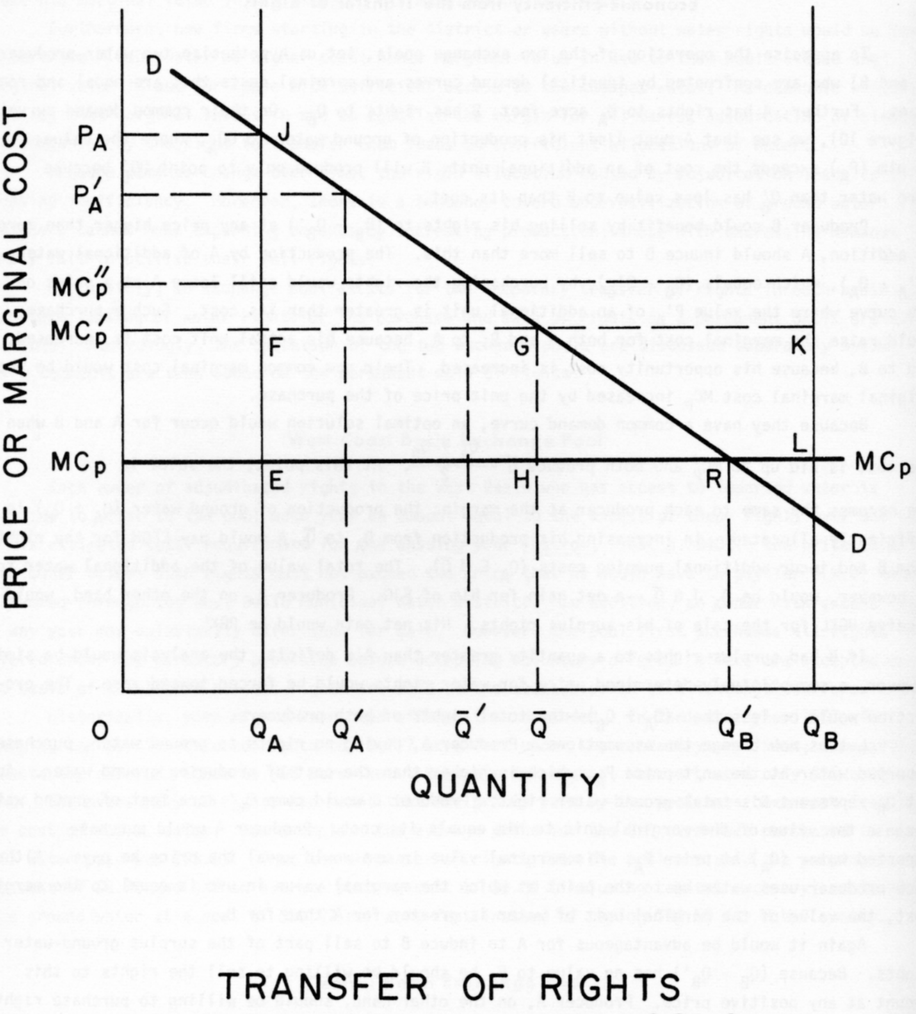
Because they have a common demand curve, an optimal solution would occur for A and B when the cost is bid up to MC_P' and both produce $\overline{Q} = \frac{Q_A + Q_B}{2}$. At this point, the value in use becomes the same to each producer at the margin; the production of ground water (Q_A + Q_B) is efficiently allocated. In increasing his production from Q_A to $\overline{Q}$, A would pay EFGH for the rights from B and incur additional pumping costs (Q_A E H $\overline{Q}$). The total value of the additional water to A, however, would be Q_A J G $\overline{Q}$ --a net gain for him of FJG. Producer B, on the other hand, would receive HGKL for the sale of his surplus rights. His net gain would be RGKL.

If B had surplus rights to a quantity greater than A's deficit, the analysis would be similar. However, a competitively-determined price for water rights would be forced toward zero. The production would be less than (Q_A + Q_B)--the total rights of both producers.

Let us now change the assumptions. Producer A, having no rights to ground water, purchases imported water at the unit price P_A, which is higher than the cost of producing ground water. Again let Q_B represent B's total ground-water right. Producer B would pump Q_B' acre-feet of ground water, because the value of the marginal unit to him equals its cost. Producer A would purchase imported water (Q_A) at price P_A. His marginal value in use would equal the price he pays. Although each producer uses water up to the point at which the marginal value in use is equal to the marginal cost, the value of the marginal unit of water is greater for A than for B.

Again it would be advantageous for A to induce B to sell part of the surplus ground-water rights. Because (Q_B - Q_B') has no value to B, he should be willing to sell the rights to this amount at any positive price. Producer A, on the other hand, should be willing to purchase rights at any price less than the difference between the price of imported water and his cost of producing ground water.

As before, the marginal cost increases for both producers--to A because, in addition to the cost of production, he must pay to obtain rights from B; to B, because the opportunity cost of retaining the rights must be added to the cost of producing ground water. For a competitive solution, A should bid the marginal cost of ground water up to MC_P" (Figure 10). At this point both A and B would produce $\overline{Q}$' acre-feet of ground water. By purchasing the rights to produce (Q_B - $\overline{Q}$'), A would be able to satisfy his demand for water by producing ground water at a total unit cost less than that of imported water, which would not have to be purchased at price P_A. It would be used only if the demand is great enough (or the supply limited enough) to force the price of ground water rights up to the price of imported water.



TRANSFER OF RIGHTS
THROUGH EXCHANGE POOLS

FIG. 10

Permanent Sale of Water Rights

Although permanent sales or long-term leases of water rights are also allowed in the Central and West Basin Replenishment District, the transfer market has been inactive [Ostrom, 1965, pp. 372-73]. For either type of transfer, a prospective purchaser should be willing to pay no more than his own estimate of either the present value of the future net benefits that would accrue from owning the rights or the discounted future stream of costs of purchasing M.W.D. water, including capital recovery. A potential seller should also determine the present value of retaining his ground-water rights; his position should also depend on his view of the discounted future net benefits, as well as his forecast of M.W.D. prices.

