# ECONOMIC AND INSTITUTIONAL ANALYSIS OF COLORADO WATER QUALITY MANAGEMENT

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# ABSTRACT

Waste products of production and consumption activities are often discharged into the nation's watercourses. The objective of this study was to develop information on economic and institutional aspects of water quality management in Colorado. An economic conceptualization of the water quality management problem is presented. The legal and institutional settings within which the present water pollution control program operates is reviewed and described. Two economic case studies are presented. One provides estimates of the economic value of water for waste dilution and the other examines economic impacts of programs for control of saline irrigation return flows in western Colorado.

## TABLE OF CONTENTS

## TABLE OF CONTENTS (continued)

## LIST OF FIGURES

# LIST OF TABLES

## LIST OF TABLES (continued)

APPENDIX

# CHAPTER I

# INTRODUCTION

## A. BACKGROUND, OBJECTIVES AND PLAN OF REPORT

Kenneth Boulding [1966] has observed that mankind is in the middle of a long transition in the nature of the image which man has of himself and of his environment. Until recently, there has always been some place else to go whenever a deterioration of the natural environment occurred in places where people happened to live. We must now accustom ourselves to the notion of a closed sphere of human activity, which Boulding evocatively terms the "spaceship earth."

The economic processes of a society may be thought of in terms of a continuous flow of materials. Mineral and ecological materials are taken from the environment and are transformed into numerous goods and services. These final products are, in turn, are consumed. In the processes of production and consumption, materials are transformed into waste products which are largely returned to the environment. The unwanted waste products may be in solid, liquid or gaseous forms. In a static society, (one without change in population, technology or capital formation), the Law of Mass Conservation requires that the output of waste materials must equal the natural materials which entered the system. Thus, as emphasized by Ayres and Kneese [1969], in a modern industrial economy, waste materials and effluent emissions are likely to be created in excess of the environment's capacity to assimilate them. Pollution levels are likely to reach levels causing damage, in the form of adverse health, aesthetic or economic impacts, on subsequent users.

Substantial portions of the waste products of production and consumption activities are discharged into the nation's waters. While an estimate of the economic damages associated with waste discharge is unavailable, some indications of the magnitude of the problem can be found. A recent report by the U.S. Council on Environmental Quality [1973] indicated that water pollution control expenditures in 1971 reached $6 billion, and the expected cumulative expenditures from 1972-1981 needed to meet standards set by the Federal Water Pollution Control Act Amendment of 1972 could total $121 billion.

Coloradoans are faced with these same issues of water quality degradation noted above. This study was designed to develop information on economic and institutional aspects of water quality management in Colorado. Specific objectives included:

1. Review, describe and analyze the legal and institutional settings within which the present water pollution control program in Colorado developed, and appraise the program for efficiency and effectiveness.

2. Determine the economic optimum methods and levels of management for selected sectors in Colorado, with emphasis on the agricultural sector.

This report is organized as follows. In the remainder of this chapter, an economic conceptualization of the water quality management problem is presented. In Chapter II, the legal-institutional analysis is provided. The remaining chapters present economic case studies of selected water quality management issues.

## B. ECONOMIC CONCEPTS

A predominantly private enterprise economy such as our own performs the functions of producting and distributing goods and services through voluntary exchange within a system of markets. Prices and profits provide the guiding mechanism for allocating resources and commodities as the members of the economy seek to enhance their individual well being. Economics as a discipline studies the operation and functioning of economic systems, seeking to describe, explain and predict the behavior of the elements of that system.

Our economy is mixed, in the sense that a public sector exists side by side with the private market economy. An important part of the public economy consists of environment and ecosystem management; consider as examples, air and water quality as well as the forests, grasslands and game herds managed for the public by state and federal agencies. Economics makes an important contribution to problems of public resource allocation.

One of the most important functions of economics is to evaluate public policy. Economics, contrary to common understanding, begins with the postulate that man is the measure of all things. Things which contribute to human health and happiness are more directly "economic," and therefore more important than property, which is simply an intermediate means to health and happiness. Neither do economists regard "economic" as a synonym for "pecuniary." Rather, money is but one of many means to ends as well as a useful measure of value.

Rational planning involves prediction of the consequences of alternative policies and selection of a best plan according to some ethical or normative criterion. Therefore, evaluation of public policy involves value judgments, and there must be some means of thinking about them systematically, and if possible, quantifying them. Allen Kneese [1967] has noted that the importance of economics to the process derives from the fact that the price and allocation theory of economics and its prescriptive applications to problems of human welfare is a theory of social values. This prescriptive theory is called welfare economics. It is a theory of social values sufficiently detailed, precise and logical to assist in the derivation of decision criteria and to provide a structure for systematic, quantitative measurement. Most important, the theory reflects the judgment that individual tastes and preferences are to govern the use of resources in a free society, a value judgment widely accepted in our culture.

Economic analysis serves an essential function in social decision making, arbitrating among the rival claims of different interest groups and disciplines. There is little room in it for absolution. This is why the economist tends to speak in terms of demands and preferences, rather than requirements and needs. The basis upon which welfare economics establishes the commensurability of different goods and services is the willingness of consumers to pay for the resources necessary to produce them in view of the willingness of the same or other consumers to pay for the use of those resources in alternative employments. In this game, there are no external standards for a "good result." Rather, the desirable result is deemed to be the one that goes furthest in satisfying human wants, given limitations on resources and the prevailing distribution of income.

An idealized competitive economy will yield an allocation of resources such that no alternative pattern of resource use will make any individual better off without making someone else worse off. Such an allocation of resources is said to be "economically efficient," and given the distribution of income and the availability of resources, is the pattern of resource allocation which will most completely satisfy human wants.

Market Failure and Environmental Management. The question of managing the environment can be viewed as a problem of allocating scarce environmental resources among competing ends or uses. Under appropriate conditions, as said above, a market economy can yield an allocation of resources which is efficient. This result is achieved by generating signals--in the form of prices of commodities and resources to be used by producers and consumers in the economy. Prices indicate to the members of the economy the relative gains and costs of utilizing goods and resources for various purposes, and so help him decide how to allocate goods and services among competing uses. The pervasive fact of resource scarcity provides an incentive for the individual to get the most out of any given level of expenditure. Resources and commodities are guided by prices into the most desirable use when they pass through markets that are competitive. (See Wykstra, (1971) for a detailed discussion.)

Should markets not function properly, or not exist for certain valuable resources or commodities, "market failure" is said to exist. In such event, prices do not correctly reflect the social value of resources and commodities, and a misallocation of resources has occurred.

It is increasingly recognized by economists that the market system fails to deal adequately with environmental problems. [See Barkley and Seckler (1972), Freeman, et al., (1973), Dales (1968).] Two important types of market failure are usually involved in environmental decay. The first discussed here is commonly termed an external effect or externality (or alternatively, "spillover" or "third-party" effects). An externality occurs when one party's production or consumption activities creates an uncompensated cost or benefit for other parties. The individual decision-maker has no incentive to consider his external effects, and so is not taking all the appropriate costs or benefits into account in making resource allocation decision. A less than optimal allocation of resources then occurs.

"Public goods" constitutes the other type of environment related market failure. A public (or collective) good, in contrast to private goods, can be used simultaneously by more than one individual. National defense and radio or TV broadcasts are standard examples of public goods. Producers of public goods are unable to collect revenues from beneficiaries, since users cannot be excluded for non-payment of the price. Each user will expect to reap the benefits whether or not he pays the cost. The private market is therefore unlikely to supply optimal amounts of goods with collective consumption characteristics.

Water quality problems in the Colorado River exhibit both of these aspects of market failure. Man-made waste discharges from cities, farms and factories constitute an external diseconomy on downstream users, since the detrimental side effects are not compensated. Improved levels of water quality however measured have a public good character, since such improvements would benefit all users. Since a private purveyor of improved water quality would find it difficult to capture the increased value, a private market approach would not be likely to succeed in degraded water quality would find an improvement in that quality to be of value. However, the amount it would be willing to pay would be bounded by the dollar cost of accommodating the pollution (or equivalently, the dollar value of increased output which would follow from an improvement). Finally, assume that the cost of treatment to reduce pollutant levels are known and also can be expressed in dollar values.

Figure 1a illustrates the relationships between first, total treatment costs and concentration of the pollutants and, second, the total damages (in dollars) and pollutant concentration. The diagram can be thought of as referring to total treatment costs and damages for all affected parties in a specific environmental system, such as a river basin, and during a specified time period. As the concentration of pollutants increases, total damages, (represented by the curve labelled D) increases. Damages are zero at zero or negligible concentration levels, but increase with concentration. Thus D slopes upward to the right. In contrast, zero treatment costs imply high pollution levels. Reduction of pollution is accomplished only at increasing total cost. Therefore, the treatment cost curve, (labelled T) slopes down to the right.

The optimal level of pollution (or treatment) is obtained when the sum of treatment costs (T) and pollutant damages (D) are a minimum. Of course, (assuming emitters and receptors are separate groups) those responsible for the pollutants have an interest in lower treatment costs, while those experiencing damages would prefer to have those effects minimized. However, in economic efficiency terms, the social objective should be to minimize the sum of costs involved, including both costs of treatment and the costs of benefits foregone by reduced water quality. That is to say, the optimal level of water quality control is satisfied by minimizing

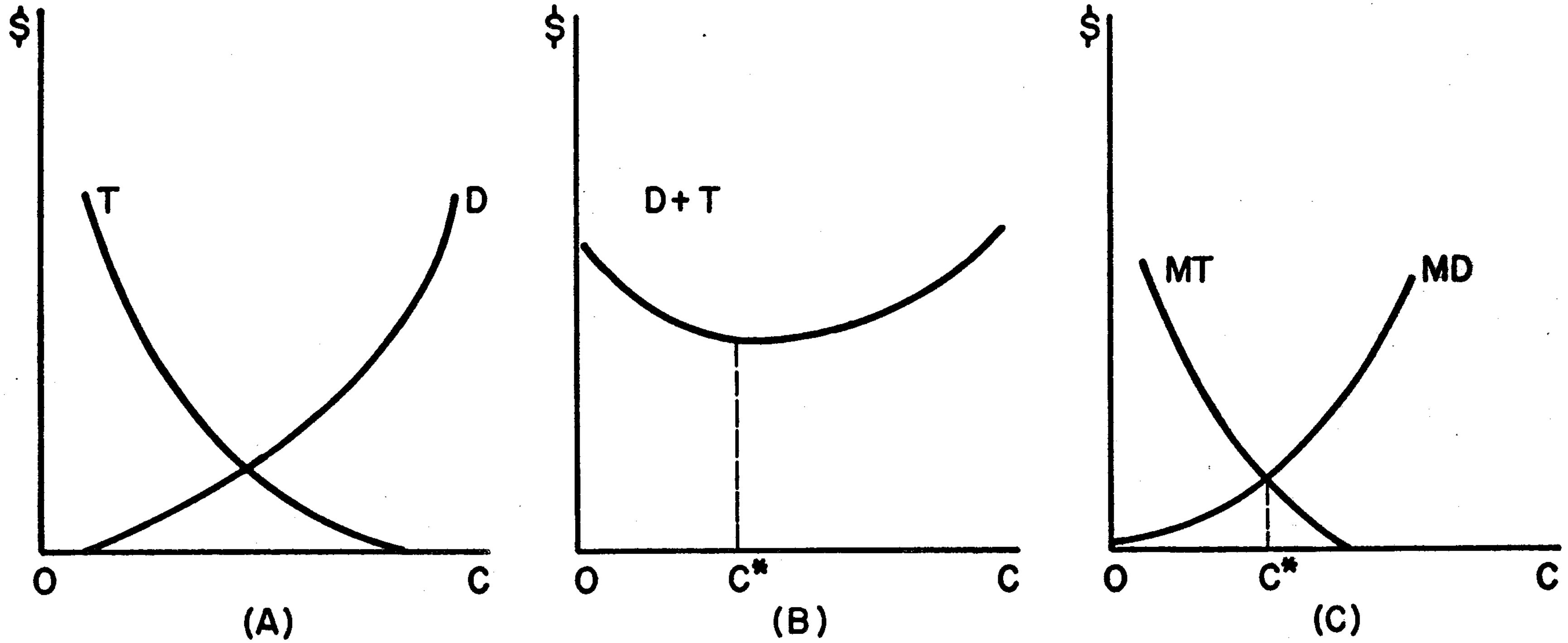

Figure 1.1. Damages and treatment costs as related to pollutant concentration.

the sum of damages and treatment (D+T), at concentration c*. This is shown in Figure 1b.

Given the usual assumptions about continuity of the functions and the satisfaction of second order conditions, the optimal condition occurs where marginal treatment cost is equated with marginal damage. In Figure 1c, the incremental damage associated with a small change in the concentration of pollutants is represented by the curve M D. Similarly, the reduction in treatment cost associated with an increase in pollutant or residual concentration is shown as M T. At concentrations greater than c*, the increment of treatment cost is less than the increment of damages avoided. Thus, the added benefits from treatment exceed the added costs, and the additional treatment should be undertaken (i.e., a move to the left is desirable). Conversely, at pollutant concentrations less than c*, the incremental cost of treatment exceeds the incremental benefit, and further improvement is not justified by its cost. The optimal level of treatment and the optimum concentration of pollutant occurs at c*, where marginal damage is equated with marginal treatment costs.

The above solution may also be derived by use of the calculus. Let total pollution costs be denoted P. Then:

$$P = D + T \tag{1-1}$$

The conditions for unconstrained maximization require setting the derivative of (1-1) with respect to pollution concentration equal to zero.

$$\frac{dP}{dc} = \frac{dD}{dc} + \frac{dT}{dc} = 0 \tag{1-2}$$

The derivatives in (1-2) may be interpreted, respectively, as marginal user damages and marginal treatment costs. Therefore, the optimum solution equates marginal user damages and marginal treatment costs, as shown graphically above.

(The above model which yields the most efficient degree of treatment and pollution load leaves aside crucial matters as to who is to pay for treatment. Considerations of economic and legal equity which are beyond the scope of this report are involved. [Kneese and Bower, (1968), Chapter 7])

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# CHAPTER II

# WATER QUALITY CONTROL LEGISLATION AND ADMINISTRATION

## A. Federal Law

Water quality control did not originate with the states. It began through the efforts of the federal government in controlling discharges into navigable waterways. Initial federal activity began with the Rivers and Harbors Act of 1899 which granted jurisdiction of discharge control to the Army Corp of Engineers.

It was not until 1956 that significant federal legislation for water pollution control was enacted.[1] From 1956 to 1972 national water pollution control went through an evolutionary period which culminated into the present program with new approaches and more effective programs.[2]

The theory and scope of water pollution enforcement was drastically revised with the passage of Federal Water Pollution Control Act of 1972.[3] This law extends federal enforcement to intrastate waters and calls for national enforcement based primarily on effluent limitations rather than on what effluent the waterway receives.

The change in approach to water pollution was necessitated by the shortcomings of laws based on water quality. Only one suit was ever filed under the old Water Pollution Control Act and experience showed that polluters relied on the difficulty of proving responsibility for a polluted stream to ignore the law.

Now that enforcement is based on effluent standards, the procedure is one of measuring the effluent of a polluter to ascertain if it is within the standards set for the user involved.

The 1972 law establishes a national system of permits to control discharges by industry, municipalities and other sources of pollution. The permits are to be issued by the EPA or by the states operating under an EPA approved program. Each permit must specify which substances may be discharged, in what amounts, and how soon the effluent quality must be improved. It is unlawful to discharge any pollutant into a waterway unless in compliance with the 1972 Act. The national goals are to have the "best practicable available technology" adopted for point source discharges by July 1, 1977, and "best available technology economically achievable" adopted by July 1, 1983.[4] Zero pollution is the goal for 1985.[5]

On the international level, the latest action deals with salinity control on the Colorado River. The 93rd Congress enacted into law H.B. 12165 which directs the Secretary of the Interior to institute and oversee activities relevant to building a desalting plant near the Welton-Mohawk Drainage Project. This desalting plant is to provide sweet water to both the United States and Mexico.

## B. STATE LAW -
## COLORADO WATER QUALITY CONTROL ACT OF 1973

Water pollution control among the states has followed a similar history to the federal activities. Sewage control and other health protection measures were undertaken by states and cities very early in our history. These programs were usually curative of social welfare ills related to diseases.

It was not until the 1965 Federal Water Quality Act that states began developing affirmative control measures aimed at both curative and preventative. States were required by federal law to develop stream quality standards and implementation plans to limit discharges that would exceed the set standards. Each state created an agency to carry out the state law and where necessary the federal standards.

Colorado was no exception. Prior to 1966, water pollution control was in the Health Department with actual control a matter for local or county health officers. In 1966, the General Assembly enacted the Colorado Water Pollution Control Act to prevent, abate and control pollution of the state's waters and establish stream standards.[6] In 1967, the law was amended to permit adoption of effluent standards to remedy particular discharge problems that exceeded the stream standards. The Colorado Water Pollution Control Commission was created to administer the law.

Similar problems were experienced by the federal government under the control and enforcement procedures called for in the 1965 and 1966 Acts. The solutions were curative and enforcement was a nightmare. Colorado thus followed suit in updating its laws and adopted the Water Quality Control Act of 1973.[7] The Act was passed in recognition of the fact that pollution of state waters constitutes a menace to public health, a nuisance to the public, is harmful to wildlife and aquatic life, detrimental to beneficial uses of waters of the state and in close correlation to water pollution problems in adjoining states.[8]

The Act was adopted pursuant to the declared public policy to "conserve state waters and to protect, maintain, and improve the quality thereof for public water supplies, for protection and propagation of wildlife and aquatic life, and for domestic, agricultural, industrial, recreational, and other beneficial uses."[9] Regarding the matters of pollution, general policy further provided "that no pollutant be released into any state waters without first receiving treatment or other corrective action necessary to protect the legitimate and beneficial uses of such waters and to prevent, abate and control new or existing water pollution and to cooperate with other states and the federal government in achieving these objectives."[10]

Among the accomplishments of the Act are the following:

1. Creation of a Water Quality Control Commission;[11]
2. A plan to classify state waters;[12]
3. Standards by which to describe water quality;[13]
4. A method for promulgating water quality control regulations;[14]
5. A method for reviewing the adequacy of individual sewage disposal systems;[15]
6. Administrative machinery to supervise loans and grants and to coordinate with other state bodies;[16]
7. A chain of command for administering and enforcing water quality control programs;[17]
8. A system for administratively proceeding to effect the regulations of the commission;[18]
9. A permit system for the discharge of pollutants;[19] and
10. Enforcement provisions.[20]

## C. WATER QUALITY CONTROL COMMISSION

It is crucial to the success of any program that responsibility be centered in one agency. Therefore, an important step in state water quality management was taken with creation of the Water Quality Control Commission.[21] This Commission consists of one member of the State Board of Health or its administrative staff, a member of the Wildlife Commission or its staff and a member of the Water Conservation Board or its staff; the Executive Director of the Department of Natural Resources or his designee; and seven citizens of the state who are appointed by the governor. The law requires that there shall be one of these citizens from each Congressional district with the remainder to come from the state at large. The problem that appears here is that there may be too many members with varying interests and responsibilities on the Commission. While eleven people in itself is not a large number, it can be difficult to get members from various governmental agencies to agree to a decision or to a general policy. Placing people from all parts of the state on the Commission may have the same effect though this was clearly a necessity if the bill was to pass a body which needs to be re-elected.

