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Transfer Restrictions and Misallocation of Irrigation Water

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TRANSFER RESTRICTIONS AND MISALLOCATION OF IRRIGATION WATER

by

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INTRODUCTION OF THE PROBLEM AND JUSTIFICATION FOR RESEARCH

Water is among the most abundant of all materials known to man. In all its various forms, water covers 75 percent of the earth's surface. It is estimated that the total physical quantity of water on the earth is 326,000,000 cubic miles (14). This apparent abundance belies the true nature of the water resource as it relates to the needs of man. At any given point in time, only a rather minute portion of this vast quantity of water is found in those forms and locations which render it useful to man. This may be attributed to the fact that utility in water is perishable and the efforts of man to amend the hydrological cycle have been successful only to a limited extent (1).

Presently, expanded economic activity coupled with population increases threaten to exhaust the economic supply in some areas. This is especially true in some major urban centers and in the arid western United States. If current projections concerning population and water use patterns materialize in the future, human ingenuity will do well to keep pace with burgeoning demand.

Water is not a single use resource. Uses range from the aesthetic such as the fountain which enhances the beauty of a park, to the common, such as irrigation and the dilution of sewage. Quantity, quality, and location of water is often such that it may be used by any one of a multiplicity of uses or users. When water is scarce, this gives rise to competition within and among uses such as agriculture, manufacturing, and domestic consumption. This is not to say that all uses are competitive. Water stored in a reservoir for irrigation may also be used for recreation or to generate hydro-electric power without reducing the quantity available for irrigation. The relationship here is supplementary and perhaps even complementary. However, an allocation problem does exist any time supply is insufficient to satiate demand and uses are competitive (10, p. 34-36).

Future resource availability for any use or user is dependent upon one or both of two areas of activity (10, p. 32). The first involves augmentation of the usable physical supply by effecting greater control of the hydrological cycle. Examples of this include such activities as converting sea water, seeding clouds, tapping glacier ice; and more commonly, watershed management, reservoir construction, canal lining, use of underground storage, and adaptation of more efficient application methods.

The second area of activity involves the allocative machinery which determines the disposition of both existing and potential supplies. In Utah and throughout the United States, these are composed of a heterogeneous accumulation of institutions, given credence by formal law and community mores. The term institution is used here in the broader sense of an established practice, law or custom, which is usually, but not always, represented by some formal organization. These institutions vary greatly in organization and function, but in certain respects their influence on the allocation of water among competing uses and users appears to be a critical factor in determining what benefit society may obtain from a limited quantity of water.

Any statement concerning the relative merits of the development of new supplies versus refinement or abandonment of some of the present allocative machinery as a means of meeting the increasing demand for water is subject to conjecture. Both alternatives merit consideration, and they are interrelated. In this study, water institutions received primary focus.

A multiplicity of methods could be used to effect a different allocation of water among competing uses. They could be expected to run the entire gamut from seizure and distribution by an unquestioned authority to laissez-faire. The one extreme seems to imply that a supposed omnipotent person, bureau, agency, etc., has unassailable knowledge and authority which allows it to effect the best allocation for society. The other extreme suggests that society is best served when each individual with an interest in water is allowed to make and effect his own decisions. It should be obvious that neither extreme can be entirely applicable.

Much of the current literature tends to support schemes approaching the more authoritative methods of allocation. These are modified in some instances by reservations with respect to compensation for loss of rights and a limitation to specific uses. A limited amount of support can be found for a more laissez-faire approach to water allocation. These are tempered by a recognition of the need for institutions which insure property rights and provide for flexibility in control of the resource. With few exceptions there is a surprising lack of empirical evidence to support a general movement toward either approach.

Decisions made by legislators, administrators, policy-makers, etc., at various times in the past have suffered from lack of sufficient evidence pertaining to the alternatives at hand. This study was an attempt to provide some enlightenment in the area of water allocation by evaluating the efficiency implications associated with a removal of selected transfer restrictions affecting irrigation water.

OBJECTIVES OF THE STUDY

In Utah, water allocation is subject to administrative manipulation under the appropriative doctrine of water law. Because it is an economic necessity, flexibility in the control of water is probably as great as it is in any other state. Many decisions of the administrative agencies have allowed increased flexibility and more efficient utilization of existing supplies (25). Evidences of market allocation can be found throughout the state. Even so, certain influences are present in the institutions pertinent to water which restrict free transfer and might possibly effect a misallocation of the resource.

No attempt was made in this study to identify and explore the ramifications of all possible impediments to transfer which may result from the influence of institutional factors. Rather, this study was an attempt to determine if market allocations of water under conditions of comparatively free transfer conditions were more efficient, in the economic sense, than allocation by administrative rules and legal rights.

Objectives

Specific objectives of the study were as follows:

1. To describe the water market,
2. To determine the market values placed on the rights to water

within a given use,

3. To identify selected changes in the institutional factors pertinent to water which restrict free transfer of water, and to determine how critical they are in misallocation.

The first two objectives were preliminary steps toward the accomplishment of the third and primary objective of the study.

The first objective, to describe the water market, was accomplished by summarizing the data supplied by persons familiar with market practices found in the study area, giving special emphasis to the development, operation, and flexibility of the water rental market.

The second objective, to determine the values placed on the rights to water within a given use, was accomplished by capitalizing the average annual rental price at an "appropriate" rate of interest. In an effort to simulate uncertainties found in the real world, an expectation model was incorporated into these calculations.

In order to accomplish the third objective, it was necessary to identify policy changes affecting the study area which a priori would have influenced flexibility. In addition, it was necessary to find a measure of value which would yield some indication of the relative efficiency of allocation before and after such changes in the institutional factors. The annual rental price of water (real terms) was deemed most appropriate for this purpose.

Reliability of the measures used in this analysis was determined by applying various tests of significance. The three statistical techniques employed were a multiple regression analysis, a test of the difference between means, and a co-variance analysis. The two latter techniques were somewhat repetitious, but served to confirm each other.

The extent or cost of misallocation for the area was determined by capitalizing the differential in rental price occurring between alternative allocative arrangements.

SOURCES OF DATA

Accurate historical data concerning market allocation of water were considered vital to the success of this endeavor. For this reason, the geographic scope of this study was limited to the Delta area in Utah where data of this nature were available.

Both primary and secondary sources of data were utilized. The principal primary sources included the records of the following: irrigation companies on both upper and lower Sevier River, the Millard County Assessor, the Millard County Recorder, the Millard County Soil Conservation Office, the Delta Farmers Home Administration Office, and the Office of the State Engineer. Other primary data were acquired by personal interview with farmers, irrigation company officers, river commissioners, bankers and lawyers who were familiar with the problems pertinent to this study.

The secondary sources included publications dealing with soil, climate, agricultural production, prices, irrigation and historical features of the study area. Included among these were several bulletins and articles published by the Utah State Agricultural Experiment Station, the United States Department of Agriculture, and the United States Department of Labor.

REVIEW OF LITERATURE

A review of all the literature pertinent to water resources would be a very formidable task. In keeping with the objectives of the study, this review has been limited to a few carefully selected publications which are concerned with allocative efficiency.

Hirshleifer, et al. (10, p. 32-73) present a very lucid description of water supply and give an application of economic theory to water allocation. Their discussion is limited to "existing water supplies", an abstraction which serves to clarify their argument.

They begin their discussion by defining supply and establishing the existing supply as a scarce good. This is followed by an application of economic theory to determine whether alternative allocation propositions are desirable or undesirable. Care is exercised to point out the difference between efficiency and distribution effects and the position of economics in relation to these questions. The remainder of the discussion is concerned with existing water allocative practices, illustrating both correct applications and violations of economic principles.

Water supply is said to consist of recurring annual flows resulting from the hydrologic cycle, stocks in storage and water which may be reused. Existing water supply is defined as that part of the above mentioned supply for which man has developed utilization systems.

Possible difficulties in interpretation of the concept of existing supplies include the following: (a) Fluctuations in annual and seasonal precipitation introduce variability over time to the nation as a whole and more so for a given locality; (b) Withdrawal from stocks may be at a rate greater than the rate of recharge; (c) Locality, seasonality, quality, etc., establish water as something less than a perfectly interchangeable commodity; (d) Water used directly without using human diversion facilities is excluded and is a part of existing supplies; (e) Double counting is possible where multiple use occurs, i.e., water is withdrawn, discharged, and reused.

Competition for the use of nature's resources is said to be an obvious fact of life. If the amount of a resource employed in one use is increased, there will be a lesser amount available for other uses. If an additional quantity of water is diverted for irrigation or municipal uses, downstream uses such as navigation and power production may be impaired. Lower stream flow may cause pollution problems which will have an adverse affect on fish and wildlife, thus affecting recreational uses. Where water is pumped from a common aquifer, an increase in withdrawal by one user will directly affect the quantity available and costs of the other users.

Other types of competition cited include regional, such as Upper Basin versus Lower Basin on the Colorado River, and present versus future use of nonrenewable stocks.

Needs for water are indefinitely expandable and there will always be competition for the use of existing supplies. Attempts to eliminate competition by assigning the allocation problem to politicians or administrators merely shift competition from the market place into the political arena.

Granted that competition exists, economics is the science most appropriate for evaluating alternative allocative propositions. The economic effects of any proposal can be divided into two possible categories. These are "efficiency" and "distribution" effects. Economics can show us how to attain efficiency in allocation; also something of the distributional consequences of alternative possible policies, or institutional arrangements, but stops short of telling us how to distribute any gains from increased efficiency. This is a question left to the branch of philosophy known as ethics.

In allocating a scarce resource, economic efficiency is characterized by what Hirshleifer, et al. call the principle of "equimarginal value in use." The maximum amount of resources (dollars) a consumer is willing to pay in order to obtain a unit of water is said to be the "value in use" of that unit of water. The "marginal" value in use is said to be the "value in use" of the last unit of water consumed.

The principle of "equimarginal value in use" then, is that the resource (water) should be so allocated that the value in use of the marginal unit is equal for all consumers or users of the resource in question. Should a disparity in the marginal value exist between users, it will be mutually advantageous for both users if the resource moves from the use of lower value to that of higher value, resulting in a gain in efficiency. When no mutually advantageous exchanges are possible between any pairs of persons desiring the resource, it is said to be an efficient allocation.

It is suggested that an institutional arrangement with well-defined property rights where free trading is permitted will lead to an efficient allocation. Given these conditions, the market price of a specified right to water should tend to the marginal value in use of those users in the market. Market price measures marginal value in use to its consumers for any commodity in which free trading is permitted and perfect rights may be conveyed. If for some reason trading is restricted or conditional, an efficient allocation will have been prevented.

Within the context of equimarginal value in use, Hirshleifer, et al., lists two rules of behavior which are necessary for an efficient allocation, irrespective of institutional arrangement. The first, if rights to water are vested as property, there should be no restriction on purchase and sale of such rights, so long as third parties are not affected. This was discussed above. The second, if water is sold, the price should be equal for all customers. This is inferred in the discussion above where the statement of equimarginal value in use is said to characterize a situation in which the marginal value in use, for all users is equal.

Further, it was inferred that the marginal values in use, under the assumption of free transfer and perfect title, tended toward the price of the resource subject to allocation. If the marginal values in use are equal, and these in turn approximate the selling price of the resource, then, the price of the resource to all users should also be equal.

In practice, a number of limitations are imposed on a voluntary exchange of water rights. Examples cited include the attachment of water to a specific tract of land, transfers subject to the approval of an administrative agency, and legal codes which establish priority of uses. Any restriction such as these upon free transfer and disposition of the resource, whether restricted with regard to place, purpose or transfer to other persons interfere with market processes and preclude a more efficient allocation.

With the exception of adequate protection of the rights of third parties, Hirshleifer, et al., find little reason to support the imposition of these restrictions to transfer. They intimate that third parties are often overprotected, priorities are often a one-way street especially where condemnation proceedings are applicable, and court definitions of "reasonable use" to prevent waste, at best, could only accomplish the same objectives as the market processes.

Gaffney (7) presents a vivid description of diseconomies in resource use (water) which may result from institutional rigidities. An example is drawn from a case study of the Kaweah River system in Tulare County, California.

Gaffney begins by describing apparent diseconomies found throughout the river system. Included among these are the following : (a) There is a strong indication of wide dispersion of marginal revenue productivities of water; (b) Annual variability in supply is greater for the individual diversions than the natural variability for the whole system; (c) There is considerable excess diversion capacity and overlapping of service areas; (d) Conveyance losses are considerable and vary greatly between systems; (e) There is inadequate reuse of water; (f) Unwarranted segregation of streams has resulted in greater losses.

Gaffney then evaluates the role of water law in perpetuating these diseconomies. This is done by listing numerous examples from the Kaweah system where institutional rigidities have prevented a more efficient use of the water supply.

Diseconomies are said to be associated with water law in the following respects: (a) Productivity is not the initial basis of water rights. Law recognizes time and location; (b) Once a right is established, water users are isolated from social opportunity costs; (c) Allegations of transferability are not supported by any general demonstrations in practice; (d) Transfers actually achieved have been severely hampered by legal impositions involving points of diversion; (e) Excess water available to holders of riparian and correlative rights are by law completely nontransferable; (f) Sale of surplus water from a right contingent upon "beneficial use" could be interpreted to mean that the surplus never was used beneficially, therefore it should revert directly to other junior appropriators; (g) Third parties are often overprotected. Settlement is not necessarily limited to the amount of actual damage.

The remainder of the paper is concerned with what Gaffney satirically entitles the dynamic evolution shaped by water law.

Water law tends to reinforce other economic and political pressures, which result in premature overdevelopment. Gaffney characterizes legal perception of economic values as resembling the near-sighted Mr. Magoo. It responds to the general outline of things, however inappropriately. The tendency of legal response has been to present a stonewall of disapproval upon inexpensive local adjustments, thus accentuating the necessity for interregional transfers. This attitude has materially accelerated the move toward heavily subsidized interregional transfers while existing local supplies continue to be used inefficiently.

The large increment of water usually required for a successful import project results in a cycle of overdevelopment. Lagging private development on project-served lands encourage more starts than the market can ultimately absorb.

Gardner (9) presents a discussion of allocative efficiency in publicly owned grazing. Because of the apparent similarities between grazing permits and water rights, a review of the methodology should be helpful.

The technique employed in determining allocative efficiency rests upon the assumption that a perfectly competitive market can be used as the optimum allocating device. Under this assumption, the equilibrium price of a specified service should be the same for all users and equal to the value of the marginal product derived from that service. Whether or not misallocation is indicated becomes a matter of determining if significant differences exist between the selling price and the expected value of the marginal product derived from that service.

This problem becomes somewhat more complicated when applied to grazing permits. Grazing services are sold at administered prices by government agencies. Prices are often set below the expected value of the marginal return. This results in the permit taking on a value somewhat greater than the purchase price. This is not necessarily a market value, but represents the value in use to the permit holder. If permits are transferable, the selling price should approximate the capitalized value of the difference between the administered price and the value of the marginal product derived from the permit.

Gardner measures the extent of misallocation by determining the difference, per unit of service, between the value of the marginal return as measured by a net price paid for comparable private grazing services, and the administered prices for public grazing. After incorporating an expectation model to account for uncertainty, this difference is capitalized and compared with the market price of permits. If the selling price of the permit is less than this capitalized value, it is evidence of misallocation.

THEORETICAL CONSIDERATIONS AND CONCEPTUAL SOLUTION TO THE PROBLEM

Theoretical Framework

When a resource, such as water, is scarce, an allocative scheme which enables society to obtain a maximum social product or utility from that resource is usually considered to be most desirable. The problem then becomes one of finding criteria or common measure by means of which alternative allocation possibilities can be evaluated.