A water user with surplus rights should be willing to sell them because their value in use viewed from the present is less than their cost viewed from the present. A user with "insufficient" rights should be willing to purchase these rights net benefits because their present-value net benefits exceed their present-value costs. Such trading of rights should result in a bidding up of prices until marginal costs and marginal values in use are equated. This analysis also holds for a user of imported water in buying rights from a ground-water user.

OPTIMAL CONJUNCTIVE USE

Allowing for the transfer of rights satisfies a necessary but, by itself, insufficient condition for economic efficiency. An optimal allocation requires that: (1) values in each use or to each user be equated at the margin; and (2) the common marginal value in use be equal to the marginal social cost. It follows that, for more than one source of water, the entire supply is optimally allocated when the marginal social costs of both sources are equated--provided, of course, that the first condition is satisfied.

If the water-rights markets in the District operated perfectly, marginal values in use and marginal private costs would be equated, but they would not necessarily be equal to the marginal social cost. Because more than one price prevails, the market is imperfect.

The deviation between marginal private and marginal social costs is briefly discussed again here to clarify the existing situation. Market impediments in the two basins are examined to isolate the reasons for unequated marginal costs and values in use. Finally, the requirements for restoring economic efficiency are discussed, and the desirability of rationing ground-water rights through adjudication vis a vis pumping charges to bring about equality of marginal costs is explored.

Discrepancies between Social and Private Marginal Costs

As noted in the preceding section, the exchange of water rights tends to equate the marginal private costs of the trading parties. In a perfect market, trading would take place to the point where the value of each increment would be the same in each use. If the resultant common incremental cost were achieved in the District, however, it would still deviate from the incremental cost of ground water to society.

It was previously noted that the marginal cost of ground water in the District exceeds marginal private costs by at least the total of the unit variable costs that are transformed into fixed costs through ad valorem taxes. This disparity is not eliminated by the trading of rights. Trading between ground-water users tends to raise marginal private costs, but social costs increase by the same amount or more. In the long run, the private incremental cost includes pumping costs, the pumping assessment, capital recovery costs, and the unit purchase price. Incremental social cost includes, in addition, the ad valorem taxes used to meet variable costs. Moreover, if trading is sufficient in amount to cause a noticeable drawdown in water levels, pumping costs must rise throughout the District, with additional replenishment and barrier protection being required. Thus, under present financing arrangements, the gap between private and social costs tends to widen as rights are traded. The same result attends the sales of ground-water rights to users of imported water.

Discrepancies in Private Marginal Costs

It will be recalled that different marginal costs stem from the different transfer procedures in the two exchange pools. In 1967, West Coast Basin rights were purchased for a one-year period for $13.97 per acre-foot. Addition of pumping and capital recovery costs and the pumping assessment brings the total marginal private cost of this exchange water to $29.97. The marginal private cost for exchange water in the Central Basin was $42.80 during the same period.

The seeming paradox that water rights should sell for any price differing from the cost of M.W.D. water is explained after a little reflection. In the West Coast Basin, the only probable annual offers for surplus rights come from those who have wells with excess capacity. There is no guarantee that the rights will continue to sell at a low price, because increased demands could raise it to the M.W.D. price level. Hence, users who regard the low cost of rights as temporary are unlikely to drill wells. The total demand for water from wells with excess capacity is apparently insufficient to push up the price to equality with the M.W.D. price of $40.50.

The West Coast Basin requirement that mandatory-provision rights be sold first also impedes economic efficiency. The time may come when users subject to the provision will have higher values in use than the maximum price. The requirement that they sell first would represent a waste if other users desire to sell lower-valued rights but are prevented from doing so by the regulation.

A different situation exists in the Central Basin. In 1967 the cost of ground water ($26.80) purchased from the exchange pool appeared to be greater than the cost of the M.W.D. alternative. Pumping costs, capital recovery, and the pumping assessment raised the total marginal cost to $42.80, which exceeded the M.W.D. price by $1.80. A plausible explanation is that the purchasers in the Central Basin pool do not have connections to M.W.D. laterals. Otherwise they would not buy the more expensive ground water.

Water users in the Central Basin can depend on being able to purchase ground water from their pool at a price $1.80 higher than the M.W.D. rate. Whether or not a user would buy exchange water rather than M.W.D. water would depend, then, upon his cost of connecting to M.W.D. A decision to purchase exchange water, uncertainty aside, requires that the present value of a connection exceed that of the future quantity evaluated at $1.80 and reduced by the complement of the marginal corporate income tax rate (T_t). If we use the notation of Chapter III, pool purchases will be made, if, for user having a cost of capital k,

$$\sum_{t=o}^{n} [K_o + (1 - T_t)(A_t + M_t) - S_t - T_t D_t] (1 + k)^{-t} > \sum_{t=o}^{n} (1 - T_t) \$1.80 (Q_t) (1 + k)^{-t} \qquad (4\text{-}3)$$

where K_o = initial cost of connection to the M.W.D., A_t = operating cost in year t, M_t = maintenance cost in year t, S_t = salvage value, D_t = depreciation allowance for the line in the t^{th} year, and Q_t = the quantity of water used in year t.

Economic efficiency could be improved by competitive bidding. Very likely some unpurchased offers of water in 1967 had relatively low values in use to prospective sellers and the specified pool price prevented their sale. Both prospective sellers and purchasers could have gained from transactions at prices lower than the agreement-stipulated price of $26.80. The existing regulation does not lead to the equating of either marginal values in use or marginal costs of ground water. Social costs would be raised if additional water use, in a quantity sufficient to lower water levels, were to result from the bidding. The added social costs would have to be considered in the overall efficiency calculations.