The Commission has responsibility for developing a comprehensive and effective program for the prevention, control, and abatement of water pollution and for water quality protection throughout the entire state.[22] In connection with this directive the Commission shall classify the state's waters, promulgate water quality standards and regulations to implement those standards, issue waste discharge permit regulations, supervise sewage treatment plants, both municipal and individual, review applications for underground detonations and shall review these standards and regulations every three years. In October of each year, a public hearing shall be held to comment on water pollution problems within the state.

## Classification of Waters and Water Quality Standards

The Commission is directed to classify all state waters.[23] The classification is to be by regulation and may use such relevant characteristics as the extent of pollution existing or the maximum to be tolerated as a goal; source of pollution, present uses and the uses for which the water is to become suitable as a goal; the character and use of the land bordering the water; the need to protect the water for human use, wildlife and aquatic life and the type of water, i.e., subsurface, lake, stream or ditch and its volume, depth, flow, temperature, stream gradient and the variability of such factors on a daily or personal basis. It can be seen from this list that existing pollution is the thrust of concern in the classification and that the statute shall be applied to remedy pollution problems.

When setting quality standards, the law requires the Commission to take into account particular water characteristics relating to pollutants and the regulations to be promulgated for their control. These pollutants range from toxic substances, to salinity and alkalinity, to suspended solids to turbidity and temperature.[24]

The regulations promulgated shall set forth the standards, prohibitions and effluent limitations of any of the pollutants specified that any person may discharge into a specified class of water and shall also describe pre-treatment requirements, prohibitions, standards, concentrations and effluent limitations on wastes that any person may discharge into any specified class of streams from any specified facility, process, activity or waste pile, including, but not limited to, all types specified in Section 306 (6)(1)(A) of the Federal Water Pollution Control Act.[25] The same regulations shall also describe the measures, both mandatory and prohibitory that must be taken by a person owning or operating any facility which is causing or might cause the quality of any state waters to be in violation of an applicable water quality standard.

Regulations shall be promulgated in light of need, practicality of enforcement, the intermittant or continuous flow of the pollution, the flow of the stream, the need for safety precautions and the class of water involved.[26] In promulgating such regulations, there shall be coordination between the Water Conservation Commission, the oil and gas commission, the State Board of Health and other interested agencies to avoid overlapping or redundant regulations.[27]

## Administration

The water quality programs adopted by the Commission shall be administered by the Division of the State Department of Health of which the Commission forms a part.[28] The Division of the Department of Health shall monitor for waste discharges, administer the waste discharge permit system and carry out the enforcement provisions of the statute, including seeking criminal prosecution or other judicial relief which may be appropriate.[29]

## Monitoring, Recording and Reporting

An owner of a facility, process or activity which discharges pollutants into state waters shall, in accordance with Commission instructions, maintain records, use monitoring methods, sample discharges and make reports on his activities relating to the discharge of pollutants into streams.[30] The Division of the Department of Health has the power to enter and inspect at any reasonable time and in a reasonable manner any property, place or premise for the purpose of investigating actual or suspected pollution to ascertain compliance or noncompliance with a Commission regulation. Records may also be copied during this entrance. If entry is refused, a warrant may be issued from any district and county court of the state.

In emergencies, the Division may issue immediate cease and desist orders to said owner of the premises, place or property along with seeking a restraining order or injunction.[31]

## Procedure for Hearing

The Commission or Division may hold hearings, subpoena witnesses and take testimony in their rule making function or enforcement proceeding in the case of a violation. The statute provides that the Commission or Division shall have sole discretion as to who may appear before it.[32]

Prior to promulgating a regulation, a hearing shall be conducted with notice of such hearing given at least sixty days prior thereto.[33] Anyone wishing to propose a different regulation may do so by filing the proposed regulation with the Commission not less than twenty days before the hearing.[34]

## Permit System

A system of requiring a permit has been established for those persons wishing to discharge pollutants into state waters. An application for a permit system which was made under the federal act is deemed to be an application for a permit under the Colorado statute, however, even though permits issued under the federal act shall be deemed to have expired as of 30 June 1975.[35]

Applications for permits shall be sent to the Department of Health which has discretion to issue, deny, modify, suspend, revoke or otherwise administer the discharge of pollutants into state waters.[36] The responsibility for issuing regulations covering permits and in line with the general policy of the Act lies with the Water Quality Control Commission.[37]

Each applicant for a waste discharge permit shall send one hundred dollars ($100.00) with the application. Public notice of every complete application shall be circulated to inform all interested persons and potentially interested persons of the proposed discharge and of the proposed determination to issue or deny the permit. The notice shall be circulated[38] within the geographical areas of the proposed discharge and notice shall be mailed to any person or group on request.[39]

The permit shall be issued unless it conflicts with a federal or state statutory or regulatory requirement relating to the application or the proposed permit. No discharge of waste will be allowed if it will conflict with a duly promulgated state, regional or local land use plan unless the requirements of such plans are met or will be met pursuant to a schedule of compliance.[40]

Permits for individual sewage disposal systems shall be issued in a similar manner except that no public notice is provided for (assuming, of course that the disposal "system" is not merely puring raw sewage into a stream). The fee accompanying the application is seventy-five dollars ($75.00).

No permit is required by the state for agricultural wastes or flows or return flows from irrigation waters unless so required by federal act or regulations.[41]

Restrictions placed on disposal of nuclear, toxic or radioactive wastes are much stricter than the restrictions placed on the disposal of other waste. Before a permit may be issued to allow the discharge of such wastes, it must be proved beyond a reasonable doubt--the highest burden of proof--that no pollution will result from the discharge of these wastes or, if there will be pollution, that it will be limited to a specified area with no migration.[42]

Violations

Though the Act is not as strong as it could be, it is clearly the intention of the legislature to provide enforceable standards instead of merely issuing a set of formalized good intentions. In the control of pollution, the public is the strongest ally. Progress in the area depends heavily on community understanding and sympathy. Industries naturally do not want the type of adverse publicity capable of being generated in this area or to acquire a reputation of being indifferent to the community's problems. With the above in mind it is noted that any person or agency of the state or federal government may apply to the Division to investigate and take action upon any suspected or alleged violation of any provision of the Act or any order, regulation or permit issued.[43]

Any person who is engaged in an activity which results in a spill or discharge of oil or any other substance which may[44] pollute the waters of the state shall report it to the Division of the Department of Health.[45] This notification is to be used against the person in a criminal case except that it may be used for perjury or false swearing[46] if deliberately incorrect. Failure to so report a spill or discharge is punishable by a fine of ten thousand dollars, a jail term in the county jail for not more than one year, or both.[47]

When notice has been given of an alleged violation, such notice shall be conveyed to the alleged violator. This notice shall state the provision alleged to be violated, the facts constituting the alleged violation and may include the nature of corrective action contemplated.[48] Public hearings on the violation are required but shall not be held sooner than fifteen days after notice of the alleged violation occurs.[49]

## Remedies and Penalties

The Department of Health has several options open to it for remedying a violation. These include suspension, modification or revocation of the permit,[50] cease and desist orders,[51] and clean up orders[52] which may be followed by a restraining order or injunction[53] issued by the district court in a suit instituted by the district attorney or attorney general. The restraining order or injunction is sought if the cease and desist order or clean up order is ignored. In addition to the above, civil penalties of up to ten thousand dollars per day are permitted,[54] as well as criminal fines[55] for violation of a permit, cease and desist order, or clean up order. Tampering with a monitoring device is punishable by a fine of ten thousand dollars or six months in the county jail or both.[56]

## Sewage Treatment Works

In order to fully maintain control over water quality, the Water Quality Control Commission is directed to enter into contracts with municipalities when construction of sewage works is to begin or when collector lines and interceptor lines and pumps associated with such lines are to be replaced.[57] Moreover, the Department of Health is charged with developing plans for coordinated waste treatment management prusuant to Section 303(e) and 208 of the federal act.[58] It is further provided that no person shall begin construction or expansion of a sewage treatment works designed to serve more than twenty people unless:

1. site location and the construction have been approved by the Water Quality Control Commission; and
2. a permit has been issued pursuant to Section 66-28-501 (6).

In determining the suitability of a site, a long-range plan for the area shall be considered as well as the possibility of consolidation of sewage treatment works to avoid a proliferation of small sewage treatment works.[59]

## Regulations

Regulations enabling Colorado to participate in the National Pollutant Discharge Elimination System (NPDES) were approved by the Water Quality Control Commission of 20 August 1974. The regulations establish two state permit programs--one to control industrial and municipal discharges and another to control agricultural discharges in line with federal guidelines for participation in NPDES.

Companion regulations approved by the Commission established effluent limitations applicable to all waste water discharge except storm runoff and agricultural discharges. The standards, which go into effect "as soon as reasonable and practicable" or by July, 1977, at the latest, were set at 30 milligrams per liter (mg/l) (monthly average) for five-day biological oxygen demand and suspended solids; 0.5 mg/l for residual chlorine; 6.0-9.0 for pH; 10 mg/l or at concentrations producing no visible sheen, whichever is lesser, for oil and grease; and for fecal coliforms 200 organisms per 100 milliliters (geometric mean) in a test involving three samples during 30 consecutive days or 400 organisms in a two-sample, seven-day test. For toxic materials, the standard was set at "none at levels toxic" to health and welfare.

In addition to the above, regulations have been promulgated in the areas of classifying interstate and intrastate streams by river basin, those which set forth guidelines and criteria for review of solid waste disposal facilities for water pollution control site approval, for control of pollution for feedlots, and for design, operation and maintenance of mill tailing ponds. Along with these are standards for discharge of wastes, rules for subsurface disposal systems, regulations governing individual sewage disposal systems, and guidelines for control of water pollution from mine drainage.[60]

## C. SELECTED CASES: WATER QUALITY DEGRADATION

It has been noted by one author that laws developed under the appropriation system should be separated into two major questions with respect to water quality.[60] These questions are:

(1) What protection is afforded to senior appropriators against pollution by upstream junior appropriators?

(2) What protection is afforded the junior appropriators against pollution by upstream senior appropriators?

Colorado has had water quality cases in each of these two groupings. These cases are discussed below.

### Rights of Senior Appropriators

This issue of the rights of senior appropriators against juniors, concerning the pollution problem, was handled in the case of Humphreys Tunnel and Mining Co. v. Frank.[61] In this case, the plaintiff homesteaded 168 acres, part of which was irrigated by water directed from Willow Creek, to which a decreed priority date of July 1895 was attached, and 60 acres of which were natural meadow lands along the stream that grew as a result of the overflow of the stream. The defendant in 1902 began to operate a reduction mill to process various minerals. The mill was located approximately one and a half miles upstream from the plaintiff's headgate. The plaintiff contended that the continued operation of the mill would result in the destruction of his lands.

Based on Section 3176, Rev. Stat. 1908 and additional legislation that "prohibits any person from flooding the property of another by water, or washing down the tailings of his or their sluice upon the property of other persons," the court held that the "defendant is liable in damages for this pollution of the stream which has injured plaintiff."[62]

The court held, based on the Suffolk case which will be discussed later, "that it was entirely practical and feasible for defendant, with a comparatively small expenditure and within a few weeks time, to take care of the tailings and waste material upon its own premises."

The court also set forth the opinion that the defendant, a junior appropriator in this case, does not have:

> the absolute right to discharge into the stream the waste water mixed with hurtful slimes, or absolve it from liability for resulting injuries to third persons who have lawfully acquired prior rights to use the waters thereof for any beneficial purpose, regardless of the fact that the waters used were not a part of the natural flow of the stream.

The court held that the rights of the plaintiff were subject only to the rights acquired by prior appropriators and that the plaintiff's rights were such that he should be allowed "to have the natural waters and all accretions come down the natural channel undiminished in quality as well as quantity."

Though the above case dealt with physical tailings being washed downstream the rights of the downstream senior appropriator are clear. A much more recent case dealt with degradation in the quality of water in which there was no physical debris washed into the stream but the quality of the water was lowered.

In the case of Game and Fish Commission v. Farmers Irrigation Company,[63] the defendant Game and Fish Commission had degraded the water by simply running the stream through a fish hatchery and returning it to the mainstream. Plaintiffs contended that this activity degraded the quality of water which was used for domestic purposes. The court held for the plaintiffs and assessed the damage at the amount which was expended to obtain a new water source. The case establishes the right to quality as well as quantity to be delivered to an appropriator.

Rights of Junior Appropriators

An earlier case than the one previously mentioned, concerned the right of a junior downstream appropriator against a senior upstream polluter. This case is referred to as Suffolk Gold Mining and Milling Co. v. San Miguel Consol Mining and Milling Co.[64] In this case, the Suffolk Compound in the 1880's built a stamp mill on Howard's Fork of the San Miguel River and applied the water to run its equipment and furnish water for the reduction process. The water after use was returned to the stream. Modifications were made to the mill in 1892 and 1893. In 1890 the San Miguel Company was organized for the purpose of furnishing power and and light to the mines in the area. The company ran a pipe from Howard's Fork to its plant to operate a Pelton wheel, which furnished electircal power. After a time, the San Miguel Company noticed that its pipe and other equipment was being damaged, and concluded that the Suffolk Mill above their point of diversion was responsible for the damage. The mill refused to correct the cause of the problem in response to the company's request.

The Suffolk Company claimed that they were "first comers" and as such had a

> right to use the stream as they chose, and that the subsequent comer must take the water flowing down the fork as he found it when he came, and that he was without right to complain because of the pollution of the waters, or the method of user.[65]

The major issue as seen by the court concerned:

> the title which an appropriator of the waters of this state acquires by acts duly performed under the constitution and statutes regulating its acquisition, and the rights which he does or may acquire with reference to other appropriators along the line of the stream, though subsequent in time.[66]

The court noted that "an appropriator acquires a right of property in that which he has appropriated." The court went on to point out, however, that the title is necessarily subject to many conditions. The result of these conditions is that the title to this water is not absolute, rather it is relative, and that a first comer's rights must be taken as subject to conditions and limitations.

The court, in making its ruling, stated that it would apply only to cases where part of the water was still open to appropriation. Under this condition, the court held that:

> the title and rights of the prior appropriating company were not absolute, but conditional, and they were obligated to so use the water that subsequent locators might, like lower riparian owners, receive the balance of the stream unpolluted, and fit for the uses to which they might desire to put it.[67]

The court further stated that it was:

> practical for the Suffolk Company to have the full beneficial use of its title, and at the same time, preserve the waters unpolluted, so that they may be fully enjoyed by one who subsequently takes the water from the stream and is, as we think, entitled to it free from any pollutions which can be prevented by reasonable means.[68]

The court upheld the lower court's decision that "at a very slight expense, and at a very slight inconvenience, the Suffolk Company could prevent the injury."[69] Thus the concept of reasonable use was adopted to deny the right of a senior to pollute the waters to the detriment of downstream juniors.

## D. REFERENCES

[1] Federal Water Pollution Control Act of 1956, P.L. 84-660,0, July 9, 1956.

[2] The basic act was amended by:
1) Federal Water Pollution Control Act Amendments of 1961, P.L. 87-88, July 20, 1961,
2) Water Quality Act of 1965, P.L. 89-234, October 2, 1965,
3) Clean Water Restoration Act of 1966, P.L. 89-753, November 3, 1966,
4) Water Quality Improvement Act of 1970, P.L. 91-224, April 3, 1970.

[3] Federal Water Pollution Control Act Amendments of 1972, P.L. 92-500, October 18, 1972.

[4] Ibid, Sec. 301(b).

[5] For an elaboration of the Federal Water Pollution Control Act of 1972 and the programs initiated thereunder, see: Reitze, A., Environmental Law, North American International 1972 and supplements. Chapters 4, 9.

[6] For an excellent discussion of water quality control under the 1966 Act see: "A Survey of Colorado Water Law," 47 Den L.J. 226 (1970).

[7] C.R.S. 25-8-101 to 25-8-704 (1973). Radosevich, G.E., and P. Allen, Colorado Water Quality Control and Administration, Laws and Regulations, E.R.C. Information Series No. 12, Center for Economic Education, C.S.U. 1974 and supplement for a current compilation of water quality control laws and Commission regulations.

[8] C.R.S. 25-8-102(1).

[9] C.R.S. 25-8-102(2).

[10] Ibid.

[11] C.R.S. 25-8-201+

[12] C.R.S. 25-8-203+

[13] C.R.S. 25-8-204+

[14] C.R.S. 25-8-205+

[15] C.R.S. 25-8-206+

[16] C.R.S. 25-8-207+

[17] C.R.S. 25-8-301+

[18] C.R.S. 25-8-401

[19] C.R.S. 25-8-501+

[20] C.R.S. 25-8-601+

[21] Sapra note 11.

[22] C.R.S. 25-8-202(1) to (6)

[23] C.R.S. 25-8-203(1) to (2)

[24] C.R.S. 25-8-204(1) to (3)

[25] C.R.S. 25-8-205(1)

[26] C.R.S. 25-8-205(2)

[27] C.R.S. 25-8-205(4)

[28] C.R.S. 25-8-301

[29] C.R.S. 25-8-302(a) through (e)

[30] C.R.S. 25-8-304(a) through (e)

[31] C.R.S. 25-8-607

[32] C.R.S. 25-8-401. This section could be unconstitutional if strictly administered for the basic reason that one whose property interests are at stake or one who may incur a criminal penalty is entitled to due process, which allows him to be heard. Due process is not to be doled out at the whim of a commission.

[33] C.R.S. 25-8-402(1)

[34] C.R.S. 25-8-401(2)

[35] C.R.S. 25-8-501(1)

[36] C.R.S. 25-8-501(2)

[37] C.R.S. 25-8-501(3)

[38] There has been no definition of the word "circulated" but it would seem prudent to publish the notice in a daily paper at least once every week for four weeks and post a notice at major public places such as post offices and courthouses.