Economic theory postulates certain schema pertinent to allocation which describe the necessary conditions to attain a maximum product from a given quantity of resource. Assuming that the perfectly competitive market can be used as the optimum allocating device, and that social product and private product are equal, an application of economic theory can be quite helpful in providing qualified answers to these questions.

Within the contest of this abstraction, the supply to the market can be assumed to be fixed. Individuals desiring quantities of the resource greater than they presently hold may obtain them only by bidding away existing supplies from other individuals now holding the resource. Units of the resource will move from one use or user to another any time the marginal social product or the expected marginal social product is greater when employed by the second alternative. These mutually beneficial adjustments or exchanges will continue until the marginal social product of an identical resource is equal for all users in the market. When this equilibrium position is attained, the supply price, usually in dollars, for a unit of the resource will approximate the value of the marginal social product for that quantity of the resource. These two propositions may be expressed symbolically as:

$$\frac{MSP_x}{P_r} = \frac{MSP_y}{P_r} = \ldots = \frac{MSP_n}{P_r} \geq 1 \text{ and } (MSP \cdot P_{sp}) = P_r,$$

Where:

MSP = marginal social product,

P = the market price,

r = the resource employed,

sp = the social product,

x, y, ..., n = specific uses or users.

Where x and y are the only uses or users of the resource, maximum social productivity at varying levels of resource use is depected in Figure 1. This assumes that prices of the aggregate output or benefit derived from the resource are constant. The maximum return positions are at F, F', and F'', depending on the level of resource use. Where the rate of substitution between the possible uses or users is equal to the output price ratio, the cost of foregoing the use of one unit of the resource in Y is just equal to the return from that unit when employed in X. Assuming that the resource is infinitely divisible, any point along the expansion path from F to F'' represents the most efficient allocation

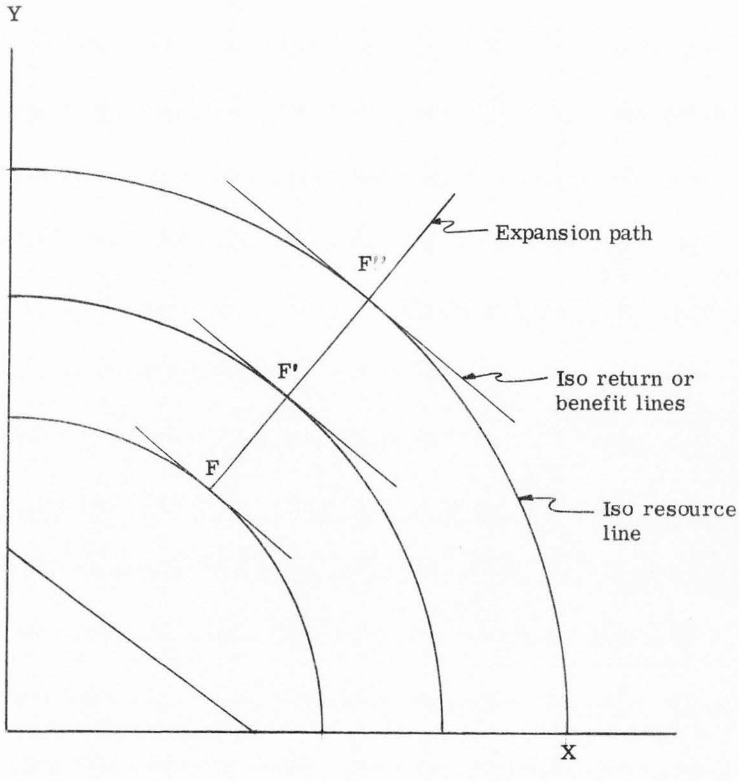

Figure 1. Graph depicts a most efficient allocation among competing uses at varying levels of resource use where X and Y are the only alternative uses.

for that level of resource.

Figure 2 shows the maximum quantity of resource which can profitably be absorbed into a particular use or by a particular user. Equilibrium is attained at point E where P_r interesects the value of the marginal social product function. It is at this point that the cost of procuring the last unit of resource is just equal to the value of the resulting increase in social product and (MSP . P_{sp}) = P_r.

Throughout this discussion it has been assumed that the pricing mechanism yielded an adequate indication of the desires of society and that social benefits or utility derived from a resource could be expressed in dollar terms. In a situation where a resource price is an administered price or no market price has been established, it may be necessary to use choice indicators other than price. However, this does not invalidate the market mechanism as a means of determining allocative efficiency. Rather, the problem becomes one of finding other nonmarket indicators which lend themselves to an application of traditional economic theory (8).

It was assumed that the water market in the study area was sufficiently competitive to allow the average seasonal rental price per acre foot of water to be the choice indicator of the value placed on that quantity of water. Although the size of the market area and prevailing conditions within the market have been somewhat variable over time, this assumption was not considered especially heroic because there is very little evidence, if any, of uses whose valuation would not be reflected in this market price.

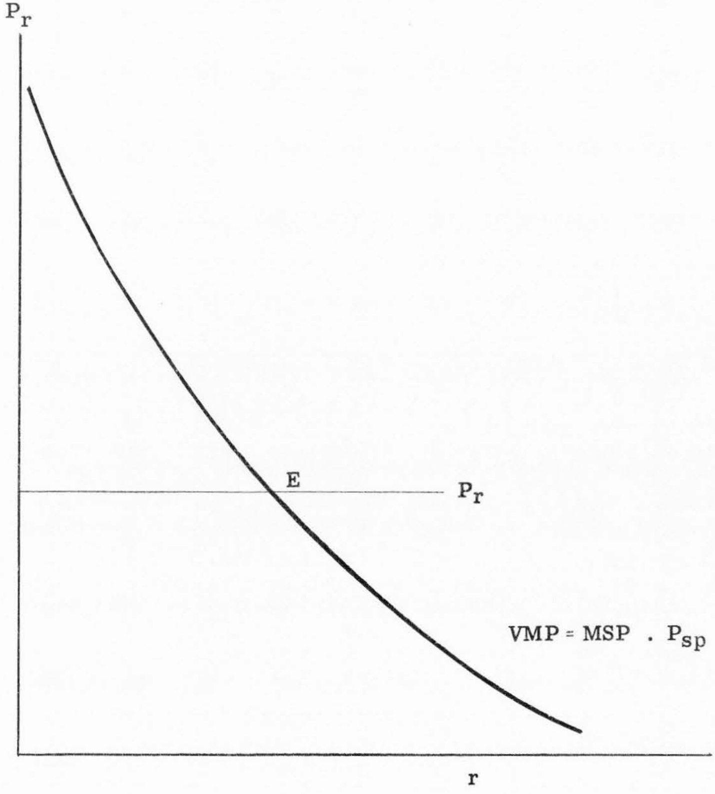

Figure 2. Graph illustrating maximum quantity of a resource that can profitably be absorbed by a particular use or user.

Water is an intermediate good in most instances and is used almost entirely as an input factor in the production of field crops.

Within the market area, the marginal cost of water to each farmer is essentially equal. Each farmer is assumed to be able to buy any quantity of water which he might need at the prevailing market price. The action of one farmer will not exert a discernable affect on the price of water or product prices.

Conceptual Solution

The perfectly competitive market was considered an appropriate model for evaluating the performance of two alternative allocative schemes which have been used in the study area. Relatively free market conditions have existed in this area for many years. Records of the companies indicate a history of 30 to 40 years of rental and sale of irrigation company stock. Early residents indicate that "trades" were common practice even before formal records were considered necessary.

For the purpose of this study, the water resource was regarded as that limited part of the total physical quantity of water which possess utility for irrigation purposes under utilization systems presently found in the study area. This does not preclude an expansion of the supply in the future, nor does it cast any reflection on other uses not considered here. It merely serves to restrict the means of controlling the hydrological cycle to those which are currently in operation. Our purpose was to abstract from the real world situation in order to gain some insight concerning allocation and possible utilization of a fixed supply without the added complication of considering the development of new supplies.

From the foregoing, it is deduced that a given supply of irrigation water should be allocated such that the value of the marginal product should be equal among all users. Further, the market price of a specified unit of water should approximate the value of the marginal product derived from the use of that quantity of water.

The determinant of supply and demand for water could be expected to influence the market price of a specified unit of water. A priori the total quantity of water available to the area appears to be an important variable on the supply side. The demand side appears to be influenced by the level of technology, the prices and quantities of other productive services which may be used as substitutes or in combination with water, and the prices of products produced by water.

The price of water may be further influenced on the side of both supply and demand by the institutions which determine allocation among users. In order to determine the relative efficiency of alternative allocative policies, as measured by changes in the price of water, the influence on water price of all factors other than the change in allocative policy must be held constant.

Assuming that all expectations concerning the supply and demand determinants affecting water prices could be held constant over time, then the price of water could also be expected to remain constant. Should a given change in pertinent water institutions be accompanied by a significant change in the price of water, there would be evidence that selected changes in the institutions have an affect on the efficiency of water allocation. Depending upon the magnitude and direction of this response, it should be possible to determine whether that affect is favorable or unfavorable. A more efficient allocation is indicated by a higher price, a less efficient by a lower price.

An approximation of the net gain or loss which would accrue to society is obtained by capitalizing the product of the difference between the per unit prices associated with any two allocative arrangements and the total units of water available to the market area.

DESCRIPTION OF THE STUDY AREA

Physical Description

The Delta area is located in the west-central part of the State of Utah, approximately 140 miles south and west of Salt Lake City. It lies in the northeastern corner of Millard County and is a part of the Sevier Desert. The total land area comprises approximately 180 square miles or 115, 000 acres. Area tilled and irrigated appears to vary from 35 to 60 percent of this amount or from 40, 000 to 80, 000 acres (12).

Topography of the area is generally smooth with slopes ranging from less than 5 up to 20 feet per mile. The surface elevation ranges from about 4, 565 to 4, 650 feet (17).

The climate of the Delta area is definitely arid as the mean annual percipitation is less than 8 inches. Summer rains occur only infrequently and are inadequate for most types of crop production. Seasonal temperatures vary from over 100 degrees during the summer months to -15 degrees in winter. Killing frosts usually occur in early September but have been known to occur as much as three weeks earlier. The last killing frosts in spring usually come late in May. Frosts during the growing season do occur infrequently but are not a serious element of uncertainty. Hot spring and summer winds are common. These have an adverse affect on soil moisture and can be injurious to various hay and seed crops (17).

Soils consist of alluvial materials deposited in main part by the Sevier River as its waters entered the ancient Lake Bonneville. Disposition of soil types is wide and varied, apparently owing to sizable fluctuations in the level of this lake. Texture of the soils ranges from slick clays to dune sand, the clay types being most prevalent. Soluable salts are present in varying concentrations throughout the area. Meticulous irrigation and drainage practices are necessary to prevent serious alkali problems from developing (17). Acreage of different soil types are shown in Table 1.

As is intimated above, irrigation is a prerequisite for crop production. Irrigation waters are derived from mountain and desert watersheds to the east and south. These enter the area via the natural course of the Sevier River. During the period 1934 to 1963, the annual water supply has varied between 58, 233 and 151, 235 acre feet. The mean annual delivery for this same period was 115, 006 acre feet. In order to augment and stabilize the water supply, rather extensive storage and diversion facilities have been constructed along the course of this river. These have a combined storage capacity of approximately 250, 000 acre feet. Except in periods of prolonged drought, these facilities serve admirably for their intended purpose.

Crops well suited to the area under irrigation include alfalfa for hay and seed, and small grains. At the present time, 80 to 90 percent of the irrigated acreage is in alfalfa. Sugar beets and potatoes could also be grown given a more adequate supply of water. Some idea of land

Table 1. Acreage of different soils, Delta Area (12)

Soil	Number of acres	Percent
Oasis clay	28,480	24.7
Gordon clay	12,992	
Friable phase	1,856	13.2
Slick phase	384	
Oasis silty clay		
Loam	14,400	
Light-textured bench phase	448	12.9
Oasis fine sandy loam	13,440	
Bench phase	128	11.8
Abbot clay	8,960	
Silty phase	3,136	10.5
Cache silty loam	11,392	9.9
Woodrow clay loam	9,024	7.8
Woodrow clay	5,376	4.7
Lynndyl gravelly sandy loam	1,856	1.6
Cache loam	1,408	1.2
Lahontan clay loam	1,344	1.2
Dune sand	512	.4
Rough stony land	64	.1

use can be obtained by observing the data for Millard County in Table 2. Roughly two-thirds of these totals can be attributed to the Delta area.

The economy of the Delta area is dependent almost entirely upon the income derived from agricultural sources. The two largest sources of income are alfalfa seed and livestock (22). In both cases, the production of these products is either directly or indirectly dependent upon irrigation. Hence, the allocation of irrigation water is a problem of primary importance to the economy of the Delta area.

Development

A brief description of the settlement and development of Mormon communities in general should be helpful in evaluating the subsequent institutions which pertain specifically to the Delta area.

Settlement and construction of irrigation facilities

The first permanent settlement in the Delta area was established in 1860. As was the case in all of Utah and in limited areas in surrounding states, this settlement was effected by Mormon families selected specifically for that purpose by the authorities of the Latter-Day Saints Church. These colonization efforts by the Mormons were communal in nature, being planned and directed by the Church authorities. Companies of settlers were usually limited to those groups large enough to supply the labor necessary for construction of the various essential fixtures, and to discourage attacks

Table 2. Land use in Millard County (22)

Land use	Irrigated farms	Percent of total	Total for whole county	Percent of total
Number of farms	768		905	
Land in farms (acres)	533, 662	100.00	593,390	100.00
Acres of cropland	163, 499		175, 850	
Cropland harvested	81, 425	15.26	84, 165	14.18
Hay	39, 762[a]		45, 875[b]	
Corn	3, 162[a]		3, 179[b]	
Small grains	15, 311[a]		27, 403[b]	
Alfalfa seed	21, 285[a]		24, 577[b]	
Irish potatoes	350[a]		350[b]	
Sugar beets	319[a]		319[b]	
Other	32[a]		51[b]	
Cropland used only for pasture	31, 754	5.95	35, 438	5.97
Cropland not harvested and not pastured	50, 320	9.43	56, 247	9.48
Woodlands	12, 980	2.40	14, 225	2.40
Other pasture	334, 377	62.66	379, 209	63.91
Other land (lots, roads, waste)	22, 806	4.30	24, 106	4.06
Total land irrigated	75, 793		75, 793	
Irrigated cropland harvested	68, 016		68, 016	
Other irrigated land (not cropland harvested)	7, 777		7, 777	

[a] and [b]These do not sum to A. Cropland harvested because of double counting hay and alfalfa seed acreage.

by hostile Indians. Families "called" or selected usually owned or were supplied with the necessary implements, livestock, seed, etc., making the group as nearly self-sufficient as was possible. Upon arrival at the proposed site of settlement, building a fort, platting the townsite, erecting fences, clearing fields, and building the irrigation facilities were all accomplished by community effort under the direction of the bishop (11, p. 9-13).

This communal approach to colonization was undeniably successful and probably the only means by which the desert could have been conquered at that time. However, certain inefficiencies were inherent in the system with regard to land and water use. Projects were small of necessity because there was dire need for quick development and immediate returns. Ditches were constructed where diversion was most easily accomplished with little thought of potential development of either land or water. Knowledge essential for the construction of efficient irrigation systems was still in the developmental stages and much of the construction equipment was improvised and crude.