A strong market in long-term rights would tend to equate marginal private costs and marginal values in use even if the exchange pools failed to do so. Because this market is inactive, however, it does little to establish efficiency. A plausible explanation for the inactivity is that future M.W.D. prices are shrouded in uncertainty. Although it is known that future M.W.D. prices will be considerably higher, this knowledge in itself is probably insufficient to establish the firm basis required for long-term investments in ground-water rights.

Requirements for Restoring Efficiency

If we assume no change in adjudicated rights, the changes that would have to be made to restore economic efficiency in the District are: (1) the recovery of certain variable ground-water costs through pumping charges instead of ad valorem taxes; (2) the deletion of the West Basin Exchange Pool requirement that rights be sold first under the mandatory provision; (3) the providing for bidding among prospective purchasers of Central Basin Exchange Pool water (which would require deletion of the agreement-stipulated price); and (4) the furnishing of a firm schedule of future prices for M.W.D. water by which a long-term rights market could be based.

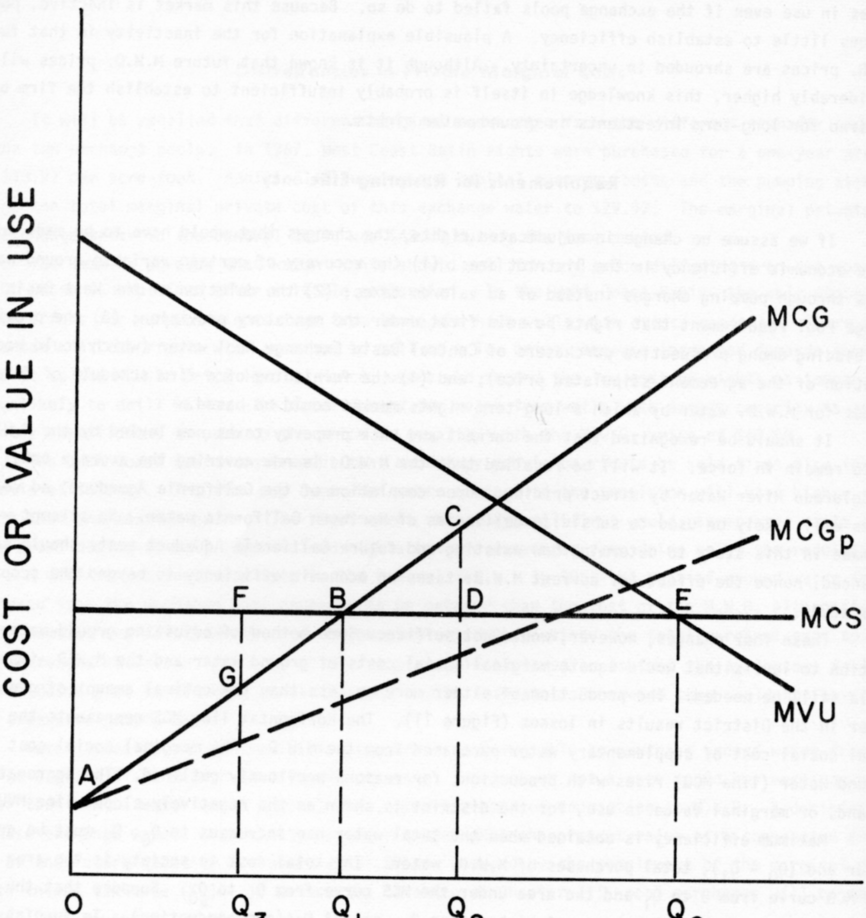
It should be recognized that the current and back property taxes now levied by the M.W.D. would remain in force. It will be recalled that the M.W.D. is now covering the average total cost of Colorado River Water by direct pricing. Upon completion of the California Aqueduct, ad valorem taxes will likely be used to subsidize deliveries of Northern California water. No attempt will be made in this study to determine how existing and future California Aqueduct costs should be financed; hence the effect of current M.W.D. taxes on economic efficiency is beyond the scope of this study.

These four changes, however, would not suffice. Some method of adjusting ground-water production to levels that would equate marginal social costs of ground water and the M.W.D. imports would still be needed. The production of either more or less than the optimal amount of ground water in the District results in losses (Figure 11). The horizontal line MCS represents the marginal social cost of supplementary water purchased from the M.W.D. The marginal social cost of ground water (line MCG) rises with production, for reasons previously outlined. The aggregate demand, or marginal value in use, for the district is shown as the negatively-sloped line MVU.

Maximum efficiency is obtained when the total water use increases to Q_0; Q_1 must be ground water and $(Q_0 - Q_1)$, total purchases of M.W.D. water. The total cost to society is the area under the MCG curve from 0 to Q_1 and the area under the MCS curve from Q_1 to Q_0. Suppose that the production of ground water has been set higher than Q_1, say at Q_2 (overproduction). To furnish the total demand Q_0, the quantity $(Q_0 - Q_2)$ would have to be purchased from the M.W.D., with the total social cost being the area under the MCG curve from 0 to Q_2 and the area under the MCS curve from Q_2 to Q_0. The triangular area BCD increases the total cost to society above that for optimum production and therefore represents a loss to society.