[39] C.R.S. 25-8-502(1) through (4).

[41] C.R.S. 25-8-503. This type of provision is both necessary and unfortunate. It is needed to avoid the trauma of sudden action but has provided a way for long delays in compliance in the past which frequently extend beyond the schedule of compliance.

[41] C.R.S. 25-8-506(1)(2)

[42] C.R.S. 25-8-505

[43] C.R.S. 25-8-601(1)

[44] The word "may" could be too indefinite to meet constitutional standards.

[45] C.R.S. 25-8-601(2)

[46] Id.

[47] Id.

[48] C.R.S. 25-8-602. The notice should contain the nature of the corrective measure in order that the alleged violator may fairly meet the charge and the threat posed to him.

[49] C.R.S. 25-8-603(1)

[50] C.R.S. 25-8-604

[51] C.R.S. 25-8-605

[52] C.R.S. 25-8-606

[53] C.R.S. 25-8-607

[54] C.R.S. 25-8-608

[55] C.R.S. 25-8-609

[56] C.R.S. 25-8-610

[57] C.R.S. 25-8-702

[58] C.R.S. 25-8-703, referring to the Act of October 2, 1965, 79 Stat. 909, 33 U.S.C. § 466(g).

[59] C.R.S. 25-8-704. The state's authority to regulate sewage treatment works was dealt with in Erie Water and Sanitation District, County of Weld v. George Mazzini and Pearl Mazzini, Civil Action No. 14048. In that case, the defendant's contentions were that the act permitting sanitation districts to be formed was unconstitutional and that the action of the district in forcing them to connect with a sewer line 400 feet from their home was unconstitutional.

The trial court dismissed both claims. It said that sanitation districts are quasi-municipal corporations which are born out of the state and may be formed by the state so long as the purposes for forming them are reasonable. The court found that sanitation control was within the scope of regulation provided by the police power of the state and that the sanitation districts were, therefore, reasonable.

The defendant's second contention was dismissed as a result of the first finding. Since the state could regulate sanitation, it followed that individuals could not be allowed to set up their own facilities, no matter how good they were. If it were otherwise, the state would lose its control. The court further found that requiring the defendants to connect with a line 400 feet from their home was not unreasonable -- though the court did say that unreasonable compliance could not be enforced.

[60] These regulations may be obtained from the Colorado Department of Health, Water Pollution Control Commission, 4210 East 11th Ave., Denver, Colorado 80220. They may also be found in a Compilation of Colorado Water Quality Control and Administration, Laws and Regulations, compiled and edited by George E. Radosevich and Peggy Allen. It is available from the Cooperative Extension Service, Environmental Resources Center, Colorado State University, Fort Collins, Colorado 80523.

[61] Meyers, Charles J., Functional Analysis of Appropriation Law, Report NWC-L-71-006, National Water Commission, Legal Study No. 1, July 1, 1971, p. 19.

[62] 46 Colo. 524, 105 P. 1093 (1909)

[63] Id., p. 1095

[64] Game and Fish Commission v. Farmers Irrigation Co. , 426 P. 2d 562 (1967)

[65] 9 Colo. App. 407, 48 P. 828 (1897)

[66] Id., p. 829

[67] Id., p. 830

[68] Id., p. 832

[69] Id., p. 833

[70] Id., p. 833

# CHAPTER III

# THE ECONOMIC VALUE OF WATER FOR WASTE DILUTION: REGIONAL FORECASTS TO 1980[*]

## A. INTRODUCTION

The processes of production and consumption in advanced economies yield vast amounts of residual waste materials and energy. Disposal of these materials has important implications for community health, well-being and quality of life and has become a problem of great social significance (Kneese, _et al_., 1970). Many waste materials undergo chemical change when discharged into the environment and may eventually be converted to forms which have no undesirable consequences for humans. While such natural processes can accommodate some wastes, more and more frequently waste discharges exceed levels which can be naturally assimilated.

Water has long been utilized as a medium for disposal and assimilation of wastes, and it has become customary for individuals, businesses and communities to avoid transportation and treatment costs by discharging residuals into streams or other bodies of water. However, if the assimilative capacity of the receiving medium is exceeded, the cost savings achieved by the waste discharge may be more than matched by damages suffered by other users in the form of increased costs or decreased productivity to producing firms or detriments to health or aesthetic values to water consumers. Concerns with damages caused by lower water quality have led to the establishment of quality standards which act to control the circumstances and the amounts of waste which can be discharged into water supplies. It seems clear that potential waste loads are rapidly

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[*] This chapter was prepared by S.L. Gray and R.A. Young.

increasing as a consequence of population growth and increasing quantities of goods and services produced by the economy.

One means of abating water pollution is to dilute degraded water with a higher quality source. Water released for the purpose of waste dilution has economic value to the extent that either damage to subsequent users or expenditures for effluent treatment are reduced. However, the use of water for this purpose incurs costs, such as construction of impoundments to store the resource. Also, release of water for dilution can foreclose on other uses of water, such as recreation, navigation, power generation or withdrawal for municipal, industrial or agricultural uses. Hence, public agencies charged with water quality control are faced with significant resource allocation decisions concerning both water utilization and pollution control. Estimates of the economic value of dilution water can be important aids in making such decisions.

In this chapter, we develope forecasts of the value of water for diluting wastes in each of several major regions in the United States. The present discussion is limited to wastes in terms of BOD loadings only. In the following sections we discuss conceptual issues in resource allocations, describe methods for estimating economic value and, finally, discuss our chosen conceptual framework, sources of data and forecasts of the regional values of dilution water for 1980.

## B. CONCEPTUAL ISSUES

Optimal resource allocation. As we discussed in more detail in Chapter I, the model of the competitive market system provides an abstract statement of the conditions for optimal resource allocation. Given certain normative postulates concerning consumer sovereignty and the adequacy of distribution of assets and, given further assumptions concerning the nature and behavior of producing and consuming units, it can be shown that the market system will provide a desired bundle of goods at least cost. On the producer's side of the market, prices represent the value or opportunity costs of factors used in alternative lines of employment and thus serve as guides to investment decisions. For consumers who attempt to maximize satisfaction obtained from dollar expenditures, market prices emerging from the competitive system reflect the relative valuation of the worth of a good or service and thus convey consummers' desires to the producer.

Optimal allocation of resources in the face of pollution. While the competitive market model is useful as the ideal standard of efficiency against which actual economic organization can be compared, few would argue that the conditions of the model meet reality. A number of circumstances in which the market may not optimally allocate resources (market failures) have received attention in the economic literature. These failures include the existence of uncompensated consumption and production side effects (externalities), decreasing cost industries, resource immobilities, lack of markets and others. All of these may be of importance in water resources but it is upon the first, the existence of externalities, that our discussion centers.

Kneese and Bower (1968) have likened externalities or "spillover effects" to the side effects of medication. They are the unintended effects on others of a particular course of action. The existence of uncompensated impacts, whether positive or negative, results in a divergence between the private costs (benefits) facing economic units and the social costs (benefits) of their actions and hence, in a less than optimal allocation of resources. In the use of natural bodies of water for the disposition of residual waste materials the individual discharger may reap positive benefits because he does not bear the costs of his action. Water thus used for waste assimilation is considered a free good. However, costs external to the firm may be incurred by other firms or the remainder of society and, if uncompensated, indicate a suboptimal allocation of resources.

In their analysis of the economic optimum in water quality regulation, Kneese and Bower rely upon the concept of the basin-wide firm. This hypothetical entity would, in principle, "internalize" any external costs and benefits in its pursuit of the optimal level of pollution and treatment. At the optimum, the sum of treatment and damage costs would be minimized.

While it is not argued that the hypothetical entity mentioned above is practicable nor desirable as a method of solving problems posed by interdependencies in water use it does serve to point up the nature of the problem. Natural water supplies have a valuable capacity to assimilate residual wastes. Complete elimination of such wastes would remove the assimilative burden to water supplies but would also be extremely costly. However, if no value is attributed to water in this use, an overuse will result and yield a suboptimal allocation. The basin-wide firm concept focuses attention on the question of estimating values and using these values in the social allocation of resources. It is to the valuation issue that we now turn.

Methods of valuing water in waste assimilation. We follow Marglin in defining value as the amount a rational user would be willing to pay for the resource in question. Estimating value or willingness to pay for water in waste assimilation is rendered difficult by the fact that all users are not affected equally by reduction in water quality. Some uses--hydropower generation, navigation and certain industrial uses--suffer negligible damage from heat, chemical or bacterial content or low levels of oxygen while other uses including recreation, fish and wildlife and municipal water supply have very low tolerance. Thus, value will be greatly affected by the particular use configuration in conjunction with waste dispersion.

The most direct means of determining water value in waste load assimilation is to estimate the relative damages associated with various water quality levels. The benefits from water used for low flow augmentation are taken to be the associated reduction in costs or damages. However, it is extremely difficult, if not impossible, to estimate accurately all factors in the damage function. For example, the detrimental effects of a degradable effluent on a receptor depend on the distance downstream, temperature, rates of flow and the quality of the receiving waters. Also, it is very difficult to assess the dollar value of the effects of water quality on the wide range of production and consumption activities. In cases where it is impossible to obtain precise estimates of damage functions, the analyst may be forced to resort to the alternative cost approach to derive estimates of value or benefits. In general, alternative cost refers to the cost of a substantially different means of accomplishing the same end. The alternative must be economically feasible and the imputed values must be those of the least cost alternative (Steiner, 1965). For the case considered here, waste treatment prior to discharge is taken to be the relevant alternative means of achieving improved water quality. Our value estimates are based on the cost of treating effluent to achieve an improvement in water quality equivalent to that provided by a unit of dilution water of a specified quality. In general, the value of dilution water depends upon the cost of treating wastes before discharge, the quality of the receiving water and the desired water quality standards.

## C. A FRAMEWORK FOR VALUING DILUTION WATER

Merritt and Mar (1969) have employed the alternative cost approach in formulating a framework for estimating the marginal value of dilution water. We have adopted their approach in deriving the forecasts presented here. While the analysis is limited to Biochemical Oxygen Demand (BOD) the procedure has general applicability to other types of pollutants.

Merritt and Mar define the marginal value of dilution water as equivalent to the marginal cost of treatment, i.e., the cost required to achieve the same quality of water as would be obtained by the addition of the marginal unit of dilution water of a specified quality. In their formulation, Merritt and Mar express total annual treatment costs as a function of the proportion of waste removed by a treatment process.

Thus,

1) $y = f(e)$ where $y$ is total annual treatment cost for BOD removal and $e$ is the efficiency level

The slope of the treatment cost function, that is, the change in total annual treatment costs given selected changes in efficiency is defined as:

2) $dy/de = a$ (\$/yr. at efficiency e)

Let $L_s$ be the yearly BOD input and assume e to apply continuously throughout the year. Then the amount of BOD removed, $L_w$ at efficiency e is:

3) $L_w = L_s e \big/ 100$ (#BOD/year)

The rate of change in BOD removed as the treatment level changes is:

4) $dL_w/de = L_s/100$ (#BOD/year)

The marginal cost of treatment, denoted m, is obtained by dividing equation (2) by equation (4) to get

5) $m = dy/dL_w = 100a/L_s$ ($/#BOD removed)

The second step is to determine the quantity of water required to dilute the discharged BOD to achieve the quality standard. In the formulation of Merritt and Mar, the quantity of receiving water with some initial BOD concentration, necessary to dilute a unit of discharged BOD to a desired standard is

6) $Z = 10^6/C_d$ (#Water/BOD), where $C_d$, is the difference between the concentration of BOD after receiving effluent discharge and the concentration in the original receiving water. This parameter is evaluated considering the physical configuration of the river and the proximity of waste discharges.

The variables m and $Z$ of equations (5) and (6) are defined respectively as the cost of removing a unit of BOD by treatment and the quantity of water containing an initial level of BOD necessary to dilute a pound of BOD to a specified acceptable level. These two variables provide the information necessary to estimate the imputed value of water for BOD assimilation which is defined as:

7) $p = m/Z$ ($/#water)

With the appropriate conversion, value may be expressed in terms of dollars per acre foot, the units used in our forecasts.

## D. REGIONAL FORECASTS OF DILUTION WATER VALUE, 1980

The framework outlined above is used in this paper to provide forecasts of the marginal value of water in diluting municipal and industrial BOD for major regions of the United States. The procedure is applied by utilizing data on treatment cost and dilution water requirements presented by Wollman and Bonem (1971). We adopt what appears to be a realistic assumption, given the present political climate regarding pollution, that municipal and industrial wastes will be treated at least to the extent of removing 70 percent and 50 percent of BOD content, respectively. It is recognized that the use of these assumed minimum treatment levels may yield water values which are not "optimal." However, recent statements on public policy pertaining to "clean water" appear to be consistent with the assumption. Additional justification may be found in the fact that some states, such as Colorado, currently require treatment of municipal and industrial wastes at these and higher levels.

The estimates of value which follow are projected values to the year 1980. The initial set of estimates, found in Table 3-3, were developed directly from the data presented in Tables 3-1 and 3-2. These estimates assume 1965 prices, a discount rate of 3.75 percent, a fifty-year life of treatment facilities and minimum treatment levels of 70 and 50 percent, respectively, for municipal and industrial waste discharge. The second set of estimates found also in Table 3-3 is derived using as a basis for derivation the minimum cost combination of treatment and flow augmentation specified by Wollman and Bonem for 1980. All estimates assume a required water quality standard of 4mg/1 dissolved oxygen, a maximum of .1 ppm phosphorus and 1 ppm nitrogen.

TABLE 3-1: Physical Data Necessary for Deriving Value Estimates, by Region (All data for 1980 medium projections).

| Region | (1) BOD to Freshwater without Treatment (1000#)[1] | (2) BOD Removed @ 35% Treatment (1000#) | (3) BOD Removed @ 70/50% Treatment (1000#)[2] |
|---|---|---|---|
| N Eng | 677440 | 237067 | 422670 |
| D & H | 2882587 | 1008860 | 1514932 |
| Ches | 2075846 | 726532 | 1091532 |
| Ohio | 5905152 | 2066812 | 3192929 |
| EGL | 1856937 | 649882 | 992709 |
| WGL | 2336821 | 817874 | 1222202 |
| U Miss | 3960797 | 1386270 | 2156694 |
| LMO | 654354 | 229037 | 360108 |
| SE | 4754125 | 1663944 | 2635300 |
| Cumb | 889414 | 311254 | 458622 |
| Tenn | 1254049 | 438912 | 896075 |
| L Miss | 1252771 | 438456 | 668589 |
| LAWR | 924180 | 323481 | 508080 |
| U Mo | 1257151 | 440007 | 717407 |
| UAWR | 662657 | 231957 | 379691 |
| W Gulf | 2910145 | 1018532 | 1573880 |
| RG-P | 215532 | 75464 | 141529 |
| Colo | 333427 | 116709 | 215624 |
| G Basin | 176569 | 61776 | 93166 |
| S Pac | 278221 | 97364 | 154395 |
| C Pac | 958125 | 335344 | 530436 |
| PNW | 1643869 | 575331 | 853735 |

[1] Source: Wollman and Bonem, Tables 34 & 36.

[2] _Ibid_.

TABLE 3-1: Continued

| Region | (4) BOD Removed @ Minimum Cost Combination (1000#)[3] | (5) BOD Discharged after Treatment @ 35% (1000#)[4] | (6) BOD Discharged after Treatment @ 70/50% (1000#)[5] |
|---|---|---|---|
| N Eng | 422670 | 440373 | 254770 |
| D & H | 2810500 | 1873727 | 1367655 |
| Ches | 1972095 | 1349314 | 984314 |
| Ohio | 3663322 | 3838340 | 2712223 |
| EGL | 1764136 | 1207055 | 864228 |
| WGL | 2278421 | 1518947 | 1114619 |
| U Miss | 2772540 | 2574527 | 1804103 |
| LMO | 458048 | 425317 | 294246 |
| SE | 4278712 | 3090181 | 2118825 |
| Cumb | 800445 | 578160 | 430792 |
| Tenn | 1003202 | 815137 | 357974 |
| L Miss | 772887 | 814315 | 584182 |
| LAWR | 508080 | 600699 | 416100 |
| U Mo | 1206872 | 817144 | 539744 |
| UAWR | 646050 | 430700 | 282966 |
| W Gulf | 2837419 | 1891613 | 1336265 |
| RG-P | 210149 | 140068 | 74003 |
| Colo | 325124 | 216718 | 117803 |
| G Basin | 172189 | 114793 | 83403 |
| S Pac | 271286 | 180857 | 123826 |
| C Pac | 934217 | 622781 | 327689 |
| PNW | 1479527 | 1068538 | 790134 |

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[3] Derived from Table 76, Wollman and Bonem

[4] Col. 1 - Col. 2

[5] Col. 1 - Col. 3

TABLE 3-1: Continued

| Region | (7)* BOD Discharged after Treatment @ Minimum Cost Combination (1000#)[6] | (8) Change in BOD Removed 35% - 70/50% (1000#)[7] | (9) Change in BOD Removed 70/50% - Minimum Cost (1000#)[8] |
|---|---|---|---|
| N Eng | 254770 | 185603 | |
| D & H | 72087 | 506072 | 1295568 |
| Ches | 103751 | 365000 | 880563 |
| Ohio | 2241830 | 1126117 | 470393 |
| EGL | 92801 | 342827 | 771427 |
| WGL | 88400 | 404328 | 1056219 |
| U Miss | 1188257 | 770424 | 615846 |
| LMO | 196306 | 131071 | 97940 |
| SE | 475413 | 971356 | 1643412 |
| Cumb | 88969 | 147368 | 341823 |
| Tenn | 250847 | 457163 | 107127 |
| L Miss | 479884 | 230133 | 104298 |
| LAWR | 416100 | 184599 | |
| U Mo | 50279 | 277400 | 489465 |
| UAWR | 16607 | 147734 | 266359 |
| W Gulf | 72726 | 555348 | 1263539 |
| RG-P | 5383 | 66065 | 68620 |
| Colo | 8303 | 98915 | 109500 |
| G Basin | 4380 | 31390 | 79023 |
| S Pac | 6935 | 57031 | 116891 |
| C Pac | 23908 | 195092 | 403781 |
| PNW | 164342 | 278404 | 625792 |

[6] Col. 1 - Col. 4

[7] Col. 3 - Col. 2

[8] Col. 4 - Col. 3

* The treatment levels consistent with the minimum cost program are presented in Table 5.