As the settlements grew and new lands were required to support the population, old ditches were extended and increased in size. The next step, in many areas, was to build parallel facilities at higher and higher levels which could supply the less convenient bench lands. The result of this short-run policy was a maze of duplicate ditches, diversion facilities and management personnel in areas where one well-designed facility could have provided service to all users in a more efficient manner. In many areas, this sporadic period of growth resulted in greater losses of water, water-logging of fertile low lands, higher maintenance costs, management problems, and it increased the possibility of conflicts between users. It should be recognized that these seemingly important factors were probably considered mere trivia to the Mormon pioneer who faced starvation during the first winter if immediate returns were sacrificed for future efficiency.

Ownership of land was usually limited to small parcels in an effort to discourage speculation and to encourage a more intensive agriculture. It also tended to localize the population while at the same time it encouraged a more uniform social order and reduced the threat of Indian harassment. Where settlers shared equally in initiating the community, ownership of property within the townsite was determined by drawing lots. Other lands were apportioned somewhat arbitrarily, usually in accordance with need and ability to give proper care to the land. In both cases, a proportionate share of the community water supply was assumed to accompany the entitlement to land. In other instances, the amount of land granted was proportional to the amount of labor contributed in the development of a water supply, or conversely, obligation of labor toward the construction and maintenance of the irrigation system was dependent upon the size of the land holding. Ownership rights to land and water use thus acquired, were later recognized by the State of Deseret, the Territory of Utah, and by the United States Government (11, p. 14-15).

From earliest times the building, maintenance, and management of the various water systems had been subject to the direction of the local church authority or his appointee and were an integral part of the ecclesiastical regimen. However, as settlements became more firmly established and the people attained a reasonable degree of security, a cleavage developed between the religious and the secular organizations. Control of the water supply appears to have been among the first segments of community life to have been affected. Intuitively, this should have resulted following an influx of nonmembers who did not accept the authority of the Church or its leaders, but this did not prove to be the case. Local members usually provided the impetus for change (11).

Prior to the establishment of civil government, it became customary in many settlements for the men of the community to meet regularily, in mass, to discuss problems affecting the general welfare of the settlement. These meetings provided an excellent opportunity to usurp the power of the Church leaders in secular affairs. They still presided on these occasions, but suffered a considerable diminution in power as questions brought before these meetings were usually decided in favor of the consensus of those present. The establishment of civil government and the added influence of increasing numbers of non-Mormons tended to crystallize this movement. If the Church authorities continued to wield considerable influence in secular matters, it could usually be attributed to reasons other than their position in the Church.

Institutions

Early water organizations were very informal. Control by Church authorities was replaced by committees or representatives selected by the majority of the water users. With the advent of civil government, public officials, especially town officers, became the heir apparent. This was a logical secession in the typical Mormon community where almost all persons lived within the confines of the town. The interests of the city dwellers no doubt coincided with those who worked and irrigated the farms because they were the same people. As the towns grew, conflicts of interest developed between urban and rural users. The usual result of such conflicts was a realignment of the user groups, each one sympathetic to its own divergent interests (11, p. 16-27). This gradual transition of control and refinement of purposes in the various water user groups plus the application of a formal legal structure gave rise to several of the more formal water institutions which have carried over to the present.

Many features of early water law and custom in Utah foreshadowed current appropriative doctrine. In 1852, the first territorial legislature declared that natural resources, including water, were property of the public and were to be administered by the county courts. As is intimated above, ownership of land, water, and ditches were closely associated.

Water was not readily transferable and was usually considered to be a part of the land. The right was acquired by development and use, and water could be used on lands not necessarily bordering the initial source of supply. Water institutions in Utah were unique in that they were generated in an agricultural economy, whereas the institutions of other arid states were borrowed from the laws and customs of the miners. Agricultural use of water outside Utah was incidental until much later (13, p. 220-241).

Unique Features of the Delta Area

Development in the Delta area was similar in most respects to the remainder of Utah, but differs in certain important respects. Foremost among these was the difficulty encountered in making diversion from the Sevier River and its subsequent affect on the type of development to occur. Most settlements made prior to this time were accomplished on small streams where relatively little effort and material were needed to effectively divert irrigation water into a canal. The usual diversion facility was constructed of a few well placed cottonwood trees, rock and native hay.

Diversion in the Delta area was not so easily accomplished. Brush and rock dams, even solid earthen dams, were repeatedly undermined and washed away owing to the erosive nature of the soil. After repeated failures, the first attempt to settle was abandoned. It was apparent that the usual methods of diversion would not be successful in this area.

In order to justify a more elaborate facility capable of effecting diversion under these adverse circumstances, the project would necessarily be larger, and require more labor and materials. When settlement was attempted a second time in 1860, it was by a much larger group. It was decided to build a dam of solid rock. This rock fill was extended well into the river banks and pilings were used on the lower side of the dam. Diversion was accomplished and several thousand acres of land were soon brought under cultivation (4).

This was the first and last settlement effected by the Latter-Day Saints Church, per se, in the Delta area. In 1866, the diversion dam again failed and the first of several cooperative irrigation enterprises was begun. Reconstruction and subsequent new development after that time were effected mainly by Mormon people, but under forms of organization other than the Church. The most predominant organization to emerge was the mutual irrigation company. The rather active communal spirit imparted by the Church, the aura of common interest, plus the advent of user control of the water delivery systems provided a natural basis for the development of the mutual company. Although mutual irrigation companies were common in other parts of the state, the rather unique problems involved in the Delta area gave rise to much larger organizations. The four mutual companies which have emerged in that area have approximately 80, 000 acres under their canal systems, an average of 20, 000 acres per company (22). This is more than ten times as large as the average company in the state. This feature alone went far in reducing some of the inefficiencies mentioned above which are associated with the smaller systems.

Organizations of this type were better suited for acquiring the capital needed for the construction of extensive irrigation facilities essential for the development of the Delta area. In addition, they afforded much greater flexibility in water use. Stock ownership entitles its owner to a specified portion of the water in the system, which can be used on any land which can be reached by that company's system, and may be sold or rented if the owner does not need it. There are no restrictions as to the area within the canal system upon which this water may be used; its owner uses his judgment in that matter (13, p. 235, 236).

In summary, the Delta area was settled by Mormon families who were accustomed to working together for a common purpose. Policies regarding use of water reflected its dear qualities and in many respects resembled present day appropriative doctrine. The usual transition of control of the water supply experienced in other parts of the state was greatly abbreviated in the Delta area. Substantially greater labor and material requirements needed to develop a water supply necessitated a more extensive development than had heretofore been the case. Although initial development was abortive and more costly, many of the problems associated with the smaller developments in other parts of the state were fore gone. The primary organization to emerge was the mutual irrigation company. Policies associated with these organizations led to much greater flexibility in water use.

Other unique features found in the Delta area such as type of rights, location of land with respect to supply, flexibility of control, and third party affects will be considered in detail in the following section.

THE WATER MARKET

The reliability of many of the measures used in this analysis hinges upon the assumption that a market for water rights does exist, and that the market price for a specified quantity of water is a good approximation of the value of the marginal product derived from that quantity of water. This initiates query as to the degree of competition, homogeneity of product and factors, flexibility of water movement, and the state of knowledge associated with the study area. For this reason, a description of the water market in the study area was considered an essential part of the analysis.

In economics, a market is often described as a group of individuals, buyers, and sellers of a particular product, with facilities for trading with each other. In Utah, several rather distinct markets have developed which tend to coincide with this description. A survey of irrigation companies in the Sevier River Basin reveals that 90 percent of the respondents have some approximation of a market where water rights are exchanged between buyer and seller. Transfers are of three general types: (a) Sale of water rights on a stream for changing point of diversion, (b) sale of irrigation company stocks, and (c) rental of water or of irrigation company stocks.

In a majority of these cases, the market is quite inactive. Sales are initiated only under extreme circumstances such as death of the owner, sheriffs' sales, etc. However, in a few selected areas the water market is very active. This is especially true in areas where water can be rented either seasonally or on a per unit basis. The study area is a notable example of this latter group.

Factors Contributing Toward the Development of a Market

There are a number of factors which appear to contribute toward the development of a workable market for irrigation water. Included among these are the following:

1. The supply is sufficiently scarce to make transfers between users desirable; i.e., water must be a scarce "economic commodity;

2. The laws and customs governing irrigation water use will accommodate transfers between users;

3. The water supply is of such quality, locality, and seasonality that any part of the total supply is readily substitutable for any other part.

Not all of the above mentioned conditions are similar in areas where markets have developed and the presence of these factors is no guarantee that a market exists or may develop. However, these are the factors most often associated with areas where operable water markets have developed.

Scarcity

Transfers become desirable any time the cost of developing new supplies is greater than the consideration required to attract a similar quantity of the existing supply. Perhaps a more relevant question is the relative scarcity of water to each individual within a group dependent upon a fixed supply. Here transfer is desirable any time a disparity occurs in the marginal valuation placed on a given quantity of water by different users. This ignores third party effects which will be discussed below, but generally, it can be stated that any time an individual in a probable market area desires a quantity of water to such extent that he is willing to compensate other persons now holding the right to water in an amount which will induce them to give up a unit voluntarily, transfer is desirable.

A uniform distribution of supplies per acre or per user, does not lessen the need of transfers between users; in fact, it increases it. Soils, crops, choice of other inputs, and managerial ability, all of which may have a substantial effect on the value of the marginal product of water are not usually distributed evenly. Varying combinations of these elements will necessitate some adjustments in the amount of water allocated to each user if value of the marginal product is to be equal among all users. Thus when supplies are scarce and other inputs are variable, it appears that transfer would be desirable.

In the study area, irrigation water supplies are definitely limited. Total water available at the farm for each season and water available per irrigated acre are listed in Table 3.

Table 3. Water available for use at the farm, 1950-1964

Year	Total water available[a]	Water available per irrigated acre[b]	
		Acre feet	Acre inches
1950	92, 693.2	1.8168	21.8
1951	71, 111.2	1.3938	16.7
1952	114, 371.9	2.2417	26.9
1953	113, 521.0	2.2250	26.7
1954	70, 266.8	1.3772	16.5
1955	71, 178.5	1.3951	16.7
1956	48, 170.0	.9441	11.3
1957	49, 564.9	.9715	11.7
1958	94, 260.5	1.8475	22.2
1959	72, 096.3	1.4131	17.0
1960	52, 686.4	1.0327	12.4
1961	42, 086.5	.8249	9.9
1962	74, 716.0	1.4644	17.6
1963	44, 945.5	.8809	10.6
1964	53, 333.5	1.0454	12.5

[a]An aggregate of credit per share multiplied by shares outstanding.

[b]Acreage is based upon County Assessor's records, 1965.

From 1950 through 1964, the average quantity available per irrigated acre was 16.7 acre inches with standard deviation 5.4 acre inches. Figures on consumptive use for a similar area in central Utah list the following annual consumptive use for major field crops: alfalfa, 35.4 inches; corn, 21.2 inches; sugar beets, 26.4 inches; wheat, 22.4 inches; other small grains, 20.7 inches; and potatoes, 21.0 inches (5). A comparison of these consumptive use requirements with the water available at the farm, serves to emphasize the degree of scarcity. Certainly if stringent supply provides an impetus for the development of a market, this requirement is fully satisfied in the study area.

Water law and local custom

Water law and local custom are factors which can either enhance or restrict the development of a water market. Generally, water laws tend to reflect economic pressures; however, position action is sometimes delayed to the point that it does little to expedite transfers (7). Local customs appear to be endowed with an inertia which tends to perpetuate accepted practices. This is not surprising, because specific and reliable evidence of monetary benefits is extremely scarce. It seems perfectly rational for water users to maintain the status quo when evidence is inconclusive and only suggests betterment (18).

In order for any market transfer arrangement to work satisfactorily, water rights must be secure and sufficiently well defined by law so that the product may be positively identified and rights conveyed to subsequent owners. Provisions for changing ownership, point of diversion, place of use, and character of use should be maintained subject only to the adequate protection of third parties (10).

Basically there are two types of security considerations pertinent to water. The first involves legal certainty or security of tenure and the second physical certainty. Where water markets are concerned, it is this element of legal certainty which is important. Buyers and sellers of water should be able to determine without question who owns specifically defined rights to water supply. Under the appropriate doctrine, legal certainty means that prior appropriators are protected against junior users, and juniors are protected against increased use by the senior right holders (10).

Physical certainty as such is not dependent on the law, but is subject to the laws of nature because droughts, floods, rainfall, etc. are not responsive to man-made laws (10).

Third party effects, or spillover benefits and losses, become a serious impediment to transfer only when the definition of the water right is incomplete. In a situation where the water is not entirely consumed in its initial use and subsequent rights are granted on the basis of return flows, identification problems may become very complex. This does not reduce the desirability of free transfer, but tends to re-emphasize the necessity of finding reliable measures of return flow so that transfers can be effected when desirable and third parties can be protected.

In the study area, as in all of Utah, the appropriative doctrine is the accepted body of water law. All water is declared to be property of the public. Rights to the use of unappropriated water are acquired on the basis of "first in time, first in right" and are contingent upon continuous "beneficial use" (24, 73-1-1, 73-1-3, 73-3-21). Under the appropriative doctrine, a water right is generally considered as real property. So long as the water flows in the natural water course, rights are limited to usufractuary rights or right to use. After diversion from the water course, water may be reduced to physical possession and as such is considered as personal property of the right holder (10, p. 231). It is important to note that mere possession of a water right may not guarantee a supply of water to the owner of the right. Prior rights must be satisfied before any water accrues to junior right holders. When the stream is appropriated in excess of flow or when dry years occur, the supply may be such that junior rights must give way to prior right holders (24, 73-3-21).

Under the appropriative system, a water right is not usually contingent upon the ownership of certain lands. The water right ordinarily accompanies the land, but when deed separately it may be sold separate from the land (24, 73-1-10). Appurtenance does exist in some cases, usually as a by-product of an earlier effort to obtain credit for irrigation works. Assignment of the water to specific tracts of land was thought to reduce speculation and provide an added degree of security for the investor (19, p. 231-243). In certain cases, these have outlived their intended purpose and now serve only as a barrier to flexibility.

General provisions in Utah water law with regard to changing ownership, point of diversion, and place and character of use appear to accommodate flexibility in water use in most respects (25). As is pointed out above, a water right, subject to certain limitations, may be treated as any other real property. Thus, any of the foregoing changes may be accomplished provided the limitation is not unsurmountable. However, problems associated with water right identification and third party effects are not always resolved. The possibility of involvement in litigation and the inconvenience and uncertainty of having to submit proposals of change to an administrative agency or the courts for approval might have a dampening effect on transfers (2).

In the study area, much has been done to positively identify water rights. In 1936, the Fifth Judicial District Court in Millard County rendered a decree adjudicating all rights along the Sevier River. Four mutual irrigation companies, which service all of the study area, control the water rights for the irrigation of about half of the irrigated lands along the Sevier River (4). Within these companies the various water rights accorded under the appropriative law, with their varying priorities, have been maintained in order to satisfy legal requirements and to apportion yearly supply among the four companies. The usual confusion and litigation ordinarily associated with water rights is minimal, apparently owing in large part to the small number of claimants involved and their long history of collective endeavor.

Further complication involving return flows is virtually nonexistent because of the location and topography of the study area. Virtually all of the water entering the area is consumed. The Sevier River follows the highest contour of the Sevier Desert area. Surface strata slope away from the river, thus return flows are negligible. Water which may run off is collected in artificial drains and is of such poor quality that it is unsuitable for further irrigation uses (4). It is evident that transfers in the study area encounter fewer obstacles because identification is easier and third party affects are at a minimum.