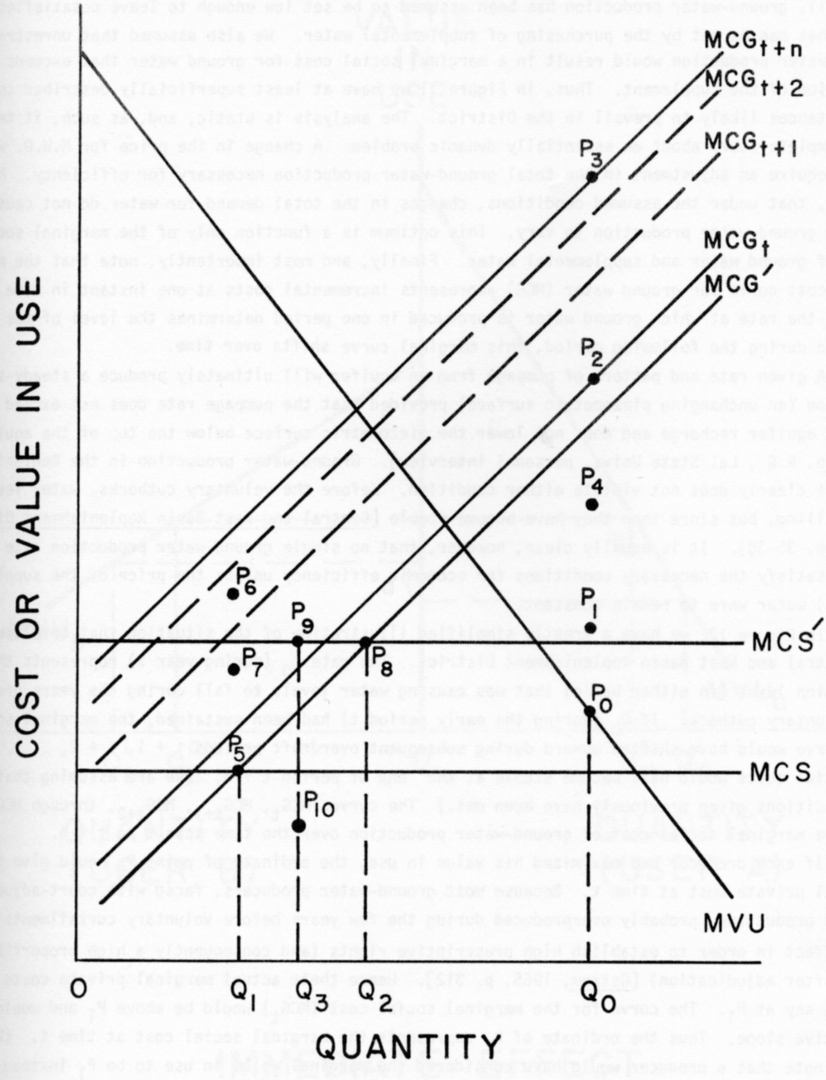
Although the quantity $(Q_2 - Q_1)$ is produced at a social cost greater than the purchase price of the same amount obtained from the M.W.D., users would still favor ground water more than M.W.D. water at the aggregate output Q_2. Their marginal private costs follow the dashed line MCG_p, which lies below the marginal social cost curve MCG. (Note that the MCG_p curve in Figure 11 has a positive slope, indicating a rise in marginal private cost as the output increases, but that the MC_p line in Figure 7 is horizontal, indicating a constant marginal private cost. This apparent conflict is resolved when we recall that Figure 7 is the demand curve for the individual producer who, by himself, does not produce enough to affect water levels throughout the District, and that Figure 11 is the aggregate demand curve for the entire District.)

A similar loss to society (increased total social cost) results from underproduction of ground water. If the allowable production has been set lower than Q_1, say at Q_3, the total cost to society would be the area under the MCG curve from 0 to Q_3 and the area under the MCS curve from Q_3 to Q_0. This cost is greater than that for optimum production by the triangular area GFB.



LOSSES RESULTING FROM OVERPRODUCTION OR UNDERPRODUCTION OF GROUND WATER

FIG. II



GROUND-WATER COSTS
AT
VARIOUS OUTPUT LEVELS

FIG. 12

At this point we should clarify several aspects of the previous discussion. First: in Figure 11, ground-water production has been assumed to be set low enough to leave unsatisfied demands that can be met by the purchasing of supplemental water. We also assumed that unrestrained ground-water production would result in a marginal social cost for ground water that exceeds the unit price of the supplement. Thus, in Figure 11 we have at least superficially described the circumstances likely to prevail in the District. The analysis is static, and, as such, it tells an incomplete story about an essentially dynamic problem. A change in the price for M.W.D. water would require an adjustment in the total ground-water production necessary for efficiency. Note, however, that under the assumed conditions, changes in the total demand for water do not cause the optimum ground-water production to vary. This optimum is a function only of the marginal social costs of ground water and supplemental water. Finally, and most importantly, note that the marginal social cost curve for ground water (MCG) represents incremental costs at one instant in time only. Because the rate at which ground water is produced in one period determines the level of the cost function during the following period, this marginal curve shifts over time.

A given rate and pattern of pumpage from an aquifer will ultimately produce a steady-state condition (an unchanging piezometric surface) provided that the pumpage rate does not exceed the rate of aquifer recharge and does not lower the piezometric surface below the top of the aquifer [Kazmann, R.G., La. State Univ., personal interview]. Ground-water production in the Replenishment District clearly does not violate either condition. Before the voluntary cutbacks, water levels were falling, but since then they have become stable [Central and West Basin Replenishment District, 1966, pp. 35-38]. It is equally clear, however, that no single ground-water production rate could always satisfy the necessary conditions for economic efficiency unless the price of the supplemental (M.W.D.) water were to remain constant.