TABLE 3-1: Continued

| Region | (10) Ruling Dilution Flow Requirement @ 70/50% (Mil. acre-feet)[9] | (11) Ruling Dilution Flow Requirement @ Minimum Cost (Mil. acre-feet)[10] |
|---|---|---|
| N Eng | 21.1 | 21.1 |
| D & H | 33.3 | 1.7 |
| Ches | 83.3 | 8.7 |
| Ohio | 33.0 | 28.0 |
| EGL | 58.2 | 6.2 |
| WGL | 182.5 | 6.5 |
| U Miss | 29.6 | 25.5 |
| LMO | 3.1 | 1.7 |
| SE | 420.4 | 94.3 |
| Cumb | 19.2 | 7.3 |
| Tenn | 52.8 | 22.3 |
| L Miss | 12.1 | 8.0 |
| LAWR | 16.2 | 16.2 |
| U Mo | 39.3 | 18.7 |
| UAWR | 12.3 | .5 |
| W Gulf | 134.8 | 7.3 |
| RG-P | 10.2 | .7 |
| Colo | 76.2 | 5.4 |
| G Basin | 17.1 | .9 |
| S Pac | 13.8 | .8 |
| C Pac | 59.6 | 3.3 |
| PNW | 243.6 | 50.7 |

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[9] Derived from Table 48, Wollman and Bonem.

[10] *Ibid*.

TABLE 3-2: Economic Data Necessary to Derive Value Estimates, by Region (All data for 1980 medium projections)

| Region | Annual Treatment Cost Discharge to Freshwater 35% Treatment (Mil.$)[1] | Annual Treatment Cost Discharge to Freshwater 70/50% Treatment (Mil.$)[2] |
|---|---|---|
| N Eng | 9.1 | 12.8 |
| D & H | 13.2 | 18.7 |
| Ches | 10.9 | 14.9 |
| Ohio | 33.1 | 47.2 |
| EGL | 9.9 | 14.1 |
| WGL | 10.7 | 15.3 |
| U Miss | 24.7 | 35.4 |
| L Mo | 4.2 | 5.9 |
| SE | 38.9 | 53.7 |
| Cumb | 3.2 | 4.5 |
| Tenn | 6.0 | 8.4 |
| L Miss | 6.9 | 9.6 |
| LAWR | 7.5 | 10.2 |
| U Mo | 10.2 | 14.7 |
| UAWR | 5.9 | 8.5 |
| W Gulf | 17.4 | 24.9 |
| RG-P | 3.5 | 4.9 |
| Colo | 4.9 | 6.9 |
| G Basin | .7 | 1.2 |
| S Pac | 2.0 | 2.9 |
| C Pac | 6.6 | 9.7 |
| PNW | 12.8 | 16.2 |

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[1] Derived from Tables 54 and 55, Wollman and Bonem.

[2] *Ibid*.

TABLE 3-2: Continued

| Region | (3) Annual Treatment Cost Discharge to Freshwater Minimum Cost Combination (Mil.$)[3] | (4) Change in Annual Treatment Cost 35% - 70/50% (Mil.$)[4] | (5) Change in Annual Treatment Cost 70/50% Minimum Cost (Mil.$)[5] |
|---|---|---|---|
| N Eng | 12.8 | 3.7 | |
| D & H | 46.7 | 5.5 | 28.0 |
| Ches | 31.5 | 4.0 | 16.6 |
| Ohio | 50.8 | 14.1 | 3.6 |
| EGL | 27.2 | 4.2 | 13.1 |
| WGL | 40.7 | 4.6 | 25.4 |
| U Miss | 41.5 | 10.7 | 6.1 |
| L Mo | 6.9 | 1.7 | 1.0 |
| SE | 89.0 | 14.8 | 35.3 |
| Cumb | 7.8 | 1.3 | 3.3 |
| Tenn | 12.2 | 2.4 | 3.8 |
| L Miss | 10.3 | 2.7 | .7 |
| LAWR | 10.2 | 2.7 | - |
| U Mo | 25.8 | 4.5 | 11.1 |
| UAWR | 19.2 | 2.6 | 10.7 |
| W Gulf | 58.2 | 7.5 | 33.3 |
| RG-P | 11.1 | 1.4 | 6.2 |
| Colo | 15.5 | 2.0 | 8.6 |
| G Basin | 2.7 | .5 | 1.5 |
| S Pac | 7.0 | .9 | 4.1 |
| C Pac | 23.4 | 3.1 | 13.7 |
| PNW | 33.4 | 3.4 | 17.2 |

[3] Ibid.

[4] Col. 2 - Col. 1

[5] Col. 3 - Col. 2

TABLE 3-2: Continued

| Region | (6) Cost per Pound BOD Removed as Treatment Level Proceeds from 35% - 70/50% ($)[6] | (7) Cost per Pound BOD Removed as Treatment Level Proceeds from 70/50% - Min. Cost ($)[7] |
|---|---|---|
| N Eng | .020 | .020 |
| D & H | .011 | .022 |
| Ches | .011 | .019 |
| Ohio | .012 | .008 |
| EGL | .012 | .017 |
| WGL | .011 | .024 |
| U Miss | .014 | .010 |
| L Mo | .013 | .010 |
| SE | .015 | .021 |
| Cumb | .009 | .010 |
| Tenn | .005 | .035 |
| L Miss | .012 | .007 |
| LAWR | .015 | .015 |
| U Mo | .016 | .023 |
| UAWR | .018 | .040 |
| W Gulf | .013 | .026 |
| RG-P | .021 | .090 |
| Colo | .020 | .078 |
| G Basin | .016 | .019 |
| S Pac | .016 | .035 |
| C Pac | .016 | .034 |
| PNW | .012 | .027 |

[6] Col. 4 Table 3-2 ÷ Col. 8 Table 3-1.

[7] Col. 5 Table 3-2 ÷ Col. 9 Table 3-1.

TABLE 3-2: Continued

| Region | (8) Acre-Feet Required per Pound BOD Discharged at 70/50% (Acre-Feet)[8] | (9) Acre-Feet Required per Pound BOD Discharged at Minimum Cost Treatment (Acre-Feet)[9] |
|---|---|---|
| N Eng | .083 | .083 |
| D & H | .024 | .024 |
| Ches | .085 | .084 |
| Ohio | .012 | .012 |
| EGL | .067 | .067 |
| WGL | .164 | .074 |
| U Miss | .016 | .021 |
| L Mo | .010 | .009 |
| SE | .198 | .198 |
| Cumb | .045 | .082 |
| Tenn | .147 | .089 |
| L Miss | .021 | .017 |
| LAWR | .039 | .039 |
| U Mo | .073 | .372 |
| UAWR | .043 | .030 |
| W Gulf | .101 | .100 |
| RG-P | .138 | .130 |
| Colo | .647 | .650 |
| G Basin | .205 | .204 |
| S Pac | .111 | .116 |
| C Pac | .182 | .138 |
| PNW | .308 | .309 |

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[8] Col. 10 Table 3-1 ÷ Col. 6 Table 3-1.

[9] Col. 11 Table 3-1 ÷ Col. 7 Table 3-1.

TABLE 3-3: Estimated Marginal Value of Water for BOD Dilution, 1980 for 70/50% and Minimum Cost Levels of Treatment

| Region | (1) Marginal Value 70/50% Treatment[1] | (2) Marginal Value Minimum Cost Combination[2] |
|---|---|---|
| N Eng | .24 | .24 |
| D & H | .46 | .92 |
| Ches | .13 | .23 |
| Ohio | 1.00 | .67 |
| EGL | .18 | .25 |
| WGL | .07 | .32 |
| U Miss | .87 | .48 |
| L Mo | 1.30 | 1.11 |
| SE | .07 | .11 |
| Cumb | .20 | .12 |
| Tenn | .03 | .39 |
| L Miss | .57 | .41 |
| LAWR | .38 | .38 |
| U Mo | .22 | .77 |
| UAWR | .28 | 1.33 |
| W Gulf | .13 | .26 |
| RG-P | .15 | .69 |
| Colo | .03 | .12 |
| G Basin | .08 | .09 |
| S Pac | .14 | .30 |
| C Pac | .09 | .25 |
| PNW | .04 | .09 |

[1] Col. 6 Table 3-2 ÷ Col. 8 Table 3-2.

[2] Col. 7 Table 3-2 ÷ Col. 9 Table 3-2.

TABLE 3-4: Estimated Value of Water For BOD Dilution, 1980 Assuming 6% Discount Rate and 30 Year Plant Life[1]

| Region | Marginal Value 70/50% Treatment | Marginal Value Minimum Cost Combination |
|---|---|---|
| N Eng | .68 | .68 |
| D & H | 1.31 | 2.62 |
| Ches | .37 | .65 |
| Ohio | 1.85 | 1.91 |
| EGL | .51 | .71 |
| WGL | .20 | .91 |
| U Miss | 2.48 | 1.37 |
| L Mo | 3.70 | 3.16 |
| SE | .20 | .31 |
| Cumb | .57 | .34 |
| Tenn | .08 | 1.11 |
| L Miss | 1.62 | 1.17 |
| LAWR | 1.08 | 1.08 |
| U Mo | .63 | 2.19 |
| UAWR | .80 | 3.79 |
| W Gulf | .37 | .74 |
| RG-P | .43 | 1.97 |
| Colo | .08 | .34 |
| G Basin | .23 | .26 |
| S Pac | .40 | .85 |
| C Pac | .26 | .71 |
| PNW | .11 | .26 |

[1] These estimates were obtained by adjusting costs of treatment to reflect a 6% rate of discount and a 30 year plant life.

Table 3-4 presents estimated marginal values of dilution water under an alternative set of assumptions about the discount rate, prices and the time period. Here, our own biases lead us to employ a six percent discount rate coupled with a 30-year plant life as opposed to the 3.75 percent discount rate and 50-year period used by Wollman and Bonem.

Tables 3-1 and 3-2 below present the physical and economic data necessary for the derivation of value estimates. Footnotes at the bottom of the tables indicate the source and/or means of computing the table components.

The values presented in Table 3-3 are derived under the assumed rate of discount of 3.75 percent, 1965 prices and a 50-year life associated with treatment facilities. Table 3-4 presents the estimated regional values of water when adjusted for a six percent discount rate, 30-year project life and 1972 prices.

The estimates presented in Column 2 of both Table 3-3 and Table 3-4 are associated with the least-cost combination of treatment and water storage facilities for waste dilution projected to 1980. Wollman and Bonem present three alternative programs for meeting the water quality standard specified previously. These programs identify the treatment level necessary to minimize flow, to minimize treatment and to minimize the costs of treatment for 1980. The last of these appears to present a statement of the optimal combination of treatment and flow and we use the treatment levels specified in this program as a basis for computing the second set of estimates. The same basic procedure outlined above is used to obtain the estimates of value. The point of departure is the assumed treatment of municipal BOD at 70 percent and industrial BOD at

50 percent. Table 3-5 presents the treatment levels by region, associated with the minimum cost program.

The values presented in Tables 3-3 and 3-4 generally imply that water used in waste load assimilation will continue to be low valued relative to most other uses. At an assumed level of treatment at the 70/50 percent municipal/industrial levels, values range from as low as $.03 per acre foot in the Colorado and Tennessee regions to a high of $1.30 per acre foot in the lower Missouri. As higher levels of treatment must be utilized to meet specified standards, the alternative costs can become quite large depending on the factors cited previously. Our estimates under the conditions assumed, however, indicate the largest projected value in 1980 to be $1.33 per acre foot in the Upper Arkansas-White-Red region, where low flow and high waste discharge will combine to require 97.5 percent treatment in order to maintain the specified standards.

Even with the use of the six percent discount rate and a much shorter plant life, coupled with the use of current prices the estimated values do not reach levels great enough to compete with other uses of water. At the assumed treatment level of 70/50 percent the maximum estimated value reaches only $3.70 per acre foot in the Lower Missouri region and, under the minimum cost program, the maximum estimated value is $3.79 per acre foot in the Upper Arkansas-White-Red region.

It should be noted that the values presented in Tables 3-3 and 3-4 pertain to rather large increments to treatment levels as thus might be more appropriately termed "average marginal values" than marginal values (as would be appropriate given completely divisible increments to treatment levels and water use). Also, for types of pollutants other than BOD, and in the short-run context, say, for the removal of salinity and

TABLE 3-5: Minimum Cost Treatment Levels, by Region, 1980.[1]

| Region | Treatment Level |
|---|---|
| N Eng | 70/50 |
| D & H | 97.5 |
| Ches | 95.0 |
| Ohio | 70/60 |
| EGL | 95.0 |
| WGL | 97.5 |
| U Miss | 70.0 |
| L Mo | 70.0 |
| SE | 90.0 |
| Cumb | 90.0 |
| Tenn | 80.0 |
| L Miss | 70/60 |
| LAWR | 70/50 |
| U Mo | 95.0 |
| UAWR | 97.5 |
| W Gulf | 97.5 |
| RG-P | 97.5 |
| Colo | 97.5 |
| G Basin | 97.5 |
| S Pac | 97.5 |
| C Pac | 97.5 |
| PNW | 90.0 |

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[1] Source, Wollman and Bonem, Table 76.

toxic agents, alternative cost imputations may yield much greater values, reaching the order of tens of dollars per acre foot of dilution water. Scattered evidence, however, indicates that downstream damages would not be this great and in such cases the actual damage becomes the appropriate measure of value. The regional differences in imputed values are apparently caused by different mixes of municipal and industrial discharge and hence different treatment costs, as well as by differences in the assimilative capacity of streams.

It must be emphasized that the estimates presented here are appropriate to intermediate to long-run planning contexts and that short-run values may be much greater in magnitude. Treatment plants are designed for specific scales of operation and do not have the flexibility necessary to increase output or efficiency instantaneously. Thus, when added plant capacity cannot be provided immediately, the short-run value of small amounts of dilution water can be very great. It may also be the case that seasonality may cause short-run values of water for dilution purposes to be quite high, i.e., low flows and high levels of pollution concentration would make additional water for dilution at certain periods quite high valued. The estimates may be subject to wide errors because uncertainty regarding the accuracy of cost data, uncertainty as to regional dilution flows and over-simplification in the conceptual model. However, the relative magnitudes do have the significance in the long run, and from a policy standpoint indicate that reliance on dilution to maintain water quality standards is a more costly alternative than is provision for water treatment.

## E. SUMMARY AND CONCLUSION

Markets to allocate water resources seldom exist, so synthetic techniques must be drawn upon to develop a basis for comparing the value of water in alternative uses.

Water released for dilution has economic value in that it may reduce damages (in the form of reduced productivity or increased treatment costs). Precise estimates of damages have proven very difficult to derive directly. Hence it appears appropriate in most cases to use the alternative cost of treating effluent to achieve an improvement in water quality equivalent to that provided by a unit of dilution water of specified quality as a measure of value. The imputed value of dilution water depends upon the assimilative capacity of the water, the level of treatment and the marginal treatment costs at different treatment levels, the effluent concentrations and the quality of the receiving water.

Our results support other estimates of value in the literature which indicate that the marginal value of dilution water is relatively low on the order of pennies to a few dollars per acre foot.

# F. APPENDIX: NOTATION

$y$ = total annual treatment cost for BOD removal

$e$ = the treatment efficiency level in percent of BOD removed

$a$ = the slope of the treatment cost function computed as the change in total treatment costs associated with specific changes in the treatment level, e

$dy$ = the change in total treatment cost

$de$ = the change in treatment level

$L_s$ = the yearly BOD input to freshwater from all sources

$L_w$ = the amount of BOD removed from freshwater at a particular treatment level

$dL_w$ = the change in quantities of BOD removed by treatment given changes in the treatment level

$m$ = the marginal cost of treatment

$Z$ = the quantity of receiving water, of given quality, necessary to dilute a unit of discharged BOD to a desired quality standard

$p$ = the estimated marginal value (in \$) per acre foot of water used for dilution

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# CHAPTER IV

# SELECTIVE LAND RETIREMENT AS A MEANS OF CONTROLLING SALINE IRRIGATION RETURN FLOWS: A CASE STUDY OF THE GRAND VALLEY, COLORADO*

## A. INTRODUCTION

This chapter reports on a preliminary evaluation of land retirement as a salinity abatement option for the Grand Valley in western Colorado. Heretofore much of the research effort by physical and social scientists concerned with controlling rising levels of salinity in the Colorado River Basins has focused on structural technologies. These means typically require extensive technical and material input often leading to substantial public and private investments.

However, a voluntary program of selective land retirement may be an economically feasible means of control on a limited scale, and could be implemented competitively with other more costly structural measures in the Grand Valley.

Nature of the problem. In arid and semi-arid regions where soils typically are high in natural salts, the practice of irrigation can have deleterious consequences on water quality. Mineral solids may be leached from the soil profile or underlying geologic structure and be picked up in large quantities in irrigation drainage water. Since drainage water or "return flows" contribute appreciably to the volume of many rivers and streams in the arid west, the importance of saline return flow on water quality is readily apparent.

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* This chapter prepared by K. L. Leathers and R. A. Young

The modification of water flows in the course of development of a river basin's resources for human purposes can further contribute to the concentration of dissolved salts in the water. Examples of such sources include evaporation from storage reservoirs which concentrates existing salt loads and return flows from irrigation and urban or industrial withdrawals which have picked up more dissolved salts in addition to concentrating the salt load already present.

Approximately half of the irrigated crop production in the United States and one-third throughout the world is cultivated on somewhat saline soil [Casey, 1972]. Areas in the United States with salinity concentrations exceeding the damage threshold are found in the western region, particularly in the Colorado River Basin, the Rio Grande Basin and the San Joaquin Valley in California.

Problem setting. The Colorado, which is the largest river on the continent that flows through primarily arid terrain, extends over 1300 miles in length and drains a basin area of nearly 250,000 square miles [National Academy of Sciences, 1968]. The basin can be subdivided into three geographic regions: the upper basin, including portions of Wyoming, Colorado, Utah and New mexico; the lower basin, including portions of Nevada, Arizona and California; and the extreme lower basin below the international boundary where the river enters the Gulf of California in the Republic of Mexico (Fig. 4.1).