As is intimated above, community attitude or custom may have considerable affect on eventual development of water markets. In the absence of tangible evidence of potential gain, local interests may lack the impetus to initiate changes in policy which will benefit the majority of water users. In at least one such case, a public agency assumed the responsibility of assembling specific and reliable information concerning irrigation company activities, and of making recommendations for sound, workable improvements

In 1936, the Utah Agricultural Experiment Station completed an investigation of the study area. It was a comprehensive study of irrigation and drainage, soil, economic and social conditions. In the following spring, the Experiment Station, under the direction of O. W. Israelsen, went to the area for the purpose of initiating some of the recommendations of this study.

Foremost among these was a proposal to consolidate all of the irrigation companies and drainage districts in the area. In spite of what appeared to be undeniable evidence in its favor, it met with opposition from local irrigation officials. However, all was not lost. In the years following, the merits of these proposals became generally known among the stockholders of the various companies, with the eventual result that most of the major recommendations were initiated by the efforts of the local water users (4).

Homogeneity of the factor

The quality, locality, and seasonality of water are of extreme importance if water is to be transferred successfully between uses. Where transfer within a given use is concerned, water quality does not appear to be restrictive except in the case of some extremely sensitive crops. Generally, water used to irrigate one crop or farm is equally well suited for the irrigation of other crops or farms. Quality and location may be related to some extent where coveyance from one place to another reduces quality. However, location is a greater problem because of the physical barriers it presents in effecting transfers. Even where conveyance facilities exist, losses incurred between places of use may prohibit transfer. Even if a specified quantity of water were valued at ten dollars in its present use and twenty dollars in its alternative use, there would be little point in transferring it if half of the water were lost in conveyance.

Seasonality of supply may tend to encourage transfer. Where both direct flow and storage rights are held by different individuals, transfers may have a highly complementary effect upon the supply. During the early season when irrigation requirements exceed direct flow, transferred storage water could be used to good advantage by the direct flow right holders. Later in the season when storage is depleted and river flows increase, it may be advantageous for the storage right holders to obtain water from the direct flow right holders. This would have the effect of extending the supply over the season and making the water available at a time when it is most useful to crops.

In the study area, water quality is not good. Along the upper portion of the river, there are several tight dams, where all the flow is diverted. That part of the water not consumed eventually returns to the river where it is again diverted for irrigation. In this manner the waters are used over and over again along the 225 mile extent of this river. This complete use is not accomplished without certain negative consequences. Each time the water is used, additional quantities of soluable salts are retained in solution, thus reducing the quality of the water appreciably. However, with adequate drainage, it still can be used successfully for the irrigation of all crops commonly grown in the area.

Locality of water with respect to arable lands is favorable in the study area. With the exception of a small amount of underground water, all of the supply enters the area via the Sevier River, such that it can be diverted into any of the four systems. All storage water can be used by any one of the four companies with the exception of 4, 000 acre feet which is sometimes stored in the Gunnison Bend Reservoir.

The dispersion of irrigable lands favors the concentration of water in the Delta vicinity. This allows the water to be used on the best soils while at the same time foregoing excessive canal losses which are associated with the irrigation of lands farther from the source (23).

In the study area, the water rights of two of the companies are based largely upon direct flow from the river, while the remaining two are dependent primarily upon storage. Storage is made up of river flow for the period October 1 to March 1 of each year. Fall and late winter storms favor the storage rights, while spring and summer storms favor the direct flow rights. Transfer of water between companies tends to reduce variability in supply for all four companies (4).

Operation of the Water Rental Market

Credits

The technique employed in handling transfers of water in an irrigation company resembles the accounting system of a bank. Each year in the early part of April, a water dividend based on reservoir storage and anticipated runoff from snowpack, less estimated system losses, is announced and credited to the accounts of each of the four companies in accordance with their respective water rights. These amounts are then credited to the accounts of the individual shareholders in proportion to the amount of stock they hold in the company. If the water supply improves, an additional dividend may be declared at a later date which is credited in the same manner. Persons responsible for making this estimate exercise extreme care because of the ruinous situation which can develop if book credits greatly exceed actual supply. The individual account of each farmer represents his water supply for the season, and he makes his plans accordingly. It would be disconcerting, at best; a disaster, at worst, to discover in midseason that the actual supply was exhausted when plans based on established water credits called for additional irrigation.

Transfers and "basis of exchange"

Withdrawals for irrigation and all types of transfer are reflected in both the individual accounts and those of the companies. It should be noted that not all recorded transfers of water between companies result from a rental or purchase of water from another system. Often one landowner will have acreage under two or more of these systems. Under these circumstances water may move from one system to another with no accompanying change in ownership.

Prior to 1948, only intracompany transfers were permitted. Transfer between individuals within the same company was a relatively simple matter. The account of the person giving up water was debited and the account of the person receiving water was credited. Following a change in policy in 1950, exchanges have been possible on both an intracompany and an intercompany basis among all four companies. The water credits of any one company may be transferred to the credit of any other, subject to the established "basis of exchange."

This "basis of exchange" is an amount in addition to the face amount to be transferred which is debited to the company giving up the water and credited to the company receiving the water. Suppose farmer A in company X wishes to rent 10 acre feet of water to farmer B in company Y. Where the common "basis of exchange" is 40 percent, farmer A will be debited for 10 acre feet, company X will be debited for 16.67 acre feet, company Y will be credited with 16.67 acre feet, and farmer B will be credited with 10 acre feet. It is essentially a means of accounting for system loss in the various companies; however, it appears rather ineffectual when the rate is the same for all companies regardless of system losses. If percentage losses in each of the systems were exactly the same, there would be little problem in establishing a "basis of exchange." It should be an amount just equal to the loss incurred in making delivery.

When losses vary between systems, a common "basis of exchange" tends to favor certain companies and discriminate against others depending upon two factors. The first concerns their losses relative to the "basis of exchange", and the second hinges on whether a company is primarily an exporter or an importer of water. Members of a system having losses in excess of the accepted "basis of exchange" would suffer if substantial quantities of water were rented into the system because the "basis of exchange" would not be sufficient to offset actual losses incurred in delivery. If the full amount of the transfer is delivered into the second system, the supply for that system will be reduced by an amount equal to the amount by which system losses exceed the "basis of exchange." Conversely, when the "basis of exchange" is substantially greater than actual losses incurred in delivery, all users in the system would benefit from a transfer into that company.

The relative position of each company with respect to the "basis of exchange" has some rather obvious implications on the prevailing rental price. These will be considered under the discussion of price below.

In practice, this "basis of exchange" has been set at what appears to be an amount at least equal to the greatest system loss. This would allow transfer into any company without adversely affecting the amount of water available to other users in that company. A policy on this order would favor the importer company and discriminate against the exporter. Every company is wholly compensated for system loss on imported water and others having lower system losses should realize a net gain from imports. From the perspective of the exporter company, a "basis of exchange" set at the highest system loss may be restrictive to transfer. To transfer out of the company would cause a net loss to that system of an amount equal to the difference between the "basis of exchange" and the actual system losses.

Accounts showing net intercompany transfers for the years 1951 through 1962 are shown in Table 4. In this series of years, company B shows a marked tendency to export, company C to import. A priori this would suggest that more marginal users are associated with company B. Although this may be true in other instances, a closer examination of this company reveals that its location and water supply relative to irrigated acreage within the system probably account for this export position. Company B is almost completely surrounded by the other companies. Supply to this company per irrigated acre is consistently higher than the other companies. Where water supplies are greater and the service area cannot be expanded, it seems logical to assume that water will move out of this system.

Company C, the importer, consistently has less water per irrigated acre than the other companies. The current "basis of exchange" may favor this company as an importer because of reduced system losses resulting from canal lining. Under these circumstances, company C could be expected to import a greater amount of water.

Net debits and credits resulting from intercompany transfer in the remaining companies appear to be quite random in occurrence. However, if the water supply for the whole area is compared with the debit-credit position of each company, a certain pattern can be ascertained. When the water supply tends downward, the storage companies initially

Table 4. Intercompany transfers for the years 1951 through 1963

	Company A		Company B		Company C		Company D	
Year	Export	Import	Export	Import	Export	Import	Export	Import
1951		85	680			620	25	
1952		1, 011		146		1, 476	2, 633	
1953								
1954								
1955		595	1, 205			187		423
1956		410	726			376	60	
1957		1, 458	66		594		798	
1958		761	629			166	298	
1959	639		1, 286			1, 516		409
1960	36		328		21			385
1961	28			355	431			104
1962		414	953			659	120	
1963	2, 471		615			383		2, 703
Total	3, 174	4, 734	6, 488	501	1, 046	5, 383	3, 934	4, 024

Source: Records of the four companies in the Delta Area.

become debtors, exporting water to the direct flow companies. If the declining trend persists, they tend to move back to the position of a creditor and import water. When a recovery in supply begins, the direct flow companies tend to become debtors and export to the storage companies.

This is illustrated in Table 5 where the annual water supply for the area and the debit-credit positions of company A, a storage company, and company D, a direct flow company, are compared. With but one exception, in the period of years 1951 through 1963, the position of the storage company was opposite that of the direct flow company. A marked recovery in 1952 saw company D exporting, company A importing; a downward movement in supply in 1956 provides the exception; but supplies up to that point were probably so stringent that storage was already depleted. A recovery in 1958, a decline in 1959, a recovery in 1962, and a decline in 1963 all follow the prescribed pattern.

Where the "basis of exchange" represents an amount that is mutually acceptable to all of the companies and is subject to revision, should it be desired, it seems logical to assume that this figure would represent an equilibrium exchange position among the companies. Thus, over a period of years including a complete cycle in supply conditions, the problems associated with the "basis of exchange" will probably average out.

In the future as water becomes even more scarce than at present,

Table 5. Export-import position of typical storage and primary right companies under various supply conditions

Year	Water available	Change in supply[a]	Company A storage[b]	Company D primary[b]
	(acre feet)	(acre feet)		
1951	71, 111.2	(21, 582.0)	-	+
1952	114, 371.9	43, 260.7	-	+
1953	113, 521.0	(850.9)	—	—
1954	70, 266.8	(43, 254.2)	—	—
1955	71, 178.5	911.7	-	-
1956	48, 170.0	(23, 008.5)	-	+
1957	49, 564.9	1, 394.9	-	+
1958	94, 260.5	44, 695.6	-	+
1959	72, 096.3	(22, 164.2)	+	-
1960	52, 686.4	(19, 409.9)	+	-
1961	42, 086.5	(10, 599.9)	+	-
1962	74, 716.0	32, 629.5	-	+
1963	44, 945.5	(29, 770.5)	+	-

[a]Decreases in water available are denoted by parentheses ( ).

[b]A net export is denoted by (+), and a net import is denoted by (-).

Source: Records of the four companies in the Delta Area.

it seems reasonable to assume that much will be done to reduce system losses. It may well be that this is one of the cheapest sources of additional supply still available to the area. Should system losses be substantially reduced and tend to converge at that point where water becomes cheaper to secure from other sources, it should help to reduce problems associated with intercompany transfer of water, especially the "basis of exchange" problem. Ideally, all system losses would converge at zero and the "basis of exchange" could then be ignored.

Rentals

In the study area, most transfers involving the market are of three general types. These include sale of irrigation company stock, the rental of irrigation company stock, and the rental of water on a per acre foot basis. The last of these is by far the most common.

Records indicate that rentals have occurred in some of the companies for more than 30 years. Undoubtedly "trades" were common practice long before any formal records were kept.

Price

A rental agreement can be initiated in a number of ways. In most instances, a dollar value per acre foot is agreed upon before an exchange is culminated, although other arrangements are sometimes involved.[1] Many farmers who rent water regularly have rather well defined sources of supply. Price and quantity are determined and the agreement is reported to the record clerk who records the changes in debits and credits in their respective accounts. In other instances, farmers having water to rent leave word with the record clerk who serves as a quasi broker and passes the information on to others who may wish to rent additional water. It is not uncommon for individuals having water for rent to engage the record clerk or some other person closely associated with the water market to rent their water for them. Accounts where water is held separate from the land or where land has been abandoned and the water rights retained, are often handled in this manner. Where irrigation companies hold water credits which are to be rented, care is taken not to enter the market before the rental price has been fairly well established by the transactions of individual farmers. This precludes criticism with regard to price setting and institutionalized prices. Thus, it appears that price is determined largely by the interaction of supply and demand conditions which prevail in the area at the time each rental agreement is initiated.

Rental prices fluctuate between years and to some extent within

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[1]Late in the irrigation season, storage water is sometimes rented on the basis of an acre foot now for an acre foot in return in the following spring. This allows the person having unused water at the end of a season to forego an inevitable 15 or 20 percent reservoir shrink. This practice may also be used in connection with direct flow water, but the incentives are not nearly so obvious.

years. Average annual rental price per acre foot of water appears to be inversely correlated with the water available at the beginning of the irrigation season. Other factors which could be expected to have some effect on the rental price include product prices, other inputs, and technology. These variables will be considered in more detail in the next section.

Within year variation in water rental prices may be attributed to a multiplicity of factors. Foremost among these would be changes in the water supply not accounted for in the dividend. Natural disasters and abrupt changes in the prices of other inputs or products produced may also introduce within season price variation.

Company policy on hold over water is another factor influencing within season price change. If a farmer is prudent and has unused water at the end of the season, it may be rented or stored, depending upon the company and the type of right. If he has the option to store it, the rental price should be higher than would be the case if he would lose the water if it were not used during the current season. Prior to 1938, any water that remained in the Sevier Bridge Reservoir at the end of the irrigation season became common water and was used to make up the storage rights for the next year. Because only two of the companies depended primarily upon storage and the others on direct flow, this policy tended to work in favor of the storage companies. This resulted in waste of water, because the holders of direct flow rights attempted to use up all of their water supplies during the current season, rather than allow them to accrue to the storage companies. This was further accentuated by the fact that there were no intercompany transfers at that time. Since 1938, the four companies in the study area have allowed any water remaining in the Sevier Bridge Reservoir at the end of the irrigation season to belong to the company which had right to it during the current year. This water can be held over by that company to be used in the following season. The same privilege is also extended to the accounts of the individual shareholders within the companies. This policy has contributed greatly to the stability of the water supply because more water is carried over in years of abundance (4).

With the advent of intercompany transfers, the rental price may be further affected. As was noted above, when system losses are less than the prevailing "basis of exchange", the importing company may realize a net surplus from the transaction. Suppose a given system has a 25 percent system loss and the "basis of exchange" is 40 percent. There is a net gain of 15 percent which accrues to the importing system. Thus in aggregate, the water users in the second system receive an amount of water greater than the face amount of the transfer effected between the individuals involved. This "surplus" is first reflected in the company account and will eventually be reflected in the accounts of all the individuals holding stock in the company. Whether it becomes available to the farmer in the current season or during the following season is dependent upon the action taken by the company officials. They may declare a dividend in which case it will be available during the current season, or they may hold it over, using it to make up individual water credits for the following season. In either case, it eventually accrues to all stockholders in the company in proportion to their respective holdings in the company. If this is generally recognized among the users in the importing system, it would have the affect of biasing the rental price upwards. It may appear that they are renting one acre foot, when in fact, they are renting one acre foot plus a proportionate share of the 15 percent.

A similar bias may be present in the case of the exporting company having system losses somewhat less than the "basis of exchange." If this aggregate loss to the system is realized by the individual users on the system, they will demand a price which will compensate for it. Thus, ceretis paribus the presence of this type of influence would cause the rental price to be higher.