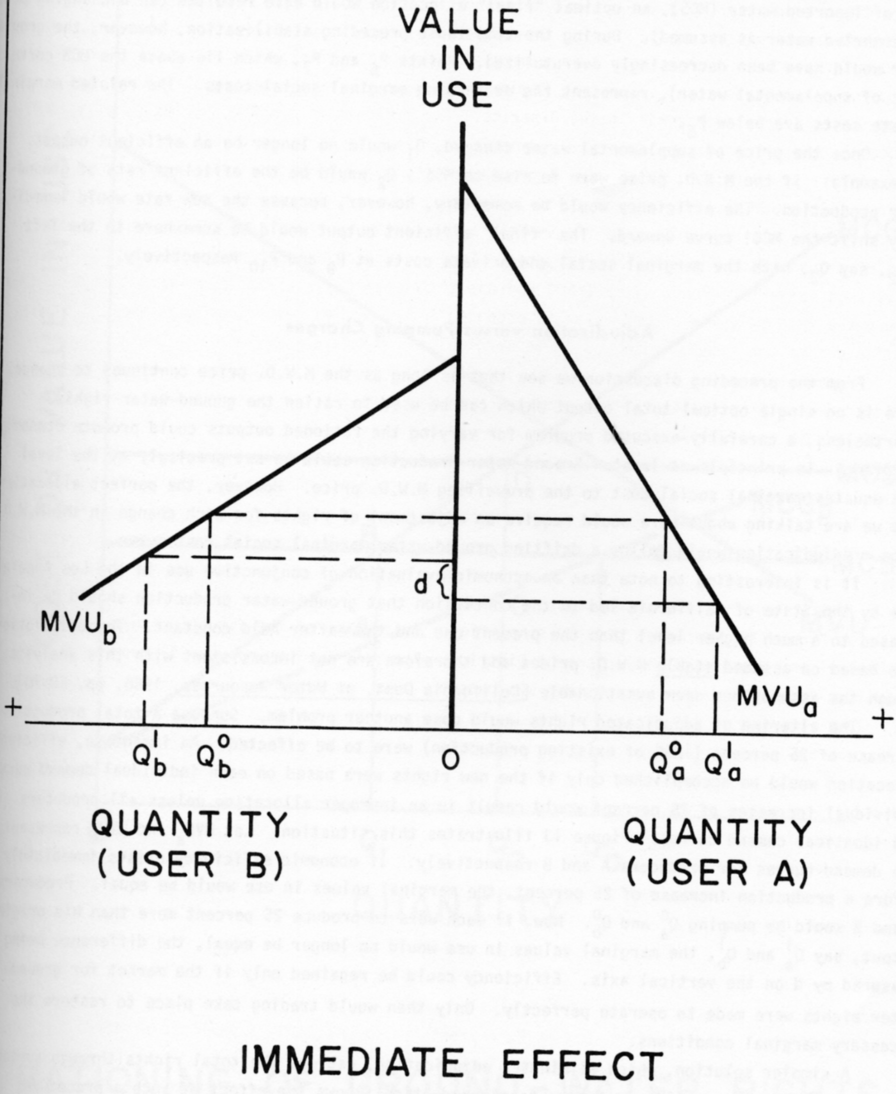
In Figure 12, we have a greatly simplified illustration of the situation that developed in the Central and West Basin Replenishment District. The rate Q_0 (during year t) represents the production level (in either basin) that was causing water levels to fall during the years preceding the voluntary cutback. If Q_0 (during the early period t) had been sustained, the marginal social cost curve would have shifted upward during subsequent overdraft periods t + 1, t + 2, . . ., t + n. The social costs would have become stable at the end of period t + n. (We are assuming that the two conditions given previously have been met.) The curves MCG_t, MCG_{t+1}, MCG_{t+2}, through MCG_{t+n} give the marginal social cost of ground-water production over the time span t to t + n.

If each producer had maximized his value in use, the ordinate of point P_0 would give the marginal private cost at time t. Because most ground-water producers, faced with court-adjudicated, reduced production, probably overproduced during the few years before voluntary curtailments went into effect in order to establish high prescriptive rights (and consequently a high proportionate share after adjudication) [Ostrom, 1965, p. 312]. Hence their actual marginal private costs were higher, say at P_1. The curve for the marginal social cost (MCG_t) would be above P_1 and would have a positive slope. Thus the ordinate of P_2 represents the marginal social cost at time t. (We should note that a producer would have considered the marginal value in use to be P_1 instead of P_0. The difference between the two costs was his temporary willingness to pay in order to gain prescripitive rights--thus a future increased value in use.)

When the water levels had dropped to a certain level after the period t + n, just before the beginning of the cutbacks, the marginal social cost reached a high point, P_3, that positions the curve MCG_{t+n}. The marginal private cost (P_4) was less than the social cost.

While the ground-water levels were still falling, the District began purchasing supplementary water (Colorado River) at a constant unit price, which equals the marginal cost (line MGS in Figure 12). At the same time, ground-water production was curtailed. The new pumpage rate (Q_1) resulted in downward-shifting marginal cost curves until stable water levels were reached. Graphs of well levels indicate that the time lag between curtailment and stabilization was two to three years [Bookman and Edmonston, 1966, pp. 35-38].

If, by some fortune, the marginal social cost curve for the stabilized post-curtailment



IMMEDIATE EFFECT
OF
AN INCREASE IN INDIVIDUAL
GROUND-WATER RIGHTS

FIG. 13

rate had been MCG', with point P_5 at the intersection of ground-water quantity Q_1 and the marginal cost of imported water (MCS), an optimal "final" allocation would have resulted (an unchanging price for imported water is assumed). During the time lapse preceding stabilization, however, the ground water would have been decreasingly overutulized. Points P_6 and P_7, which lie above the MCS curve (cost of supplemental water), represent the decreasing marginal social costs. The related marginal private costs are below P_5.

Once the price of supplemental water changed, Q_1 would no longer be an efficient output. For example: if the M.W.D. price were to rise to MCS', Q_2 would be the efficient rate of ground-water production. The efficiency would be momentary, however, because the new rate would immediately shift the MCG' curve upward. The "final" efficient output would be somewhere to the left of Q_2, say Q_3, with the marginal social and private costs at P_9 and P_{10} respectively.