The modification of the Colorado River's flows have yielded benefits in the form of irrigation, power generation, recreation, industrial and domestic water supply, transportation and waste disposal. In recent years manufacturing and service industries have experienced rapid growth,

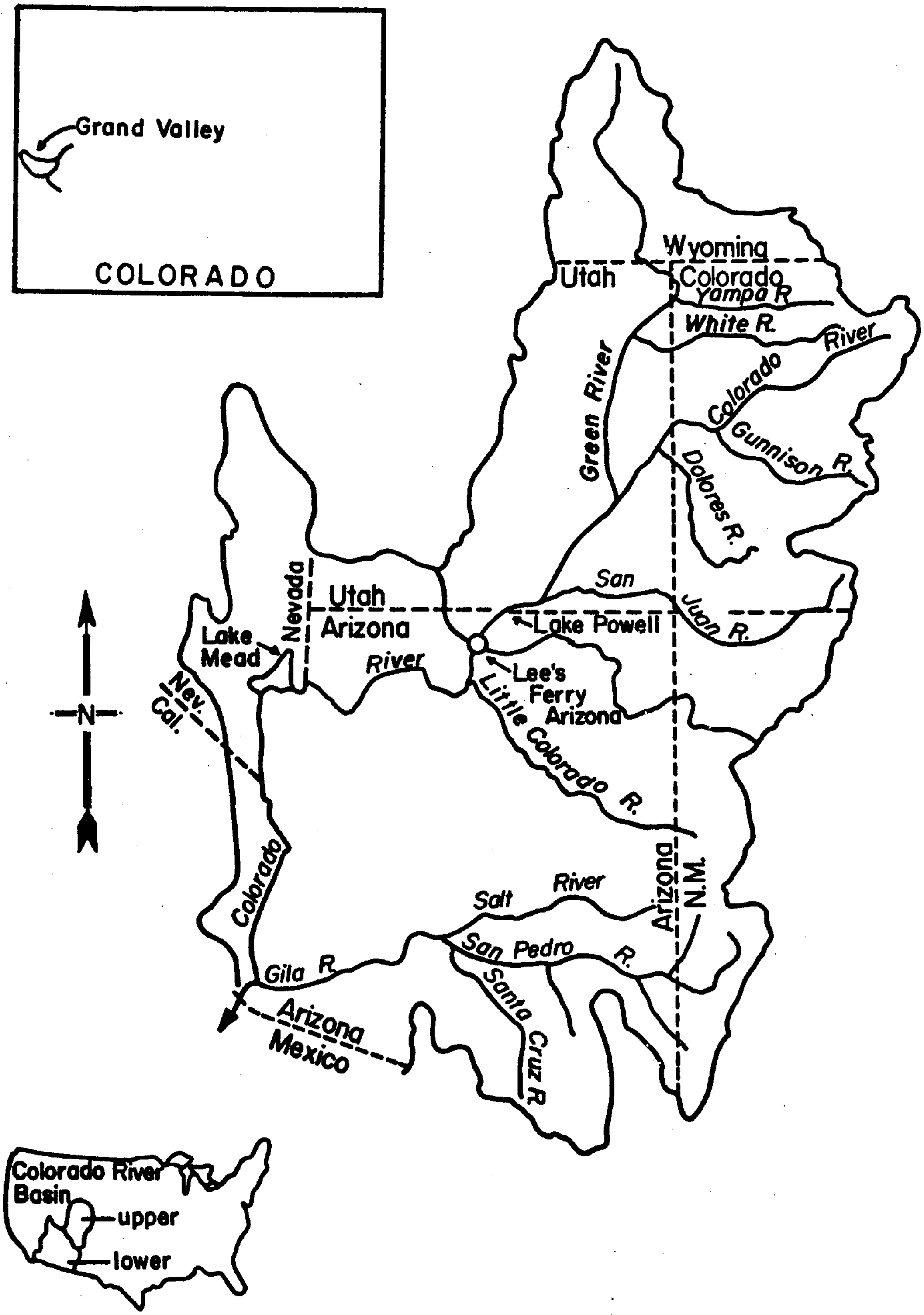


Figure 4.1. The Colorado River Basin.

surpassing mining and agriculture in economic importance in all seven basin states. Presently, agricultural use accounts for ninety percent of total basin withdrawals including both surface and ground water.

Population density throughout the basin is characteristically sparse. Over half of the basin population of 3.5 million live in the State of Arizona. However, an extended service area provided through extensive stream flow diversions to population centers outside the physical limits of the basin supports an additional 18 million people, primarily southern Californians. The lower basin states rank among the highest in the nation in growth rates of population and per capita income.

Salinity damage. Increased salt concentrations in water supplies typically have detrimental impacts on water users. Such detriments include decreased productivity and/or increased production costs for both agricultural and industrial water users, and in household uses, lowered palatability of drinking water, increased detergent consumption, the expense of water softening, reduced life of water pipes, and at higher concentrations of some elements, adverse health effects.

The River's salinity content ranges from an average of 50 parts per million (ppm) at its source to over 800 ppm at Imperial Dam, Arizona, the last major U. S. diversion point before the water reaches Mexico. The salt load passing Lee Ferry, Arizona, the boundary between the Upper and Lower Basins, between 1941 and 1966 average 8.2 million tons per year. As of 1970, the annual salt load at Lee Ferry was around 8.5 million tons.

Salinity threatens to become a critical obstacle to future development of water resources in the Basin. Economic penalties resulting from the use of saline water in the lower reaches have been projected to reach $25.4 million annually (in 1960 dollars) by 2010 [Environmental Protection Agency, 1971]. More recent estimates have direct damages at $49 million in 1973 with projections to the year 2010 approaching $126 million [Bureau of Reclamation, 1974].

The damaging affects of increasing salinity in the lower basin are substantially an unintended result of upper basin water development activity. However, future water development by upper basin states, primarily basin out-transfers for municipal use and reservoir storage, will reduce further the water available to dilute present salt loads causing increased salinity concentrations in coming years. If all proposed and authorized development projects are completed as scheduled, present penalty costs are expected to more than double in the next thirty years. [Upper Colorado Region Interagency Group, 1971]. Furthermore, these projections may underestimate potential damages to Arizona and Nevada and totally exclude consequences in the Republic of Mexico.

Problem areas. Preliminary identification of separate area contributions to salinity from point and diffuse sources has been accomplished in a number of reconnaissance level investigations conducted by governmental agencies and private commissions over the last five years [Bureau of Reclamation, 1972]. Deep percolating return flows from irrigated land situated over shale formations which contain very high levels of soluble natural salts are cited as the chief contribution from man-made sources. Combined with reservoir evaporation and consumptive use these man-made sources account for approximately half of the river's total salt burden (Table 4.1).

The Grand Valley in Colorado and the Price River Valley in Utah have the highest annual rates of salt pickup in the basin, averaging more than eight tons per irrigated acre. The Uncompaghre and Lower Gunnison Valleys, also in western Colorado, contribute slightly less per irrigated acre but

TABLE 4-1. EFFECT OF VARIOUS FACTORS ON FUTURE SALT CONCENTRATIONS OF COLORADO RIVER AT HOOVER DAM (1947-61 PERIOD ADJUSTED TO 1960 AND PROJECTED 2010 CONDITIONS)[a/]

| | 1960 | | 2010 | |
|---|---|---|---|---|
| Factor | Change in concentration (mg/1) | % of total | Change in concentration (mg/1) | % of total |
| Natural Diffuse Sources | 275 | 39 | 275 | 28 |
| Natural Point Sources | 59 | 8 | 59 | 6 |
| Irrigation (Salt Contribution) | 178 | 26 | 212 | 21 |
| Irrigation (Consumptive Use) | 75 | 11 | 134 | 14 |
| Municipal and Industrial Sources | 10 | 1 | 37 | 4 |
| Exports out of Basin | 20 | 3 | 72 | 7 |
| Reservoir Evaporation | 80 | 12 | 197 | 20 |
| TOTAL | 697 | 100 | 990 | 100 |

[a/] Source, Environmental Protection Agency (1971) (Summary Report, Tables 1,2) far exceed rates of pickup in any area in the lower basin. Total residual contributions from irrigation in the upper basin account for 38 percent of the total damages expected to accrue to lower basin water users.

The multiplicity of sources of salinity, the variety of potential means for their abatement and the fact that the receptors of damage from salinity pollution are located in different political jurisdictions than the principal sources of pollution implies that region-wide management practices must be adopted.

## B. CHARACTERISTICS OF THE STUDY AREA

The Grand Valley is an interesting and challenging area to physical and social scientists alike for investigating salinity abatement measures for future implementation in the Valley and elsewhere. Constraining factors have been encountered at all levels of study: in modeling physical and hydrosalinity relationships, institutional inflexibilities governing private water use and ownership, and identification of socio-economic consequences for communities directly and indirectly affected.

Irrigated Agriculture. The Grand Valley is located in West Central Colorado at the confluence of the Gunnison and Colorado rivers in Mesa County. Paralleling the Colorado River for about 30 miles, the Valley averages 7 miles in width and about 4400 feet in elevation. Summer weather is characteristically hot and dry and the winters cold. Beginning in April, the normal growing season averages about 190 days. With an annual rainfall seldom exceeding 8 to 10 inches, irrigation is necessary to maintain a viable commercial agriculture in the Valley.

Agriculture is an important source of employment and income to a local population of about 50,000 people in the immediate area. However, in recent years, basic manufacturing and service industries have become the mainstay for an otherwise traditional agricultural community. Approximately 70,000 acres of land is presently cultivated out of a total arable area exceeding 100,000 acres. Urban and industrial expansion, service roads and farmsteads, and idle and abandoned lands account for most of the balance not farmed [Walker and Skogerboe, 1971].

The diversified agricultural industry in the Valley is comprised of both livestock and crop production activities. Major crops grown include corn, alfalfa, sugar beets, small grains and permanent pasture. Slightly less than 10 percent of the irrigated acreage is planted to pome and deciduous orchards, the produce of which, processed locally, may be shipped as far as the Atlantic seaboard. The Grand Valley has long been a favored wintering area for cattle and sheep grazed on high mountain summer range to the east.

Following settlement in the late 1870's, irrigation companies were organized to divert water for agricultural use. Many of the original companies have since been consolidated leaving five which presently supply all the water diverted under original decrees: The Grand Valley Irrigation Company (1882), the Grand Valley Water Users Association (U.S. Bureau of Reclamation, 1905), the Palisade and Mesa County Irrigation Districts (1890's), and the Redlands Water and Power Company [Skogerboe and Walker, 1972]. Because service acreages were typically overestimated within the newly formed irrigation districts, and due partially to a gradual decline in irrigated acreage, Grand Valley farmers have always had an abundant supply of water.

Early evaluations of irrigation efficiency on these farms, which sprang from immediate drainage problems on the lower-lying lands, documented Valley-wide efficiencies of 30 to 40 percent [U.S.D.A. and Colorado

Ag. Experiment Station, 1957, and Decker, 1951]. However, the threat of rising water tables and salinity problems encountered on waterlogged soils was not enough incentive to offset wasteful use of very low-priced project water. Average charges in 1974 were less than two dollars per acre foot. Average river diversions frequently exceed 600,000 acre feet annually, but only 175,000 acre feet are required to meet normal crop consumptive use [Skogerboe, _et_ _al_., 1974].

Soils vary throughout the Valley in surface textures ranging from loam to fine silty clay but share a common parent material in subsurface structure derived from Mancos shale [Soil Conservation Service, 1955]. Being low in organic matter, these soils are prone to nutrient leaching (especially nitrates) and have restricted internal drainage at lower elevations. The prevailing topographical slope of the Grand Valley ranges between 50 and 80 feet per mile, which effectively limits irrigation methods to furrow techniques [Bishop, _et_ _al_, 1967].

_Hydro-salinity Aspects_. Selected Geological Survey gauging stations located above and below the Valley have been the chief source for estimates of annual salt pickup in recent years [EPA, Appendix A, 1971]. Average annual salt pickup attributable to irrigated agriculture is estimated at 700,000 tons of total dissolved solids. Historical data suggest a range in annual contributions of less than 400,000 tons in low flow years to over 1,000,000 tons in years of high water flow [Bureau of Reclamation, 1973].

The primary source of salinity comes from extremely saline aquifers (as high as 10,000 ppm) overlying a marine-deposited Mancos shale formation. Lenses of salts contained in the shale are dissolved by water entering and coming into chemical equilibrium with this formation before returning to the river channel. Water enters these aquifers by seepage from the irrigation conveyance system (delivery canals, laterals and drains) and by irrigation practices which lead to excessive deep percolation from irrigated fields. Recent research indicates that proportionate contributions to total salt loading are 55 percent and 45 percent, respectively [Westesen, 1974]. Because Mancos shale is so widely distributed in the upper drainage area of the Colorado River Basin, the likelihood of other irrigated localities confronting similar water quality situations suffice to justify extensive research in the Grand Valley for immediate applications elsewhere.

Proposed Salinity Controls. Degraded irrigation return flows, by way of seepage and deep percolation through saline soils and underlying geologic formations returning increased salt loads to the river system, make the Grand Valley one of the most significant man-made sources in the entire river basin. Until the initiation of the present study, previous research concentrated on various structural control technologies including lining of conveyance systems and on-farm drainage improvements. Although a program of scientific irrigation scheduling designed to improve on-farm water management has been under study since 1972, feasibility analyses have been limited to a few selected farms with no detailed Valley-wide evaluations being attempted. Other nonstructural control possibilities have had little serious consideration.

Several lengths of canals and laterals have been lined since 1970 in a demonstration area on the east side of the Valley [Skogerboe and Walker, 1972]. These researchers estimate that 70 to 80 percent of total seepage losses could be prevented by lining all canal and laterals (including on-farm delivery ditches). However, the costs of such a program could be quite high--$10 to $20 per ton of salts removed [Westesen, 1974].

Inefficiency in on-farm water use, stemming from a combination of abundant supply, low water charges, and problematic soil-topographic characteristics, has encouraged interest in irrigation scheduling as a Valley-wide possibility [Bureau of Reclamation, July 1974]. The results of irrigation scheduling are presently inconclusive, but the program holds much promise as a low-cost control measure [Skogerboe and Walker, 1973; and Anderson, *et al.*, 1974]. Improved on-farm efficiencies would likely have local as well as downstream benefits including increased yields and additional productivity on previously water-logged soils.

Research on the use of drainage technologies has emphasized interception of deep percolating water below the root zone before it has reached chemical equilibrium in the saline aquifers [Skogerboe *et al.*, 1974]. Because the deep open ditch-type drains in use since the early 1920's are largely ineffective, a drainage program would also have to include extensive renovation of existing structures to be effective. Costs of field drainage and renovation appear to be quite high, and resulting water quality improvement uncertain. Additionally, drainage improvements without improving on-farm water use efficiency would possibly make matters worse than they are [Skogerboe *et al.*, 1974].

## C. OBJECTIVE AND METHODOLOGY

The primary objective of this investigation has been to perform a preliminary evaluation of the economic feasibility of retiring selected irrigated land in the Grand Valley as a measure to control salinity. Land retirement is one of many nonstructural control options that should have careful empirical study in addition to the other structural alternatives.

Nonstructural controls typically include policy instruments designed to modify land use patterns through positive and negative incentives on users of productive resources. Defined as an effective transfer of land and capital out of the irrigated agricultural base of the Valley, land retirement was selected among other nonstructural options chiefly for two reasons: (1) this measure would likely be the most effective and at the same time the most costly to implement, and (2) the impacts of the program would be easier to measure than others in the class of nonstructural salinity controls.

The conventional theory of the firm was the conceptual basis from which the problem was formulated for empirical analysis. The approach followed makes use of the "representative firm" concept [Day, 1963]. An economic model of the irrigated agricultural industry, composed of representative farm types, was designed to approximate as closely as possible actual production levels and activity in the Grand Valley [Leathers, 1975]. Under alternative price and cropping assumptions, models of representative farms have proven useful in assessing production response and decision behavior relating to a broad range of policy issues [Kelso, *et al.*, 1974].

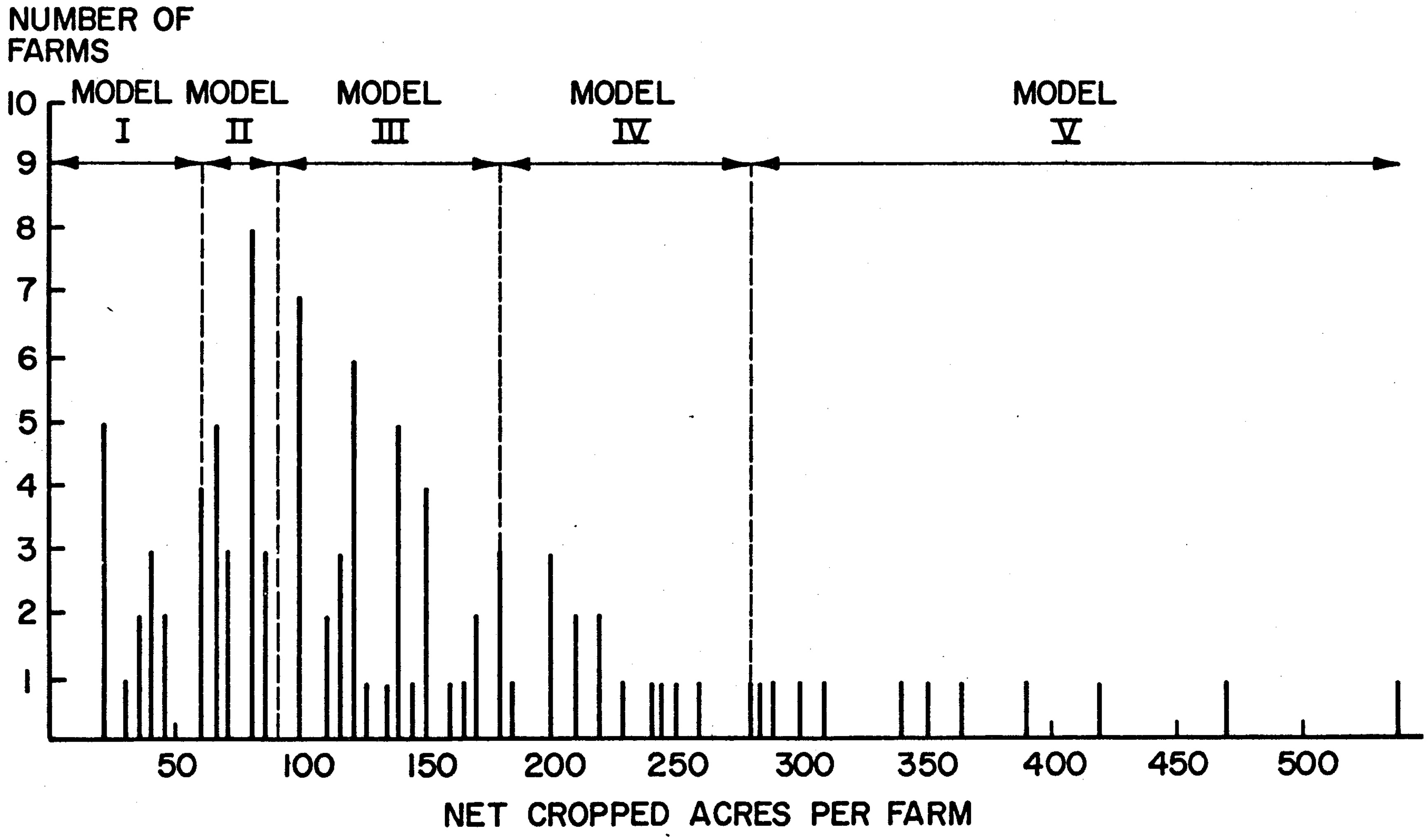
*Data Base and Sampling Method*. Actual production information collected from Grand Valley farmers during the summers of 1972 and 1973 was the principal source of data for this study. Personal interview participants were randomly selected from water user lists provided by the irrigation companies and associations which divert Colorado and Gunnison River water for agricultural use in the Valley. Since these lists typically include numerous small users (one to three acres in size) as well as commercial farms, all users with less than a forty-acre water appropriation were excluded from the population of farmers surveyed. Subsequently, from a population of approximately 350 irrigated farms, 98 complete interviews were secured representing a sampling rate of 28 percent.