In both instances, the affect of influences of this type on rental price would appear to be dependent upon two factors. The most obvious is the amplitude of the disparity between the "basis of exchange," and the system losses. The second is dependent upon the reaction of individuals to group incentives. Where all of the companies alternate, at least to some extent, between the roles of exporter and importer, these net effects resulting from the "basis of exchange" may not persist long enough to be recognized and exploited by the companies to the point that the rental price reflects its influence.

Evidences of Flexibility

Transfers

The rental price, the number of transfers, and the percent of the water supply transferred under varying supply conditions should provide indicators of flexibility between users. These data are presented in Table 6. Intercompany transfers in which the water did not change ownership are not included in these data. The physical quantities transferred ranged from 5, 305 acre feet to 20, 993 acre feet per season. This amount does not vary greatly until the water available drops below 70, 000 acre feet, after which it tends to diminish rather abruptly. As the total supply diminishes, it seems logical that less water would be available for rental.

A somewhat different picture is presented where each year's transfers are expressed as a percentage of the water available for that year. Column 5 in Table 6 includes the result of this calculation. As water supply diminishes, the percentage transferred tends to increase until supplies drop below the 70, 000 acre foot level. Below this point, the percentage of the water available that is transferred tends to drop off, as do the physical quantities.

It is interesting to note that at 70, 000 acre feet each irrigated acre in the area has a theoretical supply of about 1.4 acre feet per acre. Persons familar with the area estimate that this is a bare minimum of water to sustain production under present cropping patterns. If the area

Table 6. Changes in quantity transferred, rental price, and number of transfers at decreasing levels of water available, 1950-1964[a]

Year	Water available for delivery	Quantity transferred	Rental price per acre foot[b]	Transfers as a percentage of total water available	No. of trans-fers[c]
	(acre feet)	(acre feet)			
1952	114,371.9	12,709.26	3.95	11.11	389
1953	113,521.0	17,913.20	2.70	15.78	468
1958	94.260.5	17,868.90	4.98	18.96	629
1950	92,693.2	20,992.66	3.55	22.65	486
1962	74,716.0	12,466.24	9.94	16.68	462
1959	72,096.3	13,537.75	6.96	18.78	561
1955	71,178.5	15,851.55	6.44	22.23	541
1951	71,111.2	18,612.92	5.66	26.17	604
1954	70,266.8	20,409.77	6.46	29.05	596
1964	53,333.5	6,976.49	15.00	13.08	324
1960	52,686.4	10,531.13	15.89	20.22	494
1957	49,564.9	6,683.35	15.15	13.48	375
1956	48,170.0	8,283.66	10.40	17.20	406
1963	44,945.5	9,089.67	16.95	20.22	483
1961	42,086.5	5,305.29	19.94	12.61	291

[a]Includes only those transfers in which a change in ownership was apparently involved.

[b]Adjusted to real terms by using the U. S. Wholesale Price Index, 1957-59 base.

[c]Does not include those transfers to church and city property of less than 2.5 acre feet.

Source: Records of the four irrigation companies in the Delta area.

is rather homogeneous with respect to crops grown and water use per acre, it seems logical to assume that adjustments downward from this point would come about only as substantially higher water prices because it would entail an abandonment of land. Although land costs are fixed and probably would not influence this decision, farm labor is quite immobile and alternative employment in the area is scarce. The uncertainty connected with finding a market for his unused labor off the farm may cause the behavior of an individual farmer to appear irrational in the short-run. He may retain water even though the rental price is greater than the expected marginal return he envisions.

The reduction in quantity transferred and number of transfers at lesser levels of supply is further explained by the reaction of water users to an increased price for water. Except in the case of Giffen's Paradox, a rational individual will always demand less of a commodity at higher prices than at lower prices. This is illustrated in Figure 3 using hypothetical data for illustrative purposes. Three acre feet will clear the market when the price is five dollars, but when this price is increased to fifteen dollars, only 1 acre foot will be taken.

As the rental price becomes higher and higher, the value of marginal product of fewer and fewer users will be great enough to allow them to purchase additional water. By comparing Column 3 and Column 4 in Table 6, it is readily apparent that quantity transferred varies inversely with the rental price.

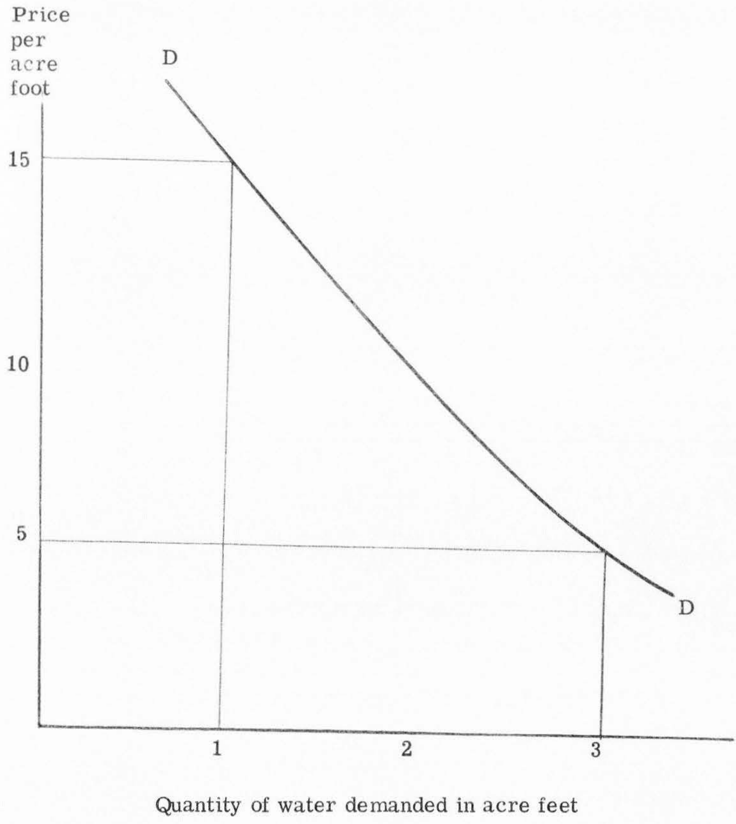

Figure 3. Hypothetical demand curve for water.

The quantity of water involved in intercompany transfers should also be indicative of flexibility of control within the area. The gross amounts of intercompany transfers for the years 1951 through 1963 are shown in Table 7. It should be noted that these figures come from the company accounts and, as such, they include the "basis of exchange" and transfers which involved no change in ownership. For these reasons, they are not comparable to those data presented in Table 6. The supply figure used here is the aggregate quantity diverted into the various systems during each year.

Physical quantities transferred between companies reveal a rather incoherent pattern under increasing drought conditions. In periods of sustained drought, these percentages tend to increase signaling the importance of intercompany transfer under drought conditions. Four miniscule changes in the "basis of exchange" during this period of time probably serve to confound some of the implications which might be drawn from these data. The rather gradual increase in the percentage and quantity of water transferred since 1954 may be accounted for in part by adjustments toward a mutually satisfactory "basis of exchange" among the companies.

Variability in supply

Flexibility is indicated by a reduction in the variability in supply between years. Data and statistical measures presented in Table 8 tend to verify this observation. For the series of years 1950 through 1963,

Table 7. The affect of changes in annual water deliveries upon the quantity of water involved in inter-company transfers, 1951-1963

Arrayed in terms of river diversion				Arrayed by years			
Year	Total annual river diversion at the head of canals	Quantity transferred[a]	Percentage of total transferred[a]	Year	Total annual river diversion at the head of canals	Quantity transferred	Percentage of total transferred
	(acre feet)	(acre feet)			(acre feet)	(acre feet)	
1953	150, 155	3, 895.00	2.59	1951	126, 279	5, 416.57	4.29
1958	147, 103	4, 519.39	3.07	1952	132, 739	4, 241.08	3.20
1952	132, 739	4, 241.08	3.20	1953	150, 155	3, 895.00	2.59
1954	131, 055	1, 135.00	.87	1954	131, 055	1, 135.00	.87
1951	126, 279	5, 416.57	4.29	1955	115, 486	3, 055.93	2.65
1959	116, 315	4, 005.30	3.44	1956	83, 479	2, 165.22	2.59
1955	115, 486	3, 055.93	2.65	1957	79, 890	3, 115.05	3.90
1962	102, 061	8, 621.73	8.45	1958	147, 103	4, 519.39	3.07
1960	85, 568	2, 325.48	2.72	1959	116, 315	4, 005.30	3.44
1956	83, 479	2, 165.22	2.59	1960	85, 568	2, 325.48	2.72
1957	79, 890	3, 115.05	3.90	1961	67, 209	6, 013.79	8.95
1963	76, 446	9, 839.28	12.87	1962	102, 061	8, 621.73	8.45
1961	67, 209	6, 013.79	8.95	1963	76, 446	9, 839.28	12.87

[a]Figures listed here are not comparable to those in Table 6 because these figures were taken from the company accounts, not individual farmer accounts. These figures also include transfers from one system to another with no accompanying change in ownership.

Table 8. River diversions with and without adjustment for intercompany transfers, 1950-1963[a]

Year	Company A With	Company A Without	Company B With	Company B Without	Company C With	Company C Without	Company D With	Company D Without
	(acre feet)		(acre feet)		(acre feet)		(acre feet)	
1950	20, 327	19, 467	37, 930	38, 790	51, 830	51, 830	26, 239	26, 239
1951	17, 838	17, 247	39, 007	39, 032	45, 598	45, 484	23, 836	24, 516
1952	22, 735	21, 259	37, 384	40, 017	48, 250	47, 239	24, 370	24, 244
1953	24, 033	20, 138	42, 162	45, 750	58, 135	58, 442	25, 825	25, 825
1954	23, 660	22, 525	38, 930	40, 065	46, 180	46, 180	22, 285	22, 285
1955	19, 550	19, 363	34, 219	33, 796	40, 243	39, 648	21, 474	22, 679
1956	12, 620	12, 371	22, 944	22, 878	31, 410	31, 036	16, 505	17, 194
1957	16, 010	16, 605	23, 624	24, 421	26, 048	24, 590	14, 208	14, 274
1958	25, 710	25, 544	42, 293	42, 591	51, 780	51, 019	27, 320	27, 949
1959	18, 365	16, 849	32, 325	31, 916	43, 660	44, 299	21, 965	23, 251
1960	13, 242	13, 263	24, 453	24, 068	29, 448	29, 484	18, 425	18, 753
1961	11, 656	12, 087	18, 125	18, 021	23, 847	23, 875	13, 581	13, 226
1962	19, 411	18, 752	32, 058	32, 210	32, 598	32, 020	18, 097	19, 079
1963	12, 751	12, 391	24, 011	21, 295	26, 056	27, 563	14, 988	15, 197
Mean	18, 422.4	17, 704.36	32, 109.14	32, 489.29	39, 648.79	39, 479.21	20, 651.29	21, 049.36
Standard deviation from mean	4, 649.61	4, 116.74	2, 543.22	2, 827.89	3, 559.23	3, 555.86	4, 671.97	4, 754.35

[a]Differences between diversions shown here for companies C and D and those shown in the river reports are due to losses in canal A.

Source: Records of the four companies in the Delta area.

two series of annual water diversions are listed for each company. In each case, the column titled "with" indicates the quantity of water diverted into that company's system after adjustment for intercompany transfers. Similarly, the column titled "without" indicates the physical quantities that would have been diverted into each company's system without intercompany transfer.

A comparison of the standard deviations for each company, with and without transfer, indicate that variability in supply is reduced in two companies, remains substantially the same in one, and increases only in company A. The unique position of company A may be partially explained by the fact that it is a consistent importer of water. Even in years of relatively abundant supply as in 1952, 1953, and 1958, this company continued to import water. This initiates speculation concerning the possibilities for expanding the irrigated acreage within that company's system to correspond with each season's water supply.

Rental price versus sale price

In a world free of uncertainty in which impediments to transfer do not exist, the capitalized value of the expected annual rental price should approximate the selling price of a perpetual right to a similar quantity of water. A comparison of these two values is presented in Table 9.

Several refinements were made in the data in order to facilitate a meaningful comparison. Because rental and sale price observations were

Table 9. A comparison of the sale price per acre foot of water expected to be delivered and the capitalized value of the expected rental price per acre foot

Year	Company A		Company B		Company C		Company D	
	Capitalized rental price	Sale price	Capitalized rental price	Sale price	Capitalized rental price	Sale price	Capitalized rental price	Sale price
1955	93.80	65.24	--	--	--	--	93.80	74.99
1956	97.80	69.80	97.80	71.48	--	--	97.80	82.77
1957	130.00	63.57	130.00	58.05	130.00	81.00	130.00	85.82
1958	192.20	76.64	192.20	99.60	--	--	192.20	95.82
1959	184.00	97.54	--	--	184.00	119.76	184.00	100.75
1960	187.00	120.08	--	--	187.00	116.82	187.00	105.94
1961	215.00	120.12	--	--	215.00	138.82	215.00	109.96
1962	238.80	122.26	--	--	238.80	149.42		
1963	263.60	159.91	263.60	101.05	263.60	140.01		
1964	313.60	164.45	313.60	161.82				
Mean	191.58	105.96	199.44	98.4	203.07	124.30	157.11	92.72
t value	3.363*		2.296[a]		3.635**		3.356*	

**Indicate significance at the α .01 level.

*Indicate significance at the α .05 level.

[a]Would be significant at the α .051 level.

taken over a considerable period of time, it seemed appropriate that they should be converted to real terms. The wholesale price index was used for this purpose.

In order to account for the uncertainty found in the real world, a conversion to expected deliveries per share and expected rental prices was necessary. Several variations of two basic methods of obtaining expected values were tested to determine which method gave the best result. The methods tested were a simple moving average and an expectations model which assigns various weights to each observation in accordance with its position in time with respect to the present. In the expectation model the heaviest weight is given to the most recently observed values. A "best model" was determined by observing the deviations of the expected values from the observed. The method in which the sum of the squared deviations from the observed data were least was considered the most appropriate.

The results of these tests indicated that a five-year moving average was the most consistent indicator of the observed water deliveries, and rental prices were best approximated by incorporating a form of the expectation model in which the expectation coefficient (β) was assumed to be .5.

Information obtained from the four major loan institutions in the area indicated that since the early 1940's, the major portion of loans made for the purchase of water stock have carried an interest rate of about 5 percent per annum. For this reason, an interest rate of 5 percent was used in capitalizing the annual rental price.

At the α .05 level, a t test of the difference between the means of the capitalized annual rental prices and the sale prices of a permanent right which is expected to deliver the same quantity of water reveals that all but one are significantly greater than zero, indicating that the means of sale and capitalized rental prices are significantly different. Because the means of the capitalized rental values are greater than the means of the sale prices, there is evidence that the market for annual use rights is somewhat more flexible than that for perpetual rights. It should be noted that this does not suggest that impediments to flexibility do not exist in either case. It is simply implied that the degree of flexibility in the rental market is apparently greater than that which exists in the market for permanent rights.

DEVELOPMENT OF VARIABLES AND PROCEDURE

Hypothesis

The hypothesis to be tested is that changes in the institutions which eliminate barriers to free transfer of a limited resource will result in an increase in the economic benefits derived from that resource. For the purposes of this study, the limited resource is the irrigation water supply for the Delta area in Utah. The institutions of concern are those community mores, irrigation company policies, and state water right laws which may affect (facilitate or impede) transfer of water between users. Because irrigation water is primarily an input factor used in the production of agricultural crops, evidence of benefit derived will be expressed in dollar terms as determined by an appropriate indicator of the value of marginal product produced by irrigation water.