Adjudication versus Pumping Charges

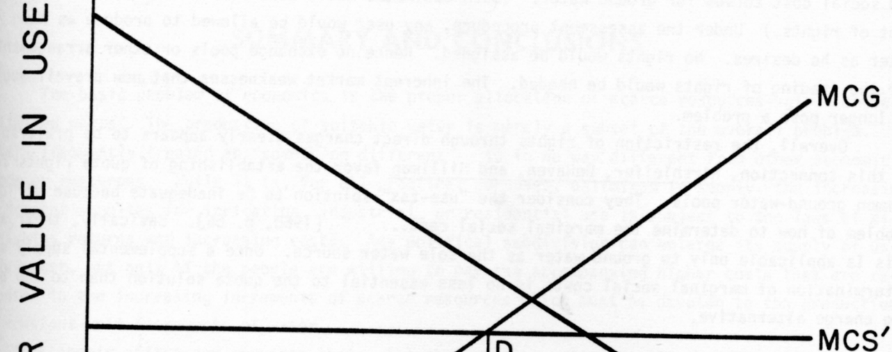
From the preceding discussion we see that as long as the M.W.D. price continues to change, there is no single optimal total output which can be used to ration the ground-water rights. Nevertheless, a carefully-executed program for varying the rationed outputs could promote economic efficiency--in principle at least. Ground-water production could be set precisely at the level that equates marginal social cost to the prevailing M.W.D. price. However, the perfect allocation that we are talking about here would require an adjustment of rights for each change in the M.W.D. price. Adjudication would follow a drifting ground-water marginal social cost curve.

It is interesting to note than an economic evaluation of conjunctive use in the Los Angeles area by the State of California led to the conclusion that ground-water production should be increased to a much higher level than the present one and thereafter held constant. The calculations were based on assumed stable M.W.D. prices and therefore are not inconsistent with this analysis, though the assumptions seem questionable [California Dept. of Water Resources, 1966, pp. 68-70].

The altering of adjudicated rights would pose another problem. Suppose a total production increase of 25 percent (125% of existing production) were to be effected. An immediate, efficient allocation would be accomplished only if the new rights were based on each individual demand curve. Individual increases of 25 percent would result in an improper allocation unless all producers had identical demand curves. Figure 13 illustrates this situation. Let MVU_a and MVU_b represent the demand curves for producers A and B respectively. If economic efficiency exists immediately before a production increase of 25 percent, the marginal values in use would be equal. Producers A and B would be pumping Q_a^0 and Q_b^0. Now, if each were to produce 25 percent more than his original output, say Q_a^1 and Q_b^1, the marginal values in use would no longer be equal, the difference being measured by d on the vertical axis. Efficiency could be regained only if the market for ground-water rights were made to operate perfectly. Only then would trading take place to restore the necessary marginal conditions.

A simpler solution, which eliminates adjudication, rations the total rights through variable pumping charges. Figure 14, depicting total production, shows the effect of such a procedure. If rights were not rationed, the quantity Q_0 would be pumped because the marginal private cost of ground water, MCG_p, equals the price of the imported supply, MCS. Assessment of an additional unit pumping charge AB would cut back the pumpage to Q_1. As a result, the marginal private and social costs (MCG) of ground water would be forced into equality with each other and with the marginal social cost of the imported supply. If the price of the supplemental supply rises to MCS', the additional charge CD would satisfy the efficiency requirements.

In essence, the procedure recommended in this study entails marginal cost pricing. It is therefore subject to the existing criticisms of welfare economics. In particular, the problems associated with the use of consumers' and producers' surpluses to measure utility or social welfare, with "second-best" optima and with interdependent individual utility functions, are obstacles which have not been overcome [Mishan, 1967, pp. 154-222].



RATIONING OF GROUND-WATER RIGHTS
BY
VARIATIONS IN PUMPING CHARGES

FIG. 14

Of course, constant changing of the pumping assessment would be necessary, but it would be no more difficult than the continual changing of water rights. In practice, it would probably be undesirable to change the pumping assessment more than once a year. Estimates could be made of the appropriate assessment for the beginning and ending dates of the water year and a unit charge set somewhere between the two. These assessments would have to be based on estimated marginal private and social cost curves for ground water. (Such estimates would also have to be made for reassignment of rights.) Under the assessment procedure, any user would be allowed to produce as much water as he desires. No rights would be assigned. Hence no exchange pools or other arrangements for the trading of rights would be needed. The inherent market weaknesses that now prevail would no longer pose a problem.

Overall, the restriction of rights through direct charges clearly appears to be preferable. In this connection, Hirshleifer, DeHaven, and Milliman favor the establishing of quota rights for common ground-water pools. They consider the "use-tax" solution to be inadequate because of "the problem of how to determine the marginal social cost... ." [1960, p. 66]. Basically, their analysis is applicable only to ground water as the sole water source. Once a supplemental supply exists, determination of marginal social costs is no less essential to the quota solution than to the pumping charge alternative.

SUMMARY

An analysis of ground-water costs in the Central and West Basin Replenishment District of Los Angeles County, California, has disclosed a significant difference between marginal private and marginal social costs. This difference results from the existing practice of financing several variable costs through the use of ad valorem taxes. In effect, this use transforms these variable costs into costs that are fixed from the viewpoint of the individual user. This, coupled with a higher marginal social cost of imported water and the failure to equate marginal costs, has led to misallocation of water resources in the District.

Further, economic inefficiency is associated with the importing of Metropolitan Water District water. The Colorado River Aqueduct apparently was constructed prematurely. However, after completion, the Metropolitan Water District seems to have been justified in its practices of price discrimination, charging less than average total cost and recovering the deficit through ad valorem taxes. Recently, though, this imported water has been underpriced. Deliveries have increased up to the aqueduct capacity. M.W.D. has contracted for Northern California water, which will cost significantly more than Colorado River water. If the marginal cost of Northern California water is used as the price (which is as it should be), it is unlikely that much of this water will be sold. Los Angeles County has failed to use the marginal price system to ration its available water. Perhaps largely as a result of the appropriative water rights doctrine, it has turned to a very expensive source of water when cheaper alternatives were available.