Orchard enterprises, representing about 10 percent of the total irrigated acreage, are typically quite small in the Valley, very diversified in production techniques, processing and tenure arrangements, hence impractical to "model" in terms of the "representativeness" required in the analytical approach followed. For these reasons, orchard operations were not actively studied, although the method of sampling effectively reduced the incidence of orchards in the sample due to the small size of most orchard operations.

The interview schedule was designed to obtain information concerning the numbers and sizes of farms; land tenure, planning and management practices; resource inventories and production technology; crops and livestock grown, cropping patterns and cultural practices; prices paid and received; and related data specific to the study area. Supplemented with secondary data to corroborate the survey results, a series of farm models was constructed to provide a representative characterization of the irrigated agricultural industry in the Grand Valley for the 1972 production year.

The Models and Assumptions. A number of common farm characteristics was statistically evaluated to discern appropriate model parameters, model sizes and numbers, and the accuracy of aggregation. Such characteristics included resource inventories emphasizing heavy farm machinery and buildings, farm location and size, tenure and management, hired labor, livestock enterprises, crop rotations and yields among others. Five models were selected as representative of the size of the sampled farms: 40, 80, 130, 210, and 370 acres--Models I through V, respectively. The size distribution of the farm population and model acreage parameters are depicted in Figure 2.

Figure 4.2. Frequency Distribution of Sample Farm Size and Model Acreage Parameters



Subject to size and other parameters including levels of constraining resources, detailed enterprise budgets were derived to estimate and compare expected costs and revenues for each representative farm model. Due to wide variability observed in some farm practices and not others, a number of assumptions and limiting conditions were necessary. For example, livestock enterprises were extremely heterogeneous from farm to farm, and with no definitive patterns ascertained either between farm size categories or among farms of the same size, all aspects of livestock husbandry were systematically deducted from farm costs and returns. One notable exception was in valuing gross returns from permanent pasture enterprises. These assumptions include:

(1) the wide array of soil types and classes found in the Valley are uniformly distributed among each of the model size categories;

(2) cropping patterns (enterprise combinations) for each of the model categories suffice to represent synthesized "crop rotations" and are "model specific" as well as crop yields, input levels and technology, and managerial talent;

(3) cultural practices (land preparation, planting and harvesting dates, etc.) and base period (1972) market prices are uniformly applicable to all models;

(4) all livestock enterprises and associated managerial, labor and capital requirements are excluded from farm income determination and, accordingly, model incomes represent net contributions of all crop enterprises above variable and fixed costs; and

(5) the results of the budgeting procedure uniformly apply to all Grand Valley farms with the exception of small farm units of less than forty acres in size and the orchard and livestock enterprises.

It will become apparent in the sections to follow that a large percentage of farms surveyed fall in a class of "marginal farms," i.e., farm sizes that have a limited inherent capacity to earn self-supporting levels of income from crop production. Since many of the operators maintain full or part-time jobs elsewhere in the local economy, it is reasonable to conclude that "farming" in the Grand Valley, for some, is as much a "consumption good" as it is a productive activity. This means that one of the traditional assumptions in economic theory--profit maximization--would be erroneously applied under these circumstances. Therefore, it was further assumed that existing cropping patterns (synthesized crop rotations) reflect utility preference for some operators (perhaps models I, II or III), while others (models IV and V) combine resources and select enterprise combinations in an optional, profit maximizing manner.

Finally, since it is difficult to justify any particular set of prices upon which to estimate long-run costs and returns, selecting a base period is somewhat arbitrary. General farm prices began to rise in late 1972 and in 1973 and 1974 attained the highest levels on record [USDA, 1975]. Choice of 1972 as the base period for analysis means that the "price ratios" which prevailed in 1972, i.e., the relative prices of farm inputs to farm products, were thought to be more representative of long-run conditions than either price ratios of other years or actual prices paid and received in any given year.

These models reflect "typical" farm resource organizations and farming practices in the study area. In aggregate they account for nearly 100 percent of total crop production in the Grand Valley. Based upon the above procedure and assumptions, the synthesized farm incomes are thought to be representative of the majority of farms falling into the respective model size categories.

## D. ESTIMATION OF MODEL FARM INCOMES

Estimated annual crop income for each model farm, under the assumptions outlined above, are presented in summary form in tables 4.2 through 4.6. Different "measures" of income were used to compare annual returns by model from some alternative points of view. These measures include: (1) net revenue--net returns to all productive resources over production costs (variable, fixed and direct overhead); (2) net income--net revenue less all indirect costs (costs not directly chargeable to any specific crop); (3) investment income--net income less adjustments for the opportunity cost of management time in calculating net returns to invested capital; and (4) management income residual--investment income less adjustments for the opportunity cost of capital in calculating residual net returns to management.

Although all models show positive net returns, i.e., variable, fixed and direct overhead costs are covered (Part A), net crop incomes vary widely with model size, ranging from a negative $1,210 with Model I to $36,000 with Model V (Part B). This may be partially explained by economies of size phenomenon as indicated by a decline in indirect overhead costs per acre as farm size increases (Table I, Appendix). However, it is more likely a function of both resource use efficiency and the incidence of greater managerial talent on larger farms. This inference appears to be supported by higher average yields and a greater proportion of higher valued (and higher risk) crops grown on larger as opposed to smaller farms (Figure 1 and tables 2 and 3, Appendix).

A second useful measure of farm performance is found in the comparison of income earned by a set of resources (Capital) invested in crop production activities with the expected income those same resources might earn

TABLE 4.2. SUMMARY ANALYSIS OF ANNUAL CROP RETURNS ON 40 ACRE (MODEL I) FARMS

| A. Net Crop Revenue | | Net Return Over Production Costs | |
|---|---|---|---|
| | Harvested Acreage[1] | Per Acre[2] | Total |
| Alfalfa | 22.5 | $53.36 | $1201.00 |
| Irrigated Pasture | 9.5 | -9.07 | -86.00 |
| Corn Grain | 3.0 | 41.58 | 125.00 |
| Corn Silage | 5.0 | 42.58 | 213.00 |
| Sugar Beets | | | |
| Oat Grain | | | |
| Oat Hay | | | |
| Malt Barley | | | |
| Wheat | | | |
| Cultivated Grasses | | | |
| Other | | | |
| Total Cropped Acreage and NET REVENUE | 40.0 | | $1453.00 |
| B. Total Indirect Overhead Charges (Table 1, Appendix) | | | -2663.00 |
| NET CROP INCOME | | | -1210.00 |
| C. Opportunity Cost of Manager's Time | | | |
| Residual Man Months (Table 4, App.) | | 2.5 | |
| Valued at $700.00/mo.[3] | | | -1750.00 |
| INVESTMENT INCOME | | | -2960.00 |
| Capital Investment (Table 5, App.) | | $56,408.00 | |
| Percent Return on Investment | | | (-5.25) |
| D. Opportunity Cost of Capital | | | |
| Interest on Capital Investment @7%[4] | | | -3949.00 |
| MANAGEMENT INCOME RESIDUAL | | | $-6909.00 |

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1/ Refer to Table 2, Appendix.

2/ File Report, Dept. of Economics, Colorado State University (forthcoming).

3/ Suggested by consensus of Grand Junction O.E.O. officials as a representative "opportunity" wage for local farm owner-operations.

4/ Average interest rate prevailing in 1972 for time saving deposits in the Colorado Banking System.

TABLE 4.3. SUMMARY ANALYSIS OF ANNUAL CROP RETURNS ON 80 ACRE (MODEL II) FARMS

| | Harvested Acreage[1] | Net Return Over Production Costs: Per Acre[2] | Net Return Over Production Costs: Total |
|---|---|---|---|
| A. Net Crop Revenue | | | |
| Alfalfa | 30.5 | $54.53 | $1663.00 |
| Irrigated Pasture | 12.5 | -6.29 | -79.00 |
| Corn Grain | 13.0 | 50.20 | 653.00 |
| Corn Silage | 12.5 | 51.20 | 640.00 |
| Sugar Beets | 4.0 | 161.45 | 646.00 |
| Oat Grain | | | |
| Oat Hay | | | |
| Malt Barley | | | |
| Wheat | | | |
| Cultivated Grasses | | | |
| Other | | | |
| Total Cropped Acreage and NET REVENUE | 72.5 | | $3523.00 |
| B. Total Indirect Overhead Charges (Table 1, Appendix) | | | -3965.00 |
| NET CROP INCOME | | | -442.00 |
| C. Opportunity Cost of Manager's Time | | | |
| Residual Man Months (Table 4, App.) | | 4.5 | |
| Valued at $700.00/mo.[3] | | | -3150.00 |
| INVESTMENT INCOME | | | -3592.00 |
| Capital Investment (Table 5, App.) | | 85,634 | |
| Percent Return on Investment | | | -4.19 |
| D. Opportunity Cost of Capital | | | |
| Interest on Capital Investment @7%[4] | | | -5994.00 |
| MANAGEMENT INCOME RESIDUAL | | | -5986.00 |

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1/ Refer to Table 2, Appendix.

2/ File Report, Dept. of Economics, Colorado State University (forthcoming).

3/ Suggested by consensus of Grand Junction O.E.O. officials as a representative "opportunity" wage for local farm owner-operations.

4/ Average interest rate prevailing in 1972 for time saving deposits in the Colorado Banking System.

TABLE 4.4. SUMMARY ANALYSIS OF ANNUAL CROP RETURNS ON 130 ACRE (MODEL III) FARMS

| A. Net Crop Revenue | Harvested Acreage[1] | Net Return Over Production Costs | |
|---|---|---|---|
| | | Per Acre[2] | Total |
| Alfalfa | 45.5 | $87.12 | $3964.00 |
| Irrigated Pasture | 17.0 | 2.70 | 46.00 |
| Corn Grain | 25.0 | 65.35 | 1634.00 |
| Corn Silage | 15.5 | 63.00 | 976.00 |
| Sugar Beets | 3.5 | 187.89 | 658.00 |
| Oat Grain | 5.0 | .95 | 5.00 |
| Oat Hay | | | |
| Malt Barley | 8.0 | 71.07 | 569.00 |
| Wheat | 6.0 | 59.45 | 357.00 |
| Cultivated Grasses | | | |
| Other | | | |
| Total Cropped Acreage and NET REVENUE | 125.5 | | $8209.00 |
| B. Total Indirect Overhead Charges (Table 1, Appendix) | | | -5085.00 |
| NET CROP INCOME | | | 3124.00 |
| C. Opportunity Cost of Manager's Time | | | |
| Residual Man Months (Table 4, App.) | | 6.0 | |
| Valued at $700.00/mo.[3] | | | -4200.00 |
| INVESTMENT INCOME | | | -1076.00 |
| Capital Investment (Table 5, App.) | | 153,566 | |
| Percent Return on Investment | | | -0.7 |
| D. Opportunity Cost of Capital | | | |
| Interest on Capital Investment @7%[4] | | | -10,750.00 |
| MANAGEMENT INCOME RESIDUAL | | | -11,826.00 |

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[1] Refer to Table 2, Appendix.

[2] File Report, Dept. of Economics, Colorado State University (forthcoming).

[3] Suggested by consensus of Grand Junction O.E.O. officials as a representative "opportunity" wage for local farm owner-operations.

[4] Average interest rate prevailing in 1972 for time saving deposits in the Colorado Banking System.

TABLE 4.5. SUMMARY ANALYSIS OF ANNUAL CROP RETURNS ON 210 ACRE (MODEL IV) FARMS

| A. Net Crop Revenue | Harvested Acreage1/ | Net Return Over Production Costs |  |
|---|---|---|---|
|  |  | Per Acre2/ | Total |
| Alfalfa | 52.5 | $109.37 | $5742.00 |
| Irrigated Pasture | 12.5 | 15.90 | 199.00 |
| Corn Grain | 21.5 | 86.40 | 1858.00 |
| Corn Silage | 35.0 | 88.20 | 3087.00 |
| Sugar Beets | 29.5 | 284.37 | 8389.00 |
| Oat Grain |  |  |  |
| Oat Hay | 3.0 | 9.39 | 28.00 |
| Malt Barley | 20.5 | 78.32 | 1606.00 |
| Wheat | 3.0 | 73.29 | 220.00 |
| Cultivated Grasses | 12.5 | 86.00 | 1075.00 |
| Other |  |  |  |
| Total Cropped Acreage and NET REVENUE | 190.0 |  | $22,204.00 |
| B. Total Indirect Overhead Charges (Table 1, Appendix) |  |  | -7,496.00 |
| NET CROP INCOME |  |  | 14,708.00 |
| C. Opportunity Cost of Manager's Time |  |  |  |
| Residual Man Months (Table 4, App.) |  | 4.8 |  |
| Valued at $700.00/mo.3/ |  |  | -3,360.00 |
| INVESTMENT INCOME |  |  | 11,348.00 |
| Capital Investment (Table 5, App.) |  | 227,966.00 |  |
| Percent Return on Investment |  |  | -4.98 |
| D. Opportunity Cost of Capital |  |  |  |
| Interest on Capital Investment @7%4/ |  |  | -15,960.00 |
| MANAGEMENT INCOME RESIDUAL |  |  | -4,612.00 |

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1/ Refer to Table 2, Appendix.

2/ File Report, Dept. of Economics, Colorado State University (forthcoming).

3/ Suggested by consensus of Grand Junction O.E.O. officials as a representative "opportunity" wage for local farm owner-operations.

4/ Average interest rate prevailing in 1972 for time saving deposits in the Colorado Banking System.

TABLE 4.6. SUMMARY ANALYSIS OF ANNUAL CROP RETURNS ON 370 ACRE (MODEL V) FARMS

| A. Net Crop Revenue | Harvested Acreage[1] | Net Return Over Production Costs | |
|---|---|---|---|
| | | Per Acre[2] | Total |
| Alfalfa | 85.5 | $108.30 | $9260.00 |
| Irrigated Pasture | 11.5 | 14.02 | 161.00 |
| Corn Grain | 118.0 | 81.52 | 9619.00 |
| Corn Silage | 22.0 | 83.32 | 1833.00 |
| Sugar Beets | 73.0 | 313.84 | 22,910.00 |
| Oat Grain | 6.5 | .25 | 2.00 |
| Oat Hay | 6.0 | 8.35 | 50.00 |
| Malt Barley | 26.0 | 80.94 | 2104.00 |
| Wheat | 2.5 | 72.25 | 181.00 |
| Cultivated Grasses | 3.5 | 83.00 | 290.00 |
| Other | | | |
| Total Cropped Acreage and NET REVENUE | 354.5 | | $46,410.00 |
| B. Total Indirect Overhead Charges (Table 1, Appendix) | | | -10,409.00 |
| NET CROP INCOME | | | 36,001.00 |
| C. Opportunity Cost of Manager's Time | | | |
| Residual Man Months (Table 4, App.) Valued at $700.00/mo.[3] | | 9.2 | -6,440.00 |
| INVESTMENT INCOME | | | $29,561.00 |
| Capital Investment (Table 5, App.) Percent Return on Investment | | $399,750.00 | (7.39) |
| D. Opportunity Cost of Capital | | | |
| Interest on Capital Investment @7%[4] | | | -27,982.00 |
| MANAGEMENT INCOME RESIDUAL | | | -1,579.00 |

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[1] Refer to Table 2, Appendix.

[2] File Report, Dept. of Economics, Colorado State University (forthcoming).

[3] Suggested by consensus of Grand Junction O.E.O. officials as a representative "opportunity" wage for local farm owner-operations.

[4] Average interest rate prevailing in 1972 for time saving deposits in the Colorado Banking System.

in an alternative employment during the same time period. This is accomplished by estimating the value of the manager's time over and above his direct labor input (Table 4, Appendix) on the basis of his probable earnings in nonfarm employment, and deducting this "opportunity income" from net crop returns. The resulting residual is the payment to invested capital, or investment income (Part C).

Farm models I, II and III show negative investment incomes which translate to negative percentage returns to invested capital or declining net worth. Only models IV and V generate acceptable percentage returns to capital from a financial viewpoint. The slightly negative investment income for Model III would suggest that farms in this size category likely face a financial condition characterized by static net worth.

Management income (Part D) measures the residual return or "bonus" to managerial skills and risk bearing after appropriate payments are made out of net crop income for the operator's labor and capital resources. Because capital requirements are substantial in crop production, even for small farming operations, the annual opportunity cost of invested capital (interest earnings foregone) can be quite extensive. Models I through IV bear this out: these farm-size categories generated negative management income residuals. Only on relatively large farms of 370 acres or more does crop production appear to provide a positive bonus for managerial talent.

## E. ESTIMATED COSTS OF LAND RETIREMENT

To test the proposition that selective land retirement is or is not a feasible salinity control alternative, two sources of information are required: (1) the direct and indirect costs of removing land from irrigation, and (2) the net benefits or incremental reduction in damages as a consequence.

Direct costs should accurately reflect the incomes foregone from irrigated farming of the retired lands. Included in the indirect costs should be the net effects of costs and benefits issuing from resource reallocation, social transition, impacts on environmental amenities, and other consequences in the affected region. Net benefits of the program also account for direct and indirect effects: direct effects to include the increment of technological externality removed or penalty avoided, and indirect effects to trace the resulting "net" improvements in socio-economic welfare [James and Lee, 1971].

Voluntary vs. Involuntary Programs. Land retirement mechanisms might include one or more of a number of options, and can be either voluntary or involuntary depending on the level of public acceptance and participation in the program. The program objective is to discontinue irrigation on selected acreage altogether, thus eliminating all future salt loading from these sources.