Changes in the Institutions to be Tested

A rather exhaustive persual of local policy and customs pertinent to water transfer discloses one major change in policy which could be expected to have a significant influence on water transfer in the area. The change in question involves a policy gradually initiated between 1946 and 1950 which allowed the water of any one irrigation company to be transferred into the systems of any of the other three companies in the area. This increased the effective market area for water by about 400 percent and should have gone far to eliminate disparities in the marginal productivities which may have existed between the companies.

Because this change in transfer policy was not instantaneous but required five years to become fully operable, it necessitated the comparison of rental price observations occurring in different time periods. Also, by introducing a time difference, factors other than the change in transfer policy could be expected to influence the rental price. Water supply, prices of products and other inputs, technology and changes in the transfer conditions might all be expected to influence rental prices over time. Even under comparatively stable conditions, the significance attached to any differential which may occur between the two series of rental prices is necessarily dependent upon how well the influences of variables other than the change in transfer policy can be identified and quantified.

Empirical Procedure

Of primary concern in the statistical analysis was the determination of any significant difference between two series of irrigation water rental prices, each series having been associated with a different transfer policy. In order to accomplish this objective, it was necessary to test the significance of variables which a priori might have influenced the rental price occurring over the two time periods.

Three statistical tools were used to provide this information. The first was a multiple regression analysis. The second involved a t test for significant differences between means of the same variable associated with each of two time periods. Commonly this technique is known as mean difference analysis. The third was a covariance analysis. In all cases, these techniques were utilized to determine the significance of various factors and to specify the degree of statistical confidence which could be attached to certain relationships found in the data.

Multiple regression analysis

Multiple regression is a technique which determines the effect of several independent variables upon a single dependent variable. Various tools have been devised to determine the absolute and relative importance of the various independent variables which a priori could have a significant influence on the dependent variable. The general model used was as follows:

$$Y = f(X_1, X_2, X_3)$$

Where:

Y = the dependent (explained) variable,

X_1, X_2, X_3 = the relevant independent (explanatory) variables.

Significant independent variables were determined by testing the significance of numerous sample statistics which provide estimates of the population parameters and by ranking them. Included among these were the simple partial coefficients of correlation, the simple partial coefficients of determination, the regression coefficients, and the standard partial regression coefficients.

A t test was used to determine whether the simple partial correlation coefficients were significantly different from zero (6). Sample partial coefficients of determination were calculated and ranked in the order of their apparent effect on the dependent variable. The significance of regression coefficients for the various independent variables was determined by setting up the null hypothesis that $\beta = 0$ and using a t test. Finally, the standard partial regression coefficients were utilized to rank each independent variable in relation to the others.

The results of these measures were used only as indicators of the significance of each variable. When contradictory results were obtained, a judgment had to be made on the basis of other criteria. Among these were the correlation coefficients for the model obtained from stepwise regression and the presence or absence of apparently significant interaction among the independent variables. If indicators consistently showed strong significance, the variable was considered significant.

Variables determined to be significant in the multiple regression analysis were included in the mean difference and covariance analyses.

Mean difference analysis

Mean difference analysis is a group comparison technique based on students' t test. A t test of the difference between means is used for the purpose of determining, within the laws of probability, if the difference between calculated means may be attributed to differences in population mean or to random variation (15).

In the mean difference analysis, t is calculated in the following manner:

$$t = \frac{(\bar{x}_1 - \bar{x}_2) - (M_1 - M_2)}{S\, \bar{x}_1 - \bar{x}_2}$$

Where:

M_1 and M_2 = the means of the respective populations and are assumed to be equal,

$\bar{x}_1$ and $\bar{x}_2$ = the respective sample means of the same variable occurring in the two separate groups,

$S\, \bar{x}_1$ and $\bar{x}_2$ = the standard error of the difference between the two sample means and is analogous to the $S\, \bar{x}$ used in a simple t test.

The null hypothesis relevant to this method of analysis is HO: $M_1 - M_2 = 0$, for each variable to be tested. A significant difference is indicated by a calculated t value which exceeds the tabular value at some previously determined probability level with degrees of freedom equal to the sum of the observation occurring in each group minus two.

Covariance analysis

Covariance analysis is essentially a combination of regression and analysis of variance. The technique is designed to eliminate the effect of uncontrolled environmental conditions from treatment effects thus increasing the precision of the estimate of variation due to treatments (3).

The dependent variable is regressed within each treatment on the independent variable or variables, the influence of which is to be eliminated from the treatment effects. Sample estimates of the regression coefficients and variables for each regression within treatments are tested to be certain that a covariance technique is applicable to the data. In general, the regression coefficients within treatments should not be significantly different from each other, and the variance about the regression should not be significantly different between treatments. Also if the correlation coefficient is less than .3, the possibility of increasing precision with covariance is questionable.

In this analysis, rental price was the dependent variable and different transfer policies were the treatments. Independent variables included were those found significant in the multiple regression analysis.

Selection and Development of Variables

An a priori selection of variables thought to be important in accounting for the variation in water prices are: water supply available, alfalfa seed prices, livestock prices, other inputs, and technology (16). Each of these will be examined in detail within this section.

Table 10 contains data for the dependent variable and all independent

Table 10. Data used in the statistical analysis

Year	Allocative policy in effect[a]	Rental price per acre foot[b]	Water available per irrigated acre	Expected alfalfa seed price per 100 lb. clean seed	Expected livestock price per 100 lb. live weight
		(dollars)	(acre feet)	(dollars)	(dollars)
1934	1	3.49	1.2986	25.43	12.01
1935	1	5.71	.7420	35.62	10.87
1936	1	4.12	1.0203	31.78	12.39
1937	1	2.52	1.9478	37.05	13.11
1938	1	2.02	2.1333	46.16	13.95
1939	1	2.37	1.8551	43.88	14.15
1940	1	2.91	1.8551	42.66	15.43
1941	1	2.55	2.1333	37.94	16.53
1950	2	3.55	1.8168	40.93	24.12
1951	2	5.66	1.3938	48.96	26.19
1952	2	3.95	2.2417	50.07	29.15
1953	2	2.70	2.2250	40.01	28.54
1954	2	6.46	1.3772	31.43	23.29
1955	2	6.44	1.3951	36.47	20.38
1956	2	10.40	.9441	27.65	18.45
1957	2	15.15	.9715	29.76	16.72
1958	2	4.98	1.8475	28.23	17.17
1959	2	6.96	1.4131	25.00	20.22
1960	2	15.89	1.0327	25.80	21.87
1961	2	19.94	.8249	24.94	21.01
1962	2	9.94	1.4644	30.99	20.65
1963	2	16.95	.8809	38.09	20.06
1964	2	15.00	1.0454	32.00	20.46

[a] A (1) indicates that only intracompany transfers were permitted. A (2) indicates that intercompany transfers were permitted.

[b] Rental prices have been adjusted to real terms by using the U. S. Wholesale Price Index, 1957-59 base.

variables which could be quantified and included in the statistical analysis.

Price of water

The dependent (explained) variable was the annual rental price of water. In order to obtain a measure of the efficiency implications associated with a change in transfer policy, it was necessary to find an indicator of the value of the marginal product of irrigation water both before and after this change occurred. Preferably it should be such that differences occurring could be tested statistically. The water rental market appeared to be sufficiently competitive to permit the rental price per acre foot to be used for this purpose.

Since 1950, one rental price per acre foot has prevailed in all of the companies during any given irrigation season. Prior to that time reliable price data were available for only one of the four companies. Because of this limitation, it was necessary to assume that the companies did not vary greatly and that the data obtained from this company was typical of conditions found in the other companies. This did not appear to be an especially heroic assumption because this company has the largest irrigated acreage and the rental market for water has been more active in it than in any of the other companies. Besides, water use and agriculture under this system are not dissimilar from those of the other companies in the area. If bias enters the analysis because of this extrapolation, it is most certainly on the side of conservatism. Ceteris paribus, the relatively large irrigated acreage and active rental market within this company would cause it to be affected by a lesser amount with the introduction of a free transfer policy than would the other companies where the market area was smaller and the rental market was not so completely developed.

From these data, two series of rental prices were selected to approximate the value of the marginal product associated with each of the two institutional arrangements. These price observations were drawn from the years prior to and immediately following the transition to a relatively free transfer policy.

The length of these two series was limited by a number of factors. Among these were the availability of reliable data, governmental activity in the water market, and the depressed economic conditions occurring prior to 1934. Although data were available before 1934, forced sales of water stock and generally chaotic financial adjustments occurring within the area and irrigation companies suggest that rental prices may not have been reliable indicators of value of marginal product during this period.

The period 1934 through 1941 was relatively stable in this water market. The debts of the irrigation companies and drainage districts had been readjusted and placed on a sound basis of refinancing, the amount of irrigated land remained virtually constant and prices and general economic conditions were somewhat more stable (23).

In 1942, the government began purchasing water stock at a price somewhat above the market price in order to obtain a water supply for the Topaz War Relocation Project that was to be constructed in the area. Approximately 20,000 shares of stock, enough to irrigate 8,000 to 10,000 acres, were purchased between 1942 and 1947 after which time it was resold to the farmers in the area. This action by the government had the affect of curtailing the rental market to such extent that few rentals occurred and virtually no rental price data were available for the years 1942 through 1947. This, plus the typical wartime distortion of prices and market conditions prompted the exclusion of this period from the earlier series. Thus the rental prices occurring during the series of years from 1934 through 1941 were used to approximate the value of the marginal product derived from water under the allocative policy which limited transfers to the extent of each individual company's canal system.

Since 1950, there have been relatively few data problems. Consequently, it was possible to include all of the rental prices occurring in the series of years from 1950 through 1964 in the later group. This group represents the rental price associated with a relatively free transfer policy in which the water of any company could be transferred into the system of any other company.

Rental prices for the earlier period were obtained from data compiled for an earlier research effort by Dudley Crafts, a prominent lawyer and water authority who resides in the area. These rental prices were taken from records of the rental of rather large blocks of nonfarmer-owned stock. During this period of time approximately 25 percent of the active shares of this company were held by persons and agencies other than farmers and were rented regularly. Because there was no apparent reason for nonfarm owners of water stock to react differently than farm owners, one could expect the rental price to be a very good approximation of the value of the marginal product derived from the last unit of water used.

The prevailing conditions which existed in the water market area and the suitability of the rental price in approximating the return from the use of water as described in the Wartime Water Facilities Plan as follows:

> This condition of buyers and sellers dealing to effect the renting of approximately all of the available stock year after year has presented a fairly open market where supply and demand have been prime factors in determining the prices paid.
>
> Special significance attaches to the prices paid by farmers for the rental of water stock. In general these rentals seem to indicate the amount that farmers are willing to pay for the use of the water and this price is no doubt based largely on the estimated value of the water to the farmer in terms of crop production. (23, p. 24)

Rental prices for the later period were obtained from a rental record of the water represented by 385 shares of company A stock. This estimate of the market rental price is more accurate than the size of the sample would indicate because it is customary to wait until the market price is well established before offering company water for rent.

Because these two series of price data covered a rather long period of time in which there were sharp changes in the aggregate price level, it was necessary to deflate them so that they would be comparable in terms of purchasing power. The wholesale price index for all commodities was used for this purpose (21).

Water available

It seems logical to assume that the rental price of water will be greatly affected by changes in the quantity of water available. Ceteris paribus, a reduction in the supply of water will cause the market price to increase. When water is in short supply, it will be used only in more valuable uses, thus the value of the marginal product should rise. For this reason a careful evaluation of the water supply was deemed a prerequisite to subsequent comparison of rental prices since this variable might explain much of the variation in the marginal value products of water in the two periods. If so, one would be less confident about drawing conclusions concerning the effect of changes in transfer regulations.

Despite rather extensive storage facilities, the irrigation water supply for the Delta area remains quite volatile. As a result, any attempt to estimate the expected delivery for any year or period of years in the future is greatly complicated. However, when working with the rental price, this area of uncertainty is largely circumvented. After April 1 of any given season, the water credits available have been determined, making it possible to plan with a minimum of uncertainty. In most rental transactions, the farmer bargains for a specified quantity of water and not some expected quantity. For this reason the aggregate water credit available to the farmers at their headgates was deemed the most appropriate supply variable to include in this analysis.

Because the price data for the early period were representative of just one company, and that of the later period were for the aggregate of companies, the supply figure or water available for any given season had to be reduced by a common denominator in order to facilitate any meaningful comparison. Due to the nature of water use in this area, the most appropriate common denominator for water available appeared to be the number of irrigable acres to which this supply could be applied. Appropriate acreage figures were obtained from the Millard County Assessor's Office. Thus the variable representing supply was reduced to water available per irrigated acre as shown in column 4 of Table 10.

Expected price of products

The price which a farmer will pay for a unit of water is dependent in part upon the price he expects to receive from his crops. A farmer should be willing to apply an input factor up to that point where the marginal factor cost equals the value of the marginal product. The value of the marginal product is a function of the product price. As the expected product price rises a farmer will find it profitable to employ more of the factor of production. Therefore high product prices are consistent with greater quantities of factors employed. The inverse is also true. A decrease in product prices will cause the value of the marginal product to fall, thus the farmer will be able to employ the same quantity as formerly only at a lower factor price. Therefore low product prices are consistent with lesser quantities of the factor employed.

Because alfalfa seed and livestock products are the major sources of income for the area (20), the expected price of alfalfa seed and a measure of the expected price for livestock were included as variables in this analysis as indicators of the effect of product prices upon the rental price of water.

Alfalfa seed prices. In the census years 1939, 1944, 1949, 1954, and 1959, the alfalfa seed crop accounted for an average of 61 percent of the value of all field crops sold in Millard County (22). The Delta area comprises about 75 percent of the irrigated acreage in Millard County and specialization in alfalfa seed production is even more intense there than in the remainder of the county. Irrigation company officials estimate that 80 to 90 percent of the irrigated acreage in the area is planted to alfalfa. This can be attributed to the scarcity of water and to the predominance of heavy clay soils which tend to favor the alfalfa crop.

Because alfalfa seed produced in the Delta area represents about 60 percent of the total production of the state, prices for the state were considered a good approximation of this variable for the study area. The price of alfalfa seed is set nationwide and the supply produced by the state of Utah is a very small part of the total national supply. Therefore, what happens in the area of alfalfa seed production has little to do with the state or national price. Basic data used in calculating the expected alfalfa seed prices used in the analysis were obtained from data released by the Statistical Reporting Service.

Livestock prices. In census years since 1939, sale of livestock and livestock products have accounted for an average of 59 percent of the value of all farm products sold in Millard County. In the same years, sale of cattle and calves accounted for an average of 59 percent of the value of livestock and livestock products sold (22). Because of the relative importance of cattle and calves in the livestock group, the expected price variable for this analysis was based on a weighted average of cattle and calf prices.[2]

On a priori grounds, the livestock price may not appear to have been an appropriate variable because livestock are a rather indirect product of irrigation water. However, census data for Millard County indicate that a rather large amount of alfalfa hay is grown, with only a small percentage being marketed directly. This indicates that a substantial portion of the hay was marketed through livestock. If the expected price of livestock were relatively high, more water could be demanded for the production of hay.

The expected livestock price thus may have an affect on the rental price of water. Basic price data on cattle and calves were obtained from livestock price data recently made available by the Statistical Reporting Service.

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[2]Livestock price was determined by calculating a weighted average of cattle and calf prices. Weights were determined by calculating the percentage each of these contributed to the total value of cattle and calves sold.

Refinements of both alfalfa seed and livestock price data included an adjustment to a common price index and the determination of an expected price for each year. As in the case of the rental price variable, the wholesale price index was used to convert the prices to real terms.