An optimal conjunctive-use system, in which the marginal values in use of ground-water and imported-water are equated, with a common marginal social cost, is suggested for the District. This system would require the elimination of adjudicated rights and depend instead on assessment of pumping charges that would vary with changes in the price of M.W.D. water.

CHAPTER V

SUMMARY AND CONCLUSIONS

The basic problem of economics is the proper allocation of scarce resources--given society's unlimited wants. The production of suitable water is merely a subset of the overall problem. Water--frequently treated as "something different"-- is in no way different from other economic goods or resources. While it is, for all practical purposes, unlimited in supply, the increasing of present supplies for irrigation, industrial, or residential use is subject to the laws of diminishing returns and increasing costs. Any political subdivision can enlarge its supply of usable water, but only if the people are willing to pay the accompanying higher costs that are reflected in the increasing increments of scarce resources which must be devoted to the production of constant-unit increments of water.

Economic efficiency requires that: (1) the existing water supplies be allocated in a way that will maximize their contribution to social welfare; (2) a proposed water project be foregone unless it is warranted by the demands of society; and (3) any project that is undertaken be the least costly of the available alternatives.

The study at hand had the objective of determining if these three requirements have been, or can be, met under the existing laws and practices. To this end, allocation of existing groundwater supplies was examined. A decision rule for community action was then devised and some of its welfare implications were discussed. Finally, a case study of the conjunctive uses of ground and surface water was presented. The major findings of the whole study are presented in the remainder of this chapter.

ALLOCATION OF EXISTING WATER SUPPLIES

Water law in the conterminal United States may be classified as either riparian or appropriative. Essentially, the riparian doctrine holds that a landowner may use water that flows over, under, or adjacent to his land--provided his use is "reasonable" as determined by the courts. This doctrine is adhered to in the eastern United States. Under the appropriative doctrine, an individual or political entity gains a usufructory right to water merely by appropriating it to his use. Senior water rights develop from the earliest use; junior rights accrue to later appropriators. Such rights need not pass the test of "reasonableness," although the use of the water must be considered "beneficial." The appropriative doctrine is widely used in the western United States.

In general, we may say that neither the riparian nor the appropriative doctrine provides an owner with firm water rights that may be sold in the marketplace. Moreover, there is a decided trend toward public ownership and public administrative control of water production and allocation, with less private ownership and its accompanying tradeable rights.

If we assume the existence of a perfect market without external economies or diseconomies, a system of private ownership of rights and marginal pricing will properly allocate the water resources in a community. The optimal conditions will be satisfied when marginal social costs are equal to marginal social values in use for all uses.

Several factors may prevent such a system from bringing about the optimal situation. Imperfect competition, to the extent that it may exist, would raise the spectre of "second best," and render the problem unsolvable. Other possible factors are economies of scale and external diseconomies. However, these may be corrected through appropriate subsidies or charges to simulate a perfect market. These subsidies and charges may be superimposed on a framework of private ownership and tradeable rights. Thus--whether or not the listed disturbing factors exist, a system of firm private rights and market prices would provide a basis for optimal resource allocation--something that present water laws cannot accomplish because they allow no transfer from low- to high-valued uses.

In the case study of the Central and West Basin Water Replenishment District of Los Angeles (Chapter IV), the suggestion was put forth that private (adjudicated) water rights should be abandoned, despite the fact that the law now provides for their sale. For a private rights-market price system to provide optimal allocation, the market must be strong and active. A perfect market depends on perfect knowledge of prices. The tradeable rights system fails to operate properly because of much uncertainty about the price of the supplemental M.W.D. water. If the Los Angeles area had adequate information about the pricing of its imported water, the solution of Chapter IV would have to give way to the tradeable-property-rights approach.

SUPPLEMENTING OF LOCAL WATER SUPPLIES

Investment decisions concerning local water projects may be made by the use of a model that incorporates benefit-cost analysis. The relevant cost is the present-value unit cost obtained by discounting costs to be incurred over time by the community cost of capital, or, simply, the interest rate of the bonds. The relevant benefit is the present-value unit cost of the best alternative to the action being considered, including the cost of no action at all. Because private (corporate) water users may decide to augment their own supplies, the benefit can be taken as the present-value unit cost of the best corporate alternative. However, corporate costs of capital are not easily measured. Thus it is necessary that we discount the benefit stream by a range of trial discount rates.

A hypothetical comparison made between a corporate and a non-profit community project showed that, with constant returns to scale and equality of costs of capital, the present-value unit cost of water is lower for the corporate project. The divergence is caused by the corporate income tax structure. Nevertheless, the after-tax unit cost incurred by a corporation that purchases water from a community project is less than the present-value unit cost of the corporate project itself. Hence the benefit-cost ratio is greater than unity, and the community should undertake the non-profit project.

This conclusion is strengthened by the differences in the costs of capital that are likely to exist. Economies of large-scale production will also favor the community project. On the other hand, diseconomies of scale will tend to favor the corporate project, although it is quite unlikely that they will be strong enough to overcome the other inherent advantages of the collective project.

From the viewpoint of national welfare, however, the local decision-making process may not be optimal. A project which is optimal from the community standpoint could misallocate some resources. A correction of this problem can only be accomplished by changes in the corporate income tax structure, the primary cause of misallocation.

THE CASE STUDY

A study of the conjunctive use of ground and imported water in the Central and West Basin Replenishment District of Los Angeles disclosed a number of economically inefficient practices. Several variable ground-water costs are being financed by ad valorem taxes. From the user's standpoint, these costs are fixed in both short- and long-run production although from the community's standpoint they are variable. This results in a portion of ground-water production being applied to uses that are valued less than the cost to society. At the same time, higher-valued uses are going unsatisfied. The marginal cost of water to users if imported water is considerably higher than the marginal cost of ground water. Although the District provides for the sale and leasing of ground-water rights, the marginal costs of imported water and ground water, hence marginal values in use, are not equal, and consequently, the allocation of the District's water supply is not optimal.