Withholding irrigation water from previously cultivated acreage in the Grand Valley might be accomplished on a voluntary basis by State purchase of existing water rights from willing sellers [Trelease, 1960]. Because of the Grand Valley's arid natural climate, this would mean that farmland is taken out of production altogether, eventually returning to desert. State purchase of privately-held water rights from legal condemnation proceedings would constitute an involuntary mechanism [Gross, 1965]. Both would, in effect, amount to land purchase since desert-grazing land is of nominal value by comparison.

If a voluntary land retirement program is to be viable, this implies that some farmers in the Valley would be willing to sell their farms (or a portion of their acreage) at a price offer that exceeds the present value of their long-run, capitalized earnings. In the case of "marginal" farms, this would mean that some individuals would be willing to trade the present value of farming (in the long run) as a "consumption activity" for an alternative activity made available by the price offer. Under an involuntary program, it would probably be necessary that the sales price exceed the present market value of representative irrigated acreage. The program would have an added flexibility if willing sellers under a voluntary retirement scheme could select the marginal acreages on their farms (perhaps difficult areas to irrigate where water losses are high and productivity low) for purchase by the State--analogous to the soil bank program [Public Law 89-321]. On this basis the cost of a "selective" land retirement program might be reduced appreciably.

Capitalization vs. Market Value Approach. Clearly, the selection of a method for valuing irrigated lands to be retired is dependent upon ownership and present use. The capitalizing of future earnings of a marginal farm, situated in an area where the fair market value of comparable land is well in excess of the capitalized value, is certainly not a workable approach under a voluntary program. Income capitalization is a very precise method for valuing a productive resource, but its applications are limited in some circumstances. As a general rule market forces have a more direct influence on property values.

Market values reflect alternative uses as well as present use, and, accordingly, fair market values tend to run higher than capitalized values for the same resource. But in cases where land has only one use (its present use), capitalized and fair market values converge. This phenomonen is usually observed in traditional agricultural areas such as the midwest, and is likely true in the Grand Valley. Larger, more efficient farms typically establish land prices through marginal additions to land holdings thereby setting a general price level which prevails for other farmers in the immediate area [Tweeten, 1971]. For this reason the capitalization approach was employed in this analysis to establish a lower bound to the fair market value for land and water resources for the purpose of estimating land retirement costs.

Direct Program Costs. The model farms provide an estimate of the capitalized value of farm land for representative farm sizes in the Grand Valley. These models also provide some insight into individual decisions concerning land retirement options as well as the aggregate consequences of those decisions Valley-wide. Estimating land values, i.e., the capitalized residual returns to land and water resources, for each model farm involves determining the residual return out of annual crop income after deducting appropriate payments to management and mobile resources. Thus, an additional adjustment was made on investment income (part C of Tables 4.2 through 4.6) by deducting the opportunity cost of machinery and equipment capital or "mobile resources" (Table 4.5, Appendix). The resulting transformation is summarized in Figure 4.3, which graphically illustrates the correspondence between net crop income, opportunity costs of mobile resources, and net residual to land, buildings and water resources for each model farm on a per acre basis.

The shaded area, which includes farm models I through III, denotes a range of negative net returns to land and water resources. This means, in effect, that capitalized values under these three size categories would also be negative. It is also interesting to note that these three models were designed to represent approximately 73 percent of the farmers who farm 40 or more acres, and over 50 percent of the total cropped acreage in the Grand Valley. These observations are depicted in Figure 4.4.

Figure 4.3. Comparison of Per Acre Net Crop Incomes, Residual Returns to Land and Water, and Opportunity Cost of Mobile Resources on Model Farms, 1972

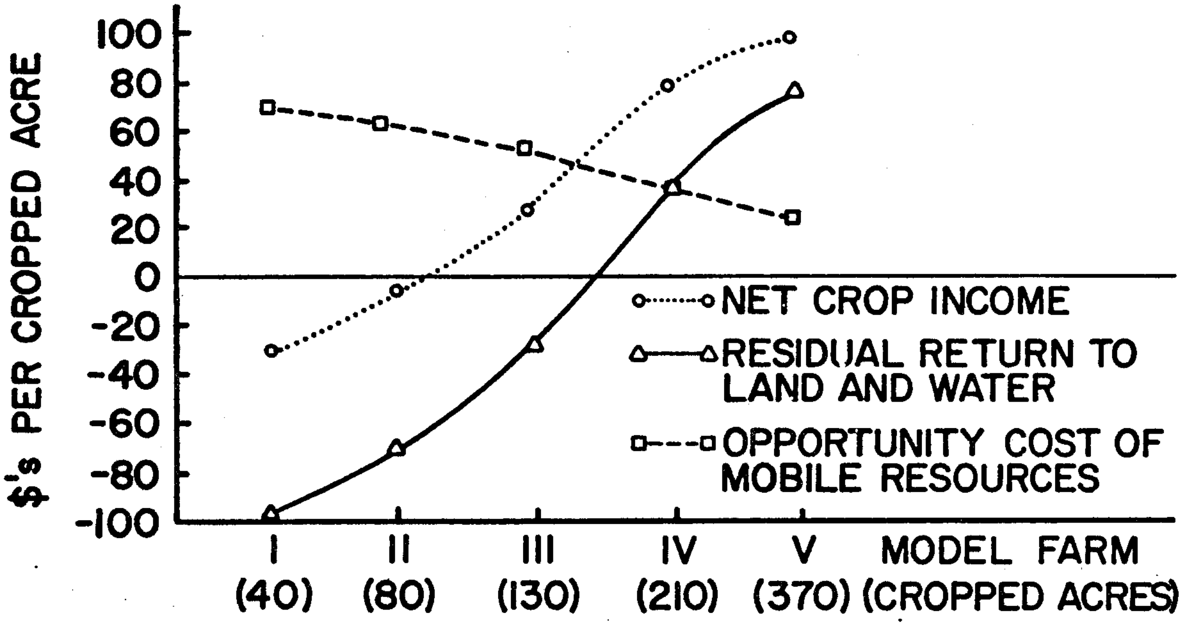
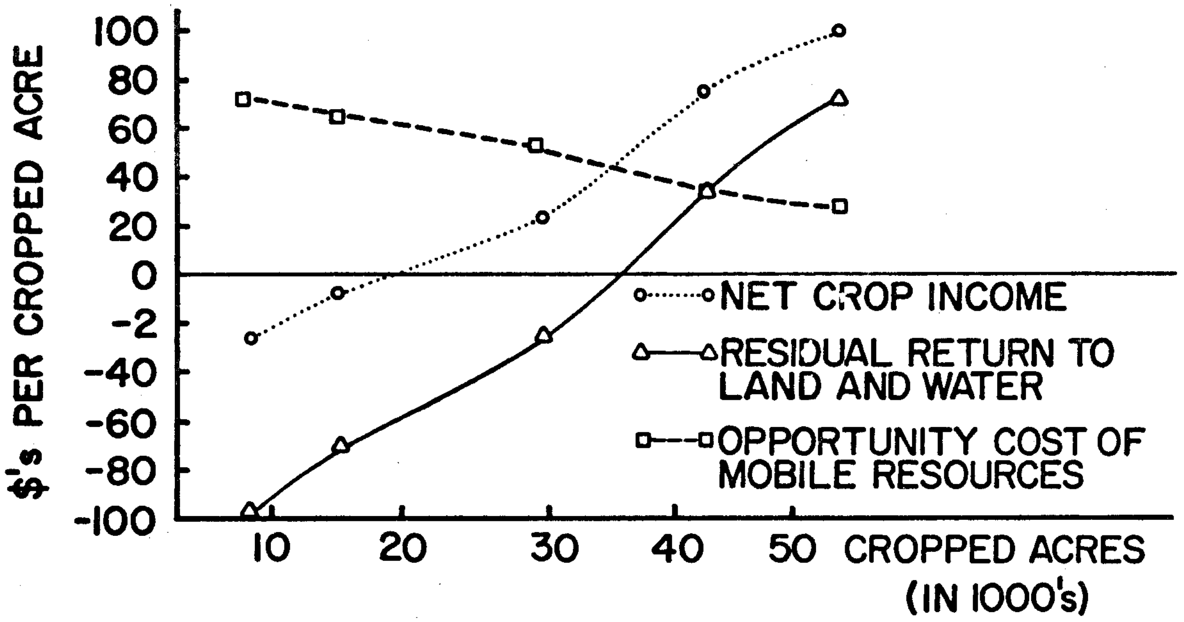


Figure 4.4. Net Crop Income, Residual Returns to Land and Water, and Opportunity Cost of Mobile Resources Per Acre in the Grand Valley, 1972



Total Valley acreage under irrigation, excluding 6,962 acres in orchards, is measured on the coordinate and depicts the aggregate picture with respect to the size distribution of sampled farms. The first increment on the scale of accumulating cropped acreage, an amount of 6,492 acres, is an estimate of the balance of cropped acres in the Valley composed of units less than 40 acres in size.

Data summarized in Figures 4.3 and 4.4 provided the basis for estimating the direct land retirement program costs. The following discounting formulation was used:

$$PV_c = C_o + \sum_{t=i}^{T} \frac{NR_t}{(1+r)^t} \tag{1}$$

where:

$PV_c$ = Present Value of future program costs

$C_o$ = Land transfer cost (administrative)

NR = Annual net returns to land and water resources

r = Discount rate

t = 1,2,....T (indefinite time in years)

Costs borne by government agencies to administer the program, $C_o$ in [1], were not estimated and therefore assumed to be "zero" in this analysis. These costs would not be substantial unless a new agency was formed specifically to implement and monitor the program. Three alternative interest rates were used in the discounting formula to provide some sensitivity to the estimated values. These results are summarized in Table 4.7.

Recent land sales in the Grand Valley suggest that typical farm land including improvements and an ample water supply (four or more acre feet per acre) would sell for a per acre price not below $1,000.00 [Mesa County

TABLE 4.7. PRESENT VALUES OF ESTIMATED ANNUAL NET RETURNS PER CROPPED ACRE ON MODEL FARMS, 1972: SENSITIVITY ANALYSIS OF TWO MEASURES

| Farm Model | Measure of Annual Net Return per Cropped Acre[1] | Present Value Discounted at[2] | | |
|---|---|---|---|---|
| | | 5 Percent | 7 Percent | 9 Percent |
| | | - - - - - IN DOLLARS - - - - - - | | |
| | A. Net Return to All Productive Resources[3] | | | |
| Model I | -30.25 | - - - (Negative Values) - - - | | |
| Model II | - 6.10 | - - - (Negative Values) - - - | | |
| Model III | 24.89 | 498 | 356 | 277 |
| Model IV | 77.41 | 1,548 | 1,106 | 860 |
| Model V | 101.55 | 2,031 | 1,451 | 1,128 |
| | B. Net Return to Land and Water Only | | | |
| Models I-III | < 0 | - - - (Negative Values) - - - | | |
| Model IV | 39.68 | 794 | 567 | 441 |
| Model V | 70.91 | 1,418 | 1,013 | 788 |

[1] Refer to Figure 4.3.

[2] Based on an infinite time horizon, equation [1].

[3] Corresponds to part B, Tables 4.2 through 4.6.

Assessors Office, February 5, 1975]. Under the assumptions of this study, the lower bound on fair market values for irrigated land could range from less than \$800 per acre to slightly over \$1,400 per acre depending upon the rate of discount used (model V farms, part B, Table 4.6). Regardless of the discount rate, the program offer price would be the greater of market value or capitalized value. This means that the offer price would not be less than \$1,000 (the assumed fair market value). Table 4.8 summarizes the total direct cost computations for a full range of implementation at an offer price of \$1,400 per acre.

These estimates clearly demonstrate how critical the interest rate can be in evaluating program costs. For example, direct costs of an involuntary program designed for small farms (Model I) range from \$1,918,000 to \$3,451,000, nearly doubling due to a change in the discount rate of 9 to 5 percent.

Direct Net Benefits. Salinity damages avoided downstream as a direct result of retiring lands in the Grand Valley are used as the direct benefits of the program. Because "local" benefits to farmers that may issue from the program (e.g., increased productivity on remaining farms) are not presently measurable and therefore not included, direct benefits are "net" of these factors.

Present values for a range of possible downstream salinity damage levels were determined from the following discounting formulation:

$$PV_b = \sum_{t=i}^{T} \frac{D_t}{(1+r)^t} \tag{2}$$

where:

$PV_b$ = present value of future direct damages avoided

D = annual direct damages in year t

TABLE 4.8. SUMMARY OF GRAND VALLEY ACREAGES BY FARM MODEL, ANNUAL GROSS REVENUES FORGONE, AND TOTAL DIRECT PROGRAM COSTS: SENSITIVITY ANALYSIS OF THE ESTIMATES

| Farm Models | Total Valley Acreage | | Annual Gross | Total Direct Program Costs Discounted at[1] | | |
|---|---|---|---|---|---|---|
| | Included | Cumulative | Revenue Forgone | 5 Percent | 7 Percent | 9 Percent |
| | | | - IN DOLLARS - | - - - - IN MILLIONS OF DOLLARS - - - - - | | |
| Model I | 2,434 | 2,434 | 320,832 | 3.451 | 2.466 | 1.918 |
| Model II | 4,931 | 7,365 | 741,992 | 6.992 | 4.995 | 3.886 |
| Model III | 16,624 | 23,989 | 2,606,938 | 23.573 | 16.840 | 13.100 |
| Model IV | 9,523 | 33,512 | 1,991,303 | 13.504 | 9.647 | 7.504 |
| Model V | 13,960 | 47,472 | 3,244,318 | 19.725 | 14.141 | 11.000 |
| TOTALS | | | 8,905,383 | 67.245 | 48.089 | 37.408 |

[1] Based on an infinite time horizon, equation [1], and an offer price of $1,400 per acre.

r = discount rate

t = 1,2,3,....T (infinite time in years)

A sensitivity analysis was also performed on estimates of the program benefits. These results are summarized in Table 4.9.

Damages were estimated from secondary data and reflect a broad range of the annual monetary damage of Grand Valley's average effluent discharge from irrigated agriculture, measured in tons of total dissolved solids (TDS) per acre, impacted in the lower reaches of the Colorado River Basin. For example, if an average irrigated acre in the Grand Valley discharges eight tons TDS per year into the river system, and the average downstream direct penalty happens to be $5.00 per ton TDS per year, this translates to a $40.00 per acre annual net benefit to the land retirement program. Discounted at 7 percent, a direct benefit of $571 would be gained by permanently removing one acre from irrigation.

Evaluation. To test the economic feasibility of the program as a means of salinity control, the two options--voluntary and involuntary land retirement--help to establish a high and low range of program costs. It was assumed that an involuntary option would be "acceptable" to a majority of participants if payments equaled or exceeded fair market values for representative lands. This option would establish a high range to program costs. The low range is established by the voluntary option, since some farmers would probably participate if the offer price was below the fair market value but exceeded expectations of long run earnings. Acreage to be retired would be selected by State and/or federal agencies in the case of the involuntary option while farmers themselves could participate in the selection process under the voluntary option. The latter case has the implication that farmers could produce crops more efficiently upon receiving

TABLE 4.9. PRESENT VALUES FOR POSSIBLE LEVELS OF DOWNSTREAM SALINITY DAMAGE PER CROPPED ACRE DUE TO IRRIGATED FARMING IN THE GRAND VALLEY: SENSITIVITY ANALYSIS OF THE ESTIMATES

| Possible Levels of Annual Downstream Salinity Damage per Cropped Acre[1] | Present Value of Annual Downstream Salinity Damages per Cropped Acre Discounted at[2] | | |
|---|---|---|---|
| | 5 Percent | 7 Percent | 9 Percent |
| | - - - - - - - - - IN DOLLARS | - - - - - - - - - | |
| 10 | 200 | 143 | 111 |
| 20 | 400 | 286 | 222 |
| 30 | 600 | 429 | 333 |
| 40 | 800 | 571 | 444 |
| 50 | 1,000 | 714 | 555 |
| 60 | 1,200 | 857 | 666 |
| 70 | 1,400 | 1,000 | 777 |
| 80 | 1,600 | 1,143 | 888 |
| 90 | 1,800 | 1,286 | 999 |
| 100 | 2,000 | 1,429 | 1,111 |
| 110 | 2,200 | 1,572 | 1,222 |
| 120 | 2,400 | 1,715 | 1,333 |
| 130 | 2,600 | 1,858 | 1,444 |
| 140 | 2,800 | 2,001 | 1,555 |
| 150 | 3,000 | 2,144 | 1,666 |

[1] This range of damage estimates reflects possible combinations of two variables: (1) total dissolved solids (TDS) expressed in tons per cropped acre per year as an effluent discharge by the Grand Valley into the Colorado River, and (2) annual monetary damage of the total effluent discharge impacted in the lower reaches of the Colorado River Basin expressed in dollars per ton TDS.

[2] Based on an infinite time horizon, equation [2].

fair compensation by the State to dispose of their unproductive acreage. In fact, it is even possible that unproductive soils in the Valley contribute more to salinity than do productive soils [Soil Conservation Service, 1951]. However, economic analysis of these implications is beyond the scope of the present study.

To evaluate and compare the program options, the level of net benefits were based on the assumption that an average irrigated acre in the Valley contributed 10 tons TDS to the river system annually--700,000 tons ÷ 70,000 irrigated acres [Skogerboe, et al, 1974]. Using one recent estimate of direct damages in the lower basin--$49 million ÷ 10,000,000 tons TDS--penalty costs may be as high as $5 per ton [Bureau of Reclamation, 1974]. Multiplying by 10 tons TDS per acre, the present value of future penalties avoided or net benefits could range from $555 to $1,000 per acre, depending upon the interest rate selected.

The direct cost estimates presented in Table 4.8 are applicable to the involuntary option since these reflect an offer price of $1,400 determined by capitalization of returns on large farms (part B, Table 4.7). Table 4.10 summarizes the direct benefits and costs for involuntary land retirement at different levels of implementation. These estimates are based on a 7 percent discount rate. Although the levels of direct benefits and costs will vary with the rate of discount, the B/C ratio remains the same. Since B/C ratios for all model size categories are less than unity, a program predicated on involuntary options would not be economically justifiable under these assumptions: retiring any or all cropped acreage in the Grand Valley would appear to generate a loss of 30 cents per dollar invested.