In this analysis, expected prices were deemed more appropriate than observed prices for explaining the actions of farm operators. During any given season, the decisions a farmer makes are based on what he expects will happen. It seems reasonable to assume that what a farmer expects in the future is some function of phenomena he has observed in the past. In the static model or in the case of an administered price which is fixed, future price expectations would be exactly equal to the most recently observed past price. Under these conditions the expected price is a function of the last previous price giving 100 percent of the weight to that value. Variables other than previous prices could be evaluated but they would not contribute to the analysis under these circumstances.

Most commodity prices, including those of alfalfa seed and livestock, are somewhat volatile. Under these circumstances it seems reasonable to assume that future price expectations will include a considerable number of past observations of the same variable. Probably the least complicated method of calculating an expected price using one variable is a simple average of previous prices. This gives equal weight to each observation included in the average. In the absence of a trend or oscillations which are of a uniform or predictable nature this would appear to be the most appropriate tool. However, an expectation model which utilizes a weighted average of past observed prices, giving the highest weights to the most recent observations, might generate more realistic price expectations.

A widely used model of this type was used in calculating the expected prices to be used in this analysis. It utilizes only one variable, past prices, and attaches decreasing weights to each price observation as determined by its relative position in time with respect to the present. This particular function used in this study is as follows:

$$P_e = \beta P_t + (1 - \beta)\beta P_{t-1} + (1 - \beta)^2 \beta P_{t-2} + \ldots + (1 - \beta)^{n-1} \beta P_{t-(n-1)}$$

Where:

P = the observed price for alfalfa seed,

P_e = the expected value of P,

$P_t, P_{t-1}, \ldots P_{t-(n-1)}$ = the observed values of P for n time periods beginning with $P_{t-(n-1)}$ and extending forward to the current period t,

$(1 - \beta), (1 - \beta)^2, \ldots (1 - \beta)^{n-1}$ = the weights to be applied to the P's observed in the periods t back to t - (n - 1).

It was assumed that $\beta = .5$. A coefficient of this size weights the most recently observed price just equal to the proportion of the total weight assigned to all other observations. Under this assumption, 99.9 percent of the total weight attached to the expected price is accounted for in ten years or from t - 9 through t time periods.

These expected prices for alfalfa seed and livestock are listed in Table 10 together with water available per irrigated acre and the annual rental price per acre foot (real terms).

Other inputs

The quantities of other inputs used in conjunction with water could also be expected to have some effect upon the rental price of water. If quantities of other factors used jointly with water are increased, the marginal physical product of water is driven up as is the value of the marginal product. Foremost among these other inputs is land.

Land. Although the amount of water applied per acre is variable, in an arid region where some irrigation water is absolutely essential for production, there is some minimum level of supply per acre where water and land may become technical complements. Given these conditions, it seems logical to assume that substantial changes in the acreage to be irrigated without a corresponding change in the water supply would have a considerable affect on the rental price of water. Given a fixed water supply, an expansion in irrigated acreage should drive up the value of the marginal product of water.

Data found in the Water Facilities Plan (23) indicates that between 1934 and 1941 the irrigated acreage in the study area was relatively constant at 39, 700 acres. These data were taken from the Millard County Assessor's records. In all of Millard County, land in farms irrigated was 72, 897 in 1939 and 77, 140 in 1944 (22).

In the later period, 1950 through 1964, the number of acres irrigated in the study area also appears to have been quite constant. Data from the Soil Conservation Service indicated an irrigated acreage of 51, 306.9 in 1959. Assessment roles list 51, 020.0 acres as of the end of 1964. For all of Millard County, land in farms irrigated in census years was 77, 740 acres in 1949, 81, 919 acres in 1954, and 75, 793 in 1959 (22).

The figures for Millard County would necessarily show more fluctuation than the study area because Millard County data includes one rather large high water irrigation company. For the most part this company has rights of low priority and very little water is available for it until the rights of the four companies in the study area are filled.

Because the irrigated acreage tended to be constant within each time period, it was possible to exclude variation in irrigated acreage as a variable affecting rental price.

Technology

New technology could be expected to affect the price of water. The introduction of a technological advance, such as hybrid corn, may generate a new production function such that a greater output of product is obtained with the same expenditure of resources. This would have the affect of shifting the value of the marginal product curve to the right, thus increasing the demand for water. Under these circumstances, either more water will enter the market or a higher price will be paid for the former quantity depending whether or not the supply to the area is fixed.

Since 1940, several supposed improvements in technology have been introduced which may have had some affect on the rental price of water. Among these are commercial fertilizers, insecticides, mechanization, and new crop varieties. For the most part, technological development is output increasing and should be reflected in increased crop yields per acre. Assuming that the study area is not substantially different from the state and that alfalfa seed yields can be used as an indicator of the effect of new technology, there is little evidence that any of these were effectual either singly or collectively. The average yield of clean alfalfa seed per acre in the state was 155.38 pounds for 21 years prior to 1940, and 153.53 pounds for the last 25 years.

A closer examination of certain unique features of the study area may help to explain why possible technological improvements were rather ineffectual. Foremost among these is the fact that soil and water limitations have resulted in a virtual one crop economy, that being alfalfa.

New varieties. Although several new varieties of alfalfa have been developed, it is extremely doubtful that any variety was introduced because of its higher seed yields. Increased tonnage should be a positive factor; however, the impact would be quite slow in becoming apparent because alfalfa stands are not changed readily. The usual duration of a stand is from 5 to as much as 20 years.

Fertilizer. Soil studies conducted in the area in 1919 indicated that no commercial fertilizer and very little manure were used in the area at that time (17). A later study indicates that the soils of the area contain ample quantities of all fertilizer elements but nitrogen (12). The first record of fertilizer use in the census (22) came in 1954 when 1, 331 tons were used on 9, 077 acres in all of Millard County. By 1959, this amount had decreased to 888 tons used on 5, 193 acres. If it is assumed that all of the fertilizer were used on irrigated lands, only 11.1 percent of the irrigated acreage in Millard County received some fertilizer in 1954, and 6.8 percent in 1959. During these same years the water supply for the study area was virtually constant with 70, 266.8 acre feet available in 1954 and 72, 096 available in 1959. Judging from this data it would appear that fertilizer application is independent of water supply and the quantity used has decreased between two years when other inputs (land and water) remained quite constant. In addition, 80 to 90 percent of the area is planted to alfalfa, a nitrogen fixing crop, which has little need for fertilizer on the relatively new soils found in the Delta area. Under these circumstances it is possible that farmers realize little or no response from the use of fertilizer except on crops other than alfalfa. Because crops other than alfalfa make up such a small portion of the total of crops produced, there is little reason to believe that fertilizer has a substantial affect on the value of the marginal product of water and thus on water rental prices.

Mechanization. Although new mechanical tools have been introduced, there is no evidence available which would indicate that they have affected yields. The total labor input per acre may even be less because of the more extensive methods usually associated with large scale operations. Also, it seems highly improbable that machinery serves in any was as a substitute for water. Therefore, it was concluded that the effect of increased mechanization on the rental price of water was negligible.

Insecticides. The introduction of insecticides should have had a positive affect on alfalfa seed yields. However, some farmers in the area indicate that careless use of chemicals may have reduced the number of pollinators to the extent that seed yields were decreased. It is not likely that this is a trend which will persist. If insecticides have resulted in increased alfalfa seed yields, these increases have been more than absorbed by other negative factors. On this basis it was concluded that the introduction of insecticides did not affect the value of the marginal product of water during the period of time included in this analysis.

ANALYSIS AND RESULT

This section includes a listing of the analysis and results obtained from the multiple regression, mean difference, and covariance analyses.

Multiple Regression

In the regression model let:

Y = average annual rental price per acre foot (dollars),

X_1 = water available annually per irrigated acre (acre feet),

X_2 = expected price of alfalfa seed per hundred weight (dollars),

X_3 = expected price of livestock per hundred weight (dollars).

Scatter diagrams of the relationship between the dependent variable (Y) and each independent variable (X_1, X_2, X_3) are presented in Figures 4 through 6.

Results of the regression equation were as follows:

$$X = 16.052622 - 7.8872741X_1 - .13344741X_2 - .40234719X_3$$

$$S_b = \quad (.053165356) \quad (.75555729) \quad (.12533946)$$

$$t = \quad (148.3536) \quad (.17662) \quad (3.21006)$$

Values in parentheses under the regression coefficient are the standard errors (S_b) and calculated t values for each coefficient. Twenty-three sets of annual observations for Y, X_1, X_2, and X_3 were included in the analysis. Using three independent variables and one dependent variable

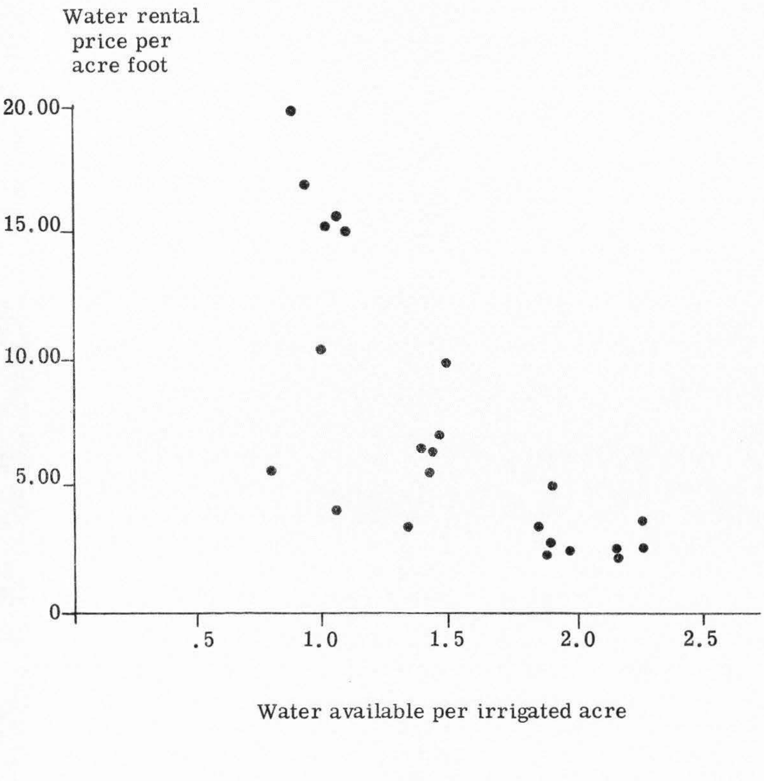

Figure 4. Scatter diagram for water rental price per acre foot and water available per irrigated acre.

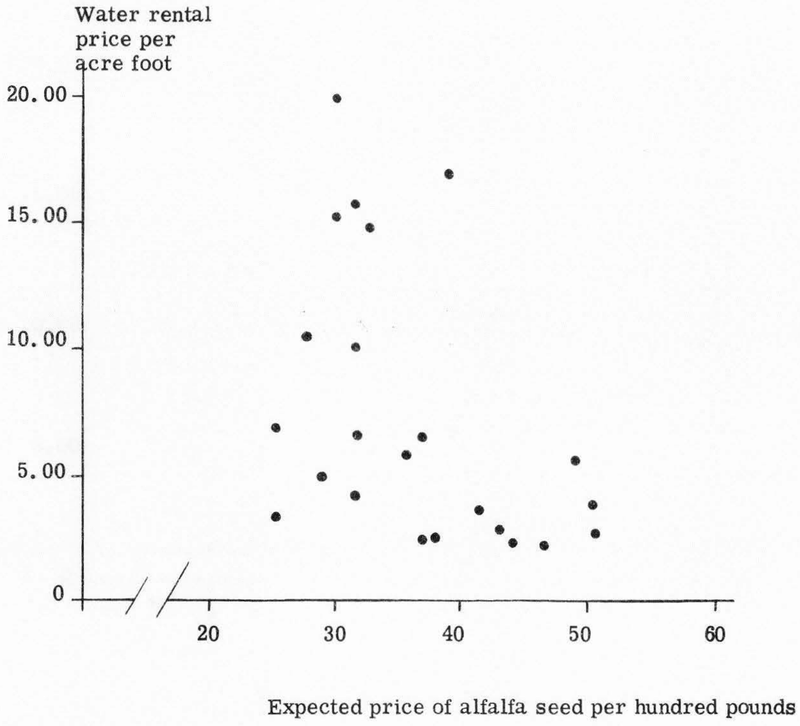

Figure 5. Scatter diagram of water rental price per acre foot and expected price of alfalfa seed per hundred pounds.

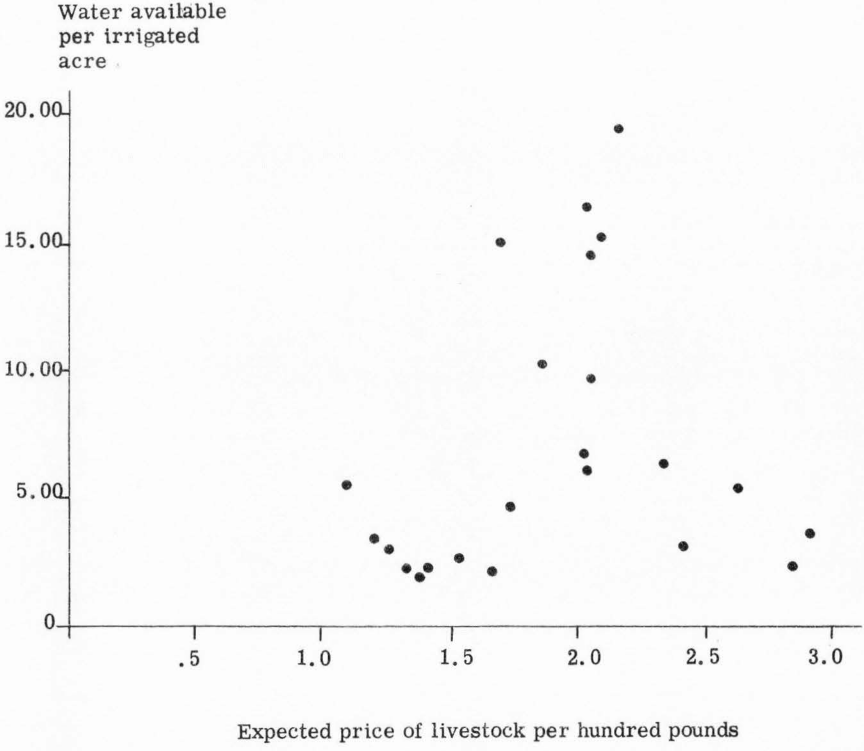

Figure 6. Scatter diagram for water available per irrigated acre and expected price of livestock per hundred pounds.

left 19 degrees of freedom (n - 4). With 19 degrees of freedom, calculated values of t greater than 2.093 at the 5 percent level and greater than 2.861 at the 1 percent level differ significantly from zero.

Determination of significant variables

Simple partial correlation coefficients, simple partial coefficients of determination, standard partial regression coefficients as well as the partial regression coefficients were obtained from the multiple regression analysis. Simple partial correlation coefficients between water rental price and each independent variable as well as the partial regression coefficients were subjected to a t test to see if they differed significantly from zero. Simple partial coefficients of determination were ranked in the order of their apparent influence on the water rental price variable. Also, the standard partial regression coefficients for each independent variable were ranked, each in relation to the others.

The results of these tests for significance and rank of importance for each independent variable are presented in Table 11. Independent variables chosen for further analysis were determined by evaluating the results shown in this table.