Provision for the sale of firmly-established ground-water rights normally provides the basis for an efficient conjunctive-use system. Again, problems that may arise can be corrected by superimposing some type of charge or subsidy upon the firm rights-market price system. In the Los Angeles case, however, this procedure cannot be adopted because the ground-water rights market is weak and ineffective. The problem appears to be one of imperfect knowledge. The users of ground water and imported water cannot accurately forecast the future prices of water imported by the Metropolitan Water District, the agency that provides the imported water as an alternative to ground water.

A strong rights market requires an adequate knowledge of alternative prices. The absence of this condition in the District suggests another approach, one that would eliminate individual adjudicated rights and replace them with the right of each individual to produce as much water as he desires. Pumping charges would be assessed to bring the marginal cost of ground water to the appropriate level--the marginal cost of the imported M.W.D. water.

AN OVERVIEW

Several important conclusions may be drawn from the study. Existing water laws tend to misallocate water. The trend toward increasing bureaucratic control of water in the United States can aggravate the misallocation. An improvement would be the establishment of firm and tradeable water rights. A market in water rights would provide the basis for efficient use of ground-water production. In the Los Angeles area, an existing market does not properly allocate water because the area is dependent on an <u>outside</u> agency for its supplemental supply, prices for which are not predictable. A locality that provides its own supplementary water can make its pricing policy clear to potential customers and thus establish this necessary condition for a strong market in ground-water rights.

A community that undertakes a project to obtain additional water supplies may take the steps that are optimal from its own point of view. The result for the nation as a whole, however, may be resource misallocation. Any corrective of this situation would depend on changes in the corporate income tax structure.

Finally, a case study shows that inefficiency exists in one local conjunctive-use system--most probably due to laws which reward the premature appropriation of water. Until the institutional setting is altered, this misallocation of ground water will continue.

Provision for the sale of firmly-established ground-water rights normally provides the basis for an efficient conjunctive-use system. Again, problems that may arise can be corrected by superimposing some type of charge or subsidy upon the firm rights-market price system. In the Los Angeles case, however, this procedure cannot be adopted because the ground-water rights market is weak and ineffective. The problem appears to be one of imperfect knowledge. The users of ground water and imported water cannot accurately forecast the future prices of water imported by the Metropolitan Water District, the agency that provides the imported water as an alternative to ground water.

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APPENDIX

COST CALCULATIONS

The average total water costs presented in Tables 5 and 8 are intended to be representative of the unit costs paid by industrial firms in the Central and West Basin Water Replenishment District. Example 1 (below) is a typical calculation of the average costs given in Table 5.

Example 1

Calculation of Typical Ground-Water Cost

Assumptions:

Assessment Ratio--	45 percent (industrial property)
Plant Valuation---	\$10 million, consisting of \$7 million in land and improvements and \$3 million in "personal" property
M.W.D. Tax Rate---	\$0.14 per \$100 of assessed valuation on all property
Cost of Capital---	7 percent (before tax)-- This is a conservative figure that tens to understate the costs to private firms. However, it is probably on the high side for a municapality. Hence the costs may be slightly overstated when the cost of capital is the interest rate on municipal bonds.)
Water Pumpage Rate-	10,000 acre-feet per year
Life of Wells------	20 years
Cost per Well------	\$10,000 up to 200 gpm capacity (322 acre-feet/yr) \$21,000 up to 500 gpm capacity (807 acre-feet/yr) \$42,000 up to 1,500 gpm capacity (2,420 acre-feet/yr)

Unit-Cost Calculation:

Pumping Cost		\$7.00
Pumping Assessment (1966-67)		6.20
Ad Valorem Taxes		
Assessed Valuation		
45% of \$7,000,000 = \$3,150,000		
45% of \$10,000,000 = 4,500,000		
Flood Control District Zone I or III \$0.05 x 1/100 x \$3,150,000	1,575.00	
General Fund --F.C.D. \$0.00369 x 1/100 x \$3,150,000	116.24	
M.W.D. \$0.14 x 1/100 x \$4,500,000	6,300.00	
Replenishment Distriict \$0.0020 x 1/100 x \$3,150,000	63.00	
Total Ad Valorem Taxes \$	7,991.24	
7,991.24 ÷ 10,000 = Ad Valorem Taxes/Acre Foot		0.80

Capital Recovery Cost
(Capital Recovery Factor for 20-year project life at 7% = 0.09439
10,000 Acre-Feet per Year Pumpage furnished by 1 well at \$10,000
4 wells at \$42,000 each

\$178,000 x 0.09439 = \$16,801.42/Year
16,801.42 ÷ 10,000 = Capital Recovery/Acre-Foot = 1.68

Total Cost/Acre-Foot = \$ 15.68

Example 2

Calculation of Typical M.W.D. Water Costs

Assumptions:

Assessment Ratio--	45%
Plant Valuation---	$10 million (30% "personal" property)
M.W.D. Price------	$40.00 per acre-foot (1966-67 price, filtered and softened water)
M.W.D. Tax Rate---	$0.14 per $100 of total assessed value
Cost of Capital---	7% before tax
Water Use---------	10,000 acre-feet/year
Cost of Connection to M.W.D. Feeder-----	$40,000

Unit Cost Calculation

M.W.D. Rate	$40.00
Ad Valorem Taxes (See Example 1)	0.80
Capital Recovery Cost (Assuming a perpetual project Life) $40,000 x 7% = $2,800/year 2,800 ÷ 10,000 = Capital Recovery Cost/Acre-Foot	0.28
Total Cost/Acre-Foot	$41.08
West Basin Municipal Water District, =	0.50
	$41.58