To test the economic feasibility of voluntary options a number of possible offer prices were considered. These payments in the initial year to participating farmers would have to be less than fair market values if

TABLE 4.10. RATIOS OF DIRECT NET BENEFITS TO DIRECT COSTS FOR INVOLUNTARY LAND RETIREMENT OF MODEL FARM SIZE GROUPS

| Model farms | Direct Net Benefits | Direct Costs | B/C Ratio1/ |
|---|---|---|---|
| | - - - - - DOLLARS IN | MILLIONS - - - - - | |
| Model I | 1.738 | 2.446 | .70 |
| Model II | 3.529 | 4.995 | .70 |
| Model III | 11.870 | 16.840 | .70 |
| Model IV | 6.799 | 9.647 | .70 |
| Model V | 9.967 | 14.141 | .70 |
| TOTALS | 33.903 | 48.069 | .70 |

1/ Ratio of benefits per dollar cost.

TABLE 4.11. RATIOS OF DIRECT NET BENEFITS TO DIRECT COSTS PER TON TDS AT SELECTED VOLUNTARY LAND RETIREMENT OFFER PRICES: A SENSITIVITY OF THE ESTIMATES

| Offer Price Per Acre | Direct Costs1/ | Direct Net Benefits2/ | | | B/C Ratio3/ | | |
|---|---|---|---|---|---|---|---|
| | | 5% | 7% | 9% | 5% | 7% | 9% |
| $400 | 40 | 100.00 | 71.40 | 55.50 | 2.50 | 1.78 | 1.39 |
| 500 | 50 | 100.00 | 71.40 | 55.50 | 2.00 | 1.43 | 1.11 |
| 600 | 60 | 100.00 | 71.40 | 55.50 | 1.67 | 1.19 | .92 |
| 700 | 70 | 100.00 | 71.40 | 55.50 | 1.43 | 1.02 | .79 |
| 800 | 80 | 100.00 | 71.40 | 55.50 | 1.25 | .89 | .69 |

1/ Offer price ÷ 10 tons TDS per acre.

2/ Based on an infinite time horizon, equation [2].

3/ Ratio of benefits per dollar cost.

B/C ratios are to exceed unity. This test is summarized in Table 4.11. Again, the estimated benefits and subsequent B/C ratios are very sensitive to rate of discount: at an offer price of $600 per acre, the B/C ratio ranges 1.67:1 to .92:1. The results show a clear preference for a voluntary mechanism on the basis of B/C ratios. However, it is not clear how much land would be retired at any given offer price or to what extent farmers in particular size groups would participate.

If classes of land to be retired are negotiable between the participants and responsible agencies, participation could be broadly distributed among different sized farms. A careful inventory of land to qualify for selective retirement is a necessary precondition to implementation. This inventory could specify an appropriate scale of offer prices and estimate the acreage that would qualify for retirement.

Estimating Indirect Costs and Benefits. Indirect impacts could change the above results decidedly on either the cost or benefit side. Conceptually, indirect costs and benefits can occur at both the "local" and "downstream" level [James and Lee, 1971]. For the purposes of this study, it was assumed that the appropriate indirect impacts associated with land retirement are those which are contiguous to the Grand Valley economic area.

Local indirect benefits could include "efficiency effects"--increased productivity on the balance of irrigated acreage not included in the program--and "grant effects"--the introduction of lump-sum cash payments to participating farmers for reinvestment in the local economy [Boulding, 1973]. Both could significantly enhance program benefits. Local indirect costs might include "transition effects"--unemployed resources and individuals in the Valley displaced by the program--and "amenity effects"--selected tracts of land returned to desert flora after once "blooming" under irrigation.

Indirect costs of temporarily unemployed resources and individuals would be higher for a compulsory program as opposed to a voluntary one. Willing participants would likely be those who are near retirement age, those who would like to retire marginal lands, or those who already have full or part-time employment in the local community.

The net effect of local indirect costs and benefits would be difficult to ascertain without more information and detailed study. However, the literature on indirect effects of irrigated agriculture on regional economies would suggest that this sector is not a high income generator [Howe and Orr, 1974, and Kelso, *et al*, 1973]. The Arizona studies by Kelso and others have shown that common perceptions greatly overestimate regional income interdependency upon agriculture.

The water released from present use *vis a vis* land retirement could be used beneficially elsewhere in the State. This is especially important now in light of emerging demands for additional water to meet energy development and other needs in the upper basin [Bureau of Land Management, 1974]. The amount of water transferred out of agriculture could be substantial, and its values in alternative uses could far exceed retirement costs after a reasonable period of economic adjustment [Howe and Orr, 1974].

## F. SUMMARY AND CONCLUSIONS

This chapter has reported a preliminary evalaution of land retirement as a salinity abatement option for the Grand Valley in western Colorado.

The facts examined in this study show that a voluntary program of selective land retirement may be an economically feasible means of control on a limited scale, and could be implemented competitively with other more costly structural measures.

The study further illustrates the importance of a phase-out of marginal irrigation agriculture, since improved water use efficiency and reduced consumption use could accompany water quality enhancement.

The program evaluated in this study included both compulsory or involuntary and voluntary options. The "compulsory" option assumes all lands would be retired at the average fair market value, estimated at $1400 per acre. Further assuming a total pickup of ten tons of salt per acre and a downstream damage of $5.00 per acre of salt, it was shown that strict economic feasibility conditions would fail by a large margin to be met. The "voluntary" option presupposes a variation in the quality and productivity of land, and that there would be willing sellers of some marginal lands at prices which exceeded their present value in agricultural production. It was shown that with a seven percent discount rate, such purchases would be economically feasible at purchase prices of up to $700 per acre. However, the amount of land which would be available at this price is estimated to be not more than fifteen percent of the irrigated acreage in the study area. These estimates do not consider indirect costs to the regional economy; however, indirect costs would likely be relatively small, since the retired acreage would be less productive than the average. Nevertheless, even a modest program would encounter impediments, due to the institutional arrangements on water reallocation and the strong objections of water administrators and the public to retiring irrigated lands as a tool of public policy.

# G. APPENDIX: TABLES AND FIGURES

TABLE 4.1. SUMMARY OF ANNUAL DIRECT AND INDIRECT OVERHEAD CHARGES BY MODEL SIZE, 1972

| Item and Source | Farm Model I | II | III | IV | V |
|---|---|---|---|---|---|
| | - - - - - IN DOLLARS - - - - - - - - | | | | |
| Direct Overhead Charges[1] | | | | | |
| Interest on Net Production Costs | 177 | 357 | 580 | 945 | 2,049 |
| Irrigation Water | 280 | 508 | 878 | 1,330 | 2,482 |
| Property Tax | 393 | 635 | 1,153 | 1,641 | 3,177 |
| Stand Establishment | 396 | 477 | 545 | 559 | 943 |
| Total | 1,246 | 1,977 | 3,156 | 4,475 | 8,651 |
| Per Cropped Acre | 31.15 | 27.27 | 25.15 | 23.55 | 24.40 |
| Indirect Overhead Charges[2] | | | | | |
| Building & Permanent Structures | 457 | 550 | 1,162 | 1,740 | 3,493 |
| Transportation | 1,519 | 2,489 | 2,853 | 4,505 | 5,355 |
| Other Equipment | 387 | 626 | 670 | 651 | 761 |
| Miscellaneous Business Expenses | 300 | 300 | 400 | 600 | 800 |
| Total | 2,663 | 8,965 | 5,085 | 7,496 | 10,409 |
| Per Cropped Acre | 66.58 | 54.69 | 40.52 | 39.45 | 29.36 |
| Total Overhead Charges | 3,909 | 5,942 | 8,241 | 11,971 | 19,060 |

1/Amenable to straight forward per acre allocation to selected crops produced. These figures were summarized from applicable unit budgets pertaining to each farm model cropping system.

2/Charges for insurance, depreciation, taxes and repairs not readily allocated per acre to any particular crop.

3/Assumed to provide an estimate of annual costs for utilities, miscellaneous supplies, association memberships and other minor expenses chargeable to crop production.

TABLE 4.2. SYNTHESIS AND COMPARISON OF FARM ACREAGE IN CROPS AND OTHER LAND USE ON MODEL FARMS, 1972[1/]

| Land Use Item | Farm Model<br>I | II | III | IV | V |
|---|---|---|---|---|---|
| Alfalfa | 22.5 | 30.5 | 45.5 | 52.5 | 85.5 |
| Pasture | 9.5 | 12.5 | 17.0 | 12.0 | 11.5 |
| Corn Grain | 3.0 | 13.0 | 25.0 | 21.5 | 118.0 |
| Corn Silage | 5.0 | 12.5 | 15.5 | 35.0 | 22.0 |
| Sugar Beets | | 4.0 | 3.5 | 29.5 | 73.0 |
| Oat Grain | | | 5.0 | | 6.5 |
| Oat Hay | | | | 3.0 | 6.0 |
| Malt Barley | | | 8.0 | 20.5 | 26.0 |
| Wheat | | | 6.0 | 3.0 | 2.5 |
| Cultivated Grasses | | | | 12.5 | 3.5 |
| Total Crops | 40.0 | 72.5 | 125.5 | 190.0 | 354.5 |
| Idle/Fallow | 2.0 | 2.0 | 8.0 | 9.0 | 22.0 |
| Cropland | 42.0 | 74.5 | 133.5 | 199.0 | 376.5 |
| Farmsteads | 13.5 | 13.5 | 24.5 | 32.0 | 68.0 |
| Other | 1.5 | 2.5 | 6.5 | 3.0 | 9.0 |
| Farm Acreage | 57.0 | 90.5 | 164.5 | 234.0 | 453.5 |

[1/] Acreage by land use item rounded to nearest one-half acre.

TABLE 4.3. COMPARISON OF PRICES RECEIVED BY FARMERS AND YIELD ASSUMPTIONS WITH 1972 COUNTY AVERAGES, DISTRIBUTED BY MODEL SIZE

| Crop | Unit of Value | Prices Received |  | County Average 1/ | Yield Per Acre |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Sample Acreage | County Average 1/ |  | Farm Model |  |  |  |  |
|  |  |  |  |  | I | II | III | IV | V |
|  |  | ($/unit) |  |  |  |  |  |  |  |
| Alfalfa--1st Year | TON | - - - | 37.50 | N.A. | 1.5 | 1.5 | 1.8 | 2 | 2 |
| Mature | TON | 41.00 | 37.50 | 3.5 | 4 | 4 | 4.5 | 5 | 5 |
| Permanent Pasture--1st Year | AUM | - - 2/ | N.A. | N.A. | 1.3 | 1.3 | 1.5 | 1.7 | 1.7 |
| Mature | AUM | - - 2/ | N.A. | N.A. | 2.5 | 2.5 | 3 | 3.5 | 3.5 |
| Oats--Grain | BU. | - - - | 1.71 | 75 |  |  | 65 | 70 | 70 |
| Mixed hay | TON | 36.00 | 33.50 | N.A. | 2.2 | 2.2 | 2.4 | 2.6 | 2.6 |
| Nurse Crop Grain | BU. | 1.60 | N.A. | N.A. | 40 | 40 | 45 | 50 | 50 |
| Corn--Grain | BU. | 1.55 | 1.45 | 114 | 100 | 100 | 115 | 130 | 130 |
| Silage | TON | 9.40 | 9.00 | 16 | 16 | 16 | 18 | 20 | 20 |
| Barley--Malting | BU. | 2.37 | N.A. | N.A. |  |  | 65 | 70 | 70 |
| Feed | BU. | 1.50 | 1.58 | 53.4 |  |  | 80 | 95 | 95 |
| Wheat | BU. | 1.60 | 1.58 | 60.4 |  |  | 70 | 80 | 80 |
| Sugar Beets | TON | - - - | 20.50 | 24.2 |  | 185 | 20 | 22 | 23 |
| Cultivated Grasses--Pasture | AUM | - - 2/ | N.A. | N.A. |  |  | 2 | 2 | 2 |
| Seed | LBS. | .80 | N.A. | N.A. |  |  | 350 | 350 | 350 |

1/ Colorado Department of Agriculture, Colorado Agricultural Statistics,(1972 Final), Denver, Colorado, 1974.

2/ Since farmers were unable to provide reliable yield estimates for permanent pasture, representative agronomic data were consulted to facilitate an approximation. See Stewart, William G., "Irrigated Pastures for Colorado", Cooperative Extension Service, Colorado State University, April 1973. Following Stewart, prices for both permanent pasture and cultivated grasses are converted to pounds of "cow-calf" beef gain equivalents valued at an average price of 46¢/lb.

TABLE 4.4. SUMMARY OF ANNUAL CROP LABOR REQUIREMENTS ON MODEL FARMS AND SUBSEQUENT HIRED AND MANAGERIAL LABOR INPUTS IN MAN DAYS

| Item and Source | Farm Model I | II | III | IV | V |
|---|---|---|---|---|---|
| | - - - - - | man days | - - - - - - | | |
| A. Crop Labor Requirements[1] | 36 | 66 | 106 | 197 | 350 |
| B. Hired Labor | 15 | 25 | 30 | 66 | 343 |
| Residual Labor Requirement (A less B) | 21 | 41 | 76 | 131 | 7 |
| C. Manager's Annual Labor[2] | 80 | 150 | 220 | 245 | 245 |
| Residual Management Time | 59 | 109 | 144 | 114 | 238 |

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[1] These requirements are based on estimates of labor input per acre, excluding custom labor, developed in the various unit budgets for each crop and farm model.

[2] Respondents' estimate of their own annual labor input chargeable to crop production. Residual management time is the balance remaining after total labor requirements have been satisfied. Hence, the management residual reflects supervisory and/or machinery maintenance and general farm upkeep not accounted for in the aggregated crop labor requirement estimates.

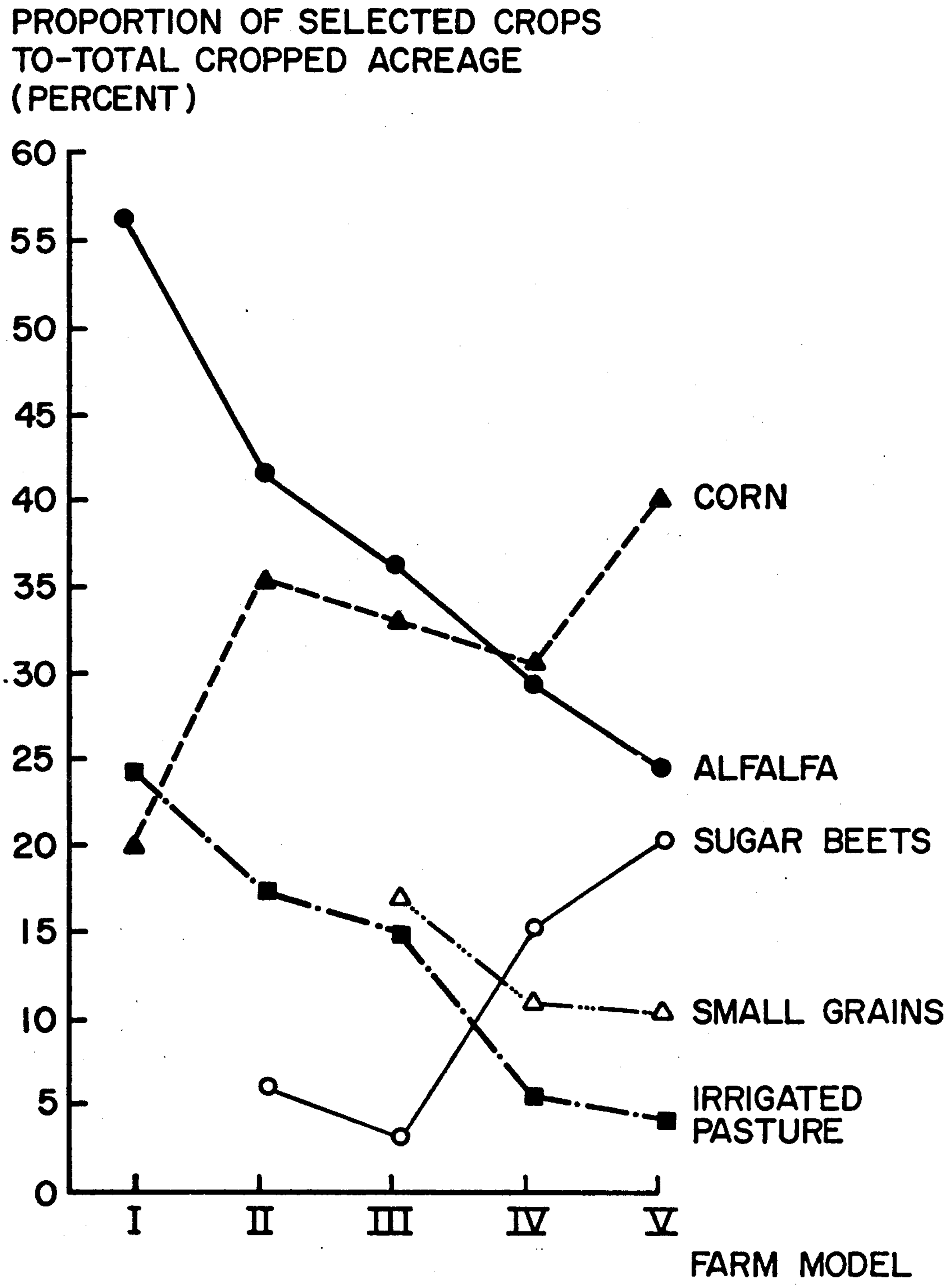
TABLE 4.5. AVERAGE CAPITAL INVESTMENT IN CROP PRODUCTION RESOURCES ON MODEL FARMS, 1972

| Investment Item | Allowance for Remaining Useful Life1/ | Farm Model | | | | |
|---|---|---|---|---|---|---|
| | | I | II | III | IV | V |
| | (% of 1972 values) | - - - - - - - - - - - IN DOLLARS - - - - - - - - - - | | | | |
| Machinery & Equipment | 50% | 14,745 | 19,150 | 31,902 | 54,416 | 63,180 |
| Buildings & Permanent Structures | 50% | 2,323 | 2,994 | 6,374 | 9,500 | 18,910 |
| Land @ $700/acre2/ | 100% | 39,340 | 63,490 | 115,290 | 164,080 | 317,660 |
| Total Capital Investment | | 56,408 | 85,634 | 153,566 | 227,996 | 399,750 |
| Per Cropped Acre | | 1,410 | 1,181 | 1,224 | 1,200 | 1,128 |

1/ Reflects a consensus among sample respondents' estimates as to the "physical" depreciation of their capital stock. Replacement values in 1972 were used as the base in approximation.

2/ An estimate provided by the Mesa County Assessors Office for the fair market value of "representative" irrigated farm land in the Grand Valley during the 1972 production year.

Figure 4.1. Acreage of Selected Crops as a Percentage of Total Cropped Acres on Model Farms, 1972



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