Water available per irrigated acre. A test of the partial regression coefficient for this variable was highly significant. The standard partial regression coefficient was ranked number one and was nearly twice as great as that of either of the other variables. The simple partial

Table 11. Measures of significance and rank for each independent variable

Independent variable	Partial regression coefficient	Standard partial regression coefficient	Coefficient of correlation	Coefficient of determination
Water available per irrigated acre X_1	-7.8872741[a]	-.7030 (1)[b]	-.73744821[a]	54.383% (1)[b]
Expected price of alfalfa seed/cwt. X_2	-.13344741	-.1881 (3)	-.51958773	26.997% (2)
Expected price of livestock per cwt. X_3	.40234719	.3766 (2)	.18203542	3.314% (3)

[a]Calculated t values differed significantly from zero at both the $\propto$ .05 and the $\propto$ .01 probability levels.

[b]The number in parentheses is the rank or order number.

coefficient of correlation was significantly different from zero at the α .01 level. The simple partial coefficient of determination also ranked first in importance at 54.383 percent.

In comparison, this variable was rated first in importance by all four criteria. On this basis, it was concluded that water available per irrigated acre was a significant variable and that it should be included in any subsequent analyses.

Expected price of alfalfa seed. The partial regression coefficient for this variable was not significantly different from zero even at α .50 level. The standard partial regression coefficient was of least importance. The simple partial coefficient of correlation was not significantly different from zero at the .05 level; however, the simple partial coefficient of determination was second in importance at 26.997 percent.

Thus, three of the four criteria indicated that this variable was of very little importance in the model. The fourth indicated that 26.997 percent of the variability in water rental price was explained by this variable when other independent variables were held constant at their means.

This apparent inconsistency may be explained by the presence of a significant interaction between this variable and the variable representing water available. The sign of this interaction is positive indicating that increases in the water available per acre accompany increases in expected alfalfa seed prices or vice versa. Because there appears to have been no logical basis for this relationship, it must have been spurious correlation and can be attributed only to chance.

Since three of the four criteria indicated that this variable was of little importance in the model, it was concluded that it could be eliminated from subsequent statistical analyses.

Expected price of livestock. A t test of the partial regression coefficient for this variable was highly significant. The standard partial regression coefficient was second in importance, about one-half the magnitude of the variable of highest rank. The simple partial regression coefficient was nonsignificant at the α .05 level and the simple partial coefficient of determination was the least of any variable at 3.314 percent.

In the previous section it was noted that this variable was included on rather questionable a priori grounds because of its indirect relationship with irrigation water. Of the four criteria used to determine significance, only one ranked this variable as significant. Under these circumstances, it was considered a bit presumptuous to include the variable in subsequent analyses unless all criteria indicated that it was significant. For these reasons the expected price of livestock was excluded from further analyses.

Additional test of the two variables not significant

After it was determined that water available per irrigated acre was the only independent variable significantly affecting the rental price variable, a new regression model was formulated using only water available per irrigated acre as the independent variable. Expected prices of alfalfa seed and livestock were not included. This facilitated a comparison of the multiple coefficient of determination (R^2) for the two models, one including all independent variables, the other including only significant variables. If the multiple coefficient of determination was not reduced significantly by removal of these variables, it would indicate that little explanatory power would be lost by leaving them out of the analysis. The exclusion of these two independent variables resulted in an 11 percent decrease in the multiple coefficient of determination. This indicated that the explanatory value of the model was not greatly reduced by the removal of nonsignificant variables.

In observing the scatter diagram of rental price per acre foot and water available per irrigated acre as presented in Figure 4, there was some indication that a curvilinear model would give a better fit of the data. This did not seem to be true with the price of livestock and price of alfalfa seed variables. Rental price and water supply variables were therefore converted to logarithms and the computations made again. In this analysis the coefficient of determination (R^2) for the model was increased by 5.24 percent. Although the fit was slightly better, it seems doubtful that it was enough better to justify complicating the interpretation of the result. If a curvilinear model were used, it would be very difficult to test the assumptions pertinent to the covariance technique which was to be used later in the analysis. Thus, the linear model was retained.

Mean Difference Analysis

The rental price variable and the water available variable were subjected to a mean difference analysis. The purpose of this test was to determine if mean difference for these variables differed significantly from zero under the two allocative arrangements considered in this study. The rental price of water per acre foot and water available per irrigated acre were tested in this manner.

Interpretation of the results of the mean difference analysis

The mean annual rental price for these years when intercompany transfers were not permitted was $3.21 per acre foot. During the later period under more liberal transfer arrangements the mean annual rental price was $9.60 per acre foot. The means of water available were found to be 1.61 and 1.39 acre feet respectively for the same time periods. Mean differences for rental price and water available were found to be $6.39 and .23 acre feet respectively.

Calculated values of t used for testing the significance of the mean differences associated with each of these variables are shown in Table 12.

The mean difference of water supply did not differ significantly from zero even at the α .20 level. However, the mean difference for rental price was highly significant.

Table 12. "t" values for mean difference analysis of water available per irrigated acre, and rental price of water

Variable tested	t value
Water available	1.084287[a]
Rental price	4.224*

[a]Not significant at α .05 level.

*Significant at α .01 level.

When the mean values of the water supply are not significantly different between time periods, it is an indication that the average affect upon the rental price variable was essentially the same in both time periods. Assuming that this variable explains a major part of the variability in rental price, the significant difference occurring between the means of the rental price variable can then be attributed to the change in transfer policy.[3]

Covariance Analysis

The ultimate purpose of the covariance analysis is to obtain mean

[3]Within each of the two separate groups of rental prices for the years 1934-1941 and 1950-1964, a linear regression of water supply on rental price indicated that 90 percent and 75 percent of the variability in rental price was accounted by changes in the water supply. Thus it would appear that variables other than those evaluated here have little affect on the rental price.

values for the dependent variable which have been adjusted for the variation attributed to the independent variable. There were two treatments or groups in the analysis, each corresponding to a period of time in which a particular transfer policy was in effect. Water rental prices per acre foot were regressed within each treatment against water available per irrigated acre. Thus two separate regression lines were fitted to the data, each one reflecting the relationship between the water rental price per acre foot and water available per irrigated acre within each treatment.

Before proceeding further, measures obtained from these regressions were utilized to test certain assumptions pertinent to the covariance analysis. In covariance analysis, it is assumed that all samples within treatments are drawn from normal populations with common variances, and that the slopes of the regressions are the same or not significantly different between treatments. Estimates of the variances about the regression lines and the respective regression coefficients were subjected to an F test to establish whether or not they differed significantly. Should the result of these tests of the sample statistics fail to coincide with the assumptions pertinent to covariance, it would necessitate the use of an approximate test.

Techniques used in the approximate test vary depending upon which assumptions are violated. When the residual variances between treatments are found to differ significantly, the usual tests are employed, however, the number of degrees of freedom used in testing is ordinarily reduced.

Should both assumptions be violated, the approximate test becomes somewhat more complicated. Instead of adjusting the treatment regressions along a common regression,all treatment regressions are adjusted along their respective slopes or planes to a predetermined value for the independent variable. The significance of differences due to treatment for predicted values of the dependent variable can then be tested at that level of the independent variable. In this test the number of degrees of freedom is again reduced because it is an approximation.

Preliminary tests of the regression coefficients and residual variances indicated that both are significantly different between treatments. Although the technique is not usually invalidated by failure to meet the assumptions, results obtained from any subsequent analysis would be suspect and should be regarded as approximate rather than exact (3, p. 83).

In order to minimize the effect of this discrepency on subsequent measures, a conservative approximate test was used. Instead of adjusting treatment regressions along a common regression, they were adjusted in terms of their respective slopes and compared at a given level of water available. Degrees of freedom used in testing the significance of differences between predicted rental prices at given levels of water available were reduced from 21 to 7.

Result of the covariance analysis

When water available was assumed to be equal to the 23 year average of water available per irrigated acre, a t test of the difference in predicted rental prices between treatments was highly significant. At probability level .01 with seven degrees of freedom tabular t is 3.499. The calculated t value was 136.919. Results of this magnitude dispell any doubt that the rental prices do not vary with transfer policy.

At the assumed level of water available, predicted rental prices for the treatments were \$8.75 and \$3.54 per acre foot. This indicated that a price differential of \$5.21 could be attributed to variations in the transfer arrangements.

Determination of allocative efficiency

In both the mean difference and covariance analyses, it was determined that a significant differential existed between the rental price occurring under different transfer policies. Special significance attaches to this differential when it is recalled that the market price of a commodity is a good approximation of the value of the marginal product derived from its use. An examination of this differential should provide information concerning the relative efficiency of the two allocative policies in question.

A dollar measure of the annual gain or loss associated with alternative allocative policies was obtained by multiplying the differential in the per acre foot rental prices by the average number of acre feet available at the farm. A certain amount of error may enter this calculation because of an inability to predict future water deliveries. However, the mean quantity available at the farm should be a reasonable approximation where a rather large number of years are involved, if it can be assumed that variations in precipitation and other weather conditions which may affect supply are completely random in occurrence over time.

The product of the differential in rental price and average water available per season should be considered as an annual flow for as long as a particular allocative policy is in affect. The present value of this flow over any future period of time can be calculated by incorporating the following capitalization equation.

$$PV = \frac{d_a}{i} (1 - (+ i)^{-n})$$

Where:

PV = the present value of the annual flow of gain or loss associated with a given allocative policy over some future period of time,

d_a = the annual differential in rental prices multiplied by the average quantity of water available at the farm,

i = the interest rate,

n = the number of years into the future over which the present value of the flow is being estimated.

It should be noted that if n is allowed to go to infinity, the equation shown above simplifies to:

$$PV = \frac{d_a}{i}$$

Results of this calculation using both measures of the differential in rental prices and at various interest rates are shown in Table 13.

The capitalized value of the differential in rental prices is a measure of the increase in value of the limited water resource. Because this increase in value was associated with the initiation of a new allocative policy, it can be said that this new policy was more efficient than the former arrangement.

Table 13. Present value (dollars) of the gain or loss associated with alternative allocative policies for the average quantity of water available for irrigation in the Delta area, Utah

Source of the measure	Average annual value (dollars)[a]	Expected duration of the policy in years	Interest rate 4	6	8	10	12
Mean difference analysis (6.39)	453, 690	10	3, 679, 886	3, 339, 164	3, 044, 265	2, 787, 930	2, 563, 353
		20	6, 165, 659	5, 203, 834	4, 454, 337	3, 862, 724	3, 388, 617
		30	7, 845, 222	6, 245, 055	5, 107, 652	4, 276, 944	3, 654, 480
		40	8, 979, 903	6, 826, 233	5, 410, 263	4, 436, 643	3, 740, 227
		50	9, 746, 187	7, 151, 075	5, 550, 454	4, 498, 345	3, 767, 449
		∞	11, 342, 272	7, 561, 514	5, 671, 136	4, 536, 908	3, 780, 757
Covariance analysis[b] (5.21)	369, 910	10	3, 000, 345	2, 722, 542	2, 482, 101	2, 273, 101	2, 089, 995
		20	5, 027, 086	4, 242, 876	3, 631, 783	3, 149, 419	2, 762, 863
		30	6, 396, 496	5, 091, 821	4, 164, 455	3, 437, 148	2, 979, 630
		40	7, 321, 643	5, 565, 676	4, 411, 185	3, 617, 357	3, 049, 544
		50	7, 946, 422	5, 830, 532	4, 525, 487	3, 667, 664	3, 071, 738
		∞	9, 247, 768	6, 165, 178	4, 623, 884	3, 699, 107	3, 082, 589

[a]Average water available at the farm per season (70, 000. 14) multiplied by the differential in rental price of water per acre foot.

[b]Estimate derived from the approximate test.

SUMMARY AND CONCLUSIONS

Statement of the Problem

Water is among the most vital of all resources. Increased demand has resulted in a high degree of competition to secure the rights to water both among and within uses.

In order to attain the maximum social productivity, allocation should be such that the value of the marginal social product of water is equal in all uses. Because of the dynamic nature of the uses for water, the maximum productivity can be achieved only if the resource can be freely moved from places and uses of lower marginal value to higher ones.

This study was concerned with value of rights to water, transfer of rights in the water market, and restrictive influences as they affect the optimum allocation of irrigation water.

Primary Objective and Procedure

The primary objective of this study was to determine the relative efficiency of different allocative schemes for irrigation water. Alternatives considered in this analysis included a comparison of two market situations, one in which only intracompany transfers were permitted, and a second in which intercompany transfers were allowed.

Efficiency of allocation was determined by comparing indicators of the value of the marginal product associated with the two allocative arrangements. A rather long history of water market activity in the study area made it possible to use the annual rental price of water as the indicator of the value of the marginal product of water. Formal records indicated that very active markets have been in existence for more than 30 years. Ceteris paribus, the higher the value of the marginal product (rental price) the greater the efficiency of allocation.

Because this comparison of value of the marginal products (rental prices) was made over a considerable period of time, other variables besides the change in transfer policy which could be expected to influence the rental price of water were also considered. Included in this group of variables were water available, product prices, other inputs, and technology. Each of these variables was evaluated to determine its relative importance and what influence, if any, it had on the rental price of water. Those found significant were included in subsequent statistical comparisons of rental prices.

Results

The water available per irrigated acre was determined to be a significant explanatory variable. It was then possible to account for this significant relationship in establishing the "true" effect of the two transfer policies on rental prices.

<u>Mean difference analysis</u>

The average rental price under the policy which permitted intercompany transfer of water was $9.60 per acre foot. The average rental price under the more restrictive policy in which only intracompany transfers were permitted was $3.21 per acre foot. A mean difference of $6.39 was significantly different from zero at the α .01 level, indicating that the average rental price was significantly higher under the free transfer policy.

The means of water available per irrigated acre during the same periods of time were 1.39 and 1.62 acre feet respectively. The mean difference of .23 acre feet was not significantly different between the different allocative arrangements. This indicated that any difference in the means of this variable between periods could be attributed only to chance.

<u>Covariance approximation</u>

Predicted values of the rental price at 1.47 acre feet per irrigated acre were $8.75 and $3.54 per acre foot respectively. The higher rental value was again associated with that policy which permitted intercompany transfers. A difference of $5.21 between predicted rental values at the average level of water available was significantly different from zero at the α .01 level.

Conclusions

Statistically significant differences between the mean values and also the predicted values of the rental price under different allocative policies provides strong evidence that transfer policies influence the efficiency of allocation. In both tests the indicator of the value of the marginal product of water was higher under the transfer policy which was most flexible and permitted intercompany transfers. Using the most conservative estimate of difference in water value, it was determined that the value of the water was increased by 147 percent by permitting greater flexibility between users. It was concluded that an allocative policy which permits intercompany transfers was more efficient than a policy which allows only intracompany transfers.

In view of the recent clamor for more authoritative methods of allocating water, this introduction of intercompany transfer in the study area represents a bold step in the opposite direction. The ingenuity and resolve displayed by these farmers in implementing this allocative policy is remarkable, and the study clearly indicates the large efficiency gains to the individual irrigator and to the agricultural community that have resulted from this market development.

Suggestions for Further Research

This study alludes to more questions than were answered within the limited scope of this thesis. Several problems which received only superficial treatment here would be interesting subjects for further research. A brief list of these includes:

1. A more complete analysis of the effects of the "basis of exchange" used in intercompany transfer.

2. A more complete appraisal of the apparent differences in flexibility between the sale and rental markets for water.

3. A comparison of the value of land, both with and without a water supply.

The results of this analysis are conclusive and the implication for similar areas is obvious. However, because the study area was unique in many respects, further research should be conducted in other areas where conditions are not so conducive to the development of a water market. Particular emphasis should be placed on the feasibility of determining spillover gains and losses which might result from a free transfer policy.

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